E. F. NORTHRUP.

LADLE HEATING BY HIGH FREQUENCY CURRENTS.

APPLICATION FILED NOV. 30, 1918.

1,378,188. Patented May 17, 1921.

2 SHEETS—SHEET 1.

Fig. 1.

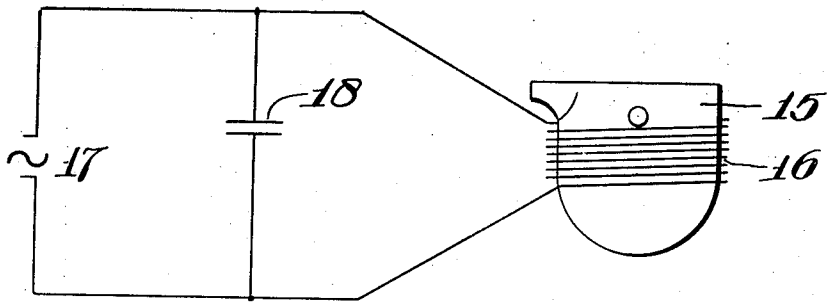


Fig. 2.

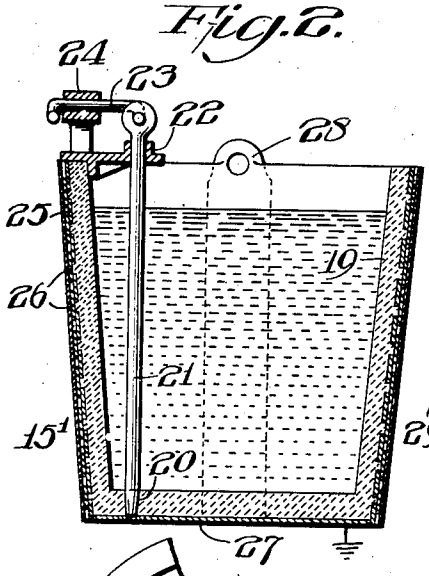
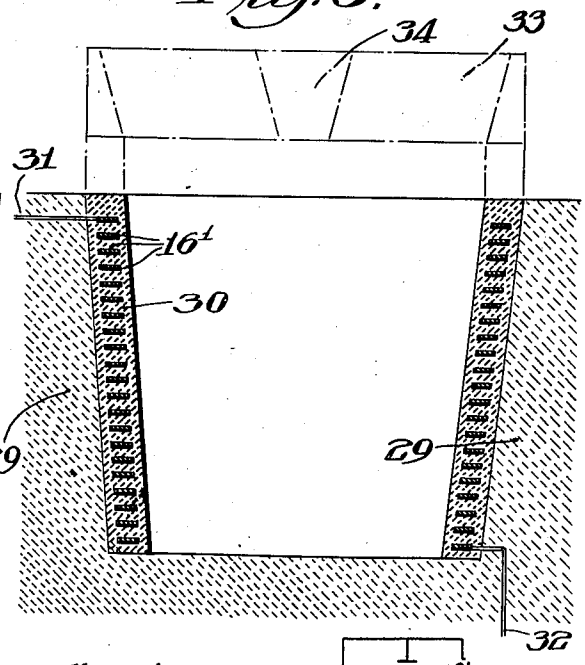


Fig. 3.



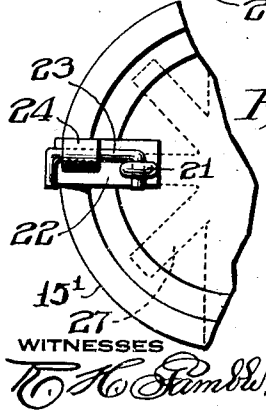
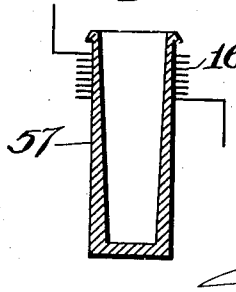


Fig. 4.

WITNESSES

T. H. Ramsdell.

Fig. 12.



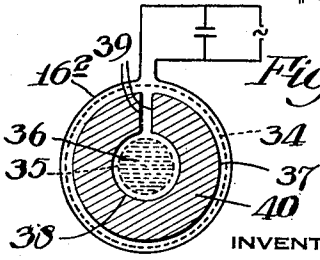


Fig. 5.

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2 SHEETS—SHEET 2.

Fig. 6.

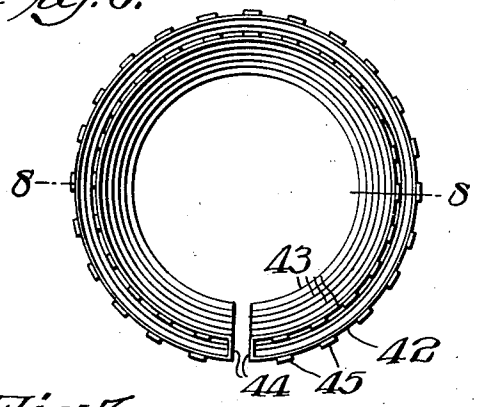


Fig. 9.

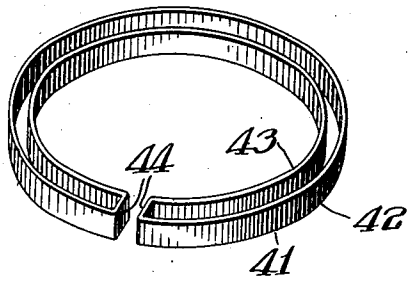


Fig. 7.

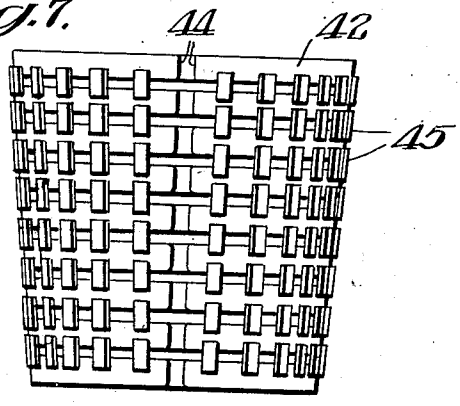


Fig. 10.

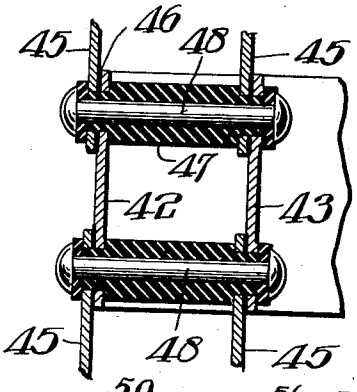


Fig. 8.

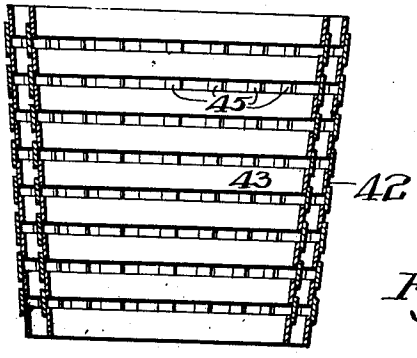
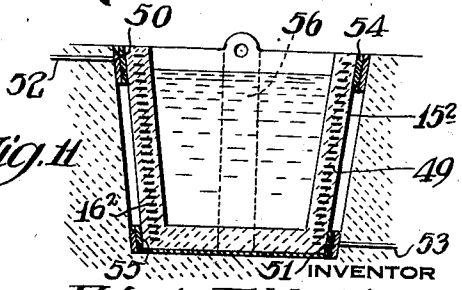


Fig. 11.



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UNITED STATES PATENT OFFICE.

EDWIN F. NORTHRUP, OF PRINCETON, NEW JERSEY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO AJAX ELECTROTHERMIC CORPORATION, OF TRENTON, NEW JERSEY, A CORPORATION OF NEW JERSEY.

LADLE-HEATING BY HIGH-FREQUENCY CURRENTS.

1,378,188. Specification of Letters Patent. Patented May 17, 1921.

Continuation of applicaton Serial No. 133,474, filed November 25, 1916. This application filed November 30, 1918. Serial No. 264,808.

To all whom it may concern:

Be it known that I, EDWIN F. NORTHRUP, a citizen of the United States, residing at 30 Wiggins street, Princeton, in the county of Mercer and State of New Jersey, have invented a certain new and useful Ladle-Heating by High-Frequency Currents, of which the following is a specification.

The purpose of my invention is to control the heat of molten metal in a ladle during settling of the metal; adding thereto, as may be desired, by the inductive effect of high frequency currents; which may be induced in the metal itself through the agency of inductor coils carried by the ladles themselves, located in "nests" within which the ladles are placed, or by a combination of these which permits the use of spacing inductor coils within the ladle walls.

A further purpose is to induce electric current in the metal within a mold to prevent piping.

A further purpose is to utilize the supporting metal of the ladle or mold, as part of an inductor coil, subject to the inductive influence of a surrounding coil through which high frequency current is passed.

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

I have preferred to illustrate my invention largely diagrammatically, and with a view to disclosing types rather than specific structure even where structure is shown, presenting a few forms only which have been selected primarily with a view to illustrating the principles of my invention.

Figure 1 is a diagrammatic view illustrating my invention.

Figs. 2 and 3 are central vertical sections of a ladle and nest therefor, illustrating one form of my invention.

Fig. 4 is a fragmentary top plan view of the form shown in Fig. 2.

Fig. 5 is a sectional view, largely diagrammatic, showing a second form of my invention.

Fig. 6 is a top plan view of a focus inductor which may be used in the form shown in Fig. 5.

Fig. 7 is a side elevation and Fig. 8 is a section upon line 8—8 of Fig. 6, showing the same form of the invention.

Fig. 9 is a perspective view showing one of the focus inductor coils utilized in Figs. 6, 7 and 8.

Fig. 10 is a partial enlarged sectional view showing a detail.

Fig. 11 is a mixed diagrammatic and vertical sectional view showing another form.

Fig. 12 is a diagrammatic sectional view showing my invention applied to a mold.

In the drawings, similar numerals illustrate like parts.

My invention induces high frequency alternating current within molten metal in ladles to maintain the temperature of the metal during the settling interval which has been found desirable, particularly in the casting of steel.

Previous attempts have been made to heat metal such as steel in molds, for example, to prevent piping, by passing alternating current about the molds. These attempts have been unsuccessful because, *inter alia*, of the low frequency and, consequently, the extremely low power factor of the alternating current supplied and because the molds used were themselves iron or steel (electrically conducting) and the induced current was set up in the molds rather than in the molten metal. The larger the cross section of the mold the less effective and efficient became the attempt to heat the metal or to maintain its heat by heating the mold.

My invention overcomes the first objection through the use of corrective means to improve the power factor. I avoid the second objection by breaking up electric circulation about the casing or shell of the mold or of the ladle or utilizing it to advantage in one form, so as to induce current directly in the molten metal.

In Fig. 1, I show a ladle at 15 surrounded by a coil 16 to which high frequency current is to be applied, as in Fig. 11 of my copending application for patent for oscillation current method and apparatus, Serial No. 133,474, filed November 25, 1916, of which, in this particular, this application is intended to be a continuation. The coil may be carried by the ladle, within a ladle nest or a combination of these as preferred. The source of high frequency current 17 and capacity 18 are intended to apply to any source and any type of power factor correction, by which unity power factor or a close

approximation thereto may be obtained. The tremendous rate of change of the high frequency current makes it highly efficient without necessity for interlinkage of transformer iron, whether the conducting secondary be steel or some non-magnetic conductor.

This construction thus shown diagrammatically, is excellent and fully operative with the (primary) high frequency coil about the ladle merely, except where an electrically-conducting ladle shell such as the ordinary ladle casing constitutes a secondary for the induced current.

Where the ladle itself does not have a metal casing, or where the electric circuits which would otherwise be presented by the casing are broken up by division of the metal, this system is entirely practicable and is applied in Figs. 2–4.

In Fig. 2 any shape or form of ladle 15′ is shown as having an electrically-insulating refractory lining 19, a pouring aperture 20 and a plug closure 21 therefor, guided at the top by a bracket 22 and lifted by any means such as a link 23 which is supported in an arm 24.

As these ladles hold tons of metal, as ordinarily used in steel furnace practice, the ladle is shown as having a metallic covering or casing 25, which, however, is split up into insulated bands, as seen. The bands are united by strips 26, insulated therefrom, or the casing is otherwise broken up into parts to prevent excessive waste of energy in Foucault currents.

The bottom of the ladle is shown at 27 as of star formation for the same purpose. It may be united with the rest of the metal casing through insulated connections, as desired, to provide a strong mechanical support for the ladle without excessively dissipating electric energy through current induced in the casing. The ladle is ordinarily lifted by a crane, whose hooks engage eyes in a yoke 28. The bottom member of the yoke may be the bottom of the ladle casing as shown. It is shown as grounded to avoid accident.

Whether the ladles of Fig. 2 have a metallic casing or reinforcement or not, therefore, I intend to provide for induction across from a coil into the molten metal content without presenting another path for the induced current.

In Fig. 3 is shown a nest of shape corresponding to the ladle and within which the ladle is adapted to be rested. The nest comprises a supporting body 29, a refractory lining 30 and an edge-wound spiral coil 16′ of truncated cone contour, connected within some such circuit as that of Fig. 1 by terminals 31 and 32.

At 33 I have dotted in an outline of a guide to position the ladle above the nest and insure registry therewith. The crane hooks are adapted to pass through slots 34.

In Fig. 5, I have shown diagrammatically, the use of my invention with a focus inductor coil located within the walls of the ladle, selecting the character of this diagrammatic illustration to bring out the relation between this figure and Fig. 22 of my application for focus inductor furnace, Serial No. 257,506, filed October 9, 1918, copending herewith.

In this figure, the outer coil 16^2 may be a spiral, as in Fig. 1. It surrounds the ladle whose outer and inner walls are shown dotted at 34 and 35, the molten metal being shown at 36. Within the walls is located a focus inductor coil of the same character as one of the forms shown in my application for patent, Serial No. 257,506, above noted, having an outer coil or loop 37, which may form the outer casing of the ladle, and an inner coil or loop 38 which may also be used to stiffen and support the material or walls of the ladle.

The two loops are connected by neck portions 39 and, as shown, are embedded in refractory material 40.

High frequency current passing through the coil 16^2 induces current in the reverse direction in the loop 37 and in the same direction, *i. e.*, reversely to that in 37, in the loop 38. So far as their effect upon the metal at 36 is concerned, the currents in the outer spiral 34 and in the loop 37 neutralize each other, leaving the equal current passing through the loop 38, to affect the metal and induce in it current in the opposite direction. This will circulate largely in the outer part or circumference of the metal, because of skin effect and also of the law of circulation stated in my said application, Serial No. 257,506, whereby the induced alternating current so divides and circulates as to make the coupling as close as possible.

In practical construction, it is very desirable to stratify the metal of inductor coils such as loops 37 and 38 into a number of strips or bands, even though they may be connected in multiple as in some of my forms in said application; so as to cut off the Foucault currents which would otherwise circulate in the masses of metal presented.

In Figs. 6–10, I have illustrated the focus inductor for one form of construction by which such an arrangement can be carried out, the strips or bands being shown as wider than would be the case in practice. This is selected from among the many by which the invention may be practised, and in size and shape is designed to lie within such a nest as is shown in Fig. 3.

The metal structure shown will be lined with refractory and partially, at least, embedded in it. I have brought loops 37 and

38 close together, in order to reduce the thickness of walls required. The refractory need not be a very good electrical insulator as the voltages here are low.

The individual coils 41 are preferably welded to make joints of good conductivity and lie quite close together but are insulated from each other.

The inductor coils 41 are made up of outer bands 42 and inner bands 43 connected by neck bands 44. In order to give mechanical strength, adjoining inductor coils 41 are united mechanically by strips 45, preferably joining the outer bands 42 of adjoining coils and permissibly joining the inner bands also.

The strips 45 are united to the bends through insulation 46 and the insulation may be used as shown in Fig. 10 to provide spacing means 47 to space or separate the bands 42 and 43. The bands or strips 45 are secured by rivets 48.

Though I prefer to fix the spiral coil by which the current is initially induced, within a nest or seat into which the ladle is to be placed or rested, it is evident that the coil may be carried by the ladle itself where the weight of metal to be handled and the thickness and character of heat-insulating material permits or where auxiliary ladle-stiffening strips may be used which are not circumferentially continuous.

With the intent to indicate that my invention is of utility under such circumstances also, I have shown in Fig. 11 a ladle carrying the spiral coil 49 and having surface contacts connected therewith adapted to make engagement with corresponding contacts within a nest in which the ladle may be placed. I have not considered it necessary to show this in any great detail, as the view is intended to be chiefly diagrammatic.

Here the nest is provided with contacts 50 and 51 with which is connected a source of high frequency 52, 53 corrected as to power factor, as in the other cases. The ladle 15^2 is provided with coöperating contacts 54 and 55, which are connected with the coil 16^2 within the refractory. The ladle is reinforced by vertically-extending bands 56, which are not intended to extend circumferentially.

In Fig. 12 I apply a high frequency coil 16 about the mold 57, corresponding in this particular to the showing and description of my copending application Serial No. 133,474. By the use of the high frequency I am able to lift the power factor substantially to unity, using some such means as that typified in Fig. 1, thus overcoming one serious objection to the induction means for preventing piping.

As in the case of alternating current coils of low frequency surrounding the mold, which has been proposed for the prevention of piping, if a full metallic mold be used, the electric current will be induced in the mold rather than in the contents owing to skin effect and the tendency previously referred to of an induced current to so flow as to increase the closeness of coupling. However, even in this case, it is advantageous because the heating of the mold at this point tends to reduce the radiation of the heat from the cooling metal keeping it molten a longer time and assisting in the prevention of the piping.

Where the mold is non-metallic, or where its contour is interrupted circumferentially by electrically-insulating refractory material, the induction takes place directly in the metal and the heat is applied in the molten metal itself. In this form it is most desirable.

My invention is applicable to ladles without regard to the character of molten contents which they carry, since the electric current will be induced therein whenever this content is electrically-conducting and without dependence upon the magnetic character of the material itself. The tremendous rate of change of the high frequency currents passed through the primary coil makes my invention free from dependence upon transformer iron and also free for the same reason from dependence upon the presence of iron or steel in the ladle, though well suited to operation upon these metals.

As will be noted, the question of whether the inducing coil be a primary-inducing coil within the refractory of the ladle itself, or a primary-inducing coil within a seat into which the ladle is rested, and in the latter case of whether the ladle shall contain a spacing inductor, such as is shown in Figs. 6–8 or not, is a matter to be determined by the designer according to the shape of the ladle intended, the amount of metal being handled by the ladle, the permissible thickness of ladle walls, the refractory intended to be used, the extent and character of handling which is required for the ladle, as affecting the necessary mechanical strength, the presence or absence of reinforcing metal within the ladle walls, the character of metallic reinforcement of the ladle where it is used, particularly the character of subdivision, and other conditions or circumstances present. In view of the information herein, supplying the combinations of elements and functions involved, the final design must be left to the judgment of the designer to suit the needs of the case at hand.

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

1. In casting mechanism, a pouring ladle carrying an induction coil and free from interlinkage of a transformer magnetic circuit therewith.

2. In casting mechanism, a pouring ladle in combination with a coil thereabout free from interlinkage of a transformer magnetic circuit therewith, and a source of high frequency current for said coil.

3. In casting mechanism, a pouring ladle and a high frequency induction heater movable with the ladle and adapted to set up currents of electricity within the content of the ladle.

4. In casting mechanism, a pouring ladle, a coil thereabout, a source of alternating electricity for said coil and corrective means for causing the power factor of said source to approach unity.

5. In casting mechanism, a ladle having an induction coil embedded in its walls, a source of alternating current therefor and a capacity across said source.

6. In casting mechanism, a ladle having refractory walls and an outer electrically-conducting shell broken up electrically so as to interrupt the flow of stray current.

7. In casting mechanism, a ladle having a refractory wall and an outer casing comprising bands which are not electrically continuous in circumferential direction.

8. A casting ladle having an electric winding within its walls and external contacts therefor upon the surface of the ladle adapted to receive electric current.

9. In casting mechanism, a nest having contacts therein adapted to supply a current of alternating electricity in combination with a ladle adapted to seat within the nest, an induction coil carried by the ladle and coil contacts carried by the ladle coöperating with the contacts of the nest.

10. A nest or seat for a ladle comprising walls having an induction coil thereabout adapted to act upon the container or its content and high frequency current supply for the coil.

11. A nest or seat for a container having an induction coil thereabout in combination with a ladle adapted to rest therein and free from continuous circumferential metallic walls.

12. In casting mechanism, a ladle having a focus inductor in the walls thereof.

13. In casting mechanism, a ladle having a focus inductor in the walls thereof and an inducing coil adapted to act upon the focus inductor.

14. In casting mechanism, a pair of circumferentially-interrupted metallic loops of different diameters, neck pieces joining the interrupted ends of the loop and a refractory lining forming a ladle and inclosing one of the loops.

15. In casting mechanism, a pair of circumferentially-interrupted metallic loops of different diameters, neck pieces joining the interrupted ends of the loops, a refractory lining forming a ladle and inclosing one of the loops and a high frequency primary acting upon the loops.

16. In casting mechanism, a ladle having refractory walls, a plurality of focus inductors within the walls, each comprising outer and inner loops connected by neck pieces and mechanical connections between the inductors electrically-insulated therefrom.

17. In casting mechanism, a ladle comprising a plurality of focus inductor strips, a refractory thereabout forming a ladle wall, a nest or seat within which the ladle is adapted to rest and an induction coil within the nest or seat.

18. In casting mechanism, a mold which is not electrically-conducting about its circumference, an induction heater about the upper part of the mold to retard cooling at this point and current supply therefor corrected to give substantially unity power factor.

19. In casting mechanism, a mold and an inductive heater about a part of the mold in combination with high frequency current supply for said heater.

20. The method of handling metal which is being cast which consists in transferring it from the furnace to an intermediate container, maintaining its heat therein by inducing current of electricity in the metal while it is settling and at the same time maintaining the power factor of the inducing current and then pouring the metal.

21. The method of handling metal being cast, which consists in transferring it from the furnace to an intermediate container, maintaining its heat therein by electric current generated inductively directly in the molten metal, and at the same time maintaining the power factor of the inducing current and subsequently pouring the metal.

22. The method of applying inductive current to metal in a ladle, which consists in providing a seat for the ladle, in supplying the seat with means for inducing electric current and in placing the ladle within the seat to receive the inductive effect from the means.

23. The method of applying inductive current close to the molten metal of a ladle, which consists in providing inductive means for transfer of electricity within a seat and utilizing coaxial current paths of different diameter within the outer and inner sides of the lining or wall of the ladle, to receive the induction and transmit it to the metal of the ladle.

24. The method of maintaining the heat of molten metal in a ladle which consists in applying electric energy to a current path near the outside of the ladle by induction, in conducting the energy to a current path nearer the metal therein and in applying the energy to the molten metal from the last current path by induction.

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