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Van Laar et al.

[11] 3,752,638

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[54] BOTTOM OF A SHAFT FURNACE, A SHAFT FURNACE PROVIDED WITH SUCH A BOTTOM AND A METHOD FOR COOLING SUCH A BOTTOM

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[51] **Int. Cl.** **F27b 1/24**

[58] **Field of Search** 263/44, 46; 266/32, 266/43; 432/4, 252

[56] **References Cited**

UNITED STATES PATENTS

2,673,083 3/1954 MacPherson et al. 263/44

2,859,030 11/1958 Snyder 266/32

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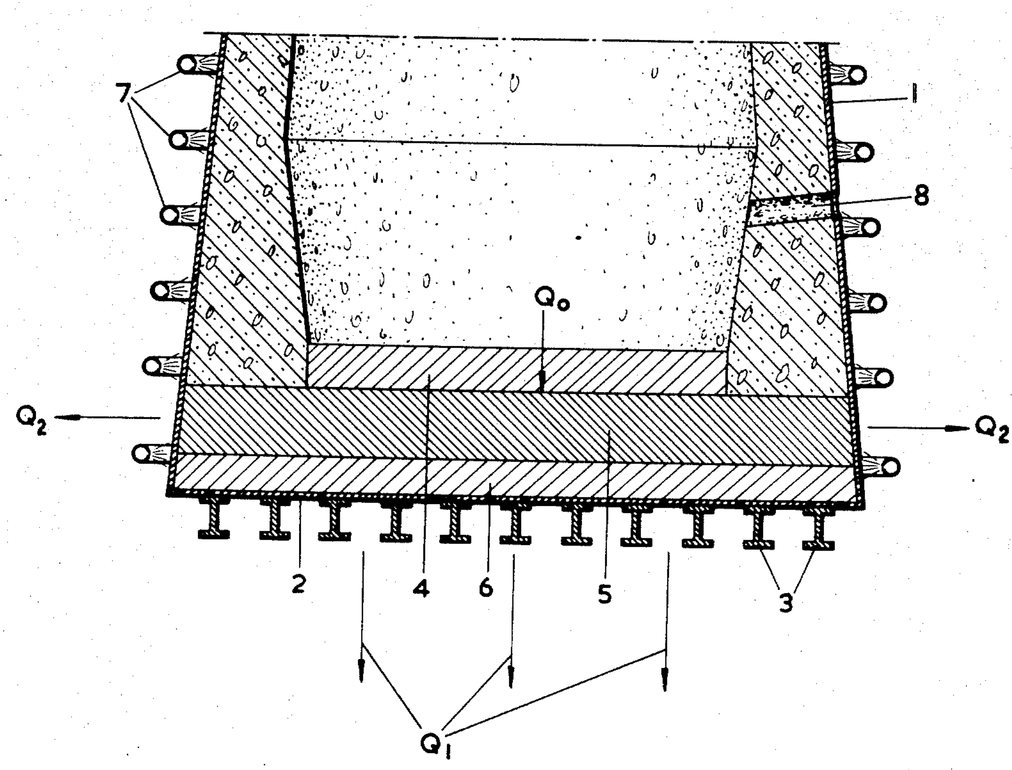
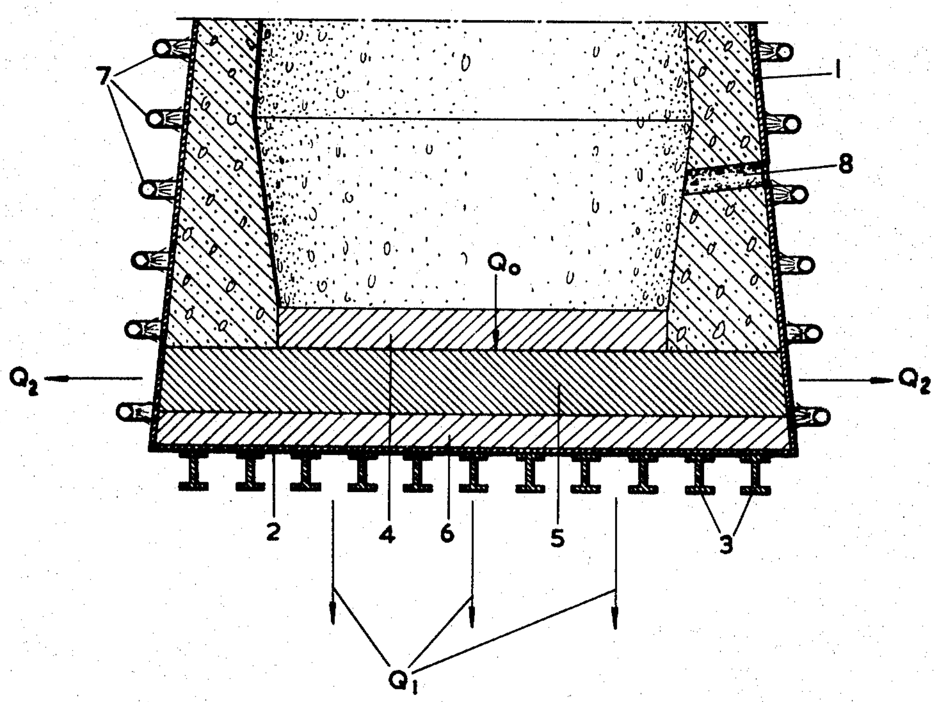
[57] **ABSTRACT**

A shaft furnace, e. g., blast furnace for iron manufacture, having liquid cooling of its periphery and air cooling of its bottom which contains a horizontal layer of refractory material with a heat conduction coefficient λ (cal/m/h/°C) which under operating conditions is higher than 20, includes the improvement that said layer is enclosed between upper and lower layers of refractory of much lower heat conducting coefficient λ. With the bottom surface cooled to below about 150° C, the thicknesses of said upper and lower layers, depending on their said coefficients, are preferably such that only 20 to 60 percent, more preferably 25 to 40 percent, of the heat discharge through the intermediate layer is transmitted to the lower layer; the periphery of the bottom being kept at about 50° C. The intermediate layer may consist of graphite with a λ-value of 60 to 100; the lower, of refractory e. g., carbon bricks, of a λ-vslue of 2 to 5; and the upper layer of refractory, e. g., semi-graphite, may have a λ-value of 20 to 30.

In particular embodiments the three layers, from top to bottom may have λ-values of about 25, 80 and 4, and thicknesses about 60, 120 and 60 cm, and the upper layer may be shielded by a top layer, e. g., of magnesite of a thickness of about 35 cm.

15 Claims, 1 Drawing Figure

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BOTTOM OF A SHAFT FURNACE, A SHAFT FURNACE PROVIDED WITH SUCH A BOTTOM AND A METHOD FOR COOLING SUCH A BOTTOM

This invention first of all relates to a bottom of a shaft furnace, in particular of a blast furnace for iron manufacture, of the type with liquid cooling along the periphery and air cooling along the lower surface, in which this bottom contains a horizontal layer of refractory material with a heat conduction coefficient λ, which under operating conditions is higher than 20 kcal/m/h/°C. Moreover the invention relates to a method for cooling such a bottom and to a shaft furnace, provided with such a bottom.

It is remarked that liquid cooling in this specification and in the claims not only means spray cooling, but also evaporation cooling and cooling by convection.

The invention will be described in more detail below with particular reference to the application thereof to a blast furnace for iron production, but the invention could in corresponding manner be applied to the bottoms of other shaft furnaces such as cupola-furnaces and the like.

In a blast furnace the bottom is subjected to a continuous heavy thermal load as a result of the quantity of liquid iron present immediately on top of this bottom. The temperature in the zone of the tap hole is about 1,400° to 1,500° C. The bottom should be resistant against such high temperatures, but moreover it has the function to support a considerable part of the blast furnace structure and the contents thereof.

In order to meet the requirement of its supporting funtion it is necessary that the bottom in those parts, which substantially support the structure, be sufficiently low in temperature.

A complication for blast furnace bottoms consists in that they are gradually attacked by the liquid iron. It may be said that for most refractory matrials used for the bottom this liquid iron has the tendency to penetrate into it to a depth where the temperature of this bottom material about corresponds to the solidification temperature of the iron, which is 1,120° to 1,140° C. The zone above this temperature limit will gradually be attacked and deteriorated, so that the said temperature limit is displaced downwardly until a situation of equilibrium has been reached.

In the space thus obtained, the so-called salamander, a temperature gradient is found over the height thereof. This salamander is filled from above to its lower end with liquid iron and in part possibly with solidified iron, and often also in part with a coke matrix.

It is of the utmost importance that in this situation of equilibirum the salamander has the lowest possible height. This is so because a high salamander means not only that there is much loss of material in the bottom of the furnace, but also has as a result that the temperature in the foundation of the bottom becomes higher, which is an even much more serious disadvantage. It is even possible that thereby the supporting function of this foundation is spoiled. Also for other reasons relating to the production of pigiron it is undesirable that a high salamander is formed. Thus it has been aimed at in the past to embody the bottom structures in such a way that the salamander remains as shallow as possible and that the temperature in the foundation remains as low as possible. A modern development consists in that the bottom is embodied with a relatively small thickness and that along the periphery it is cooled with the aid of liquid cooling and along the lower surface it is cooled with the aid of aircooling. In "Journal of the Iron and Steel Institute" of September 1967 such a structure has been described, which for the rest is for the greater part built up of carbon bricks. In this structure the bottom rests on a bottom plate or slab, which at its lower surface is cooled by air circulation, there being a thin layer of graphite, having a thickness of about 30 cm, positioned upon this steel slab. This graphite layer has as its function to warrant a good thermal contact between the refractory bottom material and the steel slab. In this structure a considerable part of the total heat flow will be discharged through the lower surface of the bottom. An advantage of this solution consists in that the bottom can be relatively thin and that it is possible to decrease the salamander additionally.

For very large furnaces this structure does, however, not give a satisfactory solution. It has appeared that in such large structures there is still the need to decrease the size of the salamander additionally, or the heat discharge through the lower surface of the bottom becomes so considerable that a cooling with air of this lower surface is not sufficient. If it is nevertheless desired to restrict the temperature of the bottom slab to about 100° C, it will be necessary to apply water cooling of the lower surface of the bottom. Such a solution will, however, entrain great risks as by a disturbance or a fall-out of this water cooling system of the lower surface of the bottom the temperature will rapidly rise to undesired values, which gives considerable risk of collapse of the bottom. The said disadvantage of a salamander which is too deep could be removed by manufacturing the entire bottom from a material which is better heat-conductive, but in this case the disadvantage will remain or the danger will even increase that the operation of a furnace with such a bottom entrains great risks, particularly in case of fall-out of the water cooling of the lower surface.

In view of the above the present invention aims at giving a structure which does not show the disadvantages of such known structures and which nevertheless only forms a salamander of small dimensions and particulary of small height.

In view thereof the invention is characterized in that the bottom contains a horizontal layer of refractory material in a manner known as such, with a heat conduction coefficient λ under operating conditions meeting the requirement that it be higher than 20 kcal/m/h/°C, and that this layer at its upper and lower surface is enclosed by an upper layer and a lower layer of refractory material with a very much lower heat conduction coefficient λ than the first said intermediary layer. Due to this structure of the bottom it is possible to embody the cooling of the bottom according to the present invention in such a way that during operation the lower surface of the bottom is kept cooled to a temperature below about 150° C in a manner known as such, preferably by air cooling, a bottom being used of which the thickness of the upper layer and of the lower layer are chosen depending on the heat conductive properties thereof and in which only 20 to 60 percent of the heat discharge by the intermediary layer with a high heat conduction coefficient is transferred to the lower layer.

The refractory upper layer has primarily as its function to protect the intermediary layer positioned below it. This is so because said last layer is made from a material which usually is much more expensive than usual refractory materials.

As a suitable material for this thermally high conductive intermediary layer it is according to the invention preferred to use graphite with a heat conduction coefficient of 60 to 100 kcal/m/h/°C. By covering the graphite layer by a less expensive layer from a material which is thermally more insulating, the temperature of the graphite layer is decreased to below the melting temperature of the iron, so that it is avoided that the salamander is able to penetrate into the graphite layer.

The lowermost layer, which again consists of a less conductive material, restricts the heat flow to and through the steel bottom slab. The remainder of the heat is thereby discharged to the periphery of the graphite layer, where the temperature is kept low by liquid cooling.

Due to the good heat conduction through the graphite layer it is possible in applying the invention to obtain a temperature gradient from the top to the bottom which from place to place along the bottom is almost the same everywhere, in the same way as would be possible if the heat flow through the graphite layer would mainly be discharged to the lower surface of the bottom. Due to the good and uniform heat discharge it is thus only possible that a very shallow and particularly a very flat salamander is formed.

An important advantage of the structure and the method according to the invention moreover consists in that even for very large furnaces a cooling by air of the lower side of the bottom is possible. The considerable risks of water cooling in that zone are thus avoided.

It moreover appears that when decreasing the cooling, even with a total fall-out of the air cooling, the temperature of the steel bottom slab rises only very slowly and reaches a temperature of 200° C only after a very long time, which opens the possibility to repair and switch on the air cooling again in time before the bottom temperature has risen too high.

It is remarked that a water cooling along the periphery of the furnace bottom gives considerably less risks than a water cooling of the lower surface of the bottom. When falling out of the cooling along the periphery it is always possible to cool this periphery in a simple way by spraying water onto it by hand.

In U.S. Pat. No. 2,673,083 it has been proposed to build in a horizontal graphite layer in the bottom of a furnace for the discharge of heat in a sideways direction to a water cooling in the proximity of the periphery of the bottom. However, in this case the graphite layer is enclosed in a massive refractory structure without cooling along the lower surface. This gives a heat discharge substantially entirely in a sideways direction, with as a result a relatively deep profile of the isothermal surfaces in the bottom. In such cases it appears necessary to cover the graphite layer with a thicker upper layer in order to protect it, and there will also be a deeper salamander. In general it may be said in this respect that for the modern very large furnaces bottom structures without cooling along the lower surface become too heavy and too expensive to be attractive.

Particularly favourable results were obtained according to the invention if 25 to 40 percent of the heat flowing through the intermediary layer with high heat conduction coefficient is discharged to the lower layer, and if the periphery of the bottom is kept at a temperature of about 50° C. Structurally it appears very well possible to realize such a situation, if in the lower bottom layer a material is used with a heat conduction coefficient of 2 to 5 kcal/m/h/°C. Due to this low thermal conduction it is possible to apply only a thin layer for this lower layer. Good results can be obtained by applying amorphous carbon bricks in that area.

In the upper layer it is in principle possible to apply bricks of carbon, magnesite or chamotte (fire clay). Due to the very good resistance against attack the application of a semi-graphite material is preferred with a λ -value of 20 to 30 kcal/m/h/°C. A particularly suitable bottom was obtained with the structure having as characteristics that the three layers from top to bottom have λ -values of about 25, about 80 and about 4 kcal/m/h/°C respectively and that they have thicknesses of about 60, 120 and 60 cm respectively.

Also very good results were according to the invention obtained if the bottom structure was moreover covered with a top layer with a thickness of about 30 cm, the several layers from top to bottom consisting respectively of magnesite ($\lambda = 2$ to 3), carbon ($\lambda =$ about 5), graphite ($\lambda =$ about 80) and carbon ($\lambda = $ 3 to 4), and having thicknesses of about 35, 60, 120 and 60 cm respectively.

The invention not only relates to the bottom structure and the method as described above for cooling thereof, but in particular also to shaft furnaces and in particular to blast furnaces for iron production, which are provided with such novel bottoms. It has appeared that it is possible to design such furnaces with lighter weight and that the controllability of the bottom temperature is more simple than in other comparable furnaces.

As to the choice of the heat conduction coefficient λ and the thickness of the lower layer which together determine the thermal resistance of this layer, the following is remarked. If the thermal resistance is higher (e.g., by a low λ), the bottom slab will be cooler, but the salamander will also be deeper. For a low thermal resistance of the lower layer more heat will be discharged through said layer, the temperature of the bottom slab below the lower layer will increase, but the salamander will be less deep and more plane.

By varying the structure of the lower layer such that of the total heat flow through the intermediary layer between 20 and 60 percent is transported through the lower layer, there will be obtained circumstances in hhich both the depth of the salamander and the temperature of the bottom slab will be within acceptable limits.

The invention will now be explained in more detail with reference to the enclosed drawing giving diagrammatically a possible embodiment of the new bottom structure according to the invention.

In said figure reference numeral **1** indicates a steel jacket around a refractory bottom structure. This jacket merges into a steel bottom slab **2**, resting on a structure with supporting steel beams **3**. The bottom itself is built up of three layers **4, 5** and **6.** The upper layer **4** with a thickness of 60 cm consists of semi-graphite. Of this semi-graphite the heat conduction coefficient λ is about 20 kcal/m/h/°C. Layer **5** has a thickness of 120 cm and consists of graphite with a λ of about 90 kcal/m/h/°C.

Layer **6** has thickness of 60 cm and consists of carbon bricks with a λ of about 4 kcal/m/h/°C. The said λ values relate to the values under operating conditions and temperatures. The furnace diameter in the furnace hearth is about 13 m. By means of water spray cooling indicated by the spray pipes **7** jacket **1** is cooled to about 60° C. A fan not shown with a power of 100 horse power serves to cool the steel bottom slab by air to keep its temperature below 100° C. The total quantity of heat Q_0 discharged through layer **5** is divided into two components. Heat flow Q_1 through the bottom slab **2** is about 200,000 kcal/h and the quantity of heat Q_2, discharged through the jacket part of layer **5** is about 240,000 kcal/h. In the zone of the tap hole **8** the temperature within the furnace is about 1,400° to 1,500° C. In the centre of the bottom the isotherm for 1,100° C does not reach the upper side of layer **4**, which is an indication that no salamander is able to form and that the bottom is not attacked.

It will be clear that the invention is not restricted to this embodiment, which only serves to illustrate one possibility of realizing the invention. In particular it is also possible to obtain good results by replacing the upper layer of semi-graphite by a carbonlayer of the same thickness with a λ value of 5 kcal/m/h/°C, which is covered by a layer of magnesite of a thickness of 30 cm and a λ value of 2 to 3 kcal/m/h/°C.

We claim:

1. A bottom construction of a blast furnace or the like, which comprises, in combination:

a. a metal jacket around the periphery of the bottom of the furnace,

b. liquid cooling means around said metal jacket,

c. a metal bottom plate under the bottom of the furnace,

d. air cooling means beneath said bottom plate for cooling the same, and

e. three superimposed horizontal layers of refractory material supported on said metal bottom plate, constituting an upper layer, an intermediate layer, and a lower layer,

f. said intermediate layer having a heat conduction coefficient λ, which under operating conditions, is higher than 20 kcal/m/h/°C, and

g. said heat conduction coefficient of said intermediate layer being substantially higher than those of said upper and lower layers.

2. A bottom construction as claimed in claim **1**, said intermediate layer having a λ value of 60 to 100 kcal/m/h/°C.

3. A bottom construction as claimed in claim **2**, said intermediate layer being a graphite layer.

4. A bottom construction as claimed in claim **2**, said lower layer having a λ value of 2 to 5 kcal/m/h/°C.

5. A bottom construction as claimed in claim **4**, said lower layer being a carbon brick layer.

6. A bottom construction as claimed in claim **4**, said upper layer having a λ value of 20 to 30 kcal/m/h/°C.

7. A bottom construction as claimed in claim **6**, said upper layer being a semi-graphite layer.

8. A bottom construction as claimed in claim **1**, said upper, intermediate and lower layers having λ values of about 25, 80 and 4 kcal/m/h/° C, respectively, and thicknesses of about 60, 120 and 60 centimeters, respectively.

9. A bottom construction as claimed in claim **8**, said upper, intermediate and lower layers being semi-graphite, graphite, and carbon-brick layers, respectively.

10. A bottom construction as claimed in claim **9** there being a fourth layer interimposed on said upper layer, said fourth layer being a magnesite layer and having a thickness of about 35 centimeters.

11. A bottom construction as claimed in claim **1**, the λ values and thicknesses of said upper, intermediate and lower layers being such that the ratio of heat flows from the intermediate layer to said metal jacket and to said metal bottom plate, respectively, lies in the range of 80:20 to 40:60.

12. A bottom construction as claimed in claim **11**, wherein said ratio of heat flows lies in the range of 75:25 to 60:40.

13. A bottom construction as claimed in claim **12**, wherein said ratio of heat flows is about 240:200.

14. A bottom construction as claimed in claim **1**, wherein during operation, the air cooling of the bottom plate maintains its temperature below 150° C.

15. A bottom construction as claimed in claim **14**, wherein, during operation, the air cooling of the bottom plate maintains its temperature below 50° C.

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