March 30, 1954 J. M. EDWARDS 2,673,922

PARTIAL-TURN INDUCTOR COIL

Filed April 7, 1951

Fig.1.

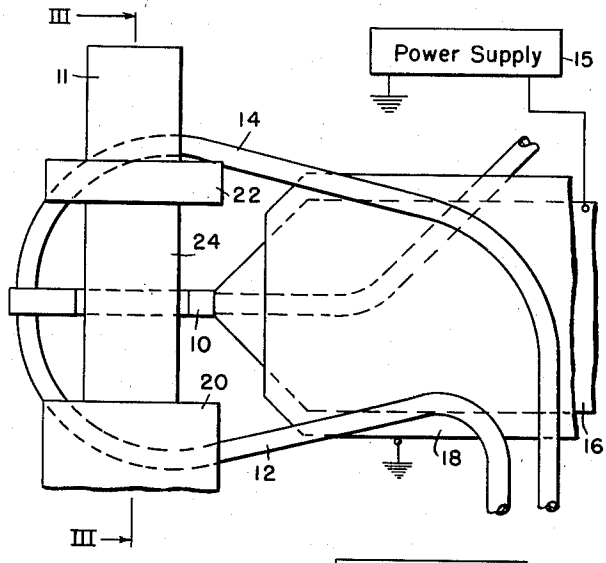


Fig.2.

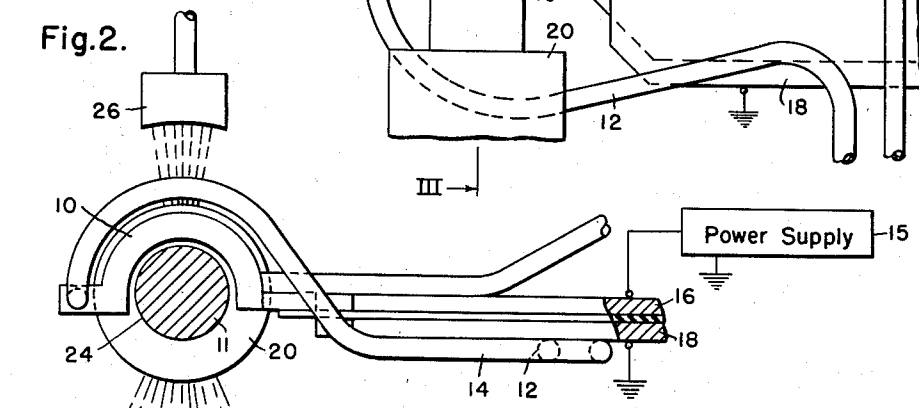
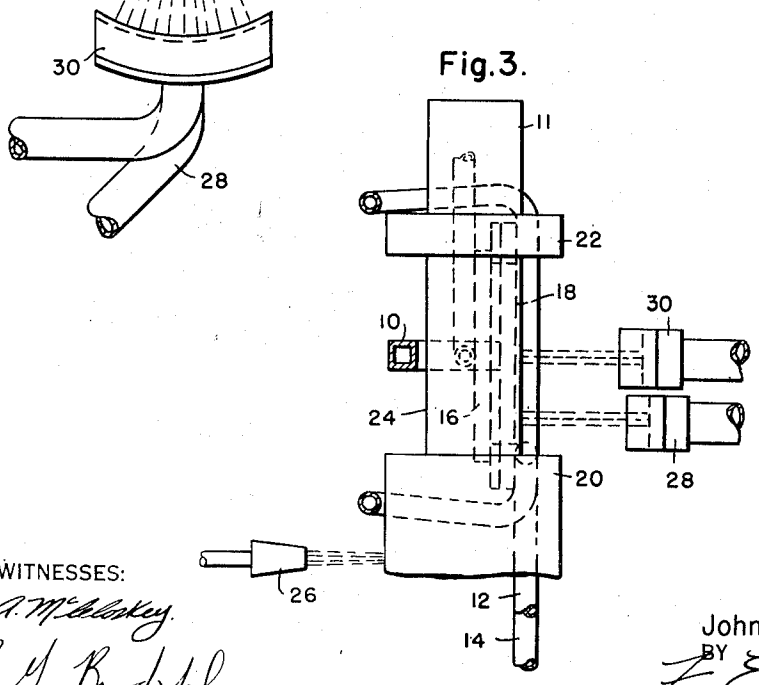


Fig.3.



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Patented Mar. 30, 1954

2,673,922

UNITED STATES PATENT OFFICE

2,673,922

PARTIAL-TURN INDUCTOR COIL

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Application April 7, 1951, Serial No. 219,843

4 Claims. (Cl. 219—10.79)

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My invention relates to the heat treatment of particularly metallic objects and, more specifically, to a partial-turn inductor apparatus, and method for its use in such heat treatment.

In the treatment of particularly irregularly shaped workpieces, which cannot easily be passed through the conventional full-turn coil, the prior art heating apparatus is not too satisfactory. One effort to overcome this has been the split-turn coil, which has two sections, one of them being movable relative to the other such that the coil can be opened and the workpiece inserted into the opening therebetween. The two coil sections are then closed, and the heating current applied to the workpiece. This type of split-turn coil has proven to be relatively expensive to manufacture in that it is rather difficult to construct. Also, it is subject to the objection that the satisfactory concentration of heating power in a relatively narrow surface area of the workpiece is rather impractical to accomplish.

Accordingly, it is an object of my invention to provide a novel type of induction coil for the heat treatment of workpieces and, particularly, workpieces having irregularly shaped surfaces.

It is a further object of my invention to provide a coil for use with particularly irregularly shaped workpieces, which is relatively inexpensive to manufacture and the construction process therefor is not too complicated.

It is a still further object of my invention to provide a coil for especially the described type of induction-heating purposes, which allows relatively simple workpiece positioning relative thereto for the heat treatment of said workpiece.

It is another object of my invention to provide an induction coil for the heat treatment of particularly irregularly peripheral-shaped workpieces, said coil being capable of effectively concentrating the induced heat energy into a relatively narrow surface area of the workpiece.

It is still another object of my invention to provide an induction heating coil which has no portion requiring movement thereof in the process of loading or unloading irregularly shaped workpieces relative thereto.

It is an additional object of my invention to provide a method for heating or hardening workpieces, which is more satisfactory than prior art methods, particularly respecting workpieces having irregular surfaces.

It is still an additional object of my invention to provide a novel method for hardening particularly workpieces having irregularly shaped surfaces, which includes cooling the surface portions of the workpiece, which it is desired not be subjected to the hardening treatment, concurrently with the application of heat energy.

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It is a different object of my invention to provide a novel method for the scansion heating or hardening treatment of particularly workpieces having an irregularly shaped surface, which method provides for the cooling of those workpiece surfaces, which are not desired to be heat treated, concurrently with the heating and/or hardening treatment of other surfaces of the workpiece.

In accordance with my invention, I provide a partial-turn induction coil for the heat treatment of workpieces. This type of coil is especially suitable for workpieces having irregularly shaped surfaces, such that the workpieces cannot be threaded or passed through the conventional full-turn type of induction coil. The proposed heating coil and apparatus comprises a first section made up in the form of a partial-turn coil, which provides heat energy for only a portion of the radial surface of the workpiece, the complete radial surface being effectively heat treated by rotation of the workpiece relative to the coil or movement of the coil relative to the workpiece such that the entire radial surface of the workpiece is exposed to the heating influence of said partial-turn coil. The apparatus includes a second section which comprises one or more current-carrying members for conducting the heating current between the partial-turn section and the power supply generator. This second section is connected to one end of the partial-turn coil in a particular manner such that the resultant field of the current carried by it does not have any substantial heating effect upon the surface of the workpiece undergoing treatment.

The preferred form of my heating apparatus comprises a partial-turn coil consisting of approximately a semicircular turn made of square copper tubing, which is generally shaped and adapted for close coupling to the workpiece surface to be heat treated. The second section of my heating apparatus comprises two parallel-connected return sections made of copper tubing, the latter return sections being so positioned relative to the surface of the workpiece undergoing heat treatment that the current is returned to the power supply, with no workpiece heating effect by the magnetic field set up by the current in the return sections.

For the purpose of hardening treatment of particularly workpieces having irregularly shaped

surfaces, a plurality of quenching means and a method of scansion hardening treatment of the workpieces are provided. The above-described coil and heating apparatus and the workpiece are first relatively positioned for the heat treatment of a chosen section of the workpiece surface. If desired, a first quench means is provided to apply a coolant to the main body of the workpiece or any surfaces which it is not desired be heated by the magnetic field of the partial-turn coil. Depending upon the workpiece to be treated, the heating apparatus including the partial-turn coil can be left stationary relative to the workpiece surface, or the heating apparatus including the partial-turn coil and workpieces can be moved relative to each other at the initial stages of the treatment.

In the case of particularly shaft members having collars and/or shoulders, with journal sections therebetween, it is more desirable to allow the partial-turn coil to remain stationary in the initial treatment stages, and near the corner between the journal and collar portion. During such initial period, the first quench means can be applying a coolant to the main body of the shaft to prevent undesirable heating therein.

After a predetermined interval of time, the workpiece and partial-turn coil section can be moved relative to each other, such that the partial-turn coil starts to scan along the surface of the workpiece. A second quenching means can be employed at this time to apply a coolant for the desired hardening effect of the heated workpiece surface. At the end of such scansion operation and any desired delay or "soak" periods, a third quenching means can be employed, if desired, to apply a coolant to the heated surface. For example, the latter surface may be adjacent an irregularity in the workpiece surface, such as a collar, and at the corner which is formed between a journal section and such collar. The third quench means effectively quenches and thereby hardens the workpiece surface directly beneath the partial-turn coil.

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 its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawing in which:

Figure 1 shows a side view of my heat treatment apparatus positioned relative to a vertically arranged workpiece surface for treatment thereof,

Figure 2 is a plan view, partially in section, of my apparatus as shown in Fig. 1; the section being taken perpendicular to the axis of the illustrated workpiece, and

Figure 3 shows a sectional view of my heat treatment apparatus taken along line III—III of Figure 1.

The workpiece treatment apparatus shown in Figure 1 comprises a partial-turn coil member **10** consisting of approximately a semicircular or arcuate section of about one-half of a conventional full-turn induction heating coil, said partial turn **10** comprising square copper tubing and shaped to be positioned relative to the surface of a workpiece **11** such that a close coupling is obtainable therebetween. A pair of parallel-connected current-return sections **12** and **14** are shown connected to one end of the partial-turn section **10**, said parallel-connected current-return sections being adapted for connection to the opposite terminal of a power supply source **15** than the terminal to which the other end of the partial-turn section **10** is electrically connected. The latter electrical connection from the parallel-connected current-return sections **12** and **14**, if desired, can be through ground, as illustrated in Figure 1. The parallel-connected current-return sections **12** and **14** are made of copper tubing such that a coolant, for example water, can be passed through the partial-turn coil **10** and through the current-return sections **12** and **14** to effect the desired cooling of the heating apparatus. A pair of relatively insulated current conductors **16** and **18** is shown in Figure 1, connected respectively to one end of the partial-turn coil section **10** and connected to the parallel-connected current-return sections **12** and **14** to provide a complete circuit for the heating current.

The illustrated workpiece **11** comprises a shaft member, having an irregularly shaped surface along its axial dimension, in the form of a shoulder member **20**, a collar member **22** and a journal surface **24** therebetween, with particularly sharp corners between the journal surface **24** and both the collar and shoulder members **22** and **20**.

The initial heating position of the partial-turn coil **10**, for purposes of illustration, can be adjacent the shoulder member **20**, in position to heat the journal surface **24** near said shoulder member **20**, and the corner therebetween. In actual practice the partial-turn coil **10** has been positioned approximately $\frac{1}{32}$ inch from the shoulder **20** in such location. During the heating operation, the partial-turn coil **10** was subsequently moved relative to the journal surface **24** in a direction parallel to the axis of the shaft member comprising the illustrated workpiece **11**. The scansion movement of the partial-turn coil **10** was then stopped, when it was approximately $\frac{1}{32}$ inch from the collar member **22**.

In Figure 2 is shown an end view of the workpiece **11** showing the partial-turn coil **10** positioned relative thereto for the heat treatment of the surface of the journal portion **24** of the workpiece **11**. Heating current supplied from the power supply **15** enters one end of the partial-turn coil **10** through a first current conductor **16** and is returned from the other end of the partial-turn coil **10** by means of the parallel-connected pair of tubular current-return members **12** and **14** to the second current conductor **18** and back to the power supply source **15** through a ground connection.

A first quench means **26** is shown for the purpose of cooling the shoulder member **20** and main body of the workpiece **11** during, particularly, the initial stages of the treatment cycle. A second quench means **28** is shown for cooling the heated surface of workpiece **11** following the movement of the partial-turn coil **10**, and a third quench means **30** is shown for cooling the surface immediately adjacent and beneath the partial-turn coil **10** at, particularly, the termination of the heat treatment cycle.

In Figure 3 is illustrated the workpiece **11** showing the partial-turn coil **10** in relative heating position and during its scansion movement respecting the journal surface **24** to be treated. The first quench means **26** is shown in position to direct a coolant upon the shoulder member **20** and main body of the workpiece **11** to be treated.

The second quench means 28 is shown directed toward the heated surface, of the journal section 24 of the workpiece, that has already been heated and is in the process of being quenched, after the passage of the partial-turn inductor coil 10. The third quench means 30 is shown in a position to direct a coolant toward the surface of the journal section 24, which is immediately below and under the influence of the partial-turn inductor coil 10, when it is desired that a coolant be so applied.

In the operation of the work treatment apparatus, and method of treatment therewith, described herein and in accordance with my invention, the partial-turn inductor coil 10 is first positioned adjacent the surface of the journal section 24 of the illustrated workpiece 11, which is initially chosen as the surface of the journal section 24 adjacent the shoulder member 20.

It is to be understood by those skilled in the art that many types of workpieces can be either heat treated or hardened by means of the described apparatus and in accordance with my invention, and it need not have, in particular, collar or shoulder members thereon. It is to be further understood that the partial-turn coil 10 need not be scanned relative to the workpiece surface, and is suitable for the heat treatment of any given portion of the workpiece surface for heating and, if desired, hardening thereof by means of any of the illustrated quench means.

With the partial-turn inductor 10 positioned relative to the surface of the journal section 24 for the heat treatment of that surface immediately adjacent the shoulder member 20, heating current is applied to the partial-turn inductor 10. If desired, the partial-turn inductor 10 is allowed to remain in a stationary position relative to the axial direction of the workpiece 11 undergoing treatment. During the entire heat treatment operation, it is to be understood that the shaft member may be concurrently rotated at a desirable speed, such speed being determinable for every workpiece by experiment or in accordance with the well-known teachings of the prior art. The first quench means 26 can be employed at least during the initial heating period to apply a coolant to the shoulder member 20 and main body of the workpiece 11, which it is desired be not heated by the induced current from the partial-turn inductor 10.

After a predetermined interval of time, such that the surface of the journal section 24 and corner thereof, adjacent the shoulder member 20, is heated to the desired extent, the partial turn inductor 10 is started on its scansion cycle in a direction away from the shoulder member 20. The rate of scansion of such partial-turn inductor 10 is determinable for each work-piece experimentally, or can be chosen in accordance with the known teachings of the prior art as understood by those skilled in this particular art. It is further to be understood that this scansion movement need not progress at a constant rate along the workpiece surface. After the partial-turn inductor member 10 has moved away from a given heated surface of the journal section 24, and a suitable delay period has been provided for purposes of any desired soaking or temperature leveling effects, the second quench means 28 is employed to apply a coolant to that heated surface and effect the desired hardening thereof. The partial-turn inductor member 10 through its movement cycle continues its scanning, followed in movement by at least the second quench means 28 such that the surface of the journal section 24 is heated by the partial-turn inductor member 10 and subsequently is quenched and thereby cooled to effect the desired hardening by the second quench means 28. When the partial-turn inductor member 10 reaches the end of its scansion cycle, such that the surface and corner of the journal section 24 immediately adjacent the collar member 22 has been heated to the desired extent, the third quench means 30 is employed to apply a coolant to that surface and corner, and effect the desired hardening thereof.

In practical operation, as the partial-turn inductor scanning movement progressed along the surface of the journal section 24, the surface for a short distance ahead of the inductor coil 10 was heated by induced current from its magnetic field, and the scanning movement was terminated when the inductor coil 10 was approximately 3/32 inch from the collar member 22. Further, in practice, the heating current was applied to the partial-turn inductor member 10 for a short time interval after its scanning movement stopped to insure proper heat penetration into particularly the corner between the collar member 22 and the journal section 24. After the latter time interval, the heating current was discontinued to the partial-turn inductor member 10, and the third quench means 30 was employed to apply a coolant for the adequate quenching of the surface of the journal section 24 in addition to the corner betwen the journal section 24 and the collar member 22.

With the illustrated workpiece 11 comprising a shaft having a journal section 24 intermediate between a shoulder member 20 and a collar member 22, the described heating and hardening method provided a hardened case along the journal section 24 up to within about 1/64 inch of both corners, respectively, the corner between the journal section 24 and the collar member 22 and the corner between the journal section 24 and the shoulder member 20. The journal section 24 had an outer diameter of 7/100 inch with a 1/4 inch collar 22 and shoulder member 20. A 20-kilowatt, 450-kilocycle power supply source was employed in the actual practice of my invention.

While I have shown and described certain specific embodiments of my invenion, many modifications thereof are possible. For example, the inductor member 10 may have only one current-return section, in lieu of the parallel-connected current-return sections 12 and 14, as shown in Fig. 1 of the drawing. My invention, therefore, is not to be restricted, except as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. An inductor for heat treating a sectional area of an article, said inductor being adapted for carrying heating current from a suitable power supply source having a pair of terminals, said inductor comprising a first sector having an arcuate shape and an axis and having a pair of end portions, one of said end portions being adapted for connection to one of said terminals, said end portions having the greatest physical separation of any two portions of said first sector, and a second sector including at least one current-carrying branch, said branch including an arcuate shaped portion and being connected to the other one of said end portions, said branch being positioned in the same direction relative to said axis as said first sector and being so shaped and positioned relative to said first sector that

the current carried by said branch of said second sector does not have any substantial heating effect on said sectional area.

2. The apparatus in accordance with claim 1 in which the second sector includes at least a pair of parallel-connected branches, which are commonly connected to the same end of the first sector, with the common connection between the one end of the first sector and the parallel-connected branches positioned in a perpendicular manner to said end of the first sector at the point of common connection therebetween.

3. An inductor for heat treating a sectional area of an article with high-frequency power from a suitable power supply source having a pair of output terminals, comprising a partial-turn inductor member having an axis and having a pair of ends with one end connected to one terminal of said power supply source, a pair of parallel-connected current conductors, each of said conductors having a pair of ends, said parallel-connected current conductors respectively having one end commonly connected to the other end of said partial-turn inductor member in respectively a perpendicular relationship thereto and their opposite ends respectively connected to the other terminal of the power supply source, said pair of conductors including respectively a substantially arcuate shaped portion and being positioned on respectively the same side of said axis as the partial-turn inductor member.

4. In apparatus for the hardening treatment of a sectional area of an article, a partial-turn inductor member having an axis and having a pair of ends, a first and a second current conductive member respectively having a pair of ends,

each of said current conductive members having one end connected to a first end of said partial-turn inductor member in respectively a perpendicular relationship thereto and a second end adapted for connection to one terminal of a suitable power supply source, said partial-turn inductor member having its second end adapted for connection to the other terminal of said power supply source, said partial-turn inductor member being adapted for relative movement respecting said sectional area to be hardened in a direction along an axis substantially perpendicular to a plane containing said partial-turn inductor member, with each of said current conductive members being positioned respectively in the same relative direction from said axis as the partial-turn inductor member.

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