METHOD OF MAKING LINER IN AN INDUCTION MELTING FURNACE

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FIG. 1.

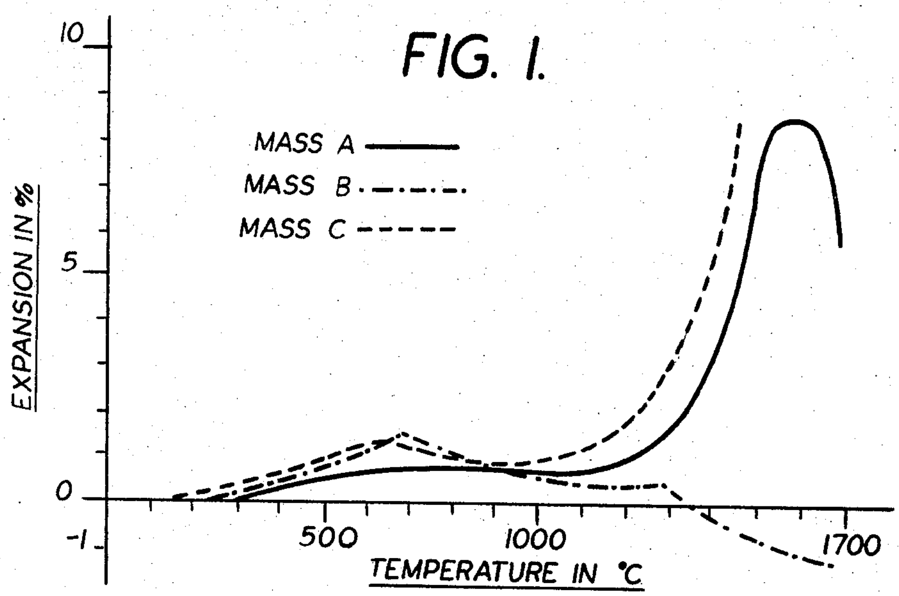


FIG. 3.

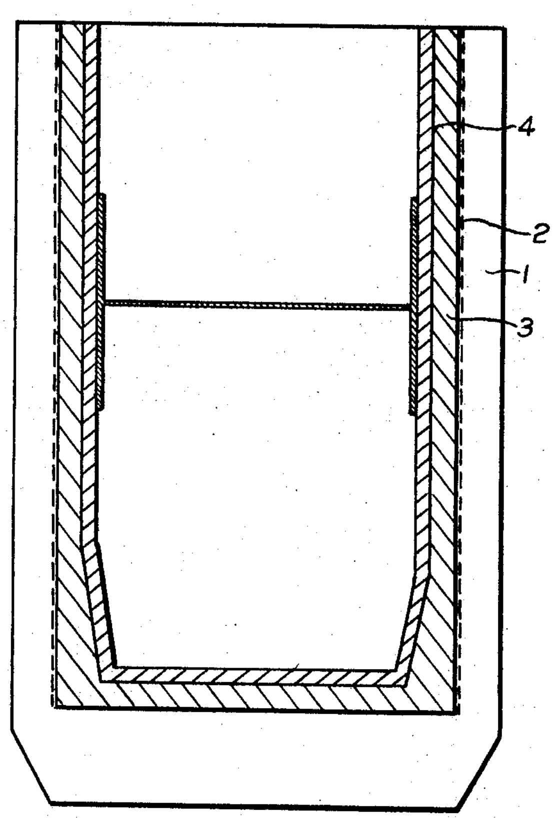
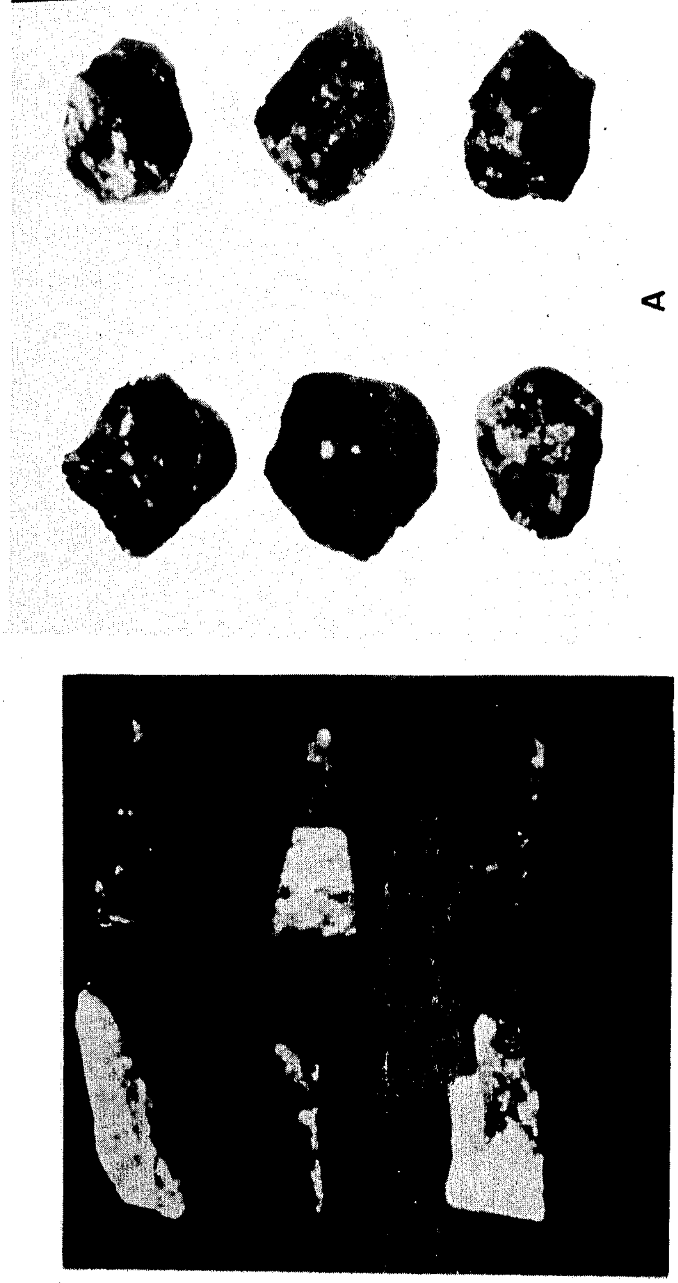


FIG. 2.



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METHOD OF MAKING LINER IN AN INDUCTION MELTING FURNACE

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ABSTRACT OF THE DISCLOSURE

A method of preparing a self supporting liner for an induction melting furance is disclosed.

A dry refractory tertiary quartzite granular composition is filled between the furnace wall and a form defining the inner shape of the liner and densified as by vibration applied to the form. The form is removed to leave a self-supporting liner. The exposed inner surface of the liner is impregnated with a binder to a depth less than the total thickness of the liner to form an inner strengthened shell having a thickness of from 1–8 mm. The inner shell is then sintered leaving the outer zone of said linear unsintered.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates to a liner in an induction melting furnace, which is self-supporting, i.e., does not receive support from an internal form that preserves the shape which it has achieved under densification.

The invention further relates to a method of making the liner by densification with a vibrator system, followed by removal of the re-usable form, impregnating an inner shell of the liner with a binder, which strengthens during heating.

Discussion of the prior art

Induction melting furnace of the crucible and trough type are generally lined with plastic, semi-plastic and/or dry compositions having a base of a refractory metal oxide such as MgO, Al_2O_3, SiO_2, spinels, and the like. The refractory lining is rammed up with the refractory composition, also called fritting composition, with the aid of a precisely centered sheet-metal form which creates a cavity, or the composition is poured in and vibrated. It is then necessary to frit the refractory composition, i.e., a heating and drying process must be performed on the furnace lining, which is a tedious procedure depending on the nature of the refractory material, so that the present time from 12 to 24 hours of preparation are required when a dry composition is used, and up to a week or more when plastic compositions are used. There is a genuine need to reduce the amount of time required for the lining of the furnace to make the melting unit ready for operation.

An improvement can be achieved by using absolutely dry granular mixtures as the refractory composition. In this case the sintering agent, which is usually in the form of boric acid, must be mixed in dry form with the composition. Such dry compositions are rammed up or vibrated in place with the aid of a form which in this case serves both for the transfer of the energy, e.g., by vibration to densify the loose granular mixture, and, mainly, for the purpose of giving stability to the granular mixture.

In the known state of the art it is not possible to make a self-supporting refractory liner in an induction melting furnace from a loose composition without using a form until the sintering of the granular mixture is completed. This means that the form, which generally costs several times as much as the refractory composition, remains in the furnace, is heated up with a gas or oil flame or by electrical power to the point where the granular mixture containing the sintering agents solidifies ceramically. In this process the form is melted; otherwise, it eventually melts when the furnace is charged with molten material or a solid charge is melted down in it.

According to "Giesserei 57" (1970), pp. 450–451, tests were recently started on a plastic quartzite composition with a binder consisting of several components (monoaluminum phosphate, inorganic polymeric binders having a polyoxychloride base and other components), with a re-usable form. A number of advantages are expected from this. However, the fact that the liner solidifies into an integral pot from the inside surface all the way to the outside surface does not prevent the danger of cracks running all the way through enabling the melt to penetrate through to the water-cooled coil.

The object of the invention is to create a self-supporting liner which eliminates the losses involved in forms expended during construction of the liner, but provides the greatest possible protection against mechanical and thermal stresses.

SUMMARY OF THE INVENTION

Broadly, this invention contemplates a self-supporting liner for an induction melting furnace constructed of an unsintered densified mass of a refractroy oxide or mixture of oxides having on its inside surface intergral therewith a shell consisting of the same mass but containing a binding agent which becomes stronger at elevated temperatures.

This invention further contemplates a method for preparing a self-supporting liner for an induction melting furnace which method comprises the steps of:

A. Filling the space between a form defining the shape of the liner to be constructed and the furnace wall with a dry refractory granular composition and a dry sintering agent and densifying the liner mass
B. Removing said form
C. Applying to the inside wall of the liner a binding agent which becomes stronger at elevated temperature
D. Heating the so-treated liner to effect formation of an integral shell on the inside surface of said self-supporting liner before or during sintering said internal shell.

Generally speaking, a self-supoprting liner for an induction furnace is made, pursuant to the present invention, by filling a form within the furnace which form defines the space to be filled. Such space when filled constitutes the liner. The liner is filled with a dry refractory material, especially a refractory material of the tertiary quartzite type having a grain configuration of round to cubic. The refractory material is in admixture with a sintering agent, desirably dry boric acid.

Vibrational energy is applied to the so-filled form. This energy effects compacting the loose granular mixture to a dense mass and provides stability to the granular mixture.

After the vibrational energy is applied, the form is withdrawn to expose the inside wall of the liner. To the inner surface of the liner is applied a binding agent which becomes stronger at elevated temperatures. Particularly suitable binding agents include phosphate binding agents especially monoaluminum phosphate and derivatives thereof containing phosphorus. The binding agent's effect is to impart durability and mechanical strength to the liner before and when being sintered. While the amount of binding agent can vary over a wide range, a quantity between 0.05 and 0.07 cubic centimeters of binding agent per square centimeter of surface area treated is enough. Generally spoken, the quantity of binder suffices which is sucked in by the dry liner material on the inside surface.

After the binding agent is applied to the inside wall of the liner, the inside wall is subjected to a temperature between 400 and 700° C. to effect strengthening the inner shell of the wall and to provide the same with good mechanical properties.

DESCRIPTION OF PREFERRED EMBODIMENTS

In accordance with the invention, a self-supporting liner comprising, on the coil side exclusively, a highly compacted, dry granular structure of refractory oxide or oxide mixture to which a dry sintering agent, preferably boric acid, has been added is provided. The inner surface layer of said liner has an integral shell comprising a binding agent which becomes stronger at elevated temperatures which has been subjected to elevated temperatures.

It is desirable for the thickness of the strengthened shell to amount to between 1 and 8 mm. This strengthening shell is preferably provided by applying to the inner surface layer a binding agent especially a phosphate binding agent, particularly a monoaluminum phosphate binder with variable phosphate members. Other suitable binders include, for example, sodium silicates of varying soda to silica ratio (such as water glass), silicic acid esters, tar, dextrine solutions, and sulfite waste liquor.

Preference is given to an acidic lining, since induction furnaces for the melting of non-ferrous metals and gray iron, ductile iron and cast steel are today mostly (more than 90%) lined with refractory compositions of an acidic substance. In accordance with the invention, the preferred starting material for these refractory compositions are quartzites having a tertiary quartzite base, since they have a round to cubic grain which is particularly well suited for dense packing. These quartzites are fine to coarsely crystalline in their mineralogical nature, and they may or may not contain a binding agent, for example, the so-called basal cement. Depending on the temperature and the transformation tendency, thermal stresses are present for the formation of the individual modifications which exists, ranging from more than 10% down to shrinking tendencies in the temperature range up to 1600° C. Shrinkage is determined also by the sintering agent in the case of certain types of quartzites. Conventional fritting compositions can be employed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a graph summarizing the effect of temperature of expansion for three different compositions.

FIG. 2 shows the grain size and configuration of refractory metals used in the liner of the present invention.

FIG. 3 is a cross-sectional diagram showing a liner, form and furnace during construction.

In FIG. 1 this situation is summarized by the example of three compositions, A, B and C. FIG. 1 shows the expansion characteristics of the compositions as a percentage, in relation to the temperature in ° C. The three compositions show a like expansion up to about 100° C., but above this temperature they differ, in that Composition B tends to shrink while Composition A and Composition C have an expansion of just under 9% at about 1600° C. The invention utilizes these expansion characteristics, and it is pointed out that in crucible furnaces the refractory liner is an annular body which in the case of expansion, due to the effect of temperature, for example, can only increase in diameter. This is advantageous for the liner, because if the grain size analysis is correct, the loose granular mixture will thus be further compressed to such an extent that its porosity can be reduced to values in the neighborhood of 10%.

If, however, a composition behaves like the one in Example B, the result will be cracks in the refractory lining, due to the fact that the composition shrinks owing, for example, to the influence of the sintering agent. These cracks impair the life of the liner and lead to an early failure of the furnace. According to the invention, therefore, it is proposed that the thermal expansion characteristics be adjusted on the basis of the mineralogy of the refractory liner, preferably tertiary quartzite, and on the basis of the amount of sintering agent used, in such a manner that in the 1600° C. temperature range, and with a sintering agent content of 1%, an expansion of the refractory composition of 7 to 9% will be achieved.

In addition to the mineralogy of the raw material, which greatly affects the transformation and expansion characteristics of the refractory composition, the shape of the grains and the grain analysis are of great importance for the achievement of an optimum packing density towards the solution of the problem to which the invention is addressed. Example A is best performed by a liner having a tertiary quartzite base material with round to cubic grain form. The grain form can be produced by appropriate precessing of the very hard rock. The tertiary quartzite with a basal cement structure, which is used here, is substantially harder than a rock quartzite. The least suitable grain form is also shown in FIG. 2, and is marked "B." It is a grain form existing preferably in crushed rock quartzites, see curves B and C in FIG. 1.

Another feature of the invention is the adjustment of the grain analysis in such a manner that, on the one hand, an optimum compaction is possible, and on the other hand, there is still room for further compaction in grain interstices when the annular furnace liner undergoes thermal expansion. Examples of the grain composition of the invention are given in Table 1 at the end of this description, by way of example. Accordingly, 60 to 40% of the grain composition consists of grains of 5.0 to 0.6 mm., 30% of grains smaller than 0.06 mm., and the balance of 0.6 and 0.06 mm. grains. By means of a suitable vibrator system, energy is delivered through the inserted form which establishes the cavity in the refractory grain mixture, to a sufficient extent to produce an optimum density.

In Table 2 below the crude densities are given which were determined in a three-ton furnace and which were found on the basis of test body sleeves vibrated into the furnace liner. At the net density peculiar to this type of quartzite, of 2.63 g./cm.^{3}, total porosities of 16 to 20% were achieved. Texture data are thus available which represent optimums even in the case of formed and fired refractory bricks. In a number of series of experiments it was determined that a granular mixture compacted in this manner is sufficiently stable even without additional strengthening means to be self-supporting after removal of the form. This furnace lining is not, of course, sufficiently stable to withstand mechanical stresses, such as, for example, those produced by the vibrations of the electrical energy of the induction coil. In a subsequent step in accordance with the invention, therefore, a phosphate binder is added to the self-supporting furnace liner after removal of the form.

The laminated liner prepared in this manner can be seen in FIG. 3. FIG. 3 is a cross section of the crucible of an induction furnace which consists of an outer wall **1**, an intermediate form **2** and the refractory liner **3**. The latter is adjoined on the inside by the form **4**, which is removed after the compaction or densification in order then to permit the application of the phosphate binder to the surface of the refractory liner **3**, which is preferably performed by spraying. In the laminated liner of the invention, a special mineral-chemical binder is added to the portion of the liner adjacent the melt. This is a phosphate binder, preferably a monoaluminum phosphate binder with variable phosphate members. The following compositions, for example, are thus possible:

1. Monaluminum phosphate P_2O_5 33.20%, free P_2O_5 2.06%, Al_2O_3 7.50%, free Al 0%, Al (H_2PO_4) 46.50%
2. Acid phosphate binder with 40–45% by weight solid content, residue after firing consisting of P_2O_5, Al_2O_3, Cr_2O_3
3. Phosphate binder having condensed alkaline phosphates with a linear chain.

These binders, which may also contain chromium oxide additives, develop strengths between 10 and 20 kg./cm.^{2} even at room temperature when added in quantities of 6 to 8% to the dry granular mixture.

It is desirable to prepare a liner in accordance with the invention in such a manner that the dry, refractory granular composition, mixed with the dry sintering agent, is compacted in the furnace to a total pore volume of 16 to 24%, using a removable, re-usable form. The form is then removed and the inner layer of the liner is impregnated with the binding agent.

It is advantageous to spray the phosphate binder onto the inside surface of the liner, a sufficient quantity being 0.05 to 0.07 cm.^{3} of binding agent absorbed by each square centimeter of surface area in the predetermined depth. This small amount of binding agent makes possible a very rapid and effective drying, an advantage being that the slight amount of moisture can easily escape into the open furnace area.

It is also desirable to heat up the furnace chamber by means of a fuel burner such that the refractory composition in the shell attains a temperature of 400 to 700° C. When the liner has this temperature the crystallization water is driven out of the binding agent and its crystal structure is destroyed, so that if it is necessary to let the liner stand exposed to the air so that it cools, hygroscopicity is no longer present.

The furnace can be started up in the customary manner using a burner system, a starting ingot and/or a batch of molten metal, because the liner creates conditions no different from those known in the past.

EXAMPLE

A middle frequency induction crucible furnace having a capacity of 1.5 tons was given a liner of 80 mm. thickness. A divided reusable form having an outer diameter of 70 cm. was put into the furnace.

The cavity between furnace wall and form was filled up with dry tertiary quartzite having a grain size composition as described in Example 1 of Table 1 in mixture with dry boric acid (1% of the mass). A vibrator driven by compressed air was attached to the form and put into operation for 6 minutes. Thereafter the form was removed from the furnace. On the interior surface of the liner monoaluminum phosphate was sprayed in a quantity of 1 litre per square meter of the surface. Thereafter, the lining was heated to 400° C. by induction heating. Finally the furnace was charged with material to be melted and heated to melting temperatures above 1500° C. During this heating the inner shell of the liner was sintered, whereas the outer zones of the liner remained unsintered.

TABLE 1

Grain size composition (mm.)	Example 1 (percent)	Example 2 (percent)	Example 3 (percent)
4.0–5.0	0.85	1.20	0.45
3.0–4.0	12.05	17.60	13.55
2.0–3.0	6.20	6.10	7.55
1.0–2.0	16.05	17.10	21.30
0.6–1.0	8.30	12.60	14.30
Total	43.45	54.60	57.15
0.3–0.6	7.95	5.95	4.65
0.2–0.3	3.70	2.20	1.40
0.1–0.2	10.60	4.75	6.00
0.06–0.1	5.35	2.80	3.50
Below 0.06	28.95	29.70	27.30
Total	56.55	45.40	42.85

TABLE 2

Test Number:	Density in grams per cubic centimeter
1	2.10
2	2.00
3	2.20
4	2.10
5	2.10
6	2.30
7	2.10
8	2.20

We claim:

1. Method for preparing a self-supporting liner for an induction melting furnace which comprises:

(a) preparing a mixture of a dry refractory granular quartzite composition having a tertiary quartzite base, said composition consisting of 40% to 60% of grains having a size between 0.6 and 5.0 mm., up to 30% of grains having a size of less than 0.06 mm. and balance grains having a size between 0.6 and 0.06 mm., said grains being round to cubic in configuration;

(b) filling the space between the furnace wall and a form defining the inner shape of the liner to be formed with the mixture prepared in (a);

(c) applying vibrational energy to densify the mixture in said space to a dense mass having a total pore volume of 16 to 24%;

(d) removing said form leaving a self-supporting liner;

(e) impregnating the exposed inner surface layer of said self-supporting liner with a binding agent to a predetermined depth less than the total thickness of the self-supporting liner thereby imparting durability and mechanical strength to said liner prior ot and during sintering of said impregnated surface layer;

(f) heating said liner to form an inner strengthening shell having a thickness between 1 and 8 mm.; and thereafter

(g) sintering the inner shell of said liner, the zone of said liner between said inner shell and said furnace wall remaining unsintered.

2. Method of claim **1** wherein the inner surface layer of said liner is sprayed with said binding agent in an amount such that between about 0.05 and 0.07 cubic centimeters of said binding agent are absorbed by each square centimeter of surface area in said predetermined depth.

3. Method of claim **1** wherein heating step (e) is carried out at a temperature between 400 and 700° C.

4. Method of claim **1** wherein said binding agent is a phosphate binding agent.

5. Method of claim **4** wherein said phosphate bonding agent is a monoaluminum phosphate.

6. Method of claim **1** wherein said binding agent is selected from the group consisting of sodium silicates, silicic acid esters, tar, dextrine solutions and sulphite waste liquor.

7. Method of claim **1** wherein the space between the furnace wall and said form is annular.

8. Method of claim 4 wherein said phosphate binding agent is an acid phosphate binder having a solids content between 40 and 45% by weight.

9. Method of claim 1 wherein said refractory granular composition is acidic.

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U.S. Cl. X.R.

13—30; 264—62, 71, 133