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(54) **HIGH PRESSURE DIFFERENTIAL ELECTRICAL CONNECTOR**

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(51) **Int. Cl.**[7] **H02G 15/02**

(52) **U.S. Cl.** .... **174/75 B**

(58) **Field of Search** .... 174/151, 74 R, 174/74 A, 75 B, 79, 110 R, 117 R; 333/24 R, 24 C, 260, 4, 245; 343/906, 870; 29/559

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5,203,723	*	4/1993	Ritter	439/589

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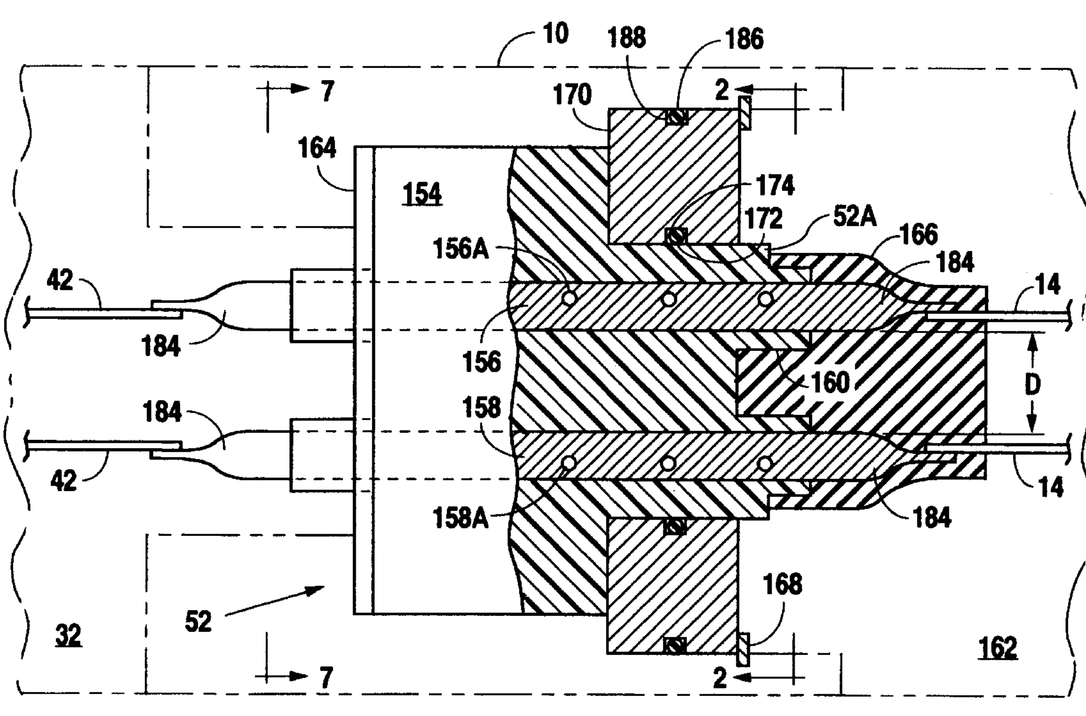
(57) **ABSTRACT**

The present invention is directed to a downhole, high-current, low-impedance, feed-through connector for passing electrical current, preferably high frequency AC current, between a tool compartment having relatively high pressure and another tool compartment having relatively low pressure. The primary intended application of the present invention is to connect a radio frequency transmitter/receiver antenna to the antenna's tuning capacitors, but the present invention is applicable to any downhole application requiring the transmission of high electrical current across a barrier having a high pressure differential. This invention minimizes the force acting on the connector due to the high pressure differential by providing a conductor preferably having either a wave-like cross-section or a multi-finned cross-section, thereby minimizing the overall cross-sectional area of the connector yet providing sufficient cross-sectional area of the conductor to carry the necessary amount of electrical current.

74 Claims, 5 Drawing Sheets



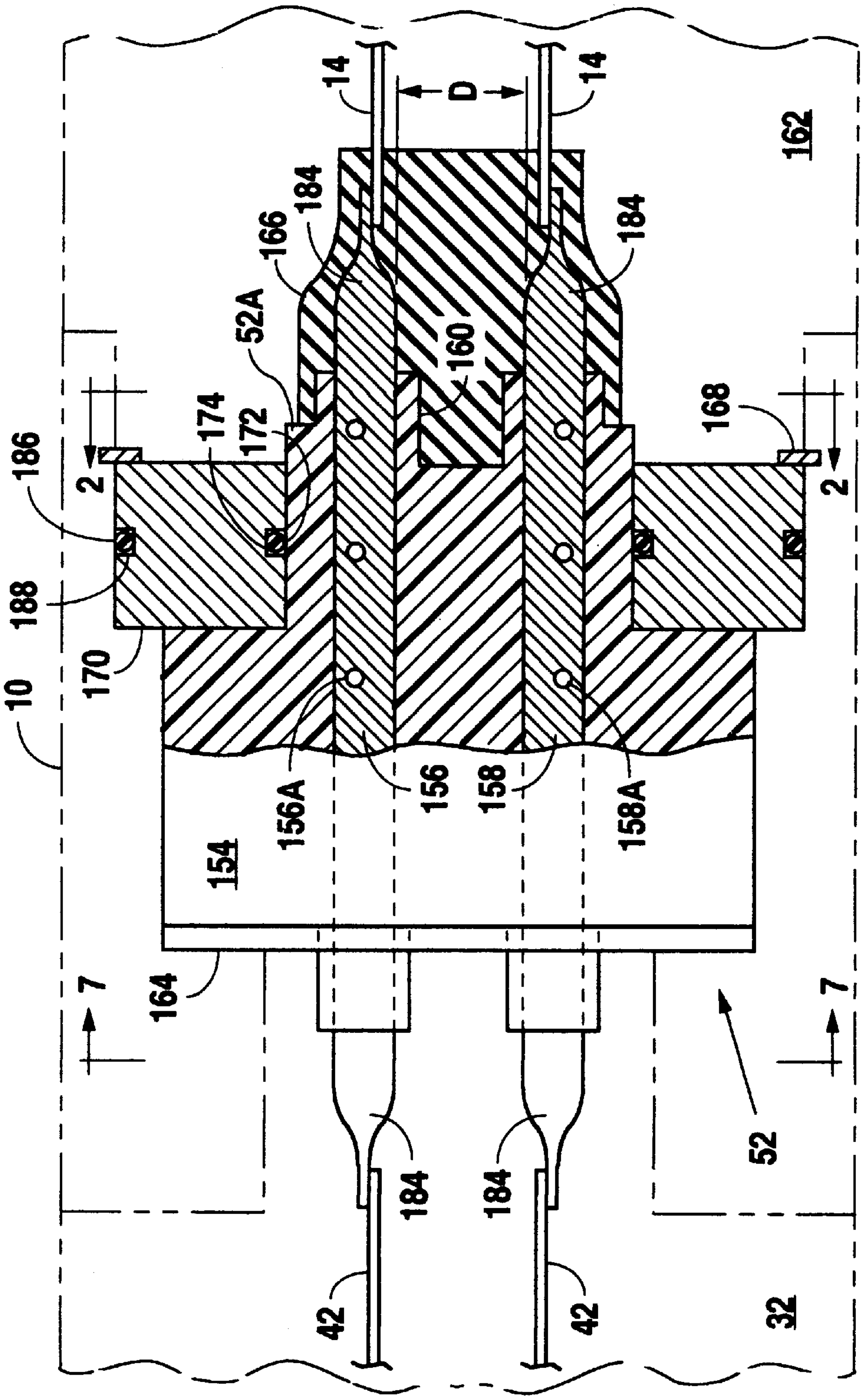

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Fig. 1

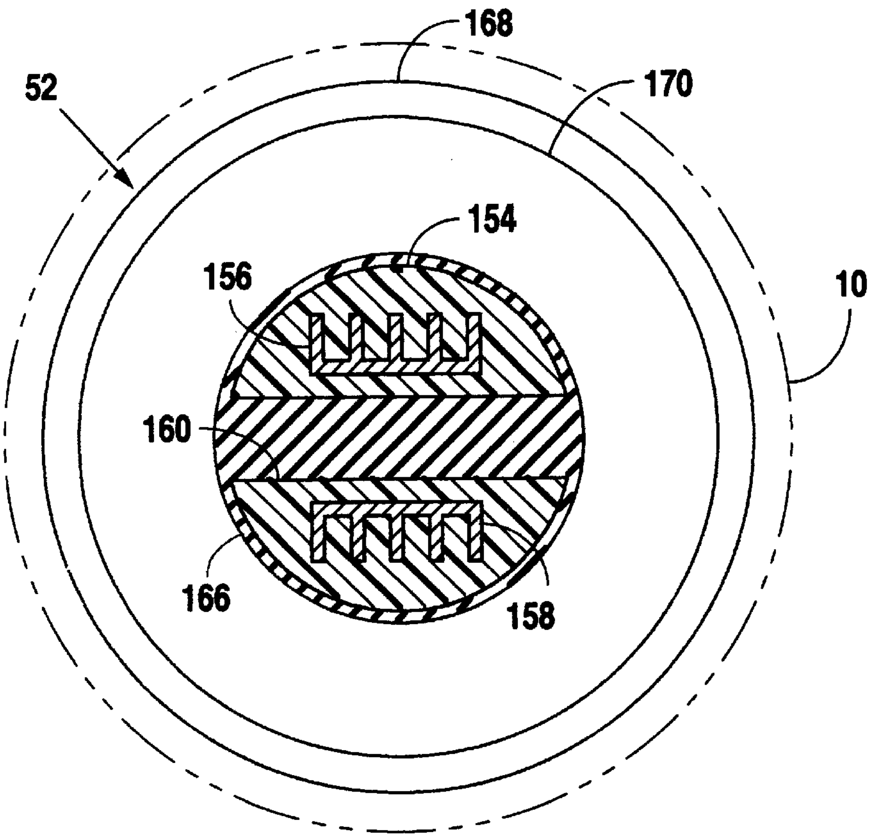

Fig. 2

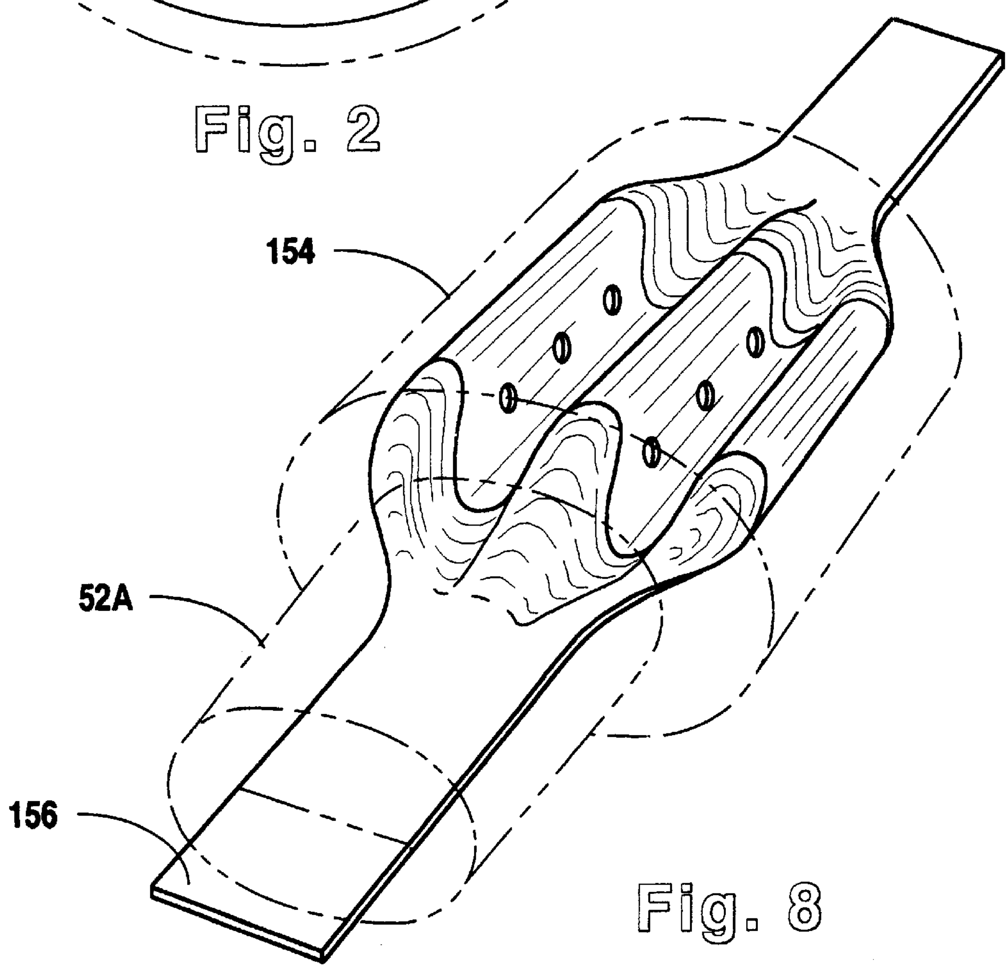

Fig. 8

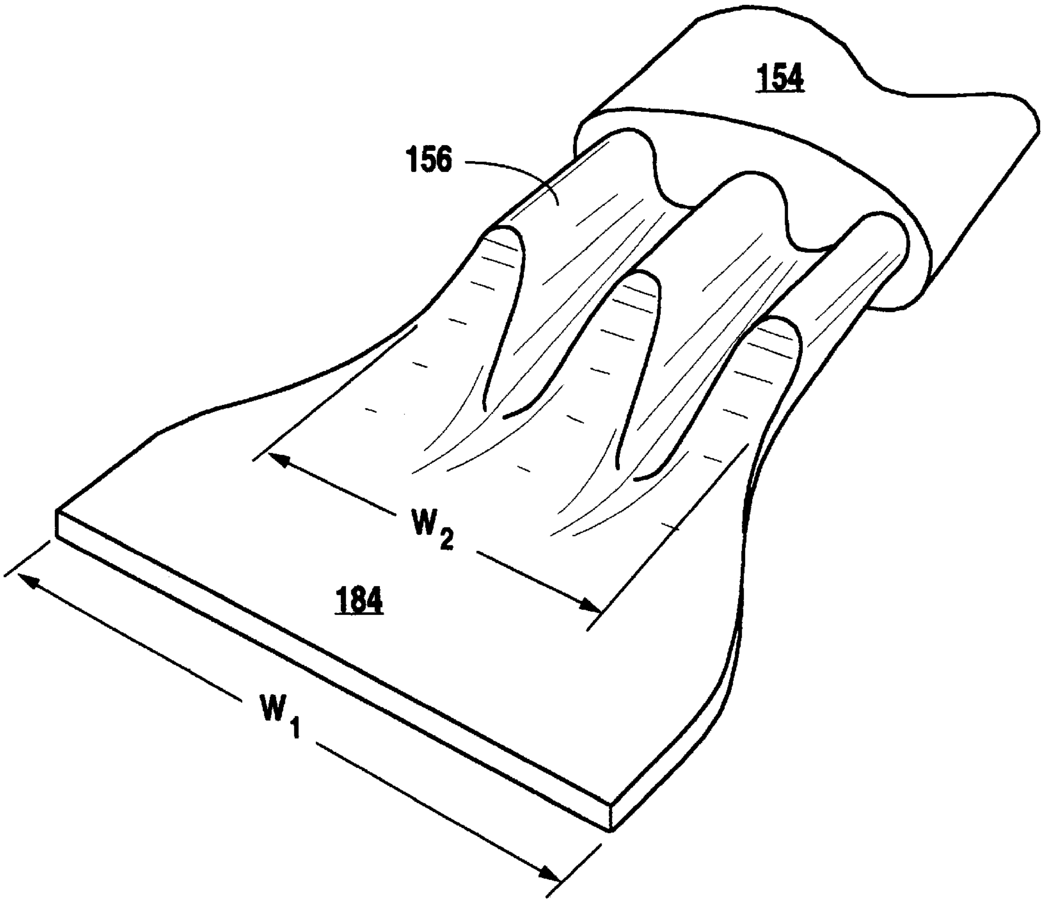

Fig. 3

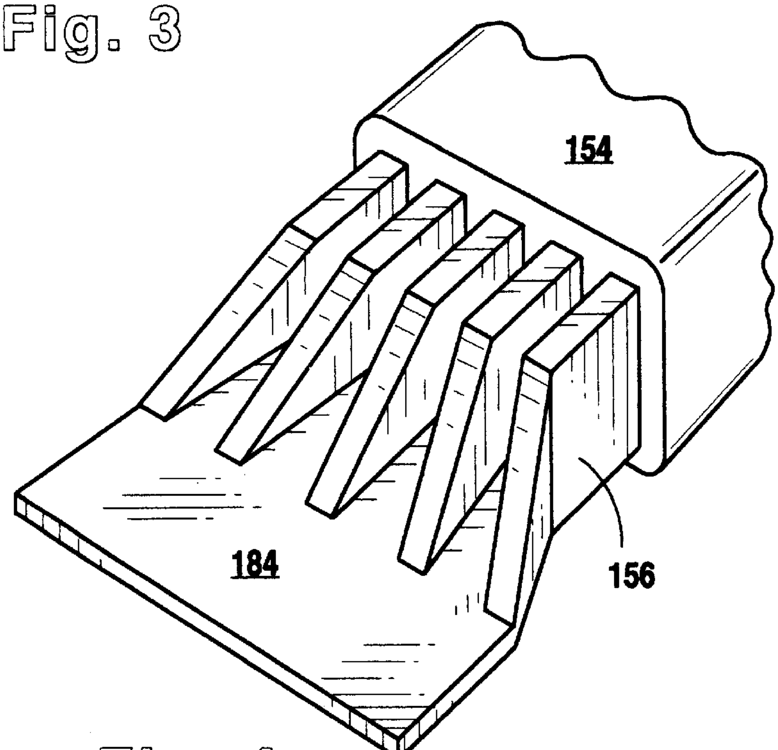

Fig. 4

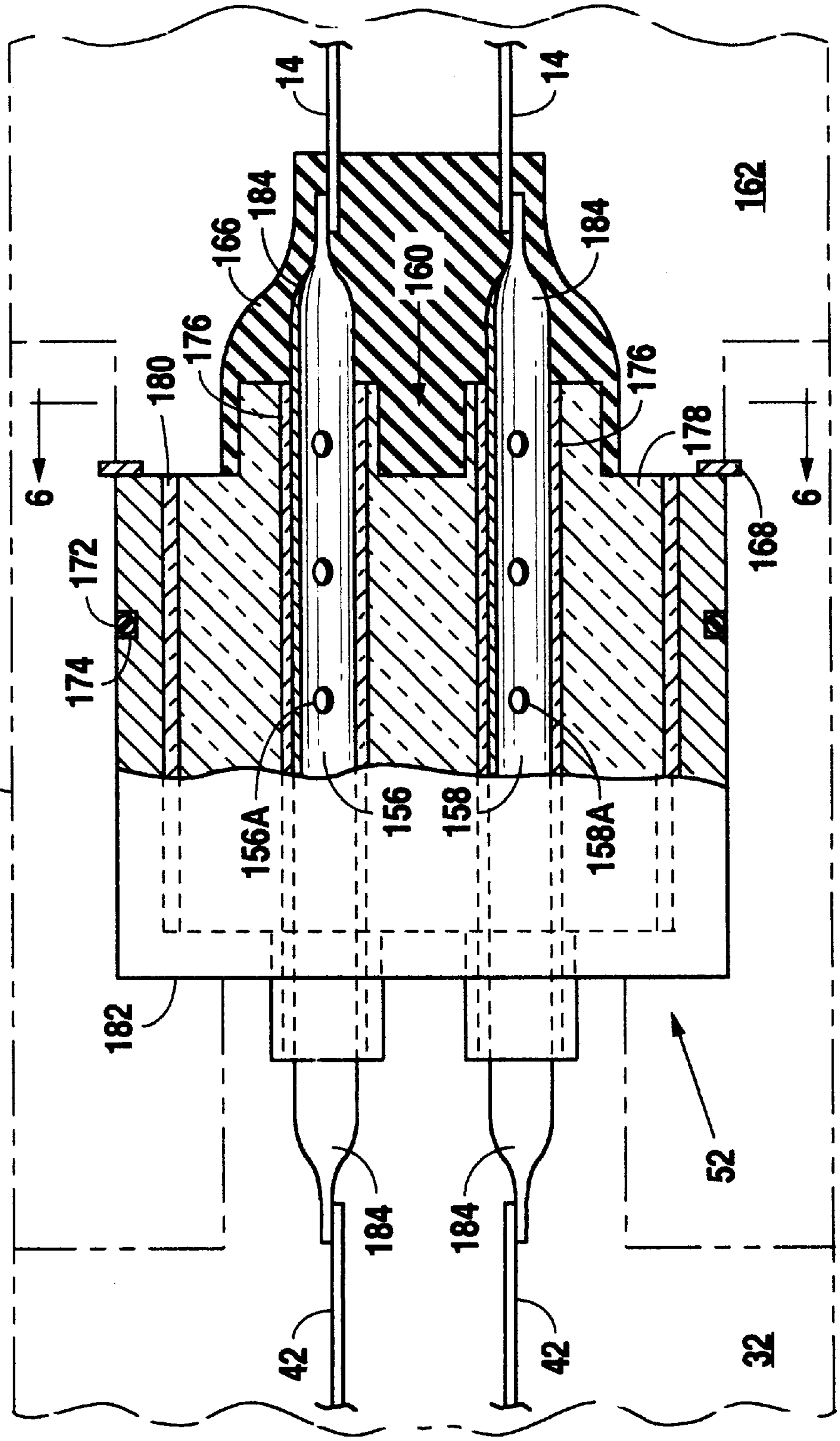
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Fig. 5

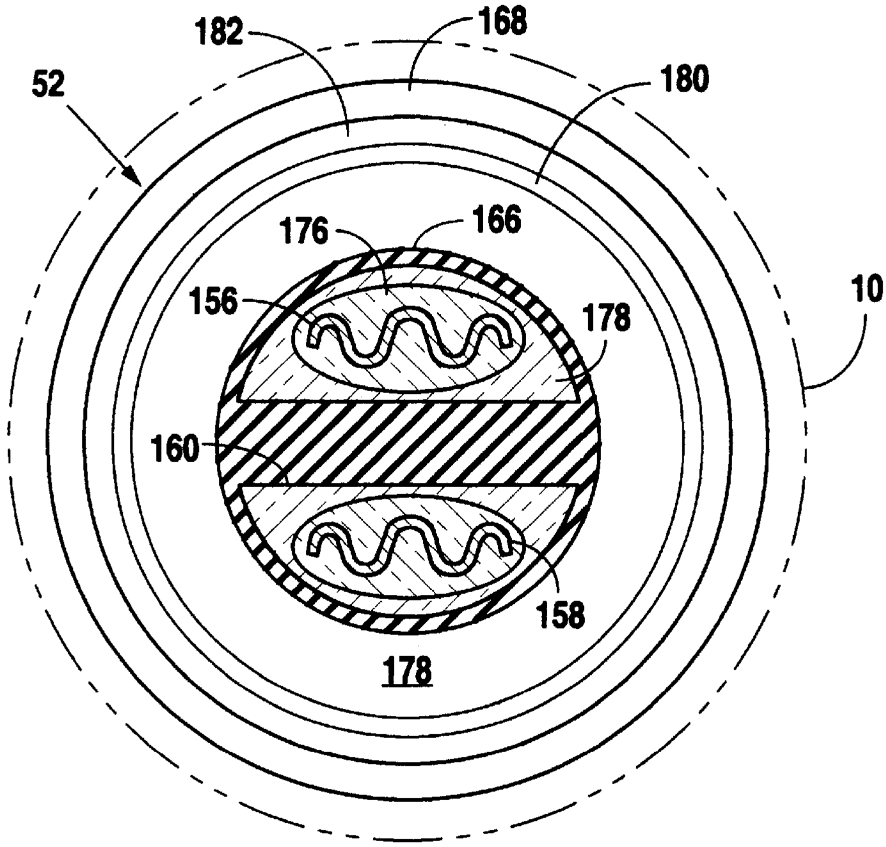

Fig. 6

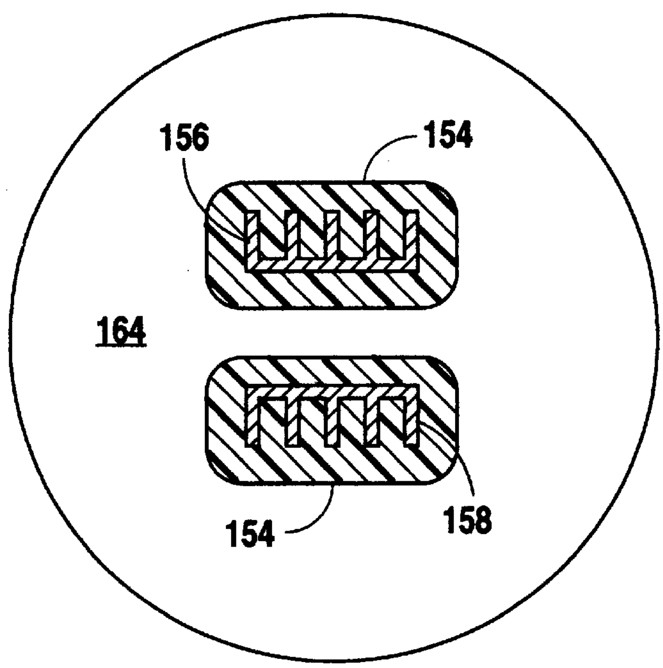

Fig. 7

HIGH PRESSURE DIFFERENTIAL ELECTRICAL CONNECTOR

This application claims priority from U.S. provisional application Ser. No. 60/071,606 filed Jan. 16, 1998.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to an apparatus for carrying electrical current in petroleum well drilling and logging tools. More specifically, this invention relates to a downhole apparatus for carrying high electrical current between a compartment having relatively high pressure and another compartment having relatively low pressure.

2. Description of the Related Art

Modern petroleum well drilling and logging tools frequently require the passage of electrical current between an area having relatively high pressure and another area having relatively low pressure. For example, in many pulsed nuclear magnetic resonance (NMR) measuring while drilling (MWD) tools, an antenna disposed generally on the periphery of the tool is used both to transmit radio frequency electromagnetic wave pulses into the surrounding earth formation and to receive NMR signals from the formation. In such tools, tuning capacitors are utilized in the antenna electronics (driving circuitry) to match the impedance of the antenna so that the antenna will resonate at the desired natural frequency. However, the tuning capacitors are sensitive items and require protection from the high pressures and temperatures of the harsh borehole environment.

Before the advent of tools such as that described in U.S. Pat. No. 5,557,201, issued to Kleinberg et al. on Sep. 17, 1996, that problem was solved by selecting capacitors with minimal pressure and temperature sensitivities and isolating the capacitors from the borehole fluids in an oil-filled compartment of the drill collar. The compartment seal separated the capacitor compartment from the borehole fluids, but the seal did not form a pressure seal and therefore the compartment realized the ambient borehole pressure. Consequently, the compartment was filled with oil to transmit the ambient pressure uniformly around the capacitors and thereby prevent the capacitors from being crushed by the high differential pressure. Moreover, because oil expands and contracts with changing temperature and pressure, those earlier devices had to include a means of varying the volume of the compartment to compensate for the temperature and pressure changes. Thus, such a scheme was very cumbersome.

Tools such as the '201 apparatus solved that problem by housing the antenna driving circuitry in a compartment that was not only sealed off from the borehole fluids but was also sealed off at constant atmospheric pressure. Thus, the compartment was simply filled with air instead of oil, and there was no need for a volume-regulation device. That method of protecting the capacitors made the manufacturing of the tool much simpler and less costly. However, because the pressure in the vicinity of the antenna (i.e., the borehole environment) is much higher than the pressure in the capacitor compartment, the apparatus for feeding the antenna into the capacitor compartment must withstand a severe pressure differential. For example, it is not uncommon for the borehole ambient pressure to be 1700 to 1900 times higher than standard atmospheric pressure. With such a high pressure differential, one would desire to minimize the area of the antenna feed-through apparatus to minimize the force acting on it. On the other hand, because certain NMR MWD tools

require a very high electrical power in the antenna (for example, on the order of 10,000 watts at 600 volts and 16.7 amperes), the area of the feed-through apparatus must be large enough to accommodate a conductor of sufficient size to meet the high power requirement. Additionally, the feed-through area must be large enough to supply a sufficient gap between the two leads of the antenna loop.

Although several existing U.S. patents disclose various designs for carrying electrical current, none of the existing designs appears to be directed to solving the aforementioned problems. For example, U.S. Pat. No. 5,203,723, issued to Ritter on Apr. 20, 1993, discloses a pin-type electrical connector comprising one or more conductor pins disposed through a plastic body for use in high pressure and high temperature downhole environments. The '723 design is primarily directed to providing a hermetically sealed electrical connector between a relatively high pressure area and a relatively low pressure area and to improving connector performance and service life over a large number of elevated temperature and pressure cycles. However, the '723 design does not appear to be directed to providing a conductive path for very high electrical current through as small a cross-sectional area as possible.

Similarly, U.S. Pat. No. 4,237,336, issued to Kostjukov et al. on Dec. 2, 1980, discloses a thermocompensating electrical conductor for providing an electrical path between a dean zone and a contaminated zone, such as a nuclear reactor. The '336 conductor, which is preferably configured in the shape of a wave in the direction of electrical current flow and preferably comprises a stack of crimped metal strips, is primarily directed to improving thermal compensation and reducing electrodynamic loading when used for heavy electrical currents. Again, however, the '336 device does not appear to be directed to providing a conductive path for very high electrical current through as small a cross-sectional area as possible.

U.S. Pat. No. 4,222,029, issued to Marquis et al. on Sep. 9, 1980, discloses a vibration isolator having a sinuously configured, electrically conductive wire disposed within an elastomeric resilient member. Similar to the conductor of the '336 device, the wire of the '029 device has a wave-like shape in the direction of electrical current flow. The wave-like shape of the wire is directed to permitting linear extension of the wire in the direction of electrical current flow without breaking when the device is flexed by vibratory loads. However, the '029 device does not appear to be directed to providing a conductive path for very high electrical current through as small a cross-sectional area as possible, and the '029 device is not directed to accommodating a high pressure differential.

U.S. Pat. No. 3,994,552, issued to Selvin on Nov. 30, 1976, discloses a cylindrical metal electrical connector having a bellows configuration in the axial direction for connecting submersible pipes. The bellows configuration is directed to alleviating axial manufacturing tolerance problems. Once again, however, the '552 device is not directed to solving the need for a downhole electrical connector capable of carrying high electrical currents between a high pressure compartment and a low pressure compartment through as small a cross-sectional area as possible.

It would, therefore, be a significant advancement in the art to provide an improved downhole apparatus for supplying high electrical current between a compartment having relatively high pressure and another compartment having relatively low pressure through as small a cross-sectional area as possible.

SUMMARY OF THE INVENTION

Accordingly, this invention is directed to a downhole, high-current, low-impedance, feed-through connector for passing electrical current, preferably high frequency AC current, between a tool compartment having relatively high pressure and another tool compartment having relatively low pressure. Although the primary intended application of the present invention is to connect an antenna to the antenna's tuning capacitors in a downhole NMR MWD tool, persons reasonably skilled in the art of petroleum well drilling and logging will realize that the present invention is applicable to any downhole application requiring the transmission of high electrical current across a barrier having a high pressure differential. This invention solves the problem posed by the above-mentioned conflicting area requirements by providing a conductor with a corrugated or wave-like cross-section for the feed-through connector. The wave-like shape of the conductor provides sufficient cross-sectional area to carry a high current, yet the conductor requires much less feed-through area for the connector than that which would be required for a conventional conductor having a flat cross-sectional shape. Thus, this wave-like design minimizes the force on the feed-through connector while still accommodating the necessary current. Moreover, the wave-like design improves the bond between the conductor and the surrounding connector material by providing more bonding area. Alternatively, the same objectives may also be achieved by using a conductor having a cross-section with multiple fins.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention may best be understood by reference to the following drawings:

FIG. **1** is a schematic side elevational, partially cross-sectioned view of an electrical connector in accordance with the present invention.

FIG. **2** is a schematic cross-sectional view taken in direction **2**—**2** of FIG. **1** showing a multi-finned cross-section for the electrical conductors of a connector in accordance with the present invention.

FIG. **3** is a perspective view of an end portion of a preferred electrical conductor for a connector in accordance with the present invention.

FIG. **4** is a perspective view of an end portion of an alternative electrical conductor for a connector in accordance with the present invention.

FIG. **5** is a schematic side elevational partially cross-sectioned view of an alternative electrical connector in accordance with the present invention.

FIG. **6** is a schematic cross-sectional view taken in direction **6**—**6** of FIG. **5** showing a preferred cross-section of the electrical conductors of a connector in accordance with the present invention.

FIG. **7** is a schematic cross-sectional view taken in direction **7**—**7** of FIG. **1** showing a back plate of the electrical connector of FIG. **1**.

FIG. **8** is a perspective view showing an alternative embodiment of a connector in accordance with the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** illustrates an electrical connector **52** in accordance with the present invention. Connector **52** preferably comprises a pair of longitudinal electrical conductors **156** and **158** disposed within a connector body **154** made of an electrically insulating material, preferably a thermoplastic material. Connector **52** is designed for carrying high electrical current between a low pressure compartment **32** and a high pressure compartment **162** in a downhole drilling or logging tool. The preferred embodiment shown is for connecting the two leads of a loop antenna **14** in compartment **162** to respective tuning capacitor leads **42** in compartment **32**. In a typical tool, compartment **162** is exposed to the high ambient borehole pressure, but compartment **32** is sealed off from the borehole environment so that the tuning capacitors remain at atmospheric pressure instead of being exposed to the high borehole pressure. A typical antenna **14** comprises flat copper strips about 1 inch wide and about 0.030 inch thick. The major portion of antenna **14** is mounted on the external surface of a drill collar **10**, and antenna **14** is fed into an interior tuning capacitor compartment **32** using feed-through connector **52**.

Referring to FIG. **6**, conductors **156** and **158** preferably have a corrugated or wave-like cross-section to minimize the cross-sectional area required for connector **52** and thereby minimize the force acting on connector **52** due to the high differential pressure between compartments **162** and **32**. As shown in FIG. **6**, the crests and troughs of the wave-like cross-sections of conductors **156** and **158** are preferably aligned "in phase" in order to maximize the distance between conductors **156** and **158**. Alternatively, conductors **156** and **158** may have a multi-finned cross-section as shown in FIG. **2**. Indeed, many other suitable cross-sectional shapes of conductors **156** and **158** could be formed in accordance with the spirit of the present invention, with the understanding that a primary objective is to provide a sufficient cross-sectional area for conductors **156** and **158** to accommodate the necessary level of electrical current yet minimize the overall cross-sectional area of connector **52** exposed to the high pressure. Concomitantly, it is also desirable to minimize the width of conductors **156**, **158** as they enter body **154** on the high pressure (compartment **162**) end because that is an important factor in determining the overall diameter of the cross-sectional area of connector **52** exposed to the high pressure. The foregoing consideration concerning the selection of a desirable cross-sectional shape for conductors **156** and **158** must be balanced against another objective, namely, to make the impedance of conductors **156**, **158** as low as possible. Another design objective for conductors **156**, **158** is to provide them with as much surface area as possible because electrical current generally tends to flow in the outer portions of electrical conductors for high frequency AC electrical signals, which is the primary intended use of a connector in accordance with the present invention. For DC electrical signals and low frequency AC signals, the current generally travels uniformly throughout the conductor cross-section; however, as the frequency of AC signals increases, the more the current tends to migrate toward the exterior surface of the conductor. Moreover, an additional benefit of increased surface area for conductors **156**, **158** is to provide more bonding area between conductors **156**, **158** and connector body **154**.

Because a typical antenna has a flat cross-section, as mentioned above, conductors **156** and **158** must provide a suitable transition between the flat cross-section of the antenna and the wave-like, multi-finned, or other suitable cross-section of conductors **156** and **158**. Thus, for wave-like conductors **156**, **158**, each end of the conductors preferably comprises a transition portion **184** as best shown in FIG. **3**. A similar transition portion **184** for a multi-finned conductor is shown in FIG. **4**. For a connector body **154** manufactured using an injection molding process, transition portion **184** may be an integral part of conductors **156**, **158** by making conductors **156**, **158** from a flat strip of metal, preferably copper or a copper alloy, having a width W_1 equal to that of the antenna and pressing the middle portion of the strip into a mold having the desired wave-like shape of width W_2 (see FIG. **3**). For example, widths W_1 and W_2 could be 1.0 inch and 0.38 inch, respectively. However, because a preferred connector **52** having an injection molded body **154** preferably comprises a backing plate **164**, as shown in FIGS. **1** and **7** and discussed in more detail below, having openings through which conductors **156** and **158** closely fit on the low pressure (compartment **32**) end of connector **52**, the transition portions **184** on the low pressure ends of conductors **156** and **158** are preferably connected to conductors **156** and **158** using a suitable fastening technique, such as welding, after backing plate **164** is installed onto connector **52**. The same concept also applies to an alternative embodiment shown in FIG. **5** which has a metal housing **182** having openings through which conductors **156** and **158** closely fit on the low pressure end of connector **52**.

Referring again to FIG. **1**, connector **52** preferably comprises a back plate **164** having openings through which extensions of connector body **154** and conductors **156**, **158** protrude (also illustrated in FIG. **7**). Back plate **164** bears on an interior surface of tool **10** and prevents the high differential pressure from extruding body **154** through the opening between compartment **162** and compartment **32**. For additional protection against such extrusion tendencies, conductors **156** and **158** may be provided with one or more transverse holes **156**A, **158**A such that the material of body **154** (which is preferably an injection molded thermoplastic) flows through transverse holes **156**A, **158**A during the injection molding process and thereby enhances the bond between conductors **156**, **158** and body **154**. A similar effect could also be achieved with notches in the edges of conductors **156**, **158**. Holes **156**A, **158**A and backing plate **164** also help to prevent the effects of creep in the material of body **154** due to elevated temperatures and high stresses. Holes **156**A, **158**A may be placed in any convenient portion of conductors **156**, **158** that will be disposed within body **154**. For example, for wave-like conductors **156**, **158** manufactured using a stamping and forming process, holes **156**A, **158**A could be stamped into conductors **156**, **158** at convenient locations. Alternatively, for multi-finned conductors **156**, **158** manufactured using a machining process, holes **156**A, **158**A could be machined into conductors **156**, **158** at desirable locations.

Still referring to FIG. **1**, to reduce the overall force on connector **52** due to the high differential pressure between compartment **162** and compartment **32**, connector **52** preferably has a portion **52**A of reduced cross-section on the high pressure (compartment **162**) end. A filler **170** is used to fill the remaining cross-sectional area around connector **52** on the high pressure end. To form the necessary pressure seal, filler **170** preferably has interior and exterior slots **174** and **188** for receiving O-rings **172** and **186**, respectively. Filler **170** and connector **52** are preferably held in place by a retaining ring **168** which fits inside a corresponding slot in tool **10**; however, any suitable fastening means may be used to perform this function. Conductors **156** and **158** should be separated by a sufficient distance D to prevent arcing between conductors **156** and **158**. To provide additional protection against such arcing, connector body **154** preferably has a slot **160** to create a more tortuous path between conductors **156** and **158** along the surface of body **154**.

Finally, a molded rubber boot **166** or other suitable encapsulant is preferably bonded to body **154** over conductors **156**, **158** on the high pressure end of connector **52** to seal off conductors **156**, **158** from the borehole fluids. The foregoing apparatus thus provides a hermetically sealed electrical connection between the antenna **14** in compartment **162** and the capacitor leads **42** in compartment **32**.

Referring to FIGS. **5** and **6**, an alternative embodiment of connector **52** comprises metal (preferably copper or copper alloy) conductors **156**, **158** disposed within glass sheaths **176**, which form a glass-to-metal seal between conductors **156**, **158** and sheaths **176**. To provide additional insulation, sheaths **176** are preferably bonded within a ceramic body **178**, which is bonded inside a cup-shaped metal housing **182** with a glass layer **180**. Conductors **156** and **158**, sheaths **176**, and surrounding portions of body **178** protrude through close-fitting openings in the end of housing **182** similar to the openings in back plate **164** mentioned above for the preferred embodiment shown in FIGS. **1**, **2** and **7**. Similar to the above-described preferred embodiment, this alternative embodiment comprises a slot **160** in body **178** to help prevent arcing between conductors **156** and **158** and an encapsulating boot **166** to seal off conductors **156**, **158** from the borehole fluids in compartment **162**. This alternative embodiment is preferably sealed to drill collar **10** by an O-ring **172** seated in a slot **174** about the circumference of housing **182**, and the apparatus is preferably held in place with a retaining ring **168**, as discussed above. Although the alternative embodiment shown in FIG. **5** does not include a filler **170** as in the preferred embodiment shown in FIG. **1**, such a filler may be used in conjunction with this alternative embodiment, if desired, to reduce the cross-sectional area exposed to the high pressure of compartment **162**. The glass-to-metal seals of this alternative embodiment do not tend to creep as readily as the thermoplastic bonds of the preferred embodiment discussed above.

As discussed above with regard to FIG. **1**, one of the advantages of providing a transition portion **184** for conductors **156**, **158** outside body **154** is compactness, which provides a reduced cross-sectional area on the high pressure end to thereby reduce the overall force acting on connector **52** due to the differential pressure between compartments **162** and **32**. However, if compactness is not an overriding concern for a particular application of this invention, the transition portion **184** may be disposed within body **154**. Although such an embodiment would not retain the benefit of a reduced overall force on connector **52**, such an embodiment would achieve the advantage of reducing the force acting on conductors **156**, **158** by reducing the cross-sectional area of conductors **156**, **158** which is exposed to the high pressure. Such an embodiment would also retain the benefit of enhanced bonding between conductors **156**, **158** and body **154** due to increased surface area of conductors **156**, **158** and holes **156**A, **158**A. Thus, such a configuration would help reduce the possibility of extruding conductors **156**, **158** through body **154**.

Although the preferred embodiment illustrated herein comprises two conductors for use with the two ends of a loop antenna, other desirable configurations may comprise only one conductor or more than two conductors, depending on the particular application. Additionally, although the embodiments described herein are of circular overall cross-section, other overall cross-sectional shapes may be utilized to advantage. Furthermore, depending on the various requirements of a particular application, some of the objectives of this invention may be achieved using conductors **156**, **158** having a conventional, flat cross-sectional shape.

For example, referring to FIG. **8**, conductors **156**, **158** may start with a relatively narrow, flat cross-sectional shape as they enter body **154** on the high pressure end, and traverse through portion **52**A of reduced cross-section transition into a wider, corrugated cross-sectional shape in the interior of a portion of body **154** having a larger diameter, and then narrow back down to a flat shape before exiting body **154** on the low pressure end.

Thus, although the foregoing specific details describe a preferred embodiment of this invention, persons reasonably skilled in the art of electrical power transmission in petroleum well drilling and logging tools will recognize that various changes may be made in the details of the apparatus of this invention without departing from the spirit and scope of the invention as defined in the appended claims. Therefore, it should be understood that this invention is not to be limited to the specific details shown and described herein.

I claim:

1. An apparatus for carrying electrical current in a downhole tool between a first compartment having a relatively high pressure and a second compartment having a relatively low pressure, said first and second compartments being separated by a structure having an opening for receiving said apparatus, comprising:

an electrically insulting body capable of being inserted into said opening, said body having a first end for exposure to said relatively high pressure and a second end for exposure to said relatively low pressure;

a pressure seal for sealing said body between said first and second compartments; and

at least one conductor comprising an electrically conductive material traversing through said body between said first end and said second end, said at least one conductor being sealably bonded to said body and having a cross-sectional shape designed to minimize the cross-sectional area of said first end of said body and maximize the surface area of said at least one conductor.

2. The apparatus of claim **1** wherein said cross-sectional shape of said at least one conductor is wave-like.

3. The apparatus of claim **1** wherein said cross-sectional shape of said at least one conductor comprises a plurality of fins.

4. The apparatus of claim **1** wherein said cross-sectional shape of said at least one conductor is flat.

5. The apparatus of claim **1** wherein said body comprises a thermoplastic material.

6. The apparatus of claim **1** further comprising a back plate disposed on said second end of said body and having at least one opening, wherein said at least one conductor passes through said at least one opening of said back plate.

7. The apparatus of claim **6** wherein a portion of said body surrounding said at least one conductor passes through said at least one opening of said back plate.

8. The apparatus of claim **1** wherein said at least one conductor has at least one transverse hole in which a portion of the material of said body is disposed.

9. The apparatus of claim **1** wherein said at least one conductor has at least one notch in which a portion of the material of said body is disposed.

10. The apparatus of claim **1** further comprising a boot surrounding said at least one conductor on said first end of said body, said boot being sealably bonded to said body and said at least one conductor.

11. The apparatus of claim **1** further comprising a boot surrounding said at least one conductor on said second end of said body, said boot being sealably bonded to said body and said at least one conductor.

12. The apparatus of any one of claims **10** and **11** wherein said boot comprises a rubber material.

13. The apparatus of claim **1** wherein said at least one conductor comprises a transition portion having a first end with a first cross-sectional shape and a second end with a second cross-sectional shape, said second cross-sectional shape being different from said first cross-sectional shape.

14. The apparatus of claim **1** wherein said pressure seal comprises a filler element disposed about said body, a first O-ring between said body and said filler element, and a second O-ring disposed about said filler element for forming a seal between said filler element and said structure.

15. The apparatus of claim **14** further comprising a retaining ring to hold said filler element in place with respect to said structure.

16. The apparatus of claim **1** wherein said at least one conductor comprises two such conductors spaced apart from each other and wherein said body comprises a slot between said two conductors to prevent electrical arcing between said two conductors.

17. The apparatus of claim **16** wherein said two conductors are substantially parallel.

18. The apparatus of claim **16** wherein said two conductors have the same cross-sectional shape.

19. An apparatus for carrying electrical current in a downhole tool between a first compartment having a relatively high pressure and a second compartment having a relatively low pressure, said first and second compartments being separated by a structure having an opening for receiving said apparatus, comprising:

a metal housing capable of being inserted into said opening;

an electrically insulating body having a first end for exposure to said relatively high pressure and a second end for exposure to said relatively low pressure, said body being disposed within and sealably bonded to said housing with a layer of glass;

at least one conductor comprising an electrically conductive material traversing through said body between said first end and said second end, said at least one conductor being sealably bonded to said body with at least one sheath of glass; and

a pressure seal for sealing said housing between said first and second compartments;

wherein said at least one conductor has a cross-sectional shape designed to minimize the cross-sectional area of said first end of said body and maximize the surface area of said at least one conductor.

20. The apparatus of claim **19** wherein said cross-sectional shape of said at least one conductor is wave-like.

21. The apparatus of claim **19** wherein said cross-sectional shape of said at least one conductor comprises a plurality of fins.

22. The apparatus of claim **19** wherein said cross-sectional shape of said at least one conductor is flat.

23. The apparatus of claim **19** wherein said body comprises a ceramic material.

24. The apparatus of claim **19** wherein said housing further comprises a back plate disposed on said second end of said body and having at least one opening, wherein said at least one conductor passes through said at least one opening of said back plate.

25. The apparatus of claim **24** wherein a portion of said body surrounding said at least one conductor passes through said at least one opening of said back plate.

26. The apparatus of claim **19** wherein said at least one conductor has at least one transverse hole in which a portion of the material of said body is disposed.

27. The apparatus of claim **19** wherein said at least one conductor has at least one notch in which a portion of the material of said body is disposed.

28. The apparatus of claim **19** further comprising a boot surrounding said at least one conductor on said first end of said body, said boot being sealably bonded to said body and said at least one conductor.

29. The apparatus of claim **19** further comprising a boot surrounding said at least one conductor on said second end of said body, said boot being sealably bonded to said body and said at least one conductor.

30. The apparatus of any one of claims **28** and **29** wherein said boot comprises a rubber material.

31. The apparatus of claim **19** wherein said at least one conductor comprises a transition portion having a first end with a first cross-sectional shape and a second end with a second cross-sectional shape, said second cross-sectional shape being different from said first cross-sectional shape.

32. The apparatus of claim **19** wherein said pressure seal comprises an O-ring disposed about said housing for forming a seal between said housing and said structure.

33. The apparatus of claim **32** further comprising a retaining ring to hold said housing in place with respect to said structure.

34. The apparatus of claim **19** wherein said at least one conductor comprises two such conductors spaced apart from each other and wherein said body comprises a slot between said two conductors to prevent electrical arcing between said two conductors.

35. The apparatus of claim **34** wherein said two conductors are substantially parallel.

36. The apparatus of claim **34** wherein said two conductors have the same cross-sectional shape.

37. An electrical connector comprising:

an electrically insulating body having a first end and a second end; and

at least one conductor comprising an electrically conductive material traversing through said body between said first end and said second end, said at least one conductor being sealably bonded to said body and having a cross-sectional shape designed to minimize the cross-sectional area of said first end of said body and maximize the surface area of said at least one conductor.

38. The electrical connector of claim **37** wherein said cross-sectional shape of said at least one conductor is wave-like.

39. The electrical connector of claim **37** wherein said cross-sectional shape of said at least one conductor comprises a plurality of fins.

40. The electrical connector of claim **37** wherein said cross-sectional shape of said at least one conductor is flat

41. The electrical connector of claim **37** wherein said body comprises a thermoplastic material.

42. The electrical connector of claim **37** further comprising a back plate disposed on said second end of said body and having at least one opening, wherein said at least one conductor passes through said at least one opening of said back plate.

43. The electrical connector of claim **42** wherein a portion of said body surrounding said at least one conductor passes through said at least one opening of said back plate.

44. The electrical connector of claim **37** wherein said at least one conductor has at least one transverse hole in which a portion of the material of said body is disposed.

45. The electrical connector of claim **37** wherein said at least one conductor has at least one notch in which a portion of the material of said body is disposed.

46. The electrical connector of claim **37** further comprising a boot surrounding said at least one conductor on said first end of said body, said boot being sealably bonded to said body and said at least one conductor.

47. The electrical connector of claim **37** further comprising a boot surrounding said at least one conductor on said second end of said body, said boot being sealably bonded to said body and said at least one conductor.

48. The electrical connector of any one of claims **46** and **47** wherein said boot comprises a rubber material.

49. The electrical connector of claim **37** wherein said at least one conductor comprises a transition portion having a first end with a first cross-sectional shape and a second end with a second cross-sectional shape, said second cross-sectional shape being different from said first cross-sectional shape.

50. The electrical connector of claim **37** further comprising a pressure seal for sealing said electrical connector in a barrier structure having an opening for receiving said electrical connector.

51. The electrical connector of claim **50** wherein said pressure seal comprises a filler element disposed about said body, a first O-ring between said body and said filler element, and a second O-ring disposed about said filler element for forming a seal between said filler element and said barrier structure.

52. The electrical connector of claim **51** further comprising a retaining ring to hold said filler element in place with respect to said barrier structure.

53. The electrical connector of claim **37** wherein said at least one conductor comprises two such conductors spaced apart from each other and wherein said body comprises a slot between said two conductors to prevent electrical arcing between said two conductors.

54. The electrical connector of claim **53** wherein said two conductors are substantially parallel.

55. The electrical connector of claim **53** wherein said two conductors have the same cross-sectional shape.

56. An electrical connector comprising:

a metal housing;

an electrically insulating body having a first end and a second end, said body being disposed within and sealably bonded to said housing with a layer of glass; and

at least one conductor comprising an electrically conductive material traversing through said body between said first end and said second end, said at least one conductor being sealably bonded to said body with at least one sheath of glass;

wherein said at least one conductor has a cross-sectional shape designed to minimize the cross-sectional area of said first end of said body and maximize the surface area of said at least one conductor.

57. The electrical connector of claim **56** wherein said cross-sectional shape of said at least one conductor is wave-like.

58. The electrical connector of claim **56** wherein said cross-sectional shape of said at least one conductor comprises a plurality of fins.

59. The electrical connector of claim **56** wherein said cross-sectional shape of said at least one conductor is flat.

60. The electrical connector of claim **56** wherein said body comprises a ceramic material.

61. The electrical connector of claim **56** wherein said housing further comprises a back plate disposed on said second end of said body and having at least one opening, wherein said at least one conductor passes through said at least one opening of said back plate.

62. The electrical connector of claim **61** wherein a portion of said body surrounding said at least one conductor passes through said at least one opening of said back plate.

63. The electrical connector of claim **56** wherein said at least one conductor has at least one transverse hole in which a portion of the material of said body is disposed.

64. The electrical connector of claim **56** wherein said at least one conductor has at least one notch in which a portion of the material of said body is disposed.

65. The electrical connector of claim **56** further comprising a boot surrounding said at least one conductor on said first end of said body, said boot being sealably bonded to said body and said at least one conductor.

66. The electrical connector of claim **56** further comprising a boot surrounding said at least one conductor on said second end of said body, said boot being sealably bonded to said body and said at least one conductor.

67. The electrical connector of any one of claims **65** and **66** wherein said boot comprises a rubber material.

68. The electrical connector of claim **56** wherein said at least one conductor comprises a transition portion having a first end with a first cross-sectional shape and a second end with a second cross-sectional shape, said second cross-sectional shape being different from said first cross-sectional shape.

69. The electrical connector of claim **56** further comprising a pressure seal for sealing said electrical connector in a barrier structure having an opening for receiving said electrical connector.

70. The electrical connector of claim **69** wherein said pressure seal comprises an O-ring disposed between said housing and said barrier structure.

71. The electrical connector of claim **70** further comprising a retaining ring to hold said housing in place with respect to said barrier structure.

72. The electrical connector of claim **56** wherein said at least one conductor comprises two such conductors spaced apart from each other and wherein said body comprises a slot between said two conductors to prevent electrical arcing between said two conductors.

73. The electrical connector of claim **72** wherein said two conductors are substantially parallel.

74. The electrical connector of claim **72** wherein said two conductors have the same cross-sectional shape.

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