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ELECTRICAL HEATING APPARATUS

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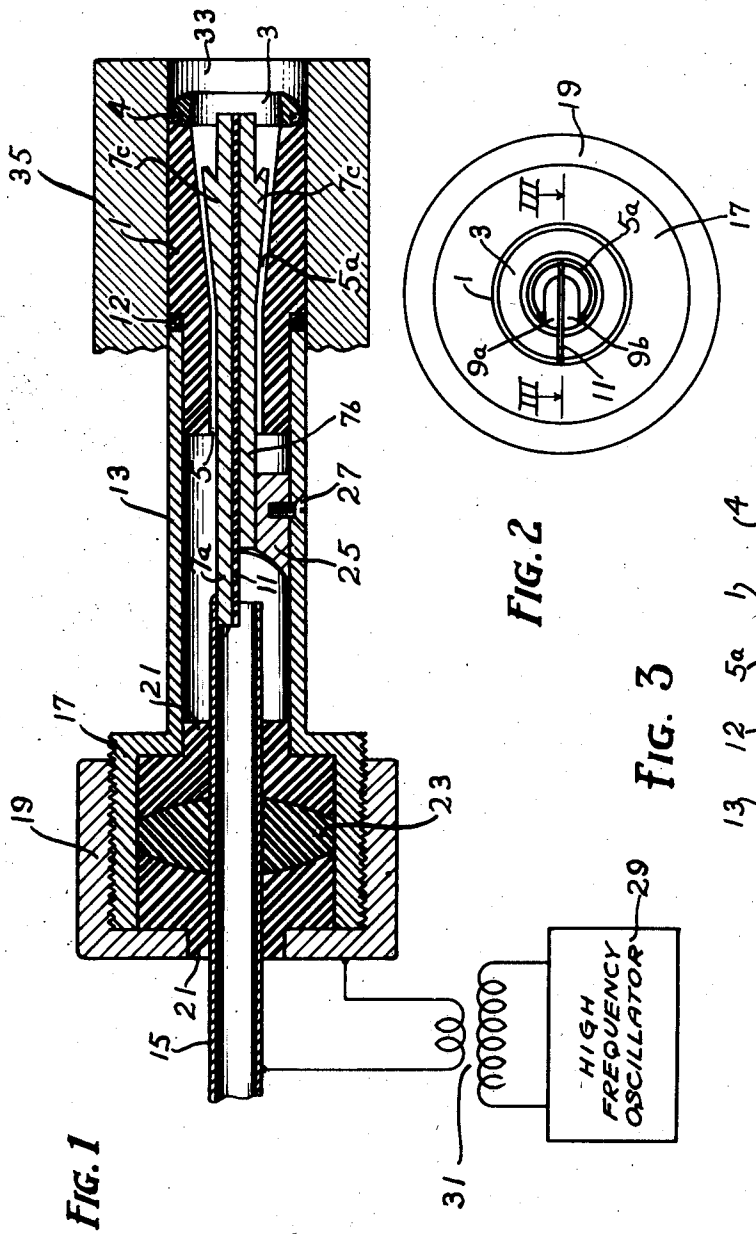


FIG. 1




FIG. 2

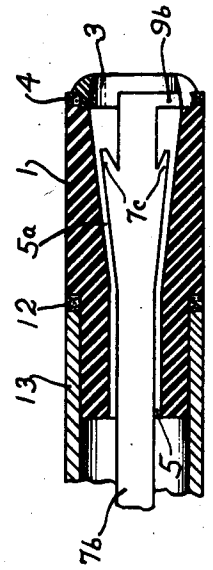


FIG. 3

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## ELECTRICAL HEATING APPARATUS

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8 Claims. (Cl. 219—13)

This invention relates to electrical heating apparatus, and more particularly to inductive heating apparatus for rapidly heating the work to be treated.

The use of radio frequency electrical energy for rapidly heating various articles is now well known. In heating metallic articles, as for hardening the surfaces thereof, there is usually employed an inductor or coupling coil in the form of a tubular member through which cooling fluid is passed for cooling the applicator coil or inductor. In general, where the outside surface of an article is to be heated, the coil is placed around the article, whereas if the inside surface is to be heated, as in the case of a cylinder bore of an internal combustion engine, the applicator is placed within the bore. In any case, the work is scanned by the coupling coil by moving one relative to the other at an appropriate rate.

In many instances, the work to be scanned is of such small diameter at the surface to be treated that the use of an applicator ring or an inductor of the type conventionally employed with radio frequency currents is not feasible, since coils of small diameter are difficult to form out of hollow or tubular conductors. Thus, for example, where the bore of a rifle is to be hardened by inductive heating at sufficiently high power from a source of radio frequency electrical energy, the conventional applicator or inductor is not suitable because it cannot be formed satisfactorily on a sufficiently small diameter.

The primary object of my present invention is to provide an improved coupling inductor which is free from the above mentioned disadvantage.

More particularly, it is an object of my present invention to provide an improved coupling inductor which is particularly suitable for use in bores of small diameter.

Another object of my present invention is to provide an improved coupling inductor as aforesaid which can be readily manufactured by machine methods and which, therefore, can be made with great accuracy.

Still another object of my present invention is to provide an improved inductor as set forth above which can be readily cooled by a fluid coolant, as by spraying water against it.

It is also an object of my present invention to provide improved inductive heating apparatus of the type set forth which is relatively simple in construction, inexpensive in cost, and highly efficient in use.

In accordance with one form of my present invention, the applicator or coupling coil proper is constituted by a split copper ring mounted at the end of a Bakelite or other suitable non-conductive cylinder which fits the bore to be heated and which acts as a guide to keep the coil centered in the bore. Power is fed to the ring or coil through a split copper rod which passes along the axis of the guide and then radially to the ring. The split rod has a diameter which is somewhat smaller than the diameter of the bore in the cylindrical guide so as to provide an annular space therebetween through which the cooling fluid may be passed. The bore in the guide and the split rod are both suitably tapered adjacent their ends so as to insure spraying of the cooling water against the inductor ring as it leaves the device.

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:

Figure 1 is a central sectional view of a heating unit formed in accordance with my present invention,

Figure 2 is a front elevation thereof, and

Figure 3 is a sectional view taken on the line III—III of Figure 2.

Referring more particularly to the drawing, wherein similar reference characters designate corresponding parts throughout, there is shown a tubular support 1 to one end of which is secured a split ring 3 of copper or the like, as by means of cement 4 or other suitable adhesive. The support 1 is formed with a bore 5 which, at least in part, tapers outwardly as it approaches the applicator ring 3.

Within the bore of the support 1 is a split copper rod constituted by the parts 7a and 7b, the rod being concentric with the support 1 and the ring 3, but being of a smaller diameter than the bore 5 whereby to provide an annular space or passage 5a between the rod 7a, 7b and the wall of the bore 5, as clearly seen from Figures 1 and 3. The rod 7a, 7b is tapered similarly to the bore 5, the tapered portions 7c thereof terminating at points short of that end of the support 1 to which the ring 3 is secured. Beyond the tapered portions 7c, each of the rod parts 7a, 7b continues on a smaller diameter and, at the extreme end,

each of the parts 7a, 7b is bent at right angles to provide offset portions 9a and 9b, respectively, which extend radially of the applicator ring 3. One of the offset terminal portions 9a is secured to one terminal of the applicator ring 3, and the other offset portion 9b is secured to the other terminal of the ring 3, as best seen in Figure 2. Thus, the main portion of each of the rod parts 7a, 7b extends longitudinally along the support 1, whereas each offset portion 9a, 9b is disposed substantially radially within the inductor 3. A strip 11 of mica or other suitable insulating material is inserted between the parts 7a and 7b.

For connecting the applicator ring to a source of radio frequency energy, there is connected to the support 1 by cement or the like 12 a tubular conductor 13 which, together with a second tubular conductor 15 connected to the rod part 7a, constitutes a concentric line. The outer conductor 13 terminates in an enlarged, outwardly threaded portion 17 on which a threaded cap 19 is received. A pair of insulated bushings 21 between which a soft rubber washer 23 is confined serve to maintain the tubular conductors 13 and 15 in concentric relation. By threading the cap 19 onto the portion 17 tight against the bushings 21, the washer 23 is compressed to form a fluid tight connection between the conductors 13 and 15. The rod part 7b is connected to the outer conductor 13 by a block of conducting material 25, which may be soldered thereto, and by a screw 27. Connection of the concentric line 13, 15 to a source of high frequency electrical energy 29, such as a vacuum tube oscillation generator operating at radio frequency, may be made through a coupling transformer 31 in well known manner.

For heating the wall of a bore 33 of the work 35, the support 1 is inserted into the bore 33 in engagement with the wall of the bore. The applicator coil 3 is of somewhat smaller diameter than the outside diameter of the support 1, wherefore the support 1 acts as a guide for maintaining the ring 3 in concentric relation with the bore 33. When power is applied and the device is moved along the bore 33, current in the inductor 3 induces heating current in the work which rapidly heats the wall of the bore 33 to the desired temperature. Scanning may be performed at whatever rate is found suitable. For cooling the applicator coil 3 and also the work (as for quenching), a cooling fluid, such as water, may be forced through the tubular conductor 15 which is open at its inner end and has communication with the passage 5a. The tapered portion of the passage 5a directs the cooling fluid toward the applicator ring 3. To insure the cooling water properly spraying the ring 3, the latter may be formed on a taper which converges or tapers inwardly away from the support 1. Thus, the cooling fluid is sure to strike at least the tapered portion of the tube 3 after which it may or may not be deflected onto the work for cooling the latter, depending upon the angle of taper of the coil 3. With this arrangement, much more cooling fluid may be utilized than in conventional coils constructed of tubular conductors.

From the foregoing description, it will be apparent that I have provided an improved heating unit which is compact, simple in construction, and highly efficient in use. The various parts of the device can be readily machined and they are, therefore, much more uniform and accurate than the tube coil types of applicators. Furthermore, by proper selection of the diameter of the supporting tube 1 and the applicator ring 3, bores of various sizes can be treated with the present invention. Also, by merely selecting proper lengths of concentric line 13, 15, it is apparent that bores of various lengths may be adequately treated.

Although I have shown and described but one embodiment of my invention, it will, no doubt, be apparent to those skilled in the art that many other modifications thereof, as well as changes in the one described herein, are possible. 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. In inductive heating apparatus, the combination of a tubular support of insulating material, a coupling coil secured to one end of said support and adapted to be brought into inductive relation with the work to be heated, said support having a bore at least part of which tapers outwardly toward said coil, and a pair of conductive members within said bore secured to the terminals of said coil and adapted to connect said coil to a source of electrical energy, said members being formed at least in part on a taper similar to that of said bore but being spaced from said support whereby to provide a passage for the reception of cooling fluid, and said coil having a portion located in the path of movement of cooling fluid passed through said passage.

2. Heating apparatus according to claim 1 characterized in that the tapered portions of said members terminate at points short of that end of said support to which said coil is secured, said members continuing beyond said points on a smaller diameter.

3. Heating apparatus according to claim 1 characterized in that said coil tapers inwardly away from said support.

4. Heating apparatus according to claim 1 characterized in that said coil tapers inwardly away from said support, and characterized further in that the tapered portions of said members terminate at points short of that end of said support to which said coil is secured, said members continuing beyond said points on a smaller diameter, and the taper of said members being such as to direct the cooling fluid onto at least the tapered portion of said coil.

5. Heating apparatus according to claim 1 wherein said coil is constituted by a single-turn, annular member, and wherein each of said conductive members includes a portion disposed substantially radially within said annular member.

6. Heating apparatus according to claim 1 wherein said coil is constituted by a single-turn, annular member, and wherein each of said conductive members includes a main portion extending longitudinally along said support and an offset portion disposed substantially radially within said annular member, said offset portions being secured one to each of the terminals of said annular member.

7. In inductive heating apparatus, the combination of a tubular support of insulating material, a coupling coil secured to one end of said support and adapted to be brought into inductive relation with the work to be heated, a pair of conductive members within said support each secured to a separate terminal of said coil, said members being spaced from said support whereby to provide a space therearound for the passage of cooling fluid, and a concentric line for external connection of said coil to a source of high fre-

quency electrical energy, said line comprising inner and outer tubular conductors the outer one of which is secured to said support and is connected electrically to one of said conductive members and the inner one of which is connected electrically to the other one of said conductive members, one of said concentric line conductors having communication with said space whereby cooling fluid forced into said last mentioned conductor will also be forced through said space.

8. Heating apparatus according to claim 7 wherein said inner conductor is the one which has communication with said space.

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