

**APPARATUS AND METHOD FOR
GEOTHERMALLY COOLING ELECTRONIC DEVICES
INSTALLED IN A SUBSURFACE ENVIRONMENT**

RELATED APPLICATION

[001] This application claims the priority of U.S. Provisional 61/698,365, filed on September 7, 2012 and entitled “GEOTHERMALLY COOLED COMPUTER HARDWARE SYSTEM DESIGNED FOR SUBSURFACE INSTALLATION”.

TECHNICAL FIELD

[002] This disclosure relates to a system and method for geothermally cooling electronic devices, including but not limited to computer systems, by installing the electronic devices in subsurface environments such as boreholes, excavations, or bodies of water.

BACKGROUND

[003] Large-scale data centers typically house hundreds or thousands of computer systems in high-density configurations (side-by-side racks, with multiple computing nodes per rack) in an above-ground building. Some sources estimate that up to 50% of the electrical power consumption for data centers is dedicated to cooling the environment in which the computer systems operate.

[004] The heat generated by the internal electronic components of computing devices has long been a significant factor determining the overall system design of computer systems. The most common forms of heat dissipation in early personal computer designs were direct physical contact between the heat-generating integrated circuit chip and a heat-conducting mass such as aluminum, and non-turbulent airflow, typically generated by electrical fans, to circulate cool air through a space interior to the computer system housing. In the early large-scale computing systems of the 1940s and 1950s, heat dissipation consisted primarily of ventilation apertures in housings, followed by ambient-air fans and blowers which cooled by forced air convection.

[005] Zelina, in U.S. Pat. No. 3,566,958 (1971), describes a means of thermally coupling heat conductors to integrated circuit chips, though without addressing how to transport the heat contained in the heat-conducting material away from the space surrounding the electrical device.

In U.S. Pat. No. 3,648,113 (1972) Rathjen describes a means of stacking planar electronic devices, with spacing between the flat planes, and cooling the entire assembly using fluid flow across the flat surfaces; the cooling fluid exits the entire assembly, thereby transporting heat away from the heat-generating electronics. Austin, in U.S. Pat. No. 3,737,728 (1973) discloses a mounting structure for fragile heat-generating devices (e.g. devices used in computer apparatuses), as well as uniformity of heat conduction and good heat dissipation away from the core assembly area. These ideas are combined in U.S. Pat. No. 3,865,183 (1975), in which Roush describes a more comprehensive means of constructing a full computer assembly with good heat dissipation characteristics of the individual circuit boards in the module, with fluid flow for removal of heat energy from the assembly.

[006] As semiconductor densities in computing devices continued to increase, progressively more heat was generated by the devices. Beginning in the 1980s a series of advancements was made in the heat removal capabilities of computer systems, primarily through the use of liquids. Oktay, in 1980 (U.S. Pat. No. 4,203,129) described the bonding of a heat sink to the surface of a heat-generating electronic device, and immersing the other surfaces of the heat sink in a liquid, which circulates through tunnels in the heat sink material. This innovation was followed by others too numerous to mention by inventor and patent number, including: jacketing the CPU of a computer and placing liquid coolant directly in contact with the CPU jacket, with or without pumps for circulation of the liquid; increasingly complex valves and other electronically controlled redundant cooling components for one or more CPUs or other heat generating electronic components; various designs for the channels and pipes carrying the liquid coolant; closed loop and open loop systems with physical contact between loop housings and varying degrees of fluid exchange between them.

[007] The cooling capacity of the earth's subsurface has long been recognized as a potential energy-saving feature of systems that cool inhabited environments. Because the subsurface maintains essentially a constant temperature at a given depth and the rock and/or artesian mass and volume of the subsurface are vast, heat can be exchanged with either warmer surface fluid, thereby providing cooling, or cooler surface fluid, thereby providing warming. Vignal and Chapuis, in U.S. Pat. No 3,965,694 (1976) describe a means of exchanging heat with the earth's subsurface via a U-shaped line or pipe buried in a deep hole bored in the earth; their design is directed at systems for warming or cooling above-ground air. Many devices since then have

been disclosed that improve on various aspects of air-conditioning designs and provide for more efficient heat transfer between above-ground fluids and subsurface rock or liquid.

[008] The use of subsurface thermal capacity to control the operating temperature of electronic equipment was disclosed by Enlund in U.S. Pat. No. 6,397,933 (2002) for equipment installed in a station and by Kidwell and Fraim in U.S. Pat. No. 7,363,769 (2008) for the cooling of electronic equipment at the base of an electromagnetic signal transmission/reception tower. The subject matter disclosed by Kidwell and Fraim describes a method and apparatus for using coaxial flow heat exchanging structures for regulating the temperature of heat-generating electronics installed in the base housing of an electromagnetic signal transmission/reception tower. The heat transfer is effected using a fluid flow loop from the surface to the underground environment and back to the surface. Chainer, in U.S. Pat. Application No. 2013/0081781 describes a system for data center cooling wherein heat transfer fluid is removed from the indoor volume of the data center and cooled via ambient air and geothermal heat exchange processes.

[009] Attlesey, et al. in U.S. Pat. No. 7,724,517 (2010) disclose a design of a case for a liquid submersion cooled electronic device; the embodiments described therein include a liquid-tight case for enclosing electronic equipment, with at least a portion of one of the walls composed of translucent or transparent material for visibility into the interior of the case. In several subsequent patents, Attlesey describes cooling of electronic equipment by means of a dielectric liquid circulating in and through a fluid-tight container. Tufty et al. disclose a similar approach in U.S. Pat. Application No. 2013/0081790 (April 2013). Campbell, et al. in U.S. Pat. No. 7,961,475 (June 2011) describe an apparatus and method for immersion cooling of one or more electronic subsystems in which cooling fluid passes in and out of one or more containers docked within an electronics rack.

[0010] In conclusion, the heat generated by computer and other electronic hardware results in significant cooling costs in environments, such as data centers, where systems are deployed in high density configurations.

[0011] Unless specifically stated as such, the preceding is not admitted to be prior art and no statement appearing in this section should be interpreted as a disclaimer of any features or improvements listed.

BRIEF DESCRIPTION OF THE INVENTION

[0012] At least one embodiment described herein provides a geothermal cooling mechanism for electronic devices and systems of devices, including but not limited to computer hardware systems, installed in a subsurface environment. The design provides a significant improvement in long-term electronic equipment operating costs by eliminating the need to remove heat from the human-inhabited environment of the facility in which the hardware is installed. The increased cooling capability of the subsurface environment is likely to lead to a lower average operating temperature of the hardware, which will translate into a longer average operational lifetime of the hardware. The design also results in a very high security physical installation for electronic equipment systems.

[0013] The computer hardware or other electronic equipment can be installed as individual units or in a high-density configuration. Designs are optimized for effective and efficient direct transfer of thermal energy away from heat-generating electronics into the surrounding environment. The computer systems dissipates internally generated heat from the surface of an enclosure to the near-infinite cooling mass of the earth's underground or a large body of water, either through direct contact, or using a heat-transporting fluid in contact with at least some portion of the outer surfaces of the individual components or subsystems within the installation. Throughout this disclosure and the accompanying claims, fluid is intended to include gases (e.g. atmospheric air, helium, nitrogen, etc), liquids (e.g. mineral oil, silicone oil, water), etc. or a combination of gases and liquids. The exterior surface of the enclosure is preferably composed of materials conducive to heat transfer. The enclosure has entrances, optionally liquid-tight, for power, networking, and other control and monitoring signals and functions. Heat may be transferred from the fluid directly into the subsurface environment via passive or forced circulation, or the fluid may be circulated away from the computer hardware enclosure or containment vessel, cooled in a remote location, then re-circulated back to the computer hardware enclosure or containment vessel at a lower temperature.

[0014] Multiple configuration options are described optimized for installation into a variety of subsurface environments, such as, but not limited to, a naturally occurring or man-made borehole, excavation, structure, well hole, or body of water (e.g. stock tank, reservoir, lake, pool, river, ocean, sea, stream, wetland, etc.). The installation can be in any orientation and can be positioned at the surface or any distance below the surface, with or without direct contact to the

above-surface environment. The computer system casing may be of solid construction, or it may be of a hollow construction that provides an increased surface area and a channel through which may flow fluid for heat transfer. Computer system casing units may be stacked or grouped together to form a single structural unit, or they may be in close proximity as single units not in direct contact with other units.

[0015] These and other aspects of the disclosed subject matter, as well as additional novel features, will be apparent from the description provided herein. The intent of this summary is not to be a comprehensive description of the claimed subject matter, but rather to provide a short overview of some of the subject matter's functionality. Other systems, methods, features and advantages here provided will become apparent to one with skill in the art upon examination of the following FIGURES and detailed description. It is intended that all such additional systems, methods, features and advantages that are included within this description, be within the scope of the appended claims and any claims filed later.

BRIEF DESCRIPTION OF FIGURES

[0016] The novel features believed characteristic of the disclosed subject matter will be set forth in the appended claims and any claims filed later. The disclosed subject matter itself, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of illustrative embodiments when read in conjunction with the accompanying drawings, wherein:

[0017] **Figure 1** shows a conceptual cross-section of a convection type geothermal cooled computer hardware system designed for subsurface installation according to an embodiment of the disclosed subject matter.

[0018] **Figure 2** shows a conceptual cross-section of a heat exchanger type geothermal cooled computer hardware system designed for subsurface installation according to an embodiment of the disclosed subject matter.

[0019] **Figure 3** shows a conceptual cross-section of a heat exchanger type geothermal cooled computer hardware system designed for a human-accessible subsurface installation according to an embodiment of the disclosed subject matter.

[0020] **Figure 4** shows a conceptual cross-section of a computer cluster designed for subsurface installation that contains computer component assemblies that are cooled by external cooling fluid circulation according to an embodiment of the disclosed subject matter.

[0021] **Figure 5** shows a conceptual cross-section of a computer cluster designed for subsurface installation that contains computer component assemblies that are cooled by interior channel and external cooling fluid circulation according to an embodiment of the disclosed subject matter.

[0022] **Figure 6** shows a conceptual cross-section of a computer cluster designed for subsurface installation that contains computer component assemblies that are cooled by internal cooling fluid circulation according to an embodiment of the disclosed subject matter.

[0023] **Figure 7** shows a conceptual cross-section of a computer cluster designed for subsurface installation that contains computer component assemblies that are cooled by interior channel and internal cooling fluid circulation according to an embodiment of the disclosed subject matter.

DETAILED DESCRIPTION

[0024] Although described with reference to certain embodiments, those with skill in the art will recognize that the disclosed embodiments have relevance to a wide variety of areas in addition to the specific examples described below. Further, elements from one or more embodiments may be used in other embodiments and elements may be removed from an embodiment and remain within the scope of this disclosure.

[0025] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein; provided, however, to the extent there exists a conflict between this disclosure and a document incorporated by reference, this disclosure shall control.

[0026] In its most basic embodiment, the design consists of a computer hardware system, either as an individual unit or as a cluster of units, installed in a case designed to conduct heat from the computer hardware system to a fluid within a containment vessel in a subsurface environment; cooling of the computer hardware system is accomplished by geothermal heat transfer from the containment vessel fluid to the external subsurface environment. The containment vessel exists primarily or entirely below ground level, and can have any size, shape, or orientation as dictated by the constraints of the particular installation requirements.

[0027] **Figure 1** depicts a basic embodiment of the design. The containment vessel **100** is a sealed or unsealed structure which is near or any distance below surface level **108**. The containment vessel **100** is installed in either a removable or non-removable fashion in surrounding physical materials **112** such as earth, water, or concrete. The sealed embodiment will have a sealing cap **104** which may be covered by surrounding physical materials **112**. The unsealed embodiment will have containment vessel walls **110** that extend to the surface of the surrounding physical materials **112**. A liquid-tight connector assembly **114** extends through any sealing cap **104** to provide an entry port for power, control and electrical signal cabling **126** to and from one or more computer hardware systems **116**, each of which consists of one or more individual electronic device subsystems. The cooling fluid **120** with surface level **122** fills some or all of the containment vessel **100** volume and surrounds the computer hardware systems **116**. The cooling fluid **120** is cooled by geothermal heat conduction into the surrounding subsurface mass; the cooled fluid moves downward convectively **124** near the containment vessel **100** wall, and the warmer fluid moves convectively upward **128** as it gains heat from the computer hardware systems **116**. Fluid flow may be augmented by an optional fluid circulator **132** which forces fluid upward from the lower region of the containment vessel **100**. Fluid flow in and around the computer hardware system **116** may be accomplished by embodiments such as those described in **Figures 4, 5, 6, and/or 7**.

[0028] **Figure 2** shows a configuration similar to that of **Figure 1**, the primary difference being that warmer fluid **172** is removed from the containment vessel **150** at higher temperature and transferred to a remote location for geothermal heat exchange **156** or other method of heat exchange; after the fluid is cooled remotely by geothermal heat exchange **156** or other method, it is transferred **176** back into the containment vessel **150**. The containment vessel **150** is a sealed or unsealed structure which is near or any distance below surface level **158**. The containment

vessel **150** is installed in either a removable or non-removable fashion in surrounding physical materials **152** such as earth, water, or concrete. The sealed embodiment will have a sealing cap **154** which may be covered by surrounding physical materials **152**. The unsealed embodiment will have containment vessel walls **160** that extend to the surface of the surrounding physical materials **152**. A liquid-tight connector assembly **164** extends through any sealing cap **154** to provide an entry port for cooling fluid, power, control and electrical signal cabling **162** to and from one or more computer hardware systems **166**, each of which consists of one or more individual electronic device subsystems. The cooling fluid **168** with surface level **170**, which fills some or all of the containment vessel **150** volume, surrounds the electronic devices or systems **166**, each of which consists of one or more electronic devices. In this embodiment the cooling fluid **168** is pumped to a geothermal heat exchange system **156** or other heat exchanger installed external to, and either adjacent to or remote from, the containment vessel **150**. The geothermal heat exchange unit **156** uses primary or secondary geothermal heat exchange such as open or closed loop earth or water geothermal heat sinks, and cools the fluid for reinsertion **176** into the interior of the containment vessel **150**. Fluid flow in and around the computer hardware systems **166** may be accomplished by embodiments such as those described in **Figures 4, 5, 6, and/or 7**.

[0029] **Figure 3** shows a configuration similar to that of **Figure 2**, the primary difference being the presence of a secondary containment vessel **210** that is sufficiently large and of the correct environment and structure to facilitate human access, inspection, and maintenance of at least a portion of the entire assembly. The containment vessel **200** is installed in either a removable or non-removable fashion inside the secondary containment vessel **210**. The secondary containment vessel **210** is installed in surrounding physical materials **202** such as earth, water, or concrete and contains a human accessible extension to the surface. The containment vessel **200** is a sealed or unsealed structure which is near or any distance below surface level **208**. The sealed embodiment will have a sealing cap **204**; the sealed and unsealed embodiments will allow human access inside the containment vessel **200**, optionally through an access panel or port **206**. A liquid-tight connector assembly **214** extends through any sealing cap **204** to provide an entry port for cooling fluid, power, control and electrical signal cabling **212** to and from one or more computer hardware system **216**, each of which consists of one or more individual electronic devices. The cooling fluid **218** with surface level **220**, which fills some or all of the containment

vessel **200** volume, surrounds the computer hardware systems **216**, each of which consists of one or more individual electronic device subsystems. The warmer fluid **222** is removed from the containment vessel **200** at higher temperature and transferred to a remote location for geothermal heat exchange **224**; after the fluid is cooled remotely by a geothermal heat exchange system **224** or other heat exchanger, it is transferred **226** back into the containment vessel **200**. The cooling fluid **222** is pumped to a geothermal heat exchange **224** installed external to, and either adjacent to or remote from, the containment vessel **200**. The geothermal heat exchange unit **224** uses primary or secondary geothermal heat exchange such as open or closed loop earth or water geothermal heat sinks, or other heat exchange system, and cools the fluid **226** for reinsertion into the interior of the containment vessel **200**. Fluid flow in and around the computer hardware systems **216** may be accomplished by embodiments such as those described in **Figures 4, 5, 6, and/or 7**.

[0030] **Figure 4** shows a conceptual cross-section of an embodiment of a grouping of electronic devices or systems; for the purpose of the embodiments depicted in **Figures 4, 5, 6 and/or 7** such grouping will be called a computer cluster. This embodiment provides an enclosure **300** for the computer cluster, with a fluid filled interior space **304**, and an entry port for power, control and electrical signal cabling **308**. The exterior surface of the enclosure **300** is in contact with a surrounding cooling fluid **312** which circulates and is cooled in any of the manners described for **Figures 1, 2, and/or 3** above. The components which are interior to the enclosure **300** include one or more power supplies **316**, one or more data storage assemblies **320** consisting of disk drives or other type of storage units, one or more motherboard assemblies **324**, and other computer hardware **328** that may be required by a particular application. The motherboard assembly **324**, power supply assembly **316**, data storage assembly **320**, and customized computer assembly **328** are assemblies that contain standard computer components that have been arranged in a manner to facilitate proper computer operation and optimal heat transfer; they may be bracket mounted and open to the interior of the computer cluster enclosure **300** or each assembly may be fully enclosed as a unit in order to either contain a secondary cooling fluid such as a dielectric or to isolate the assembly from direct contact with either the primary or another secondary cooling liquid. Each assembly **324, 316, 320, 328** will have cable entrances for power and electrical signaling that serve to interconnect the assemblies as required for computer operation. Each assembly **324, 316, 320, 328** may be mounted in such a fashion as to transfer

heat directly from the assembly to the wall of the computer cluster enclosure. The interior of the computer cluster enclosure **304** may contain fluids separated by interior partitions and control structures that serve to transfer heat from the inward facing surfaces of assemblies **324**, **316**, **320**, **328** to the outer wall of the computer cluster enclosure **300**. The electronic devices or systems interior to the enclosure **300** do not need to be arranged exactly as shown and may have various arrangements to facilitate heat transfer and operation. Multiple computer cluster enclosures **300** may be connected in a single logical and/or physical structure as to form a single operating and/or installed unit.

[0031] **Figure 5** shows a conceptual cross-section of an embodiment of a computer cluster. This embodiment has a pipe-like cylindrical or tubular enclosure of various cross-sectional geometries and lengths that allow the flow of cooling fluid **360** through one or more channels in its central space. The computer cluster has a computer cluster enclosure **350** with a gas or liquid filled interior space **354**, and an entry port for power, control and electrical signal cabling **358**. The exterior surface of the computer cluster enclosure **350** is in contact with a surrounding cooling fluid **360**. The interior space of the computer cluster enclosure **350** has a sealing cap **366** with an entry port through which the cooling fluid is forced **362**. The cooling fluid **360** is warmed by contact with the surfaces of the computer cluster enclosure **350** as it flows downward **362**; the cooling fluid **360** exits at the bottom of the computer cluster enclosure, then flows across the computer cluster enclosure **350** surfaces as it rises **364**; the cooling fluid **360** is circulated and cooled in any of the manners described for **Figures 1, 2, and/or 3** above. The computer components interior to the computer cluster enclosure **350** include one or more power supplies **370**, one or more data storage assemblies **374** consisting of disk drives or other type of storage units, one or more motherboard assemblies **378**, and other computer hardware **382** that may be required by a particular application. The motherboard assembly **378**, power supply assembly **370**, data storage assembly **374**, and customized computer assembly **382** are assemblies that contain standard computer components that have been arranged in a manner to facilitate proper computer operation and optimal heat transfer; they may be bracket mounted and open to the interior of the computer cluster enclosure **350** or each assembly may be fully enclosed as a unit in order to either contain a secondary cooling fluid such as a dielectric or to isolate the assembly from direct contact with either the primary or another secondary cooling fluid. Each assembly **378**, **370**, **374**, **382** will have cable entrances for power and electrical signaling that serve to

interconnect the assemblies as required for computer operation. Each assembly **378, 370, 374, 382** may be mounted in such a fashion as to transfer heat directly from the assembly to the wall of the computer cluster enclosure. The interior of the computer cluster enclosure **354** may contain gases and/or liquids separated by interior partitions and control structures that serve to transfer heat from the inward facing surfaces of assemblies **378, 370, 374, 382** to the outer wall of the computer cluster enclosure **350**. The computer components interior to the enclosure **350** do not need to be arranged exactly as shown and may have various arrangements to facilitate heat transfer and operation. The circulation of the cooling fluid **360** may be reversed by moving the sealing cap **366**, through which the cooling fluid is forced **362**, to the bottom of the computer cluster enclosure **350**. Multiple computer cluster enclosures **350** may be connected in a single logical and/or physical structure as to form a single operating and/or installed unit.

[0032] Figure 6 shows a conceptual cross-section of an embodiment of a computer cluster. This embodiment has a pipe-like cylindrical or tubular enclosure of various cross-sectional geometries and lengths that allow the flow of cooling fluid **410** through the interior of the computer cluster enclosure **400** and around the interior assemblies **418**. The computer cluster enclosure **400** has a fluid filled interior space **404** and an entry port for power, control, and electrical signal cabling **408**. The exterior surface of the computer cluster enclosure **400** is in contact with a surrounding cooling fluid **410**. The computer cluster enclosure **400** has a sealing cap **416** with an entry port through which the cooling fluid is forced **412**. The cooling fluid **410** is warmed by contact with the interior assemblies **418** and exits the enclosure **414** through the exit ports **440** into the containment vessel. The cooling fluid **410** is circulated and cooled in any of the manners described for **Figures 1, 2, and/or 3** above. The computer components interior to the computer cluster enclosure **400** include one or more power supplies **420**, one or more data storage assemblies **424** consisting of disk drives or other type of storage units, one or more motherboard assemblies **428**, and other computer hardware **432** that may be required by a particular application. The motherboard assembly **428**, power supply assembly **420**, data storage assembly **424**, and customized computer assembly **432** are assemblies that contain standard computer components that have been arranged in a manner to facilitate proper computer operation and optimal heat transfer; each assembly is fully enclosed as a unit in order to either contain a secondary cooling fluid such as a dielectric or to isolate the assembly from direct contact with either the primary or another secondary cooling fluid. Each assembly **428, 420, 424, 432** will

have cable entrances for power and electrical signaling that serve to interconnect the assemblies as required for computer operation. Each assembly **428, 420, 424, 432** may be mounted in such a fashion as to transfer heat directly from the assembly to the wall of the computer cluster enclosure. Alternatively or additionally, each assembly **428, 420, 424, 432** could be mounted in a fashion to maximize the assembly's **428, 420, 424, 432** contact with cooling fluid **410** within computer cluster enclosure **400**. The computer components interior to the enclosure **400** do not need to be arranged exactly as shown and may have various arrangements to facilitate heat transfer and operation. The circulation of the cooling fluid **410** may be reversed by moving the sealing cap **416** through which the cooling fluid **412** is forced to the bottom of the computer cluster enclosure **400**. Multiple computer cluster enclosures **400** may be connected in a single logical and/or physical structure as to form a single operating and/or installed unit.

[0033] Figure 7 shows a conceptual cross-section of an embodiment of a computer cluster. This embodiment has a pipe-like cylindrical or tubular enclosure of various cross-sectional geometries and lengths that allow the flow of cooling fluid **460** through one or more channels in its central space, into the interior of the computer cluster enclosure **450**, and around the interior assemblies **468**. The computer cluster enclosure **450** has a fluid filled interior space **454** and an entry port for power, control and electrical signal cabling **458**. The exterior surface of the computer cluster enclosure **450** is in contact with a surrounding cooling fluid **460**. The computer cluster enclosure **450** has one or more upper and lower sealing caps **466** through which the cooling fluid is forced **462**. The cooling fluid **460** enters the interior space **454** through one or more entry ports **470**; once inside the interior space **454**, the cooling fluid **460** is warmed by contact with the interior assemblies **468**, and the cooling fluid **460** exits the enclosure **464** through the exit ports **490** into the containment vessel. The cooling fluid **460** is circulated and cooled any of the manners described for **Figures 1, 2, and/or 3** above. The computer components interior to the computer cluster enclosure **450** include one or more power supplies **474**, one or more data storage assemblies **478** consisting of disk drives or other type of storage units, one or more motherboard assemblies **482**, and other computer hardware **486** that may be required by a particular application. The motherboard assembly **482**, power supply assembly **474**, data storage assembly **478**, and customized computer assembly **486** are assemblies that contain standard computer components that have been arranged in a manner to facilitate proper computer operation and optimal heat transfer; each assembly is fully enclosed as a unit in order to either contain a

secondary cooling fluid such as a dielectric or to isolate the assembly from direct contact with either the primary or another secondary cooling fluid. Each assembly **482, 474, 478, 486** will have cable entrances for power and electrical signaling that serve to interconnect the assemblies as required for computer operation. Alternatively or additionally, each assembly **482, 474, 478, 486** could be mounted in a fashion to maximize the assembly's **482, 474, 478, 486** contact with cooling fluid **460** within computer cluster enclosure **450**. Each assembly **482, 474, 478, 486** may be mounted in such a fashion as to transfer heat directly from the assembly to the wall of the computer cluster enclosure. The computer components interior to the enclosure **450** do not need to be arranged exactly as shown and may have various arrangements to facilitate heat transfer and operation. The circulation of the cooling fluid **460** may be reversed by removing the warmed fluid from one or more channels in central space of the computer cluster enclosure **450** and introducing the cooled fluid into the computer cluster enclosure **450** via the exit ports **490**. Multiple computer cluster enclosures **450** may be connected in a single logical and/or physical structure as to form a single operating and/or installed unit.

[0034] Although example diagrams to implement the elements of the disclosed subject matter have been provided, one skilled in the art, using this disclosure, could develop additional embodiments to practice the disclosed subject matter and each is intended to be included herein. Although many of the embodiments refer to a computer system or systems, this is merely exemplary and is not intended to limit the scope of this disclosure as the disclosed subject matter could be employed by someone skilled in the art, with the assistance of this disclosure, to cool any item which produces heat. Additionally, although discussed throughout as using geothermal cooling as the heat transfer process, one skilled in the art, with the assistance of this disclosure, could implement the teachings using alternate forms of heat transfer. Further, although discussed throughout as being positioned predominantly subsurface, one skilled in the art, with the assistance of this disclosure, could implement the teachings in a non-subsurface position. Finally, the embodiments disclosed could function without the need for traditional forced or passive air cooling.

[0035] In addition to the above described embodiments, those skilled in the art will appreciate that this disclosure has application in a variety of arts and situations and this disclosure is intended to include the same.

PARTS LIST**Figure 1.**

100 Containment vessel
 104 Sealing cap
 108 Surface level
 110 Containment vessel walls extending to surface (optional)
 112 Surrounding physical material
 114 Liquid-tight connector assembly
 116 Computer hardware system
 120 Cooling fluid
 122 Cooling fluid surface level
 124 Fluid cooled by geothermal heat transfer
 126 Power and signal cabling
 128 Fluid warmed by computer hardware systems
 132 Fluid circulator (optional)

Figure 2.

150 Containment vessel
 152 Surrounding physical materials
 154 Sealing cap
 156 Geothermal heat exchange system (or other heat exchanger)
 158 Surface level
 160 Containment vessel walls extending to surface (optional)
 162 Power and signal cabling
 164 Liquid-tight connector assembly
 166 Computer hardware system

168 Cooling fluid
 170 Cooling fluid surface level
 172 Fluid warmed by computer hardware systems
 176 Re-entering fluid cooled by geothermal (or other) heat exchange method

Figure 3.

200 Containment vessel
 202 Surrounding physical materials
 204 Sealing cap
 206 Optional panel or port for human access to containment vessel interior
 208 Surface level
 210 Secondary containment vessel
 212 Power and signal cabling
 214 Liquid-tight connector assembly
 216 Computer hardware system
 218 Cooling fluid
 220 Cooling fluid surface level
 222 Fluid warmed by computer hardware systems
 224 Geothermal heat exchange system (or other heat exchanger)
 226 Re-entering fluid cooled by geothermal (or other) heat exchange method

Figure 4.

300 Computer cluster enclosure
 304 Fluid-filled interior space
 308 Power and signal cabling

312 Surrounding cooling fluid
 316 Power supply assembly or subsystem
 320 Data storage assembly or subsystem
 324 Motherboard assembly or subsystem
 328 Customized computer assembly or
 subsystem

Figure 5.

350 Computer cluster enclosure
 354 Fluid-filled interior space
 358 Power and signal cabling
 360 Cooling fluid
 362 Forced flow of cooling fluid
 364 Upward flow of cooling fluid
 warmed by contact with electronic devices
 or assemblies
 366 Sealing cap
 370 Power supply assembly or subsystem
 374 Data storage assembly or subsystem
 378 Motherboard assembly or subsystem
 382 Customized computer or other
 electronics assembly

Figure 6.

400 Computer cluster enclosure
 404 Fluid-filled interior space
 408 Power and signal cabling
 410 Cooling fluid
 412 Forced flow of cooling fluid into
 enclosure
 414 Forced flow of cooling fluid out of

enclosure
 416 Sealing cap
 418 Cooling fluid warmed by contact
 with electronic devices or assemblies
 420 Power supply assembly or subsystem
 424 Data storage assembly or subsystem
 428 Motherboard assembly or subsystem
 432 Customized computer or other
 electronics assembly
 440 Exit port

Figure 7.

450 Computer cluster enclosure
 454 Fluid-filled interior space
 458 Power and signal cabling
 460 Cooling fluid
 462 Forced flow of cooling fluid into
 enclosure
 464 Forced flow of cooling fluid out of
 enclosure
 466 Sealing cap
 468 Cooling fluid warmed by contact
 with electronic devices or assemblies
 474 Power supply assembly or subsystem
 478 Data storage assembly or subsystem
 482 Motherboard assembly or subsystem
 486 Customized computer or other
 electronics assembly
 490 Exit port

WHAT IS CLAIMED IS:

1. An apparatus for facilitating the geothermal cooling of one or more electronic devices, the apparatus comprising:
 - a containment vessel, said containment vessel:
 - disposed predominantly in a subsurface environment; and
 - not intended to be a human-inhabited space;
 - one or more electronic devices, said one or more electronic devices disposed within said containment vessel;
 - one or more thermally conductive fluids, said one or more thermally conductive fluids in direct, indirect, or direct and indirect thermal contact with at least a substantial number of said one or more electronic devices, such that heat is transferred from said substantial number of said one or more electronic devices in thermal contact with said at least one thermally conductive fluid to said subsurface environment or another subsurface environment;
 - wherein, said containment vessel additionally comprises an opening providing cabling access between an outside of said containment vessel and at least one of said electronic devices within said containment vessel.
2. The apparatus of claim 1, said subsurface environment including at least one of:
 - a body of water;
 - a borehole;
 - an excavation; and
 - an underground structure.
3. The apparatus of claim 2, said subsurface environment being said body of water, wherein said body of water has a surface exposed to open air.
4. The apparatus of claim 1, wherein said one or more electronic devices are grouped into one or more individual subsystems, wherein each of said groups are enclosed in individual cases or housings within said containment vessel.
5. The apparatus of claim 4, additionally comprising at least two individual cases or housings and wherein each of said individual cases or housings are positioned such that at least one external surface of each of said individual cases or housings is touching at least one other external surface of another of said individual cases or housings.
6. The apparatus of claim 1, wherein:

said containment vessel is comprised of a thermally conductive material;

said one or more thermally conductive fluids is also in thermal contact with at least a portion of an inside of said containment vessel such that said heat is transferred from said one or more electronic devices to said one or more thermally conductive fluids and then to said subsurface environment or another subsurface environment via said thermally conductive material of said containment vessel.

7. The apparatus of claim 1, additionally comprising one or more internal circulating devices, said one or more internal circulating devices circulating at least a portion of one of said one or more thermally conductive fluids within said containment vessel and wherein said one or more internal circulating devices is one or more propellers, fans, or pumps.

8. The apparatus of claim 1, additionally comprising one or more cables, said one or more cables passing through said opening and said one or more cables including at least one of:

- a power cable;
- a control cable;
- a data cable;
- a communications cable; and
- a signal cable.

9. The apparatus of claim 1, additionally comprising one or more fluid-tight maintenance panels through which one or more persons may access one or more of:

- an interior of said containment vessel; and
- said one or more electronic devices.

10. The apparatus of claim 1, additionally comprising a fluid transfer device, said fluid transfer device circulating at least a portion of one of said one or more thermally conductive fluids outside of said containment vessel to one or more remote locations where said portion of one of said one or more thermally conductive fluids is cooled then circulated back into said containment vessel said circulation facilitated by auxiliary piping between said containment vessel and said remote location.

11. The apparatus of claim 10, wherein said containment vessel is disposed within a subsurface opening larger than said containment vessel to provide a human access to at least a portion of an exterior of said containment vessel.

12. The apparatus of claim 10, wherein at least a portion of said auxiliary piping passes through one or more non-subsurface environments.

13. The apparatus of claim 1, wherein said containment vessel is removable from said subsurface environment.

14. The apparatus of claim 1, wherein said containment vessel is unsealed.

15. The apparatus of claim 1, wherein at least one of said one or more electronic devices is:

- a power supply;
- a motherboard;
- a memory module;
- a central processing unit;
- a magnetic, optical, or electronic data storage unit; and
- a data transfer device.

16. A method of facilitating geothermal cooling of one or more electronic devices, the method comprising the following steps:

installing a containment vessel predominantly in a subsurface environment, said containment vessel not intended to be a human-inhabited space;

installing one or more electronic devices within said containment vessel;

filling at least a portion of said containment vessel with at least one thermally conductive fluid, said thermally conductive fluid in direct, indirect, or direct and indirect thermal contact with at least a substantial number of said one or more electronic devices, such that heat is transferred from said substantial number of said one or more devices in thermal contact with said at least one thermally conductive fluid to said subsurface environment;

providing cabling access between an outside of said containment vessel and at least one of said electronic devices within said containment vessel.

17. The method of claim 16, said subsurface environment including at least one of:

- a body of water;
- a borehole;
- an excavation; and
- an underground structure.

18. The method of claim 17, said subsurface environment being said body of water, wherein said body of water has a surface exposed to open air.

19. The method of claim 16, wherein:

said containment vessel is substantially made of a thermally conductive material; and
said one or more thermally conductive fluids is also in thermal contact with at least a portion of an inside of said containment vessel such that said heat is transferred from said one or more electronic devices to said one or more thermally conductive fluids and then to said subsurface environment or another subsurface environment via said thermally conductive material of said containment vessel.

20. The method of claim 16, with the additional step of circulating at least a portion of one of said one or more thermally conductive fluids within said containment vessel by one or more propellers, fans, or pumps thereby augmenting the rate said heat is transferred.

21. The method of claim 16, wherein one or more cables passes through said opening and said one or more cables includes at least one of:

- a power cable;
- a control cable;
- a data cable;
- a communications cable; and
- a signal cable.

22. The method of claim 16, with the additional step of circulating at least a portion of one of said one or more thermally conductive fluids outside of said containment vessel to a remote location where said portion of one of said one or more thermally conductive fluids is cooled then circulated back into said containment vessel.

23. The method of claim 16, wherein said containment vessel is removable from said sub-surface environment.

24. The method of claim 16, wherein said containment vessel is unsealed.

25. The method of claim 16, wherein at least one of said one or more electronic devices is:

- a power supply;
- a motherboard;
- a memory module;
- a central processing unit;
- a magnetic, optical, or electronic data storage unit; and
- a data transfer device.