

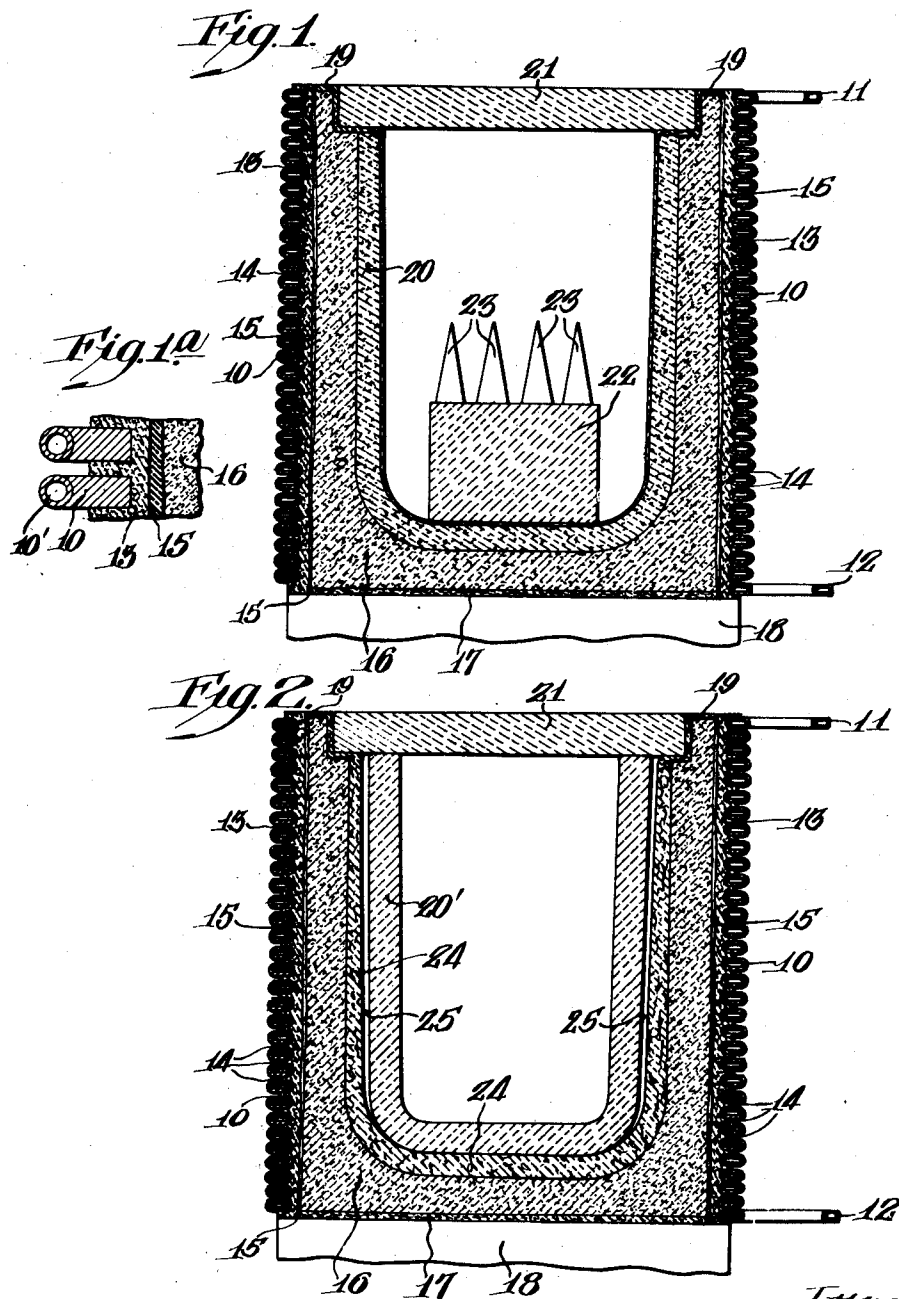
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FURNACE STRUCTURE

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FURNACE STRUCTURE

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My invention relates to methods and apparatus applicable to electric induction furnaces, and particularly to pool surrounding furnaces.

5 A purpose of my invention is to conduct heat reaching the electrical insulation near a furnace inductor rapidly to a zone of cooling application, which preferably will be the inductor itself, so that the temperature of the electrical insulation and of the adjacent refractory will remain below the melting and below the electrical breakdown points of the insulation.

10 A further purpose is to electrically insulate an inductor with material within the higher rather than the lower range of heat conductivity among heat resistant electrical insulators, using, for example, carborundum or "Vitrex."

15 A further purpose is to apply such a heat resistant electrical insulation of high heat conductivity to the inside of an inductor, and desirably to coat the inside of the electrical insulation of high heat conductivity with porcelain enamel, so that the composite layers will insulate the inductor and the porcelain enamel will mechanically protect the electrical insulation of high heat conductivity against other parts of the furnace while the electrical insulation of high heat conductivity will conduct heat escaping from the charge to a point of cooling application.

20 A further purpose is to thermally insulate an induction furnace charge from the inductor to shield the inductor from the bulk of the heat of the charge, and to conduct any heat escaping through the heat insulation rapidly to heat transfer relation to a cooling medium to be removed from the furnace.

25 A further purpose is to surround a removable furnace crucible with a layer of carborundum to bear the abrasion due to removal and insertion of the crucible and to protect the remainder of the furnace wall from cracks on account of rapid temperature changes, the carborundum itself forming a surface layer which has a low coefficient of expansion and therefore has little or no tendency to crack.

30 A further purpose is to protect the exposed parts of an oxidizable muffle, and particularly a graphite muffle, against oxidation by covering them with carborundum.

35 Further purposes appear in the specification and in the claims.

40 I have chosen to illustrate my invention by a few forms only of the many in which it might be applied, choosing them from the standpoints of easy construction, satisfactory operation and

convenient exemplification of the principles involved.

Figure 1 is a diagrammatic central vertical section of an induction furnace embodying my invention in which the thicknesses of the layers in the furnace wall have been exaggerated with respect to the size of the furnace itself in order to illustrate more clearly the positions of the various materials.

Figure 1a is an enlarged fragmentary section of a variation of Figure 1.

Figure 2 corresponds generally to Figure 1, but shows a variation in the structure of the furnace wall.

In the drawing like numerals refer to like parts.

45 In the past considerable difficulty has been encountered in electric induction furnaces because of electrical breakdown of the inductor coil. Study of the problem has taught me that the heat conductivity of the electrical insulation close to the inside of the inductor coil is very important.

50 In one experiment I coated the inside of an inductor coil with a composite heat resistant electrical insulation having, as a whole, a low heat conductivity as compared with other heat resistant electrical insulators. The electrical insulation used was a material sold on the market as "Vitrex", and containing asbestos fiber, sodium silicate and about 75% of clay (aluminum oxide with various silicates). Inside this material I placed sheets of bonded mica.

55 The asbestos-sodium silicate-clay itself has a high heat conductivity as compared with other heat resistant electrical insulation materials, but mica conducts heat very poorly, and imparts a low heat conductivity to the composite mass.

60 Inside the electrical insulation I placed a charge to be heated, and filled the space between the electrical insulation and the charge with heat insulation.

65 In operation the electrical insulation broke down electrically, short circuiting the inductor, and even melted. I then repeated the experiment upon the same furnace, eliminating the mica and using asbestos-sodium silicate-clay alone as electrical insulation for the inductor.

70 A superficial analysis of the problem would lead one to expect that elimination of the mica would be harmful, because the heat conductivity of the asbestos-sodium silicate-clay alone is greater than that of the asbestos-sodium silicate-clay in combination with mica, and the theory in the past has always been that as much and as good heat insulation should be used between the inductor

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and the charge as the space and the requirement for electrical insulation will permit.

Contrary to this supposition, however, no electrical breakdown or melting occurred where asbestos-sodium silicate-clay alone was used as the electrical insulation. The presence of mica, instead of improving the electrical insulation, was in fact destructive of the electrical insulation.

I have discovered that the electrical breakdown and melting of the electrical insulation when mica was present in the asbestos-sodium silicate-clay was due to the low heat conductivity of the electrical insulation, attributable to the mica. Some heat from the charge passed through the heat insulation and came in contact with the electrical insulation. There the heat accumulated and raised the temperature of the electrical insulation because of the low heat conductivity of the electrical insulation. The result was electrical breakdown and finally melting of the electrical insulation.

My invention involves the use of heat resistant electrical insulation of high heat conductivity inside the inductor and/or between its turns. In this way the heat which inevitably escapes from the charge through the heat insulation and comes in contact with the electrical insulation is conducted rapidly to a point of cooling application without being allowed to accumulate and raise the temperature of the electrical insulation. Electrical breakdown and melting of the electrical insulation are thus avoided.

Instead of asbestos-sodium silicate-clay I may use carborundum as a heat resistant electrical insulation of high heat conductivity, particularly in large furnaces operating at moderate voltages. In some cases I may apply the carborundum in brick form, desirably employing carborundum cement as mortar.

In general I consider that heat resistant electrical insulation materials which consist of refractories sufficiently closely bonded to approach the vitreous state will serve as my heat conductive electrical insulation.

As the highly thermally conductive electrical insulation may not be highly resistant to abrasion and may be difficult to spread smoothly, I prefer to coat its inner surface with a white porcelain enamel of which there are several on the market, one of which is known as "insulate". Porcelain enamel is a good electrical insulation, is very heat resistant, and forms a desirable protection for the highly thermally conducting electrical insulation and retaining wall for the heat insulation.

In its broadest aspects, my invention merely requires the use of a heat resistant electrical insulation of high heat conductivity, as compared with other such insulations, adjacent to the interior of the inductor coil. This is independent of the use of heat insulation between the electrical insulation and the charge.

However, my heat resistant electrical insulation of high heat conductivity cooperates with heat insulation between the electrical insulation and the charge to further advantageously avoid danger of electrical breakdown and melting of the electrical insulation and to avoid excessive cooling requirements for the inductor coil.

The heat insulation reduces the rate of heat transfer from the charge to the outer part of the furnace wall, including the electrical insulation, and, as it were, retains the heat in the charge.

But no matter how good the heat insulation and

how thick the layer of heat insulation, some heat will inevitably escape through the heat insulation to the outer parts of the furnace wall. This is particularly true because the layer of heat insulation cannot be of indefinite thickness, since the inductor coil must be relatively close to the charge for good inductive coupling.

Recognizing that some heat escape through the heat insulation is inevitable, I depart from the prior practice. In the prior art it has been assumed that the best way to provide for the heat inevitably passing through the heat insulation is to use within the inductor coil electrical insulation of low heat conductivity, so that the electric insulation will itself further reduce the rate of heat transfer. However, as explained above, heat has accumulated in the electrical insulation, causing its electrical breakdown.

I place around the heat insulation heat resistant electrical insulation of high heat conductivity so that the heat insulation prevents the escape of the bulk of the heat in the charge, and any heat which, in spite of the heat insulation, reaches the electrical insulation, is rapidly conducted to the inductor coil for removal by the cooling medium and is not allowed to accumulate in the electrical insulation to cause possible electrical breakdown or melting of the electrical insulation.

There are then two aspects of this portion of my invention. Where no heat insulation is used inside the inductor aside from the ordinary refractory holding the charge, the high heat conductivity of the electrical insulation permits rapid removal of the escaping heat and prevents electrical breakdown. To this extent, the highly thermally conductive electrical insulation makes possible the elimination of heat insulation where it would otherwise be necessary.

Secondly, the highly thermally conductive electrical insulation cooperates with the heat insulation. The heat insulation prevents the escape of the bulk of the heat, and the highly thermally conductive electrical insulation harmlessly removes the heat which does escape. Therefore my invention is advantageous both with and without heat insulation between the electrical insulation and the charge.

There is a further important feature of my invention which is applicable especially to furnaces having removable crucibles.

Particularly in the melting of precious metals, and of special alloys of which small heats only are used, it is desirable to remove the crucible bodily from the furnace and to reinsert it, without regard to whether the crucible and furnace wall are at the same temperature at the time of reinsertion.

Furthermore, as the crucible is not always accurately centered when it is removed or reinserted, it strikes or slides against the wall, abrading the wall surface. Particularly where the heat insulation is especially suited to cooperate with the highly thermally conductive electrical insulation of my invention, the heat insulation is not very resistant to mechanical shock.

I have found that these difficulties may be avoided by coating with carborundum the inside surface of the furnace wall with which the outside of the crucible comes in contact. The carborundum is best applied as carborundum cement. Carborundum cement is a mixture of silicon carbide and a binder, such as, for example, sodium silicate.

Carborundum is very resistant to abrasion, so

that the furnace wall will not suffer in spite of considerable battering and rubbing during insertion and removal of the crucible. Due to its low coefficient of expansion, carborundum will not crack when it is rapidly heated or cooled. Also, during periods of rapid heating or cooling, the carborundum distributes the heat rapidly, so that local zones of higher temperature in the furnace wall are avoided.

Thus it is seen that the carborundum inner coating makes possible the use of heat insulation inside the highly heat conducting electrical insulation in furnaces having removable crucibles where otherwise heat insulation could not be used because of abrasion, or where a second crucible would be required outside of the removable crucible to protect the heat insulation, with consequent danger of cracking the second crucible during withdrawal or reinsertion of the removable crucible.

In the drawing I illustrate several structures embodying my invention.

Referring first to Figure 1, the inductor coil 10 is intended to be conventional, and is illustrated as comprising flattened water cooled tubing supplied with water through connections not shown. The inductor coil is supplied with current from any suitable source connected at 11 and 12 and using any desired circuit connections.

In heat transfer relation with and usually against the inner surface of the inductor coil I place heat resistant electrical insulation 13 of high heat conductivity. In moderate sized furnaces this will preferably be "Vitrex," while on large furnaces carborundum may be used, particularly where the voltages are comparatively low. The high thermally conductive electrical insulation will usually be inserted between the inductor coil turns as at 14.

Asbestos-sodium silicate-clay is applied as a viscous plastic mass which hardens after application, and becomes highly heat conducting in spite of the presence of asbestos. I believe that the asbestos fails to make the mass thermally insulating because it is impregnated with sodium silicate.

In the asbestos-sodium silicate-clay, asbestos acts as an electrical insulation and mechanical binder and sodium silicate serves as a binder and as a highly thermally conducting impregnating material. Other heat resistant fibrous materials could replace the asbestos. Clay electrically insulates and gives body, and could be replaced by other bodying materials.

Without regard to replacing ingredients in the asbestos-sodium silicate-clay, any other heat resistant electrical insulation of high heat conductivity could be used.

Over the inner surface of the asbestos-sodium silicate-clay or other suitable material I spread a layer of porcelain enamel such as insalute 15 for protection and additional electrical insulation, as previously explained.

The layer of highly thermally conducting electrical insulation should be thick enough so that the temperature of the electrical insulation near the inductor coil does not rise high enough to make the highly thermally conducting electrical insulation or the porcelain enamel, where it is used, break down electrically.

The thicknesses of the various layers will of course be dependent upon the size of the furnace, the closeness of coupling with the secondary required, the temperature at which the furnace will

operate, the rate of cooling application, and many factors too numerous to mention.

In one moderate sized furnace using a six inch inductor coil, which I cite merely as an example, I have found that a highly thermally conducting insulating layer inserted between the turns of the inductor coil and extending for approximately one-sixteenth inch inside the inductor, coated with a layer of porcelain enamel approximately one-eighth inch thick, is quite satisfactory.

These dimensions are not even to be considered suggestive, because they are matters of design, and will differ widely with the practice of different designers and the uses to which the furnace is to be put.

Within the electrical insulation and outside the charge suitable heat insulation 16 is located. While the heat insulation may be of any suitable material, I preferably use a lamp black, of which several varieties are on the market, one very desirable form being known as "thermatomic" carbon. Zircon sand is satisfactory as a heat insulation for some uses. Finely divided silica or diatomaceous earth would also serve for lower temperatures.

The thickness of the heat insulation layer is again a matter of design, but in moderate sized furnaces I have found three-eighths of an inch of thermatomic carbon to be sufficient.

Where thermatomic carbon is used as heat insulation, it should be protected against oxidation. I therefore use a suitable protecting coating on the exposed surfaces of the heat insulation. As an example I illustrate carborundum at 17 above the furnace base 18, and at 19 at the top of the furnace. It will preferably be applied as carborundum cement.

The kind of charge with which my invention is to be used and the detail of the furnace as controlled by the kind of charge are immaterial to the broad aspects of my invention. To make this more clear, I illustrate in Figure 1 a muffle and in Figure 2 a crucible.

The muffle of Figure 1 is suitable for heating metals or refractories. I illustrate an electrically conducting muffle shell 20 covered at 21 and containing a refractory charge 22 and temperature measuring cones 23.

As the muffle will ordinarily be of graphite, which readily oxidizes on exposure to the air, I coat its exposed surface with carborundum which I find to be excellent to prevent oxidation provided it be not exposed to molten metal. I believe that it is new to coat a graphite muffle with carborundum to prevent oxidation, and to apply it, as I preferably will, as carborundum cement.

In operation the current passing through the inductor coil induces secondary current in the muffle 20, heating the muffle. As the muffle becomes heated, it in turn heats the charge. In spite of the heat insulation 16 and the heat insulating properties of the porcelain enamel 15, heat comes into contact with the inner surface of the heat resistant electrical insulation of high heat conductivity 13. The heat is rapidly conducted by the highly thermally conducting electrical insulation to the inductor coil because of the high heat conductivity of that material. When the heat reaches the inductor coil, it passes through its walls and is absorbed by the cooling medium flowing in the walls and carried with the medium from the furnace. It will be understood of course that other cooling means could be used, as by conducting the heat from the high-

ly thermally conducting electrical insulation to some point of cooling application other than the inductor coil.

For example in Figure 1a I show the inductor coil 10 consisting of a solid strip having a hollow water-carrying passage 10' near its outer edge. Highly thermally conducting electrical insulation 13 is placed between the turns of the inductor and over its inside edge and a coating of porcelain enamel 15 is spread over the inner surface of the electrical insulation of high heat conductivity.

Within the porcelain enamel I show heat insulation 16. Thus heat which escapes through the heat insulation 16 and the porcelain enamel 15, if porcelain enamel be used, is picked up and carried by the highly thermally conducting electrical insulation 13 to the inductor coil 10. It then passes through practically the entire width of the inductor coil turn to the outer edge where it comes in contact with the cooling medium in the passage 10' and is transferred to that medium.

The form of Figure 1a is desirable because it removes the water-carrying passages further from the heating zone, decreasing the danger of explosion in case of leakage, while still conducting the heat rapidly to the cooling medium through the heat resistant electrical insulation of high heat conductivity and the solid inductor coil walls.

Thus the highly thermally conductive path through the electrical insulation of high heat conductivity is continuous from top to bottom of the inductor coil, and distributes the heat through fins, as it were, at the outer ends of which cooling occurs.

In Figure 2 I show my invention applied to a furnace specially suited to heating electrically conducting charges, with or without melting. The best application will probably be to melting, although the insulation could be applied in many other furnaces, as for example, in continuous heating furnaces.

The furnace of Figure 2 is generally similar in construction to the furnace of Figure 1 as far as the application of the highly thermally conducting electrical insulation 13 and porcelain enamel 15 are concerned. Heat insulation is shown at 16 as before.

Inside the heat insulation I show a crucible 20', adapted to be removed from the furnace and reinserted. Over the heat insulation and around the crucible I place carborundum 24, preferably applied as carborundum cement, to protect the heat insulation mechanically from abrasion during removal and reinsertion of the crucible, as well as to protect the furnace wall against cracking from rapid changes of temperature. Because of its low coefficient of expansion, the carborundum may be rapidly heated or cooled without cracking. Because of its high heat conductivity it distributes applied heat to a large area of the wall rather than merely locally, thus avoiding unevenness in heating or cooling of the wall.

I find that one-eighth to three-sixteenths of an inch is sufficient thickness for the layer of carborundum in ordinary cases, but I do not limit myself to any particular thickness.

To provide for expansion and contraction and to permit of easy removal and reinsertion of the crucible, a space 25 is left between the carborundum and the crucible.

I believe that I am the first to prevent electrical breakdown of a heat resistant electrical in-

sulation in an induction electric furnace by conducting the heat which reaches the insulation rapidly to a point of cooling application.

I also believe that I am the first to confine the heat of the charge by heat insulation and then to dispose of any heat which escapes through the heat insulation to the electrical insulation by rapid conduction to a point of cooling application.

I also believe that I am the first to insulate an inductor coil with asbestos-sodium silicate-clay or a material containing ingredients substituted therefor.

I further believe that it is new to coat with carborundum the inside of a furnace wall adapted to engage a removable crucible.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain part or all of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. In an electrical coil which may become heated during use, a winding, means for cooling the winding and a coating containing heat resistant fibrous material and a binder on the winding to electrically insulate it.

2. In an electrical coil which may become heated during use, a winding, means for cooling the winding and a coating containing asbestos and sodium silicate on the winding to electrically insulate it.

3. In an electrical coil which may become heated during use, a winding, means for cooling the winding and a coating containing heat resistant fibrous material, heat resistant bodying material and a binder on the winding to electrically insulate it.

4. In an electric induction furnace, an inductor coil surrounding the charge, means for cooling the coil and electrical insulation for the inductor coil containing heat resistant fibrous material and a binder.

5. In an electric induction furnace, an inductor coil surrounding the charge, means for cooling the coil and insulation between and within the inductor coil turns containing heat resistant fibrous material and a binder.

6. In an electric induction furnace, an inductor coil surrounding the charge, electrical insulation for the inductor coil containing heat resistant fibrous material and a binder and porcelain enamel on the inner surface of the electrical insulation.

7. In an electric induction furnace, an inductor coil surrounding the charge, heat resistant electrical insulation of high heat conductivity between and within the inductor coil turns and porcelain enamel on the inner surface of the highly thermally conducting electrical insulation.

8. In an electric induction furnace, a hollow water cooled inductor coil surrounding the charge, electrical insulation for the inductor coil comprising heat resistant fibrous material and a heat conducting binder and heat insulation between the electrical insulation, and the charge.

9. In an electric induction furnace, a hollow water cooled inductor coil surrounding the charge, electrical insulation for the inductor and extending inside the inductor comprising heat resistant fibrous material and a highly heat con-

ducting binder and thermatomic carbon between the electrical insulation and the charge.

10. In an electric induction furnace, a hollow water cooled inductor coil surrounding the charge, electrical insulation for the inductor and extending inside the inductor containing heat resistant fibrous material and a highly heat conducting binder, porcelain enamel on the inner surface of the electrical insulation and thermatomic carbon between the porcelain enamel and the charge.

11. In an electric induction furnace, an inductor coil adapted to add heat to a charge, heat insulation of relatively low heat conductivity between the inductor coil and the charge to retain the bulk of the heat in the charge and electrical insulation between the heat insulation and the inductor coil and in intimate contact with the inductor coil, the electrical insulation being of substantially higher heat conductivity than the heat insulation and being free from electrical insulation adjacent the inductor coil on the side toward the charge having heat conductivity as low as that of the heat insulation, whereby heat which escapes from the charge through the heat insulation is dissipated quickly and not allowed to accumulate to cause electrical breakdown of the electrical insulation.

12. In an electric induction furnace, an inductor coil adapted to add heat to a charge, heat insulation of relatively low heat conductivity between the inductor coil and the charge to retain the bulk of the heat in the charge and electrical insulation between the heat insulation and the inductor coil, between the turns of the inductor coil, and in intimate contact with the inductor coil, the electrical insulation being of substantially higher heat conductivity than the heat insulation and being free from electrical insulation adjacent the inductor coil on the side toward the charge having heat conductivity as low as that of the heat insulation, whereby heat which escapes from the charge through the heat insulation is dissipated quickly and not allowed to accumulate to cause electrical breakdown of the electrical insulation.

13. In an electric induction furnace, an inductor coil adapted to add heat to a charge, artificial means for cooling the inductor coil, heat insulation of relatively low heat conductivity between the inductor coil and the charge to retain the bulk of the heat in the charge and electrical insulation between the heat insulation and the inductor coil and in intimate contact with the inductor coil, the electrical insulation being of substantially higher heat conductivity than the heat insulation and being free from electrical insulation adjacent the inductor coil on the side toward the charge having heat conductivity as low as that of the heat insulation, whereby heat which escapes from the charge through the heat insulation is conducted quickly to the cooling means and not allowed to accumulate to cause electrical breakdown of the electrical insulation.

14. In an electric induction furnace, an inductor coil adapted to add heat to a charge, artificial means for cooling the inductor coil, heat insulation of relatively low heat conductivity between the inductor coil and the charge to retain the bulk of the heat in the charge and electrical insulation between the heat insulation and the inductor coil, between the turns of the inductor coil, and in intimate contact with the inductor coil, the electrical insulation being of substantially higher heat conductivity than the heat in-

sulation and being free from electrical insulation adjacent the inductor coil on the side toward the charge having heat conductivity as low as that of the heat insulation, whereby heat which escapes from the charge through the heat insulation is conducted quickly to the cooling means and not allowed to accumulate to cause electrical breakdown of the electrical insulation.

15. In an electric induction furnace, an inductor coil adapted to add heat to a charge and electrical insulation for the inductor coil in intimate contact with the inductor coil and having heat conductivity of the order of materials of the class including carborundum and asbestos with sodium silicate, free from electrical insulation of substantially lower heat conductivity adjacent the inductor coil on the side toward the charge, which would impede heat transfer and encourage electrical breakdown of the electrical insulation.

16. In an electric induction furnace, an inductor coil adapted to add heat to a charge and electrical insulation for the inductor coil in intimate contact with the inductor coil between the turns of the inductor coil and on the side toward the charge and having heat conductivity of the order of materials of the class including carborundum and asbestos with sodium silicate, free from electrical insulation of substantially lower heat conductivity adjacent the inductor coil on the side toward the charge, which would impede heat transfer and encourage electrical breakdown of the electrical insulation.

17. In an electric induction furnace, an inductor coil adapted to add heat to a charge, means for cooling the inductor coil artificially and electrical insulation for the inductor coil in intimate contact with the inductor coil and having heat conductivity of the order of materials of the class including carborundum and asbestos with sodium silicate, free from electrical insulation of substantially lower heat conductivity adjacent the inductor coil on the side toward the charge, which would impede heat transfer to the cooling means and encourage electrical breakdown of the electrical insulation.

18. In an electric induction furnace, an inductor coil adapted to add heat to a charge, means for cooling the inductor coil artificially and electrical insulation for the inductor coil in intimate contact with the inductor coil between the turns of the inductor coil and on the side toward the charge and having heat conductivity of the order of materials of the class including carborundum and asbestos with sodium silicate, free from electrical insulation of substantially lower heat conductivity adjacent the inductor coil on the side toward the charge, which would impede heat transfer to the cooling means and encourage electrical breakdown of the electrical insulation.

19. In an electric induction furnace, an inductor coil having a hollow water-carrying passage near its outside edge, heat insulation of relatively low heat conductivity within the inductor coil and between the inductor coil and a charge to retain the bulk of the heat in the charge and electrical insulation between the heat insulation and the inductor coil, between the turns of the inductor coil, and in intimate contact with the inductor coil, the electrical insulation being of substantially higher heat conductivity than the heat insulation and being free from electrical insulation adjacent the inductor coil on the side toward the charge having heat conductivity as low as that of the heat insulation, whereby heat

which escapes from the charge through the heat insulation is absorbed quickly and not allowed to accumulate to cause electrical breakdown of the electrical insulation.

- 5 20. In an electric induction furnace, a hollow inductor coil adapted to surround a charge, means for artificially cooling the inductor coil, a heat insulating medium having low heat conductivity between the coil and the position of the charge and electrical insulation between the coil and the heat insulation in intimate heat transfer relation with said coil, and free from other insulating media which would impede transfer of heat from the charge side of the electrical insulation to the coil.
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21. In an electric induction furnace, a hollow inductor coil adapted to surround a charge, means for passing high frequency alternating current through the coil and for heating the charge to a high temperature, means for artificially cooling the inductor coil, a heat insulating medium having low heat conductivity between the coil and the position of the charge and electrical insulation between the coil and the heat insulation in intimate heat transfer relation with said coil, and free from other insulating media which would impede transfer of heat from the charge side of the electrical insulation to the coil.

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