

Jan. 5, 1932.

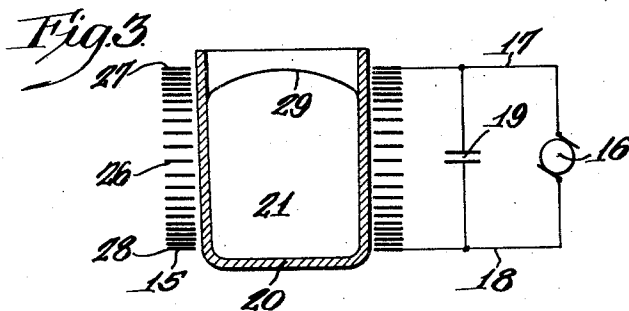
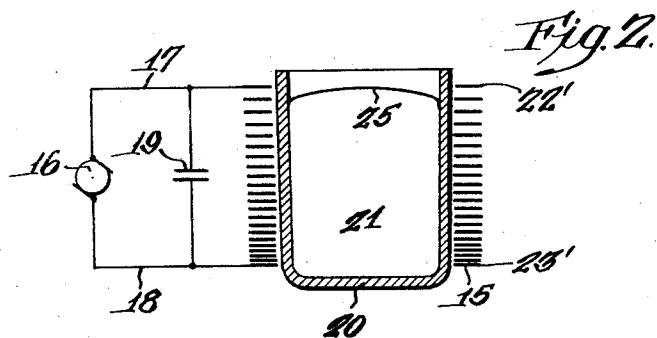
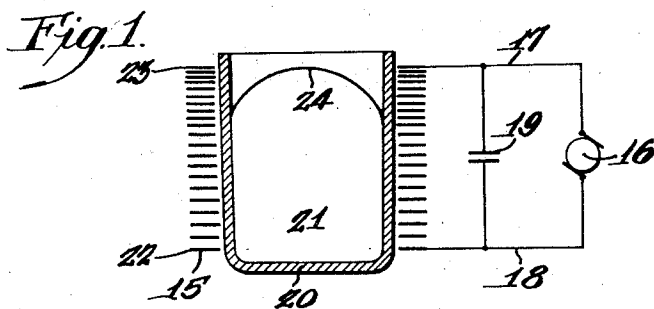
E. F. NORTHRUP

1,839,802

ELECTRIC INDUCTION FURNACE

Filed March 26, 1930

2 Sheets-Sheet 1



Witness:
H. L. Brown

Inventor:
Edwin F. Northrup
by *Wm. Steel Johnson*
Attorney

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Fig. 4.

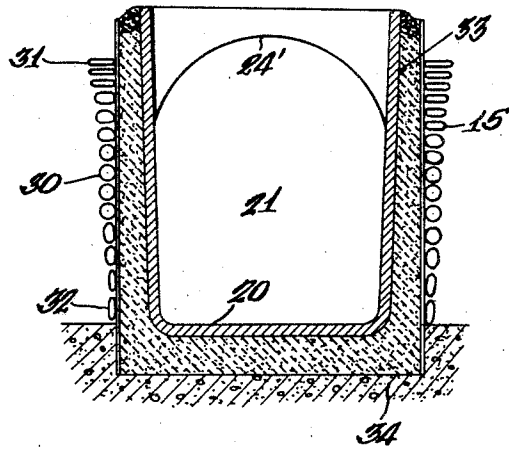
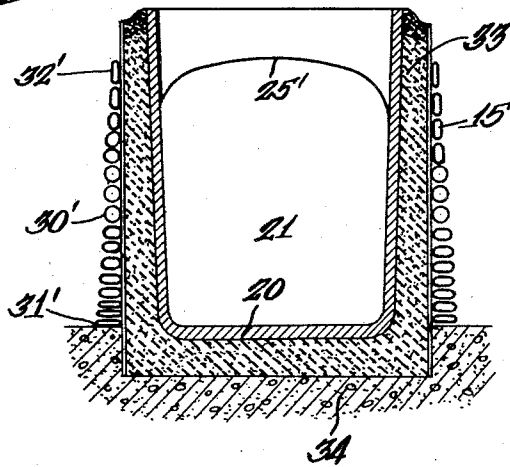


Fig. 5.



Witness:
Walter Grant

Inventor:
Edwin F. Northrup
by *W. Steel Jackson*
Attorney.

UNITED STATES PATENT OFFICE

EDWIN FITCH NORTHROP, OF PRINCETON, NEW JERSEY, ASSIGNOR TO AJAX ELECTROTHERMIC CORPORATION, OF AJAX PARK, NEW JERSEY, A CORPORATION OF NEW JERSEY

ELECTRIC INDUCTION FURNACE

Application filed March 26, 1930. Serial No. 438,967.

My invention relates to methods and apparatus for the control of stirring in a coreless induction furnace.

A purpose of my invention is to concentrate the number of ampere turns per unit axial dimension applied to one portion of the charge with respect to that applied to another portion of the charge, and so regulate the stirring in the charge.

10 A further purpose is to grade the inductor coil of an induction furnace, and to utilize the graded coil to control the stirring of the charge.

15 A further purpose is to concentrate the number of inductor coil turns at either or both extremities of the coil and to selectively control the stirring in the charge by the use of an inductor coil so graded as desired.

A further purpose is to space from center to center certain turns of a continuous conductor forming an inductor coil relatively closely with respect to the spacing of other turns of the same inductor.

20 A further purpose is to form an inductor coil of hollow water-cooled tubing, and to flatten the tubing parallel to the coil axis where the turns are to be spaced close together, transversely to the axis where the turns are to be spaced far apart, and to leave the tubing round or partially flattened as desired with progressive or abrupt transitions between these two extremes.

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

I intend the present application to include the use of a graded inductor coil to regulate or to predetermine the stirring in an induction furnace. I have filed separate applications, copending herewith, to protect other phases of the use of a graded inductor coil as shown herein, and more particularly the use of the coil to improve the efficiency of operating the furnace.

45 By a graded coil I mean a coil in which the number of turns per unit of axial dimension is increased at one point along the coil with respect to that at another point. The point of high concentration is arbitrarily referred to by me as the point toward which the coil is graded.

Ordinarily in inductor coils according to my invention the number of turns per unit axial dimension between any two arbitrarily chosen points will progressively change from that in the neighborhood of one point to that in the neighborhood of the other point.

It has previously been proposed to control the stirring in a coreless induction furnace by physically elevating or lowering the inductor coil. This I consider undesirable at times because of the mechanism required. It has 55 further been suggested that the inductor coil be provided with taps, and the power current be connected selectively to any two of the taps at a chosen height on the furnace in order to regulate the stirring. This structure is limited in utility because the idle portions of the inductor coil will be heated by the flux from the live portions of the coil, thus wasting energy and cooling capacity. Furthermore, tapping the coil is expensive and sometimes not otherwise wholly satisfactory.

Stirring in the coreless induction furnace is due to the combined action upon the charge of motor effect of the inducing current upon the charge carrying the induced current and pinch effect of the secondary current filaments upon each other. In both cases, the stirring produced is proportional to the square of the number of ampere turns per unit axial dimension in the inductor coil. I have 60 discovered that by concentrating a high number of ampere turns per unit axial dimension at one point along the inductor coil, and using a lower number of ampere turns per unit axial dimension in other parts of the coil, I may produce very pronounced effects upon the stirring in the furnace.

85 Stated in another way, I find that changes in the effective center of gravity of the inductor coil with respect to the center of gravity of the charge tend to affect the stirring in the charge in a very pronounced manner.

For the purpose of clear illustration of my invention I have chosen to show a few forms only in the drawings.

Figures 1, 2 and 3 are diagrammatic sections of my furnace provided with various types of inductor coil.

Figures 4 and 5 are axial sections showing slightly different forms of my invention suited for water-cooling.

Like numerals refer to like parts throughout.

Referring to Figures 1 to 3, the same furnace and circuit connections appear throughout. I show an inductor coil 15 supplied with current from a conventional source 16 through lines 17 and 18. The power factor may be very desirably corrected, as for example by the condenser shown at 19.

The crucible 20 holds a charge 21 which in the illustrations is assumed to be molten.

In Figure 1 the inductor coil is graded (i. e., has its turns closer together from the center of one to the center of the next) from the point 22 of low concentration at the bottom of the coil to the point 23 of high concentration at the top of the coil.

The spacing of the turns intermediate between these points of low and high concentrations varies progressively from the maximum spacing in my most desirable form.

While progressive grading is desirable, it is not necessary, and advantage might be obtained from my invention by passing abruptly from a point of low turn concentration to a point of high concentration, or by changing the intermediate spacing according to any desired law, arithmetical or geometrical.

Since in Figure 1 the number of ampere turns per unit axial dimension is high at the top and low at the bottom of the inductor coil, the point of maximum flux density in the charge will be relatively high with respect to the position which it would assume in an ungraded coil of the same size and character. As a result, the stirring in the furnace will be vigorous, and considerable arching of the top of the charge will be apparent, as shown from the elevation of the meniscus 24.

With a condition of high stirring of this type, very thorough mixing will take place in the top of the charge, and this portion of the charge will be readily exposed to the action of the atmosphere or to slagging reactions, depending upon contact of the slag with the charge. Thus, for example, carbon could be very advantageously burned off during stirring of this sort.

As seen in Figure 2, the turns are concentrated at the point 23' at or near the bottom of the coil, while the turns are relatively far apart at the point 22' at or near the top. Intermediate turns are graded from one extremity to the other.

In Figure 2 the effect of the coil will be to lower the point of maximum flux density in the charge with respect to such a point in the same character of coil ungraded. This will operate to reduce the stirring at the top of the furnace, as seen by the shape of the meniscus 25. The furnace of Figure 2 would then be desirable to heat a charge which should

be protected from the atmosphere or in which top stirring would be injurious, as for example a charge containing a high carbon content, where a high carbon content is desired in the final product.

In Figure 3 the coil is graded in both directions from an intermediate point 26 of low concentration to extremities 27 and 28 of high concentration. In this form there will be two points of high flux density, one relatively high and one relatively low in the charge. The effect upon the charge is to produce a condition intermediate between those seen in Figures 1 and 2, as shown by the shape of the meniscus 29. Moderate stirring will take place throughout the charge.

In Figures 4 and 5 the faces of the inductor coil turns are at all places relatively close together, but the turns are of variant widths, so that at points where high concentration of ampere turns is desired the turns will be wound very closely together, and where a low concentration is wished for it may also be obtained.

In Figures 4 and 5 the inductor coil is desirably formed of hollow water-cooled tubing, initially round as seen in 30, and flattened in a direction parallel to the axis as at 31 and transverse to the axis as at 32. The intermediate turns between 30 and 31 and between 30 and 32 are somewhat less flattened in the respective directions. Thus at 32 the ampere turns per unit axial dimension are very low and at 31 very high.

In general the stirring in Figure 4 will be vigorous as in Figure 1, as shown by the meniscus 24'.

The furnaces of Figures 4 and 5 are provided with heat insulation at 33, and are mounted on bases at 34.

The furnace of Figure 5 has its inductor coil graded in the opposite direction from that of Figure 4, so that the point of maximum ampere turn concentration will be at the bottom at 31', the point of minimum ampere turn concentration at the top at 32' and the intermediate point 30' will lie between.

Thus the point of maximum flux density at the axis will be relatively low in the coil and there will be little stirring according to the principles explained in connection with Figure 2. The meniscus 25' will be relatively flat.

It will be obvious that I may grade my inductor coil from the middle toward both extremities as shown in Figure 3, but nevertheless use hollow tubing as shown in Figures 4 and 5. According to the principles discussed this would produce a stirring effect intermediate between those of Figure 4 and Figure 5. This is shown in my copending applications.

Doubtless the ingenuity of the designer will suggest many other ways in which inductor coils may be wound to provide variant numbers of turns per unit axial length at various

portions of the coil. In view of my disclosure of the principles involved the point of maximum ampere turn concentration and of minimum ampere turn concentration could be variously arranged along the coil length, without using the forms shown by me in my drawings.

cooled tubing edgewound about a portion of the charge at one end of the coil and progressively wound and flat wound toward and at the other end of the coil.

EDWIN FITCH NORTHRUP. 70

- I believe that the use of variant ampere turn concentrations along different points of the same inductor coil which is carrying the same current throughout is broadly new, and I desire to be protected in the use of any structure embodying the same to control the stirring in the charge.
- 15 Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:
1. The method of increasing the normal stirring in an electric induction furnace, which consists in passing an electric current about the charge and increasing the number of ampere turns per unit axial dimension progressively from one end of the section stirred to the other. 75
 2. The method of increasing the normal stirring in an electric induction furnace, which consists in passing an electric current about the charge and progressively increasing the number of ampere turns per unit axial dimension about the charge from a minimum about the bottom of the charge to a maximum about the top of the charge. 80
 3. The method of decreasing the normal stirring in an electric induction furnace, which consists in passing an electric current about the charge and progressively decreasing the number of ampere turns per unit axial dimension about the charge from a maximum about the bottom of the charge to a minimum about the top of the charge. 85
 4. In an electric induction furnace, a source of current, an inductor coil supplied with current from the source, surrounding the charge and having its turns relatively close together at one end of the coil as compared with the spacing of the turns at the other end of the coil. 90
 5. In an electric induction furnace, a source of current, and an inductor coil supplied with current from the source, surrounding the charge and having the distance between its turns progressively increasing from a minimum about the bottom of the charge to a maximum about the top of the charge. 95
 6. In an electric induction furnace, a source of current, and an inductor coil supplied with current from the source, surrounding the charge and having the spacing of its turns progressively decreased from a maximum about the bottom of the charge to a minimum about the top of the charge. 100
 7. In an electric induction furnace, a source of current, and an inductor coil supplied with current from the source, surrounding the charge and consisting of hollow water 105