

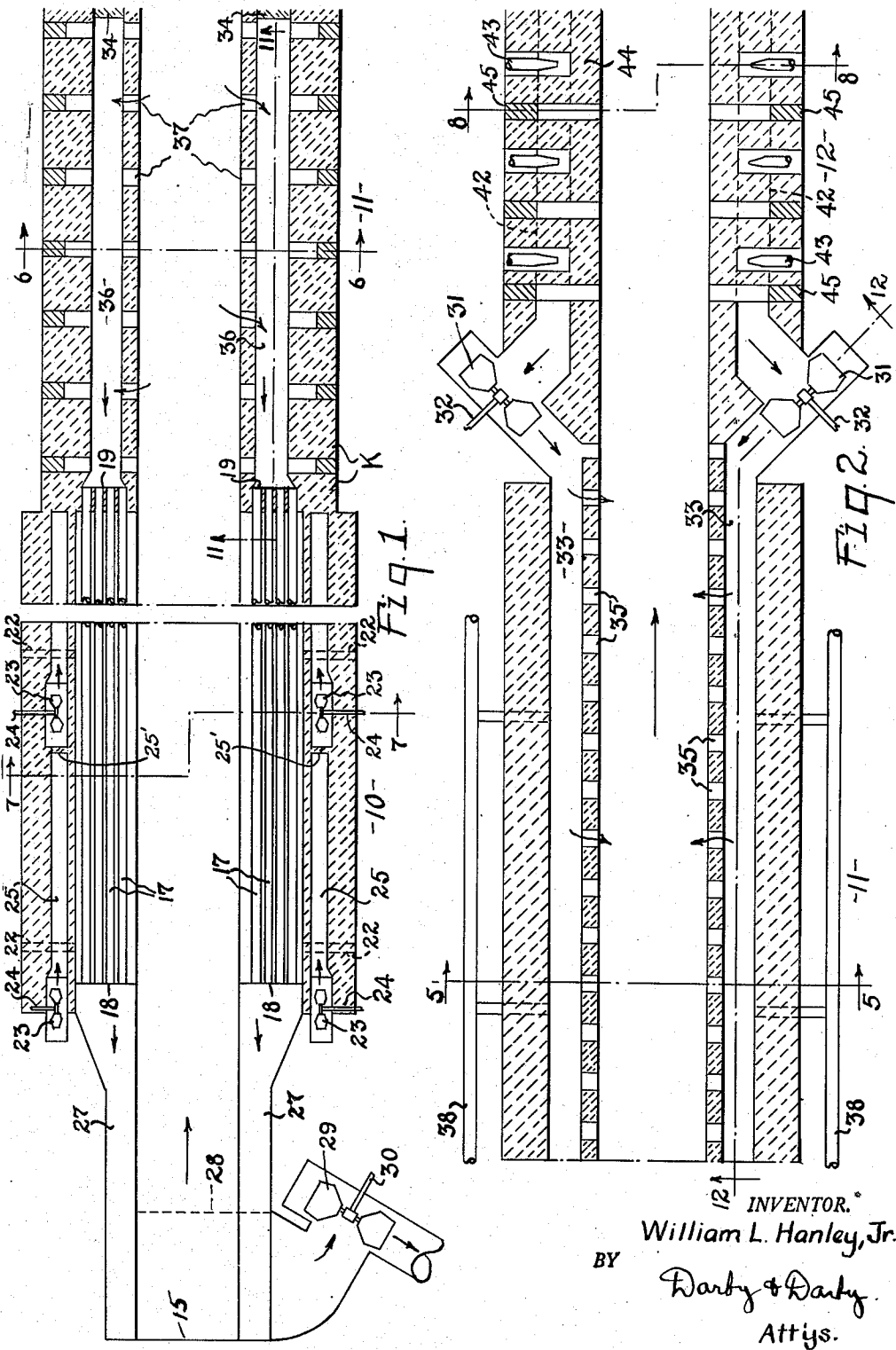
May 1, 1951

W. L. HANLEY, JR
TUNNEL KILN

2,550,807

Filed Feb. 19, 1947

6 Sheets-Sheet 1



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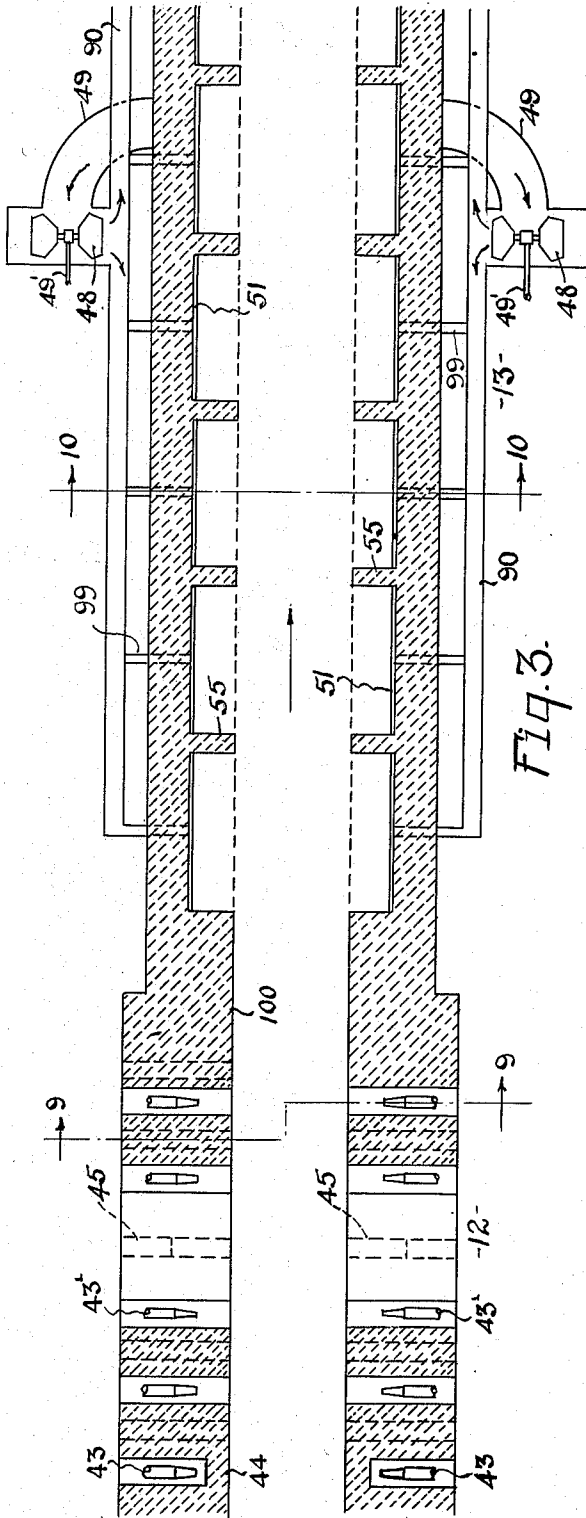
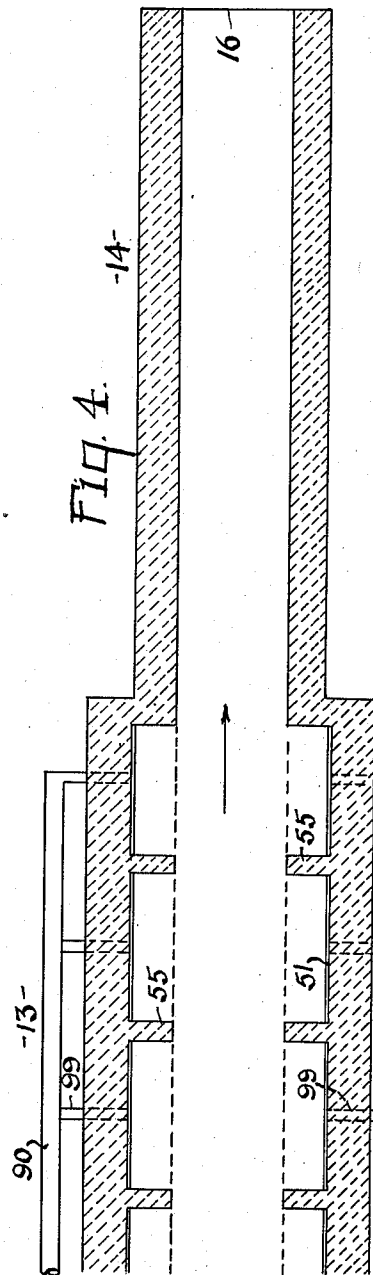
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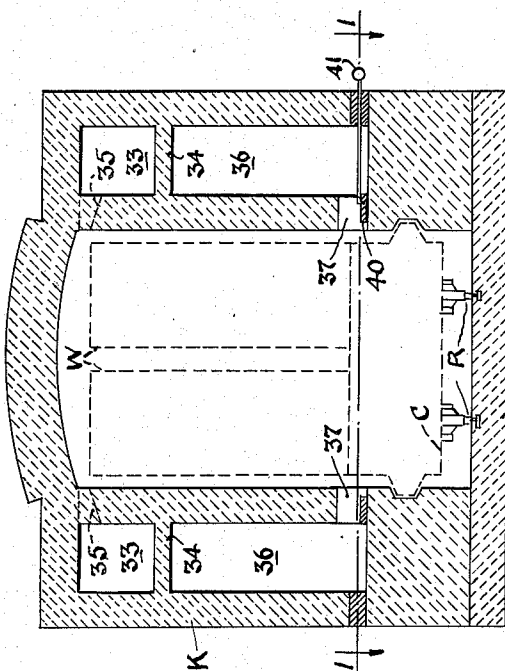


Fig. 6.

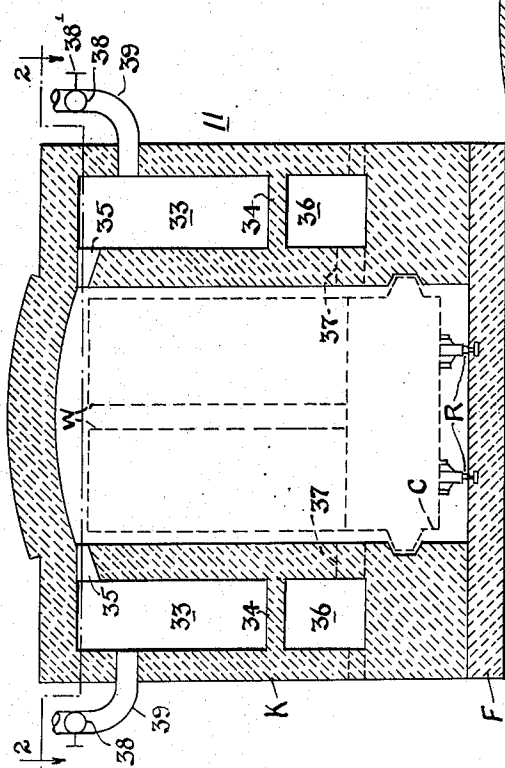


Fig. 5.

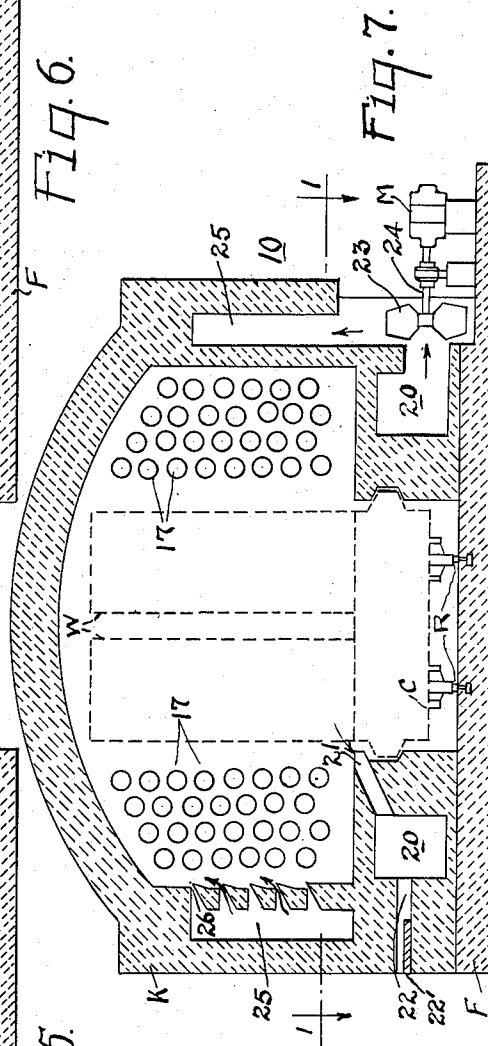


Fig. 7.

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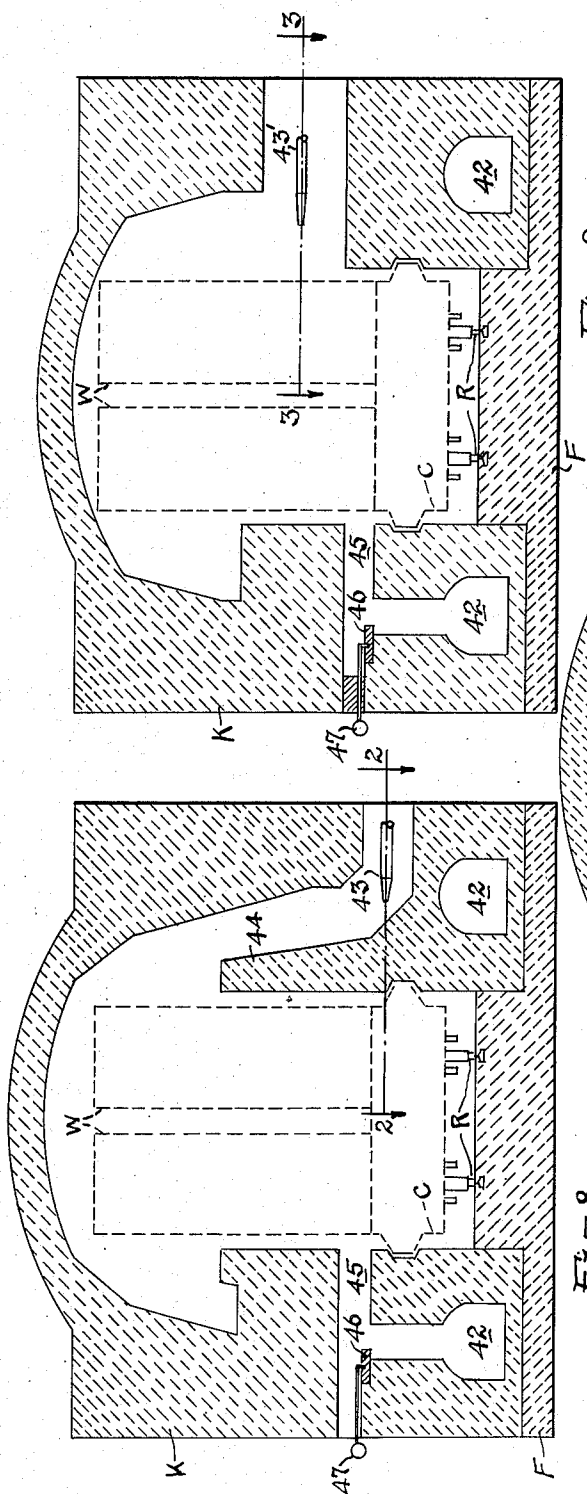
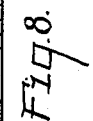
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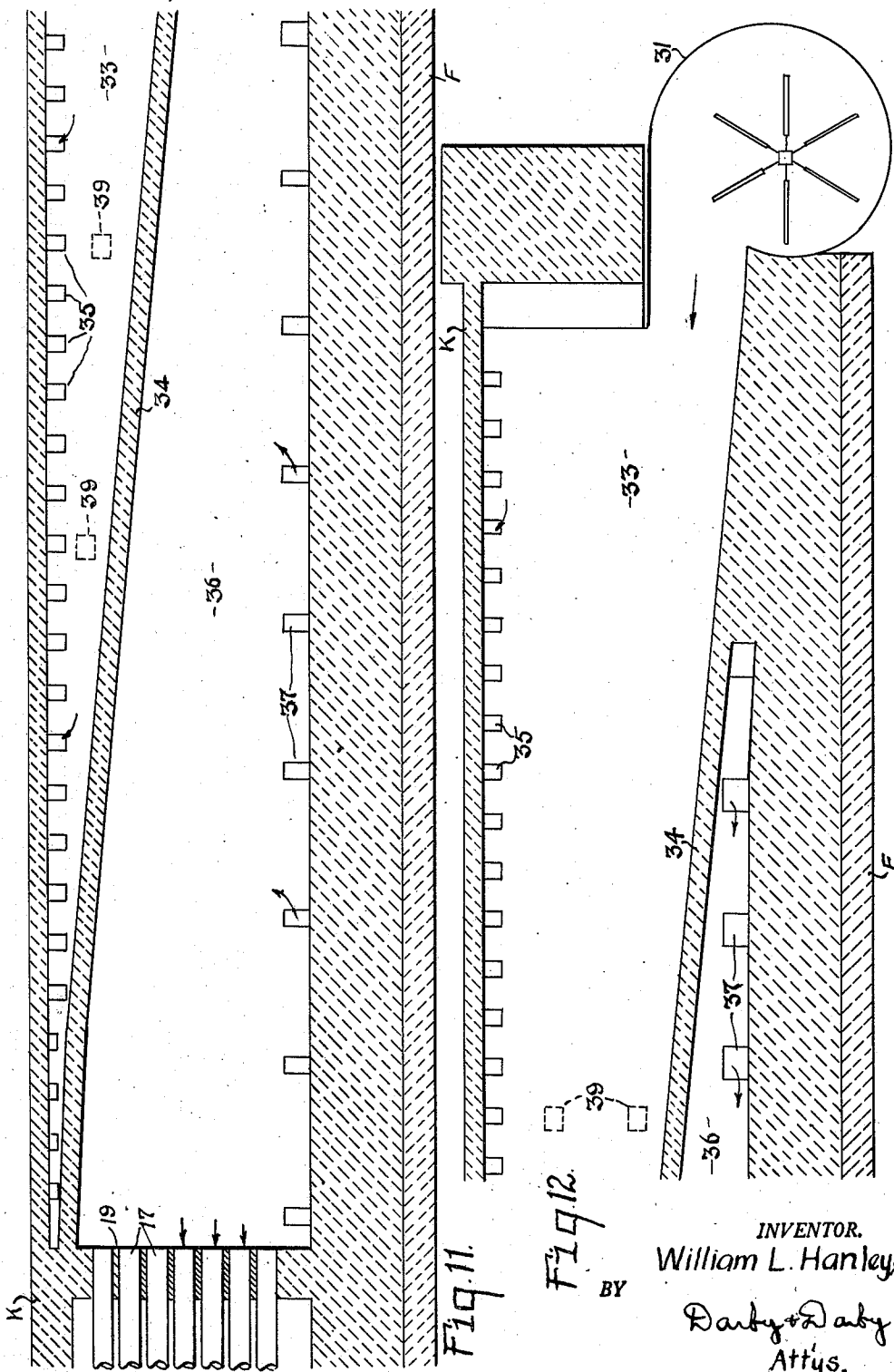


Fig. 11.

Fig. 12.

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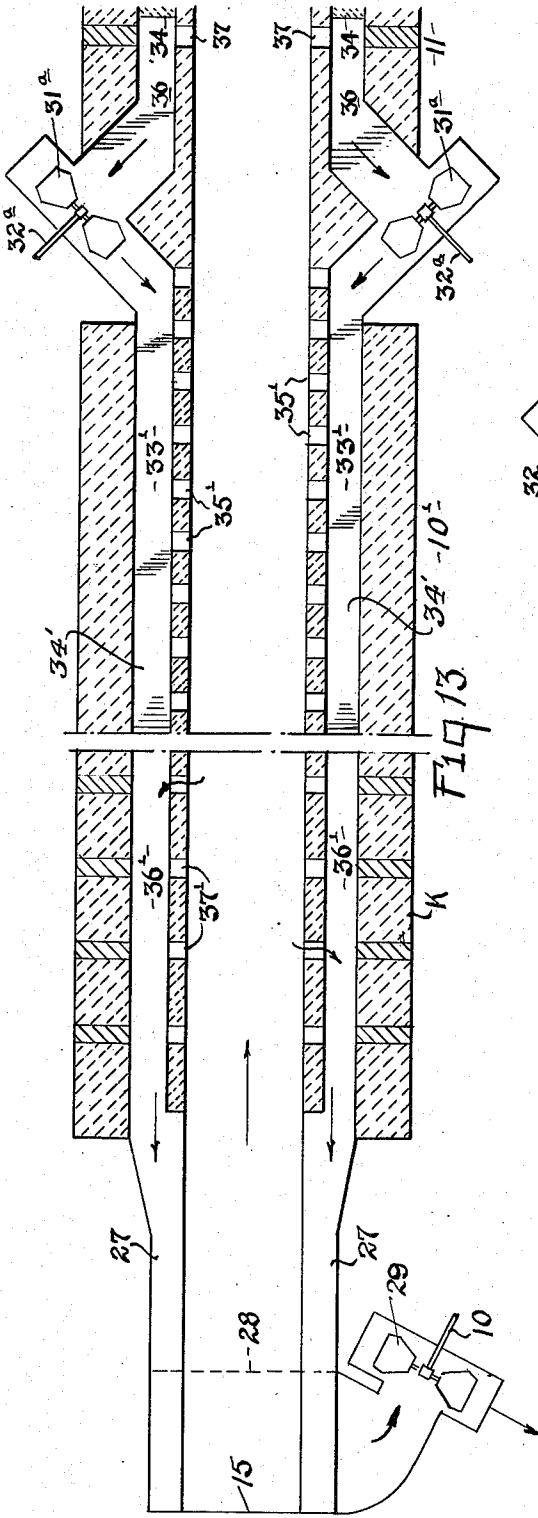
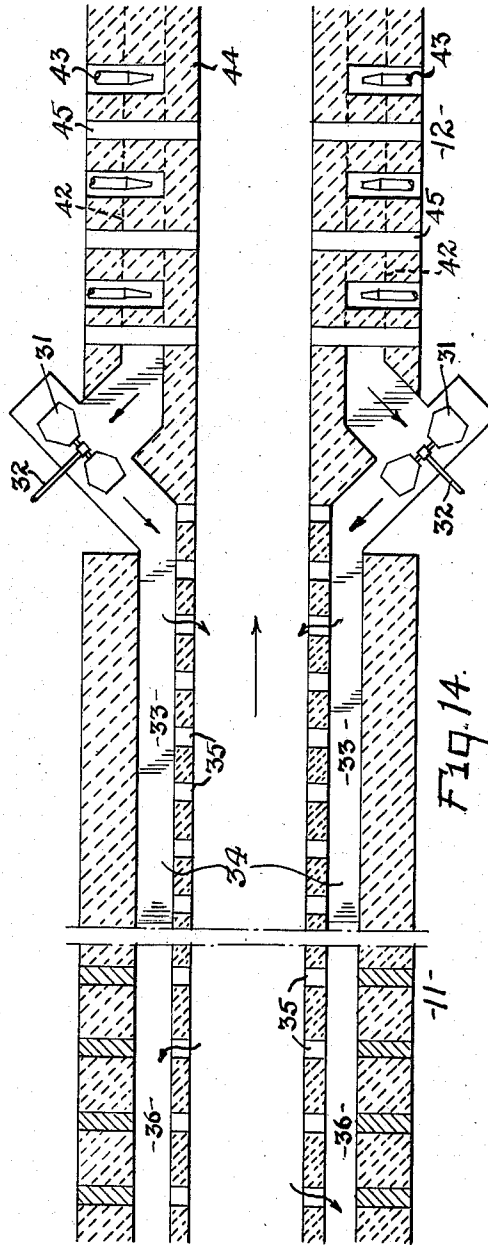
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6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,550,807

TUNNEL KILN

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Application February 19, 1947, Serial No. 729,558

29 Claims. (Cl. 25—142)

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This invention is concerned with improvements in brick and tile kilns of the tunnel type, as commonly employed for the heat treatment of such ware.

This invention relates to tunnel kilns or ovens especially designed for firing clay products such as bricks, fire brick, tile and the like, either of the glazed or unglazed types. As is usual in the use of tunnel kilns, the ware to be fired is moved progressively either continuously or intermittently, through the kiln from its entrance to its exit at a controlled speed to effect the required heat treatment thereof. The ware is placed upon cars or trucks which are in end to end contact to form a continuous line of trucks, entirely filling the kiln throughout its length. These trucks are progressed intermittently or continuously through the kiln by intermittently or continuously pushing freshly loaded cars through the entrance end of the tunnel, thereby moving the entire line, so that a truck on which the ware has been fully processed is moved out of the kiln at its exit end.

In the movement of the ware through the kiln, it passes through longitudinally spaced zones maintained and controlled at different temperatures, so that the green or unfired ware, which enters the kiln, is successively heat treated in accordance with predetermined requirements and cooled to a safe temperature for exposure to the atmosphere, at the time of discharge from the kiln.

In accordance with this invention, the kiln is effectively divided longitudinally into a plurality of zones, in each of which the temperature and atmospheric conditions can be controlled from end to end to effect a very accurate and efficient heat treatment of the ware. Fundamentally, the kiln herein disclosed may be longitudinally divided from its entrance to its exit end into a low pre-heat zone, a high pre-heat zone, a hot zone and a cooling zone.

One object of this invention is to provide a physical structure wherein these four zones may be effectively established and maintained under very accurately controlled conditions, and, wherein, within each zone both atmospheric and temperature conditions can be controlled, so as to effectively establish within each zone one or more subsidiary zones of different temperature and atmospheric conditions.

Another object of this invention is to provide a method wherein efficient heat treatment of ware of this kind, involving the establishment of different and closely controlled atmospheric and

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temperature conditions, as between zones of treatment, and within each zone, whereby any number of efficient and effective processing cycles can be produced.

Another object of the invention is to provide a tunnel kiln and methods of operating it wherein a maximum utilization of all heat put into the process is obtained.

A still further object of the invention is to provide a kiln structure which is readily adapted, with minor alterations, for the continuous treatment of glazed or unglazed ware in either small or large size.

An important object of the invention, both from a structural and operating viewpoint, is the provision of means for transferring the high temperature products of combustion from the hot zone directly into the high pre-heat zone, for heating the ware by direct contact of the products of combustion therewith, and for directly transferring these products of combustion, somewhat cooled, to the low pre-heat zone, for transfer of heat by radiation to the green ware without direct contact therewith. As a further factor of efficiency, these products of combustion are then transferred to the driers, where the freshly molded green ware is dried in preparation for introduction into the tunnel kilns.

Another object of this invention is the provision of apparatus and operations whereby the fired ware is cooled under closely controlled conditions through the various critical temperature points to minimize shrinking strains and to insure that the finished ware will issue from the kiln at a temperature which permits safe exposure to the atmosphere.

Other and more detailed objects of the invention will be apparent from the description which follows wherein the embodiment selected for illustration in the drawings is described in full detail.

This invention resides substantially in the combination, construction, arrangement, relative location of parts, steps and series of steps, all as hereinafter fully disclosed.

In the accompanying drawings—

Figure 1 is a horizontal cross sectional view taken on the lines 1—1 of Figures 6 and 7, showing the construction of the entrance end of the kiln, the low pre-heat zone and a portion of the high pre-heat zone;

Figure 2 is a horizontal cross sectional view taken on the lines 2—2 of Figures 5 and 8 showing the adjacent portions of the high pre-heat zone and the hot zone;

Figure 3 is a horizontal cross sectional view

taken on the line 2—2 of Figure 8 of the indirect hot zone; line 3—3 of Figure 9 of the direct fire zone; and line 4—4 of Figure 10 of the cooling zone;

Figure 4 is a horizontal cross sectional view taken on the line 4—4 of Figure 10 showing the cooling zone and the tunnel exit structure;

Figures 1, 2, 3 and 4 when arranged end to end in that order illustrate a horizontal cross sectional view throughout the length of the kiln taken at the various levels indicated above;

Figure 5 is a vertical cross sectional view taken on the line 5—5 of Figure 2;

Figure 6 is a vertical cross sectional view taken on the line 6—6 of Figure 1;

Figure 7 is a vertical cross sectional view taken on the line 7—7 of Figure 1;

Figure 8 is a vertical cross sectional view taken on the line 8—8 of Figure 2;

Figure 9 is a vertical cross sectional view taken on the line 9—9 of Figure 3;

Figure 10 is a vertical cross sectional view taken on the line 10—10 of Figure 3;

Figure 11 is an enlarged vertical longitudinal cross sectional view taken on the line 11—11 of Figure 1;

Figure 12 is a vertical longitudinal cross sectional view taken on the line 12—12 of Figure 2;

Figures 11 and 12 when placed end to end in that order represent a single vertical cross sectional view of the high pre-heat zone; and

Figures 13 and 14 taken together are horizontal cross sectional views similar to those of Figures 1 and 2 of a modified structure in which no tube section is employed.

As will be well understood by those familiar with the kilns of this type, the construction usually employs a suitable foundation and an overhead structural steel framework, for supporting the kiln housing proper. The housing is constructed of brick and cementing materials, and those parts thereof which come in contact with the high temperature gases are constructed of refractory brick and cements. Little further references to these materials is deemed necessary in view of the fact that from the nature of the structure and its intended use, as will appear hereinafter, the kinds of materials suitable at the various structural locations will be known.

The car receiving end of the kiln and the low pre-heat section thereof, sometimes referred to hereinafter as the pipe section, are generally indicated at 10 in Figure 1, while the high pre-heat section is indicated at 11 in Figures 1 and 2. The hot or firing zone is indicated at 12 in Figures 2 and 3, the cooling section at 13 in Figures 3 and 4, and the delivery section, which may be considered to be the terminal end of the cooling section, is indicated at 14 in Figure 4.

The receiving end consists of a double walled housing 27, which can be closed, upon introduction of each car, by means of a readily movable door, not shown. The double walled housing, as well as the remainder of the kiln structure, is supported on a suitable foundation F on which are mounted, in the usual manner, a pair of car truck rails R, over which the cars C carrying the ware W to be treated may roll through the tunnel formed by the kiln.

The remainder of the kiln housing K, as illustrated, is built up of brick of suitable types as previously mentioned. The low pre-heat section 10 is arranged as a longitudinal continuation of the double walled housing 27, and is built with a greater width, as shown in Figures 1 and 7, to

form a chamber, in which a plurality of high temperature tubes 17 are mounted. These tubes are mounted at one end in a header 18 and at the other end in a header 19, which, as illustrated, see Figure 11, may be of refractory material. These tubes are sealed at their ends in the headers, so that they are exposed throughout their substantial length to the space between the headers. Formed in the housing structure K, below the tubes 17, are a pair of parallel ducts 20, which are longitudinally divided into separate chambers. These ducts may be divided into chambers by means of cross walls 25', as diagrammatically illustrated in Figure 1, in which blowers 23 are mounted. These blowers are provided with driving shafts 24 to be driven by motors, such as the motor M illustrated in Figure 7. Each of the chambers, formed in the ducts 20, communicates with the space between the headers 18 and 19 by means of passageways 21, only one of which appears in Figure 7, because, as is clear from Figure 1, the section of Figure 7, is taken on opposite sides of the center of the tunnel at different longitudinal points. The blowers 23 are set into the ducts 20 so that their suction sides are respectively open to the chambers, into which the ducts are divided, as shown in Figure 7. The discharge sides of these blowers open into another pair of longitudinal ducts 25, which are sectionalized by cross walls so that the ducts 20 and 25 have the same number sections. The sections of the ducts 25 are provided with a series of discharge slits 26 which are shaped, as clearly shown in Figure 7, so as to direct the air discharging through these slits in an upward direction more or less tangentially to the arch of this section. As the slits 26 do not extend throughout the length of each section but they too are sectionalized, they appear only at the left-hand side of Figure 7, for the same reason that the passages 21 for both sides do not appear in that figure. Each of the compartments of the ducts 20 are provided with passages 22 connecting them with the atmosphere. These passages can be dampered to permit the introduction of controlled quantities of tempering air, when required, as will be explained later.

Special attention is drawn to one important improvement in kilns of this type as represented by the structure described above. It will be noted that the blowers 23 and their driving equipment are mounted at floor level and at the sides of the kiln so that they are easily and conveniently accessible for repair and replacement. These blowers can be standard commercial products designed to withstand the temperatures encountered and the kiln is arranged as clearly shown in Figures 1 and 7 so that they can be slipped into place at the sides of the kiln to effect by such placement direct interconnection between the ducts 20 and 25. This represents a very practical feature in the maintenance of the kiln. Another important advantage of this arrangement is present in the fact that these fans and their operating equipment are placed at the cooler level of the kiln which contributes to longer life with less maintenance. An overall advantage of this arrangement lies in the fact that in the case of breakdown of one of the fans it can be quickly replaced by a spare fan without shutting the current down and allowing it to cool as is the case with some prior kilns. Attention is also directed to the fact that in the arrangement disclosed these fans are placed at both sides of the kiln and the duct system is sectionalized so that cir-

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culuation of the pre-heating air in this zone is effected in parallel planes at right angles to the length of the zone with little or no circulation of the air along the sides of the zone. Thus, a desired heat curve of gradually increasing temperature under good control can be attained.

It will be clear from Figure 1 that the double walled housing 27 is open to the interior of tubes 17, and as indicated at 28, both sides of the double walls are interconnected by a passage 28, which leads to the inlet of a blower 29 driven by a shaft 30 to which an operating motor, not shown, is connected. Although not shown, the delivery side of the blower 29 is usually connected by means of a duct to the drying ovens, in which the fresh molded green goods are preliminarily dried, in preparation for introduction into the kiln.

Referring to Figure 2, there is shown a pair of high temperature blowers 31, provided with operating shafts 32 to be driven by means of motors, not shown. The discharge sides of these blowers are connected to a pair of ducts which extend longitudinally of the high pre-heat section 11 in the side walls of this section, as is clear from Figures 5 and 6. Built into the side walls is a longitudinally inclined division wall 34 which extends upwardly from the blowers 31 to the headers 19, see Figures 11 and 12. These walls 34 in this position divide these ducts into two passageways 33 and 36 of gradually changing cross sectional area. The passageways 33 are of gradually diminishing cross sectional area from the blowers 31 to the headers 19, while the passageways 36 are of gradually increasing cross sectional area in the same direction. The inner wall of each of these ducts forms the defining wall for the car tunnel in the section 11, as is clear from Figures 5 and 6. This wall is provided with a series of longitudinally spaced openings 35, near the tunnel arch, which establish communication between the passageways 33 and the tunnel proper. Similarly, there are formed at the bottom of these walls at longitudinally spaced points a plurality of openings 37 establishing communication between the passageways 36 and the tunnel proper. Each passageway 33 is provided at several spaced points with branch pipes 39, which connect with pipe headers 38 extending longitudinally of the kiln. By this arrangement tempering air can be fed at a plurality of points to temper the flue gas delivered by the fans 31 so as to flatten out the heat curve in this section of the kiln, if desired. The lower defining wall of each of the passages 35 is inclined upwardly so as to discharge gases from the passageways 33 tangentially of the tunnel arch. Some or all of the passages 37 are provided with dampers 40 and damper operating levers 41, operable from the exterior of the kiln for controlling, at various longitudinal points, the rate of flow of gases through the passages 37. As will appear more clearly hereinafter, the passages 35 serve to discharge gases into the tunnel proper, while passages 37 provided exhaust passages through which these gases are withdrawn into the passages 36.

By reference to Figure 11, it will be seen that the passages 36 open directly into the tubes 17.

The intake ports of the blowers 31 communicate with a pair of ducts 42 formed in and towards the bottom of the side walls of the hot zone or firing section 12 of the kiln. These ducts extend throughout the length of this section of the kiln. This section may be divided into two sub-sections in the sense that the fuel burners

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by means of which the ware is fired, in this section, are arranged to effect indirect and direct firing, in that sequence. As shown in Figure 8, a series of burners 43 are mounted on each side of the tunnel proper, only one appearing in Figure 8, because, as in the case of Figure 7, the cross section on opposite sides of the center line is at two different longitudinal points. These burners are of the type for burning gaseous fuel, which burns, in an open flame, in an upwardly extending passageway, the inner side of which is formed by a baffle wall 44. The passage opens upwardly in a direction tangential to the arch of the tunnel, as shown, so the hot gaseous products of combustion are discharged upwardly against the tunnel arch. The burners 43 are arranged at spaced longitudinal points, see Figures 2 and 3, in opposed pairs. At intermediate points, the ducts 42 are connected to the tunnel proper by means of passages 45, controlled by dampers 46 and operating levers 47. The construction of Figure 8 is that of the sub-section in which indirect firing is effected. The description of the structure of this invention has proceeded far enough to make it apparent to those skilled in the art that it is adaptable to the use of any type of fuel suitable for the firing of clay products as, for example, coal, oil and the like.

The construction of Figure 9 is in the sub-section at which direct firing occurs. In this case, as illustrated, the fuel burners 43' are arranged so that the flame directly impinges upon the ware. The burners 43', as is clear from Figure 3, are arranged in transversely aligned pairs which does not appear from Figure 9, because an offset cross section like those previously described is shown. Staggered with respect to these burners are additional passages 45 by means of which the tunnel proper is connected to the ducts 42. As before, the dampers 46 and control levers 47 are provided.

At this point it may be noted that the structure selected for illustrating the invention herein is for a specialized firing procedure which is not of general application. In the more normal firing procedure the direct firing sub-section just described would not be used. In the particular process for which this kiln was designed the direct firing sub-section is employed to even up the temperature as between the top and the bottom of the car stacks. Thus, by direct firing the temperature at the bottom of the stacks may be brought up to the temperature at the top of the stacks which is attained in the indirect sub-section.

As shown in Figure 3, the cooling section 13 is connected to the firing section and the tunnel formed thereby is restricted at the point of connection 100 so that the ware loaded cars will pass from one section to the other with a relatively close fit to prevent short-circuiting of the atmospheres of the two sections. The walls of the cooling section preferably are provided with interiorly extending opposed pairs of baffle walls 45 the inner faces of which lie in the plane of the restricted connecting section 100, previously described. Thus, the cooling section is effectively subdivided into a plurality of compartments, isolated from each other, when the loaded cars are in this portion of the tunnel. Each of these compartments is provided with a passageway 99 connected to longitudinally extending warm air supply pipes 90 which are connected to the outlet of fans 48. The inner ends of the passages open through slots 51 to the interior of the tunnel.

proper. Formed in the side walls, near the foundation level, are the longitudinally extending ducts 50, which are connected at each of the compartments referred to above with the interior of the tunnel by means of the passages 52. These passages 52 are controlled by means of dampers 53 and operating levers 54 as shown. The intake side of each of the blowers 48 is connected by means of couplings 49 with the ducts 50. These blowers are driven by means of motors, not shown, connected to the blower shafts 49'. The discharge ports of the blowers 48 are connected to conduits 90 for warm air recirculation in the cooling zone sections; and part of this air may be delivered to the drying ovens, as a source of heat to dry the freshly molded green goods, supplied, as pre-heated air, to the burner nozzles, or used for any other purpose for which this air is useful.

The terminal end 14 of the cooling section may serve as a seal through which the loaded cars move in a relatively close fit to the discharge end 16 of the kiln, which may be provided with a movable door, not shown. By making the section 14 long enough in relation to the fit which the loaded cars have therewith the opening of the door at the end 16 will not permit of the entry of air in sufficient quantity to upset the closely controlled cooling cycle desirable for most effective economical operation.

In the operation of this kiln, in accordance with the methods of this invention, the pre-dried green ware is introduced, a truckload at a time, into the tunnel kiln through the entrance 15. The initial starting period represented by the time it takes to fully load the kiln is of no consequence in the normal operation of the kiln. It will be assumed, therefore, that the entire tunnel is occupied by a line of cars, which are in end to end contact from the entrance end to the exit end. The heat treatment of a freshly introduced car will be followed as representative of all other cars during normal operation.

The door at the entrance end 15 is opened and a mechanism, not shown, causes a car loaded with greenware to be slowly forced into the kiln. At this time the door at the exit end is also open, since the introduction of one car causes the ejection of one car (fully processed). In the usual operation the cars are introduced singly, at spaced intervals, so that the movement of the line of cars is, in effect, intermittent. As soon as the car is fully introduced into the housing 27, the door at the entrance end is closed and, likewise, as a car has been ejected, the door at the exit end can be closed.

The hot gaseous products of combustion, which are delivered by the blowers 31, travel along the passageway 33 and are discharged into the tunnel proper in the high pre-heat zone 11, through the openings 25. The passage 33 gradually diminishes in cross sectional area away from the blower 31, since it has less and less gas volume to transmit. The very high temperature gases issuing through the ports 35 circulate in the tunnel proper around the ware in the high pre-heat zone. These gases are directed by the arch downwardly between the ware W which is preferably stacked on the cars C in two transversely spaced columns, as illustrated in Figure 6. As is usual, these columns are arranged so that each article is exposed as much as possible to direct contact with the hot gases. Therefore, the articles are stacked in labyrinth style to form an openwork lattice through which the gases may circulate. The gases after contacting the ware are withdrawn

through the ports 37 which connect with the passageways 36, in turn connected with the tubes 17. The passages 36 in effect are suction passages since they communicate through the tubes 17, the double walled housing 27, passage 28 with the intake of the suction blower 29. By placing the exhaust ports 37 at the bottom of the passages 36, the hot gases are caused to circulate in contact with the ware W throughout all portions thereof, so that the lower parts of the ware stacks are properly heat treated. By adjusting the dampers 40 in the passages 37, any desired rate of gas flow at different cross sectional regions of the tunnel can be effected, so that the rate of heating of the ware, as it progresses through the high pre-heat section, for example, gradually increases, insuring that the ware in leaving this zone will leave it at the proper pre-heat temperature.

The heat curve in this section can be flattened out, if desired, by the introduction of cool air through the ports 39, see Figure 12.

The hot gaseous products of combustion, now lowered in temperature, in passing through the pipes 17 make of them heat radiators, by means of which the atmosphere in the low pre-heat section may be heated by conduction through the walls of the tubes. The atmosphere surrounding the pipe 17, which is preferably clean air, is caused to continually circulate in a plurality of substantially closed parallel circuits, by reason of the blowers 23 and the sectionalized construction of the ducts 20. Each of the duct sections is provided with a passageway 22 having a damper 22' by means of which the air may be tempered by allowing entrance of relatively cool outside air therethrough. Here again, various temperature conditions can be maintained at various cross sectional regions of the low pre-heat zone. The air circulating around the pipes 17 is recirculated, and its rate of circulation can be controlled in one practical manner by varying the relative speeds of the motors M. The air is discharged through the slits 26 in a generally upward direction and in passing over the hot tubes 17 is heated to the desired temperature. This heated air circulates through the ware stacks and down between them by being directed not only onto the sides of the stacks but onto the top by the tunnel arch and down between the stacks due to the natural circulatory flow created by the relative arrangement of air supply slits 26 and exhaust passages 21.

The products of combustion still further cooled then flow through the double walled housing 27, where the freshly introduced goods is initially warmed up by the radiation of heat from the inner walls of the housing 27.

In the low pre-heat section those types of ware, that is, particularly glazed ware or face brick and tile, are raised to the proper pre-heat temperature under conditions where the sulphur and other deleterious content of the ware that is driven off in the high pre-heat zone is removed from contact therewith, preventing contamination of the ware.

The hot products of combustion are generated in the firing zone by the burning of the fuel in the burners 43. The burning fuel does not directly impinge upon the ware by reason of the bridge walls 44. The hot products of combustion, however, are discharged into the tunnel proper so as to insure, as nearly as possible, uniform firing of the ware. The gases are guided by the tunnel arch down between the ware stacks,

and these gases are withdrawn near the bottom of the stacks through the passages 45 into the suction ducts 42, so that all parts of the stacks are heated.

In the direct burner sub-section as is clear from Figure 9, the flames generated by the burners 43' directly impinge upon the sides of the ware columns as distinguished from the previous sub-section, where such impingement is prevented. Thus, at the end of the heating cycle and for a relatively short period of time the ware is subjected to the direct action of the burning fuel whereby the temperature of the ware in the stacks is evened up, as previously explained. As previously explained, all of the products of combustion of the firing zone are withdrawn through the ducts 42 by the high temperature blowers 31.

The cars then move into the cooling zone which is effectively sub-divided by the baffle walls 55 into a series of chambers in which the circulating atmosphere can be maintained at various temperatures, and generally speaking, at successively lower temperatures, whereby any desired cooling cycle may be carried out. As is well known in this art, there are particular temperature gradients to be maintained and critical temperature points through which the ware must be carried during cooling, to prevent undue shrinkage and distortion of the ware due to too rapid cooling. By this arrangement the quantity of air and its temperature entering the compartment is such that a predetermined accurate amount of heat can be withdrawn from the ware to attain these critical temperature conditions at various succeeding time intervals, so that the ware will be cooled in accordance with predetermined and known desirable conditions. It is also possible to insure that the ware, by the time it reaches the exit 16, will be at a safe temperature for exposure to the atmosphere without damaging effect. Indeed, it is usually desirable that the ware come from the kiln at a temperature at which it can be handled, which condition can readily be attained with this arrangement.

In review it will be seen that very efficient use of all heat put into the system is effected and that, for example, in the case of contaminating atmospheres, such as are generated in the high pre-heat and hot zones, the remaining heat of the products of combustion is abstracted in the heat exchanger or pipe zone 10, while preventing direct contact between the poisoned gases and the fresh incoming ware. Thus, the useful heat of the gases is abstracted in the low pre-heat zone without first requiring an intermediate processing of the hotter gases coming from the high pre-heat zone to remove therefrom contaminating gases picked up in the high pre-heat and hot zones. The structure disclosed is adapted to simple and effective control so that throughout the process the most efficient atmospheres, suitable to the processes, are provided, and their temperature and flow so controlled, as to insure accurate treatment of the ware in accordance with any desired prerequisite conditions, some of which are often dictated by the physical-chemical nature of the clay from which the products are molded.

It should be pointed out that the kiln herein disclosed, as well as the method of operating it described above, is of special value in the firing of glazed clay products and face brick and tile. However, in the firing of unglazed products, such as common brick, the danger of discoloration and

contamination of the ware, by reason of the evolution of poisoning gases in the high pre-heat zone, is prevented, so that but a single pre-heating zone is necessary. In that case the muffle comprising the pipes 17 of the low pre-heat zone can be eliminated, and what was previously the high pre-heat zone can be merged or expanded into a single pre-heating zone. In that case the hot products of combustion delivered by the high temperature blowers 31 are brought directly in contact with the fresh incoming ware throughout their pre-heating treatment, as the contaminating gases picked up during pre-heating have no effect on unglazed ware, which is commercially objectionable. Thus, in the firing of unglazed brick and tile a money saving simplification of the kiln is effected in the elimination of the relatively expensive muffle.

In the firing of some types of ware as distinguished from the specialized situation for which the structure of Figures 1 to 12, inclusive, was devised, it is practical to substitute for the tube section comprising the low pre-heat section a low pre-heat section of modified construction as shown in Figure 13. This section is illustrated in Figure 13 as the general assembly indicated by the reference numeral 10' and replaces the section 10 of Figure 1. In construction the section 10' is a substantially exact duplicate of the high pre-heat section shown in Figures 1 and 2, and section 11 is illustrated in Figures 13 and 14 to show its relationship to the new section 10'. Structurally, section 10' comprises a housing K of refractory material having ducts 33' and 36' in the side walls thereof. The righthand ends of the ducts 33 are connected to the outlets of blowers 31a having the operating shafts 32. The inlet sides of these blowers are connected to the lefthand ends of the ducts 36 of the high pre-heat section 11. The ducts 33' are of gradually decreasing cross section towards the left of section 10' just as they are in the case of section 11 and illustrated in Figures 11 and 12. Similarly, the ducts 36' are of gradually increasing cross section in the same direction and result from an inclined baffle wall 34' corresponding to the baffle wall 34. Along the side of the passage 33' which defines the tunnel proper at the top are the inlets 35' corresponding to the inlets 35 of Figures 11 and 12 and similarly, along the same wall at the bottom thereof are the passages 37'.

It will be seen then that structurally this modified low pre-heat section 10' is quite the same in construction as the high pre-heat section 11. In the modified structure there is interposed between these two sections the blowers 31a so that the hot gases withdrawn from the ducts 36 are delivered into the ducts 33' and ultimately pass from there into the tunnel through the ports 35'. From this tunnel they are withdrawn through the ports 37' into ducts 38' and from there they travel through the space 27 formed by the double walls at the entrance end of the kiln into duct 28 and thence to the blower 29 as before.

In this arrangement it will be seen that the initial or low pre-heat stage of the process is carried out by the direct contact of the heated gases delivered from the section 11 into the section 10'. This distinguishes from the arrangement previously described where these same gases were used to heat air by heated transference through a conducting wall which air in turn circulated in contact with the fresh incoming ware to give it its initial pre-heat.

It will now be apparent to those skilled in the art that the subject matter of this invention in both its structural and operational characteristics is capable of embodiment in other physical forms and uses and modifications in other ways without departing from the novel subject matter herein disclosed. I do not, therefore, desire to be strictly limited to the disclosure herein employed in an illustrative sense but only as required by the claims granted me.

What is claimed is:

1. In a tunnel kiln, the combination comprising an elongated refractory housing forming a tunnel through which stacks of ware to be heat treated may move, said housing including a preheating section and a firing section having fuel burners, means for directing the products of combustion of said burners into the tunnel kiln into contact with the ware in the firing section, means for laterally withdrawing substantially all of said products of combustion from the tunnel kiln at the firing section, and means for laterally discharging said withdrawn products of combustion under pressure into the tunnel kiln at the preheating section into contact with the ware therein.

2. In the combination of claim 1, said last two means including high temperature blowers and ducts formed in the housing walls for withdrawing the products of combustion from the tunnel kiln at the firing section and discharging them into the tunnel kiln at the preheating section at longitudinally spaced points.

3. In the combination of claim 1, said fuel burners being divided into longitudinally spaced groups, means for directing the flames from some of said burners so as to directly impinge these flames upon the lower portions of the ware stacks, and means for preventing flames of the remainder of the burners from directly contacting the ware while directing the products of combustion downwardly onto the upper portion of the ware stacks.

4. In the combination of claim 1, means in said firing section for causing the products of combustion to circulate downwardly onto the ware.

5. In the combination of claim 1, means in said firing section for causing the products of combustion to circulate downwardly onto the ware, said means for withdrawing the products of combustion from the tunnel kiln at the firing section comprising ducts opening into the tunnel kiln in the region of the bottom of the ware stacks and spaced longitudinally of the tunnel kiln.

6. In the combination of claim 1, means in said firing section for causing the products of combustion to circulate downwardly onto the ware, said means for withdrawing the products of combustion from the tunnel kiln of the firing section being distributed to effect withdrawal in the region of the bottom of the ware stacks at longitudinally spaced points, and individually adjustable means for controlling the withdrawal of the products of combustion from the tunnel kiln of the firing section at different rates at said longitudinally spaced points.

7. In the combination of claim 1, said housing including a cooling section, the walls of the tunnel in the cooling section having a plurality of pairs of longitudinally spaced and transversely aligned baffle walls effectively forming separate compartments in cooperation with the ware, and means for circulating cooling air in said compartments at different temperatures.

8. In a tunnel kiln, an elongated refractory housing forming a passageway through which ware cars having the ware stacked thereon may be moved, said housing being sub-divided into a low pre-heat and a high pre-heat zone and a firing zone, a plurality of burners for directing products of combustion into said firing zone, means for directing the products of combustion in a circulatory motion downwardly onto the ware stacks, means for withdrawing the products of combustion laterally from the firing section at the bottom of the ware stacks, means for discharging these products of combustion directly into the high pre-heat section including ports in the housing for directing the products of combustion into the passageway at a plurality of longitudinally spaced points near the top, means for withdrawing the products of combustion from the high pre-heat section at the bottom of the ware stacks at a plurality of longitudinally spaced points, a heat exchanger in the low pre-heat section through which the products of combustion pass and means for creating a plurality of effectively isolated parallel paths of air circulation over said heat exchanger and into contact with the ware stacks in planes at right angles to the path of movement of the ware stacks.

9. In the combination of claim 8, said last means including control means whereby different temperatures may be maintained in said parallel paths of air circulation.

10. In the combination of claim 8, said last means comprising longitudinal ducts in the wall of the low pre-heat section of said housing, means for sub-dividing said ducts and individual means for circulating air through said ducts sub-divisions into heat exchange relation with said heat exchanger and the ware.

11. In a tunnel kiln refractory housing forming a low preheat section through which ware stacks may be moved, means for passing heated gases through said section along confined paths, means for causing a continuous circulation of air in heat exchange relation with said last means, and means for discharging such air after absorption of heat from said first means downwardly onto the ware stacks in a series of longitudinally aligned parallel paths in planes at right angles with the path of movement of the ware stacks, and means for maintaining the air in said parallel paths at different temperatures.

12. In the combination of claim 11, said last means including means for introducing cool air in controlled amounts into said parallel paths.

13. In a tunnel kiln the combination comprising an elongated refractory housing forming a tunnel through which products to be heat treated move, said housing including a firing section having fuel burners and a preheating section having a heat exchanger therein, a pair of ducts in each side wall thereof, one duct of each pair lying in a plane above the other duct of that pair, the lower duct of each pair being near the base of the housing, means for connecting the upper duct of each pair with the tunnel of the preheating section so as to discharge air upwardly onto said heat exchanger, the lower duct of each pair being connected to the tunnel at the preheating section below the heat exchanger, and air circulating means interconnecting the lower duct of each pair with the upper duct of each pair respectively, whereby air is circulated from the lower ducts to the upper ducts to cause the air discharged onto said heat exchanger to circulate

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downwardly in the tunnel of the preheating section.

14. In the combination of claim 13, said air circulating means lying in recesses in the outer side walls of said housing at substantially the bottom level thereof.

15. In a tunnel kiln a refractory housing forming a tunnel through which cars bearing ware stacks may pass, said housing having a firing section, means for generating high temperature gaseous products of combustion at a plurality of longitudinally spaced points in said section, means for directing the products of combustion from some of said generating means so as to directly impinge them on the adjacent ware, means for directing the products of combustion from the others of said generating means upwardly to the top of said tunnel and downwardly onto the ware, and means for withdrawing the products of combustion from the tunnel of the firing section at a plurality of longitudinally spaced points in differently controlled amounts near the bottom of the tunnel.

16. In a tunnel kiln, a refractory housing having a high pre-heat section forming a passageway through which ware to be treated may be moved in stacks, means for supplying hot gases to the passageway thereof comprising pairs of ducts in the side walls thereof, the ducts of each pair being arranged one above the other, the walls forming the passageway, a plurality of longitudinally spaced ports connecting the upper duct of each pair with the passageway and ports in said walls connecting the lower duct of each pair with said passageway and means for causing hot gases to move through the upper ducts of each pair into said passageway and from said passageway into the lower ducts of each pair.

17. In the combination of claim 16, means for independently varying the size of the ports of one of the ducts of each pair to produce different temperature conditions longitudinally of the passageway.

18. In the combination of claim 16, said first ports opening into the passageway near the top of the ware stacks and said second ports opening into the passageway near the bottom of the ware stacks.

19. In the combination of claim 16, said upper ducts of each pair being of gradually diminishing cross sectional area in the direction of gas flow and the lower ducts of each pair being of gradually increasing cross sectional area in the direction of gas flow.

20. In the combination of claim 16, said housing having a low pre-heat section, and a heat exchanger in said low pre-heat section in direct communication with the lower ducts of each pair.

21. In the combination of claim 16, said housing having a low pre-heat section, and a heat exchanger in said low pre-heat section in direct communication with the lower ducts of each pair, and means for causing the circulation of air in closed circuits first in heat exchange relation with said heat exchanger and then with the ware.

22. In the combination of claim 16, said housing having a low pre-heat section, and a heat exchanger in said low pre-heat section in direct communication with the lower ducts of each pair, and means for causing the circulation of air in closed circuits first in heat exchange relation with said heat exchanger and then with the ware, said last means including ducts in the housing wall having a plurality of sets of openings ar-

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anged to discharge gases into said passageway into heat exchange relation with said heat exchanger while moving in a direction toward said passageway.

23. In the combination of claim 15, said last means including ducts in the housing wall, a high preheat section also formed by said housing, and means for directly transferring the products of combustion from said ducts directly into the tunnel of said preheat section.

24. In a tunnel kiln the combination comprising a refractory housing forming a tunnel through which ware stacks may be passed, the entrance end of said tunnel forming a preheating section, ducts in said housing at the preheating section for supplying heated gases to the tunnel at that section and removing them therefrom, said ducts being sectionalized, power driven blowers in each section of said ducts arranged at the sides and at the bottom of said housing and directly accessible from the exterior thereof.

25. In the combination of claim 23, said blowers including housings which can be set into openings in the sides of the housing to effect interconnection of said ducts.

26. In a tunnel kiln, a refractory housing forming a tunnel through which ware stacks may be moved on cars, said housing including a cooling section, means for introducing air into the tunnel kiln of the cooling section under pressure at a plurality of longitudinally spaced points, said last means being spaced laterally of the ware so that the incoming cooling air is warmed by admixture with the atmosphere in the tunnel kiln of the cooling section before it strikes the ware, and means for withdrawing the air from the tunnel kiln of the cooling section near the bottom of the ware stacks at a plurality of longitudinally spaced points.

27. In the combination of claim 26, said last means comprising ducts for introducing the cooling air into the tunnel of the cooling section at a plurality of longitudinally spaced points, whereby the cooling air is caused to circulate transversely of the tunnel in a plurality of substantially isolated bodies to maintain different temperature conditions in the tunnel.

28. In a tunnel kiln the combination comprising a refractory housing forming a tunnel through which products to be heat treated are moved, said housing including a firing section having fuel burners and a preheating section having at least one pair of ducts in the side walls thereof, each connected with the tunnel by lateral ports, one of said ducts being at the base of the housing and the other near the top, and circulating means for withdrawing the products of combustion of said fuel burners from the tunnel of said firing section into said lower duct and for discharging said products into said top duct, said products moving from said top duct through its lateral ports into the tunnel at the preheating section.

29. In the combination of claim 28, a second preheating section having at least one pair of ducts in the side walls thereof and connected with the tunnel by lateral ports, one of the ducts of that pair being at the base of the housing and the other near the top, and circulating means for withdrawing the products of combustion from the duct at the first preheating section into the lower duct of said second pair of ducts, and discharging them into the top duct of the second pair,

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whereby said products are discharged into the tunnel at the second preheating section.

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