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J. W. WILLIAMSON
HIGH-FREQUENCY INDUCTOR ARRANGEMENT FOR
CONTROLLING THE INDUCED HEAT PATTERN

2,692,934

Filed June 15, 1951

2 Sheets-Sheet 1

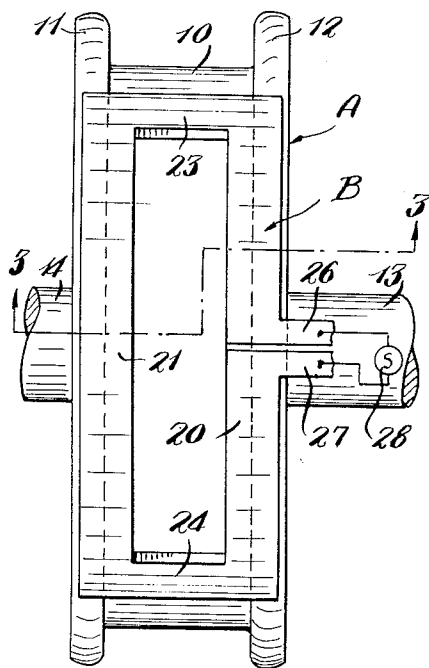


FIG. 1

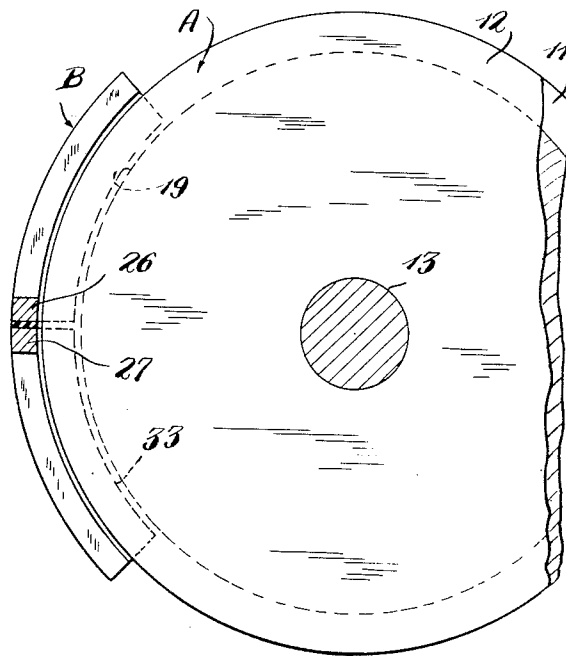


FIG. 2

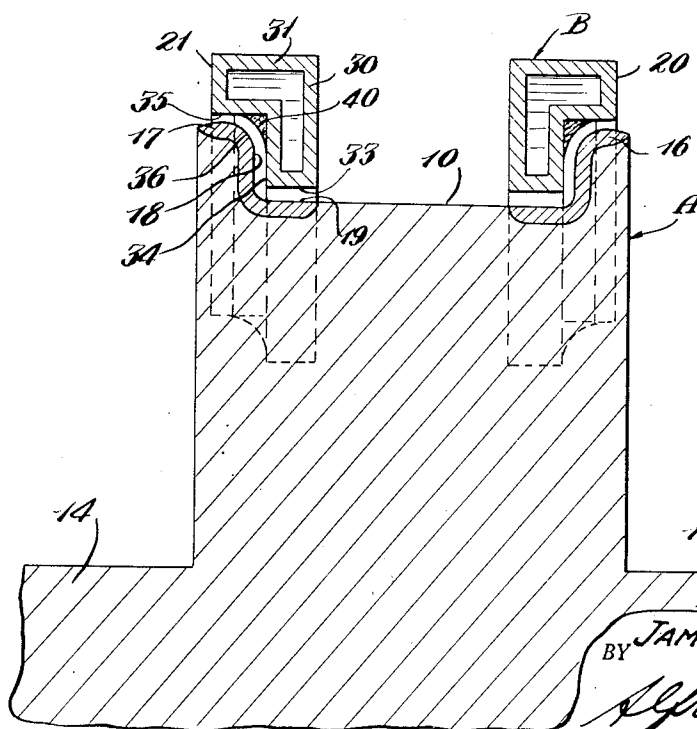


FIG. 3

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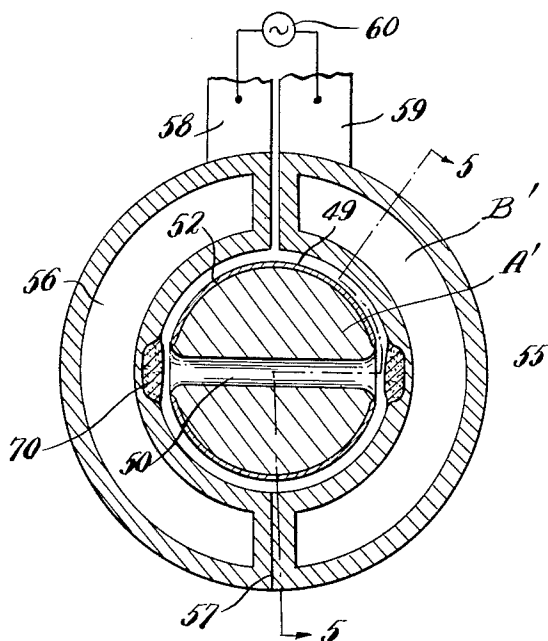


FIG. 4

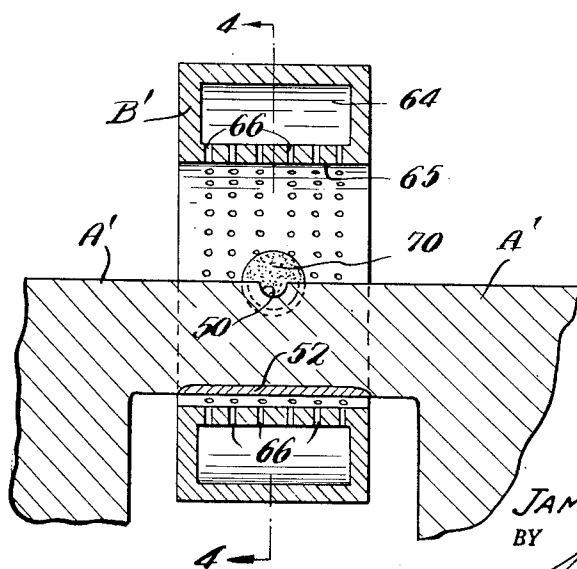


FIG. 5

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HIGH-FREQUENCY INDUCTOR ARRANGEMENT FOR CONTROLLING THE INDUCED HEAT PATTERN

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5 Claims. (Cl. 219—10.79)

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This invention pertains to the art of high-frequency induction heating and, more particularly, to a high-frequency inductor arrangement capable of accurately controlling the heat pattern in a workpiece.

In the art of high-frequency induction heating, it is conventional to position one or more conductor members energized from a high-frequency power source in close-spaced relationship with the surface of a metallic workpiece to be heated. Concentrated high-frequency currents flowing in the conductors create a high-frequency flux field which threads into the workpiece surface and induces concentrated high-frequency currents to flow in the surfaces of the workpiece, which currents rapidly heat these surfaces.

In such heating, it often occurs that there are places or portions of the workpiece under the conductor where it is not desired to heat or where the induced currents tend to concentrate and cause an excessive amount of heating; such as, the oil holes in a crankshaft bearing or on the corners of metallic members.

The present invention contemplates a high-frequency inductor arrangement which enables the heating of portions of the workpiece under the inductor to be readily controlled.

In accordance with the invention, there is provided a high-frequency inductor comprising an elongated conductor having a workpiece-facing surface adapted to be placed in close-spaced relationship to the surfaces of the workpiece to be heated, the workpiece normally having an area or areas opposite the conductor which it is not desired to heat or which normally tend to overheat, the workpiece-facing surface of the conductor having a member of high magnetic permeability fixed thereon opposite this area. This member, because of its high magnetic permeability, tends to divert the flux pattern and reduce the number of flux lines threading into the surface to be heated opposite the member thereby reducing the amount of heating at this point of the surface.

The principal object of the invention is the provision of a new and improved inductor arrangement which can control the amount of heating of portions of a workpiece immediately under the inductor.

Another object of the invention is the provision of a new and improved high-frequency inductor having a member or members of magnetically-permeable material on the workpiece-facing surface thereof for the purpose of reducing the heating opposite the members.

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The invention will be specifically set forth and defined in the claims appended to the end hereof. The invention may take physical form in a number of different-appearing embodiments and, for the purpose of illustrating the invention, preferred embodiment will be described in detail in this specification and illustrated in the accompanying drawing which is a part hereof, and wherein:

Figure 1 is a top elevational view of a workpiece in operative relationship with a high-frequency inductor embodying the present invention;

Figure 2 is a side elevational view partly in section of Figure 1;

Figure 3 is a sectional view of Figure 1 taken approximately on the line 3—3 thereof;

Figure 4 is a view partly in section of an alternative embodiment of the invention; and

Figure 5 is a sectional view of Figure 4 taken approximately on the line 5—5 thereof.

Referring now to the drawings wherein the embodiments shown are for the purposes of illustrating the invention only and not for the purposes of limiting it, Figures 1 through 3 show a workpiece A in the form of a track roller in operative relationship with a high-frequency inductor B. The roller A shown comprises generally a short cylindrical body portion 10 having at both ends short radially-extending flanges 11, 12 which are continuous around the entire periphery of the body 10. Shafts 13, 14 extend centrally from both ends of the body, generally on the axis thereof. With the workpiece A shown, the flanges 11, 12 have outer peripheral surfaces 17 and axial-facing surfaces 13 to be heated and the body 10 has a short axial portion 19 to be heated, all as shown by the heavy shaded area in Figure 3.

For the purpose of heating the portion 16, the high-frequency inductor B is employed. This inductor in the embodiment shown comprises two conductors 20, 21 extending in parallel relationship to each other around a portion of the periphery of the body 10 and the flanges 11, 12. The ends of the conductors 20, 21 are electrically interconnected by end conductors 23, 24, which conductors also serve the purpose of physically and accurately spacing the conductors 20, 21. The conductor 20 is split at its mid point and a pair of fish-tail leads 26, 27 connect one to each side of the split and to a high-frequency power source 28 through suitable impedance-matching means, not shown. Each conductor 20, 21 in cross section is generally in the shape of an L having a radially-extending leg 30 and an axially-extending leg 31. The radial leg 30 has a radially

inwardly-facing surface 33 in close-spaced relationship with the surface 19 of the member 10. The radial leg 30 also has an axially-facing surface 34 in close-spaced relationship with the surface 18. The axially-extending leg 31 has a radially inwardly-facing surface 35 in close-spaced relationship with the surface 17.

In operation, high-frequency electric energy supplied from the high-frequency power source 23 causes a high-frequency electric current to flow in the conductors 20, 21. These high-frequency currents generate a high-frequency flux field about the conductors, which flux field threads through the surfaces of the flanges 11, 12 and generates a high-frequency circumferential current flow therein. This high-frequency, high-concentrated current flow rapidly heats the surfaces of the flanges to an elevated temperature.

It was found that the corners 36 where the surfaces 17 and 18 intersect tended to badly overheat regardless of any contouring of the conductor 20 or the relative spacing between the workpiece-facing surfaces of the conductor and the surfaces of the workpiece to be heated. In accordance with the present invention, a member 40 of high magnetic permeability was positioned over the entire length of the conductors 20 and 21 in the corner formed by the intersection of the surfaces 34, 35, the effect of which is to provide a path of high magnetic permeability for the flux lines about the conductor 20 which will tend to divert the flux from the corner 36 and, thus, to limit the amount of currents generated in this corner and to reduce or prevent the overheating which occurs there.

The member 40 may take a number of different forms but, in the embodiment shown, is made from a mixture of magnetic iron particles and a high-temperature resistant binder which is mixed to the consistency of heavy putty and smoothed into the corner arc shown. In one practicable embodiment of the invention, "Smooth-On" No. 1 manufactured by the Smooth-On Manufacturing Company of Jersey City, New Jersey was employed. Obviously, magnetic iron laminations could be employed if desired. The member 40 is effective whether or not magnetic laminations are employed about the outer surfaces of the conductors 20, 21 and such laminations or other magnetic materials may be employed if desired.

It has been found that in employing the member 40, the heating in the corner 36 can be very readily controlled depending upon the dimension of the member 40 relative to the surfaces 34, 35 and their spacing from the surfaces 18, 17 respectively. The member 40 in deflecting or diverting the flux about the conductors 20, 21 from the corner 36 itself tends to heat but, as the member 40 is in close intimate contact with the surfaces 34, 35 of the conductors 20, 21, the heat generated in the member 40 is rapidly conducted to the conductors and then to cooling water in the passages shown.

Figures 4 and 5 show an alternative embodiment of the invention. In this embodiment, the workpiece A' is in the form of a pin of a crankshaft having an outer circumferential surface 49 to be hardened. The pin is provided with a diametrically-extending oil hole 50 which flares or is filleted at its outer ends into the surface 49. The heat pattern desired in the workpiece is that shown by the heavy shaded area 52.

The inductor B' shown in Figures 4 and 5 is relatively conventional and is constructed along the lines of the high-frequency inductors de-

scribed in the patent to Denneen and Dunni, 2,170,130 dated August 22, 1939 and comprises two semicylindrical members 55, 56 electrically interconnected at one end as at 57 and electrically insulated at the other end. A pair of fish-tail leads 58, 59 lead away therefrom in electrically-insulated relationship to a high-frequency power source 60. The members 55, 56 form a high-frequency inductor having a radially inwardly-facing surface in close-spaced relationship to the surface 49 of the workpiece A'. The inductor shown is of hollow construction having interior passages 64 therein, which passages are defined by an inner wall 65 through which a plurality of radially-extending openings 66 extend. Water or oil under pressure flows into the passage 64 and through the radial passage 66 onto the surface 49 after the surface has been heated to the desired temperature to quench harden this surface.

In operation, high-frequency currents flow circumferentially around the pin of the workpiece A' inducing high-frequency currents to flow in the surface 49, thus heating it very rapidly to a quench-hardening temperature. The oil hole 50, however, projects through the surface 49 and there is a tendency for the high-frequency induced currents to be more concentrated around the edges of the oil hole, thus overheating the oil holes so that they have a tendency to crack following the hardening operation. In accordance with the present invention, the workpiece-facing surface of the inductor is recessed opposite each end of the oil hole 50 and a member or plug 70 of material of high magnetic permeability is positioned in this recess. Again, this material may be of any known magnetic material but is preferably of a powdered-iron material mixed with a plastic binder to the consistency of a putty and molded into the formed recess. In the embodiment shown, the workpiece-facing surface of the member 70 projects slightly beyond the plane of the workpiece-facing surface to further increase its efficiency. It will be noted that the diameter of the member 70 is approximately equal to or slightly in excess of the maximum diameter of the oil hole where it is filleted into the surface 49. Other relative dimensions may be employed.

In the embodiment shown, there are no quench holes opening through the member 70, the effect of which is to further reduce the tendency for hardening to occur at the corners of the oil hole. If desired, however, quench openings could be provided through member 70.

In operation, the inductor B' is positioned about the pin of the workpiece A' and the member 70 aligned with the ends of the oil holes 50. High-frequency currents are flowed through the inductor to induce high-frequency currents to flow in the surface 49 and to heat the surface very rapidly to the quench-hardening temperature. Subsequently, quench water is forced through the passage 64 and through the passages 66 onto the heated surface to rapidly quench harden the surface 49 to generally the contours by the pattern 52 and by the shaded area 52.

The inductor shown in Figures 1 to 3 is preferably continuously water cooled employing the passages shown. The inductor of Figures 4 and 5 may employ the cooling effect only of the quench water flowing through the passage 64 or, if desired, auxiliary cooling passages can be provided to provide continuous cooling for the inductor shown.

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Two possible embodiments of the invention have been shown and described in detail. The invention may obviously be embodied in other forms differing radically in appearance from the embodiments shown in the drawings herein. It is my intention to include all such modifications insofar as they come within the scope of the appended claims.

Having thus described my invention, I claim:

1. A high-frequency inductor having a relatively wide elongated workpiece-facing surface positioned in close-spaced insulated relationship over the entire width thereof with the surface of a workpiece to be heated, said surface of the workpiece having a portion spaced inwardly from the edges thereof which tends to overheat when inductively heated and a member of high magnetic permeability mounted on said workpiece-facing surface spaced from the edges thereof and opposite the portion which tends to overheat whereby to reduce the heating effect of said inductor on said portions.

2. In combination, a metallic workpiece having an elongated surface to be inductively heated with a portion intermediate the edges thereof which tends to overheat and a high-frequency inductor having a workpiece facing surface generally coextensive with and in close spaced insulated relationship with said surface, said inductor surface having a member of high magnetic permeability mounted thereon, spaced from the edges thereof and disposed opposite the portion which tends to overheat whereby to reduce the heating effect of said inductor on said portion.

3. In combination, a workpiece having to an-

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gularly disposed elongated surfaces to be inductively heated, a high-frequency inductor comprising a conductor having corresponding angularly disposed surfaces in close-spaced relationship with the surfaces of said workpieces, the corner formed by the juncture of the surfaces of the workpiece tending to overheat, said conductor having a member of high magnetic permeability in the corner formed by the juncture of the workpiece-facing surfaces thereof for reducing the heating on the corner of the workpiece.

4. The combination as set forth in claim 1 wherein the workpiece to be heated has a cylindrical surface and recesses in said surface and the high magnetic permeability member is opposite said recesses.

5. The combination as set forth in claim 2 wherein the face of the workpiece has a recess and the workpiece facing surface has a corresponding depression, the latter depression being filled by said member of high magnetic permeability.

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