Fig. 3. Furnace Resistance During Typical Run

Fig. 4. Power Input to Furnace During Typical Run

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This invention relates to a method and apparatus for electric melting, and, more particularly, is concerned with a method and apparatus for the production of synthetic minerals by melting mineral batches.

The production of certain minerals by crystallization from melts poses many problems due to the existing process and apparatus limitations. Molten materials are often highly corrosive to furnace walls, and the composition of the melt may be difficult to control because of volatilization of the charge constituents at the high melting temperature involved. Such problems are presented, for example, in the synthesizing of fluoro-alumino-silicate batch mixtures by crystallization of fluoro-silicate melts of a suitable composition. Because of the high melting temperature of such batches, about 1400° C., and their high fluoride content, ranging from 9 to 13 percent, such melts are very fluid and exceedingly corrosive. Therefore, one of the problems is the finding of a container for such melts that is both corrosion resistant and refractory. Although fireclay, graphite, and silica carbide containers have been used, containers constructed of these materials frequently fail due to corrosion, are costly, can be constructed only of limited size, and may contaminate the product. Even in melting processes wherein a charge of material is maintained as a bed within the container, excessive volatilization and loss of essential fluoride constituents from the surface of the melt may take place to such an extent that a usable product of the desired composition cannot be formed.

Accordingly, an object of this invention is to provide an improved method and apparatus for the melting of mineral material.

Another object of the invention is to provide a method and apparatus whereby a large homogeneous melt may be produced without excessive volatilization of charge material and without the use of a sealed vessel.

Another object of the invention is to provide a melting method wherein the batch of material acts as a container for melting, serves as a highly effective vapor seal, and as an efficient thermal insulator.

Another object of the invention is to provide a method and apparatus for melting and crystallizing refractory materials that could not be melted in an open container.

Another object of the invention is to provide an electric furnace for melting materials of the type described whereby arcing between the electrodes of the furnace is avoided.

These and other objects of the invention will become apparent from the following description taken in connection with the accompanying drawings where:

Fig. 1 shows a vertical section of the electric furnace containing a batch of charge material prior to the start of the melting operation.

Fig. 2 shows a similar cross-section through the furnace and through the batch of the material at the end of the melting operation.

Fig. 3 is a graph showing the furnace resistance during a typical run.

Fig. 4 is a graph showing the power input to the furnace during a typical run.

The method of the invention comprises starting a conducting melt surrounded by sintered material within the interior of a charge of material by directly contacting the material with a destructible or removable resistance heater positioned in the interior thereof between the tips of vertically disposed electrodes, removing or destroying the resistor, melting a further portion of the charge and enlarging the area surrounded by said sintered shell by resistance heating between said vertical electrodes using the melt as a conducting pool, whereby said shell of sintered material maintained around the molten bath prevents volatilization from the bath, discontinuing the melting while a substantial thickness of the unfused charge material still surrounds the melt, and cooling and crystallizing the molten mass.

Referring now to the drawings for a more complete description of the invention and in particular to Figs. 1 and 2 thereof, the apparatus comprises a suitable container, which may be of sheet metal as shown, or of refractory, or other material of construction. Since the container is thermally insulated from the interior of the furnace by unfused charge material, it is merely necessary that the container have sufficient strength to support the weight of the charge. A pair of substantially horizontally disposed primary electrodes extend into the interior of the furnace in the lower portion thereof and are electrically insulated from the furnace walls by suitable electrically insulating material of asbestos or the like. Secondary electrodes extend substantially vertically upwardly from the primary electrodes, preferably about the mid-point of the furnace body where one set of electrodes are employed. A resistor of carbon, graphite, or other material, designed to be destroyed by the heat produced or otherwise removed after the charge material begins to melt, is positioned to connect the tips of the two vertical electrodes. The primary and secondary electrodes may be made of graphite, carbon, or other suitable conducting materials.

In operating the furnace, powdered material to be melted is introduced into the furnace to form a batch as shown at 20. The batch comprises substantially more material than is to be melted and may comprise, for example, approximately ten times the amount of material to be melted. By applying power to the electrodes and melting the batch adjacent to resistor 18, an electrically conducting pool of melt surrounded by sintered material is produced along the path of the resistor between the two vertically disposed secondary electrodes. As the batch melts, the level of the melt falls continuously as the melt occupies less space than unconsolidated charge. Thus, in time, the resistor 18 is exposed to an oxidizing atmosphere, which, if graphite or carbon has been used, causes it to be burned and consumed. However, by the time this happens, the pool of molten material is large enough to conduct the vertical electrodes and the path of the electric current is directly through the molten material. As the melting proceeds, a thick shell of sintered material forms within the charge as shown in Fig. 2. The internal electric resistance of the melt provides sufficient heat to continuously melt more of the surrounding sintered material and increase the size of the molten bath and charge cavity. Since the melt is directly in contact with the sintered batch, its temperature re-
mains very close to the melting point of the surrounding material. On increasing the power input, the melting rate increases without a corresponding temperature rise. This prevents excessive heating of the melt which is undesirable in most instances and in some melts would cause marked decomposition of the product.

The size of the melt is controlled by the power input and the heating time. Upon obtaining a melt of the desired size, as may be determined from previous experience, as indicated by thermocouples placed at strategic locations throughout the batch, or by observing the temperature of the furnace or of the container walls, the furnace current is turned off at a later time, or the melt may be crystallized slowly by gradually reducing the power input to the furnace.

Fig. 2 shows a typical cross-section through the furnace at the end of the melting operation. It is apparent from this figure how the batch acts as a container, seal, and thermal insulator for the melt. When the furnace batch comprises constituents for producing mineral melts, as, for example, of synthetic micas, the sintered shell is of a hard marble-like structure which forms at temperatures substantially lower than the melting temperature. The vertical electrodes burn off at their tips as the melt settles; hence, when the electrodes are vertically positioned, they remain in contact with the melt throughout the entire operation. Thus, there is no need to move the electrodes or break the automatic vapor seal formed by the sintered material.

A substantial thickness of insulating charge material is retained between the furnace wall and the sintered shell. After the melt has solidified and has cooled sufficiently, the product is obtained by a simple mining operation. The remaining material may be crushed, sized, and used for making up additional charges.

It is understood that the powdered batch materials used in this process may consist of any single chemical, or mineral, or combination of materials or minerals required to produce a fusion product. The invention is especially suitable for the manufacture of synthetic fluorine micas such as those represented by the formula

\[ \text{K}_{2}\text{MgAlSiO}_4\text{F}_4 \]

or

\[ \text{K}_{2}\text{Mg}_{2}\text{SiO}_3\text{O}_2\text{F}_4 \]

which may be made by using such batch formulas as:

\[ \text{K}_2\text{SiF}_6 + 6\text{MgO} + \text{Al}_2\text{O}_3 + 5\text{SiO}_2 \]

\[ 3\text{MgF}_2 + 3\text{MgO} + 2\text{KAl}_2\text{Si}_3\text{O}_9 \] (feldspar)

\[ \text{K}_2\text{SiF}_6 + 6\text{MgO} + 2\text{H}_2\text{BO}_3 + 5\text{SiO}_2 \]

However, the method may also be applied to the synthesis of mineral products such as fluor-tremolite, calcium fluoride (CaF_2), and potassium magnesium fluoride. Although the invention is especially important when applied to batches containing a volatile phase such as fluorides, it may also be used for the synthesis of nonvolatile compositions such as, for example, cordierite (Mg_2Al_2Si_5O_10), beta-spademunde (Li_2Al_2Si_5O_10), wollastonite (CaSiO_3), or monoclinic (CaMgSiO_3).

Figures 3 and 4 are illustrative of operating conditions within the furnace of this invention during a typical run. These data were compiled from an operation using a batch composition for production of fluorophlogopite mica using charge constituents as shown in Formula 1 above. Thus, it is noted that the resistor may burn out in three or four hours operation and the melt utilized to carry the current for the remainder of the operation which may comprise seventy hours or more.

It is evident that many modifications in the shape and size of the furnace are possible as well as in the arrangement of the electrodes which may be used.

The above-described invention obviates the necessity of providing special refractory containers for corrosive melts; it produces its own seal to retain volatile constituents (fluoride, chlorides, etc.); it provides an efficient and economical method for melting mineral batches, mainly because the charge material acts as a thermal insulator for the melt. By means of this invention, employing internal direct resistance melting, it is commercially feasible to melt large batches (tons) of fluorosilicate or other mineral batches containing volatile constituents, efficiently and cheaply. Thus, production of synthetic fluorophlogopite micas becomes commercially feasible. Of prime importance is the fact that the batch not only acts as a container for the melt but also serves as a highly effective vapor seal and as an efficient thermal insulator. The latter is especially important if the process is used for the production of large crystals by slow cooling of the melt. Because of the effectiveness, as a vapor seal, of the sintered material that forms around the melt, it is possible to control the composition of large melts, as well as to avoid the escape of noxious gases to the atmosphere.

It will be appreciated from a reading of the foregoing specification that the invention herein described is susceptible of various changes and modifications without departing from the spirit and scope thereof.

What is claimed is:

1. In an electric furnace, a pair of electrodes each extending substantially vertically upward from the lower portion of the furnace and adapted to be covered by the charge material, and a horizontally disposed removable resistor connecting the tips of said electrodes.

2. In an electric furnace, horizontally disposed spaced primary electrodes projecting through the furnace walls, secondary electrodes connected to said primary electrodes each extending substantially vertically upward into the interior of the furnace, and a horizontally disposed removable resistor connecting the tips of two said vertical electrodes.

3. In an electric furnace, horizontally disposed, spaced primary electrodes projecting through the furnace and the walls in the lower portion thereof, secondary electrodes connected to said primary electrodes extending substantially vertically upward to approximately the midsection of said furnace, a destructible resistance element connecting the tips of said vertical electrodes, the electrodes and resistance element adapted to be covered by a substantial depth of charge material, whereby a conducting melt may be formed by resistance heating through said resistance element, and resistance heating may be continued through said melt between said vertical electrodes after said resistance element has burned out.

4. A method of melting materials comprising forming a relatively large batch of said material, and heating said material from within the interior of said batch so as to form a melt surrounded by sintered material and unfused batch material, whereby the batch acts as a container for the melt, serves as a vapor seal, and thermally insulates the melt on all sides and continuing to melt said batch material by electrical resistance heating through the molten mass.

5. A method of melting volatile materials comprising starting a conducting melt in the interior of a batch of said material whereby a shell of sintered material forms around said melt and provides a vapor seal, melting a further portion of said material and enlarging the area encompassed by said sintered shell by electric resistance heating through said conducting melt, and discontinuing said melting while said sintered shell still surrounds the molten material.

6. A method for producing a melt by electric resistance heating comprising starting a conducting melt within the interior of a batch of charge material by direct resistance heating between the tips of spaced vertical electrodes positioned in said batch, continuing the heating and melting of charge material between said electrodes by resistance heating through said conducting melt, and discontinuing said heating while a substantial amount of unfused charge material remains between the melt and the walls of the batch container.
7. A method for producing mineral compositions comprising forming a batch of mineral constituents around spaced vertical electrodes connected at the tips thereof by a destructible resistance element, starting a conducting melt within the interior of said batch along said resistance element by electrical resistance heating of said element, continuing to melt said mineral constituents by electric resistance heating between said vertical electrodes through said conducting melt after said destructible resistance element has burned out, discontinuing the heating while said melt is still surrounded by sintered and unfused batch material, and cooling the melt so produced.

8. A method for the production of synthetic fluorine mica from materials providing mica constituents comprising forming a batch of said materials around spaced vertical electrodes connected at the tips thereof by a destructible resistance element, starting a conducting melt of said materials within the interior of said batch along said resistance element by electrical resistance heating of said element, continuing to melt said materials by electric resistant heating between said vertical electrodes through said conducting melt after said destructible resistance element has burned out, said heating within the interior of the batch forming a thick shell of sintered batch material around the melt which acts as a vapor seal, discontinuing the heating while said melt is still surrounded by sintered and unfused batch material, and cooling the melt to crystallize the mica product.

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