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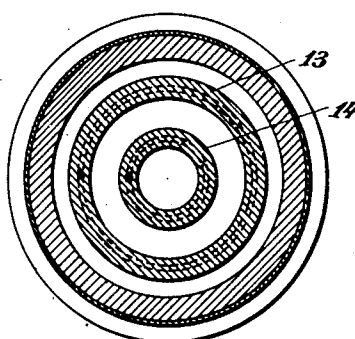
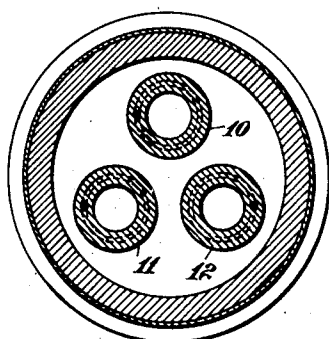
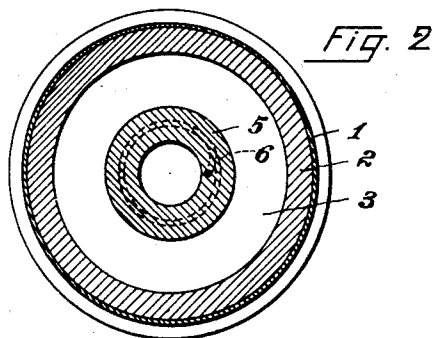
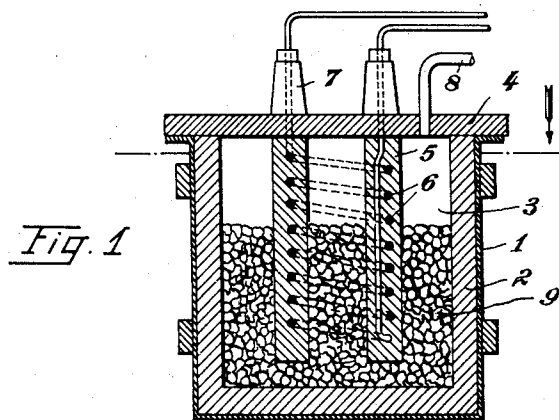
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1,837,031

HIGH FREQUENCY INDUCTION FURNACE OR HEATING APPARATUS

Filed July 20, 1927

4 Sheets-Sheet 1



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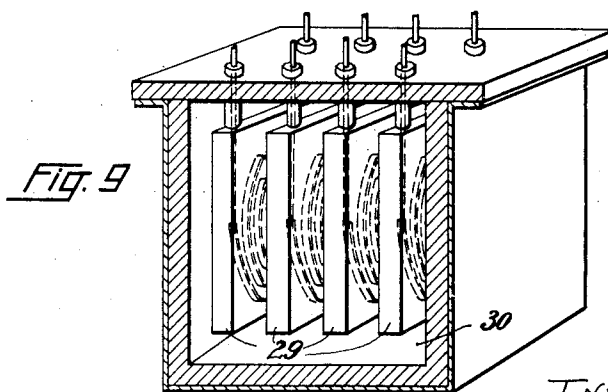
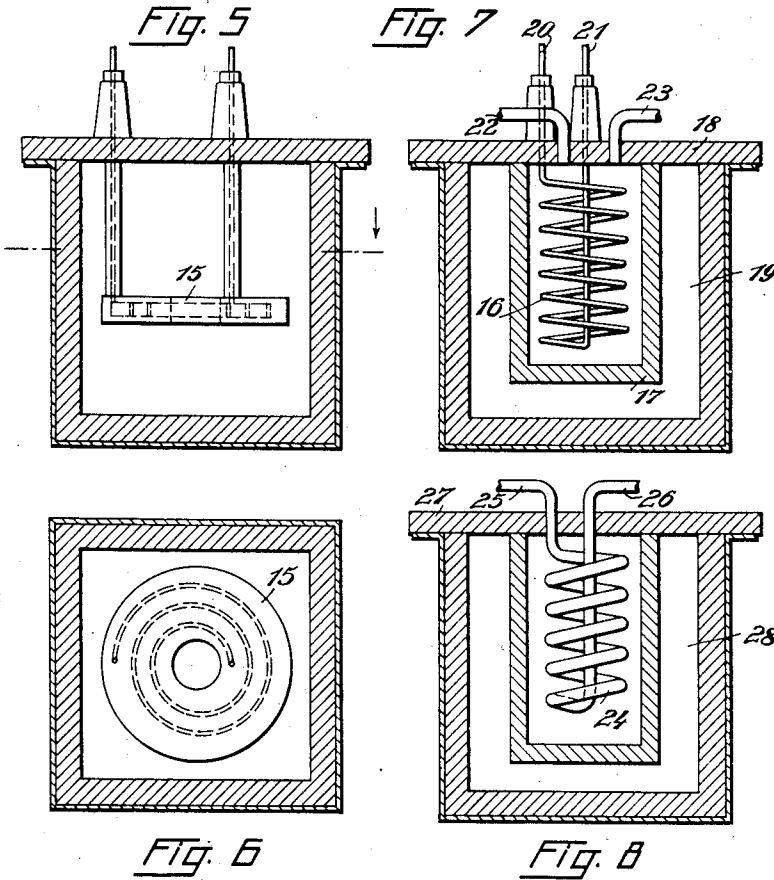
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Fig. 10

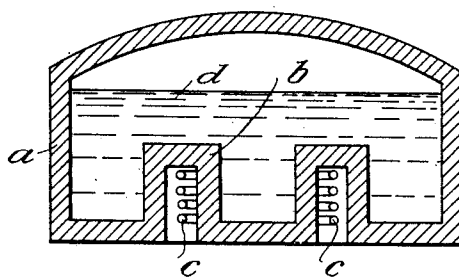
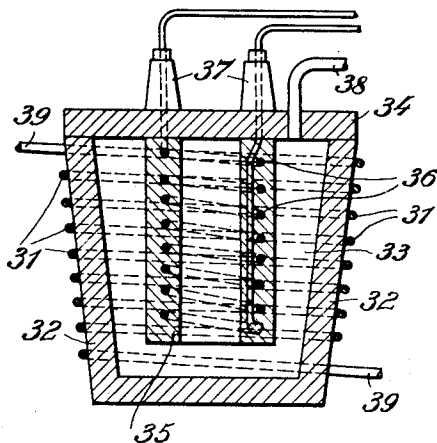


Fig. 11



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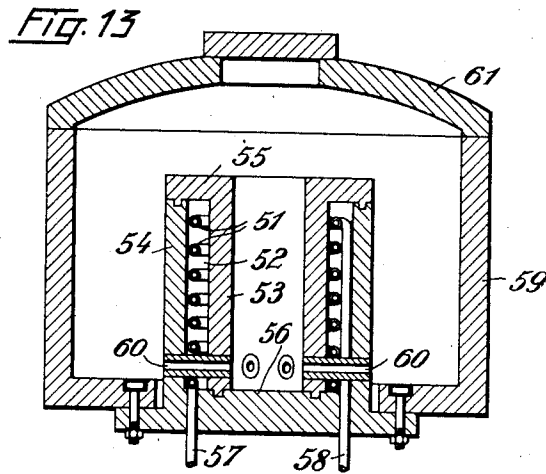
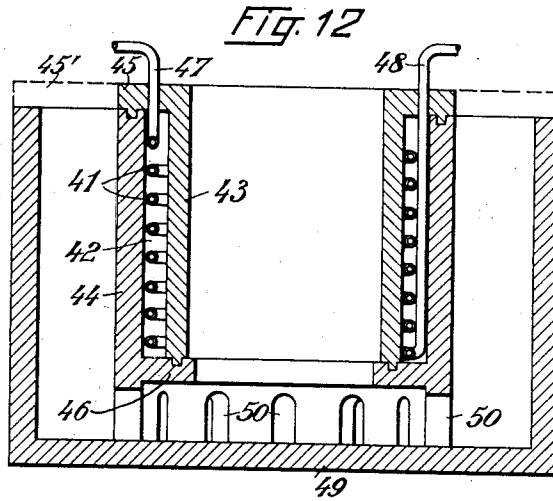
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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HIGH FREQUENCY INDUCTION FURNACE OR HEATING APPARATUS

Application filed July 20, 1927, Serial No. 207,169, and in Germany July 24, 1926.

This invention relates to a high frequency induction furnace or heating apparatus. In the hitherto known high frequency induction furnaces or heating apparatus, the inducing coil is arranged outside the material to be melted or heated through. In such case therefore the material is struck only by the electromagnetic lines of force flowing in the interior of the coil field, whilst the portion of the magnetic flux passing outside the coil, is wasted without being utilized for the generation of the melting or heating heat.

Another drawback of the high frequency coil arranged outside the material to be melted or heated, is that the lines of force passing outside the coil, make impossible the use of metallic materials for enclosing or strengthening the furnace, as these lines of force would produce an inadmissible heating of metallic parts of the furnace.

The invention avoids these drawbacks by the fact that according to the invention the heat produced by induction in the charge material, is generated by a heating coil dipped or inserted into the charge material situated in the furnace interior. All the electromagnetic lines of force produced by the high frequency coil in the material to be melted or heated, can be therefore utilized for the heating or melting process. Owing to the new arrangement, more particularly the heating effect is considerably increased and consequently the total efficiency of the furnace or of the heating apparatus considerably improved.

Several constructions according to the invention are illustrated by way of example in the accompanying drawings.

Figures 1 and 2 show diagrammatically a construction of the new induction furnace in vertical and horizontal section. Figures 3 and 4 show cross sections through two furnaces with several heating coils. Figures 5 and 6 are respectively a longitudinal section and a cross section through a modified con-

struction according to the invention. Figures 7 and 8 show in longitudinal section two different methods of cooling for the new arrangement. Figure 9 shows another construction in perspective view. Figure 10 shows in longitudinal section another construction of the new arrangement. Figure 11 is a longitudinal section through a furnace with an inner and an outer heating coil. Figures 12 and 13 are longitudinal sections through two other constructions according to the invention.

In Figures 1 and 2, 1 is the metallic furnace jacket or casing, 2 the refractory lining of the furnace, 3 the inner hearth which is closed by a cover 4. In the hearth 3 is arranged the high frequency coil 6 embedded in a refractory hollow cylinder 5, so that it dips or is immersed into the charge material 9. At 7 are indicated the insulated lead through tubes of the coil 6. A pipe connection 8 makes it possible to produce a vacuum or pressure in the interior of the furnace. The hollow cylinder 5 containing the coil 6, is secured in any desired manner to the cover 4, the lower end of the hollow cylinder not touching the bottom of the hearth.

The melting process in the furnace takes place in the following manner:—

The eddy currents generated in the charge material 9 by the coil 6 carrying the high frequency currents and eventually also the hysteresis, heat the material contained in the interior of the refractory coil body 5, as well as the material surrounding the refractory coil body. As the density of the lines of force or flux in the interior of the coil body is greater than in the molten material or charge surrounding the same, the material in the coil body 5 will accordingly have higher temperatures than the material which surrounds the coil body 5. A further advantage of this method of heating is therefore that the mixing of the charge which becomes melted, takes place in an automatic

manner owing to the thermic equalization of the material having different specific gravities, which mixing assists the dynamic stirring action which is produced as the consequence of the eddy currents in the molten charge.

Figure 3 shows diagrammatically a modified construction of the new induction furnace. In this construction are provided three heating coils 10, 11 and 12 embedded in refractory material, which in the case of single phase current, must be connected together in series, and in the case of polyphase current, for instance three phase current, are situated each in one phase. This arrangement makes possible an intensive heating through of the bath at different points. Any desired number of such coils can be used, arranged as may be considered best in each case and with regard to the metallurgical process to be carried out or to the heating process.

Figure 4 shows a furnace with two concentric induction coils 13 and 14 enclosed in refractory material. In place of these two coils 13 and 14, there could also be used any desired number of such concentric coils, according to the strength of the heating effect to be produced or according to the degree of duration of melting, the heating of the coils, which is considered the most suitable, being effected by means of a single phase or of a polyphase current. This arrangement has special advantages for large units, namely that for instance when the hearth is large, the material contained in the same is uniformly heated in all the layers, as in this construction there takes place a mutual action of the magnetic flux of the coils inwards and outwards.

In the same way such a heating device can be used with advantage for instance for the purpose of heating various objects such as wire, cylinders, etc., a considerable saving in heating space being at the same time effected.

Figures 5 and 6 show the use of a flat coil or of any desired number of flat coils 15 which can be arranged at any desired depth of bath. If desired, the level of the coils in the bath can be made adjustable, so that, according to requirements, the single layers of the bath could be heated through. The coils 15 could be arranged above and next to each other, and in the same way, the heating coils could be connected to a single phase or to a polyphase current.

Figure 7 shows the arrangement of the coil 16 in the free space in the interior of a hollow body 17 of refractory material which can be secured in a suitable manner to the covering device 18 of the melting chamber 19. The coil ends 20 and 21 project through the covering device, and the pipe branches 22 and 23 enable gaseous medium to be injected for cooling the coil which can be made of any de-

sirable shape in cross section. Liquid cooling media can also be used.

Figure 8 shows an arrangement of the coil similar to that of Figure 7, with the difference however that the high frequency coil in Figure 8 is constituted by a hollow conductor material of any desired cross section. The coil ends 25 and 26 project through the covering 27 of the heating chamber 28. The cooling of the coil could be effected by the use of suitable liquids or gases. In the constructions shown in Figures 7 and 8, several coils can also be used in the heating chambers, and they can also be connected to a single phase or to a polyphase current.

In the arrangements of the high frequency coils shown in Figures 7 and 8, though only the magnetic flux of the outer coil field is utilized, the advantage of all the other constructions is retained, namely the possibility of using iron jacketing or reinforcements in the construction of large furnace units, and moreover also the advantage of use of any desired number of heating coils.

Figure 9 shows the utilization of high frequency coils 29 in vertical arrangement in the heating chamber 30, owing to which again can be ensured a very uniform and energetic heating-through of the fusions bath or of the heating chamber and the coil can be connected to a single phase or to a polyphase alternating current.

In many cases it is advisable to introduce the induction coil through the bottom of the furnace, for instance into a hollow cylindrical inward projection at the bottom of the furnace, easily accessible from the outside, in such a manner that both the inner and the outer magnetic field of the coil passes through or traverses the charged material.

In Figure 10 is shown a construction of that kind. At the bottom of the furnace arch *a* is arranged a cylindrical inward projection *b* accessible from the outside, into which is introduced the induction coil *c*. In this case, the coil *c* could be made of ordinary solid wire or of hollow wire. It is arranged in such a manner that both its inner and its outer magnetic field traverses the charge material *d*.

In this arrangement, the induction coil can be cooled in a simple manner by air or liquid, without any tight joints being required. Moreover, this arrangement has the advantage that it is completely unnecessary to make in the furnace arch any openings such as required when introducing the coil from the top. Moreover, this construction results in a favourable distribution of space, which is of particular importance in the case of large furnaces. Finally the easy accessibility of the high frequency coil enables the coil to be quickly replaced when required on account of faults in the coil or when it is desired to work with different coils.

When used as a melting furnace, this arrangement offers the further advantage that the molten mass is heated to the greatest extent in its bottom portion, so that circulation from the top downward and back again upwards, is automatically produced in the molten mass, owing to which a favourable mixing is ensured.

The hollow cylindrical inward projection *b* could also be detachably inserted into the furnace bottom so that it could be replaced together with the coil *c*, the coil *c* being embedded in it if desired. The coil *c* instead of being made of solid wire of any desired shape, could also be made of a hollow material.

In addition to a heating coil immersed into the charge material, there could be provided if desired a further coil which is placed round the outside wall of the furnace. This makes it possible considerably to increase the heating effect, owing to the portion of the charge material which is situated between the inner coil and the furnace wall, being traversed both by the inner magnetic flux of the coil at the outside wall of the furnace, and by the outer magnetic field of the coil arranged in the interior of the hearth.

A construction of that kind is shown in Figure 11.

Round the outside wall 32 of the furnace, which is made of a refractory material, is placed a coil 31 with the connections 39. Inside the hearth 33, which is closed by a cover 34, is mounted a second coil 36 which is embedded in a hollow cylinder 35 of refractory material. In the construction illustrated, the hollow cylinder 35 is secured to the cover 34. Instead of that it could also be secured in a suitable manner to the bottom or to the walls of the furnace body. If desired, more particularly in the case of heating furnaces, the coil 36 could also be mounted on parts of the furnace without securing it. At 37 are indicated the insulated cover lead-through tubes of the coil 36. A pipe connection 38 makes it possible to produce a vacuum or a pressure in the interior of the furnace.

The two coils 31 and 36 could be fed from the same or from different sources of high frequency, for instance generators, oscillation circuits, etc. The feed currents for the coils 31 and 36 could be of the same or of different amplitude, and if desired also of different frequency, in order to obtain the best possible heating effect. This can be done, when using a single high frequency generator, in a manner well known in itself by a different kind of coupling of the two circuits containing the coils 31 and 36, to the generator, or by using suitable damping resistances etc. The outer coil 31 need enclose if desired only a portion of the hearth or of a trough or the like connected to the same.

This construction makes it possible to in-

crease or to reduce the heating effect as required, in a simple manner by switching in either both coils or only one of the coils. When using as melting furnace, first for instance the two coils 31 and 36 can be switched in until the charge material has been melted. Thereupon, for instance the outer coil 31 can be switched off, in as far as the heating effect of the inner coil 36 is sufficient for the further heating of the molten metal. It is obvious that in the arrangement according to this figure, no closed iron casing can be used for the furnace. For the rest however, any construction of the inner heating coil or heating coils can be used, which have been described with reference to Figures 1 to 9.

It is further possible to feed one of the coils 31 and 36 with low frequency current, and the other with high frequency current, or also to feed both coils with low frequency current. For working under atmospheric pressure, the furnace of this construction as well as of the construction according to Figure 1, can be built open, that is to say without cover.

The induction coil could also be covered inside and outside with refractory material acting as support, in such a manner that it will allow of an easy expansion of the coil spires, more particularly in the direction of the coil axis. This has the advantage that the ceramic material enclosing the coil is not subjected to any stresses by the coil, as the single coil spires on being heated can freely expand. As refractory material there could be used zircon, carborundum, corundum, highly burnt fireclay or the like.

In Figures 12 and 13 are shown two such constructions according to the invention. In Figure 12, the heating coil 41 is arranged in the space 42 between two hollow cylinders 43 and 44 of refractory material. The space 42 is closed at the top and at the bottom by flange like projections 45 and 46 of the hollow cylinders 43 and 44. At the places of contact, the parts 43, 45 and 44, 46 are caused to form tight joints with each other, for instance by cementing, so that they form one unit containing the coil 41. The coil support thus formed is placed, in the construction illustrated, on the bottom of the furnace 49. The bottom part of the coil support is shown in elevation in order to make visible the openings 50 which are required for a circulation of the molten metal from the space in the interior of the coil support, outwards. If desired, the coil support could also be suspended in the furnace. This could be done for instance by extending outwards the flange 45 of the inner hollow cylinder 43 as indicated by chain dotted lines at 45'. By means of these extensions, the coil support can then rest for instance on the lateral walls of the furnace 49. In place of that, the suspension of the coil support could be effected also by connecting it in a suitable manner to a furnace cover, so

that it could be removed with the latter. In the construction illustrated, the coil 41 is shown of tubular shape in order to facilitate the cooling. The connections for the cooling device are indicated at 47 and 48. If desired an outer cooling of the coil 41 could also be effected, for instance by blowing air into the space 42. If required, the walls of the coil 41 could be cooled from the outside as well as from the inside.

Figure 13 shows another construction according to the invention. A tubular heating coil 51 is arranged in the space 52 between two hollow cylinders 53 and 54 of refractory material, which overlap each other flange like at one end, at 55, and are closed at the other end by means of a cover 56. The above mentioned parts are connected together to form a single unit and introduced into the interior of the furnace through a recess in the bottom of the furnace body 59, so that the cover 56 forms a part of the furnace bottom. At 57 and 58 are indicated the leading-through tubes which are used for connecting the coil 51, the cooling of which can be effected in the same way as indicated for the coil 41, Figure 12. The coil support is secured in a suitable manner to the furnace bottom and forms a tight joint with it. In order to ensure a good circulation of the liquid molten metal from the space in the interior of the hollow cylinder 53, outwards, in the hollow cylinders 53 and 54 are provided recesses 60 which are preferably connected together by refractory conduits traversing the coil space 52.

These connections could also be made in the arrangement according to Figure 12. The arrangement according to Figure 13 can be easily built in, if desired it could be made interchangeable, and produces a thorough mixing of the molten mass as the latter is heated right from the bottom.

The high frequency coils in such an arrangement could be made of solid material of any desired cross section and of any desired shape, of high frequency strands or material of tubular cross section of any shape, the cooling being either by gas or by liquid. When air cooling is used, it is preferable to see that the surface of the coils is made as large as possible. The invention is chiefly intended for high frequency melting furnaces or heating furnaces. It can be however applied also for low frequency working. The coils can be secured either to the cover or to the lateral walls, or mounted in a suitable manner on the bottom, in which case it is preferable always to leave a free space on all sides between the coil body, on the one hand, and the hearth (bottom, cover, lateral walls), on the other hand. The coil axes, instead of being vertical or horizontal, could also be inclined at some other angle. For the generation of the primary heating current there

could be used damped or undamped vibrations. The connection of the coils could be effected either directly or through transformers or converters, to single phase or poly-phase current. In the hearth, there could be used a pressure smaller or greater than or equal to the atmospheric.

What we claim as our invention and desire to secure by Letters Patent is:

1. A high frequency induction furnace or heating apparatus for the treatment of metals or metal compounds, including an induction coil arranged in the interior of the furnace and fed with high frequency currents, and a separating element consisting exclusively of non-metallic material between the outer surface of said coil and the interior of the furnace.

2. A high frequency induction furnace or heating apparatus for the treatment of metals or metal compounds, including an induction coil arranged in the interior of the furnace and fed with high frequency currents, a separating element consisting exclusively of non-metallic material between the outer surface of said coil and the interior of the furnace, and an additional separating element composed exclusively of non-metallic material between the inner surface of said coil and the interior of the furnace.

3. A high frequency induction furnace or heating apparatus for the treatment of metals or metal compounds, including a cylindrical induction coil arranged in the interior of the furnace and fed with high frequency currents, and a hollow cylindrical body composed exclusively of non-metallic material and adapted to isolate both the inner and outer surfaces of said coil from the interior of the furnace.

4. A high frequency induction furnace or heating apparatus for the treatment of metals or metal compounds, including a body of insulating material which projects into the interior of the furnace and a high frequency induction coil supported by said body in such manner that said coil lies completely within the interior of the furnace.

5. A high frequency electric furnace comprising an insulated chamber, an induction coil located inside said chamber, said coil being of the air wound type, and a furnace chamber external to said insulated chamber, said coil and chamber being so designed that material placed in the furnace chamber will be heated when current of high frequency is applied to the coil.

6. An induction furnace comprising a container for the charge, and a tubular high-frequency coil extending into said container from above and terminating at a point above the bottom of the container, so that the charge may form a continuous body located partly within said coil and partly around the same, and so that both the inner and the

outer magnetic fields of the coil will pass through the charge.

7. An induction furnace comprising a container for the charge, a tubular carrier of insulating material, open at the bottom, extending into said container from above and terminating at a point above the bottom of the container, so that the charge may form a continuous body located partly within said carrier and partly around the same, and a high-frequency coil located in said carrier between the inner and the outer surfaces thereof, so that both the inner and the outer magnetic fields of the coil will pass through the charge.

In testimony whereof we affix our signatures.

VICTOR ENGELHARDT.
REINHOLD GROSS.