April 16, 1968 R. H. CULLEN ETAL 3,378,811

DOWNHOLE ELECTRICAL CONNECTOR APPARATUS AND METHOD OF CONNECTING SAME

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Fig. 1A

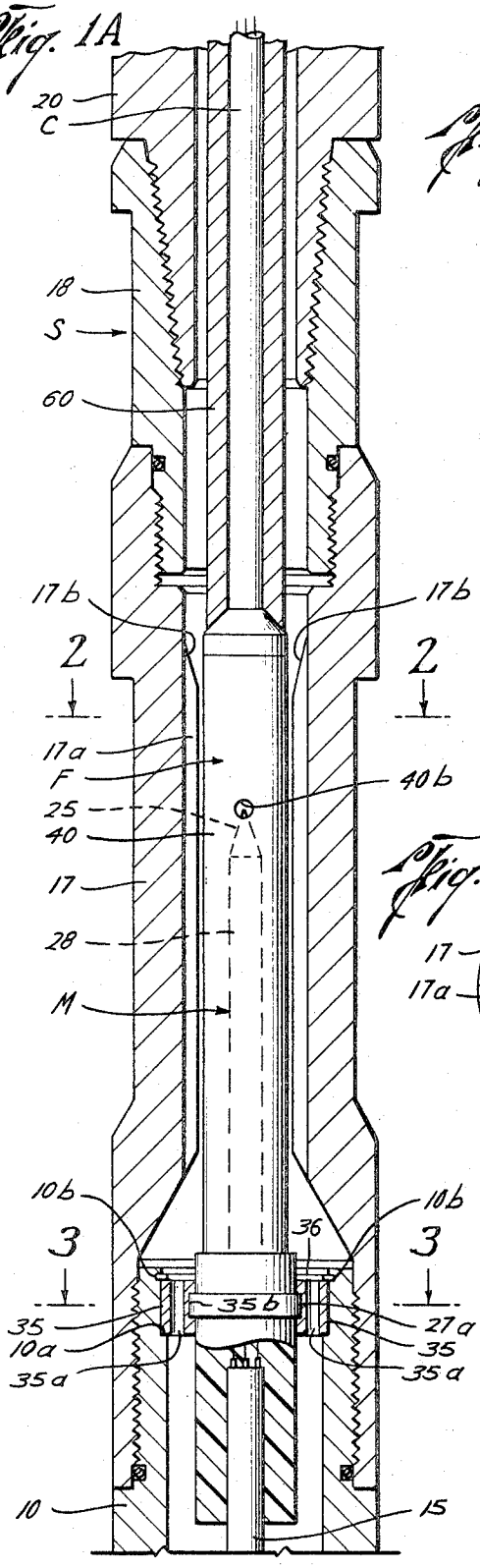


Fig. 1B

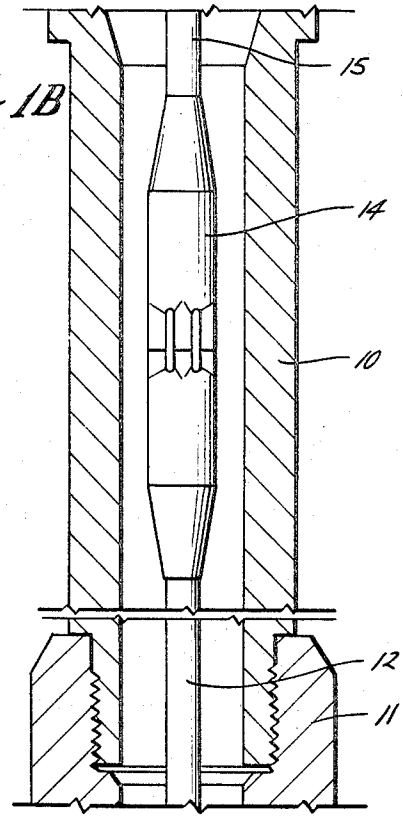


Fig. 2

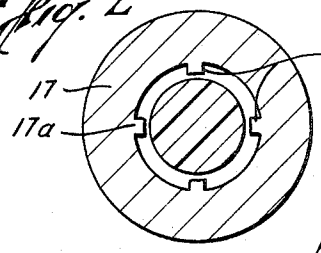
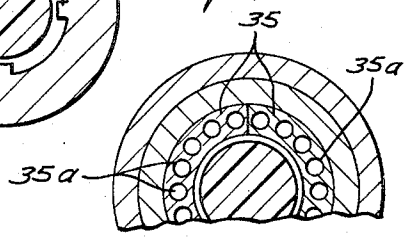


Fig. 3



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Fig. 4

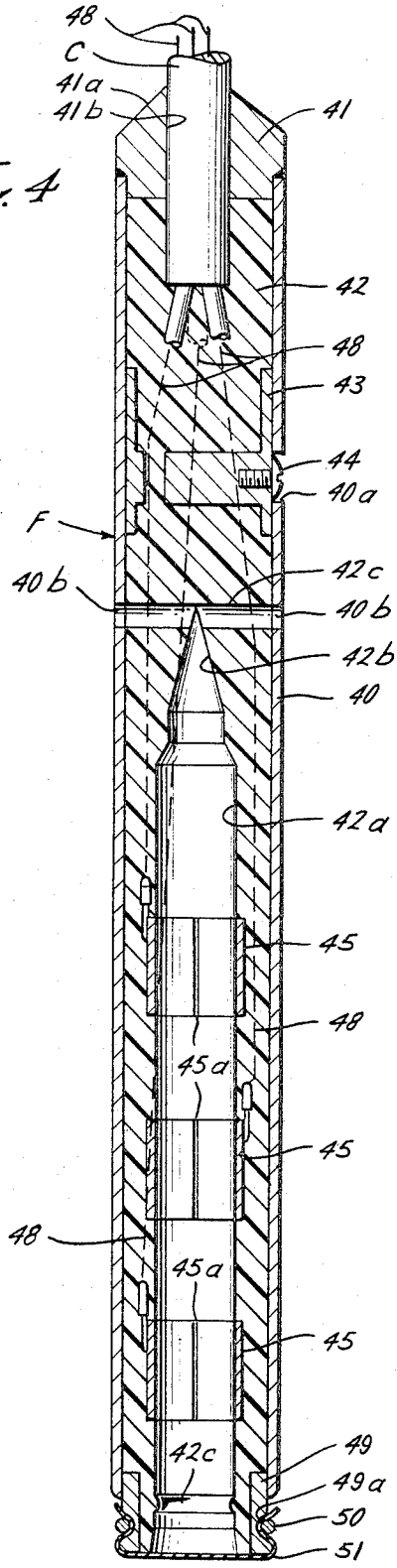
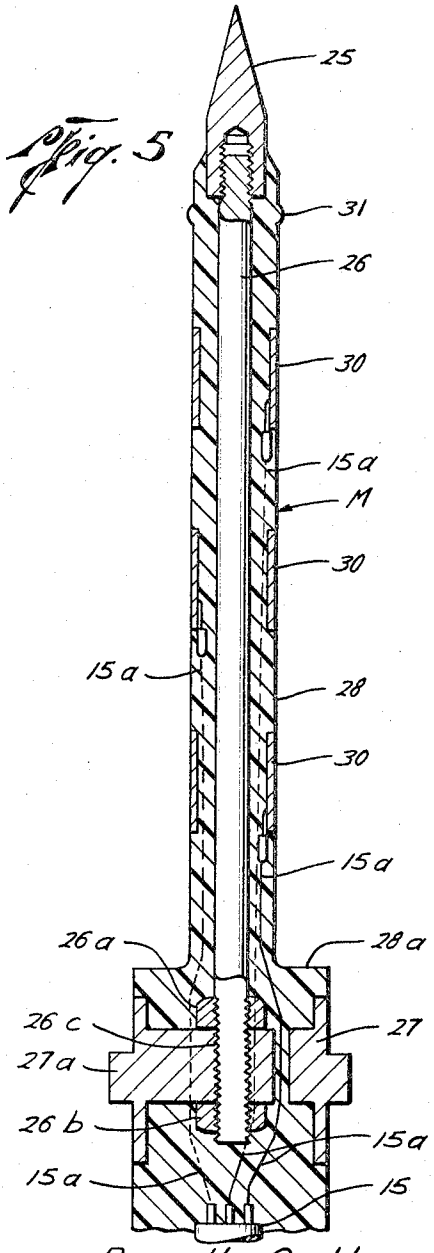


Fig. 5



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DOWNHOLE ELECTRICAL CONNECTOR APPARATUS AND METHOD OF CONNECTING SAME

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ABSTRACT OF THE DISCLOSURE

An electric connector apparatus for use in a well wherein male and female electrical connectors are provided with multiple longitudinally spaced electrical contacts and wherein means are provided for maintaining a hydrostatic balance on the connectors at all times.

It is an object of the present invention to provide a new and improved electrical connector apparatus wherein the male and female connectors thereof may be electrically engaged at a point downhole in a well or other point remote from the operator, even in the presence of water or well fluid.

A particular object of this invention is to provide a new and improved apparatus and method for making an electrical connection downhole in a well or at some other area remote from the operator, wherein a male or female connector is lowered in the well or the like on an electrical cable and is caused to electrically engage with a correlated male or female connector mounted at a point down in the well or other remote point, whereby the lowered connector may pass through a plurality of previously connected drill collar sections or the like to avoid the necessity of using separate sections of electrical cable for each drill collar section.

The preferred embodiment of this invention will be described hereinafter, together with other features thereof, and additional objects will become evident from such description.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein an example of the invention is shown and wherein:

FIG. 1A is a view, partly in elevation and partly in section, illustrating the electrical connector apparatus of this invention in the assembled or connected position within a drill string;

FIG. 1B is a view, partly in section and partly in elevation, illustrating a portion of the apparatus of FIG. 1A below the portion shown in FIG. 1A;

FIG. 2 is a cross-sectional view taken on a line 2—2 of FIG. 1A to show certain details of the guide sub of the apparatus of FIG. 1A;

FIG. 3 is a cross-sectional view taken on line 3—3 of FIG. 1A to illustrate details of the mounting means for mounting the male connector plug in the pipe string;

FIG. 4 is a view, partly in elevation and partly in section, illustrating in detail the preferred form of the female electrical connector of this invention; and

FIG. 5 is a view, partly in elevation and partly in section, illustrating the detailed view of the male electrical connector of the apparatus of this invention.

In the drawings, the letter S designates generally a string of pipe which is adapted to be disposed at a point downhole in a well or the like. With the present invention, a male electrical connector M is mounted in the pipe string S, as will be described hereinafter, and a female electrical connector F is adapted to be lowered through

a plurality of sections of the string S on an electrical cable C to make an electrical connection downhole in the well or at some point remote from the operator handling the cable C. As will be explained, the present invention makes it possible to establish an electrical connection within a string or pipe or at another point downhole within a well, event in the presence of water or well fluid. The connection between the female connector F and the male connector M may be made after a plurality of the sections of drill collar in the pipe string S have been made up or joined, whereby the cable C may be a relatively long cable and the necessity for separate electrical cable connectors at each drill collar section is thus eliminated. The present invention is valuable both during the running in of the pipe string S and during the removal of the pipe string S from a well bore or similar area, as will be more evident hereinafter.

Considering the invention more in detail, the pipe string S may take many forms, but as illustrated in the drawings, the male electrical connector M is mounted in an anchor sub **10** (FIGS. 1A and 1B) which preferably has its lower end connected with a motor housing **11**. An electric motor (not shown) is disposed in the motor housing **11**, and such motor is operatively connected with a drill bit therebelow (not shown) for drilling operations. A lower electrical cable **12** extends upwardly from the electric motor and preferably, a standard electrical connection **14** is provided for facilitating the initial mounting of the motor within the motor housing **11** at the surface of the well and prior to the lowering into the well or other similar area. Another portion of the electrical cable indicated at **15** extends upwardly from the standard connector **14** and is connected with the male electrical connector M forming a part of the present invention, as will be more fully explained.

The male connector M and ultimately the female connector F as illustrated in FIG. 1A are disposed within a guide sub **17** which also forms part of the pipe string S. Such guide sub **17** has a plurality of guide ribs **17***a* (FIGS. 1A and 2) each of which is formed with a downwardly and inwardly inclined surface **17***b* for guiding the female electrical connector F into alignment with the male electrical connector M during the making of the connection therebetween, as will be more evident hereinafter.

The pipe string S has a special adapter **18** threaded or otherwise connected at the upper end of the guide sub **17** and it receives the lowermost section of drill collar **20**. In the usual construction, the pipe string S includes a plurality of sections of drill collar which may be of the conventional type formed of relatively thick walled steel or alloy pipe. Normally, the drill string S also includes the usual drill pipe or other pipe above the drill collars **20**; such drill pipe or other pipe may be of the conventional rigid type or it may be of a flexible type such as illustrated in United States Patent No. 3,136,113.

Considering now the details of the construction of the preferred form of the male electrical connector M of the present invention, reference is made in particular to FIGS. 1A, 3, and 5. The male connector M has a sharp steel point **25** at its upper end which is threaded or otherwise mounted on a steel rod **26** which extends for substantially the full length of the male electrical connector M. The lower end of the rod **26** is threaded or is otherwise connected to a base member **27** having a retaining shoulder **27***a* formed integrally therewith. In the preferred form of the invention, the lower end of the rod **26** is secured firmly to the base flange **27** by a pair of rotatable nuts **26***a* and **26***b* which is threaded on the lower threaded portion **26***c* of the rod **26** and which engages the upper and lower surfaces of the base **27**.

A body **28** formed of neoprene, phenolformaldehyde, or any suitable insulating material is molded or otherwise

formed or assembled with the rod **26** and also the base flange **27**. Preferably, such body **28** is enlarged to provide a shoulder **28***a* in the area of the flange **27** and to also encase the upper end of the electrical cable **15** and the wires extending therefrom.

A plurality of electrical contacts **30** formed of copper, bronze, or other material are embedded or molded into the surface of the insulating body **28** at longitudinally spaced areas. Preferably, such electrical contacts **30** are formed as a split ring, although they may be annular or formed as a partial ring as desired. Each of the contacts **30** is connected with one of the wires **15***a* coming from the electrical cable **15**. Thus, the number of electrical contacts **30** depends upon the number of wires to be connected in any particular installation.

It is to be noted that the body **28** has an annular enlargement **31** which forms a seal with the internal surface of the female member F as will be more evident hereinafter. Such enlargement seal **31** is preferably integral with the body **28** and is adapted to provide an interference fit with the bore of the female member F so as to be squeezed or compressed slightly in accomplishing the seal. In some instances, the enlargement seal **31** may be replaced by an O-ring or similar sealing element. Such seal serves to keep the well fluids from contacting the electrical contacts **30** and also those of the female connector F, as will be more evident hereinafter.

In order to mount the male connector M in the anchor sub **10**, the anchor sub **10** is provided with an annular shoulder **10***a* which is adapted to receive a pair of retaining semicircular sections **35** (FIGS. 1A and 3). Such semicircular sections **35** are provided with an internal groove **35***b* which fits over the annular flange **27***a* prior to positioning the sections **35** within the anchor sub **10**. After the sections **35** have been positioned around the male member M so as to locate the shoulder **27***a* within the annular groove **35***a* provided by the two sections **35**, the two sections **35** may be both seated on the annular shoulder **10***a* as illustrated in FIG. 1A. Thereafter, the sections **35** are retained in such seated position by a releasable flexible snap ring **36** which fits within an annular groove **10***b* in the anchor sub **10**. Thus, the male member M is securely mounted in the anchor sub **10** and is thus disposed for positioning at a point in a well in proximity to the electric motor or other equipment to be operated downhole in the well. It is to be noted that the semicircular sections **35** are provided with a plurality of longitudinally extending holes or passages **35***a* through which fluid may pass. Thus, drilling mud or other fluid may be circulated down through the pipe string S to the drill bit (not shown) at the lower end of the drill string S even though the electrical cable C and the rest of the structure connected therewith are disposed within the drill string S.

Considering now the details of the female electrical connector F as illustrated in particular in FIGS. 1A and 4, it can be seen that such female connector F includes an outer housing or shell **40** which is preferably formed of steel or other similar material and which is welded or otherwise secured to an upper head section **41**. The upper head section **41** preferably has an inclined upper surface **41***a* and a bore **41***b* through which the electrical cable C is adapted to extend. A body **42** formed of neoprene, phenolformaldehyde, or other insulating material is formed within the sleeve **40** or is assembled therewith after manufacture. Preferably, a metal element forming a partial or complete ring indicated at **43** is molded or otherwise formed with the body **42** and is suitably threaded for receiving a holding screw **44** which extends through an opening **40***a* in the housing or sleeve **40**.

The body **42** is provided with a bore or internal opening **42***a* which conforms generally in shape with the external surface of the male electrical connector M. Thus, in the preferred form of the invention, the bore **42***a* is formed with a pointed upper end **42***b* which is large enough to receive the pointed end **25** of the male connector M when the two connectors are assembled. At longitudinally spaced points in the bore **42***a*, electrical contacts **45** formed of copper, bronze, or other electrically conducting material are disposed. Such contacts **45** are preferably split ring elements having a split as indicated at **45***a* so as to provide a resilient structure which is slightly smaller at its internal diameter than the external diameter of the contacts **30**, thereby providing a frictional gripping engagement by each of the contacts **45** with each of the contacts **30** when the connectors M and F are interfitted and engaged. The cable C has a plurality of electrical wires **48** extending downwardly therefrom and preferably molded within the body **42** for electrically connecting each of same with one of the contacts **45** as illustrated in FIG. 4. Again, the number of such contacts **45** may be varied depending upon the number of wires **48** to be connected or utilized.

At the upper end of the bore **42***b*, a hole extends diametrically through the body **42** as indicated at **42***c*, and such hole is in communication with the opening at the pointed upper end **42***b*. Also, such hole **42***c* is in communication with openings **40***b* in the housing or shell **40** so that fluid within the bore **42***a* may be forced out of the passage **42***c* and the openings **40***b* as will be explained.

At the lower end of the body **42**, an annular ring **49** preferably formed of metal is molded to or secured to the body **42**. Such ring **49** also interfits with the sleeve **40** as illustrated and it is provided with an annular groove **49***a* for receiving an O-ring **50** or other suitable flexible retaining member. A diaphragm **51** of rubber, neoprene, or other material fits over the lower opening of the female member F to close same when lowering into the well or other similar area. Such diaphragm **51** is secured in position on the lower end of the female connector F by the O-ring **50** which fits over the external surface of the diaphragm **51** and holds same within the groove **49***a*. Such diaphragm **51** is preferably stretched tightly so that it is capable of being readily punctured by the projection or point **25** on the male member M when it is desired to make a connection between the connectors M and F, as will become more evident hereinafter.

The bore **42***a* is provided with an annular inwardly extending enlargement **42***c* which forms a lower seal with the external surface of the male body **28** when the male and female members are fully telescoped to the connecting position, as illustrated in FIG. 1A. Thus, the enlargement **42***c* is comparable to the enlargement **31** on the male connector M and it provides the seal at the lower end while the enlargement **31** provides the seal at the upper end of the electrical contacts so as to completely seal off the electrical contacts **30** and **45** from external fluid when the connection is made in the well.

In the use or operation of the electrical connector apparatus of this invention for carrying out the method of this invention, the various drill collars **20** and the drill pipe thereabove may be connected together in advance of making the connection between the female connector F and the male connector M. The male connector M is mounted in the anchor sub **10** and is disposed downhole in the well, normally in proximity to and above the electrical motor or other electrical equipment which is to be operated through the electrical cable C.

Prior to lowering the female connector F downwardly into the drill string S, the bore **42***a* is normally filled with grease or other nonconducting viscous fluid. Also it is preferable to coat the external surface of the male electrical connector M with a grease or nonconducting viscous fluid prior to lowering it downwardly with the drill string S. During the lowering of the connector F, the grease or fluid within the bore **42***a* of the female connector F should be protected against intrusion by well fluid by means of the diaphragm **51** although both the grease and the diaphragm **51** may be omitted in some

situations. Thus, the electrical contacts 30 and 45 are protected from contact by the well fluid or other conducting liquids which might later cause a poor electrical connection or a short.

In order to urge the female connector F downwardly into engagement with and over the male connector M to the position shown in FIG. 1A, it is preferable to provide some weight with the cable C such as a weighted sleeve or cylinder 60 which may be formed of lead or other relatively heavy material. Such weight 60 may be retrieved by an operator at the surface of the well by using any kind of tool capable of engaging or attaching to the weight 60 after it has served its purpose in making the connection between the connectors F and M.

As previously pointed out, the male electrical connector M extends upwardly into the bore of a guide sub 17 so that as the female connector F is lowered into such guide sub 17, it is guided inwardly and is centered with respect to the male connector M by means of the guide ribs 17*a*. It is to be noted that the cable C may be of a relatively long length such as several hundred feet or more if desired, and the length thereof is not limited by the length of a section or sections of the drill collar 20. Thus, all of the drill collar sections 20 may be made up or threaded together at the surface of the well and lowered into the well and thereafter the female connector F with the cable C supporting same may be lowered into the bore of such drill collars. As can be appreciated, such construction thereby eliminates the necessity for using relatively short sections of cable C which would otherwise normally correspond with each of the lenghs or sections of the drill collar 20.

As the female connector F is lowered into the guide sub 17 and is guided by the guide ribs 17*a*, the diaphragm 51 is engaged by the pointed end 25 and is thereby punctured to permit the entry of the male electrical connector M into the bore 42*a* of the female electrical connector F. The grease or other nonconducting viscous fluid within the bore 42*a* is then forced upwardly and outwardly from the bore 42*a* through the hole 42c and the side openings 40*b*. As the enlargement 31 passes upwardly in the bore 42*a*, it serves as a swab for wiping the internal surfaces of the contacts 45 clean and free from the grease or nonconducting fluid which was previously in the bore 42*a*. Also, the enlargement 42*c* wipes the grease or other nonconducting fluid from the contacts 30 as they enter the bore 42*a*. In that manner, the grease or other fluid is thus removed from the electrical contacts 30 and 45 prior to the time that they become aligned with each other so as to assure proper electrical contact therebetween. Also, as previously explained, the internal diameter of the electrical contacts 45 is preferably slightly less than the external diameter of the electrical contacts 30 so that there is a frictional gripping fit between each electrical external contact 45 and each internal electrical contact 30.

When the lower end of the female connector F has seated on the surface 28*a*, the contacts 30 and 45 are in alignment and are electrically engaged. The upper seal 31 is above such contacts 30 and 45 and prevents well fluid from entering the area of the contacts from thereabove. The seal 42*c* is below the contacts 30 and 45 and thus prevents the well fluid from entering the area of the contacts from therebelow.

When it is desired to break the connection between the connectors M and F, the cable C may be pulled upwardly at the surface to pull upwardly on the female connector F and retrieve it from the drill string S. Due to the communication of the holes 40*b* and 42*c* with the bore 42*a*, the connector of this invention is hydrostatically balanced to enable the male and female connectors to be pulled apart and to be assembled together when submerged in fluid. Such retrieval can be accomplished without disconnecting the sections of the drill collar 20; and, of course, the female connector F may be later reconnected in the same manner as previously described so as to again make the connection between the connectors F and M as desired.

It should be pointed out that although this invention is particularly suitable for making a connection at a point downhole in a well below the surface of the well, it is also capable of use for making electrical connections at other points remote from the operator. It will be understood that additional electrical connections may be made with the cable C at points thereabove after making the initial downhole connection between connectors M and F, depending upon the length of the cable C which is to be connected at a particular time. Normally, the cable C will be sufficiently long to make the connection with the connectors F and M after all of the drill collars 20 are connected and prior to connecting the drill pipe or flexible pipe to the drill collar.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof and various changes in the size, shape, and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. Electric connector apparatus for use in a well pipe disposed in a well, comprising:
   (a) a male electrical connector;
   (b) a female electrical connector;
   (c) means for mounting one of said connectors in a well pipe;
   (d) said female connector having a longitudinal opening which is open at one end thereof and which has a lateral port in communication with the other end of the opening and the well pipe for maintaining a hydrostatic balance in said opening at all times;
   (e) said female connector having multiple longitudinally spaced internal electrical contacts in the wall of said opening;
   (f) said male connector being of substantially the same external diameter as the internal diameter of said opening in said female connector to provide a tight sealing fit therewith; and
   (g) said male connector having multiple longitudinally spaced external electrical contacts which are spaced apart the same distances as said contacts in said female connector for thereby engaging same when said connectors are assembled.

2. The structure set forth in claim 1, including:
   (a) guide means in the well pipe for guiding the connector which is lowered on the electrical cable to make the electrical connection downhole.

3. The structure set forth in claim 1, including:
   (a) viscous liquid in said opening of said female connector prior to assembly of the connectors;
   (b) a seal diaphragm over the open end of said opening to retain said liquid in said opening; and
   (c) said diaphragm being puncturable by said male connector to enable said male connector to enter said opening and displace said viscous liquid through said lateral port in making the electrical connection.

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