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**Christiansen et al.**

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(54) **WET MATE CONNECTOR**

(71) Applicant: **Ametek SCP, Inc.**, Westerly, RI (US)

(72) Inventors: **Matt Christiansen**, Westerly, RI (US); **Greg Marshall**, Westerly, RI (US); **Richard Miller**, Franklin, MA (US)

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***H01R 24/58*** (2011.01)

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CPC ..... ***H01R 13/523*** (2013.01); ***H01R 13/5219*** (2013.01); ***H01R 24/58*** (2013.01)

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CPC ..... H01R 13/523
See application file for complete search history.

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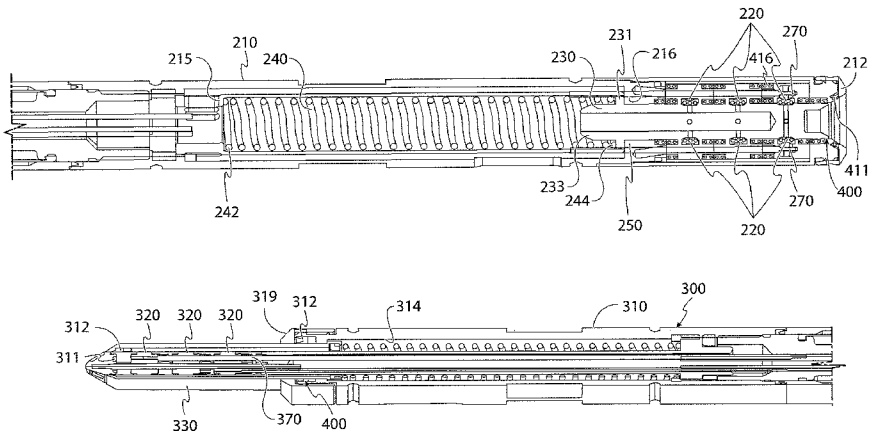
*Primary Examiner* — Ross Gushi
(74) *Attorney, Agent, or Firm* — RatnerPrestia

(57) **ABSTRACT**

A wet mate electrical connector includes a female connector and a male connector. The female connector can include a female connector body defining a central passage. The central passage can include a plurality of female contacts. The male connector can include a male connector body defining a central passage. A male pin can project from the central passage of the male connector body. The male pin can include a plurality of male contacts and be insertible into the central passage of the female connector. The male connector can also include a sleeve slidably displaceable over the male pin between a first position in which the sleeve covers the plurality of male contacts in a protected condition, and a second position in which the sleeve is retracted and exposes the plurality of male contacts.

**14 Claims, 6 Drawing Sheets**



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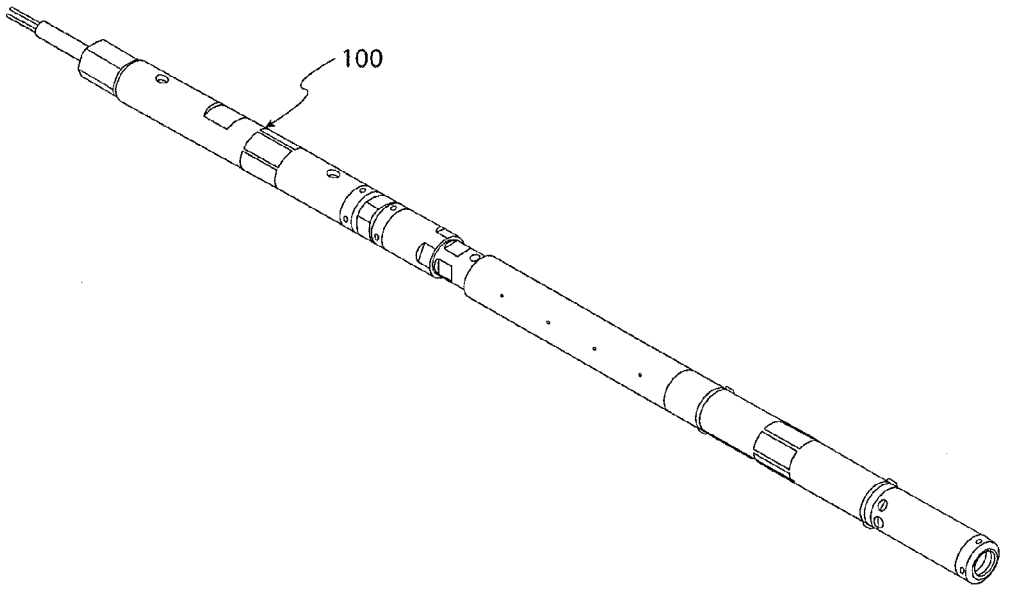



FIG. 1

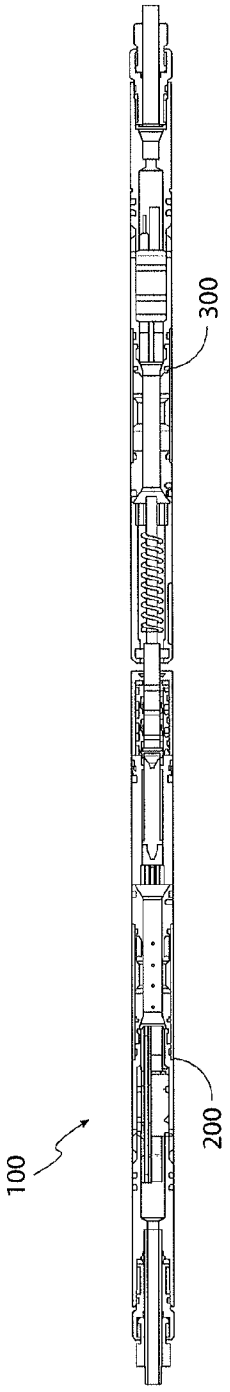



FIG. 2

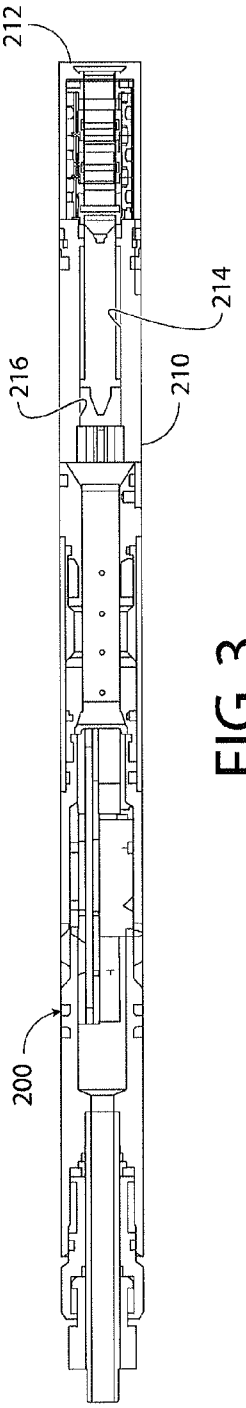



FIG. 3

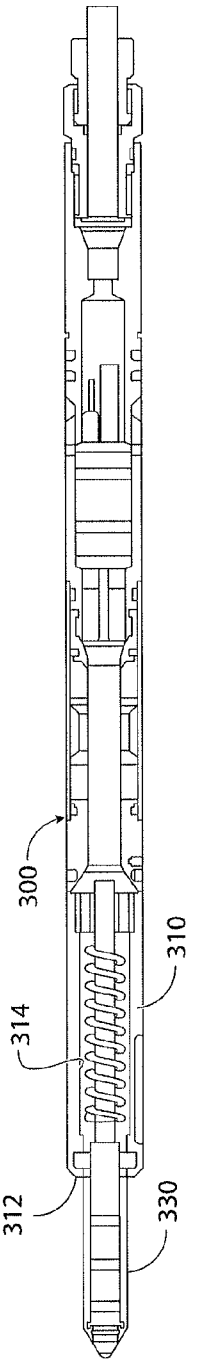
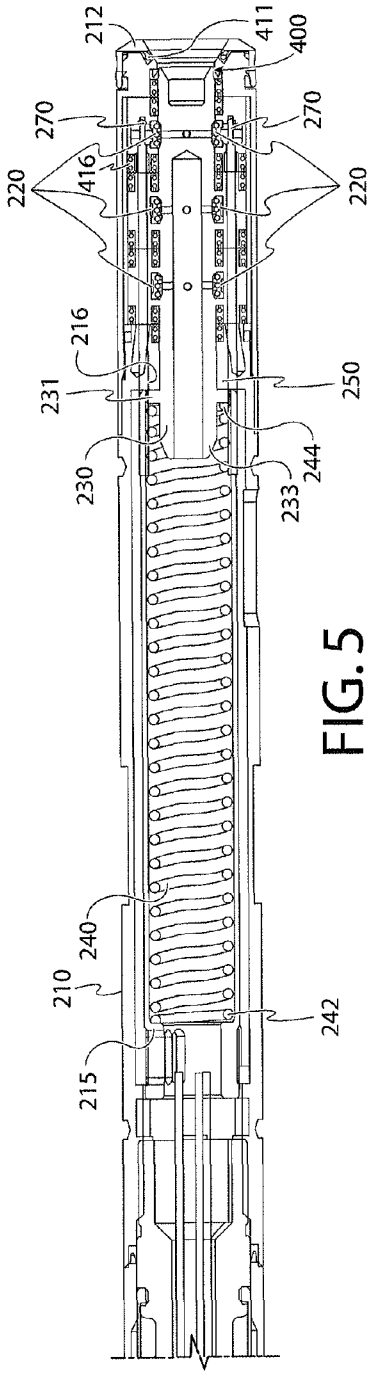



FIG. 4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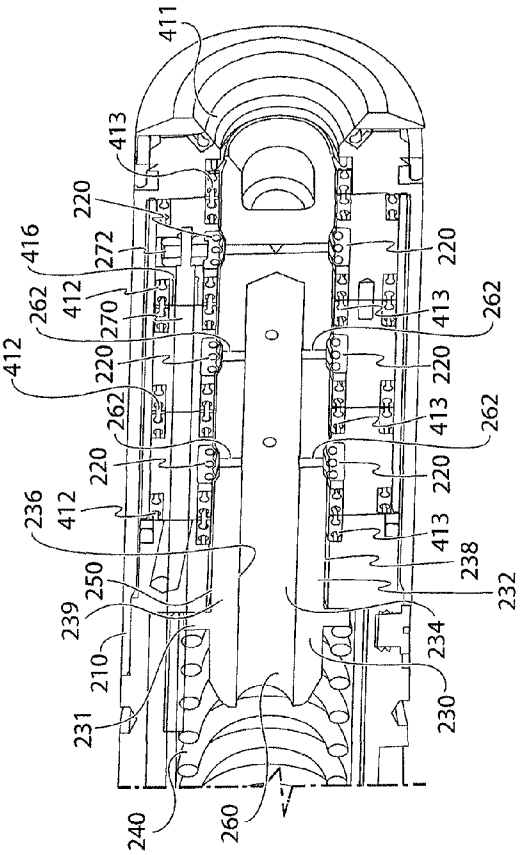
411
400
270
270
220
416
220
216
231
250
230
244
233
240
210
242
215

FIG. 5


411
413
220
416
272
220
262
412
270
262
412
220
220
262
413
220
262
220
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262
236
412
220
413
238
250
232
239
234
210
231
230
240
260

FIG. 6

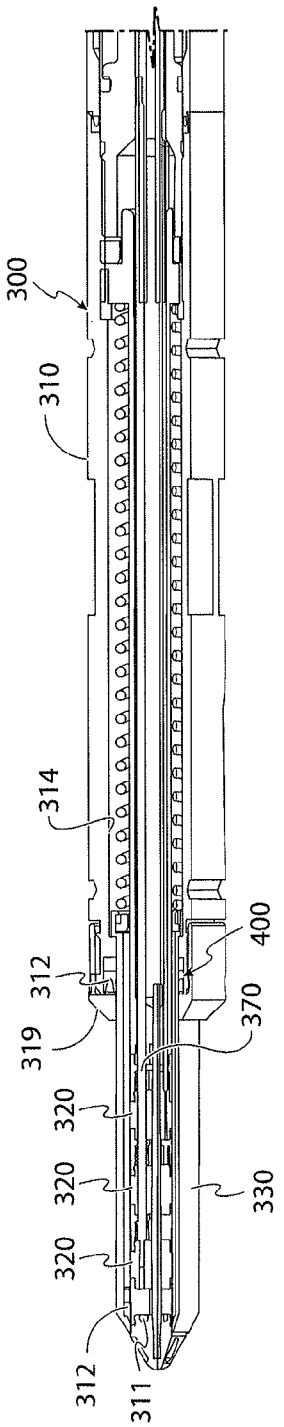
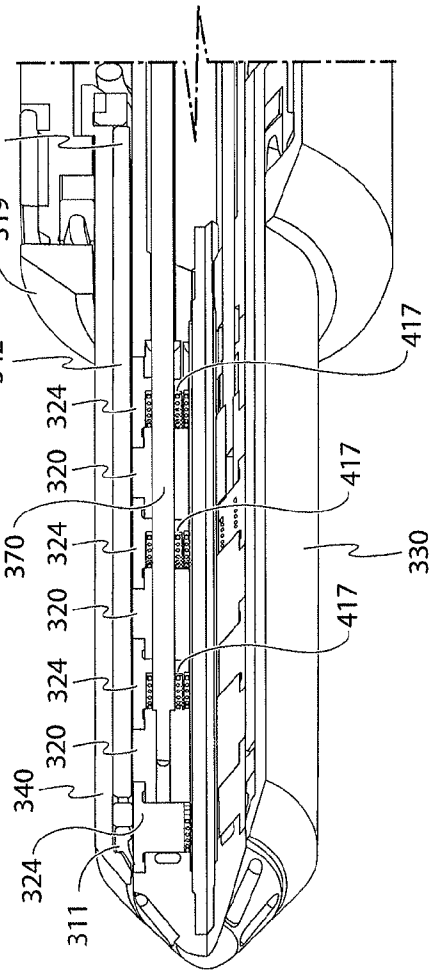

300
310
314
312
319
320
320
320
312
311
400
370
330

FIG. 7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319
342
324
320
370
324
320
324
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340
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311
417
417
417
330

FIG. 8

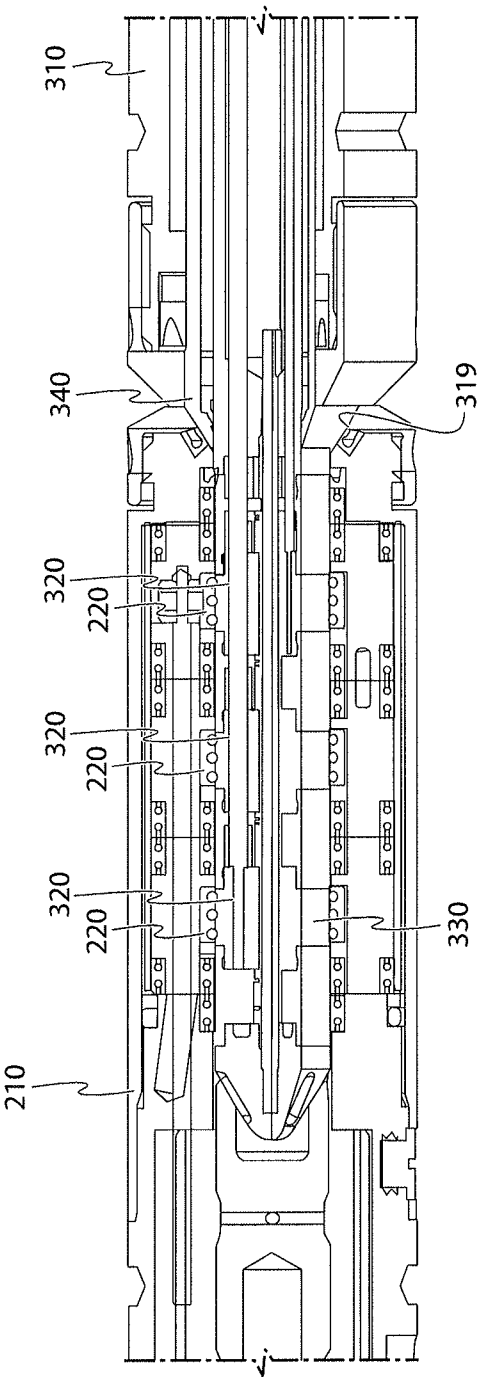


FIG. 9

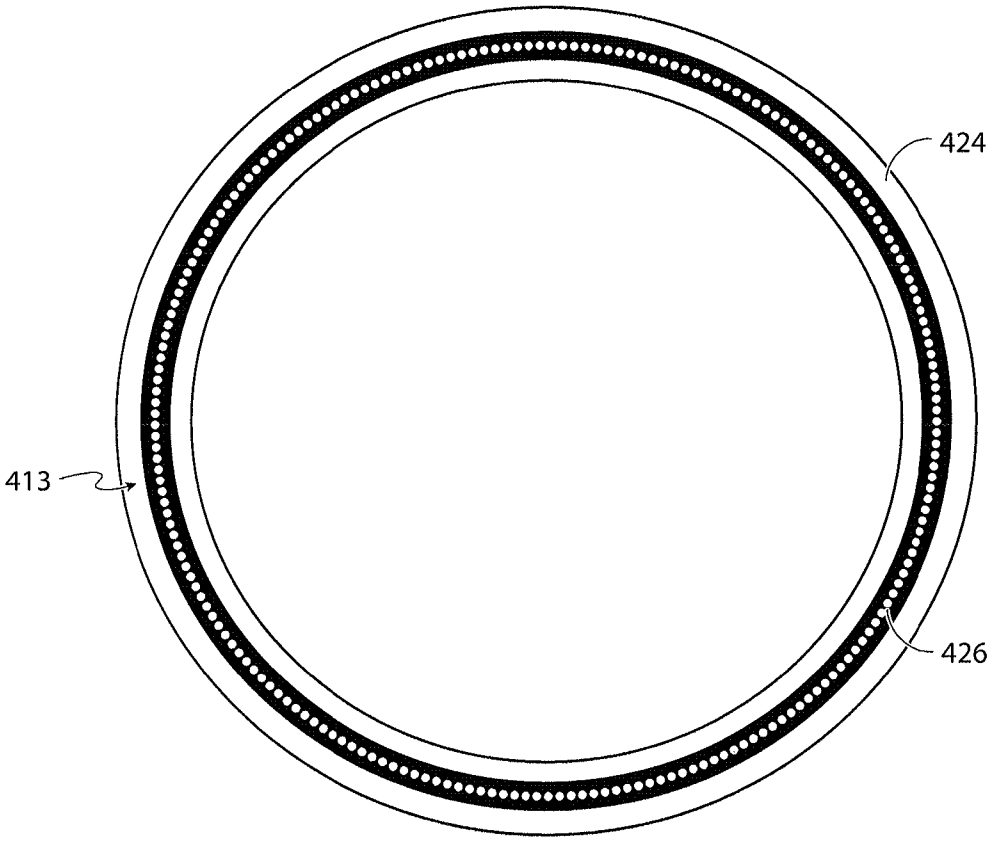


FIG. 10

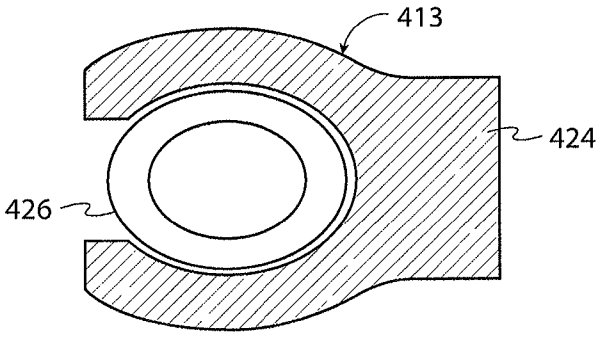


FIG. 11

# WET MATE CONNECTOR

## FIELD

The field of the invention relates generally to wet mate connectors installed in downhole and deep sea environments, and more particularly to small-diameter wet mate connectors that incorporate seals, pressure balancing mechanisms, and electrical insulating mechanisms that allow the connectors to be used in permanent or long-term installations subject to high temperatures and pressures, where conventional wet mate connectors are not suited.

## BACKGROUND

Hydraulic lines and conduits are used to provide power and data communications to equipment installed in wet environments like downhole and subsea environments. Electrical and fiber-optic cable connections must often be made deep in a well bore or at great ocean depths. Therefore, wet-mateable or "wet mate" connectors have been developed that allow equipment to be connected and disconnected in harsh wet environments.

A number of wet mate connectors feature a male end that includes a plug, and a female end that includes a socket to receive the plug. The plug and socket each include one or more electrical contacts. The electrical contacts must be protected from exposure to production fluid, seawater and contaminants during mating and disconnection of the male and female ends. In addition, interior spaces in the connector must be pressure balanced with the exterior environment so that the male and female ends can be mated and disconnected properly. Balancing interior and exterior pressure alleviates stresses on internal components and prevents components from becoming locked or jammed.

Some wet mate connectors include internal seals to protect electrical contacts. Nevertheless, many seals are designed for short-term use, and are not adequate to withstand harsh temperature and pressure conditions through repeated use in permanent or long-term installations. In addition, many connectors incorporate seals and other components for balancing pressures that occupy a relatively large amount of space, and are not small enough to be used in many well bores. In some well bores, less than an inch of space is allocated for the diameter of the connector. Unfortunately, conventional wet mate connectors cannot simply be made smaller. Even if they were to be reduced in size, they still cannot address the challenges of providing adequate pressure balancing and seal integrity, which are necessary in permanent or long-term installations subject to high temperatures and pressures.

## SUMMARY

The drawbacks and limitations of conventional wet mate connectors are resolved in several respects by wet mate connectors in accordance with the invention.

In one embodiment, a wet mate electrical connector includes a female connector having a female connector body defining a female seal end and a central passage extending through the female connector body. The central passage includes a plurality of female contacts. The wet mate electrical connector also includes a male connector having a male connector body defining a male seal end and a central passage extending through the male connector body. A male pin axially projects from the central passage of the male connector body and features a plurality of male contacts. The male pin is insertible into the central passage of the female connector.



The male connector also has a sleeve slidably displaceable over the male pin between a first position in which the sleeve covers the plurality of male contacts in a protected condition, and a second position in which the sleeve is retracted and exposes the plurality of male contacts. Upon insertion of the male pin into the central passage of the female connector, the sleeve on the male pin contacts the female seal end to displace the sleeve from the first position to the second position to expose the plurality of male contacts. The plurality of male contacts axially align with the plurality of female contacts in the female connector when the male pin is fully inserted or substantially inserted into the central passage of the female connector.

The sleeve can define a sealed space around the plurality of male contacts when the sleeve is in the first position. In addition, the sealed space can be in fluid communication with a source of oil. The source of oil can distribute oil over the male contacts to protect the male contacts when the sleeve is in the first position.

The female connector can include a female pin axially displaceable in the central passage of the female connector body. The female pin can be displaced between a first position in which the female pin is generally adjacent the female seal end and a second position in which the female pin is displaced into the female connector body away from the female seal end. The female connector can also include a female biasing element that biases the female pin toward the first position. In addition, the central passage and female pin of the female connector can be filled with oil to protect the plurality of female contacts when the female connector is in an unmated condition. The female pin can include at least one port in fluid communication with pressure balanced oil to balance pressure in the central passage of the female connector and prevent hydraulic lock.

The female connector can also include a primary seal and a secondary seal to protect the plurality of female contacts. The primary seal can feature a scraper seal at the female seal end. In addition, or as an alternative, the primary seal can include at least one spring energized seal along the central passage. Moreover, the primary seal can include a plurality of spring energized seals arranged in series along the central passage. In such an embodiment, the plurality of female contacts can be arranged in series with the plurality of spring energized seals along the central passage. In addition, each of the plurality of female contacts can be separated by another of the plurality of female contacts by one of the plurality of spring energized seals.

In embodiments that feature at least one spring energized seal, the at least one spring energized seal can include a body portion and an internal spring in the body portion. The body portion can be formed of polytetrafluoroethylene (PTFE). In addition, or as an alternative, the body portion can be formed of PEEK.

## BRIEF DESCRIPTION OF THE DRAWING FIGURES

The foregoing summary and the following detailed description will be better understood in conjunction with the following drawing figures containing non-limiting embodiments and examples, of which:

FIG. **1** is a perspective view of a female connector end of a wet mate connector in accordance with one embodiment;

FIG. **2** is a side cross section view of a wet mate connector in accordance with one embodiment;

FIG. **3** is a side cross section view of a female connector end of the wet mate connector of FIG. **2**;

FIG. **4** is a side cross section view of a male connector end of the wet mate connector of FIG. **2**;

FIG. **5** is an enlarged truncated side cross section view of a portion of the female connector end of FIG. **3**;

FIG. **6** is an enlarged truncated perspective view of an end portion of the female connector end of FIG. **3**, shown in cross section;

FIG. **7** is an enlarged truncated side cross section view of a portion of the male connector end of FIG. **4**;

FIG. **8** is an enlarged truncated perspective view of an end portion of the male connector end of FIG. **4**, shown in cross section;

FIG. **9** is an enlarged truncated side cross section view of a portion of the wet mate connector of FIG. **2** in the mated condition;

FIG. **10** is a plan view of a seal used in the wet mate connector of FIG. **1**; and

FIG. **11** is a side cross section view of the seal in FIG. **9**.

## DETAILED DESCRIPTION

Although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

Referring to FIGS. **1-8**, a wet mate electrical connector **100** is shown in accordance with one embodiment of the invention. Connector **100** incorporates seals, pressure balancing mechanisms, and electrical insulating mechanisms that allow the connector to be used in permanent or long-term installations subject to high temperatures and pressures, while occupying a cross sectional area less than one inch in diameter. As will be described, connector **100** provides pressure compensating oil over electrical contacts when the connector is mated and when the connector is unmated. Connector **100** also utilizes a ported arrangement to facilitate pressure balancing without the need for large-diameter components to provide pressure balancing. In addition, connector **100** utilizes secondary seals that do not experience compression set, enabling the connector to remain in service for the full life of a well bore or deep sea installation.

Connector **100** includes a female connector **200** and a male connector **300**. Male connector **300** is configured to connect to female connector **200** in a quick-release connection. Female connector **200** includes a female connector body **210** having a female seal end **212**. Female connector body **210** defines a central passage **214** that commences at female seal end **212** and extends through the female connector body. Central passage **214** forms a socket **216** that includes a plurality of female contacts **220** (seen best in FIGS. **5** and **6**). A plurality of wires **270** pass through female connector **200** to each contact **220**. Each wire **270** is electrically and hydraulically insulated by a plurality of O-rings **416**, as will be explained.

Referring to FIGS. **5** and **6**, female connector **200** includes a female pin **230** that is axially displaceable in central passage **214** of female connector body **210**. Female pin **230** is displaceable between a first position, in which the female pin is adjacent female seal end **212**, and a second position, in which the female pin is displaced into female connector body **210**, away from the female seal end. Female connector **200** also includes a female biasing element in the form of a female spring **240**. Female spring **240** is a helical compression spring that includes a first end **242** and a second end **244** opposite the first end. First end **242** engages a first wall **215** of central passage **214**. Second end **244** engages female pin **230**. Female pin **230** includes a flange **231** that extends radially outwardly from the pin near a first end **233** of the pin. Second end **244** of female spring **240** extends around first end **233** of female pin **230** and abuts flange **231**. In this arrangement, female pin **230** and second end **244** of female spring **240** are axially displaceable together as a unit in central passage **214**.

Female spring **240** is configured to store energy under compression when female pin **230** is displaced toward the second position. Female spring **240** is also configured to release energy and expand to displace female pin **230** toward the first position. In this configuration, female spring **240** biases female pin **230** toward the first position. When minimal or no resistance is applied to female spring **240**, the female spring expands to displace female pin **230** to the first position, which closes female seal end **212** and hydraulically seals central passage **214** so that well bore fluid, seawater, sand and debris cannot enter the central passage.

Central passage **214** and female pin **230** are filled with oil **250**. Oil **250** provides a controlled environment inside female connector body **210** that serves multiple purposes. First, oil **250** fills the spaces around female contacts **220** when the female connector is in an unmated condition to prevent entry of well bore fluid, seawater, sand and debris from entering. Entry of well bore fluid, seawater, sand or debris can damage the electrodes. Oil **250** also electrically insulates female contacts **220**. Moreover, oil **250** allows the pressure inside female connector body **210** to be balanced with the pressure in the environment outside of connector **100**. By balancing internal and external pressures, internal stresses on components in female connector body **210** caused by pressure differentials are minimized. This balancing of pressures prevents parts from binding, jamming, locking, or otherwise preventing the female connector **200** and male connector **300** from being connected or disconnected when needed.

Female connector body **210** includes a pressure balancing mechanism **260** integrated into female pin **230**. In particular, female pin **230** includes ports **262** that pass through the female pin and connect in fluid communication with oil **250**. Female pin **230** has a generally cylindrical body **232** defining a hollow central bore **234**, an inner pin surface **236**, an outer pin surface **238**, and a pin wall **239**. Each port **262** extends through pin wall **239**, connecting an interior portion of female pin **230** with central passage **214** outside the female pin. Central passage **214** is pressure balanced by oil **250**, so that the pressure inside female pin **230** and the pressure in the environment outside the connector are sufficiently balanced so that hydraulic lock between seals is prevented. Hydraulic lock can occur, for example, when female connector **200** and male connector **300** are connected in air, and air gets trapped between seals. Well bore pressure can act on oil **250**, creating a pressure differential across seals. This pressure differential can hydraulically lock the position of female pin **230**, preventing the female pin from moving and consequently preventing female connector **200** from connecting with the male connector **300**.

Referring to FIGS. **7-9**, male connector **300** includes a male connector body **310** defining a male seal end **319**. Male connector body **310** defines a central passage **314** that commences at male seal end **319** and extends through the male connector body. Male connector **300** also includes a male pin **330** axially projecting from central passage **314**.

Male pin **330** is insertible into central passage **214** of female connector **200**, and includes a plurality of male contacts **320** arranged in series along the length of the male pin. A plurality of wires **370** pass through male connector **300** to each contact **320**. Each wire **370** is electrically and hydrauli-

cally insulated, as will be explained. Each male contact **320** is separated from an adjacent male contact by an insulator **324** made of polyetheretherketone (PEEK). Female contacts **220** in female connector **200** are also separated by insulators made of PEEK.

To protect the plurality of male contacts **320**, male pin **330** features a sleeve **340** that is displaceable over the male pin in a longitudinal direction of the pin. Sleeve **340** is displaceable between a first position, in which the sleeve covers male contacts **320** in a protected condition (FIG. **8**), and a second position in which the sleeve is retracted and exposes the plurality of male contacts (FIG. **9**). Upon insertion of male pin **330** into central passage **214** of female connector **200**, sleeve **340** comes into contact with female seal end **212**, which stops the sleeve from entering the central passage. As the rest of male pin **330** enters central passage **214** of female connector **200**, sleeve **340** is displaced from the first position to the second position to expose the male contacts inside the central passage. Male contacts **320** align with female contacts **220** in female connector **200** when the male and female connectors are mated, as shown in FIG. **9**.

Sleeve **340** defines a sealed space **342** around male contacts **320** when the sleeve is in the first position. Sealed space **342** is in fluid communication with a source of oil **350**. The source of oil distributes oil **350** over male contacts **320** to protect the male contacts when male connector **300** is in an unmated condition, and when the sleeve is in the first position. Oil **350** fills sealed space **342** around male contacts **320** to prevent entry of well bore fluid, seawater, sand and debris from entering. Oil **350** also electrically insulates male contacts **320**. Moreover, oil **350** allows the pressure inside male connector body **310** to be balanced with the pressure in the environment outside of connector **100**. By balancing internal and external pressures, internal stresses on components in male connector body **310** caused by pressure differentials are minimized.

Male connector **200** and female connector **300** each feature a dual barrier mechanism **400** that lengthens the service life of the connector. Dual barrier mechanism **400** utilizes seals that are made of non-elastomeric materials, such as polytetrafluoroethylene (PTFE). As will be explained, many of the seals are reinforced so as to maintain their structural shape and integrity over periods of long-term exposure to high temperatures and pressures. This is a substantial departure from conventional wet mate connectors that typically use elastomeric seals. Elastomeric seals are prone to permanent deformation or "compression set" if they are exposed to high pressures and temperatures, causing the seals to fail, and making conventional wet mate connectors inadequate for permanent or long-term installation in well bores and deep sea environments.

Referring back to FIGS. **5** and **6**, the dual barrier mechanism **400** in the female connector will be described. Dual barrier mechanism **400** includes a plurality of primary seals that can take various forms. For example, the primary seals in female connector **200** include, but are not limited to, a dynamic scraper or "nose" seal **411** at female seal end **212**, static piston seals **412**, and dynamic rod seals **413**. Female contacts **220** are arranged in series with dynamic rod seals **413** along central passage **214**, with each female contact being separated from another female contact by one of the dynamic rod seals. When female connector **200** is mated with male connector **300**, dynamic rod seals **413** prevent or minimize channel to channel electrical losses.

Extreme pressures in well bores or deep sea installations can cause production fluid or seawater to enter a connector and replace some of the oil in the connector over long periods of service. Ingress of water can cause cavities and spaces around wires and contacts to become conductive. To prevent electrical issues from occurring, dual barrier mechanism **400** includes a plurality of secondary seals. Secondary seals allow the connector **100** to remain operative even when there is ingress of water in the connector that bypass the primary seals. Secondary seals include O-ring seals **416** around wires **270**. O-ring seals **416** surround each wire **270** in proximity to where each wire terminates at each contact **220**. These O-ring seals **416** electrically and hydraulically insulate the wires **270** to provide a secondary seal in the event that water enters into oil **250**.

Referring back to FIGS. **7-9**, the dual barrier mechanism **400** in the male connector **300** will be described. Primary seals in male connector **300** include, but are not limited to, a static "nose" face seal **311**, a dynamic scraper seal **312** in sealed space **342**, and a dynamic scraper seal **313** outside of sleeve **340**. Secondary seals in male connector **300** include O-ring seals **417** around wires **370**, similar to the O-ring seals **416** around wires **270** in female connector **200**.

Primary and secondary seals in accordance with the invention preferably include at least some seals that are spring energized. Spring energized seals in accordance with the invention are reinforced internally so that they resist or prevent compression set. Each spring energized seal can have a unique body configuration to seal a specific area inside the male or female connector. In female connector **200**, static piston seals **412** and dynamic rod seals **413** are spring energized seals. In male connector **300**, dynamic scraper seal **312** and dynamic scraper seal **313** are spring energized seals.

Referring to FIGS. **10** and **11**, one of the dynamic rod seals **413** is shown in more detail to illustrate the components of the spring energized seal. Dynamic rod seal **413** has a C-shaped jacket or body portion **424**, and an internal spring **426** inside the body portion. Body portion **424** can be formed of polytetrafluoroethylene (PTFE) or PEEK. Spring **426** is a canted coil spring. During operation, spring **426** provides reinforcement to dynamic rod seal **413** to maintain the seal's structural shape and integrity over periods of short or long-term exposure to high temperatures and pressures, thereby resisting compression set. Unlike elastomeric seals, spring **426** is sufficiently energized and resilient so that when the seal is deformed, the spring can restore the seal to its original shape as pressure around the seal drops.

While preferred embodiments of the invention have been shown and described herein, it will be understood that such embodiments are provided by way of example only. Numerous variations, changes and substitutions will occur to those skilled in the art without departing from the spirit of the invention. Accordingly, it is intended that the appended claims cover all such variations as fall within the spirit and scope of the invention.

What is claimed:

**1**. A wet mate electrical connector comprising:

A. a female connector comprising a female connector body defining a female seal end and a central passage extending through the female connector body, the central passage comprising a plurality of female contacts; and

B. a male connector comprising:

i. a male connector body defining a male seal end and a central passage extending through the male connector body;

ii. a male pin axially projecting from the central passage of the male connector body, the male pin comprising a plurality of male contacts, the male pin being insertible into the central passage of the female connector; and

iii. a sleeve slidably displaceable over the male pin between a first position in which the sleeve covers the

plurality of male contacts in a protected condition, and a second position in which the sleeve is retracted and exposes the plurality of male contacts,

wherein, upon insertion of the male pin into the central passage of the female connector, the sleeve on the male pin contacts the female seal end to displace the sleeve from the first position to the second position to expose the plurality of male contacts, the plurality of male contacts axially aligning with the plurality of female contacts in the female connector when the male pin is fully inserted or substantially inserted into the central passage of the female connector,

wherein the sleeve defines a sealed space around the plurality of male contacts when the sleeve is in the first position, and

wherein the sealed space is in fluid communication with a source of oil, the source of oil distributing oil over the male contacts to protect the male contacts when the sleeve is in the first position.

**2**. The wet mate electrical connector of claim **1**, wherein the female connector comprises a female pin axially displaceable in the central passage of the female connector body between a first position in which the female pin is generally adjacent the female seal end and a second position in which the female pin is displaced into the female connector body away from the female seal end.

**3**. The wet mate electrical connector of claim **2**, wherein the female connector comprises a female biasing element that biases the female pin toward the first position.

**4**. The wet mate electrical connector of claim **1**, wherein the female connector comprises a primary seal and a secondary seal to protect the plurality of female contacts.

**5**. The wet mate electrical connector of claim **4**, wherein the primary seal comprises a scraper seal at the female seal end.

**6**. The wet mate electrical connector of claim **4**, wherein the primary seal comprises at least one spring energized seal along the central passage.

**7**. The wet mate electrical connector of claim **6**, wherein the at least one spring energized seal comprises a body portion and an internal spring in the body portion.

**8**. The wet mate electrical connector of claim **7**, wherein the body portion is formed of polytetrafluoroethylene (PTFE).

**9**. The wet mate electrical connector of claim **7**, wherein the body portion is formed of PEEK.

**10**. A wet mate electrical connector comprising:

A. a female connector comprising a female connector body defining a female seal end and a central passage extending through the female connector body, the central passage comprising a plurality of female contacts; and

B. a male connector comprising:

i. a male connector body defining a male seal end and a central passage extending through the male connector body;

ii. a male pin axially projecting from the central passage of the male connector body, the male pin comprising a plurality of male contacts, the male pin being insertible into the central passage of the female connector; and

iii. a sleeve slidably displaceable over the male pin between a first position in which the sleeve covers the plurality of male contacts in a protected condition, and a second position in which the sleeve is retracted and exposes the plurality of male contacts,

wherein, upon insertion of the male pin into the central passage of the female connector, the sleeve on the male pin contacts the female seal end to displace the sleeve from the first position to the second position to expose the plurality of male contacts, the plurality of male contacts axially aligning with the plurality of female contacts in the female connector when the male pin is fully inserted or substantially inserted into the central passage of the female connector,

wherein the female connector comprises a female pin axially displaceable in the central passage of the female connector body between a first position in which the female pin is generally adjacent the female seal end and a second position in which the female pin is displaced into the female connector body away from the female seal end, and

wherein the central passage and female pin of the female connector are filled with oil to protect the plurality of female contacts when the female connector is in an unmated condition.

**11**. The wet mate electrical connector of claim **10**, wherein the female pin comprises at least one port in fluid communication with pressure balanced oil to balance pressure in the central passage of the female connector and prevent hydraulic lock.

**12**. A wet mate electrical connector comprising:

A. a female connector comprising a female connector body defining a female seal end and a central passage extending through the female connector body, the central passage comprising a plurality of female contacts; and

B. a male connector comprising:

i. a male connector body defining a male seal end and a central passage extending through the male connector body;

ii. a male pin axially projecting from the central passage of the male connector body, the male pin comprising a plurality of male contacts, the male pin being insertible into the central passage of the female connector; and

iii. a sleeve slidably displaceable over the male pin between a first position in which the sleeve covers the plurality of male contacts in a protected condition, and a second position in which the sleeve is retracted and exposes the plurality of male contacts,

wherein, upon insertion of the male pin into the central passage of the female connector, the sleeve on the male pin contacts the female seal end to displace the sleeve from the first position to the second position to expose the plurality of male contacts, the plurality of male contacts axially aligning with the plurality of female contacts in the female connector when the male pin is fully inserted or substantially inserted into the central passage of the female connector,

wherein the female connector comprises a primary seal and a secondary seal to protect the plurality of female contacts, and

wherein the primary seal comprises a plurality of spring energized seals arranged in series along the central passage.

**13**. The wet mate electrical connector of claim **12**, wherein the plurality of female contacts are arranged in series with the plurality of spring energized seals along the central passage.

**14**. The wet mate electrical connector of claim **13**, wherein each of the plurality of female contacts is separated by another of the plurality of female contacts by one of the plurality of spring energized seals.

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