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(54) **THREADED CONNECTION**

(57) A threaded connection is provided. The threaded connection comprises: first and second tubular components. The first tubular component comprises: at a first end region a pin with an outer surface on which is formed a male thread; and an opposite second end region. The second tubular component comprises: at a first end region a box with an inner surface on which is formed a female thread; and an opposite second end region. The male thread is arranged to engage the female thread in a made-up configuration. A male electrical contact is provided on the outer surface of the first end region of the first tubular component and insulated from the first tubular component. A female electrical contact is provided on the inner surface of the first end region of the second tubular component and insulated from the second tubular component. A first conductor extends along the outer surface of the first tubular component, in communication with the male electrical contact, and insulated from the first tubular component. A second conductor extends along the second tubular component, in communication with the female electrical contact, and insulated from the second tubular component. The male and female electrical contacts are arranged to contact with each other in the made-up configuration. The male electrical contact has a width in an axial direction of the first tubular component and the female electrical contact has a width in an axial direction of the second tubular component. The width of the female electrical contact is smaller than the width of the male electrical contact, or vice versa.

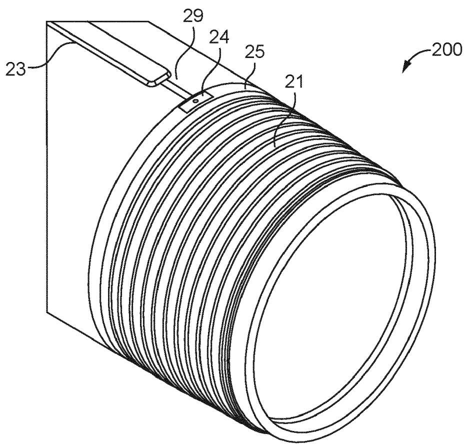

FIG. 2A

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Description

Background

[0001] During operation of downhole tools in a well bore, such as during drilling, it can be desirable to measure and communicate conditions of the well bore. This may be, for example, pressure and/or temperature readings of the downhole conditions.

[0002] Typically inserted within the well bore is a casing string which is a tubular structure inside the well bore to support the bore. Inside this, a drill sting is provided. The casing is exposed to the external well bore conditions and so must be much more robust than the drill string as this is a much harsher environment. The casing will be exposed to the reservoir pressure which can be very large, while a drill string will be exposed only to hydrostatic pressure within the casing. There can also be tubing string between the casing string and the drill string.

[0003] The drill string can typically be retrieved after a few days during which time repairs can take place. This is not the case for a casing string or a tubing string which will remain in the well bore. The sealing requirements for drill strings are also much less stringent, and may for example not require any metal-to-metal seals. Drill strings are typically provided with an outer diameter of 2.375 inches to 6.625 inches.

[0004] The use of wired sensors has generally not been successful as the harsh downhole environment can easily damage wires running down the well bore. For example, perforating explosive charges are frequently used during downhole operations which would damage wiring running to downhole sensors.

[0005] Wireless sensors have also been used, which are battery powered to avoid the need to run wiring down the well bore. As well as communication issues given the depth of the well bore and the environment being generally not conducive to wireless transmission, the batteries of course run out of power. As a result, downhole operations must be halted and tools removed while the wireless sensors are recovered for battery replacement/recharging. This halts operation of the wellbore.

[0006] The use of fibre-optics has also been considered. However this requires separate cables to be clamped to the string. These must also be carefully aligned with one another to allow for transmission along the string.

[0007] US 2021/0310350 A1 discloses a device for acquiring and communicating data between strings of oil wells or gas wells. In this system, a wire must be fed down the string to various battery-powered sensors. Alignment of threaded components will be necessary to feed this wire, and rotation could damage the device. Further, the system needs an electromagnetic field to power the batteries. This means that all components of the string need to be non-magnetic.

[0008] US 2004/0242044 A1 discloses an electrical conducting system between sections of a drill pipe string. At the distal end of the male section a connector is provided for engaging with a connector provided on the female section. This connection is provided for a drill string and so it is not exposed to the harsh conditions of a casing string. Further, the wires run internally of the drill string since the outer surface rotates in the casing and would be exposed to significant external forces making it unsuitable for wiring.

[0009] WO 2022/197745 A1 and WO 2022/094144 A1 disclose systems for downhole power and data transfer. A plurality of power transferring spring structures are provided which contact corresponding paths when the threaded connection is made-up. Each spring structure represents a different path, and so careful alignment of the spring structure and the respective path is required. This means that the two sets of contacts are the same size and to ensure alignment the connection is placed immediately adjacent a shoulder of the threaded connection. If there is any axial misalignment then the power and data transfer would not work.

[0010] There is therefore a need for an improved system for communicating sensed downhole conditions of a well bore, particularly for a casing string or a tubing string.

Summary

[0011] A threaded connection is provided. The threaded connection comprising: first and second tubular components, wherein the first tubular component comprises: at a first end region a pin with an outer surface on which is formed a male thread; and an opposite second end region, the second tubular component comprises: at a first end region a box with an inner surface on which is formed a female thread; and an opposite second end region, and the male thread is arranged to engage the female thread in a made-up configuration; a male electrical contact on the outer surface of the first end region of the first tubular component and insulated from the first tubular component; a female electrical contact on the inner surface of the first end region of the second tubular component and insulated from the second tubular component; a first conductor extending along the first tubular component, in communication with the male electrical contact, and insulated from the first tubular component; and a second conductor extending along the second tubular component, in communication with the female electrical contact, and insulated from the second tubular component, wherein the male and female electrical contacts are arranged to contact with each other in the made-up configuration.

[0012] The male electrical contact has a width in an axial direction of the first tubular component and the female electrical contact may has a width in an axial direction of the second tubular component, wherein the width of the female electrical contact is smaller than the width of the male electrical contact, or vice versa. This allows for axial variation in the connection to be accommodated while achieving an electrical contact, but minimising the impact of the width on one of the components. Particularly it is important to minimise the amount of space used for the connection on the pipe, while maximising the connectivity. Such an arrangement balances these two competing factors to deliver a structurally sound pipe with good connectivity and resilience to axial offset. In the case of multiple contacts, it is the net width of each contact - i.e. if they are axially aligned the width is just the width of a single contact. If axially unaligned then the width is the total width from first contact to last contact in the axial direction.

[0013] For example, the male electrical contact may be smaller than the female electrical contact, but located on the pipe body side of the pin where the tensile and compressive forces are greater, while the female contact may be located near the end of the box where the tensile and compressive forces are smaller and the second tubular component thinner.

[0014] The width of the larger of the male electrical contact or the female electrical contact may be greater than the width of the smaller of the male electrical contact or the female electrical contact by at least one thread pitch. This provides suitable axial tolerance for the made-up configuration.

[0015] This threaded connection allows for electrical connectivity to effectively be achieved across multiple tubular components. In particular, it is preferable that the first and/or second conductors extend along the outer surface of the first and/or second tubular component. In the context of, for example, casing strings, in contrast with drill strings (such as that discussed above), the provision of the conductor outside the string means that equipment within the string cannot damage the conductor.

[0016] The male electrical contact may extend circumferentially around the outer surface; and/or the female electrical contact may extend circumferentially around the inner surface. Having such a circumferential extent means that the two contacts do not have to perfectly align. In certain examples one electrical contact may extend around the majority or entirety of the corresponding surface, with the other contact not extending circumferentially or extending by a smaller amount. Again this can help ensure electrical contact without requiring perfect alignment. For example, in a connection in which a wedge thread (a thread which varies in width in the longitudinal direction of the connection) is used to control relative make-up in place of a shoulder, the final position of the electrical contacts would vary by a greater amount.

[0017] The first tubular component may comprise a groove formed on the outer surface and the first conductor may extend within the groove; and/or the second tubular component may comprise a groove formed on the outer surface and the second conductor may extend within the groove. A groove may be preferable to an internal bore as it can be easier to manufacture on the tubular component.

[0018] The groove may include a curved surface in cross-section, and preferably the groove is U-shaped. For example, the base of the groove may be U-shaped. This avoids stress-concentrations in the threaded connection.

[0019] The groove may have a radius of curvature of less than 5 millimetres, preferably between 1 millimetre to 2 millimetres. These radii can avoid stress-concentrations.

[0020] The threaded connection may further comprise a sealing cover attached to the outer surface over the groove. The sealing cover can protect the conductor in the groove.

[0021] The first tubular component may comprise a groove formed on the outer surface and the first conductor may extend within the groove and the groove may communicate with a bore underneath a sealing surface of the first tubular component. This avoids disrupting the sealing surface with the groove and hence a better seal can be achieved.

[0022] The male thread may be located between the male electrical contact and a terminal end of the first tubular component. These are the thread, electrical contact and terminal end in the same end region of the tubular component and not including any element of the opposite end region. It is preferable to locate the male electrical contact on the pipe body side of the male thread so that the first conductor can extend along the outer surface of the first tubular member. In this way, the connection can be made without disturbing the thread or weakening the pin.

[0023] The male electrical contact may have a width in an axial direction of the first tubular component, the width greater than 3 millimetres. This width can allow for electrical contact to be established despite variations in axial positions in the made-up configuration. As mentioned above, in the example of a connection in which a wedge thread (a thread which varies in width in the longitudinal direction of the connection) is used to control relative make-up in place of a shoulder, the final position of the electrical contacts would vary by a greater amount.

[0024] The male electrical contact may have a width in an axial direction of the first tubular component, the width less than 6 millimetres. Beyond this upper bound, the electrical contact may use up space that could be more appropriately used for mechanical engagement or fluid-tight sealing.

[0025] The male thread may have a thread lead or pitch and the male electrical contact may have a width in an axial direction of the first tubular component, the width may be within 25% of the thread lead or pitch, respectively. Linking the width and the thread lead or pitch in this way allows for the arrangement to be appropriately scaled and achieve a balance between engagement and electrical connectivity. Of course, the thread lead and pitch may be the same as one another or different.

[0026] The threaded connection may further comprise: a plurality of male electrical contacts on the outer surface of the first end region of the first tubular component, each insulated from the first tubular component, the plurality of male electrical contacts having a first circumferential length and spaced from one another by a first circumferential gap; a plurality of female electrical contacts on the inner surface of the first end region of the second tubular component, each insulated from the second tubular component, the plurality of female electrical contacts having a second circumferential length and spaced from one another by a second circumferential gap; a plurality of first conductors extending along the outer surface of the first tubular component, each first conductor in communication with a corresponding male electrical contact of the plurality of male electrical contacts, and each insulated from the first tubular component; and a plurality of second conductors extending along the second tubular component, each second conductor in communication with a corresponding female electrical contact of the plurality of female electrical contacts, and each insulated from the second tubular component, wherein: the first circumferential length is smaller than the second circumferential gap; and the second circumferential length is smaller than the first circumferential gap. This allows multiple electrical signals to be transmitted along the threaded connection, while still being accommodating for rotational offset of the threaded connection.

[0027] The male electrical contact may form at least part of an interference seal of the first tubular component. This provides a further sealing effect for the threaded connection and an efficient use of the available axial space.

[0028] The female electrical contact may be at least partially insulated from the second tubular component by an elastomeric seal for sealing with the pin. An elastomeric seal is an effective way to insulate the female electrical component from the second tubular component, whilst also forming both a seal and an electrical connection.

[0029] The female electrical contact may be located between the female thread and a terminal end of the second tubular component. Again this arrangement is beneficial for external conductors as it means that the corresponding male electrical conductor does not pass through the male thread. It is preferable to locates the female electrical contact on the pipe body side of the female thread so that the second conductor can extend along the outer surface of the second tubular member. In this way, the connection can be made without disturbing the thread or weakening the box within the area subjected to the greatest tension or compression.

[0030] The female electrical contact may comprise a deformable element biased towards the male electrical contact in the made-up configuration, or vice-versa. This can compensate for radial variation (or ovality) in the threaded connection while still achieving an electrical contact.

[0031] The deformable element may be a coil spring extending circumferentially. This is an effective way to implement the deformable element, in particular in the context of a component that will be subjected to radial interference.

[0032] The male thread and female thread may be wedge threads.

[0033] The pin may comprise an annular sealing surface for sealing by interference with a complementary annular sealing surface of the box, the annular sealing surface of the pin may be located between the male thread and a terminal end of the first tubular component. This can increase the sealing of the threaded connection.

[0034] The first tubular component may comprise a shoulder for abutment against the second tubular component, or vice versa.

[0035] The first tubular component may be a first casing or tubing tubular component and the second tubular component may be a second casing or tubing tubular component.

[0036] A string for a well bore is provided. The string comprising: a plurality of threaded connections as described herein in threaded engagement to form the string such that the first and second conductors collectively form a conductive path; and one or more sensors, positioned along the casing string or tubing string, in communication with the conductive path. This string allows for effective electrical connectivity along its length.

[0037] The conductive path may be for transmission of power to the one or more sensors and signals from the one or more sensors. This allows for a single conductive path to transmit both power and signal information.

[0038] The one or more sensors may comprise one or more of: a temperature sensor; a pressure sensor; an accelerometer; a magnetometer; an ultrasonic sensor; a flow sensor; and/or an acoustic sensor. Such sensors detect parameters of interest for a string.

[0039] The string may be a casing string or a tubing string, and each tubular component may be a casing or tubing tubular component.

Brief Description

[0040] The present description references the accompanying drawings, by way of example only, in which:

- Figure 1 shows a close-up side cross-sectional view of a threaded connection;
- Figure 2 shows a side view of a first tubular component for a threaded connection;
- Figure 3 shows a perspective cross-sectional view of a second tubular component for a threaded connection;
- Figure 2A shows a perspective view of a further first tubular component for a threaded connection;
- Figure 2B shows a front cross-sectional view of the further first tubular component of Figure 2A;
- Figure 4 shows a side cross-sectional view of a further threaded connection;

Figure 5 shows a close-up side cross-sectional view of a coupling used in the further threaded connection of Figure 4;

Figure 6 shows a perspective cross-sectional view of the coupling of Figure 5;

Figure 7 shows a close-up perspective cross-sectional view of a connector used in the coupling of Figure 6;

Figure 8 shows a side cross-sectional schematic view of the connector of Figure 7;

Figure 9A shows a cross-sectional schematic of an electrical connection which can be used with the threaded connection of Figure 1 or Figure 4; and

Figure 9B shows the cross-sectional schematic of Figure 9A in a rotationally-offset position.

Detailed Description

[0041] Figure 1 shows an example of a threaded connection 100, made up of the first tubular component 200 shown in Figure 2 and the second tubular component 300 shown in Figure 3. This threaded connection 100, including the first tubular component 200 and second tubular component 300 can be part of a casing string or a tubing string. That is, a casing string which is suitable to receive a drill string, such as those discussed above, or a tubing string disposed between a casing string and a drill string, again such as those disclosed above. Any reference to "casing string" in the present disclosure should be understood as being equally applicable to a tubing string. The casing string or tubing string may be used for many different operations, including but not limited to production, injection, etc..

[0042] A casing string will have a larger diameter than the drill string it is to be used with, particularly an inner diameter of the casing string. Outer diameters of casing strings may be between 4 inches to 24 inches.

[0043] Further, casing strings may have different types of threaded connections compared to drill strings. In casing strings these may be integral and more robust with an upset thicker section. The wall thickness of a drill string may be greater than a casing string as it typically needs to last longer. A casing string will also typically use different steel grades to a drill string.

[0044] Generally, the threaded connection 100 is formed from the first tubular component 200 and the second tubular component 300. The first tubular component 200 and the second tubular component 300 can be arranged in a made-up configuration as shown in Figure 1.

[0045] The first tubular component 200 is shown in Figure 2, particularly a first end region of the first tubular component 200. The first tubular component 200 will comprise a second end region at an opposite end. The first end region and the second end region may be substantially similar to one another, or identical, or may be different. At the first end region the first tubular component 200 comprises a pin. The pin has an outer surface on which a male thread 21 is formed. The first tubular component 200 may be generally cylindrical.

[0046] The second tubular component 300 is shown in Figure 3, particularly a first end region of the second tubular component 300. The first tubular component 300 will comprise a second end region at an opposite end. The first end region and the second end region may be substantially similar to one another, or identical, or may be different. At the second end region the second tubular component 300 comprises a box. The box has an inner surface on which a female thread 31 is formed. The first tubular component 200 may be generally cylindrical. The female thread 31 of the box may generally correspond to the male thread 21 of the pin. In the made-up configuration, the male thread 21 of the pin and the female thread 31 of the box may be engaged with one another. That is, the male thread 21 of the pin may be screwed into the female thread 31 of the box to form the made-up configuration.

[0047] The male thread 21 and the female thread 31 may be any suitable type of thread for forming a threaded connection 100. In certain examples, the male thread 21 and the female thread 31 may be wedge threads. That is, a thread which increases in axial width along its length.

[0048] The first tubular component 200 and the second tubular component 300 may form one or more seals with one another in this made-up configuration.

[0049] A male electrical contact 24 extends circumferentially around the outer surface of the first tubular component 200, particularly of the pin. This male electrical contact 24 may extend circumferentially by a small amount (which is particularly shown in Figures 2A and 2B). In other examples, the male electrical contact 24 may extend around the entire circumference of the first tubular component 200, or a part of the circumference.

[0050] The male electrical contact 24 may be offset from the male thread 21 in an axial direction. For example, the male thread 21 may be located between the male electrical contact 24 and a terminal end of the first tubular component 200, particularly of the pin. In other words an end region (such as the depicted first end region) of the first tubular component 200 may comprise, in order, the terminal end, the male thread 21 and then the male electrical contact 24. This configuration may be located at one end of the first tubular component 200 or at both ends (i.e. the first end region and the second end region) of the first tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contact 24. That is, not a terminal end at an opposite end of the first tubular component 200 which would not be in the same end region.

[0051] The male electrical contact 24 is insulated from the first tubular component 200. That is, the male electrical contact 24 may be electrically isolated and/or insulated from the first tubular component 200. For example, the male electrical contact 24 may be a conductive ring extending circumferentially around the first tubular component 200. An insulator, for example an elastomeric ring, may be provided between the male electrical contact 24 and the first tubular component 200 to electrically insulate the electrical contact 24 from the first tubular component 200.

[0052] A first conductor 22 extends along the first tubular component 200, for example in an axial direction. The first conductor 22 is in electrical communication with the male electrical contact 24. The first conductor 22 may extend exactly axially as shown in Figure 2. However, in further examples the first conductor 22 may deviate from this purely axial path. For example the first conductor 22 may also have circumferential and/or radial deviations from the purely axial path.

[0053] The first conductor 22 is electrically insulated from the first tubular component 200. For example, the first conductor 22 may be in the form of a wire with a conductive core optionally surrounded by a non-conductive covering. Alternatively, or additionally, an insulator may be provided between the first conductor 22 and the first tubular component 200.

[0054] A female electrical contact 34 extends circumferentially around the inner surface of the second tubular component 300, particularly of the box. In certain examples, the female electrical contact 34 may extend around the entire circumference of the second tubular component 300, or a part of the circumference.

[0055] The female electrical contact 34 may be offset from the female thread 31 in an axial direction. For example, the female electrical contact 34 may be located between the female thread 31 and a terminal end of the second tubular component 300, particularly of the box. In other words an end region (such as the depicted first end region) of the second tubular component 300 may comprise, in order, the terminal end, the female electrical contact 34 and then the female thread 31. This configuration may be located at one end of the second tubular component 300 or at both ends of the second tubular component 300 (i.e. the first end region and the second end region). These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the female electrical contact 34. That is, not a terminal end at an opposite end of the second tubular component 300 which would not be in the same end region

[0056] The female electrical contact 34 is insulated from the second tubular component 300. For example, the female electrical contact 34 may be at least partially insulated from the second tubular component 300 by an elastomeric seal 35. For example, the female electrical contact 34 may be embedded or otherwise permanently fixed in the elastomeric seal 35 and protrude therefrom. Alternatively, the deformable element such as the coil spring may be held between the elastomeric seal 35 and a further component such as an anti-extrusion ring. These anti-extrusion rings may be non-conductive and help to insulate the female electrical contact 34 from the second tubular component 300.

[0057] This elastomeric seal 35 may contact with the first tubular component 200, particularly with the pin, so as to form a seal with the first tubular component 200. Again, this may be a part of an interference seal or inner seal. There may further be a support ring, such as a PEEK ring. A split locking ring may be provided to hold the female electrical contact 34 and any further elements in this region in place.

[0058] A second conductor 32 extends along the second tubular component 300, for example in an axial direction. The second conductor 32 is in electrical communication with the female electrical contact 34. The second conductor 32 may extend exactly axially as shown in Figure 3. However, in further examples the second conductor 32 may deviate from this purely axial path. For example the second conductor 32 may also have circumferential and/or radial deviations from the purely axial path.

[0059] The second conductor 32 is electrically insulated from the second tubular component 300. For example, the second conductor 32 may be in the form of a wire with a conductive core optionally surrounded by a non-conductive covering. Alternatively, or additionally, an insulator may be provided between the second conductor 32 and the second tubular component 300.

[0060] In the made-up configuration as shown in Figure 1, the male thread 21 and the female thread 31 are engaged and the male electrical contact 24 contacts with the female electrical contact 34. That is, the male electrical contact 24 and the female electrical contact 34 engage with one another to form an electrical connection. This is shown in Figure 1.

[0061] As a result, an electrically conductive path is defined from the first conductor 22, through the male electrical contact 24, to the female electrical contact 34 and then to the second conductor 32. That is, making-up the first tubular component 200 and the second tubular component 300 also forms an electrically conductive path across both the first tubular component 200 and the second tubular component 300.

[0062] While the first tubular component 200 has the described pin and associated male electrical contact 24 at one end region, and it may have at an opposite end region a box generally similar to that as described in relation to the second tubular component 300. Likewise, the second tubular component 300 may have the described box and associated female electrical contact 34 at one end region, and it may have at an opposite end region a pin generally similar to that as described in relation to the first tubular component 200. Such tubular components 200, 300 may be referred to as integral connection.

[0063] Alternatively, the first tubular component 200 which may have the described pin and associated male electrical contact 24 at one end may have at an opposite end a further pin and associated male electrical contact 24. Likewise, the second tubular component 300 may have the described box and associated female electrical contact 34 at one end, and it may have at an opposite end a further box and associated female electrical contact 34.

[0064] In this sense, a string of threaded connections 100 can be formed with a continuous electrical connection extending along the entire length of the string.

[0065] Sensors arranged downhole can be connected to this continuous electrical connection, and hence electrical communication with the sensors can be established. The sensors may include temperature sensors, pressure sensors, accelerometers, magnetometers, ultrasonic sensors, flow sensors, acoustic sensors, or any other type of sensor.

[0066] In particular examples, the first tubular component 200 may comprise a groove or recess formed on the outer surface. This can be formed in any manner including by machining or milling into the outer surface. The groove may be curved in cross-section. That is, the groove may not comprise any non-rounded corners which could otherwise act as stressconcentration regions. In a specific example the groove may be U-shaped in cross section. For example, the groove may have a radius of curvature of less than 5 millimetres. In specific examples a radius of curvature of the groove may be between 1 millimetre to 2 millimetres.

[0067] The first conductor 22 may then extend within this groove. This may be such that the first conductor 22 does not extend beyond the outer circumference of the outer surface. That is, the first tubular component 200 does not have a greater outer diameter as a result of the introduction of the first conductor 22.

[0068] In order to further protect the first conductor 22 from external influences in the downhole environment, a sealing cover 23 (shown in Figures 2A and 2B) may be provided. This sealing cover 23 can be attached to the outer surface of the first tubular component 200 to cover the first conductor 22. For example, the first conductor 22 may be in the groove with the sealing cover 23 provided thereover.

[0069] As noted above, in the made-up configuration the first tubular component 200 and the second tubular component 300 may seal with one another. This may be via one or more sealing surfaces. For example there may be an inner seal and/or an outer seal. A sealing surface 29 may be provided on the first tubular component 200 for forming an interference seal with a corresponding sealing surface 39 of the second tubular component 300.

[0070] This sealing surface 29 may be arranged such that in the end region the male thread 21 is located between the sealing surface 29 and a terminal end of the first tubular component 200, particularly of the pin.

[0071] The male electrical contact 24 may be offset from the male thread 21 in an axial direction. For example, the male electrical contact 24 may be located between the sealing surface 29 and the male thread 21. In other words an end region (such as the depicted first end region) of the first tubular component 200 may comprise, in order, the terminal end, the male thread 21, the male electrical contact 24 and then the sealing surface 29. This configuration may be located at one end of the first tubular component 200 or at both ends (i.e. the first end region and the second end region) of the first tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contact 24. That is, not a terminal end at an opposite end of the first tubular component 200 which would not be in the same end region.

[0072] To avoid disrupting this sealing surface 29, the groove which the first conductor 22 is located in may communicate with a bore 28 extending underneath the sealing surface 29. This is best shown in Figure 1. In other words, the groove may be a surface groove up to near to this sealing surface 29. Then the groove may extend into the diameter of the first tubular component 200 to form the bore 28 which generally acts as a tunnel under the sealing surface 29. As such, the sealing surface 29 may be continuous (i.e. without interruption) about the full periphery of the first tubular component 200. The corresponding sealing surface 39 may, separately or additionally, be continuous (i.e. without interruption) about the full periphery of the second tubular component 300.

[0073] As shown in Figure 1, the bore 28 may comprise first and second angled sections meeting at an apex, or any other suitable shape. This shape may be formed via drilling one or more holes into the first tubular component 200.

[0074] The corresponding sealing surface 39 of the second tubular component 300 may be arranged such that in the end region corresponding sealing surface 39 is located between the female thread 31 and a terminal end of the second tubular component 200, particularly of the box.

[0075] The female electrical contact 34 may be offset from the female thread 31 in an axial direction. For example, the female electrical contact 34 may be located between the corresponding sealing surface 39 and the female thread 31. In other words an end region (such as the depicted first end region) of the second tubular component 300 may comprise, in order, the terminal end, the corresponding sealing surface 39, the female electrical contact 34 and then the female thread 31. This configuration may be located at one end of the second tubular component 300 or at both ends (i.e. the first end region and the second end region) of the second tubular component 300. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the female electrical contact 34. That is, not a terminal end at an opposite end of the second tubular component 300 which would not be in the same end region.

[0076] This sealing surface 29 and the corresponding sealing surface 39 may form at least part of an interference seal between the first tubular component 200 and the second tubular component 300. Such a seal can also be referred to as an outer seal.

[0077] Optionally, the male electrical contact 24 may also be used for sealing. The male electrical contact 24 may form a part of the interference seal, or of a separate interference seal or inner seal. That is, the contact between the male electrical contact 24 and the female electrical contact 34 may help to seal the threaded connection 100.

[0078] In certain examples, the female electrical contact 34 is at least partially insulated from the second tubular component 300 by an elastomeric seal 35. This elastomeric seal 35 may contact with the first tubular component 200, particularly with the pin, so as to form a seal with the first tubular component 200. Again, this may be a part of an interference seal or inner seal.

[0079] A further or alternative seal for the threaded connection 100 may be provided, for example an inner seal. The first tubular component 200, particularly the pin, may comprise an annular sealing surface. This annular sealing surface may seal by interference with a complementary annular sealing surface of the second tubular component 300, particularly the box. The annular sealing surface of the first tubular component 200 may be located at the first end region between the male thread 21 and a terminal end of the first tubular component 200, particularly the pin. In other words, an end region (such as the depicted first end region) of the first tubular component 200 may comprise, in order, the terminal end, the annular sealing surface of the first tubular component 200, the male thread 21, the male electrical contact 24 and (optionally) then the sealing surface 29. This configuration may be located at one end of the first tubular component 200 or at both ends (i.e. the first end region and the second end region) of the first tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contact 24. That is, not a terminal end at an opposite end of the first tubular component 200 which would not be in the same end region.

[0080] The first tubular component 200 and second tubular component 300 may comprise corresponding shoulders for mutual abutment in the axial direction. Alternatively, or additionally, when the second tubular component 300 has a box at each end, the terminal end of a first tubular component 200 inserted into one box may optionally abut the terminal end of a further tubular component 200 inserted into the other box.

[0081] In the made-up configuration, there may be some variation in the extent to which the male thread 21 and female thread 31 are engaged. That is, it may be possible to further screw the male thread 21 into the female thread 31 by applying further torque. A torque value may be specified for the made-up configuration which represents the amount of torque that should be applied to the components to bring them to this made-up configuration. The extent of engagement of the male thread 21 and the female thread 31 will affect the relative axial positions of the male electrical contact 24 and the female electrical contact 34.

[0082] The male electrical contact 24 may have a width in the axial direction in order to ensure electrical contact can be maintained with the female electrical contact 34 despite this variation in axial positions. Alternatively, of course, this width may be provided for the female electrical contact 34 in the same manner. Specifically, the width may be greater than 3 millimetres. There may also, or alternatively, be an upper bound on the width. For example, the width may be less than 6 millimetres. Beyond this upper bound, the electrical contact may use up space that could be more appropriately used for mechanical engagement or fluid-tight sealing. Thus, the combination of upper and lower bounds can provide a seal that is robust to unwanted variation in the amount of make-up of the connection, while not reducing the performance of the connection. The exact width will depend on the diameter of the tubular component 200 and the type of connection.

[0083] In certain examples, the width may be defined based on a thread lead and/or pitch of the male thread 21. Of course, since the male thread 21 engages the female thread 31 the thread leads and/or pitches may be the same. In an example, the width may be within 25% of the thread lead and/or pitch. That is, if the thread lead and/or pitch is I then the width may be between 0.75*l* and 1.25*l*.

[0084] In general, the male electrical contact 24 may have a width in an axial direction of the first tubular component 200 and the female electrical contact 34 may have a width in an axial direction of the second tubular component 300. The width of the female electrical contact 34 may be smaller than the width of the male electrical contact 24. Alternatively, the width of the male electrical contact 24 may be smaller than the width of the female electrical contact 34. In further examples the width of the female electrical contact 34 may be generally the same as the width of the male electrical contact 24.

[0085] In certain examples, the reliability of the electrical contact between the male electrical contact 24 and the female electrical contact 34 may be improved by having one of the contacts being resiliently biased towards the other in the made-up configuration. While the Figures show the female electrical contact 34 as the resiliently deformable contact, it is equally anticipated that this could be the male electrical contact 24 and the following description can be applied to the male electrical contact 24 accordingly.

[0086] In other words, the female electrical contact 34 may comprise a deformable element which is biased towards the male electrical contact 24 in the made-up configuration. Alternatively, male electrical contact 24 may comprise a deformable element which is biased towards the female electrical contact 34 in the made-up configuration. The deformable element may be itself electrically conductive and form a part of the electrical contact between the male electrical contact 24 and the female electrical contact 24. For example, the deformable element may generally be a coil spring extending circumferentially around the first tubular component 200 or second tubular component 300. The corresponding first conductor 22 or second conductor 32 can then be in electrical contact with this deformable element.

[0087] In certain examples, the deformable element such as the coil spring may be embedded or otherwise permanently fixed in the elastomeric seal 35. Alternatively, the deformable element such as the coil spring may be held between the elastomeric seal 35 and a further component such as an anti-extrusion ring. These anti-extrusion rings may be non-conductive and help to insulate the female electrical contact 34 from the second tubular component 300.

[0088] Figures 2A and 2B show a further example of a first tubular component 200. This first tubular component 200 may be as described herein in relation to the first tubular component 200 of Figures 1 and 2. Unless otherwise explicitly specified any feature of the first tubular component 200 of Figures 1 or 2 may be equally applicable to the first tubular component 200 of Figure 2A, and vice-versa.

[0089] The first tubular component 200 of Figures 2A and 2B depicts the sealing cover 23. This sealing cover 23 can be attached to the outer surface of the first tubular component 200 to cover the first conductor 22. For example, the first conductor 22 may be in the groove with the sealing cover 23 provided thereover. Such a sealing cover 23 can be used with the first tubular component 200 of Figures 1 and 2.

[0090] The first tubular component 200 of Figures 2A and 2B have a male electrical contact 24. This male electrical contact 24 is generally smaller than the male electrical contact 24 of the first tubular component 200 of Figures 1 and 2. The male electrical contact 24 still extends in a circumferential direction, but by much less than the total circumference. An insulating material 25 may be provided in a circumferential band aligned with the contact surface 25. For example, there may be a circumferential groove around the first tubular component 200. In this groove, the insulating material 25 may be inserted. The male electrical contact 24 may then be inserted on top of this insulating material 25 in the groove. The groove may have a specific recessed section for receiving the electrical contact 24 as shown in Figure 2B.

[0091] The male electrical contact 24 is in electrical communication with the first conductor 22, for example at a wire termination point.

[0092] A further threaded connection 100 is shown in Figures 4 to 8. Unless otherwise specified, any features disclosed above in relation to the threaded connection 100 of Figures 1 to 3 are equally applicable to the threaded connection 100 of Figures 4 to 8, and vice-versa.

[0093] This threaded connection 100 comprises a coupling 500. The coupling 500 is suitable for use in a threaded connection 100. The coupling 500 may be particularly suitable for use in a casing string or a tubing string. Any reference to "casing string" in the present disclosure should be understood as being equally applicable to a tubing string. The casing string or tubing string may be used for many different operations, including but not limited to production, injection, etc..

[0094] The coupling 500 acts to couple together a first tubular component 200 and a second tubular component 200. While Figure 4 shows the tubular components 200 as generally identical, this is not necessarily the case (although may be preferable) and there may be variations between the first tubular component 200 and the second tubular component 200. Specifically any feature recited herein maybe applied to only one of these tubular components 200. Any reference to each tubular component 200 must be understood in this context that it means each may independently have the described features. This threaded connection 100, including the coupling 500 and the first and second tubular components 200 can be part of a casing string or a tubing string.

[0095] Each tubular component 200 may be identical to or generally similar to the first tubular component 200 of Figures 1 to 3.

[0096] Each tubular component 200 may have a first end region at one end of the tubular component 200, and a second end region at an opposite end. The first end region and the second end region may be substantially similar to one another, or identical, or may be different.

[0097] Each tubular component 200 comprises a pin. The pin has an outer surface on which a male thread 21 is formed. The first tubular component 200 may be generally cylindrical. Each male thread 21 may be arranged for engagement with a corresponding female thread of the coupling 500 in the made-up configuration.

[0098] A male electrical contact 24 extends circumferentially around the outer surface of each tubular component 200, particularly of the pin. This male electrical contact 24 may extend circumferentially by a small amount such as less than 20° of the circumference. In other examples, the male electrical contact 24 may extend around the entire circumference of the respective tubular component 200, or a part of the circumference. A reference to the respective tubular component 200 means the tubular component 200 that the further feature is associated on or with.

[0099] Each male thread 21 may be located between the male electrical contact 24 and a terminal end of the respective tubular component 200, particularly of the pin. In other words an end region of each tubular component 200 may comprise, in order, the terminal end, the male thread 21 and then the male electrical contact 24. This configuration may be located at one end of the first tubular component 200 or at both ends (i.e. the first end region and the second end region) of the first tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contact 24. That is, not a terminal end at an opposite end of the tubular component

200 which would not be in the same end region.

[0100] Each electrical contact 24 is insulated from the respective tubular component 200. That is, each male electrical contact 24 may be electrically isolated and/or insulated from the respective tubular component 200. For example, the male electrical contact 24 may be a conductive ring extending circumferentially around the tubular component 200. An insulator, for example an elastomeric ring, may be provided between each male electrical contact 24 and the respective tubular component 200 to electrically insulate the electrical contact 24 from the respective tubular component 200.

[0101] A conductor 22 may extend along each tubular component 200, for example in an axial direction. Each conductor 22 is in electrical communication with the respective male electrical contact 24. Each conductor 22 may extend exactly axially as shown in Figure 4. However, in further examples each conductor 22 may deviate from this purely axial path. For example each conductor 22 may also have circumferential and/or radial deviations from the purely axial path.

[0102] Each conductor 22 is electrically insulated from the respective tubular component 200. For example, each conductor 22 may be in the form of a wire with a conductive core optionally surrounded by a non-conductive covering. Alternatively, an insulator may be provided between each conductor 22 and the respective tubular component 200.

[0103] In particular examples, each tubular component 200 may comprise a groove or recess formed on the outer surface. This can be formed in any manner including by machining or milling into the outer surface. The groove may be curved in cross-section. That is, the groove may not comprise any non-rounded corners which could otherwise act as stressconcentration regions. In a specific example the groove may be U-shaped in cross section. For example, the groove may have a radius of curvature of less than 5 millimetres. In specific examples a radius of curvature of the groove may be between 1 millimetre to 2 millimetres.

[0104] Each conductor 22 may then extend within the respective groove. This may be such that the conductor 22 does not extend beyond the outer circumference of the outer surface. That is, each tubular component 200 does not have a greater outer diameter as a result of the introduction of the conductor 22.

[0105] In order to further protect the conductor 22 from external influences in the downhole environment, a sealing cover 23 may be provided. This sealing cover 23 can be attached to the outer surface of the tubular component 200 to cover the conductor 22. For example, the conductor 22 may be in the groove with the sealing cover provided thereover.

[0106] These first and second tubular components 200 are each connected with a coupling 500 to form respective threaded connections 100.

[0107] A cross-section of the coupling 500 with first and second tubular components 200 engaged therewith is shown in Figure 5. The coupling may be substantially cylindrical. The coupling 500 comprises a tubular main body. This body has a first end and a second end. The first and second ends are at opposite ends of an elongate tubular main body. Each end of the body comprises a box. The box has an inner surface on which a female thread 51 is formed. The male thread 21 of the first and second tubular components 200 is configured to engage with these female threads 51 in the made-up configuration.

[0108] A first female electrical contact 54 extends circumferentially around the inner surface of the coupling 500, particularly of the box, at the first end of the coupling 500. In certain examples, the first female electrical contact 54 may extend around the entire circumference of the coupling 500, or a part of the circumference.

[0109] A second female electrical contact 54 extends circumferentially around the inner surface of the coupling 500, particularly of the box, at the second end of the coupling 500. In certain examples, the second female electrical contact 54 may extend around the entire circumference of the coupling 500, or a part of the circumference. The second female electrical contact 54 may be the same as the first female electrical contact 54, or there may be differences between each female electrical contact 54.

[0110] Each female electrical contact 54 is insulated from the tubular main body of the coupling 500. For example, each female electrical contact 54 may be at least partially insulated from the coupling 500 by an elastomeric seal. This elastomeric seal may contact with the corresponding tubular component 200, particularly with the pin, so as to form a seal with the corresponding tubular component 200. This may be a part of an interference seal or inner seal.

[0111] A longitudinal conductor 52 is included with the coupling 500. The longitudinal conductor 52 may be a single continuous conductor such as a single wire, or may comprise one or more elements in electrical communication with one another. The longitudinal conductor 52 is in electrical communication with each of the female electrical contacts 54. For example, the longitudinal conductor 52 may extend between the first electrical contact 54 and the second electrical contact 54.

[0112] The longitudinal conductor 52 is insulated from the tubular main body of the coupling 500. For example, the longitudinal conductor 52 may be in the form of a wire (or multiple connected wires) with a conductive core optionally surrounded by a non-conductive covering. Alternatively, or additionally, an insulator may be provided between the longitudinal conductor 52 and the tubular main body of the coupling 500.

[0113] The coupling 500 comprises a longitudinally-extending bore 56 extending through the tubular body, and the longitudinal conductor 52 extends through this longitudinally-extending bore 56. The longitudinally-extending bore 56 may extend over a majority of the longitudinal length of the coupling 500. In certain examples, the longitudinally-extending bore 56 may be formed between radially inner and outer surfaces of the coupling 500. The longitudinally-extending bore 56 may extend only in the longitudinal direction as shown in Figure 5. However, in further examples the longitudinally-extending bore 56 may also extend in other directions such as radially.

[0114] The coupling 500, and in particular the tubular main body, may comprise a first radially-extending bore 57 at the first end. The first radially-extending bore 57 extends from at or near to the first female electrical contact 54 to the longitudinally-extending bore 56. The first radially-extending bore 57 may in certain examples be strictly radially-extending only - i.e. without any longitudinal extent. However, as seen in Figure 5 the first radially-extending bore 57 may also extend in the longitudinal direction.

[0115] The coupling 500, and in particular the tubular main body, may comprise a second radially-extending bore 57 at the second end. The second radially-extending bore 57 extends from at or near to the first second electrical contact 54 to the longitudinally-extending bore 56. The second radially-extending bore 57 may in certain examples be strictly radially-extending only - i.e. without any longitudinal extent. However, as seen in Figure 5 the second radially-extending bore 57 may also extend in the longitudinal direction.

[0116] Collectively, the longitudinally-extending bore 56 and each radially-extending bore 57 may define a continuous passage from the first electrical contact 54, through the tubular main body, to the second electrical contact 54.

[0117] Manufacturing of the coupling 500, and particularly the longitudinally-extending bore 56, will be discussed in more detail below. However, the longitudinally-extending bore 56 may be formed as a blind-end bore. Such a blind-end bore may have an open-end at the opposite end to the blind-end. An example of such a longitudinally-extending bore 56 is shown in Figure 5.

[0118] This longitudinally-extending bore 56 can be machined into to the tubular main body. For example, this can be by drilling, electrical discharge machining (EDM), and/or milling into the coupling 500. A plug 58 may be provided to close the open end of the bore as shown in Figure 6. This plug 58 may be arranged to seal with the longitudinally-extending bore 56. This can be to prevent fluid ingress, such as drilling fluids, into the longitudinally-extending bore 56.

[0119] Likewise, the first radially-extending bore and the second radially-extending bore may each be machined into the tubular main body at the first end and second end respectively. Again, this may be by drilling, electrical discharge machining (EDM), and/or milling into the coupling 500.

[0120] In the made-up configuration, the male thread 21 of each pin of each tubular component 200 and the corresponding female thread 51 of the box of the coupling 500 may be engaged with one another. That is, the male thread 21 of the pin may be screwed into the corresponding female thread 31 of the box to form the made-up configuration. This forms the threaded connection 100. In this made-up configuration each male electrical contact 24 is in electrical contact with a corresponding female electrical contact. In this sense a continuous electrical connection can be formed between the male electrical contact 24 of the first tubular component 200, through the first female electrical contact 54, through the longitudinal conductor 52, through the second female electrical contact 54 and to the male electrical contact 24 of the second tubular component 200. This is all in the made-up configuration.

[0121] The male threads 21 and the female threads 51 may be any suitable type of thread for forming a threaded connection 100. In certain examples, the male threads 21 and the female threads 51 may be wedge threads. That is, a thread which increases in axial width along its length.

[0122] In certain examples, the reliability of the electrical contact between each male electrical contact 24 and each corresponding female electrical contact 54 may be improved by having one, or both, of the contacts being resiliently biased towards the other in the made-up configuration. While the Figures show the female electrical contact 54 as the resiliently deformable contact, it is equally anticipated that this could be the male electrical contact 24, or both.

[0123] In other words, each female electrical contact 54 may comprise a deformable element which is biased towards the corresponding male electrical contact 24 in the made-up configuration. Alternatively, each male electrical contact 24 may comprise a deformable element which is biased towards the corresponding female electrical contact 54 in the made-up configuration. The deformable element may be itself electrically conductive and form a part of the electrical contact between each male electrical contact 24 and the female electrical contact 54. For example, the deformable element may generally be a coil spring extending circumferentially around the first or second tubular component 200 or the coupling 500. The corresponding first conductor 22 or longitudinal conductor 52 can then be in electrical contact with this deformable element.

[0124] While the longitudinal conductor 52 may be a single component, such as a single wire, this can be difficult to fit into the coupling 500. Instead, the longitudinal conductor 52 may comprise a first wire 52A and a second wire 52B and any connectors as discussed below. Such an arrangement may be best seen in Figures 6 to 8. The first wire 52A and the second wire 52B may be attached to one another, such that they are in electrical communication. This attachment may be within the longitudinally-extending bore 56. Each wire may comprise a conductive core surrounded along the majority of its length by a non-conductive covering.

[0125] In particular examples, the first wire 52A is attached to the second wire 52B with a connector 600. The connector 600 may be arranged within the longitudinally-extending bore 56. The connector 600 may be any suitable connector that allows for electrical connection between the first wire 52A and the second wire 52B. A particular example of the connector 600 is shown in Figure 8. The connector 600 may be, in some form, heat-activated. That is, the application of heat changes the connector 600 in some form to attach the first wire 52A and the second wire 52B. The connector 600 may span an entire length of the longitudinally-extending bore 56, the first radially-extending bore 57 and the second radially extending bore 57, or just a portion thereof.

[0126] The connector 600 of Figure 8 may comprise a solder sleeve 62. This solder sleeve 62 is an amount of conductive material which melts when heated. The solder sleeve 62 when melted electrically connects the first wire 52A and the second wire 52B - particularly the conductive core of each wire 52A, 52B.

[0127] In use, the first wire 52A and the second wire 52B may be inserted into the connector 600 which is inside the longitudinal bore 56 of the coupling 500. The coupling 500, including the connector 600, may be heated such that the solder sleeve 62 melts and thereby attaches the first wire 52A to the second wire 52B.

[0128] Additionally, or alternatively, the connector 600 of Figure 8 may comprise heat-shrink tubing 64. That is, tubing 64 that when heat is applied thereto shrinks in inner diameter. In certain examples including both heat-shrink tubing 64 and a solder sleeve 62, the solder sleeve 62 may be provided inside the heat-shrink tubing 65. For example, the solder sleeve 62 may be provided at a longitudinal middle of the heat-shrink tubing 65.

[0129] In use, the first wire 52A and the second wire 52B may be inserted into the connector 600 which is inside the longitudinal bore 56 of the coupling 500. The coupling 500, including the connector 600, may be heated such that heat-shrink tubing 64 constricts and thereby holds the first wire 52A and the second wire 52B together and thereby attaches the first wire 52A to the second wire 52B.

[0130] In this sense, the first wire 52A and the second wire 52B can be attached together conductively (via the solder sleeve 62) and/or mechanically (via the heat-shrink tubing 64).

[0131] The connector 600 may additionally, or alternatively, comprise an adhesive 66. For example as shown in Figure 8 there may be first adhesive 66 at one end of the connector 600 and a second adhesive 66 at an opposite second end of the connector 600. The adhesive can further help to attach the first wire 52A and the second wire 52B. The adhesive 66 may be heat-activated.

[0132] In certain examples including both heat-shrink tubing 64 and the adhesive 66, the adhesive 66 may be provided inside the heat-shrink tubing 65. For example, the adhesive 66 may be provided at either end of the heat-shrink tubing 65. In certain examples further including the solder sleeve 62, the solder sleeve 62 may also be provided inside the heat-shrink tubing 65. For example, the solder sleeve 62 may be provided at a longitudinal middle of the heat-shrink tubing 65 with adhesive 66 at either end of the heat-shrink tubing 65 either side of the solder sleeve 62.

[0133] In order to manufacture the coupling 500 used in the threaded connection 100, a tubular main body may be formed with a first end and a second end. Each end has a box with an inner surface on which is formed a female thread 51 for engagement with a pin of a tubular component 200. A longitudinally-extending bore 56 is then drilled or otherwise machined into the tubular main body. An insulated conductor 52 is then inserted into the longitudinally-extending bore 56. This insulated conductor 52 electrically communicates with a first female electrical contact 54 and a second female electrical contact 54.

[0134] The first female electrical contact 54 extends circumferentially around the inner surface of the coupling 500, particularly of the box, at the first end of the coupling 500. In certain examples, the first female electrical contact 54 may extend around the entire circumference of the coupling 500, or a part of the circumference.

[0135] The second female electrical contact 54 extends circumferentially around the inner surface of the coupling 500, particularly of the box, at the second end of the coupling 500. In certain examples, the second female electrical contact 54 may extend around the entire circumference of the coupling 500, or a part of the circumference.

[0136] In examples where the insulated conductor 52 comprises a first wire 52A and a second wire 52B, this can be taken advantage of in the manufacturing process. Particularly, the first wire 52A can be inserted into the longitudinally-extending bore 56 from a first end of the tubular body, such as through a first radially-extending bore 57. The second wire 52B can be inserted into the longitudinally-extending bore 56 from a second end of the tubular body, such as through a second radially-extending bore 57. This insertion can be such that the first wire 52A and the second wire 52B are in electrical contact with one another. For example, they may contact within the longitudinally-extending bore 56.

[0137] When the coupling 500 further includes a connector 600, this connector 600 may be first positioned in the longitudinally-extending bore 56. The first wire 52A can then be inserted into the connector 600 and the second wire 52B can then be inserted into the connector 600. The connector 600 may be, in some form, heat-activated. That is, the application of heat changes the connector 600 in some form to attach the first wire 52A and the second wire 52B. The coupling 600, such as the tubular main body, can then be heated so as to activate the connector 600 and thereby attach the first wire 52A to the second wire 52B. This attachment means that the first wire 52A and second wire 52B are in electrical communication with one another.

[0138] The connector 600 may be as described above and may comprise one or more of the solder sleeve 62, heat-shrink tubing 64, and/or adhesive 66.

[0139] In certain examples, the first female electrical contact 54 may be fixed to the first wire 52A before the first wire 52A is inserted into the longitudinally-extending bore 56. For example, the first wire 52A may be embedded or otherwise permanently attached to the first female electrical contact 54. In certain examples the first female electrical contact 54 may be insulated from the tubular main body via an elastomeric insulator. This elastomeric insulator may be moulded, such as injection moulded, so as to embed a portion of the first wire 52A and the first female electrical contact 54 and thereby attach the first wire 52A to the first female electrical contact 54.

[0140] The first wire 52A can be cut to a required length such that it will reach the connector 600 in the longitudinally-extending bore 56.

[0141] This fixing of the first wire 52A to the first female electrical contact 54 may be carried out during manufacture, or may have already been carried out in a separate process before the coupling 500 is manufactured.

[0142] In certain examples, the second female electrical contact 54 may be fixed to the second wire 52B in the same way. That is, the second female electrical contact 54 may be fixed to the second write 52B before the second wire 52B is inserted into the longitudinally-extending bore 56. For example, the second wire 52B may be embedded or otherwise permanently attached to the second female electrical contact 54. In certain examples the second female electrical contact 54 may be insulated from the tubular main body via an elastomeric insulator. This elastomeric insulator may be moulded, such as injection moulded, so as to embed a portion of the second wire 52B and the second female electrical contact 54 and thereby attach the second wire 52B to the second female electrical contact 54.

[0143] The second wire 52B can be cut to a required length such that it will reach the connector 600 in the longitudinally-extending bore 56.

[0144] This fixing of the second wire 52B to the second female electrical contact 54 may be carried out during manufacture, or may have already been carried out in a separate process before the coupling 500 is manufactured.

[0145] In general, these assemblies of the first female electrical contact 54 and first wire 52A, and the second female electrical contact 54 and second wire 52B may be generally identical to one another. Alternatively, there may be differences such as the direction the respective wire 52A, 52B extends away from the female electrical contact 54.

[0146] A first radially-extending bore 57 may be drilled or otherwise machined at the first end of the coupling 500. The first radially-extending bore 57 extending from the inner surface to the longitudinally-extending bore 56.

[0147] A second radially-extending bore 57 may be drilled or otherwise machined at the second end of the coupling 500, the second end opposite the first end. The second radially-extending bore 57 extending from the inner surface to the longitudinally-extending bore 56. The insulated conductor 52 is inserted through each radially-extending bore 57 and the longitudinally-extending bore 56.

[0148] In certain examples the longitudinally-extending bore 56 may be a blind-ended bore with a blind-end at one end and an opposite open-end. The opposite open-end may be plugged, and the method may comprise a corresponding step of plugging the open-end such as with plug 58. This can thereby close the open-end, which may help to keep drilling fluids from entering the longitudinally-extending bore 56. In further examples the longitudinally-extending bore 56 may be a through bore, with open-ends at both ends. One of these open-ends can then be plugged to effectively form a blind-ended bore. The other, opposite, open-end can then be plugged in the same manner as discussed above.

[0149] When a connector 600 is used, this connector 600 may be inserted before the open-end is plugged. For example, the connector 600 may be inserted via the open-end and positioned within the longitudinally-extending bore 56. With the connector 600 positioned, the open-end can then be plugged.

[0150] Plugging the open-end(s) means that drilling fluid and other material can be prevented from ingress into the longitudinally-extending bore 56.

[0151] In this sense, a coupling 500 can be formed. This coupling 500 can then be used to form a threaded connection 100 by making-up two tubular components 200 into the coupling 500 as described above.

[0152] In general, a string for a well bore is also provided. This string comprises a plurality of tubular components 200, 300. These tubular components 200, 300 may be as described above. The plurality of tubular components 200, 300 are made-up in a threaded engagement to form a casing string or a tubing string. For example, the string may include a plurality of threaded connections as described above.

[0153] One or more sensors are positioned along this casing string or a tubing string. These sensors may be temperature sensors, pressure sensors, accelerometers, magnetometers, ultrasonic sensors, flow sensors, acoustic sensors, or any other type of sensor.

[0154] Each of the tubular components 200, 300 comprises a longitudinally-extending bore or groove. This bore or groove may be formed on an outer surface of the tubular component 200, 300. This can be formed in any manner including by machining or milling into the outer surface. The groove preferably includes a curved surface in cross-section. That is, the groove may not comprise any non-rounded corners which could otherwise act as stressconcentration regions. The groove may be entirely curved, or it may include a curved base and non-curved walls. In a specific example the groove may be U-shaped in cross section. For example, the base of the groove may have a radius of curvature of less than 5 millimetres. In specific examples a radius of curvature of the base of the groove may be between 1 millimetre to 2 millimetres. While the groove is longitudinally-extending this does not necessarily mean only longitudinally-extending. There may be other directions for the groove.

[0155] This groove may particularly be provided on an outer surface of each tubular component 200, 300.

[0156] A conductor 22, 32 is provided in this bore or groove and is electrically insulated from the tubular component 200, 300. For example, each conductor 22, 32 may be in the form of a wire with a conductive core optionally surrounded by a non-conductive covering. Alternatively, an insulator may be provided between each conductor 22, 32 and the respective tubular component 200, 300.

[0157] At a first end of each tubular component 200, 300 is a first electrical contact 24, 34, and at a second end of each tubular component 200, 300 is a second electrical contact 24, 34. In use, the electrical contacts 24, 34 of adjacent tubular components 200, 300 may contact each other in a made-up configuration.

[0158] Collectively, the conductors 22, 32 of the plurality of tubular components 200, 300 are in electrical communication with one another such that they form a continuous conductive path, for example via the electrical contacts. Each of the sensors are then in electrical communication with this conductive path.

[0159] In certain examples, there may only be a single conductive path defined by the conductors 22, 32. This single conductive path can the be used for both transmission of power to the one or more sensors and for receipt of signals from the one or more sensors. For example, there may be substantially constant power supplied along the conductive path with a varied response signal applied on top of this constant power signal. Any other suitable electronics and/or signal processing system may also be used for this transmission of power and signals.

[0160] In this sense, the string can communicate with downhole sensors to communicate downhole conditions to the surface. The tubular components 200, 300 may be as described herein. Further, the string may comprise a coupling 500 such as also described above.

[0161] One or more of the tubular components 200 may comprise at the first end a pin with an outer surface on which is formed a male thread 21. The male thread 21 may be located between the first electrical contact 24 and a terminal end of that tubular component 200.

[0162] One or more of the tubular components 300 may comprise at the second end a box with an inner surface on which is formed a female thread 31. The second electrical contact 34 may be located between the female thread 31 and a terminal end of the second tubular component 300. In certain examples, the same tubular component 200, 300 may have the pin at one end and the box at the other end.

[0163] The string may particularly be a casing string or a tubing string, as opposed to a drilling string. In this sense, each tubular component may be a casing or tubing tubular component.

[0164] The above description of all examples and embodiments refers to connections for a single conductive path. In further examples multiple conductive paths may be formed across the threaded connection. For the avoidance of doubt, this may be the case for the threaded connection 100 of Figure 1, or the further threaded connection 100 of Figure 4, or any other threaded connection 100. Figures 9A and 9B show such an electrical connection for multiple conductive paths. While Figures 9A and 9B show this electrical connection for the threaded connection 100 of the first tubular component 200 and the second tubular component 300, the electrical connection may equally be used for any threaded connection 100 as noted above, particularly the further threaded connection 100 of Figure 4.

[0165] In general, the engagement between the first tubular component 200 and the second tubular component 300 is as described above. However, a plurality of male electrical contacts 24a-24d are provided, with a corresponding plurality of female electrical contacts 34a-34d. By "corresponding" it is meant that in some examples the number of male electrical contacts 24a-24d is the same as the number of female electrical contacts 34a-34d. In other examples, the number of each may differ.

[0166] Each male electrical contact 24a-24d may be insulated from the first tubular component 200. Each female electrical contact 34a-34d may be insulated from the second tubular component 300.

[0167] Figures 9A and 9B show a schematic view of a made-up configuration. In this schematic view, the male electrical contacts 24a-24d are shown as radially spaced from the female electrical contacts 34a-34d. In reality, the male electrical contacts 24a-24d would contact the female electrical contacts 34a-34d in the made-up configuration. In fact, Figures 9A and 9B more-closely represent a partially made-up configuration where further engagement of the male thread 21 and the female thread 31 is required for the made-up configuration.

[0168] Each male electrical contact 24a-24d is spaced from one another in a circumferential direction about the first tubular component 200. In certain examples, the male electrical contacts 24a-24d may have rotational symmetry about the outer surface of the first tubular component 200. That is, with N male electrical contacts 24a-24d there may be N-fold rotational symmetry with each male electrical contact 24a-24d spaced (360/N)° from one another. Each male electrical contact 24a-24d has a first circumferential length. Each male electrical contact 24a-24d may have the same first circumferential length. Between each male electrical contact 24a-24d there is a first circumferential gap on the outer surface of the first tubular component 200.

[0169] Each male electrical contact 24a-24d may be aligned with one another in an axial direction. Each male electrical contact 24a-24d may be offset from the male thread 21 in an axial direction. For example, the male thread 21 may be located between Each male electrical contact 24a-24d and a terminal end of the first tubular component 200, particularly of the pin. In other words an end region (such as the depicted first end region) of the first tubular component 200 may comprise, in order, the terminal end, the male thread 21 and then the male electrical contacts 24a-24d. This configuration may be located at one end of the first tubular component 200 or at both ends (i.e. the first end region and the second end region) of the first tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contacts 24a-24d. That is, not a terminal end at an opposite end of the first tubular component 200 which would not be in the same end region.

[0170] A plurality of first conductors 22 extend along the first tubular component 200, for example in an axial direction. Each first conductor 22 may extend circumferentially spaced from the other first conductors 22, or may extend together in a bundle which splits out. Each male electrical contact 24a-24d is in electrical communication with a corresponding first conductor 22. Each first conductor 22 may extend along the first tubular component 200 as described above. In this sense, each first conductor 22 may carry a separate electrical signal to/from each male electrical contact 24a-24d.

[0171] Turning to the second tubular component, each female electrical contact 34a-34d is spaced from one another in a circumferential direction about the second tubular component 300. In certain examples, the female electrical contacts 34a-34d may have rotational symmetry about the inner surface of the second tubular component 300. That is, with N female electrical contacts 34a-34d there may be N-fold rotational symmetry with each female electrical contact 34a-34d spaced (360/N)° from one another. Each female electrical contact 34a-34d has a second circumferential length. Each female electrical contact 34a-34d may have the same second circumferential length. Between each female electrical contact 34a-34d there is a second circumferential gap on the inner surface of the second tubular component 300.

[0172] Each female electrical contact 34a-34d may be aligned with one another in an axial direction. Each female electrical contact 34a-34d may be offset from the female thread 31 in an axial direction. For example, each female electrical contact 34a-34d may be located between the female thread 31 and a terminal end of the second tubular component 300, particularly of the box. In other words an end region (such as the depicted first end region) of the second tubular component 300 may comprise, in order, the terminal end, the female electrical contacts 34a-34d and then the female thread 31. This configuration may be located at one end of the second tubular component 300 or at both ends of the second tubular component 300 (i.e. the first end region and the second end region). These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the female electrical contacts 34a-34d. That is, not a terminal end at an opposite end of the second tubular component 300 which would not be in the same end region.

[0173] A plurality of second conductors 32 extend along the second tubular component 300, for example in an axial direction. Each second conductor 32 may extend circumferentially spaced from the other second conductors 32, or may extend together in a bundle which splits out. Each female electrical contact 34a-34d is in electrical communication with a corresponding second conductor 32. Each second conductor 32 may extend along the second tubular component 300 as described above. In this sense, each second conductor 32 may carry a separate electrical signal to/from each female electrical contact 34a-34d.

[0174] With such a plurality of male electrical contacts 24a-24d and plurality of female electrical contacts 34a-34d, there is a risk of rotational offset connecting multiple contacts which could cause problems such as a short-circuit. To address this, the first circumferential gap between each male electrical contact 24a-24d may be larger than the second circumferential length of each female electrical contact 34a-34d; and the second circumferential gap between each female electrical contact 34a-34d may be larger than the first circumferential length of each male electrical contact 24a-24d. This means that it is not possible for a single electrical contact to span the corresponding gap and hence the problem with rotational offset is avoided. Figure 9B shows this arrangement in schematic (again noting that the electrical contacts are shown radially spaced for ease of view. Each electrical contact would sit in the corresponding circumferential gap. This means that it is not possible for two male electrical contacts 24a-24d or two female electrical contacts 34a-34d to be brought into connection with one other by the other.

[0175] While Figures 9A and 9B show the male electrical contacts 24a-24d having a first circumferential length which is smaller than the second circumferential length of the female electrical contacts 34a-34d, this is not necessarily the case and the opposite is equally possible.

[0176] In this sense, the threaded connection 100 of the first tubular component 200 and second tubular component 200 allows for multiple conductive paths while being resilient to rotational offset.

[0177] This arrangement can further be combined with having a width of each female electrical contact 34a-34d which may be smaller than the width of each male electrical contact 24a-24d. Alternatively, the width of each male electrical contact 24a-24d may be smaller than the width of each female electrical contact 34a-34d. This provides resilience against axial offset as discussed above.

[0178] In the threaded connection 100 of Figure 4 this multiple connection arrangement is generally the same as explained above, with appropriate modifications.

[0179] The coupling 500 may comprise a first plurality of female electrical contacts on the inner surface of the first end of coupling 500, and a second plurality female electrical contacts on the inner surface of the second end of the coupling 500. Each female electrical contact may be insulated from the coupling 500.

[0180] Each female electrical contact of the first plurality of female electrical contacts is spaced from one another in a circumferential direction about the coupling 500. In certain examples, the first plurality of female electrical contacts may have rotational symmetry about the inner surface of the coupling 300. That is, with N female electrical contacts in the first plurality of female electrical contacts there may be N-fold rotational symmetry with each female electrical contact of the first plurality of female electrical contacts spaced (360/N)° from one another. Each female electrical contact of the first plurality of female electrical contacts has a second circumferential length. Each female electrical contact of the first plurality of female electrical contacts may have the same second circumferential length. Between each female electrical contact of the first plurality of female electrical contacts there is a second circumferential gap on the inner surface of the coupling 500.

[0181] Each female electrical contact of the second plurality of female electrical contacts is spaced from one another in a circumferential direction about the coupling 500. In certain examples, the second plurality of female electrical contacts may have rotational symmetry about the inner surface of the coupling 300. That is, with N female electrical contacts in the second plurality of female electrical contacts there may be N-fold rotational symmetry with each female electrical contact of the second plurality of female electrical contacts spaced (360/N)° from one another. Each female electrical contact of the second plurality of female electrical contacts has a third circumferential length. Each female electrical contact of the second plurality of female electrical contacts may have the same third circumferential length. The third circumferential length may be the same as the second circumferential length. Between each female electrical contact of the second plurality of female electrical contacts there is a third circumferential gap on the inner surface of the coupling 500. The third circumferential gap may be the same size as the second circumferential gap.

[0182] Each female electrical contact of the first plurality of female electrical contacts may be aligned with one another in an axial direction. Each female electrical contact of the second plurality of female electrical contacts may be aligned with one another in an axial direction.

[0183] Each female electrical contact of the first plurality of female electrical contacts may be in electrical communication with a corresponding electrical contact of the second plurality of female electrical contacts. For example, there may be a separate longitudinal conductor 52 connecting each pair of female electrical contacts. These longitudinal conductors 52 may be as described above. Each longitudinal conductor 52 may extend along its own longitudinally-extending bore 56. Alternatively, a plurality of longitudinal conductors 52 may be provided in the same longitudinally-extending bore 56.

[0184] For the threaded connection 100 of Figure 4, each tubular component 200 may be identical to or generally similar to the first tubular component 200 described herein, particularly with reference to Figures 1 to 3.

[0185] Each tubular component 200 may further comprise a plurality of male electrical contacts 24a-24d on the outer surface of the first end region of the tubular component 200. Each male electrical contact 24a-24d may be insulated from the tubular component 200.

[0186] Each male electrical contact 24a-24d is spaced from one another in a circumferential direction about the tubular component 200. In certain examples, the male electrical contacts 24a-24d may have rotational symmetry about the outer surface of the tubular component 200. That is, with N male electrical contacts 24a-24d there may be N-fold rotational symmetry with each male electrical contact 24a-24d spaced (360/N)° from one another. Each male electrical contact 24a-24d has a first circumferential length. Each male electrical contact 24a-24d may have the same first circumferential length. Between each male electrical contact 24a-24d there is a first circumferential gap on the outer surface of the tubular component 200.

[0187] Each male electrical contact 24a-24d may be aligned with one another in an axial direction. Each male electrical contact 24a-24d may be offset from the male thread 21 in an axial direction. For example, the male thread 21 may be located between Each male electrical contact 24a-24d and a terminal end of the tubular component 200, particularly of the pin. In other words an end region (such as the depicted first end region) of the tubular component 200 may comprise, in order, the terminal end, the male thread 21 and then the male electrical contacts 24a-24d. This configuration may be located at one end of the tubular component 200 or at both ends (i.e. the first end region and the second end region) of the tubular component 200. These elements may be immediately adjacent one another, or there may be spacing between these elements. The terminal end in this sense is the terminal end nearest the male electrical contacts 24a-24d. That is, not a terminal end at an opposite end of the tubular component 200 which would not be in the same end region.

[0188] In this sense, the coupling 500 and each tubular component 200 can form a threaded connection which allows for multiple conductive paths while being resilient to rotational offset.

CLAUSES:

[0189] Embodiments and examples are considered as set out in the following numbered clauses:

A1. A threaded connection comprising:

first and second tubular components, wherein the first tubular component comprises: at a first end region a pin with an outer surface on which is formed a male thread; and an opposite second end region, the second tubular component comprises: at a first end region a box with an inner surface on which is formed a female thread; and an opposite second end region, and the male thread is arranged to engage the female thread in a made-up configuration;

a male electrical contact on the outer surface of the first end region of the first tubular component and insulated from the first tubular component;

a female electrical contact on the inner surface of the first end region of the second tubular component and insulated from the second tubular component;

a first conductor extending along the outer surface of the first tubular component, in communication with the male electrical contact, and insulated from the first tubular component; and

a second conductor extending along the second tubular component, in communication with the female electrical contact, and insulated from the second tubular component,

wherein the male and female electrical contacts are arranged to contact with each other in the made-up configuration,

wherein the male electrical contact has a width in an axial direction of the first tubular component and the female electrical contact has a width in an axial direction of the second tubular component, wherein the width of the female electrical contact is smaller than the width of the male electrical contact, or vice versa.

A2. The threaded connection of clause A1, wherein the male thread is located between the male electrical contact and a terminal end of the first end region of the first tubular component.

A3. The threaded connection of clause A1 or A2, wherein the female electrical contact is located between the female thread and a terminal end of the first end region of the second tubular component.

A4. The threaded connection of and of clauses A1 to A3, wherein:
the male electrical contact extends circumferentially around the outer surface; and/or the female electrical contact extends circumferentially around the inner surface.

A5. The threaded connection of any of clauses A1 to A4, wherein:

the first tubular component comprises a groove formed on the outer surface and the first conductor extends within the groove; and/or

the second tubular component comprises a groove formed on the outer surface and the second conductor extends within the groove.

A6. The threaded connection of clause A5, wherein the groove includes a curved surface in cross-section, and preferably the groove is U-shaped.

A7. The threaded connection of clause A6, wherein the groove has a radius of curvature of less than 5 millimetres, preferably between 1 millimetre to 2 millimetres.

A8. The threaded connection of any of clauses A5 to A7, further comprising a sealing cover attached to the outer surface over the groove.

A9. The threaded connection of any of clauses A5 to A8, wherein the first tubular component comprises a groove formed on the outer surface and the first conductor extends within the groove and the groove communicates with a bore underneath a sealing surface of the first tubular component.

A10. The threaded connection of any of clauses A1 to A9, wherein the male electrical contact has a width in an axial direction of the first tubular component, the width greater than 3 millimetres.

A11. The threaded connection of any of clauses A1 to A10, wherein the male electrical contact has a width in an axial direction of the first tubular component, the width less than 6 millimetres.

A12. The threaded connection of any of clauses A1 to A11, wherein the male thread has a thread lead or pitch and the male electrical contact has a width in an axial direction of the first tubular component, the width within 25% of the thread lead or pitch.

A13. The threaded connection of any of clauses A1 to A12, further comprising:

a plurality of male electrical contacts on the outer surface of the first end region of the first tubular component, each insulated from the first tubular component, the plurality of male electrical contacts having a first circumferential length and spaced from one another by a first circumferential gap;

a plurality of female electrical contacts on the inner surface of the first end region of the second tubular component, each insulated from the second tubular component, the plurality of female electrical contacts having a second circumferential length and spaced from one another by a second circumferential gap;

a plurality of first conductors extending along the outer surface of the first tubular component, each first conductor in communication with a

corresponding male electrical contact of the plurality of male electrical contacts, and each insulated from the first tubular component; and
a plurality of second conductors extending along the second tubular component, each second conductor in communication with a corresponding female electrical contact of the plurality of female electrical contacts, and each insulated from the second tubular component,

wherein:

the first circumferential length is smaller than the second circumferential gap; and
the second circumferential length is smaller than the first circumferential gap.

A14. The threaded connection of any of clauses A1 to A13, wherein the male electrical contact forms at least part of an interference seal of the first tubular component.

A15. The threaded connection of any of clauses A1 to A14, wherein the female electrical contact is at least partially insulated from the second tubular component by an elastomeric seal for sealing with the pin.

A16. The threaded connection of any of clauses A1 to A15, wherein the female electrical contact comprises a deformable element biased towards the male electrical contact in the made-up configuration, or vice-versa.

A17. The threaded connection of clause A16, wherein the deformable element is a coil spring extending circumferentially.

A18. The threaded connection of any of clauses A1 to A17, wherein the male thread and female thread are wedge threads.

A19. The threaded connection of any of clauses A1 to A18, wherein the pin comprises an annular sealing surface for sealing by interference with a complementary annular sealing surface of the box, the annular sealing surface of the pin being located between the male thread and a terminal end of the first tubular component.

A20. The threaded connection of any of clauses A1 to A19, wherein the first tubular component comprises a shoulder for abutment against the second tubular component, or vice versa.

A21. The threaded connection of any of clauses A1 to A20, wherein the first tubular component is a first casing or tubing tubular component and the second tubular component is a second casing or tubing tubular component.

A22. A string for a well bore, comprising:

a plurality of threaded connections according to any of clauses A1 to A21 in threaded engagement to form the string such that the first and second conductors collectively form a conductive path;
one or more sensors, positioned along the string, in communication with the conductive path.

A23. The string of clause A22, wherein the conductive path is for transmission of power to the one or more sensors and signals from the one or more sensors.

A24. The string of clause A22 or A23, wherein the one or more sensors comprises one or more of:

a temperature sensor;
a pressure sensor;
an accelerometer;
a magnetometer;
an ultrasonic sensor;
a flow sensor; and/or
an acoustic sensor.

A25. The string of any of clauses A22 to A24, wherein the string is a casing string or a tubing string, and each tubular component is a casing or tubing tubular component.

B1. A coupling for a threaded connection, comprising:

a tubular main body with first and second ends, each end having a box with an inner surface on which is formed a female thread for engagement with a pin of a tubular component;
a first female electrical contact on the inner surface of the first end, and insulated from the tubular main body;
a second female electrical contact on the inner surface of the second end, and insulated from the tubular main body; and
a longitudinal conductor in communication with the first and second female electrical contacts, and insulated from the tubular main body, wherein the tubular main body has formed therein a longitudinally-extending bore, through which the longitudinal conductor extends.

B2. The coupling of clause B1, wherein:

the first female electrical contact extends circumferentially around the inner surface; and/or the second female electrical contact extends circumferentially around the inner surface.

B3. The coupling of clause B1 or B2, wherein the conductor is formed of a first wire and a second wire attached to one another at a location within the longitudinally-extending bore.

B4. The coupling of clause B3, wherein the first wire is attached to the second wire with a connector within the longitudinally-extending bore.

B5. The coupling of clause B4, wherein the connector comprises a solder sleeve.

B6. The coupling of clause B4 or B5, wherein the connector comprises heat-shrink tubing.

B7. The coupling of any of clauses B1 to B6, wherein each female electrical contact comprises a deformable element biased inwardly of the box.

B8. The coupling of clause B7, wherein each deformable element is a coil spring extending circumferentially.

B9. The coupling of any preceding claim, further comprising:

a first plurality of female electrical contacts on the inner surface of the first end, each insulated from the tubular main body, the fist plurality of female electrical contacts having a second circumferential length and spaced from one another by a second circumferential gap; and
a second plurality of female electrical contacts on the inner surface of the second end, each insulated from the tubular main body, the second plurality of female electrical contacts having a third circumferential length and spaced from one another by a third circumferential gap.

B10. The coupling of any of clauses B1 to B9, wherein each female electrical contact is insulated from the tubular main body by an elastomeric seal, the female electrical contact and conductor embedded within the seal and partially exposed to form the female electrical contact.

B11. The coupling of any of clauses B1 to B10, wherein the tubular main body comprises a first radially-extending bore at the first end extending from the first female electrical contact to the longitudinally-extending bore and a second radially-extending bore at the second end extending from the second female electrical contact to the longitudinally-extending bore.

B12. The coupling of any of clauses B1 to B11, wherein the longitudinally-extending bore has a blind-end bore with an open-end at the first end of the tubular main body.

B13. The coupling of clause B12, wherein the open-end of the longitudinally-extending bore is closed with a plug.

B14. A threaded connection comprising:

the coupling of any of clauses B1 to B13;
first and second tubular components, wherein each tubular component comprises:

at a first end region a pin with an outer surface on which is formed a male thread, each male thread is arranged for engagement with a female thread of the coupling in a made-up configuration;
an opposite second end region;
a male electrical contact on the outer surface of the first end region of the tubular component and insulated from the tubular component; and
a first conductor extending along the tubular component, in communication with the male electrical contact, and insulated from the tubular component, wherein the male and female electrical contacts are arranged to contact with each other in the made-up configuration.

B15. The threaded connection of clause B14, wherein: each male electrical contact extends circumferentially around the outer surface.

B16. The threaded connection of clause B14 or B15, when dependent on clause B9, wherein each tubular component further comprises:

a plurality of male electrical contacts on the outer surface of the first end region of the tubular component, each insulated from the tubular component, the plurality of male electrical contacts having a first circumferential length and spaced from one another by a first circumferential gap, wherein:
the first circumferential length is smaller than the second circumferential gap and the third circumferential gap; and
the second circumferential length and the third circumferential length is smaller than the first circumferential gap.

B17. The threaded connection of any of clauses B14 to B16, wherein the first tubular component is a first casing or tubing tubular component and the second tubular component is a second casing or tubing tubular component.

B18. A method of manufacturing a coupling for a threaded connection, comprising:

forming a tubular main body with first and second ends, each end having a box with an inner surface on which is formed a female thread for engagement with a pin of a tubular component;
machining a longitudinally-extending bore through the tubular main body; and
inserting an insulated conductor into the longitudinally-extending bore to communicate with a first female electrical contact and a second female electrical contact, the first female electrical contact on the inner surface of the first end and insulated from the tubular main body, and the second female electrical contact on the inner surface of the second end and insulated from the tubular main body.

B19. The method of clause B18, wherein:

the first female electrical contact extends circumferentially around the inner surface; and/or
the second female electrical contact extends circumferentially around the inner surface.

B20. The method of clause B18 or B19, wherein the insulated conductor comprises a first wire and a second wire and inserting the insulated conductor into the longitudinally-extending bore comprises:

inserting the first wire into the longitudinally-extending bore from the first end of the tubular main body; and
inserting the second wire into the longitudinally-extending bore from the second end of the tubular main body such that the first and second wires are in electrical contact.

B21. The method of clause B20, further comprising the steps of:

positioning a connector within the longitudinally-extending bore, wherein the step of inserting the first wire comprises inserting the first wire into the connector and the step of inserting the second wire comprises inserting the second wire into the connector; and
heating the tubular main body to activate the connector and attach the first wire to the second wire.

B22. The method of clause B21, wherein the connector comprises a solder sleeve.

B23. The method of clause B21 or B22, wherein the connector comprises heat-shrink tubing.

B24. The method of any of clauses B20 to B23, wherein the first female electrical contact is fixed to the first wire before the first wire is inserted.

B25. The method of any of clauses B20 to B24, wherein the second female electrical contact is fixed to the second wire before the second wire is inserted.

B26. The method of any of clauses B18 to B25, further comprising the steps of:

machining a first radially-extending bore at the first end to the longitudinally-extending bore;
machining a second radially-extending bore at the second end to the longitudinally-extending bore,
wherein the insulated conductor is inserted through the first radially-extending bore and the second radially-extending bore.

B27. The method of any of clauses B18 to B26, wherein the longitudinally-extending bore has a blind-end.

B28. The method of any of clauses B18 to B27, further comprising the step of plugging an open-end of the longitudinally-extending bore to close the open-end.

B29. The method of clause B28, when dependent on clause B21, wherein the connector is positioned before the end is plugged.

B30. A string for a well bore, comprising:

a plurality of threaded connections according to any of clauses B14 to B17 in threaded engagement to form the string such that the first conductors and longitudinal conductors collectively form a conductive path;
one or more sensors, positioned along the string, in communication with the conductive path.

B31. The string of clause B30, wherein the conductive path is for transmission of power to the one or more sensors and signals from the one or more sensors.

B32. The string of clause B30 or B31, wherein the one or more sensors comprises one or more of:

a temperature sensor;
a pressure sensor;
an accelerometer;

a magnetometer;
an ultrasonic sensor;
a flow sensor; and/or
an acoustic sensor.

B33. The string of any of clauses B30 to B32, wherein the string is a casing string or a tubing string, and each tubular component is a casing or tubing tubular component.

C1. A string for a well bore, comprising:

a plurality of tubular components in threaded engagement to form a string;
one or more sensors, positioned along the string, wherein:

each tubular component comprises a longitudinally-extending bore or groove accommodating a conductor insulated therefrom, a first electrical contact at a first end of the tubular component and a second electrical contact at a second end of the tubular component;
the conductors of the plurality of tubular components collectively form a conductive path; and
the sensors are in communication with the conductive path.

C2. The string of clause C1, wherein the conductive path is for transmission of power to the one or more sensors and signals from the one or more sensors.

C3. The string of clause C1 or C2, wherein the one or more sensors comprises one or more of:

a temperature sensor;
a pressure sensor;
an accelerometer;
a magnetometer;
an ultrasonic sensor;
a flow sensor; and/or
an acoustic sensor.

C4. The string of any of clauses C1 to C3, wherein the longitudinally-extending bore or groove is on an outer surface of each tubular component.

C5. The string of any of clauses C1 to C4, wherein one of the tubular components is a first tubular component and comprises at the first end a pin with an outer surface on which is formed a male thread and the male thread is located between the first electrical contact and a terminal end of the first tubular component

C6. The string of any of clauses C1 to C5, wherein one of the tubular components is a second tubular component and comprises at the second end a box with an inner surface on which is formed a female thread and the second electrical contact is located between the female thread and a terminal end of the second tubular component.

C7. The string of any of clauses C1 to C6, wherein the string is a casing string or a tubing string, and each tubular component is a casing or tubing tubular component.

Claims

1. A threaded connection comprising:

first and second tubular components, wherein the first tubular component comprises: at a first end region a pin with an outer surface on which is formed a male thread; and an opposite second end region, the second tubular component comprises: at a first end region a box with an inner surface on which is formed a female thread; and an opposite second end region, and the male thread is arranged to engage the female thread in a made-up configuration;
a male electrical contact on the outer surface of the first end region of the first tubular component and insulated from the first tubular component;
a female electrical contact on the inner surface of the first end region of the second tubular component and insulated from the second tubular component;
a first conductor extending along the outer surface of the first tubular component, in communication with the male electrical contact, and insulated from the first tubular component; and
a second conductor extending along the second tubular component, in communication with the female electrical contact, and insulated from the second tubular component,
wherein the male and female electrical contacts are arranged to contact with each other in the made-up configuration,
wherein the male electrical contact has a width in an axial direction of the first tubular component and the female electrical contact has a width in an axial direction of the second tubular component, wherein the width of the female electrical contact is smaller than the width of the male electrical contact, or vice versa.

2. The threaded connection of any preceding claim, wherein:

the male thread is located between the male electrical contact and a terminal end of the first

end region of the first tubular component; and/or
the female electrical contact is located between the female thread and a terminal end of the first end region of the second tubular component.

3. The threaded connection of any preceding claim, wherein:

the male electrical contact extends circumferentially around the outer surface; and/or
the female electrical contact extends circumferentially around the inner surface.

4. The threaded connection of any preceding claim, wherein:

the first tubular component comprises a groove formed on the outer surface and the first conductor extends within the groove; and/or
the second tubular component comprises a groove formed on the outer surface and the second conductor extends within the groove, preferably the groove includes a curved surface in cross-section.

5. The threaded connection of claim 4, further comprising a sealing cover attached to the outer surface over the groove.

6. The threaded connection of any of claims 4 to 5, wherein the first tubular component comprises a groove formed on the outer surface and the first conductor extends within the groove and the groove communicates with a bore underneath a sealing surface of the first tubular component.

7. The threaded connection of any preceding claim, wherein the male thread has a thread lead or pitch and the male electrical contact has a width in an axial direction of the first tubular component, the width within 25% of the thread lead or pitch.

8. The threaded connection of any preceding claim, further comprising:

a plurality of male electrical contacts on the outer surface of the first end region of the first tubular component, each insulated from the first tubular component, the plurality of male electrical contacts having a first circumferential length and spaced from one another by a first circumferential gap;
a plurality of female electrical contacts on the inner surface of the first end region of the second tubular component, each insulated from the second tubular component, the plurality of female electrical contacts having a second circumferential length and spaced from one another by a second circumferential gap;
a plurality of first conductors extending along the outer surface of the first tubular component, each first conductor in communication with a corresponding male electrical contact of the plurality of male electrical contacts, and each insulated from the first tubular component; and
a plurality of second conductors extending along the second tubular component, each second conductor in communication with a corresponding female electrical contact of the plurality of female electrical contacts, and each insulated from the second tubular component,

wherein:

the first circumferential length is smaller than the second circumferential gap; and
the second circumferential length is smaller than the first circumferential gap.

9. The threaded connection of any preceding claim, wherein the male electrical contact forms at least part of an interference seal of the first tubular component.

10. The threaded connection of any preceding claim, wherein the female electrical contact is at least partially insulated from the second tubular component by an elastomeric seal for sealing with the pin.

11. The threaded connection of any preceding claim, wherein the female electrical contact comprises a deformable element biased towards the male electrical contact in the made-up configuration, or vice-versa,
preferably the deformable element is a coil spring extending circumferentially.

12. The threaded connection of any preceding claim, wherein the male thread and female thread are wedge threads.

13. The threaded connection of any preceding claim, wherein the pin comprises an annular sealing surface for sealing by interference with a complementary annular sealing surface of the box, the annular sealing surface of the pin being located between the male thread and a terminal end of the first tubular component.

14. The threaded connection of any preceding claim, wherein the first tubular component is a first casing or tubing tubular component and the second tubular component is a second casing or tubing tubular component.

15. A string for a well bore, comprising:

a plurality of threaded connections according to any preceding claim in threaded engagement to form the string such that the first and second conductors collectively form a conductive path;
one or more sensors, positioned along the string, in communication with the conductive path,

preferably the one or more sensors comprises one or more of:

a temperature sensor;
a pressure sensor;
an accelerometer;
a magnetometer;
an ultrasonic sensor;
a flow sensor; and/or
an acoustic sensor.

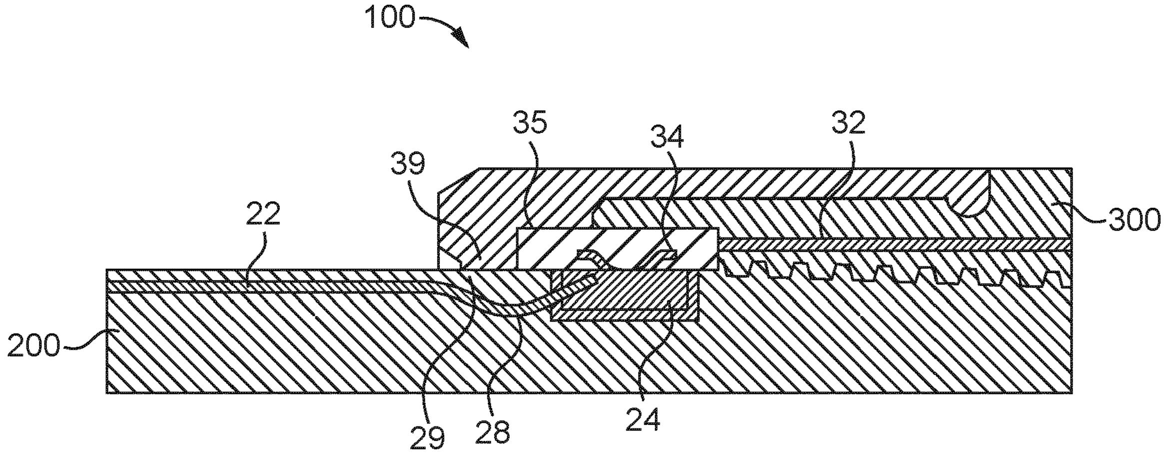

FIG. 1

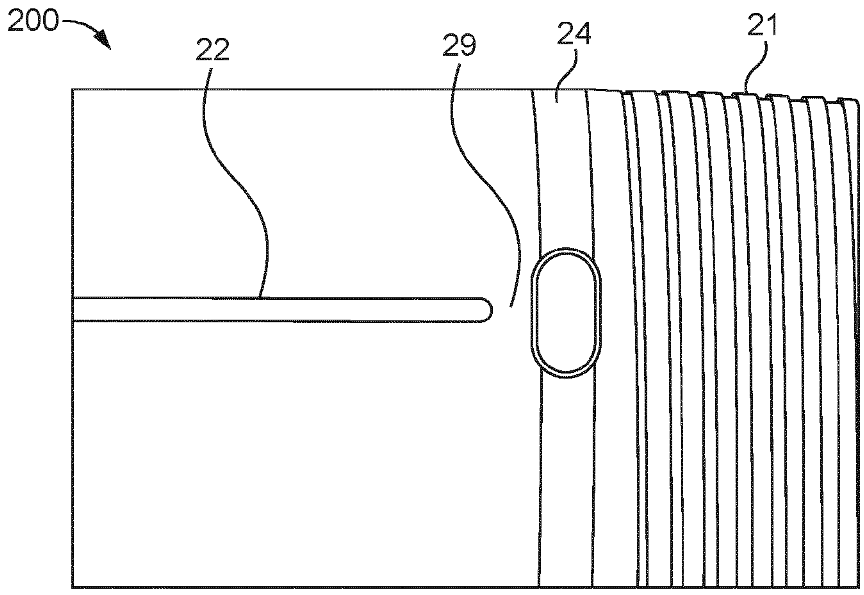

FIG. 2

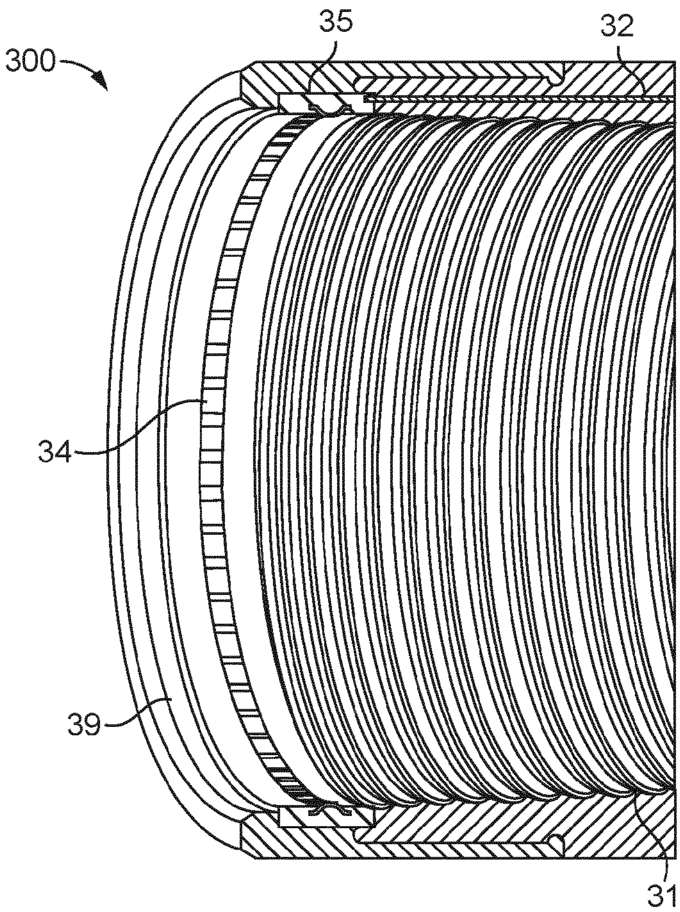

FIG. 3

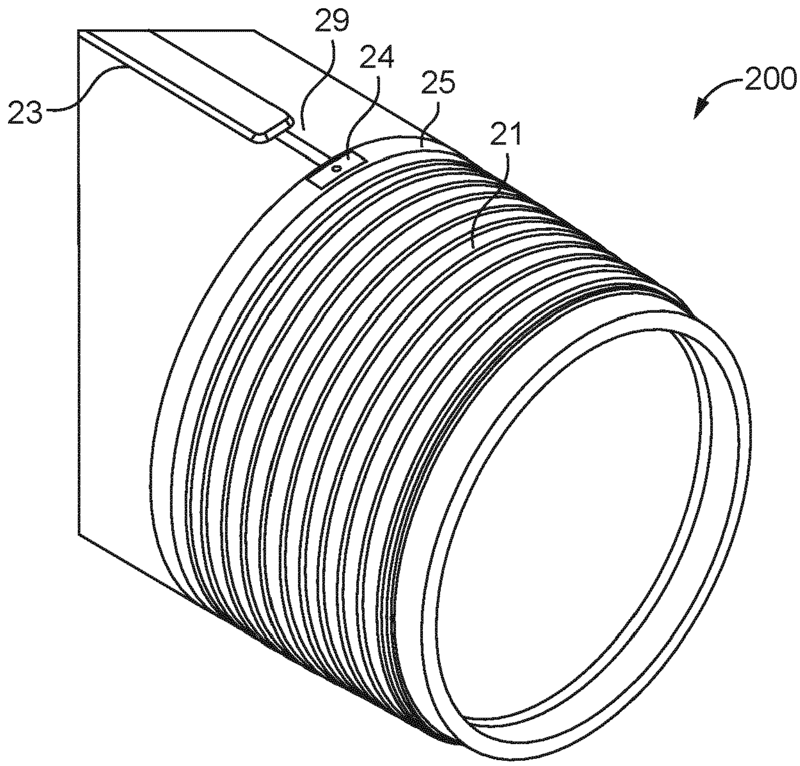

FIG. 2A

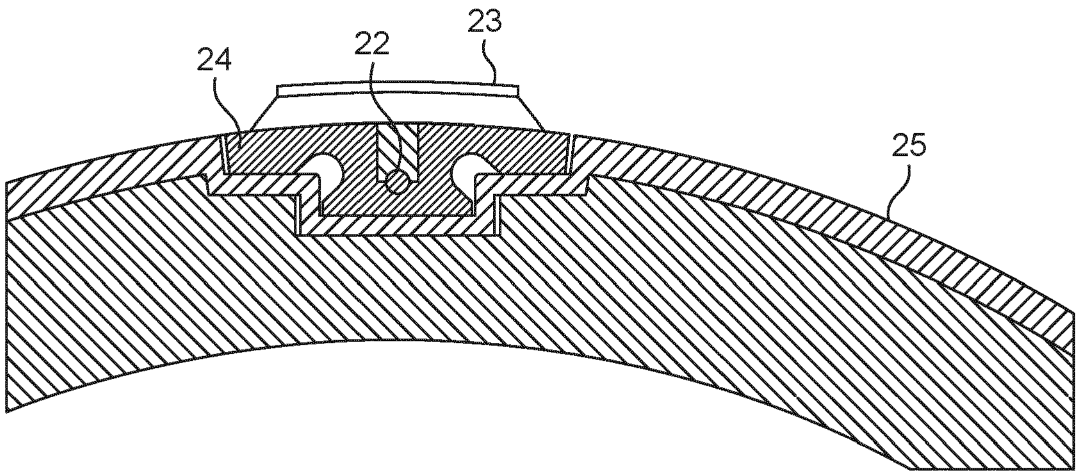

FIG. 2B

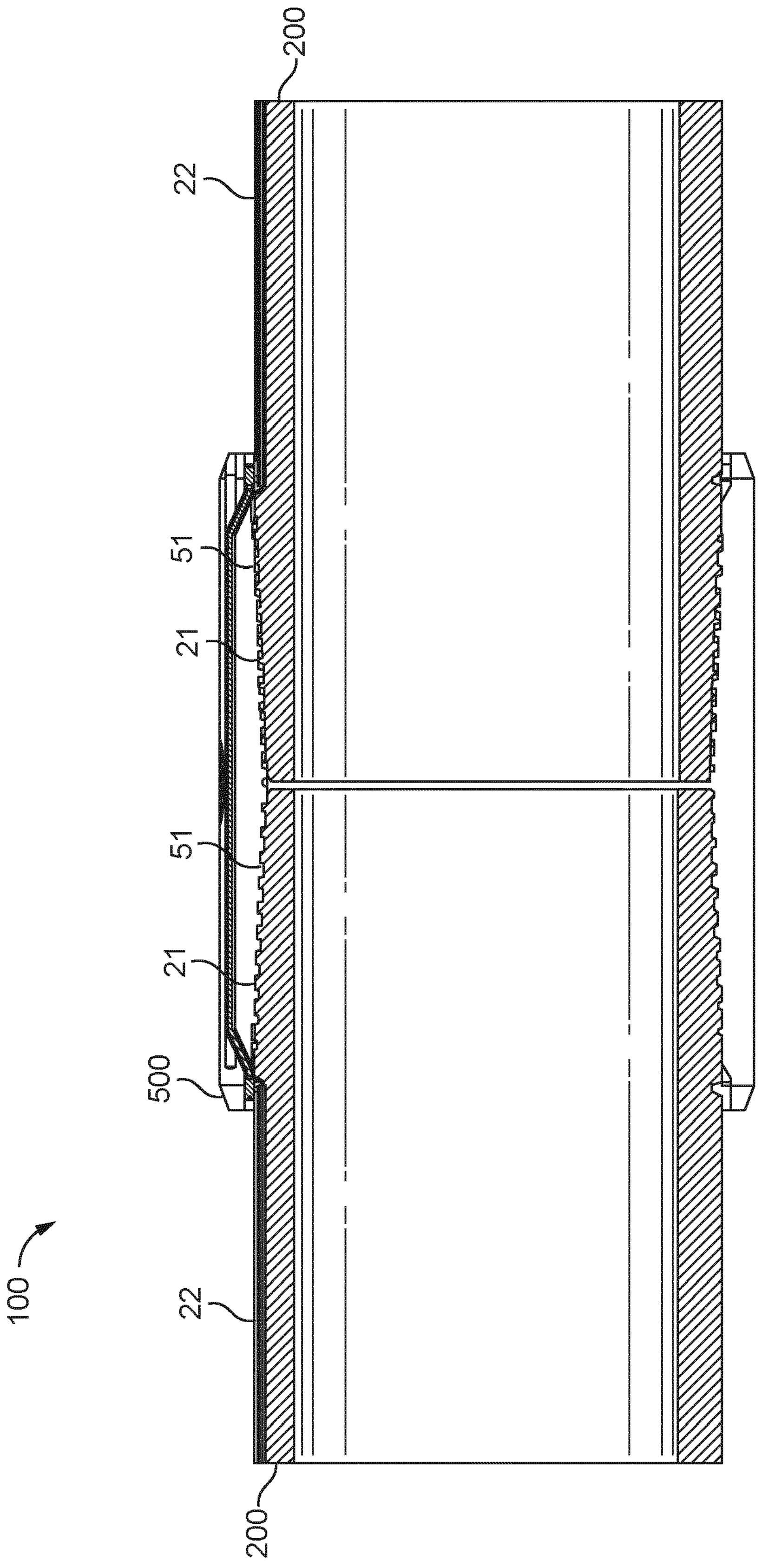

FIG. 4

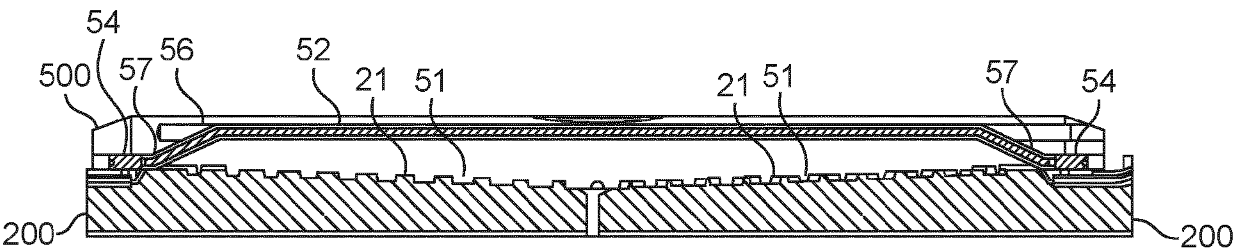

FIG. 5

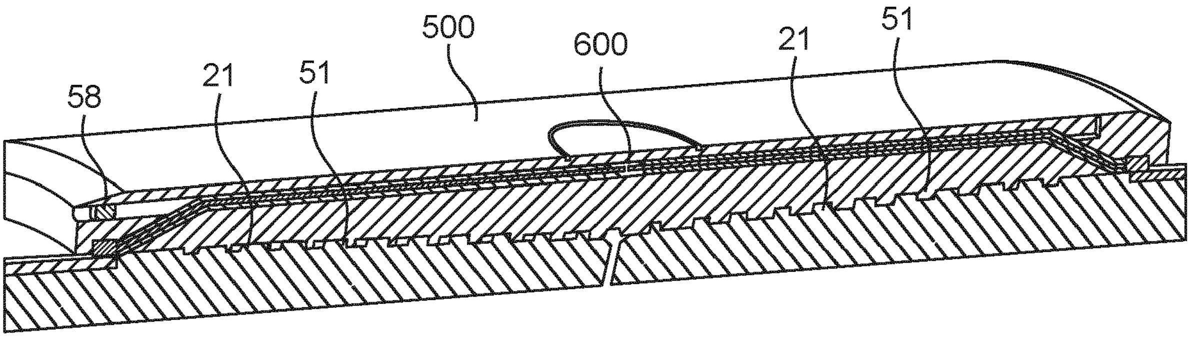

FIG. 6

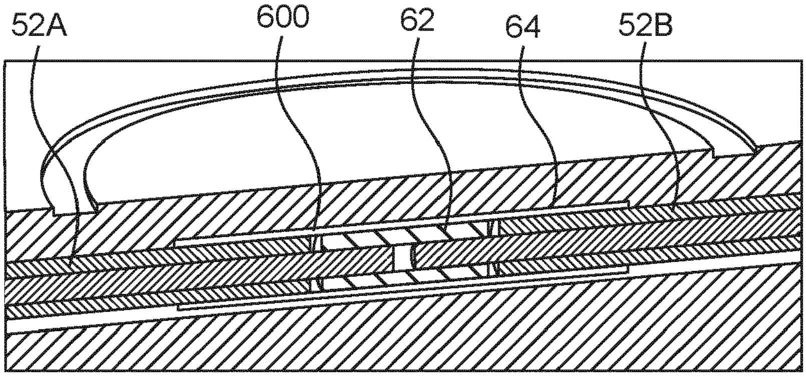

FIG. 7

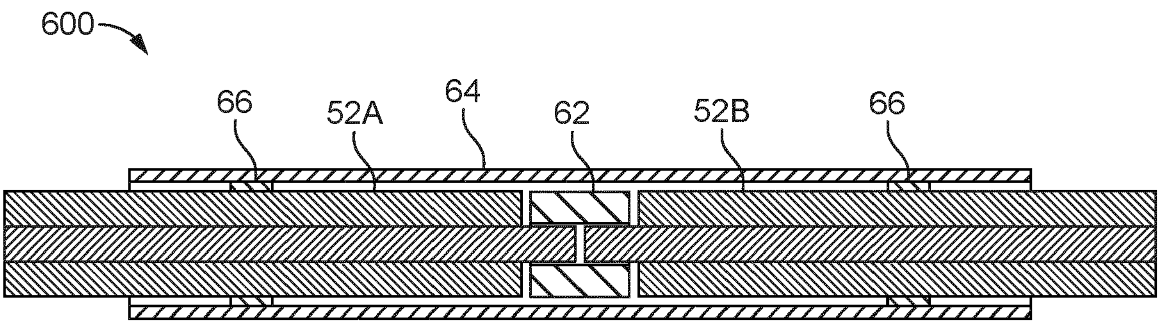

FIG. 8

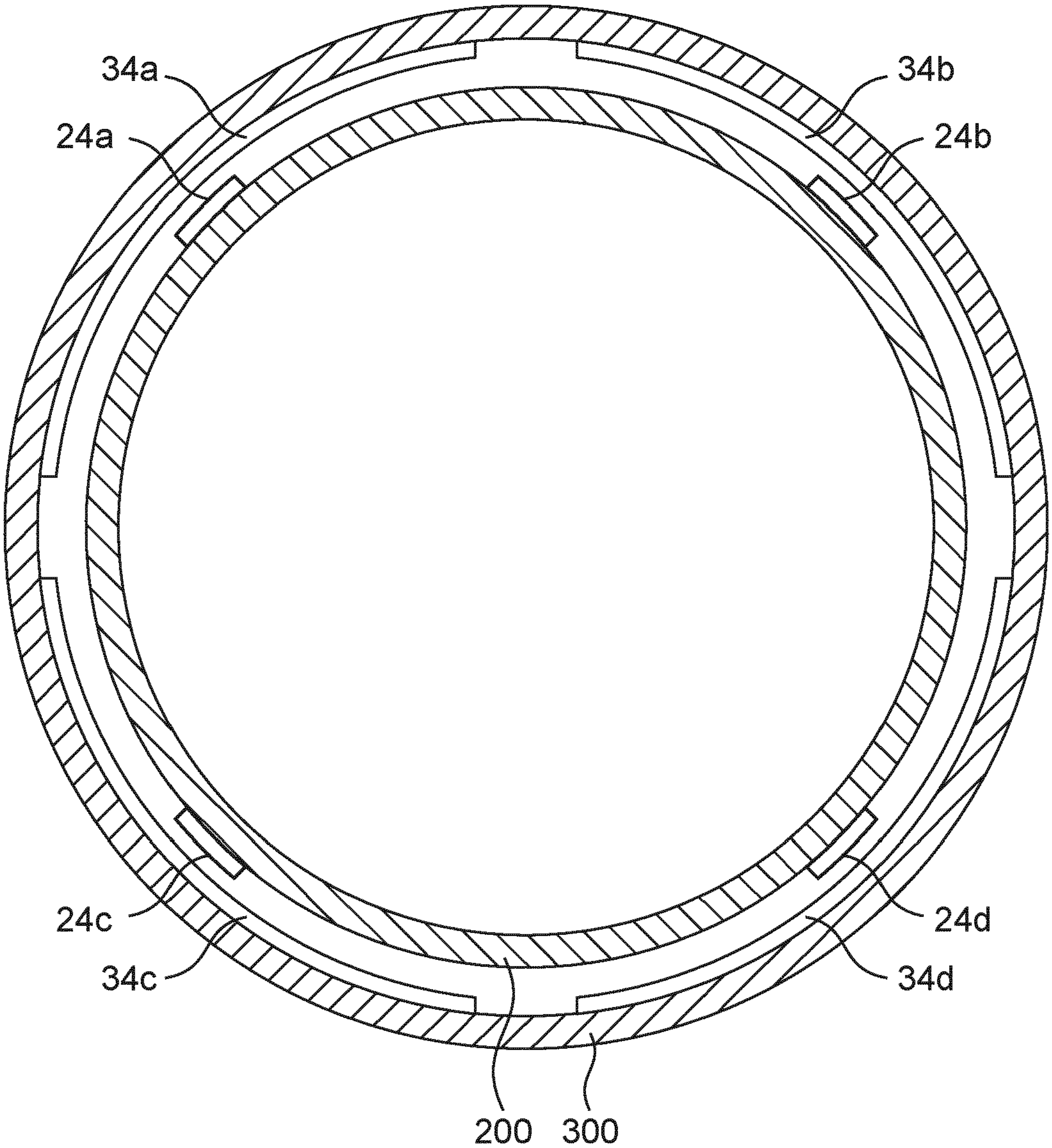

FIG. 9A

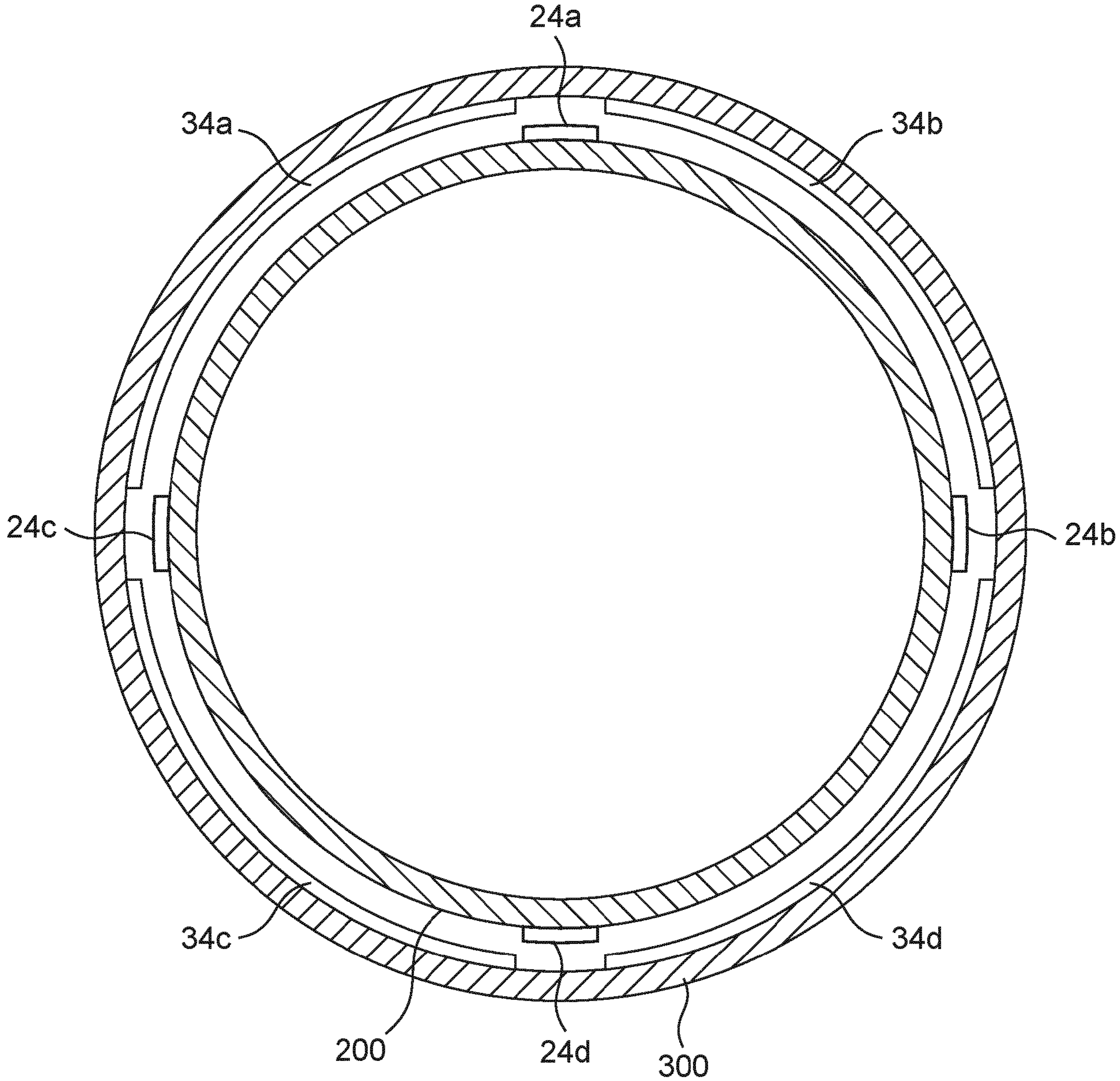

FIG. 9B

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	7 September 2023	Kecman, Ivan

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