

Nov. 13, 1934.

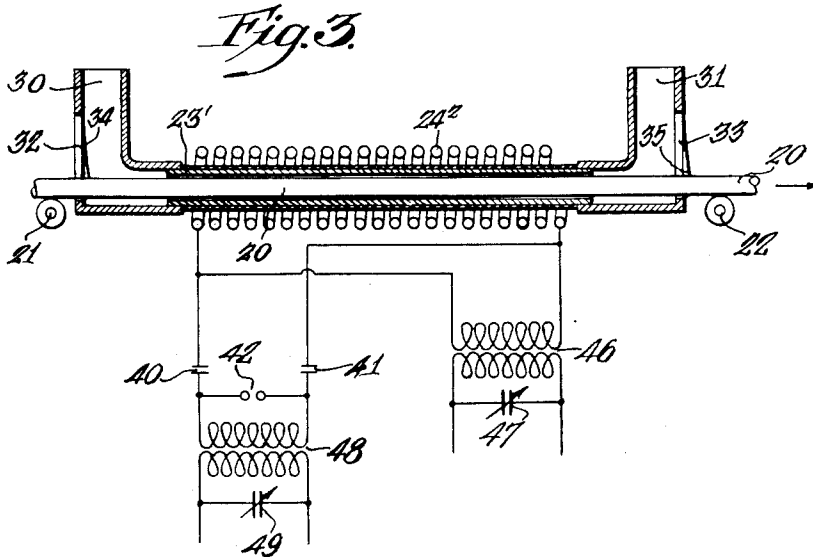
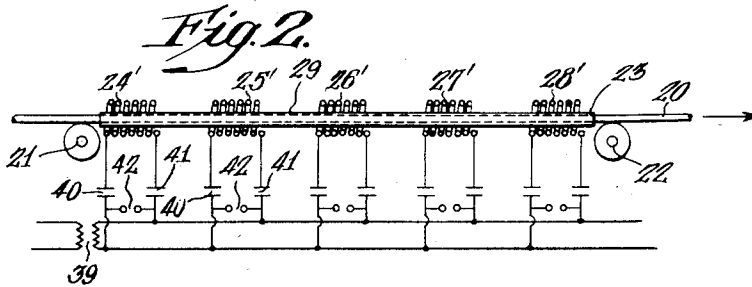
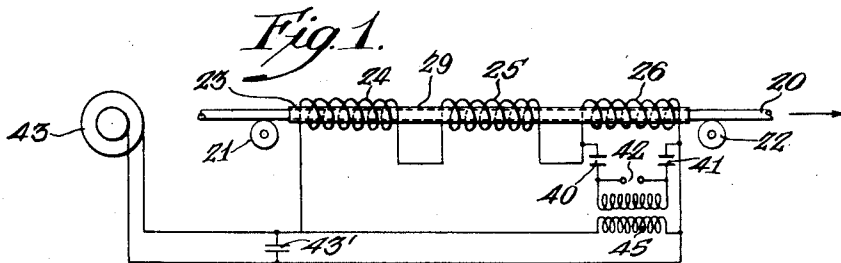
E. F. NORTHRUP

1,980,875

ELECTRIC INDUCTION FURNACE

Filed Jan. 1, 1930

3 Sheets-Sheet 1



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Nov. 13, 1934.

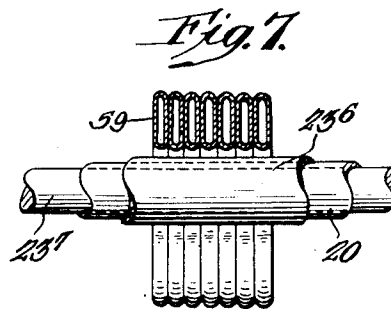
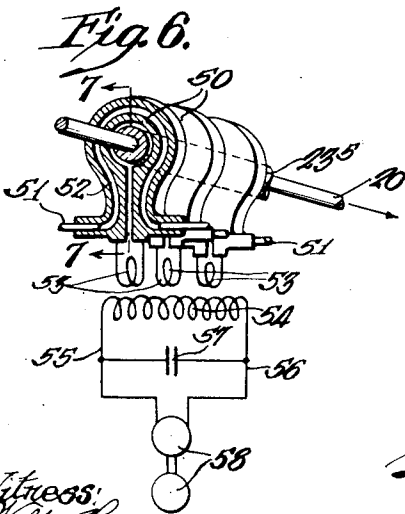
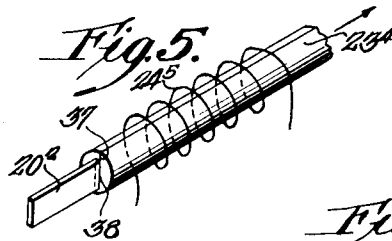
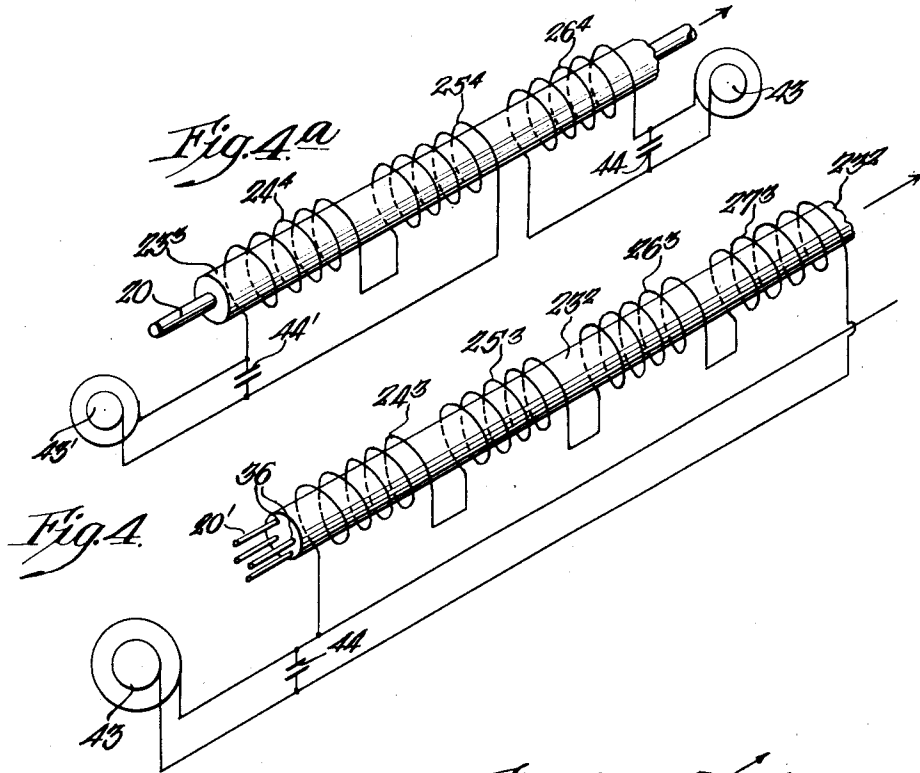
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ELECTRIC INDUCTION FURNACE

Filed Jan. 1, 1930

3 Sheets-Sheet 2



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1,980,875

ELECTRIC INDUCTION FURNACE

Filed Jan. 1, 1930

3 Sheets-Sheet 3

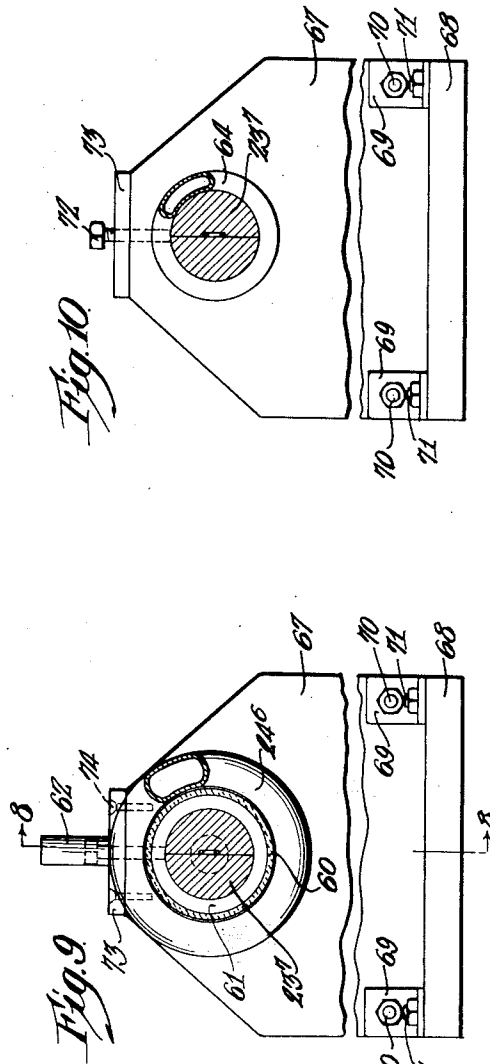
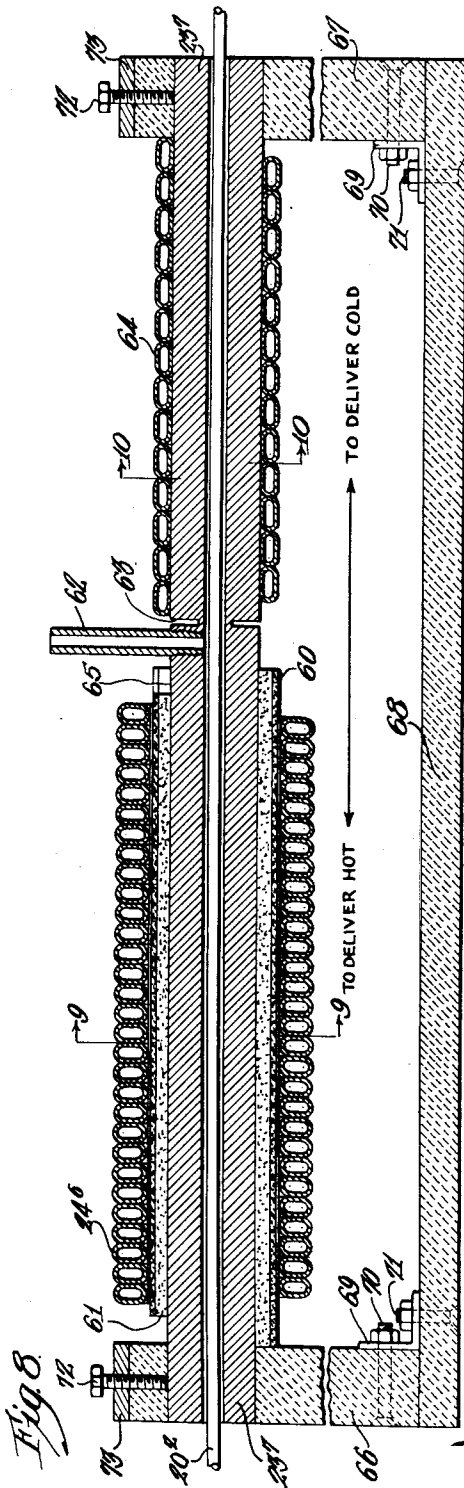
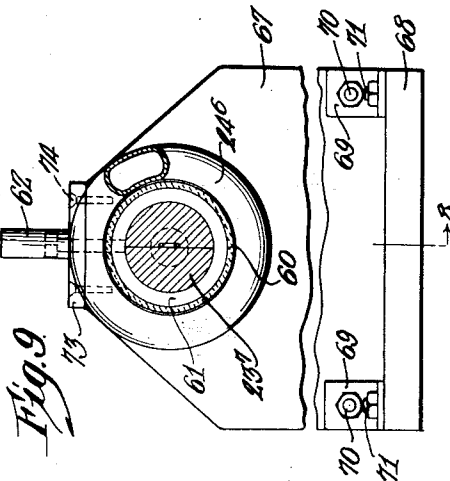


Fig. 10



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UNITED STATES PATENT OFFICE

1,980,875

ELECTRIC INDUCTION FURNACE

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New Jersey

Application January 1, 1930, Serial No. 417,835

32 Claims. (Cl. 219—13)

My invention relates to the inductive heating of muffles for the indirect heating of rods, tubes or the like passing through the muffles, and relates both to methods employed and the apparatus adapted to carry out the methods. The application contains subject matter divisional from my copending application Serial No. 76,878 for Heater for rods and tubes, filed Dec. 21, 1925.

One of the purposes of my invention is to feed solid or tubular articles through a muffle of electrically conducting material which is inductively heated by a conductor carrying high frequency current, and to heat the articles in part by current induced in them if they are conducting, but chiefly indirectly from the muffle as they pass through progressively or step-by-step.

A purpose of my invention is to heat a metal muffle with high frequency or low frequency current, either or both, according to circumstance.

A further purpose is to surround a hollow metal muffle with high frequency current in order to heat the muffle.

A further purpose is to heat a muffle with high frequency current having a corrected power factor, and to feed travelling stock through the muffle.

A further purpose is to provide a muffle of magnetic material adapted to be heated to lower temperatures by relatively low frequency and to high temperatures by relatively high frequency.

A further purpose is to inductively heat a normally magnetic muffle surrounding travelling stock with low frequency current where the muffle is below the point of decalescence and with high frequency current where the muffle is above the point of decalescence.

A further purpose is to apply water cooling to a coil surrounding a muffle used to heat travelling stock indirectly.

A further purpose is to progress travelling stock through an inductively heated muffle in an atmosphere of inert or treating gas.

A further purpose is to inductively heat a muffle protected from oxidation by inert gases.

A further purpose is to inductively muffle-heat and previously or subsequently muffle-cool travelling stock.

A further purpose is to progress metallic stock through an inductively heated muffle and heat treat the stock by carrying it through a cooled muffle portion.

A further purpose is to muffle-cool inductively muffle-heated travelling stock or to air cool the stock, either one, at the option of the operator.

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

I have preferred to illustrate a few forms only among many in which my invention may appear, selecting forms which best illustrate the principles of my invention.

Figures 1 to 6 are diagrammatic views of structures embodying somewhat different forms of my invention.

Figure 7 is a view corresponding to a section taken upon the line 7—7 of Figure 6 but showing a somewhat different form from that of Figure 6.

Figure 8 is a section along the line 8—8 of Figure 9, showing a muffle well adapted to heating stock of small cross section, such as watch springs.

Figure 9 is a section along the line 9—9 of Figure 8.

Figure 10 is a section along the line 10—10 of Figure 8.

Like numerals refer to like parts in all figures.

Describing in illustration and not in limitation and referring to the drawings:—

Although I prefer to operate at a higher frequency than that of existing current supplies and gain considerable advantage from this, features of my invention are of advantage whatever the frequency and are claimed accordingly.

In the figures I have shown different ways in which current of more than normal frequency can be supplied to an inductor comprising a single coil or spaced coils operating upon a muffle about a moving bar, rod, strip or tube of regular or irregular shape to raise the rod or other stock to the required temperature, as for the purpose of rivet heating, tube or strip annealing or for other operations.

By these different illustrations I have intended to indicate that if and where normal frequency alone is utilized the application of this current in the combination stated involved invention and that the use of abnormal frequency to this duty involves invention in addition to whatever merit may lie in the manner of applying it.

As seen in Figure 1, the travelling stock moves in the direction of the arrow over any suitable guiding means, here the rollers 21 and 22, and through the muffle 23 of electrically conducting material. One of the rollers 21 and 22 may be desirably driven by power, not shown.

The muffle is heated by induction from the primary coils 24, 25 and 26, through which current is passed at the proper frequency, later to be described.

In Figure 2 I show the same general structure of muffle and rollers, but the inductor is divided into

several portions, 24', 25', 26', 27' and 28'. The spaces 29 between the portions of the inductor may be used to admit supporting structure, not shown.

5 I have shown a method of integrating the heating effects of successive coils through which high frequency current is passed in the heating of the muffle through which a rod, tube or other stock is advanced progressively or intermittently as
10 preferred.

I have not considered it necessary to illustrate the protecting covers for preventing undue cooling of the muffle between the coils, as these could exist in great variety. The coils could be water-cooled if desired as in the case of the annular
15 coils shown in my patents.

The muffle of Figure 3 is constructed somewhat differently. The stock 20 passes over the rollers as in the other forms, through the muffle
20 23' and within the inductor 24².

The inductor coil in Figure 3 is intended to represent any single turn coil, or multiple turn coil or combination thereof, interrupted if desired for supporting mechanical or other structure.
25

I illustrate the muffle ends as being provided with inlet and outlet members 30 and 31 to adapt the muffle to receive a flow of reducing or non-reactive gas such as illuminating or flue gas in
30 order to prevent deterioration of the muffle interior by oxidation, or to protect or treat the stock.

The openings into the muffle at 32 and 33 respectively to receive and deliver the stock may desirably be closed by a curtain of asbestos or other material at 34 and 35 adapted to deflect
35 out of the way of the travelling stock but to substantially close the inlet and outlet openings by engagement with the outside of the stock.

Where the size of the stock is too small for convenient inductive heating, requiring relatively an excessive frequency, or because of the desirability of heating a number of wires or small rods at the same time or for any other reason, I provide a muffle 23² (Figure 4) which may be used
45 in many different forms but of which I have shown but one. The muffle is provided with a plurality of holes 36 through which the rods or wires 20' to be heated are passed.

The wires can be passed through the muffle continuously or step-by-step, or can be inserted until heated and then withdrawn therefrom.
50

The muffle 23³ in Figure 4a is substantially similar to that of Figures 1 and 2.

In Figure 5 I show the coil as surrounding a muffle 23⁴ which has been longitudinally split at
55 37 so that it can be grooved to provide a passage 38 through the muffle for the stock 20². The passage in cross section is much longer than it is wide, suiting it to the reception of band-saw
60 blade material or other like strips to be heated as for heat treating, for example annealing or tempering, purposes.

Obviously as many passages may be used as desired with the preference, however, that they shall not cut through to the surface, since it is desirable to have the magnetic induction in the muffle wall pass circumferentially about the outlines of the passage. The strip can be heated
65 entirely by heat conduction and radiation from the muffle or it can be placed where part of the induction passes through it.

Heat insulation is provided between the muffle and the coil.

Of course I may obtain the high frequency
75 current for the inductor from any suitable source,

and I intend the various electrical connections shown to be merely illustrative.

In Figure 2 the coils are shown as separate and as separately supplied with high frequency current through one or more transformers 39
80 whose primary or primaries receive current at existing frequencies.

The secondary or secondaries are connected to the inductor coils through condensers 40 and 41 which when charged discharge across gaps 42.
85 The inductor can be one long coil or a series of coils depending upon the rate of speed of the charge.

Such a mechanism as described is suitable, for example for indirectly heating a stock bar, rod, strip or wire from which nails or spikes are to be made.
90

Eddy currents will be present both in the tubular muffle and in the stock passing through the muffle, and the stock bar, rod, strip or wire may be delivered continuously or intermittently to the cutting mechanism of the nail or spike machine or the like at any temperature desired, as required for the heading mechanism. In addition, if either the stock or muffle be magnetic,
95 hysteresis will occur.

It will be evident that the methods and mechanism herewith are capable of use generally or to heat treat electrically conducting objects in motion or which are moved step-by-step between treatments, whether they be magnetizable or not; that the treatment may be applied to the special form of objects to be treated by accommodation of the coils in shape to these forms and that the materials primarily to be treated
100 when not electrically conducting may be treated by mounting them on or incasing them within electrically conducting objects in which the heat is developed.

Whereas in Figure 2 the supply of current to the primary of the transformer may have any frequency such as normal 60 cycle line frequency, in the structure shown in most of the other diagrammatic figures direct connection with a generator is contemplated for some at least of the inductor coils, and the frequency chosen will depend largely upon the temperature to which the charge is to be heated, the desirability of using direct line current or current from a special generator, and the cost of power factor correction.
105

If a magnetic muffle be used, where the temperature intended to be reached is below the point at which iron or steel loses its magnetic properties, a much lower frequency will suffice than is required where the final temperature intended is above this point, with the result that a choice is offered for these higher temperatures between raising the frequency of the entire equipment to a frequency which will be effective above the decalescent point or raising the temperature in a part of the range required by an inductor operating at one frequency and utilizing another higher frequency through the same or a separate inductor coil or coils to attain the higher temperatures.
115

It is very desirable that the frequency shall be high enough so that the energy induced shall not pass appreciably beyond the center of a stock bar, tube or rod passing through the muffle, and, as later pointed out, the size of stock operated upon therefore materially affects the choice of frequency.
120

However, alternators of the standard rotary multi-polar type are now available giving fre-
125

quencies of well over 500 cycles, which brings direct supply from the alternators within the range of frequency most desirable for present purposes, and frequency changers free from movable parts have made it possible to double or quadruple the frequencies without excessive cost and at a low loss in efficiency.

It is my intention to include within my generator supply such generators and such use of frequency changers as may best suit the needs of the individual installation.

In Figure 4 I show a generator 43 directly supplying an inductor seen in sections 24³, 25³, 26³ and 27³ surrounding a longitudinally perforated conducting muffle 23². The positive inductance of the coil is balanced by the capacity 44 capable as in the other illustrations of any required adjustment.

The stock is fed through the muffle continuously or intermittently as best suits the purpose for which it is heated and the needs of a particular installation.

The muffle if of magnetic material can readily be raised to approximately the temperature of decalescence by relatively low frequency current and, whatever the metal, can be raised to a much higher temperature by high frequency current by means and methods already explained.

Instead of the direct generator shown in Figures 1 and 4 continuous oscillations can be produced by making use of vacuum electron tubes, complying with the conditions for obtaining oscillations, in that the inductive reactance (condensers) and positive reactance (inductance coils) are combined in the same circuit. I have not considered it necessary to illustrate this mode of securing current.

In Figure 1 I have shown direct alternator feed with power factor correction for all of the inductor coil sections 24, 25 and 26 shown, in conjunction with transformer and discharge gap connections corresponding generally with those of Figure 2 for applying high frequency to the last section, 26 of the coil.

In this case, the high frequency is superimposed upon the lower frequency in the same coil. The coil sections may be operated separately. The primary 45 feeds a high frequency circuit corresponding with any of the high frequency circuits shown in Figure 2.

In this form the muffle, and the stock passing through the muffle, if either or both be magnetic, whether solid or tubular, regular or irregular, can be raised to the decalescence temperature in the first coils and lifted in the last coil to any required temperature above the decalescence temperature.

Figure 4a shows separate coils for carrying the high and low frequencies and separate current sources. Low frequency current from the generator 43', with its power factor corrected by the condenser 44', is passed through the coils 24⁴ and 25⁴, while high frequency from a circuit similar to that of Figure 4 is passed through the coil 26⁴. Where a magnetic muffle is used, the coil 26⁴ will preferably be placed at a point along the muffle at which the heating raises the muffle material above its point of decalescence.

In Figure 3, both high and low frequencies pass through the same inductor coil. Low frequency is obtained from a transformer 46 whose primary is shunted by a variable condenser 47 to correct the power factor. The high frequency circuit is generally similar to any of those shown in Figure 2, consisting of a transformer 48, hav-

ing a variable condenser 49 across the primary for power factor correction, a gap 42 and condensers 40 and 41.

In all of the forms where a plurality of turns per coil is used, I prefer to employ a single layer coil of edgewound flattened copper tubing and find water cooling of the tubing very desirable.

In Figure 6 I have shown a plurality of inductor loops 50 in parallel, each capable of being water cooled through pipe connections 51 and conduits 52 and each having a considerable extension along the length of the charge. These loops are shown as fed from separate secondaries 53 of a transformer having the same primary 54 supplied from any line 55, 56 across which the capacity 57 is thrown in condenser form. The muffle 23⁵ and stock 20 are inside the inductor. In order to provide for high frequency, which will ordinarily be desirable, I show the line as fed from the motor generator 58.

In Figure 7 inductor loops from a given secondary 53 are shown in parallel. They may correspond to a single loop in Figure 6, for example, and comprise edgewound flattened copper tubes 59 which require no insulation between them because the tubes are parts of the same turn or loop, differing in this from the edgewound coils such as are shown in Figure 6. Not only electric current but the water flows in parallel through these turns.

The muffle 23⁶ surrounds the hollow stock 20, and the stock passes about an internal core 23⁷, in which inductive heating takes place in addition to that occurring in the muffle.

The edgewise winding of the flattened copper tubing gives a very much larger surface of contact of copper with the cooling water than in the form shown in Figure 6, and reduces eddy currents.

In operation upon stock of the character treated herein, whether it be solid or hollow, of uniform or of irregular cross-section and whether a core for hollow stock within the muffle be used or not, the coupling increases with increased diameter of the stock, as the gap required is approximately constant.

The frequency most appropriate reduces with increase of the diameter or with increased thickness of the stock since it is desirable not to have effective induction extend beyond the center of the stock. This would apply also to the center of the core or center of the muffle. The formula for determining this frequency is

$$N = \frac{25 \times 10^{-6} \rho}{\mu l_p^2} \quad 130$$

where N is the frequency ρ the resistivity of the material, μ the permeability and l_p^2 is the "depth of penetration", approximating one-third of the distance to which the induction extends.

The higher frequencies have the advantage of requiring less capacity to correct the power factor, but have the disadvantage of requiring special generators or other equipment to supply the current. With magnetic materials low frequencies can be used even on relatively small diameters of stock; but when the stock is non-magnetic, unless it be large in diameter, high frequencies must be used if too deep penetration of induction into the stock is to be avoided.

An outside muffle can be used with hollow stock as in Figure 7 to permit use of a lower frequency to heat the muffle and stock without penetration beyond the interior of the stock than could be

used to heat the stock alone. This permits the same frequency to be used for different stocks with choice of suitable muffles or cores to control the depth of current induction or to utilize the induction to the best advantage.

My invention is independent of the number of turns per coil and of the detail of the coil and can be applied with loops as distinguished from turns, with loops in series or in parallel, with coils, single, in series or in parallel and with a great variety of current sources.

I prefer to water cool the coils, and, where the inductor coil comprises more than one turn, I prefer to use conductors having one dimension considerably greater than the other in cross-section and with the greater dimension radial to the axis of the coil, whether the coil be water cooled or not.

My invention is applicable to magnetic or non-magnetic materials, whether solid or otherwise, and to heating of hollow or solid materials directly by the RI^2 and hysteresis heat development in the materials themselves, wholly or in part, or by heat conduction and radiation from a casing or core or muffle within which RI^2 and hysteresis heat are developed.

In the form of Figures 8, 9 and 10 I employ a muffle 23', preferably of "ascology", a non-magnetic iron alloy containing 8 per cent of nickel and 18 per cent of chromium, and generally classed as a stainless steel. This material satisfactorily stands exposure to air at high temperatures.

The stock 20² may be desirably of clock or watch spring material, which will be heated by the muffle as the muffle in turn is heated by current induced from the inductor coil 24⁶, connected to any suitable current source. The inductor is formed of hollow flattened edgewound tubing through which water may be circulated. Within the inductor is shown a silica tube 60 and heat insulation 61 to protect the inductor and increase the muffle heat efficiency.

A nipple 62 has been inserted into the muffle for use in supplying an atmosphere of inert or treating gas to the muffle interior. The gas may be used to protect the stock from oxidation, to preserve the muffle interior, or to treat the stock during heating.

It is often desirable to cool the stock considerably before delivering it to the atmosphere. I therefore provide the muffle with an annular cut 63 which prevents excessive heat conduction through the muffle body toward the point where cooling occurs by means of the water carrying coil 64 about the muffle. The coil 64 is preferably flattened and flat wound about the muffle to expose a maximum surface for muffle cooling.

The structure of Figures 8, 9 and 10 permits of great flexibility in operation, since the stock may be delivered to the atmosphere at low temperature if fed from left to right, or at high temperature if progressed from right to left in Figure 8.

The muffle temperature may be controlled by observation of the muffle through the sight opening 65, and corresponding adjustment of the current supply.

The muffle support consists preferably of ends 66 and 67, mounted upon a base 68, of suitable material, such as asbestos board. The base and ends are united by brackets 69 and bolts and nuts 70 and 71. The muffle is held in place by set screws 72 in saddles 73, and the saddles are positioned by bolts 74. It will be understood that

the structure is merely illustrative, and in no way intended to limit my invention.

In the form shown in Figure 3 the muffle if of magnetic material may be of material having a relatively high decalescent point, for example pure soft iron, while the stock passing through the muffle may be of material having a considerably lower decalescent point, the stock for example comprising steel of fairly high carbon. With this arrangement the muffle will remain magnetic above the decalescent point of the stock, permitting the stock to be heated above its decalescent point by radiation from the walls of the still magnetic muffle.

It will be understood that the high frequency supply is better adapted to heat the muffle to higher temperatures than is the low frequency supply and that where the stock is to be heated to temperatures too high to be attained from a heating of the muffle to the decalescent point, the high frequency heating should be used.

In operation the material to be heated may be progressed through or about the muffle,—in that case a core—step-by-step or continuously or, much less desirably, may be inserted therein and withdrawn. Considering the continuous operation, by odds the most advantageous form, the object or material to be heated is fed through at a rate such that with the energy available and at the frequency determined upon, it will reach the required temperature at the point of use as it emerges from the final coil or turn.

Where the material is non-magnetic and unless assisted by the inclusion of magnetic material in the form of a muffle or core the heating will be performed wholly at a higher frequency than that of available line sources of supply.

In order to make clear that my invention relates to heating without melting, rather than heating for the purpose of melting, I refer in the claims to "heat treating", by which I intend to mean that the stock passed through the muffle is heated to some temperature below its melting point.

In view of my disclosure herein other forms and uses of my invention will undoubtedly occur to those skilled in the art differing from mine in adaptation to special uses, suiting the preference or whim of the individual designer or for the purpose merely of avoiding copying of my forms and it is my purpose to include herein all such as come within the reasonable spirit and scope of what I regard as a very broad invention.

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

1. The method of heat-treating travelling solid stock, which consists in surrounding solid stock of substantial length and uniform cross section by electrically conducting solid material, in progressing solid stock through the surrounding material while keeping it in contact with the material and in electromagnetically heating the surrounding conducting material while the stock is passing through it.

2. The method of heat-treating travelling solid stock, which consists in surrounding solid stock of substantial length and uniform cross section by electrically conducting solid material, in progressing solid stock through the surrounding material and in electromagnetically heating the surrounding material and heat-treating the stock directly by induction and conductively heat-treating the stock from the surrounding material while the stock is being passed through it.

3. The method of heat-treating travelling solid stock, which consists in surrounding solid stock of substantial length and uniform cross section by electrically conducting solid material, in progressing solid stock through the surrounding material and in electromagnetically inducing current within both the surrounding material and the stock directly while the stock is passing through the material.
4. The method of heat treating electrically conducting-solid travelling stock of small or irregular cross section and substantial length which consists in surrounding the electrically conducting solid traveling stock of small or irregular cross section and substantial length by an electrical conductor to yield a larger or regular cross section and heat treating the travelling stock and heating the surrounding conductor electromagnetically by the passage of high frequency alternating current about them.
5. The method of heat treating electrically conducting solid travelling stock of small or of irregular cross section and substantial length by the passage of electrical current about the stock which consists in increasing the cross section of electrically conducting material surrounded by the current so as to secure better secondary induction, in applying high frequency current about the electrically conducting solid travelling stock of small or irregular cross section and substantial length and added material and in maintaining good thermal transfer conditions between stock and the added material.
6. The method of improving inductive heat treating of solid travelling stock of small or irregular cross section and substantial length which consists in increasing the cross section by the addition of electrically conductive material in thermal contact with the electrically conducting solid travelling stock of small or irregular cross section and substantial length and in passing high frequency current about the combined stock and added material.
7. The method of making more effective high frequency inductive heat treating of travelling stock of small or irregular cross section and substantial length which consists in increasing the cross section in thermal contact with the electrically conducting solid travelling stock of small or irregular cross section and substantial length by the addition of highly magnetic material.
8. The method of increasing the effectiveness of high frequency inductive heat treating of electrically conducting solid travelling stock having small or irregular cross section and substantial length which consists in concurrently inducing high frequency current within the electrically conducting solid travelling stock of small or irregular cross section and substantial length and within thermally conductive material physically in contact with it.
9. The method of heating travelling stock electromagnetically, which consists in providing fixed magnetic material in thermally conductive relation to the stock, in electromagnetically raising the temperature of the fixed material and the stock to approximately the decalescence point of the fixed material by relatively low frequency current, and in raising the temperature of the fixed material and stock to the desired higher temperature below the melting point by higher frequency induction.
10. In inductive heat treating of travelling stock, an inductor coil, a muffle of electrically conducting material therein, having a passageway through it adapted to pass a charge to be heat treated, means for progressing a solid charge through the muffle, and a source of high frequency current for the coil.
11. In inductive heat treating, an inductor coil, a muffle of electrically conducting material therein forming a secondary for the coil and having a passageway through it adapted to pass a solid charge to be heat treated, the walls of the passageway being in contact with the solid charge to give conductive heat transfer from the muffle to the charge, means for introducing a solid charge into the muffle and a source of current for said coil.
12. In the inductive heating of articles to be heat-treated, an inductor coil, a guide for passage of the articles to be heat-treated comprising a muffle and having a plurality of passages of substantially uniform cross section for solid articles of substantially uniform cross section, the walls of which passages cooperate with the articles to form common paths of induced current flow and a source of high frequency current for the coil.
13. In inductive heat-treating, an inductor coil, a muffle of electrically conducting material therein having a passageway through it adapted to pass a charge to be heat-treated, means for supporting a solid charge of substantial length within the muffle and for guiding the charge through the muffle, a connection to the muffle adapted to receive an atmosphere of inert gas to be maintained in the muffle, and a source of high frequency current for the coil, the muffle forming a secondary for the coil.
14. In inductive heat-treating, an inductor coil, an electrically conducting muffle therein forming a secondary for the coil and having a passageway through it, means for supporting within the muffle a solid charge of substantial length and uniform cross section to be heat-treated and for guiding the charge through the muffle, a connection to the muffle adapted to receive an atmosphere of treating gas to be maintained in the muffle, and a source of high frequency current for the coil.
15. In inductive heating, an inductor coil consisting of a plurality of conducting yokes provided with water-carrying passages, inlet and outlet water connections to and from the passages, a muffle of electrically conducting material inside the coil having a passageway through it adapted to pass a charge to be heat treated, and a source of current for the coil.
16. In inductive heat treating, an inductor coil in which each turn consists of a plurality of flattened edgewound coiled water-carrying tubes in parallel, inlet and outlet water connections to and from such tubes, a muffle of electrically conducting material within the coil having a passageway through it adapted to pass a charge to be heat treated, and a source of current for the coil.
17. In inductive muffle heat treating of travelling stock, an inductor coil, a source of current for the coil, an electrically conducting muffle of magnetic material surrounded by the coil over part of its length and adapted to pass the stock to be heat treated, and means for cooling the muffle beyond the inductor coil in the direction of stock travel.
18. In muffle heat treating of travelling stock, an inductor coil, a source of current for the coil, a muffle of electrically conducting magnetic material adapted to pass the stock and within the inductor coil over part of its length, connection to the muffle for admitting a special atmosphere

to the muffle, and cooling means for cooling the stock before leaving the special atmosphere.

19. A muffle of iron alloyed with chromium and nickel, an inductor coil surrounding the muffle and a high frequency source of current therefor with condenser compensation for the power factor.

20. In inductive heat-treating, the combination of an inductor coil, an apertured core of magnetic material within the coil means for supporting a solid charge of substantial length and uniform cross section within the muffle and for guiding the charge to be heat-treated through the muffle, a source of high frequency current for said coil.

21. In inductive heat-treating, an inductor coil, a muffle of magnetic material therein having a passageway through it of non-circular section adapted to pass a metallic charge to be heat-treated of non-circular section, means for progressing a metallic charge of substantial length through the muffle, a source of current for said coil and power factor correction for said source of current.

22. In inductive heat-treating, the combination of an inductor coil, a muffle of magnetic material fixed within the coil and provided with guides within the muffle for solid material to be heat-treated, means for guiding solid material of substantial length through the muffle and a source of high frequency current for said coil.

23. In inductive heat-treating, an inductor coil and a guide for passage through the coil of articles to be heat-treated, the guide comprising magnetic material and being adapted to receive the current induced by the current within the coil, means for progressing a solid charge of substantial length through the coil and a source of high frequency current supply for said coil.

24. In inductive heat-treating, an inductor coil, a hollow muffle of magnetic material open at both ends and fixed within the coil, means for guiding solid material of substantial length to be heat-treated through the hollow of the muffle and a source of high frequency current for said coil.

25. In inductive heat-treating, an inductor coil, a muffle of magnetic material therein forming the secondary for the coil, means for guiding a solid charge of substantial length to be heat-treated through the muffle, while the charge is maintained in heat conductive contact with the secondary and a source of current for said coil.

26. In inductive heat-treating, an inductor coil, a muffle of magnetic material therein having a passageway through it adapted to pass a charge

to be heat-treated, a source of low frequency current for the coil and a source of high frequency superimposed on the low frequency in the coil.

27. In inductive heat-treating, an inductor coil, a muffle of magnetic material therein having a passageway through it adapted to pass a charge to be heat-treated, a source of low frequency current for the coil and a source of high frequency superimposed on the low frequency in the coil where the muffle is to be heated above the point of decalescence.

28. In inductive heat-treating, an inductor coil, a muffle of magnetic material therein having a passageway through it adapted to pass a charge to be heat-treated, a source of low frequency current for the coil, a second inductor coil coaxial with the first and about the muffle and charge, and a source of high frequency current for the second coil.

29. In an electric induction furnace, an inductor coil, a muffle of iron alloyed with chromium and nickel within the inductor coil, having an interior passageway for a charge and a source of alternating current for the inductor coil.

30. In an electric induction furnace, an inductor coil, a muffle of iron, alloyed with about 18% of chromium and about 8% of nickel, within the inductor coil, having an interior passageway for a charge and a source of alternating current for the inductor coil.

31. In an electric induction furnace, an inductor coil, a muffle of electrically conducting material within the inductor coil having an interior passageway for a charge of electrically conducting material and a source of alternating current connected to the inductor coil, the inductor coil, muffle and passageway being so proportioned that the charge is heat treated by induced current developed directly in it and also by induced current developed in the muffle wall and then passed to the charge as heat.

32. In an electric induction furnace, an inductor coil, a muffle of electrically conducting material within the inductor coil having an interior passageway for a charge of electrically conducting material, the passageway walls being in physical contact with the charge, and a source of alternating current connected to the inductor coil, the inductor coil, muffle and passageway being so proportioned that the charge is heat treated by induced current developed directly in it and also by induced current developed in the muffle and then conducted as heat to the charge.

EDWIN F. NORTHRUP.

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