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(54) HIGH PERFORMANCE THERMOELECTRIC SYSTEMS

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(57) **ABSTRACT**

A high performance thermoelectric system is taught which is capable of rapidly cooling a thermal load with a thermoelectric module. A thermal ballast is in simultaneous thermal communication with both the thermoelectric module and the thermal load, and compensates for the difference between the characteristics of the thermoelectric module and the demands of the thermal load, allowing a thermoelectric module to handle significantly larger thermal loads than would normally be possible, albeit for a reduced period of time. Also taught is a means to implement a demand cooler for drinking water. Also taught is a means to implement a high performance cooler for removable fluid containers, adaptable to the rapid cooling of wine bottles and the like.

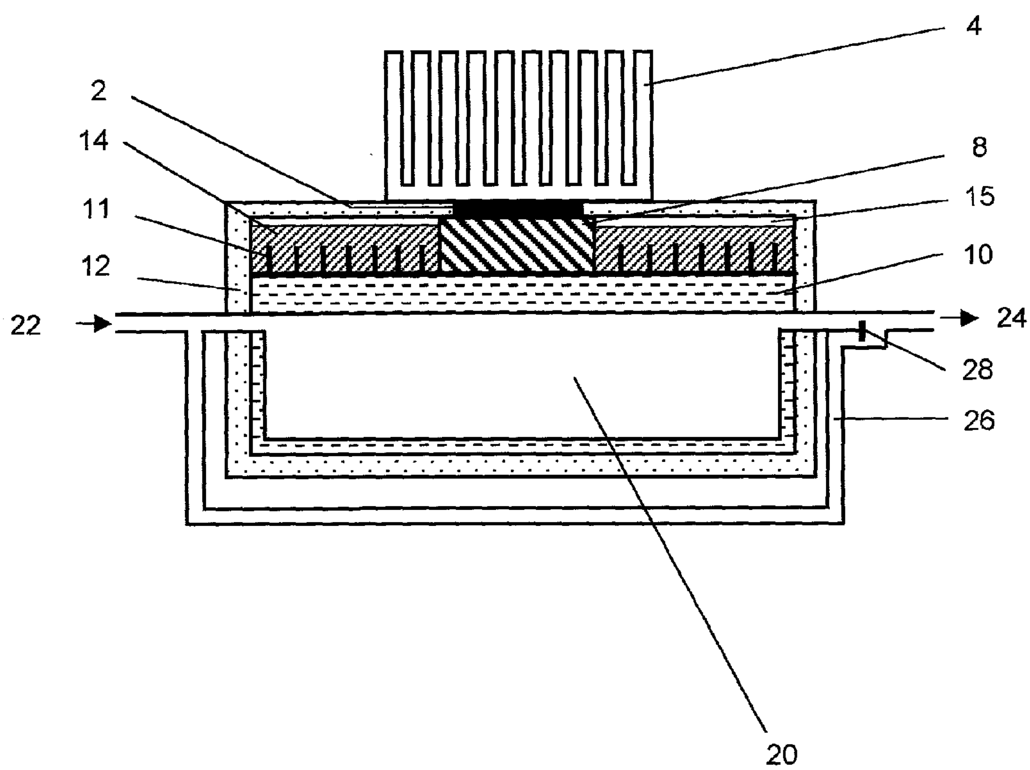


Figure 1

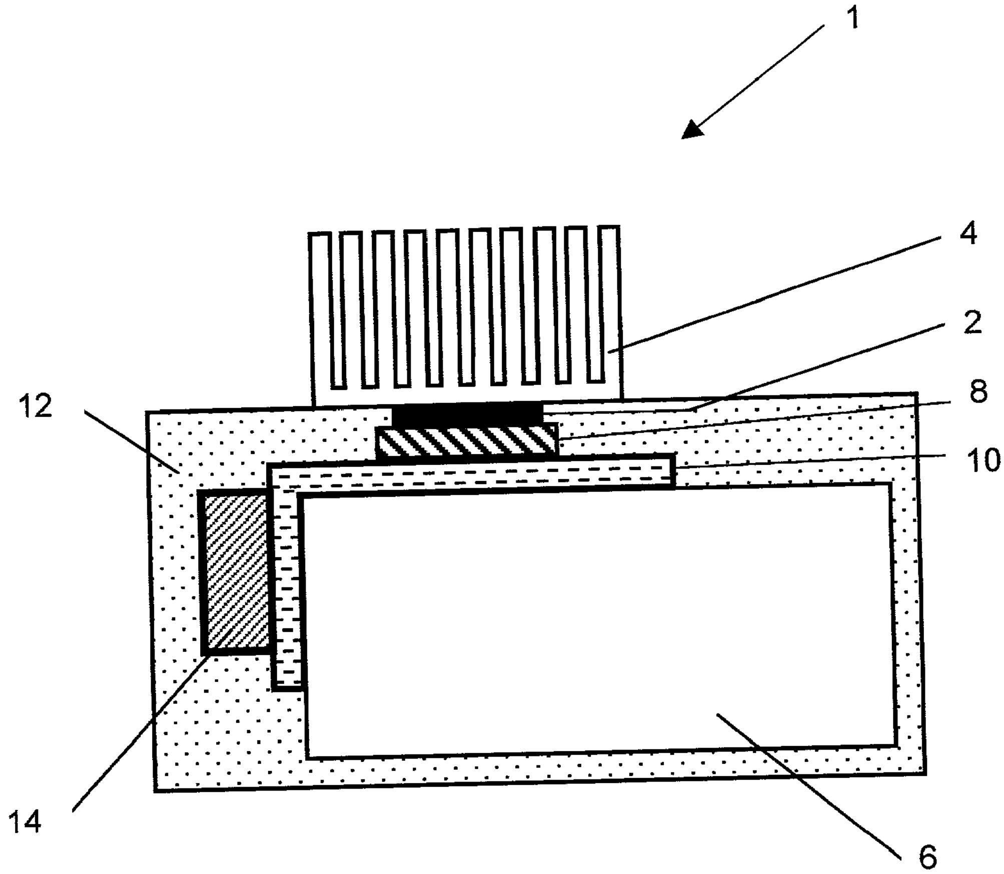


Figure 2

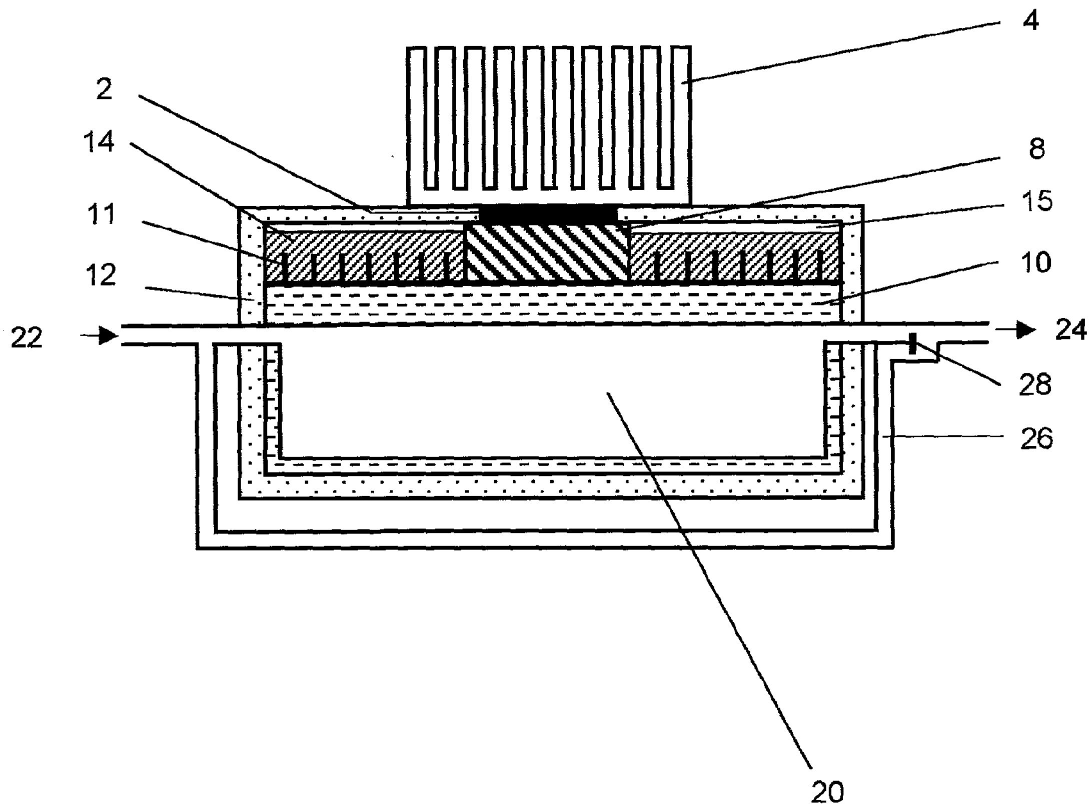


Figure 3

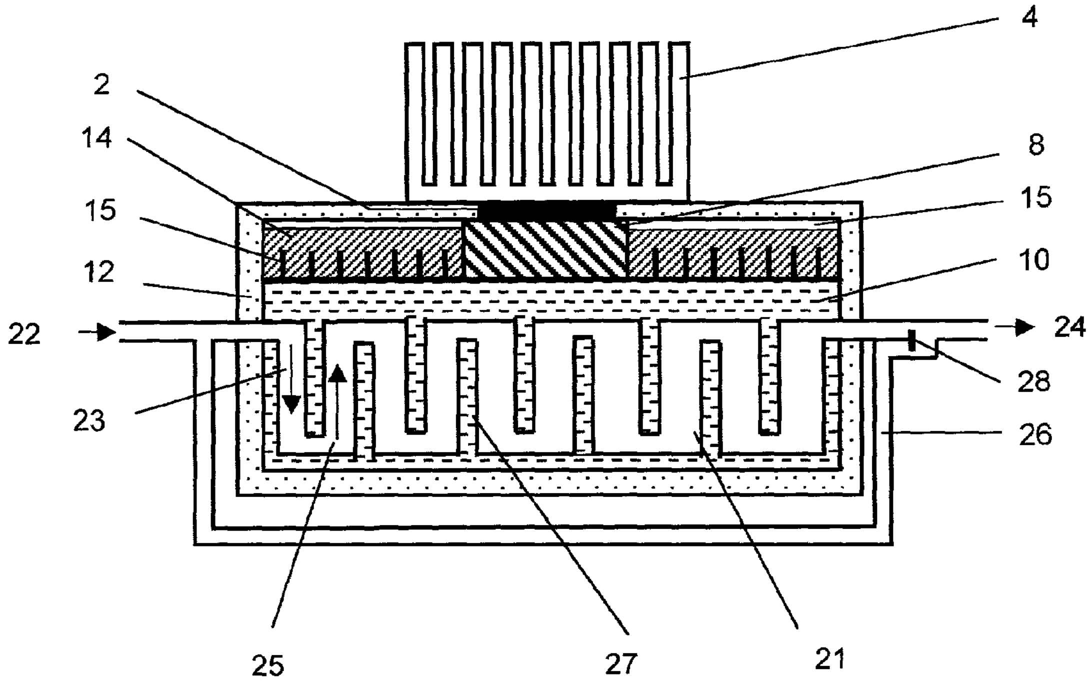


Figure 4

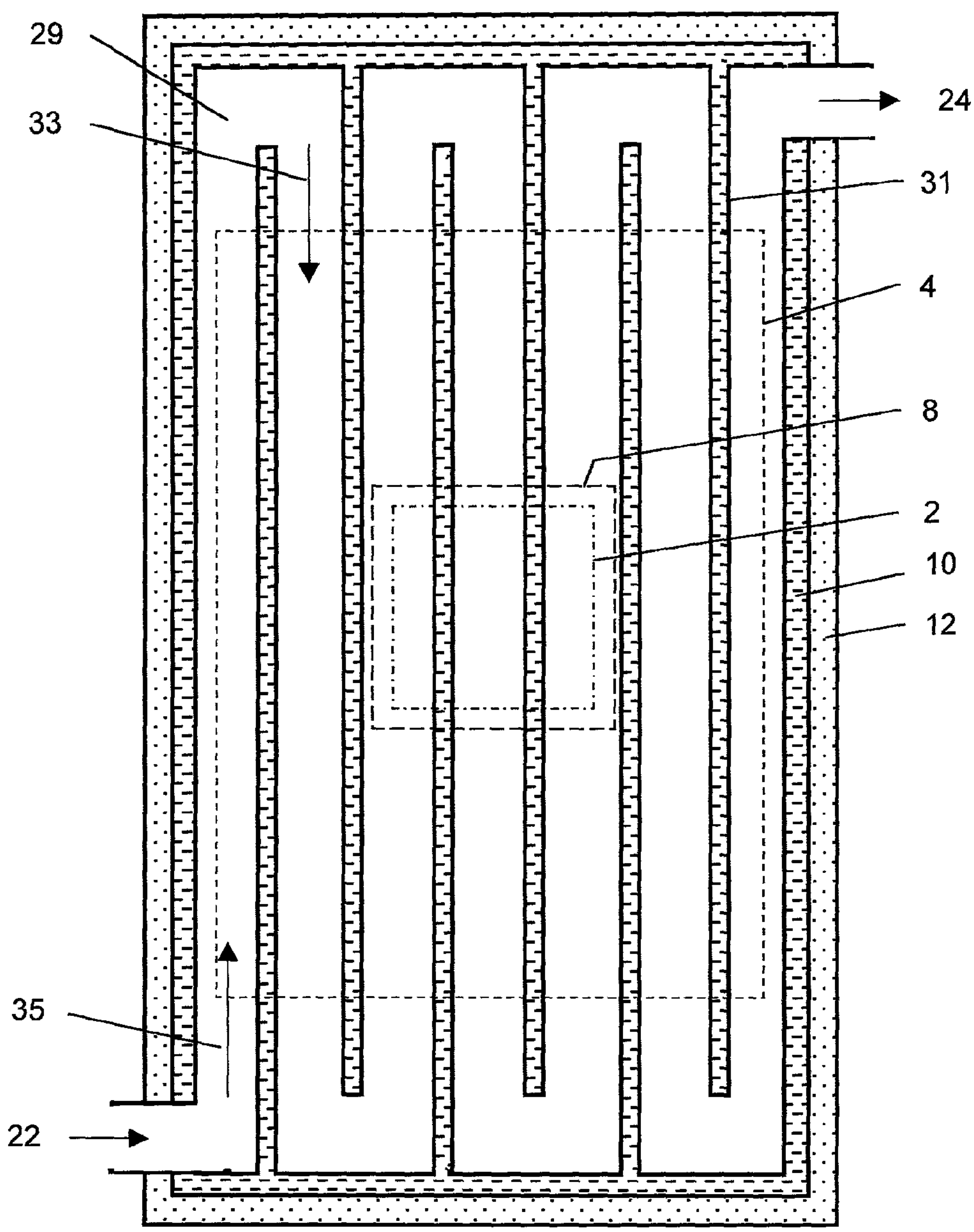


Figure 5

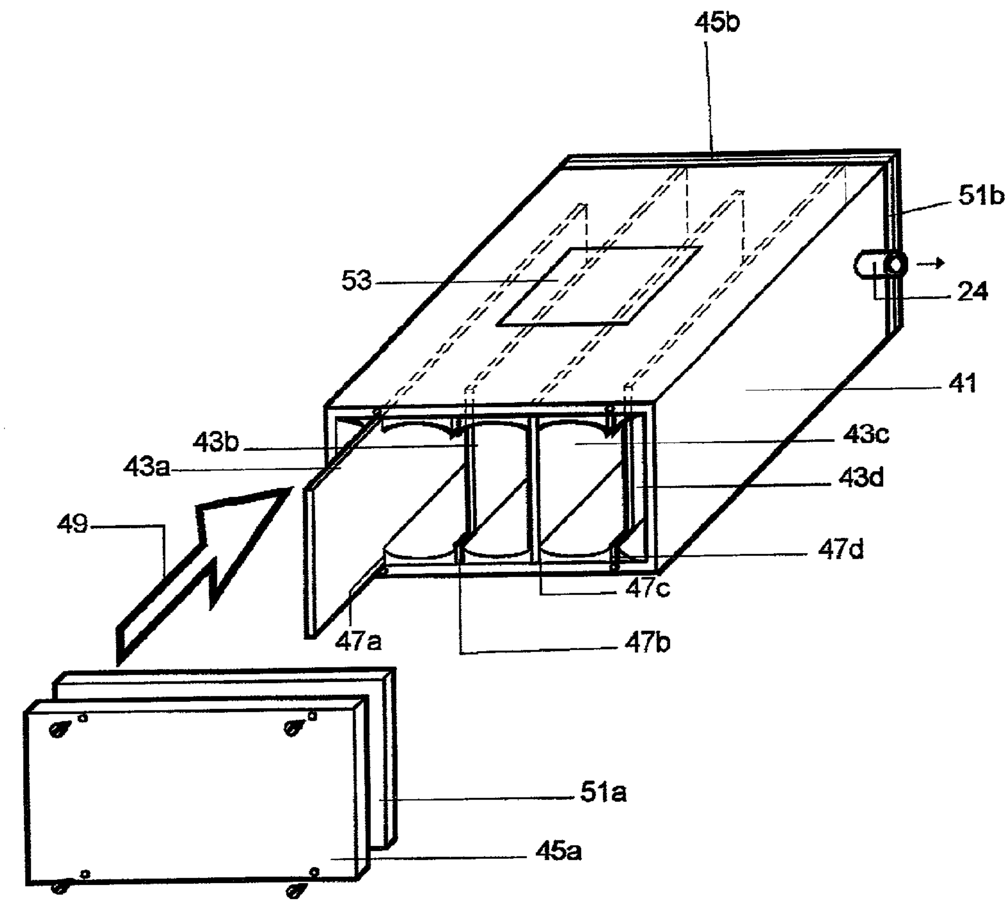


Figure 6

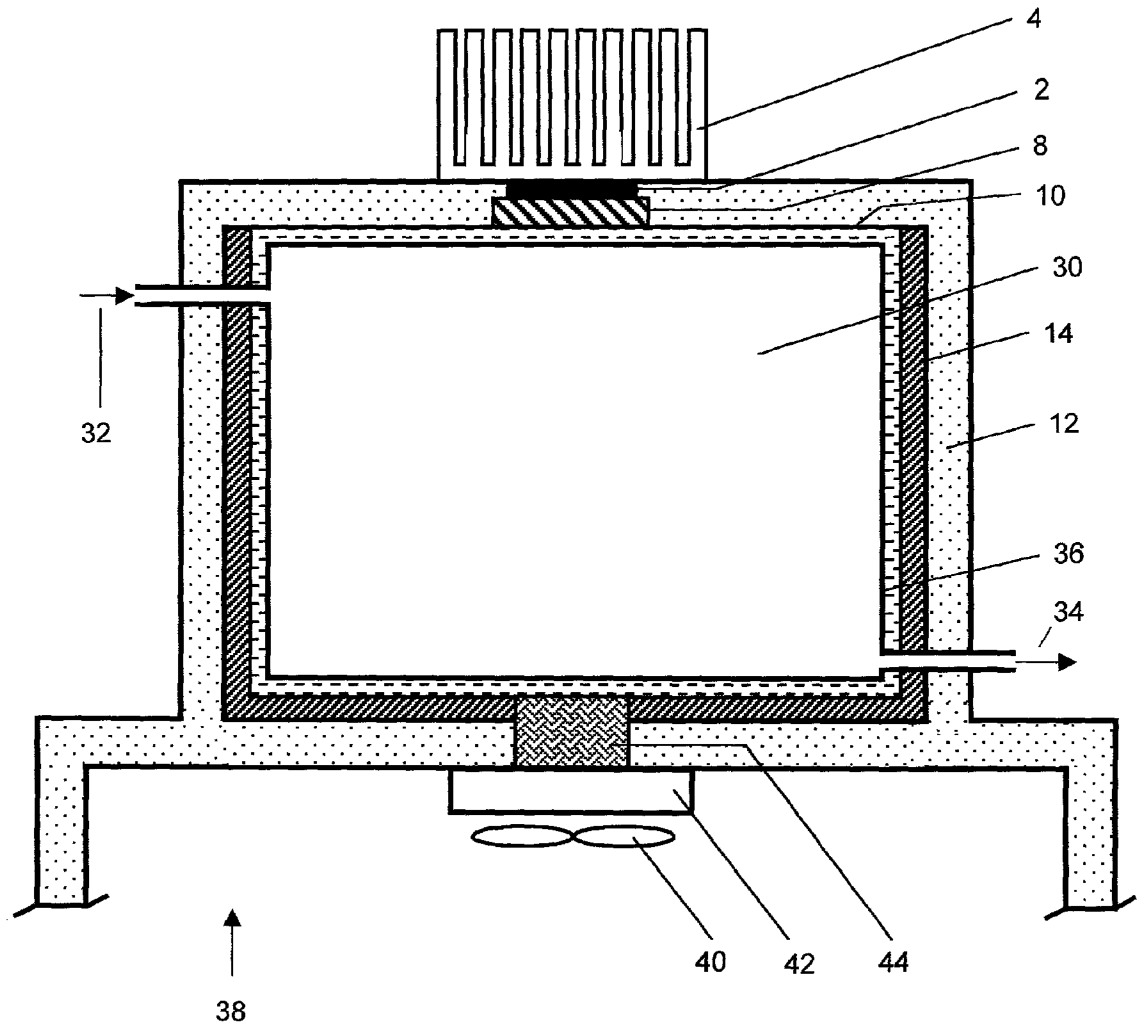


Figure 7

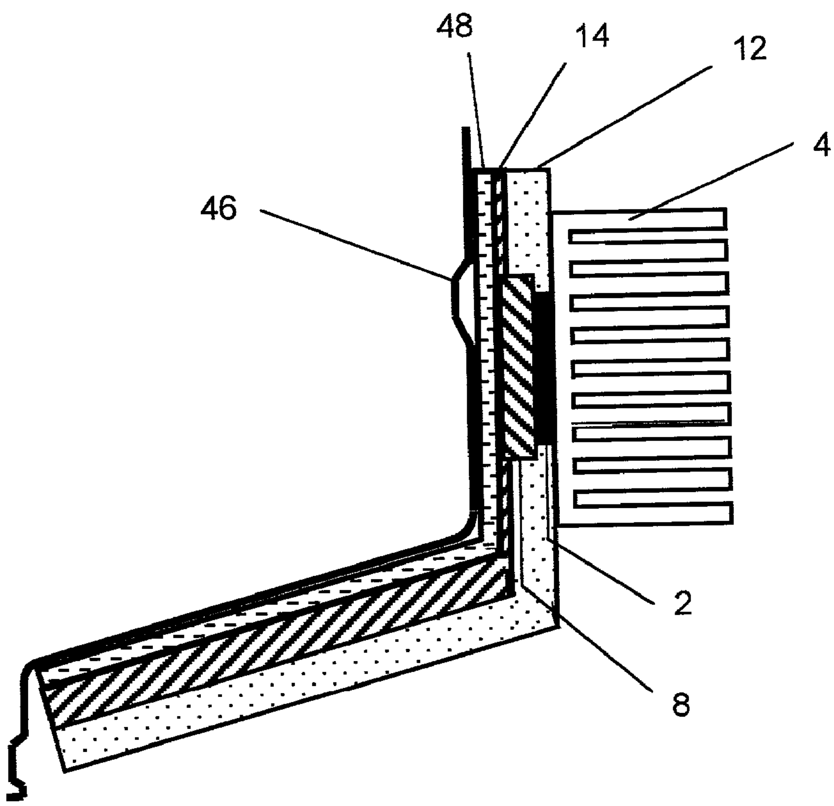


Figure 8

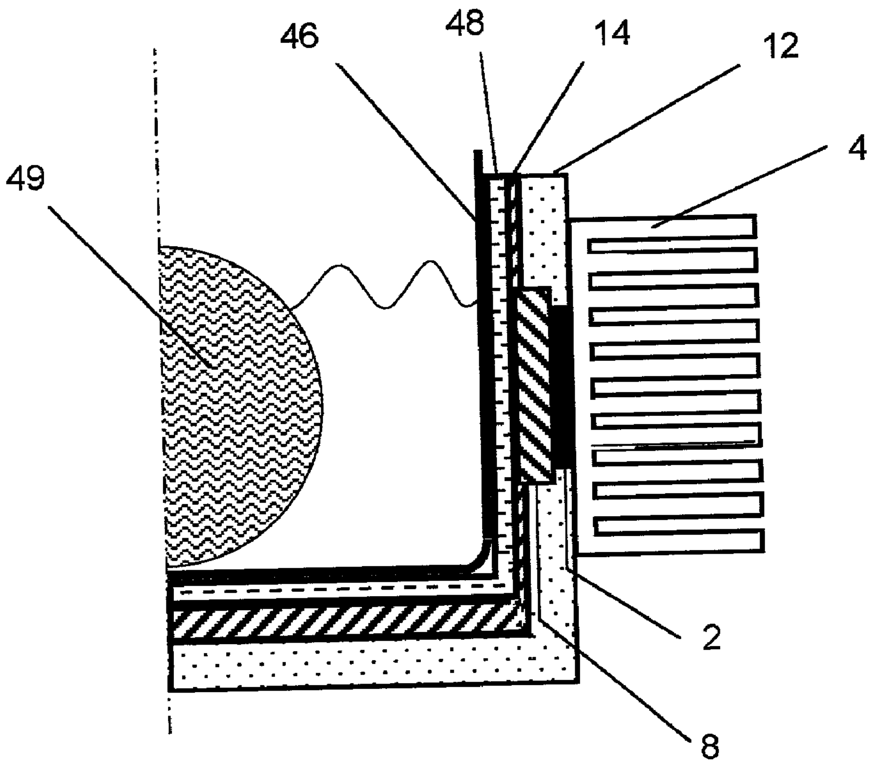
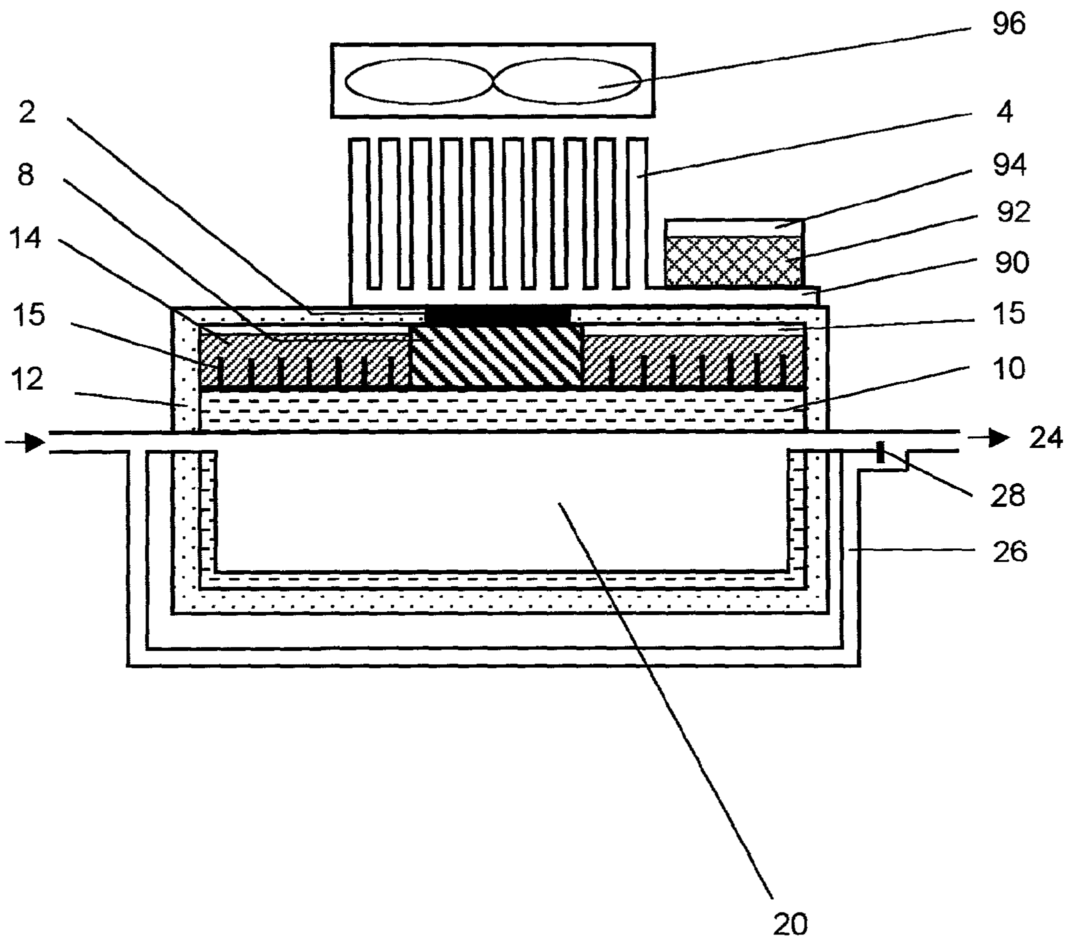


Figure 9



HIGH PERFORMANCE THERMOELECTRIC SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. patent application serial No. 60/288,418 filed May 4, 2001, which application is pending.

FIELD OF THE INVENTION

[0002] This invention relates to an optimized configuration for high performance thermoelectric systems. A thermal ballast functions as an auxiliary thermal storage device that is in simultaneous thermal communication with both the thermoelectric module and the load, and compensates for the different thermal characteristics of the thermoelectric module and the load. A thermal ballast configured in this manner allows a single thermoelectric module to handle significantly larger thermal loads than would normally be possible, albeit for a reduced period of time.

BACKGROUND OF THE INVENTION

[0003] Thermoelectric modules have been around for a number of years and offer several advantages over compressor based cooling systems including small size, portability, durability, and environmental safety. However one significant drawback of these devices is their relatively low cooling (or heating) rates.

[0004] There have been several attempts to improve the cooling rates through various thermoelectric module configurations (e.g. parallel and/or serial configurations), and improved thermoelectric module technical designs to provide higher heat pumping rates and higher temperature differentials across the module. Also, designers have attempted to improve the thermal interfaces between the thermoelectric module, heat sink, and load to improve the overall performance of the system. More recent developments include the use of a thermal battery to store the cold (or lack of heat) or heat produced by a thermoelectric module, or some other type of cooling or heating device, for later use.

[0005] U.S. Pat. No. 6,370,884 issued Apr. 16, 2002 to Kelada teaches a form of high performance thermoelectric system, however the performance is obtained by deploying a multiple of thermoelectric devices with one illustration showing a quantity of eight such devices so deployed. It is doubtful that the large quantity of heat produced by such a configuration could be dissipated rapidly enough to maintain the water flowing through the system at the stated 40F for any length of time. Further, this is an extremely expensive way to build a high performance thermoelectric system.

[0006] U.S. Pat. No. 6,247,522 issued Jun. 19, 2001, to Kaplan, et al, teaches a thermal storage unit designed for the storage and later use of thermal energy on a larger scale, for example the later use of energy purchased during low cost off-peak hours. Energy is transferred to and from the thermal storage unit using a heat transfer fluid. While this patent suggests the use of phase change material in the thermal storage unit, it does not address the use of this material in, nor is it adaptable to, high performance thermoelectric systems.

[0007] U.S. Pat. No. 6,105,659 issued Aug. 22, 2000 to Pocol, et al teaches a device for the storage and transfer of thermal energy with the storage or recharge function being accomplished through one thermal interface and the further transfer of the stored thermal energy being accomplished through a second thermal interface, the configuration being optimized for the transfer of energy between the device and a gas. This patent focuses on the two thermal interfaces (e.g. the use of metallic powders that may be attractively positioned on membrane walls) but does not address such practical matters as the removal of heat produced by the thermoelectric heat pump(s) used to recharge the system. The design is inherently inefficient because it does require two separate thermal interfaces rather than one, and it does not seem to address the issues of thermal conductivity within the phase change material used for energy storage. Further, it does not lend itself to such common and practical applications as rapidly chilling a quantity of fluid with a single thermoelectric module.

[0008] U.S. Pat. No. 4,951,481 issued Aug. 28, 1990, to Negishi (assigned to Sanden Corporation, Japan) teaches a cold preserving container including a cold accumulator enclosing a cold regenerative material. The cold regenerative material is cooled by circulating a cooling medium through an evaporating tube located between the cold accumulator and the container. This is not adaptable to high performance thermoelectric systems since it requires a circulating medium, and the configuration is optimized for the rapidly cooling the cold accumulator rather than the container. It is a well-known fact that a thermoelectric module provides a much slower rate of cooling than a compressor/evaporator system. The Negishi patent will not provide rapid cooling with a single thermoelectric module given these constraints.

[0009] The inventors of the subject invention are also the inventors of U.S. Pat. No. 5,469,708, issued Nov. 28, 1995, and U.S. Ser. No. 09/522,929, to be issued on or about May 1, 2002, the disclosures of which are incorporated herein by reference. These patents describe a water cooler and a combination ice maker and cooler, respectively, both based on thermoelectric technology.

[0010] It is an objective of the present invention to produce rapid cooling with a single thermoelectric module, making possible such devices as a demand cooler for drinking water, a high performance cooler for removable fluid containers, a rapid chiller for wine bottles, and several other embodiments not possible given the prior art. These and other objectives and advantages of the present invention will become apparent from the reading of the attached specification and appended claims.

SUMMARY OF THE INVENTION

[0011] The present inventors have optimized the performance of thermoelectric systems by configuring a thermal ballast as an auxiliary thermal storage device in order to accommodate the difference in thermal characteristics between the thermoelectric module and the load, and to maximize the combined thermal transfer rates of both the thermal ballast and the thermoelectric module when a load is present. The thermal ballast, thermoelectric module, and the load are in simultaneous thermal communication through a thermal conduit that links the three components together.

(The singular term "thermoelectric module" is understood to represent one or more thermoelectric modules, as may be required by a particular application, unless otherwise stated throughout this document.)

[0012] In most cases thermal loads are intermittent and require a high rate of heat transfer for a relatively short period of time. A thermoelectric module, on the other hand, has a substantially different characteristic since it performs best with a steady thermal load that requires a relatively low rate of heat transfer. This relatively low rate of heat transfer determines the maximum cooling rate in almost all thermoelectric applications. The usual approach is to leave the thermoelectric module on for an extended period of time such that the required amount of heat is eventually removed from the load. This does work, however it takes much longer than desirable from a user's perspective.

[0013] The present inventors have addressed this problem by devising a way to configure a thermal ballast, or auxiliary thermal storage device, such that it is in simultaneous thermal communication with both the thermoelectric module and the load. This facilitates the interflow of heat between the thermal ballast, thermoelectric module, and the load, and allows the thermoelectric module to be located where it can be configured with an appropriate heat sink to dissipate heat into the ambient air.

[0014] A thermal ballast is generally a passive component capable storing either "heat" or "cold" (i.e. the lack of heat). Further, a thermal ballast may absorb or release heat at various transfer rates. A maximum heat transfer rate may be achieved by increasing the surface area of the thermal interface between the thermal ballast and the load, and by keeping the thermal ballast relatively thin so as to not encounter limitations related to thermal conductivity within the thermal ballast itself. In a cooling application the thermoelectric module may pump heat slowly out of the thermal ballast until it is fully charged. Then the thermal ballast is ready to absorb heat very rapidly from the load over a short space of time. The thermal ballast serves as an auxiliary thermal storage device that ideally matches the basic characteristics of both the thermoelectric module and the load.

[0015] It follows that a thermal ballast may satisfy the load requirements while operating under the constraints of the thermoelectric module. The intermittent characteristic of the load means that the imbalance in heat transfer rates will only need to be supported for a short period of time. This will work providing that the total heat absorbed by the thermoelectric module from the thermal ballast substantially equals the total heat absorbed by the thermal ballast from the load over a given period of time.

[0016] The configuration may be further improved by allowing the thermoelectric module and the thermal ballast to simultaneously absorb heat from the load. This contrasts sharply with current configurations which utilize a thermal battery, rather than a thermal ballast, configured as a passive "flow through" component—i.e. the thermoelectric module can only remove heat from the thermal battery which then in turn can only remove heat from the load.

[0017] The thermal ballast, thermoelectric module, and the load are in simultaneous thermal communication through a thermal conduit that links the three components together. This allows the thermoelectric module and the thermal ballast to simultaneously absorb heat from the load, effectively increasing the rate at which heat may be removed from the load and reducing cooling times substantially. The same thermal conduit may then be used by the thermoelectric module to remove heat from the thermal ballast in preparation for the next load cycle. The thermal conduit allows for this universal flow of heat between the components as determined by standard thermodynamic principles.

[0018] A suitable analogy in this case might be a simple savings account that is used to accumulate funds for an annual vacation. The cost of the vacation (i.e. the load) is high and intermittent. On the other hand the savings rate (i.e. the thermoelectric module) will be slow and steady. The ATM network (i.e. the thermal conduit) allows the user to maximize vacation spending by accessing the saved amount (i.e. the thermal ballast) plus any further savings that might be automatically deposited during this time (additive effect of thermoelectric module while load is present) Similar to the thermal system described above, the imbalance in cash transfer rates only needs to be supported for a short period of time, and the effect may be to reduce the savings account balance to zero by the end of the vacation. Then, regular savings will resume to increase the account balance in time for the next annual vacation.

[0019] Just as in the case of the savings account, which must be "sized" to fund the annual vacation, the thermal ballast must be sized to match the characteristics of the load. Similar to the savings rate, the heat transfer rate provided by the thermoelectric module must be sufficient to ensure that the thermal ballast is prepared for the next load cycle. Whereas the savings account operates on a cash balance basis, the thermal ballast will operate on a heat energy balance basis.

[0020] There are several benefits to using a thermal ballast within a thermoelectric system, including the requirement for a smaller thermoelectric module, a smaller heat sink, and a smaller (and quieter) fan. These are significant benefits since one of the major challenges in thermoelectric design is to quickly and quietly dissipate the heat produced by the thermoelectric module into the ambient air. Since a thermoelectric module is a heat pump, the heat that must be dissipated equals the electrical energy input plus the heat removed from the load. In other words the heat must be dissipated at a greater rate than the thermoelectric module's cooling rate. Thus, a reduction in the cooling requirement by "x" watts will reduce the heat dissipation requirements by substantially more than "x" watts.

[0021] The thermal ballast itself may be made of any material that can store thermal energy, and release it at varying rates. This may be a solid, a liquid, or some combination thereof. A purely solid or liquid thermal ballast will store sensible heat, meaning that the temperature will rise as heat is absorbed or conversely drop as the heat is removed.

[0022] A combined solid/liquid thermal ballast will also store thermal energy, however in this case it is stored as latent heat as the material changes state. This type of thermal ballast may be made from a specialized Phase Change Material (PCM) that is designed to change state a very specific temperature.

[0023] A PCM thermal ballast has two important benefits: (1) the latent heat stored during the change of state is substantially greater than the sensible heat that may be stored by changing the temperature within a given state and (2) the change of state occurs at a constant temperature. The first benefit means that a PCM thermal ballast may be much smaller and compact than a solid or liquid thermal ballast. However the second benefit is of particular importance since thermoelectric systems do not have a great deal of inherent thermal stability—i.e. the temperatures within the system tend to fluctuate widely. The addition of a PCM thermal ballast may stabilize the load temperature at a steady level, and the thermoelectric module will simply act as a heat pump to transfer energy out of the PCM thermal ballast at that steady temperature.

[0024] While not as effective or compact as a PCM thermal ballast, a solid or liquid thermal ballast may be less expensive in certain applications. This type of thermal ballast may be implemented by simply adding thermal gel, water, or a metal such as copper or aluminium to the existing thermal conduit between the thermoelectric module and the load. A solid or liquid thermal ballast may not function at a steady temperature, but it will add to the thermal stability of the system since a greater amount of heat transfer will be required to effect a given temperature change.

[0025] A thermal ballast may also be used on the hot side of a thermoelectric module to increase the stability of the thermal system. Thermoelectric modules generally operate with a fixed temperature differential between the thermal interfaces, and therefore any change in the hot side temperature also tends to affect the cold side temperature. Given that hot side temperature changes are most often caused by changes in the ambient temperature, it follows that thermoelectric module cold side temperatures are also affected by ambient conditions. This sensitivity can be reduced by placing a PCM thermal ballast in thermal communication with the hot side of the thermoelectric module and the heat sink in order to keep the hot side temperature relatively constant as the ambient temperature fluctuates. The ability to accommodate changes in heat dissipation rates caused by the now fluctuating differential between hot side and ambient temperatures is an inherent function of the PCM thermal ballast as described above.

[0026] While the primary function of a thermal ballast is to act as an auxiliary thermal storage device, it can also be designed to aid in the heat transfer process by accommodating differences in the surface area of components that must be in thermal communication and/or by accommodating the impact of a variable heat flux over these surfaces. Thermoelectric modules are generally quite small with a high but constant heat flux across the thermal interfaces—i.e. they are capable of pumping a tremendous amount of heat through a relatively small surface area. Quiet often the challenge is to collect this heat from a much larger surface area and "funnel" it through the thermoelectric module. In some applications this larger surface area has a variable heat flux—i.e. the heat transferred through the surface varies from point to point across the surface, and these different heat transfer rates can fluctuate independently over time. This is, in fact, one of the major concerns when designing a cooling system for electronic components such as Intel's Pentium IV processor.

[0027] A thermal ballast is capable of transferring heat at different rates across its surface, and therefore it is effective when used in these variable heat flux applications. Further, a PCM thermal ballast may be used to effectively hold the temperature of the device constant across the surface regardless of the variations in heat flux. Finally, a thermal ballast may be designed to "collect" the heat from a large surface at varying rates, and to "funnel" the heat into the much smaller thermoelectric module at a slow but steady rate. The efficiency of this "funnelling" process may be increased by utilizing a high heat transfer rate dispersion plate as a thermal conduit between the thermal ballast and the thermoelectric module, effectively increasing the surface area of the thermoelectric module.

[0028] A dispersion plate may be used to accommodate for differences in surface area on both the cold side and the hot side of a thermoelectric module. Further, the dispersion plate may be made from a solid piece of material, one or more phase change heat pipes, a self contained circulation of heat conducting fluid, or some combination of thereof. On the hot side of the thermoelectric module, it is possible that the combination of a dispersion plate, a thermal ballast, and a heat sink with sufficient surface area and sufficient natural convection characteristics, as might be possible with some ceramic materials, may be sufficient to preclude the requirement for a forced convection cooling system. In an efficient design this type of heat sink could be built into the exterior surface of the cabinet surrounding the thermoelectric system to reduce the overall size of the device.

BRIEF DESCRITION OF THE DRAWINGS

[0029] Embodiments of the invention are described by way of example with reference to the following diagrams in which;

[0030] **FIG. 1** provides an overview of a high performance thermoelectric system with a thermal ballast and a thermal conduit,

[0031] **FIG. 2** is a side section view of a high performance thermoelectric system designed to rapidly chill a fluid,

[0032] **FIG. 3** is a side section view of a demand fluid cooler utilizing vertical partitions,

[0033] **FIG. 4** is a bottom section view of a demand fluid cooler utilizing longitudinal partitions,

[0034] **FIG. 5** is an exploded view of demand fluid cooler heat exchanger,

[0035] **FIG. 6** is a side section view of reservoir fluid cooler with an auxiliary chilled cabinet,

[0036] **FIG. 7** is a partial section view of fluid cooler for removable fluid bottles,

[0037] **FIG. 8** is a partial section view of a rapid chiller for wine bottles, and

[0038] **FIG. 9** is a side section view of a high performance thermoelectric system with a hot side thermal ballast and a hot side thermal conduit.

DESCRIPTION OF A PREFERRED EMBODIMENT

[0039] **FIG. 1** illustrates a high performance thermoelectric system **1** with thermoelectric module **2**, thermal load **6**, and thermal ballast **14**. The purpose of this system is to remove heat from, or cool, thermal load **6** and disperse this heat into the ambient air through heat sink **4**. All components except heat sink **4**, and the hot side of thermoelectric module **2**, are surrounded by insulation **12** to substantially prevent the ingress of heat from the warmer ambient air.

[**0040**] Thermal conduit **10** facilitates the simultaneous interflow of heat between thermoelectric module **2**, thermal load **6**, and thermal ballast **14**. Thermal conduit **10** allows heat from thermal load **6** to be absorbed rapidly by thermal ballast **14** through a large surface area of thermal load **6**, and then later pumped out of thermal ballast **14** by thermoelectric module **2** through a much smaller surface area of spacer block **8**. Thermal ballast **14** and thermal conduit **10** will remain at substantially the same temperature since they are in direct thermal communication.

[**0041**] Spacer block **8** allows for the installation of sufficient insulation **12** between heat sink **4** and thermal conduit **10**, such that heat does not flow directly back from heat sink **4** to thermal conduit **10**. In this application spacer block **8** and thermal conduit **10** may be further integrated to form one composite part in order to avoid any possible thermal losses in the interface between the two underlying components.

[**0042**] Thermoelectric module **2** may initially pump heat from thermal ballast **14** through thermal conduit **10** and spacer block **8**. In a cooling application thermal ballast **14** acts as an auxiliary thermal storage device by retaining this absence of heat.

[**0043**] When thermal ballast **14** is constructed of a solid or liquid material, the temperature of thermal ballast **14** and thermal conduit **10** will fall as sensible heat is removed from the combined assembly. The rate at which the temperature of thermal conduit **10** falls will be reduced by the presence of thermal ballast **14** since more heat must be removed for each degree of temperature change due to the increased mass of the combined assembly.

[**0044**] When thermal ballast **14** is made of Phase Change Materials (PCM), then the temperature of PCM thermal ballast **14** and thermal conduit **10** will fall to the freezing temperature of the PCM and remain at that temperature until PCM thermal ballast **14** completely changes state. The latent heat that must be removed to change the state of the PCM is substantially greater than the sensible heat that must be removed to change the temperature of the PCM while it remains in a single state. Therefore PCM thermal ballast **14** is capable of storing the absence of a much greater amount of heat than a solid or liquid thermal ballast **14**.

[**0045**] The freezing point of PCM thermal ballast **14** may be selected to be somewhat below the desired temperature of thermal load **6** such that a thermal gradient will exist between thermal load **6** and thermal ballast **14**, encouraging the natural flow of heat from the former to the latter through thermal conduit **10**. Note that the freezing point of PCM thermal ballast **14** may be any temperature within a very wide range, and does not necessarily mean the freezing point of water or the temperature at which ice forms. The freezing point of PCM thermal ballast **14** is the temperature at which the material within PCM thermal ballast **14** changes state from liquid to solid.

[**0046**] During normal operation thermoelectric module **2** may be turned on before thermal load **6** is applied to the system, and will continue to operate until the temperature of thermal ballast **14** and thermal conduit **10** reaches a preset value. In the case of a PCM thermal ballast **14**, this preset value may be set at a temperature somewhat below the PCM freezing point, ensuring that the PCM has completely changed state and that a maximum amount of heat has been removed from PCM thermal ballast **14** before thermoelectric module **2** is turned off again.

[**0047**] Thermal load **6**, when introduced to the system, may be at a much higher temperature than thermal ballast **14** and thermal conduit **10**. Thermal ballast **14** will immediately begin to absorb heat from thermal load **6**, through thermal conduit **10**. The temperature of thermal load **6** will drop more rapidly than possible with only thermoelectric module **6** because thermal ballast **14** is able to absorb heat much more rapidly than possible with a thermoelectric heat pump.

[**0048**] In the case of PCM thermal ballast, the temperature of PCM thermal ballast **14** will remain at the PCM freezing point as heat is being rapidly absorbed from thermal load **6** unless the net amount of heat absorbed by PCM thermal ballast **14** exceeds the latent heat required to melt the PCM contained within PCM thermal ballast **14**. This is an extremely important feature of a PCM thermal ballast since it means that an optimum temperature gradient will always exist between thermal load **6** and thermal ballast **14**, ensuring that heat from thermal load **6** will be absorbed by thermal ballast **14** at a maximum rate.

[**0049**] The heat absorbed by thermal ballast **14** will cause its temperature to rise, further causing the power to be applied to thermoelectric module **2** by a control circuit. In the case of a PCM thermal ballast **14** the temperature will initially rise to the freezing point of the PCM material, and then remain at that point as the PCM material absorbs heat and begins to melt. The control circuit will sense this initial rise in temperature, and cause power to be applied to thermoelectric module **2**, since the preset value for turning off thermoelectric module **2** may be set at a temperature just below the PCM freezing point as described in a previous paragraph.

[**0050**] Thermoelectric module **2** will then be turned on again to simultaneously pump additional heat from thermal load **6**, through thermal conduit **10** and spacer block **8**, and out through heat sink **4** to be dispersed into the ambient air using natural and/or forced convection. This will further increase the rate of cooling of thermal load **6** beyond that possible with only thermal ballast **14**. This combined cooling effect is possible since thermal load **6**, thermoelectric module **2**, and thermal ballast **14** are in simultaneous thermal communication through thermal conduit **10**.

[**0051**] Thermoelectric module **2** will continue to pump heat from thermal load **6** until such time as thermal load **6** and thermal ballast **14** are in thermal equilibrium. Then, thermoelectric module **2** will remain on to continue to pump heat from thermal load **6** and thermal ballast **14** until a set point is reached, indicating that thermal load **6** has reached its target temperature and that a maximum amount of heat has been removed from thermal ballast **14**—i.e. that the system is completely prepared for a next thermal load **6**. In the case of a solid or liquid thermal ballast, this set point may be determined by sensing the temperature of thermal ballast **14** and thermal conduit **10** at a value somewhat below the desired temperature of thermal load **6**. In the case of a PCM thermal ballast **14**, the steady state temperature of thermal load **6** will be closely linked to the fixed PCM freezing point, and the set-point may be determined by sensing a temperature of PCM thermal ballast **14** that is somewhat below the PCM freezing point.

[**0052**] A variable temperature control may be more easily implemented with a solid or liquid thermal ballast **14** because of the direct relationship between sensible heat and temperature, however performance will not match that of a PCM thermal ballast **14**. It is possible to implement a variable temperature control with a PCM thermal ballast **14**, however this is best suited to a variance of set points at or below the inherent set point based on the PCM freezing point. This is because a PCM thermal ballast **14** will act as a PCM thermal ballast **14** until frozen, and then it will act as a solid thermal ballast **14** and be responsive to sensible heat. A set point which is above the inherent set point (based on the PCM freezing point) would not allow the system to take advantage of the large latent heat absorption capabilities of the PCM material at its freezing point. Alternate strategies for variable set points may include the use of multiple PCM thermal ballasts having various freezing points within the required range of set-point temperatures. In this case the multiple PCM thermal ballasts would also be capable of storing a greater total amount of latent heat, contributing to the overall performance of the system.

[**0053**] **FIG. 2** is a side view of a high performance thermoelectric system designed to rapidly chill a fluid flowing through fluid chamber **20** having inlet **22** and outlet **24**. Thermal conduit **10** may be in thermal communication with thermal ballast **14**, and with thermoelectric module **2** through spacer block **8**. In this case spacer block **8** has been extended to create a greater space between thermoelectric module **2** and thermal conduit **10**, allowing thermal ballast **14** to be located in this area. Thermal ballast **14**, spacer block **8**, and thermal conduit **10**, containing fluid chamber **20**, may be surrounded by insulation **12** to substantially prevent the absorption of heat from the surrounding air.

[**0054**] The thermal communication between thermal conduit **10** and thermal ballast **14** may be improved through the use of thermal fins **11**. Ultimately, thermal fins **11** improve the rate at which thermal ballast **14** may absorb heat from the load, in this case the fluid within fluid chamber **20**.

[**0055**] Of note is the fact that thermal ballast **14** may be comprised of a PCM in a powder or liquid format. These types of PCM will naturally tend to flow or settle down against thermal barrier **10** and thermal fins **11** when the high performance thermoelectric cooling system is in the illustrated orientation, and this will ensure the best possible thermal interface between thermal ballast **14** and thermal conduit **10**. Air gap **15** will naturally form at the top of thermal ballast **14** as a powder based PCM settles down, or as a liquid based PCM flows down and/or changes volume during a change of state. This will not affect system performance since air gap **15** forms between thermal ballast **14** and insulation **12** (i.e. not between thermal ballast **14** and thermal conduit **10**).

[**0056**] It follows that the high performance thermoelectric cooling system in **FIG. 2** will function best in the orientation shown with thermoelectric module **2** at the top of the system. The system will also function well with the same component configuration and with thermoelectric module **2** at any side of the system since air gap **15** would then form at either end of thermal ballast **14**, perhaps exposing a small portion of thermal conduit **10** to air but otherwise not substantially affecting system performance. However the thermoelectric system in **FIG. 2** will not function well with thermoelectric module **2** at the bottom of the system since air gap **15** would then form between thermal ballast **14** and thermal conduit **10**, substantially reducing thermal communication between these two components.

[**0057**] The thermal communication between thermal conduit **10** and the fluid contained within fluid chamber **20** may be improved by extending thermal conduit **10** such that it surrounds fluid chamber **20** on all sides, thereby establishing maximum thermal contact between thermal conduit **10** and the fluid within fluid chamber **20**. This thermal contact may be further improved by pressurizing the fluid within fluid chamber **20**, and ensuring that there are no gas bubbles trapped within the system that might form a gap between the fluid within fluid chamber **20** and any part of thermal conduit **10**.

[**0058**] The system may be used to rapidly chill a fluid flowing through fluid chamber **20** by first using thermoelectric module **2** to pump as much heat as possible from thermal ballast **14** through thermal conduit **10** and spacer block **8**. In the case of a PCM thermal ballast **14**, thermoelectric module **2** must pump all of the latent heat from the PCM material in order to ensure that it is completely frozen. This process may take place over an extended period of time based on the relatively slow heat pumping capacity of thermoelectric module **2**.

[**0059**] Once thermal ballast **14** is prepared in this manner, fluid may be allowed to flow into fluid chamber **20**. Thermal ballast **14** rapidly absorbs heat from the fluid through thermal conduit **10**, extended to form the walls of fluid chamber **20**. Thermoelectric module **2** may also absorb heat from the fluid through thermal conduit **10**, albeit at a much slower rate. As a result the temperature of the fluid within fluid chamber **20** will drop more rapidly than possible with only thermoelectric module **2** or thermal ballast **14**.

[**0060**] The freezing point of the PCM material contained in thermal ballast **14** may be selected to be substantially below the desired temperature of the fluid leaving fluid chamber **20** in order to establish a wide temperature differential between the two, thus encouraging the rapid flow of heat between the two. However the PCM freezing point must be above the freezing point of the fluid so that any fluid remaining in fluid chamber **20** will not become frozen and block the further flow of fluid through fluid chamber **20**. If the fluid is water, then the PCM freezing point must be above 0 C. (32 F.) to prevent the formation of ice within fluid chamber **20**.

[**0061**] In the case of a PCM thermal ballast, the temperature of PCM ballast **14** will remain constant unless the net amount of heat absorbed by thermal ballast **14** (i.e. the heat absorbed from the fluid in fluid chamber **20** minus the heat pumped out by thermoelectric module **2**) exceeds the latent heat required to melt the PCM contained within PCM thermal ballast **14**. The latent thermal capacity of PCM thermal ballast **14** and the heat pumping capacity of thermoelectric module **2** may be designed to ensure that the temperature of PCM thermal ballast **14** does remain constant for a given total fluid flow through fluid chamber **20**.

Further, the heat pumping capacity of thermoelectric module **2** may be designed to ensure that all of the latent heat within PCM thermal ballast **14** is removed prior to the next requirement for chilled fluid.

[**0062**] The temperature of any fluid remaining in fluid chamber **20** between uses will eventually approach that of thermal ballast **14**. This temperature will be below the required chilled fluid temperature because the fluid is not flowing through fluid chamber **20**. In some cases this may be undesirable since the first fluid leaving the system at outlet **24** will be much colder than normal.

[**0063**] The initial "plug" of colder than normal fluid in fluid chamber **20** may be mixed with warmer fluid flowing through fluid bypass **26** to achieve the desired fluid temperature at outlet **24** as controlled by fluid mixing valve **28**. Besides preventing a potentially undesirable situation, this process actually improves the efficiency of the system by taking advantage of the excess sensible heat that has been removed from the fluid remaining in fluid chamber **20** between uses. Fluid mixing valve **28** may also be used to facilitate temperature control by providing a range of warmer than normal fluid temperatures at outlet **24**.

[**0064**] The contact surface area between fluid chamber **20** and thermal conduit **10** may be designed to achieve the required heat transfer rate between the fluid flowing through fluid chamber **20** and the combined heat absorption capabilities of thermal ballast **14** and thermoelectric module **2**. The required heat transfer rate is dependent upon (1) the temperature of fluid entering fluid chamber **20**, (2) the required temperature drop as the fluid flows through fluid chamber **20**, (3) the fluid flow rate through fluid chamber **20**, (4) the contact area between the fluid and thermal conduit **10**, (5) the steady state temperature of thermal ballast **14** (i.e. the PCM freezing temperature), (6) the specific heat of the fluid, and other design parameters. Once established, the heat transfer rate between the fluid in fluid chamber **20** and thermal conduit **10** will remain relatively the same for as long as the underlying parameters, including the temperature of thermal ballast **14**, remain constant.

[**0065**] **FIG. 3** depicts a configuration that substantially increases the contact area between the fluid within fluid chamber **20** and thermal conduit **10**, thereby allowing for a greater flow of fluid through fluid chamber **10**, providing that the combined capacity of thermal ballast **14** and thermoelectric module meets the increased heat absorption requirements. If designed correctly, this configuration may be used to chill a fluid to a desired temperature as it flows through the system, i.e. it may be used to chill a fluid on demand.

[**0066**] Flow through chamber **21** may be comprised of down flow channels **23** and up flow channels **25**. Fluid flowing into inlet **22** must first flow along down flow channel **23**, and then along up flow channel **25**, and so on before exiting at outlet **24**. The fluid flowing along this extended path is in greater thermal contact with thermal conduit **10**, now extended through vertical thermal partitions **27**, allowing thermal conduit **10** to absorb a substantially greater amount of heat from the fluid flowing in this manner. Fluid remaining in flow through channel **21** after flow has stopped will eventually reach the set-point temperature of thermal ballast **14**, as previously described, and may be mixed with warmer water flowing through fluid bypass **26** to achieve the desired fluid temperature at outlet **24** as controlled by fluid mixing valve **28**, again as previously described.

[**0067**] **FIG. 4** provides a bottom cross sectional view of a demand fluid chiller that may be used to chill a quantity of fluid to a required temperature as it flows through longitudinal flow chamber **29**. Fluid enters the system through inlet **22**, then flows in a first direction as indicated by forward flow arrow **35**, then flows in a second direction as indicated by backward flow arrow **33**, then repeats this process until it exist through outlet **24**. Longitudinal flow chamber **29** may be defined as having a length equal to the total length of all longitudinal sections as separated by longitudinal thermal partitions **31**.

[**0068**] As this is a bottom cross sectional view, thermal conduit **10** extends up and over the top of longitudinal thermal partitions **31**. Thermal conduit **10** is in direct thermal communication with longitudinal thermal partitions **31**, and is ideally formed of the same material as longitudinal thermal partitions **31** as indicated in **FIG. 4**. Spacer block **8**, thermoelectric module **2**, and heat sink **4** are all located above thermal conduit **10** and therefore appear as hidden lines in **FIG. 4**. The chilled components are surrounded by insulation **12** as in previous examples.

[**0069**] Thermal ballast **14** (reference **FIG. 3**) is not shown in **FIG. 4** for clarity, however it is a necessary system component and must be present for the system to function properly. It should be noted, however, that the system will not function efficiently in the upside down position depicted in **FIG. 4** since this orientation may cause air gap **15** to form between thermal ballast **14** and thermal conduit **10** (reference **FIG. 3**).

[**0070**] This configuration substantially increases the contact area between the fluid flowing through longitudinal flow chamber **29** and thermal conduit **10** as well as the duration of time that the fluid spends in longitudinal flow chamber **29** as it flows through longitudinal flow chamber **29**, thereby allowing for a greater reduction in the temperature of the fluid as it flows through the system—providing that the combined capacity of thermal ballast **14** and thermoelectric module **2** meets the increased heat absorption requirements. This configuration may be used to build a demand water cooler for drinking water using a single thermoelectric module **2** and a sufficient quantity of thermal ballast **14** (reference **FIG. 3**).

[**0071**] This configuration further enhances thermal communication between the fluid flowing through longitudinal flow chamber **29** and the large top and bottom sections of thermal conduit **10** since the fluid is in constant contact with the large top and bottom sections of thermal conduit **10**. In particular, the fluid is in constant contact with the main body of thermal conduit **10**, i.e. the large top part of thermal conduit **10** that lies closest to thermal ballast **14** and thermoelectric module **2** (reference **FIG. 3**). For these reasons longitudinal thermal partitions **31** may be made of substantially thinner material than the large top and bottom portions and sides of thermal conduit **10** since their primary function is the containment of fluid flow rather than thermal conductivity.

[**0072**] A plurality of longitudinal thermal partitions **31**, of thin format as described above, may be used to maximize the total length of longitudinal flow channel **29**, therefore optimizing the thermal contact, including surface area and duration, between the fluid flowing through longitudinal flow channel **29** and thermal conduit **10**. Ultimately this will maximize the amount of heat that may be absorbed by thermal conduit **10** from the fluid, further reducing the temperature of the fluid and increasing the effectiveness of the demand chiller.

[**0073**] **FIG. 5** illustrates a method whereby longitudinal flow channel **29** (reference **FIG. 4**) may be constructed from extruded thermal conduit **41**, inserted thermal partitions **43**, and end caps **45**. Extruded thermal conduit **41** is first formed as a hollow extrusion with longitudinal grooves **47***a*, **47***b*, **47***c*, and **47***d* using standard extruding techniques.

[**0074**] Thermal partitions **43***a*, **43***b*, **43***c*, and **43***d* are independently formed having a length less than the length of extruded thermal conduit **41** so as to allow the flow of fluid past one end or the other after being inserted into extruded thermal conduit **41**. Thermal partitions **43***a*, **43***b*, **43***c*, and **43***d* are ideally made from thermally conductive material.

[**0075**] A first thermal partition **43***a* may be inserted into longitudinal groove **47***a* as indicated by insertion arrow **49** until the rear edge of thermal partition **43***a* is flush with the rear edge of extruded thermal conduit **41**. Then, a second thermal partition **43***b* may be inserted into longitudinal groove **47***b*, however in this case it must be inserted until the front edge of thermal partition **43***b* is flush with the front edge of extruded thermal conduit **41**. It follows that thermal partition **47***c* must be inserted until the rear edge is flush, and that thermal partition **47***d* must be inserted until the front edge is flush in an alternating pattern so as to create the required longitudinal flow chamber **29** as depicted in **FIG. 4**.

[**0076**] Thermal partitions may be press fit, bonded in place with an adhesive, or crimped in place by forcing the sides of each longitudinal grooves **47***a*, **47***b*, **47***c*, and **47***d* against the respective thermal partitions, once inserted. The crimping process may be conveniently completed by forcing a slightly oversized tool between the thermal partitions such that the sides of the longitudinal grooves are forced outward against the partitions, thereby holding the partitions in place.

[**0077**] End caps **45***a* and **45***b* may be affixed with using machine screws or some other convenient method, and sealed with gaskets **51***a* and **52***b* respectively, to complete the construction process and form longitudinal flow chamber **29** (reference **FIG. 4**). Alternatively end caps **45***a* and **45***b* may be welded in place. Finally, fixtures for inlet **22** and outlet **24** may be added at either end of longitudinal flow chamber **29** (reference **FIG. 4**).

[**0078**] Thermal interface area **53** may be lapped on the top surface of extruded thermal conduit **41** to facilitate the thermal interface between extruded thermal conduit **41** and spacer block **8** (reference **FIG. 2**). Thermal ballast **14** (reference **FIG. 2**) may also be added to the top surface of extruded thermal conduit **41** as previously described.

[**0079**] **FIG. 6** is a side view of a high performance thermoelectric cooling system with two loads. This system is designed to improve the performance of a chilled water reservoir, and to provide the supplementary capability to further chill an area proximal to the chilled water reservoir.

[**0080**] Chilled reservoir **30** is typical of many water coolers where a small amount of water is allowed to drain into, or is pumped into, a reservoir, which is then chilled by a thermoelectric or compressor based cooling system. The chilled water is then dispensed, allowing additional warm water to enter the reservoir. One of the characteristic problems with this configuration, especially when a thermoelectric cooler is used, is the amount of time taken to chill the next "batch" of water, particularly after the entire reservoir has been drained of chilled water.

[**0081**] The performance of chilled water reservoir **30** may be improved with the addition of thermal conduit **10** and thermal ballast **14**. Thermal ballast **14**, the first load, i.e. the water within chilled reservoir **30**, and thermoelectric module **2** are in thermal communication through thermal conduit **10**. Thermoelectric module **2** may simultaneously pump heat from the fluid contained within chilled reservoir **30** and thermal ballast **14** through thermal conduit **10** and spacer block **8**. In the case of a PCM thermal ballast **14**, thermoelectric module **2** will pump all of the latent heat from PCM thermal ballast **14** such that the material contained therein becomes completely frozen. The freezing point of a PCM thermal ballast **14** may be selected to be slightly below that of the desired fluid temperature within chilled reservoir **30**, but not to the extent that this fluid could itself become frozen.

[**0082**] Warm fluid will enter chilled reservoir **30** through inlet **32** in response to the dispensing of chilled fluid through outlet **34**. Heat from this warm fluid is immediately absorbed by thermal ballast **14**, which acts as an intermediate heat sink to reduce the temperature of the fluid much more rapidly than would normally be possible with only thermoelectric module **2**. The heat absorbed by thermal ballast **14** is then pumped out by thermoelectric module **2** and dissipated through heat sink **4** over time. In the case of a PCM thermal ballast **14**, the temperature of reservoir **30** will remain much more constant as governed by the characteristic freezing temperature of the PCM material. Also, a much smaller PCM thermal ballast may be used since the latent heat absorbed per unit volume is substantially greater than the sensible heat that could be absorbed by a solid or liquid thermal ballast having the same unit volume of material.

[**0083**] In some cooler designs it may be desirable to simultaneously cool a food storage area **38** and chilled reservoir **30** with a single thermoelectric module **2**. Auxiliary heat sink **42** may also be in thermal communication with thermal conduit **10** through auxiliary spacer block **44**. Alternatively, auxiliary heat sink **42** may be in thermal communication with thermal conduit **10** through a heat pipe or any other means as may be required to provide the desired thermal characteristics over the required distance.

[**0084**] In this case thermal ballast **14**, a first load, i.e. the water within chilled reservoir **30**, a second auxiliary load, represented by auxiliary heat sink **42**, and thermoelectric module **2** are in thermal communication through thermal conduit **10**.

[**0085**] Auxiliary heat sink **42** may absorb heat from food storage area **38** slowly through natural convection or more quickly through forced convection by turning on auxiliary fan **40**. The rate of heat absorption may be further controlled by controlling the speed of auxiliary fan **40**. In this manner auxiliary heat sink **42** presents a steady state auxiliary load on thermoelectric module **2** when auxiliary fan **40** is off (i.e. natural convection) and an increased controllable load on thermoelectric module **2** and thermal ballast **14** when auxiliary fan **40** is on (i.e. forced convection). Thermoelectric module **2** must be specified to manage at least this incremental auxiliary load in addition to the thermal loads presented by reservoir **30**.

[**0086**] Auxiliary fan **40** may be left off at all times except when the controller has determined that the fluid within reservoir **30** is at the correct chilled temperature and that all of the sensible and latent heat has been removed from thermal ballast **14**. This condition indicates that the reservoir is ready to dispense chilled fluid and that thermal ballast **14** is conditioned to absorb a maximum amount of heat when warm fluid enters chilled reservoir **30** to replace the dispensed chilled fluid. At that time auxiliary fan **40** may be turned on to allow auxiliary heat sink **42** to absorb heat at a greater rate from food storage area **38** such that this heat may be further absorbed by thermal ballast **14**. This will cause the controller to again turn on thermoelectric module **2** so that this incremental heat, originally from food storage area **38**, may be pumped from thermal ballast **14** and dispersed into the ambient air through heat sink **4**. This process will continue until such time as auxiliary fan **40** is turned off, i.e. when food storage area **38** has reached its target temperature or when additional cooling is required in reservoir **30** as a result of chilled fluid being dispensed through outlet **34**.

[**0087**] **FIG. 7** is a side view of high performance thermoelectric cooler with a cold saddle **48** in intimate thermal contact with a removable fluid container **46**. Cold saddle **48** is a specialized type of thermal conduit that has been formed to mate with removable fluid container **46** over a large surface area in order to provide intimate thermal contact with removable fluid container **46**, and also to support removable fluid container **46**. Cold saddle **48** may be constructed of any rigid material of suitable thermal conductivity, or any flexible material of suitable thermal conductivity in order to adapt to different removable container **46** geometries. The load, represented by removable fluid container **46**, thermal ballast **14**, and thermoelectric module **2** are in thermal communication through the thermal conduit which is, in this case, cold saddle **48**.

[**0088**] Removable fluid container **46**, as shown in **FIG. 7**, is a partial view of an inverted standard 3.0 or 5.0 gallon removable fluid container. It should be noted that the principles taught here may be universally applied to any removable fluid container **46** whether in an upright, sideways, inverted or any other physical orientation.

[**0089**] Thermoelectric module **2** pumps heat from the fluid contained in removable fluid container **46**, through cold saddle **48** and spacer block **8**, and into heat sink **4** where it may be dispersed into the ambient air. Removable fluid container **46** is typically housed within an insulated container such that the entire bottle of fluid may be efficiently chilled.

[**0090**] Thermoelectric module **2** may simultaneously pump heat from thermal ballast **14** through cold saddle **48**. In the case of a PCM thermal ballast **14**, a large amount of latent heat may be pumped from PCM thermal ballast **14** at the characteristic freezing point of the phase change material. This freezing point should be selected to be slightly below the desired water temperature, but not to the extent that it would cause the fluid to freeze. Thermoelectric module **2** may be turned off when the water has reached the desired temperature and all of the latent heat has been removed from PCM thermal ballast **14**.

[**0091**] At such time as a new removable fluid container **46** is placed in the system, thermal ballast **14** will immediately absorb heat from the fluid contained therein at a rate that is faster than would normally be possible with only thermoelectric module **2**. As a result, the temperature of the water will drop faster than would normally be possible with only thermoelectric module **2**. This addresses one of the characteristic problems of a thermoelectric water cooler, that being the cool down rate of a new removable fluid container **46**, and effectively increases the performance of the overall system.

[**0092**] **FIG. 8** illustrates a high performance thermoelectric cooler that may be adapted to rapidly chill various sizes of wine bottles, water bottles, and the like. In this case fluid container **46** may be an open container, containing water or some other liquid that may further surround and provide intimate thermal contact with wine bottle **49**, and sized to accommodate the largest anticipated wine bottle **49**. Fluid container **46** may be designed to provide intimate thermal contact with cold saddle **48** as in the previous example, and may be removed for serving and for cleaning purposes. Further, fluid container **46** may be constructed of thermally conductive material to facilitate the rapid transfer of heat through its walls. Insulation **12** may be extended to provide an insulated area above cold saddle **48** such that multiple bottles may be stored above cold saddle **48**, with or without fluid container **46** in place.

[**0093**] Thermoelectric module **2** pumps heat from the fluid contained within removable fluid container **46**, through cold saddle **48** and spacer block **8**, and into heat sink **4** where it may be dispersed into the ambient air. Thermoelectric module **2** may simultaneously pump heat from thermal ballast **14** through cold saddle **48**. In the case of a PCM thermal ballast **14**, a large amount of latent heat may be pumped from PCM thermal ballast **14** at the characteristic freezing point of the phase change material. This freezing point should be selected to be slightly below the desired water temperature, but not to the extent that it would cause the fluid to freeze. Thermoelectric module **2** may be turned off when the water has reached the desired temperature and all of the latent heat has been removed from PCM thermal ballast **14**.

[**0094**] At such time as wine bottle **49** is introduced to the system, the fluid in removable fluid container **46** will immediately begin to absorb heat from wine bottle **49**, and the temperature of the fluid will begin to rise. Thermal ballast **14** will then absorb heat from the fluid at a rate that is faster than would normally be possible with only thermoelectric module **2**, keeping the temperature of the fluid at a low level where it may continue to absorb heat from wine bottle **49**. As a combined result, the temperature of wine bottle **49** will drop faster than would normally be possible with only thermoelectric module **2**. It should be noted that in this case the fluid contained within removable fluid container **46** acts as a type of intermediate thermal ballast to directly absorb heat from wine bottle **49** and add to the temperature stability of the system.

[**0095**] Thermal ballast **14** has the ability to absorb heat at different rates across its surface. This will contribute to the performance of the system since the temperature of removable fluid container **46** will be varied in this application. The temperature of wine bottle **49** will be warmer than that of the fluid contained within removable fluid container **46** when wine bottle **49** is first introduced to the system, and this will cause the temperature of removable fluid container **46** to rise in the area where it contacts wine bottle **49**. This will cause thermal ballast **14** to more rapidly absorb heat through cold saddle **48** in this area of direct contact. Thermal ballast **14** may be of thicker depth under the bottom of cold saddle **48** to take advantage of this characteristic and contribute to the overall performance of the system.

[**0096**] **FIG. 9** illustrates the use of a hot side thermal ballast **92** to improve the capabilities of the high performance thermoelectric system first presented in **FIG. 2**. Thermoelectric module **2** operates on a fixed temperature differential between cold and hot sides, as is characteristic of all thermoelectric modules. As a consequence, any increase in the hot side temperature will also increase the cold side temperature, negatively impacting the thermoelectric modules ability to pump heat from the load. The temperature of heat sink **4** is closely related to the hot side temperature of thermoelectric module **2**. It follows that a stable heat sink **4** temperature will contribute to the overall stability of the high performance thermoelectric system.

[**0097**] Heat sink **4** has been extended to form hot side thermal conduit **90**. This may be accomplished using standard extruding techniques, or by affixing hot side thermal conduit **90** such that it is in thermal communication with heat sink **4**.

[**0098**] Hot side thermal ballast **92** may be in hot side thermal conduit **90** as shown. Should hot side thermal ballast **92** include a PCM, the PCM may be selected to have a characteristic melt point that equals the desired stable temperature for heat sink **4**. PCM hot side thermal ballast **92** will then be able to absorb a maximum amount of latent heat at this temperature, and contribute to the overall temperature stability of the system. Hot side air gap **94** may form as PCM hot side thermal ballast **92** settles downwards in the case of a powder, or flows downwards in the case of a liquid. Hot side air gap **94** will have a minimal affect on the thermal communication between PCM hot side thermal ballast **92** and hot side thermal conduit **90** since it is formed on the top rather than the bottom surface of PCM hot side thermal ballast **92**.

[**0099**] Thermoelectric module **2** is in simultaneous thermal communication with heat sink **4** and hot side thermal ballast **92** through hot side thermal conduit **90**. A sudden increase in the amount of heat pumped by thermoelectric module **2**, perhaps due to the introduction of a load within fluid chamber **20**, would normally cause the temperature of heat sink **4** to rise. However in this configuration the sudden increase in the amount of heat pumped by thermoelectric module **2** may be first absorbed by hot side thermal ballast **92**. Then, this heat may be dispersed through heat sink **4** and into the ambient air, at a slower rate over time and without substantially affecting the temperature of heat sink **4**. Normal operation of thermoelectric module **2** may continue throughout this process since heat sink **4** may simultaneously disperse heat from thermoelectric module **2** and hot side thermal ballast **92** as delivered to heat sink **4** through hot side thermal conduit **90**.

[**0100**] Cooling fan **96** may be added to the high performance thermoelectric system to increase the rate at which heat may be dispersed from heat sink **4** and into the ambient air. This will be particularly important for systems using hot side thermal ballast **92** since the heat contained therein must also be dispersed into the ambient air. Cooling fan **96** may be left on during a thermoelectric module **2**"off" cycle to ensure that this heat is fully dissipated prior to the next thermoelectric module **2**"on" cycle.

[**0101**] It should also be noted that the performance of all high performance thermoelectric systems may be further improved by implementing thermal persist technology as first introduced by the present inventors as part of U.S. utility patent application Ser. No. 09/522,929. This teaches that a small forward voltage may be left on the thermoelectric module during what would normally be the "off" cycle to prevent the reverse flow of heat back through the thermoelectric module during this time. Thermal persist will be particularly important in high performance thermoelectric systems utilizing hot side thermal ballast **92** since net amount of heat stored in heat sink **4** and hot side thermal ballast **92** is substantial, to the extent that it increase the temperature of and possibly damage the load being cooled should this heat be allowed to flow in a reverse direction.

[**0102**] The high performance thermoelectric systems with thermal ballast of the present invention allow for many applications, and may be implemented in various applications to cool fluids, gasses, and many other types of thermal loads. Although reference is made to the embodiments listed above, it should be understood that these are only by way of example and to identify the preferred use of the device known to the inventors at this time. It is believed that the high performance thermoelectric systems of the present invention have many additional uses and implementations which will become obvious once one is familiar with the fundamental principles of the invention.

We claim:

1. A high performance thermoelectric system comprising:

a. A thermoelectric module,

b. A heat sink,

c. A thermal ballast,

d. A thermal load, and

e. A thermal conduit.

Said thermoelectric module, said thermal ballast, and said thermal load being in simultaneous thermal communication through said thermal conduit, said thermal ballast configured to rapidly absorb heat from said load through said thermal conduit, said thermoelectric module configured to simultaneously pump additional heat from said thermal load through said thermal conduit, said thermoelectric module further configured to pump said heat from said thermal ballast through said thermal conduit at a slower rate over time, said thermoelectric module in thermal communication with said heat sink to disperse said heat and said additional heat into the ambient air.

2. The high performance thermoelectric system as claimed in claim 1 wherein said thermal conduit may be extended around a cavity to form a fluid reservoir.

3. The high performance thermoelectric system as claimed in claim 1 further comprising a thermally conductive spacer block between said thermal conduit and said thermoelectric module, said spacer block extending through said thermal ballast to be in direct thermal communication with said thermal conduit.

4. The high performance thermoelectric system as claimed in claim 1 wherein said thermal ballast may be a Phase Change Material with a characteristic freezing point slightly below the desired temperature of said thermal load.

5. The high performance thermoelectric system as claimed in claim 1 wherein said thermal ballast may be a Phase Change Material in liquid or powder format, said Phase Change Material in liquid or powder format being further contained in a confined space in thermal communication with said thermal conduit through a thermal interface, said confined space being configured to position any air gaps that might form due to the settling of, downward flow of, or volumetric changes in said Phase Change Material in liquid or powder format away from said thermal interface.

6. The high performance thermoelectric system as claimed in claim 1 wherein said thermal conduit has thermally conductive protrusions extending into said thermal ballast.

7. The high performance thermoelectric system as claimed in claim 1 further comprising a second thermal ballast in thermal communication with said heat sink through a second thermal conduit.

8. The high performance thermoelectric system as claimed in claim 1 further comprising an auxiliary spacer block, an auxiliary heat sink, an auxiliary fan, and an auxiliary thermal load, wherein said auxiliary spacer is in thermal communication with said thermal conduit, said auxiliary heat sink is in thermal communication with said auxiliary spacer block, and wherein said auxiliary fan is adapted to control the flow of heat from said auxiliary load to said auxiliary heat sink.

9. A flow through demand cooler for fluids comprising:

a. A thermoelectric module,

b. A heat sink,

c. A thermal ballast,

d. A fluid heat exchanger, and

e. A thermal conduit.

Said thermoelectric module, said thermal ballast, and said fluid heat exchanger being in simultaneous thermal communication through said thermal conduit, said thermal ballast configured to rapidly absorb heat from said fluid heat exchanger through said thermal conduit, said thermoelectric module configured to simultaneously pump additional heat from said fluid heat exchanger through said thermal conduit, said thermoelectric module further configured to pump said heat from said thermal ballast through said thermal conduit at a slower rate over time, said thermoelectric module in thermal communication with said heat sink to disperse said heat and said additional heat into the ambient air.

10. The flow through demand cooler for fluids as claimed in claim 9 wherein said fluid heat exchanger may also be said thermal conduit.

11. The flow through demand cooler for fluids as claimed in claim 9 further comprising a thermally conductive spacer block between said thermal conduit and said thermoelectric module, said spacer block extending through said thermal ballast to be in direct thermal communication with said thermal conduit.

12. The flow through demand cooler for fluids as claimed in claim 9 wherein said thermal ballast may be a Phase Change Material with a characteristic freezing point slightly below the desired temperature of the fluid within said fluid heat exchanger.

13. The flow through demand cooler for fluids as claimed in claim 9 wherein said thermal ballast may be a Phase Change Material in liquid or powder format, said Phase Change Material in liquid or powder format being further contained in a confined space in thermal communication with said thermal conduit through a thermal interface, said confined space being configured to position any air gaps that might form due to the settling of, downward flow of, or volumetric changes in said Phase Change Material in liquid or powder format away from said thermal interface.

14. The flow through demand cooler for fluids as claimed in claim 9 wherein said thermal conduit has thermally conductive protrusions extending into said thermal ballast.

15. The flow through demand cooler for fluids as claimed in claim 9 further comprising a second thermal ballast in thermal communication with said heat sink through a second thermal conduit.

16. The flow through demand cooler for fluids as claimed in claim 9 wherein said fluid heat exchanger is comprised of a cavity with vertical or longitudinal partitions, and wherein the fluid within said fluid heat exchanger must travel around said vertical or longitudinal partitions in a zigzag pattern.

17. The flow through demand cooler for fluids as claimed in claim 9 wherein said fluid heat exchanger is comprised of an extruded cavity with sliding longitudinal partitions, said sliding longitudinal partitions inserted into pre-formed slots within said extruded cavity, said sliding longitudinal partitions held in place with a bonding agent, said longitudinal partitions also held in place by the crimped sides of said pre-formed slots, and wherein the fluid within said fluid heat exchanger must travel around said sliding longitudinal partitions in a zigzag pattern.

18. The flow through demand cooler for fluids as claimed in claim 9 further comprising an auxiliary spacer block, an auxiliary heat sink, an auxiliary fan, and an auxiliary thermal load, wherein said auxiliary spacer block is in thermal communication with said fluid heat exchanger, said auxiliary heat sink is in thermal communication with said auxiliary spacer block, and wherein said auxiliary fan is adapted to control the flow of heat from said auxiliary load to said auxiliary heat sink.

19. A high performance cooler for removable fluid containers comprising;

a. A thermoelectric module,

b. A heat sink,

c. A thermal ballast,

d. A removable fluid container, and

e. A thermal conduit.

Said thermoelectric module, said thermal ballast, and said removable fluid container being in simultaneous thermal communication through said thermal conduit, said thermal ballast configured to rapidly absorb heat from said removable fluid container through said thermal conduit, said thermoelectric module configured to simultaneously pump additional heat from said removable fluid container through said thermal conduit, said thermoelectric module further configured to pump said heat from said thermal ballast through said thermal conduit at a slower rate over time, said thermoelectric module in thermal communication with said heat sink to disperse said heat and said additional heat into the ambient air.

20. The high performance cooler for removable fluid containers as claimed in claim 19 wherein said thermal conduit may be in intimate thermal contact with said removable fluid container, and wherein said thermal conduit may form a support for said removable fluid container.

21. The high performance cooler for removable fluid containers as claimed in claim 19 further comprising a thermally conductive spacer block between said thermal conduit and said thermoelectric module, said spacer block extending through said thermal ballast to be in direct thermal communication with said thermal conduit.

22. The high performance cooler for removable fluid containers as claimed in claim 19 wherein said thermal ballast may be a Phase Change Material with a characteristic freezing point slightly below the desired temperature of fluid within said removable fluid container.

23. The high performance cooler for removable fluid containers as claimed in claim 19 wherein said thermal ballast may be a Phase Change Material in liquid or powder format, said Phase Change Material in liquid or powder format being further contained in a confined space in thermal communication with said thermal conduit through a thermal interface, said confined space being configured to position any air gaps that might form due to the settling of, downward flow of, or volumetric changes in said Phase Change Material in liquid or powder format away from said thermal interface.

24. The high performance cooler for removable fluid containers as claimed in claim 19 wherein said thermal conduit has thermally conductive protrusions extending into said thermal ballast.

25. The high performance cooler for removable fluid containers as claimed in claim 19 further comprising a second thermal ballast in thermal communication with said heat sink through a second thermal conduit.

26. The high performance cooler for removable fluid containers as claimed in claim 19 wherein said removable fluid container further contains a fluid and a wine bottle, said wine bottle being immersed in said fluid, said wine bottle in thermal communication with said fluid, and said fluid in thermal communication with said thermal conduit through said removable fluid container.

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