Sept. 9, 1952 R. E. SKINNER ET AL 2,610,217

ELECTRIC ENAMEL FURNACE

Filed Sept. 8, 1950 4 Sheets-Sheet 1

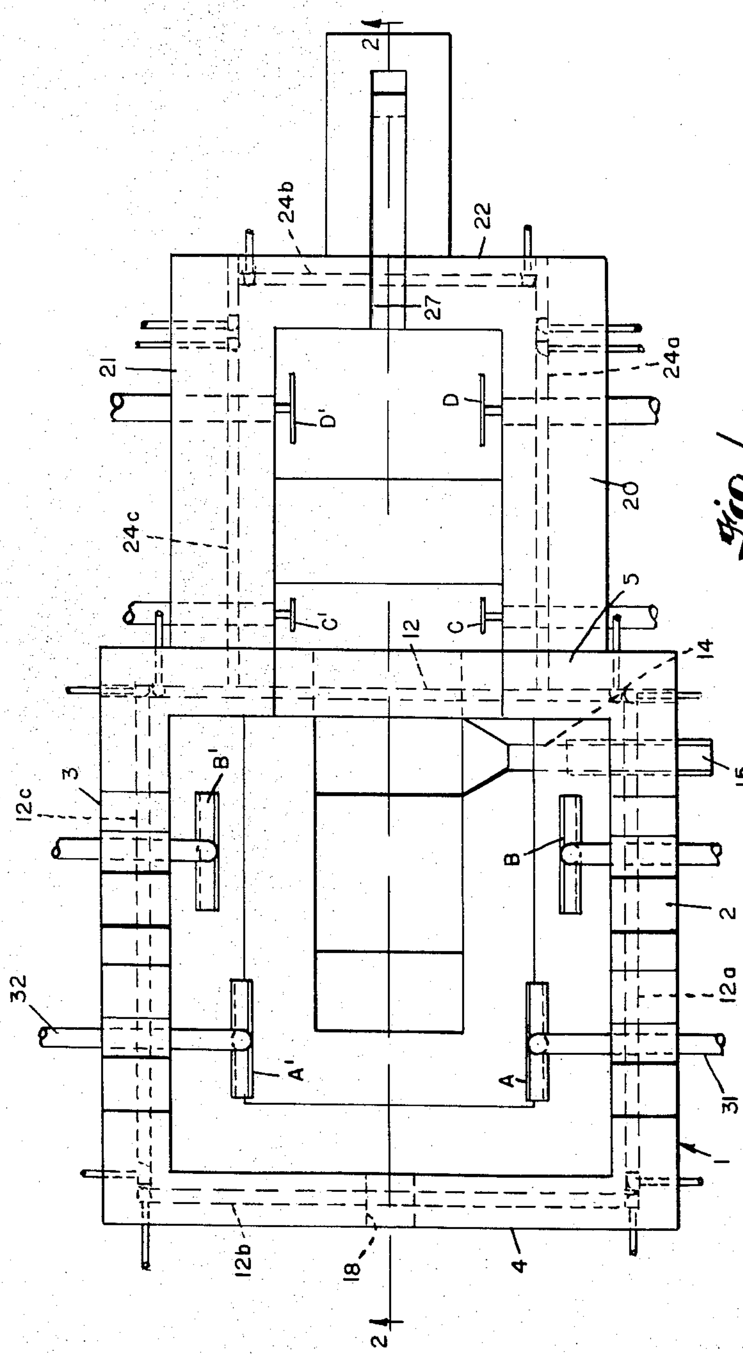

Fig. 1

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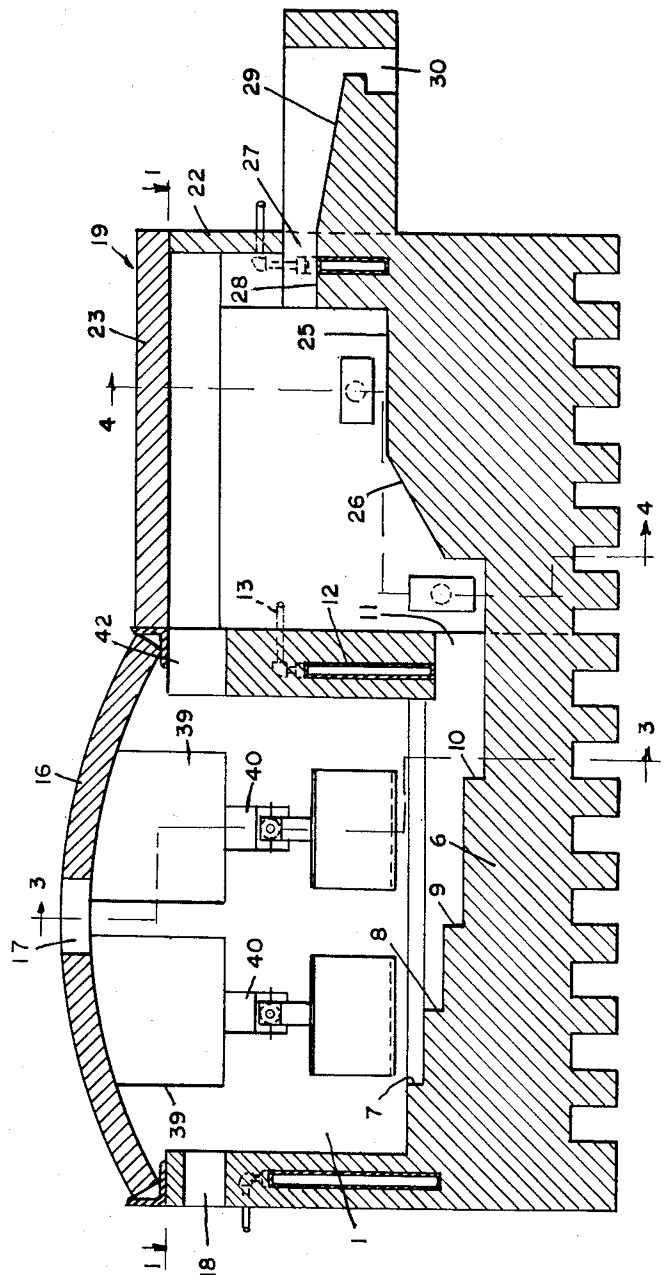

Fig. 2

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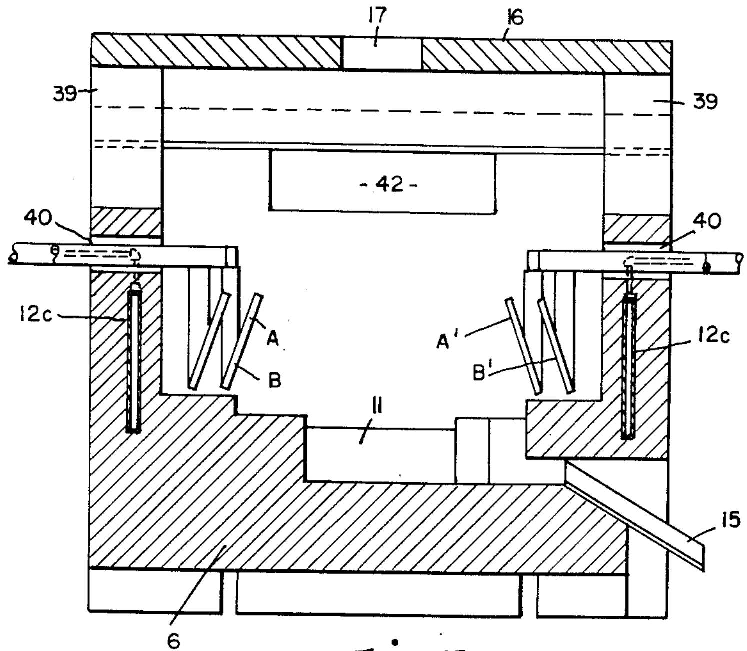

Fig. 3

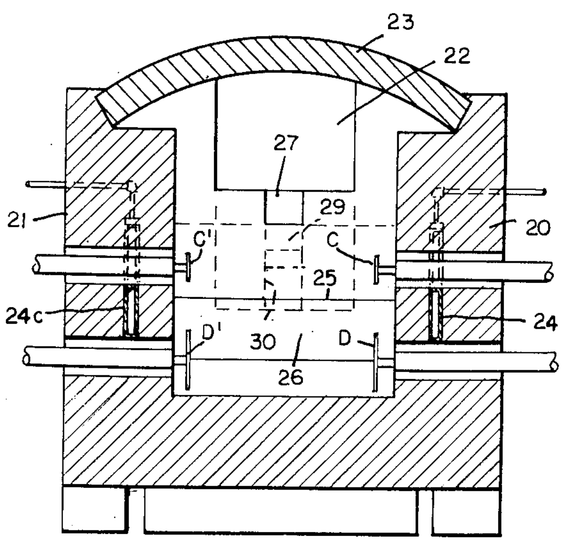

Fig. 4

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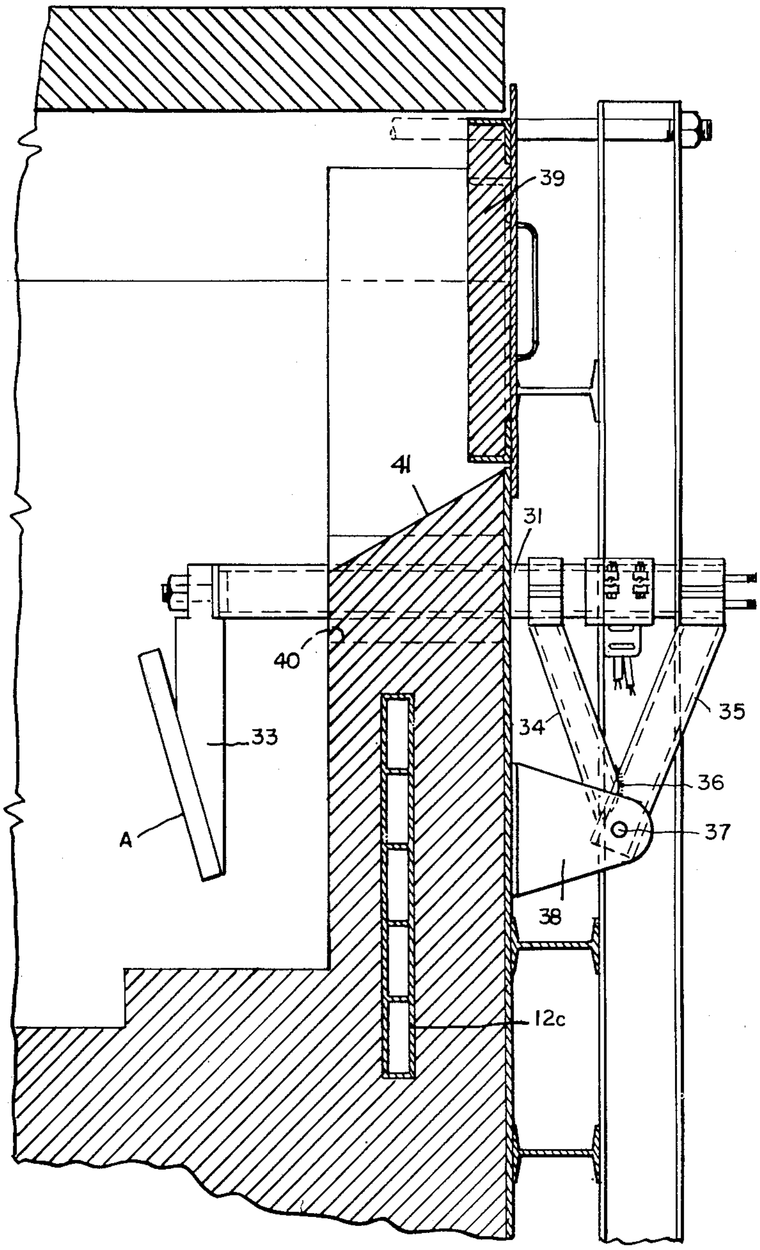

Fig. 5

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ELECTRIC ENAMEL FURNACE

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Application September 8, 1950, Serial No. 183,802

5 Claims. (Cl. 13—6)

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This invention relates as indicated to smelters for porcelain enamel frit characterized particularly in that the raw batch components from which the frit is eventually produced are melted by passing electric current through the mass so that the batch is heated as a result of its own internal electrical resistance.

The use of electric smelters for the purpose of reducing various types of raw materials to a molten state is quite old, and to a minor degree that type of heating has been employed for the production of conventional glass.

Porcelain enamel is, however, a very complex mixture of various metallic oxides and the like so that frequently the silica content of the batch is only a minor proportion of the total. It has been the general practice in most electrically heated glass tanks to deposit the raw material centrally of the tank with electrodes spaced rather uniformly about the space occupied by the batch and to then provide a submerged outlet leading to a fining chamber from which the glass is ultimately discharged. I have found that none of those glass tanks are suitable for the smelting of porcelain enamel frit in the most efficient manner. Whereas these previously used glass tanks have been patterned largely after the general principle of construction of electric furnaces employed, for example, in the smelting of metals, it has been necessary to deviate sharply from that general type of construction in providing a smelter which could be used successfully for the production of porcelain enamel.

It is a principal object of our invention to provide a smelter of the character described which not only produces a porcelain enamel frit of the desired degree of homogeneity but which is also economical not only from the standpoint of its cost of operation, but also from the standpoint of loss of raw material.

Other objects of the invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, said invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings:

Figure 1 is a top plane view of a smelter constructed in accordance with the principles of my invention, but in which the roof structures are shown removed for more clear illustration of the internal structure of the smelter. Figure 2 is a longitudinal vertical section view of the smelter illustrated in Figure 1 taken on the plane substantially indicated by the line 2—2. Figure 3 is a transverse vertical section view of the smelter illustrated in the previous figures taken on the plane substantially indicated by the line 3—3 in Figure 2. Figure 4 is a transverse vertical section view of the smelter illustrated in previous figures taken on the plane substantially indicated by the line 4—4 of Figure 2, and Figure 5 is an enlarged sectional view of a portion of the smelter as previously more clearly illustrated in Figure 3, but showing the details of construction of one of the electrodes and the adjacent smelter structure.

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Referring more specifically to the drawings and more especially to Figure 1, the smelter herein illustrated comprising a substantially rectangular refractory lined vault generally indicated at 1 which is formed of two vertical side walls 2 and 3 and first and second end walls 4 and 5. These walls extend upwardly from a hearth generally indicated at 6 which is stepped down as at 7, 8, 9, and 10 to a low point adjacent the mid-portion of the end wall 5 through which extends a discharge passage generally indicated at 11. The discharge passage 11 is substantially rectangular in form, the lower elevation of which is on the line with the bottom of the step 10, and the upper edge of which is slightly below elevation of the step 8. The wall 5 in the area just above the passage 11 is provided with a recess which contains a hollow metal insert 12 through which a cooling medium such as water may be circulated by means of the pipe 13.

As most clearly illustrated in Figure 1, each of the side walls of the vault are likewise provided with inserts 12A, 12B, and 12C constructed similarly to insert 12 and through which cooling water is adapted to be circulated by means of the pipes shown. Cooling of the side walls in the manner indicated is essential in order to reduce the corrosion and particularly erosion effect of the melted ingredients on the refractory material with which the vault is lined.

Extending laterally through the wall 2 as most clearly illustrated in Figure 1 is a passage 14 leading to a discharge spout 15 and through which the contents of the smelter may be drawn off in preparation for a shutdown of the smelter.

Supported on the side walls 2—5 inclusive is an arched roof 16 provided with a stack opening 17 centrally thereof.

The material to be smelted is fed to the smelting vault through an opening 18 provided in the wall 4 on the longitudinal axis of the smelter and opposite to the discharge passage 11.

In the position adjacent the vault which was just described is a fining chamber generally indicated at 19, which as most clearly illustrated in Figure 1 comprises side walls 20 and 21 and an end wall 22, the wall 5 of the smelting vault closing the other wise of the fining chamber. A roof, generally indicated at 23 completes the enclosure of the fining chamber. Walls are similar to the walls of the smelting vault provided with metallic inserts such as 24A, 24B, and 24C through which water may be circulated for the purpose of cooling such walls.

The floor of the fining chamber is arranged at an elevation indicated at 25 which is higher than the elevation of any portion of the bottom of the smelting vault. The edge of the floor of the fining chamber adjacent the discharge opening 11 through which the preliminarily smelted material is received by the fining chamber from the smelting vault is relieved as at 26 in order to reduce floor resistance.

In the wall 22 of the fining chamber there is provided a passage 27 on the longitudinal axis of the smelter, the lower edge of the opening 27 comprising wier 28 over which the finished material is discharged over a trough-like extension 29 in which there is provided a vertically directed passage 30 which permits the fined material to drop vertically either into a water bath or into the space between parallel quenching rolls. The entire body of the smelter is preferably formed of refractory material usually used in the construction of equipment of this kind. It is well-known, of course, that in such construction the body of the structure is made of appropriate refractory blocks and the surfaces such as the hearth of the smelting chamber, the side walls of the smelting and fining chamber and the floor of the fining chamber are all lined with special refractories, particularly suited to withstand attack from the material produced by the smelter. The details of such construction which is indicated as conventional in the art has not been shown.

From the foregoing description of the entire smelter which includes the smelting vault and fining chamber, it will be noted that the line 2—2 on Figure 1 represents the longitudinal axis of the smelter and also indicates the line of flow of the material previously admixed and blended to a substantial homogeneous mass is introduced through the opening 18, and after being thoroughly smelted and fined it is distributed at the opposite end of the wier 28.

The raw material is reduced to finished form by being heated electrically by its own internal resistance. This is accomplished by the arrangement in the smelter of a plurality of pairs of electrodes which are arranged in successive downstream relation with reference to the axial floor line 2—2 of Figure 1. The first pair of such electrodes comprises those indicated at A and A′ which are substantially rectangular plates supported on either side of the smelting vault by being secured to the inner ends of rods 31 and 32 respectively. The latter rods projecting outwardly through openings provided therefore in the walls of the vault 1. The openings through which the supporting rods thus pass are well above the bath line in the smelter as determined by the elevation of the wier 28 so that it is not necessary to provide a seal through which the electrodes supporting rods pass. The electrodes themselves are substantially rectangular plates which are preferably supported by brackets such as 33, most clearly illustrated in Figure 5 and arranged at a slight angle to the vertical with the upper edges of such plates closer together than their bottom edges. This arrangement of the electrodes has been found to give best results since the resistance per unit of lineal distance between the upper edges of the bath between the electrodes is generally somewhat less than the electrical resistance of a corresponding unit of the lineal distance between the lower edges of the electrode. The further spacing of the lower edges as compared with the upper edges also tends to produce a current disposition through the bath which has been found to have a desirable effect. It is important to note that in my smelter as illustrated in the drawings, the first pair of electrodes between which flows the first current to which the bath is subjected are placed down-stream from the point of entry of the raw material. Moreover, in the preferred embodiment of my invention as illustrated most clearly in Figure 2, the first pair of electrodes are just down-stream from the first step in the hearth of the vault. This has been found to be an important condition in insuring uniformity in smelting of the complex mixture of raw materials from which porcelain enamel is produced. The second step in the hearth is underneath the first pair of electrodes, this arrangement insuring a certain amount of mechanical turbulence imparted to the material passing downwardly over the hearth in addition to the turbulence which naturally results from the passage of the current through the bath.

The second pair of electrodes generally indicated at B and B′ is arranged downstream from the first pair of electrodes and preferably just downstream of the third step 9 in the hearth bottom. In addition to this relationship of this pair of electrodes to the hearth bottom and the stream of material flowing through the smelter, it is important to note that in the preferred embodiment of my invention this pair of electrodes are preferably spaced apart by distances slightly greater than the corresponding space between the first pair of electrodes A—A′. Here again the arrangement of the electrodes has been found to be important in order to insure proper current disposition in the bath as the the material flows from the feed end to the discharge end in the smelter.

The third set of electrodes generally indicated at C and C′ is located downstream just below the passage 11 through which the preliminarily smelted material is fed to the fining chamber. It will be noted that these electrodes are very closely adjacent to the passage 11 in order to maintain the bath at this point in a highly fluid state and also to insure that the preliminarily smelted material in passing from the smelting vault to the fining chamber must necessarily flow directly through the space lying between the opposed faces of electrodes C and C′. This will insure that any material which may not have been fully smelted be physically carried along by the stream of the material which has been smelted will be reduced to a molten state before passing into the fining or soaking chamber. It will be noted that the physical size of the electrode faces C and C′ as compared with the dimensions of the throat 11 through which the partially smelted material must pass is such that the condition just described is insured. In this connection the relative proportions of the parts as shown in Figure 2 has been carefully drawn to scale in order to illustrate the preferred relationship in size between these critical portions of the structure.

The fourth pair of electrodes generally indicated at D and D' are arranged just upstream of the wier 28 over which the fully smelted and fined material is discharged. This location of the last pair of electrodes is important likewise, not only from the standpoint of insuring that the materials to be discharged are of the proper fluidity but also to prevent the occurrence of a dead area in the fining bath just upstream of the wier faces. The disturbance created in the bath by the passage therethrough of the electrodes B and B' maintains the bath in this area in a highly mobile condition so as to prevent the occurrence of the dead areas just referred to.

Each of the electrodes B—B', C—C', and D—D' are supported on rods passing through the side walls of the smelter. It will be noted that the electrodes C—C', and D—D' are carried by rods which pass directly through the sides of the smelter below the batch level. This is practical since it has been found that these electrodes will require very little of any adjustment during the normal operation of the smelter whereas it may be desirable to occasionally adjust the lateral spacing between the first two pairs of electrodes which are positioned in the smelting vault. This need for adjustment may be occasioned by changes in composition of the raw material being smelted, and this adjustability of the space between the electrodes of each pair is an important feature of my construction which makes possible the adaptation of the smelter for the most efficient operation on individual raw base compositions. By having specific reference to Figure 5, it will be noted that each of the electrodes A—A' and B—B' is preferably supported by mechanism like that illustrated in this figure in which the rod such as 31 by which the electrode A is ultimately supported is carried by angularly related brackets 34 and 35 which are secured together as by welding as at 36 and pivotally connected by means of a pin such as 37 to a bracket 38. The permanent side wall of the smelter vault is provided with an opening which is normally closed by a door 39 and the lower edge of the door opening as most clearly illustrated in Figure 2, each of such door openings has a recess generally indicated at 40. The rods which support the electrode are positioned in the bottom of such recesses and a block such as 41 is then dropped into the slot on top of the rod 31 before the door 39 is closed. For removal of the electrodes for the purpose of inspection, repair, or replacement, it is necessary only to remove the door 39, lift the block 41 out of the slot 40 and then rotate the electrode holder clockwise as shown in Figure 5 until the electrode A has passed out through the opening normally closed by the door 39. This construction just described makes possible also ready vertical adjustment of the electrode within the smelting vault. It has been found that with the parts having about the relative size shown in Figure 5, the necessary adjustment for normal operation of the smelter can be accomplished by slight rotation of the electrode holder about the axis of the pin 37 on which it is supported. This clock-wise and counter-clock-wise adjustment from its position as shown in Figure 5 of the electrode holder not only raises and lowers the electrode in the bath, but slightly changes the angular relation of the electrode face with respect to the vertical. In general, best results will be secured by having the electrode face at an angle of about 10° in respect to the vertical and with the upper edge of the electrode face in the horizontal plane which includes the upper edge of the discharge wier 28.

The ready adjustability of the electrodes is of the utmost importance in the electric smelting of porcelain enamels. There are many different kinds of porcelain enamels each containing a different amount of volatile components. It is the volatile components of the porcelain enamel formulae which determines the amount of boiling action in the smelting vault of the smelter, and the amount of boiling in turn determines the amount of formation of a crust on the top of the melting raw batch. The crust is formed by the escaping volatiles. Since the raw batch is heated from the bottom up and there is a minimum of heat at the extreme top of the raw batch, the escaping volatiles tend to solidify at the top forming a crust. The crust formed at the top prevents incoming raw materials from reaching the lower hot zone of the smelting chamber. However, with an arrangement of electrodes as previously described it is now possible to bring the electrodes closer to the top, or to lower the electrodes as needed thus controlling the undesirable crust formation. From the foregoing it can now be seen that the adjustment of electrodes is vital, since every different porcelain enamel needs a readjustment of the electrodes.

A further and important feature of our construction is the arrangement of the flue or stack passages. In this connection it will be observed that the main stack outlet is centrally in the roof of the smelting vault. It is preferable to provide a stack height as compared with the other critical factors so that the stack just above the roof of the smelter has at least a slight negative pressure. Since the smelting operation is performed by the passage of current through the mass, there is very little loss of raw material as by decomposition, which must be carried away by the stack. In this connection it is a notable feature of my invention that by heating the raw material by the passage of current therethrough there is very considerably less loss of raw materials due to decomposition than in the other types of conventional smelting wherein the mass is heated by a flame. Actually, in the case of fluorine, for example, it will be found that for a given fluorine content in the resultant frit, the fluorine contained in the raw batch fed to the electric smelter must be considerably less than in the raw batch smelted by means of a flame. It has been shown by actual analysis that only about ⅓ as much fluorine is lost when operating my electric smelter as occurs when smelting the same raw batch mixture by means of a flame.

The principal gases which pass upwardly through the stack are the air streams which enter the smelter through its openings and which become heated and then rise upwardly through the stack. In this connection it should be noted that care should be exercised to prevent air ingress through the materal feed opening 18 so that the ingress of air to the smelter is through the discharge opening at the end of the fining chamber. The air thus entering the fining chamber passes through the opening 42 which is formed on the axial line of the smelter directly above the passage 11 through which the partially smelted material flows from the smelter vault to the fining chamber. It will thus be observed that the flow of gases or rather heated air is substantially counter-current to the flow of the solid material. This is an important feature since this sweep of air precludes any unsmelted finely divided material finding its way into the fining chamber.

In the selection of the material from which the electrodes are to be made care should be exercised in order to prevent their reduction by the material being smelted. It has been found that the material from which are made those portions of the electrodes which are actually in contact with the material being smelted should be lower in the electromotive series than the materials which are present in the raw batch in the form of oxides. Thus, for example, when smelting a frit batch containing substantial amounts of zirconium, it is desirable to use an electrode made of molybdenum. While graphite electrodes can be used, especially when smelting certain types of porcelain enamel such as ground coat enamels containing substantial amounts of cobalt and nickel oxides, best results will be secured by the use of metallic electrodes selected in the manner described.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

This application is related to copending applications Serial No. 198,790, filed December 2, 1950, Serial No. 81,478, filed March 15, 1949, and Serial No. 91,394, filed May 4 1949 now Patent 2,559,683, all having the same assignee as the present application.

We therefore particularly point out and distinctly claim as our invention:

1. A smelter for porcelain enamel frit comprising a substantially rectangular refractory-lined vault the bottom of which is stepped down longitudinally from one end wall to a low point adjacent the opposite end wall of said vault, a fining chamber adjacent to and down-stream from said vault and being in communication with the interior thereof at said low point and in a separate area above said low point, a discharge weir in the wall of said fining chamber which is opposite to the wall thereof through which communication is had with said vault, said weir being at an elevation substantially above the floor of said vault, the vertical wall of said vault adjacent said low point provided with a discharge opening arranged on the longitudinal axial line of the smelter which passes through the part of communication between said vault and said fining chamber and said weir, said axial line extending along the line of flow of the material through the smelter, said vault provided with a material charging opening arranged on said axial line, a plurality of pairs of electrodes respectively arranged on opposite sides of said axial line and arranged in successive down-stream arrangement, the first pair of such electrodes being in said vault adjacent and down-stream from said charging opening, the second pair of such electrodes in said vault and down-stream from said first pair, a third pair of electrodes arranged down-stream from said second pair and adjacent the port of communication between said vault and fining chamber, and a fourth pair of electrodes arranged down-stream from said third pair and adjacent said weir.

2. A smelter for porcelain enamel frit comprising a substantially rectangular refractory-lined vault, the bottom of which is stepped down longitudinally from one end wall to a low point adjacent the opposite end wall of said vault, a fining chamber adjacent to and down-stream from said vault and being in communication with the interior thereof at said low point and in a separate area above said low point, a discharge weir in the wall of said fining chamber which is opposite to the wall thereof through which communication is had with said vault, said weir being at an elevation substantially above the floor of said vault, the vertical wall of said vault adjacent said low point provided with a discharge opening arranged on the longitudinal axial line of the smelter which passes through the port of communication between said vault and fining chamber and said weir, said axial line extending along the line of flow of the material through the smelter, said vault provided with a material charging opening arranged on said axial line, a plurality of pairs of electrodes respectively arranged on opposite sides of said axial line and arranged in successive down-stream arrangement, the first pair of such electrodes being in said vault adjacent and downstream from said charging opening, the second pair of such electrodes in said vault and down-stream from said charging opening, the second pair of such electrodes in said vault and down-stream from said first pair, a third pair of electrodes arranged down-stream from said second pair and adjacent the port of communication between said vault and fining chamber, and a fourth pair of electrodes arranged down-stream from said third pair and adjacent said weir, said first and second pairs of electrodes each having vertically inclined current receiving and discharging faces intersected by a horizontal plane which includes the lower edge of the opening of said weir.

3. A smelter for porcelain enamel frit comprising a substantially rectangular refractory-lined vault, the bottom of which is stepped down longitudinally from one end wall to a low point adjacent the opposite end wall of said vault, a fining chamber adjacent to and down-stream from said vault and being in communication with the interior thereof at said low point and in a separate area above said low point, a discharge weir in the wall of said fining chamber which is opposite to the wall thereof through which communication is had with said vault, said weir being at an elevation substantially above the floor of said vault, the vertical wall of said vault adjacent said low point provided with a discharge opening arranged on the longitudinal axial line of the smelter which passes through the port of communication between said vault and fining chamber and said weir, said axial line extending along the line of flow of the material through the smelter, said vault provided with a material charging opening arranged on said axial line, a plurality of pairs of electrodes respectively arranged on opposite sides of said axial line and arranged in successive down-stream arrangement, the first pair of such electrodes being in said vault adjacent and down-stream from said charging opening, the second pair of such electrodes arranged downstream from said first pair, a third pair of electrodes arranged down-stream from said second pair and adjacent the port of communication between said vault and fining

chamber, and a fourth pair of electrodes arranged downstream from said third pair and adjacent said weir, said first and second pairs of electrodes each having vertically inclined current receiving and discharging faces intersected by a horizontal plane which includes the lower edge of the opening of said weir, and the active faces of said third and fourth pairs of electrodes lying substantially below said plane.

4. A smelter for porcelain enamel frit comprising a substantially rectangular refractory-lined vault, the bottom of which is stepped down longitudinally from one end wall to a low point adjacent the opposite end wall of said vault, a fining chamber adjacent to and down-stream from said vault and being in communication with the interior thereof at said low point and in a separate area above said low point, a discharge weir in the wall of said fining chamber which is opposite to the wall thereof through which communication is had with said vault, said weir being at an elevation substantially above the floor of said vault, the vertical wall of said vault, adjacent said low point provided with a discharge opening arranged on the longitudinal axial line of the smelter which passes through the port of communication between said vault and fining chamber and said weir, said axial line extending along the line of flow of the material through the smelter, said vault provided with a material charging opening arranged on said axial line, a plurality of pairs of electrodes respectively arranged on opposite sides of said axial line and arranged in successive down-stream arrangement, the first pair of such electrodes being in said vault adjacent and down stream from said charging opening, the second pair of such electrodes arranged down-stream from said first pair and having a materially greater distance therebetween than said first pair, a third pair of electrodes arranged downstream from said second pair and adjacent the port of communication between said vault and said vault and fining chamber, and a fourth pair of electrodes arranged down-stream from said third pair and adjacent said weir, said first and second pairs of eletctrodes each having vertically inclined current receiving and discharging faces intersected by a horizontal plane which includes the lower edge of the opening of said weir, and active faces of said third and fourth pairs of electrodes lying substantially below said plane.

5. A smelter for porcelain enamel frit comprising a substantially rectangular refractory-lined vault, the bottom of which is stepped down longitudinally from one end wall to a low point adjacent the opposite end wall of said vault, a fining chamber adjacent to and down-stream from said vault and being in communication with the interior thereof at said low point and in a separate area above said low point, a discharge weir in the wall of said fining chamber which is opposite to the wall thereof through which communication is had with said vault, said weir being at an elevation substantially above the floor of said vault, the vertical wall of said vault adjacent said low point provided with a discharging opening arranged on the longitudinal axial line of the smelter which passes through the port of communication between said vault and fining chamber and said weir, said axial line extending along the line of flow of the material through the smelter, said vault provided with a material charging opening arranged on said axial line, a plurality of pairs of electrodes respectively arranged on opposite sides of said axial line and arranged in successive down-stream arrangement, the first pair of such electrodes being in said vault adjacent and down-stream from said charging opening, the second pair of such electrodes arranged down-stream from said first pair and having a materially greater distance therebetween than said first pair, a third pair of electrodes arranged down-stream from said second pair and adjacent the port of communication between said vault and fining chamber, the distance between said third pair being substantially less than the distance between said second pair, and a fourth pair of electrodes arranged downstream from said third pair and adjacent said weir, said first and second pairs of electrodes each having vertically inclined current receiving and discharging faces intersected by a horizontal plane which includes the lower edge of the opening of said weir, and the active faces of said third and fourth pair of electrodes lying substantially below said plane.

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