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HIGH FREQUENCY INDUCTION HEATING APPARATUS

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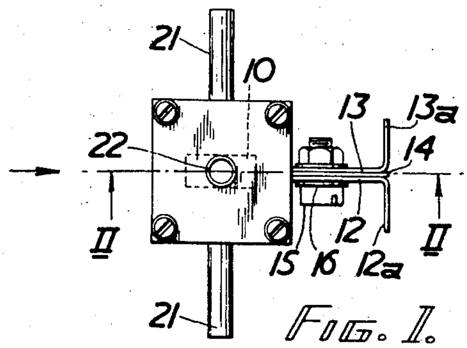

FIG. 1.

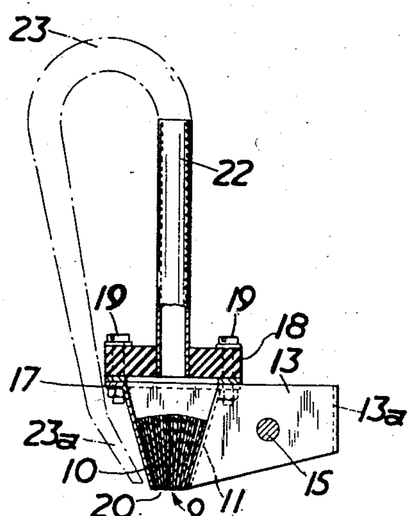

FIG. 2.

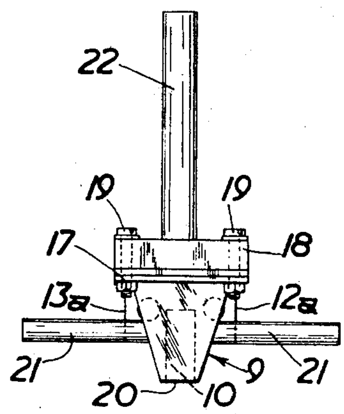

FIG. 3.

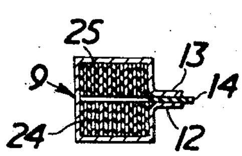

FIG. 4.

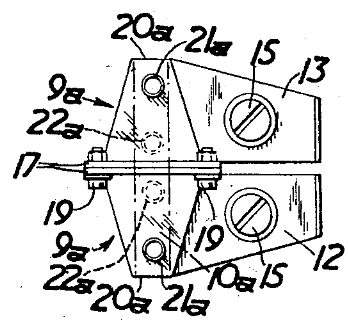

FIG. 5.

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HIGH FREQUENCY INDUCTION HEATING APPARATUS

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13 Claims. (Cl. 219—10.49)

This invention relates to high frequency induction heating apparatus and is particularly concerned with means for improving the concentrtaion or transmission of the high frequency energy by the inductor of the apparatus on or to the workpiece.

Means for concentrating the H. F. or R. F. flux from the inductor of such apparatus to the workpiece are already known, such means taking the form of a core placed within the induction coil and projecting into close proximity with the workpiece. Such cores, however, tend to become overheated during use even when used with normal high frequency apparatus due to the heat generated in the core by eddy currents and hysteresis losses, with the result that the material from which the core is constructed rises above the Curie temperature, that is the temperature at which the material loses its magnetic properties. At radio frequencies the heating of the core is much more pronounced and cores employed for radio frequency work have hitherto been constructed of insulated powdered magnetic material, or of a ferrite material, such latter cores being non-conductors, or substantially non-conductors, and possessing marked ferro-magnetic properties while having a reduced eddy current loss factor at high frequencies.

The main object of the present invention is to provide an alternative construction of flux-concentrating core for the foregoing purpose which can be used in conjunction with induction heating apparatus operating at either normal high frequencies or radio frequencies and which is simple in construction and efficient in operation and lends itself to cooling to enable the heat generated in the core to be effectively removed from the area of maximum flux concentration.

Another object of the invention is to provide an inductor having a flux concentrating core comprising a multiplicity of thin elongated elements cooled by directly exposing them to a fluid cooling medium flowing through the inductor so that the elements are washed by the cooling medium.

A further object of the invention is to provide a novel form of inductor for high frequency induction heating apparatus, said inductor comprising a hollow fluid-tight casing, a core including a multiplicity of thin elongated elements of magnetic material insulated from each other and extending in the direction in which it is required to concentrate the high frequency energy of the inductor, said elongated elements being arranged in side by side relationship and extending into the casing from at least one end thereof, and means for passing a fluid cooling medium through said casing into direct contact with a portion of said elongated elements to cool said elements and thereby conduct heat away from the heating face of the core.

The thin elongated elements may be in the form of laminae and may be composed of steel, a suitable type being one of the nickel iron alloys since they have a high permeability with low hysteresis loss. In order to keep eddy current losses, and thus the heat generated in the core, to a minimum the laminae must be made from material of thin gauge. A thickness of .002 in. is suitable for a frequency of 500 kc./s. but this thickness may be increased for lower frequencies. Practical considerations will limit the minimum thickness of the laminae to approximately .00075 in.

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Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a plan of the inductor,

Figure 2 is a sectional elevation of the inductor shown in Figure 1 on the line II—II of that fiure,

Figure 3 is a rear elevation of the inductor in the direction of the arrow shown in Figure 1,

Figure 4 is a sectional view of an inductor intended for use with work of substantial width and in which the laminae are divided longitudinally into two separate sections, and

Figure 5 illustrates alternative forms of an inductor in which two similar cores, or a single core, are arranged to provide two heating faces for the inductor which face in opposite directions.

Referring to Figures 1 to 3 of the drawings, the inductor for the high frequency induction heating apparatus includes a hollow copper casing **9** within the lower end of which a core comprising steel laminae **10** is enclosed, the casing being of inverted truncated pyramidal shape and formed from one sheet of material. The sides of the casing **9** are non-continuous, three of such sides being plane whilst on the fourth side **11** the material is bent outwardly at right angles to such side on each side of the vertical centre line of the core to form mounting plates **12**, **13** which are insulated from each other and spaced apart by a sheet **14** of insulating material. These plates are held together by a bolt and nut **15**, which are insulated from both plates by insulating washers **16**, and at their free ends are bent at right angles away from each other, as shown at **12*a***, **13*a***, to form tabs which are apertured and serve as connections by which the high frequency energy from the induction heating apparatus is transmitted to the casing **9** which forms the induction coil of the inductor. The induction coil formed by the casing is thus in the form of a substantially closed loop open at its ends and the core extends in the general direction of the axis of the loop.

At its upper end the casing **9** is provided with an outwardly turned flange **17** to which a rectangular closure plate **18** of insulating material is secured by bolts **19** so as to close the upper end of the casing, which is filled with a cooling medium, in a liquid-tight manner. The steel laminae **10** are of rectangular shape and are constructed of nickel iron alloy, such laminae extending upwardly in side by side relationship from the lower end of the casing. As shown in Figure 2, the laminae **10** lie closely adjacent each other at their lower ends and spread outwardly away from each other towards their upper ends so that they are disposed substantially in the form of a quadrant or fan the narrower end of which forms the heating or work face **20** of the core. This face is held in close proximity to the workpiece and is sealed to prevent escape of the cooling medium by means of an adhesive or varnish interposed between the individual laminae and between the latter and the casing **9** so that this end of the core is closed and presents a solid appearance. Such adhesive or varnish must possess good electrical insulating properties and must be capable of withstanding temperatures in the region of 250–300° C. Alternatively the lower end of the core may be sealed by a sheet of mica or similar material cemented or otherwise secured to the lower end of the casing **9**.

Cooling of the core is effected by a liquid cooling medium, such as oil or water, which is fed into two opposite sides of the lower end of the casing 9 through pipes 21 in such manner that the cooling medium impinges upon the end edges of the laminae and cools them, such medium then passing along the laminae and upwardly to escape through an outlet pipe 22 secured in an aperture in the closure plate 18. The laminae must be insulated from each other and this is effected by interleaving them with insulating laminae of heat-resisting material, such as mica, which will withstand a temperature in the region of 300° C., such insulating laminae having, for example, a thickness of .0005 in. As an alternative the steel laminae may be insulated by having their surfaces oxidised or varnished. In either case the work face 20 of the core is preferably ground to a plane surface after assembly of the laminae.

The arrangement described permits very effective removal of the heat generated in the core by eddy current and hysteresis losses since the cooling medium is in direct contact with each of the laminae which towards their upper ends have spaces or gaps between them through which the cooling medium flows. The work face end 20 of the core is also restricted to a temperature below Curie point as heat is conducted away from this face along the metal laminae. This is of particular importance since the work face 20 is normally in very close proximity to the workpiece and as the latter is at a very high temperature heat is transmitted therefrom to the core so that it is essential to have effective means for removing such heat. Should overheating of the work face end 20 of the core occur such end rises above Curie point and loses its magnetic properties as a result of which the workpiece is no longer effectively heated. By means of the invention, therefore, the core-cooling difficulties hitherto experienced with the dust cores used in radio frequency work due to the insulating nature of the core material and the sectional thickness of the latter are overcome and cores constructed in accordance with the invention can be used for higher powered work than the present known constructions.

Moreover, as the Curie temperature of the nickel iron laminae 10, that is the temperature at which the material loses its magnetic properties, is considerably higher than that of the insulated powdered magnetic materials hitherto employed for dust cores, the problem of cooling is made very much easier, since the core can be run at a higher temperature, say 200–300° C., whereas previously with such dust cores the temperature has had to be limited to approximately 80° C. Also the bonding material itself used in normal dust cores will not withstand high temperature so that it has not been possible to use such cores for high power concentration work.

Quenching of the heated workpiece may be effected by the liquid cooling medium employed for cooling the core, particularly if water is used for the latter purpose. The outlet pipe 22 may constitute the inlet end of a duct 23, shown in broken lines in Figure 2, which extends down the outer surface of the casing 9 to a point at the rear end of the working face 20 of the latter, the open end 23*a* of the duct forming a nozzle for the discharge of a quenching jet of the cooling medium on to the heated workpiece.

When the core section has to be of substantial width, for example when required to fill the tooth spaces of gear wheels with wide-pitched teeth, it may be desirable to split the laminae of the core longitudinally into two or more separate sections, as shown at 24, 25 in Figure 4, in order to reduce eddy current losses between the large multiplicity of laminae to the minimum.

Figure 5 illustrates an arrangement in which two casings and cores each similar to the casing and core illustrated in Figures 1 to 3 are bolted directly together by their flanges 17 so that the cores face in opposite directions and provide two opposite heating or working faces 20*a*, 20*a*. By means of this arrangement of the cores two workpieces, or two spaced portions of the same workpiece, can be heated simultaneously. The fluid cooling medium is admitted to the interior of the casings 9*a* by inlet pipes 21*a*, 21*a* disposed at the outer ends of the casings and escapes from the latter through outlet pipes 22*a*, 22*a* at the inner ends of the casings. Separate groups of laminae are arranged in each of the casings in the manner previously described so that the groups of laminae extend inwardly from the work faces 20*a*, 20*a* towards each other to leave a gap between their inner ends. If desired, however, a single group of laminae of more elongated form may be employed which extends through both casings 9*a*, as shown in broken lines at 10*a*, the opposite ends of the laminae terminating at each of the work faces 20*a*, 20*a*.

I claim:

1. For high frequency induction heating apparatus, the combination of an inductor including a hollow fluid-tight casing and an induction coil flux concentrating core comprising a multiplicity of thin elements of conducting magnetic material insulated from each other and extending in the direction in which it is required to concentrate the high frequency energy of the inductor, said elements being arranged in side by side relationship and extending into said casing from at least one side thereof, and means for passing a fluid cooling medium through said casing so that said cooling medium comes into direct heat-conducting contact with a portion of said elongated elements to cool said flux concentrating core.

2. For high frequency induction heating apparatus, the combination of an inductor including a hollow fluid-tight casing and an induction coil flux concentrating core comprising thin laminae of conducting magnetic material insulated from each other and extending in the direction which it is desired to concentrate the high frequency energy of the inductor, said laminae being arranged in side by side relationship and extending into said casing from at least one side thereof, and means for passing a fluid cooling medium through said casing into direct contact with a portion of said laminae to cool said flux concentrating core.

3. The structure of claim 2, characterized in that said laminae are separated for at least a portion of their length to leave spaces therebetween to which said fluid cooling medium has access and where heat is transmitted to said fluid cooling medium from the spaced surfaces of the laminae.

4. For high frequency induction heating apparatus, the combination of an inductor including a hollow liquid-tight casing and a flux-concentrating core comprising a multiplicity of thin elements of conducting material insulated from each other and extending in the direction in which it is required to concentrate the high frequency energy of the inductor, said elements being arranged in side by side relationship and extending into said casing from at least one side thereof, and means for passing liquid cooling medium through said casing to cool said elements with surfaces of which said liquid cooling medium is in heat-conducting contact, the sides of the casing being of electrically conducting material and constructed in the form of an open loop, the high frequency energy from said heating apparatus flowing round said loop whereby the sides of the casing form an induction coil for said inductor.

5. For high frequency induction heating apparatus, an inductor including in combination a hollow liquid-tight casing, a flux-concentrating core comprising thin laminae of conducting magnetic material insulated from each other and extending in the direction in which it is required to concentrate the high frequency energy of the inductor, said laminate being arranged in side by side relationship and extending inwardly into the casing from one end thereof, which forms the heating face of the core, at which end the laminae lie closely adjacent each other and spread outwardly away from each other to-

wards their opposite ends so that they are disposed substantially in the form of a quadrant, and means for continuously feeding liquid cooling medium through said casing which cooling medium flows between the spaced ends of said laminae.

6. The structure of claim 5, characterized in that the liquid cooling medium is fed to said casing at a point adjacent said heating face and escapes from the opposite end of said casing.

7. The structure of claim 5, characterized in that said casing is of truncated pyramidal shape and the laminae extend from the truncated end of said casing into the interior of the latter.

8. The structure of claim 2, characterized in that said laminae are split longitudinally into a plurality of separate sections in order to reduce eddy current losses.

9. For high frequency induction heating apparatus, an inductor including in combination a hollow liquid-tight casing, two substantially similar induction coil flux concentrating cores arranged coaxially and each comprising thin laminae of conducting material insulated from each other and arranged in side by side relationship, said cores extending inwardly into the casing from opposite sides thereof which sides form heating faces of the inductor, and means for passing a fluid cooling medium through said casing so that said cooling medium comes into direct heat-conducting contact with a portion of said laminae to cool said flux concentrating cores.

10. For high frequency induction heating apparatus, an inductor including in combination a hollow liquid-tight casing, an induction coil flux concentrating core comprising a multiplicity of thin elongated elements of conducting magnetic material insulated from each other, said elongated elements being arranged in side by side relationship and extending through said casing from side to side thereof to form two heating faces for the inductor which face substantially in opposite directions, and means for passing a liquid cooling medium through said casing so that said cooling medium comes into direct heat-conducting contact with a portion of said elongated elements to cool said flux concentrating core.

11. For high frequency heating apparatus, an inductor including in combination a hollow liquid-tight casing, a flux-concentrating core comprising thin elongated laminae of conducting material insulated from each other, said laminae being arranged in side by side relationship and extending through said casing from side to side thereof to form at their opposite ends two heating faces for the inductor which face in substantially opposite directions, and means for passing a liquid cooling medium through said casing so that said cooling medium comes into direct heat-conducting contact with a central portion of said laminae to cool said flux concentrating core, the sides of the casing being of electrically conducting material and constructed in the form of an open loop around which the high frequency energy from said apparatus flows.

12. For high frequency induction heating apparatus, the combination of an inductor including a hollow casing having an opening in a side thereof and a flux concentrating core comprising a multiplicity of thin elements of conducting magnetic material insulated from each other which extend in the direction in which it is required to concentrate the high frequency energy of the inductor, said elements being arranged in side by side relationship and extending through said opening to form a heating face of the core and to close the opening in the casing in a fluid-tight manner, and means for passing a fluid cooling medium through said casing so that the fluid cooling medium flows directly over the portion of said elements within the casing to cool said flux concentrating core.

13. In a high frequency induction heating apparatus, the combination of an induction coil constructed in the form of a substantially closed loop open at its ends, an induction coil flux concentrating core extending within the loop from one end thereof, said core comprising a multiplicity of elongated relatively thin elements of conducting magnetic material insulated from each other, said elements extending in the general direction of the axis of the loop and effectively closing the said one end of the loop and forming an end working face of the induction coil for the flux concentration of the core, closure means for the other end of the loop, and means for circulating a cooling medium directly over portions of the core elements confined within and between the closed ends of the loop to cool the flux concentrating core.

References Cited in the file of this patent

UNITED STATES PATENTS

1,981,629	Northrup	Nov. 20, 1934
2,003,855	Fredrickson	June 4, 1935
2,244,056	Denneen	June 3, 1941
2,459,971	Stanton	Jan. 25, 1949
2,493,950	Dow et al.	Jan. 10, 1950
2,509,713	Achard	May 30, 1950
2,512,718	Grumel	June 27, 1950
2,582,955	Body	Jan. 22, 1952
2,582,963	Cachat	Jan. 22, 1952
2,596,770	Groven	May 13, 1952
2,599,086	Beckius et al.	June 3, 1952
2,606,997	Backuis et al.	Aug. 12, 1952
2,672,550	Vaughan	Mar. 16, 1954