MEDICAL TRAVEL PACK WITH COOLING SYSTEM

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ABSTRACT
The present invention provides a device for keeping medical materials, such as medicine, cool. The device allows for easy transportation provided infrequent access to electricity. The device incorporates a thermoelectric cooler (TEC) inside an insulated container. The TEC is in contact with a freezeable material which is frozen when the TEC is electrically powered. Upon disconnect from electrical power, the freezeable material provides passive cooling inside the container while the medical material is transported. This portable device helps patients to travel with their medicines confidently and safely.
FIG. 7

FIG. 8

3.6V BATTERY

STK502

AT MEGA169p

LCD

VOLTAGE REGULATOR

FAN

AC/DC CONVERTER

NTC THERMISTOR (MEDICINE TEMPERATURE)

COOLER PIN

TEC

POWER MOSFET

1MΩ

27Ω
FIG. 9

INITIALIZATION

CONTROL LOOP

LCD UPDATE

TEMPERATURE UPDATE

TEC ON?

NO

T > T_hi?

YES

TEC ON

YES

T < T_lo?

TEC OFF

NO

TEC ON

YES
FIG. 10

\[ y = 0.6225x + 0.1576 \]

\[ R^2 = 0.9869 \]

FIG. 11

\[ T_{ambient} = 104 \text{ F} \]

\[ T_{ambient} = 85 \text{ F} \]

\[ T_{ambient} = 70 \text{ F} \]

\[ T_{ambient} = 50 \text{ F} \]

TIME (hours)
**FIG. 12**

\[ y = 0.156x + 0.1361 \]

\[ R^2 = 0.9845 \]

**FIG. 13**

- \( T_{\text{ambient}} = 85 \text{ F} \)
- \( T_{\text{ambient}} = 104 \text{ F} \)
- \( T_{\text{ambient}} = 70 \text{ F} \)
- \( T_{\text{ambient}} = 50 \text{ F} \)
FIG. 18

- DYN 15mm: $y = 0.238x + 4.490$, $R^2 = 1.000$
- YS TECH: $y = 0.284x + 5.812$, $R^2 = 0.999$
- DYN 25mm: $y = 0.232x + 3.352$, $R^2 = 0.999$
MEDICAL TRAVEL PACK WITH COOLING SYSTEM

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 60/940,895, filed May 30, 2007, hereby incorporated herein by reference.

TECHNICAL FIELD

The present invention relates generally to a portable insulated temperature controlled container adapted for storing medical materials. Further, the present invention relates to storage or transport of items under conditions of temperature control relative to typical ambient temperatures. More particularly, the present invention relates to insulated containers using thermoelectric modules.

BACKGROUND

Many medications which are prescribed to be taken on a daily or regular basis must be kept in a controlled-temperature environment. If the temperature of these medications is not carefully controlled, these medications lose their stability and potency, and may in fact present health hazards. Such medications include insulin, antibiotics reconstructed in sterile water, allergy and other serums, vaccines, suppositories, snake anti-venom, and many others. It is especially an issue for people with chronic illnesses, requiring long-term treatment, who travel frequently. Hence, the need for refrigerating medicines is a serious problem in third world countries/remote parts of the world and in the United States for people suffering from chronic illnesses that must travel for some period of time.

In the United States alone, approximately twenty million people have been diagnosed with diabetes and three hundred-ninety thousand with multiple sclerosis. Particular problems arise when a multiple sclerosis or diabetes patient travels. An adequate supply of required medication for the necessary time needs to be transported under suitable conditions and stored at the destination. In such situations the use of a simple box of ice for transport may not provide adequate temperature control. Usually, the patient calls ahead to his or her lodgings in hopes of finding a refrigerator. If he or she is unable to plan ahead, the probability of not finding a refrigerator is high and he or she might have to resort to a shared refrigerator. A shared refrigerator poses problems related to lack of privacy, cleanliness and safety.

Because of the desire to have medicines both readily available and maintained at a certain temperature, insulated containers have been available for transporting insulin and other similar medications during travel. However, most such devices are passive insulated containers filled with blocks of ice or frozen gel packs which rely on a freezer compartment of a refrigerator for refreezing. Thus there remains a need for a self-contained, compact and portable freezer/storage system for transporting items that require temperature control.

SUMMARY

In view of the foregoing and other considerations, the present invention relates to a portable medical storage device that can be used as a portable medicine storage device that can maintain medicines and other items at proper temperatures. The present invention also relates to a portable medicine storage device that allows people suffering from chronic or serious diseases to travel with adequate supply of their medication stored and kept at proper temperature. Further, the microcontroller may be powered by a battery, but can use alternating current (AC) commonly available in hotels and motels to provide the required power to the thermal electric cooler system.

Accordingly, described herein is a portable medical storage device, comprising an insulated container; a freezable gel disposed within the container; and a thermoelectric cooler in thermal communication with the freezable gel.

Additionally, described herein is a portable medical storage device comprising an insulated container with an insulated lid; a freezable gel disposed within the container; a storage unit in contact with the freezable gel; a cooling assembly in thermal communication with the freezable gel, said cooling assembly comprising a cold plate, a thermal conduction member, a thermal electric cooler, a heat sink, and a fan; a temperature sensor for sensing the temperature within the container; and a microcontroller in electrical communication with the thermoelectric cooler and the temperature sensor.

Also, provided is a method for controlling the temperature of a medical material comprising providing portable medical storage device described supra to maintain the temperature of said medical material at a predetermined temperature.

The foregoing has outlined some of the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and aspects of the present invention will be best understood with reference to the following detailed description of a specific embodiment of the invention, when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a portable medical storage device;

FIG. 2 shows a portable medical storage device;

FIG. 3 shows an insulated lid of a medical storage device used in passive mode;

FIG. 4 shows an insulation and an inner concentric container containing a freezable gel of a portable medical storage device;

FIG. 5 shows a cooling assembly;

FIG. 6 shows an active cooling configuration for a portable medical storage device;

FIG. 7 shows a passive cooling configuration for a portable medical storage device;

FIG. 8 shows an electronic circuit for a microcontroller connecting a thermoelectric cooler and a temperature sensor to a microcontroller;

FIG. 9 shows an algorithm used by a microcontroller to regulate the operation of a thermoelectric cooler;

FIG. 10 shows a comparative non-dimensional temperature log plot to determine m-value for Insulpak;

FIG. 11 shows a comparative plot of temperature curve of water in Insulpak for various ambient temperatures;

FIG. 12 shows a non-dimensional temperature log plot to determine m-value for Thermos®;

FIG. 13 shows a plot of temperature curve of water in Thermos® at various ambient temperatures;

FIG. 14 shows a temperature curve of water in Thermos®.
FIG. 14 shows a plot of the temperature retention time of frozen gel within Thermos®;
FIG. 15 shows a comparative plot of the temperature retention time of frozen gel within Insulpak;
FIG. 16 shows a plot of the freezing test results for a portable medical storage device;
FIG. 17 shows a plot of thawing test experimental setup and the results for a portable medical storage device; and
FIG. 18 shows a fan testing experimental setup and results for a portable medical storage device.

DETAILED DESCRIPTION

In the following description, various embodiments of the present invention will be described. For the purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the embodiments. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. Furthermore, well-known features may be omitted or simplified in order not to obscure the embodiments being described.

Refer now to the drawings wherein depicted elements are not necessarily shown to scale and wherein like or similar elements are designated by the same reference numeral through the several views.

Referring to FIGS. 1 through 4, an exemplary portable medical storage device or Travelfridge 10 comprises a container 20, whose configuration and construction are represented in FIG. 1. The container 20 is a double-walled vessel consisting of an inner wall 21a and an outer wall 21b, a space between walls 21a and 21b being insulated and/or exhausted of air. The container 20 further comprises a concentric inner shell 30 filled with a freezable gel 40. Other phase change materials (PCMs) where the phase change point of the PCM about equals the temperature desired for the medicine, are also contemplated. Between the inner shell 30 containing the freezable gel 40 and the inner wall 21a of the container 20, is a hydrophobic insulation 50. An example of a hydrophobic insulation is the rigid foam insulation as Foamlular®. Disposed within the freezable gel 40 in the container 20 is a storage part 22 which may be configured to hold items such as small glass bottles, syringes, and vials supplying individual doses of drugs, vaccines or the like. Storage part 22 may be configured to hold the items in such a way so as to protect them against shock.

At the top of the container 20 there is disposed a cooling assembly 23. A thermal conduction member 61 extends as part of a cooling assembly 23 and is disposed into the freezable gel 40 contained in the container 20. Above these components is a circular lid 100 insulated with a hydrophobic insulation 50, for example Foamlular®. This lid 100 is removed when the Travelfridge 10 is in the active cooling configuration so that heat from the cooling process can be rejected to the air rather than being trapped in the container 20. The lid 100 will only be on the Travelfridge 10 in the passive cooling configuration. To reduce heat loss, insulation is desirable. The lid may have a vacuum-walled insulator. Insulating materials like Foamlular® may be used as an insulator for its low heat transfer coefficient and hydrophobic capabilities. Foamlular® minimizes heat loss through the lid and also serves as a secondary insulator within the container, while not degrading if water is present from condensation.

Referring to FIG. 5, the cooling assembly 23 comprises of a cold plate 60, a thermal conduction member 61, thermoelectric cooler (TEC) 62, heat sink 63, an insulation 50 between the TEC 62 and the heat sink 63 and the fan 64 (not shown). The TEC 62 is used to freeze the gel 40. A freezing temperature of the gel between 2 and 8°C was targeted. Other variations where the freezing point of the gel about equals the temperature desired for the medicine, are also contemplated. The TEC 62 has a thermal conduction member 61 extending from it. The thermal conduction member 61 is disposed within the freezable gel 40, when the Travelfridge 10 is in operation, to conduct heat to the TEC 62.

The thermal conduction member transfers cold into the phase change material. A portion of the thermal conduction member extended into the phase change material. The portion may be a fin or a specialized heat transfer member known as a “heat pipe” (a sealed metal tube which has an inner lining of wick-like material and a small amount of fluid in a partial vacuum) in which heat is absorbed at one end by evaporation of the vapor and released at the other end by condensation of the vapor. In selecting the size and shape of the fin or heat pipe, it is desired that there be a tradeoff between phase change material displaced volume and contact surface area between the phase change material and the fin. It is desired that the phase change material freeze, or otherwise change phase, uniformly. According to some embodiments, the fin has a cylindrical shape. The thermal conduction member may be one piece. That is, its portions are integrally formed. For example, a cold plate portion is integrally formed with a conduction fin portion.

TEC’s use the Pellet effect to cool and may be adjusted depending on amount of input current. To power the TEC 62 any common wall outlet may be used. Since TEC’s cool by creating a temperature difference, one side will cool but the other will heat up. In conjunction with the TEC 62, a heat sink 63 and fan 64 are used to expel heat to the outside environment along with a cooling plate 60 on the opposite side to conduct the cold into the container. Thus, Travelfridge is cooled by the cold plate 64 touching the cold side of the TEC 62 and conducting heat away from the freezer gel 40 that is directly surrounding the thermal conduction member 61.

An exemplary TEC is manufactured by TETech, specifically product number HP-199-1.4-1.15P, has a maximum temperature gradient of 69°C, measures 40 mm x 40 mm x 3.6 mm, and is epoxy sealed. A 4.5 Ampere (A) and 16.5 Volt (V) power source can be used to power this TEC in the Travelfridge. Further, an exemplary fan 64 is made by Dynatron and measures 60 mm x 60 mm x 25 mm, uses 12 V and 0.6 A, and has 38 cubic feet per minute heat pumping capabilities. Additionally, an exemplary heat sink 63 is made by Cool Innovations, specifically product number 2-52514R, measures 2.5” x 2.5” x 1.4”, and has a thermal resistance of 0.24°C/Watt.

TEC 62 is also surrounded by hydrophobic insulation 50. The hydrophobic insulation 50 is in place to minimize condensation around the TEC 62. The bottom of the heat sink 63 touches the hot side of the TEC 62 and with the help of the fan 64, excess heat is expelled to the environment.

A total active cooling configuration system is depicted in FIG. 6. In this configuration a power source 170 regulates the power to the TEC 62 and the fan 64. A combined operation of active (connected to a typical AC outlet) cooling and passive (disconnected from an AC outlet) cooling was selected as more efficient and practical, in which a gel acts in
the present device as a thermal battery. FIG. 7 shows the passive cooling configuration where the lid is on the TravelFridge. All components remain inside, but there is no external power being used. Alternatively, the TravelFridge may also be considered to actively cool in operation, with an electric battery used when the unit is unplugged.

The TravelFridge may have associated therewith a data storage and a display member, e.g. a LCD display, by which information pertaining to the TravelFridge may be stored or displayed as required. By way of example and not limitation such data may include: date, time, a record of the temperature inside the TravelFridge, the state of charge of the batteries in the container, and any other pertinent information essential to the functioning of the device. A microcontroller 180 associated with the TravelFridge may be used to take user input, refresh the temperature display, and control power to the other electrical components. FIG. 8 depicts an exemplary electronic circuit of the microcontroller 180 having a suitable software.

The microcontroller 180 is connected to a built in LCD 70. Additionally, the microcontroller 180 has a chip that is able to produce a pulse-width modulated output. In active cooling mode, the microcontroller 180 controls current to the TEC 62 based on the current temperature in the container 20 and the desired temperature of the medicine, and alternately displays the current temperature of the medicine inside the container 20. In active mode, an AC/DC power adapter 190 powers the fan 64 and TEC 62.

The microcontroller 180 is powered by an on-board pack of rechargeable batteries 300 of any appropriate type, for example a 3.6 V Lithium battery, fitted within the lid 100. Such a battery pack may be recharged in situ if the container 20 is connected to an AC supply or a low voltage power supply where one is available, or can be replaced by a fresh battery pack if required. The battery pack provides sufficient electrical power storage capacity to enable the functions of the TravelFridge to operate satisfactorily for 24 to 48 hours away from an external power supply. A digital input/output (I/O) cooler pin 200 on the micro-controller 180 controls the operation of the TEC 62 by driving the gate voltage of a power Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) 300. One or more temperature sensors 400 may be provided to the user to set a required temperature depending on what is being stored or carried in the TravelFridge. An example for such a temperature sensor is an NTC Thermistor. The thermistor may have an analog input proportion to the temperature. There is a single digital output. The cooler pin 200 is thus on or off. The cooler pin 200 is connected to a high power MOSFET.

The positive lead of the TEC 62 is hooked up to the +19V coming out of an AC/DC power adapter 80. The MOSFET's 300 drain is hooked up to the negative lead of the TEC 62, and its source is grounded. Thus, the MOSFET 300 acts as an on/off switch, where the TEC is powered on at a little below 19V when the gate of the MOSFET 300 is pulled high, and the TEC 62 has no current flow through it when the gate of the MOSFET is pulled low.

Fan power control will be simpler than TEC power control because the fan 64 will always run when the unit is plugged in. A 12V voltage regulator is hooked up with its input being the 19V source from the wall adapter, and its output going to the positive lead of the fan.

FIG. 9 depicts the algorithm used in the operation of the microcontroller 180. In a typical operation, temperature sensor 400 provides an analog signal indicating temperature, which is read into the microcontroller's analog to digital converter (ADC) for digital readout. In step 600, the microcontroller initializes every time it is turned on and then enters into a control loop 1000 with three main stages. In the first stage 700 the liquid crystal display (LCD) is updated with the contents of a global buffer that is updated by the different parts of the program. In the second stage 800 the voltage is read on the thermistor and converted into a temperature, updating the LCD buffer accordingly. Finally, in the last stage 900 the microcontroller 180 decides whether the TEC 62 is selected to be on or off depending on the current temperature of the gel.

There are two set points which limit oscillations in the TEC on/off cycling in stage 900 in the control loop 1000. If the TEC is already on, the user may check to see if the temperature is below the low set point temperature, in which case the TEC is turned off. If the TEC is off, the user may need to see if the temperature is above the high set point temperature, in which case the TEC is turned back on. This prevents the TEC from turning on and off rapidly when the temperature in the TravelFridge reaches the desired temperature.

It will be understood that a variation of on/off control that is contemplated is as follows. Pulse width modulation may used. Pulse width modulation may have the advantage of using less power. When a simple on/off control is used, there may be a 100% duty cycle. The TEC may be on for the entire cooling period, e.g. overnight, e.g. 8 hours. Associated with on/off control, there may be oscillations in the medicine temperature. In contrast, when a pulse modulation control is used, there may be a less than 100% duty cycle. Some percentage of time, the TEC is on. When a pulse modulation control is used, the current is controlled, e.g. in magnitude, in addition to on or off. Associated with pulse width modulation control, there the medicine temperature may be maintained substantially constant.

It will be understood that voltages shown in diagrams in the present disclosure, may include voltages that are adapted for the configuration of the circuit. Other suitable voltages and configurations are contemplated.

It will be understood that one version of the invention not only maintains a proper temperature in hot environments, but can provide heating if the ambient temperature gets too low.

And advantages is the ability to maintain medicines placed inside the TravelFridge to be at a low initial temperature for an extended time regardless of the external environment. Additionally, the efficient integration of TECs and an active control system into the TravelFridge is an advantage.

An exemplary operation of the device may include removing the lid of the device and plugging in to an AC outlet overnight for the active cooling mode of operation. The current will be transformed to low voltage DC current to recharge the device. The current will be used to charge the batteries and maintain the medicine at the desired temperature or used to refreeze the ice pack during the night. In the morning the device is unplugged from the AC outlet, the lid replaced for passive cooling mode of operation. The operation may include repeating the next night.

It will be understood that there is no fixed limit on the size of the device. However, there is a trade off with respect to cooling capacity. If the device is larger, the device tends to be plugged in for longer to achieve cooling.
The following examples, as well as the other examples described herein, are presented to further illustrate the invention and, are not to be construed as unduly limiting the scope of this invention.

**EXAMPLE 1**

**Development of Dimensional Constraints for the TravelFridge**

A design challenge for the TravelFridge was to create an optimally insulated container. The effects of convection, conduction, and radiation were minimized so that the final product is sufficiently close to a perfect insulator. The main parameters in this design are surface area, insulation, conductivity, volume of liquid to be cooled, and manufacturing cost.

The diabetes and MS medicine dimensions and required temperatures for the maintenance of these medicines were used as reference dimensional constraints for developing an exemplary TravelFridge. Table 1 summarizes these dimensional constraints.

<table>
<thead>
<tr>
<th></th>
<th>Physical constraints of medicines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (mL)</td>
</tr>
<tr>
<td>Diabetes Vials</td>
<td>10</td>
</tr>
<tr>
<td>MS Cartridges</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The upper dimensional constraints thus come from the diabetes medicines. It was decided that the container can have the capability to carry up to four vials, meaning that at the minimum the interior chamber must be greater than 5 cm in diameter and 5.5 cm in height. Additionally, the interior chamber must stay at temperatures between 2-8°C for a minimum of 24 hours without active cooling. The medicines must also be safe from breaking during the regular jostle of travel and the interior temperature must be displayed to confirm that the medicines are properly cooled.

**EXAMPLE 2**

**Temperature Decay Test**

The only potential competition to TravelFridge is a device called Insulpak. Insulpak is 12"x9"x3.5" made with foam insulation and is cooled with a removable, freezeable ice-pack. This product is priced at $48.95, which is less than the projected price of TravelFridge, but does not contain all of the features TravelFridge does. The main problems are that an external refrigeration device is still needed to freeze the ice-pack and the insulation is poor. With TravelFridge, the external refrigeration would not be necessary because it uniquely offers active cooling through the use of a TEC along with improved insulation. All other features of Insulpak including temperature readout, insulation, and portability are either met or improved upon by TravelFridge.

For choosing a container to develop an exemplary TravelFridge, temperature decay tests were performed. Temperature decay tests were compared for a foam insulated container, like Insulpak and a vacuum insulated container like, Thermos®.

**0058** Briefly, a beaker filled with 200 mL of water at 38°F was placed inside Insulpak. This assembly was placed inside a drying oven set to 104°F with an RTD (resistance temperature device) measuring the water and oven temperature. From this data, a log plot to determine the m-value for this test was created, which is depicted in FIG. 10. This m-value was then used to extrapolate temperature curves at other ambient temperatures. FIG. 11 shows the plot with the results from these calculations graphed as a curve of water temperature versus time.

**0059** The results were not satisfactory for the specification of keeping medicines within the desired temperature range (36-46°F) for extended periods of time. For this reason, a vacuum insulated container, i.e., a Thermos® food container, was tested. This container had the desired dimensional constraints with the same approximate interior size and design as storage area specified for the diabetes and MS medications. A similar test to the Insulpak test was run where 200 mL of water at 35°F was poured directly inside the Thermos® and placed inside a drying oven at 104°F. The oven temperature and water temperature were once again measured and similar data was collected as shown in FIGS. 12 and 13. By comparing the m-values found along with the temperature decay, it can be seen that the Thermos® shell will have much better temperature performance characteristics than Insulpak. Therefore, an insulation design similar to this was used in TravelFridge.

**0060** To improve the cooling capabilities further, an ice-pack (manufactured by Cold Ice®) may be used to store a passive cooling capacity. Table 2 compares the heat capacity and heat of fusion of Cold Ice® and water (data from the manufacturer of Cold Ice®).

<table>
<thead>
<tr>
<th>Heat Capacity and Heat of Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Cold Ice®</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

This shows that Cold Ice® has a higher heat of fusion than water meaning that Cold Ice® absorbs more energy before it melts. By using the heat of fusion value of Cold Ice® and the m-values from the Thermos® and Insulpak tests, FIGS. 14 and 15 compare the calculated temperature retention time with respect to Cold Ice® mass at ambient temperatures of 66°F, 86°F, 106°F. From these two graphs, it can be seen that the temperature retention time of the Thermos® is significantly longer than that of Insulpak. These calculations indicate with a mass of 1 lbm of Cold Ice® in the Thermos® at an ambient temperature of 86°F, it will take much longer for the temperatures to reach 46°F (the temperature where the medicine may become unusable) as compared to the Insulpak. According to this data, travelers may be able to expose TravelFridge for extended periods of time at outdoor temperatures with their medicines remaining at the required temperatures. This also justified making a container that may keep medicines cool for up to 24 hours with passive cooling alone.
EXAMPLE 3

TEC

[0062] TEC’s are tested by tracking the temperature at various voltages as a certain amount of Cold Ice® (starting with 0.5 lb) is tracked from starting out at room temperature to being frozen. Calculations are done to determine the amount of heat that the TEC will expel in order to get a temperature difference down to 35°F. The results of these calculations were used to determine the theoretical heat sink geometry and fan speed necessary to dissipate the excess heat generated by the TEC.

[0063] Upon selection of the appropriate geometries and fan speeds, testing with the TEC, heatsink, fan, thermal grease and gel was done to determine the amount of time it takes to cool the gel at different voltages. Based on this data the input voltage to the TEC and recommended time to freeze is determined.

EXAMPLE 4

Development of the TravelFridge

[0064] A Nissan Thermos® was used for the vacuum insulated container. The lid was modified. First a heat sink was cut to fit inside the Thermos® so that it can be used as a cold plate. A spacer was attached to the cold plate and a TEC to the spacer. A second heat sink with a fan was attached to the other side of the TEC so that the TEC is effectively sandwiched between the heat sink and cold plate. All junctions were made as thermally conductive as possible and therefore were coated with thermal grease.

[0065] The microcontroller used came mounted on an expansion board designed by Atmel. A temperature sensor was attached near the medicine and the signal fed directly into the ADC of the microcontroller. The microcontroller supplies a control signal to the FET sourcing the TEC. The LTD used for reading out the medicine temperature was integrated on the expansion board.

[0066] The microcontroller was programmed to run the TEC at high power when the medicine temperature is higher than the desired temperature, and to turn off when the desired medicine temperature is achieved in the active cooling mode. The fan will run at all times that the unit is plugged into an AC outlet.

[0067] Clasps were provided to hold lids onto the Thermos®, to ensure that the TEC-heatsink-cooling assembly stays together and fits securely on the top of the Thermos®. The Thermos® purchased in order to compare to the Insulpak was used for the final design of the TravelFridge. A commercial shipping gel, called “Cold Ice®” was used. The gel comes in a plastic bag. The bag was cut and the gel poured into a cylinder. In an alternative embodiment, the gel can be left in the bag itself and any suitable air tight container can be used for the gel.

[0068] A custom designed thermal conduction member was used. The gel was contained in an aluminum container. A medicine vial may contact the aluminum container holding the gel. A portion of the thermal conduction member extended into the gel. The portion was a fin. The fin had a cylindrical shape. The thermal conduction member was one piece. That is, a cold plate portion was integrally formed with a conduction fin portion. The present inventors custom machined the thermal conduction member for the TravelFridge. For the size of the fin, accordingly, in an exemplary embodiment, the fin takes up to 10% of the volume. Thus, instead of 1 pound of gel, as without the thermal conduction member, the device contained ¾ pound of gel.

EXAMPLE 5

Design Testing and Validation

[0069] To determine the performance of the TravelFridge, following its construction, three distinct testing phases were performed. These are broken into freezing tests, thawing tests and fan tests. The freezing tests were to determine the performance of the TravelFridge in the “active” mode when power is being supplied to the unit. The thawing tests were consequently designed to test the passive performance of the system after the freezing test was completed. The heatsink and fan combination are a critical part of the thermoelectric assembly, therefore testing of various fans was conducted to decide which one gave the best performance.

EXAMPLE 6

Freezing Test Experimental Setup and Results

[0070] For the freezing tests, the TravelFridge was first hooked up to electrical power. The TEC was powered by a variable power supply set between 4.5-5.5 A. The fan was powered with a 12V power supply. Also, four thermistors were used to measure temperature of the heatsink, cold plate, gel and medicine. Data was taken using an NI-DAQ hooked up to a laptop running a Labview VI. Power was supplied to the TEC and then data was taken for 8 hours. The temperatures were then plotted, as seen in FIG. 16.

EXAMPLE 7

Thawing Test Experimental Setup and Results

[0071] Once the freezing test was completed, a thawing test was started. The power to the TEC and the fan was removed. Also, only data for the gel and medicine temperatures were taken. The lid of the TravelFridge was replaced and fastened, and then data was taken for approximately 30 hours continuously. Typical results are depicted in FIG. 17.

EXAMPLE 8

Fan Testing Experimental Setup and Results

[0072] Fan testing was performed on three different fans, a Dynatron 15 mm fan, a Dynatron 25 mm fan and a Y.S. Tech 25 mm fan. First, the TravelFridge was arranged in the “active” configuration. Different inputs to the TEC were chosen, and the voltage, current and heatsink temperature were recorded at each point. Once the data was collected, a graph of heatsink temperature vs. input wattage was constructed to determine which fan performed the best. Two separate tests were done, one with the fans running at 12V and the other with the fans running at 15V. We do not advise running the fans above 12V however, as we had one burn out during a test which resulted in the TEC burning out. The results for the 15V case are shown in FIG. 18. It is clear from the results that the Dynatron 25 mm fan performed the best. This fan was used for all of the freezing tests to get the best performance possible.

[0073] Many freeze and thaw tests were conducted to validate the accuracy of data. In most cases, the data correlated well with other tests, indicating that the experimental procedures were valid. The general results of testing were that the
gel was frozen thoroughly after 8 hours and the gel stayed in the desired temperature range for around 25 hours.

All patents and publications referenced herein are hereby incorporated by reference. It will be understood that certain of the above-described structures, functions, and operations of the above-described embodiments are not necessary to practice the present invention and are included in the description simply for completeness of an exemplary embodiment or embodiments. In addition, it will be understood that specific structures, functions, and operations set forth in the above-described referenced patents and publications can be practiced in conjunction with the present invention, but they are not essential to its practice. It is therefore to be understood that the invention may be practiced otherwise than as specifically described without actually departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A portable medical storage device, comprising:
   an insulated container;
   a freezable gel disposed within the container; and
   a thermolectric cooler in thermal communication with the freezable gel.

2. The portable medical storage device according to claim 1, further comprising:
   a thermal conduction member adapted for providing the thermal communication, the thermal conduction member comprising:
   a cold plate portion integrally formed with a conduction fin portion, wherein the cold plate portion is adjacent the thermolectric cooler and the conduction fin portion extends into the gel.

3. The portable medical storage device according to claim 2, wherein the conduction fin comprises a rod.

4. The portable medical storage device according to claim 2, wherein the conduction fin comprises a heat pipe.

5. The portable medical storage device according to claim 4, wherein the conduction fin comprises a plurality of heat pipes.

6. The portable medical storage device according to claim 1, wherein the freezable gel comprises a material having a freezing temperature about equal to a minimum storage temperature of the medicine.

7. The portable medical storage device according to claim 6, wherein the minimum storage temperature is about 2°C.

8. The portable medical storage device according to claim 1, wherein the device maintains medicine stored in the container at a temperature between about 2°C and about 8°C for at least about 24 hr.

9. The portable medical storage device according to claim 1, further comprising a controller circuit in electrical communication with the thermolectric cooler.

10. The portable medical storage device according to claim 9, wherein the controller circuit is configured to transform an input signal dependent on medicine temperature to an output signal regulating the on/off state of the thermolectric cooler.

11. The portable medical storage device according to claim 10, further comprising an AC/DC adaptor in electrical communication with the controller circuit.

12. The portable medical storage device according to claim 10, further comprising a source of portable electric power mounted in said device.

13. The portable medical storage device according to claim 12, wherein said portable electric power provides the operating power for the controller circuit to regulate the thermolectric cooler in the absence of an AC outlet.

14. The portable medical storage device according to claim 13, wherein said portable electric power comprises rechargeable batteries.

15. The portable medical storage device according to claim 1, wherein the container comprises an inner cylindrical wall.

16. The portable medical storage device according to claim 15, wherein the wall is at least about 5 cm in diameter.

17. The portable medical storage device according to claim 1, wherein the container comprises at least one medicine receptacle sized so as to hold a 10 ml medicine vial.

18. The portable medical storage device according to claim 1, wherein the container comprises at least one medicine receptacle sized so as to hold a 1 ml syringe.

19. The portable medical storage device according to claim 1, further comprising a fan adjacent the thermolectric cooler.

20. The portable medical storage device according to claim 1, wherein the insulated container comprise vacuum insulation.

21. A portable medical storage device, comprising:
   an insulated container comprising an insulated lid;
   a phase change material disposed within the container; a storage unit in contact with the phase change material;
   a cooling assembly in contact with the freezable gel, said cooling assembly comprising a cold plate, a thermal conduction member, a thermal electric cooler, a heat sink, and a fan;
   a temperature sensor adapted for sensing the temperature within the container; and
   a microcontroller in electrical communication with the thermolectric cooler and said temperature sensor.

22. The portable medical storage device according to claim 21, wherein said cold plate is integrally formed with the thermal conduction member and adjacent to the thermolectric cooler.

23. The portable medical storage device of claim 22, wherein the conduction member extends into the phase change material.

24. The portable medical storage device according to claim 23, wherein said storage unit is configured to hold an item selected from among small glass bottles, syringes, and small vials.

25. The portable medical storage device according to claim 24, wherein said system is adapted for storing liquid phase sterile mediums, for administering to individuals in need thereof, at a temperature slightly above its freezing temperature.

26. The portable medical storage device according to claim 25, wherein said system is adapted for storing personal use medicines required to be kept at a predetermined temperature during travel.

27. A method for controlling the temperature of a medical material, comprising:
   providing the portable medical storage device according to claim 21;
   maintaining the temperature of said medical material at a predetermined temperature.

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