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[54] **TUNNEL KILN**

[75] Inventors: **Kurt Heldt,** Kronberg; **Hans Lappe,** Frankfurt, both of Germany

[73] Assignee: **Deutsche Gold-und Silber-Scheideanstalt vormals Roessler,** Frankfurt (Main), Germany

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[58] **Field of Search** 432/212, 213, 123

[56] **References Cited**

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Primary Examiner—John J. Camby

Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

There is provided a flame heated tunnel kiln for the firing or sintering of elongated ceramic molded articles. The articles are arranged in hanging fashion on a moveable arched cover over the upper shaft opening of the kiln. The kiln comprises a tunnel chamber having separating side walls opening outwardly into the flame zone in the region of the firing zone. There are also provided thin walled, fire resistant hollow blocks in said region. These hollow blocks are arranged so that they prevent relative movement to each other transversly of the furnace axis. Openings are provided in the blocks, burners are directed toward such openings. Hot gasses are removed in a composition below a cool air flow channel which is bounded by the upper tunnel chamber and opens thereto and a gap is provided for the inflow of outer air between the arched cover and the outer contour of the cool air flow channel.

8 Claims, 6 Drawing Figures

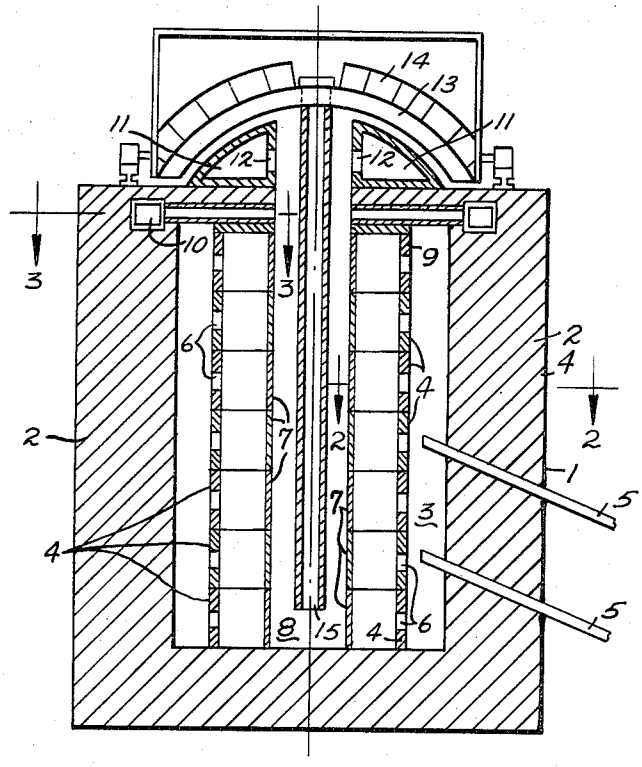
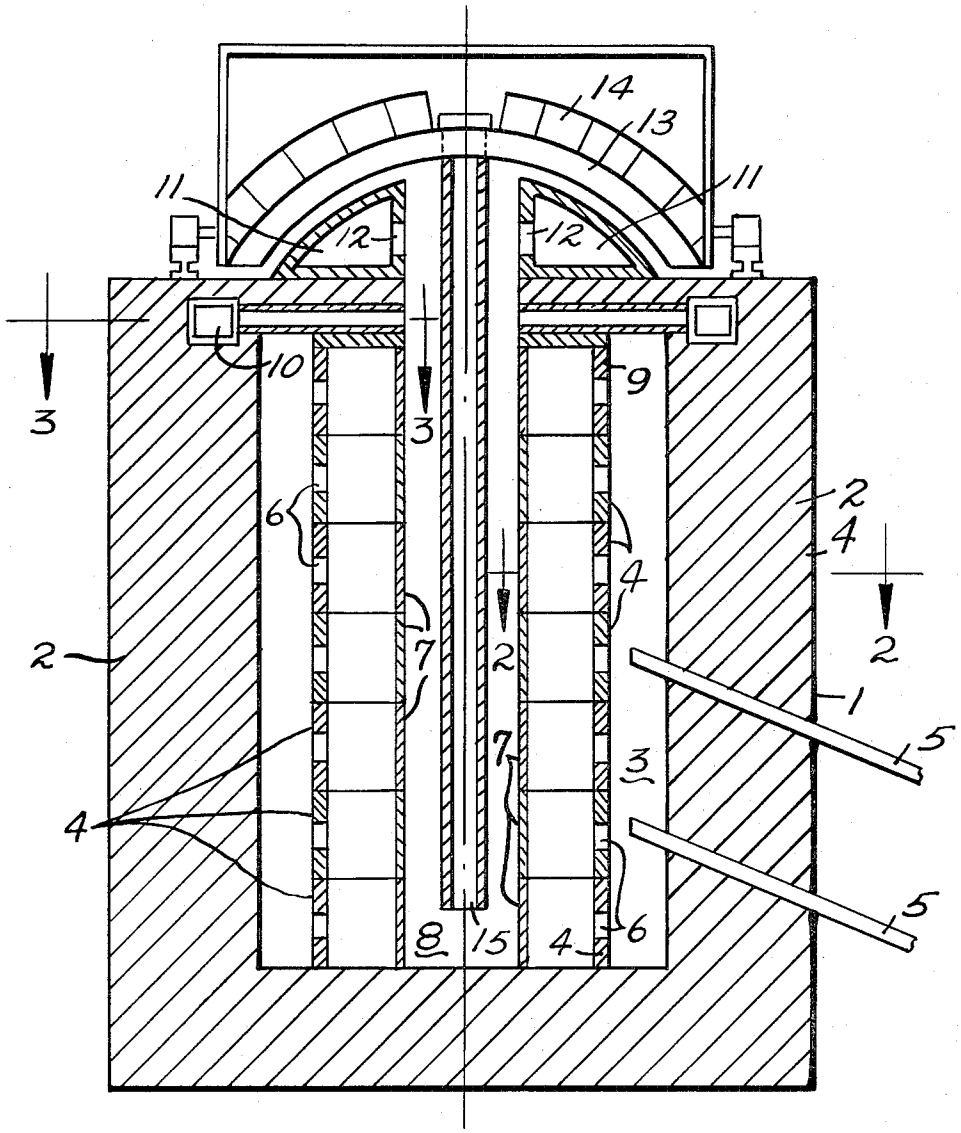


Fig. 1.



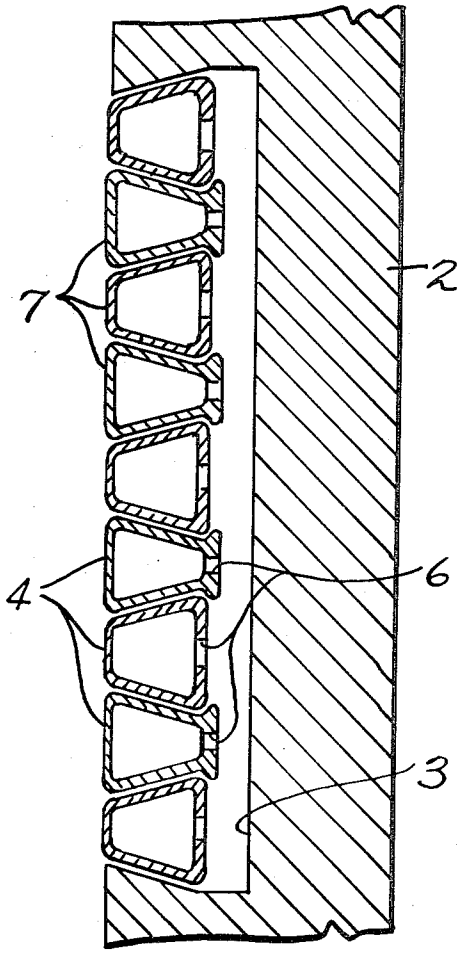


Fig. 2.

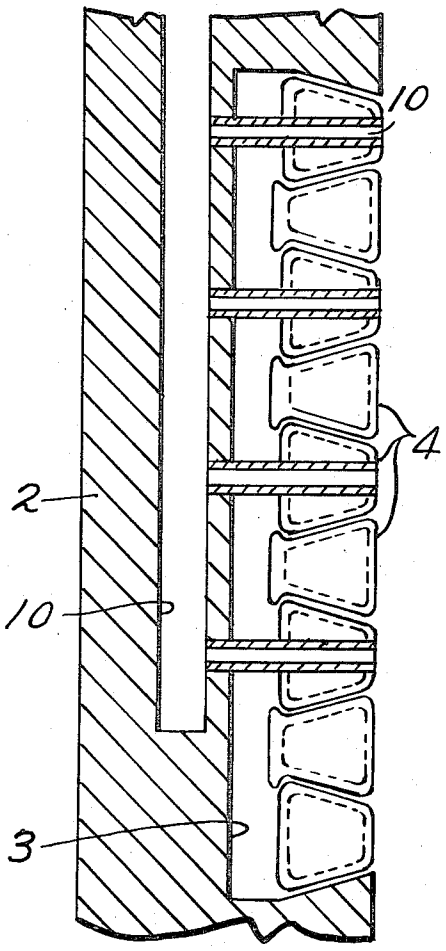
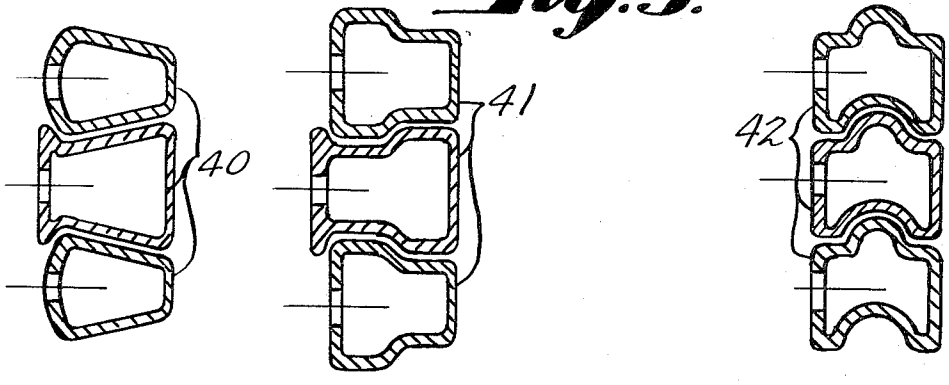


Fig. 3.

Fig. 4.

Fig. 6.

Fig. 5.



TUNNEL KILN

The invention relates to a flame heated tunnel furnace or kiln for the continuous firing or sintering of elongated ceramic molded articles suspended on an arch cover slidable over the upper shaft opening of the furnace.

In the heat treatment of articles made of ceramic raw material, a continuous method of operation or pass-through principle is used, in which the material that is to be treated is moved in or on supports continuously or in batches through the heating chamber of an elongated kiln. The conveying arrangements and the heating of such tunnel kilns are made in such a way that the goods which are mechanically still very sensitive and have been newly formed only by compression or slip casting are capable of withstanding the stresses of conveyance and the thermal demands during the slow heating process.

A special problem in the heat treatment of elongated molded articles, such as tubes, bars or strips is presented in that whenever they are moved in a horizontal position through such kilns, they are inclined to distortion and bending even when they are supported in numerous places. The heat treatment of elongated molded articles from ceramic materials, such as for example high melting oxides, which cannot be directly plastically deformed, present considerable difficulties. These molded articles are introduced into the kiln in a compressed or cast state for strengthening by means of sintering. The strength of such articles at the same time essentially is based on their content of organic and inorganic binders. The strengthening of the articles can be connected with a considerable shrinkage, the values of shrinkage amounting to between 5 and 25 percent of the original dimensions depending on the conditions of production and sintering.

Heretofore, elongated objects, such as for example, tubes, bars or strips, were fired mostly in periodically operating muffle furnaces or compartment kilns. In the case of a horizontal arrangement of the material to be fired, however, a considerable distortion develops as a result of the shortening connected with the shrinkage, since the material does not slide without friction on the support and since the heat affects it unevenly. Of course, this distortion can be decreased by the supports being built in the form of a prism or a supporting tube, but even in this case, the danger of bending cannot be excluded altogether. Also, the placing of several objects on top of one another in order to increase the stability of the entire bundle only limitedly remedies this situation, apart from the fact that in the case of many raw materials the molded bodies stick together. In the case of tubes, the distortion not only acts lengthwise, but also on the diameter, so that undesirable changes of the cross section occur.

For these reasons the art has changed over to subjecting elongated molded objects made of ceramic raw materials to a heat treatment in a vertical position. Molded articles, the length of which in comparison to the diameter is at a ratio of about 5:1 to maximally 10:1, can be fired upright, i.e., on the floor of the furnace, or they can be placed on a support moved through the tunnel kiln. Longer molded articles, however, will bend under the heat treatment. For this reason, molded articles with a larger ratio of length to diameter are subjected to the heat treatment while suspended in a vertical direction. For this purpose, periodically operating shaft kilns are used, in which the molded articles either are suspended in a furnace cover provided with perforations or they are mounted in so-called capsule towers which are closed on top with sewage blocks for the reception of the tubes.

These discontinuously operated shaft kilns naturally operate less economically than continuously operated kilns, and they are exposed to considerable wear and tear as a result of the periodic heating and cooling of the brick lining.

The transfer of the method of operation of the heat treatment of suspended molded articles from the shaft kilns to continuously operating tunnel kilns is not possible. For this purpose, it would be necessary to suspend the tubes, as in the shaft kiln, in sewage blocks which rest on capsules. Such a construction, however, is not sufficiently stable in the case of long molded articles to withstand the stresses of the continuous conveyance or conveyance by batches through such kilns at the high temperatures required for the sintering of pure metal oxides.

The heat treatment of elongated molded articles in continuous operation and in operation by batches also has already been made in such a way that the molded articles are suspended from supports which are guided along topside of the heating chamber of the furnace in the direction of its longitudinal axis. As a result of that, molded articles of any desired length can be subjected continuously to a heat treatment. This process per se is suited basically for the firing of ceramic molded articles such as tubes, bars or strips; however, a drawback is that the flame heated furnaces available for this purpose expose the material that is to be fired or sintered to the direct flame of the burner, whereby the strong turbulent affect causes frequent warping of the articles that are to be fired. To this must be added that the arch lid movable along and above the tunnel space and provided with suspending supports for the material to be fired is considerably exposed to the exhaust gases of the heating flames, which is a cause for continuous damage, such as formation of cracks or distortion. Of course, attempts have been made to prevent the flame gases from sweeping across the lid of the furnance by attaching projections at the underside of the arch lid which are to cooperate like a sand seal with longitudinal grooves containing grainy material, such as sand or corundum, disposed laterally on the upper side of the furnace. With this it was possible perhaps to hold back the hot flame gases but no satisfactory cooling of the arch lid could be achieved.

The object of the invention is to create a flame heated tunnel kiln (or tunnel furnace) which does not have the disadvantages described and which as a result makes possible an operation free of disturbances while avoiding the accumulation of waste.

This object is achieved by means of a flame heated tunnel kiln for the continuous firing or sintering of elongated ceramic molded articles arranged suspended on an arched cover slidable across the upper shaft opening of the kiln, which kiln is characterized by side walls separating the tunnel kiln in the area of the firing zone from the flame zone. The side walls are made of refractory hollow block elements constructed with thin walls toward the firing zone and open toward the flame zone, the shape and arrangement of which prevent relative movements with reference to one another trans-

versely to the kiln axis. The burners are directed toward the openings of the hollow block elements. Hot gas exhausts are removed by suction below a flow channel for cooling air bounding the upper tunnel chamber and opening toward it, whereby there is provided a gap for the inflow of outside air between the arched cover and the outside contour of the flow channel for the cooling air which is adjusted to it.

The hollow block elements serving to form the side walls can be made of the conventional refractory materials, such as for example chamotte, sillimanite and sintered corundum. The side walls shut off the burner space from the actual kiln chamber. The flames or waste gases therefore cannot directly strike the material that is to be fired, as a result of which there is avoided any mechanical influencing of the material to be fired which is sensitive in its untreated state by strongly eddying flame gases. The thickness of the side walls is dimensioned in such a way that a good heat transfer is maintained. Generally speaking, in the case of manufacture of hollow block elements from ceramic materials, material thicknesses between 10 and 40 mm will be needed. Ordinary places of this thickness placed one on top of the other would, however, not have sufficient stability in the case of temperatures up to 1,900°C occurring in the kiln. By incorporating the needed thin-walled heat transfer plate as a wall element into the hollow block elements used according to the invention, and which, moreover, have statically load bearing walls, this problem is solved in a surprisingly simple manner. The block elements, the hollow space of which receives the hot flame gases, therefore respresent an essential element of the invention. They also can be used as an advantageous construction element in known tunnel kilns which lack the remaining characteristics of the objects of the application.

While the hollow block elements can be assembled beside one another or on top of one another into a connected wall, with the use of a fire resistant mortar adapted to the sintering temperature, it is also effective to stack the elements only loosely on top of one another because, as a result of that, they retain a free movability during thermal expansion. The hollow block elements preferably are open at their top and undersides. In this way it will be possible for the flame gases, flowing into the lower wall element from the burners disposed, for example, in the lower part of the kiln, to flow upwards within a tower of elements located on top of one another and thus a temperature balance results between the lower and the upper parts of the kiln.

A considerable increase in the stability of the wall of the elements will be achieved by using elements, the shape and arrangement of which will prevent relative movements with reference to one another and especially in the direction transversely to the longitudinal axis of the kiln. A particularly effective form of the invention provides for the assembly of hollow block elements with a wedge-shaped cross section within a horizontal row of elements in alternating head/tail orientation. Slippage to the inside toward the kiln space and to the outside toward the burner space will be reliably prevented by these wedge-shaped wall elements pointing in the opposite directions.

A further variation of the invention provides hollow block elements succeeding each other within a horizontal row of elements, which engage one another at their lateral contact surfaces in meshing or tongue and groove fashion.

Finally, every second hollow block element disposed within a horizontal row of elements also can at least partially overlap the adjacent elements with one of its overhung surfaces. The burners leading to the hollow block elements opposite the apertures are adjusted best slantingly, preferably slanting upwards against the direction of movement of the material that is to be fired. This is advantageous in that a natural temperature gradient will appear as a result of the cooling waste gases, so that the material to be fired is heated slowly. The waste gases, as is customary, are suctioned off by way of a collecting channel and are used mostly to preheat the combustion air.

Another object of the invention is to avoid the overheating of the arched cover closing the firing or sintering zone of the tunnel kiln on top. This object is achieved by suctioning off the hot waste gases prior to their reaching the arched cover. In the case of stacked but not cemented connection of wall elements, the hot gases will penetrate in small quantity through its joints, however, by sucking in cold air at the same time through the gap between the cover and the discharge channel for cooling air connected via an aperture with the upper tunnel space and being under vacuum as a result of an induced draught.

At the same time, the removal by suction of hot gas can be accomplished by way of pipes, preferably ceramic, connected with a collecting line and disposed above the hollow block elements of the uppermost horizontal row of elements. The discharge channel for the cooling air, according to an advantageous embodiment of the invention, consists of elements made of refractory material connected at least at one end of the formed channel with an exhaust and assembled as a horizontal row, provided toward the tunnel space with at least one aperture and open on both sides in the longitudinal direction of the kiln.

According to another illustrative form of the tunnel kiln according to the invention however, the gap through which the cooling air is to flow from the outside can be connected with a source for compressed air.

The invention will be explained in more detail below on the basis of a preferred embodiment which is described in connection with the attached drawings wherein:

FIG. 1 is a vertical sectional view through the firing zone of a tunnel kiln according to the invention;

FIG. 2 is an enlarged fragmentary sectional view taken along the line 2 — 2 of FIG. 1;

FIG. 3 is an enlarged fragmentary sectional view taken along line 3 — 3 of FIG. 1;

FIG. 4 is a partial fragmentary sectional view similar to FIG. 2 showing another form of the hollow elements generally in the shape of a wedge;

FIG. 5 is a view similar to FIG. 4 of still another form of the hollow elements; and

FIG. 6 is another view similar to FIG. 4 of still another form of the hollow elements.

In FIG. 1 the reference number 1 designates, generally, the kiln which includes a housing defined by a surrounding brick lining or wall 2. The latter encloses a flame zone 3 which extends into a multiplicity of open ended hollow block elements 4, made of refractory ceramic raw materials, stacked one on top of the other to

form a pair of partitions or side walls. The flames are produced by burners 5. Each of the hollow block elements 4 has an opening 6 and a wall 7 acting as a heat radiating surface. The walls 7 provided by the elements 4 separate the flame zone 3 within the housing from a firing zone 8. The cross section of wall 7 is dimensioned smaller than that of the remaining walls of the hollow body. These remaining walls are dimensioned in such a way that the lowest elements of the wall are able to support the weight of the elements piled on them. In the case shown, wall 7 is 15 mm thick while the statically bearing walls have a thickness of 35 mm.

Above the uppermost hollow block element, indicated at 9, there are ceramic tubes 10 serving to suck off the waste gases diffused in the firing zone. The discharge channel 11 for the cooling air constitutes the upper closure of the firing chamber. The discharge channel 11 in the embodiment shown, consists of elements made of refractory material formed and placed one beside the other in a horizontal row and provided with an aperture 12 to the tunnel chamber. One end of the channel is connected with a suction and the opposite end of the channel is closed. The outside contour of the channel elements conforms to the inside contour of the arched cover 13 but is spaced at a distance relative to it to form a gap. The arched cover is provided with an outside insulation 14 which consists of individual meshing parts about 1 m long, disposed slidably by means of rollers running on rails on the uppermost side of the kiln in the direction of the tunnel chamber or firing zone. It closes the firing chamber over the entire length of the kiln. It serves as a so-called kiln car and it carries the material 15 which is to be treated and which is suspended downwards into the firing chamber. The supports for the material that is to be treated are attached to the arch lid outside the heating chamber (not shown). They also can be attached in the heating chamber itself, i.e., on the underside of the arch lid.

The wall of hollow block elements 4 consists, according to FIG. 2, of elements of a generally wedge-shaped cross section, which have been joined inside a horizontal row of elements in an alternating head/tail orientation. FIG. 3 shows the arrangement of the suction tubes for the hot gas above the hollow block elements.

In FIG. 4 an alternative embodiment of hollow block elements 40 is shown, in which each second hollow block element disposed within a horizontal row of elements partly overlaps with one of its contacting surfaces the adjacent elements, and thus ensures the total formation against displacement.

FIGS. 5 and 6 finally relate to hollow block elements 41 and 42 constructed to mesh with one another, of which the FIG. 5 arrangement additionally shows the overlapping effect. FIG. 6 shows a tongue and groove mesh.

The tunnel kiln 1 according to the invention, operates in the following manner;

The flame gases flowing from the burners 5 fill the flame zone 3, penetrating through the opening 6 into the hollow block element 4 and thereby heating the thin walls 7 of said elements. The latter radiate the thermal energy onto the material 15 which is to be treated and which is guided slowly through the firing zone 8 suspended from the arch lid 13. The hot gases diffused through the piled up wall, are removed from the kiln for the greater part by way of hot gas suctions. The discharge channel 11 for the cooling air is connected with a suction fan and sucks in fresh air from the outside via aperture 12 through the gas between the kiln and the kiln cover 13. At the same time the latter is cooled effectively.

The tunnel kiln according to the invention has numerous advantages as compared to known shaft kilns operated discontinuously, of which there can be mentioned particularly:

1. Now elongated ceramic molded articles can be fired or sintered continuously. The kiln can be continuously kept at an even temperature so that damage to brick linings are avoided during heating and cooling as a result of the occurrence of thermal stress.

2. An absolutely even firing curve can be achieved. As a result the material that is to be fired can be produced in a precisely reproducible quality.

3. The wear and tear caused by thermal stresses and occurring at the kiln car in the case of known tunnel kilns and the breakdowns caused by that are eliminated.

4. The cumbersome charging and removal of the material to be fired in shaft kiln capsules is eliminated.

What is claimed is:

1. In a flame heated tunnel furnace for continuously firing or sintering elongated ceramic molded objects suspended on a movable arched cover over an upper shaft opening of the furnace, the improvement in combination therewith which comprises side walls dividing the furnace into a flame zone and a firing zone, said side walls including thin-walled fire resistant hollow block elements joined to one another and having a form and arrangement to prevent relative movement of each transversely to the furnace axis, openings in said hollow block elements forming part of said flame zone, burners in said flame zone, hot gas removal means for said firing zone adjacent the upper portion of said side walls, and a cool air flow channel means above said hot gas removal means defining with said arched cover gap means for the inflow of outer air.

2. A tunnel furnace according to claim 1 wherein the hollow block elements are assembled with a high temperature mortar.

3. A tunnel furnace according to claim 1 wherein the hollow block elements are open at their upper and lower ends.

4. A tunnel furnace according to claim 1 wherein the hollow block elements have a wedge shaped cross section and are joined together inside a horizontal element series in alternating head-tail orientation.

5. A tunnel furnace according to claim 1 wherein said hollow block elements are arranged in a horizontal series one after the other and are interlocked on their alternating lateral surface of contact in tongue and groove fashion.

6. A tunnel furnace according to claim 1 wherein said hollow block elements are arranged in a horizontal series of elements, said elements having a free lying surface, every other block of said series having at least its free lying surface partially overlapping the next element.

7. A tunnel furnace according to claim 1, wherein said hollow block elements include a plurality of horizontal series of hollow block elements, said hot gas removal means being disposed over the hollow block elements of the uppermost horizontal element series, said removal means comprising pipes joined to a collection conduit.

8. A tunnel furnace according to claim 1 wherein said cool air flow channel means opens on both sides out into the furnace longitudinal direction, and is provided toward the tunnel chamber with at least one opening, said cool air flow channel means comprising hollow block elements joined in horizontal series and having connected to at least one end thereof a suction conduit of fire resistant material.

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