Jan. 17, 1939. T. R. KENNEDY 2,144,377

INDUCTION HEATER

Filed Sept. 11, 1937

Fig. 1

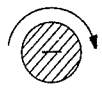


Fig. 2

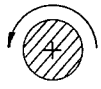


Fig. 3

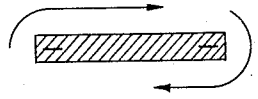


Fig. 4

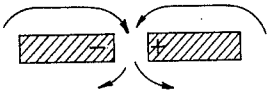


Fig. 5

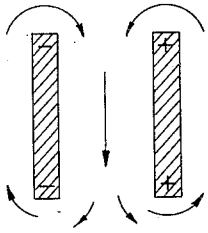


Fig. 6

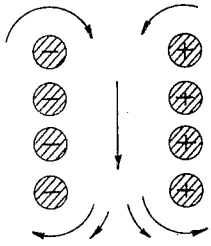


Fig. 7

Fig. 8

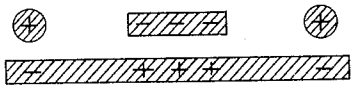


Fig. 9

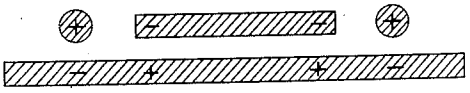


Fig. 10

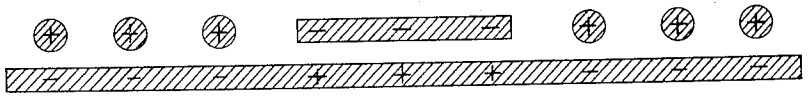


Fig. 11

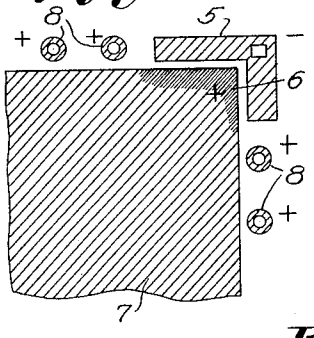


Fig. 12

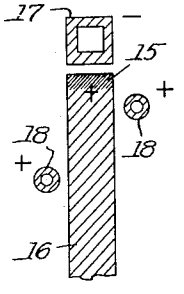


Fig. 13

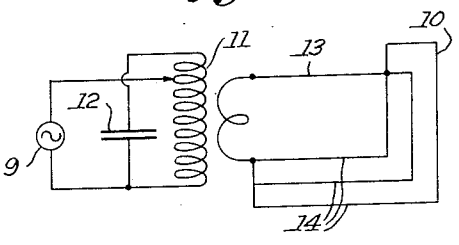
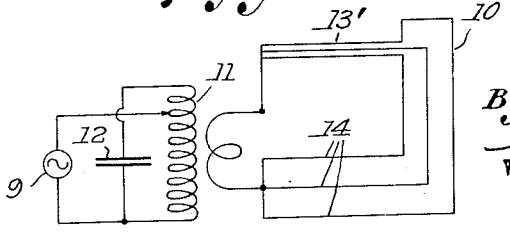


Fig. 14



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By Frank T. Chesnut

Attorney.

Patented Jan. 17, 1939 2,144,377

UNITED STATES PATENT OFFICE

2,144,377

INDUCTION HEATER

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Application September 11, 1937, Serial No. 163,340

5 Claims. (Cl. 219—11)

My invention has to do with inductive electric heating and relates to methods and apparatus for local or differential heating.

A purpose of my invention is to provide a single inductor with a multiple return path.

A further purpose is to provide an inductor, with a single current path, wherein a high current may be made to flow, obtaining thereby a maximum of inductive heating in a charge piece adjacent thereto, in series with multiple current paths, each path in close proximity to the charge piece but separated from other return paths, reducing and minimizing the inductive effect of the current in the multiple paths.

A further purpose is to provide a focus inductor having outward and return paths closely surrounding an electrically conducting charge, having the paths convergent over the portion of the charge it is desired to heat and divergent elsewhere about the charge.

A further purpose is to enhance the heating of a portion of the surface of a charge by providing an unusually concentrated inductive and hysteresis effect at the point of heating.

Other purposes will appear in or be evident from the specification and claims.

By way of illustration of my invention I have used fourteen figures, choosing examples which well represent the invention but which are in no way intended to limit its application or scope.

Figures 1 to 6 inclusive show the relative fields and current concentrations in single and multiple conductors carrying alternating current.

Figures 7 to 10 inclusive show the relative inductive effects of narrow and broad inductors having single and multiple return paths.

Figures 11 and 12 show applications of my invention to certain representative objects. Figure 11 represents a corner edge, as of a shear block. Figure 12 represents a broader edge.

Figures 13 and 14 are circuit diagrams of two electric circuits which may be used in carrying out my invention.

Inductive heating is extremely versatile in its application, and economic or technical considerations control to a large extent whether or not it can be applied to any specific case. It has always been a problem, for instance, to effectively heat thin flat sheets, in competition with fuel fired furnaces or electric resistance furnaces. The thin flat sheets do not offer a good inductive load. Likewise it has been difficult to heat the edge portion of shear blades, rails, and like charge pieces by direct induction and with sufficient uniformity and efficiency to make the operation commercially successful. Such pieces have been heated by a combination of resistance conduction and induction heating, but in many cases it has not been desirable to make actual contact with the piece to effect the conduction of the necessarily large heating currents. Heretofore where straight induction has been relied upon to effect the heating of such pieces, the effective coupling between charge and inductor has been so poor that impractically large currents have been required in the inductor; or the coupling has been made better, with the effect that additional heating has been incurred at positions remote from the desired location.

By my invention I am able to greatly augment the current induced, and hence the heating, in a desired portion of a charge piece without unduly heating other parts of the charge. The current induced into the charge heats the charge in proportion to the square of its magnitude, and when the current paths are divided as herein described the heating effect may be sharply limited to a desired part. On the other hand the coupling between the inductor and charge over the portion of the charge it is desired to heat and over the portion it is not desired to heat may remain close and constant. It is by keeping this overall coupling close that I am able to so greatly augment the current flow where desired. In addition I have devised methods of shaping specific inductors whereby the magnetic field ordinarily associated therewith may be concentrated into a section of a magnetic charge piece, adding a very effective hysteresis heating to the already augmented inductive heating.

In Figures 1 to 12 inclusive electrical conductors of many shapes and spacings are shown. Each piece shown in section may be assumed to have length extending downward through and perpendicular to the plane of the paper. The minus sign indicates an instantaneous value of alternating current flowing downward into the conductor while the plus sign indicates current flowing upward from the plane of the paper. No distinction has been made in marking main or induced current.

In Figure 1, with current flowing downward into the conductor, the magnetic field surrounds the conductor in a clockwise direction. In Figure 2 the directions of current and magnetic field are reversed. In Figure 3 the conductor is shown as having substantial width, with the induction effect operating to make the current flow in paths apart from each other. It should be noted that the induction effect of alternating

current is enhanced with increased frequency, and that applicant is here dealing with the higher frequencies, common in the induction heating field. In Figure 3 the magnetic field loops the conductor as a whole and flows in the same direction around both current paths. In Figure 4 two conductors are shown carrying current in opposite directions. The magnetic fields of the current buck each other over the conductors, but combine between the conductors resulting in a more concentrated field at this point. The currents, being of opposite polarity, crowd toward adjacent edges of the elongated conductors, overcoming to a large degree the spreading effect described in connection with Figure 3.

Figures 5 and 6 show the typical magnetic fields and current paths set up in helical inductors of unit and multi-turn coils respectively.

In Figures 7 to 10 inclusive I have shown sections of plate, inductively disposed beneath conductors carrying alternating current. In each of the examples I have shown one main inductor in which the current is designated by the minus sign, and one or more return conductors, in which the current is designated by the plus sign, which carry a total current equal to that in the main conductor. I have also noted in the plates the corresponding induced currents, marking the plate with plus or minus signs as the case may be.

In Figure 7 there is only one return conductor. In this case the same current flows in the return as in the main conductor, and the heating current induced in the plate will be as great under the return as under the main inductor.

In Figure 8 the main inductor is broadened a little, and two return conductors are supplied. The return conductors are spaced from the main conductor to such a degree that there is little tendency for the current in the main conductor to spread to the ends by induction from these return conductors. There is a corresponding tendency for the current to flow more or less uniformly in the main inductor because of the attraction from the induced current in the plate beneath it. Assuming that the main inductor covers the same area as each return conductor, which, because of its extra width it of course does not, the current induced by the main inductor is twice as great as that induced by either of the return conductors. The heating due to currents induced in the plate by either return conductor will be only one-quarter of that due to the main conductor; the heating varying with the square of the current induced. With the current divided as described and even with the added width of the main inductor it is obvious that the area under the main inductor will be heated to a greater extent than under the return paths. However, due to the close proximity of the return paths to the charge the coupling of the system as a whole is good.

By extending the method, the division of the return current may be carried still further. In Figure 10, I have shown six return paths, each increasing the coupling between inductor and charge, but each carrying only one-sixth the current carried by the main. The heating due to currents induced in the plate by each of the return conductors will be only a small percentage of that produced by the main inductor, again taking into account its added width. It will be seen that by my invention I can distribute the current to effect a maximum or a minimum degree of heating in a charge piece without impairing the over-all coupling.

In Figure 9 I have shown an extreme case where the main inductor is very wide and where two return inductors are so closely spaced to it that the induced plate currents are unable to hold the main current uniform over its whole section. The main current is practically halved and the induced current under each edge of the main inductor is substantially equal to that induced by each return path. Dark or unheated areas are left beneath the mid portion of the main inductor, and between the main and return conductors in the plate. In a critical heating job the coupling, spacing, and division of the inductor must be carefully studied.

In describing the foregoing I have referred to main and return conductors, but my invention is not intended to be limited by such wording. The inductor may be of any shape, or it may be divided and united as much as is required for a given job.

In Figure 11 I have shown in sectional view the arrangement of conductors found suitable for heating one edge of a broad shear blade. A main inductor **5** is disposed angularly around the edge **6** of the shear block **7** to be heated. Return conductors **8** improve the coupling of the main inductor with the charge, divide the return current path to prevent heating except under the main inductor, and incidentally decrease the total impedance of the inductor circuit.

One electrical circuit used to energize the heating device described above and elsewhere in this specification is shown in Figure 13. A high frequency generator **9** feeds a focus inductor **10** through the medium of a step down transformer **11**. Capacitors **12** are used to correct the power factor. The focus inductor is shown in the above figure as having a main inductor **13** and a plurality of auxiliary conductors **14**. An arrangement is shown in Figure 14 where the main inductor **13** comprises a plurality of closely spaced parallel conductors.

In Figure 12 the edge **15** of a bar **16** is shown in position for heating. Here the main inductor **17** is placed directly over the edge to be heated, while return paths **18** are arranged at spaced positions on the sides of the bar to distribute and minimize the heating effect due to current flowing in them.

While I have made no special point of water cooling the inductors and/or conductors described herein, it is obvious that they may be so cooled. It is also obvious that after reviewing my specification many applications other than those herein described will be evident to persons skilled in the art of inductive heating, and it is requested that United States Letters Patent be granted for all that is claimed.

I claim:

1. An induction heating device comprising conductors adapted to make a loop around, and substantially throughout the length of the loop, to lie close to the position of a charge, the conductors as a group being concentrated and carrying current in substantially the same direction over the portion where heating is desired and divided over the remaining portion.

2. An inductor comprising a single current path adapted to lie close to the position of a charge to be heated and a plurality of other conductors connected in parallel with respect to each other and in series with respect to the single current path lying close to the position of other

parts of said charge, each of said other conductors comprising with said single current path a substantial loop about a portion of the charge.

3. An induction heating device comprising single and multiple parts in series, the coupling between all parts and the position of a charge being close, but free from electrical contact therewith.

4. An induction heating device comprising a main inductor lying close to the position of a charge to be heated and a plurality of auxiliary conductors in parallel with each other but in series with the main inductor, the auxiliary conductors substantially throughout their length being close to the position of the charge, each, in conjunction with the main inductor, surrounding a different portion of the charge but spaced from each other and from the main inductor.

5. An inductor comprising a single current path adapted to lie close to the position of a charge to be heated, a return conductor in series therewith having parts adapted to lie close to the position of other parts of the charge and providing, in conjunction with a charge, separated current paths, each, with said single current path, forming a substantial loop about a portion of the charge.

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