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Fisher et al.

[11] **3,713,066**

[45] **Jan. 23, 1973**

[54] **INDUCTORS WITH STRAIN RELIEF LEADS AND METHODS OF MAKING THE SAME**

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[73] Assignee: **Kuhlman Electric Company,** Troy, Mich.

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[21] Appl. No.: **111,849**

[52] **U.S. Cl.**.....**336/192,** 29/602

[51] **Int. Cl.**.....**H01f 15/10**

[58] **Field of Search** 336/192; 29/602

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Primary Examiner—E. A. Goldberg
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[57] **ABSTRACT**

This invention relates to methods and apparatus for connecting coil leads to coil winding conductors and for protecting the winding conductors from damage due to strain placed on the lead conductors which are particularly well suited for use with transformers and the like utilizing soft wires such as aluminum. In an exemplary form of the invention, an insulation pad having an opening for entry of the lead conductor is folded about a connector which electrically connects the conductors. The ends of the folded pad are captured within the coil so that the fold and connector are positioned outside of the coil. Abutment of the connector on the pad at the fold provides an external strain relief. The external strain relief is supplemented by an internal strain relief provided by capturing an end portion of the lead conductor within the interior of the coil. The folded pad limits bending of the connector assembly so as to enhance the durability of the connection. Additional pads may be provided which surround the folded pad to further reinforce the connector assembly and to provide additional high voltage insulation. The lead connecting methods and constructions of this invention may be used for start, end or finish, and tap lead conductors.

24 Claims, 17 Drawing Figures

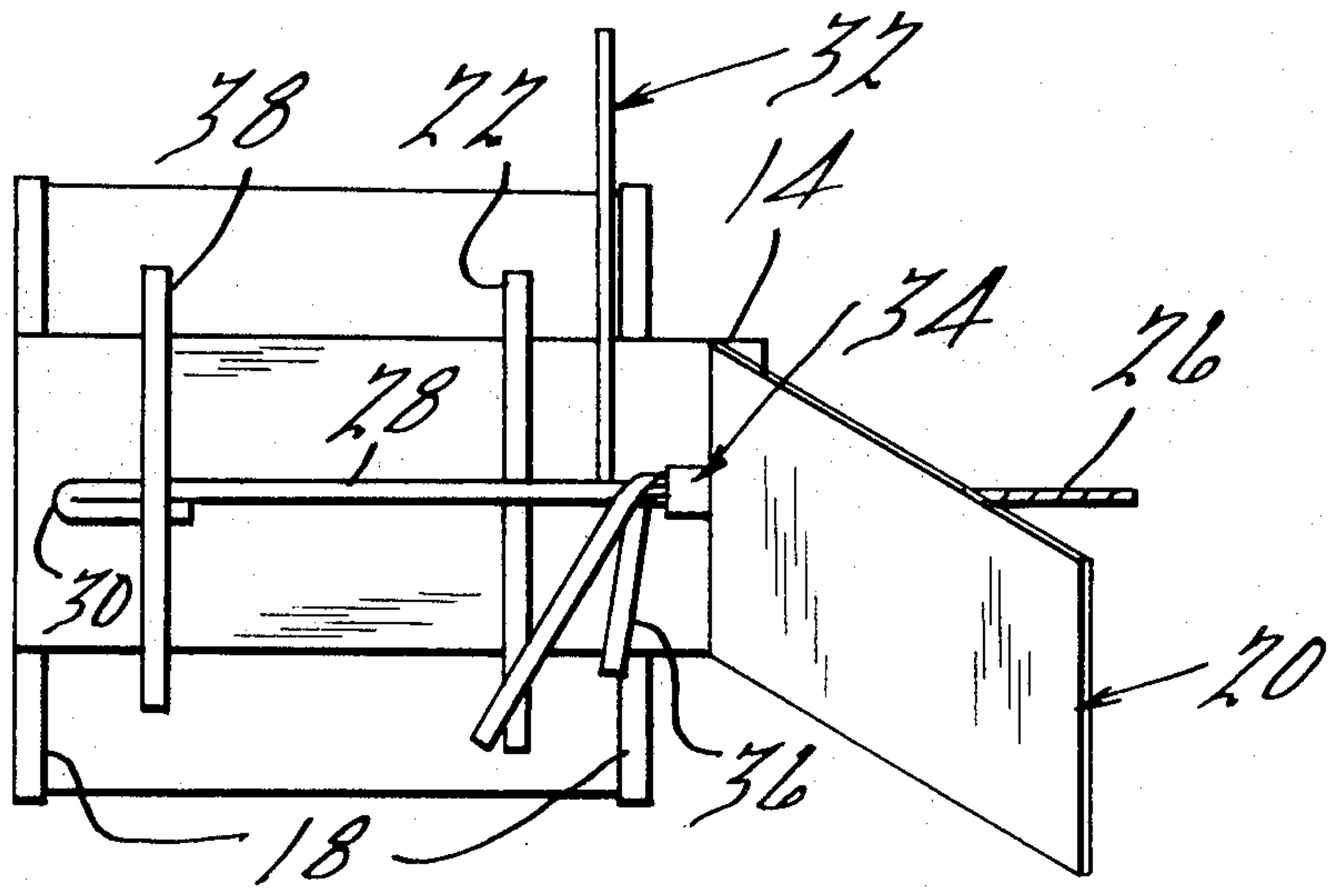

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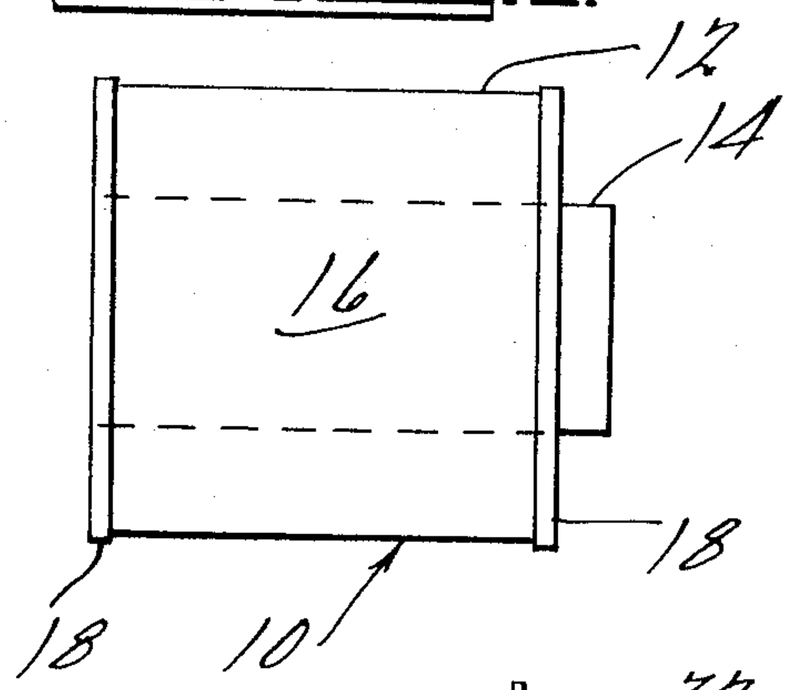
Fig. 1.



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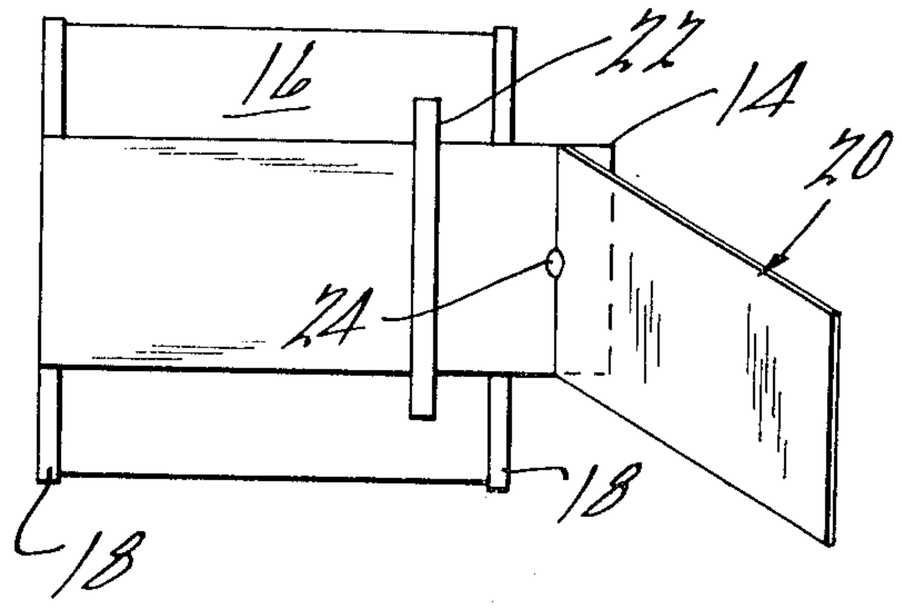


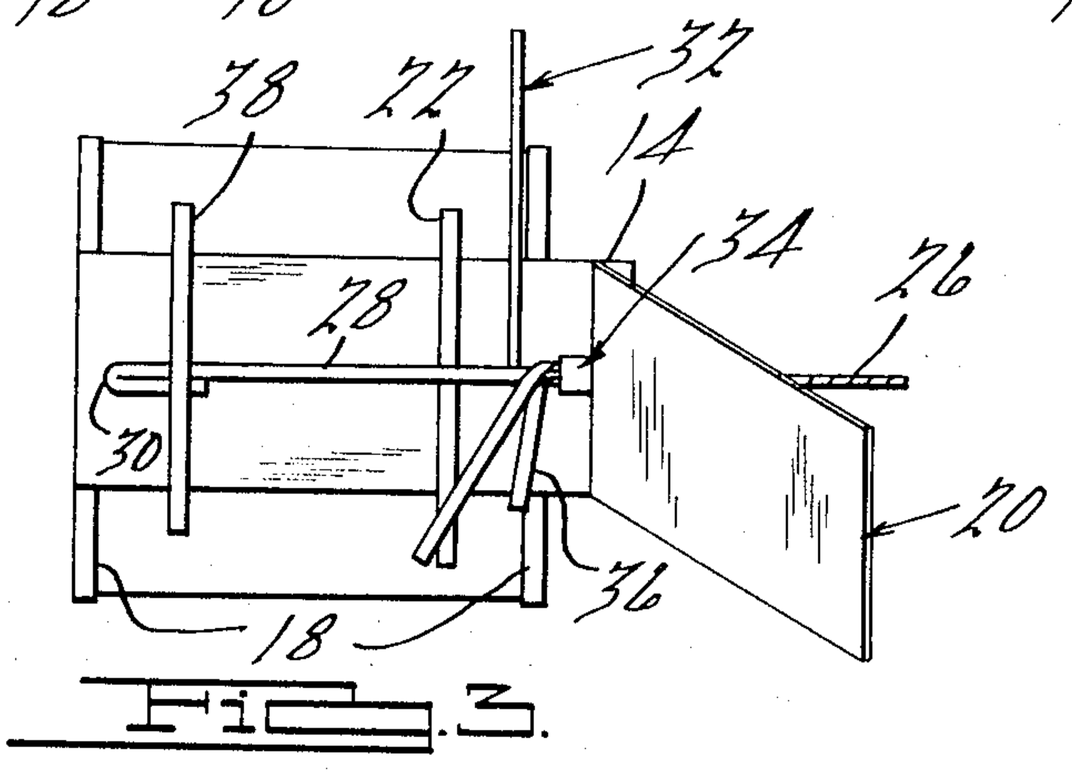
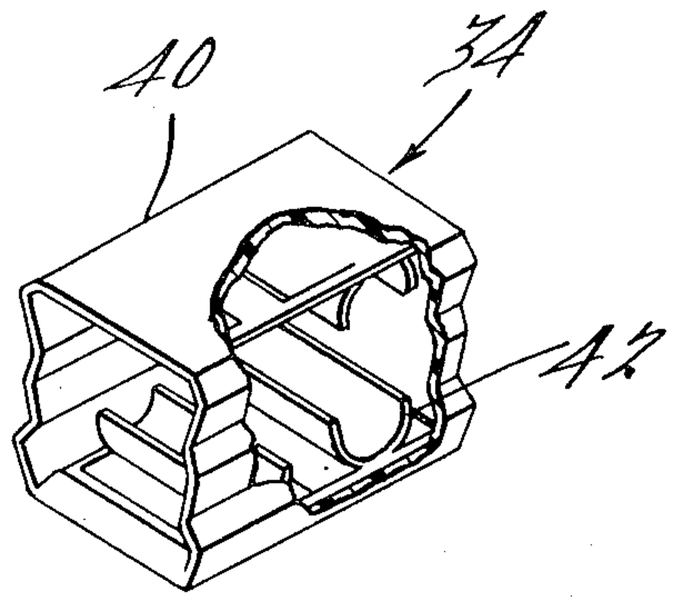


Fig. 3.



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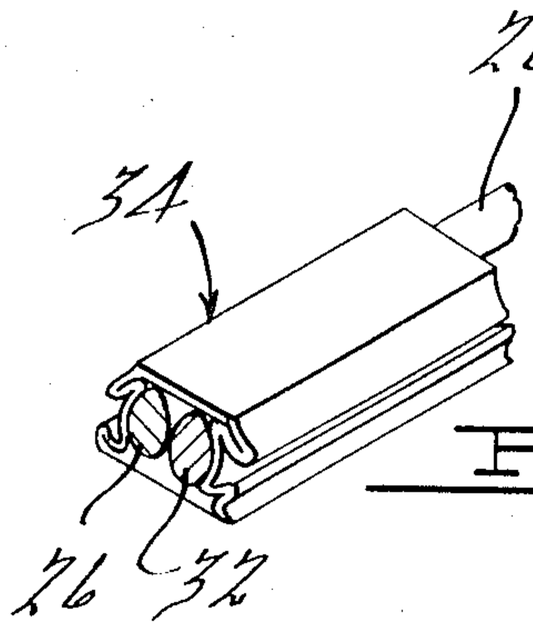

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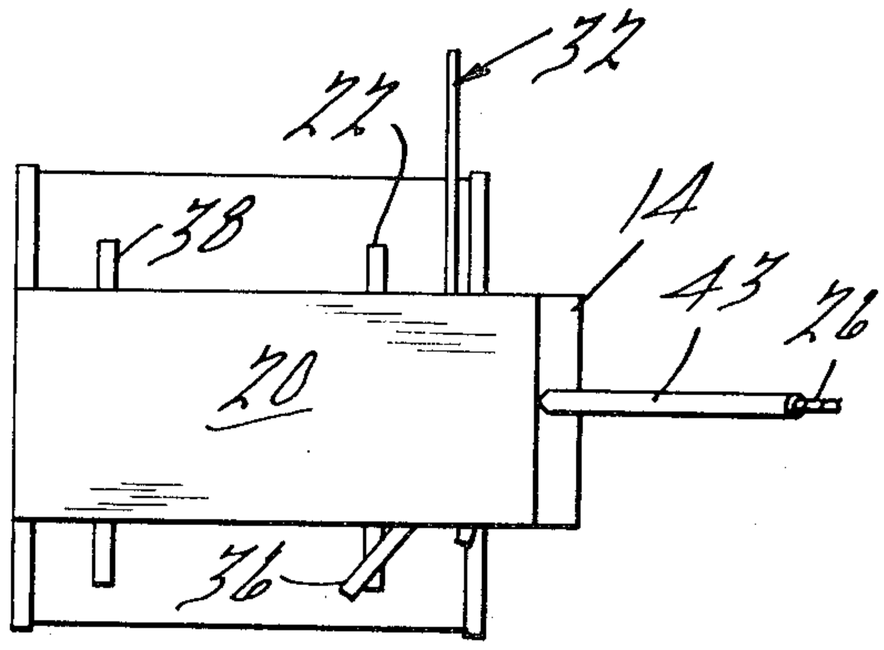

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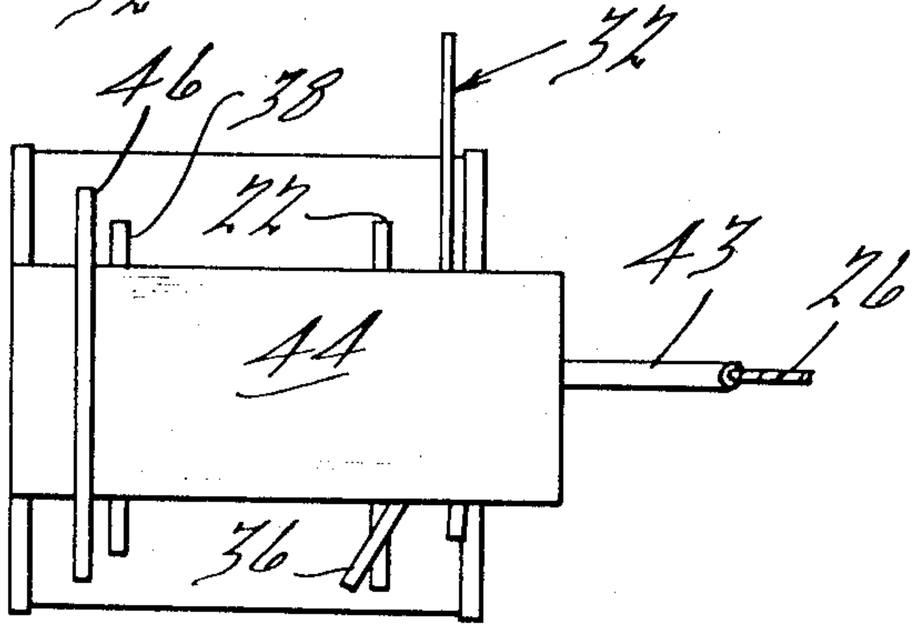

Fig. 7.

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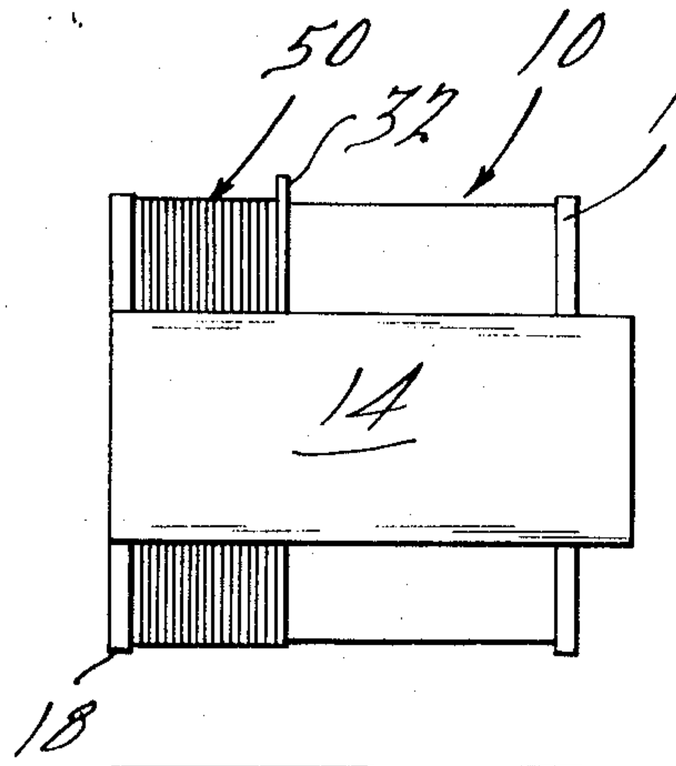

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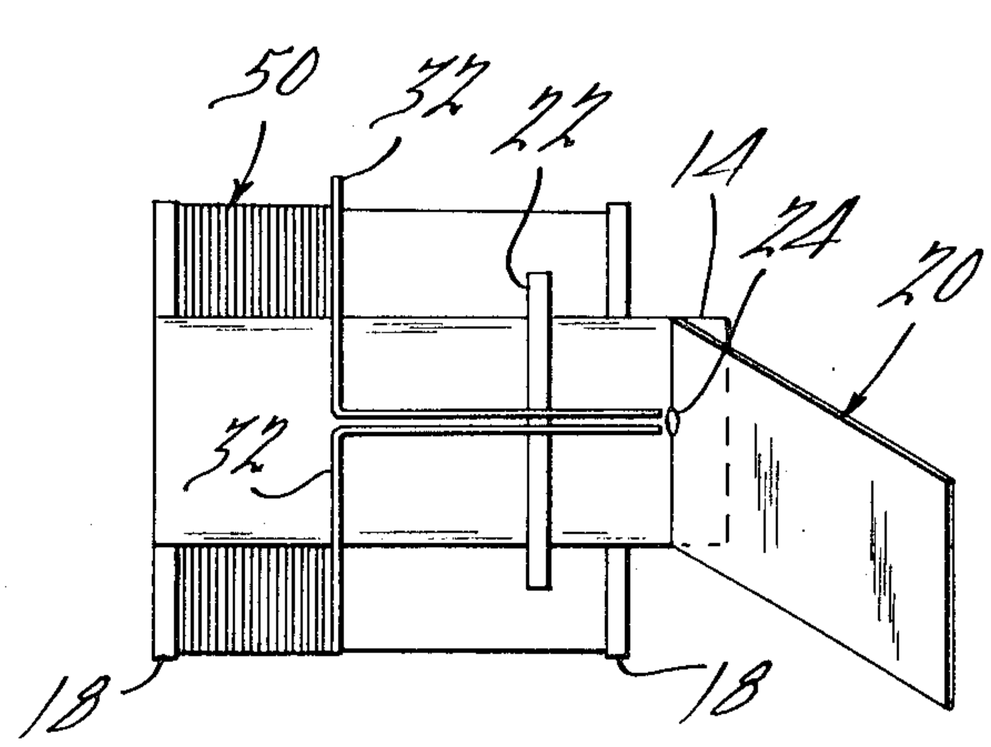

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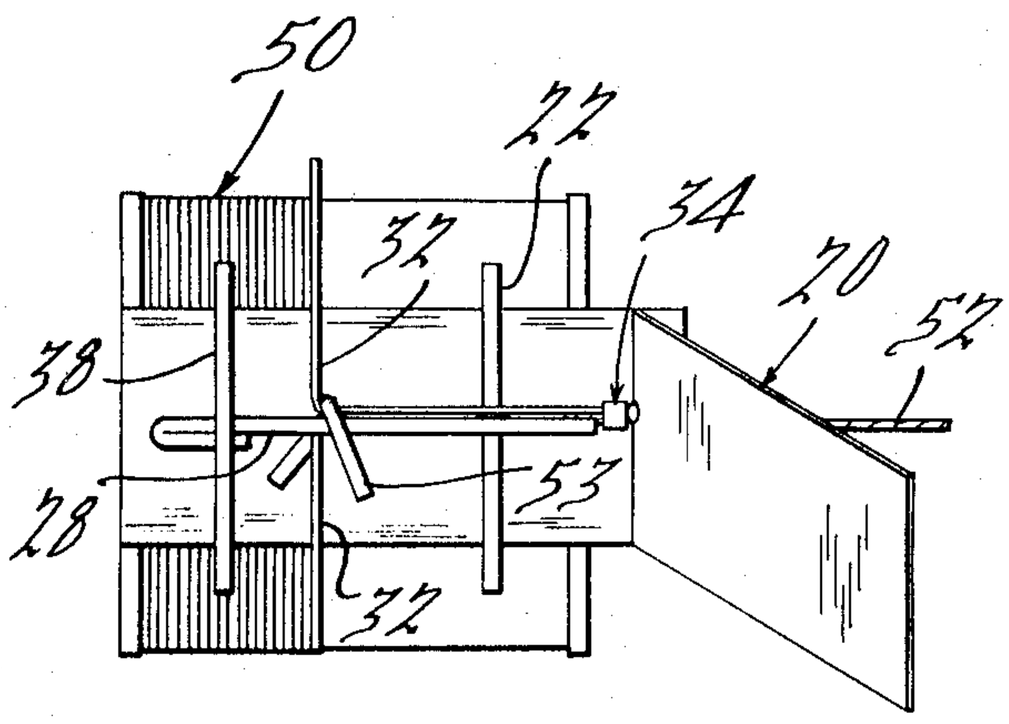
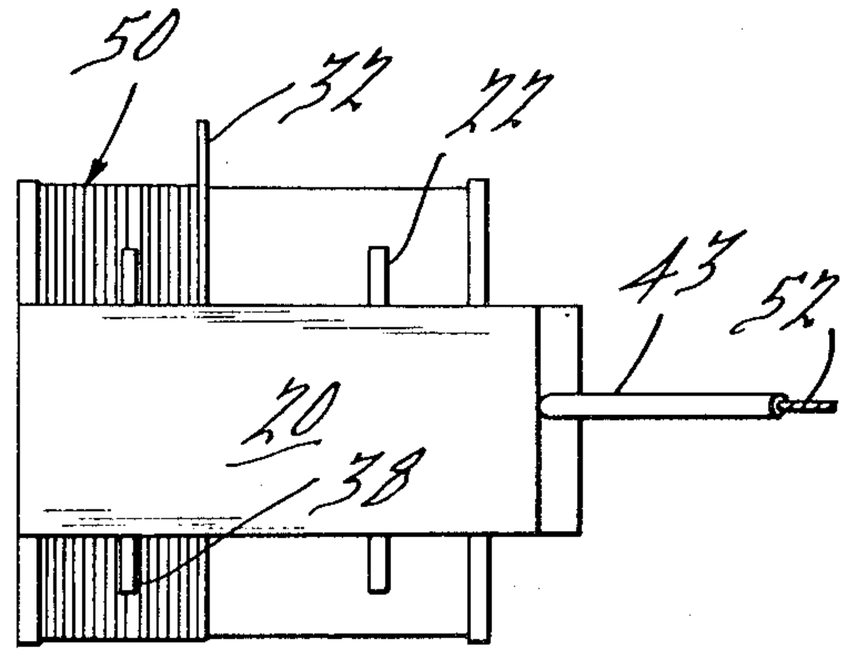


Fig. 10.



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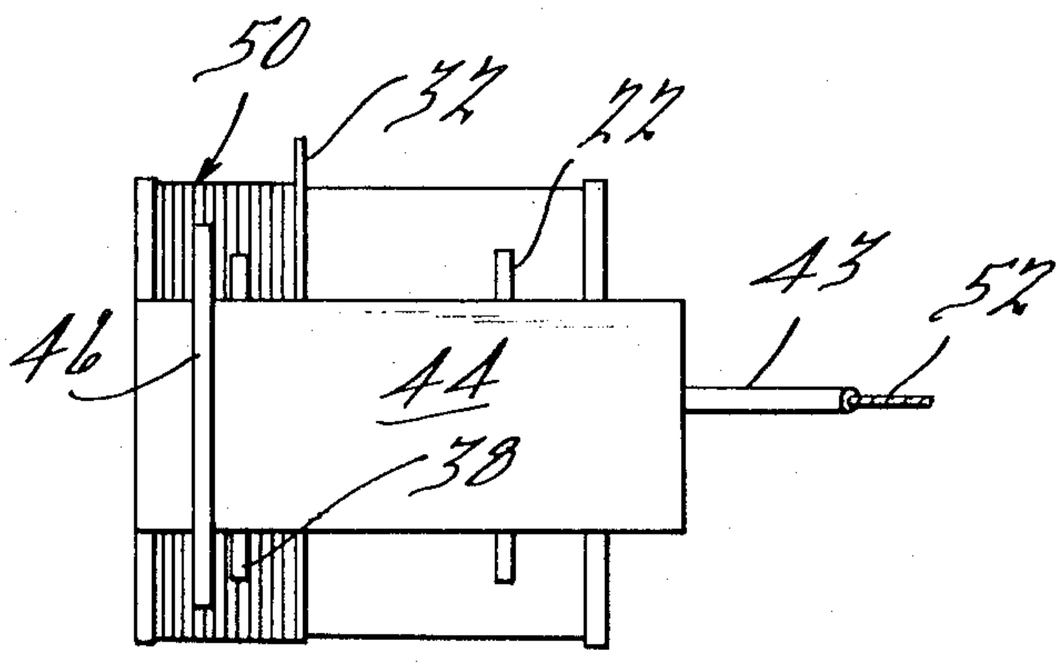

Fig. 12.

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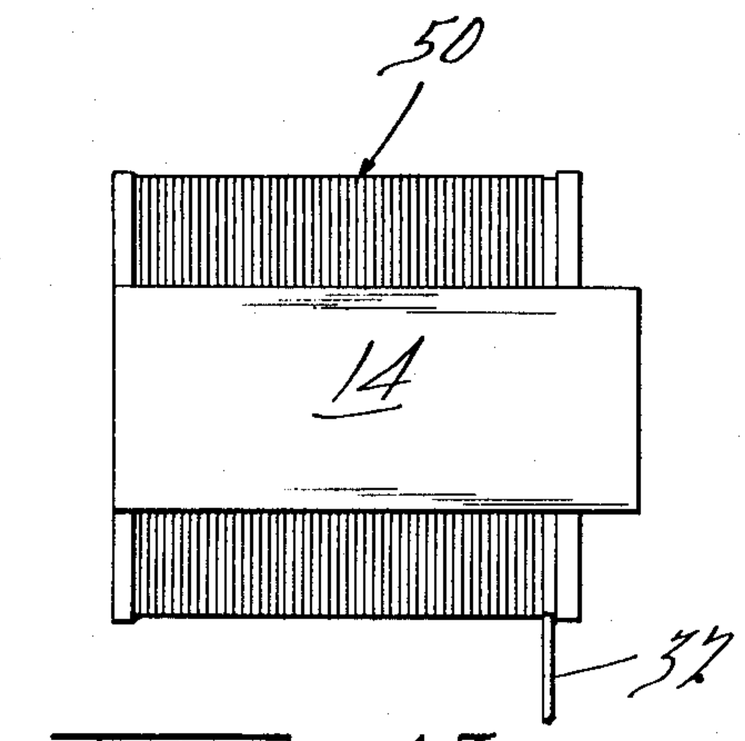

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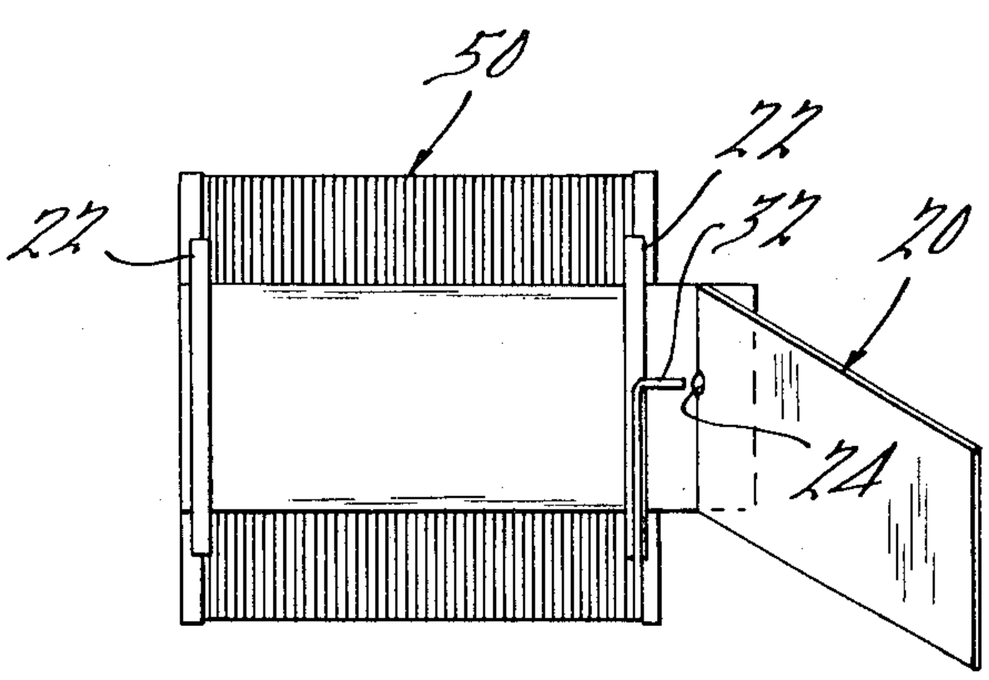
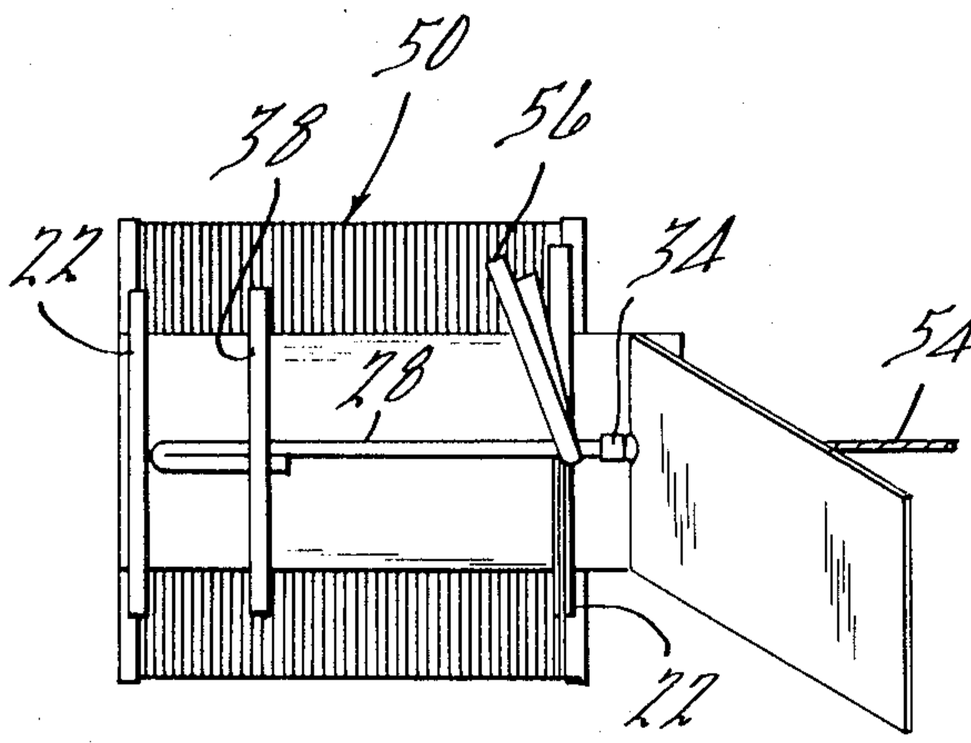


Fig. 14.



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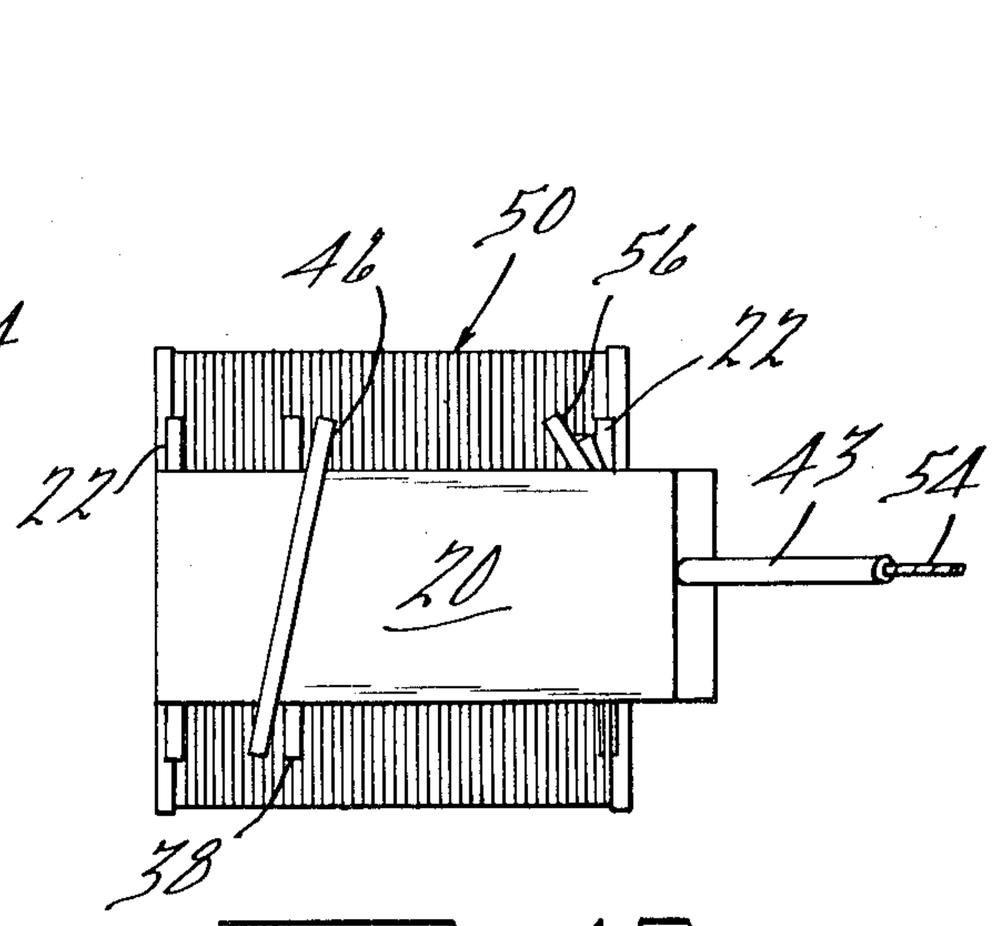

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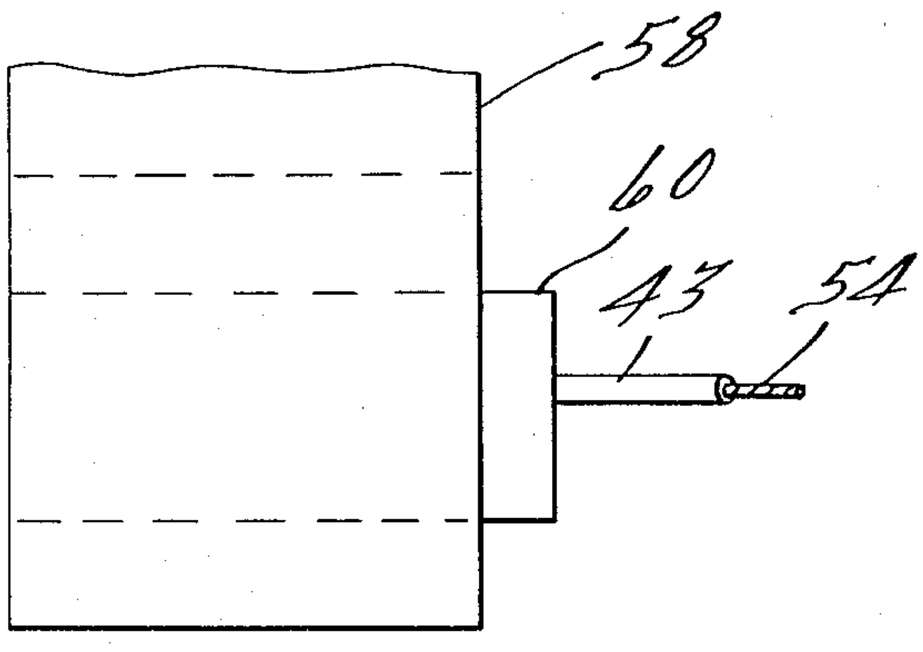

Fig. 17.

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INDUCTORS WITH STRAIN RELIEF LEADS AND METHODS OF MAKING THE SAME

SUMMARY OF THE INVENTION

In recent times, aluminum wire has been substituted for copper wire in transformers and the like due to the shortage of copper. Since aluminum is a relatively soft metal as compared to copper, it is prone to failure when subjected to strains imposed through lead conductors, i.e. conductors which extend externally of the coil for various input and output functions.

The present invention provides methods and apparatus for securing and electrically connecting the lead conductors to a winding conductor of the coil which provides effective strain relief to protect the winding conductor. In an exemplary construction according to this invention, the tail end of a lead conductor is captured by the coil to limit movement thereof so that any strain placed on the lead conductor is not transmitted to the winding conductor. The lead conductor may be connected to the winding conductor by a relatively enlarged connection or connector which is positioned outside of the coil body and which engages an insulation pad folded about the connection having its folded portions captured within the coil to provide an external strain relief. An opening in the folded pad is provided at the fold through which the lead conductor extends. It will be appreciated that the connection is supported in its exterior location by the surrounding folded pad so as to resist bending movement of the conductors at the connection. Resistance to bending movement at the connection may be increased by the provision of additional pads on each side of the folded pad. Furthermore, it can be seen that placement of the connection outside of the coil avoids a coil build which is uneven or of excessive dimension.

In view of the above description it can be seen that effective strain relief for the winding conductor is provided internally of the coil by the captured lead conductor tail and externally of the coil by the folded pad providing an engagement surface for the connector. In addition to these advantageous strain relief features, the methods and apparatus of this invention provide an efficient coil construction, since the connection is placed outside of the coil.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1–7** are illustrations of an exemplary method according to this invention for connecting a start lead conductor to a winding conductor;

FIGS. **8–12** are illustrations of an exemplary method according to this invention for connecting a tap lead conductor to a winding conductor; and

FIGS. **13–17** are illustrations of an exemplary method according to this invention for connecting an end or finish lead conductor to a winding conductor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. **1–7**, an exemplary method according to this invention is illustrated for connecting a start lead conductor to a winding conductor for a coil. As seen in FIG. **1**, a coil assembly **10** consists of a core having a barrier **12** wound on the core to partially encapsulate a plurality of insulating pads **14**, e.g. shellac coated paper

boards. For example, the pads **14** may be wound into the barrier beginning two turns from the initial layer of barrier **12**. As can be seen in the figure, the pads **14** extend outwardly of the main assembly **10**. The area in which the coil is to be wound is indicated at **16** which is bounded on each side by a barrier cuff **18**. With reference now to FIG. **2**, a folded shellac coated paper board **20** is positioned over the winding portion **16** and is secured with a tape strip **22** which may be a glass-filament tape with a Mylar backing to provide acceptable strength. As can be seen in FIG. **2**, the fold of the paper board **20** is positioned beyond the core structure **10** a distance less than the first pads **14**. By way of illustration, the first pads **14** may extend one inch from the core structure **10** whereas the folded pad **20** may extend five-eighths of an inch. The folded sheet **20** is provided with an opening **24** located at the fold of the sheet **20** which is of predetermined size to accommodate a lead conductor **26**. As seen in FIG. **3**, the lead conductor **26**, serving as a start lead, is inserted through the opening **24** in the folded pad **20** and is provided with a crepe tubing cover **28**. Preferably, the left end of the lead conductor **26** is folded at **30** to provide an interference fit after winding of the coil to resist pull out of the lead **26** from the winding, and additionally, to assure that the end of the lead conductor **26** will not extend out of the opposite side of the coil to cause creepage failure during operation. A coil conductor **32** is connected to the lead conductor **26**, for example, by an insulation piercing connector **34**. After the connection, a tape strip **36** may be positioned on the crepe tubing as shown and the lead conductor **26** and the connector **34** may be rotated approximately 360° to wind the winding conductor **32** around the crepe insulating tube **28**, the conductor **26**, and the tape **36** to further secure the winding conductor **32** to the lead conductor **26**. After the rolling operation, the splayed ends of the tape strip **36** are fastened to the assembly as shown in a direction opposite the winding direction to absorb some of the winding tension. An additional strip of tape **38** is used which overlies the folded lefthand portion of the crepe tubing covered conductor **26**.

The connector **34** may be of the type illustrated in FIG. **4** which has a generally tubular body **40** through which the lead conductor **26** and the winding conductor **32** extend, and a plurality of insulation piercing devices **42** therein. After the conductors **26** and **32** are positioned within the housing **40**, the connector **34** may be crimped as illustrated in FIG. **5** to electrically connect the conductors **26** and **32**. By way of example, the connectors **34** as illustrated in FIGS. **4** and **5** may be of the variety obtainable from the Thomas and Betts Company, Division of Thomas and Betts Corporation, Elizabeth, N.J., and specifically, may be a connector listed by the aforementioned company as catalog number 214420. The above connector may be used in combination with a 14 Awg. aluminum magnet wire and a 10 Awg. stranded lead conductor. It will be understood, however, that other connectors may be used, and in fact, an electrical connection may be made without the use of a prefabricated connector. As will be apparent hereinafter, it is desirable that the connection or connector assembly is of a size which is substantially larger than the opening **24** for the lead conductor **26** so that it cannot pass through the opening **24** under ex-

pected strain conditions to provide an external strain relief. For example, the opening **24** may be 0.094 for No. 14 and 18 Awg. conductor and the above specified connector.

After the operations illustrated in FIG. **3** are performed, the pad **20** is folded over the tail of the lead conductor **26** as illustrated in FIG. **6**, and a crepe insulation tube **43** is positioned on the external portion of the lead conductor **26** as illustrated in FIG. **6**. Additional pads **44** of shellac coated paper board are positioned on top of the folded pad **20** and are secured by an appropriate tape strip **46** as shown in FIG. **7**. Thereafter, the operation of winding the conductor **32** may be commenced.

After winding, the tail end of the lead conductor **26** and the ends of the folded pad **20** are captured within the coil by the pressure exerted by the winding of conductor **32**. The aluminum magnet wire **32** is strain relieved internally by the wound-in tail of the lead conductor **26**. In this regard, it can be seen that the lead conductor **26** passes directly through the connector **34** and is held in position to absorb strains imposed on the lead conductor **26** without transmission of the strains to the winding conductor **32**. Additionally, the winding conductor is strain relieved externally by the partial encapsulation of the connector **34** within the folded pad **20**. The connector **34** is allowed to abut the fold in the folded pad **20** also to prevent any strains placed on the lead conductor **26** from being transmitted to the winding conductor **32**. It can also be seen that the connector **34** is placed outside of the coil so as to avoid uneven build of the coil. As a still additional advantage, the conductors at the connector **34** are protected from damage through flexing since the connector **34** is intermediate relatively rigid pads including the folded pad **20**, the lower pads **14** and the upper pads **44**. It will be appreciated further that the coils are ordinarily wound on cylindrical forms, and accordingly, the pads will be bowed in accordance with the form to provide additional strength and resistance to flexing at the connector **34**.

Since like components are used in the following methods of FIGS. **8–12** and FIGS. **13–17**, like numbers will be used to designate like components. In FIGS. **8–12**, a method is illustrated for connecting a tap lead conductor to the winding conductor after the winding **40** is partially completed. With reference now to FIG. **8**, it can be seen that two base pads **14** are laid over the partially completed coil assembly **10** with the pads **14** projecting from the coil assembly **10**. Thereafter, a folded pad **20** having an opening **24** at the fold is positioned over the pads **14** with the fold projecting from the coil assembly **10** and is secured in position by a tape strip **22**. Next, the winding conductor **32** is provided with a 90° bend as shown and is extended to the right to have a portion positioned externally of the coil opening **10** adjacent the opening **24** in the folded pad **20**. It may be terminated at that point as shown. The winding conductor **32** returned to the left and provided with another 90° bend so as to be aligned with the last winding of the coil so that the winding operation may be continued after the lead conductor is connected and secured. A tap lead conductor **52** is inserted through the opening **24** in the folded pad **20** and is fastened to the two ends of the winding conductor **32** by a connector **34**. As can be seen in FIG. **10**, the tap lead conductor **52** has a tail extending substantially along the entire width of the coil assembly **10** which has been provided with an insulating crepe tube **28** and has been folded at its end portion as previously described. The tail of the tap conductor **52** may be secured by a tape **38** and the extensions of the winding conductors **32** may be secured by a tape **53** which has splayed ends affixed to the folded pad **20** generally in a direction opposite the direction in which strain due to continued winding is imposed. After the above steps, the folded pad **20** is folded over the connector **34** and the tail of the tap lead conductor **52** as illustrated in FIG. **11**. A crepe tube **43** is inserted onto the tap lead conductor **52** and additional pads **44** are placed over the folded pad **20**, and are secured by a tape **46**. After this operation, the winding operation is continued so as to encapsulate the above structure to provide a strain relief for the winding conductor **32** by virtue of the captured tail of the tap conductor **52** and the capture of the connector **34** by the folded pad **20**.

In FIGS. **13–17**, a method along the lines of the above methods is disclosed for connecting the last turn of the winding **50** to a lead conductor. According to this method a plurality of pads **14** and an overlying folded pad are secured by a pair of tape strips **22**. The end of the winding conductor **32** is extended over the folded pad **20** and a right angle is formed at its end so that its end is adjacent the opening **24** in the folded pad **20** as illustrated in FIG. **14**. The final lead conductor **54** is inserted through the opening **24** so that a substantial portion of its tail extends over the coil assembly. The tail is provided with a crepe tube **28** and folded as shown in FIG. **15**. The end of the winding conductor **32** and the lead conductor **54** are connected by a connector **34** in the manner previously described. Thereafter, a tape **56** is placed over the winding conductor **32** and the lead conductor **54** and the lead conductor **54** and the connector **34** are rotated approximately 360° to wrap the winding conductor **34** about the crepe covered lead conductor **54** and the tape **56**. The splayed ends of the tape **56** are then secured to the assembly **10** generally in a direction opposite the direction of the winding conductor **32** so as to oppose the winding strain thereon. A tape **38** is laid over the fold tail portion of the end lead conductor **54** to secure the tail of the lead conductor **54**. Finally, the pad **20** is folded as illustrated in FIG. **16** and is secured in the folded position by a tape **46**. A crepe insulating tube **43** is inserted over the conductor **54** as shown in FIG. **16**. Thereafter, an outer barrier **58** is wrapped one turn about the assembly and several pads of shellac coated paper board **60** are placed on the barrier **58** as shown in FIG. **17**, after which the winding of the barrier **58** is completed.

The various pads **14**, **44** and **60** are determined in number and size in accordance with established engineering considerations. For example, the thickness and width of pads are established in part to prevent the winding from cutting through the pads to prevent electrical puncture, and to allow some misalignment of the tail of the lead conductor without shorting. The length is normally established in accordance with coil width to provide even coil build so that the paper and winding conductors will track evenly while being wound. More

pad layers are used under the connection **34** for the start lead conductor than over the connection **34** for since the start lead is a high voltage lead which is immediately above the low/high barrier, and consequently, the puncture and creepage voltage stress is quite severe at that locality, while the voltage stress from the start lead conductor to the next upper layer of the primary winding is considerably less.

In view of the above description of exemplary methods according to this invention, it can now be seen that the winding conductor is strain relieved both internally of the coil and externally of the coil by a combination of a captured tail of the lead conductor and a folded pad restraining the connector. Although these are most effectively used in combination, each of these features may be used individually. In addition to the excellent capture advantages of this invention, excessive coil build up at connection locations is avoided since the connectors are placed outside of the coil.

While it will be apparent that the teachings herein are well calculated to each one skilled in the art, the method of making preferred embodiments of this invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope of meaning of the subjoined claims.

What is claimed is:

1. An apparatus comprising:
a coil body;
coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil; and
a lead conductor connected to said external portion of said winding conductor having one end extending and terminating internally of said coil means and including a folded portion externally of said coil so as to be captured by an interference fit between said folded portion and the adjacent portion of said coil means to protect said winding conductor from strains imposed on said lead conductor.

2. An apparatus according to claim **1** further including connector means providing said connection between said winding conductor and said lead conductor.

3. An apparatus according to claim **1** wherein said lead conductor is a start conductor for said coil means, said portion of said winding conductor extending externally of said coil is proximate a beginning of said winding conductor, and at least part of one layer of said winding conductor overlies said one end of said lead conductor to capture said one end.

4. An apparatus according to claim **1** wherein: said lead conductor is a tap lead conductor, an intermediate portion of said winding conductor extends externally of said coil and at least a part of one layer of said winding conductor overlies said one end of said lead conductor to capture said one end.

5. An apparatus according to claim **1** wherein: said lead conductor is an end lead conductor, said portion of said winding conductor extending externally of said coil is proximate an end of said winding conductor, and wherein at least part of one layer of said coil means which is not a layer of said winding conductor overlies said one end of said lead conductor to capture said one end.

6. An apparatus comprising:
a coil body;
coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil;
a lead conductor connected to said external portion of said winding conductor having one end extending internally of said coil means so as to be captured thereby in a manner to protect said winding conductor from strains imposed on said lead conductor; and
insulation pad means extending externally of said coil on each side of said connection of said lead conductor and said external portion of said winding conductor for supporting said connection and extending internally of said coil so as to be captured thereby.

7. An apparatus comprising:
a coil body;
coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil;
a lead conductor connected to said external portion of said winding conductor having one end extending internally of said coil means so as to be captured thereby in a manner to protect said winding conductor from strains imposed on said lead conductor;
connector means providing said connection between said winding conductor and said lead conductor; and
insulation pad means extending externally of said coil on each side of said connector for supporting said connector and extending internally of said coil so as to be captured thereby.

8. An apparatus comprising:
a coil body;
coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil;
a lead conductor connected to said external portion of said winding conductor; and
insulating pad means extending internally of said coil to be captured thereby and extending externally of said coil for supporting said connection between said winding conductor and said lead conductor and for restraining said connection in a manner to protect said winding conductor from strains imposed on said lead conductor.

9. An apparatus according to claim **8** further including connector means at said connection providing said connection between said winding conductor and said lead conductor.

10. An apparatus according to claim **8** wherein: said insulating pad means is a member having a fold exterior of said coil with an opening through said pad member at said fold, said lead conductor extends through said opening to the interior of said folded pad, said connection is relatively enlarged with respect to said lead conductor for abutting the interior of said folded pad at

said opening so as to be captured thereby in a manner to protect said winding conductor from strains imposed on said lead conductor.

11. An apparatus according to claim **10** further including connector means providing said connection between said winding conductor and said lead conductor which is relatively enlarged with respect to said lead conductor and which abuts said pad member at said opening.

12. An apparatus according to claim **10** further including additional pad means on each side of said folded pad for providing additional support for said connection between said winding conductor and said lead conductor.

13. An apparatus according to claim **8** wherein: said insulating pad means extends externally of said coil on each side of said connection for supporting said connection.

14. An apparatus according to claim **8** wherein: said insulating pad means including a portion adapted to be abutted by said connection for providing said restraint of said connection.

15. An apparatus comprising:

a coil body;

coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil;

a lead conductor connected to said external portion of said winding conductor having one end extending internally of said coil means so as to be captured thereby; and

insulating pad means extending internally of said coil to be captured thereby and extending externally of said coil for supporting said connection between said winding conductor and said lead conductor and for restraining said connection;

said capture of said one end of said lead conductor and said connection restraint being adapted to protect said winding conductor from strains imposed on said lead conductor.

16. An apparatus according to claim **15** further including connector means providing said connection between said winding conductor and said lead conductor.

17. An apparatus according to claim **15** wherein insulated pad means extends externally of said coil on each side of said connection for supporting said connection.

18. An apparatus according to claim **15** wherein insulation pad means including a portion adapted to be abutted by said connection for providing said restraint and said connection.

19. An apparatus comprising:

a coil body;

coil means wound on said body including at least one layer of a winding conductor, at least one portion of said winding conductor extending externally of said coil; and

a lead conductor connected to said external portion of said winding conductor having means associated therewith extending externally of said coil means so as to be captured thereby and restraining said connection in a manner to protect said winding conductor from strains imparted on said lead conductor.

20. An apparatus according to claim **19** wherein said associated means is a portion of said lead conductor.

21. An apparatus according to claim **19** wherein said associated means includes a restraining member other than a portion of said lead conductor.

22. A method for connecting a lead conductor to a winding conductor for a coil comprising the steps of;

extending at least one portion of said winding conductor externally of said coil;

connecting an external portion of said winding conductor to said lead conductor;

positioning a portion of said lead conductor internally of said coil so as to be captured thereby;

fixing an insulation pad means to said coil; and

restraining said connection with said insulation pad;

said capture of said lead conductor and said connection restrain being accomplished in a manner to protect said winding conductor from strains imposed on said lead conductor.

23. A method for connecting a lead conductor to a winding conductor for a coil comprising the steps of:

extending at least one portion of said winding conductor externally of said coil;

connecting an external portion of said winding conductor to said lead conductor;

folding an end of said lead conductor; and

positioning said folded end of said lead conductor internally of said coil so as to be captured thereby in a manner to protect said winding conductor from strains imposed on said lead conductor.

24. A method for connecting a lead conductor to a winding conductor for a coil comprising the steps of:

extending at least one portion of said winding conductor externally of said coil;

connecting an external portion of said winding conductor to said lead conductor; and

fixing an insulation pad means to said coil; and

restraining said connection with said insulation pad in a manner to protect said winding conductor from strains imposed on said lead conductor.

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