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Kohl et al.

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[54] **METHOD OF LINING METALLURGICAL FURNACES AND A LINING MATERIAL**

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[51] **Int. Cl.** **F27d 1/16**

[58] **Field of Search** 264/30; 266/43

[56] **References Cited**

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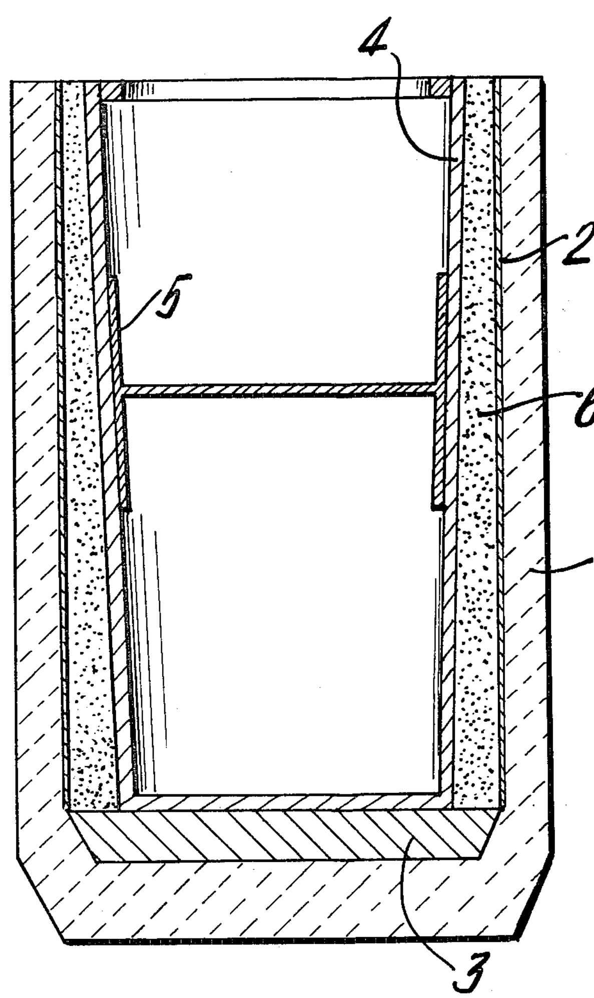
[57] **ABSTRACT**

A method of lining a metallurgical furnace particularly induction furnaces using a form which is placed at a spaced location from the furnace wall comprises filling the hollow space between the furnace wall and the form with a granular and dry refractory material, compacting the material, subjecting the compacted material to a ceramic sintering process by heating it to an intermediate termperature in the range of from about 300° to 800° C. until the material attains a sufficient stability of shape, thereafter removing the form and subjecting the refractory material to a further ceramic sintering process by further heating. A self supporting lining for the metallurgical furnaces comprises a highly compacted and dry structure of a refractory oxide or an oxide mixture to which a dry sintering agent is added and which has been consolidated at a temperature of from between 300° to 800° C.

9 Claims, 3 Drawing Figures



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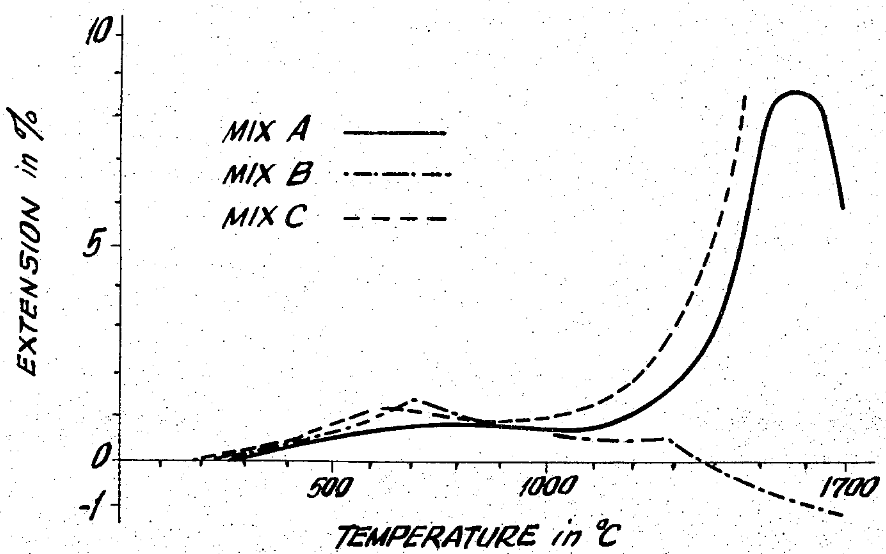

FIG.1

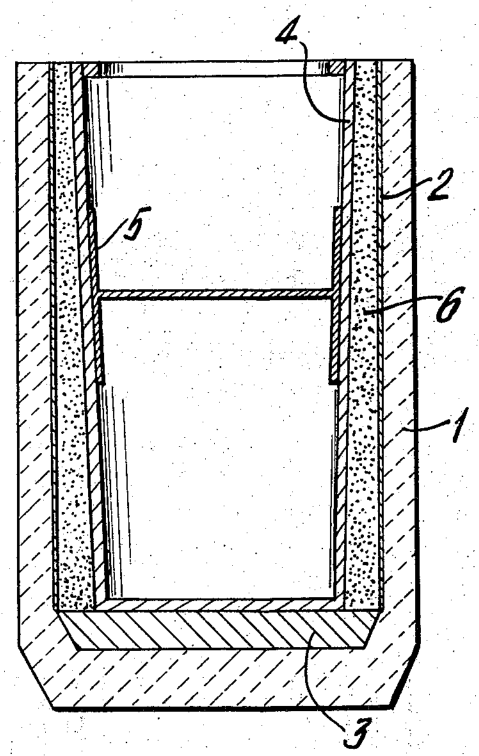

FIG.2

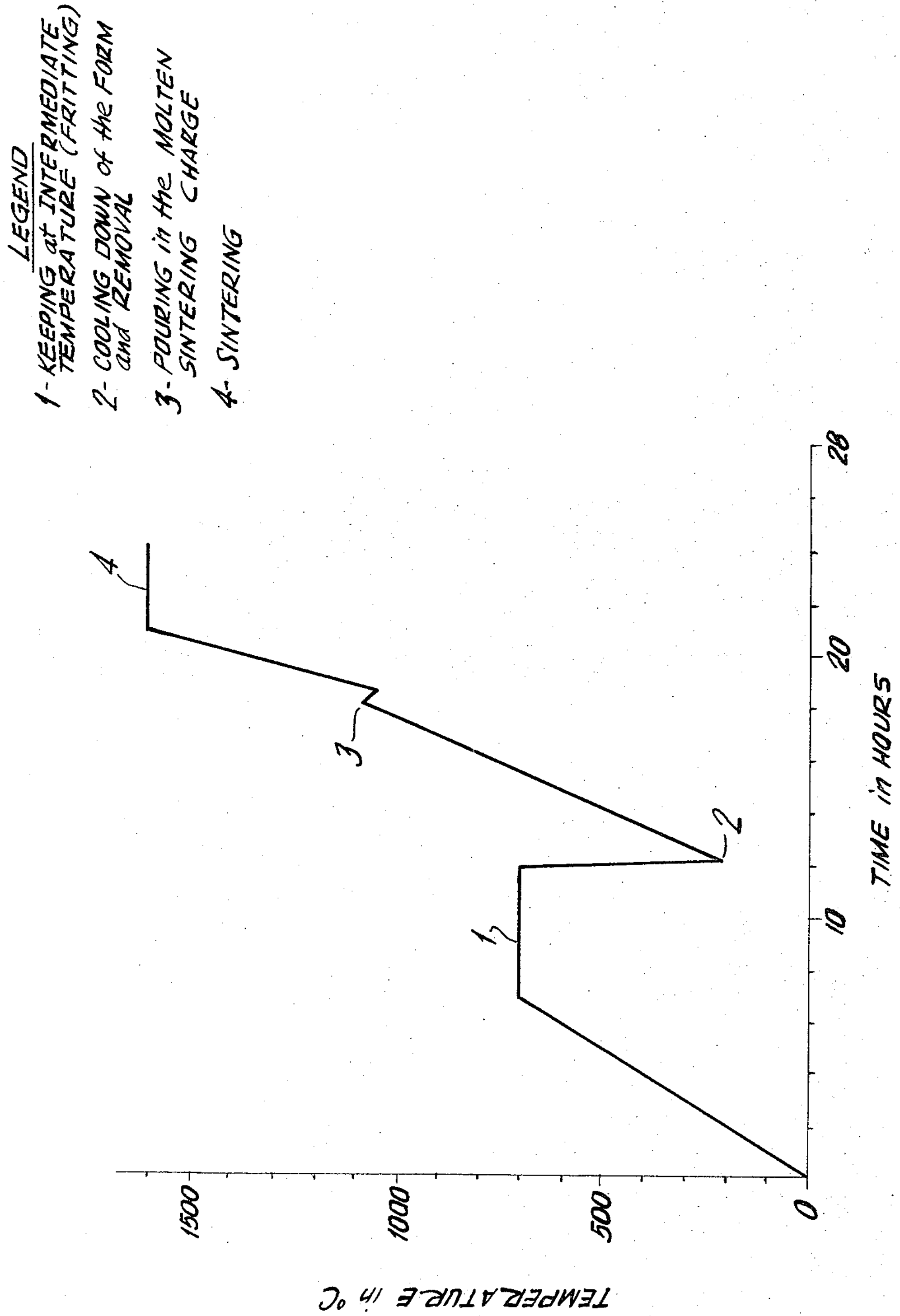
LEGEND
1- KEEPING at INTERMEDIATE TEMPERATURE (FRITTING)
2- COOLING DOWN of the FORM and REMOVAL
3- POURING in the MOLTEN SINTERING CHARGE
4- SINTERING
1
2
3
4
0
500
1000
1500
TEMPERATURE in °C
10
20
28
TIME in HOURS

FIG.3

METHOD OF LINING METALLURGICAL FURNACES AND A LINING MATERIAL

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates in general to furnace wall construction and in particular to a new and useful method of lining metallurgical furnaces, particularly induction furnaces, wherein a granular and dry refractory material containing a sintering additive is filled in a hollow space formed by a furnace wall and a lining form, compacted and thereupon submitted to a sintering process by heating, and to an improved lining material.

2. DESCRIPTION OF THE PRIOR ART

Metallurgical furnaces for iron and steel melting and/or treatment, unless they are lined with refractory stones, frequently comprise a lining made of ramming masses with the use of lining forms. This particularly applies to induction furnaces where the wearing crucibles are generally lined with a plastic, half-plastic and/or dry refractory mix on the basis of SiO_2, MgO, Al_2O_3, spinels, etc. In such cases, the refractory material introduced into the hollow space between the furnace wall and the form is either rammed down or the compaction is obtained after the filling by vibration.

A substantial disadvantage of plastic refractory masses, which regularly contain 6 to 8 percent of water, is the lengthy drying process under heat which they require, so that the entire preperation time of the furnace, i.e., the time necessary for the lining, drying and sintering, amounts up to a week or even more. The sintering process results in a homogenous body throughout the whole thickness of the wall so that, as a rule, cracks occurring under heavy stresses penetrate the whole wall and the risk of destroying the water cooled induction coil cannot be eliminated. On the other hand, this drawback is accomplished by the advantage that after the ramming down, the lining form can be removed and used again as a permanent one.

Induction furnaces for melting nonferrous metals and any iron and steel alloy are today mainly lined with refractory masses of the acid type, particularly with quartzite mixes. Experiments are known and described, for example, in the periodical "Giesserei," 1970, p. 450, to plasticize a refractory quartzite mix by adding an appropriate quantity of a liquid binder composed of several constituents (monoaluminium phosphate, inorganic polymeric binders on the basis of peroxychloride, and the like) so that after the usual compacting, a self supporting furnace lining body is formed and, consequently, a permanent form may be used.

A considerably shorter total lining time of the order of about 12 to 24 hours can be obtained in using dry refractory materials with admixed sintering additives, mostly boric acid. Besides, it should be noted that dry quartzite masses are particularly low-priced. Ordinarily, the proceeding is such that dry refractory material is filled into the hollow space formed by the furnace wall, for example, the permanent lining, and the lining form, compacted by vibration, and with the form in place and with a solid or molten sintering charge, the furnace is heated up to and kept at a temperature necessary to obtain a ceramic sintering of the lining.

According to the present state of art, it is considered impossible to set up the crucible or the wearing lining of metallurgical furaces, particularly induction furnaces, as a self supporting refractory body by merely pouring and compacting a dry refractory material. It has rather been considered necessary to support the compacted dry and refractory material during the whole time up to the sintering and therefore to keep the form in the furnace throughout the heating time, to let it melt and be absorbed by the sintering charge which then will support the linging body. However, because the costs of the lost form substantially exceed the other lining expenses, the use of permanent forms is a worthwhile objective.

SUMMARY OF THE INVENTION

The inventive method provides a lining for metallurgical furnaces, particularly induction furnaces, with a wearing layer of dry refractory materials in order to obtain a very short preparation time, and which uses a permanent form in order to substantially lower the lining costs and also to assure that the finished wearing lining will stand the high thermal and mechanical stresses at least as well as the known linings.

In accordance with the invention, a refractory material is compacted within a form and the form and the compacted material containing a sintering additive is heated up to and kept at an intermediate temperature until the refractory material attains a sufficient stability of shape, and subsequently removing the form and heating the self-supported lining body up again to obtain a ceramic sintering of the refractory material.

With the usual dry refractory quartzite mixes, particularly such ones containing boric acid as a sintering additive, it is possible, as a rule, to proceed so as to heat the compacted refractory material up to an intermediate temperature of approximately 400° to 800° C., preferably to 500° to 700° C., and to keep this temperature for about 0.5 to 5 hours, according to the dimensions of the furnace, then to remove the form and to heat the formed self supporting lining body as well as the sintering charge up again to a sintering temperature and keep this temperature until the process of ceramic sintering is terminated.

Surprisingly, it has been found that with the usual dry compacted refractory materials there is possible already at a moderately high temperature to obtain such a solidification of the lining that the lining becomes self supporting and can stand a sintering charge without any mechanical support.

The inventive method can be carried out in a particularly simple manner by using a steel sheet form which, after the stability of shape of the refractory material is obtained, is cooled down with respect to the intermediate temperature, for example, by compressed air, so that the form contracts and can be removed from the furnace without difficulties. For the lining of crucible-type induction furnaces, the steel sheet form may advantageously be made in one piece and conical, preferably over its whole length, or at least over the greatest part thereof. This not only facilitates the removal of the permanent form but also substantially extends the crucible life with respect to the service of life of the usual, mostly cylindrical crucibles which are tapered only in their bottom part. Of course, multipart permanent forms may be used particularly for metallurgical furnaces with complicated hearth shapes, where such forms permit a simple removal and, when using reinforcements against warping, a high dimensional stability of the lining.

Most of the various usual dry refractory materials on the basis of SiO_2, MgO, Al_2O_3 and spinels, are appropriate for the inventive method. By suitably selecting the nature and quantity of the sintering additive, a chemical solidfying reaction in the refractory material can be obtained already at moderately high intermediate temperatures, with the result that after sintering, the self supporting lining body is capable fully to meet all requirements. In particular, the wearing linings set up in accordance with the invention also have the advantage of all of the dry materials that, in contrast to plastic masses which always form a homogenous body, only a part of the lining thickness becomes sintered while the remaining zone of the lining thickness is solidified only partially. Therefore, cracks starting from the interior, in most cases penetrate the lining only partially and the danger the furnace would break through is accordingly reduced.

Also, the inventive method can be carried out with a particular advantage in using dry quartzite ramming mixes to which usually boric acid, specially dry boric acid powder (H_3BO_3), is admixed as a sintering additive.

A particularly long life of the crucible may be obtained with a tertiary quartzite mostly having rounded or cubical grains and prepared with the following grain-size distribution: 60 to 40 percent of grains with 5.0 to 0.6 mm, up to 30 percent of grains below 0.06 mm, and the rest grains with 0.6 to 0.06mm in diameter. If approximately 1 percent of boric acid powder as sintering agent is added to such a tertiary quartzite mix and the mass is filled in the hollow space between the permanent form and the furnace wall (or the permanent lining) and then, by means of known vibrators, compacted to a porosity between 16 and 24 percent, a highly wear-resistant lining is obtained after the sintering, which meets the requirements in a particularly high measure. In terms of geometry, the refractory lining of a crucible furnace represents an annular body whose diameter increases with the increasing temperature. Because the outer periphery of the crucible is cool and partially clamped, an increase of temperature in the interior favorably results in a post-compression of the mentioned lining material from the interior so that after the sintering, the porosity is reduced to only about 10 percent. Such a lining is particularly immune to an undesired penetration of the fused mass.

Accordingly it is an object of the invention to provide an improved method of lining a metallurgical furnace wherein a dry refractory material is placed in a space between the furnace wall and a form and it is compacted and then subjected to an intermediate temperature in the range from 300° to 800° C at which no ceramic sintering occurs until it attains a stability of shape and thereafter the form is removed and the material is again heated to subject it to a further heating to a temperature high enough to effect the ceramic sintering process.

A further object of the invention is to provide a self supporting lining which comprises a highly compacted dry granular structure of a refractory oxide having a dry sintering agent added thereto which has been consolidated therewith at a temperature in the range from between 300° to 800° C.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawing:

BRIEF DESCRIPTION OF THE DRAWING

In the Drawing:

FIG. **1** is a graph indicating variation in temperature with extension for three different refractory mixes;

FIG. **2** is a view of a furnace having a permanent form therein for the lining thereof in accordance with the invention; and

FIG. **3** is another graph indicating variations in temperature and time for the various steps of the process.

GENERAL DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in particular, the choice for a refractory dry material which is specially suitable for the inventive method, is based on the fact that especially above approximately 1,000° C., the mixes show a variable expansion depending on the nature and composition of the refractory material and of the sintering additive.

Reference is made in this respect to FIG. **1** where the extension of three different mixes A, B and C based on quartzite is plotted as a function of the temperature. While with the mixes A and C, a good post-compressed wearing lining may be obtained, the mix B is not recommendable because of its contraction at high temperatures.

Crucible-type furnaces as well as channel-type furnaces for the aluminium treatment can advantageously be lined, in accordance with the invention, with a dry ramming mix on the fire-clay basis containing about **38%** of Al_2O_3 to which, for example, glass frit is added as a sintering agent. At an intermediate temperature of 300° C. kept for approximately 3 hours, the compacted ramming mix solidifies to a self supporting furnace lining so that the permanent form may be removed and the lining may be sintered at a temperature of about 1,000° C. Highly aluminous refractory mixes with, for example, 90 percent of Al_2O_3 also proved very useful for the purpose in question.

In the following, examples of application of the invention method are given with regard to the drawings.

Into the crucible of a **13**t-induction-furnace according to FIG. **2** where the permanent lining **1** had an inside diameter of 1,400 m and a height of 2,440 mm, an intermediate form **2** was applied against the inner surface of this lining, and a completely conical one-part steel form **4** with a wall thickness of 6 mm, a bottom diameter of 1,040 mm, a border diameter of 1,140 mm, and a reinforced rim is inserted, after ramming a 380 mm thick bottom **3.** An entirely dry quartzite ramming mix **6** with 1.4 percent of dry boric acid powder and a free water content of less than 0.2 percent is vibrated into the hollow space between the permanent form **4** and the permanent lining **1.** Owing to the action of the vibrator **5** across the permanent form **4,** the quartzite mix **6** has been compacted to a porosity of about 22 percent. The quartzite mix contained rounded cubical grains of the following distribution:

Grain-size mm	Content %
4.0 – 5.0	1.20
3.0 – 4.0	17.60
2.0 – 3.0	6.10
1.0 – 2.0	17.10

-Continued

Grain-size mm	Content %
0.6 – 1.0	12.60
0.3 – 0.6	5.95
0.2 – 0.3	2.20
0.1 – 0.2	4.75
0.06– 0.1	2.80
Below 0.06	29
	100.00 %

Using a gas burner located in the crucible, the steel sheet form **4** and the refractory mix **6** is heated for 7 hours to approximately 700° C and kept at this temperature, with drops not below 600° C., for 5 hours. Thereby, the refractory mix is consolidated so that the ling becomes self supporting. The permanent form **4** is then quickly cooled down by compressed air, within 20 minutes, to about 200° C., so that the form contracts in diameter and is removed from the furnace without difficulties. Thereupon, the furnace is immediately heated up again to a temperature of about 1,100° C. within 5 hours. Molten pig iron is then poured in as a sintering charge, super heated to 1,600° C. and kept at this temperature for about 3 hours whereyy the lining **6** is passed through a ceramic sintering process and the furnace becomes ready for normal service.

In FIG. **3**, the heating process is illustrated diagrammatically. An inductive heating with a starting block instead of the gas burner may be used for heating if desired. Also, particularly in middle- or high-frequency induction furnaces, a solid charge may be used as the sintering charge instead of the molten one.

As indicated in FIG. **3** the refractory material is heated up and maintained at the intermediate temperature as indicated at **1**. Thereafter it is cooled down to the temperature indicated at **2** for the removal of the form and is subsequently heated until at the location **3** the molten sintering charge is poured into the refractory and the heating continues until the sintering temperature at **4** is reached.

Crucible and channel-type furnaces for melting and treating aluminun and aluminum alloys have been lined as follows: An entirely dry ramming mix on the fire-clay basis with about 38 percent of Al_2O_3, a grain size of 0 to 5 mm, and mixed with glass frit as a sintering additive, is poured by layers into the hollow space between the permanent lining and a maltipart easily-removable-iron-sheet permanent-form of 5 mm thickness, and compacted with the aid of an electric vibrating rammer. In those parts of the furnace where the consolidation through high temperature is not possible, 6 percent of a phosphate binder have been added to the ramming mix. The form and the compacted ramming mix is then heated up by means of a gas burner, at a rate of 50° to 100° C. per hour, to an intermediate temperature of 300° C. and kept at this temperature for 4 to 5 hours. Thereby, the ramming mix is consolidated to a self supporting wearing lining. After cooling down, the permanent form is disengaged from the lining and easily removed. The self supporting lining is reheated by means of the gas burner and, at the temperature of 800° C, molten aluminium as sintering charge is poured into the furnace. The aluminium charge has been heated inductively up to 1,000° C. and this sintering temperature is kept for 12 hours, so that the fire-clay lining becomes sintered and the furnace can be put into normal service.

A 3 ton-low-frequency induction furnace for melting bronze is lined with a quartzite dry ramming mix containing 98 percent of SiO_2 and boric acid as a sintering additive. The hollow space between the permanent lining and an easily removable, 8 mm thick one-part iron sheet permanent form is filled up to the upper border with the mix which has then been compacted by means of a known vibratory sifting device. Thereupon, the form and the compacted ramming mix are heated by means of a gas burner and at a rate of 100° – 150° C. per hour, to a temperature of 500° – 600° C. and kept at this temperature for 4–5 hours. Thereby, the ramming mix becomes consolidated to a self supporting wearing lining. After cooling down, the permanent form is disengaged from the lining and could easily be removed. The furnace is then charged with a solid charge and inductively brought to the melting temperature, at a rate of 100° – 150° C. per hour. The melting temperature is about 1,150° C. The furnace is superheated to 1,250° C. and kept at this temperature for 8 hours until the sintering process is fully terminated. Now, the furnace is ready for service. For heating up the furnace to the sintering temperature after the removal of the form, certainly the gas burner may be used again, instead of the inductive heating of the solid charge.

The use of permanent forms of sheet iron is particularly economical for the first melting of heavy-metal alloys. The normal use of melt-down forms requires a form of the same material composition as the heavy-metal alloy because another composition would result in a corresponding impurity. The considerably cheaper permanent forms of sheet iron which, according to their purpose, are removed from the furnace before the alloy is charged, avoid this drawback.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method of lining a metallurgical furnace, particularly an induction furnace, using a form which is spaced inwardly from the furnace wall or from a similar inner form, comprising adding a granular and dry refractory material to this space between the form and the wall and compacting the material therein, heating the compacted refractory material up to an intermediate temperature below the sintering temperature and maintaining this material at the intermediate temperature until it becomes self-supporting, thereafter removing the form from the furnace, so that the self-supporting refractory material is unsupported, and heating the self-supporting refractory material to a ceramic sintering temperature to form the self-supporting permanent refractory wall of the furnace.

2. A method of lining metallurgical furnaces according to claim **1**, wherein the compacted refractory material is heated up to an intermediate temperature of a range approximately from 300° to 800° C., preferably to 500° to 700° C. and kept at this intermediate temperature for ½ to 5 hours, that the form is then removed and the formed self supporting furnace lining, adding a sintering charge, and heating the lining and charge further to a sintering temperature and maintaining them at this temperature until the ceramic sintering process in the lining is terminated.

3. A method of lining metallurgical furnaces according to claim 1, wherein the intermediate temperature range is from 500° to 700° C.

4. A method of lining metallurgical furnaces according to claim 1, wherein after the refractory material has attained its stability of shape, the form is cooled down with respect to the intermediate temperature and then removed from the furnace.

5. A method of lining metallurgical furnaces according to claim 1, wherein the lining is for a crucible-type induction furnace, and a one-part steel sheet form is used which is of conical shape.

6. A method of lining metallurgical furnaces according to claim 1 wherein the refractory material comprises a dry quartzite ramming mass to which boric acid, particularly dry boric acid powder (H_3BO_3) is admixed as a sintering additive.

7. A method of lining metallurgical furnaces according to claim 1, wherein the refractory material comprises a tertiary quartzite which has grains of rounded to cubical shape and have the following grain-size composition:

60 – 70 percent of grains of the size 5.0 – 0.6 mm
up to 30 percent of grains below 0.06 mm
the rest grains of the size 0.6 – 0.06 mm.

8. A method of lining metallurgical furnaces according to claim 1, wherein the refractory material comprising a tertiary quartzite to which 1 percent of boric acid powder has been admixed as a sintering additive, is compacted by means of known vibrators to a porosity of 16 – 24 percent.

9. A method of lining a metallurgical furnace, according to claim 1, wherein the refractory material comprises a dry ramming mass on the fire-clay basis containing about 38 percent of Al_2O_3 to which glass frit as sintering agent has been admixed, refractory material is compacted and heated up to an intermediate temperature of 300° C. and kept at this temperature for 3 hours, the form is removed from the furnace and the formed self supporting furnace lining is heated up again to 800° C. by means of a gas burner, and the furnace is charged with molten aluminium and inductively heated up to a sintering temperature of 1,000° C at which it is kept for 12 hours so that the sintering process in the lining may come off.

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