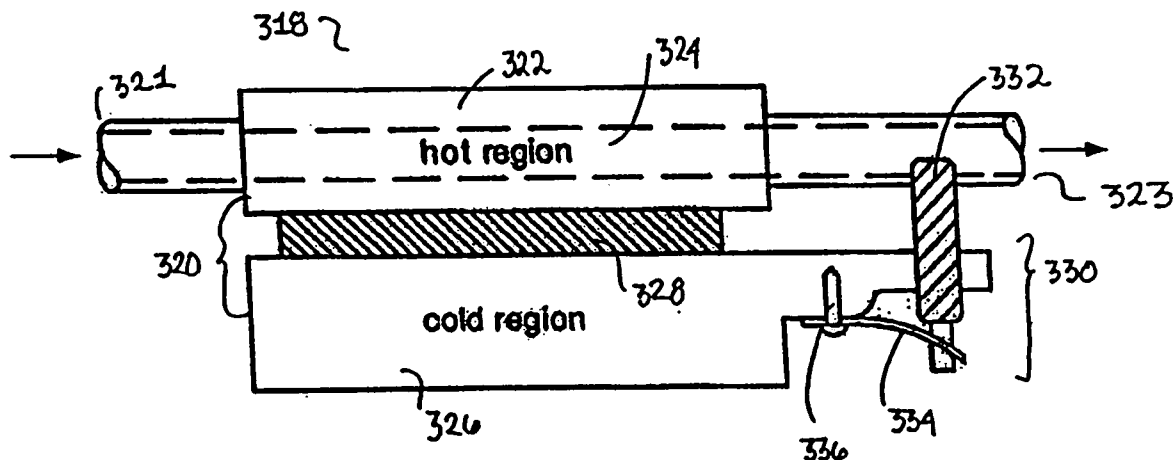




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(19) **United States**(12) **Patent Application Publication**
Krempel(10) **Pub. No.: US 2005/0103040 A1**(43) **Pub. Date: May 19, 2005**(54) **SYSTEMS FOR REGULATING THE
TEMPERATURE OF A HEATING OR
COOLING DEVICE USING NON-ELECTRIC
CONTROLLERS AND NON-ELECTRIC
CONTROLLERS THEREFOR**(52) **U.S. Cl. 62/383; 165/276; 165/277;
165/96**(76) **Inventor: Benjamin J. Krempel, San Francisco,
CA (US)****Correspondence Address:**
MORRISON & FOERSTER LLP
755 PAGE MILL RD
PALO ALTO, CA 94304-1018 (US)(21) **Appl. No.: 10/714,468**(22) **Filed: Nov. 14, 2003****Publication Classification**(51) **Int. Cl.⁷ F25D 3/12; F28F 27/00**(57) **ABSTRACT**

Described here are systems for regulating the temperature of a heating or cooling device using a non-electric controller and non-electric controllers therefor. In general, the systems described here comprise a heating or cooling device and a controller, or a heating or cooling device and a fluid circuit. The heating or cooling device typically comprises a cold region and a hot region, there being a temperature difference between the two, and an input of constant energy. The controllers are configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region, and are configured to create a path for heat exchange between the portions of the contacted hot and cold regions. The heat exchanged may be controlled and the temperature of the system may be user adjustable, or it may be automatically controlled.



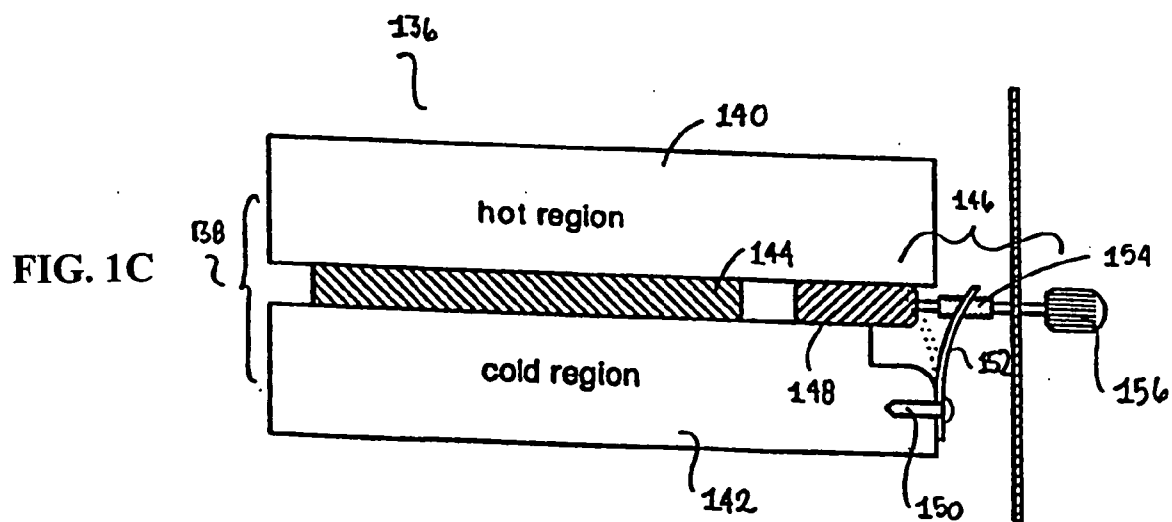
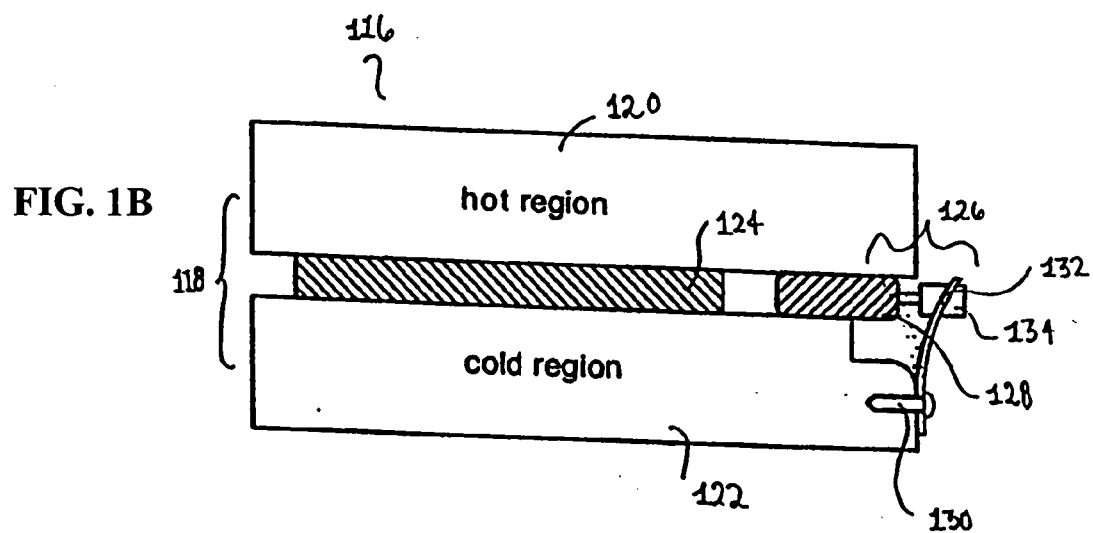
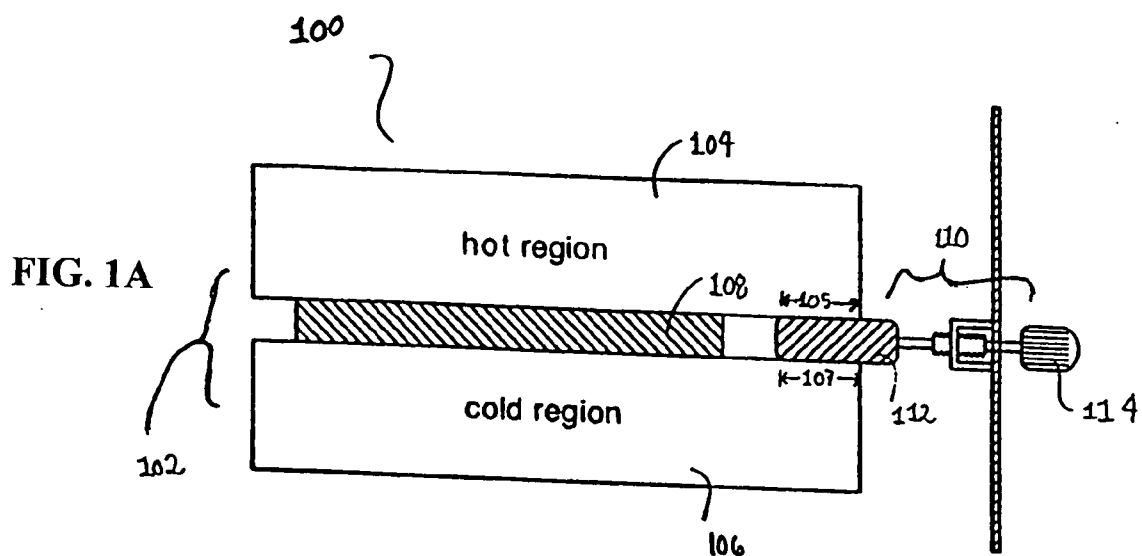


FIG. 2A

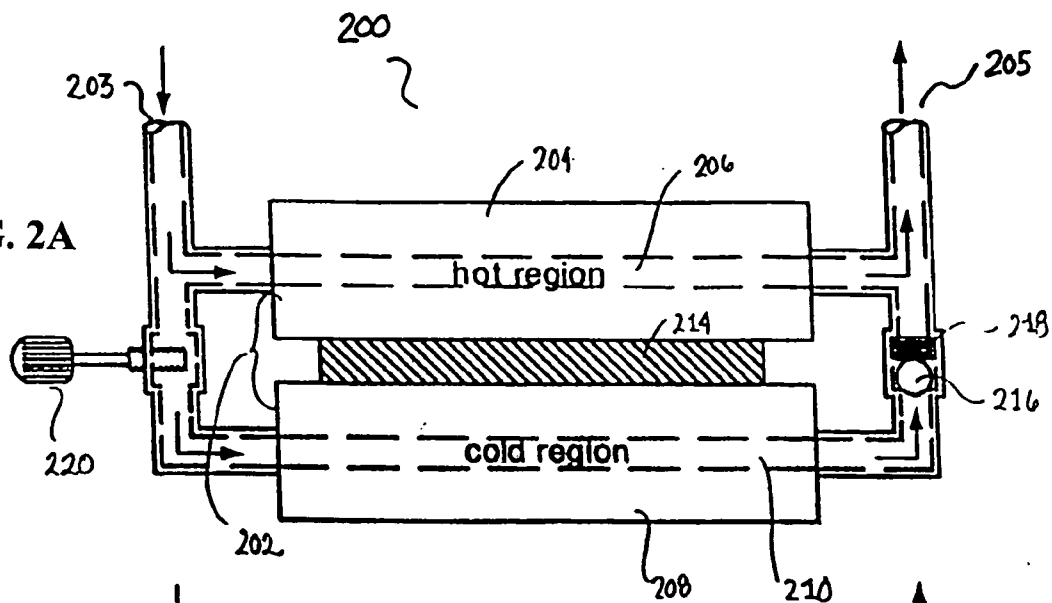


FIG. 2B

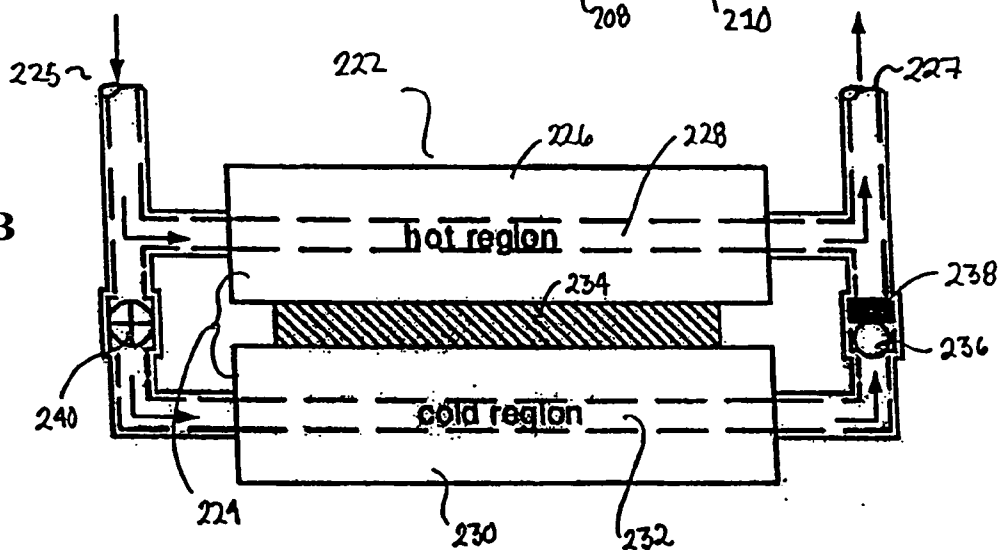
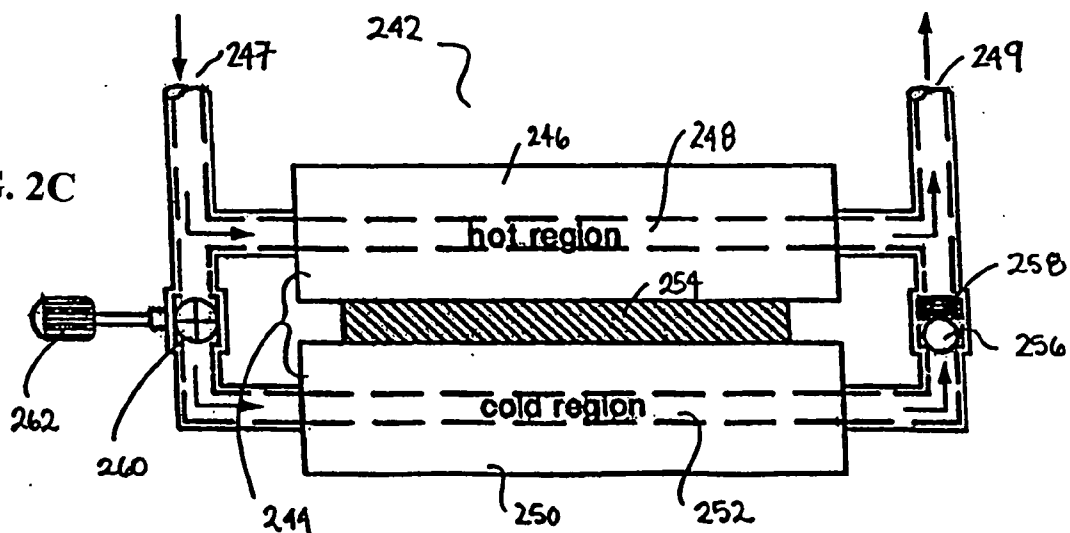


FIG. 2C



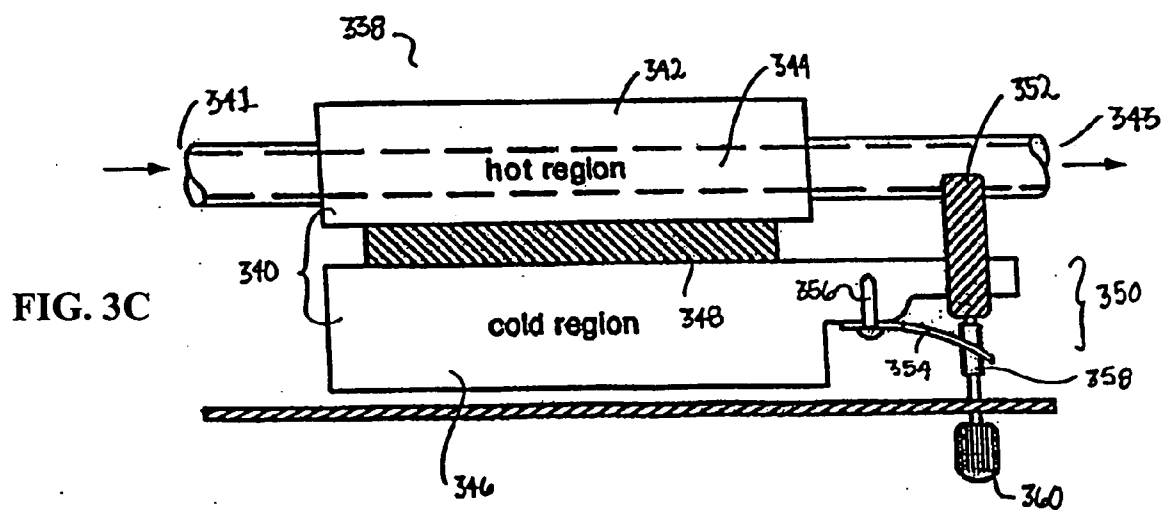
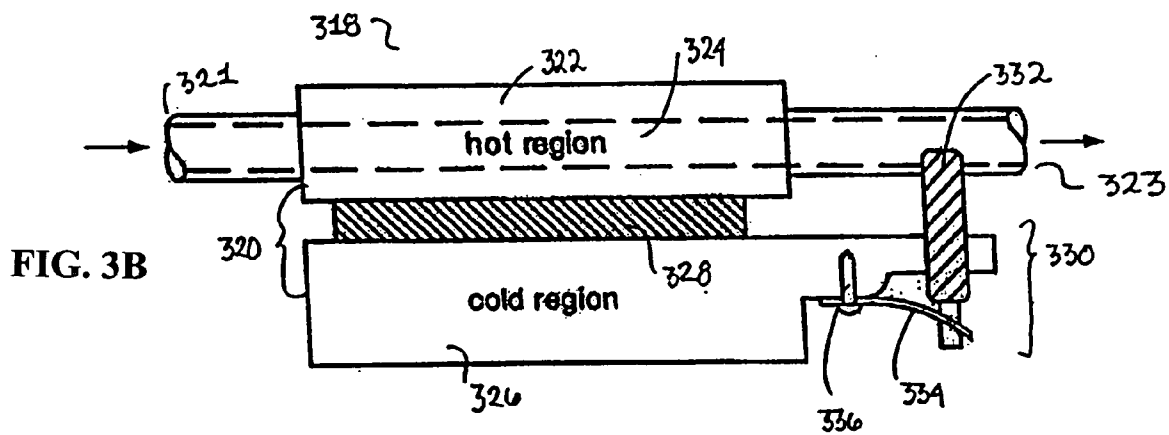
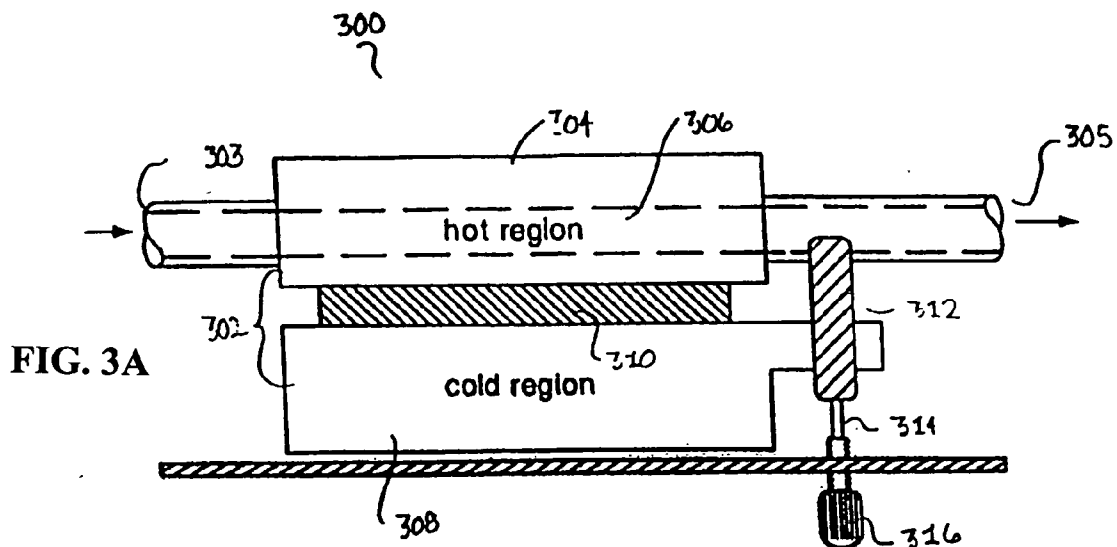


FIG. 4A

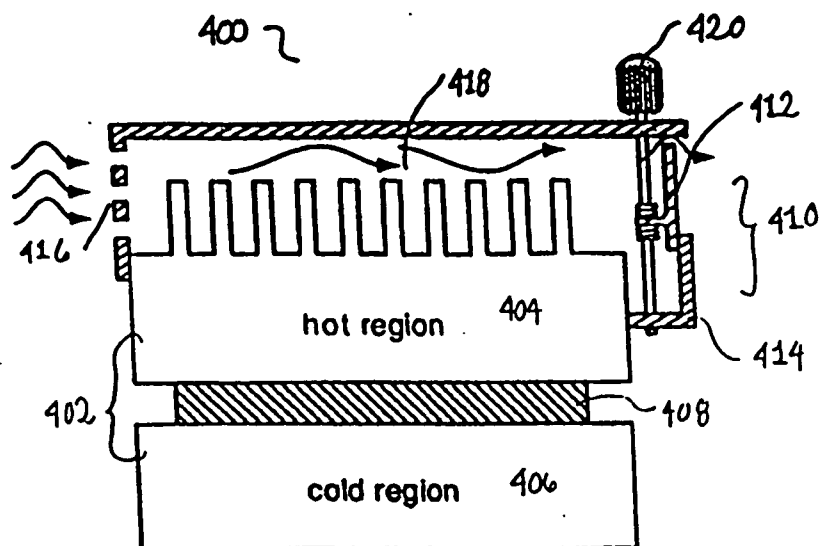


FIG. 4B

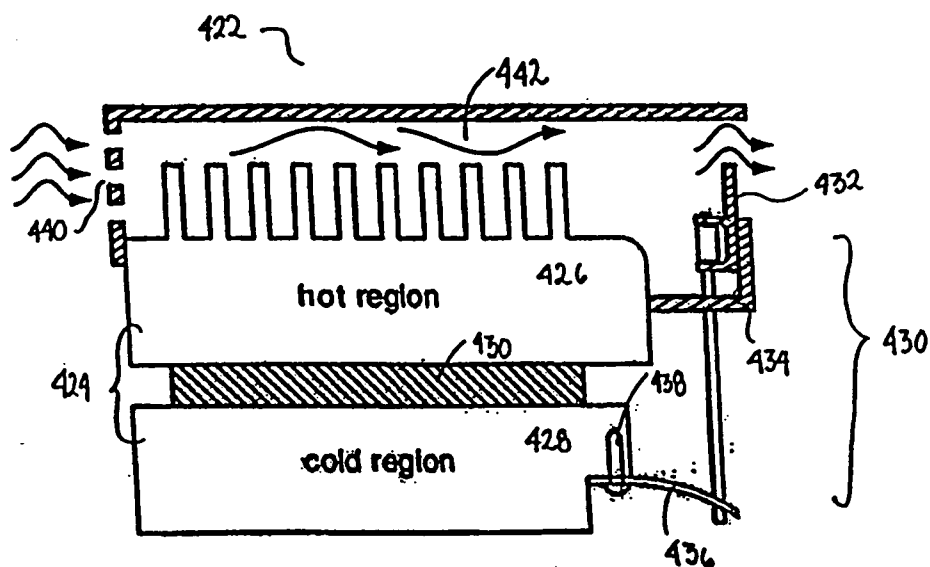
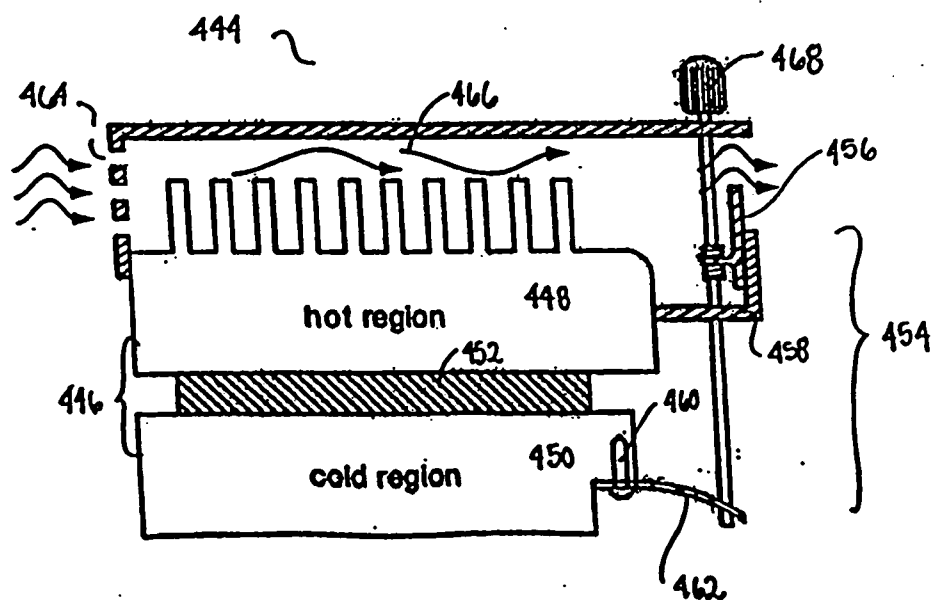


FIG. 4C



**SYSTEMS FOR REGULATING THE
TEMPERATURE OF A HEATING OR COOLING
DEVICE USING NON-ELECTRIC CONTROLLERS
AND NON-ELECTRIC CONTROLLERS
THEREFOR**

BACKGROUND

[0001] It is often desirable to regulate the temperature of a heating or cooling system. In this respect, controllers and control systems are commonly used. These controllers and controls systems help obtain, maintain, or change the temperature of the system. Typically, controllers for heating or cooling systems are electric in nature. These controllers are termed "electric" because they function by regulating or modulating some electrical aspect of the system, such as the system voltage, or the system power.

[0002] Thermostatic and steady-state electric controllers are among the most common types of controllers for thermoelectric module ("TEM") based heating or cooling systems. Compared to compressor driven refrigerators and resistive electric heaters, TEM based systems typically operate at higher currents and on DC rather than AC current. This has heretofore made traditional low-cost controllers such as bimetal thermostats, unacceptable for use as controllers for TEM based systems.

[0003] A thermostatic controller operates by maintaining a temperature between two temperature limits. That is, a thermostatic controller operates to control the temperature of a cooling system by turning on or off cooling power when certain temperatures are reached. For example, when the temperature of the system gets too high, the controller turns on the cooling power to cool the system down. When the lower temperature limit is reached, the cooling power is turned off, and this cycle repeats itself to maintain the system temperature within the upper and lower temperature limits. The difference between the two set temperature limits is known as the system's hysteresis.

[0004] A steady-state controller, on the other hand, is designed to continually hold a set-point temperature with very little variation. It is often the controller of choice when a system temperature must be maintained with a high degree of certainty. When the steady-state temperature is disrupted, (e.g., by a change in ambient conditions) the controller acts to quickly bring the temperature back to the steady-state temperature. Steady-state control is often achieved with some variant of a proportional controller.

[0005] Electromechanical devices such as bimetal snap disks or relays are typically not used to control the temperature of TEM based systems. This is because direct current switching leads to contact pitting and premature wear from arcing, and because the number of switching cycles of the mechanical component limits the life of the device. In addition, the hysteresis of an electromechanical system is often set undesirably large in order to avoid premature device failure. Furthermore, snap disks are difficult to incorporate into an adjustable set-point device. This has led to an almost uniform adoption of electric controllers as necessary components of TEM based systems. Some devices employ an electric controller plus additional structural components for altering between heating and cooling modes. The selection of a suitable controller is often one of the biggest

considerations when designing heating or cooling systems, especially since electrical controllers have proven to be very costly.

[0006] Accordingly, improved controllers and control systems capable of regulating the temperature of TEM based heating or cooling systems would be desirable.

SUMMARY

[0007] Described here are systems for regulating the temperature of a heating or cooling device using non-electric controllers and non-electric controllers therefor. For example, one described system comprises a heating or cooling device and a controller. The heating or cooling device comprises a cold region, a hot region, and an input of constant energy, there being a temperature difference between the cold and hot region. The controller comprises an element of high thermal conductivity that is configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region. The element is further configured to create a path for heat exchange between the portion of the contacted hot region, and the portion of the contacted cold region. In this way, heat exchange may be controlled to regulate the temperature of one of the regions, resulting in a controlled region and a non-controlled region. The element may comprise a metal, or a mixture of metals. Suitable metals, for example, include aluminum, copper, silver, and gold. In some variations, the element has a thermal conductivity of at least $50 \text{ (W)(m}^{-1}\text{)(}^{\circ}\text{C}^{-1}\text{)}$.

[0008] The system could further comprise a bimetal, which is thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region. In some variations, the heat exchange between the non-controlled region and the controlled region is regulated, at least in part, by thermal expansion of the bimetal. The temperature of the system may be user adjustable, or it may be automatically controlled.

[0009] Another system described herein comprises a heating or cooling device and a fluid circuit. The heating or cooling device comprises a cold region, a hot region, and an input of constant energy, there being a temperature difference between the cold and hot region. The fluid circuit comprises a channel with a fluid therethrough, which is configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region. The fluid circuit is further configured to create a path for heat exchange between the portion of contacted hot region and the portion of contacted cold region. In this way, the heat exchange may be regulated to control the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

[0010] The system may further comprise an adjustable valve for controlling the path and flow rate of the fluid in the fluid circuit. The system may also comprise an element having a high thermal conductivity, which is configured to be placed in thermal contact with the fluid circuit and one of the regions. The element may comprise a metal, such as aluminum, copper, silver, or gold, or may comprise mixtures of metals. In some variations, the element has a thermal conductivity of at least $50 \text{ (W)(m}^{-1}\text{)(}^{\circ}\text{C}^{-1}\text{)}$. The system may further comprise a bimetal, which is thermally insulated

from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region. In some variations, the heat exchange between the non-controlled region and the controlled region is regulated, at least in part, by thermal expansion of the bimetal. The temperature of the system may be user adjustable, or it may be automatically controlled.

[0011] Yet another system described herein comprises a heating or cooling device and a controller configured to alter an airflow rate. The heating or cooling device comprises a cold region, a hot region, and an input of constant energy. In this system, there is a temperature difference between the cold and the hot region, and airflow over them. The controller is configured to alter the airflow rate over one of the regions. In this way, heat is exchanged to the environment in a controlled manner to regulate the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

[0012] This system may comprise a bimetal, which is thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region. In some variations, heat exchange between one of the regions and the environment is controlled, at least in part, by thermal expansion of the bimetal. The temperature of the system may be user adjustable, or it may be automatically controlled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIGS. 1A-1C are illustrative depictions of systems for regulating the temperature of a heating or cooling device where solids are used to transfer heat.

[0014] FIGS. 2A-2C are illustrative depictions of systems for regulating the temperature of a refrigeration device where liquids are used to transfer heat.

[0015] FIGS. 3A-3C are illustrative depictions of systems for regulating the temperature of a refrigeration device where both solids and liquids are used to transfer heat.

[0016] FIGS. 4A-4C are illustrative depictions of systems for regulating the temperature of a refrigeration device where both solids and gases are used to transfer heat.

DETAILED DESCRIPTION

[0017] Described here are systems for regulating the temperature of a heating or cooling device using a non-electric controller and non-electric controllers therefor. In general, the systems described here comprise a heating or cooling device and a controller, or a heating or cooling device and a fluid circuit. The heating or cooling device typically comprises a cold region and a hot region, there being a temperature difference between the two, and an input of constant energy. The controller is configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region, and is configured to create a path for heat exchange between the portions of the contacted hot and cold regions. In this way, heat exchange may be controlled to regulate the temperature of the hot or cold region, thereby resulting in a controlled region and a non-controlled region.

[0018] The non-electric controllers useful with the described systems may provide several advantages over the

traditional electric controllers typically employed with TEM based systems. For example, the non-electric controllers described herein may be capable of reducing electromagnetic interference when compared with pulse-width modulation controllers. In addition, the non-electric controllers may be capable of switching between cooling and heating systems without reversing the polarity across the TEM. This in turn may help to reduce the thermal cycling of the TEM and consequently, may result in a higher reliability of the TEM over time. In addition, the non-electric controllers described herein may be made at a low cost without sacrificing the high performance typically achieved with traditional electric controllers. In this way, the controllers and systems for regulating temperature described herein may be especially useful in cold therapy devices, as well as small or portable refrigerators.

[0019] The controllers may be configured in any number of ways. For example, they may employ liquids, gases, solids, or some combination thereof, in order to aid in the transferring of heat. In addition, the systems described herein may be useful as heaters or as coolers. The difference between the heating and cooling system is typically dependent upon, for example, the configuration of the output side, and the region the non-electric controller references in regulating the system temperature. Turning now to the drawings, wherein like numerals indicate like elements throughout the views, there is shown in FIGS. 1A-1C systems in which the hot and cold regions have a solid, highly conductive junction, which is used in transferring heat.

[0020] As shown in FIG. 1A, the system (100) comprises a refrigeration device (102), and a controller (110). The refrigeration device (102) comprises a hot region (104), a cold region (106), and a TEM (108). It should be noted that while a TEM is depicted throughout the figures, a TEM is not required. Indeed, any suitable heat pump may be used with the systems described herein. The controller comprises an element (112) having a high thermal conductivity, which is configured to be placed in thermal contact with at least a portion of the cold region (106) and at least a portion of the hot region (104).

[0021] The hot region (104) may be made from any number of suitable materials. For example, it can be made from a highly conductive material, capable of dissipating heat, such as certain metals. Suitable metals include, but are not limited to, aluminum, copper, and mixtures thereof. The cold region (106) may similarly be made from any number of suitable materials, for example, it may be made of a highly conductive material, or made of a material capable of functioning as a heat sink. Suitable metals include, but are not limited to, aluminum, copper, and mixtures thereof. The hot and cold regions may be of any suitable dimension, which is typically dependent on the overall system size. In this way, the heat pumped through the system may be transferred. The hot region (104) and cold region (106) may also be configured to be reversible in some capacity.

[0022] The element (112) depicted in FIG. 1A may take on any number of configurations. In FIG. 1A, element (112) is shown as a manual slide, or a block. However, element (112) need not take such form. Indeed, any geometry permitting element (112) to be placed in thermal contact with at least a portion of the hot region (104) and at least a portion of the cold region (106) may be suitable.

[0023] Similarly, the element (112) may be made from any suitable material. For example, the element may comprise a metal or a mixture of metals. Suitable metals include aluminum, copper, silver, gold, and the like. In some variations it may be desirable that the element has a thermal conductivity of at least $50(W)(m^{-1})(^{\circ}C^{-1})$. The element (112) is configured to be placed in thermal contact with at least a portion of the cold region (106) and at least a portion of the hot region (104) and to create a path for heat exchange between the portion of contacted hot region (105) and the portion of contacted cold region (107). In this way, element (112) creates a path for heat to flow from the hot region (104) to the cold region (106) in order to regulate the system temperature. Typically, the extent of heat transfer between the two regions is dependent upon the extent of surface area contact between element (112) and the hot (104) and cold (106) regions. Accordingly, element (112) is often movable, so that it can be moved or positioned to have greater or lesser surface area contact with the hot (104) and cold (106) regions.

[0024] For example, when element (112) is moved into contact with the hot region (104) and the cold region (106), the thermal resistance of the system is decreased, allowing heat to flow from the hot region to the cold region. The greater the contact between the hot and cold regions and the element, the greater the heat that gets transferred. The system (100) shown in FIG. 1A is user adjustable. That is, a user may turn the adjustment control knob (114) to adjust the position of element (112). In this way, the system output may be made hotter or colder and the temperature of the system regulated. It should be noted, however, that while the system of FIG. 1A is capable of providing for a range of temperatures, the range will typically be relative to the ambient temperature or the temperature of the surrounding environment. Therefore, the user would be able, for example, to make the system temperature cold, colder, or coldest in the case of a cooler, and hot, hotter, or hottest in the case of a heater.

[0025] FIG. 1B shows another system (116) where the temperature is automatically controlled using a bimetal. As shown in FIG. 1B, system (116) comprises a refrigeration device (118) and a controller (126). The refrigeration device comprises a hot region (120), a cold region (122), and a TEM (125). Again, while a TEM (125) is depicted, any suitable heat pump may be used. The controller (126) comprises an element (128), a bimetal securing screw (130), a bimetal strip (132), and a bimetal adjuster (134).

[0026] The bimetal strip (132) may be made out of any suitable bimetal, i.e., any material comprising two different metals having different coefficients of thermal expansion, which are bonded together. The bimetal industry is a mature one having certain standards (e.g., ANSI standard, etc.), and any of these known industry bimetals, for example, are acceptable. The bimetal threaded adjuster may be made of any material, for example, stainless steel. However, in some instances it may be desirable for the threaded adjuster to be made of an engineering polymer, or some other thermal insulator, so as not to alter the bimetal temperature.

[0027] The bimetal strip (132) is configured to connect to, or otherwise configured to facilitate movement of, element (126). In this way, expansion or contraction of bimetal strip (132) regulates the position of element (126) relative to the

hot (120) and cold regions (122) in order to control the system temperature. That is, the bimetal strip (132) typically deforms at a measurable rate, as a function of its temperature throughout its effective range, due to the thermal expansion of the bimetal and the chosen bimetal properties. Typically, the bimetal strip (132) is thermally insulated from the non-controlled region and is configured to be placed in thermal contact with at least a portion of the controlled region.

[0028] As noted above, the system to be regulated may be either a heating or cooling system. Illustratively depicted in FIG. 1B is a cooling system. In operation, for example, as the temperature of the cold region (112) changes, the bimetal expands or contracts to move element (128) in towards TEM (124). The contact of element (128) with hot region (120) and cold region (122) creates a path for heat exchange, allowing heat to transfer from hot region (120) to cold region (122). In this way, bimetal strip (132) helps to control and regulate the temperature of the system. That is, unlike system (100) depicted in FIG. 1A, whose temperature regulation is dependent upon the ambient temperature, the system (116) of FIG. 1B has a fixed temperature which is controlled in a self-regulating, or automatic fashion.

[0029] Another system (136) is depicted in FIG. 1C. The system of FIG. 1C is similar to system (116) depicted in FIG. 1B, but system (136) has a user adjustment knob (156). The adjustment knob (156) allows a user to adjust the temperature within a set range of temperatures. The allowable temperature range is typically dictated by the selection of the bimetal material used to make bimetal strip (152).

[0030] The adjustment knob (156) of FIG. 1C, like the adjustment knob (114) of FIG. 1A, and the other knobs depicted throughout the figures, may be any acceptable knob, for example, the type of knob most commonly used as a radio dial. Indeed, structurally, the knobs may of any configuration capable of changing the position of element (148) with respect to bimetal strip (152). Similarly, bimetal securing screws (130) and (150) may be made out of any material, for example, stainless steel or various engineering polymers. However, selection of metallic bimetal securing screws may help insure that the temperature of the bimetal is close to the reference temperature.

[0031] FIGS. 2A-2C depict systems having a fluid circuit, where the hot and cold region junction employs a liquid to transfer heat. FIG. 2A shows a user adjustable system (200). As shown there, the system (200) comprises a refrigeration device (202) and a fluid circuit. The refrigeration device comprises a hot region (204) having a fluid channel (206) passing therethrough, a cold region (208) having a fluid channel (210) passing therethrough, and a TEM (214). The system (200) shown in FIG. 2A also has a check valve (216) and a check valve spring (218).

[0032] The hot and cold regions are of the same type as those described in FIGS. 1A-C, and accordingly, as noted above, can be made of any suitable material and be of any suitable dimension. For example, the hot and cold regions may be made of a thermally conductive material, such as a metal. The fluid channels traversing through the hot and cold regions may carry any number of suitable fluids. In some variations, water is used in the fluid circuit. The check valve may be any check valve useful in preventing the fluids from

mixing when it is not desirable for them to do so. Similarly, the check valve should permit the fluids to mix when it is desirable for them to do so.

[0033] One way that system (200) may be operated, is illustratively depicted in FIG. 2A. When the control valve (220) is completely closed, the fluid flows only through the hot region channel (206). That is, the fluid enters from input channel (203), flows through hot region channel (206), and then flows out through output channel (205). As noted above, the system may be used as a heater or a cooler, depending on the nature of its configuration. For example, the system may be configured such that input channel (203) and output channel (205) are connected to a pump, and optionally a radiator, and the system be made suitable as a cooler. In this variation, the cold region (208) could be the output side, and may be used, for example, like a cold plate. Conversely, if it were desirable to have hot region (206) as the output side, then system (200) could be configured as a heater. In this variation, for example, the flow out of the output side (205) could go to a heating pad, or other heating or warming device.

[0034] Typically, the check valve (216) is actuated by pressure within system rather than by gravity. For example, if control valve (220) is completely closed, then the cold region (208) is typically at a lower pressure than the hot region (204). This pressure difference causes the check valve to prevent the fluid from mixing. Similarly, when the control valve (220) is opened, the pressure within the system equalizes and the check valve ball moves into spring (218) compressing it, creating a space. The space created by the spring compression allows the fluid to pass through, and therefore, mix together. That is, when check valve (216) is partially open, fluid flows in from input channel (203) and flows both through hot region channel (206) and cold region channel (210).

[0035] In this way, a user can regulate the temperature of the system by adjusting the control valve (220). For example, a user can heat up a system that is too cold, or the user can cool down a system that is too hot. However, without more components, the system depicted in FIG. 2A, is typically not self regulating. Instead, the user would have only relative temperature control (e.g., cold, colder, coldest in the case of a cooler, and hot, hotter, hottest in the case of a heater).

[0036] FIG. 2B illustrates a system (222) having a fixed temperature set point. Thus, unlike the system (200) of FIG. 2A where temperature is controlled in a relative fashion, the temperature of system in FIG. 2B, is regulated in an absolute fashion. Turning now to FIG. 2B, there is a refrigeration device (224), and a bimetal (240). The refrigeration device comprises a hot region (226) having a fluid circuit (228) passing therethrough, a cold region (230) having a fluid circuit (232) passing therethrough, and a TEM (234). Also shown is check valve (236) and check valve spring (238).

[0037] The system of FIG. 2B is similar in operation to the system of FIG. 2A, however, in FIG. 2B, the temperature of the system is regulated, at least in part, by thermal expansion of bimetal (240). Typically, the bimetal (240) is thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region. Thus, as shown in FIG. 2B,

if it is desirable, to regulate the temperature of the cold region (230) the bimetal (240) would be placed in thermal contact with cold region (230) to use it as a reference temperature. Similarly, the system may be modified so as to regulate the temperature of hot region (226) by placing the bimetal (240) in thermal contact with hot region (226) so as to use the hot region (226) as a reference temperature.

[0038] Another system is illustrated in FIG. 2C. Shown there is a system involving aspects of both FIG. 2A and FIG. 2B. That is, the system (242) provides a fixed temperature with an adjustable range. As shown in FIG. 2C, system (242) comprises a refrigeration device (244) and a bimetal (260). The refrigeration device comprises a hot region (246) having a fluid circuit (248) therethrough, a cold region (250) having a fluid circuit (252) therethrough, and a TEM (254). Also shown in FIG. 2C are a check valve (256), a check valve spring (258), and a user adjustment knob (262).

[0039] In operation, the system (242) of FIG. 2C functions in a fashion similar to that of systems (222) and (200). That is, the check valve (256) is actuated by the pressure within the system and compression into check valve spring (258) creates a space for fluid to flow therethrough. The system (242) has a user adjustment knob (262) which allows the user to adjust the temperature of the system. The range of temperatures for which the user can achieve is set by the bimetal (260). Therefore, while the system is user adjustable, it is adjustable within a set range of temperatures, typically dictated by the selection of bimetal (260).

[0040] FIGS. 3A-3C illustrate other systems for regulating the temperature of a refrigeration device. As shown therein, the hot and cold region junctions are regulated using both solids and liquids. For example, shown in FIG. 3A is a system (300) comprising a refrigeration device (302), a hot region (304) having a fluid channel (306) therethrough, a cold region (308), and an element having a high thermal conductivity (312). Also shown therein is a user adjustment knob (316) and a mechanism (314) to connect the element (312) to the user adjustment knob (316), here, shown as a rod.

[0041] As noted above, the systems described in FIGS. 3A-3C may be configured to operate as heaters or coolers, for example, by selecting the system output region or by selecting the reference region. That is, the output may be configured to be on the side of either the cold or hot region of the system, depending on what is desirable. For example, if it is desirable to have the system output on the cold region, then the system can operate as a cooler. In this variation, the temperature of the cold region could be regulated, and the cold region could function as a cold plate, or the like. This may be useful, for example, during laboratory experimentation, where it may be desirable to have a cold plate to regulate the temperature of certain samples. In this variation, the input (303) and output (305) channels of hot region (304) could be connected to a pump, and an optional radiator or fan to remove heat from the hot region, thereby cooling down the system temperature.

[0042] Similarly, if it is desirable to have the system output on the hot region, then the system could function as a heater. In this variation, for example, the input (303) and output (305) channels of hot region (304) could be connected to a heating pad, or other heating or warming device.

In some variations a radiator may be desirable in order to transfer heat to, and therefore, heat up, the hot region. Again, while the fluid channel is depicted traversing through the hot region, it is also possible for the fluid channel to traverse through the cold region, and it should be understood that the systems described here are not so limited so as to exclude these variants.

[0043] One illustrative example of how system (300) may be operated is depicted in FIG. 3A. As shown in FIG. 3A, element (312) is partially in contact with fluid channel (306). Movement of element (312) into and out of fluid channel (306) controls the heat exchange between the hot and cold region, and thus the system temperature. This movement can be controlled by a user by adjustment knob (316). As noted above, the knob (316) may be any knob suitable for facilitating movement of element (312) into, or out of, fluid channel (306).

[0044] As the user turns adjustment knob (316), element (312) is moved into the path of fluid flow in the fluid channel, thereby exposing more of element's (312) surface area to the passing fluid. As more of the element's surface area gets exposed to the passing fluid, the more heat gets transferred. The element (312) can take any suitable configuration, and be made of any suitable material. In some variations, the element (312) is made out of a highly conductive material having an o-ring. In some variations, the element is made out of a metal selected from the group consisting of aluminum, copper, silver, and gold. Mixtures of metals or alloys may also be suitable. In some variations, the element has a thermal conductivity of at least $50(W)(m^{-1})(^{\circ}C)^{-1}$.

[0045] System (318) of FIG. 3B illustrates a system similar to that of system (300) of FIG. 3A, however, in FIG. 3B, the temperature of the system is regulated, at least in part, by thermal expansion of bimetal (334). As shown in FIG. 3B, the system (318) comprises a refrigeration device (320), and a controller (330). The refrigeration device (320) comprises a hot region (322) having a fluid channel (324) therethrough, a cold region (326), and a TEM (328). The controller comprises an element of high thermal conductivity (332), a bimetal (334), and a bimetal securing screw (336).

[0046] In operation, the system of FIG. 3B functions in a similar fashion to the system of FIG. 3A, however, whereas the system of FIG. 3A is user controlled and operates only upon relative temperatures, the system of FIG. 3B is automatically controlled about a range of temperatures, which are typically determined by the selection of the bimetal material. As noted above in the description of the systems of FIGS. 11B and 2B, the temperature of the system is regulated, at least in part, by thermal expansion of the bimetal. That is, as bimetal (334) expands, it moves element (332) into the path of fluid flow, thereby effecting greater heat transfer.

[0047] FIG. 3C illustrates another variation of a solid-liquid system, in which the temperature is user adjustable about a fixed set point. As shown in FIG. 3C, the system (338) comprises a refrigeration device (340) and a controller (350). The refrigeration device (340) comprises a hot region (342) having a fluid channel (344) traversing therethrough, a cold region (346), and a TEM (348). The controller (350) comprises an element of high thermal conductivity (352), a

bimetal (354), a bimetal securing screw (356), a user adjustment knob (360), and a bimetal threaded adjuster (358).

[0048] The adjustment knob (360) allows a user to adjust the temperature of the system within a set range of temperatures, the range typically determined by the selection of the bimetal used to make bimetal strip (354). As noted above, the adjustment knob (360) may be any acceptable knob. Similarly, bimetal securing screw (356) may be made out of any suitable material, for e.g., the same material used to make securing screws (130) and (150).

[0049] FIGS. 4A-4C illustrate systems where a gas and a solid are used at the hot and cold region junctions to transfer heat. That is, opposed to the systems described in FIGS. 3A-3C, which utilize fluids to dissipate heat, the hot region of the systems illustrated in FIGS. 4A-C, dissipate heat using a gas. A heat sink having a gaseous current running by it is illustratively depicted in FIGS. 4A-C.

[0050] Turning now to FIG. 4A, there is shown a user adjustable system (400) comprising a refrigeration device, and a controller (410). The refrigeration device comprises a hot region (404), a cold region (406), and a TEM (408). The controller (410) comprises a vent door (412), and a housing (414). Also shown in FIG. 4A is a user adjustment knob (420). Depicted in FIG. 4A is a heat sink (418), here in the form of a ridged structure as part of hot region (404).

[0051] In operation, the gas enters system (400) through opening (416), and exits on the right when vent door (412) is open. When the vent door (412) is closed, convection is restricted, and the gas flow cannot exit. Any number of suitable gases can be used with the systems described here. For example, the gas may be air, or some other inert gas. In the system depicted here, the rate of heat dissipation is regulated by controlling the path of the gas as it crosses hot region (404) and heat sink (418).

[0052] The user adjustment knob (420) controls the vent door (412). That is, as knob (420) is turned, the vent door (412) opens, and more gas is permitted to escape. If the knob is turned in the opposite direction, the vent door closes. In this way, the vent door is used to regulate the amount of gas flow exiting the system. The more gas that passes over the hot region (404), the more heat that gets dissipated. That is, when the vent door (412) is completely open, there is maximum cooling or heat dissipation.

[0053] The vent door (412) need not be made out of any particular material. For example, the vent door (412) could be made out of a conductive or insulating material. For example, sheet metal or engineering polymers may be used. Suitable knobs were described above, as were materials and dimensions suitable for the hot and cold regions.

[0054] FIG. 4B illustrates a system (422) having a fixed temperature set point. As shown in FIG. 4B, the system comprises a refrigeration device (424), and a controller (430). The refrigeration device (424) comprises a hot region (426), a cold region (428), and a TEM (430) positioned between the two and in thermal contact therewith. The controller (430) comprises a vent door (432), a housing (434), a bimetal (436), and a bimetal securing screw (428).

[0055] System (422) of FIG. 4B illustrates a system similar to that of system (400) of FIG. 4A, however, in FIG. 4B, the temperature of the system is regulated, at least in

part, by thermal expansion of bimetal (436). That is, whereas the system of FIG. 4A is user controlled and operates only upon relative temperatures, the system of FIG. 4B is automatically controlled about a range of temperatures, which are typically determined by the selection of the bimetal material. As bimetal (436) expands, it pushes on a connecting element (here shown as a rod) attached to vent door (432), thereby causing the vent door to close.

[0056] Another variation of the systems described herein is illustrated in FIG. 4C, which depicts a user adjustable system (444) adjustable about a fixed temperature set point. As shown in FIG. 4C, the system comprises a refrigeration device (446), and a controller (454). The refrigeration device (446) comprises a hot region (448), a cold region (450), and a TEM (452) positioned between the two and in thermal contact therewith. The controller (454) comprises a vent door (456), a housing (458), a bimetal (462), and a bimetal securing screw (460). Also shown is a user adjustment knob (468).

[0057] The adjustment knob (468) controls the vent door (456) and therefore allows a user to adjust the temperature of the system within a set range of temperatures, the range typically determined by the selection of the bimetal used to make bimetal strip (462). As noted above, the adjustment knob (468) may be any acceptable knob. Similarly, bimetal securing screw (460) may be made out of any suitable material, for e.g., the same material used to make securing screws (130) and (150) and (356).

[0058] Although illustrative variations of the systems and controllers have been described above, it will be evident to a skilled artisan that various changes and modifications may be made without departing from the true scope and spirit of the systems and controllers described above and herein claimed.

What we claim is:

1. A system for regulating the temperature of a heating or cooling device using a non-electric controller, comprising:

a heating or cooling device comprising a cold region, a hot region, and an input of constant energy, there being a temperature difference between the cold region and the hot region; and

a controller comprising an element of high thermal conductivity, the element configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region, the element further configured to create a path for heat exchange between the portion of contacted hot region and the portion of contacted cold region, whereby the heat exchange is controlled to regulate the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

2. The system of claim 1 wherein the element comprises a metal selected from the group consisting of aluminum, copper, silver, and gold.

3. The system of claim 1 wherein the element has a thermal conductivity of at least $50 \text{ (W)(m}^{-1}\text{)(}^{\circ}\text{C}^{-1}\text{)}$.

4. The system of claim 1 further comprising a bimetal, the bimetal being thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region.

5. The system of claim 4 wherein the heat exchange between the non-controlled region and the controlled region is regulated, at least in part, by thermal expansion of the bimetal.

6. The system of claim 1 wherein the temperature of the controlled region is user adjustable.

7. The system of claim 5 wherein the temperature of the controlled region is automatically controlled.

8. A system for regulating the temperature of a heating or cooling device using a non-electric controller, comprising:

a heating or cooling device comprising a cold region, a hot region, and an input of constant energy, there being a temperature difference between the cold region and the hot region; and

a fluid circuit, the fluid circuit comprising a channel with a fluid therethrough, the fluid circuit configured to be placed in thermal contact with at least a portion of the cold region and at least a portion of the hot region, the fluid circuit further configured to create a path for heat exchange between the portion of contacted hot region and the portion of contacted cold region, whereby the heat exchange is regulated to control the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

9. The system of claim 8 further comprising an adjustable valve for controlling the path and flow rate of the fluid in the fluid circuit.

10. The system of claim 8 further comprising an element having a high thermal conductivity, the element configured to be placed in thermal contact with the fluid circuit and one of the regions.

11. The system of claim 10 wherein the element comprises a metal selected from the group consisting of aluminum, copper, silver, and gold.

12. The system of claim 11 wherein the element has a thermal conductivity of at least $50 \text{ (W)(m}^{-1}\text{)(}^{\circ}\text{C}^{-1}\text{)}$.

13. The system of either of claims 8 or 10 further comprising a bimetal, the bimetal being thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region.

14. The system of claim 13 wherein the heat exchange between the non-controlled region and the controlled region is regulated, at least in part, by thermal expansion of the bimetal.

15. The system of claim 8 wherein the temperature of the controlled region is user adjustable.

16. The system of claim 13 wherein the temperature of the controlled region is automatically controlled.

17. A system for regulating the temperature of a heating or cooling device using a non-electric controller, comprising:

a heating or cooling device comprising a cold region, a hot region, and an input of constant energy, there being a temperature difference between the cold region and the hot region, and an airflow over them; and

a controller configured to alter the airflow rate over one of the regions, whereby heat is exchanged to the environment in a controlled manner to regulate the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

18. The system of claim 17 further comprising a bimetal, the bimetal being thermally insulated from the non-controlled region and configured to be placed in thermal contact with at least a portion of the controlled region

19. The system of claim 18 wherein the heat exchange between one of the regions and the environment is controlled, at least in part, by the thermal expansion of the bimetal.

20. The system of claim 19 wherein the temperature of the controlled region is user adjustable.

21. A controller for regulating the temperature of a heating or cooling device comprising:

an element of high thermal conductivity, the element configured to be placed in thermal contact with at least a portion of a cold region of a heating or cooling device and at least a portion of a hot region of a heating or cooling device, the element further configured to create a path for heat exchange between the portion of contacted hot region and the portion of contacted cold region, whereby the heat exchange is controlled to regulate the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

22. A fluid circuit for regulating the temperature of a heating or cooling device comprising:

a channel with a fluid therethrough, the fluid circuit configured to be placed in thermal contact with at least a portion of a cold region of a heating or cooling device and at least a portion of a hot region of a heating or cooling device, the fluid circuit further configured to create a path for heat exchange between the portion of contacted hot region and the portion of contacted cold region, whereby the heat exchange is regulated to control the temperature of one of the regions, resulting in a controlled region and a non-controlled region.

23. A controller for regulating the temperature of a heating or cooling device wherein the controller is configured to alter the airflow rate over a cold or hot region of a heating or cooling device, whereby heat is exchanged to the environment in a controlled manner to regulate the temperature of one of the cold or hot regions, resulting in a controlled region and a non-controlled region.

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