Oct. 2, 1945. W. M. WITTY 2,385,904

ELECTRICAL HEATING APPARATUS

Filed June 30, 1943

Fig. 1.

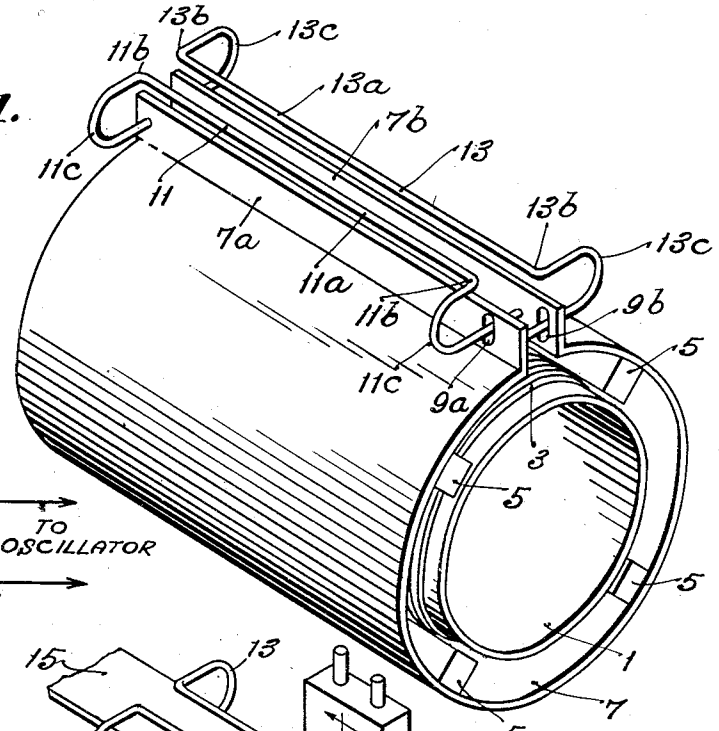


Fig. 4.

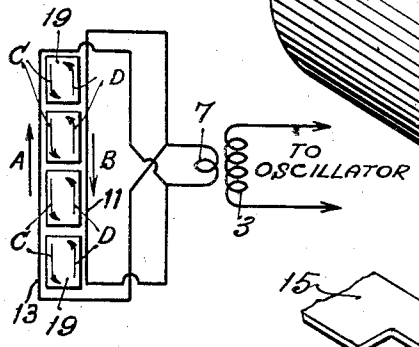


Fig. 2.

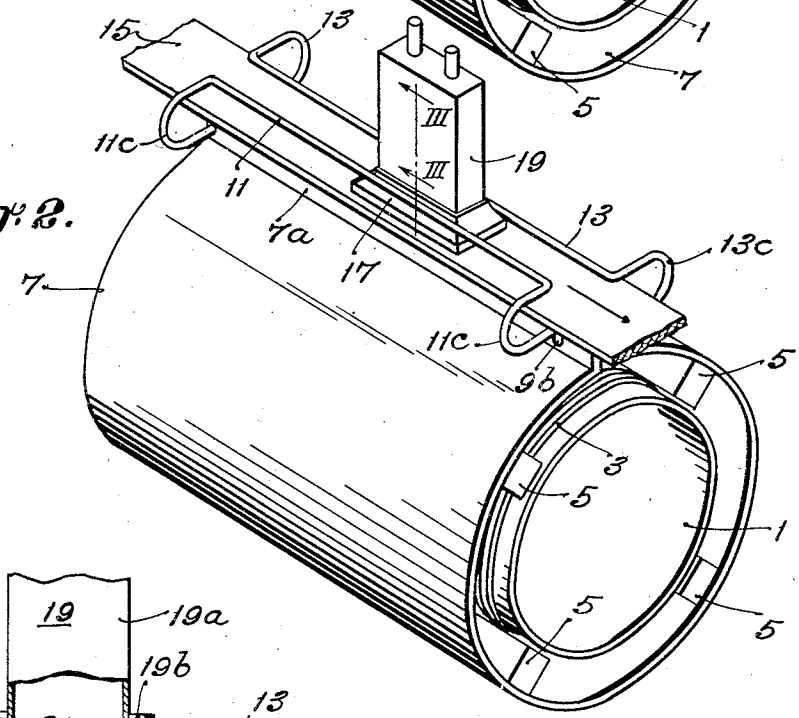
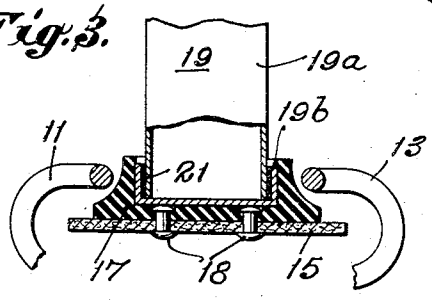


Fig. 3.



Inventor

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ELECTRICAL HEATING APPARATUS

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Application June 30, 1943, Serial No. 492,821

13 Claims. (Cl. 219—13)

This invention relates to electrical heating apparatus, and more particularly to apparatus for heating electro-conductive articles by induction with the aid of high frequency electrical energy.

In many industrial applications, it is necessary, during the manufacture of various articles, to apply heat thereto. In some cases, it is desirable to apply the heat only locally and with fair rapidity. One such example is in the case of capacitor cans comprised of a receptacle and a cover which is soldered thereto.

It has been proposed, heretofore, to employ radio frequency energy for heating electro-conductive articles by induction. In accordance with customary practice employing radio frequency energy, applicator coils or inductors are used which are placed around the work, particularly where the work is small. An arrangement of this sort is obviously unsuited to a continuous heating operation where a plurality of articles are to be heated, as in conveyor belt operation.

The primary object of my invention is to provide an improved apparatus for applying radio frequency energy inductively to a succession of discrete articles to be heated.

More particularly, it is an object of my present invention to provide an improved apparatus for inductively heating electro-conductive articles by means of radio frequency energy, which apparatus is highly suitable for high speed production in continuous operations.

Another object of my present invention is to provide an improved apparatus as aforesaid which is particularly suited in the application of radio frequency induction heating to effect soldering.

Still another object of my present invention is to provide an improved inductive heating apparatus by means of which electrical energy can be applied efficiently to the articles to be treated during manufacture for the purpose of selectively generating heat within the articles while they are moved along continuously on a conveyor belt.

A further object of my present invention is to provide improved inductive heating apparatus as above set forth wherein the leakage reactance is reduced to a minimum.

Still a further object of my present invention is to provide improved inductive heating apparatus as above set forth which is inexpensive in cost and in operation, and which is extremely efficient in use.

In accordance with the present invention, I make use of specially shaped inductor devices as applicators which form the load coupling circuit of a radio frequency generator and obtain thereby very efficient coupling to the articles which are to be selectively heated, as for soldering or the like, when such articles are passed along continuously between these inductors. The inductors are arranged in physically parallel relation and the work is passed between them in such a manner as to obtain close coupling thereto. The inductors are also connected in parallel relation electrically across the terminals of the secondary winding of a coupling transformer which couples the inductors to the generator, the arrangement being such that the radio frequency currents will flow in opposite directions instantaneously in each of the inductors. According to one form of my present invention, the inductors may be constituted by elongated conductors the ends of which are offset with respect to the body portion, with the ends constituting very short leads for connection to the transformer. This, together with the fact that the two inductors are connected together electrically in parallel relation as far as the generator is concerned, results in less effective leakage reactance; and this, in turn, together with the effect of series coupling insofar as the load is concerned, results in a very high percentage of overall efficiency.

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 perspective view of one form of heating device or unit constructed in accordance with my invention,

Figure 2 is a similar view but showing, in addition, a portion of the endless conveyor and one unit of the work thereon in relation to the heating device,

Figure 3 is an enlarged, fragmentary sectional view taken on the line III—III of Figure 2, and

Figure 4 is a wiring diagram showing the connection of the coupling inductors to the transformer and the relation of the inductors to the work.

Referring more particularly to the drawing wherein similar reference characters designate corresponding parts throughout, there is shown a tubular supporting member 1 of insulated material on which is wound the primary winding 3

of a transformer coupled to a suitable high frequency oscillation generator (not shown), such as a vacuum tube oscillator. Surrounding the primary winding 3 and spaced therefrom by plurality of circumferentially distributed, longitudinally disposed, insulated spacing members 5 is a single turn secondary winding 7 of copper sheet material. The ends 7a and 7b of the secondary winding 7 are bent outwardly to form a pair of spaced, terminal members, and they are formed, respectively, adjacent one end with the slots 9a and 9b.

Connected to the secondary winding terminals 7a and 7b are a pair of inductor coupling devices or applicators 11 and 13 by means of which heating currents are induced in the work in the manner shortly to be described. The applicators or devices 11 and 13 are constituted by conductors having elongated, intermediate body portions 11a and 13a formed with substantially right angle bends 11b and 13b. The body portions 11a and 13a are disposed physically in spaced relation and are arranged generally parallel to each other. Beyond the bends 11b and 13b, the applicators are formed with reverse or U-bends 11c and 13c to provide end portions which are disposed in substantially parallel planes approximately at right angles to the plane in which the body portions 11a and 13a lie. As best seen from Figure 1, the inductor or applicator 11 is connected at one end to the terminal 7a, its other end passing through the slot 9a without contacting the terminal 7a and being connected to the terminal 7b. Similarly, the inductor or applicator 13 is connected at one end to the terminal 7b, its other end passing through the opening 9b out of contact with the terminal 7b and being connected to the terminal 7a. Thus, the two inductors 11 and 13 are not only arranged in physically parallel relation relative to each other, but are also connected in parallel relation electrically across the secondary winding 7, as will be noted from Figure 4.

Between the loops formed by the U-bends 11c and 13c, there is movably carried an endless conveyor belt 15. A plurality of insulated receptacles 17 are secured to the belt 15, as by means of rivets 18 (only one receptacle being shown in the drawing by way of illustration). The receptacles 17 are so dimensioned that the sides thereof will be disposed in as close proximity to the body portions of the inductors 11 and 13 as is feasible while the receptacles 17 are being advanced between the inductors by the endless belt 15. Each of the receptacles 17 is adapted to receive one or more work units 19.

By way of illustration, the work units 19 have been shown as constituted by capacitor cans of conducting material and comprised of a case 19a to which a bottom cover 19b is to be secured. For this purpose, the inner surface of the bottom 19b, or lower portion of the outer surface of the case 19a, or both, may be coated with a layer of relatively low melting point solder 21. During manufacture, the cases 19a and their covers 19b are asembled and one or more of them placed in each receptacle 17. The successive receptacles 17 and their contents are advanced by the endless conveyor 15 through the space between the applicators 11 and 13, as shown in Figs. 2 and 4. The radio frequency currents passing through the inductors 11 and 13 will then induce in the conductive cases 19a and the covers 19b currents of sufficient intensity to melt the solder for the purpose of uniting the cover to the case in each instance. Close magnetic coupling between the work 19 and the inductors 11 and 13 is obtained by reason of the fact that the receptacles 17 are in close proximity to the inductors.

Since the inductors 11 and 13 are so connected to the secondary winding 7 that currents will flow therein in opposite directions instantaneously, as represented by the arrows A and B of Figure 4, it is apparent that the currents A and B will induce in the load constituted by each of the work units 19 currents represented by arrows C and D. Because the currents C and D are in series, it is apparent that they will be cumulative or additive in effect. Moreover, since the leads constituted by the U-bends 11c and 13c which connect the body portions 11a and 13a of the inductors to the secondary terminals 7a and 7b are very short, the leakage reactance will be reduced to a minimum. This factor, taken with the series coupling of the inductors insofar as the load is concerned, results in a very high percentage of overall efficiency.

From the foregoing description, it will be apparent that my improved heating apparatus affords an arrangement for heating the work on an endless conveyor set-up with great efficiency. The speed of the conveyor belt 15 and the power input into the work will, of course, depend upon various factors, such as the rate at which an operator can load the work, the lengths of the inductors 11 and 13, the temperature to which it is desired to bring the work, etc. In one installation, for example, where the work was loaded at a rate of about 2500 units per hour, where the inductors 11 and 13 were approximately six inches in length, and where 4 kw. of power were delivered to the inductors at a frequency of 350 kc. per second, the belt 15 was advanced at a rate of about 20 feet per minute. In this particular installation, the inductors 11 and 13 and the primary winding 3 were all made of copper tubing through which water was passed for cooling.

Although I have shown and described but one embodiment of my invention, it will undoubtedly be apparent to those skilled in the art that many other forms thereof, as well as variations in the one described, 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 pair of inductor coupling devices disposed one along each side of a predetermined path with the major portion of their lengths extending along at least a portion of said path, means for coupling said devices to a source of high frequency electrical energy, means connecting said devices to said first named means in parallel relation electrically and providing a small leakage reactance, and a movable carrier arranged for movement along said path adjacent to said devices, said carrier being adapted to support a plurality of electro-conductive work units thereon and to move said units in succession along said path in inductive relation to each of said devices, the current passed through both said devices serving to induce heating current in each of said units as they are advanced along said path.

2. In inductive heating apparatus, the combination of a pair of inductor coupling devices disposed one along each side of a predetermined path with the major portion of their lengths ex-

tending along at least a portion of said path, means for coupling said devices to a source of high frequency electrical energy, means providing a small leakage reactance connecting said devices to said first named means in parallel relation electrically in such a manner that current will flow through said devices instantaneously in opposite directions, and a movable carrier arranged for movement along said path adjacent to said devices, said carrier being adapted to support a plurality of electro-conductive work units thereon and to move said units in succession along said path in inductive relation to said devices, the current passed through said devices serving to induce heating current in said units as they are advanced along said path.

3. Heating apparatus according to claim 2 wherein said inductor coupling devices include short leads whereby they are connected to said means.

4. Heating apparatus according to claim 2 wherein said inductor coupling devices are comprised of relatively elongated members disposed in physically parallel relation, said members terminating in relatively short offset portions constituting leads for connection thereof to said means.

5. Heating apparatus according to claim 2 characterized by the addition of a plurality of work supporting members on said carrier, each adapted to receive at least one of said work units.

6. Heating apparatus according to claim 2 characterized by the addition of a plurality of work supporting members secured to said carrier and each adapted to receive at least one of said work units, and characterized further in that said work supporting members are so arranged on said carrier as to be in close proximity to said inductor coupling devices as said members are advanced along said path whereby to effect close magnetic coupling between said devices and the units in said members.

7. In inductive heating apparatus, the combination of a transformer of which the primary winding is adapted to be connected to a source of high frequency electrical energy, a pair of inductor coupling devices, means connecting said inductor coupling devices in electrically parallel relation across the terminals of the secondary winding of said transformer and providing a small leakage reactance, said devices comprising a pair of elongated conductors disposed in physically parallel, spaced relation along at least a portion of a predetermined path with the major portion of their lengths extending parallel to said path portion, and a movable conveyor adapted to support a plurality of electro-conductive work units arranged for movement along said path to advance said units through the space between said devices and in close proximity thereto whereby to bring said units successively into inductive relation with each of said devices.

8. Heating apparatus according to claim 7 characterized in that said conveyor is constituted by an endless belt.

9. Heating apparatus according to claim 7 characterized in that said conveyor is constituted by an endless belt, and characterized further by the addition of a plurality of work receiving receptacles secured to said belt, said receptacles being of such dimensions and being so disposed on said belt that the sides thereof are in close proximity to said conductors while they are being moved through said space.

10. In inductive heating apparatus, the combination of a movable carrier, a plurality of work supporting elements mounted on said carrier and adapted to be moved through an endless path thereby, a pair of inductor devices disposed in physically parallel relation one on each side of said path with the major portion of their lengths extending along at least a portion of said path whereby said elements will be moved between said devices, said devices being also connected in parallel relation electrically, means for coupling said devices to a source of high frequency energy, and means providing a small leakage reactance connecting said devices to said coupling means.

11. In electrical heating apparatus, the combination of a transformer having a multi-turn primary winding and a single-turn, conductive, sheet member inductively related to said primary winding and constituting the secondary winding of said transformer, said secondary winding having a single pair of output terminals, and a pair of inductor coupling members connected in parallel relation electrically across said secondary winding output terminals, said members each comprising an elongated conductor having its end portions offset from the body thereof, and the terminals of said end portions being connected to said secondary winding output terminals.

12. In electrical heating apparatus, the combination of a transformer having a multi-turn primary winding and a single-turn, conductive, sheet member inductively related to said primary winding and constituting the secondary winding of said transformer, said secondary winding having a single pair of elongated output terminals, and a pair of inductor coupling members connected in parallel relation electrically across said secondary winding output terminals, said members each comprising an elongated conductor disposed along a separate one of said elongated output terminals and having its end portions offset from the body thereof, and the terminals of said end portions being connected to said secondary winding output terminals.

13. An inductor coupling device comprising an elongated conductor having end portions bent substantially at right angles to the body portion thereof, said end portions having reverse bends in parallel planes each substantially normal to said body portion, and said reversely bent portions extending generally in the same direction.

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