

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

[75] Inventors: **John L. Fisher**, Lexington; **Alan L. Wilks**, Versailles, both of Ky.

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

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

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

[56] **References Cited**

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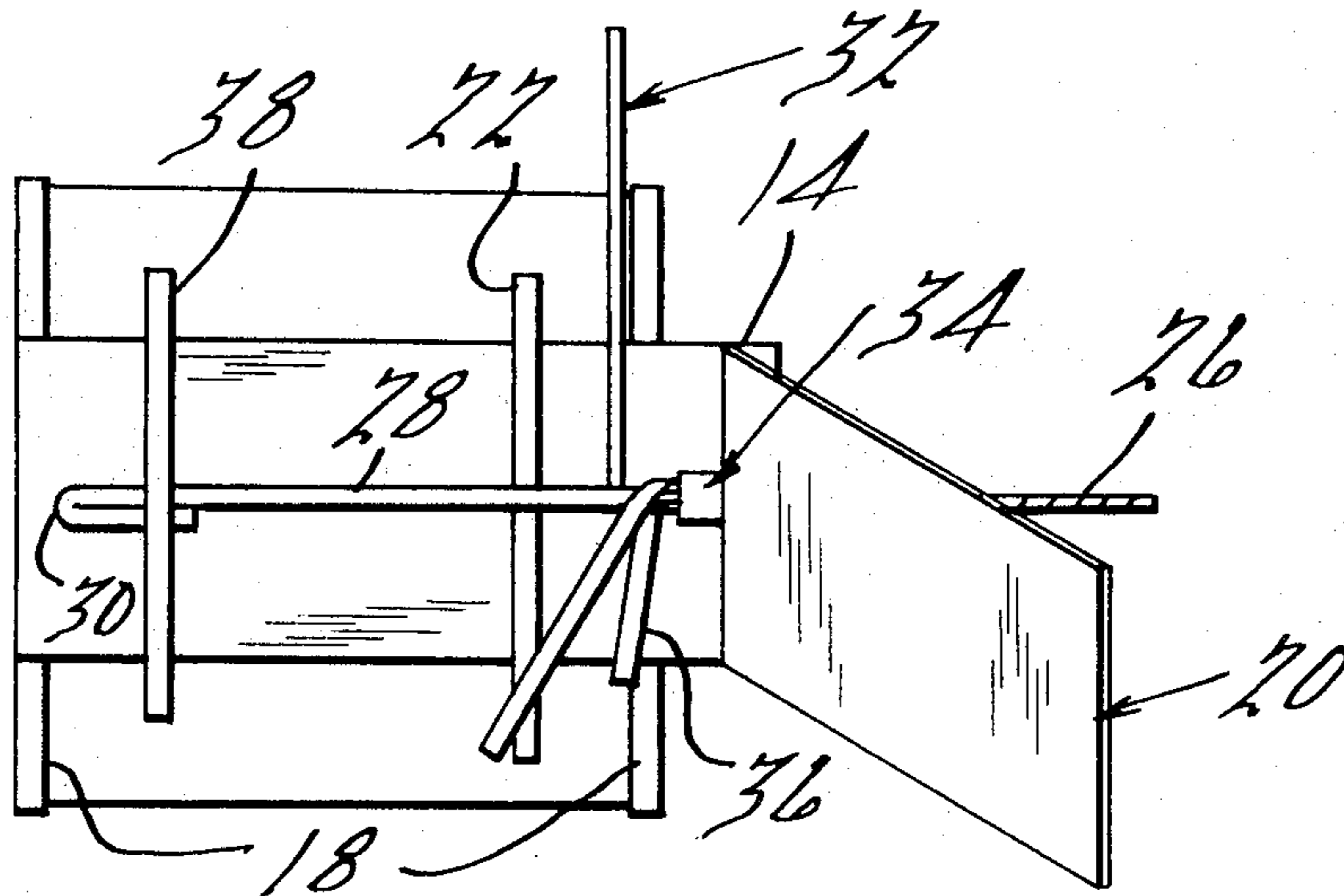
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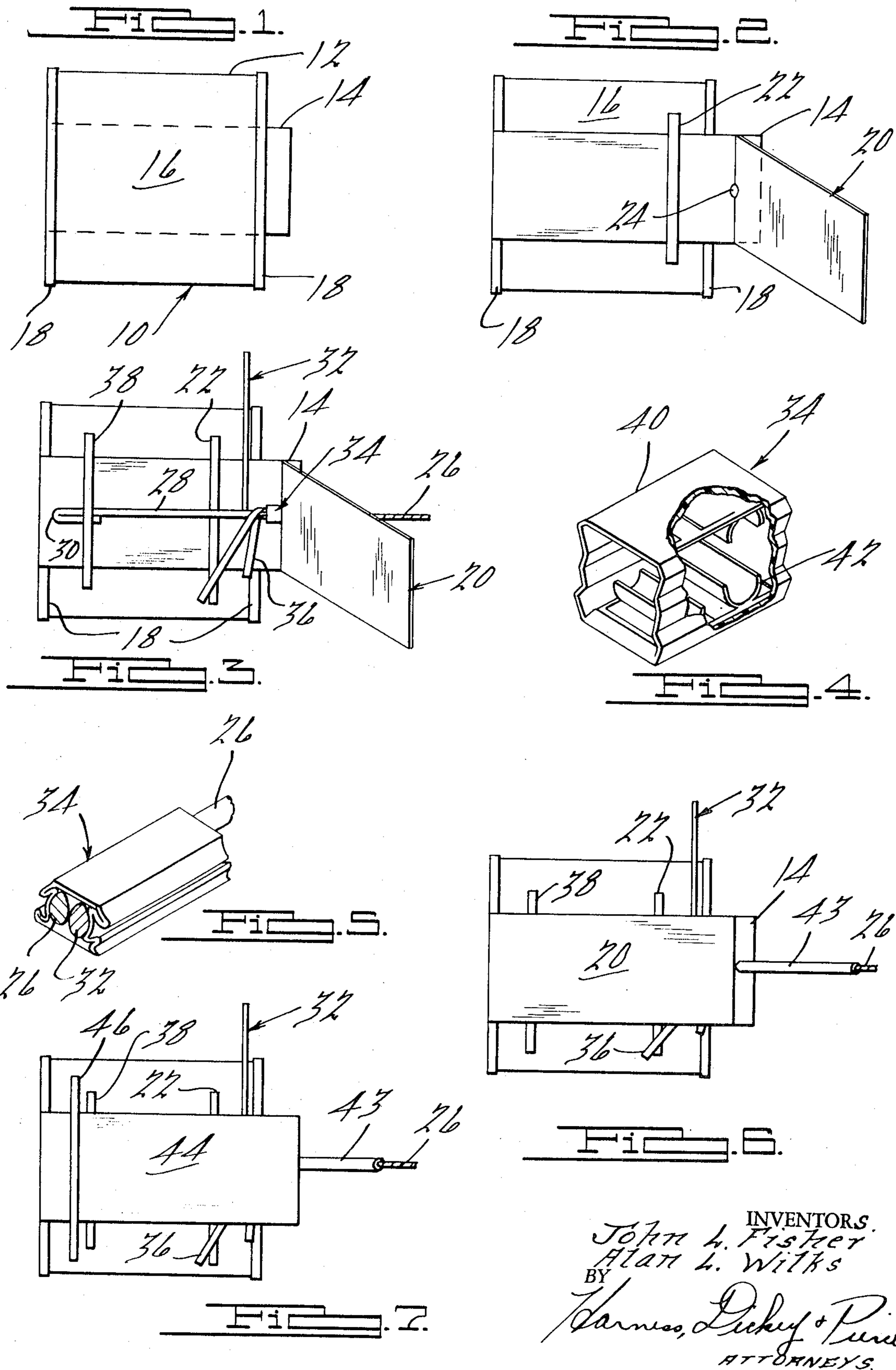
Primary Examiner—E. A. Goldberg
Attorney—Harness, Dickey & Pierce

[57] **ABSTRACT**

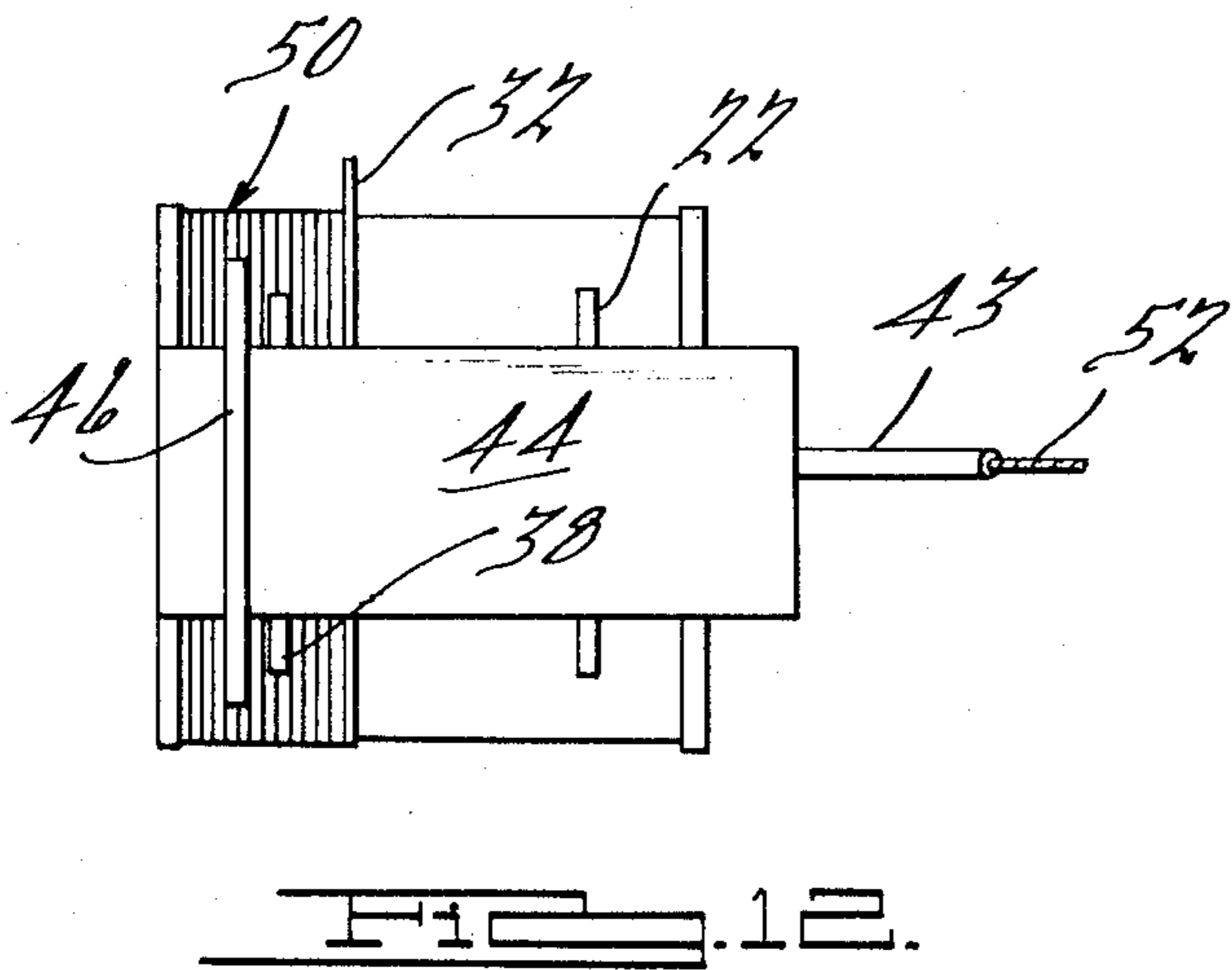
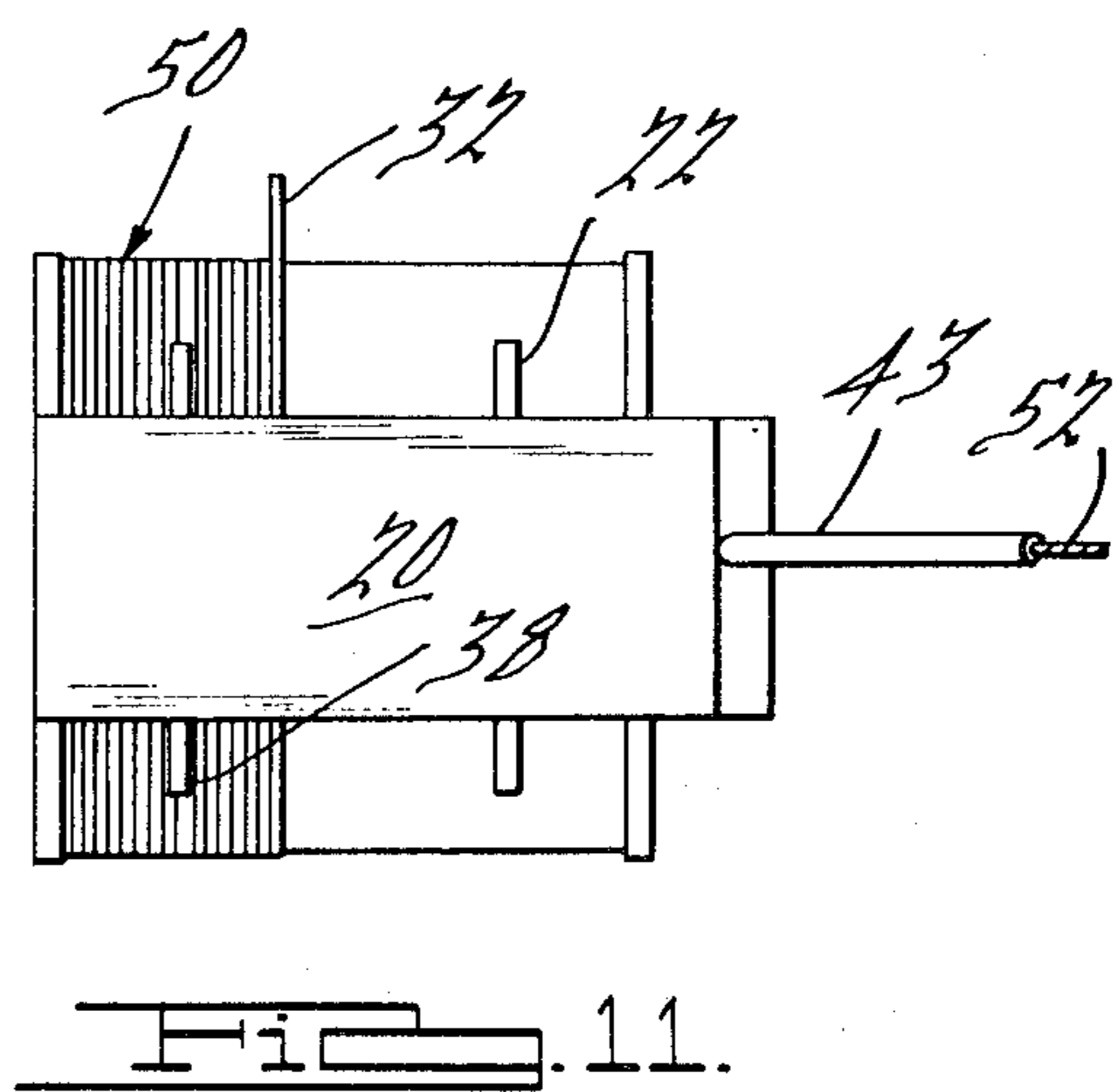
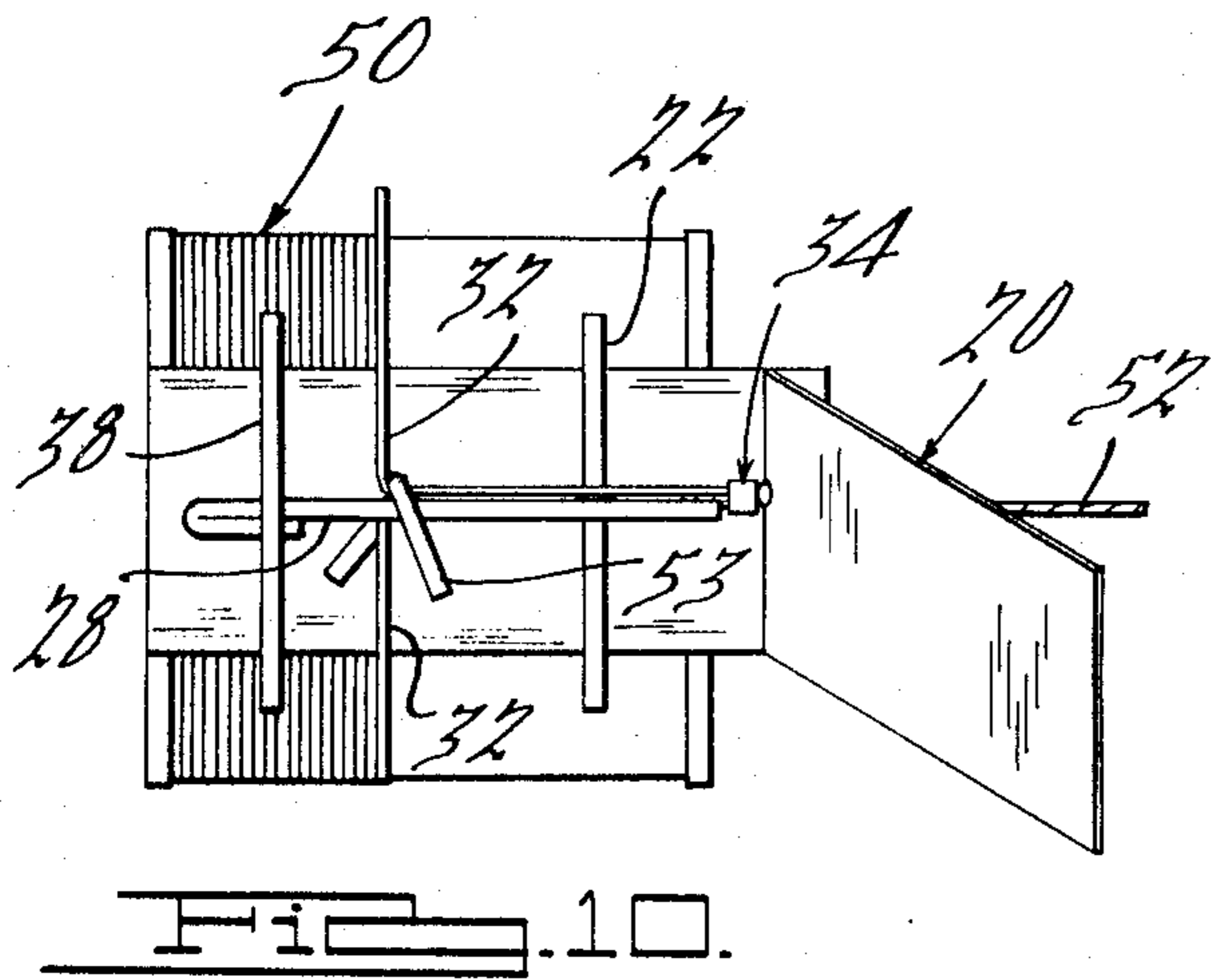
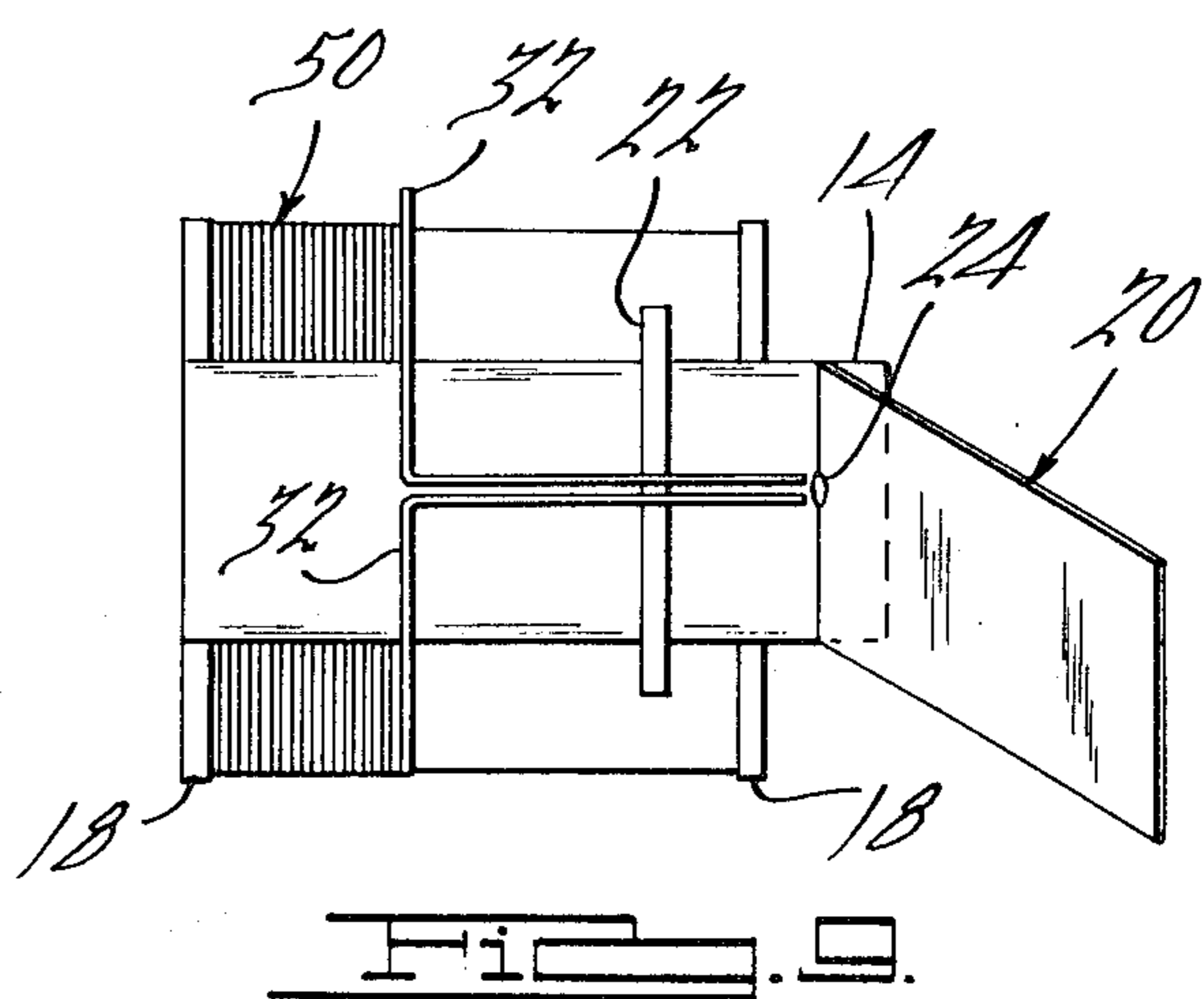
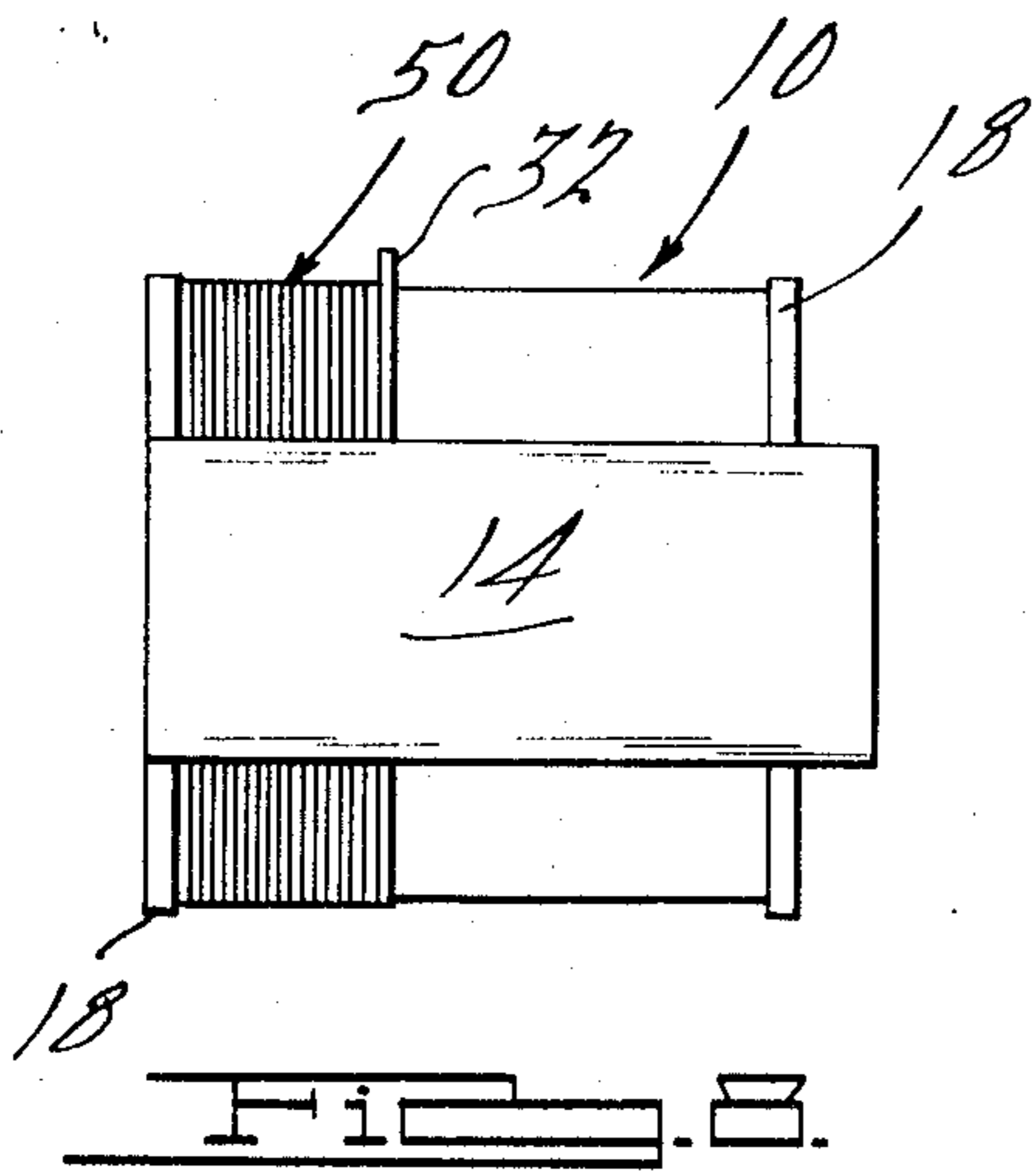
This invention relates to methods and apparatus for connecting coil leads to coil winding conductors and for protecting the winding conductors from damage due to strain placed on the lead conductors which are particularly well suited for use with transformers and the like utilizing soft wires such as 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





INVENTORS
John H. Fisher
Alan H. Wilks
BY
Harnes, Dickey & Piers
ATTORNEYS.



INVENTORS
John H. Fisher
Alan H. Wilks
BY
Harness, Dickey & Purie
ATTORNEYS.

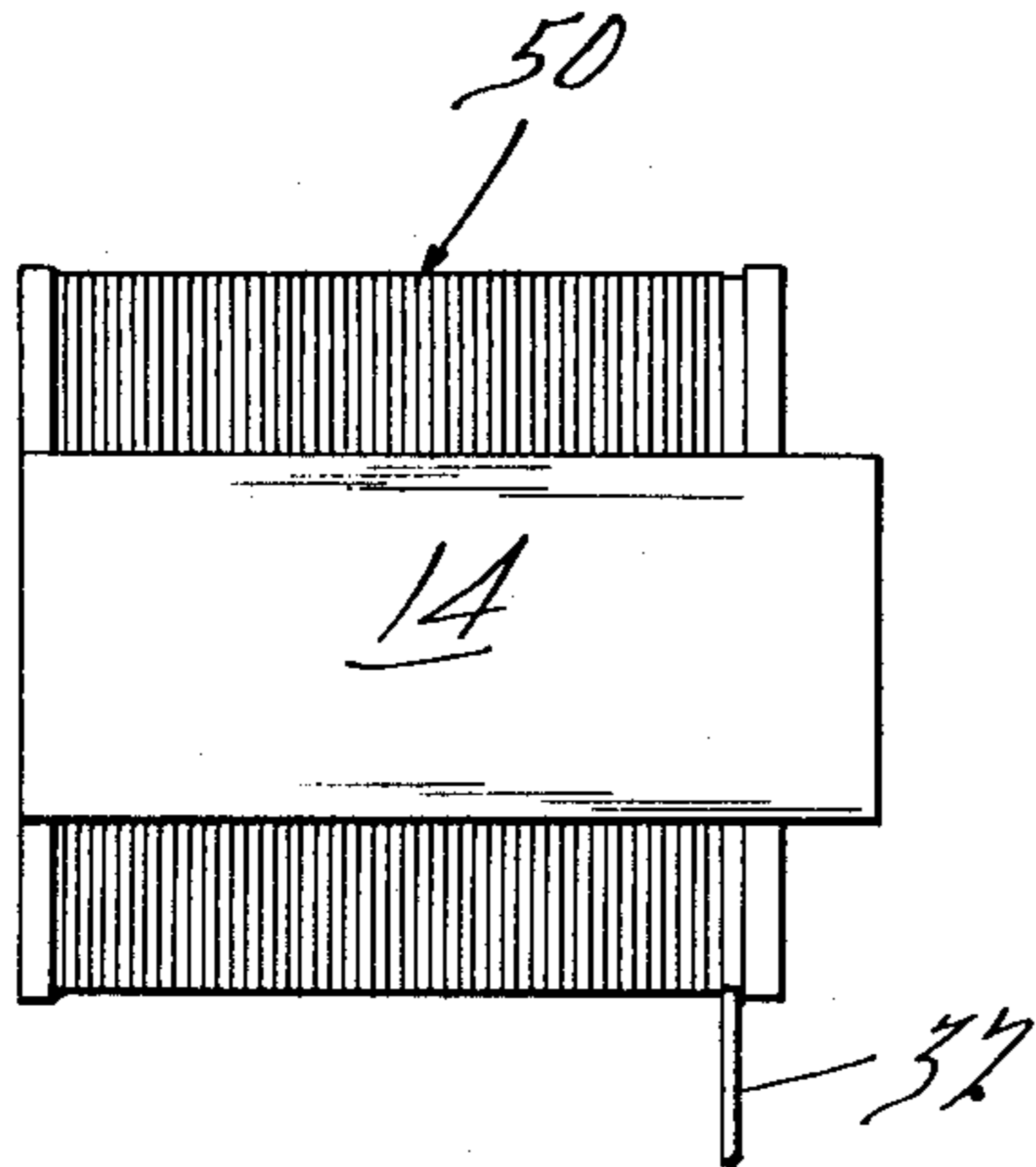


FIG. 13.

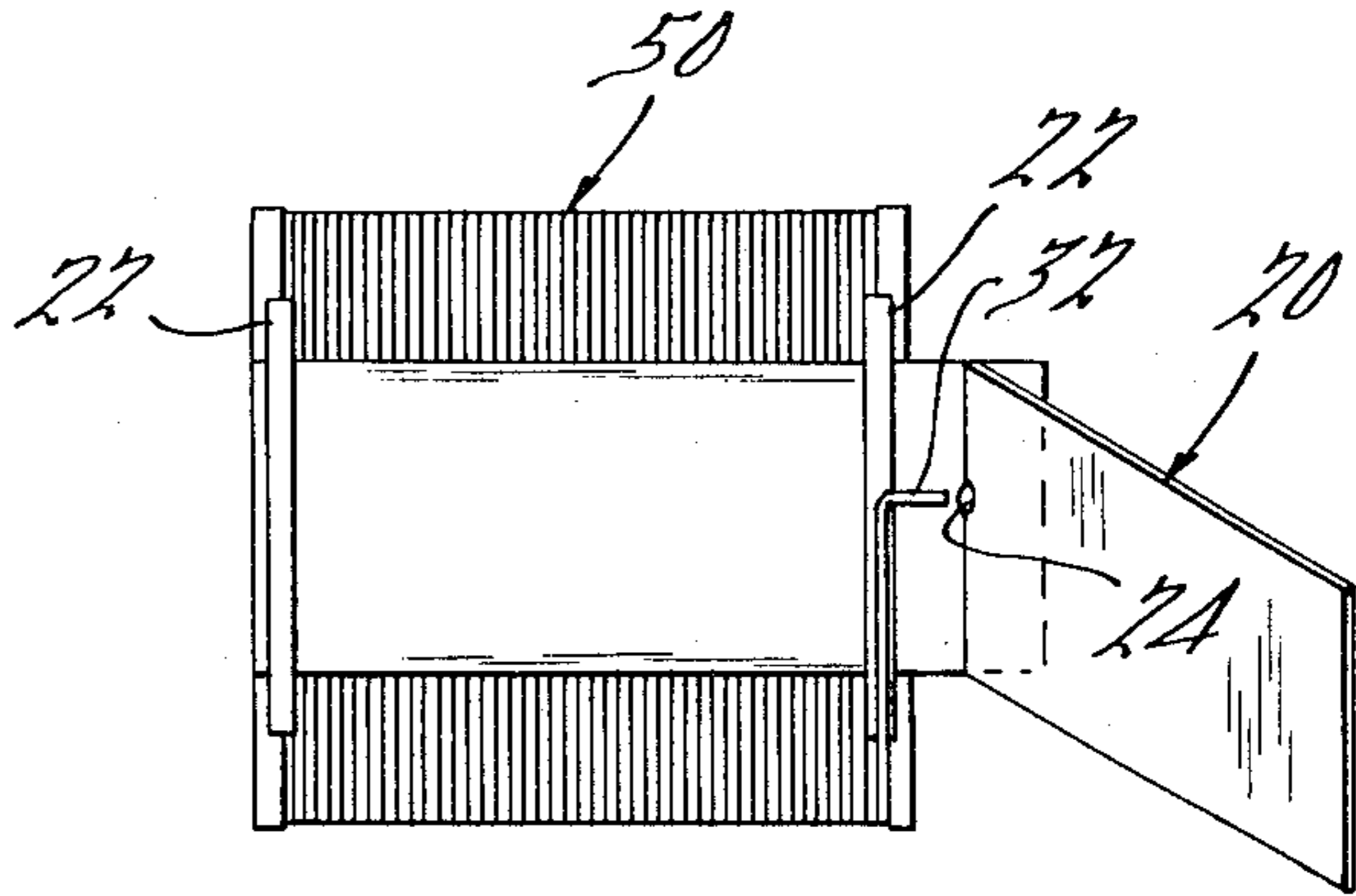


FIG. 14.

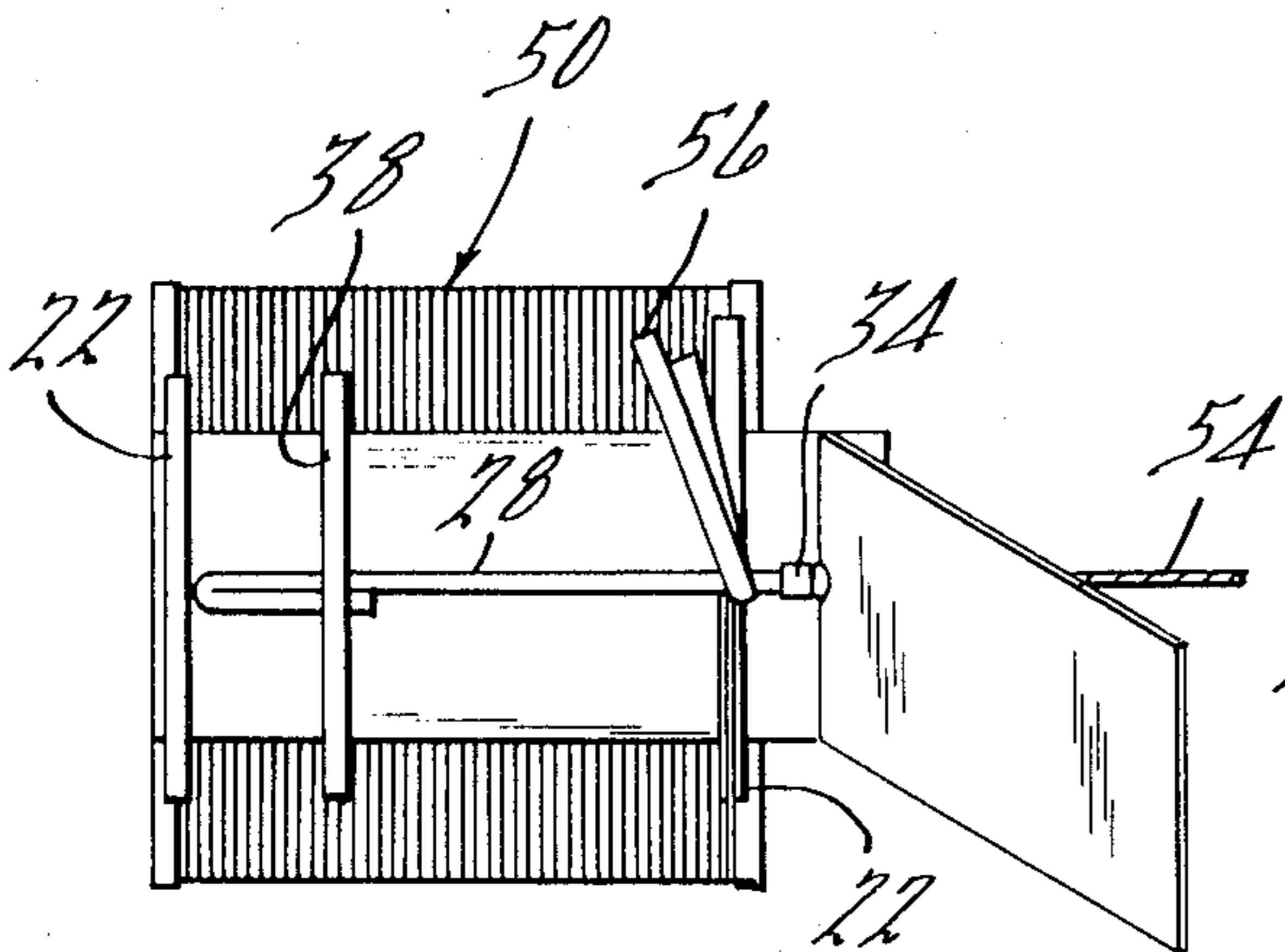


FIG. 15.

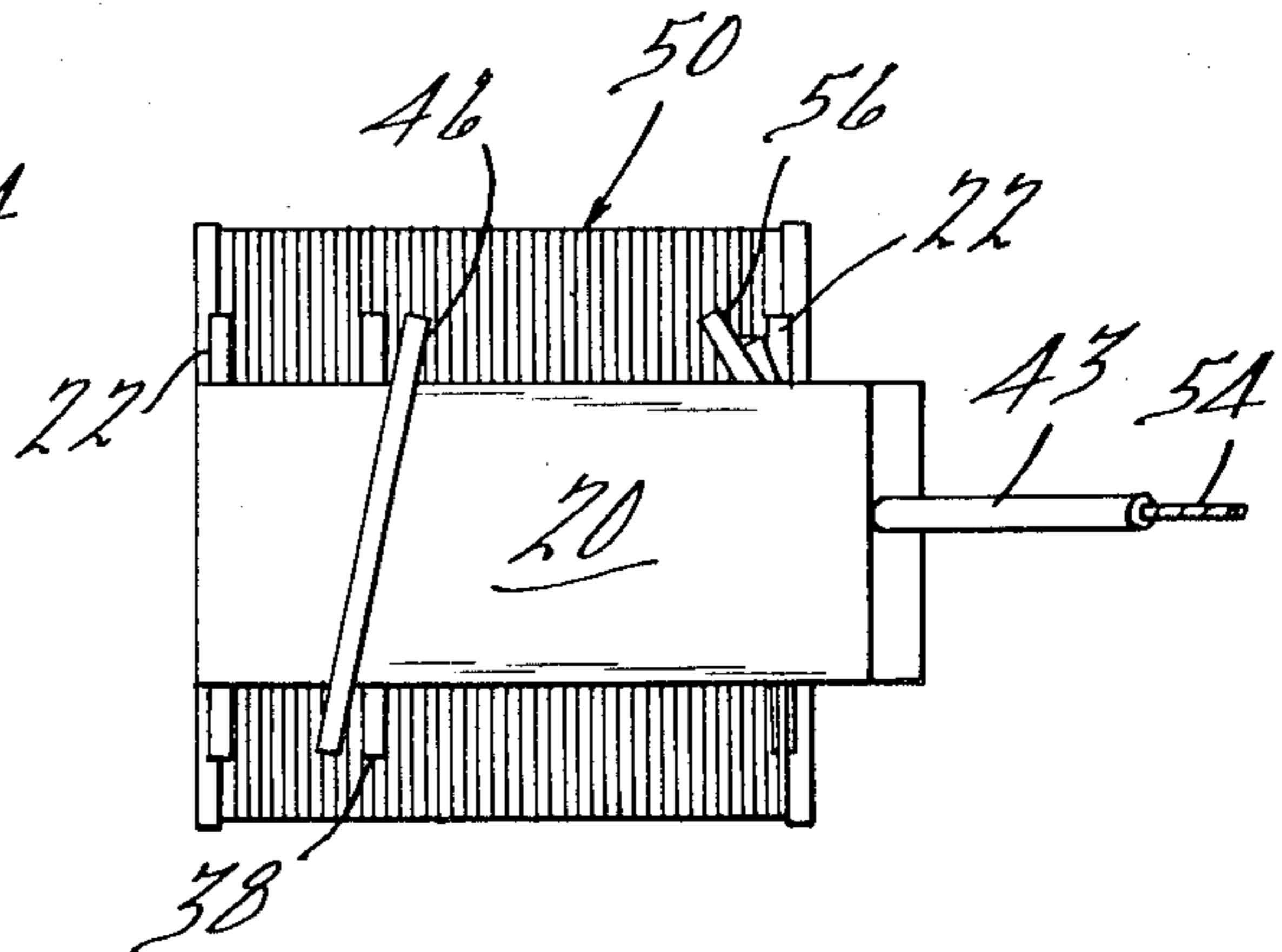


FIG. 16.

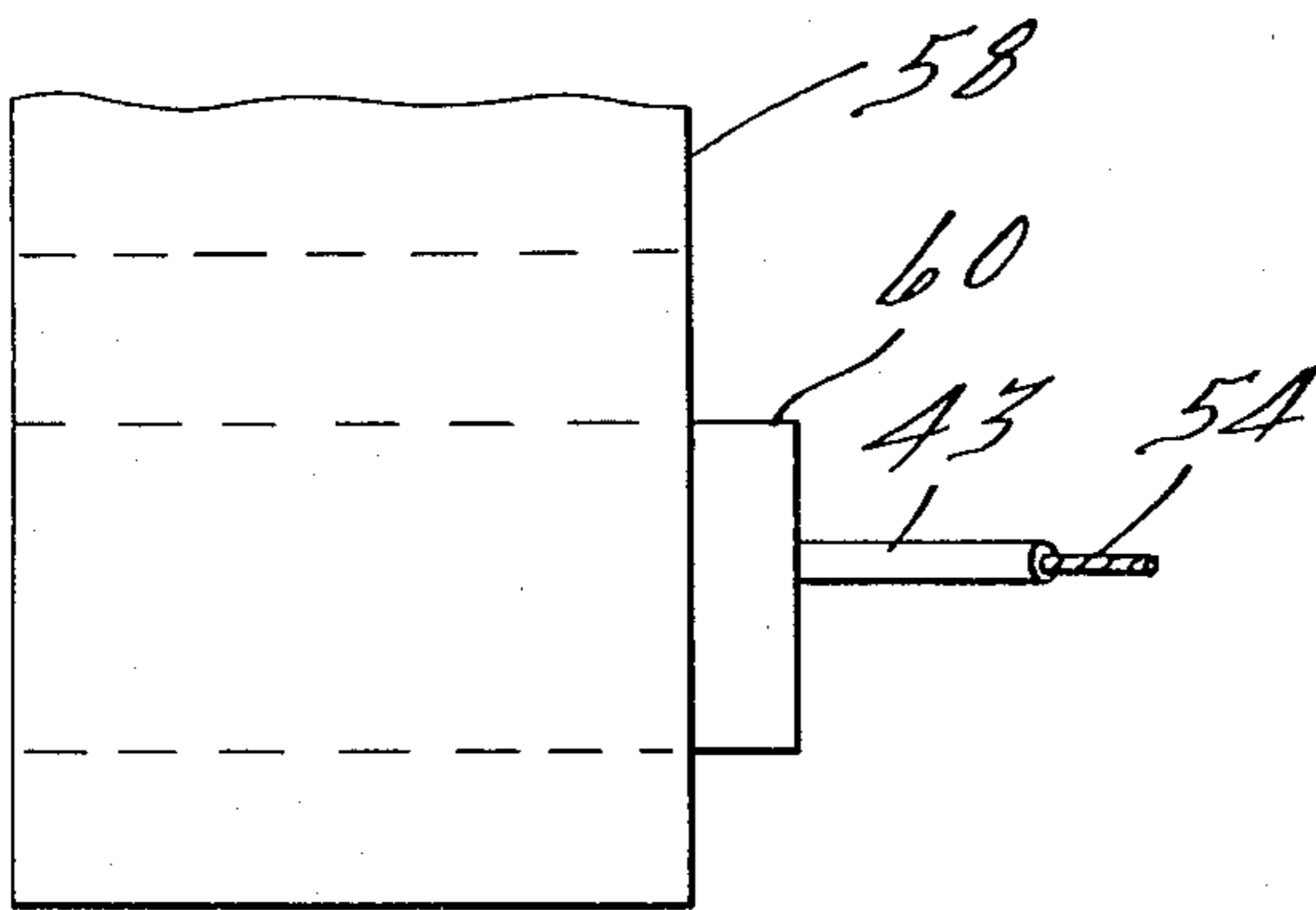


FIG. 17.

INVENTORS.
 JOHN L. FISHER
 ALAN L. WILKS.
 BY
James, Dickey & Pease
 ATTORNEYS.

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 connec-

tor 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 restraint 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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