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[54] **PLUG-IN ELECTRICAL BUSHING**
3 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** .... **324/122,** 174/11 R, 174/142, 339/177 R, 339/259 R
[51] **Int. Cl.** **G01r 13/36.** H01r 11/22
[50] **Field of Search** 324/122; 174/18, 142, 143, 11; 339/259, 143, 177

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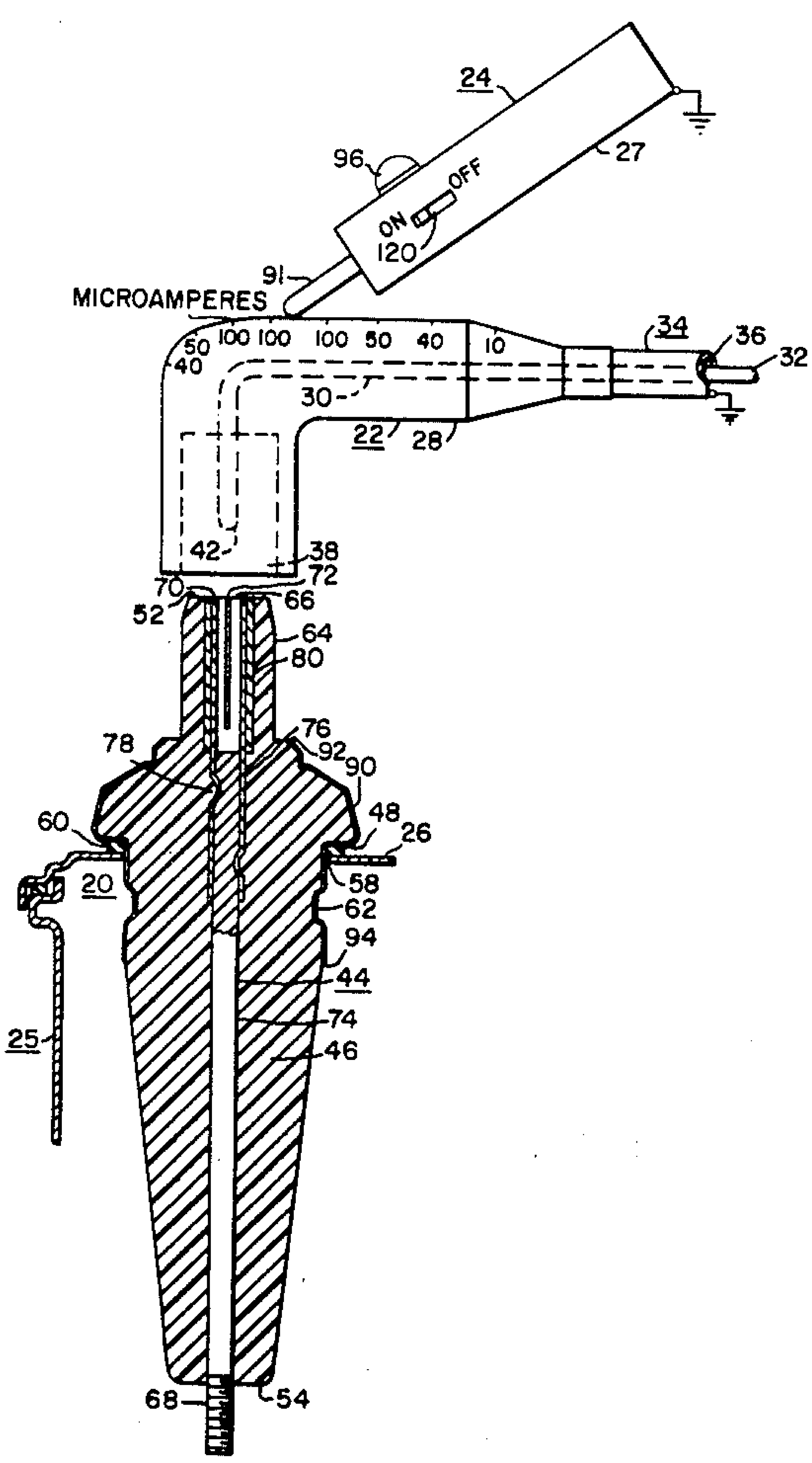
ABSTRACT: A plug-in-type high-voltage bushing assembly having a body portion formed of a cast resin insulation system, and a conductor assembly. The conductor assembly includes a conductor, a pressure type terminal disposed on one end of the conductor, and resilient, compressible means disposed about the pressure terminal. The conductor assembly is embedded in the cast resin system of the body portion, with the conductor and resilient compressible means being in contact with the cast resin system. The resilient means surrounds and protects the pressure terminal from the cast resin, enabling the pressure terminal to retain its ability to provide tight electrical joints with a mating plug-in connector, while being surrounded by the cast solid insulation system of the body portion of the bushing.



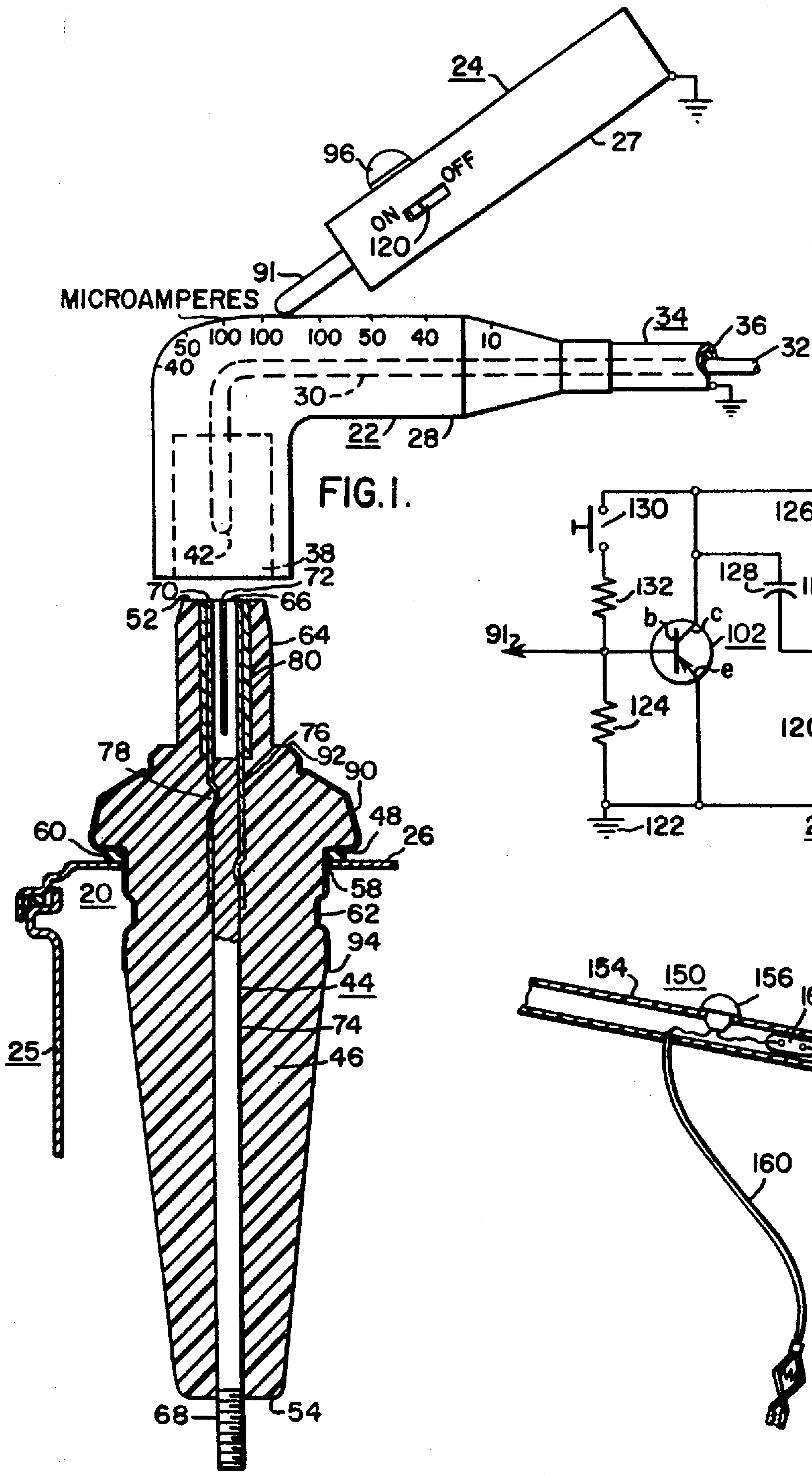


FIG.1.

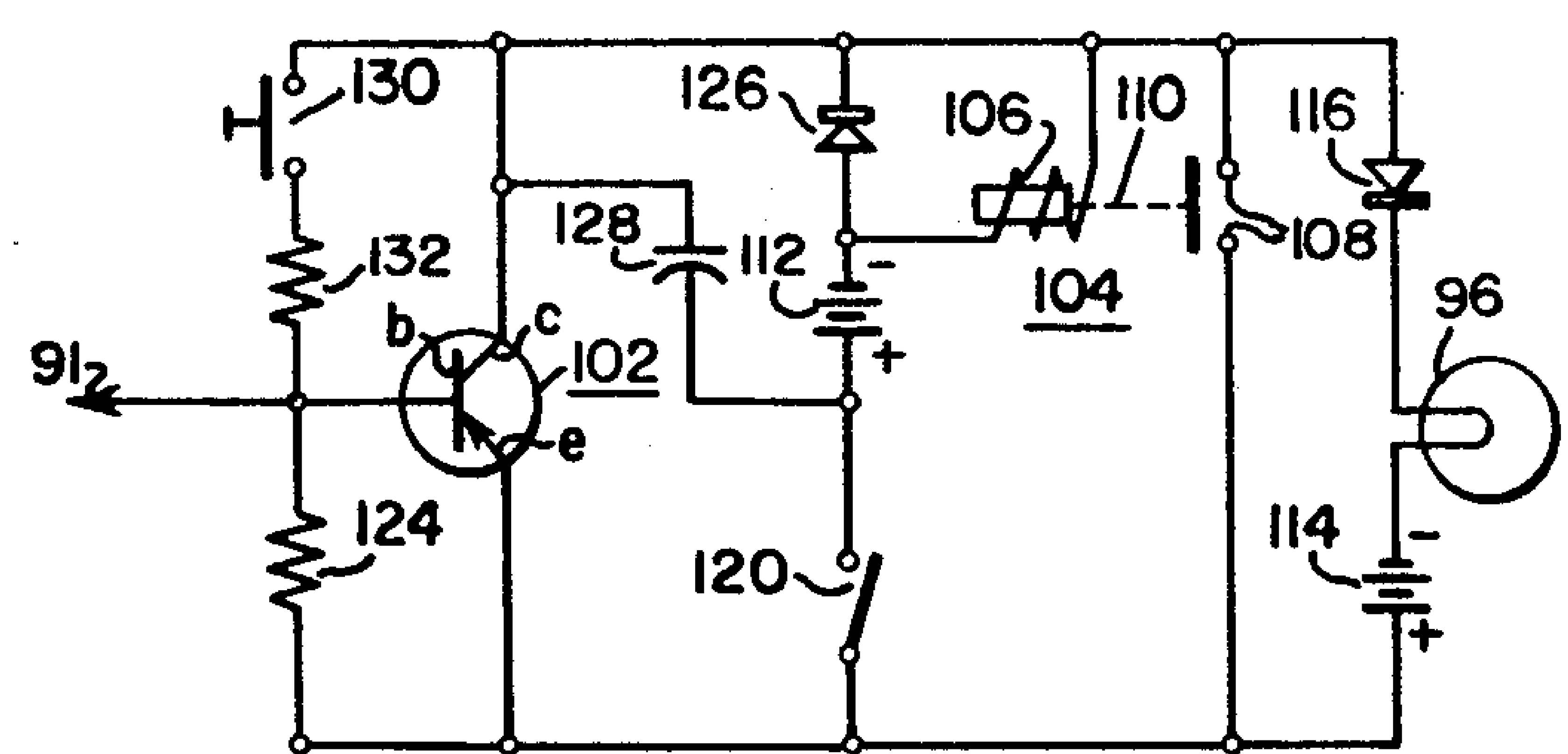


FIG. 2.

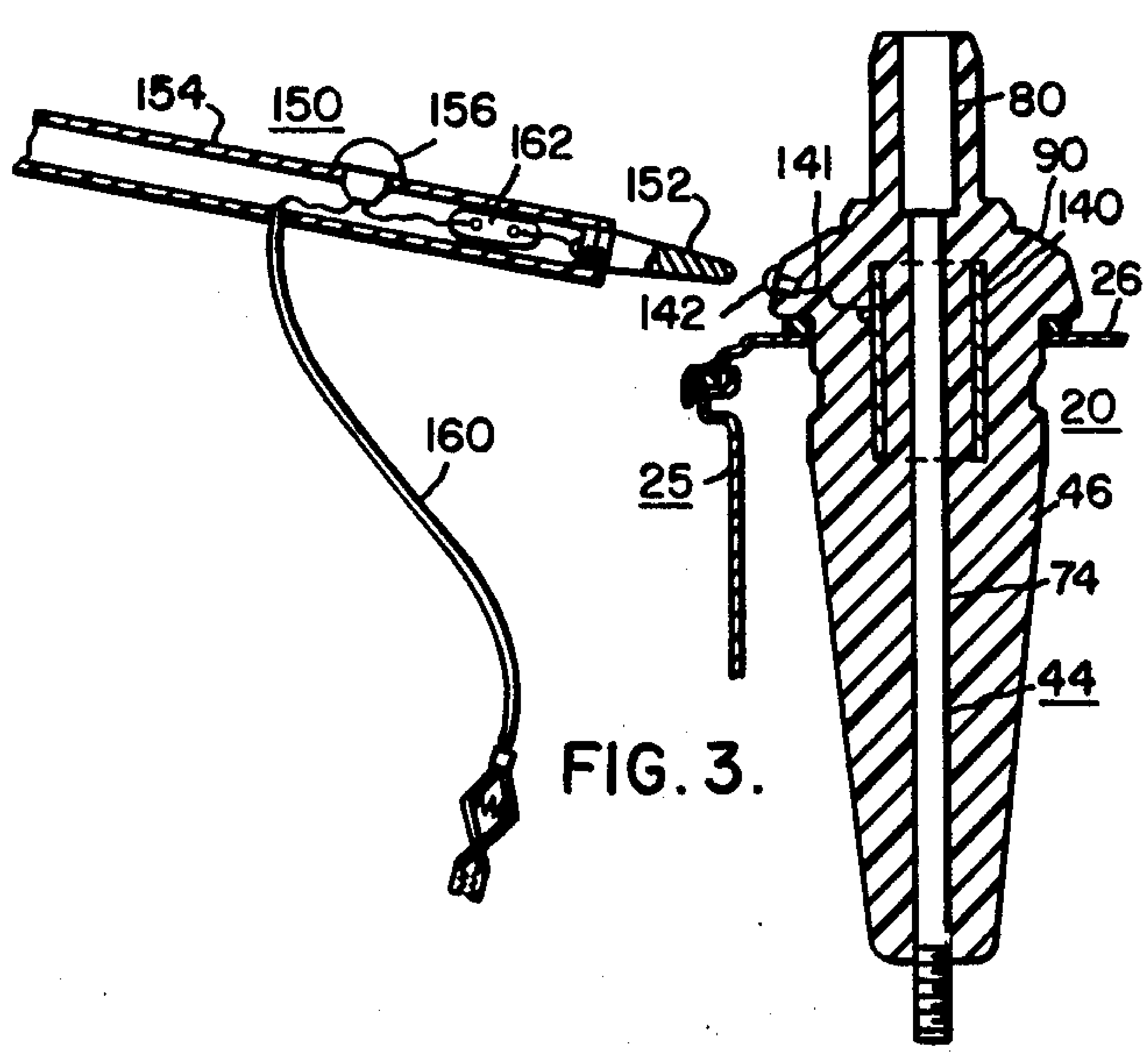


FIG. 3.

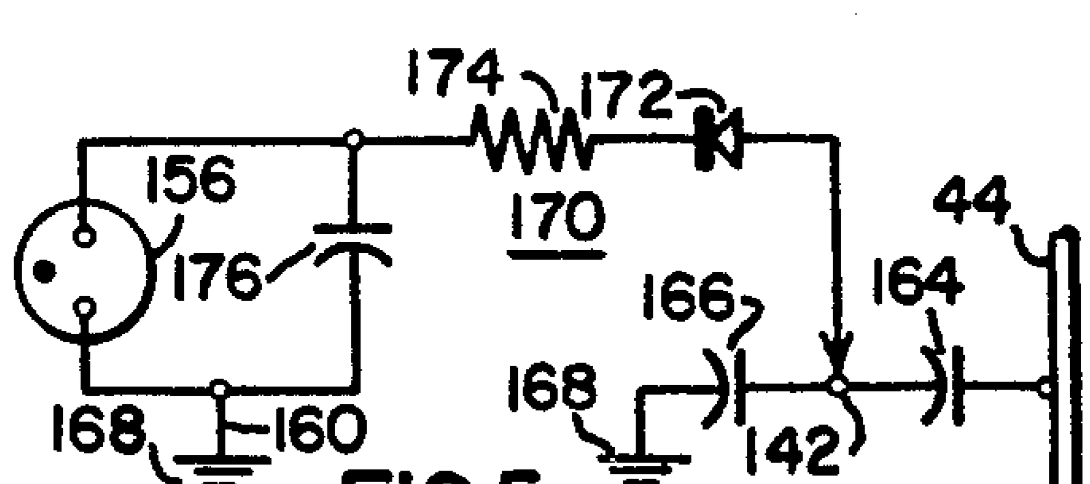


FIG.5.

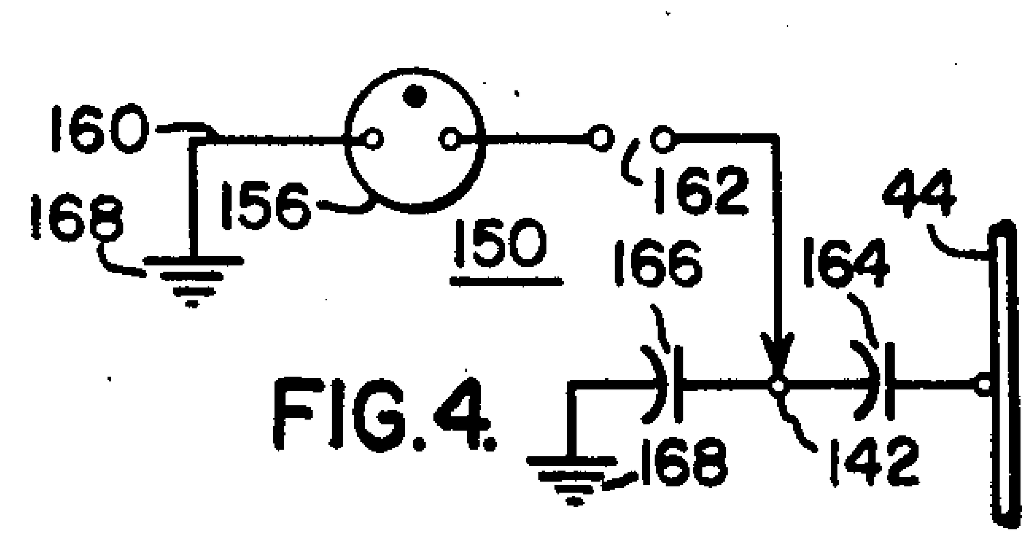


FIG.4.

PLUG-IN ELECTRICAL BUSHING

This a continuation of application Ser. No. 489,339, filed Sept. 22, 1965.

This invention relates in general to high-voltage bushings, and more specifically to the construction of sealed, plug-in-type high-voltage bushings for electrical transformers, and the like, and means for detecting whether or not the bushing conductor is energized.

Shielded plug-in connectors have been developed for connecting shielded high-voltage cable to distribution transformers in underground electrical distribution systems. These connectors make it possible to continue the cable ground to the transformer tank, and provide a quick, effective sealed connection with the transformer winding. The transformer bushings developed for use with the plug-in cable connector, however, have the disadvantages of requiring special access openings through the transformer casing and special mounting hardware, and also require special protective cones to protect the bushing from the transformer oil, as the bushing material is not oil resistant. Also, the cost of these bushings is many times the cost of a conventional transformer bushing. Thus, it would be desirable to provide a new and improved electrical bushing which will receive the plug-in-type cable connector, that may be mounted on a transformer in exactly the same manner as a conventional transformer bushing, using the same access opening and mounting hardware, which may be disposed below the oil level of the transformer without auxiliary protective means, and which is comparable in cost to the conventional bushings.

Further, the sealed-type high-voltage plug-in connector and bushing has two operating disadvantages. First, the plug-in connector has no load-breaking ability. Thus, before unplugging the cable connector from the plug-in-type bushing, it is imperative that the connector be deenergized. The second operating disadvantage is the fact that it is difficult to determine whether or not the cable is energized. The cable ground is continued through the cable connector and bushing to the transformer casing, making present methods of determining whether or not the cable is energized, inoperative. Thus, it would be desirable to provide new and improved apparatus for determining whether or not the high-voltage cable is energized, in order to determine if the plug-in connector may be safely removed from the transformer bushing.

Accordingly, it is an object of the invention to provide a new and improved plug-in-type high-voltage bushing for electrical transformers.

Another object of the invention is to provide a new and improved plug-in-type high-voltage bushing for electrical transformers which may be mounted on a transformer using the same mounting hardware and transformer opening as conventional bushings.

A further object of the invention is to provide a new and improved oil resistant high-voltage bushing that may extend below the surface of the transformer oil without special protective means.

Still another object of the invention is to provide a new and improved plug-in-type high-voltage bushing which has a cost competitive with conventional high-voltage bushings.

Another object of the invention is to provide a new and improved apparatus for quickly and effectively determining whether or not a high-voltage cable connected to a plug-in-type transformer bushing is energized.

Briefly, the present invention accomplishes the above cited objects by providing a new and improved high-voltage bushing cast of an oil resistant, electrical grade resin, such as an epoxy. The bushing is provided with an undercut shoulder for gasketing to the transformer casing, and a circumferential groove disposed to allow it to be secured to the transformer by electroswaging a sleeve into holding relation by electromagnetic energy, or the bushing may have threads molded or cut therein for receiving the standard spring grip nut. To complete the electrical shielding and stress grading from the cable shield and plug-in connector to the transformer tank, the bushing is coated with electrically conductive means, such as a conductive paint or a metallized spray coating, from a location which makes contact with the shielding means on the plug-in cable connector to a location which contacts the metallic transformer casing. The internal conductor of the bushing has a pressure terminal means adapted to receive the conductor from the plug-in cable connector, and it is slotted to provide the spring necessary for excellent electrical contact. Resilient means is disposed between the cast body portion of the bushing and the slotted portion of the pressure terminal, to provide the resilience necessary for proper functioning of the pressure terminal.

In order to determine whether or not the plug-in connector is energized, a first embodiment of the invention capacitively couples a shield to the bushing conductor, which is cast into the body portion of the bushing and electrically connected to a test point in the form of a metallic contact button, which is disposed at a predetermined point on the external surface of the bushing. A probe incorporating indicating means, such as a gas discharge or glowlamp, may then be used to indicate the presence of potential by merely touching the probe to the test point. A spark gap disposed in series with the glowlamp has been found to greatly increase the light intensity of the lamp for a given current magnitude.

Another embodiment of the invention does not require any modification to the electrical bushing, as it utilizes the small surface potentials developed upon the outer surface of the conductive rubber shield of the standard plug-in connector, to energize indicating means in a probe which is disposed in contact with the plug-in connector.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 is an elevational view of a plug-in-type high-voltage bushing, connector and probe, constructed according to the teachings of one embodiment of the invention;

FIG. 2 is a schematic diagram of apparatus that may be incorporated in the probe detector shown in FIG. 1;

FIG. 3 is an elevational view, in section, of a high-voltage plug-in bushing and probe constructed according to the teachings of another embodiment of the invention;

FIG. 4 is a schematic diagram equivalent of the probe and bushing structure shown in FIG. 3; and

FIG. 5 is a schematic diagram illustrating the bushing structure of FIG. 3 and another probe structure that may be utilized.

Referring now to the drawings, and FIG. 1 in particular, there is illustrated a high-voltage bushing assembly **20**, in section, constructed according to the teachings of the invention, as well as a conventional plug-in-type connector **22** and a new and improved probe **24** for indicating when cable connector **22** is energized. In general, high-voltage bushing assembly **20** is of one-piece cast, plug-in-type construction, which incorporates all of the functions of the conventional electrical high-voltage transformer bushing, and may be mounted using conventional bushing mounting hardware and conventional bushing openings in the transformer cover **26**. Bushing assembly **20**, in addition to performing the conventional bushing functions, must receive cable connector **22** and provide an excellent pressure electrical contact that is sealed to the atmosphere and electrically shielded and graded. The cable connector **22** has a molded rubber body portion **28** which surrounds a central electrical conductor **30**. Electrical conductor **30** is connected to the electrical conductor **32** of shielded cable **34**. The outer layer of connector body portion **28** is formed of an electrically conductive rubber, which is connected to the grounded shield **36** surrounding cable **34**. Cable connector **22** has a cylindrical opening or chamber **38**, in which the cable conductor **30** is terminated in the form of a projecting metallic member 42 which extends coaxially into the chamber 38. Thus, the bushing assembly 20 must provide the function of mating with the projecting conductive member 42, and provide a good electrical contact that will not deteriorate with time and with electrical current flow. Also, the conductive rubber layer on the body portion of cable connector 22 must be connected to the transformer casing 25, which includes the cover 26, in order to complete the shielding and electrical grading. Further, the bushing assembly 20 must be resistant to the cooling dielectric disposed within the transformer tank 25, and must have a construction which will allow it to be manufactured at a cost competitive with conventional-type bushings.

Bushing assembly 20 accomplishes these functions by a one-piece, cast assembly, which includes a central electrical conductor 44 which is integrally cast into body portion 46. Body portion 46 has a generally cylindrical, elongated shape, with an undercut shoulder 48 disposed intermediate its upper and lower ends, 52 and 54, respectively. The undercut shoulder 48 allows the bushing to be disposed in sealed engagement with a transformer cover 26, by disposing the bushing assembly 20 perpendicularly through an opening 58 in the cover 26, and by disposing a gasket member 60 between the shoulder 48 and cover 26.

Body portion 46 also has a circumferential groove 62 disposed intermediate its upper and lower ends, 52 and 54, which is located a predetermined distance below the shoulder 48, for purposes of receiving an electromagnetically swaged metallic sleeve, as described in copending application, Ser. No. 332,538, filed Dec. 23, 1963 now U.S. Pat. 3,214,511, and assigned to the same assignee as the present application, or the body portion may be threaded for receiving the standard garter spring clamping ring.

Body portion 46 of bushing assembly 20 has a cylindrical upper projection 64 which is sized to allow chamber 38 of cable connector 22 to be telescoped thereover with a very close fit between the outer surface of projection 64 and the internal surface of chamber 38.

The electrical conductor 44 of bushing assembly 20 is embedded in and bonded to the cast body portion 46, and is disposed coaxially with the cylindrical shaped elongated body portion 46. Electrical conductor 44 extends to a position which is substantially flush with the upper end 52 of body portion 46, and extends a predetermined distance below the lower end 54. The projecting portion 68 may have threads thereon for receiving fastening means for connecting an electrical conductor from the transformer coils to the electrical conductor 44. The upper portion 70 of electrical conductor 44 is tubular in shape, having an inner opening 66 which has a diameter slightly smaller than the outside diameter of projecting member 42 of cable connector 22. The upper end 70 has its wall portion cut or slotted, as shown at 72, in order to provide a pressure connection which has the desired resiliency or spring for insuring a tight pressure fit and electrical connection between conductive member 42 and electrical conductor 44. Electrical conductor 44 may be formed from two separate metallic members, if desired, with the lower portion 74 being formed of a metallic tubular member, the latter being slotted at 72 to provide the pressure terminal. The rod 74 may be joined to tubular member 76 by crimping, as shown at 78, by screw threads, or any other suitable fastening means. Rod 74 and tubular member 76 are formed of any good electrical conductive material, such as copper or aluminum.

In order to maintain the spring effect of slotted tubular member 76 once it has been cast integrally with solid body portion 46, at least a portion of the slotted length of tubular member 76 has resilient means 80 disposed about its periphery, thus allowing the tubular member 76 to spring apart upon receiving the projecting conductive member 42 from cable connector 22, by compressing the resilient means 80. Resilient means 80 may be any suitable means, such as one of the elastomers in the form of a tape, which is taped tightly around tubular member 76 for a predetermined length and a predetermined thickness.

Body portion 46 of bushing assembly 20 may be formed of any suitable electrical grade resin system, preferably having filler means which provides a coefficient of expansion for the resin-filler combination which approximates that of the electrical conductor 44. For example, an epoxy resin system having a filler of particulated beryllium aluminum silicate, described in more detail in copending application Ser. No. 406,102, filed Oct. 23, 1964, now abandoned and assigned to the same assignee as the present application, has been found to be excellent, possessing superior physical properties at elevated temperatures, high thermal conductivity, excellent crack resistant characteristics, and a low coefficient of thermal expansion which approximates that of the metallic insert, i.e., the electrical conductor 44. This resin system is also resistant to oil and other dielectric fluid cooling means commonly used in electrical transformers, which allows the lower end 54 of bushing assembly 20 to be disposed below the level of the fluid coolant in the transformer casing, without any additional protective means.

In order to complete the shielding and electrical grading of the cable 34 and cable connector 22 to the grounded transformer casing 26, a coating 90 of electrically conductive paint is disposed to surround the outer surface of the body portion 46 from the shoulder 92 to a predetermined point 94 adjacent the groove 62. The conductive paint coating 90, such as a metallized spray coat of copper or aluminum, performs the function of terminating the cable shield 36 and outer conductive rubber coating of cable connector 22 to the transformer casing 25, and also provides a ground shield for electrical grading purposes. The conductive paint coating 90 makes contact with the outer conductive rubber coating of the cable connector 22 when the connector 22 is plugged into the bushing assembly 20, and it makes contact with the cover 26 of the transformer, as the body portion 46 proceeds through the opening 58.

The electrical shielding of cable 34, cable connector 22, and bushing assembly 20, however, makes the conventional means for determining whether the cable 34 is energized, ineffective. Since the cable connector 22 has no interrupting capability, it is essential that the cable 34 be deenergized before the cable connector 22 is removed from the bushing assembly 20. FIG. 1 illustrates a probe assembly 24 having a metallic extension 91, indicating means 96, on-off switch 120, and an insulated outer casing 27, in addition to means for connecting the probe to ground. Probe assembly 24 is designed to pick up and detect the small surface potentials that exist at the outer surface of cable connector 22 when it is energized. These small potentials exist at the outer surface of cable connector 22, even though the outer surface is formed of an electrically conductive rubber, because of the resistance of the conductive rubber shield. FIG. 1 indicates the current in microamperes at various points on the surface of cable connector 22, that will flow from the cable surface to ground through a 2,200 ohm resistor. Any suitable probe circuit for detecting the surface potentials and operating signal means such as the indicating light 96, may be used. For example, a solid-state circuit having a sensitivity which will indicate potentials inside the connector 22 as low as 2,000 volts, is shown in FIG. 2.

FIG. 2 illustrates probe assembly 24, having a metallic probe extension 91 for contacting the surface of cable connector 22, and an indicating light 96. In general, the detector or probe 24 includes a semiconductor switching device, such as a transistor 102 having a base electrode *b*, collector electrode *c*, and an emitter electrode *e*, a relay 104 having an electromagnetic coil 106 and normally open contacts 108, actuated by mechanical linkage 110, and first and second means for providing a unidirectional potential, such as batteries 112 and 114.

A first series loop is formed by relay contacts 108, asymmetrically conductive device, such as a diode 116, indicating light 96, and battery 114, with the diode 106 being poled to allow current flow through indicating light 96 when relay contacts 108 are closed.

A second series loop is formed by the emitter-collector electrodes *e* and *c*, respectively, of transistor **102**, the coil **106** of relay **104**, battery **112**, and on-off switch **120**. Current will flow from battery **112** through relay coil **106**, energizing relay **104** to complete the first series loop and energize-indicating light **96**, when transistor **102** is switched to its conductive condition.

Probe **24** has its metallic pickup extension **91**, which is manually disposed to contact the cable connector surface by the operator, connected to ground **122** through a resistor **124**. Transistor **102** is made responsive to the current flowing through resistor **124** and the voltage drop across resistor **124**, by connecting the base-emitter electrodes, *b* and *e*, respectively, across resistor **124**. Thus, when the switch **120** is closed and the metallic probe extension member **91** is disposed to contact the surface of cable connector **22**, if the cable connector **22** is energized, a current will flow through resistor **124**. The potential developed across resistor **124** produced by the current flow, will forward bias the base-emitter junction of transistor **102**, causing it to switch to its conductive condition. When transistor **102** switches to its conductive condition, current will flow from the positive (+) terminal of the battery **112**, through switch **120**, through the collector-emitter junction of transistor **102**, through relay coil **106**, back to the negative terminal (−) of battery **112**. When relay coil **106** is energized, relay contacts **108** close by virtue of the mechanical linkage **110**, which completes the first series loop, and current will flow from the positive (+) terminal of battery **114**, through relay contact **108**, through diode **116**, through indicating light **96**, to the negative (−) terminal of battery **114**. An asymmetrically conductive device, such as a diode **126** is connected across relay coil **106**, and poled to provide a discharge path for the energy in the electromagnetic coil **106** when relay **104** is deenergized. A capacitor **128** may be connected across the collector-emitter electrodes, *c* and *e*, respectively, of transistor **102** to provide surge voltage protection for the transistor.

In order to check the condition of all components of the probe **24**, a test circuit comprising pushbutton **130** and resistor **132** may be connected across the base-collector electrodes, *b* and *c*, respectively, of transistor **102**. Pressing pushbutton **130**, with switch **120** closed, will forward bias transistor **102** due to current flow from battery **112**, operating relay **104** which energizes indicating light **96**. Thus, the condition of the batteries **112** and **114**, transistor **102**, and relay **104** are all quickly and effectively checked.

The existence of potential on cable **134** and connector **122** may also be quickly checked by slightly modifying the bushing assembly **20** of FIG. **1**, as shown in FIG. **3**. Like reference numerals in FIGS. **1** and **3** indicate like components.

In general, FIG. **3** illustrates the bushing assembly **20** shown in FIG. **1**, and hereinbefore described, with the addition of a capacitive voltage divider and a probe test point. More specifically, shielding means or pickup shield **140** is disposed within body portion **46** of bushing assembly **20**, in predetermined spaced relation with electrical conductor **44** and the ground shield or conductive coating **90** disposed on the surface of body portion **46**. Shielding means **140** may be a tubular metallic member, having either a solid wall or perforated, such as a screen, or it may be a conductive coating sprayed on a precast insulating cylinder which is disposed about the electrical conductor **44** before the body portion **46** is cast. The pickup shield or shielding means **140** is electrically connected by conductor **141** to a probe test point or metallic contact button **142** disposed at the outer surface of body portion **46**. To check for potential on electrical conductor **44**, a probe **150** having a metallic contact point **152**, insulated handle **154** and signal means, such as indicating light **156**, may be used. The light **156**, which may be a neon glowlamp, is connected to ground through ground lead **160**, and the contact point **152** is touched to the test point **142** to detect whether the electrical conductor **44** is energized. It has been found that the operating voltage range of probe **150** may be greatly increased by adding a spark gap **162** in series with the glowlamp **156**. The spark gap **162** generates radiofrequency currents upon breakdown, which increases the light output of the gas in the glowlamp for a given current magnitude. The spark gap **162** is preferably of the sealed type, having a breakdown level of a few hundred volts.

FIG. **4** schematically indicates the capacitive voltage divider and probe arrangement of FIG. **3**. Capacitor **164** represents the capacitance between the pickup shield **140** and the electrical conductor **44**, capacitor **166** represents the capacitance between the pickup shield **140** and the ground shield **90**, terminal **142** represents the probe test point, and ground **168** represents the casing ground. Probe **150** is illustrated connected to probe test point **142** and ground **168**.

FIG. **5** schematically illustrates a probe **170** which may be used instead of probe **150**, in the event that it is desired to have a flashing signal. Probe **170** has an asymmetrically conductive device **172**, such as a diode, and resistor **174**, connected in series circuit relation with the glowlamp **156** and ground lead **160**, and a capacitor **176** connected across glowlamp **156**. This arrangement forms a relaxation oscillator. The component values may be selected to provide any desired frequency. For example, if a one second flashing rate is desired, the glowlamp may be neon bulb size NE–2, the capacitor may be 0.25 microfarads, and the resistor may be 680,000 ohms.

While the capacitive voltage divider and probe arrangement shown in FIGS. **3**, **4** and **5** may be utilized with the bushing assembly construction of FIG. **1**, it will be apparent that these embodiments of the invention may be utilized with any type bushing construction, it only being necessary to modify the bushing structure to include the pickup shield, a test point electrically connected to the pickup shield, and a ground shield.

In summary, there has been disclosed a new and improved plug-in-type high-voltage bushing assembly for electrical inductive apparatus, which may be utilized with conventional plug-in-type shielded cable connectors. The bushing assembly provides the conventional bushing functions of bringing an electrical conductor through a grounded transformer casing, allows a conventional opening in the casing and conventional bushing connecting hardware to be used, allows the bushing to extend into the transformer cooling fluid without auxiliary protection, provides a secure pressure contact from the electrical lead within the bushing to the electrical lead within the cable connector, and completes the cable shield to the transformer casing. Further, the bushing assembly accomplishes these functions with a simple, rugged structure that facilitates manufacture at a cost competitive with standard bushing structures.

There has also been disclosed new and improved apparatus for detecting the existence of a potential in the electrical cable conductor. One embodiment teaches apparatus that may be used with any bushing structure, as it is completely self contained, detecting small surface potentials on the outside conductive portion of the cable connector. Another embodiment modifies the bushing assembly slightly, by disposing a pickup shield between the bushing electrical conductor and bushing ground shield, which is connected to a test point accessible on the bushing surface. The cooperating probe for this last embodiment need employ only a glowlamp, a glowlamp and spark gap, or a glowlamp and relaxation oscillator circuit. The apparatus for detecting the existence of potential have a low cost, but are very reliable and eliminate the hazards to operating personnel which are present in disconnecting the cable connector from the plug-in bushing without effective means for determining whether the cable is energized.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

We claim as our invention:

1. A plug-in bushing for electrical inductive apparatus adapted for connection to an electrical cable connector, comprising:

a body member including first and second ends, and a cylindrical projection which starts at said first end and extends toward said second end for a predetermined dimension, said body member being formed of a solid and rigid cast resin insulating material,

an electrical conductor assembly, including a tubular, slotted pressure terminal disposed at one end of an electrical conductor, said pressure terminal being free of encircling metallic members,

and elastomeric means disposed to surround and everywhere contact at least the slotted portion of said pressure terminal,

said electrical conductor assembly being disposed in said body member, with said pressure terminal being accessible at the first end of said body member,

said elastomeric means and said electrical conductor being in contact with said body member, with said elastomeric means separating at least the slotted portion of said pressure terminal from the cast insulating material which forms the cylindrical projection of said body member,

said elastomeric means and said cylindrical projection forming a continuous solid wall about the slotted portion of said pressure terminal, extending from the outer surface of said pressure terminal to the outer surface of said cylindrical projection,

the cast solid insulating material of which said body portion is formed being selected to provide a rugged structure which cooperates with said elastomeric means and said pressure terminal when an electrical cable connector is plugged into the plug-in bushing, to compress said elastomeric means between the solid wall of the cylindrical projection of said body member and said pressure terminal and provide the resilience required by said pressure terminal.

2. The bushing of claim 1, including an electrically conductive coating disposed on a predetermined portion of the body member, adapted to provide an electrical path from a predetermined portion of the cable connector to the casing of the associated electrical apparatus, when the plug-in bushing is mounted on the electrical apparatus and connected to a cable connector.

3. The bushing of claim 2 including shielding means embedded in the cast body member, in spaced relation between the electrical conductor and the conductive coating, and terminal means accessible at a predetermined point on the surface of said body member connected to said shielding means, said terminal means providing a test point for determining the existence of a potential on the electrical conductor.