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Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) Publication number:

**0 493 375 A2**

(12)

**EUROPEAN PATENT APPLICATION**(21) Application number: **92105421.9**(51) Int. Cl.<sup>5</sup>: **H01R 13/523**(22) Date of filing: **23.06.87**

This application was filed on 30 - 03 - 1992 as a  
divisional application to the application  
mentioned under INID code 60.

(30) Priority: **23.06.86 GB 8615272**  
**11.11.86 GB 8626901**

(43) Date of publication of application:  
**01.07.92 Bulletin 92/27**

(60) Publication number of the earlier application in  
accordance with Art.76 EPC: **0 251 655**

(84) Designated Contracting States:  
**FR GB IT NL SE**

(71) Applicant: **Tronic Electronic Services Limited**  
**Sandside Road**  
**Ulverston Cumbria, LA12 9EF(GB)**

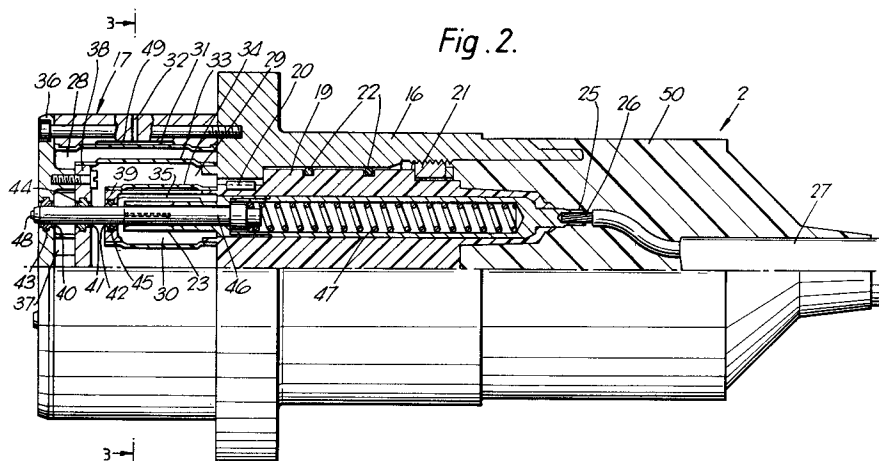
(72) Inventor: **Alcock, John Malcolm**  
**Tides Reach, Canal Foot**  
**Ulverston, Cumbria, LA12 9EN(GB)**  
Inventor: **Nicholson, Joseph Alan**  
**Hogg House, Foxfield**  
**Broughton-In-Furness, Cumbria(GB)**

(74) Representative: **Piesold, Alexander J.**  
**Frank B. Dehn & Co. Imperial House 15-19**  
**Kingsway**  
**London WC2B 6UZ(GB)**

(54) **Electrical connector.**

(57) An underwater electrical connector comprises male and female parts (1,2) which are brought together to make an electrical connection. The female part (1) includes outer, intermediate and inner closed chambers (28,29,30) containing electrically insulating fluid media, the intermediate chamber (29) being located within the outer chamber (28), and the inner chamber (30) being located within the intermediate chamber (29). An electrically insulating shuttle piston

(46) extends through a contact socket (23) disposed in the inner chamber (30) and through respective aligned openings (40,41,42) of the inner chambers. The shuttle piston (46) is arranged to be urged back by a contact pin (3) of the male part of the connector during insertion thereof such that the contact pin is received and directly engaged by the contact socket (23) in the inner chamber (30) to effect the electrical connection.

**Fig. 2.****EP 0 493 375 A2**

The invention relates to an underwater electrical connector comprising male and female parts which are brought together to make an electrical connection.

Underwater electrical connectors are known in which the female part has an electrical contact disposed within a closed chamber filled with an insulating grease or oil to provide a protected area around the contact where a connection is to be made. It has been proposed in US-A-3 729 699 and US-A-4 142 770 to provide the oil filled chamber with an opening which is sealed by a spring biased slidable shuttle piston arranged to be pushed back by engagement of a projecting male contact pin with the piston. By thus providing a shuttle piston, very little, if any, distortion of the opening is required, and the opening can be quite large to permit large pin diameters for heavy current and/or a multi-service arrangement such as a coaxial connection.

The opening of the chamber is closed either by the shuttle piston in the unmated condition of the connector or by the male contact pin when the male and female parts of the connector are brought together. A seal for the opening is provided in the form of a pair of spaced O-rings for engaging the shuttle piston or the contact pin, depending on which of these extends through the opening. With this arrangement there is a risk of deterioration of the seal which may result in water or contaminants entering the chamber where the electrical connection is made.

It is known from US-A-4 192 569 to provide a connector for connecting two ends of a coaxial cable underwater, having a central bulkhead and on each side thereof inner and outer chambers for receiving a respective coaxial cable end. Each chamber is closed by a valve formed by a flexible diaphragm through which the coaxial cable end is pushed to open the valve.

According to the invention there is provided an underwater electrical connector comprising male and female parts adapted to be interengaged to establish an electrical connection, the male part having a contact pin and the female part having contact means within a housing containing electrically insulating fluid media, the housing being provided with an opening closed in sealing manner by a resiliently biased shuttle piston which extends through the opening and is arranged to be engaged and urged back by the contact pin during insertion thereof to cause the electrical connection to be established with the contact means of the female part, characterised in that the female part includes outer and inner chambers containing electrically insulating fluid media, the inner chamber being located within the outer chamber and the contact means being located within the inner chamber, the

outer chamber being provided with said opening closed in sealing manner by the shuttle piston, the inner chamber being provided with an opening axially aligned with said opening of the outer chamber, the shuttle piston extending through both said openings when the male and female parts of the connector are disengaged from one another and the contact pin extending through and sealing both said openings when the male and female parts are interengaged.

If for example the quality of the seal of the outer chamber opening deteriorates and allows entry of water or contaminants, then the provision of the inner chamber located within the outer chamber ensures that the region where the contact means is located is not contaminated. Thus a reliable, electrically insulated electrical connection can be ensured. The electrically insulating fluid media in the chambers will generally be a dielectric fluid such as oil, grease or the like.

It is desirable that the connector can withstand high pressures so that it can be used underwater at depth. Thus, the connector may include means for effecting balancing of the fluid media pressure in the respective chambers relative to the pressure outside the connector. This can be done by making the chambers containing insulating fluid media variable in volume so as to adapt to pressure changes and thus inhibit the entry of water through the respective openings. This may be achieved by means of a piston or the like, but preferably the outer and inner chambers have a respective wall formed at least partly of a flexible membrane so as to permit variation of the volume of the respective chamber. Each flexible membrane may be formed as part of the same member in which the chamber opening is defined, or it may be provided separately at a convenient location.

The electrical integrity of the outer and inner chamber connector can be further improved by providing an intermediate chamber containing electrically insulating fluid media, the inner chamber being located within the intermediate chamber and the intermediate chamber being located within the outer chamber, the intermediate chamber having an opening axially aligned with the other openings and through which the shuttle piston passes, and the intermediate chamber having a wall formed at least partly of a flexible membrane. In the event of breakdown of the sealing of the opening to the outer chamber, then the intermediate chamber provides further protection for the region where the electrical connection is made.

The shuttle piston might have a conducting portion which is engaged by the contact pin and which engages the contact means within the inner chamber when the piston is pushed back, thereby completing the electrical connection. However, the

shuttle piston is preferably formed of electrically insulating material and extends through a female contact socket located within the inner chamber, whereby the electrical connection is established by the contact pin pushing back the shuttle piston to be received and directly engaged by the contact socket. This arrangement, while providing the advantages of a shuttle piston referred to above, avoids the need for a double electrical connection i.e. that between the contact pin and the piston and that between the piston and the female contact means.

Since the contact socket is provided within a chamber containing electrically insulating fluid media, it can be "live" prior to and during mating of the male and female parts of the connector.

In preferred embodiments, the inner chamber opening is axially spaced from the outer chamber opening by a region containing electrically insulating fluid media. The openings of the outer and inner chambers are generally formed in respective front walls thereof, and in one preferred embodiment each chamber has a flexible membrane in a side wall thereof, the flexible membrane of the inner chamber being laterally inwardly spaced from the side wall of the outer chamber. In this arrangement the outer chamber membrane is arranged to be exposed to the pressure of ambient water while the inner chamber membrane is exposed to the pressure of media in the outer chamber. If an intermediate chamber is provided this can also have a flexible membrane in a side wall thereof laterally inwardly spaced from the outer chamber side wall.

In another embodiment in which the openings are formed in respective front walls of the chambers, the chambers share a common outer side wall. Thus the inner chamber is located inwardly of the outer chamber. It will therefore be appreciated that in this specification the word "within" used in relation to the chambers is intended to encompass an arrangement in which one chamber is located inwardly of another, such chambers sharing a common outer side wall. A flexible membrane for each chamber might then be provided in the outer side wall, each flexible membrane being exposed to the pressure of ambient water, but preferably the flexible membranes are provided in the respective front walls.

The male part of the connector may include a slidably mounted wiper seal engaging the contact pin and resiliently biased towards the contact end thereof, the seal being arranged to be moved back over the pin during mating of the male and female parts. The wiper seal may, for example, be mounted by a slidable piston which defines the forward end of a chamber for the contact pin.

The male part of the connector may be pro-

vided with a single contact pin or it may have a plurality of pins with the female part having the same number of contact means. Preferably four or more contact pins are provided, and they might for example be uniformly spaced around the central longitudinal axis of the connector. If an outer chamber, intermediate chamber and inner chamber are provided, the inner chamber might enclose all the female contact means collectively, but preferably each contact means corresponding to a respective contact pin is separately enclosed by an individual inner chamber.

Certain preferred embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which:-

Fig. 1 is a partly sectioned side elevation of the male part of an electrical connector;

Fig. 2 is a partly sectioned side elevation of the female part of the connector;

Fig. 3 is a part section on the lines 3-3 of Figure 2;

Fig. 4 is a section through the male part of a second embodiment of electrical connector; and

Fig. 5 is a section through the female part of the connector of Figure 4.

The electrical connector basically comprises a male part 1 to be connected underwater with a female part 2. Referring firstly to Figure 1, the male part 1 includes four projecting contact pins 3 bonded to an insert 4 held by a retaining ring 5 in a connector socket 6. The connector socket may be moulded or it may be fabricated e.g. by machining to the correct size and shape. The insert 4, which may be formed of epoxy resin or other suitable insulating material, is correctly located by means of a key and key-way 8 at its rear end and is sealed to the connector socket 6 by a pair of insert O-rings 9. The connector socket is provided with three bulkhead seals 10 to ensure sealed engagement with a bulkhead. At its forward end the connector socket has an outer shroud 11 surrounding the four contact pins and having a key-way 12 for accurate mating with the nose of the female connector part 2. Slots 13 are provided for displacement of water as the outer shroud 11 receives the nose of the female part. The contact pins are each provided at the rear end with a solder cup 14 for connection with a respective conductor and at the front end with a cone-shaped recess 15 for positive engagement with a corresponding projection of the female part during mating.

Referring to Figures 2 and 3, the female part 2 of the connector includes a connector plug 16 to which is secured the nose 17 having a key 18 for engagement with the key-way 12 of the male part during mating. Other location/guidance arrangements could be used. Similarly to the arrangement of the connector socket 6, the connector plug 16 is

provided with an e.g. epoxy resin insert 19 located by a key and key-way 20 and held by a retaining ring 21, the insert being sealed to the connector plug by a pair of O-rings 22. Four tubular contact sockets 23 are bonded within the insert 19 and are each provided at the rear end with a solder cup 25 for connection with a respective conductor 26 of a cable 27. Alternatively, a crimped or other type of connection might be used. The connection is encased in a polyurethane moulding 50 bonded to the connector plug 16, the insert 19 and the cable 27. The female part of the connector could also be provided in a form which is more readily installable on site.

At their forward ends the tubular contact sockets 23 project into the connector plug nose 17. Within the nose 17 are defined an outer chamber 28, an intermediate chamber 29, and four individual inner chambers 30 each enclosing the projecting end of a respective contact socket 23. All the chambers are filled with insulating media such as a dielectric fluid e.g. oil, grease or the like. The outer chamber 28 has an annular outer wall comprising a flexible membrane 31 the outer surface of which is vented to the outside by a pressure compensating vent hole 32. This ensures that when the connector is submerged and is subject to increasing pressures, the membrane deflects inwardly to decrease the volume of the chamber and so balance the pressure. In this way any tendency for water from the outside to enter the chamber is reduced. An annular space 49 around the outside of the membrane 31 allows dielectric fluid displacement when the contact pins enter the chambers during mating. The intermediate chamber 29 is enclosed within the outer chamber 28 and is similarly provided with an annular flexible membrane 33. The individual inner chambers 30 also each have an annular flexible membrane 34, each carried by lantern type supports 35 projecting from the insert 19.

The outer chamber 28 is closed by a front plate 36 which has rearwardly projecting lugs 37 supporting a front plate 38 of the second chamber. The front plate 39 of each inner chamber 30 is supported by the lantern supports 35. The front plates 36, 38 and 39 of the respective chambers are respectively provided with openings 40, 41 and 42, each having an annular seal 43, 44 and 45. Referring to the arrangement associated with just one of the four inner chambers 30, a slidable shuttle piston 46 extends through the three aligned openings 40, 41 and 42 so as to close the chambers. In fact, the annular seal 45 of the inner chamber is an O-ring which has a slight clearance from the shuttle piston to reduce drag thereon, although the contact pin 3 is of larger diameter so that the seal 45 forms a close fit on the pin during mating. The shuttle piston is formed of an insulat-

ing material and is forwardly biased by a spring 47 retained within the contact socket 23. The front of the shuttle piston is formed as a cone-shaped projection 48 for positive engagement with the correspondingly shaped recess 15 of the male connector part.

To make the connection between the male and female parts of the connector the plug nose 17 is inserted into the outer shroud 11 while being guided by the mating key 18 and key-way 12. Each of the four contact pins 3 engages a corresponding shuttle piston 46 and pushes it back against the force of the spring 47. The pin passes successively through the three aligned openings 40, 41 and 42 to be received in the contact socket 23 and thereby to complete the electrical connection.

Figures 4 and 5 respectively show male and female parts 101 and 102 of a second electrical connector. Referring firstly to Figure 4 the male part 101 includes a single contact pin 103 projecting from an insert 104 and surrounded by an outer shroud 111 which defines a contact pin chamber 150. The forward end of the chamber 150 is closed by a piston 151 split into two parts which receive therebetween a wiper seal 152 engaging the outside of the contact pin. The piston is urged by a spring 153 to a forward position in which a radial projection 154 of the piston engages an abutment ring 155 secured on the end of the shroud 111. The piston is located in this forward position when the connector is in the unmated condition and the major length of the contact pin is then protected. When the male part 101 is mated with the female part 102 the piston 151 is pushed rearwardly and carries the wiper seal 152 which slides axially along the surface of the contact pin. On decoupling the connector, the spring 153 ensures that the piston and wiper seal return to the forward position, so that the contact pin chamber 150 is protected at all times from the entry of debris.

Referring to Figure 5, the female connector part 102 includes a plug nose 117 in which is mounted a tubular contact socket 123 having a slidable shuttle piston 146 extending axially there-through, as in the embodiment of Figures 1 to 3. Within the plug nose 117 are defined an outer chamber 128 and an inner chamber 129 which encloses the contact socket 123. The forward wall of the outer chamber comprises a one-piece closure member 156 having a central axial opening 157 through which the shuttle piston 146 extends. The closure member 156 is formed of a flexible material and has an inner ring seal 158 defining the opening 157 and an outer ring seal 159 in sealed engagement with the inside surface of the plug nose 117. The ring seals 158 and 159 are connected together by an integral, relatively thin, flexible membrane 160 of the closure member which is

arranged to project rearwardly into the outer chamber 128 and to flex so as to allow volume changes thereof, similarly to membrane 31 of the first embodiment. The closure member 156 is retained in position on its forward side by a nut 161 having axial passages therethrough to communicate the outside of membrane 160 with ambient water pressure, and on its rear side by a cage support 162 which also serves to support the membrane.

A second closure member 163 separates the outer and inner chambers 128 and 129. The member 163 has an inner ring seal 164 defining an opening 165 for the shuttle piston, an outer ring seal 166 in sealed engagement with the inside surface of the plug nose 117, and an integral flexible membrane 167 connecting the ring seals together. The closure member is retained on its forward side by a washer 168 having axial holes therethrough to communicate the membrane 167 with the pressure in the outer chamber 128, and on its rear side by a cage support 169 which abuts against the forward end of a sleeve 170 disposed inside the plug nose 117.

To make the connection between the male and female parts 101 and 102 of the connector the plug nose 117 is inserted into the outer shroud 111. The piston 151 of the male part is pushed back by the nose 117 and the contact pin 103 pushes back the shuttle piston 146 to pass successively through the opening 157 to the outer chamber and the opening 165 to the inner chamber. The contact pin is received in the contact socket 123 to complete the electrical connection within the inner chamber.

Although the embodiment of Figures 4 and 5 has only one pin and socket, a plurality of such pins and sockets could be provided in a connector.

It is to be noted that in both embodiments the various chambers containing electrically insulating media are separate and sealed from each other, the only communication between adjacent chambers being provided by the openings through which either the shuttle piston passes in the unmated condition of the connector or the contact pin passes when the male and female parts of the connector are brought together.

Modifications to the broad aspects and the specific embodiment of the invention may be apparent to a person skilled in the art and it is intended that this disclosure should extend to any such modifications.

## Claims

1. An underwater electrical connector comprising male (1;101) and female (2;102) parts adapted to be interengaged to establish an electrical connection, the male part (1;101) having a contact pin (3;103) and the female part (2;102)

having contact means (23;123) within a housing (17;36;117,161) containing electrically insulating fluid media, the housing being provided with an opening (40;157) closed in sealing manner by a resiliently biased shuttle piston (46;146) which extends through the opening (40;157) and is arranged to be engaged and urged back by the contact pin (3;103) during insertion thereof to cause the electrical connection to be established with the contact means (23;123) of the female part, characterised in that the female part (2;102) includes outer (28;128) and inner (30;129) chambers containing electrically insulating fluid media, the inner chamber (30;129) being located within the outer chamber (28;128) and the contact means (23;123) being located within the inner chamber, the outer chamber being provided with said opening (40;157) closed in sealing manner by the shuttle piston (46;146), the inner chamber being provided with an opening (42;165) axially aligned with said opening (40;157) of the outer chamber, and the shuttle piston (46;146) extending through both said openings (40,42;157,165) when the male and female parts of the connector are disengaged from one another and the contact pin (3;103) extending through and sealing both said openings when the male and female parts are interengaged.

2. A connector as claimed in claim 1, wherein the outer (28;128) and inner (30;129) chambers each have a respective wall formed at least partly of a flexible membrane (31,34;160,167) so as to permit variation of the volume of the respective chamber.

3. A connector as claimed in claim 2, wherein a vent hole (32) is provided in the housing (17;36;117,161), whereby the outer surface of the outer chamber flexible membrane (31;160) is exposed to the pressure outside the connector.

4. A connector as claimed in claim 2 or 3, wherein the openings (40,42) of the chambers are formed in respective front walls (36,39) thereof, the flexible membrane (31,34) of each chamber being provided in a side wall thereof, and the flexible membrane (34) of the inner chamber being laterally inwardly spaced from the side wall of the outer chamber.

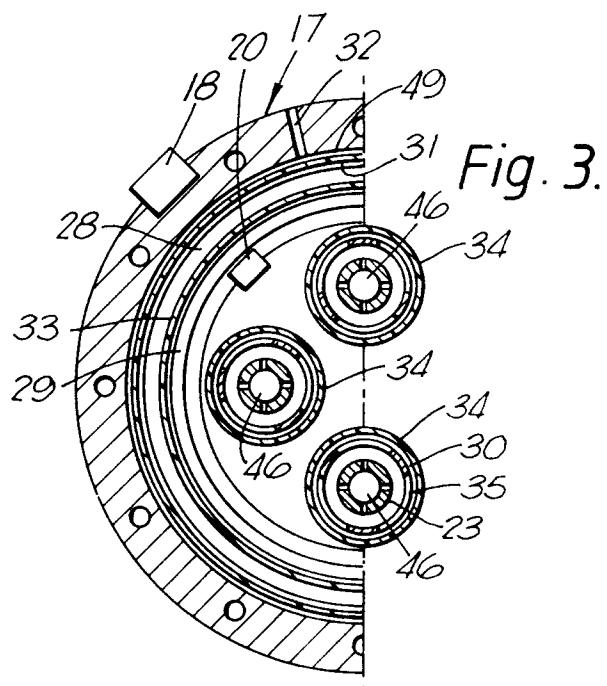
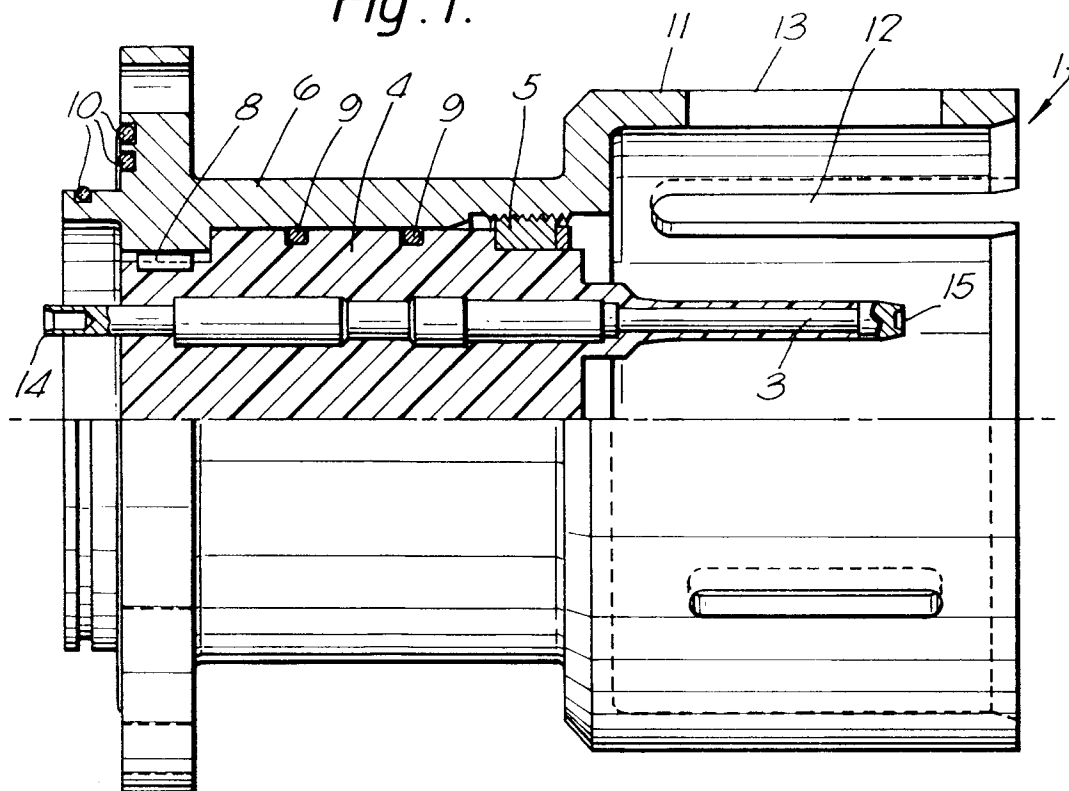
5. A connector as claimed in claim 4, wherein an annular space (49) is defined between the outside of the outer chamber flexible membrane (31) and the housing (17).

6. A connector as claimed in claim 4 or 5, wherein the opening (42) to the inner chamber (30) is provided with an annular seal (45) having a slight clearance from the shuttle piston (46). 5
7. A connector as claimed in claim 4, 5 or 6, including an intermediate chamber (29) containing electrically insulating fluid media, the inner chamber (30) being located within the intermediate chamber (29) and the intermediate chamber being located within the outer chamber (28), the intermediate chamber (29) having an opening (41) axially aligned with the other openings (40,42) and through which the shuttle piston (46) passes, and the intermediate chamber (29) having a wall formed at least partly of a flexible membrane (33). 10 15
8. A connector as claimed in any of claims 4 to 7, wherein the male part (1) has a plurality of contact pins (3) and the female part (2) has a corresponding plurality of contact means (23), the female part (2) further comprising a plurality of inner chambers (30), each inner chamber being located within the outer chamber (28), and each inner chamber having a respective contact means (23) located therein. 20 25
9. A connector as claimed in claim 1, 2 or 3, wherein the opening (157) of the outer chamber (128) is formed in a flexible member (156), and wherein the outer chamber flexible membrane (160) is integral with said flexible member (156). 30 35
10. A connector as claimed in claim 1, 2, 3 or 9 wherein the opening (165) of the inner chamber (129) is formed in a flexible member (163), and wherein the inner chamber flexible membrane (167) is integral with said flexible member (163). 40
11. A connector as claimed in claim 1, 2, 3, 9 or 10, wherein the openings of the outer and inner chambers (128,129) are formed in respective front walls thereof and the chambers share a common side wall, the flexible membrane (160,167) of each chamber being provided in its respective front wall. 45 50
12. A connector as claimed in any preceding claim, wherein the male connector part (101) includes a slidably mounted wiper seal (152) engaging the or each contact pin (103) and resiliently biased towards the contact end thereof, the seal (152) being arranged to be moved back over the pin during mating of the 55

male and female parts.

13. A connector as claimed in any preceding claim, wherein the inner chamber opening is axially spaced from the outer chamber opening by a region containing electrically insulating fluid media.

Fig. 1.



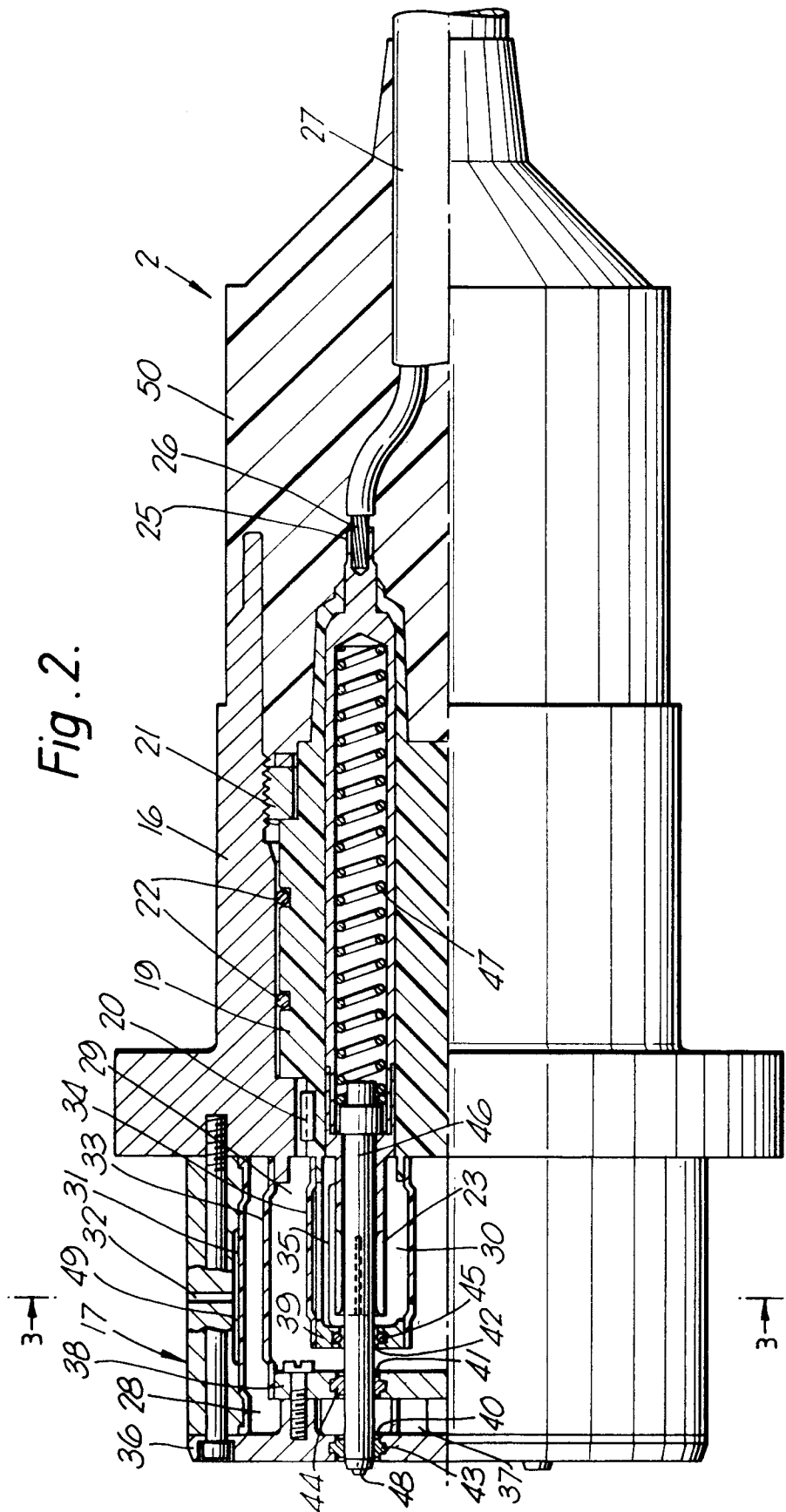


Fig. 4.

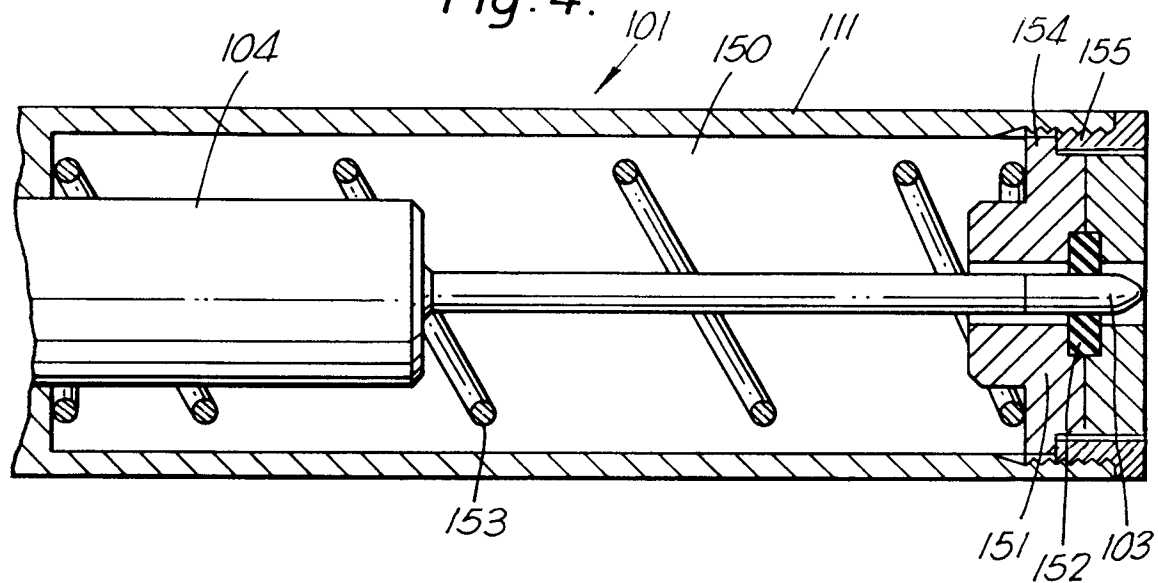


Fig. 5.

