

Feb. 13, 1951

M. TAMA
UNIDIRECTIONAL FLOW IN PLURALITY
CHAMBER INDUCTION FURNACE

2,541,841

Filed June 20, 1947

3 Sheets-Sheet 1

Fig. 1.

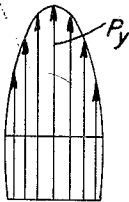
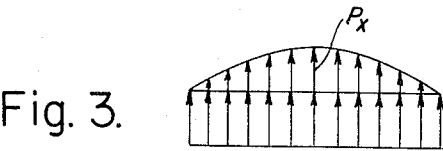
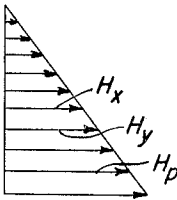
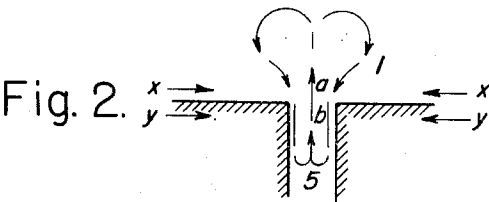
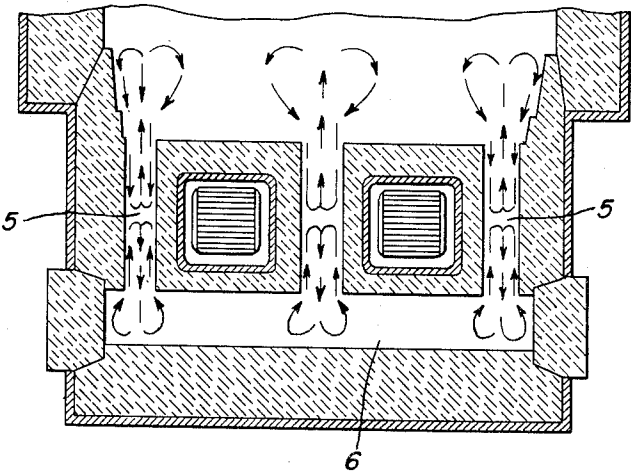


Fig. 5.

Fig. 3.

Fig. 4.

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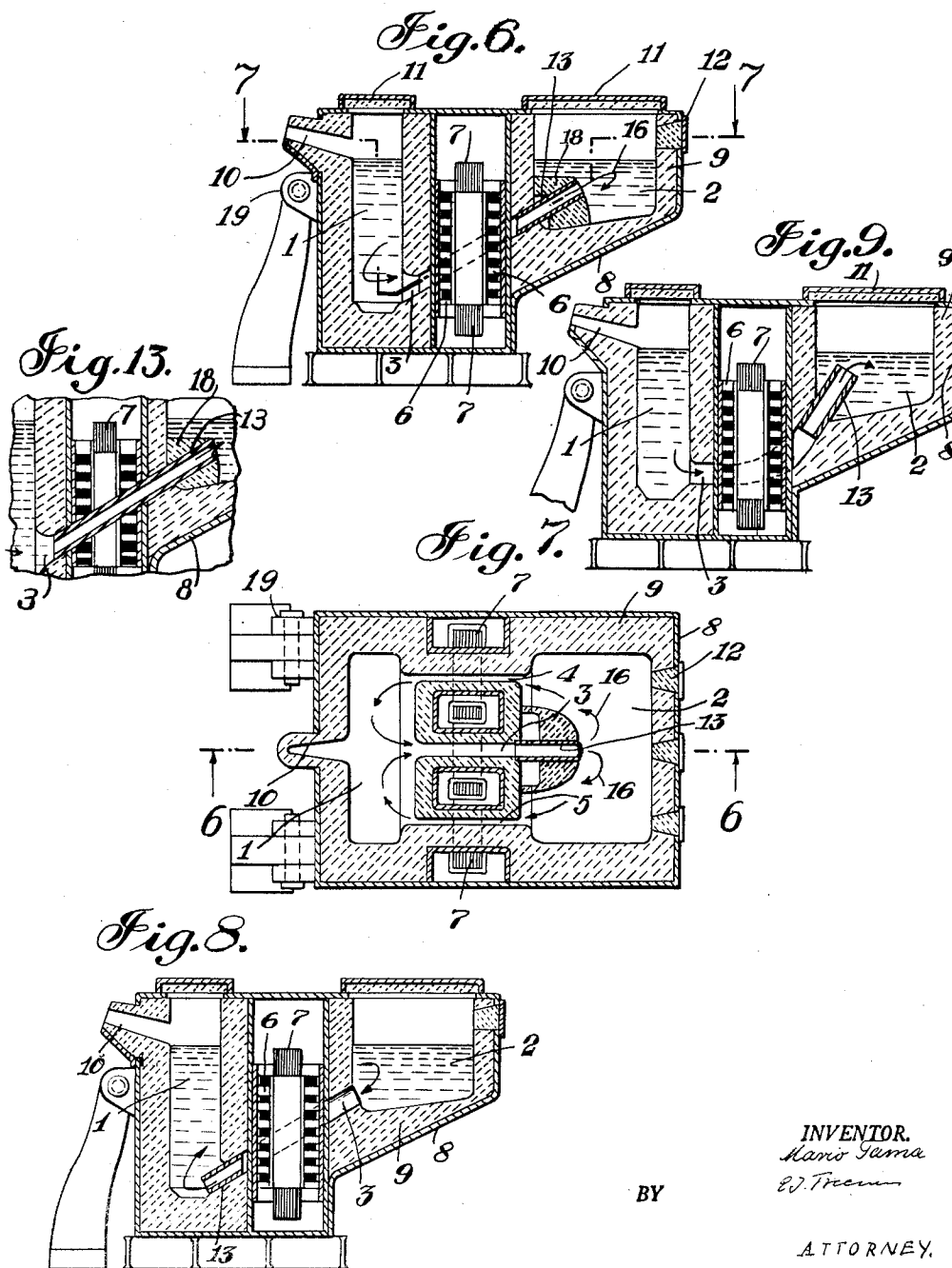
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

Fig. II.

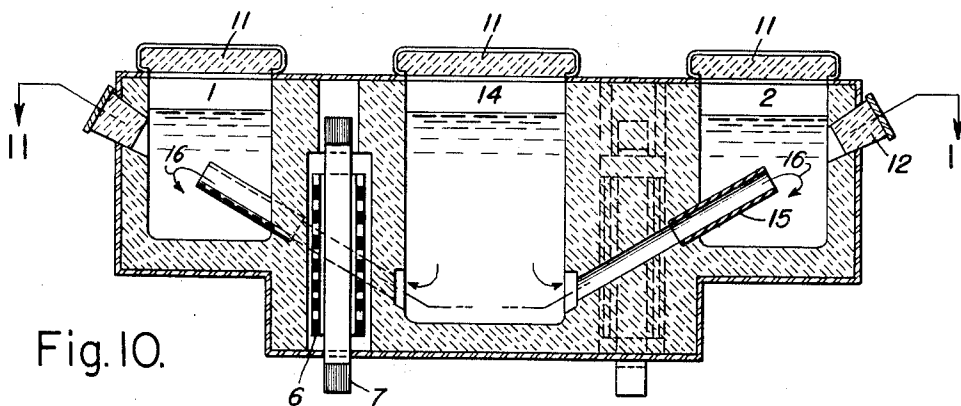
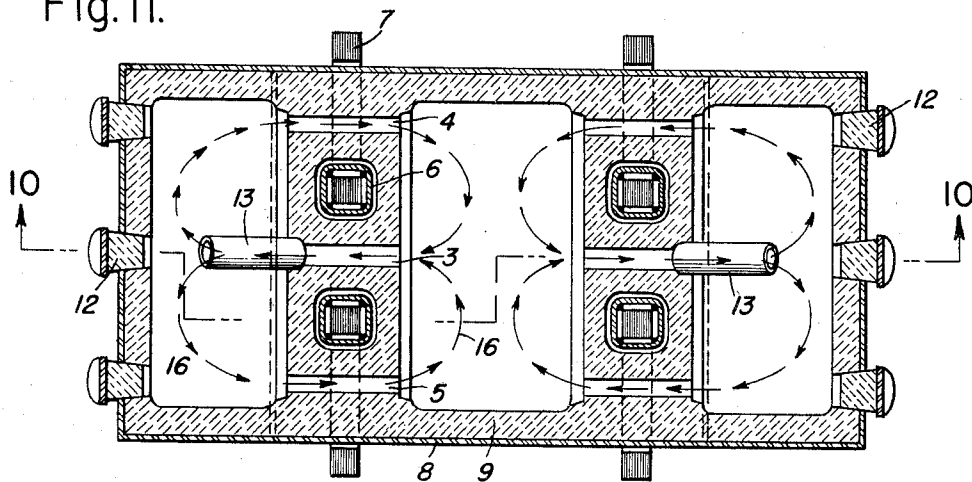


Fig. 10.

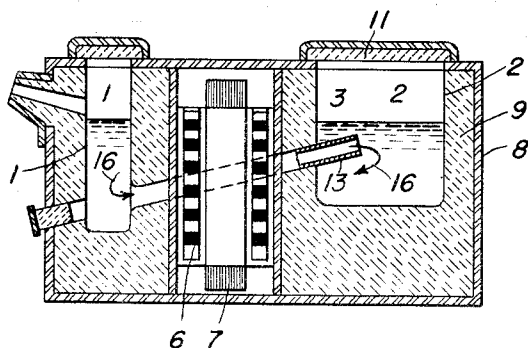


Fig. 12.

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2,541,841

UNIDIRECTIONAL FLOW IN PLURALITY
CHAMBER INDUCTION FURNACEMario Tama, Morrisville, Pa., assignor to Ajax
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Application June 20, 1947, Serial No. 755,886

12 Claims. (Cl. 13—29)

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This invention relates to an induction furnace and particularly to a multi-chamber induction furnace of the stationary and of the tiltable type.

These furnaces are generally provided with two or more metal holding chambers or hearths and these chambers (or hearths) are connected by a system of channels or ducts forming the secondary melting loop; the channels are in the customary manner threaded by primary transformer units.

The furnaces are frequently equipped with a rocking or rotating device; the rocking of the furnace imparts to the molten metals an agitating and mixing action in order to equalize the metal charges held in the various chambers or hearths.

The customary rocking or rotating means are of a purely mechanical nature and the furnaces are for this purpose often supported on rollers and similar means.

The invention relates in contradistinction to the above described art to non-rocking, that is to stationary and tiltable multi-chamber induction furnaces, and it is its main purpose to equalize the metal melts in the individual chambers or hearths by stationary or non-movable means; at the same time it is an important aim of the invention to effect a rapid and uniform transmission of the heat which is inductively created by the primary transformer unit or units to the metal charges in the various holding chambers.

Prior attempts to impart to induction furnaces an effective and fast distribution of the inductively created heat to the molten metal charge and to produce uniform metal melts have been based on the production of a metal movement by the creation of temperature differences in the secondary melting channels, which for this purpose were equipped with sections of a smaller and a larger cross-area; it was assumed that a higher temperature could be obtained in the places of smaller cross-section whereby a one-directional metal flow would be initiated. However, these and other attempts to create a unidirectional flow or circulation of the molten metal charge in induction furnaces have remained entirely unsuccessful.

The creation of a one-way or unidirectional flow of the metal is indeed highly desirable in induction furnaces and particularly in those of the submerged resistor type and many suggestions have been continuously made in the source of the past forty years to satisfactorily solve this problem.

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These suggestions include:

The provision of a plurality of separate and of moving electromagnetic fields,

Of open loop reservoirs for the charge and closed loop channels connecting with the reservoir at remotely separated places.

The arrangement of hearth entering ends of the loop at vertically different levels,

The gradual enlargement of the loop cross-area from one to the other hearth entering points,

The co-axial arrangement of the primary and the secondary and

The displacement from each other in an axial direction.

Some of the known constructions utilize the pinch-effect and some have been designed with the purpose to prevent the disruption of the metal flow by the latter.

The above recited numerous endeavors demonstrate the importance of a satisfactory flow control of the molten metal in induction furnaces; but none of them has attained the status of practical usefulness because they are based on constructional changes of the secondary loop itself.

Even if a unidirectional pressure flow is shown in the prior art from one outlet of the secondary loop through the charge into another outlet of the loop and a return flow through the latter, this flow is, on account of the heavy weight of the superposed metal charge, necessarily confined to its lower portion; this is particularly true of deep charges where the flow impetus of the metal emerging from the loop into the hearth is soon counteracted by the weight of the charge.

As mentioned above, the movement of the molten metal in induction furnaces of the submerged resistor type is greatly influenced by the pinch-effect.

Due to this effect a strong suction is produced at the emergence point of the melting channels into the hearth effecting a direct return movement of the molten charge into the same channels.

The metal flow produced by the pinch effect in a submerged resistor type induction furnace having a melting loop composed of a channel spaced from the hearth and a plurality of substantially straight channels connecting the spaced channel with the hearth is illustrated in attached Fig. 1, showing the melting loop and the bottom section of the hearth.

The electromagnetic field of highest intensity is located in the center section of the straight melting channels at about half their length. The metal is formed from this center section in

an upward and in a downward direction through the melting channels, as indicated by the arrows. The molten metal stream emerging from the ends of the channels draws the metal from adjacent portions of the charge into the same channels, whereby two lateral flow branches result which are again outwardly forced as they approach the center portion of the channels. Under the direct influence of the electromagnetic field the well known flow of the melt in opposite directions results through the same channel, as shown for instance in U. S. Patent Sasnett No. 1,660,209 and indicated by the arrows in Fig. 1.

Within the range of its highest intensity the electromagnetic field has the tendency to compress the molten conductor; if the current input is sufficiently high, it may happen that the conductor is interrupted or pinched; thus the term "pinch effect" was created.

However, and as above stated, the direct return of the metal into the melting channel is the consequence of the metal pressure produced by the electromagnetic field and the resulting sucking effect in coaction with the pressure distribution in melting channels; it will therefore not take place in those portions or layers of a molten metal charge, which are not influenced by the electromagnetic field.

The pressure distribution resulting in the adjacent sections $x-x$ and $y-y$ at the transition point of the metal from the channel mouth into the hearth is illustrated in Figs. 2 to 5.

The hydrostatic pressure HP which increases from the surface of the melt downward is shown in Fig. 5; at the point x it is H_x , at the point y it is H_y .

The pinch effect produces a superimposed inwardly directed pressure which, as can be shown by simple calculation, increases on a parabolic curve from the periphery of the channel toward its center, where the pressure attains its maximum. This pressure is

$$P = \frac{I^2}{\pi r^2}$$

where I denotes the current and r the radius of the conductor.

It is obvious that the pressure maximum P_y in the smaller section $y-y$ is smaller than the pressure P_x in the larger section $x-x$. The adjacent points a and b are consequently subjected to various pressures and, as will appear from Fig. 4, the pressure at b is higher than that at a . This causes the liquid conductor to be squirted-out in the direction b to a ; the metal upwardly propelled in the direction of the center arrow is replaced by metal drawn back from adjacent portions of the charge, as shown by the lateral arrows in Figs. 1 and 2. A similar metal flow is produced at the emergence of channels 5 into channel 6, Fig. 1.

This metal transport through the melting channels of the furnace has its advantages; it prevents, for instance, the overheating of the metal in the melting channels. However, the non-controlled metal movement is locally limited and obviously insufficient to have a decided influence on the equalization of the charge and the distribution of the heat thereto; moreover, the current input is limited and the high power factor required for the steadily increasing capacity of modern induction furnaces cannot be obtained because current increase involves the danger of the conductor being interrupted in the zone of the highest field intensity. Some of the

known suggestions to create a unidirectional flow also involve difficulties in the construction of the furnace itself and greatly raise its manufacturing costs.

It is therefore the primary object of this invention to create in a multi-chamber induction furnace an equalization of the metal melts in the various chambers and uniformity with regard to chemical composition and temperature.

It is a further object of the invention to achieve this aim without rocking the furnace and without the application of rotatable devices, such as supporting rollers and the like.

It is another important object of the invention to create in these furnaces a continuous unidirectional closed metal flow through the various chambers with adherent uniformity of the metal in the same; this is of particular importance in the mass-foundry and die-casting practice of, particularly, light metals where the production of uniform castings is a dominant postulate which has hitherto not been satisfactorily met within the customary mechanically rocked induction furnaces.

It is a further object of the invention to permit a practically unlimited increase of the power factor or current density without incurring the danger of interrupting the conductor or clogging the melting loop.

It is a further important object of the invention to successfully melt in these furnaces small-sized metal materials such as scrap, turnings, borings, chippings and even fine metal powders.

It is a further object of the invention to optionally increase the power factor of the furnace and to obtain with the same amount of iron in the transformer a larger power input.

It is also an object of the invention to greatly reduce slag deposition in the melting loop and particularly in the center section of the melting channels as the continuous unidirectional metal flow through the entire channel length prevents the slag particles from coming to rest.

With the above recited and other objects in view, which will become apparent as this specification proceeds, the invention comprises as its main element a one-way or unidirectional extension of continuation of the metal movement initiated by the induced electromagnetic field from the secondary melting loop into a section of a metal holding chamber where the field intensity is strongly reduced or entirely eliminated; the thus created metal impetus draws metal from another chamber; the metal flow from this other chamber is naturally replaced by metal flowing in an opposite direction from the first chamber through the melting loop into the other chamber.

In this manner, the molten metal is forced to participate in a continuous one-way or unidirectional circulation through the various chambers and a highly satisfactory equalization of the charge is obtained which is far superior to the rocking of the same, is far less expensive and is equally applicable to stationary and tiltable furnaces.

The inductively created heat is equally and uniformly distributed throughout the entire charge of the various chambers. Small-sized metal scrap and metal powders may be molten without difficulty, which hitherto has been unattainable in multi-chamber induction furnaces.

A simple means to obtain the above described closed and unidirectional flow of the entire charge consists in the location of a current conductive refractory tube, for instance, a graphite

or carbon tube in a melting channel or directly above its upper end in such a manner that the tube forms an extension of the channel; the tube ends within or above a section of the melt which is practically free from the influence of the induced electromagnetic field.

The invention relates to an induction furnace of the submerged resistor type as disclosed in copending U. S. patent applications Serial No. 647,831, filed Feb. 15, 1946, now Patent No. 2,536,325, issued Jan. 2, 1951; Serial No. 683,115, filed July 12, 1946, now Patent No. 2,539,215, issued Jan. 23, 1951; Serial No. 671,818, filed May 23, 1946, now Patent No. 2,536,859, issued Jan. 2, 1951; and Serial No. 735,851, filed Mar. 20, 1947.

The invention is based on the general idea also inherent in these copending patent applications of creating in the submerged resistor type furnace a unidirectional metal flow from the melting loop into a zone which is essentially free from inductive influence; for this purpose a refractory tube is inserted with its one end into the melting loop; the tube reaches with its other end into a zone which is essentially not influenced by induction.

The above referred-to copending patent application Serial No. 683,115, filed July 12, 1946, generally claims this inventive idea.

Patent application 647,831, filed February 15, 1946, claims the insertion of a refractory tube into the melting loop of the furnace in such a manner that the end of the tube is spaced from the channel wall and freely reaches into the channel.

Patent application Ser. No. 671,818, filed May 23, 1946, claims a method of pumping a molten metal from an induction furnace by inserting a refractory, current-conductive tube into a melting channel; certain claims include the maintenance of a small clearance between the outside of the inserted tube and the inside of the melting duct, the insertion of an additional refractory tube into the melting channel and the application of the unidirectional flow principle to a duplex induction furnace consisting of a large capacity and a small capacity melting furnace.

Patent application Ser. No. 735,851, filed Mar. 20, 1947, claims the creation of a unidirectional closed metal flow within the melting loop and the hearth of a single induction furnace by the connection of a refractory, current conductive tube with the melting loop.

The present application claims the application of the above recited general inventive idea of creating a unidirectional metal flow by the insertion of a refractory tube into a melting loop to an induction furnace having a plurality of chambers connected by this loop and the creation of the closed metal flow through these chambers and the melting loop.

Induction furnaces embodying the hitherto known metal movement in the melting channels and the one-way or unidirectional circulation of the melt in accordance with the invention will now be described in detail and with reference to the attached drawings.

In the drawings,

Fig. 1 is a vertical section of the lower part of a submerged resistor type induction furnace illustrating the customary metal flow under the influence of the pinch effect,

Figs. 2-5 illustrate the pressure conditions which prevail in this furnace at the emergence of the melt from a melting channel into the hearth,

Fig. 6 is a vertical section of a double chamber induction furnace on line 6-6 of Fig. 7, equipped to produce a unidirectional metal circulation through both furnace chambers according to this invention,

Fig. 7 is a sectional view on line 7-7 of Fig. 6,

Figs. 8, 9 and 12 are vertical sectional views of further modifications of the tiltable double-chamber furnaces shown in Figs. 6 and 7.

Fig. 10 is a vertical sectional view of a three-chamber furnace on line 10-10 of Fig. 11 equipped in conformity with this invention,

Fig. 11 is a sectional view of the same furnace on line 11-11 of Fig. 10,

Fig. 13 is a vertical sectional view of the furnace similar to that of Fig. 6 showing a further modification.

The furnace shown in Figs. 6 and 7 is equipped with two metal holding chambers or hearths 1, 2. The secondary melting loop is located between these two chambers.

The loop consists of three melting channels 3, 4, 5 which connect the two chambers 1, 2 and are threaded by primary transformer units composed of coils 6 of insulated copper wire and an iron core 7 which is closed toward the coil windings.

The furnace is housed in casing 8 lined with a refractory material 9, has a pouring opening 13, covers 11, closing plugs 12, and is tiltably supported in bearings 19; customary means, such as electric hoists and hydraulic cylinders, will be provided to effectuate the tilting.

As apparent from the drawings, the melting channels 3, 4, 5 are parallel and equally inclined in such a manner that straight cleaning tools can be inserted through the openings closed by plugs 12 into the channels while the same are full with the molten metal. Therefore the furnace can be kept in full operation during the cleaning of the melting channels; this is true for the position shown in the drawings and for any tilted position of the furnace. In the hitherto known multi-chamber furnaces of this type the furnace had to be emptied for the insertion of the cleaning tools and the cleaning of the melting channels from the outside of the furnace could not be effected in the tilted position while the furnace was in operation and the melting channels were kept full of the molten metal.

The means creating the homogenization of the metal in the two chambers 1, 2 consist of a current conducting refractory, for instance, graphite tube 13 which, as illustrated in the drawings, is inserted into channel 3; however, these tubes may be also inserted in the lateral channels, whereby the metal circulation would be reversed insofar as the metal will then flow from channels 4, 5 into chamber 2, from there into channel 3, then through chamber 1 and back into channels 4, 5.

The free end of tube 13 extends into a section of the metal bath held in chamber 2 which is practically free from the influence of the electromagnetic field; the proper length of the tube will vary in accordance with the particular operating conditions of the furnace; however, that section of the hearth which is practically free of induced current and which therefore decides the length of the tube may be ascertained without difficulty as the extent of the electromagnetic field produced in these furnaces can be easily determined.

The upper or front portion of tube 13, which is not under the influence of the electromagnetic field, is protected by a body of a suitable refrac-

tory material, such as refractory brick 18, to prevent the breakage of the tube by the metal which is charged into the furnace chamber 2. The portion of the tube directly adjacent to the transformer unit, however, remains unprotected and leaves the way open for the flow of the current through the electrically conductive tube 13.

Due to the fluid pressure created by the induced electromagnetic field in channel 3 the metal is forced to flow from tube 13 in the direction of arrows 16; the outflowing metal is replaced by metal flowing in the direction of the arrows from chamber 1 into channel 3; accordingly metal must flow from chamber 2 through channels 4, 5 into chamber 1 and from there again into channel 3.

In this manner a steady continuous one or unidirectional circulation of the charge is produced through both chambers and a thorough homogenization achieved of the melts in the two chambers without the application of mechanical or furnace rocking means.

The tube 13 may extend, if desired, through the whole length of the melting channel as illustrated in Fig. 13.

In the modification of the invention shown in Fig. 8 the tube is so inserted into channel 3 that it extends into chamber 1. The metal flow will accordingly be reversed to that shown in Figs. 6 and 7. However, the unidirectional circulating and homogenizing action of tube 13 remains unaltered.

In the furnace shown in Fig. 9 which otherwise is not different from those shown in Figs. 6-8 arcuated melting channels are provided which contrary to the furnaces of Figs. 6 and 8 could not be cleaned by straight cleaning tools during the operation of the furnace.

The furnace shown in Figs. 10 and 11 is a three chamber furnace which is equipped with metal holding chambers 1, 14, 2.

Two secondary melting loops are located between chambers 1 and 14 and between chambers 2 and 14. The loops consist as in the case of the previously described furnaces 6 to 9 of melting channels 3, 4, 5 which connect the metal holding chambers and are threaded by the primary transformer units composed of coils 3 of insulated copper wire and iron cores 7.

The furnace is housed in a refractory lined casing 8, has covers 11 for the three chambers and sealing plugs 12.

The means for creating the unidirectional metal circulation from the center chamber 14 into the lateral chambers 1 and 2 and the return flow into center chamber 14 consist of the refractory current conductive tubes 13 inserted into the center channels 3.

The free ends of tubes 13 extend, as previously described, into a section of the metal bath which is substantially free from the influence of the electromagnetic fields created by the inductor units. The refractory protective brick 18 may also here be applied to tube 13 in the previously described manner.

Due to the extension of channels 3 by the tubes 13 the metal flows from these tubes into chambers 1 and 2, from there through channels 4, 5 into the center chamber 14 and back into channels 3; thereby the same continuous unidirectional metal flow, as previously described, is created in a three chamber furnace.

As apparent from Fig. 12, the invention is here applied to a double-chamber furnace where the melting channels are only accessible to the introduction of cleaning tools after the charge

has been emptied-out; the furnace is otherwise equipped in the same manner as the furnaces shown in Figs. 6 to 9.

As previously mentioned, the here described furnaces are particularly well suited for the melting of metal scrap and also light metal scrap. The heat is generated at the bottom of the furnace and immediately transferred to the cold scrap from the melting channels by liquid contact due to the continuous unidirectional metal flow. Therefore the fine metal particles are not subjected to high temperature from above. Hence the rate of oxidation before melting is reduced considerably. As a further consequence of the unidirectional bath movement, the heat transfer and therefore the speed of melting is considerably increased and any oxide formed is detached from the scrap particles and expelled to the surface of the bath.

I claim:

1. In an induction furnace, a plurality of chambers located in spaced-apart relationship for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metals between the said chambers through the melting loop, said means including a refractory current conductive tube extending from a melting channel into a chamber below the normal operating level of the metal and shifting the connection of said melting loop with said chamber into a chamber section of reduced electromagnetic field intensity.

2. In an induction furnace, a plurality of chambers located in spaced-apart relationship for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in the said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metals between the said chambers through the melting loop, said means including a refractory current conductive tube extending from a melting channel into a chamber below the normal operating level of the metal and shifting the connection of said melting loop and said chamber into a chamber section which is free from the influence of the induced electromagnetic field.

3. In an induction furnace, a plurality of chambers located in spaced-apart relationship for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between the said chambers through the melting loop, said means including a current conductive refractory tube connected with its one end to an outlet of the loop into a chamber and terminating with the other end beneath the normal operating level of the metal in a section of the metal holding chamber which

is substantially free from the influence of the electromagnetic field.

4. In an induction furnace, a plurality of chambers located in spaced-apart relationship for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in the said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metals between the said chambers through the melting loop, said means including a current conductive refractory tube inserted with the one end into a melting channel and terminating with the other end beneath the normal operating level of the metal in a section of the metal holding chamber which is substantially free from the influence of the electromagnetic field.

5. In an induction furnace, two chambers located in spaced-apart relationship for holding molten metals, a secondary loop composed of melting channels connecting the bottom portion of the two chambers, at least one primary transformer unit threading the said secondary melting loop adapted to create an electromagnetic field and to hold the metal in the two chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between said chambers through said melting loop, said means including a current conductive refractory tube connected with its one end to an outlet of the melting loop into a chamber and extending with the other end beneath the normal operating level of the metal into a section of said chamber which is substantially free from the influence of the electromagnetic field.

6. In an induction furnace, two chambers located in a spaced-apart relationship for holding molten metals, the bottom of the said chambers being at different levels, a secondary loop composed of inclined melting channels connecting the bottom portion of the said two chambers, at least one primary transformer unit threading the said secondary melting loop adapted to create an electromagnetic field and to hold the metal in the two chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between said chambers through said melting loop, said means including a current conductive refractory tube connected with the one end to an outlet of the said melting loop into the chamber having its bottom at the higher level and extending with the other end beneath the normal operating level of the metal into a section of said chamber which is substantially free from the influence of the electromagnetic field.

7. In an induction furnace, two chambers located in a spaced-apart relationship for holding molten metals, the bottom of the said chambers being at different levels, a secondary loop composed of inclined melting channels connecting the bottom portion of the said two chambers, at least one primary transformer unit threading the said secondary melting loop adapted to create an electromagnetic field and to hold the metal in the two chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between said chambers through said melting loop, said means including a current conductive refractory tube connected with the one end to an outlet of the melting loop into the chamber having its

bottom at the lower level and extending with the other end beneath the normal operating level of the metal into a section of said chamber which is substantially free from the influence of the electromagnetic field.

8. In an induction furnace, a center chamber and two lateral chambers located in spaced-apart relationship for holding molten metals, secondary loops composed of a plurality of melting channels connecting the said center chamber with the said lateral chambers, at least one primary transformer unit threading each of the said secondary melting loops adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of unidirectional closed flows of the molten metal between the center and the lateral chambers through said melting loops said means including current conductive refractory tubes connected with the one end to an outlet of the loops into a chamber and terminating with the other end below the normal operating level of the metal in a section of the metal holding chamber which is substantially free from the influence of the electromagnetic field.

9. In an induction furnace, a plurality of chambers located in spaced-apart relationship for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between said chambers through melting loop, said means including a current conductive refractory tube connected with its one end to an outlet of the loop into a chamber and terminating with the other end beneath the normal operating level of the metal in a section of the metal holding chamber which is substantially free from the influence of the electromagnetic field and a refractory metal resistant protective body applied to the said tube on a major portion of its length extending in a metal holding chamber.

10. In an induction furnace, a plurality of chambers located in spaced-apart relationship, for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of a unidirectional closed circulation of the molten metal between said chambers through melting loop, said means including a graphite tube connected with its one end to an outlet of the loop into a chamber and terminating with the other end beneath the normal operating level of the metal in a section of the metal holding chamber which is substantially free from the influence of the electromagnetic field.

11. In an induction furnace, a plurality of chambers located in spaced-apart relationship, for holding molten metals, at least one secondary loop composed of a plurality of melting channels connecting the said chambers, at least one primary transformer unit threading said secondary melting loop adapted to create an electromagnetic field and to hold the metal in said chambers in the molten state, means for the production of a unidirectional closed circulation of

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the molten metal between said chambers through melting loop, said means including a carborundum tube connected with its one end to an outlet of the loop into a chamber and terminating with the other end beneath the normal operating level of the metal in a section of the metal holding chamber which is substantially free from the influence of the electromagnetic field.

12. A method of producing homogeneous metal melts in multi-chamber induction furnaces which are provided with a secondary loop composed of melting channels connecting the chambers and with at least one transformer unit threading said loop and adapted to create an electromagnetic field, comprising holding by means of the said field a metal charge in the said chambers in a molten state, advancing the outflow of the metal from a melting channel into a section of a metal holding chamber which is substantially free from the influence of the said electromagnetic field, creating a continuous unidirectional flow of the metal through the said chambers and the said melting loop and obtaining hereby complete homogenization of the molten metal.

MARIO TAMA.

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