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(54) TUNNEL FURNACE FOR A BAKING PROCESS FOR CERAMIC MATERIALS

(57) The invention relates to a tunnel furnace for a baking process for ceramic materials, comprising a heating-, a firing- and a cooling zone. The firing zone comprises a stoking zone and a sintering zone and the stoking zone comprises burning zones equipped with gas burners, each burning zone having an initial and an end temperature set value.

The tunnel furnace comprises a system steering - during the residence of the ceramic materials in a burning zone of the stoking zone - the temperature in the burning zone from the initial value till the end value according to a curve situated equal to or beneath the linear curve of the initial value till the end value of the burning zone. The invention also relates to a method for baking ceramic materials implementing the above steps. The tunnel furnace and method yield a substantive reduction in gas consumption and in fallout of disapproved baked products.

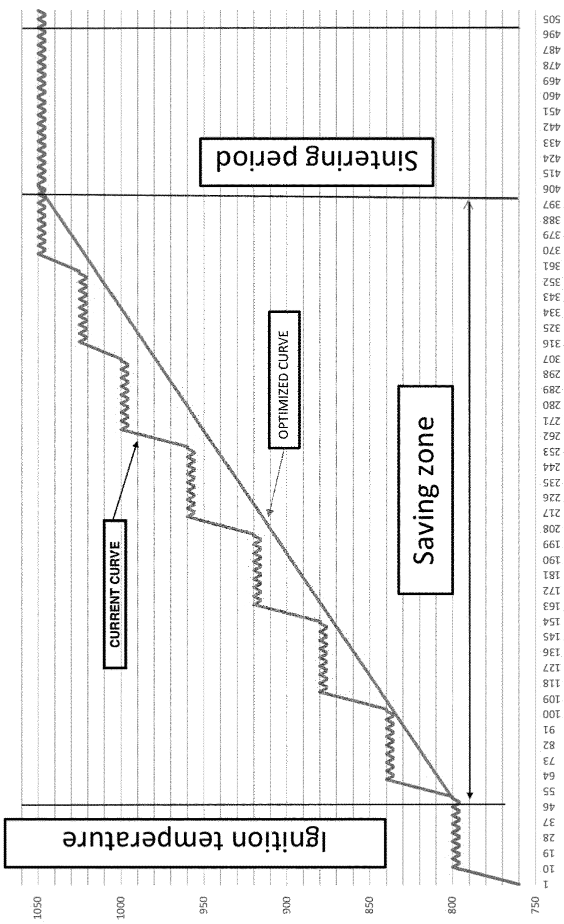

FIG. 3

EP 3 663 688 A1

Description

Field of the invention

[0001] The present invention relates to a tunnel furnace and a related method comprising a temperature control for a baking process for ceramic materials. More in particular the invention relates to a tunnel furnace and a related method whereby the baking process in the burner zones of the tunnel furnace is steered according to an intelligent control. This leads on the one hand to a substantive economy of gas, on the other hand to a more qualitative product by reducing the losses relating to disapproved baked material.

Background of the invention

[0002] A brick factory or brick bakery, also called a brick furnace, is a factory wherein ceramic materials are produced, more in particular bricks and often also related products like (roof) tiles and brick tubes or pipes, brick strips, ...

[0003] An important issue for brick factories was the availability of clay, so many brick factories were established in clay-rich geographic areas. In line herewith, brick factories and roof tile factories have been built on the edge of clay-rich, resp. peat-rich areas. Along the big rivers clay was available and the baked bricks were transported by ship to the final customers. In view of the abundant presence of clay in Flanders, Belgium, a tradition of bricklaying has been established and along with this, large brick factories have been built.

[0004] Ceramic products traditionally have been manufactured the same way as bricks. In this process raw materials are first mixed and then put into their final product form. The so formed products are then dried and baked. Only after the baking process, the formed products are characterized by their final product features, only at that stage these products are called ceramic products.

[0005] Irrespective of the way the products are formed in the factory -products made by hand form or e.g. by extrusion - the product needs to be baked. The vast majority of these products are baked in a fully oxidizing environment. This means that oxygen is always present to have the mineral raw materials burned. As burning materials, use can be made of oil, coal or gas. In most cases gas is used as gas is easy to control, to deliver and still is relatively cheap. However, the cost of gas still is one of the three biggest cost factors in the manufacturing process; also, the burning process inherently causes a substantive air pollution.

Periodical and continuous furnaces:

[0006] As the burning and baking process is an energetically intense and economically expensive process, it is of the utmost importance to optimize the baking technology.

[0007] In the ceramics industry, two types of furnaces or baking processes are known: a periodical or a continuous execution of the baking process.

[0008] The development from a periodical to a continuous furnace system is a result of the need to reduce the energy required for the baking process. In case of periodical furnaces, a lot of energy is lost since after each baking cycle the complete furnace should be cooled and the heat is lost. For periodical furnaces, the temperature of the flue gasses corresponds to the actual temperature of the products, whereas in the case of continuous furnaces, this heat is used for the warming up and drying of the products. Despite this more economical approach, this kind of furnace still requires very substantive baking costs.

[0009] The present invention relates to the continuous type of furnace, this is also the more common type of furnace in present day use.

[0010] In figure 1 a schematic view of a continuous type of furnace is shown.

[0011] The small platform trailers (kilncar) whereupon the materials to be baked are loaded, enter the furnace gallery at the left side, they are moved throughout the furnace to the right side until they are carried away from the furnace at the utmost right side.

[0012] This type of continuous baking furnace is called a tunnel furnace since the products to be baked are moved throughout this furnace in a tunnel-like fashion. In the furnace, three zones should be distinguished: the heating zone, situated at the entrance of the products in the tunnel (left in the figure), the firing zone in the middle of the furnace and the cooling zone at the way-out of the tunnel (at the right side of the figure).

The course of the baking process in a continuous furnace:

[0013] One may distinguish the baking processes of the various ceramic products according to the different temperature course throughout the various zones and timing of the furnace.

[0014] The heating and cooling rate may vary substantially from a few degrees up until hundreds of degrees per hour.

Also, the top temperatures may vary substantially from 800 up tot 2 000 degrees.

[0015] Figure 2 shows an example of a so-called baking curve: this curve shows the evolution of the temperature throughout the furnace (in ordinate is set out the temperature, ranging from room temperature till 1 200 °C at its top; the abscissa sets forth the residence time of the ceramic materials in the furnace, expressed in minutes.)

[0016] In the example shown in figure 2, the ceramic materials to be baked remain altogether 3 630 minutes in the furnace, so 60 hours and 30 minutes.

[0017] Also, one may distinguish the various zones and corresponding residence periods of the ceramic materials in these zones in the furnace:

- a heating zone, subdivided into a pre-heating period, resp. zone and a heating period, resp. zone;
- a firing zone, subdivided into a stoke period, resp. stoke-zone and a sintering period, resp. a sintering zone;
- a cooling zone, subdivided into a quick or rapid cooling period, resp. zone and a natural cooling period, resp. zone.

[0018] The course of the heating should be selected such that the changes brought about for the product to be baked during the heating cycle, such as shrinkage and extension (in particular around the quartz inversion point) should not give rise to damage. To this end, the heating velocity is usually set at a value not exceeding 25 °C/hour around the quartz inversion point of around 580°C instead of an average value of 50°C per hour in the pre-heating zone. In the pre-heating zone there is no firing. In this zone, use is only made of the residual heat of the firing zone. The ignition temperature of gas is achieved in the firing zone. In this zone gas is effectively used. Mostly in this zone in a number of consecutive steps the temperature is increased until the product has reached its required top temperature. The top temperature is retained until the product is completely sintered, this process being achieved in the sintering zone.

[0019] In the firing zone the temperature management system according to the invention is applied, resulting in a substantial saving of gas consumption.

[0020] As soon as the product has reached its top temperature, upon leaving the sintering zone, in the quick cooling zone, cooling is applied until reaching the sensitive quartz inversion point. Thereafter, further cooling takes place of the baked product in the natural cooling zone.

[0021] Cooling air is recycled for the drying of the products.

Present-day developments in view of gas-savings:

[0022] During the last couple of decennia, mankind has been increasingly aware of the fact that the natural resources of the earth in terms of energy are not unlimited. In view hereof, more advanced technologies have been developed so as to manage energy needs in a more efficient manner.

[0023] The theoretical amount of energy required for baking amounts to 400 KJ per kg of material. In practice, much more energy is used in present-day baking processes; for tunnel furnaces one uses on average 3500 up to 5500 KJ per kilogram of product.

[0024] The energy crisis of the mid-seventies gave rise to processes that are characterized by less losses of energy in the firing process. During this period, better insulation products were used, in turn resulting in less losses of energy. With the advent of up-to-date industrial processes, it quickly appeared that human control was not sufficient to master complex technological processes. As a result more precise measuring instruments were used, in most cases thermo-couples, to accurately measure and steer the temperature course in the firing process.

[0025] Present day systems make use of measure- and control instruments in the process, coupled to a PLC, a Programmable Logic Controller and a central computer.

[0026] By means of a display or monitor screen, desired values can be set and measured values can be visualized. By means of such a system the valves for the input of gasses in the firing zone of a tunnel furnace can be steered, controlled or managed. However, up to now, the baking process for ceramic materials in a tunnel furnace has not been optimized, in particular has not been optimized in view of an efficient gas consumption.

[0027] German published patent application Nr. DE 3438347 A1, published April 24, 1986 by W. Leisenberg, describes a tunnel furnace for the baking of ceramic materials. The overall furnace comprises a pre-heating zone, a baking zone and a cooling zone, whereby the temperature in the various zones can be steered by a steering system. The steering system comprises a computing device (Prozessrechner) that takes into account the measured temperatures in a given zone and steers the process in such a manner that the measured temperature follows as closely as feasible the set temperature course throughout the various zones of the furnace. Nowhere in this specification however, mention is made of a specific manner according to which for a given burning zone the temperature should be steered in view of gas-consumption savings.

[0028] In view of the above, there remains a need for methods and systems to reduce the gas consumption in the baking process of ceramic materials in a tunnel furnace, without compromising or jeopardizing the quality of the baked products, and without reducing the overall baking capacity of the furnace.

Summary of the invention

[0029] An object of the present invention is to provide a tunnel furnace for a baking process for ceramic materials,

- comprising a heating-, a firing- and a cooling zone,
- the firing zone comprising a stoking zone and a sintering zone,
- the stoking zone comprising burning zones equipped with gas burners,
- each burning zone having an initial and a final temperature set value.

[0030] The tunnel furnace is suitable for stepwise passing through of ceramic materials through the zones abovementioned.

[0031] The tunnel furnace is thereby characterized in that it comprises a temperature steering system, suitable to steer during the residence of the ceramic materials in a burning zone of the firing zone, the temperature in the burning zone from the initial value till the final value according to a curve situated equal to or beneath a linear curve of the initial value till the final value of the burning zone.

[0032] The invention also relates to a tunnel furnace whereby the temperature is actually steered by the temperature steering system as abovementioned.

[0033] The invention also relates to a method for the baking of ceramic materials, whereby the temperature throughout the baking process is steered by the abovementioned steering system.

[0034] More in particular the present invention comprises the tunnel furnaces and methods as set forth in the appended claims.

[0035] The invention is defined and characterized in the main claim, while the dependent claims describe other characteristics and specific features for preferred embodiments of the invention.

[0036] Further aspects and advantages of the embodiments described will appear from the following description taken together with the accompanying drawings.

Brief description of the drawings

[0037] The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of a preferential form of an embodiment of the invention, as illustrated in the accompanying drawings, given as a non-restrictive example.

[0038] It will be appreciated that for simplicity and clarity of illustration, elements shown in the drawings/figures have not necessarily been drawn to scale, nor are these elements necessarily to scale relative to each other. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. So, in the drawings, the same reference numerals may identify the same elements of structure in each of the several figures where appropriate.

[0039] In the figures, the thickness of certain lines, layers, components, elements or features may be exaggerated for clarity. Broken lines illustrate optional features or operations unless specified otherwise.

FIG. 1 is a schematic illustration of a continuous type of baking furnace or tunnel furnace wherein the invention may be applied;
FIG. 2 shows the course of the temperature throughout the various zones of the tunnel furnace;
FIG. 3 shows the course of the temperature according to the state of the art and according to the invention of a load of ceramic materials throughout the stoking and sintering zones of a tunnel furnace;
FIG. 4 shows schematically the stoking zone of a tunnel furnace with nine burning zones;
FIG. 5 shows schematically the steering system according to the invention;
FIG. 6 shows schematically a gas burner for use in a tunnel furnace;
FIG. 7 shows schematically the course of the temperature throughout one burning zone as a function of the passing of various loads of ceramic materials through said burning zone;
FIG. 8 shows the detail of the temperature curve throughout one burning zone for one single passing of a load of ceramic materials.

Description of the invention

[0040] As set forth supra, the invention comprises the following aspects:

1) a tunnel furnace wherein a steering system for the temperature is implemented;

2) a method for the baking of ceramic materials according to the above steering system.

[0041] The following is a detailed description of preferred embodiments of the invention, reference being made to the drawings.

[0042] It will be appreciated that for simplicity and clarity of illustration, where considered appropriate, numerous specific details are set forth in order to provide a thorough understanding of the exemplary embodiments described herein. The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. However, it will be understood by those of ordinary skill in the art that the embodiments described herein may be practiced without these specific details. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0043] In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the embodiments described herein.

[0044] The steering system according to the invention and/or the method applying such steering system can be implemented in an existing tunnel furnace without undue effort. It also can be implemented in newly constructed or to be built tunnel furnaces.

[0045] As an illustration hereof, at the end of this description is set forth how such a steering can be implemented by means of a Siemens ® PLC.

[0046] According to a preferred embodiment of the invention, the temperature curve takes a parabolic shape as from the initial temperature up to the final temperature of a given burning zone.

[0047] According to a further preferred embodiment of the invention, the temperature of the burning zones of the tunnel furnace is steered such that the initially set temperature is equal or higher than the gas ignition temperature.

[0048] According to a still further aspect of the invention, the temperature is steered by controlling the gas input and/or the air input in the burning zones as a function of the following input parameters:

- the in the burning zone desired or set temperature in conformity with the curve;
- the in the burning zone measured temperature.

[0049] According to a still further preferred mode of operation of the invention, the gas input in each of the burners of the stoking zone is steered as a function of the input parameters by optimization of the pulse time of the gas burners and/or the air supply.

[0050] According to a preferred embodiment, the temperature in the burning zone is measured by means of a thermocouple.

[0051] As set forth supra, figure 4 shows the stoking zone of a tunnel furnace wherein, solely as an illustration and without limiting the invention in such sense, nine burning zones are shown (indicated by the numbers 1 through 9).

[0052] In each of these burning zones, upon arrival of a trailer loaded with ceramic materials, the temperature should rise from a pre-determined initial value till a set or desired final value.

[0053] The values of the temperature increase gradually as a function of the trailer passing through the tunnel furnace. In the last burning zone, the top temperature is reached and maintained.

[0054] In figure 5 is shown how the temperature control or steering system of the tunnel furnace according to the invention steers the gas burners by means of their respective gas valves so as to reach the desired final temperature in a given burning zone according to a well-defined curve.

[0055] According to a preferred embodiment of the invention, this system is applied to all of the burning zones of the stoke zone of the tunnel furnace. To that end, use is made of a thermocouple, positioned in each of these burning zones, as set forth on the figures 4 and 5. The thermocouple will at each point of time during the operation of the tunnel furnace measure and transmit the actual temperature of the burning zone the so-called 'IST' value, or value actually measured to the steering system of the tunnel furnace.

[0056] The steering system will compare this actual or 'IST' value with the desired or 'SOLL' value for that point in time for said burning zone and as a function of the difference between both values, will steer the gas valves in the manner as set forth hereinafter.

[0057] Figure 5 shows how the temperature steering system steers the gas burners. As an illustration, twelve bas burners are provided in the burner zone. In a typical configuration these are positioned at both sides of a central gas supply line.

[0058] In the middle of the burning zone, the thermocouple is positioned that measures the actual temperature in the burning zone and transmits same to the steering system according to the invention.

[0059] The steering system of the tunnel furnace according to the invention is designated by the block indicated 'ESA-technics', this is the provisional denomination of the steering system to be implemented in the tunnel furnace.

[0060] The output of this steering system is the position to be held by the gas valve and the air valve of the respective burning zone: the input parameters that are processed by this temperature steering system are the desired initial and final values of the temperatures in the respective burning zone, as well as the shift-time, this is the residence time as determined for the tunnel furnace and for the respective load of ceramic materials in the respective burning zone. (the shift-time is the time a trailer loaded with to be baked materials resides in a given burning zone; this time is the same for all of the burning zones, as the trailer passes stepwise and gradually through the entire tunnel furnace.)

[0061] Usually on a trailer, various loads of to be baked materials are placed near to each other, whereby openings are left between the various piles of materials in order to enable the hot air and the baking heat to reach each pile in a more or less uniform manner.

[0062] Usually two piles or rows of materials are loaded after each other in the moving direction of the trailer, leaving sufficient space between both piles.

[0063] Usually the trailers pass beneath the burners, positioned on top thereof.

[0064] In some cases, burners are also placed sideways in the burning zones.

[0065] When a trailer passes through a burning zone, the trailers usually are placed such that the flames of the burners positioned on top of or sideways of the trailers pass through the middle of the piles of loads of ceramic materials on the trailers.

[0066] For the burners positioned on top of the burning zone, the flames are directed downwards; for the burners positioned sideways of the burning zone, the flames are directed sideways.

[0067] According to such orientation of the flames, a quite uniform baking of all of the ceramic materials loaded on the trailers is obtained.

[0068] During the transfer of a trailer to the next following burning zone, the burners are not working. This procedure is followed so as to avoid that the top, resp. outer pile of ceramic materials on the trailer is baked too hard.

[0069] For a tunnel furnace comprising for example seven burning zones and whereby the temperature of the trailer loaded with ceramic materials and the ambient flue gases upon arrival in the first burner zone amount to approximately 800°C, and assuming that the final baking temperature is set at 1 000°C, in each burning zone a temperature increase of approximately 30°C should be realized (1 000 - 800 = 200, /7 = approx. 30°C).

[0070] However, it is not a requirement that an identical temperature increase in each burning zone should be realized; in some cases in the first zone(s) a greater temperature increase is achieved, e.g. 40°C or more, whereby the required temperature increase in the following zone(s) may be more moderate, e.g. around 30°C.

[0071] For the case that the residence time (or shift-time) of a trailer in a burning zone amounts to approximately one hour, this implies that a temperature increase of 30°C should be reached within one hour, so on average 1°C per 2 minutes of time. Hereupon, the trailer can be transferred to the next following burning zone, whereby the same process should be repeated.

[0072] For a tunnel furnace with nine burning zones, the table set forth hereinbelow illustrates what the desired initial- and final temperatures could be:

Zone Nr.	Initial-temperature	End-temperature	Delta temperature
0	760	800	40
1	800	840	40
2	840	880	40
3	880	920	40
4	920	960	40
5	960	1000	40
6	1000	1025	25
7	1025	1050	25
8	1050	1050	0
9	1050	1050	0

[0073] The course of the temperature in each of the burning zones of this example is illustrated in figure 3, upper curve.

[0074] The nine zones indicated above are also set forth on the curve shown in Figure 3. According to a preferred embodiment of the invention, in the first zone, wherein the temperature is below the gas ignition temperature, the steering or control system of the tunnel furnace according to the invention, is not applied. According to a further preferred embodiment, the system also is not applied in the two last zones.

[0075] In the seven zones of the so-called 'savings-zone', the system is applied.

[0076] In Figure 3, the upper curve indicates the course of the temperature according to the state of the art.

[0077] In each burning zone, according to the temperature steering systems known in the state of the art, the temperature is steered from the initial value for said burning zone until the final value for said burning zone in a way such that a quite strong increase of temperature is achieved in the initial stage or phase. As soon as the desired or set temperature is then reached, the temperature is kept constant, which is shown by the horizontal part of the curve for each burning zone.

[0078] In the above example, the first zone is numbered 0. The initial temperature in said zone is situated below the gas ignition temperature; as a result, this zone is not comprised within the so-called savings-zone of the steering system of the present invention.

[0079] Further, the last two zones are numbered 8 and 9, the sinter-zones; in these zones the temperature of the ceramic materials is kept constant and no further temperature increase is performed.

[0080] According to the steering system of the tunnel furnace according to the invention, the temperature in each of the burning zones of the 'savings zone' will evolve according to a course or a curve that is clearly situated below the abovementioned temperature curve according to the state of the art. As set forth supra, the 'savings zone' is the zone starting as from the gas ignition temperature until reaching the maximum temperature in the tunnel furnace, the latter being the temperature upon which the sintering process starts. In this case either a linear curve is followed, like the curve indicated in figure 3, or a curve that globally is situated below such linear curve.

[0081] The term 'linear curve' for a burning zone should be understood as the curve that for the given burning zone shows the course of the temperature as a function of time and whereby the temperature increases steadily, uniformly or linearly in the given burning zone from the initial temperature value until the final or end value for the given burning zone, as a function of the residence time of the to be baked ceramic materials in this burning zone. This residence time is referred to supra as the 'shift time'.

[0082] The characteristic feature of the invention resides in the fact that the temperature in a burning zone is steered or controlled by the temperature steering system of the tunnel furnace of the invention in such a way that for a given burning zone the actually followed temperature course is situated equal to or below this linear or regular curve for the said burning zone.

[0083] The temperature curve obtained in such a way may for example be a parabolic curve, the initial value whereof corresponds to the initial temperature in a given burning zone and the final or end value whereof corresponds to the set or desired temperature in the given burning zone. The characteristic feature of such a curve is that the temperature increase in the burning zone at the initial stage of phase of residence of the ceramic materials in the burning zone is less pronounced and that up near the end of this residence time, the temperature increases in a more steep manner, for instance according to the abovementioned parabolic curve, until the set or desired final temperature for the given burning zone has been reached.

[0084] Figures 7 and 8 show an example of such a parabolic curve. In these figures the ordinate indicates the temperature and the abscissa indicates the time for a given burning zone.

[0085] Figure 7 shows how the temperature for a given burning zone is steered and as a result hereof varies as a function of time, more in particular as a function of the residence time of the to be baked ceramic materials.

[0086] All in total four 'cycles' are shown in figure 7, whereby each cycle is characterized by an increasing curve, followed by a (strongly) decreasing curve.

[0087] The increasing part of the curve shows the increasing temperature in the given burning zone, as soon as a load of ceramic materials has arrived in the given burning zone. In the example shown in figure 7, the temperature in the burning zone is increased from approximately 780°C to approximately 800°C, this is the desired or set value for the temperature in this burning zone.

[0088] More in general terms, the temperature in the burning zone should be increased from an initial value situated in the range varying from 750°C to 850°C, more preferably from 790°C to 835 °C to a final value situated in the range from 950°C up to 1150°C, more preferably from 975°C up to 1100°C, still more preferably from 1000 °C up to 1075 °C.

[0089] The figure clearly shows how the course of the increasing temperature globally is situated under the linear curve of the initial set value of 780°C up until the final or end set value of 800°C. As soon as the final temperature for the given burning zone has been reached, in this example 800°C, the load of ceramic materials is transferred to the next burning zone and a new load of ceramic materials is loaded in the given burning zone.

[0090] In this period, the temperature in the given burning zone decreases from the final value of 800°C down to the initial temperature, in this particular case, 780°C. During this period, the gas burners are off. As soon as the new load of ceramic materials has arrived in the burning zone, the gas burners are activated again according to the steering system of the invention and the temperature will again increase up until the set value for the given burning zone.

[0091] The above is illustrated by the second increasing temperature curve of this figure 7. Once the final temperature again has been reached, the loads of ceramic materials again are shifted through the tunnel furnace and the temperature in the given burning zone again decreases, illustrated by the second decreasing line of the curve shown in figure 7. These temperature courses or evolutions throughout a burning zone are repeated as long as the passing of the ceramic materials through the tunnel furnace continues.

[0092] Figure 7 in total shows such four cycles. The temperature course in each cycle follows the course of a parabolic curve.

[0093] Figure 8 shows an alternate temperature course for such parabolic curve, for a single cycle.

[0094] The temperature increases from about 780°C till about 800°C as shown in this figure. Compared to the temperature course as shown in figure 7, the temperature increase and decrease in this case is slower.

[0095] The course of the temperature during the heating stage in the given burning zones also in this case follows a parabolic curve.

[0096] According to the way the burners are steered following the control systems known in the state of the art, the burners are fully operational, this means they operate at full or maximum power upon arrival of the trailers in the burning zone until the set final temperature for the given burning zone has been reached. As soon as such temperature has been measured by the thermocouple, the burners are off. Only when thereafter the temperature decreases with a set value of e.g. 1°C, the burners are temporarily again activated until the set value has been reached.

[0097] Given the capacity of the burners, in most of the tunnel furnaces and for the vast majority of ceramic loads, such set value for the temperature is quickly reached, e.g. after 5 minutes of a set shift time of e.g. 60 minutes. This implies that during 55 minutes the to be baked ceramic materials on the trailer in the given burning zone are stabilized at that temperature.

[0098] Figure 6 shows a gas burner as it is commonly installed in a tunnel furnace.

[0099] It comprises a supply line for the gas and a separate supply line for air. Each burner installed in a tunnel furnace is equipped with variable valves for gas and air. Upon installation of the temperature steering system as described in the present specification in a tunnel furnace, these valves are not changed; they keep their fixed positions upon commissioning of the tunnel furnace. Only the pulse time of the burners is being steered by the steering system as described in this specification.

[0100] In the steering system of the tunnel furnace according to the invention, the gas burners are not continuously operational, but intermittently.

[0101] In a steering system according to the state of the art, the gas burners are being operated at full power when the difference between the desired temperature and the temperature measured by the thermocouple is sufficiently high.

[0102] When the delta between both temperature values is smaller, a state-of-the-art steering system will not have the gas burners work at full power, but at a lower rate. In such a case however, the length of the flame varies. This in turn has a negative impact on the quality of the baked ceramic materials; in particular it gives rise to uneven or not-uniformly baked materials.

[0103] In such a case indeed, the materials that are situated on top of the pile of materials loaded on the trailers will be baked longer or more intensively compared to the materials that are situated lower in the pile of loaded materials on the trailer. These 'upper' materials indeed are in closer contact with the flames of the burner compared to the 'lower' materials. To compensate for these drawbacks, in a number of cases a higher supply of air is used, giving rise to sufficient turbulence and as a result hereof a more uniform heating of the materials residing in the burning zone.

[0104] In the temperature steering system of the tunnel furnace according to the invention, use is being made of pulse-wise steering. In such a steering system, the burners are regularly put on and off again (pulse-wise burning).

[0105] The big advantage thereof compared to the state of the art is that - always when the burners are on or operational - the length of the flame is constant, whereas at the same time a sufficient degree of turbulence is achieved in the burning zone. This in turn gives rise to an increased quality level of the baked ceramic materials. The burners are steered according to a small air surplus or excess resulting in a more even or uniform baking of the ceramic materials. According to a further preferred embodiment, the burners may be operated alternately or in turn, again given rise to an enhance quality of the final baked products.

[0106] Also a decrease of the load of ceramic materials on the trailers may yield an increase of quality of the final baked products.

[0107] So as to achieve a sufficient degree of turbulence in the burning zones, in the state of the art, an extra air supply could be applied. This however yielded a degree of air excess which was too high, often more than a factor 2. This means that the amount of air is twice the supply of gas. The ratio of air over gas is steered on the basis of the temperature of the furnace. The air excess level can then be controlled at a lower level. But given the fact that there are multiple variable factors that influence the rate of burning, this does not have an ideal effect on the gas consumption, given the fact that one needs to adjust manually the settings for burning and pause. It is impossible to perform manually the necessary corrections so as to reach the ideal burning curve, given the fact that there are not many variables that have an influence, such as the volume of the loads of ceramic materials, losses throughout the process, ambient air temperature, ...

[0108] The tunnel furnace according to the invention does not make use of a pulse and pause timing sequence that can be manually set. These appear to react too slowly upon changes in the oven to effectively save on gas consumption. Contrary thereto, the furnace and method according to the invention calculates at set time intervals, situated between 10 and 60 seconds, e.g. every 10, 15, 20, 25, 30, 35, 40, 45 50 55 or 60 seconds, the required pulse so as to obtain the desired temperature course in a burning zone. In this way, the furnace and the method according to the invention will quickly and accurately detect differences between the temperature as measured by the measurement means (e.g. a thermocouple) (this is the 'IST' value) and the desired or set value for such temperature in the given burning zone (this is the 'SOLL' value). On the basis of such temperature difference, the furnace and method will then react so as to clear away such difference by steering the pulse and pause time of the burners of the given burning zone. This steering method allows to reach the pre-set or desired temperature for a given burning zone only at the point in time when the pre-set residence time for a load of ceramic materials in the given burning zone is reached. The longer such temperature is reached, the less gas will be consumed.

[0109] The effective reduction or saving in gas consumption in the furnace according to the invention will depend on the particular dimensions and operational process of the furnace.

[0110] The quality improvements that are obtained by the pulse-wise operation of the gas burners are remarkable. The different way of achieving the end or final temperatures in the burning zones even give rise to substantive improvements in quality of the baked ceramic materials.

[0111] Other external factors (such as ambient air, losses, defects, air supply systems,...) that may have an influence on the actual gas consumption, are also taken into account in the steering system of the tunnel furnace according to the invention.

[0112] In the tunnel furnace according to the invention, the steering system and method as described supra is only implemented in the burning zones that have an influence on the quality and the color of the ceramic materials to be baked. This implies that the steering system and method is preferentially not applied in such zones that operate below the gas ignition temperature and not in the sintering zones that maintain the temperature such that the baked ceramic materials are in conformity with the applicable standards.

[0113] With respect to the practical implementation of the steering system and method in a tunnel furnace: so as to reach the above set goals, the inventors have installed the steering system and method in a steering box of a tunnel furnace. In such box the program as written and designed by the inventors (named 'ESA-technics') was implemented on a Siemens Simatic manager S7-1200. The inventors obtained from the owner of the tunnel furnace the measured values of the temperature in the burning zones, so that remotely the baking curves could be steered and monitored.

Practical mode of implementation:

[0114] The steering system and method according to the invention as applied in a tunnel furnace in a real productive baking process; its results were compared to the operation of a traditional or state of the art steering system.

[0115] This yielded the following results:

1) Operation according to the state of the art:
energy consumption of the furnace: 1 797 MWh per month for 450 loaded trailers in that month;
2) Operation according to the steering system and method according to the invention:
natural gas consumption amounted to 1 509 MWh per month for the same load and cycles.

[0116] As is illustrated by the above example, the application of the steering system and method in the tunnel furnace according to the invention gave rise to a substantive saving in energy.

[0117] Such saving in energy in turn leads to a corresponding decrease in the output of CO_2. The invention consequently also contributes to the reduction of CO_2 output as imposed upon industry.

[0118] Surprisingly, apart from the reduction in gas or energy consumption brought about by the implementation of the present invention, also the fallout ratio of disapproved products on the basis of the steering of the temperature according to the system and method of the invention could be substantially decreased.

[0119] This is an unexpected but quite important effect obtained by the implementation of the present temperature steering system and method according to the invention. Evidently, apart from the gas consumption savings, this unexpected effect of the invention yields an important added value for the operators of tunnel furnaces in the baking process of ceramic materials, provided the temperature is steered in accordance with the system and method of the present invention.

[0120] In the claims as set forth hereinafter, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

[0121] In the claims, the claimed methods are not limited to the order of any steps recited unless so stated thereat.

Claims

1. Tunnel furnace for a baking process for ceramic materials passing stepwise through the furnace,

- comprising a heating-, a firing- and a cooling zone,
- the firing zone comprising a stoking zone and a sintering zone,
- the stoking zone comprising burning zones equipped with gas burners,
- each burning zone having an initial and a final temperature set value,

characterized in that
the tunnel furnace comprises a system for steering during the residence of the ceramic materials in a burning zone of the stoking zone, the temperature in the burning zone from the initial set value to the final set value according to a curve situated equal to or beneath the linear temperature curve from the initial set value to the final set value of the burning zone.

2. Tunnel furnace according to claim 1, wherein the system steers during the residence of the ceramic materials in a burning zone of the stoking zone, the temperature in the burning zone from the initial set value to the final set value according to a curve situated beneath the linear temperature curve from the initial set value to the final set value of the burning zone.

3. Tunnel furnace according to claim 1 or 2, wherein the system steers the temperature of all burning zones of the stoking zone as from the burning zone for which the set initial value is equal or higher than the gas ignition temperature.

4. Tunnel furnace according to one of the preceding claims, comprising a thermocouple for the measurement of the temperature in the burning zone.

5. Method for baking ceramic materials passing stepwise throughout a tunnel furnace,

- the tunnel furnace comprising a heating-, a firing- and a cooling zone,
- the firing zone comprising a stoking zone and a sintering zone,
- the stoking zone comprising burning zones equipped with gas burners,
- each burning zone having an initial and a final temperature set value,

whereby the tunnel furnace comprises a temperature steering system,
characterized in that,
during the residence of the ceramic materials in a burning zone of the stoking zone, the system steers the temperature in the burning zone from the initial value till the final temperature set value according to a curve situated equal to or beneath the linear curve from the initial value till the end value of the burning zone.

6. Method according to claim 5, wherein in the burning zone the temperature is steered by controlling the gas supply as a function of the following input-parameters:

- the temperature set value according to said curve;
- the measured temperature.

7. Method according to claim 6, wherein the gas supply in the burner of the stoking zone is controlled as a function of the input parameters by optimization of the pulse time of the gas burner.

8. Method according to any of the claims 5 through 7, wherein the temperature course follows a parabolic curve as from the initial temperature till the final temperature.

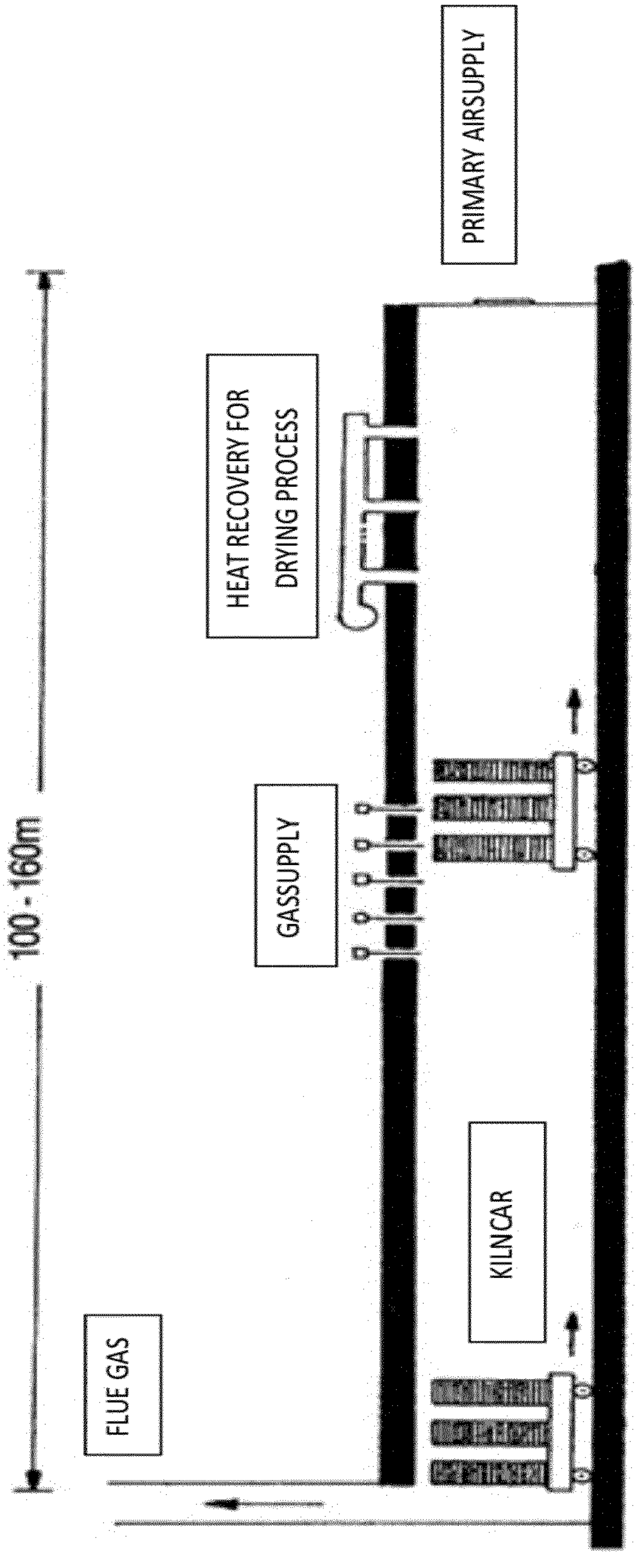
PRIMARY AIRSUPPLY
HEAT RECOVERY FOR DRYING PROCESS
100 - 160m
GASSUPPLY
KILNCAR
FLUE GAS

Fig. 1

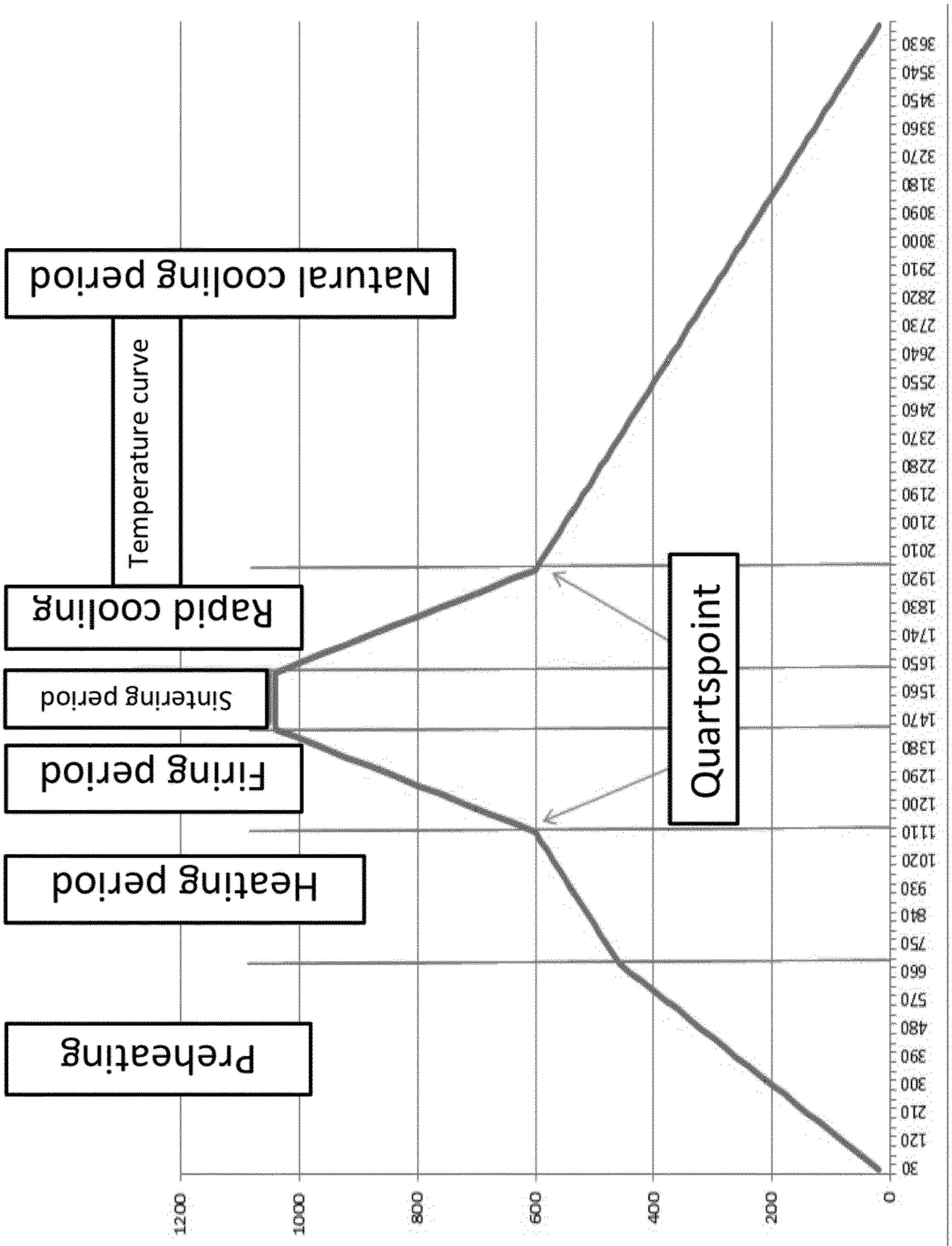
Preheating
Heating period
Firing period
Sintering period
Rapid cooling
Natural cooling period
Temperature curve
Quartspoint
0
200
400
600
800
1000
1200
30
120
210
300
390
480
570
660
750
840
930
1020
1110
1200
1290
1380
1470
1560
1650
1740
1830
1920
2010
2100
2190
2280
2370
2460
2550
2640
2730
2820
2910
3000
3090
3180
3270
3360
3450
3540
3630

FIG. 2

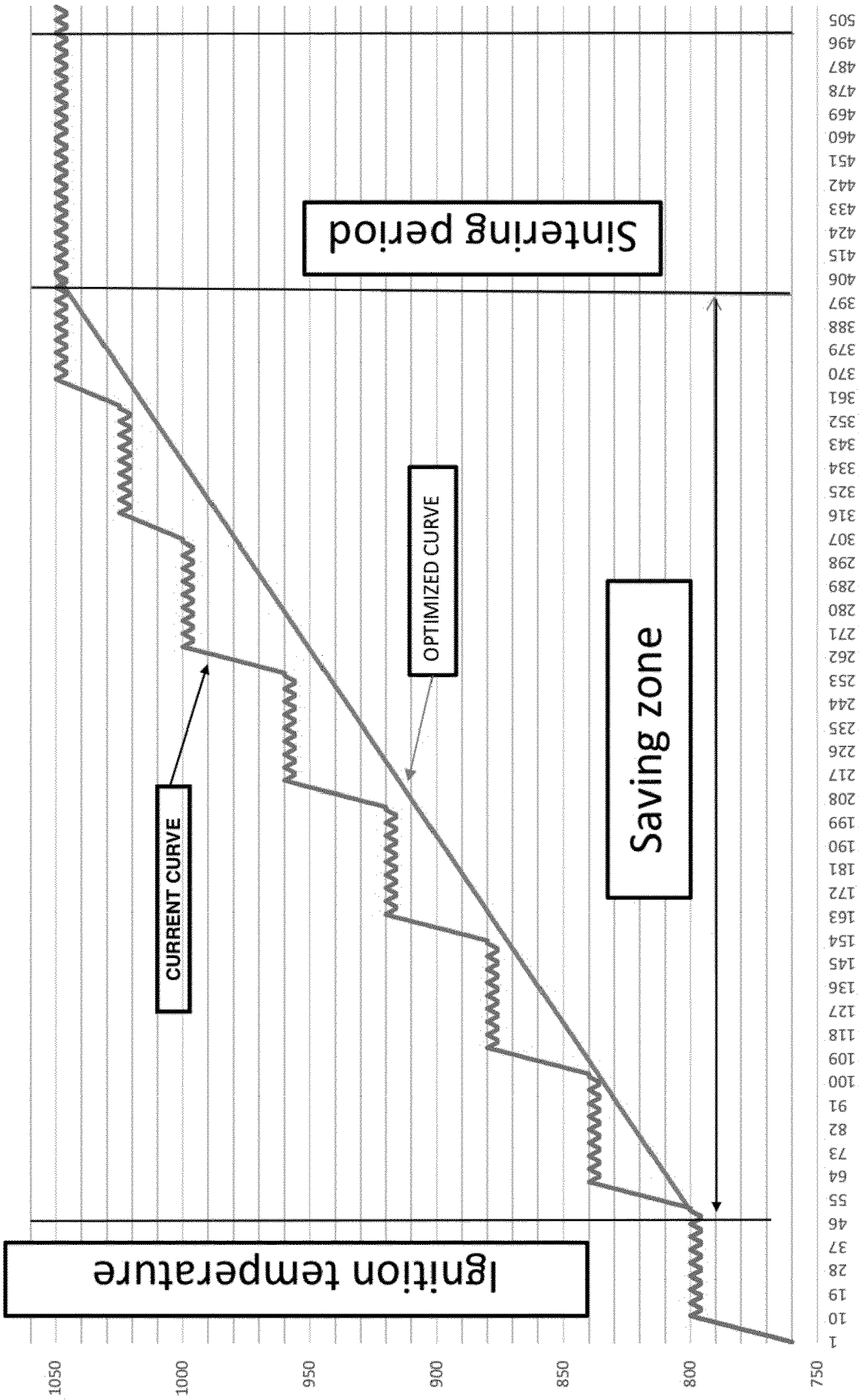
Sintering period
Saving zone
OPTIMIZED CURVE
CURRENT CURVE
Ignition temperature
1050
1000
950
900
850
800
750

FIG. 3

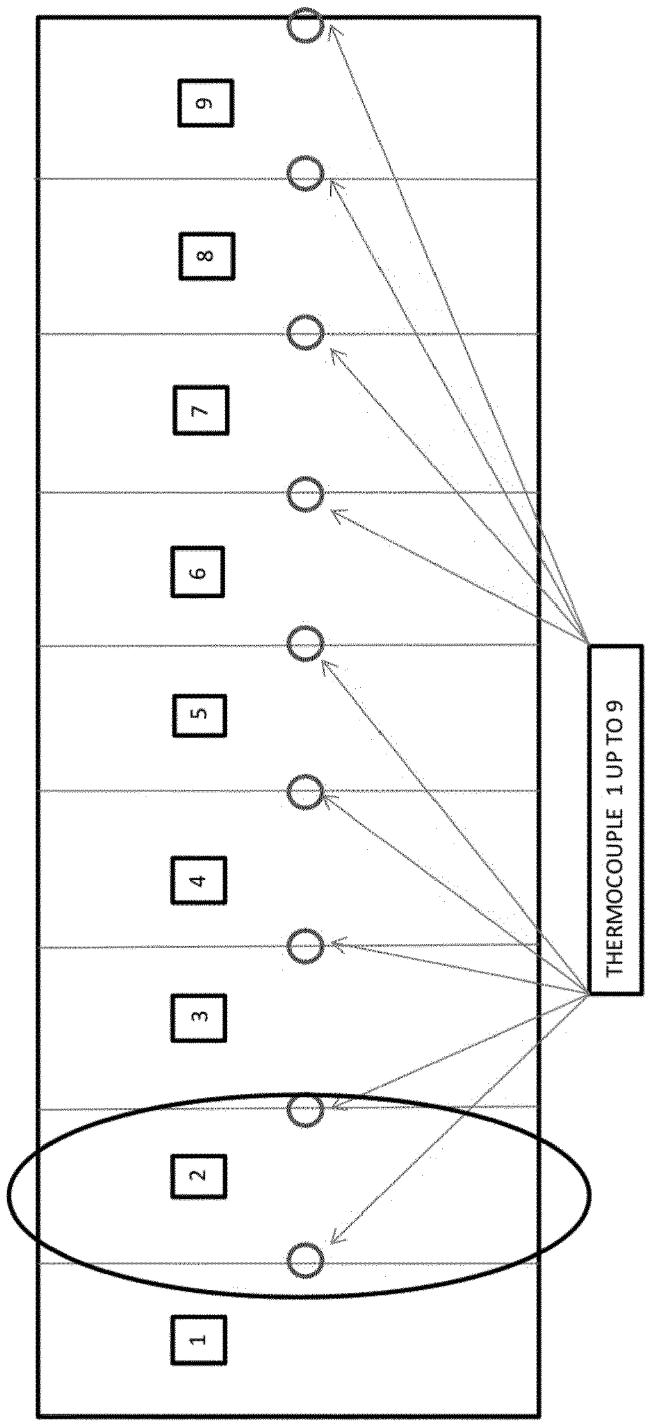

FIG. 4

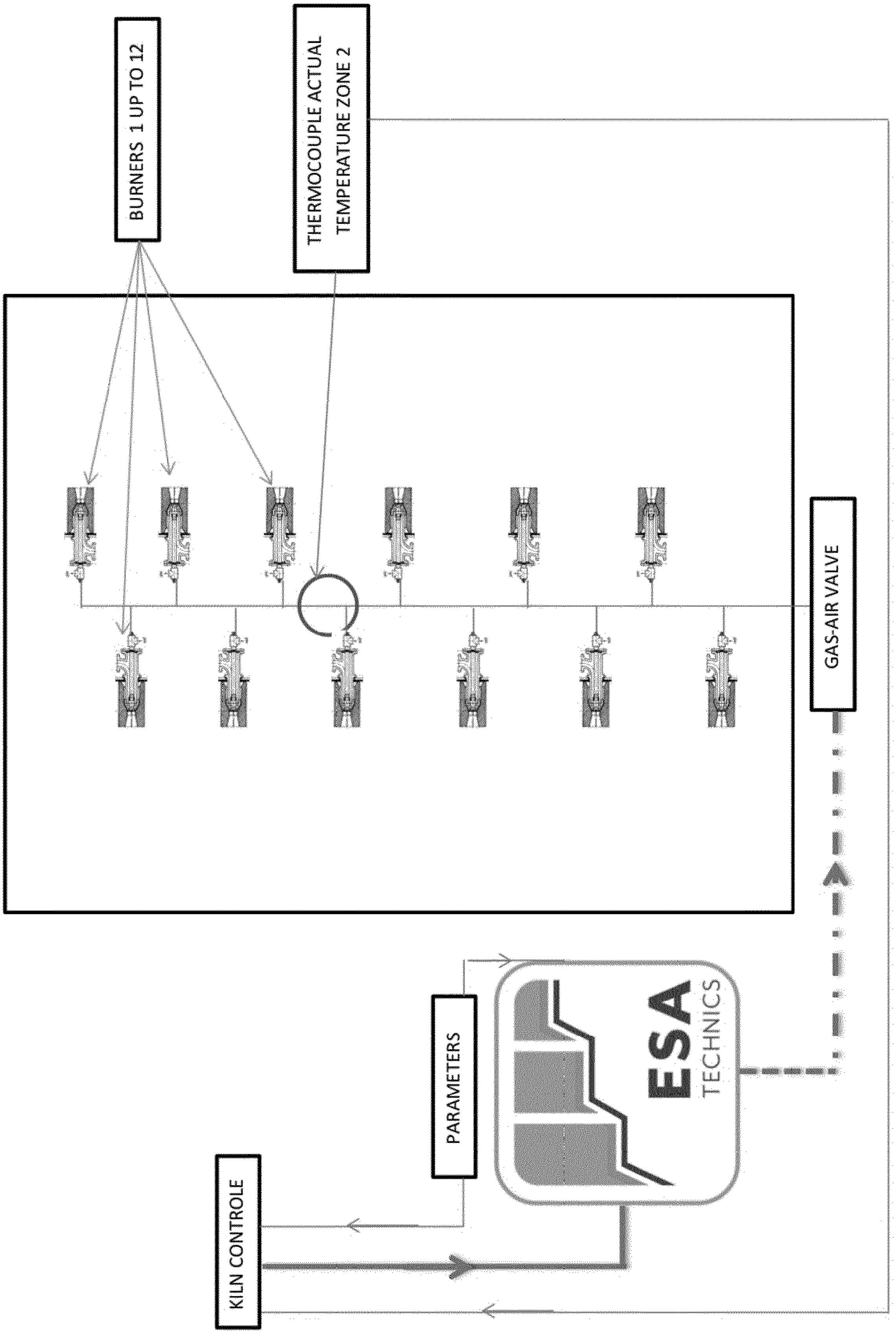
BURNERS 1 UP TO 12
THERMOCOUPLE ACTUAL TEMPERATURE ZONE 2
GAS-AIR VALVE
PARAMETERS
ESA
TECHNICS
KILN CONTROLE

FIG. 5

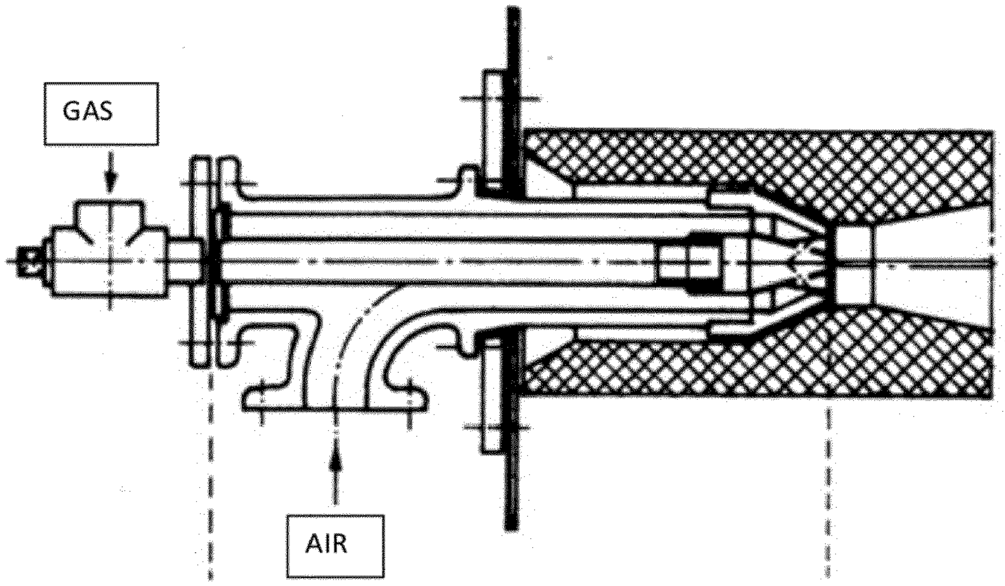

FIG. 6

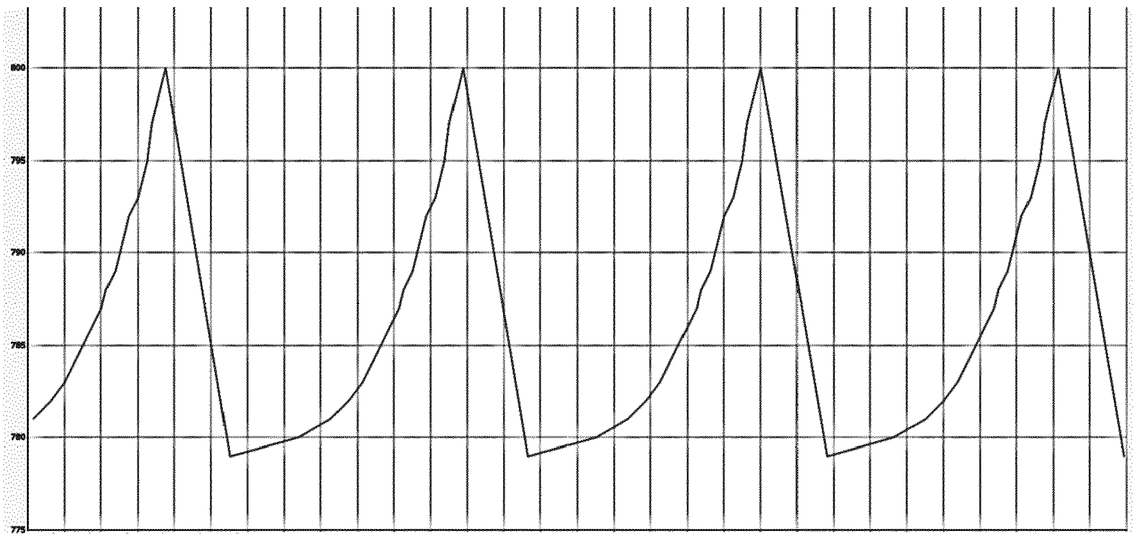

FIG. 7

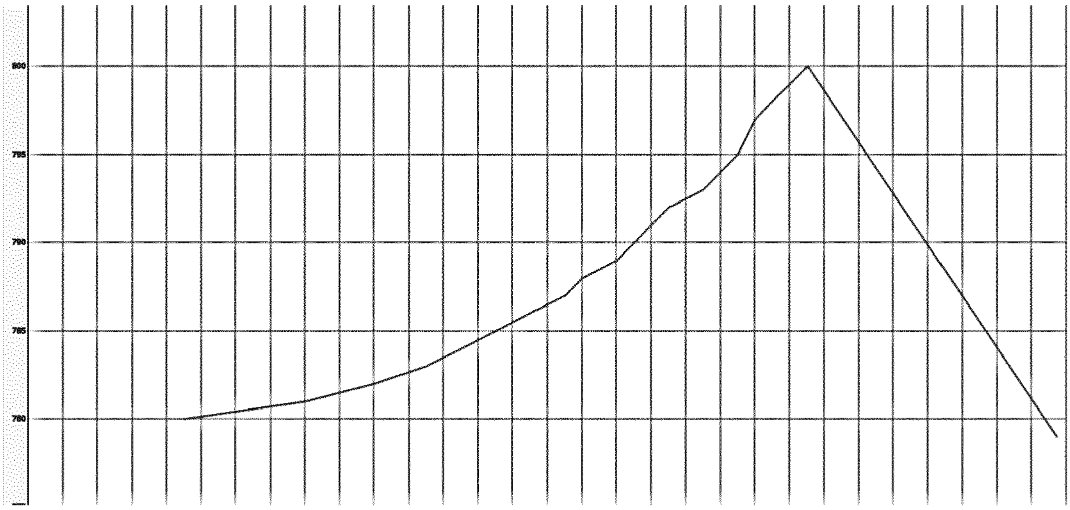

FIG. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 18 02 0628

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 966 547 A (OKUYAMA TAKASHI [JP] ET AL) 30 October 1990 (1990-10-30) * figures 1,2 * * column 3, line 29 - line 35 * * example 2 * -----	1-8	INV. F27B9/40
X,D	DE 34 38 347 A1 (LEISENBERG WOLFGANG [DE]) 24 April 1986 (1986-04-24) * figures 1-3 * * page 14, line 16 - page 16, line 8 * -----	1-4	

TECHNICAL FIELDS SEARCHED (IPC)

F27B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	23 April 2019	Peis, Stefano

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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23-04-2019

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US 4966547 A	30-10-1990	JP H01252886 A	09-10-1989
		US 4966547 A	30-10-1990
DE 3438347 A1	24-04-1986	DE 3438347 A1	24-04-1986
		EP 0178401 A2	23-04-1986

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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