

March 25, 1969

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3,434,823

METHOD FOR DEGASSING METALLIC MELTS BY SONIC VIBRATIONS

Filed Dec. 11, 1964

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FIG. 1

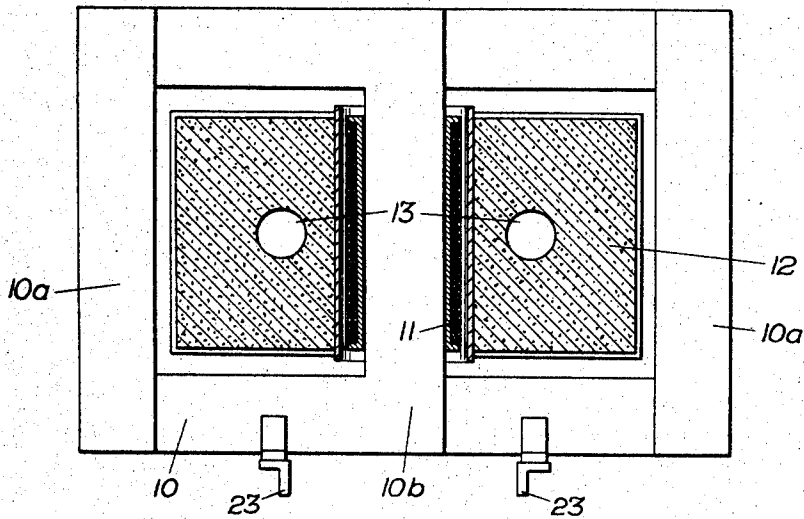
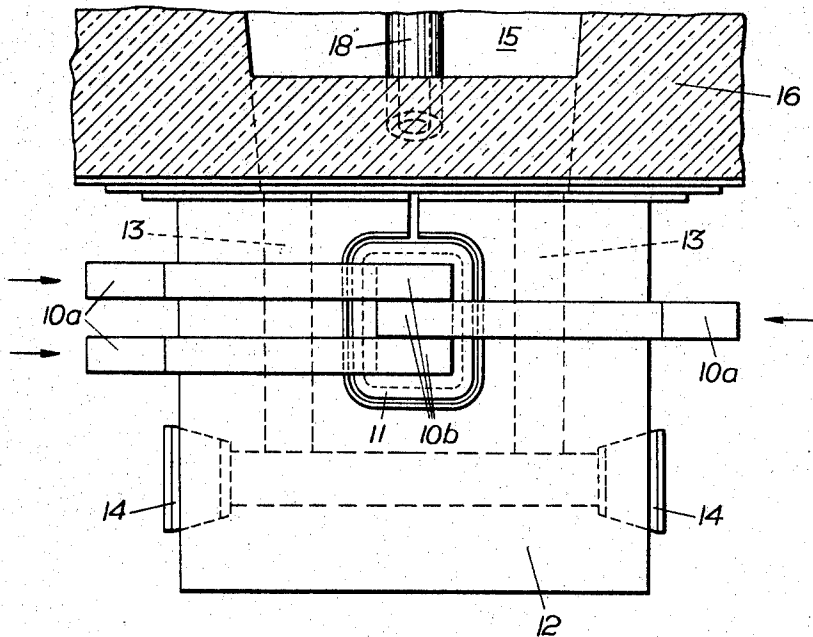


FIG. 2



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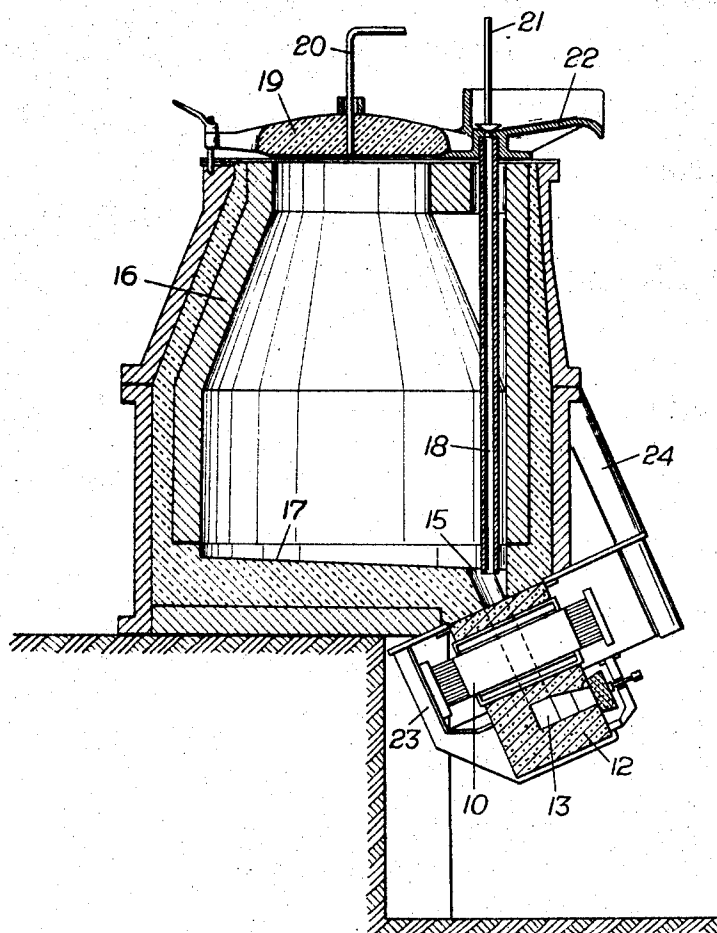
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FIG. 3



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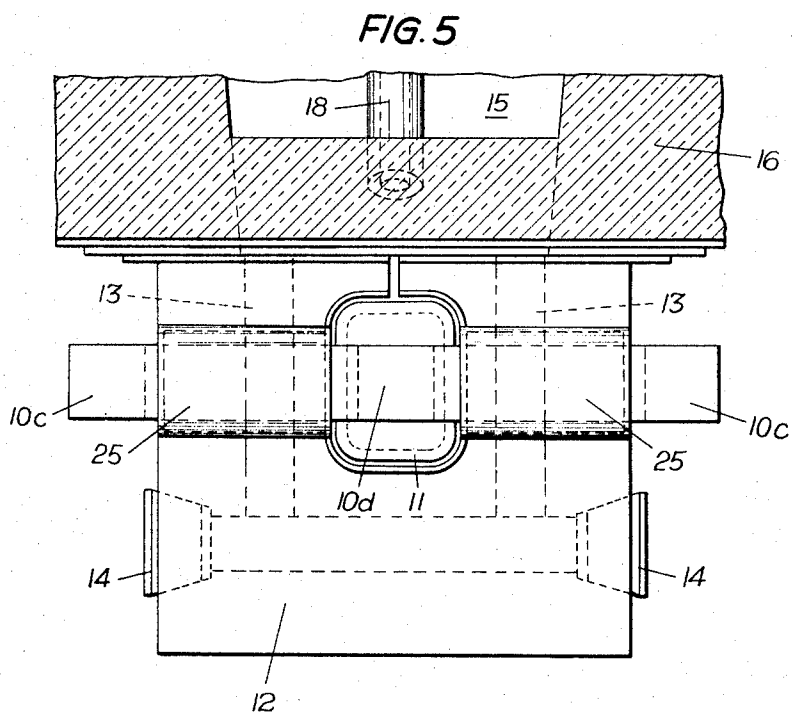
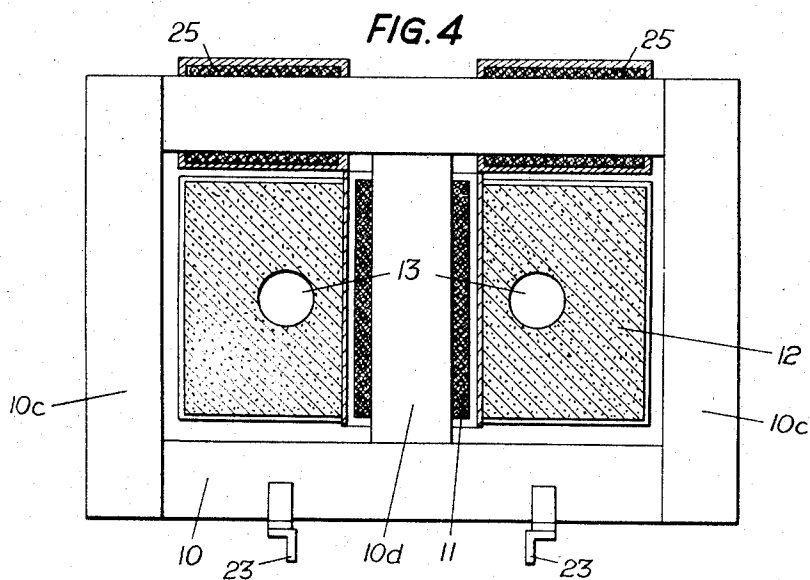
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FIG. 6

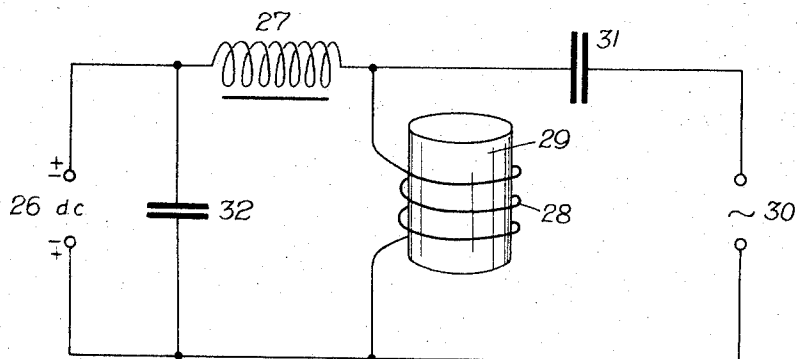
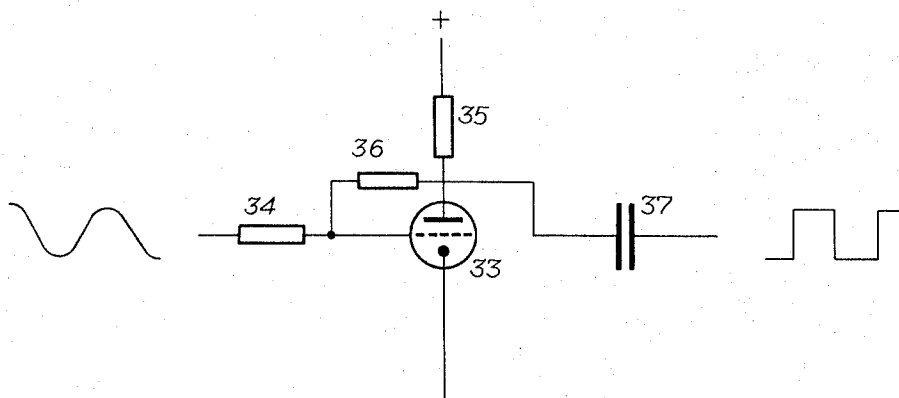


FIG. 7



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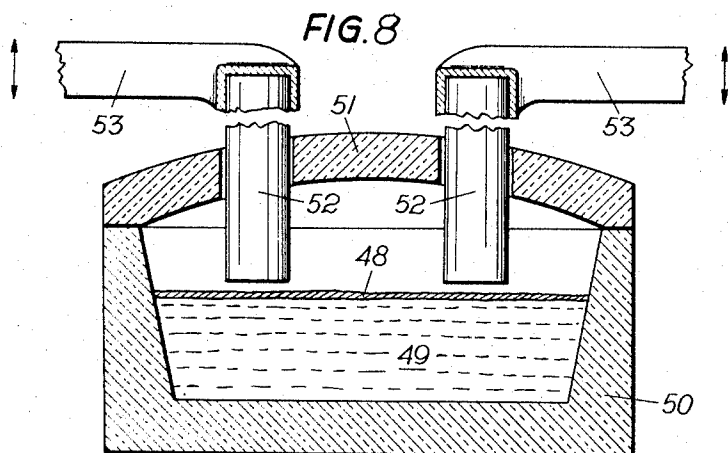
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3,434,823

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A 10,069/63

Int. Cl. C22d 7/00; H05b 5/00

U.S. Cl. 75—10

8 Claims

ABSTRACT OF THE DISCLOSURE

Method for degassing metallic melts by vibrations uses the ponderomotive effect provided by an alternating current. The current is supplied from a source at commercial frequencies, and the alternating currents are distorted to increase their harmonics. The distortion of the alternating current can be effected by abrupt limitations of amplitude to produce a pulse type current.

The method may comprise a supply transformer which can be loaded beyond the saturation range, as by providing special laminations or by magnetically preloading the transformer. Alternatively, the distortion of the alternating current can be effected electronically.

This invention relates to the degassing of metallic melts and, more particularly, to an improved and simplified method thereof utilizing alternating current at low frequencies, preferably with distortion of the wave form of the alternating current to increase the harmonic content thereof.

Due to the constantly increasing requirements with respect to the quality of cast products, with the concomitant increasing requirements with respect to the molten metal used for a casting, the gas content of metallic melts has become a very important problem in metallurgy. Many proposals have been suggested for reducing the gas content of metallic melts. At the present time, the following degassing procedures are used most commonly, particularly for light metals:

(1) Letting the melt stand at temperatures in the range of from 600° to 700° C.

(2) Introduction of chlorine into the melt.

(3) Introduction of nitrogen, either alone or in combination with chlorine.

(4) Treatment with agents capable of separating chlorine or fluorine.

However, all of these methods have one common disadvantage from the standpoint of the foundry operator, and this common disadvantage is that the treatment requires a considerable amount of time. The amount of time required has a very disadvantageous influence, on the one hand, on the over-all production or output and, on the other hand, on efficient and economic utilization of available furnace capacity. In addition, and in dependence upon the particular degassing procedure used, numerous aids and treatment agents are required and these likewise have a disadvantageous influence on the cost of the finished product.

The foregoing facts have resulted in further serious study of the degassing problem, to develop more desirable procedures from the economic standpoint. Thus, for example, the use of sonic and ultrasonic waves for degassing metallic metals has achieved a certain importance in the last few years. The main feature of the sonic or ultrasonic degassing method consists in that the sound energy is produced outside the melt and applied to the melt through an elastic body. Though the various transmission

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losses, such as reflections at the separating surfaces and absorptions in the transmission member, can be determined mathematically to a great extent, there has not yet been found any suitable material for a transmitter member dipping into the metallic melt. This latter factor is quite possibly the main reason why sonic or ultrasonic degassing procedures have not yet met with pronounced commercial or practical success.

Accordingly, attempts have been made to apply sonic and ultrasonic degassing procedures without using any solid body as a sound transmitter. In these procedures, sound waves are produced in the melt itself using forces which originate from apparatus arranged exterior to the melt. According to a fundamental law of electrodynamics, which finds its concrete expression in the well-known left hand rule, forces of the desired type appear when current carrying conductors are subjected to the action of a magnetic field. If the current, or the field, or both are periodic, the resultant movements will likewise be periodic and will manifest themselves as mechanical vibrations.

These conditions are satisfied particularly in the bath or melt of a so-called induction furnace, and the known bath movement in this type of furnace is based on the existence of electrodynamic forces. A thorough investigation shows that these forces can be represented, at any particular time, as the sum of two forces, one of which is constant and causes the above-mentioned bath movement, while the other of which is periodic and produces mechanical vibrations of double the frequency of the alternating current supplied to the furnace. In the usual design of induction furnaces, these mechanical vibrations have been almost completely disregarded, since the temporal mean value of the movement is zero and therefore does not contribute anything to the stirring movement proper. It is this stirring movement proper which so far has had the exclusive attention of experts in the art.

Investigations of metallic melts have shown that induction heating per se, as contrasted to resistance heating, already effects a partial degassification of the melt. It is thus possible to increase the intensity of the mechanical vibrations by sufficiently strong electrodynamic forces and to an extent such that the melt is rapidly and extensively liberated of gas. However, this objective cannot be achieved in a satisfactory manner merely by increasing the power in an induction furnace because, if the power is increased, the temperature of the bath is unduly increased. To separate slags from molten metal, it is already known to make use of a combination of forces, generated on the one hand by the current flowing through the melt and, on the other hand, by electromagnetic the melt and, on the other hand, by electro-current flowing through the melt. In order to create the additional magnetic field, solenoids or "magnetic shields" are used, which are arranged outside the housing in which the metal to be melted is located. It has also been attempted to cause the separation of metal and slags (impurities) by means of two electromagnetic fields which are arranged at certain directions relative to each other.

Further, it is known from U.S. Patents Nos. 2,415,974 and 2,381,523 to separate slags and impurities from the metal melt in "submerged resistor type induction furnaces," by arranging at least two melting channels in such a manner that the direction of flow of the liquid conductor (metal) is abruptly changed at the transfer from one melting channel into the other. The electromagnetic pressure gradient in one melting channel—the channel being easily accessible for cleaning (a vertical melting channel)—is, by suitable choice of the cross section of the channel and the electromagnetic field which is induced by an exteriorly located coil in the molten

metal, increased to such an extent that the less well conducting parts contained in the melt are forced against the wall of said channel and are held there.

From U.S. Patent No. 2,013,653 (W. Hoke) it is known to treat a conducting material for the purpose of eliminating non-conducting or less conducting impurities in such a manner that an electric current is conducted through the material in its liquid condition and that, simultaneously, electromagnetic forces are induced in the material, which are "unidirectional" or essentially "unidirectional" relative to such current. The forces with different effective directions, which are normally generated in the passage of current, are completely, or virtually completely, eliminated. It is thus necessary to create at least one additional magnetic field in order to achieve the required alignment of the forces. At least one additional current source is thus also required.

A research report by Professor Esmarch, dated 1940, contained, for example, in this connection the following information:

The desired objective can be achieved if the high frequency heating current in high frequency furnaces is kept within moderate limits, so that a certain favorable metal temperature is established, and if, at the same time, a possibly intensive stationary magnetic field is superposed on the high frequency field. The ponderomotive force produced by this additional field in the melt is proportional to the product of the current density of the high frequency current and the intensity of the static magnetic field; its temporal means value is zero. We can thus obtain intensive mechanical vibrations in the bath without at the same time increasing the force of the stirring movements.

There is still some difference of opinion about the role of the frequency in the various technical applications of ultrasonics; most authors seem to ascribe a specific effect to the frequency, and it has therefore sometimes been tried to find a frequency optimum. Tests made with the degassing of liquid and metallic melts indicate that it is very likely that, at least within the rather narrow interval generally used for technical applications, i.e. about between 500 and 15,000 c.p.s., the effectiveness of the vibrations depends mainly on the velocity amplitude, i.e. in the last analysis on the mean energy density of the sound radiation, so that the same effects can be achieved with low frequencies (500 c.p.s.) as with higher frequencies (app. 10,000 c.p.s.) if the radiation density is the same in both cases. The specific influence of the frequency is, if at all, only of secondary importance.

This report thus shows, inter alia, that it has been assumed up to the present that frequencies used for degassing melts by the ponderomotive effect had to be in excess of 500 cycles. Furnaces fed with these frequencies, which are the so-called "high frequency furnaces" are costly, however, and sensitive, as far as their maintenance is concerned. Besides, their output is limited, as a practical matter, this limit being below the individual furnace outputs most required.

In accordance with the present invention, the foregoing disadvantages are eliminated by providing for the use of low frequency AC sources, including commercial frequencies, such as 50 cycle AC mains. In the latter case, the necessity of a separate generator is eliminated, thus providing a very substantial advantage. As long as sufficiently large feed mains are provided, any desired output can be attained without an undue increase in cost for a separate source. The use of frequencies less than 50 cycles is, in any event, rarely desirable. In only a few cases will it be necessary to use frequencies over 50 cycles as supply frequencies, and even then these can be obtained from commercial frequencies by static frequency multiplication without having to use a separate generator.

Accordingly, an object of the present invention is to provide a method for degassing metallic melts by sonic vibrations produced in the melt by ponderomotive effects

caused by alternating currents flowing through the melt.

The invention is characterized by the fact that, in order to use a low frequency AC source, preferably a commercial frequency source, to produce the sound vibrations, the alternating currents are subjected to a distortion of their periodic course in order to increase their harmonics, thus enhancing the degasification.

Accordingly, another object of the invention is to provide a method for degassing a metallic melt by vibrations which are produced in the melt by ponderomotive effects caused by alternating currents in the melt and which are subjected to a distortion of their periodic course to increase their harmonic contents.

In the method of the invention as thus mentioned above, the presence of the deliberately produced harmonics increases the maximum velocity amplitude appearing the sonic vibrations, and thus increases the degassing effect as compared to the effect obtained using only the fundamental frequency, and while requiring only the same current input. It is this factor which permits the use of low input frequencies in the commercial frequency range.

A further object of the invention is to provide a method for degassing a metallic melt by sonic vibrations produced in the melts by ponderomotive effects caused by alternating currents flowing in the melts, and using, as the alternating current, the alternating current normally used to heat the melt, with the alternating current being temporarily or constantly distorted as mentioned above for degassing the melt.

In this latter case, the use of separate currents and fields for the degasification in the melt is unnecessary.

The distortion of the alternating current in the sense of the invention can be effected by abrupt limitation of its amplitude before it reaches a periodic maximum amplitude in at least one direction of flow, so that a pulse type current flow is produced. The thus limited or clipped alternating current half waves are induced in a known manner into the melt, for example, by at least one similarly limited or clipped alternating magnetic field. An increase of the ponderomotive effect can be obtained if the stationary magnetic field is superposed, in a known manner, on the melt. In cooperation with the alternating current flowing in the melt, this increases the ponderomotive effect.

Accordingly, yet another object of the invention is to provide a method for degassing metallic melts by sonic vibrations produced in the melts by ponderomotive effects caused by alternating currents in the melts and to increase the ponderomotive effects by superposing a stationary magnetic field on the alternating currents flowing in the melts.

In its simplest form, apparatus for performing the method of the invention comprises a supply transformer which can be loaded beyond the saturation range of the magnetic induction.

The same effect can be obtained, however, if the iron core of the transformer is magnetically preloaded, preferably by providing at least one DC winding thereon. Thereby, the primary current in at least one direction of flow effects a saturation of the magnetic induction in the iron core even before the specific values are obtained. The resulting stationary magnetic field is superposed in a known manner on the AC field, so that the ponderomotive effect in the melt is also increased by the inductive action of the two fields on the melt.

Transformers of this type are suitable for use as transformers for induction furnaces, where the secondary circuit is formed by the molten material flowing in a closed melting channel of the furnace. In particular, such a transformer can be used in a suitably dimensioned reheating furnace.

In further accordance with the invention, the distortion of the alternating current wave forms can be effected in another manner. In this other manner at least one recti-

fier, or a controllable electronic valve, can be connected in the supply circuit so as to transform the alternating current to the AC portion thereof. Furthermore, the electric current can be introduced in the melt by means of electrodes such as used in so-called resistance heated furnaces. Additionally, the frequency of the alternating current derived from a commercial frequency source can be increased up to seven times by using so-called static frequency converters.

For an understanding of the principles of the invention, reference is made to the following description of a typical embodiment thereof as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a transverse sectional view of a furnace transformer embodying the invention illustrating the iron core thereof in its initial state, with the ceramic body containing the furnace loop and the primary winding being sectioned along the center of the transformer core;

FIG. 2 is a top plan view of the transformer shown in FIG. 1, with a portion of the crucible shown in section;

FIG. 3 is a central vertical sectional view through a low pressure founding furnace embodying the invention, with a transformer, such as shown in FIGS. 1 and 2, illustrated in side elevation;

FIG. 4 is a front elevation view, partly in section, partly in section, of another embodiment of a melting furnace in accordance with the invention;

FIG. 5 is a partial top plan view of the melting furnace shown in FIG. 4;

FIG. 6 is a schematic wiring diagram, with a schematically illustrated furnace crucible, illustrating another arrangement embodying the invention;

FIG. 7 is a schematic wiring diagram illustrating the principle of an electronic circuit for distorting the alternating current wave forms; and

FIG. 8 is a transverse sectional view of a conventional arc-type resistance furnace to which the principles of the invention may be applied.

Referring to FIGS. 1 and 2, the transformer has a closed iron core 10 comprising three stacks of laminations mounted in juxtaposition. The center stack is displaced laterally with respect to the two outer stacks, so that its right leg 10a protrudes from the right hand side of the transformer core, whereas the left legs 10a of the two outer stacks protrude from the left hand side of the transformer core. The left leg of the center stack forms, with the right legs of the two outer stacks, the central leg 10b of the transformer core which is embraced by the primary winding 11. Transformer core 10 embraces a ceramic body 12 in which there is formed a heating channel 13 extending around center leg 10b. A part of channel 13, extending parallel to the plane of core 10, is closed by means of plugs 14 which can be removed for cleaning of the channel, as best seen in FIG. 2.

Referring to FIGS. 2 and 3, on the side opposite the plugs 14, channel 13 opens into a funnel-shaped mouth 15 formed in the storage crucible 16 of the low pressure founding furnace. Mouth 15 opens into the bottom surface 17 of storage crucible 16.

A filling tube 18 is positioned inside storage crucible 16 and extends along a wall thereof from the top of the crucible. The lower end of tube 18 projects into the mouth 15 of heating channel 13. The open top of crucible 16 is closed by a swivel cover 19 having a pressure gas pipe 20 extending therethrough. Filling tube 18, which is disposed laterally of the cover 19, is closed by means of a stopper 21 of the valve type, and communicates with a trough 22. The furnace transformer is suspended on supporting elements 23 and 24.

If the melt is to be degassed during operation of the

founding furnace, at least one of the legs 10a of transformer core 10 is removed. In this manner, if the normal magnetic field in the iron core 10 is 12,000 gauss, the field is increased to about 18,000 gauss so that the transformer is working in the saturation range. Thus, the wave form of the current in the melt forming the secondary conductor and in the heating channel 13 is distorted without any increase in current input. Naturally, in normal operation with a field of about 12,000 gauss, there is a certain degassing effect, since the energy density in the cross section of the heating conductor formed by the melting channel 13 is rather high.

When molten material is to be removed from the furnace, valve stopper 21 is lifted, after which the melt will rise in filling tube 18 under the effect of pressure gas fed to pipe 20 and will flow off through trough 22. As filling tube 18 projects into the mouth 15 of channel 13, in which latter the degassing occurs and is brought about relatively rapidly, it is possible to remove continuously quantities of degassed molten material without first having to degas the entire contents of storage crucible 16. It is thus possible to operate with relatively low energy inputs, such as those merely sufficient to keep the melt warm or molten and to degas the material that, at any given moment, is in channel 13. With a frequency of 50 cycles, the depth of penetration of the induction in iron is about 7.5 cm., and in aluminum about 3.5 cm. It will be appreciated that other embodiments of reheating and founding furnaces come within the scope of the invention as previously mentioned.

FIGS. 4 and 5 show a melting furnace in which, in accordance with the invention, the magnetic core of the transformer is provided with an initial DC bias or pre-charging. For this purpose, a pair of DC windings 25 are mounted on the core 10 as illustrated in FIGS. 4 and 5. Coils preferably are polarized in such a manner that the unidirectional magnetic fluxes resulting therefrom extend in opposite directions through the two halves of the magnetic core 10 of the transformer, especially through their outer legs 10c, this core including central legs 10d through which the DC magnetic fluxes extend in the same direction. The strength of the steady magnetic fields produced by windings 25 are determined in such a manner, through the selection of the value of the DC current flowing in windings 25, that the AC current in primary winding 11 causes, in one direction of flow, a saturation of the magnetic induction of the core 10 before the AC current attains its peak values. Thereby, the ponderometric effect in the melt is increased.

FIG. 6 is a schematic wiring diagram of another arrangement for superposing a stationary magnetic field on the transformer core. Referring to FIG. 6, DC current from a DC source 26 flows through a choke 27 to the induction coil 28 surrounding a melting crucible 29. This induction coil is also supplied with alternating current from an AC source 30 through a condenser 31. Choke 27, in combination with filter condenser 32, prevents flow of alternating current to the DC source 26. The degassing effect which the distorted alternating field has on the melt is substantially increased by the superposed DC magnetic field. Furthermore, the steady magnetic field may be disconnected at will, and could also be produced in a winding separate from the AC induction winding 28.

FIG. 7 illustrates the principle of current limitation using controllable electronic valves, and which current limitation can be used with advantage, in accordance with the invention, to increase the degassing effect. Referring to FIG. 7, the control electrode of an electronic valve 33 has a sinusoidal AC voltage applied thereto through a series resistance 34. Since the voltage applied to the control electrode through a working resistance 35, and through a resistance 36 connected in parallel with the anode and the control electrode, has a tendency to maintain a zero potential, a narrow strip is cutoff of the AC wave near the zero line. The amplified output voltage

corresponding to this strip, and which can be tapped from the working resistance 35 through the coupling condenser 37, has a substantially rectangular wave form and is very rich in harmonics, which enhance the degassing effect.

FIG. 8 is a schematic representation of a conventional resistance-type arc furnace. Its electrodes 52 have a current applied thereto, whose wave form is distorted to enhance the degassification. The melt 49, which is covered by a slag layer 48, is maintained in the lining or crucible 50 which is closed by means of the cover 51. Carbon electrodes 52 protrude through apertures in cover 51 and into the interior of the furnace up to about the slag layer 48, so that the arcs are formed between the lower ends of the electrodes 52 and the surface of the melt 49. The electrodes 52, which are suspended in holders 53, can be raised or lowered by means of these holders as required to maintain the arcs.

Although specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising supplying low frequency alternating currents to the melt from a source thereof at substantially commercial frequencies; and distorting the wave shape of the alternating currents to increase their harmonic contents to enhance the degassification.

2. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising heating the melts with alternating currents supplied from a source thereof at substantially commercial frequencies; and, during at least part of the heating operation, distorting the wave form of the alternating currents to increase their harmonic contents to enhance the degassification provided by said ponderomotive effects.

3. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising, traversing the melts with low frequency alternating currents from a source thereof at substantially commercial frequencies; and sharply clipping at least alternate half waves of the alternating currents to limit their peak value and to produce a series of current pulses increasing the harmonic contents of the half waves to enhance the degassification.

4. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising traversing the melt with a low frequency alternating current supplied from a source

thereof at substantially commercial frequencies; and increasing the effective harmonic contents of the alternating current to enhance the degassification of the melt.

5. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising traversing the melt with low frequency alternating currents from a source thereof at substantially commercial frequencies; sharply clipping at least alternate half waves of the alternating current to reduce the peak amplitudes of said alternate half waves to increase the harmonic contents thereof to enhance the degassification of the melt; utilizing a low frequency alternating magnetic field to induce the alternating currents to traverse the melt; and clipping at least alternate half waves of the alternating magnetic field to reduce the peak amplitudes of such alternate half waves of the magnetic field.

6. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising traversing the melt with low frequency alternating current from a source thereof at substantially commercial frequencies; distorting the wave form of the alternating currents to increase the harmonic contents to enhance the degassification of the melts; and augmenting the ponderomotive effect by superposing a substantially constant magnetic field in the melt.

7. In a method for degassing metallic melts by vibrations produced in the melts by ponderomotive effects produced by alternating currents traversing the melts, the improvement comprising providing a source of alternating current at substantially commercial frequencies; transforming alternating current from said source into a pulsating direct current; and traversing the melts with such pulsating direct current.

8. In a method for degassing metallic melts, the improvement as claimed in claim 7 further comprising combining a variable value constant direct current potential with the pulsating direct current; and regulating the variable value direct current potential to control the ratio between the variable value direct current potential and the pulsating direct current.

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U.S. Cl. X.R.

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