Sept. 24, 1946. W. M. ROBERDS 2,408,229

ELECTRICAL HEATING APPARATUS

Filed April 30, 1943

Fig. 1.

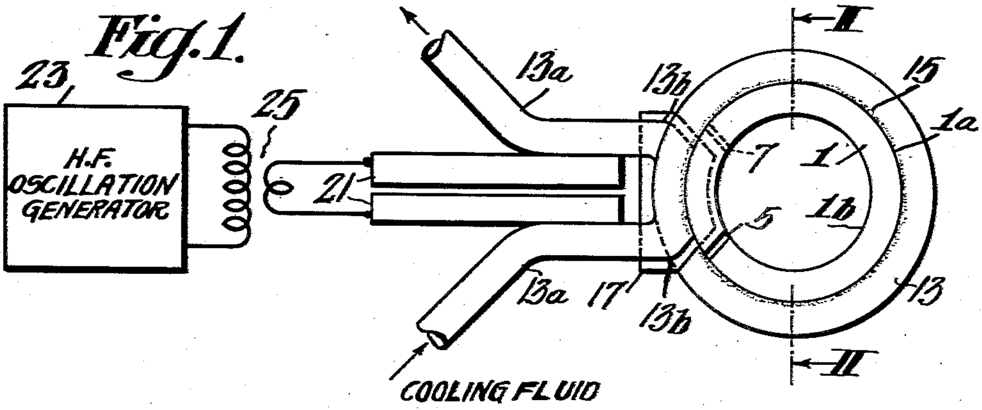


Fig. 2.

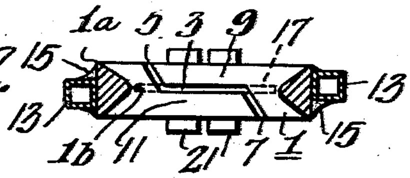


Fig. 3.

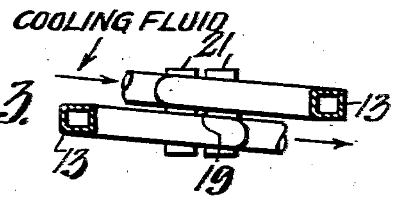
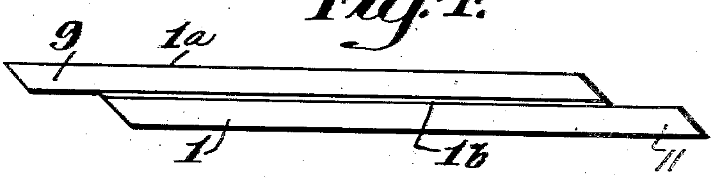


Fig. 4.



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ELECTRICAL HEATING APPARATUS

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12 Claims. (Cl. 219—13)

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This invention relates to electrical heating apparatus, and more particularly to an induction heating applicator coil useful in induction heating apparatus.

The use of high frequency electrical energy for case hardening ferrous metals is now fairly well known. In general, the work to be hardened is scanned by an inductor coupling coil which is connected to a source of radio frequency energy, the coil heating the work fairly instantaneously by induction. The form of coupling coil most generally employed is a substantially single turn, helical winding with its ends overlapped in slightly spaced relation longitudinally of the coil in order to embrace the entire circumference of the work. While such a coil usually provides satisfactory results where the entire surface of the work is to be hardened, it is not satisfactory in all cases for the reason that it does not heat the work instantaneously along a circular portion thereof, but along a helical portion. Thus, when the work is scanned at certain rates, some parts thereof become heated twice due to the overlapped ends of the coil.

Aside from the foregoing, there are some cases in which it is desirable to harden only a portion of the work, as, for example, the base or some other small circumferential area of a cylindrical member. In such cases, the helical coupling coil is not at all satisfactory for the reason that it forms a helically shaped, hardened layer, instead of a circularly shaped layer.

The primary object of my present invention is to provide an improved inductor coupling coil which will be free from the aforementioned disadvantages.

More particularly, it is an object of my present invention to provide an improved inductor coupling coil which will produce, for practical purposes, uniform heating along a circle which lies in a given plane through the work.

Another object of my present invention is to provide an improved inductor coupling coil as aforesaid which will produce practically uniform heating of the work opposite the point where the current enters and leaves the coil, as well as at other points on the work embraced by the coil.

Still another object of my present invention is to provide an improved inductor coupling coil as aforesaid which is simple in construction, can easily be fabricated, is economical in cost, and is highly efficient in use.

In accordance with my present invention, I provide an inductor coil which is formed of a single turn, annular conductor having substantially

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uniform overall thickness throughout its entire circumference, as distinct from the helical form of coupling coil which, at its overlapped ends, has a thickness in excess of twice the thickness of the conductor of which it is made. My improved coupling coil is formed with a circumferential slot extending clear through from the outer to the inner perimeter thereof and with which communicate two longitudinally extending slots each extending from an opposite end of the coil. In this way, there are formed on my improved coupling coil two overlapping terminal portions separated from each other by the gap provided by the aforementioned circumferential slot.

Preferably, although not necessarily, the annular conductor of which my improved coupling coil is made has a substantially triangular cross section, its minimum thickness being either on the outside perimeter or on the inside perimeter of the coil depending upon whether the coil is to surround the work or whether it is itself to be surrounded by the work. The coupling coil is mounted upon a suitable support which may comprise a tubular coil formed similarly to the prior art helical coils, and the aforementioned longitudinal slots are so formed in my improved coupling coil that they will converge toward each other from the outside perimeter to the inner perimeter of the coil, whereby the current will be led into and out of the coupling coil as nearly tangentially as is feasible. Each of the overlapping terminal portions of my improved coil has an overall thickness which is slightly less than half of the overall thickness of the conductor of the coil. Thus, the entire coil has a substantially uniform thickness throughout its circumference.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description of one embodiment thereof, when read in connection with the accompanying drawing, in which

Fig. 1 is a plan view of one form of inductor coil according to my present invention, the coil being shown schematically connected to a high frequency oscillation generator,

Fig. 2 is a sectional view taken on the line II—II of Fig. 1,

Fig. 3 is a view similar to Fig. 2 but with my improved coupling coil removed in order to show more clearly the supporting member therefor, and

Fig. 4 is a developed view of my improved coupling coil.

Referring more particularly to the drawing, wherein similar reference characters indicate corresponding parts throughout, there is shown an annular coupling coil 1 which consists preferably of a machined ring of conductive material having a preferably triangular cross section, as clearly shown in Fig. 2. The ring 1 is formed substantially midway between its ends with a circumferential slot 3 which extends radially through the ring 1 from its outer perimter 1a to its inner perimeter 1b and preferably, although not necessarily, lies in a plane perpendicular to the axis of the coil 1.

The ring 1 is also provided with a longitudinal slot 5 which extends from the upper end thereof downwardly to and communicates with the slot 3, as well as with a second longitudinal slot 7 which is spaced circumferentially from the slot 5 and extends upwardly from the lower end of the ring 1 to and also communicates with the slot 3. The ring 1 is thus provided with a pair of overlapped terminal portions 9 and 11 separated in a direction parallel to the axis of the coil 1 by the slot 3 which constitutes a gap therebetween. As will be noted most clearly from Fig. 2, the terminal portion 9 ends at the slot 5, and the terminal portion 11 ends at the slot 7. The slots 5 and 7 converge toward each other as they approach the inner perimeter 1b of the ring 1 (see Fig. 1) and may or may not extend through the ring 1 in a radial direction, as may be found most suitable. In any case, the overall thickness of the coil or ring 1 throughout its entire circumference, that is, at its outer perimeter 1a, is substantially uniform, the overall thickness of each terminal portion 9 and 11 being somewhat less than half the overall thickness of the coil itself.

The ring member or coupling coil 1 is supported on a single turn, helically formed tubular member 13 to which it may be secured in any suitable manner in concentric relation therewith. Where, for example, the tubular support 13 is formed of metal, such as copper, the ring member 1, also preferably of copper, may be soldered thereto, as shown by the solder 15 in Figs. 1 and 2. A suitable cooling fluid, such as cold water, may be fed through the tubular support 13 to cool the coupling coil during operation and to prevent the solder from melting. Preferably, an insulating strip 17 of mica or any other suitable insulating material having a high dielectric strength is inserted in the gap 19 between the overlapped ends of the tube 13 as well as in the gap provided by the slot 3, which is in substantial alignment with the gap 19, to prevent sparking between the terminal portions 9 and 11 of the annular coil 1. The end portions 13a of the supporting tube 13 may have suitable input terminals 21, preferably also of tubular construction, connected thereto. The coil 1 is coupled to a high frequency oscillation generator 23 through the terminals 21 and a coupling transformer 25 in well known manner.

The form of my improved coupling coil shown in the drawing is particularly adaptable for use with a cylindrical rod, shaft, or the like, the surface of which is to be hardened along a thin, circular area by placing the coil 1 around it and applying radio frequency power thereto. Thus, the coupling coil 1 illustrated in the drawing is thickest at its outer perimeter and gradually tapers down to a minimum thickness at its inner perimeter 1b. Of course, where the inner surface of a hollow, cylindrical member is to be hardened, as in the case of a cylinder bore of an internal combustion engine, the ring 1 will be made thinnest at its outer perimeter and thickest at its inner perimeter, the coupling coil 1 then being connected to the outer perimeter of the supporting tube 13 instead of being nested within and connected to the inner perimeter thereof, as illustrated in Figs. 1 and 2. In any case, it should be apparent to those skilled in the art that, with my improved coupling coil, due to its uniform overall thickness throughout its entire circumference, uniform heating of the work along a circular path or area will result, and that the heating opposite the point where the current enters and leaves the coil will be the same as elsewhere around the coil.

Although I have shown and described but one embodiment of my invention, it will be apparent to those skilled in the art that many other variations thereof, as well as changes in the one described, are possible. For example, instead of mounting the coupling coil 1 on a conductive support, such as the tube 13, it may be mounted on a non-conductive support and the input leads 21 connected directly to the overlapped terminal portions 9 and 11. Also, the longitudinal slots 5 and 7 may extend either in a radial direction across the coil 1 or in some other suitable direction, it being preferable, however, that they shall converge toward each other as they approach the inner perimeter 1b in such a manner relative to the bends 13b of the tube 13 that the current will be led into the coil 1 from one supporting tube end 13a and led out of the coil 1 through the other supporting tube end 13a as nearly tangentially as possible, so as to avoid sharp or abrupt current path changes. Other variations will, no doubt, readily suggest themselves to those skilled in the art. I therefore desire that my invention shall not be limited except insofar as is made necessary by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. An inductor coupling coil for electrical heating apparatus comprising a single turn, annular conductor having overlapped terminal portions spaced from each other in a direction parallel to the axis of said turn to provide a gap therebetween, said turn having substantially uniform overall thickness in said direction throughout the entire circumference thereof.

2. An inductor coupling coil according to claim 1 characterized in that each of said terminal portions has an overall thickness in said direction which is less than half of the overall thickness of said conductor in said direction.

3. An inductor coupling coil for electrical heating apparatus comprising a single turn, annular conductor of substantially uniform overall thickness throughout its entire circumference in a direction parallel to the axis thereof, said conductor having a circumferential slot extending radially therethrough and having also a pair of circumferentially separated longitudinal slots therein communicating with said circumferential slot, one of said longitudinal slots extending from one end of said turn toward said first named slot and the other of said longitudinal slots extending from the other end of said turn toward said first named slot to thereby provide

a pair of opposed, overlapping terminals spaced from each other by said first named slot.

4. An inductor coupling coil according to claim 3 characterized in that said longitudinal slots extend from the outer perimeter to the inner perimeter of said turn.

5. An inductor coupling coil according to claim 3 characterized in that said longitudinal slots extend from the outer perimeter of said turn to the inner perimeter thereof, and characterized further in that said longitudinal slots converge toward each other as they approach said inner perimeter.

6. An inductor coupling coil according to claim 3 characterized in that said longitudinal slots extend from the outer perimeter of said turn to the inner perimeter thereof each in substantially a direction radially of said turn.

7. An inductor coupling coil for electrical heating apparatus comprising a single turn, annular conductor having a cross section of varying thickness with its minimum thickness at one of its perimeters, said turn having a uniform overall thickness throughout its entire circumference in a direction parallel to the axis thereof, said conductor having a circumferential slot therein extending radially therethrough substantially midway between the ends of said turn and in a plane normal to that of the axis of said turn, and said conductor also having a pair of circumferentially separated, longitudinal slots therein extending through said conductor from the outer to the inner perimeter of said turn and each communicating with said circumferential slot, one of said longitudinal slots extending from one end of said turn toward said circumferential slot and the other of said longitudinal slots extending from the other end of said turn toward said circumferential slot to thereby provide a pair of opposed, overlapping terminals spaced from each other by said circumferential slot.

8. In electrical heating apparatus, the combination of an inductor coupling coil comprising a single turn, annular conductor having overlapped terminal portions spaced from each other in a direction parallel to the axis of said turn to provide a gap therebetween, and a substantially single turn, helical supporting member therefor having overlapping portions also spaced from each other to provide a second gap therebetween, said coil having a substantially uniform overall thickness in a direction parallel to its axis and being secured to said member in concentric relation thereto, and said gaps being in substantial alignment with each other.

9. The invention set forth in claim 8 characterized by the addition of a member of insulating material in said gaps.

10. The invention set forth in claim 8 characterized in that said coupling coil is nested within said supporting member.

11. The invention set forth in claim 8 characterized in that said supporting member is of tubular construction and is adapted to have a cooling fluid passed therethrough.

12. The invention set forth in claim 8 characterized in that said coupling coil has substantially uniform overall thickness throughout the entire circumference thereof.

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