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(54) SMART MATERIAL COUPLER

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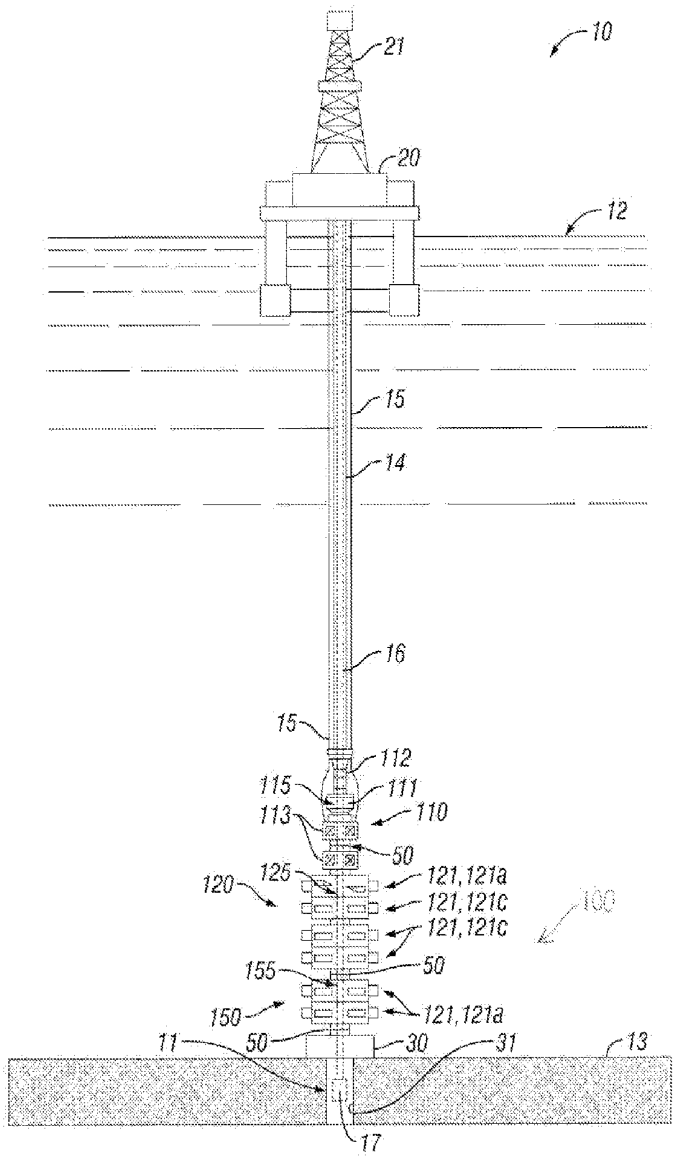
(57) **ABSTRACT**

An apparatus is used to dissipate heat. The apparatus includes a heat sink, an electronic component, and a coupler. The coupler includes a smart material movable into an engaged position such as to be engaged with the heat sink to dissipate heat from the electronic component to the heat sink through the coupler.



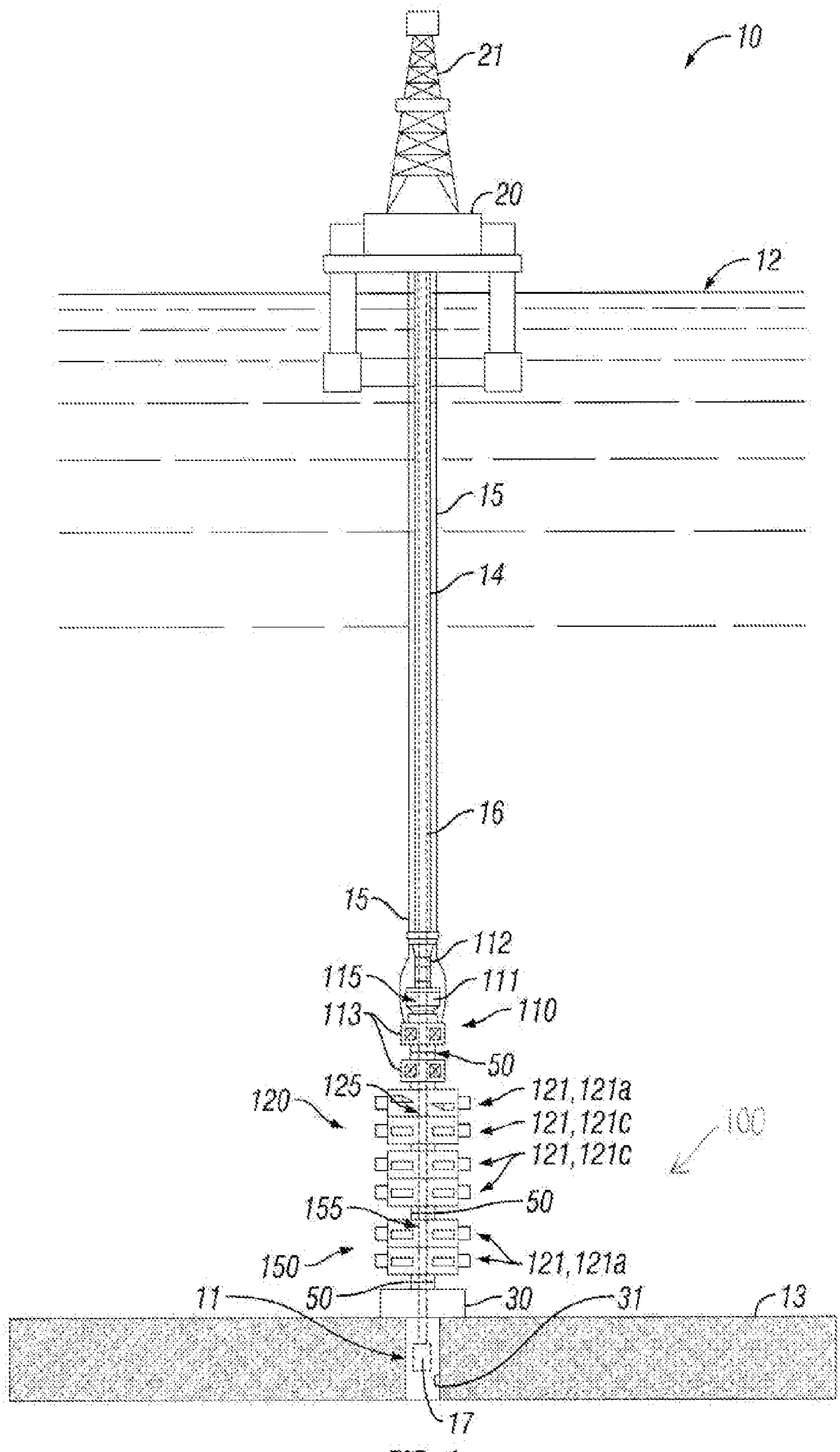

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FIG. 1

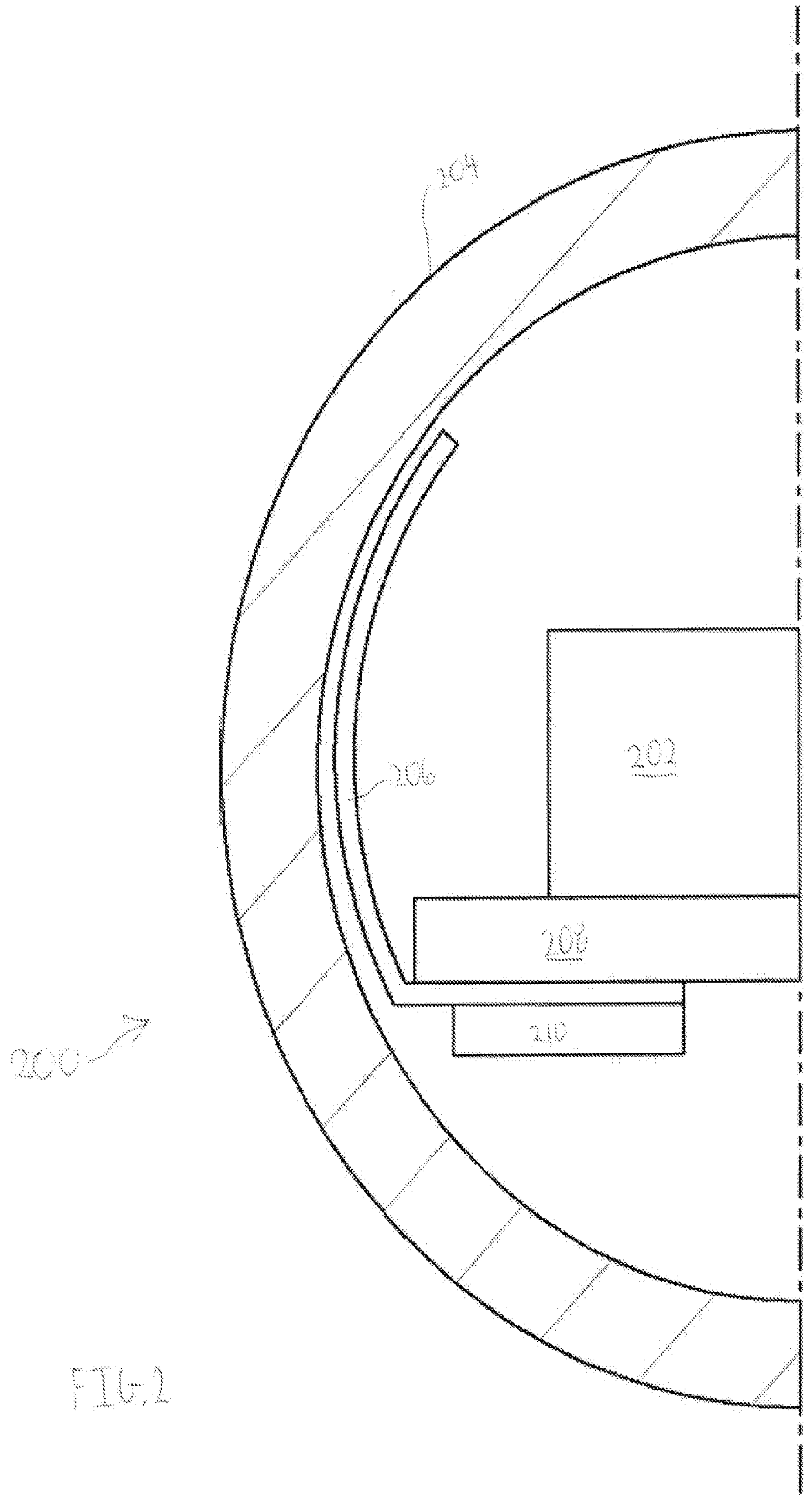

FIG. 2

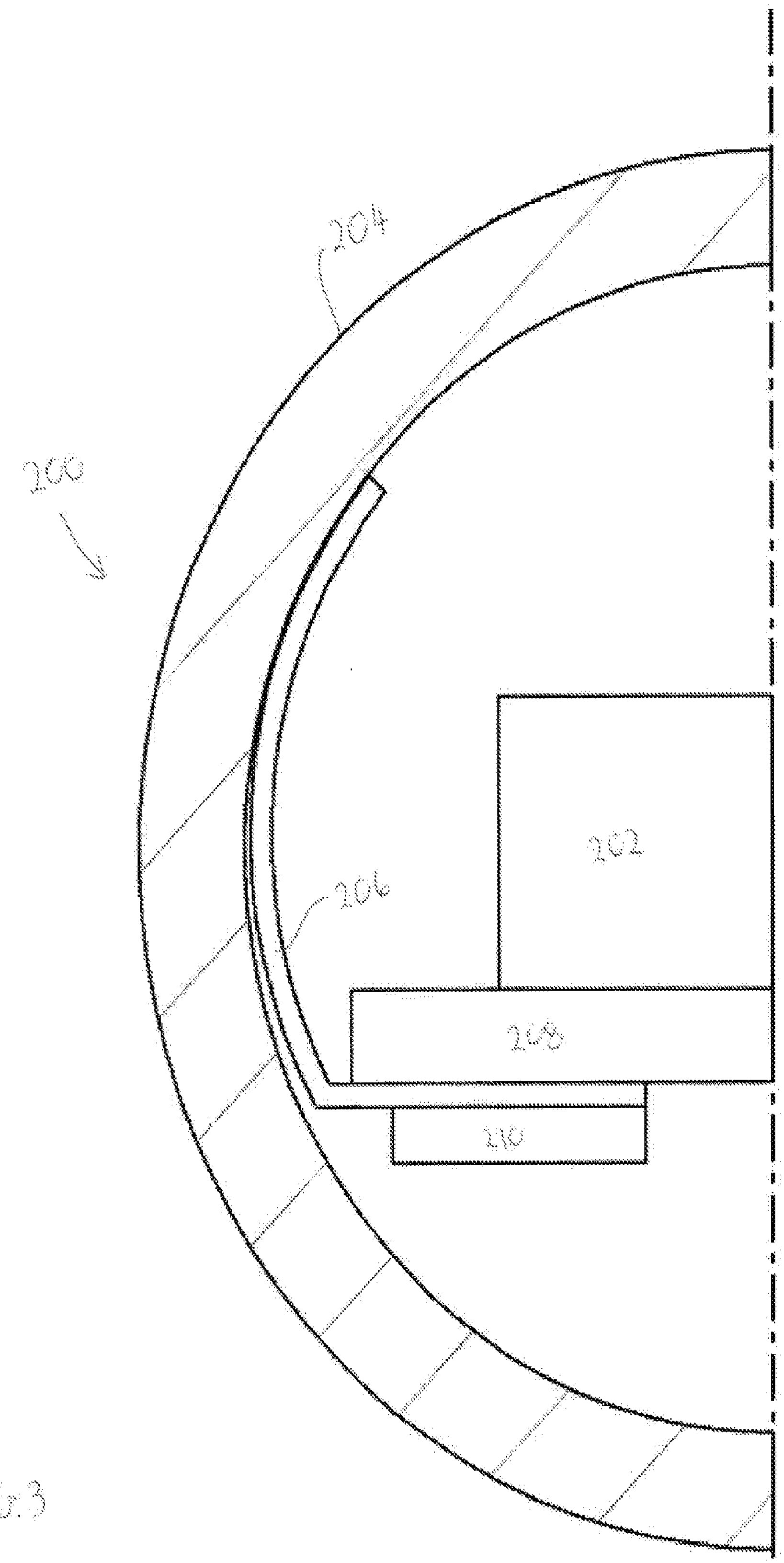

FIG.3

SMART MATERIAL COUPLER

BACKGROUND

[0001] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the presently described embodiments. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present embodiments. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0002] In order to meet consumer and industrial demand for natural resources, companies often invest significant amounts of time and money searching for and extracting oil, natural gas, and other subterranean resources from the earth. Particularly, once a desired subterranean resource is discovered, drilling and production systems are often employed to access and extract the resource. These systems may be located onshore or offshore depending on the location of a desired resource. Further, such systems generally include a wellhead assembly through which the resource is extracted. These wellhead assemblies may include a wide variety of components, such as various casings, valves, fluid conduits, and the like, that control drilling or extraction operations.

[0003] More particularly, in most offshore drilling operations, a wellhead at the sea floor is positioned at the upper end of the subterranean wellbore lined with casing, a blowout preventer (BOP) stack is mounted to the wellhead, and a lower marine riser package (LMRP) is mounted to the BOP stack. The upper end of the LMRP typically includes a flex joint coupled to the lower end of a drilling riser that extends upward to a drilling vessel at the sea surface. A drill string is hung from the drilling vessel through the drilling riser, the LMRP, the BOP stack, and the wellhead into the wellbore.

[0004] During drilling operations, drilling fluid, or mud, is pumped from the sea surface down the drill string, and returns up the annulus around the drill string. In the event of a rapid invasion of formation fluid into the annulus, commonly known as a "kick", the BOP stack and/or LMRP may actuate to help seal the annulus and control the fluid pressure in the wellbore. In particular, the BOP stack and LMRP include closure members, or cavities, designed to help seal the wellbore and mitigate the risk of high-pressure formation fluids being released from the wellbore.

[0005] For most subsea drilling operations, the BOP stack and LMRP are operated by one or more control units. The control units may be positioned subsea, such as along with the components of the BOP stack and/or the LMRP stack. However, as these control units may include electronic components, the operation of these components may generate heat that may affect performance or even lead to damage or failure of the control units. As such, measures may be taken to increase the reliability and use of electronic components, particularly in remote locations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] For a detailed description of the preferred embodiments of the present disclosure, reference will now be made to the accompanying drawings in which:

[0007] FIG. **1** shows a schematic view of an offshore system for drilling and/or producing a wellbore in accordance with one or more embodiments of the present disclosure;

[0008] FIG. **2** shows a cross-sectional view of an apparatus to dissipate heat from an electronic component in a disengaged position in accordance with one or more embodiments of the present disclosure; and

[0009] FIG. **3** shows a cross-sectional view of an apparatus to dissipate heat from an electronic component in an engaged position in accordance with one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0010] The following discussion is directed to various embodiments of the present disclosure. The drawing figures are not necessarily to scale. Certain features of the embodiments may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

[0011] Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but are the same structure or function.

[0012] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . ." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. In addition, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis. The use of "top," "bottom," "above," "below," and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0013] Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present disclosure. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0014] Referring now to FIG. **1**, a schematic view of an offshore system **10** for drilling and/or producing a wellbore **11** is shown. In this embodiment, the system **10** includes an offshore vessel or platform **20** at the sea surface **12** and a subsea BOP stack assembly **100** mounted to a wellhead **30** at the sea floor **13**. The platform **20** is equipped with a derrick

21, and a tubular drilling riser **14** extends from platform **20** to the BOP stack assembly **100**. During drilling operations, the riser **14** returns drilling fluid or mud to the platform **20**. One or more hydraulic conduits **15** may extend along the outside of the riser **14** from the platform **20** to the BOP stack assembly **100**. The conduits **15** supply pressurized hydraulic fluid to the assembly **100**. Further, the casing **31** extends from the wellhead **30** into the subterranean wellbore **11**.

[0015] Downhole operations are carried out by a tubular string **16** (e.g., drillstring, production tubing string, coiled tubing, etc.) that is supported by the derrick **21** and extends from the platform **20**, through the riser **14**, through the BOP stack assembly **100**, and into the wellbore **11**. A downhole tool **17** is connected to the lower end of the tubular string **16**. In general, the downhole tool **17** may comprise any suitable downhole tool(s) for drilling, completing, evaluating and/or producing the wellbore **11** including, without limitation, drill bits, packers, cementing tools, casing or tubing running tools, testing equipment, perforating guns, and the like. During downhole operations, the string **16**, and hence the tool **17** coupled thereto, may move axially, radially, and/or rotationally relative to the riser **14** and the BOP stack assembly **100**.

[0016] The BOP stack assembly **100** is mounted to the wellhead **30** and is designed and configured to control and seal the wellbore **11**, thereby containing the hydrocarbon fluids (liquids and gases) therein. In this embodiment, the BOP stack assembly **100** includes a lower marine riser package (LMRP) **110**, a primary BOP or BOP stack **120**, and a secondary BOP or BOP stack **150**. The secondary BOP stack **150** serves as a backup to the primary BOP stack **120** and the LMRP **110** in the event the primary BOP stack **120** and/or the LMRP **110** fail, malfunction, or lose control communication with the vessel **20**. Accordingly, the secondary BOP stack **150** may also be referred to as a backup BOP stack or a BOP stack of last resort.

[0017] In this embodiment, the connections between the wellhead **30**, the secondary BOP stack **150**, the primary BOP stack **120**, and/or the LMRP **110** may include hydraulically actuated, mechanical wellhead-type connections **50**, though any suitable connection may be used without departing from the scope of the present disclosure. The LMRP **110** may include a riser flex joint **111**, a riser adapter **112**, an annular BOP **113**, and one or more control units or pods. A flow bore **115** extends through the LMRP **110** from the riser **14** at the upper end of the LMRP **110** to the connection **50** at the lower end of the LMRP **110**. The flex joint **111** allows the riser adapter **112** and the riser **14** connected thereto to deflect angularly relative to the LMRP **110** while wellbore fluids flow from the wellbore **11** through the BOP stack assembly **100** into the riser **14**. The annular BOP **113** includes an annular elastomeric sealing element that is mechanically squeezed radially inward to seal on a tubular extending through the LMRP **110** (e.g., string **16**, casing, drillpipe, drill collar, etc.) or seal off the bore **115**. Thus, the annular BOP **113** has the ability to seal on a variety of pipe sizes and/or profiles, as well as perform a "Complete Shut-off" (CSO) to seal the bore **115** when no tubular is extending therethrough.

[0018] A main bore **125** extends through the primary BOP stack **120** from the LMRP **110** at the upper end of the stack **120** to the backup BOP stack **150** at the lower end of the stack **120**. A main bore **155** then extends through the secondary BOP stack **150** from the primary BOP stack **120** at the upper end of the stack **150** to the wellhead **30** at the lower end of the stack **150**. In this embodiment, the secondary BOP stack **150** includes two ram BOPs **121**, an upper ram BOP **121** including opposed blind shear rams or blades **121***a*, and a lower ram BOP **121** including opposed blind shear rams or blades **121***a*. In addition, the primary BOP stack **120** includes a plurality of axially stacked ram BOPs **121**. Each ram BOP **121** includes a pair of opposed rams and a pair of actuators that actuate and drive the matching rams. In this embodiment, the primary BOP stack **120** includes four ram BOPs **121**, an upper ram BOP **121** including opposed blind shear rams or blades **121***a* for severing tubular string **16** and sealing off wellbore **11** from riser **14**, and multiple lower ram BOPs **120** including opposed pipe rams **121***c* for engaging the string **16** and sealing the annulus around the tubular string **16**. One or more control units may then be used to operate one or more components of the LMRP **110**, the primary BOP stack **120**, and/or the secondary BOP stack **150**, in which the control units may include one or more electronic components.

[0019] Referring now to FIGS. **2** and **3**, multiple cross-sectional views of an apparatus **200** to dissipate heat from an electronic component **202** in accordance with one or more embodiments of the present disclosure are shown. In particular, FIG. **2** shows the apparatus **200** in a disengaged position, in which heat may not be dissipated from the electronic component **202** to a heat sink, and FIG. **3** shows the apparatus in an engaged position, in which heat may be dissipated from the electronic component **202** to the heat sink. For example, as discussed more below, heat may be dissipated from the electronic component **202**, through a coupler **206**, and to a housing **204** (e.g., heat sink), thus coupling the electronic component **202** to atmospheric conditions through the housing **204** (e.g., subsea conditions). Further, FIGS. **2** and **3** each provide a centerline extending therethrough for purposes of convenience and simplicity.

[0020] The apparatus **200** includes a heat sink, such as the housing **204**, with the electronic component **202** positioned adjacent the heat sink. For example, the electronic component may be positioned within or adjacent the housing **204**. Further, the coupler **206** is coupled to the electronic component **202**, either directly, or indirectly as shown in FIGS. **2** and **3**. The coupler **206** is movable into engagement, such as between the disengaged position in FIG. **2** and the engaged position in FIG. **3**, to dissipate heat from the electronic component **202**, through the coupler **206**, and to the heat sink (e.g., housing **204**). The heat sink may be at a temperature that is lower than that of the electronic component **202**, particularly when the electronic component **202** receives power thereto and/or is in operation, and therefore heat dissipates from the electronic component **202** to the heat sink through the coupler **206**. For example, the housing **204** may be positioned subsea, such as by including the housing **204** within one or more of the components discussed above (e.g., control units for the LMRP **110**, the primary BOP stack **120**, and/or the secondary BOP stack **150** in FIG. **1**, in addition to subsea processing and/or subsea production components). This may expose the exterior of the housing **204** to a subsea environment. As the housing **204** may be exposed to a subsea environment, the seawater in contact with the housing **204** may be colder than that of the electronic component **202**, particularly during operation, thereby enabling the housing **204** to act as a heat sink to dissipate heat from the electronic component to the housing **204** through the coupler **206**.

[0021] The coupler **206** includes and/or is formed of one or more smart materials. A smart material is a programmable material and/or a designed material with one or more properties that can be changed in a controlled manner by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields. For example, a smart material may include a shape memory material and/or shape memory technology. In one embodiment, a smart material may include a piezoelectric material that may produce a stress when voltage is applied thereto, and/or vice-versa. In such an embodiment, the piezoelectric material is able to bend, expand, and/or contract when a voltage is applied thereto. In another embodiment, a smart material may include a temperature-dependent shape-memory material that produces a stress when it undergoes a temperature change. In such an embodiment, a temperature-dependent shape-memory material is able to bend, expand, and/or contract when it undergoes a temperature change. In yet another embodiment, a smart material may include a magnetic-dependent shape-memory material that produces a stress when under the influence of a magnetic field and/or is exposed to a change in a magnetic field, and/or vice-versa. In such an embodiment, a magnetic-dependent shape-memory material is able to bend, expand, and/or contract when under the influence of a magnetic field and/or change in a magnetic field.

[0022] Continuing, in another embodiment, a smart material may include an electric-dependent shape-memory material that produces a stress when under the influence of an applied electric field and/or applied voltage or current. In such an embodiment, an electric-dependent shape-memory material is able to bend, expand, and/or contract when under the influence of the applied electric field and/or voltage or current. In yet another embodiment, a smart material may include a pH-dependent shape-memory material that produces a stress when it undergoes a pH change and/or under the influence of a certain or predetermined amount of pH. In such an embodiment, a pH-dependent shape-memory material is able to bend, expand, and/or contract when a pH change is applied thereto and/or under the influence of a certain or predetermined amount of pH. Further, in yet another embodiment, a smart material may include a moisture-dependent shape-memory material that produces a stress when it experiences a moisture change and/or is under the influence of a certain or predetermined amount of moisture. In such an embodiment, a moisture-dependent shape-memory material is able to bend, expand, and/or contract when subjected to the moisture change and/or the certain or predetermined amount of moisture.

[0023] The stress discussed above, such as a change when a smart material bends, expands, and/or contracts, may either be temporary and/or permanent. In an embodiment in which the stress or change is temporary, the smart material may retract back to an original form once no longer under the influence from the external stimuli. In an embodiment in which the stress or change is permanent, the smart material may not retract back to the original form and may remain in the stressed or changed state even once no longer under the influence from the external stimuli. Further, those having ordinary skill in the art will appreciate that one or more other types of smart materials may be used within the scope of the present disclosure, though not specifically discussed above.

[0024] The apparatus **200** optionally further includes a heat path component and/or chassis **208**. The chassis **208** is positioned within the housing **204**, and more particularly, is positioned and/or attached between the electronic component **202** and the coupler **206**. The chassis **208** facilitates the transfer of heat from the electronic component **202** to the coupler **206**. Further, in one or more embodiments, a controller **210** may be included within the housing **204**, such as positioned on and/or attached to the coupler **206**. The controller **210** controls the coupler **206** to facilitate movement of the coupler in a more predictable fashion. This can be helpful when the environment and the stimuli affecting the coupler **206** are unpredictable, uncontrollable, and/or outside of a predetermined range for the stimuli. As such, the controller **210** may be used similar to a filter, thereby reducing the external stimuli noise received by the coupler **206** such that the coupler **206** is controlled by the controller **210** and responds to ranges of stimuli as required by the controller **210**.

[0025] As discussed above, the coupler **206** includes or is formed from one or more smart materials. In an embodiment in which the coupler **206** includes a piezoelectric material or an electric-dependent shape-memory material, the coupler **206** can change shape (e.g., bend, expand, and/or contract) when under the influence of a voltage and/or a current. For example, in one embodiment, the coupler **206** changes shape when the electronic component **202** receives power (e.g., a voltage and/or current). A portion of the power may be redirected to the coupler **206**, such as through the electronic component **202**, such that the coupler **206** receives power at the same time the electronic component **202** receives power. Once the electronic component **202**, and therefore the coupler **206**, receives power, the coupler **206** may move from the disengaged position in FIG. **2** to the engaged position in FIG. **3**. Thus, when the electronic component **202** is receiving power and is generating heat from use, the coupler **206** is in the engaged position to dissipate heat from the electronic component **202** to the housing **204** through the coupler **206**. The coupler **206** may also be movable into the engaged position with the housing **204** without any type of manual engagement with the coupler **206** (e.g., no mechanical device interaction). The coupler **206** may instead automatically move from the disengaged position into the engaged position when power is received by coupler **206**.

[0026] In one or more embodiments, the coupler **206** moves from the disengaged position to the engaged position once the external stimuli is above a threshold or predetermined amount. For example, in an embodiment in which the coupler **206** includes a piezoelectric material or an electric-dependent shape-memory material, the coupler **206** moves from the disengaged position to the engaged position when a voltage and/or a current above a predetermined amount is received by the electronic component **202** and/or the coupler **206**. In an embodiment in which the coupler **206** includes and/or is formed from a temperature-dependent shape-memory material, the coupler **206** moves from the disengaged position to the engaged position when a temperature above a predetermined amount is received by the electronic component **202** and/or the coupler **206**. Those having ordinary skill in the art will appreciate that this rationale may apply to other types of smart materials as well.

[0027] Referring still to FIGS. **2** and **3**, when in the disengaged position, there is a gap between the coupler **206** and the housing **204**. Not being in contact facilitates assembly/disassembly of the apparatus **200**. Once assembled, the coupler **206** may then be operated to engage the housing **204** in the engaged position. The housing **204** and/or the coupler **206** may include one or more flat surfaces and/or one or more curved surfaces. As such, in one embodiment, the housing **204** and the coupler **206** may each include a radius. For example, the housing **204** may be cylindrical, as shown in

FIGS. **2** and **3**, and the coupler **206** may include at least a portion that may be an arc or a curve. As such, the radius of the coupler **206** changes when the smart material of the coupler **206** experiences external stimuli. In particular, the radius of the coupler **206** may be smaller than the radius of the housing **204** when the coupler **206** is in the disengaged position (e.g., the electronic component **202** and/or the coupler **206** does not receive power in the embodiment above). Then, the radius of the coupler **206** may be larger than the radius of the housing **204** to move the coupler **206** into the engaged position (e.g., the electronic component **202** and/or the coupler **206** receives power in the embodiment above).

[0028] The present disclosure, while discussed in relation to the use with oil and gas equipment, is not so limited. For example, an apparatus and/or system in accordance with the present disclosure may be used with other types of equipment in which heat dissipation may be needed, such as any other type of equipment or component that includes an electronic component. Further, other subsea applications may include marine renewables and underwater exploration and mining, in addition to other subsea applications that include the use of subsea components. Accordingly, the present disclosure is not limited to only the above figures and descriptions shown above.

[0029] While the aspects of the present disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. But it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

What is claimed is:

1. An apparatus to dissipate heat, the apparatus comprising:

a heat sink;

an electronic component; and

a coupler comprising a smart material movable into an engaged position such as to be engaged with the heat sink to dissipate heat from the electronic component to the heat sink through the coupler.

2. The apparatus of claim **1**, wherein the coupler is movable into the engaged position when the electronic component receives power.

3. The apparatus of claim **2**, wherein power is received by the coupler when power is received by the electronic component to be movable into the engaged position.

4. The apparatus of claim **1**, wherein:

the coupler is movable between the engaged position and a disengaged position such as to not be engaged with the heat sink,

the coupler is movable to the engaged position when power is received by the electronic component, and

the coupler is movable to the disengaged position when power is not received by the electronic component.

5. The apparatus of claim **4**, wherein the coupler is movable to the engaged position when a voltage or a current above a predetermined amount is received by the coupler.

6. The apparatus of claim **4**, wherein the coupler is movable to the engaged position when temperature above a predetermined amount is sensed by the coupler.

7. The apparatus of claim **1**, wherein the heat sink comprises a housing, and wherein the electronic component is positioned within the housing.

8. The apparatus of claim **7**, wherein:

the housing comprises a housing radius,

the coupler comprises a coupler radius,

the coupler radius is larger than the housing radius when power is received by the electronic component, and

the coupler radius is smaller than the housing radius when power is not received by the electronic component.

9. The apparatus of claim **1**, wherein the smart material comprises at least one of a piezoelectric material, a temperature-dependent shape-memory material, a stress-dependent shape-memory material, a magnetic-dependent shape-memory material, an electric-dependent shape-memory material, a pH-dependent material, and a moisture-dependent shape-memory material.

10. The apparatus of claim **1**, further comprising a chassis positioned between the electronic component and the coupler.

11. The apparatus of claim **1**, further comprising a controller coupled to the coupler.

12. The apparatus of claim **1**, wherein the housing comprises a subsea component.

13. A subsea apparatus to dissipate heat, the apparatus comprising:

a subsea heat sink;

an electronic component; and

a coupler comprising a smart material movable between an engaged position such as to be engaged with the subsea heat sink to dissipate heat from the electronic component to the subsea housing through the coupler when in the engaged position and a disengaged position such as to not be engaged with the subsea heat sink.

14. The apparatus of claim **13**, wherein the coupler is movable to the engaged position when power is received by the electronic component, and wherein the coupler is movable to the disengaged position when power is not received by the electronic component.

15. The apparatus of claim **14**, wherein power is received by the coupler when power is received by the electronic component to be movable into the engaged position, and wherein power is not received by the coupler when power is not received by the electronic component to be movable into the disengaged position.

16. The apparatus of claim **13**, wherein the coupler is movable to the engaged position when a voltage or a current above a predetermined amount is received by the coupler.

17. The apparatus of claim **13**, wherein the coupler is movable to the engaged position when temperature above a predetermined amount is sensed by the coupler.

18. The apparatus of claim **13**, wherein:

the subsea heat sink comprises a subsea housing;

the electronic component is positioned within the subsea housing;

the subsea housing comprises a housing radius,

the coupler comprises a coupler radius,

the coupler radius is larger than the housing radius when the coupler is in the engaged position, and

the coupler radius is smaller than the housing radius when the coupler is in the disengaged position.

19. The apparatus of claim **13**, wherein the smart material comprises at least one of a piezoelectric material, a temperature-dependent shape-memory material, a stress-dependent shape-memory material, a magnetic-dependent shape-memory material, an electric-dependent shape-memory material, a pH-dependent material, and a moisture-dependent shape-memory material.

20. The apparatus of claim **13**, further comprising:

a chassis positioned between the electronic component and the coupler; and

a controller coupled to the coupler.

21. The apparatus of claim **13**, wherein the subsea heat sink comprises a component in the oil and gas industry.

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