Jan. 4, 1966 ONG TJING GIE ETAL 3,227,782

METHOD OF PRODUCING CERAMIC MATERIALS

Filed June 25, 1962 2 Sheets-Sheet 1

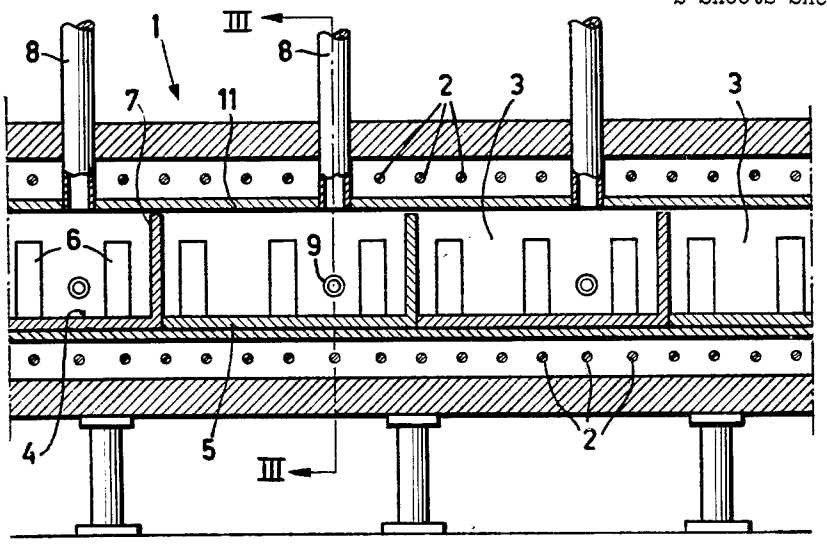


FIG. 1

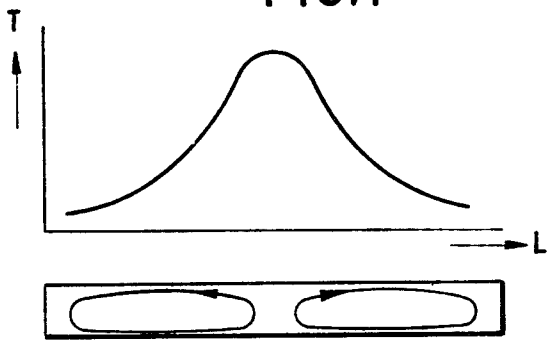


FIG. 2

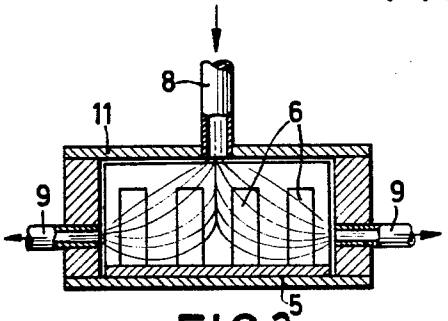


FIG. 3

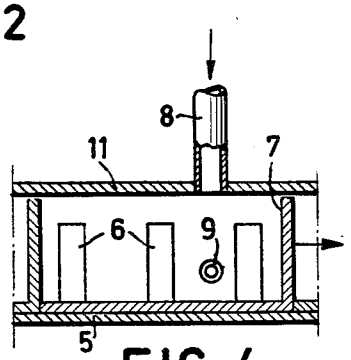


FIG. 4

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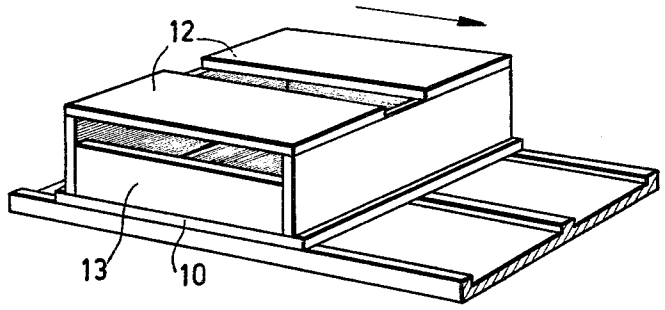


FIG.5

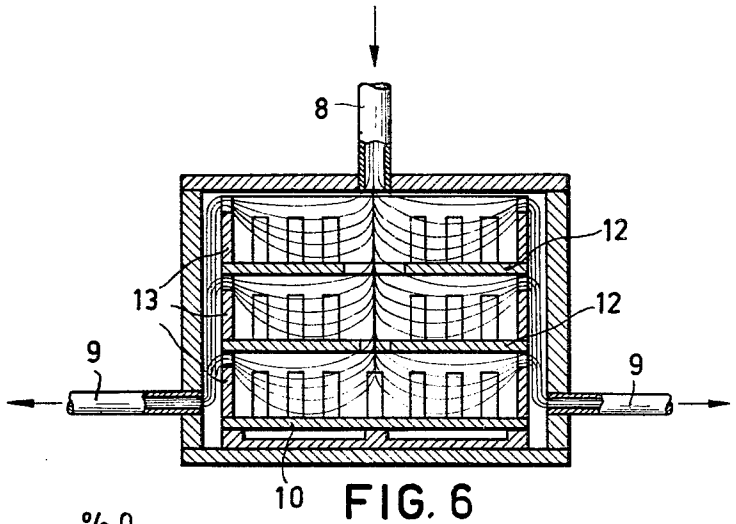


FIG. 6

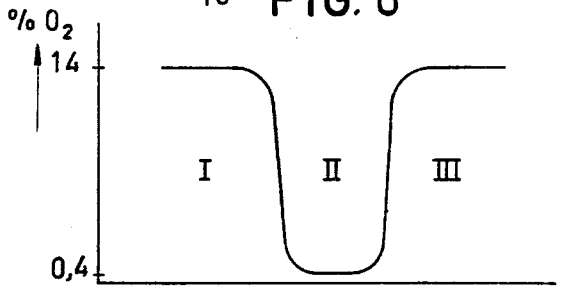


FIG.7

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METHOD OF PRODUCING CERAMIC MATERIALS

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The invention relates to a method of producing ceramic materials, which are passed on transport elements through the channel of a furnace having zones of different temperatures and gas conditions. The invention furthermore relates to a device for carrying out the said method and to the ceramic material manufactured by this method. In a known embodiment the different zones in the furnace channel are in open connection with each other. The furnace wall is provided with channels for supplying gases and with channels for conducting away these gases. These channels are arranged so that the gases follow a given path through a part of the furnace, while a gas having a desired oxygen content has to circulate only in the desired part of the furnace and has to brush past the material at the local temperature. Owing to the different temperature zones in the furnace, however, and the open connection of the zones a natural flow will occur in the longitudinal direction of the furnace. Therefore the gas condition in a zone will be influenced by gases of other zones so that the desired gas condition at a given place can be obtained only with difficulty.

In order to treat the materials to be produced accurately in a given gas atmosphere, the material may be passed through different furnaces, in each of which prevails the desired temperature and the gas condition. However, this method is complicated and costly owing to the use of different furnaces, which must be linked to each other by sluices for conveying the material from one furnace to the other.

The invention very effectively reduces the disadvantages of the known method. This is achieved by dividing, in the method according to the invention, the furnace channel by the transport elements supporting the materials in the longitudinal direction into separation, displaceable chambers, in each of which the working gas of the desired composition is passed in the transverse direction of the furnace channel over the materials. Owing to the formation of separate chambers in the furnace, while only a small space is left between the chambers and the wall of the furnace, the natural gas circulation in the longitudinal direction of the furnace is suppressed. This effect is even raised by the transverse flow of the gases in each of the chambers, so that in adjacent chambers gas atmospheres having, for example, very different oxygen contents can be effectively maintained. The transport element may be moved discontinuously by steps of an extent equal to the length of one chamber. A continuous movement of the transport elements also provides satisfactory results.

In the method according to the invention the gas with which the materials are treated during their transport through the furnace, is preferably fed into each chamber with the desired composition via a channel located opposite the transport element, while the gas is conducted away through a duct in each of the side walls of the furnaces, so that per unit time the quantities of supplied gas and drained gas are kept equal. Thus an effective flow of the gases along the material to be treated is obtained, while the desired gas atmosphere is ensured in the chambers.

With a further preferred embodiment of the invention the materials are arranged in two or more layers one above the other for their transport through the furnace, while the layers are separated by an intermediate wall, in which an opening is provided for maintaining the same flow of gas along each of the layers. In the case of a low height of the materials to be treated the capacity of the furnace may be considerably enhanced. Experiments have shown that the flow of gas along the materials with this preferred embodiment is effective.

The invention furthermore relates to a device for carrying out the method, which device comprises a furnace which is provided with inlet and outlet channels, spaced apart from each other by a given distance and intended for the supply and the draining of gases desired for the treatment with a locally desired composition and comprising furthermore transport elements for the materials to be treated.

In accordance with the invention the transport elements are formed each by a supporting member adapted to be displaced in the furnace and serving for the materials, the supporting member being provided with at least one upright wall, which engages fairly accurately the walls of the channel of the furnace. The upright walls constitute the partitions between the chambers in the longitudinal direction of the furnace.

In a preferred embodiment of the invention the transport elements are formed by L-shaped members. The horizontal limb thereof serves as a supporting body for the materials and the upright limb as an intermediate partition. This partition may be shaped in a form conducive to the flow.

In a further embodiment of the device according to the invention the transport elements are each formed by a sliding plate, on which a frame is disposed, on which frame two supporting elements may be arranged, which, in turn, may support a further frame, and so on, so that the sliding plate and the supporting elements can convey the materials and the front side and the rear side of the frame, viewed in the direction of the furnace channel, constitute the walls of a chamber.

By way of example the invention will now be described more fully with reference to the drawing.

Herein, FIG. 1 is a longitudinal sectional view of part of the furnace, in which L-shaped transport elements are employed.

FIG. 2 shows the temperature variation and the resultant heat circulation in a furnace.

FIG. 3 shows part of a section III—III of FIG. 1.

FIG. 4 shows an L-shaped transport element in the furnace.

FIG. 5 shows a further embodiment of the transport element and FIG. 6 shows a flow diagram of the embodiment of FIG. 5.

FIG. 7 shows a possible curve of the oxygen content of gases in three adjacent chambers.

The furnace **1**, in which the ceramic materials **6**, for example ferrites are sintered, is preferably formed by a muffle furnace. The heating elements **2** are arranged on the top and bottom side of the furnace channel. Since heating element are not taken through the wall of the furnace channel, no difficulties arise in sealing. The materials transported through the furnace in this embodiment obtain a uniform heat radiation. The top walls and side walls of the furnace are provided at equal distances

with duct 8 for supplying gases having, for example the locally desired oxygen content, and duct 9 for conduct in away these gases.

FIG. 2 shows the temperature variation in the longitudinal direction of the furnace. Owing to the temperature differences gases will perform a natural circulation in the furnace channel, which is illustrated in this figure. Owing to the natural, longitudinal flow it is difficult to obtain different zones in the furnace channel having each the desired gas atmosphere, for example with the desired oxygen content. It has been found that a small height of the furnace channel collaborates in suppressing the longitudinal flow.

In order to maintain the desired gas atmosphere at any place in the furnace, the furnace channel is divided into a plurality of chambers 3. These chambers are formed by means of transport elements 4. In the embodiment shown in FIGS. 1, 3 and 4 the transport elements comprise a tile 5, on which the materials 6 to be sintered, for example ferrites, are arranged. The tile has an upright wall 7, which fairly accurately corresponds to the height and transverse size of the furnace channel. The upright wall may be formed in a shape which is conducive to the flow. A number of these L-shaped transport elements 4, arranged one behind the other, form chambers 3, into which gas having a given oxygen content is fed via ducts 8, this gas flowing around the materials and being conducted away via ducts 9. The ducts 8 are arranged at equal distances, in accordance with the length of the transport elements, in the top wall 11 of the furnace channel and the openings 9 are provided in the side walls of the furnace channel. Since the walls of the transport elements are fairly accurately in contact with the furnace walls, the desired gas atmosphere can be satisfactorily maintained in each chamber, while the natural longitudinal flow in the furnace channel is practically suppressed, so that in adjacent chambers gas atmospheres having highly different oxygen contents can be obtained. By arranging the ducts 8 associated with one chamber in a plane transverse to the furnace channel, a transverse flow of the gases is ensured so that the effect of the natural longitudinal flow is further suppressed. The supplied gases flow around the materials to be sintered, while by supplying and conducting away the same quantity of gas per unit time the oxygen content in each chamber is kept constant as long as the chamber is in the region of the channels concerned.

The transport elements pass consecutively all the inlet and outlet channels, so that the material to be sintered is constantly surrounded by gas having the locally desired oxygen content, which may vary with the locally prevailing temperature and with the material to be treated. The temperature in each chamber may be varied by controlling the voltage difference of the heating elements.

In the embodiment shown in FIGS. 5 and 6 each transport element comprises a sliding plate 10, on which a frame 13 is arranged. The front side and the rear side of the frame constitute in the furnace channel the walls of a chamber. On the frame may be arranged two tiles 12, between which a small space is left for passing gas. On the two tiles may again be arranged a frame and so on. With this embodiment the materials to be sintered are arranged on the sliding plate and on the tiles; in the case of materials having a small height a high furnace capacity may be attained.

With the two embodiments a quantity of gas having a given oxygen content is supplied into each chamber per unit time through the ducts 8, which are located opposite the transport elements in the central wall of the furnace wall. Through each of the ducts 9 in the side walls half of the quantities of gases is drawn away per unit time. The oxygen content of the gas for the treatment is thus maintained constant in each chamber. An effective flow of gas around the materials is obtained, while the gas does not whirl around in the chamber. The transverse flow in each chamber completely obviates the effect of the natural

longitudinal flow, which had already been reduced by the shape of the chamber. It has been found that with chambers having a length and width of 30 cms. and a height of 10 to 12 cms. favourable results are obtained with respect to the gas condition to be maintained and to the flow of gas in the chambers.

FIG. 7 shows the result of an examination of the gas conditions in adjacent chambers. It appears that in adjacent chambers gas atmospheres having highly different oxygen contents can be excellently maintained. In the chambers I and III, for example, a gas having an oxygen content of 14% and in the intermediate chamber II a gas having an oxygen content of 0.4% can be maintained. As a matter of course, other ratios between the oxygen contents are possible. It is obvious that with the embodiment according to the invention any desired gas curve can be obtained in the longitudinal direction of the furnace, which has hitherto not been possible. The openings 9 may be arranged at the lower end of the side walls of the furnace channel, but also at different places suitable for the flow. In the heating zone the gases may be supplied through the openings 9 and be conducted away through the openings 8. It is thus avoided that the channels 9 are blocked by the binder of the materials.

What is claimed is:

1. A method of firing ferrite ware in a muffle furnace having an elongated imperforate channel through which said ware is conveyed; said method comprising the steps of applying heat externally to said channel to provide a determined temperature gradient longitudinally of said channel, introducing and withdrawing treating atmospheres containing varying quantities of oxygen in said atmospheres at spaced intervals along said channel to define a plurality of discrete treatment zones transversely of said channel, and maintaining atmospheric pressure throughout each zone of said furnace channel.

2. A method of firing ferrite ware in a muffle furnace having an elongated imperforate channel through which said ware is conveyed; said method comprising the steps of applying heat externally to said channel to provide a temperature gradient longitudinally of said furnace, introducing and withdrawing treating atmospheres containing varying quantities of oxygen in said atmospheres at spaced intervals along said channel to define a plurality of discrete treatment zones transversely of said channel, maintaining the volume of treating atmosphere entering a zone substantially equal to the volume of atmosphere being withdrawn from the same zone and maintaining the pressure within each zone of said channel at atmospheric pressure.

3. A method of firing ferrite ware in a muffle furnace having an imperforate elongated channel through which said ware is conveyed, said method comprising the steps of applying heat externally to said channel to provide a temperature gradient longitudinally of said furnace, introducing and withdrawing treating atmospheres containing varying quantities of oxygen in said atmospheres at spaced intervals along said channel to define a plurality of discrete treatment zones transversely of said channel, maintaining the volume of treating atmosphere entering a zone substantially equal to the volume of atmosphere being withdrawn from the same zone, maintaining the pressure within each zone of said channel at atmospheric pressure, and conveying said ware through each said zone in a plurality of discrete units in which each unit is practicably isolated from the succeeding unit.

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