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(54) **Cooling system and method for a downhole tool**

(57) Present embodiments relate to systems and methods for providing cooling to temperature sensitive components 52 of a downhole tool with an intermittent power supply. To provide one example, a downhole tool may include a temperature sensitive component 52, an enclosure 54, a cooling unit 56, and a heat exchanger 58. The heat exchanger 58 may also disable heat transfer between the temperature sensitive component 52 and the cooling unit 56 when the cooling unit is not providing the active cooling.

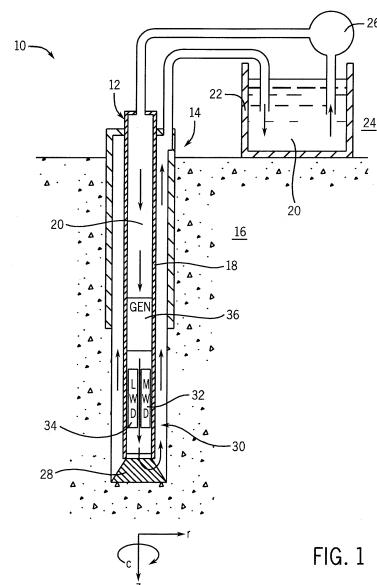


FIG. 1

Description

BACKGROUND

[0001] The present disclosure relates generally to downhole tools and, more particularly, to systems and methods for providing consistent cooling to temperature sensitive components of a downhole tool.

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present techniques, which are described and/or claimed below. 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 disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] A drill bit attached to a string of drill pipe, generally referred to as the drill string, may be used to drill a borehole for an oil and/or gas well. In addition to the drill bit, the drill string may also include a variety of downhole tools to measure or log properties of the surrounding rock formation or the conditions in the borehole. To generate power for these tools to operate, a turbine generator may convert hydraulic power of drilling fluid moving through the drill string. Some downhole tools may include batteries that provide limited power for tool operation.

[0004] Downhole tools often include electronics, sensors, or other components that may be susceptible to the high ambient temperatures of the downhole environment. Such components are designed to operate only within a certain range of temperatures, and these acceptable temperatures may be lower than the temperature in the borehole. In such contexts, maintaining the temperature sensitive components within the acceptable temperature range may prevent heat-related failures. Various systems have been developed to provide protection to such temperature sensitive components. These systems, however, have several disadvantages. For example, thermal insulation of the temperature sensitive components alone is generally not effective for providing long-term cooling in a downhole environment. Active cooling systems can provide more long-term cooling, but these systems rely on power to operate. Unfortunately, downhole tools incorporated into the drill string receive only an intermittent or limited power supply, since the drilling fluid is not constantly flowing through the drill string, and onboard batteries may not provide enough power for active cooling.

SUMMARY

[0005] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass

a variety of aspects that may not be set forth below.

[0006] Present embodiments relate to systems and methods for providing cooling to temperature sensitive components of a downhole tool with an intermittent power supply. To provide one example, a downhole tool may include a temperature sensitive component, an enclosure, a cooling unit, and a heat exchanger. The enclosure may be designed to provide thermal insulation to the temperature sensitive component. The cooling unit may intermittently provide active cooling while the downhole tool is being operated. The heat exchanger may facilitate heat transfer from the temperature sensitive component to the cooling unit when the cooling unit is providing the active cooling. The heat exchanger may also disable heat transfer between the temperature sensitive component and the cooling unit when the cooling unit is not providing the active cooling.

[0007] In another example, a drilling system may include a generator used to intermittently provide electrical power to components of a downhole tool. The drilling system also may include a cooling unit of the downhole tool, and this cooling unit may provide active cooling when the electrical power is provided. In addition, the drilling system may include a temperature sensitive component of the downhole tool and an enclosure to thermally insulate the temperature sensitive component. Further, the drilling system may include a heat exchanger that facilitates heat transfer from the temperature sensitive component to the cooling unit when the electrical power is provided. The heat exchanger may prevent heat transfer between the temperature sensitive component and the cooling unit when the electrical power is not provided.

[0008] A method in accordance with an embodiment may involve reducing heat transfer to a temperature sensitive component of a downhole tool via a thermally insulating enclosure located about the temperature sensitive component. The method also may involve transferring heat from the temperature sensitive component to a cooling unit that may provide active cooling when the cooling unit receives power. In addition, the method may involve preventing heat transfer between the cooling unit and the temperature sensitive component when the cooling unit does not receive power.

[0009] Various refinements of the features noted above may exist in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:

[0011] FIG. 1 is a schematic diagram of a drilling system that may employ a downhole tool with a cooling system, in accordance with an embodiment;

[0012] FIG. 2 is a block diagram of components of a downhole tool with an intermittent power supply, in accordance with an embodiment;

[0013] FIG. 3 is a flowchart of a method for operating the components of FIG. 2 when power is supplied to the downhole tool, in accordance with an embodiment;

[0014] FIG. 4 is a flowchart of a method for operating the components of FIG. 2 when no power is supplied to the downhole tool, in accordance with an embodiment;

[0015] FIG. 5 is a schematic block diagram of an example of the components of FIG. 2, in accordance with an embodiment;

[0016] FIG. 6 is a schematic block diagram of another example of the components of FIG. 2, in accordance with an embodiment; and

[0017] FIG. 7 is a schematic block diagram of another example of the components of FIG. 2, in accordance with an embodiment.

DETAILED DESCRIPTION

[0018] One or more specific embodiments of the present disclosure will be described below. These described embodiments are only examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0019] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0020] As mentioned above, this disclosure relates to cooling temperature sensitive components in a downhole tool with an intermittent power supply, such as a downhole tool used in a drill string. Specifically, drilling a borehole for an oil and/or gas well often involves a drill string—several drill pipes and a drill bit, among other things—that grinds into a rock formation when drilling fluid is pumped through the drill string. In addition to the drill bit, the drill string may also include several electrically powered tools. The tools in the drill string may include, for example, logging-while-drilling (LWD) tools, measurement-while-drilling (MWD) tools, steering tools, and/or tools to communicate with drilling operators at the surface. In general, the borehole may be drilled by pumping drilling fluid into the tool string, causing the drill bit to rotate and grind away rock as the drilling fluid passes through. The hydraulic power of the drilling fluid may also be used to generate electricity. Specifically, a turbine generator may convert some of the hydraulic power of the drilling fluid into electrical power. The electrical power may be used to operate one or more downhole tools.

[0021] A downhole tool may include temperature sensitive equipment that may fail if the temperature of the equipment exceeds a particular range. Presently disclosed embodiments are directed to systems and methods for providing such cooling to the temperature sensitive equipment. However, power supplied to the downhole tool is intermittent because the drilling fluid is not always being pumped into the tool string. The downhole tool may therefore utilize a heat exchanger that facilitates unidirectional or disableable heat transfer from the temperature sensitive components to a cooling system. When power is available, the cooling system provides active cooling and the heat exchanger facilitates heat transfer from the temperature sensitive components to the cooling system. When no power is available, the heat exchanger prevents heat transfer between the cooling system and the temperature sensitive components. The temperature sensitive components may be located within a thermally insulating enclosure to reduce heat transfer from the environment to the temperature sensitive components, regardless of the availability of power. Thus, despite an intermittent power supply, the temperature of the temperature sensitive components of the downhole tool may remain relatively stable.

[0022] A drilling system 10, shown in FIG. 1, may benefit from the heat exchanger mentioned above. The drilling system 10 of FIG. 1 includes a drill string 12 used to drill a borehole 14 into a rock formation 16. A drill collar 18 of the drill string 12 encloses the various components of the drill string 12. Drilling fluid 20 from a reservoir 22 at the surface 24 may be driven into the drill string 12 by a pump 26. The hydraulic power of the drilling fluid 20 causes a drill bit 28 to rotate, cutting into the rock formation 16. The cuttings from the rock formation 16 and the returning drilling fluid 20 exit the drill string 12 through an annulus 30. The drilling fluid 20 thereafter may be recycled and pumped, once again, into the drill string 12.

[0023] A variety of information relating to the rock formation 16 and/or the state of drilling of the borehole 14 may be gathered while the drill string 12 drills the borehole 14. For instance, a measurement-while-drilling (MWD) tool 32 may measure certain drilling parameters, such as the temperature, pressure, orientation of the drilling tool, and so forth. Likewise, a logging-while-drilling (LWD) tool 34 may measure the physical properties of the rock formation 16, such as density, porosity, resistivity, and so forth.

[0024] These tools and others may rely on electrical power for their operation. As such, a turbine generator 36 (e.g., generator coupled to a drilling fluid turbine) may generate electrical power from the hydraulic power of the drilling fluid 20. The turbine generator 36 may provide a generally stable supply of electrical power as the drilling fluid 20 is pumped through the drill string 12. There may be periods of time throughout a drilling operation, however, when the pump 26 does not drive the drilling fluid 20 through the drill string 12. For example, when new lengths of drill pipe are added to the drill string, or services are performed on the drilling equipment, the pump 26 may not provide the drilling fluid 20 to the turbine generator 36. Consequently, the turbine generator 36 may generate intermittent power for operation of the MWD tool 32 and the LWD tool 34. These downhole tools may include systems for cooling and thermally protecting temperature sensitive equipment that would otherwise overheat in the borehole 14. Such systems, described in detail below, may protect the temperature sensitive equipment both when the turbine generator 36 supplies power to the downhole tools and when the generator 36 is not generating power.

[0025] As seen in FIG. 1, the drill string 12 is generally aligned along a longitudinal z-axis. Components of the drill string 12 may be located within the drill string 12 at various radial distances from the z-axis, as illustrated by a radial r-axis. Certain components, such as the turbine generator 36, may include parts that rotate circumferentially along a circumferential c-axis. The coordinate system shown in FIG. 1 will be used throughout the various drawings discussed below to represent the spatial relationship between various system components.

[0026] Certain components of a downhole tool 50 are shown as a block diagram in FIG. 2. The downhole tool 50 may include the MWD tool 32, the LWD tool 34, or any other tool containing one or more temperature sensitive components 52. As shown in FIG. 2, the downhole tool 50 also includes a thermal enclosure 54, a cooling unit 56, and a heat exchanger 58. The temperature sensitive component 52 is located within the enclosure 54, which may substantially reduce heat exchange between the downhole environment and the temperature sensitive component 52. The heat exchanger 58 may be disableable or unidirectional, allowing heat transfer from the temperature sensitive component 52 to the cooling unit 56 when the cooling unit 56 is active. The heat exchanger 58 may prevent or significantly reduce heat transfer be-

tween the cooling unit 56 and the temperature sensitive component 52 when the cooling unit 56 is off. Embodiments of the heat exchanger 58 are provided in detail below.

[0027] There may be many different types of temperature sensitive components 52 that can be protected via components of the downhole tool 50 provided in FIG. 2. For example, the temperature sensitive component 52 may include one or more electronic components, electronics boards, sensors, or any other temperature sensitive equipment located in the downhole tool 50. Such sensors and electronics may perform various functions in the downhole tool 50, such as determining physical properties of formation fluid samples, sensing drilling parameters, executing control functions within the downhole tool 50, and so forth. The temperature sensitive component 52 may operate effectively within a certain temperature range, which may include temperatures below a target temperature. For example, the target temperature may be approximately 175 °C, while the downhole environment, depending on the depth of the borehole 14 and type of rock formation 16, may have a temperature between approximately 150°C and 250°C. As a result, the temperature sensitive component 52 may be susceptible to overheating due to the high temperatures of the downhole environment. This may damage or negatively affect performance of the temperature sensitive components 52, or make the components operate outside a desired temperature range, unless appropriate cooling is provided by other components of the downhole tool 50.

[0028] The enclosure 54 may provide protective thermal insulation of the temperature sensitive component 52 when no power is available to the downhole tool 50. To that end, the enclosure 54 may be formed from any suitable thermally insulating material. In an embodiment, the enclosure 54 may include a vacuum flask (e.g., Dewar flask), which includes two nested flasks with a vacuum pulled between them to reduce an amount of heat transfer between the outside flask and the inside flask. This reduces an amount of heat transfer between the outside environment and the enclosed temperature sensitive component 52, for a certain amount of time. However, the enclosure 54 may not be effective at thermally insulating the temperature sensitive component 52 over long periods of time. In addition, the enclosure 54 may not be appropriate for reducing heat transfer to the temperature sensitive component 52 when the component itself generates heat. Therefore, the enclosure 54 may be particularly useful for shielding the temperature sensitive component 52 from high ambient temperatures of the well during periods of limited power supply to the downhole tool 50.

[0029] The cooling unit 56 may include any system capable of providing active cooling to components of the downhole tool 50. For example, the cooling unit 56 may include one or more phase change coolers, sterling pumps, pulse tubing pumps, thermoelectric coolers, heat pumps, or any other system that uses power to provide

cooling. As mentioned previously, the power supplied to the downhole tool 50 may not be consistent over time, because the drilling fluid 20 is not continuously pumped through the drill string 12 and past the turbine generator 36. As a result, the cooling unit 56, which runs on this power supply, may intermittently provide active cooling while the downhole tool 50 is being operated. The cooling unit 56 may be operable through the use of mechanical power, electrical power, or any other power available to the downhole tool 50. When no power is available, however, the active cooling provided by the cooling unit 56 may stop altogether.

[0030] The heat exchanger 58 may act as an efficient thermal conduit between the cooling unit 56 and the temperature sensitive equipment 52 held in the enclosure 54. That is, the heat exchanger 58 allows heat transfer from the temperature sensitive component 52 to the cooling unit 56 when the cooling unit 56 is providing active cooling. This is the case when power is available to the downhole tool 50. When power is not available, however, the cooling unit 56 may turn off and begin to increase in temperature, no longer providing active cooling. To keep excess heat of the cooling unit 56 from heating the temperature sensitive component 52, it may be desirable for the heat exchanger 58 to be disableable or unidirectional. Disabling the heat exchanger 58 may interrupt or greatly reduce an amount of heat transferred between the cooling unit 56 and the temperature sensitive component 52. Unidirectional embodiments of the heat exchanger 58 may facilitate heat transfer only (or preferentially) from the temperature sensitive component 52 to the cooling unit 56, and not the other way around. Whether disableable or unidirectional, the heat exchanger 58 may facilitate heat transfer from the temperature sensitive component 52 to the cooling unit 56 when power (and therefore active cooling) is available, and prevents heat transfer between these components when no power is available. During periods of no available power, heat exchange between the temperature sensitive component 52 and the environment may be limited to thermal leaks of the enclosure 54. This may maintain the temperature sensitive component 52 within a desirable temperature range for a longer time, until power returns to make the cooling unit 56 operational again.

[0031] The downhole tool 50 also may include power/control circuitry 60, which provides power and/or control signals to the various components of the downhole tool 50. The power available through the circuitry 60 may be generated by the turbine generator 36, as described with reference to FIG. 1. The control signals communicated from the circuitry 60 may be signals output from a processor of the circuitry 60 based on whether power is supplied to the circuitry 60. In some embodiments, the control signals may be generated based on sensor feedback, which may include feedback indicative of a temperature in the downhole tool 50.

[0032] The circuitry 60 may provide intermittent power generated by the turbine generator 36 to the cooling unit

56 to facilitate active cooling. Simultaneously, the circuitry 60 may provide power to the heat exchanger 58, enabling heat transfer from the temperature sensitive component 52 to the cooling unit 56. When power is no longer provided to the heat exchanger 58, heat transfer between the cooling unit 56 and the temperature sensitive component 52 may be disabled. In some embodiments, the cooling unit 56 may provide an amount of active cooling based on a control signal received from the circuitry 60. Similarly, the heat exchanger 58 may facilitate heat transfer from the temperature sensitive component 52 to the cooling unit 56 based on a control signal. The circuitry 60 may provide such control signals based on a desired amount of cooling and/or heat transfer to be provided to the temperature sensitive component 52. This may be based on temperature feedback collected via a sensor in the downhole tool 50.

[0033] FIGS. 3 and 4 describe methods 80 and 82, respectively, of operating components of the downhole tool 50 of FIG. 2. Specifically, FIG. 3 describes how cooling is provided to the temperature sensitive components of the downhole tool 50 when power (block 84) is available. FIG. 4 describes how cooling is provided when no power (block 86) is available. The method 80 of FIG. 3 shows that when power (block 84) is supplied to the downhole tool 50, the enclosure 54 may reduce (block 88) heat transfer from an outside environment to the temperature sensitive component 52. In addition, the method 80 may include transferring (block 90) heat from the temperature sensitive component 52 to the cooling unit 56. This heat transfer is enabled via the heat exchanger 58 since the power (block 84) is available to facilitate active cooling via the cooling unit 56. Further, the method 80 may include controlling (block 92) the heat transfer from the temperature sensitive component 52 to the cooling unit 56, via a control signal from the circuitry 60. The method 82 of FIG. 4 shows that when no power (block 86) is available, the enclosure 54 may reduce (block 94) heat transfer from an outside environment to the temperature sensitive component 52. It should be noted that the enclosure 54 may provide thermal insulation in this manner regardless of whether any power is supplied to the downhole tool 50. The method 82 also may include preventing (block 96) heat transfer between the temperature sensitive component 52 and the cooling unit 56 via the heat exchanger 58. In some embodiments, this may include the heat exchanger 58 disabling heat transfer between these parts of the downhole tool 50. In other embodiments, the heat exchanger 58 may only allow heat transfer in one direction (from the temperature sensitive component 52 to the cooling unit 56), which may not occur unless power is provided to the cooling unit 56.

[0034] FIG. 5 illustrates an embodiment of the cooling components used in the downhole tool 50 of FIG. 2. The heat exchanger 58 of this particular embodiment includes a pump 110, which may provide disableable heat transfer from the temperature sensitive component 52 to the cooling unit 56. In addition, the heat exchanger 58 may in-

clude piping 112 through which the pump 110 circulates a cooling fluid. The piping 112 may function as a flowpath loop between the temperature sensitive component 52 and the cooling unit 56. The flow of the cooling fluid through the piping 112 may facilitate heat transfer through forced convection.

[0035] In the illustrated embodiment, the enclosure 54 may be a Dewar flask equipped with plugs 114 to allow passage of the piping 112 into the enclosure 54. Although not shown, the enclosure may also be equipped with an electrical feedthrough for providing power and other connections between components inside and outside the enclosure 54. In other embodiments, the enclosure 54 may include any enclosure made from a thermally insulating material. The cooling unit 56, in the illustrated embodiment, includes a thermoelectric cooler 116 that converts electrical energy into forced heat transfer. More specifically, the thermoelectric cooler 116 may include two plates 118 and 120 with several semiconductors 122 located therebetween. When a current is applied to the thermoelectric cooler 116, the plate 118 (e.g., cold plate) absorbs heat exchanger 58 and the plate 120 (e.g., hot plate) expels the absorbed heat from the heat according to the Peltier effect. In this way, the cooling unit 56 provides active cooling of whatever structures (e.g., heat exchanger 58) are thermally coupled to the cold plate 118. From the hot plate 120, the heat may be expelled to a heat sink 124, or to a heat spreader 126 in contact with the heat sink 124. The heat sink 124 may include an external structure, such as a chassis or housing, of the downhole tool 50. The heat sink 124 may otherwise include an internal structure used to direct the heat from the hot plate 120 to the chassis or the housing. It should be noted that the cooling unit 56 could include any active cooling system that uses electrical or mechanical power to provide cooling to a portion of the heat exchanger 58.

[0036] In addition to the pump 110 and the piping 112, the heat exchanger 58 may include a hot block 128 thermally connected to the temperature sensitive component 52 and a cold block 130 thermally connected to the cooling unit 56. In some embodiments, the hot block 128 may include part of the temperature sensitive component 52, and the cold block 130 may include the cold plate 118 of the thermoelectric cooler 116. As illustrated, the hot block 128 may be located inside the enclosure 54 with the temperature sensitive component 52. The piping 112 may be thermally connected to both the hot block 128 and the cold block 130. Specifically, the piping 112 forms a loop for routing a cooling fluid between the hot block 128 and the cold block 130, and the pump 110 circulates the cooling fluid through the loop. The cooling fluid may include water, oil, molten metals, or any other fluid appropriate for the desired amount of heat transfer through the heat exchanger 58.

[0037] The illustrated components may be arranged in any desired orientation and/or configuration relative to each other and to other components of the downhole tool 50. For example, the piping 112 may extend in a longi-

tudinal direction, as shown, and this longitudinal direction may align with the z-axis of the drill string 12. In other embodiments, the piping 112 may include various bends for routing the cooling fluid between other components of the downhole tool 50. It may be desirable to position the hot block 128 and the cold block 130 a certain distance away from each other in the downhole tool 50, so that no heat transfer may occur between the components except via the heat exchanger 58.

[0038] When power is supplied to the cooling unit 56, heat may be pumped from the cold plate 118 to the hot plate 120 and expelled from the hot plate 120 to the heat spreader 126 and heat sink 124. The power may also activate the pump 110, which circulates the cooling fluid through the piping 112. In some embodiments, the pump 110 may be activated to pump the cooling fluid at a constant flow rate whenever the power is available. In other embodiments, the pump 110 may be activated based on a control signal from the power/control circuitry 60. The control signal may be generated based on a processed sensor signal indicating a desired amount of cooling for the temperature sensitive component 52. Once activated, the pump 110 may be controlled to move the cooling fluid through the piping 112 at one of multiple pre-determined flow rates based on a control signal. To that end, the pump 110 may be designed to operate at a continuously variable pump speed or at two or more discrete pump settings, to facilitate controllable heat transfer through the heat exchanger 58.

[0039] Again, when power is available to the downhole tool 50, the heat exchanger 58 is able to transfer heat from the temperature sensitive component 52 to the cooling unit 56. In the illustrated embodiment, this involves a movement of heat from the temperature sensitive component 52 to the hot block 128. The cooling fluid being pumped through the piping 112 then transfers the heat via forced convection from the hot block 128 to the cold block 130. From the cold block 130, the heat is transferred through the cooling unit 56 (from the cold plate 118 to the hot plate 120) before being rejected to the heat sink 124.

[0040] When no power is available to the illustrated downhole tool 50, the thermoelectric cooler 116 and the pump 110 may stop functioning. The cold block 130 no longer receives active cooling from the thermoelectric cooler 116, and thus may return progressively to an ambient temperature of the downhole tool 50. At the same time, the pump 110 stops circulating the cooling fluid through the piping 112, effectively disabling heat transfer through the heat exchanger 58. This may keep any accumulated heat in the cold block 130 from transferring back to the temperature sensitive component 52. The enclosure 54 may provide thermal insulation of the temperature sensitive component 52 until the downhole tool 50 is operational again.

[0041] Another embodiment of the downhole tool 50 may include a unidirectional heat pipe configuration of the heat exchanger 58, as shown in FIG. 6. The heat

exchanger 58 includes a heat pipe 150 for facilitating heat transfer from the temperature sensitive component 52 to the cooling unit 56. The cooling unit 56 in the illustrated embodiment includes the same type of thermoelectric cooler 116 introduced in FIG. 5, which cools the cold block 130 when power is supplied to the downhole tool 50. The heat pipe 150 may include a tube containing a heat exchange fluid. A first end 152 of the heat pipe 150 may be coupled with the cold block 130, thermally connecting the first end 152 with the cold plate 118 of the thermoelectric cooler 116. Similarly, a second end 154 (opposite the first end 152) of the heat pipe 150 may be coupled with the hot block 128, thermally connecting the second end 154 with the temperature sensitive component 52.

[0042] Heatpipes are generally used vertically, transferring heat from the bottom end (e.g., second end 154) to the top end (e.g., first end 152). The heat transfer fluid inside the heat pipe 150 may be in a liquid state at the second end 154, and as the temperature increases in the hot block 128 the liquid evaporates to become gaseous. The heated gaseous fluid rises up the heat pipe 150 before recondensing at the first end 152. This state change in the heat pipe 150 transfers heat from the temperature sensitive component 52 to the cooling unit 56, but not the other way around. Therefore, the heat pipe 150 may function as a unidirectional heat exchanger 58 for the purposes of the present disclosure. Since the heat pipe 150 relies on gravity to operate, it may be beneficial to maintain the heat pipe 150 in a vertical position, as shown, oriented substantially parallel to the z-axis. For this reason, it may be desirable to use another embodiment of the heat exchanger 58 for drilling inclined wells, horizontal wells, and the like. It should be noted, however, that the heat pipe 150 may function at an incline, as long as the first end 152 is maintained relatively higher than the second end 154.

[0043] When power is supplied to the downhole tool 50, the cooling unit 56 may operate to cool the cold block 130, facilitating heat transfer up the heat pipe 150. When no power is supplied to the downhole tool 50, the cooling unit 56 may shut down, allowing the cold block 130 to progressively increase in temperature. Eventually the temperature of the cold block 130 (and cooling unit 56) may increase above the temperature of the hot block 128 (and temperature sensitive component 52). Due to operating principles of the heat pipe 150, heat transfer between the first and second ends 152 and 154 may be substantially limited at this time. No liquid would evaporate from the second end 154 and no gas would recondense at the first end 152, because the first end 152 would be at a higher temperature than the second end 154. This allows the heat pipe 150 to function as a unidirectional heat exchanger 58, preventing the transfer of heat between the cooling unit 56 and the temperature sensitive component 52 during periods of no power.

[0044] Another embodiment of components of the downhole tool 50 is illustrated in FIG. 7. In this embodi-

ment, the heat exchanger 58 may include a switch 170 capable of disabling heat transfer across the heat exchanger 58. The switch 170 may include an electromagnetic switch that receives intermittent electrical power from the turbine generator 36. In addition, the heat exchanger 58 may include thermally conductive materials 172 that may form a bridge between the temperature sensitive component 52 and the cooling unit 56. The thermally conductive materials 172 may have any desired shape, including bars, blocks, and so forth. In addition, the thermally conductive material 172 may have a thermal conductivity within a range that facilitates a desired level of heat transfer between the downhole components. The illustrated switch 170 may actuate a portion of the thermally conductive material 172 based on whether power is provided to the downhole tool 50. For example, the switch 170 may close a thermally conductive bridge between the temperature sensitive component 52 and the cooling unit 56 when power is provided to the downhole tool 50. As current flows to the switch 170, the switch may generate a magnetic field that brings a portion of the thermally conductive material 172 into contact with the other thermally conductive materials in the heat exchanger 58. This may allow heat transfer to occur from the temperature sensitive component 52 to the cooling unit 56 across the conductive bridge. When no power is provided to the switch 170, no current may flow to the switch 170 for generating a magnetic field to hold the thermally conductive material 172 in place. This may effectively break the link between the temperature sensitive component 52 (or block 128) and the cooling unit 56 (or block 130).

[0045] Although the illustrated embodiment specifically features an electromagnetic actuator (e.g., switch 170), any other type of actuator may be used to move a portion of the conductive material in one direction when power is available and to move the portion in another direction when the power is unavailable. In certain embodiments, the switch 170 may be controlled via a control signal from the power/control circuitry 60. More specifically, the switch 170 may actuate the portion of thermally conductive material 172 into partial contact with the other thermally conductive materials 172. This may reduce an amount of heat transfer possible through the portion of thermally conductive material 172 based on an increased resistance to heat transfer through the portion.

[0046] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

Claims**1.** A downhole tool, comprising:

a temperature sensitive component of the downhole tool;
 an enclosure configured to provide thermal insulation to the temperature sensitive component;
 a cooling unit configured to intermittently provide active cooling while the downhole tool is being operated; and
 a heat exchanger configured to facilitate heat transfer from the temperature sensitive component to the cooling unit when the cooling unit is providing the active cooling, and configured to disable heat transfer between the temperature sensitive component and the cooling unit when the cooling unit is not providing the active cooling.

2. The downhole tool of claim 1, wherein the heat exchanger is configured to disable heat transfer between the temperature sensitive component and the cooling unit when power is not supplied to the heat exchanger.

3. The downhole tool of claim 1, wherein the heat exchanger is configured to facilitate heat transfer based on a control signal.

4. The downhole tool of claim 1, wherein the cooling unit is configured to receive power from a generator of a drilling system.

5. The downhole tool of claim 1, wherein the cooling unit is configured to provide the active cooling when the cooling unit intermittently receives power.

6. The downhole tool of claim 1, wherein the cooling unit is configured to provide the active cooling based on a control signal.

7. The downhole tool of claim 1, wherein the heat exchanger comprises a pump configured to pump fluid through a flowpath loop between the cooling unit and the temperature sensitive component.

8. The downhole tool of claim 1, wherein the heat exchanger comprises an electromagnetic switch configured to disable the heat transfer.

9. The downhole tool of claim 1, wherein the enclosure comprises a vacuum flask.

10. The downhole tool of claim 1, wherein the cooling unit comprises a phase change cooling system, a sterling pump, a pulse tubing pump, a thermoelectric

cooler, or any combination thereof.

11. A drilling system, comprising:

a generator configured to intermittently provide electrical power to components of a downhole tool;
 a cooling unit of the downhole tool configured to provide active cooling when the electrical power is provided;
 a temperature sensitive component of the downhole tool;
 an enclosure configured to thermally insulate the temperature sensitive component; and
 a heat exchanger configured to facilitate heat transfer from the temperature sensitive component to the cooling unit when the electrical power is provided;
 wherein the heat exchanger is configured to prevent heat transfer between the temperature sensitive component and the cooling unit when the electrical power is not provided.

12. The drilling system of claim 11, wherein the heat exchanger comprises a heat pipe configured to provide unidirectional heat transfer from the temperature sensitive component coupled to a lower vertical end of the heat pipe to the cooling unit coupled to an upper vertical end of the heat pipe.

13. The drilling system of claim 11, wherein the heat exchanger comprises a pump configured to pump fluid through a flowpath loop between the cooling unit and the temperature sensitive component when the electrical power is provided.

14. The drilling system of claim 11, wherein the heat exchanger comprises an electromagnetic switch configured to close a bridge of conductive material between the cooling unit and the temperature sensitive component when the electrical power is provided.

15. The drilling system of claim 11, comprising control circuitry configured to provide control signals to the cooling unit and/or to the heat exchanger to control the heat transfer from the temperature sensitive component to the cooling unit.

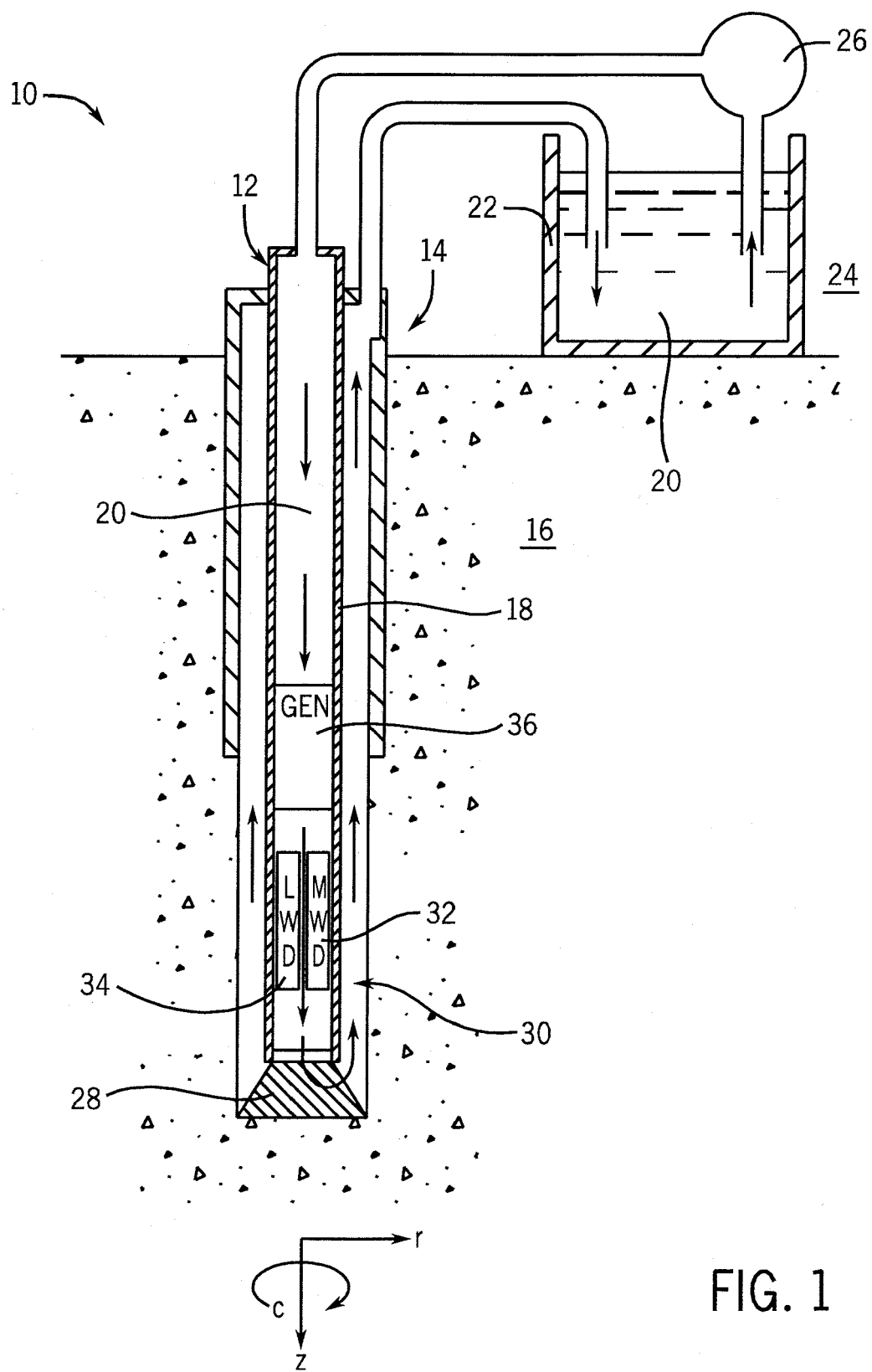


FIG. 1

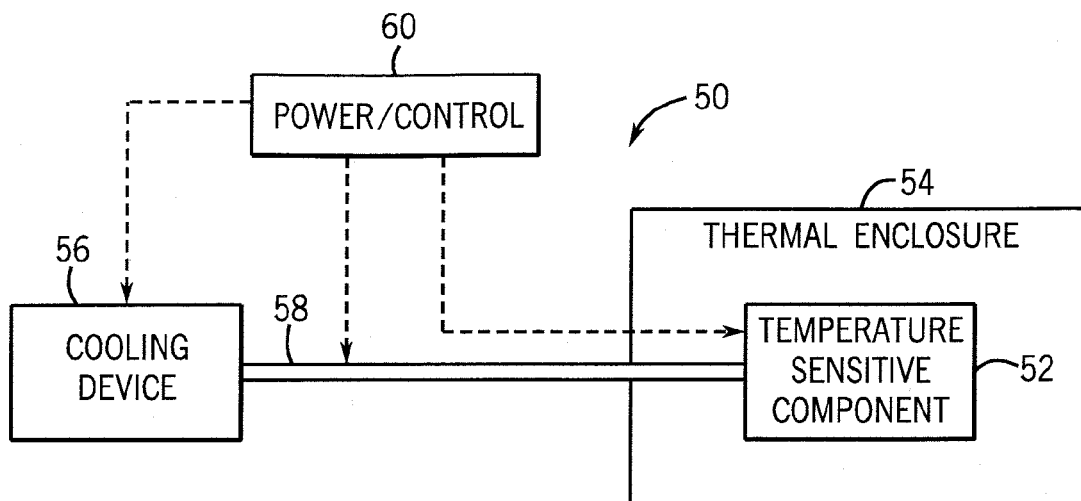


FIG. 2

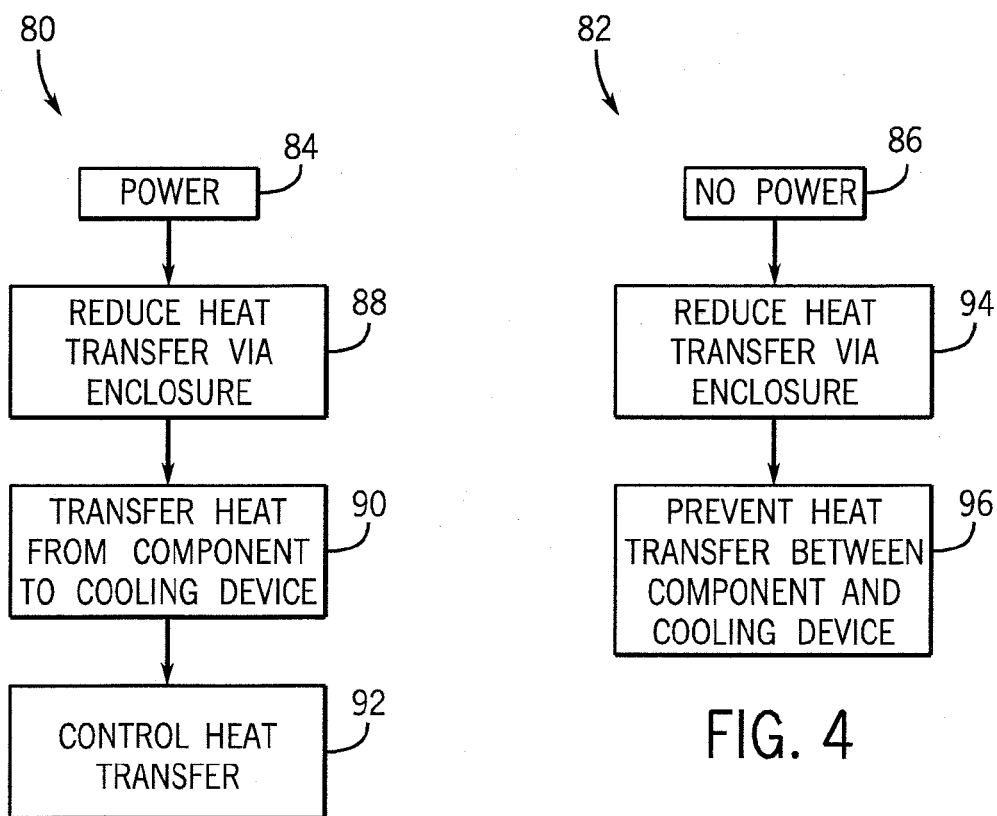


FIG. 3

FIG. 4

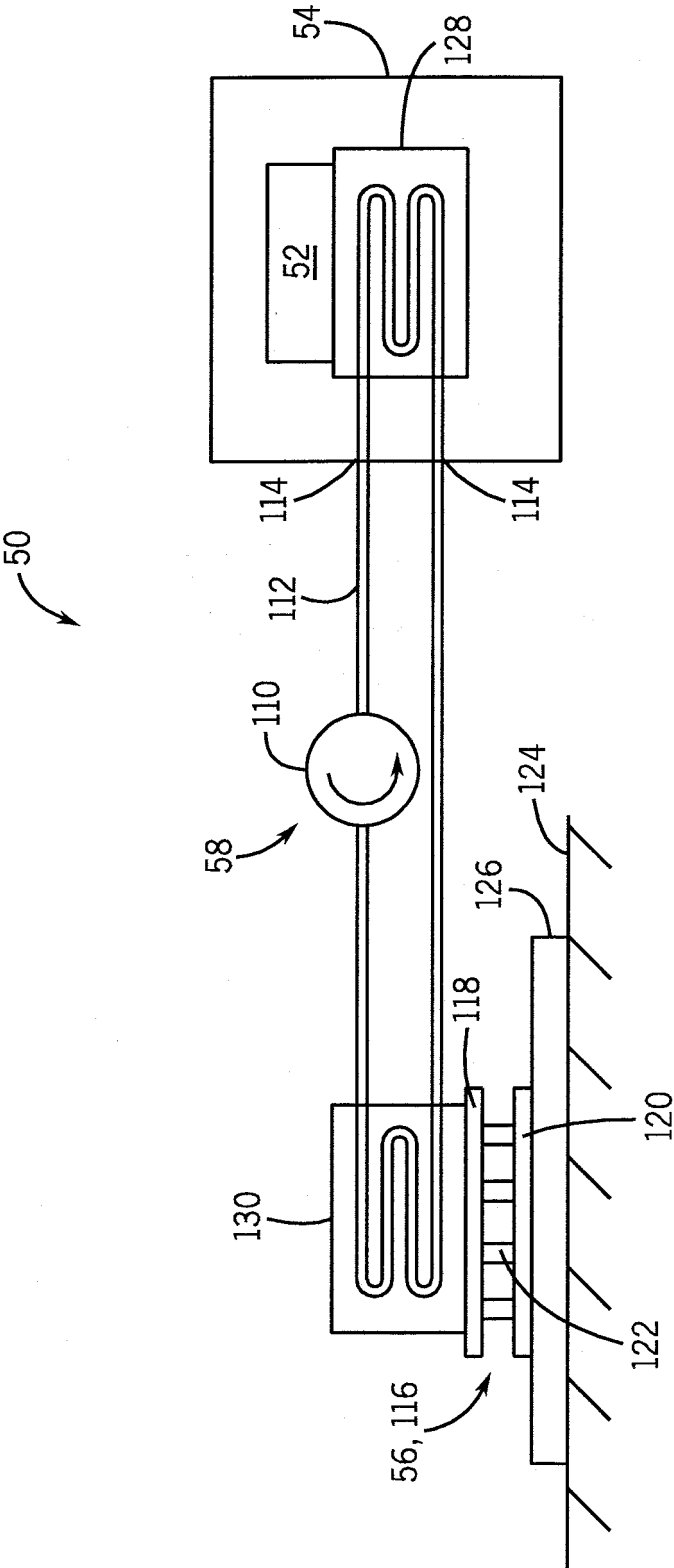


FIG. 5

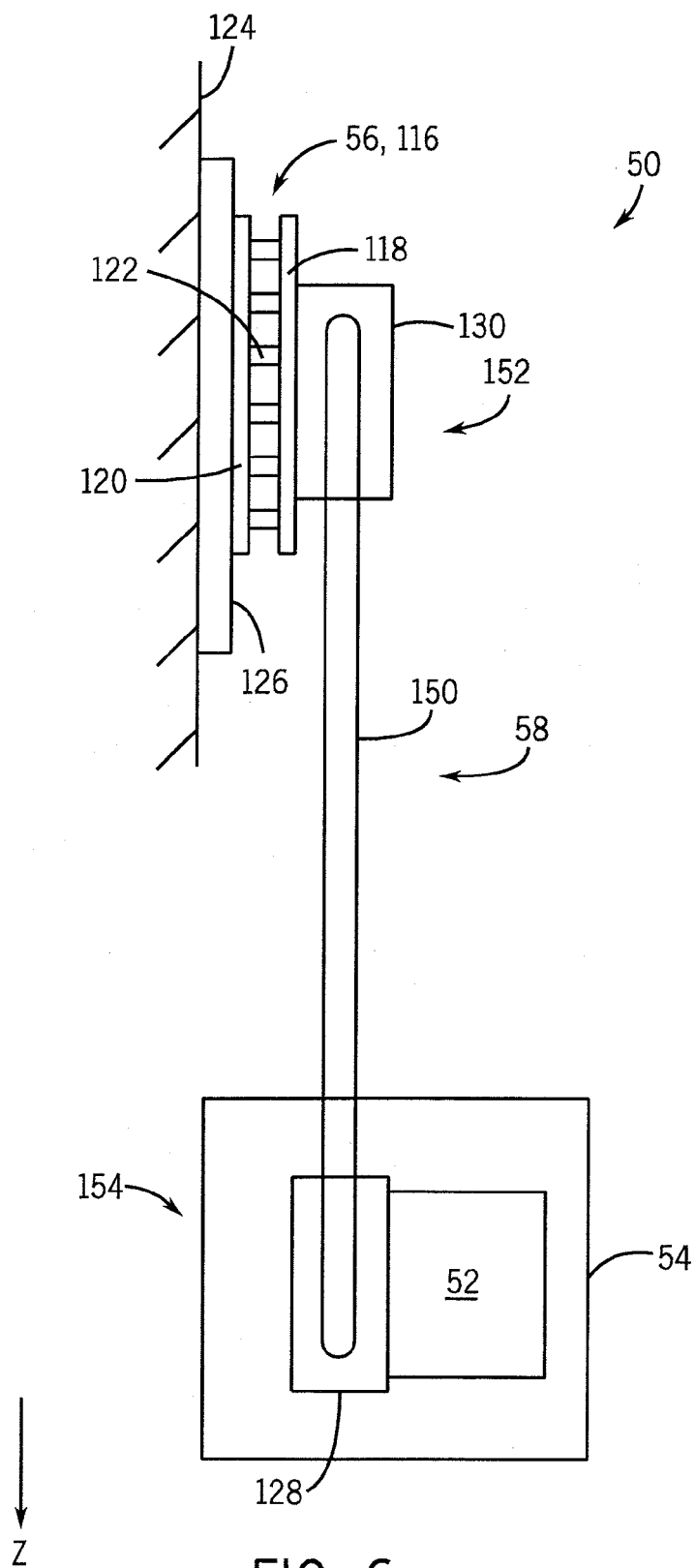
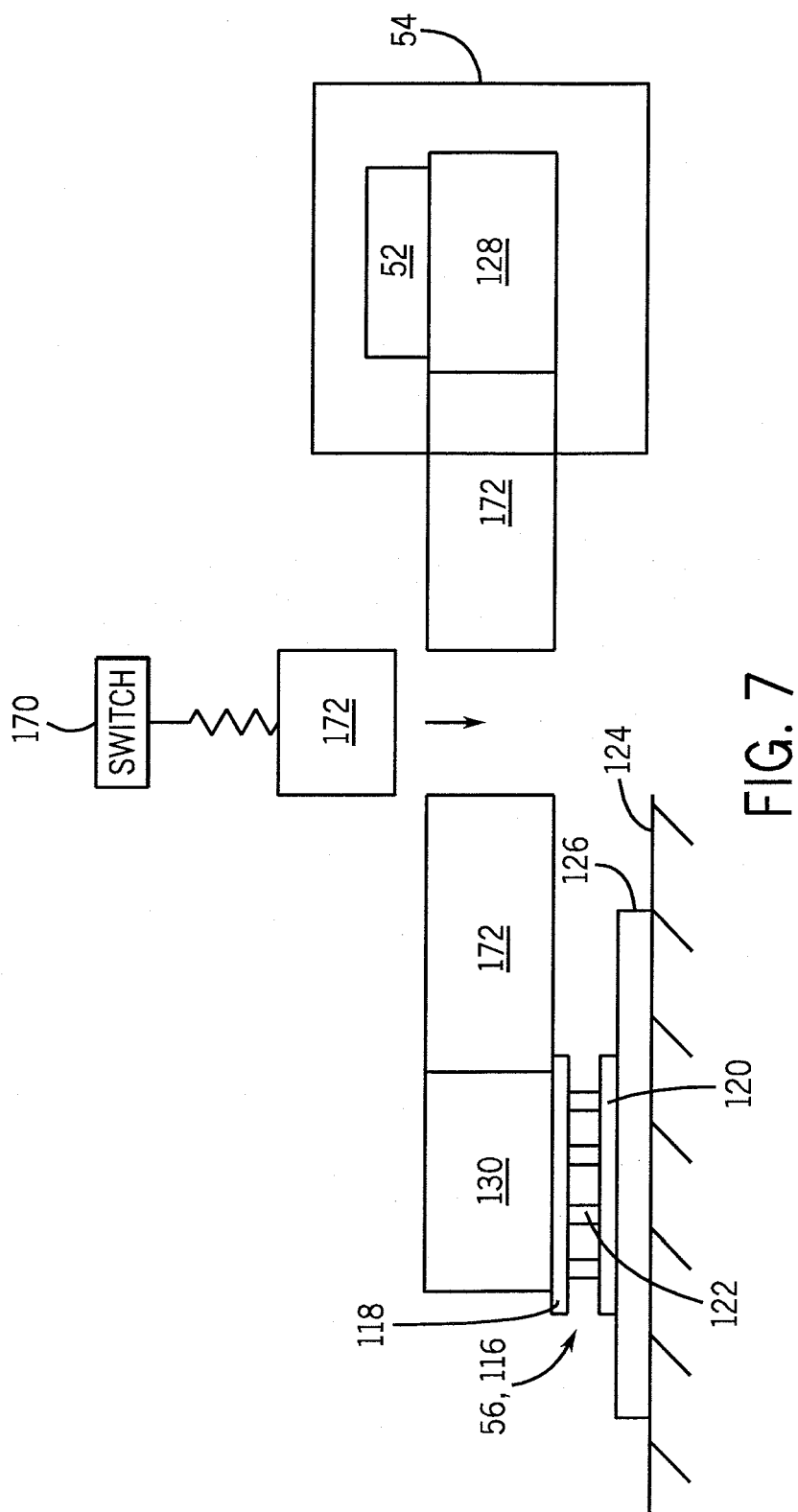


FIG. 6





EUROPEAN SEARCH REPORT

Application Number
EP 12 30 6533

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 April 2013	Examiner Schneiderbauer, K
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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