HIGH FREQUENCY HEAT TREATING APPARATUS

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Fig.1

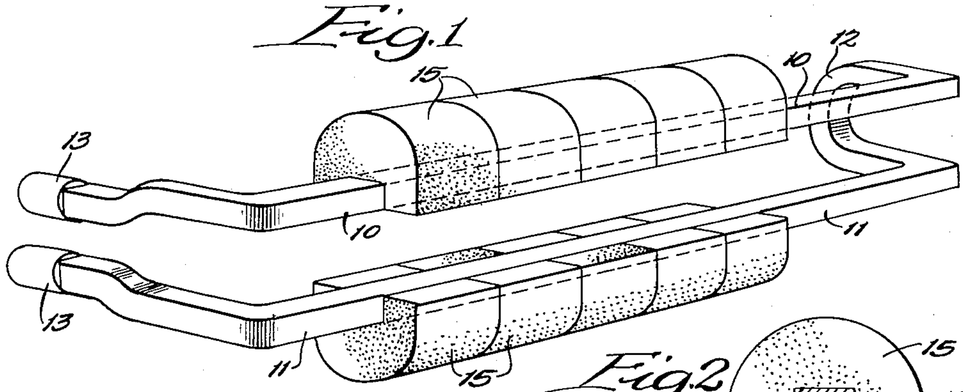


Fig.2

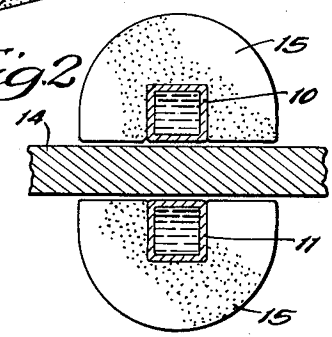


Fig.3

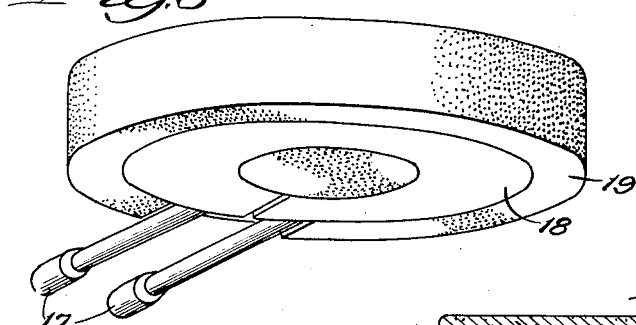


Fig.4

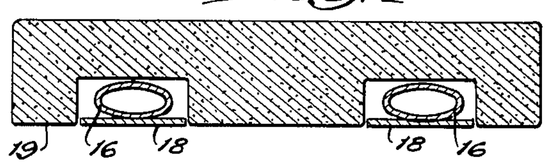


Fig.5

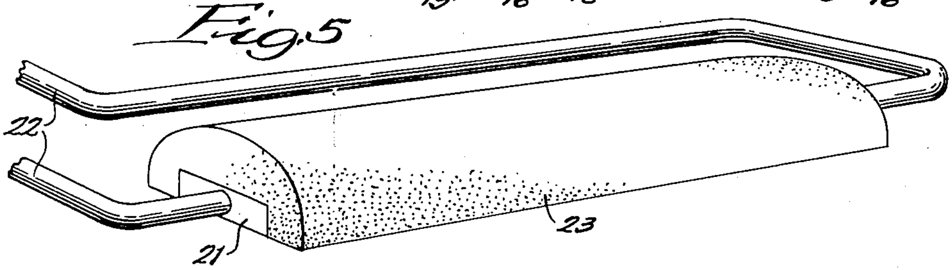
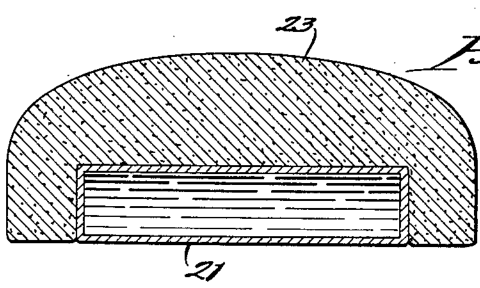


Fig.6



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HIGH FREQUENCY HEAT TREATING APPARATUS

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This invention relates to high frequency heat treating apparatus and more particularly to the construction of a high frequency coil for heat treating objects of various kinds by high frequency current.

In high frequency heat treating, it is the common practice to provide a coil through which high frequency electric current passes and which may be positioned adjacent to objects to be heated to induce heating current therein. For effective operation it is desirable to confine the flux developed by passage of current through the conducting portion of the coil as closely as possible to the work so that stray field losses will be minimized and heating of the work will be confined to the desired areas.

It is impossible to use conventional solid or laminated core material for this purpose with current whose frequency is in excess of about 50 kc. due to excessive heating of the core itself. In the high frequency range of 100 kc. and over, which range is referred to herein by the term "high frequency," it has heretofore been impossible to confine the flux with the result that stray field losses occur and difficulty has been encountered in confining heating of the work pieces to the desired areas.

It is one of the objects of the present invention to provide a high frequency heat treating apparatus in which a core element is provided associated with the coil to confine the flux to the desired path and which is so constructed that it will not be heated by the flux.

It is a specific object of the invention to provide a high frequency heat treating apparatus in which the coil conductor has associated therewith a core element formed of fine particles of magnetic material suspended in spaced relationship in non-conducting material. Such core elements are non-conducting and therefore will not be heated by induced current while serving to confine the flux substantially to the desired path.

Other objects relate to the provision of high frequency heat treating apparatus including coils and core elements specially shaped and associated to accommodate special heating problems.

The above and other objects and features of the invention will be more readily apparent from the following description when read in connection with the accompanying drawing, in which:

Figure 1 is a perspective view of a hairpin coil embodying the invention;

Figure 2 is a transverse section through the coil showing a work piece associated therewith;

Figure 3 is a perspective view of a pancake coil;

Figure 4 is a transverse section through the coil of Figure 3;

Figure 5 is a perspective view of a single turn bus coil; and

Figure 6 is a transverse section through the coil of Figure 5.

In the construction shown in Figures 1 and 2 the invention is applied to a conventional hairpin coil having tubular straight conducting portions **10** and **11** spaced parallel to each other and connected at one end by an

offset loop **12**. At the opposite ends the conductors **10** and **11** are bent substantially at right angles and end in terminals **13** for connection to a source of high frequency current on the order of 100 kc. or more. Preferably the entire coil is tubular and the terminals **13** are formed to circulate cooling fluid such as water through the coil.

In using a hairpin coil of the type shown, a work piece, as indicated at **14** in Figure 2, is passed between the straight conducting portions **10** and **11** in close proximity thereto. The high frequency current will induce heating current in the surface portions of the work piece adjacent to the conductors to heat the work piece for tempering, annealing, or other purposes. It will be understood that the work piece may be a flat plate which is positioned between the conductors, may be a tubular piece which is rolled between the conductors for surface hardening, or may be any other type of work piece to be treated.

In operation of the apparatus flow of the high frequency current through the conductors produces a magnetic field around the conductors which penetrates the work piece to induce heating current therein. In the conventional high frequency heat treating apparatus the magnetic field around the conductors is not confined so that substantially stray field losses are encountered and so that heating of the work piece is not sharply confined to the desired areas.

To reduce the stray field losses and to confine the heating effect on the work piece more sharply, core elements as shown at **15** are provided according to the present invention. Such core elements may be in the form of relatively short semi-cylindrical pieces having flat faces grooved to fit over the conductors as shown so that the flat faces of the core elements are substantially flush with the inner faces of the conductors. With this construction any desired number of core elements can be placed on the conductors in end-to-end relationship as seen in Figure 1 and for some purposes the core elements might be spaced to produce concentrated space heating spots. In any event, the core elements are formed of magnetic material so that they will confine the flux path around the conductors and will confine the path of the flux which intersects the work piece to heat it. Therefore the stray field losses are reduced and the area of the work piece which is to be heated is sharply defined.

If the core elements were formed of conventional magnetic material, such as solid or laminated iron, the high frequency current would induce heating currents therein which would cause excessive heating of the core elements and would make them unuseable. According to the present invention this effect is eliminated by forming the core elements of fine particles of magnetic material suspended in a non-magnetic, non-conducting material. Preferably the particles of magnetic material are iron filings or iron dust, although any metal particles having good magnetic properties can be used. These particles are mixed with a non-conducting material, such as a plastic material, porcelain, or the like, which is then molded to the desired shape so that the particles are held in solid suspension therein in spaced relationship. Due to the heating of the core material by proximity to the heated work piece, it is preferred to use a non-conducting material such as porcelain which will withstand relatively high temperatures without damage. Since the metallic particles are spaced in the core elements, the core elements themselves are non-conducting so that no current will be induced therein by flow of heating current through the conductors. Therefore the core elements will remain relatively cool except for heating due to their proximity to the heated work piece and can be used indefinitely without damage.

I have found that the magnetic particles in the core elements must be of a fineness such that they will not be heated by the effect of the induced flux on the individual particles. For high frequency heating current as contemplated herein having a frequency of 100 kc. or more, the particles must be on the order of 10 microns or less in size to prevent this heating effect. For still higher frequencies, on the order of 400 kc., the particles should be 5 microns or less in size. As the frequency is increased the size of the magnetic particles must be further reduced in order to avoid heating of the core elements. With core elements formed in this manner substantially no internal heating in the cores occurs and the core elements can be used over a substantially indefinite period without damage.

Figures 3 and 4 illustrate application of the principles of the invention to a pancake coil as used for surface heating. This coil is made up of a conducting tube **16** bent into an annulus and having terminals **17** projecting therefrom for connection to a source of heating current and for circulation of cooling fluid therethrough. Preferably the coil **16** is secured as by welding or brazing to a flat annular strip **18** which is separated between the terminals **17** to provide a greater conducting surface. The coil and strip **18** are received in an annular groove in a flat circular core element **19** which is formed of the same material as the core elements **15** of Figures 1 and 2.

In using this construction the core element **19** confines the flux developed by the annular coil closely to a path around the conductors and between the annular edge and the center portion of the core element to confine the heating effect to the desired area.

Figures 5 and 6 illustrate application of the invention to a single turn bus coil for proximity heating. As shown, this coil is formed by a substantially rectangular elongated box **21** formed of conducting material connected at its ends to tubular terminals **22**. The box **21** fits into an elongated groove in a core element **23** which is formed of the same material as the core elements **15** of Figure 1. In using this construction the exposed face of the box **21** and of the core element are positioned adjacent to the surface of a work piece to be heated so that flux will be confined to the desired surface area thereof.

While several embodiments of the invention have been shown and described in detail, it will be understood that these are illustrative only and are not to be taken as a definition of the scope of the invention, reference being had for this purpose to the appended claims.

What is claimed is:

1. A high frequency heating coil comprising an electrical conductor, terminals on the conductor to connect

it to a source of current having a frequency on the order of at least 100 kilocycles, and a core element partially encircling the conductor and having a smooth face substantially flush with one side of the conductor and at which side the conductor is exposed for positioning of a work piece close to the conductor and the core element, the core element being formed of fine particles of magnetic material suspended in spaced relationship in non-conducting material.

2. A high frequency heating coil comprising an electrical conductor, terminals on the conductor to connect it to a source of high frequency heating current, and a core formed of a plurality of core elements, each core element having a smooth surface formed with a groove therein in which the conductor fits and the core elements being assembled end to end on the conductor, the core element being formed of particles of ferrous magnetic material of a size not over about ten microns suspended in spaced relationship in non-conducting material.

3. A high frequency heating coil comprising an electrical conductor having an elongated substantially straight portion, terminals on the conductor to connect it to a source of high frequency heating current, and a core comprising a plurality of core elements each formed with a flat face having a groove therein in which the straight portion of the conductor fits, the core elements being assembled end to end on the straight portion of the conductor, each core element being formed of particles of magnetic material of a size not over about ten microns suspended in spaced relationship in non-conducting material.

References Cited in the file of this patent

UNITED STATES PATENTS

1,981,629	Northrup	Nov. 20, 1934
2,167,798	Denneen et al.	Aug. 1, 1939
2,226,871	Nicholas	Dec. 31, 1940
2,240,494	Denneen et al.	May 6, 1941
2,493,771	Marquardt et al.	Jan. 10, 1950
2,493,950	Dow et al.	Jan. 10, 1950
2,623,081	Schorg	Dec. 23, 1952
2,628,104	Shardlow	Feb. 10, 1953
2,654,019	Body	Sept. 29, 1953
2,671,846	Body	Mar. 9, 1954

FOREIGN PATENTS

635,421	Great Britain	Apr. 12, 1950
980,873	France	May 18, 1951