Aug. 14, 1956 R. V. LACKNER 2,759,087

LAMINATED METAL LINER FOR INDUCTION COILS

Filed Jan. 2, 1953

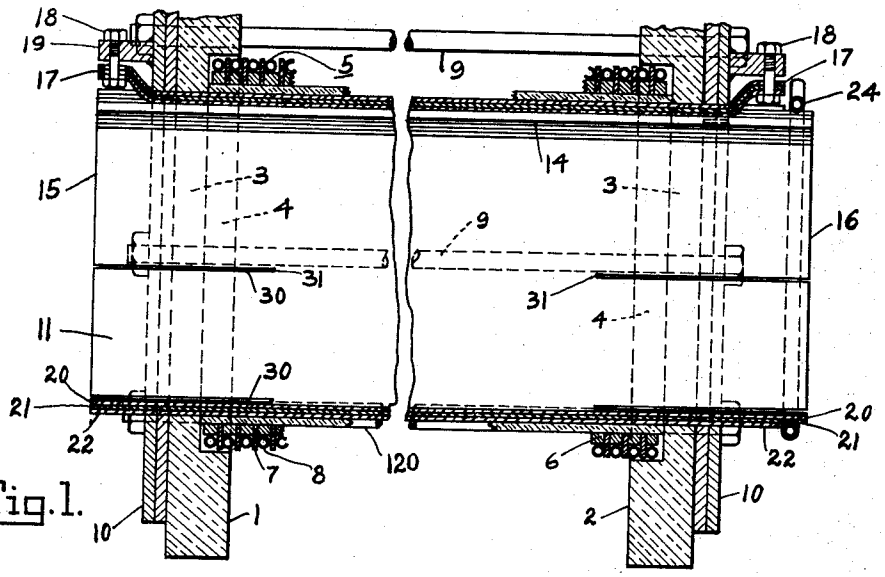


Fig. 1.

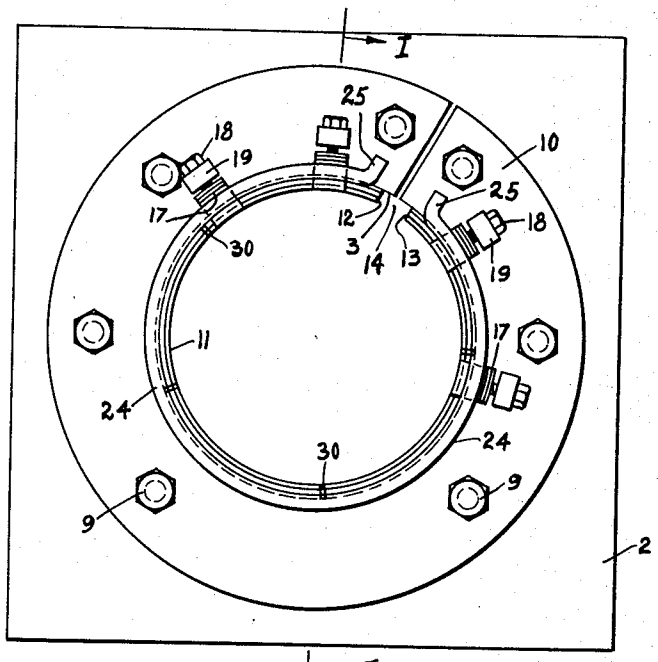


Fig. 2.

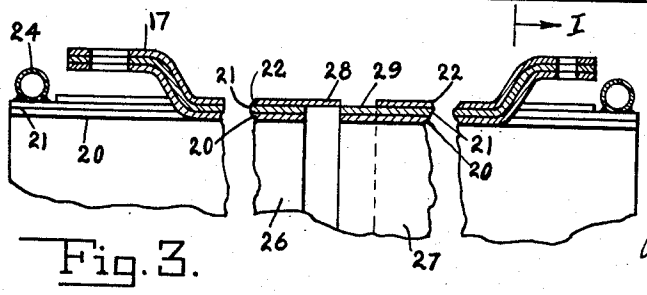


Fig. 3.

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United States Patent Office 2,759,087 Patented Aug. 14, 1956

2,759,087

LAMINATED METAL LINER FOR INDUCTION COILS

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Application January 2, 1953, Serial No. 329,390

12 Claims. (Cl. 219—10.79)

This invention relates to an improved metal protective liner for induction coils used in the electrical heating of metal billets, and, more particularly, to an improved liner of laminated construction having thermal and electrical characteristics which increase its working life.

In the metal working art, the advantages of electrically heating billets by the use of induction coils, both high frequency and low frequency, are well recognized. In billet heating installations using induction coils, the billet is positioned centrally of the induction coils which may be either singular or plural in number and have an overall axial length somewhat longer than the billet so that the ends of the billet will be positioned inwardly of the ends of the coil. Since it is desirable to keep the gap between the inner surfaces of the induction coils and the outer surface of the billet at a minimum, metal liners are employed to protect the induction coils during insertion and withdrawal of the billet, such liners of necessity having a relatively close fit about the billet. By reason of the close fit of the liner with respect to the billet and the high temperatures encountered, conventional liners in practice have a short life and must be replaced frequently.

As indicated, this invention has as its principal object the provision of an improved metal liner of laminated construction having improved thermal and electrical characteristics for dissipating its heat to provide a lower working temperature. The laminar structure of the liner includes an inner lamination of a tough wear-resistant metal of relatively low electrical conductivity which is exposed to the surface of the billet being heated, and an outer lamination of a softer more highly conductive metal having one entire surface thereof in intimate thermal contact with the outer surface of the inner lamination. In the preferred practice of the invention, the inner lamination is steel and the outer lamination is copper.

Other objects and advantages of the invention will be apparent from the following description.

In the drawings, there is shown a preferred embodiment of the invention. In this showing:

Fig. 1 is a longitudinal sectional view of an electrical induction heating unit taken substantially along the line I—I of Fig. 2, a center portion of the unit being omitted;

Fig. 2 is an end view of the unit shown in Fig. 1; and

Fig. 3 is a fragmentary sectional view of a liner taken in a plane similar to that of Fig. 1 illustrating an arrangement particularly adapted to facilitate replacement of the liner.

In the drawings, the numerals 1 and 2 designate spaced end boards of insulating material respectively provided with circular openings 3 through which the ends of the liner of this invention project in a manner to be described. Adjacent surfaces of the end boards are provided with annular grooves 4 about the inner edges of the openings 3 providing spaces for the reception of the ends of an electrical induction heating unit designated as a whole

by the numeral 5. The induction unit 5 includes a helical coil 6 of rectangular copper conducting bar having strips 7 of glass board or other suitable insulation between adjacent convolutions thereof and a water cooling conduit 8 brazed to and extending spirally along its outer surface. The unit 5 is of conventional construction and the usual electrical taps and water connections have been omitted from the drawings. It extends over the entire distance between the boards 1 and 2 and may be formed of single coil or plural coils in accordance with conventional practice. The boards 1 and 2 are provided with stay-bolts 9 the ends of which engage and hold split rings 10 about the openings 3 for maintaining the end boards and unit 5 in assembled relation.

The unit 5 is wound on a thin-walled metal liner 11 of cylindrical shape with an intervening layer 120 of asbestos and high temperature cement or other suitable thermal and electrical insulation for protecting the coil 6 from the heat of the liner. The liner 11 is fabricated from a thin rectangular sheet of laminated metal which is bent to the form of a cylinder having an internal diameter only slightly larger than the diameter of the billet to be accommodated therein, and with opposite edges 12 and 13 spaced slightly from each other to provide an axially extending gap 14 interrupting the circumferential continuity of the cylinder. The gap 14 is essential for minimizing the induction of circulating heating currents in the liner by the unit 5. The cylindrical liner 11 has a length such that its ends 15 and 16 project through and beyond the openings 3. The ends 15 and 16 have plural tangs 17 which are lanced out of the end edges of the liner material. Openings are formed in the tangs 17 for the reception of bolts 18 for fastening the ends of the liner to lugs 19 on the end rings 10 to thereby hold the liner against axial movement. The openings in the tangs 17 on one end 15 of the liner are enlarged in a direction axially of the liner to allow for expansion and contraction of the liner in response to temperature changes.

As in conventional practice, the heating unit 5 has an axial length such that its ends will project beyond, generally about four inches, the terminal ends of the billet to be heated. The overall length and diameter dimensions will, of course, vary with the size of the billet. The capacity of the presses available today for forming billets act as a limitation on the size of the units. Generally stated, presses are available for forming billets with a diameter of from about 3" to a maximum of about 30" to 40", and a length of up to about 80", and these dimensions will govern the size of the heating units. As press capacities are increased, the maximum sizes of the heating units may be increased correspondingly.

The liner 11 is fabricated from a rectangular thin metal sheet of laminar construction consisting of three laminations of metal designated respectively by the numerals 20, 21 and 22. The liner 11, in actual practice, has a thickness much less proportionately to its diameter than shown in the drawings, its thickness having been increased in the drawings to facilitate a showing of the laminar construction. This change in the showing of the thickness of the liner results in the tangs 17 being shown extending radially outwardly of the outer surface of the liner 11 a greater distance than will be the case in actual practice. In actual practice, the tangs 17 extend radially outwardly a distance such that their outer surfaces will clear the inner surfaces of the coils 6 when the liner is moved axially of the induction unit 5 in its removal and replacement. The insulation 120, of course, is damaged upon removal of a liner and is replaced before a new liner is inserted.

Referring again to the laminated structure of the liner, it will be noted that the lamination 20 is an inner lamina-

tion and the lamination **22** is an outer lamination, both of these laminations being formed of a tough wear-resistant non-magnetic metal of about unit permeability and of relatively low electrical conductivity and in the preferred practice of the invention being formed of high-tensile strength stainless steel. The stainless steel in the inner and outer laminations **20** and **22**, as in conventional liners of non-laminated construction, is a high chrome and high nickel steel alloy, preferably the American Iron and Steel Institute Type Number 310 having a chromium content of 24–26% and a nickel content of 19–22%. This steel is very tough and non-magnetic and has the property of retaining its strength at high temperatures. The intermediate lamination **21** is an outer lamination relative to the inner lamination **20** and is formed of a softer and more highly conductive, both thermal and electric, metal and in the preferred practice of the invention is formed of copper. While copper is the preferred metal for the intermediate lamination **21**, it will be understood that other metals having the properties of high electrical and thermal conductivity, such as silver, may be used. The copper and metal laminations **20**, **21** and **22** are in intimate contact with each other and bonded together over their entire engaging surfaces. Liners **11** constructed of steel and copper laminations **20**, **21** and **22** in this manner and installed in induction heating units under commercial operating conditions have operated at lower temperatures and have had a longer working life than conventional liners formed entirely of steel. The lower operating temperature of the laminated liner indicates better thermal conductivity with respect to dissipation of heat absorbed by the liner from the billets being heated and a reduction of the direct heating of the liner by induced electrical currents circulating therein.

The provision of the lamination **21** of a relatively high heat conducting material, such as copper, in intimate contact with the inner liner **20** provides an improved action which will be better understood by giving consideration to the heating operation which is had when a billet is being heated. When a billet is inserted in the liner, it rests on and is in contact with the bottom of the liner **11** along a line of contact extending axially of the inner surface of the inner liner **20**, and upwardly of this line of contact, on both sides of the billet there is a small space which progressively increases in size to a maximum at the top of the billet. As the billet temperature is raised upon circulation of current through the coil **6**, the heat transmitted to the liner is greatest in a small area about this line of contact, and in which excessive liner temperatures are experienced in liners of conventional construction. With a laminated liner fabricated as described above, the relatively higher heat conducting metal of the intermediate or outer lamination **21** is effective to conduct the heat away from the critical area about the line of billet and liner contact in a direction upwardly and around the sides of the liner where it may be dissipated more quickly. This results in a liner temperature which is much lower over the entire surface of the liner, and particularly in the area of billet and liner contact, than is had with conventional liners of single ply construction. While there is shown in the drawings a liner of three ply construction having the third outer lamination **22** of steel, it will be understood that the principles of this invention apply equally well to a liner formed of only two laminations and in which the outer lamination **22** shown in the drawings is omitted.

In Fig. 1, a portion of the outer steel lamination **22** at the end **16** is shown removed to expose the copper lamination **21** over a short length axially of the liner. A water cooling pipe **24** is intimately engaged with this exposed portion of the copper lamination **21**, being preferably brazed thereto, to further increase dissipation of heat from the liner. The pipe **24** has terminals **25** for connection to water supply conduits (not shown).

While a cooling pipe **24** is shown at only one end **16** of the liner in Fig. 1, both ends **15** and **16** may be so provided as demonstrated by the showing of Fig. 3. In Fig. 3, the liner **11** is formed of two axially aligned halves **26** and **27** which have their adjacent ends formed to provide a telescopic connection for facilitating removal and replacement of the liner with respect to the induction unit **5** and its mounting structure. This telescopic connection is formed by removing a short axial portion of the liners **20** and **21** from the end of the half **26** to provide an annular part **28** projecting axially from the inner end of the half **26**, and by removing a short axial portion of the liner **22** from the inner end of the half **27** to provide an annular part **29** projecting axially from the inner end of the half **27**. The annular parts **28** and **29** are telescopically engageable upon movement of the halves **26** and **27** toward each other to provide surfaces interiorly and exteriorly of the liner which are in effect uninterrupted in a direction axially of the liner, the liner shown in Fig. 3 having an axially extending circumferential gap **14** (not shown) as explained in connection with Figs. 1 and 2. A liner constructed of telescopically engageable halves **26** and **27** as shown in Fig. 3 may be removed from an induction unit **5** for example, by pulling the half **26** outwardly through the opening **3** in the end board **1**, and by pulling the half **27** in an opposite axial direction outwardly through the opening **3** in the end board **2**. A new liner formed of halves **26** and **27** may be replaced by a reversal of these operations. The liner in Fig. 3 is provided with an induction coil unit **5** and mounting structure including terminal boards **1** and **2** as in Fig. 1, these parts having been omitted from the showing of Fig. 3 in the interest of simplicity.

The laminated liner of this invention has particular utility in induction heating units which are to be used in heating metal billets to working temperatures of 1500° F.–2300° F. Metals having working temperatures in this range are, for example, the coppers, brasses, copper-nickel alloys, and steel alloys. For metals having working temperatures substantially lower than 1500° F., the laminated liner of this invention is not essential since a single ply liner of stainless steel will stand up satisfactorily under the temperatures encountered.

In the heating of billets of steel or steel alloys having relatively high permeability, excessive heating of the liner in an annular area immediately outwardly of the end of the billet is had during the initial portion of the heating cycle. This excessive heating is due to a concentration of flux density at the ends of the billet and disappears when the billet is heated to a temperature, known as the Curie point, at which its magnetic property is substantially destroyed. To eliminate this temporary and excessive heating condition, the liner is provided with a plurality of saw slots or kerfs **30** extending axially inwardly from both ends **15** and **16** of the liner. The circumferential spacing of the slots **30** about the ends of the liner is dependent on the heating rate of the induction unit, the density of the flux, frequency of the heating current, and any other factors affecting the temperature of the liner ends. Generally stated, a spacing of about four inches between adjacent slots will be found satisfactory, but it will be understood that such spacing may be increased or decreased as circumstances require. The embodiment shown in the drawings illustrates a liner and heating unit adapted to receive a billet of about seven inches in diameter, and shows the slots **30** about four inches apart from each other in a circumferential direction. The kerfs **30** extend inwardly a distance such that their inner ends **31** are positioned inwardly, preferably about four inches, of the ends of heating coil and slightly inwardly of the ends of the billet. While it is preferable that the ends **31** terminate at a point slightly inwardly of the ends of the billet being heated, satisfactory results may be obtained by having the ends **31** terminate at a point coinciding with the ends of the billet. The provision of the kerfs **30** breaks up the area in which in-

duced currents may circulate through the metal of the liner and eliminates the excessive heating of the liner which is had until the temperature of the billet passes through its Curie point. The provision of kerfs **30** is desirable for the reasons stated not only in a liner of laminated construction as described above but also in conventional liners of single ply construction.

While the above specification and accompanying drawings illustrate and explain a preferred embodiment of the invention, it will be understood that this is merely by way of illustration, and that various changes may be made therein within the contemplation of the invention and under the scope of the following claims.

I claim:

1. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled cylinder of metal of interrupted circumferential continuity; the invention herein described wherein the metal wall of said liner is of laminar structure and includes an inner lamination of a tough wear-resistant and substantially non-magnetic metal of relatively low electrical conductivity, and an outer lamination of a softer metal of relatively high electrical and thermal conductivity positioned between said coil and said inner lamination, said outer lamination having intimate thermal contact with the said inner lamination, together with a layer of thermal and electrical insulating material secured between said laminar lining and said coil.

2. The invention defined in claim 1 characterized by said inner metal lamination being a high chrome and high nickel steel alloy and said outer metal lamination being copper.

3. The invention defined in claim 1 characterized by said liner being formed of two axially aligned portions having adjacent ends detachably connectable, the inner lamination extending beyond the outer lamination at one of said ends to provide a first axially projecting annular part, the outer lamination extending beyond the inner lamination at the other of said ends to provide a second axially projecting annular part, said axially projecting annular parts being telescopically engageable to provide a detachable connection between said portions intermediate the ends of the liner.

4. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled cylinder of metal of interrupted circumferential continuity; the invention herein described wherein the metal wall of said liner is of laminar structure and includes spaced inner and outer laminations of a tough wear-resistant and substantially non-magnetic metal of relatively low electrical conductivity, and an intermediate lamination of a softer metal of relatively high electrical and thermal conductivity in intimate contact with, and completely filling the space between, said inner and outer laminations together with a layer of thermal and electrical insulating material secured between said laminar lining and said coil.

5. The invention defined in claim 4 characterized by said inner and outer laminations being a high chrome and high nickel steel alloy, and said intermediate lamination being copper.

6. The invention defined in claim 4 characterized by said liner being formed of two axially aligned portions having adjacent ends detachably connected, one of said laminations projecting beyond the other two laminations at one of said ends to provide a first projecting annular part, said other two laminations projecting beyond said one lamination at the other of said ends to provide a second projecting annular part, said projecting annular parts being telescopically engageable to provide a detachable connection between said portions intermediate the ends of the liner.

7. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled cylinder of metal of interrupted circumferential continuity and having end portions which project beyond the ends of the coil; the invention herein described wherein the metal wall of said liner is of laminar structure and includes an inner lamination of a tough wear-resistant and substantially non-magnetic metal of relatively low electrical conductivity, an outer lamination of a softer metal of relatively high electrical and thermal conductivity in intimate thermal contact with the inner lamination, and a cooling conduit embracing at least one of said projecting end portions beyond the induction coil proper and in thermal contact with said outer lamination together with a layer of thermal and electrical insulating material secured between said laminar lining and said coil.

8. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled cylinder of metal of interrupted circumferential continuity and having end portions which project beyond the ends of the coil; the invention herein described wherein the metal wall of said liner is of laminar structure and includes spaced inner and outer laminations of a tough wear-resistant and substantially non-magnetic metal of relatively low thermal conductivity, an intermediate lamination of a softer metal of relatively high electrical and thermal conductivity in intimate contact with and completely filling the space between said inner and outer laminations, said intermediate lamination having an axial length greater than the axial length of said outer lamination whereby said intermediate lamination has an exposed annular area on at least one of said end portions, and a cooling conduit embracing said one end portion in intimate contact with said intermediate lamination in said exposed annular area beyond the induction coil proper.

9. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled cylinder of metal of interrupted circumferential continuity and having end portions which project beyond the ends of the coil; the invention herein described wherein the metal wall of said liner is a tough wear-resistant and substantially non-magnetic metal and is provided with a plurality of saw kerfs at spaced intervals about its periphery and extending axially inwardly from each end thereof, each of said kerfs having its inner end terminating at a point axially inwardly of said coil.

10. The invention defined in claim 1 characterized by said liner being provided with a plurality of saw kerfs at spaced intervals about its periphery and extending axially inwardly from each end thereof, each of said kerfs having its inner end terminating at a point axially inwardly of said coil.

11. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled tube of metal of interrupted peripheral continuity and having end portions which project beyond the ends of the coil; the invention herein described wherein the metal wall of said tubular liner comprises a tough wear-resistant and substantially non-magnetic metal provided at least at one of the projecting ends thereof with a plurality of slots at spaced intervals about its periphery, said slots extending inwardly from the end of the tube and each slot having its inner end terminating at a point inwardly from the respective end of said coil.

12. In an electrical induction coil for heating billets or the like comprising an electrical conductor in the form of a helical coil, and a liner for such coil comprising a thin-walled tube of metal of interrupted peripheral continuity; the invention herein described wherein the metal wall of said liner is of laminar structure and includes an inner lamination of a tough wear-resistant and substantially

non-magnetic metal, and an outer lamination of a softer more highly conductive metal positioned between said coil and said inner lamination and in intimate thermal contact with the said inner lamination, said liner being provided at least at one of its ends with a plurality of slots at spaced intervals about its periphery, said slots extending inwardly from such end of the liner and terminating at points located inwardly from the respective end of the coil.

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