Oct. 23, 1923.

1,471,875

L. A. WITTE

TUNNEL KILN

Filed June 24, 1918

5 Sheets-Sheet 1

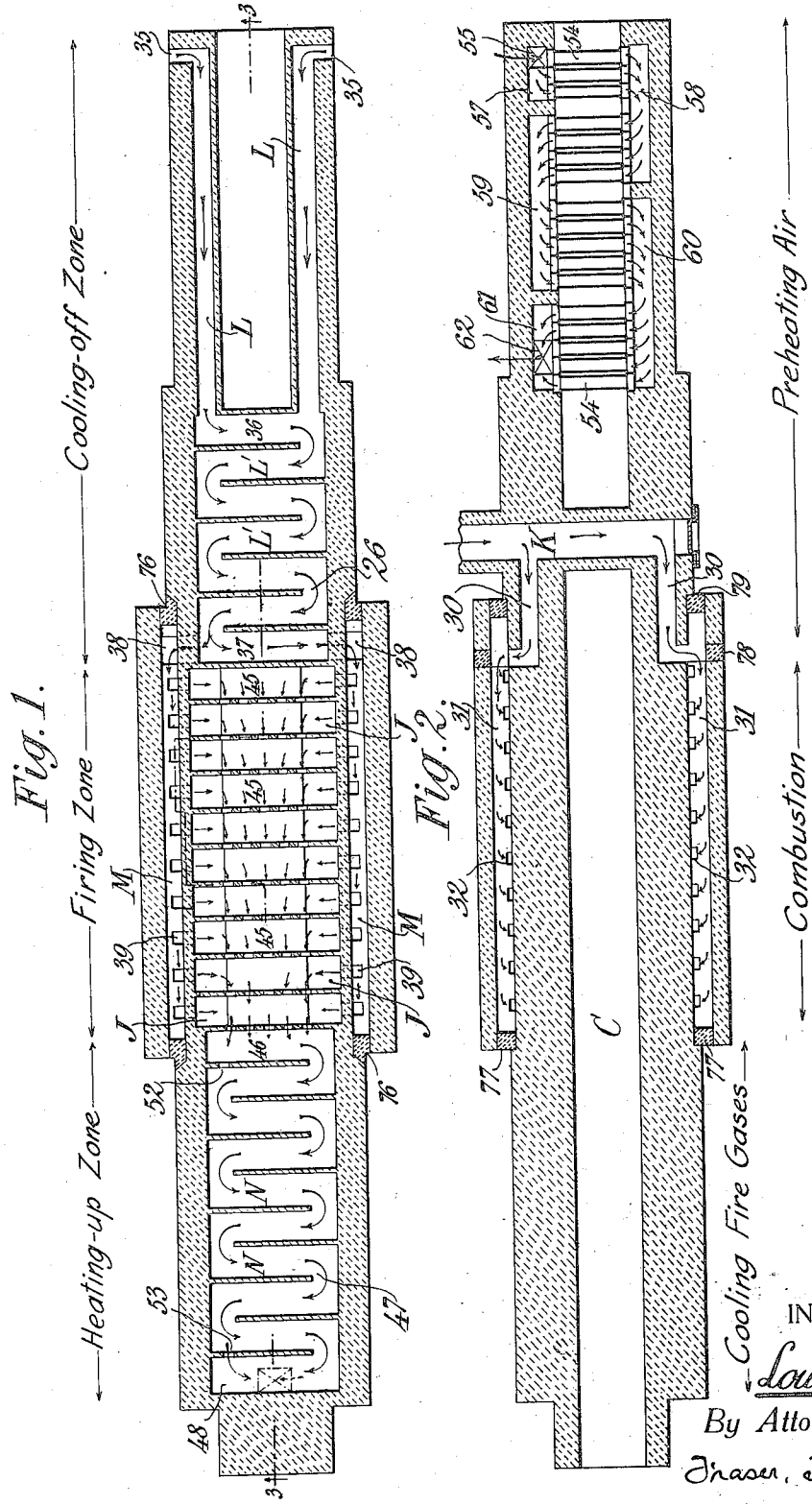


Fig. 1.

Fig. 2.

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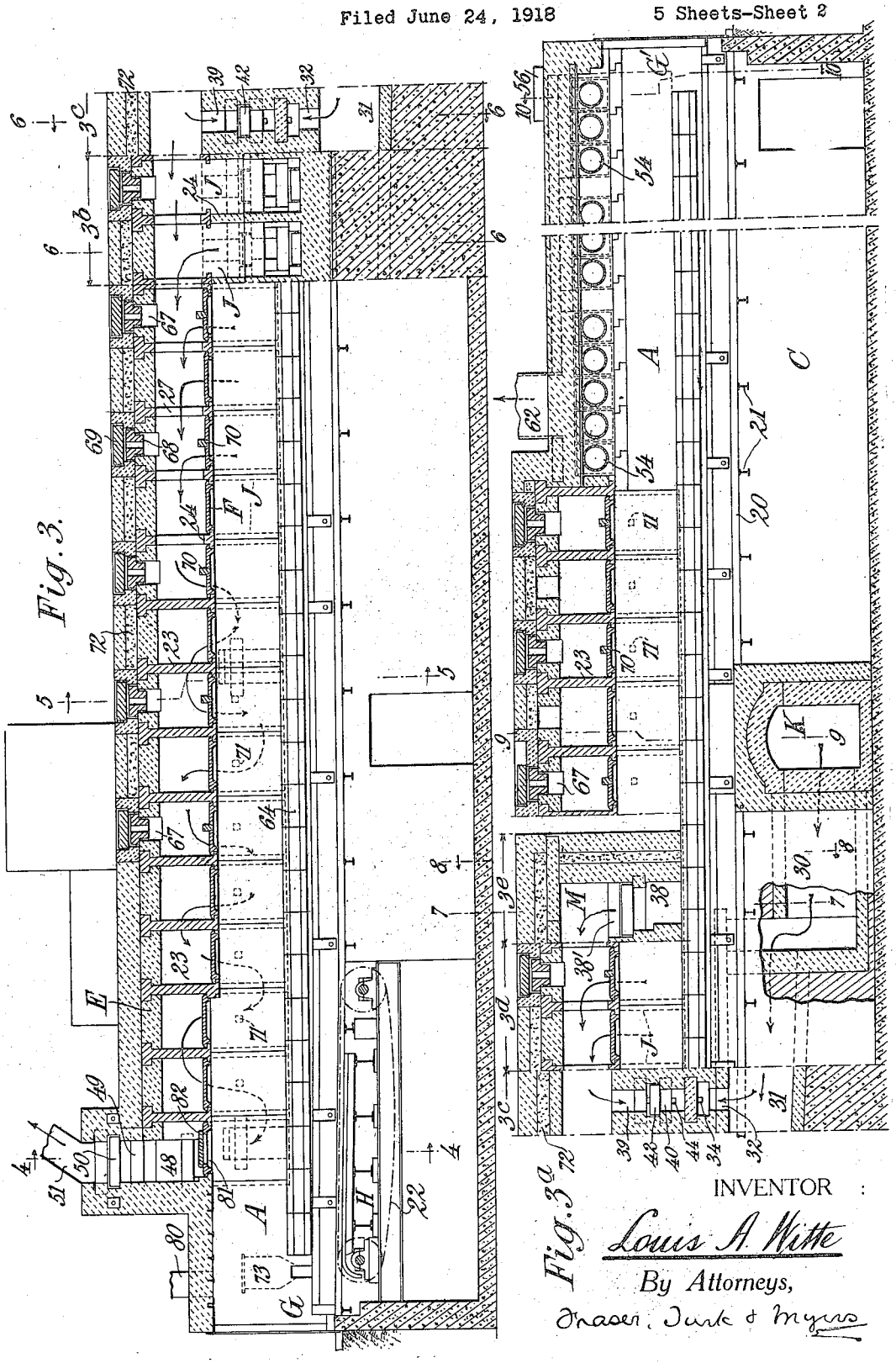


Fig. 3.

Fig. 3a

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Fig. 4.

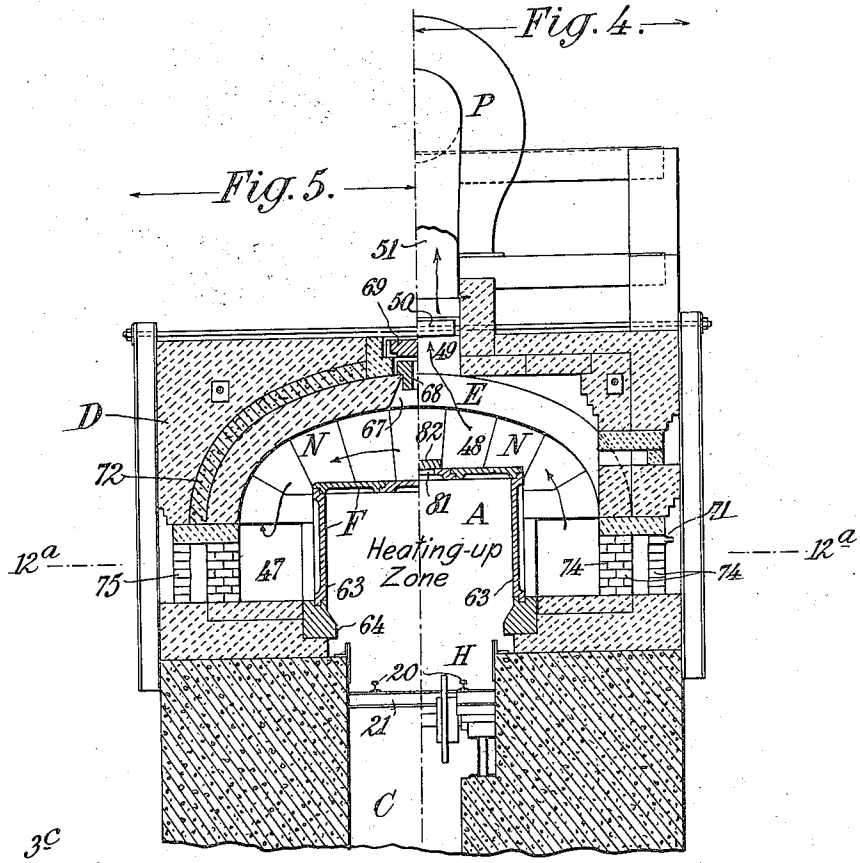
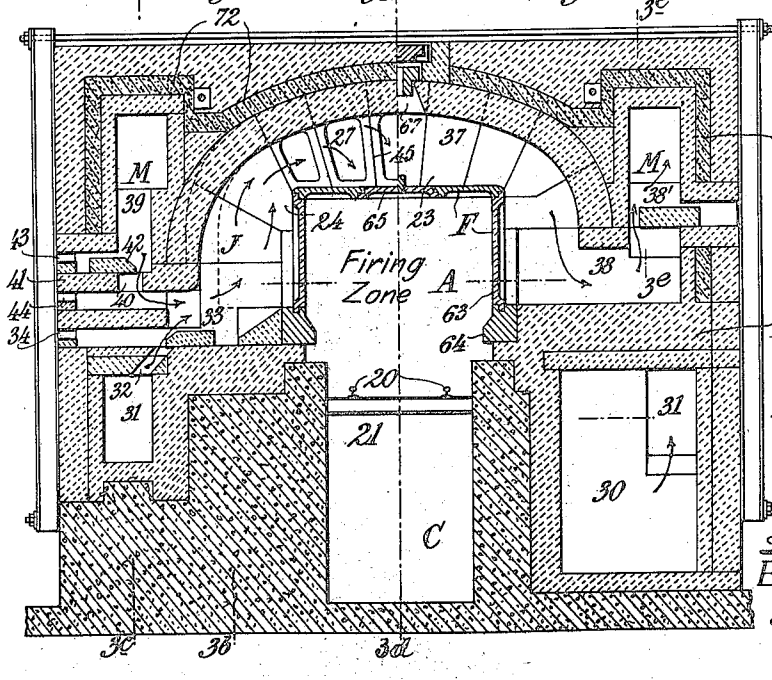


Fig. 5.

Fig. 6.

Fig. 7.



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Fig. 9. Fig. 8.

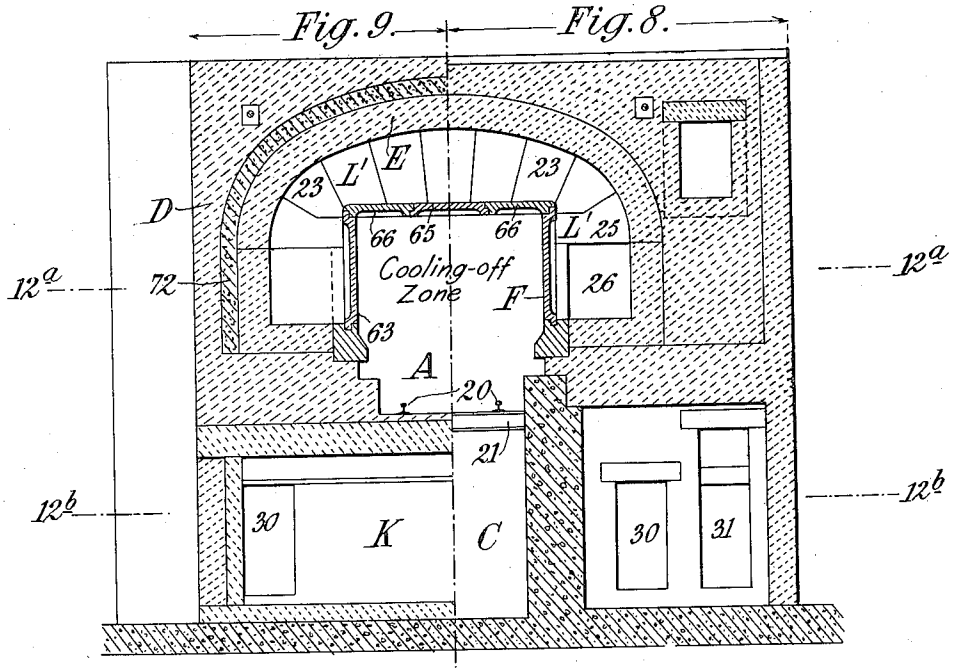


Fig. 11. Fig. 10.

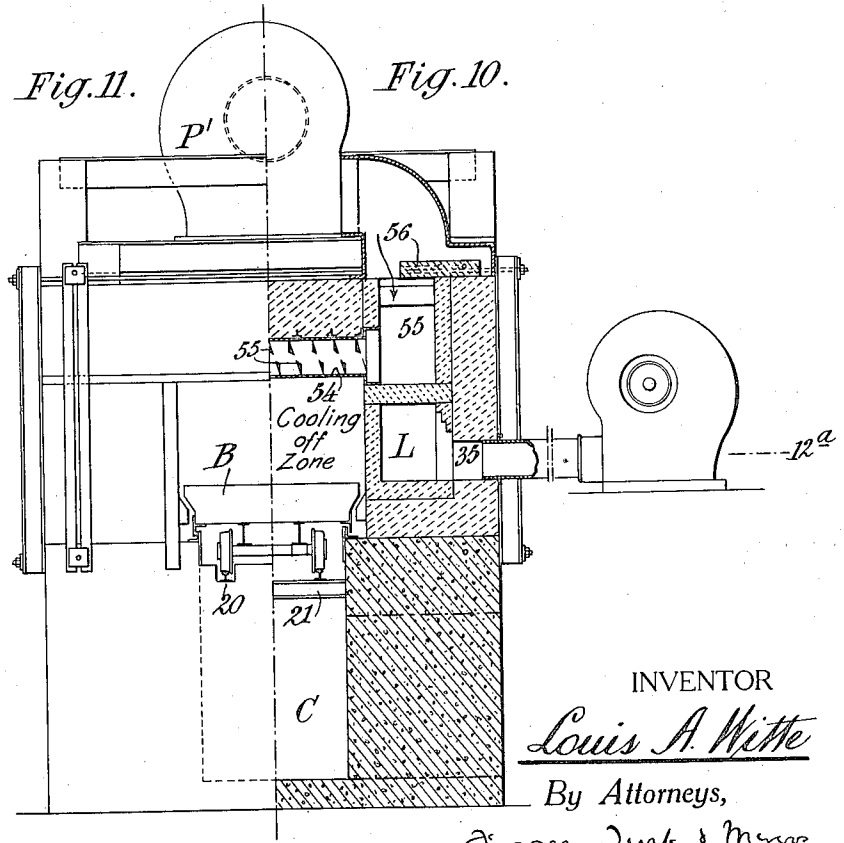


Fig. 17.

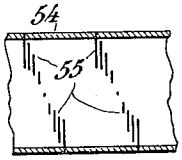
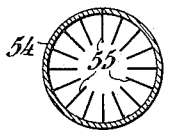


Fig. 18.



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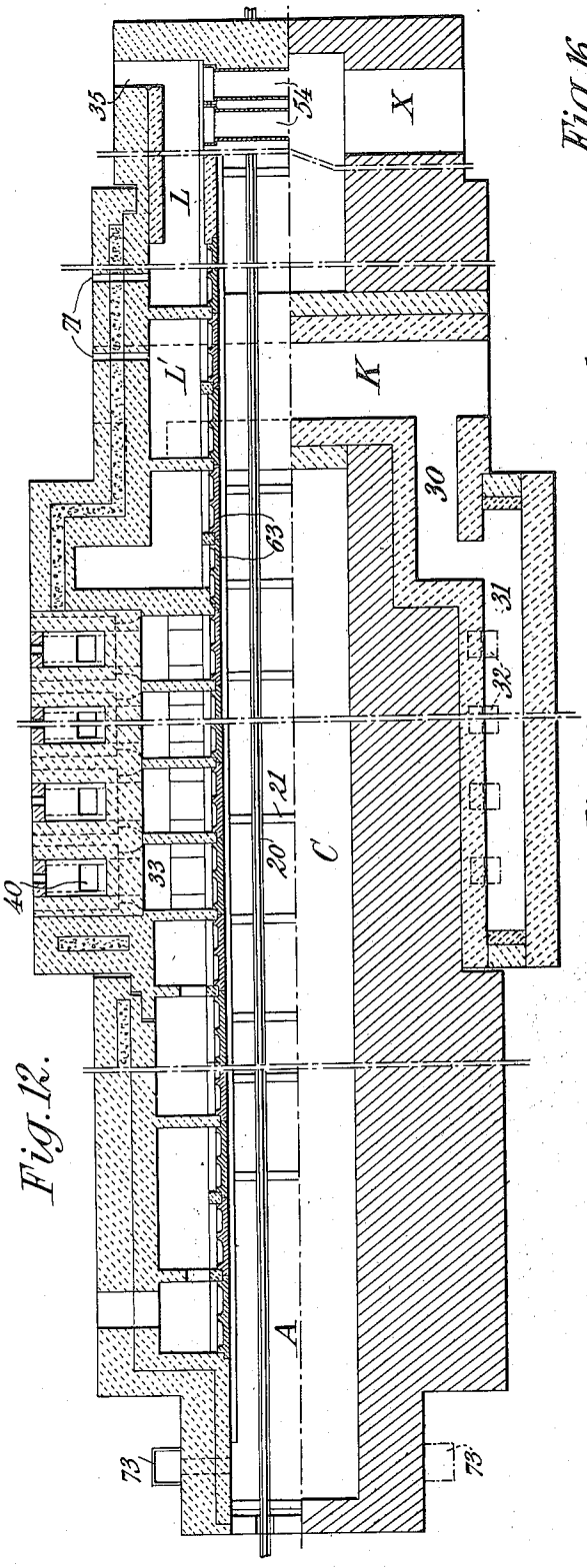


Fig. 12.

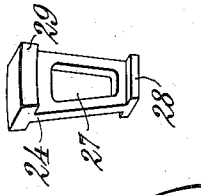


Fig. 16.

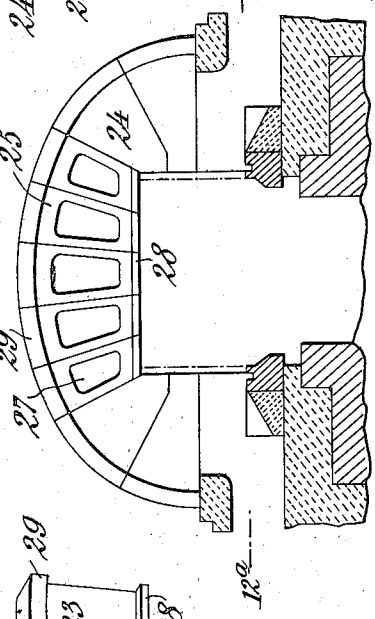


Fig. 15.

Fig. 14.

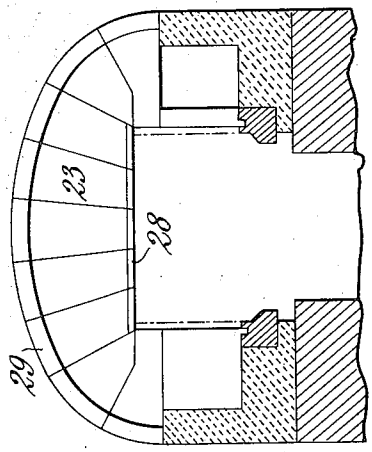


Fig. 13.

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Patented Oct. 23, 1923. 1,471,875

UNITED STATES PATENT OFFICE.

LOUIS A. WITTE; ELIZABETH WITTE ADMINISTRATRIX OF SAID LOUIS A. WITTE, DECEASED, OF METUCHEN BOROUGH, NEW JERSEY.

TUNNEL KILN.

Application filed June 24, 1918. Serial No. 241,472.

To all whom it may concern:

Be it known that I, LOUIS A. WITTE, a citizen of the United States of America, residing in borough of Metuchen, in the county of Middlesex and State of New Jersey, have invented certain new and useful Improvements in Tunnel Kilns, of which the following is a specification.

This invention relates to kilns or ovens of the tunnel type, the wares to be subjected to heat treatment being carried through a longitudinal tunnel chamber on suitable cars. Such kilns are useful for various baking, roasting, annealing or firing operations. They are used for example for the annealing of metal articles and for the firing of porcelains.

Tunnel kilns are of two general types: (1) those in which the wares to be fired (or their enclosing receptacles or saggers) are exposed to direct contact with the flames or with the hot fire gases or products of combustion, such kilns being commonly used for the firing of earthen ware or porcelain, and for the firing of bricks or the like, and for other similar purposes; and (2) those of the type of muffle furnaces in which the tunnel chamber is formed with a lining or shell which is heated externally by the combustion of gases, and through which the heat is transmitted to the wares or their receptacles carried on the cars so that the wares or receptacles are not exposed to direct contact with fire gases.

The present invention relates particularly to the latter or muffle type of tunnel kilns, although in its generic features it is applicable in part to the former or open tunnel type.

In either type of tunnel kiln it is customary to divide the length of the tunnel into three zones, viz: (1) a heating-up zone in traversing which the car-loads of wares to be treated are exposed to the heat of the waste fire gases, and are thereby gradually heated up as they progress toward the zone of highest temperature; (2) the firing zone, or zone of highest temperature, where the heat treatment is accomplished and which approximately coincides with the zone in which the combustion of fuel takes place; and (3) the cooling-off zone, in which the wares as they progress away from the firing zone are gradually cooled, their heat being commonly economized by being used to preheat the entering air which is to support the combustion.

The principal object of the present invention is to provide for the more effective control or grading of the temperature longitudinally of the furnace throughout the firing zone. Heretofore in tunnel kilns the heat has been generated in combustion chambers extending longitudinally of the tunnel, and in chambers thus located it is impossible to accomplish any close regulation or grading of the temperature, because the burning gases or flames travel in a longitudinal direction. Attempts to control the combustion by introducing thereto fuel at successive longitudinal points in such combustion chambers have been only partially successful. According to the present invention heat is generated in a series of distinct combustion chambers arranged transversely of the tunnel, and in each of which the combustion is regulated independently of the others. Any desired number of such combustion chambers may be provided according to the desired length of the firing zone. By this means any desired heating effect may be obtained, the greatest heat being imparted either at the beginning, middle or end of the firing zone, or a level temperature being maintained throughout such zone, as may be required for any particular service; or the firing zone may be lengthened or shortened by throwing one or more of the combustion chambers into or out of service.

Another important object of the present invention is to provide means for more effectively utilizing the heat of the waste fire gases for preliminary heating up of the wares to be treated; and for more effectively accomplishing the cooling off of the treated wares and utilizing the heat radiated therefrom for the heating of air for supporting combustion, or for other uses. To these ends flues are provided between the muffle or tunnel lining and the masonry structure of the kiln, in which the air or gas is caused to flow repeatedly back and forth across the roof of the tunnel and against the sides thereof.

The invention further provides an improved tunnel kiln structure, possessing many advantages in the building of the

kiln, in the repair or replacement of burnt-out parts, and in the adjustment or adaptation of the kiln for varying requirements.

The preferred form of muffle kiln embodying this invention is illustrated in the accompanying drawings, wherein,—

Figs. 1 and 2 are schematic plans in horizontal section, the former illustrating the circulation of the entering air, of the combustion gases and the waste fire gases; and the latter illustrating at the right-hand end the air circulation for the final cooling-off of the treated wares, and in its remaining portion the circulation of gaseous fuel.

Fig. 3 is a vertical longitudinal section of the furnace, and Fig. 3ª is a continuation thereof. These views are in vertical mid-section except for the portions indicated by the arrows 3ᵇ, 3ᶜ, 3ᵈ and 3ᵉ which are respectively in vertical longitudinal planes denoted by the correspondingly lettered dotted lines in the later figures.

Figs. 4 to 10 inclusive are one-half sections grouped in pairs (Fig. 10 with Fig. 11) and being respectively upon the planes of the correspondingly numbered lines in Figs. 3 and 3ª.

Fig. 11 is a half elevation at the emerging end where the cars pass out.

Fig. 12 is a horizontal section, the upper half being on the plane of the lines 12ª in Figs. 4–10 and 15; the lower half is in the plane of the line 12ᵇ in Figs. 7–9.

Figs. 13 and 15 are transverse sections in the same planes respectively as Figs. 8 and 6, showing the furnace partly built.

Fig. 14 is a perspective of one of the partition tiles in Fig. 13, and

Fig. 16 is a similar perspective of one of the tiles in Fig. 15.

Figs. 17 and 18 are respectively an enlargement of a flue 54 shown in Fig. 10, and a cross-section thereof.

The entire structure is built up of masonry upon suitable foundations so as to form a tunnel chamber A through which travel cars B (Figs. 10 and 11) running on rails 20 supported on girders 21 which bridge across a pit C.

The main masonry structure of the tunnel designated as a whole by the letter D comprises side walls, and a roof, the latter formed preferably as an arch E. This masonry structure or arch (whatever may be its form) is considerably larger than the tunnel chamber A, so as to afford between them a flue space, as is clearly shown in Figs. 8 and 9; or a corresponding combustion space as is shown in Fig. 6. This flue or combustion space is separated from the tunnel chamber by a succession of relatively thin refractory tiles forming the muffle partition or tunnel lining F. The tunnel chamber A is continuous from the entering end (Fig. 3), which is provided with a door G, to the emerging end (Fig. 3ª) which is provided with a door G′. The cars carrying the goods or wares to be treated are introduced through the door G and are propelled forward through the tunnel, either continuously or intermittently by means of any known or suitable mechanism, such for example as a chain propeller apparatus such as is schematically indicated at H in Figs. 3 and 4, an endless chain 22 being carried on pulleys and driven from any suitable source of power and carrying any suitable means for engaging the cars to push them ahead; such apparatus being well understood and forming no part of this invention, requires no further description.

The flue space between the arch or other structure E and the muffle partition or tunnel lining F is divided at frequent intervals to provide transverse flues and combustion chambers by means of partitions 23 between the flues and 24 between the combustion chambers. These partitions project inwardly from the masonry structure, being pendant partitions at the roof portion, and serve to support and locate the tiles forming the tunnel lining F. Their specific construction will be described later.

Throughout the middle or firing zone of the kiln the transverse partitions 24 form a succession or series of combustion chambers J J flanking the tunnel chamber, one such combustion chamber being shown in Fig. 6, and others in the section 3ᵇ of Fig. 3. The number of these chambers may vary according to requirements, the kiln illustrated having, for example, ten pairs of such combustion chambers, of which all or any part may be used.

The fuel for heating the kiln may be either gas or oil, or solid fuel, as coal or coal dust. If oil is used, it will be injected into the combustion chambers by means of an atomizer in the well-known manner, by using either compressed air or steam. If gas is used, it may be either producer gas, natural gas or gas from other sources. For using coal dust any of the known means may be used for flowing it in. For burning solid coal, the usual grate bars will be provided.

The furnace illustrated is designed for using gas, which is admitted through a gas main K, Fig. 2. This main extends across the pit C, as shown in Fig. 3ª, so as to serve both sides of the kiln. From it lead flues 30 which lead to distribution flues 31 on opposite sides, these flues extending longitudinally through the flanks of the kiln, and beneath the level of the combustion chambers. From these flues gas inlets 32 lead upward into the bottoms of the combustion chambers (see Fig. 6), the flow of gas through each of such inlets being controlled by means of a damper 33 consisting

of a brick or tile resting on the hearth of the combustion chamber, and which may be moved by means of a poker inserted through a hole 34 to close more or less of the inlet opening 32.

The air to support combustion enters at the emerging end of the furnace through inlet openings 35 on opposite sides (Fig. 1), one such inlet being shown in Fig. 10; and flows thence longitudinally through air heating flues L L, which are shown in Fig. 1, alongside the tunnel chamber in the cooling-off zone, where heat is being given off by the wares as they cool. The air flows in a direction contrary to the movement of the cars, and consequently as it becomes heated, it enters continually a hotter portion of the cooling-off zone. The flues L L unite in a flue 36, whence the air flows back and forth through a succession of transverse flues L′ L′ (Fig. 1) which pass back and forth across the top of the tunnel chamber and extend down the sides thereof, as shown in Figs. 8 and 9. These flues are separated by the partition tiles 23 already referred to, which on each alternate side extend down to the floor of the masonry (as shown in Fig. 9), the intervening tiles terminating at 25, so as to leave an opening 26 beneath (as shown in Fig. 8) through which the air flows to the next transverse flue ahead. The air is thus given a zigzag course surrounding the hottest portion of the cooling-off zone of the kiln. The terminal cross flue 37 (Figs. 1 and 7) discharges to both sides of the kiln through an outwardly directed branch 38, and thence upwardly, as shown in Fig. 7, under control of a damper 38′ into a trunk flue M. The flues M on opposite sides are located with respect to the combustion chambers J in the manner shown in Fig. 6, and from them lead downwardly branches 39 from which the air flows through openings 40 into the respective combustion chambers. Each opening 40 is formed in a ledge or sole-plate 41, over which is placed a damper 42 consisting of a brick or tile, which may be adjusted by a poker inserted through a hole 43 to more or less close the opening 40, and thereby regulate the admission of air. Beneath the sole-plate 41 is a peep-hole 44 through which the combustion may be observed, and through which a pyrometer may be inserted into the combustion chamber J if desired.

In each combustion chamber J the combustion is regulated by suitably adjusting the dampers 33 and 42 according to the quality of gas used, the intensity of the heat to be generated in the combustion chamber, and any other controlling conditions. Normally the combustion chamber J will be more or less filled with flames or burning gases according to the amount of fuel admitted, the desirable adjustment of the air damper being such as to perfect the combustion. The hot fire gases rise through the upright portion of the combustion chamber, imparting heat to the side tiles of the tunnel lining F, and thence follow the arch over the top of the tunnel chamber, whereby the top lining tiles thereof are heated. From the pair of combustion chambers on opposite sides of the tunnel the fire gases flow together in transverse eduction chamber 45, and pass out through openings 27 in the upper tiles 24, flowing thence in the direction indicated by the small arrows in Fig. 1 toward the stack or outlet and into the next following transverse chamber 45, uniting the next pair of combustion chambers in advance. The openings 27 may vary in number and size, five openings being shown partly in the half section (Fig. 6) and partly in Fig. 15, which shows the entire series of tiles.

From this construction there results a cumulative flow of fire gases or hot products of combustion from the connecting chambers 45 of the successive pairs of combustion chambers. As compared with taking the fire gases immediately upward from the pairs of combustion chambers into an overhead trunk flue leading to the stack, this construction has the advantage of keeping the hot gases down close against the ceiling of the tunnel lining F so that their heat is most efficiently imparted to such lining, whereby the top of the tunnel lining, which is the most difficult portion to heat, is thereby heated in the most efficient manner. In the successive chambers 45 there is, following the flow of the gases, an increasing or cumulative volume of gases flowing, and this varying volume may be provided for by proportionately varying the sizes of the openings 27, if such be desired, or be in any given case found necessary. The tiles 24 may be formed with openings of graded sizes, or the openings may be of the maximum size and be more or less restricted by blocking them by inserting fire bricks, or other refractory medium.

From the last of the chambers 45 the totality of fire gases enters a transverse flue 46 (Fig. 1) which constitutes the first of a series of zig-zag transverse waste gas flues N N, these flues being shown in Figs. 4 and 5. The construction is the same as was explained with reference to Figs. 8 and 9, that is to say, the partitions extend alternately to the floor of the masonry on opposite sides, so that alternate openings 47 are provided beneath the partitions, whereby the waste gases are caused to flow alternately back and forth over the top of the tunnel chamber and down the sides thereof, whereby their waste heat is effectively imparted to heat the tunnel lining F, and thereby transmit heat to heat up the wares which are progressing

through the heating-up zone toward the firing zone. The final transverse flue 48, shown in Figs. 1 and 4, leads to an outflow opening 49, controlled by a damper 50 and leading to the intake 51 of a suction fan P. Preferably the partitions limiting the flues 46 and 48 are provided with openings 52 and 53 respectively (Fig. 1) for short-circuiting a portion of the flow of gases.

The air inlet trunk flues L absorb only a portion of the heat given off by the treated wares in the cooling off zone. Ordinarily, these wares give off more heat than can be utilized for preheating the air to support combustion. It is desirable to utilize this surplus heat and to afford the most efficient cooling of the treated wares; and for these purposes this invention provides additional air cooling means comprising transverse flues, crossing and re-crossing the top of the tunnel chamber, and through which the air is caused to flow. The preferred construction is that shown in Figs. 2, 3ª and 10. Large tubes 54 which may be of cast iron are arranged to cross the top of the tunnel chamber A, these being arranged in successive series, as shown in Fig. 2. Air is forced in by means of a fan P′ (Figs. 10 and 11) through an inlet 55 controlled by a damper 56 into a flue 57 which distributes the air to the transverse pipes 54 of the first cross-over series (shown as three pipes in Fig. 2), whence the air enters a flue 58 on the opposite side which distributes it to the next cross-over series of pipes 54 (shown as consisting of four pipes); from these the air enters a flue 59, whence it is distributed to the third cross-over series of iron pipes (comprising five pipes as shown), and from these it enters flue 60, whence it flows through the last series of cross-over pipes (shown also as comprising five pipes), and is collected in a flue 61, whence it passes to an uptake 62 (Fig. 3ª), from which a conduit may lead the heated air to any place where its heat may be utilized, as for example for feeding a gas producer. As the heat from the car-loads of hot wares tends to rise, it is very efficiently conducted to the extended surface of the pipes 54, and from these pipes the heat is imparted to the forced currents of air flowing through them.

The length of the cooling zone with cross-over pipes 54 may be varied as required, and consequently the number of these pipes, and the number of groups of pipes may be greatly varied.

To facilitate the conduction of heat to the air, it is desirable to provide the pipes 54 with internal projections which are best constructed as shown in Figs. 17 and 18. These figures show lugs or slender projections 55, such as iron nails, which are cast integrally with or fastened strongly to the pipe 54, and project a suitable distance into the pipe, so that they enter the stream of air and conduct the heat effectively thereto.

Certain details of construction remain to be described.

Nearly the entire length of the tunnel chamber A is enclosed by the lining F, which is formed of tiles or slabs of suitable refractory material. These tiles are located by the successive transverse partitions 23 and 24, which partitions are built into the masonry structure at their outer portions and project thence inwardly, terminating coincidently with the outline of the tunnel chamber. The sides of the tunnel chamber are formed by the lining tiles 63 (Figs. 4 and 5) which rest on the member 64 which is built into the hearth portion of the kiln in the usual manner. This member 64 has in its upper face a groove which makes a free engagement with a flange on the bottom of the tiles. In building the furnace the masonry structure is erected, and the lining tiles are last applied. The side tiles 63 are first put in place from the inside. These tiles are of a width equal to the distance between centers of the partitions 23, 23 and 24, 24, and are pushed outwardly into place against these partitions, being located as shown in Fig. 12. The top tiles are then put in place and serve to prevent the tiles 63 from falling inward. The top tiles have each a width equal to the flues or chambers formed between the partitions 23, 23 and 24, 24. These partitions are formed with a bottom flange 28, shown in Figs. 13–16 on each side on which flanges the top tiles rest, as shown in Figs. 3 and 3ª. The middle top tile 65 is first put in place, and then the lateral top tiles 66—66 (Figs. 8 and 9) are applied, resting partly on the tile 65 and partly on the tops of the side tiles 63 and interlocking with the latter, so as to hold their upper ends in place.

The partitions 23 and 24 are best made of segmental tiles of fire-brick, as shown in Figs. 13 and 15, in which figures the tunnel lining F is omitted. These radial tiles, of which examples are shown in Figs. 14 and 16, are interlocked with the masonry arch at their outer portions, being for this purpose preferably built with upper or outer flanges 29. The tiles for the partition 24 differ from the tiles 23 only in that those over the top of the tunnel chamber are formed with the openings 27, as shown in Figs. 15 and 16. The described construction of the partitions 23 and 24 provides a very convenient means of forming the respective combustion chambers and transverse zig-zag flues, and at the same time gives very secure support to the lining tiles of the tunnel chamber. These tiles are made as thin as possible consistent with strength, in order to transmit heat readily, and are therefore the weakest part of the

entire structure; by the means described they are so effectively supported that breakage is extremely unlikely.

It is desirable to be able to get access to the respective combustion chambers, flues 45, and flues L' and N without disturbing the lining tiles F. For this purpose man-holes are provided through the roof of the kiln. As it is usually sufficient to be able to get access to every alternate chamber or flue, it is sufficient to provide such alternate ones with man-holes. For this purpose man-holes 67 are formed in the roof. These are closed by a perforated slab 68 and by a close fitting lid 69. By removing the lid 69 when the kiln is in operation the temperature in the chamber or flue beneath may be taken by introducing a pyrometer. The tile directly beneath this man-hole has a central stopper 70, which may be removed to insert a pyrometer into the tunnel chamber proper. When it becomes desirable to make repairs or readjustments, it is only necessary to shut off the gas for a suitable time, and then remove the lid 69 and cover 68 from any man-hole, whereupon a workman may reach down with suitable tools into the flue or chamber beneath, and make any necessary repairs to the partitions on either side, or in the same way access may be had to the openings 27 for enlarging or contracting them as occasion may require. Man-holes may be provided for all the chambers or flues instead of the alternate ones if preferred.

For more conveniently taking the temperature in the successive flues or combustion chambers, peep-holes 71 indicated in dotted lines in Figs. 3 and 3ª, or in section in Fig. 4, may be provided. These with the peep-holes 44 (Fig. 6) for giving access to the combustion chambers will enable all necessary temperature measurements to be taken.

The inner facings of all combustion chambers and flues should, of course, be formed of fire-brick or tile. The outer structural portions of the kiln may be built of ordinary brick. In between these it is preferable to provide a layer of insulating brick or other heat insulating medium, as shown at 72 in the respective figures. The masonry structure will be stiffened in the well understood manner by the use of tie-rods and bolsters. The cars used should have refractory floors, and to prevent undue heat reaching their running gear or entering the pit C, the usual sand luting is provided, the sand being introduced through hoppers, one of which is shown at 73 in Fig. 3.

For getting access to the several flues, clean-out openings are left at suitable positions in the permanent masonry, these openings being filled with brick laid loose and grouted with any suitable plastic material, such as clay, which can be broken out when it is desired to open the clean-outs. Such clean-out openings filled with loose bricks are indicated at 74 in Fig. 4, at 75 in Fig. 5, and at 76 in Fig. 1 for getting access to the air flue M, and at 77, 78 and 79 in Fig. 2 for getting access to the gas flues 31.

In operating the described furnace, it is generally preferable to maintain a slight pressure in the air and gas admission flues, combustion chambers and waste gas flues, as thereby a higher temperature is maintained which greatly increases the capacity of the kiln, and the heating is more uniform. To attain this result, it is only necessary to force in the fuel-gas, and the air for maintaining combustion, by means of blowers or other forcing apparatus.

In treating articles coated with oil or containing volatile hydrocarbons, it is desirable to draw off the hydrocarbon gas generated by the heat, either continuously or intermittently. This gas if rich enough may be utilized for combustion purposes. Where the gas is produced continuously in sufficient quantities, it is preferable to draw it off continuously by means of a special suction fan which should be located at the admission end of the kiln. This gas may for example be drawn off through an outlet conduit 80 (Fig. 3). Where the gases produced are not so rich, or are produced in very small quantities, it is sufficient to draw them off at intervals. When the gases are not of sufficient value to justify separate treatment, it is nevertheless important to remove them in order to avoid their generating any objectionable pressure in the tunnel which might occasion difficulty in operating the end doors, or which might lead to possible explosions. To this end an opening 81 is provided through the top tile communicating with the terminal flue 48 of the series N or elsewhere adjacent to the uptake 49, this opening being covered by a lid or damper 82 which may be operated through any suitable opening whereby it may be displaced either occasionally for intermittent drawing off of the gases, or very slightly for continuous drawing off thereof, by the exhaust fan. Instead of an exhaust fan drawing from the flue 51, a stack or chimney may be used.

It must not be inferred from the detailed illustration and description given that the invention is necessarily limited to the precise construction shown, or to any closely resembling this construction, as it is within the invention to vary the constructive features within wide limits as determined by the skill and judgment of the designing engineer, in order to adapt the kiln to any specific purpose for which it may be desired. The essential features of the invention are those first hereinbefore stated, and those

particularly set forth in the following claims:

I claim as my invention:—

1. A tunnel kiln comprising a continuous lining forming a tunnel chamber and an enclosing masonry structure forming an intervening space divided by transverse partitions, said structure having a central zone with combustion chambers, a heating up zone with flues for the circulation of combustion gases through such space around the chamber, and a cooling zone with air flues for heating air for combustion purposes by means of the heat transmitted through the walls of the chamber.

2. A tunnel kiln comprising a masonry structure and a lining at top and sides forming a tunnel chamber with an intervening space, and such space subdivided on opposite sides to form a succession of lateral combustion chambers flanking the tunnel chamber, with independent fuel and air inlets to such opposite chambers, and means for independently controlling the combustion in the individual chambers.

3. A tunnel kiln comprising a masonry structure and a lining forming a tunnel chamber enclosed thereby with an intervening space, and transverse partitions dividing the intervening space into combustion chambers, with independently controllable fuel and air inlets to such combustion chambers.

4. A tunnel kiln comprising a masonry structure and a lining forming a tunnel chamber enclosed thereby with an intervening space, and transverse partitions dividing the intervening space into combustion chambers, with independently controllable fuel and air inlets thereto, and openings in the successive partitions above the tunnel chamber for the cumulative outflow of fire gases.

5. A tunnel kiln comprising a tunnel chamber, a masonry structure enclosing it, successive transverse combustion chambers formed in the intervening space, longitudinal air and gas flues and inlets branching therefrom, and entering the respective combustion chambers, and dampers controlling such inlets.

6. A tunnel kiln comprising a masonry structure, and a tunnel lining enclosed thereby with transverse partitions sub-dividing the intervening space, and man-holes through the roof of the structure for giving access to the spaces between such partitions.

7. A tunnel kiln comprising a masonry structure, and a tunnel lining enclosed thereby with transverse partitions subdividing the intervening space, and manholes through the roof of the structure for giving access to the spaces between such partitions, said manholes having a closure comprising a lower perforated tile for the admission of a pyrometer and an upper tile for closing this opening.

8. A tunnel kiln comprising a masonry arch having inbuilt inwardly projecting refractory partitions, such partitions having flanges at their inner projecting ends, and tiles resting on such flanges and shorter than the spaces between the partitions, and free to be removed and replaced without disturbing the partitions.

9. A tunnel kiln comprising a masonry arch built with inwardly projecting refractory partitions having projections interlocked with the masonry of such arch, and having flanges at their inner projecting ends, and lining tiles for such tunnel chamber shorter than the space between such partitions and supported between such partitions by resting on the inner lateral projections thereof.

10. In a tunnel kiln, a masonry structure and refractory transverse partition tiles built into such structure, having on their outer portions lateral projections interlocking with the masonry, such tiles projecting inwardly therefrom to a tunnel chamber and having lateral projections on their inner edge portions, and lining tiles for such tunnel chamber shorter than the spaces between such partitions and supported between such partitions by resting on the inner lateral projections thereof.

11. A tunnel kiln comprising a tunnel lining and an enclosing masonry structure with refractory transverse partitions built into and interlocked with such structure and projecting inwardly to such lining, the lining comprising upright side tiles resting on the sole member of the masonry, and supported against outward displacement by contact with the upright portions of such partitions, and top tiles supported by said partitions and entering between the top of said side tiles whereby to hold them against inward displacement.

12. A tunnel kiln comprising an arched masonry structure, comprising an outer wall having poke holes, a tunnel lining, transverse combustion chambers, longitudinal feed flues and communicating branch flues, said branch flues having controlling means comprising slidable dampers, said dampers comprising horizontal sliding bricks adapted to be operated independently by pokers introduced through said holes.

13. A tunnel kiln comprising an arched masonry structure, a tunnel lining, transverse combustion chambers and longitudinal feed flues respectively for the induction of air and gas, and means for controlling the inlet of air to said air flue, comprising a vertical inlet opening to such flue and a tile damper slidable horizontally over said opening.

14. A tunnel kiln comprising a masonry arch with transverse partition tiles built into such structure and projecting inwardly, said tiles being built together in arch form and having continuous outer flanges interlocked with such masonry arch.

15. A tunnel kiln comprising a tunnel lining and an enclosing masonry structure, with partition tiles interlocked with such masonry and projecting inwardly therefrom to engage said lining, and the lining having side and top tiles jointed together and the top tiles supported by the partition tiles.

16. A tunnel kiln comprising an arched masonry structure with successive transverse partitions built thereinto and projecting inwardly therefrom, a tunnel lining engaging such partitions, the intervening lateral spaces constituting combustion chambers and the spaces above the tunnel lining forming eduction chambers, and the partitions formed with coinciding outflow openings through which the fire gases pass from said eduction chambers in longitudinal direction.

17. A tunnel kiln comprising a tunnel lining and an enclosing masonry structure, with transverse partitions built into such structure, said lining comprising side and top tiles, said side tiles having bottom flanges fitting in grooves to prevent their displacement and held against the partitions by the top tiles which fit between them and prevent their upper ends falling inward.

18. A tunnel kiln comprising an arched masonry structure, a tunnel lining, transverse combustion chambers and longitudinal gas and air feed flues, said feed flues communicating with said chambers by a series of branch flues, and dampers independently controlling said branch flues.

19. A tunnel kiln comprising an arched masonry structure, a tunnel lining, transverse combustion chambers, longitudinal feed flues and communicating branch flues, said branch flues having controlling means, comprising slidable dampers operating to regulate the combustion in said chambers.

20. A tunnel kiln having a continuous tunnel lining, and an enclosing masonry structure with combustion chambers formed in the intervening space, air heating flues extending from the discharge end of the kiln through such masonry longitudinally along the tunnel lining, and means for causing air to flow therethrough in direction opposite to the travel of the wares through the tunnel, whereby the air is heated from such wares, and controllable means for conducting such heated air to such combustion chambers for feeding the combustion.

21. In a tunnel kiln, means located toward the emerging end thereof for utilizing the heat radiated from the treated wares, while cooling, comprising successive pipes crossing the tunnel chamber transversely, and means for flowing air successively through said pipes, said means comprising a fan and controlling means comprising a slidable damper operating to regulate the flow of air into said pipes.

22. A continuous tunnel kiln comprising a tunnel lining and an enclosing masonry structure with combustion chambers formed in the intervening space, and transverse partitions dividing the intervening space, to form a zigzag flue, said partitions each extending across the top and partly down one side of said lining and down the opposite side to the bottom, and said partitions being alternated to connect the flue on alternately opposite sides, whereby the gases in such flue circulate over the top and sides of the tunnel lining.

23. In a tunnel kiln comprising a tunnel lining and an enclosing masonry structure with intervening transverse partitions, combustion chambers formed in such structure and zigzag flues conducting the waste gases from such chambers formed between such partitions, whereby the fire gases circulating through such flues communicate heat through the tunnel lining to heat the wares advancing through the tunnel toward the firing zone.

24. In a tunnel kiln comprising a masonry structure and a tunnel lining enclosed thereby with intervening partitions forming combustion chambers and flues, and an outlet for fire gases from such flues to an exhaust, means for drawing off from the tunnel chamber gases generated therein consisting of a damper-controlled opening communicating between such tunnel chamber and exhaust.

25. In a tunnel kiln, means located toward the emerging end thereof for cooling the treated wares, comprising successive pipes crossing the tunnel chamber transversely, and means for flowing air successively through said pipes.

26. In a tunnel kiln, means located toward the emerging end thereof for cooling the treated wares, comprising successive pipes crossing the tunnel chamber transversely, means for flowing air successively through said pipes, such pipes being grouped in series and connected to header flues at opposite ends, and means for flowing air through such flues and successive groups of pipes.

27. In a tunnel kiln, means located toward the emerging end thereof for cooling the treated wares, comprising successive pipes crossing the tunnel chamber transversely, and means for flowing air successively through said pipes, said pipes having inward heat conducting projections intercepting the flow of air.

28. A continuous muffle furnace comprising a tunnel lining for the top and sides of

the tunnel chamber, combustion chambers for directly heating such lining, and flues formed against said lining on the top and sides at a different longitudinal position of the furnace for leading in and preheating air to support combustion.

29. A continuous muffle furnace comprising an enclosing masonry structure, a tunnel lining within it, and a plurality of independently controllable lateral combustion chambers formed in the intervening space over a firing zone in said furnace for directly heating such lining, a common longitudinal exhaust passage through said space connecting with each of said combustion chambers to receive and unite the fire gases therefrom, and a single circuitous flue formed directly against said lining between said zone and the entering end of the furnace receiving the united gases from said passage and leading such gases in a circuitous path over a zone of the furnace between its entering end and the combustion chambers to preheat the wares traveling through the tunnel.

In witness whereof, I have hereunto signed my name.

LOUIS A. WITTE.