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[54] **OPEN-CYCLE PORTABLE REFRIGERATOR**
 17 Claims, 4 Drawing Figs.

[52] U.S. Cl..... **62/222,**
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 [51] Int. Cl..... **F25b 41/04**
 [50] Field of Search..... 62/331,
 371, 457, 514, 531, 222, 430, 223

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ABSTRACT: A portable refrigerator employing an open-cycle system. A stored compressed gas, such as carbon dioxide, is passed from its storage container through an evaporator which comprises a serpentine passageway for the gas and a surrounding medium, such as water, an aqueous solution, which is maintained frozen due to the passage of the expanding compressed gas through the coiled passageway. The temperature of the evaporator medium is lower than the ambient temperature of the interior of the container comprising the storage portion of the refrigerator, which is cooled thereby. The gas passing through the evaporator may be exhausted into the interior of the container whereby the cooler air which is next to the evaporator medium is circulated throughout the interior of the container.

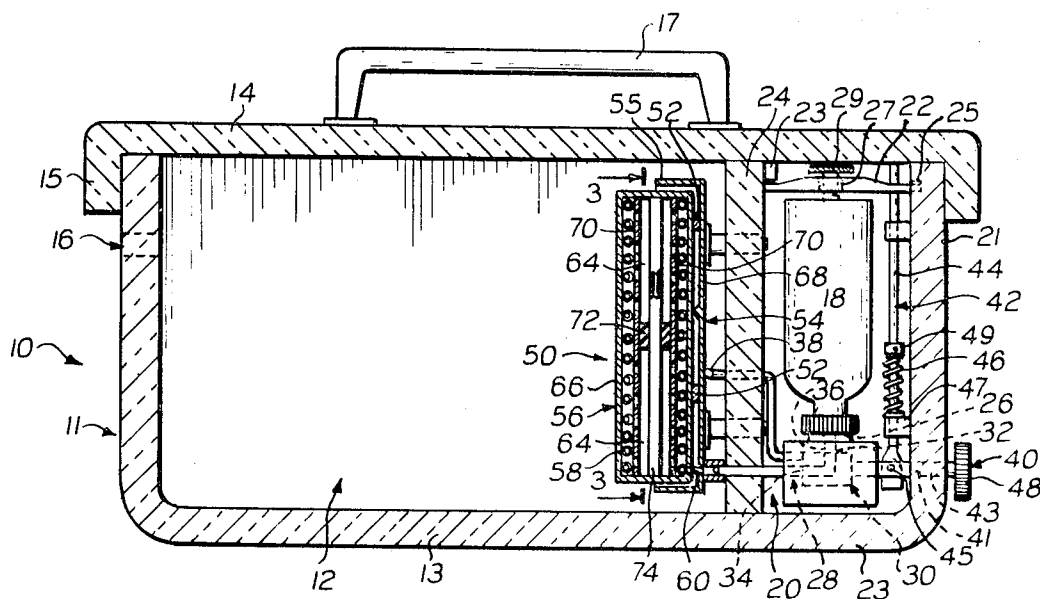


FIG. 1.

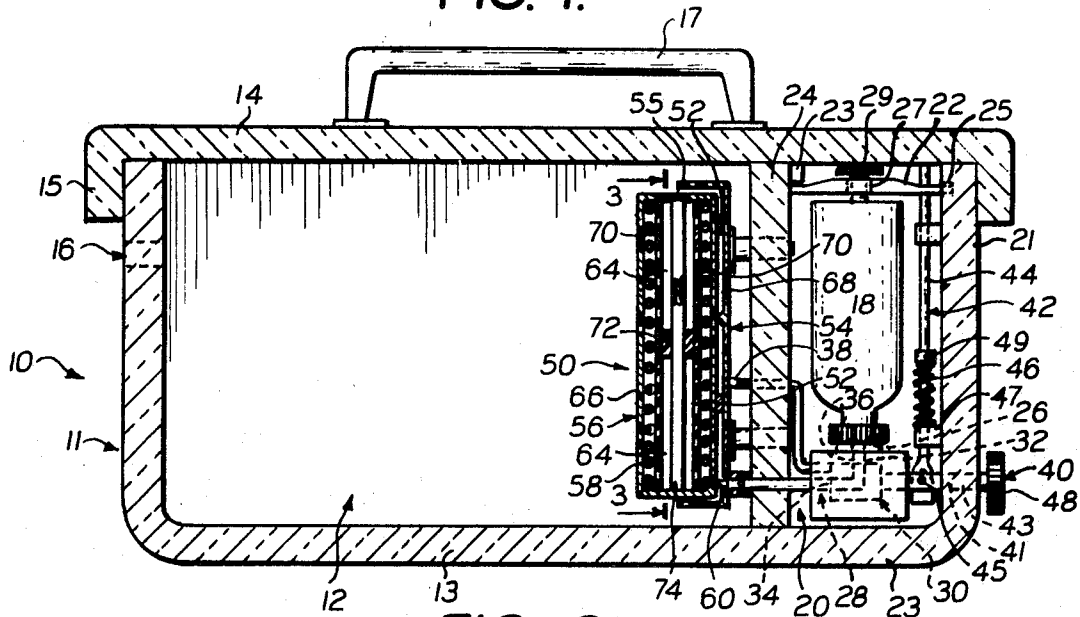


FIG. 2.

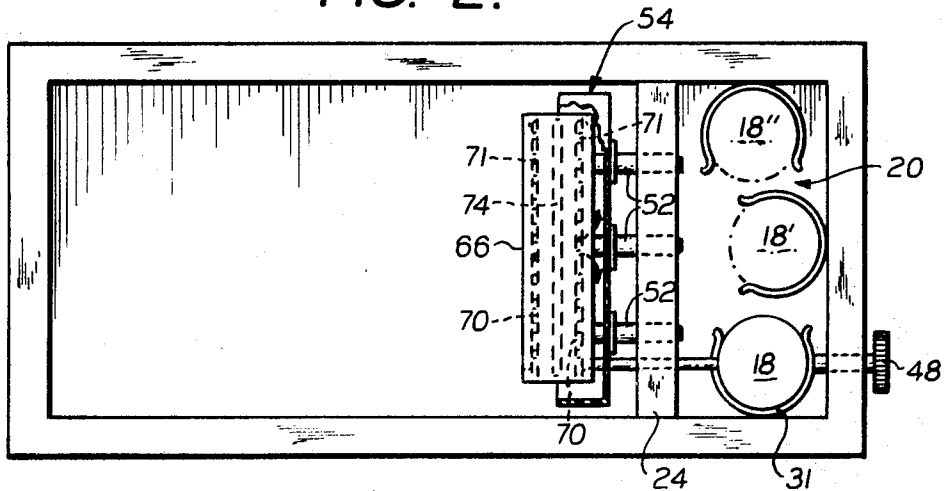


FIG. 3.

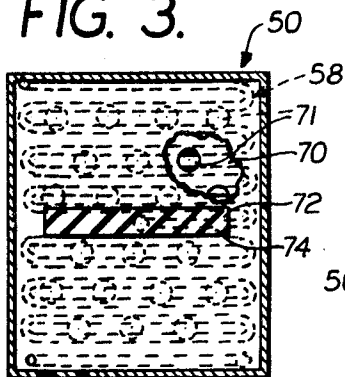
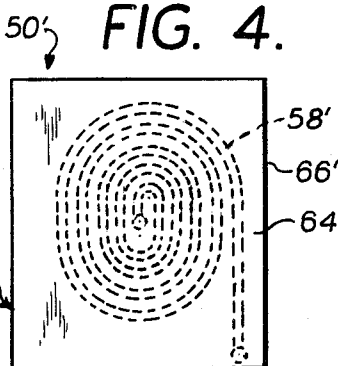


FIG. 4.



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OPEN-CYCLE PORTABLE REFRIGERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to refrigerators, and more particularly to open-cycle portable refrigerators.

2. Description of the Prior Art

Prior art refrigeration systems are generally of the closed-cycle type. Such a closed-cycle system requires the use of a compressor and a motor to cause circulation of the refrigerant through the closed-cycle system. In systems of this type utilizing a compressed gas as a coolant, or refrigerant, a compressor is utilized to compress the gas which is expanded as it passes through an evaporator. The expanded gas must then be compressed again to complete the cycle. In such closed-cycle systems it has been known to utilize an evaporator in which the evaporator coil is disposed within a liquidtight container which contains water or an aqueous salt solution. However, such closed-cycle systems have never been portable because of the considerable weight associated with the compressor and motor necessary for the closed-cycle system.

It has of course long been recognized that expanding a compressed bottled gas results in cooling the surrounding atmosphere. However, such cooling effect is only transitory at best and gives no long-lasting refrigeration.

No commercially successful portable mechanical refrigerator has yet appeared on the market. To date portable cooling has been achieved mainly either by ice chests, which are bulky and often messy or by the use in an insulating container of a prefrozen canned coolant, which often does not provide sufficient duration of cooling.

SUMMARY

An open-cycle portable refrigerator is constructed which includes a storage container defining a storage space therewithin, a container of compressed gas, and an evaporator inside of the storage space which comprises a housing having a tube therewithin and a liquid medium disposed within the housing in substantially surrounding relation with the tube. The tube has an inlet and an outlet. A duct means connects the compressed gas container to the inlet of the tube through an outlet in the compressed gas container. The tube outlet is in communication with either the storage space or the ambient atmosphere surrounding the storage container.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view of the preferred embodiment of the present invention;

FIG. 2 is a plan view of the embodiment shown in FIG. 1 with the cover removed, with one modification therein;

FIG. 3 is a partial sectional view taken along line 3—3 in FIG. 2; and

FIG. 4 is an end view showing an alternative embodiment of the evaporator shown in FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail and particularly to FIG. 1 thereof, a portable refrigerator generally designated by the reference character 10 includes an insulating container 11 which encloses a storage space 12 in which food or other articles may be stored for refrigeration. Disposed within the refrigerator adjacent one end 21 of the container 11 is a bottle 18 containing compressed gas which serves as the refrigerant, an evaporator 50 in which the compressed gas expands to effect the cooling of the space 12, and duct means 28 interconnecting the bottle 18 with the evaporator 50. Preferably a valve and regulating means 30 is interposed in the duct means 28 for regulating gas flow in accordance with temperature and for shutting off gas flow when desired.

The insulating container 11 is formed preferably of a lightweight insulating material such as compressed

polystyrene pellets (Dow trademark "Styrofoam"), polyurethane foam, or the like. As shown and as presently preferred, the container 11 includes a base or bottom 13 having a bottom wall and an upstanding peripheral sidewall defining top opening therein. A cover or lid 14 is provided for opening and closing the top opening. Lid 14 has a downwardly extending peripheral sidewall 15 proportioned to overlap the upwardly extending peripheral sidewall of the container 11. The lid 14 is shown provided with a handle 17 for putting the lid on and removing the lid from container 11. Of course, in lieu of a fully removable lid 14, the lid may be constructed as a member hingedly connected to the upstanding peripheral sidewall of the container 11. It will also be understood that container 11 could be provided with suitable handles or handhold recesses for transporting the refrigerator 10.

The bottle 18 for an expandable compressed gas such as carbon dioxide is preferably of the well-known rechargeable type although disposable bottles may be employed. Bottle 18 is provided with an outlet 26 which is preferably controlled by a quick connect-disconnect, although some other suitable means to prevent gas loss when the bottle is not connected to the duct means 28 may be employed. As shown and as is preferred, the duct means 28 is connected to the outlet 26 of the bottle 18 for the reception of compressed gas as it passes out through the bottle. The duct means passes through the valve and regulating means 30 which will be described in detail hereinafter, and then is connected to an inlet 60 of a serpentine evaporator tube 58 which is enclosed in a conductive housing 56 for the evaporator 50. The outlet end of the serpentine evaporator tube 58 is directed into the space 12, preferably in a direction away from the open storage space for food, as will be described hereinafter. Thus, as compressed gas flows from the bottle 18 through the duct 28 and into the serpentine coil 58 through the inlet 60, it will commence expanding in the serpentine coil whereby to cool the material which surrounds it and thereby effect refrigeration.

As is presently preferred, the serpentine coil 58 has two serpentine portions, both of which are arranged in a planar array, one adjacent the front wall 66 of housing 56 and the other adjacent rear wall 68 of evaporator housing 56, with each of the serpentine tube halves mounted on respective perforated mounting plates 70, as by soldering or the like, for reasons which will become apparent hereinafter. Thus, as may best be seen in FIG. 1, the left- and right-hand halves of the tube 58 are arranged in two vertically extending parallel planes, one immediately adjacent the front wall 66 and one immediately adjacent the rear wall 68 of housing 56, with both portions sandwiched between their respective front and backwalls and the adjacent perforated mounting plate 70.

Substantially the entire space within housing 56 unoccupied by the serpentine coil 58 and its two mounting plates 70 is filled with a liquid medium, preferably a freezable liquid medium such as water or an aqueous solution of a suitable salt or permanent antifreeze such as ethylene glycol, both of which tend to depress the freezing point below 32° F. To improve the ability of water or a salt solution of water to be frozen and thawed an indefinite number of times without impairing the function of the system to maintain low temperatures over a long period of time, a colloid such as starch may be added to the liquid medium 64. However, such colloid is not required if ethylene glycol is employed to depress the freezing point of the liquid medium. It will be noted that due to the inclusion of apertures 71 in plates 70, both serpentine halves of tube 58 are substantially surrounded by the liquid which will insure good surface contact between liquid and tube to maximize heat transfer. To further improve heat transfer, housing 56, plates 70 and tube 58 are all made preferably of a highly conductive lightweight metal such as aluminum.

It is well known that when a water or an aqueous solution freezes, there is a substantial volumetric increase. Such an increase could have a serious stressing effect upon the evaporator housing 56 and could lead to a rupture of the housing and the subsequent loss of water or the aqueous solution therein.

To avoid this problem, a readily compressible member such as a hollow rubber tube 74 is disposed within the housing 56 between the two apertured plates 70 with the ends of the tube 74 sealed to prevent the water or solution from entering into the interior thereof. Thus, when the water is frozen in the manner to be described hereinafter, the expansion will be taken up in a compression of the tube 74 rather than in a significant stressing of the housing 56.

With the structure as described to this point, when it is desired to cool the storage space 12, gas is permitted to pass out of the bottle 18 through the duct means 28 and into the serpentine tube 58 where the gas may experience a large volumetric expansion. As is well known, the expansion of a gas requires heat from the surrounding atmosphere whereby to effect a cooling thereof. As already noted, the surrounding atmosphere for the coil 58 is almost entirely liquid 64 in which the coil is immersed. Accordingly the gas within the serpentine coil 58 will take heat from the water and depress its temperature and finally remove the heat of fusion therefrom, whereby to cause a freezing of the water. For reasons which will become apparent hereinafter, the expanded gas is vented from the tube 58 through an outlet 54 into space 12. The frozen water will serve as a cooling medium for a substantial period of time and thereby maintain the temperature depressed in the storage space 12 to cool the contents thereof. When the temperature commences rising, whereby to melt the liquid medium 64, the gas can once again be permitted to flow from bottle 18 through evaporator 50 to refreeze the water and thereby restore the temperature in the storage space to its depressed valve.

As previously noted, a regulator and valve means 30 is interposed in the duct means 28 for controlling the flow of compressed gas from bottle 18 to evaporator 50. Although it is not necessary to the present invention, as shown and preferred, the regulating means 30 includes a thermostatic control means 38 for controlling the valve 30 in accordance with temperature in the proximity of the thermostatic control means or bimetal 38. Thus, as shown in FIG. 1, the temperature controlling the operation of means 30 is to the rear of the evaporator 50. Naturally, other points inside of the enclosure 11 could be selected as the temperature control point. In addition to the automatic control by regulating means 30, the regulating means 30 has associated therewith a manual on-off means of well-known design. Such manual means includes a handle 40 which operates an operating shaft 41 that closes and opens the valve 30. Preferably, the knob or handle 40 is situated outside of container 11 adjacent end wall 21 whereby to require an opening 43 in said end wall to permit the operating shaft 41 to pass therethrough. This eliminates the need for removing lid 14 to operate manually handle 40. However, it will be understood that operating member 40 could be disposed within the interior of housing 11.

Thus it will be seen that by operation of the manual control mechanism 40, 41 of the regulating means 30, the flow of gas from bottle 18 can be shut off entirely, whereby to override the thermostatic control means 38. However, when the regulating means 30 is opened manually, the thermostatic means 38 will control the flow, whereby to permit gas to flow through duct means 28 when the measured temperature is above a predetermined value and to cut off such gas flow when the temperature is below the predetermined value. It is obvious, and has already been indicated, the present invention may be constructed without employing the thermostatic control means. In the alternative, the thermostatic control means could be included and the manual valve means 40 could be eliminated.

In the preferred form of the invention shown in FIG. 1 a third means for controlling the flow of gas from the bottle 18 to the evaporator 50 is shown. This means may be termed a cover interlock means 42 including a vertically extending rod 44 that is pivotally connected to a rod 45 that is fixed and radially outstanding from the shaft 41. The shaft 44 slidably extends through bushings 47 secured to end wall 21 and has on

its central portion a suitable fixed collar 49. Disposed about shaft 44 between the lower bushing 47 and the collar 49 is a compression spring 46. When the cover or lid 14 is removed from the container 11, rod 44 will move upwardly under the urging of spring 46 and thereby rotate shaft 41 by virtue of pin 45 to close the manually controlled valve portion of regulating means 30, and thereby cut off any gas flow during the time that the lid 14 is off the container 11. When the lid is pressed down upon the base and thus restored to the position illustrated in FIG. 1, the rod 44 will be moved downwardly against the bias of spring 46 to compress the spring and will, through pin 45 rotate shaft 41 in the reverse direction to reopen the manually controllable portion of valve 30. Thus, no gas will flow when the container 11 is open to thereby prevent the unnecessary loss of expanded refrigerant.

As shown and as preferred, the bottle 18 is vertically oriented with the outlet at the bottom in order to permit any water condensate therein to be drained therefrom. However, the bottle could be disposed in any desired orientation such as horizontal, or vertical with the outlet at the upper end. To hold the bottle 18 in its illustrated orientation, two means are shown, one in FIG. 1 and one in FIG. 2. Referring first to the FIG. 1 bottle-holding means, an arm 22 is mounted beneath an extension from the peripheral sidewall of the container 11 which extension is designated by the reference numeral 23, and within a recess 25 in the end wall 21, whereby to cause the arm to be held above the bottle 18. Threadably mounted in a threaded aperture 27 in arm 22, is a thumb screw 29 which may be rotated to move it downwardly and thereby press the bottle 18 downwardly so as to firmly engage outlet 26 with duct means 28. Alternatively, and as shown in FIG. 2, the bottle 18 may be held in the illustrated position by one or more arcuate spring clips 31. (This is the only difference in the FIG. 1 and FIG. 2 embodiments.)

Depending on the size of the compressed gas bottle 18 and on the intended effective cooling time of the refrigerator 10, one or more bottles 18 may be included. Thus, as shown in FIG. 2, three bottles 18, 18' and 18'' are included within the container 11, the bottles 18' and 18'' serving as spares to be employed as bottle 18 when the compressed gas in bottle 18 is exhausted. In the alternative, a suitable duct and valving means could be included to interconnect bottles 18, 18' and 18'', whereby to switch them in and out of connection with evaporator 50 as desired.

Some difficulty may be experienced if the compressed gas within bottle 18 is subjected to the coldness of the remainder of the container when the refrigerator is operating. To minimize the refrigerator effect upon the compressed gas in the bottle 18, an insulating partition 24 may be included, which partition extends across the container in parallel spaced relation with the end wall 21 to define a bottle chamber 20. The wall 24, being made preferably of the same material as the remainder of the container 11, will have excellent insulating qualities and will thereby protect the contents of the bottle 18 from the cold.

As previously noted, the outlet 62 of the serpentine coil 58 is through the rear or back surface of the housing 56 of the evaporator 50. The purpose of this, as will now be described, is to circulate that air closest to the evaporator, and hence coldest, to equalize temperature and improve refrigeration effectiveness. Mounted on wall 24 in spaced relation to the back surface 68 of evaporator housing 56 is a deflection plate 54 which is in close confronting relation with housing 56 to define a space or passage therewith for the fully expanded gas being vented from the outlet 62 to flow through. Thus when the gas passes out from the outlet 62 in a direction towards the partition wall 24, it will be deflected vertically and horizontally in the plane of the deflection plate 54 and then to the outer edges of the housing 56, where it will pass therearound by means of an inwardly extending peripheral sidewall 55 on deflection plate 54 to direct the gas forwardly into the storage area 12. As already noted, this flow of the gas around the outside of the housing 56 will tend to remove the cold layer of air

immediately adjacent housing 56 and cause that cold air to circulate, whereby to more efficiently and uniformly refrigerate the contents within the space 12 and the space 12 itself.

Clearly the passage of the expanded refrigerant into the space 12 will tend to elevate the pressure therewithin. To relieve that pressure, a suitable relief valve 16 may be provided in the peripheral sidewall of the housing 11. In the alternative, gas pressure relief might be effected merely by the normal leakage that may be expected between the lid 14 and the container 11.

In accordance with another improvement of the present invention, the evaporator 50 may be removably positioned within the enclosure 12 as by suitable detachable mounting means such as the clamps 52 of FIGS. 1 and 2. Naturally, with such a removable mounting, there is preferably a suitable quick connect-disconnect between the inlet 60 of tube 58 and the outlet of duct means 28. With such a removable feature, the user can, prior to actually filling refrigerator 10 with its contents, remove the evaporator 50 from the inside of enclosure 12 and place it in a home freezer or the like to cool the liquid medium 64 therein down below its freezing point. Thereafter, the evaporator 50 can be reconnected inside space 12 by clamps 52 and reconnected to the duct means 28. Such a feature will eliminate the need for expending a substantial amount of compressed gas for the initial cooling of liquid 64, this being done by the home freezer instead. Accordingly, the refrigerant or compressed gas within the bottle 18 will be employed merely to maintain the refrigerator temperature, not to achieve it. This will effect significant economies in operation and a reduction in weight by requiring fewer bottles of compressed gas 18 for a given span of operation.

Referring now to FIG. 4, a modified form of evaporator 50' is illustrated in which the cooling coil 58', instead of being serpentine as in FIGS. 1 and 2, is in fact arranged in a spiral coil. Clearly, the particular arrangement for elongating the coil 58 within the enclosure 56 is of no great moment so long as the coil is long enough and the convolutions or flights are spaced far enough apart to provide for a large surface area for heat transfer.

In using the preferred embodiment, prior to going on a picnic or to the beach, the user will open the lid 14 and remove the evaporator 50 from the clamps 52 simultaneously effecting a disconnection between the inlet 60 of the tube 58 and the duct means 28. No gas will flow from bottle 18 due to the lid interlock 42. The evaporator 50 will then be placed in a home freezer to cause the liquid 64 therewithin to freeze, which freezing will not adversely affect the outside housing 56 by virtue of the compression of the compressible tube 74 disposed within the liquid medium 64 inside of the evaporator 50. After the freezing has been accomplished the evaporator 50 is removed from the freezer and repositioned within the enclosure 12 on clamps 52 whereby to reconnect the inlet 60 to the duct means 58.

With the frozen evaporator 50 repositioned inside the enclosure, the thermostatic control means 38 will rapidly sense the reduced temperature, whereby to further close the regulating means 30 so that when the lid 14 is placed back on to the base 14 to close the space 12 with the contents to be refrigerated disposed therewithin, no gas will flow from the bottle 18. During the course of the day, due to normal radiation and conduction, the temperature within the enclosure 12 will rise, which increase will primarily be retarded by virtue of the additional heat being used mainly to convert the frozen liquid 64 from solid back to liquid. This reliance on the heat of fusion tends to stabilize greatly the temperature within the enclosure 12. However, once the liquid is all restored to the liquid state, additional heat furnished to the evaporator will commence raising the temperature of the evaporator liquid and hence of the space 12 and the contents therein. At some preselected temperature, the thermostatic control means 38 will operate regulating means 30 to open duct means 28 and cause compressed gas within bottle 18 to flow out and into the

evaporator coils 56 and 56' where a rapid expansion of the gas will occur whereby to significantly cool the liquid medium and ultimately to refreeze it. Upon refreezing, the thermostatic control means will sense the reduction in temperature below the freezing point and will once again shut off the regulating means 30 until the temperature again rises above a preselected maximum level. In this manner the temperature within the enclosure 12 can be maintained within quite narrow limits. Naturally, if the thermostat control means 38 is not included, then the user would operate the valve 30 by turning the handle 40 periodically on a time schedule basis, if desired.

With the combination of the open cycle evaporator including the freezable liquid medium therein, together with the compressed gas refrigerant, an extremely convenient lightweight mechanical refrigerator is achieved, whereby to eliminate the need for ice which melts and often ruins sandwiches and the like by virtue of the melted water. Also, the described refrigerator is far superior to the use of simple canned freezable liquids, in that their range or time of use is extremely limited. With the present embodiment the freezable liquid can be refrozen on the site whereby to extend significantly the term of use on a given day. While the present invention has been described in connection with a liquid 64 that is freezable at or somewhat below 32° F. (perhaps down to about 0° F.), which is the preferred form of the invention, significant temperature stability is gained even from the inclusion of non-freezable liquids, that is, liquids that freeze below about 0° F., such as, for instance, ethyl, methyl isopropyl and butyl alcohol, ethylene glycol, etc.

We have spoken of the refrigerant in bottle 18 as a "compressed gas." Of course, by the term compressed gas we intend to include not only gases which have been compressed but remain in the gaseous state, but gases which have been converted to the liquid state by such compression.

While we have shown and described the preferred form of the present invention and have suggested modifications thereof, other changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of this invention.

What is claimed is:

1. A portable open-cycle refrigeration system comprising: a storage container defining a storage space therewithin; a container of compressed gas, said compressed gas container having an outlet; an evaporator inside of said storage space and comprising a housing having a tube therewithin, said tube having an inlet and an outlet, a liquid medium in said housing in substantially surrounding relation with said tube; and duct means for connecting the outlet of said compressed gas container to the inlet of said tube, said tube outlet being in communication either with said storage space for effectuating circulation within said storage space interior of the storage space interior ambient atmosphere adjacent said evaporator housing, or with the ambient atmosphere surrounding said storage container.
2. An open-cycle portable refrigerator in accordance with claim 1 further including a means for removably inserting said gas container adjacent said evaporator.
3. An open-cycle portable refrigerator in accordance with claim 1 further including a means for removably inserting said evaporator inside of said storage space.
4. An open-cycle portable refrigerator in accordance with claim 1 wherein said compressed gas is carbon dioxide.
5. An open-cycle portable refrigerator in accordance with claim 1 wherein said liquid medium is water, an aqueous salt solution, or a permanent antifreeze solution.
6. An open-cycle portable refrigerator in accordance with claim 1 further comprising a means for regulating the passage of compressed gas from said gas container outlet, said regulating means being interposed in said duct means for regulating the passage of said gas to said evaporator.
7. An open-cycle portable refrigerator in accordance with claim 6 wherein said regulating means comprises an adjustable valve.

8. An open-cycle portable refrigerator in accordance with claim 7 wherein said storage container includes a removable cover, a resiliently mounted shutoff control means is biased against said cover, said control means closing said adjustable valve and preventing the passage of said gas from said gas container outlet when said cover is removed.

9. An open-cycle portable refrigerator in accordance with claim 1 wherein said tube comprises a serpentine passageway for said compressed gas, said passageway providing a large area for heat exchange so as to effect expansion of said compressed gas.

10. An open-cycle portable refrigerator in accordance with claim 9 wherein said medium is water, an aqueous salt solution, or a permanent antifreeze solution and said compressed gas is carbon dioxide.

11. An open-cycle portable refrigerator in accordance with claim 10 wherein said regulating means comprises an adjustable valve and a thermostatic control means for controlling the operation of said valve so as to maintain a desired refrigeration temperature.

12. An open-cycle portable refrigerator in accordance with claim 1 wherein said evaporator includes a compressible member disposed with said liquid medium, said member being compressed upon expansion of said liquid medium.

13. An open-cycle portable refrigerator in accordance with claim 12 wherein said evaporator further comprises a thermally conductive plate in confronting relation with an inwardly facing portion of said tube, and a resilient member, said plate having apertures therein to permit the passage of said liquid medium therethrough, said housing having a thermally conductive end wall, said tube is adjacent said end wall, and said resilient member biasing said plate against said tube so as to form a thermally conductive sandwich with said tube.

14. An open-cycle portable refrigerator in accordance with

claim 13, wherein said evaporator includes another thermally conductive plate in confronting relation with another inwardly facing portion of said tube, said tube being adjacent another thermally conductive end wall, said resilient member being interposed between said plates and biasing said other plate against said tube so as to form another thermally conductive sandwich with said tube.

15. An open-cycle portable refrigerator in accordance with claim 1 wherein a deflection plate is adjacent the end wall having said storage space communicating tube outlet therein, and is spaced therefrom; said deflection plate partially surrounding said housing so as to form a deflection channel for the gas exhausting from said tube outlet.

16. An open-cycle portable refrigerator in accordance with claim 1 wherein said storage container includes a gas container storage portion insulated from said evaporator and the remainder of said storage portion, said gas container being disposed therein.

17. A portable open-cycle refrigeration system comprising: a storage container defining a storage space therewithin; means on said storage container for mounting a container of compressed gas having an outlet;

an evaporator inside of said storage space and comprising a housing having a tube therewithin, said tube having an inlet and an outlet, a liquid medium in said housing in substantially surrounding relation with said tube; and

duct means for connecting the outlet of said compressed gas container to the inlet of said tube, said tube outlet being in communication either with said storage space for effectuating circulation within said storage space interior of the storage space interior ambient atmosphere adjacent said evaporating housing, or with the ambient atmosphere surrounding said storage container.

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