Abstract: A multiple convective cushion seating and sleeping system includes the use of tubular spacer material including tubular spacer fabric. A power unit including a heat pump and blower is in fluid communication with a first convective cushion by a first duct and with a second convective cushion by a second duct to provide the temperature modified air to both convective cushions for controllably heating or cooling multiple users. A thermoelectric heat pump, a Stirling cycle heat pump or other type of heat pump can be used. The invention includes the use or one or more valves to control the air flow to one or more of the convective cushions and provides for manual operation, electronic control and operation by a remote telecommunications unit. The invention can be utilized in vehicles, such as tractor trailers and recreational vehicles, and in buildings such as apartments, dorm rooms and houses.
RELATED APPLICATION DATA

This application is a continuation-in-part of the U.S. Patent Application entitled "Improved Convective Seating and Sleeping Systems" filed on June 19, 2007.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This present invention relates to convective cooling and heating of seats, mattresses, mattress pads and other articles used as a cushioning device.

2. Description of Related Art

There are many applications and situations where it is desirable to provide for convective cooling or heating of various articles including seats, mattresses and other articles used for supporting individuals while either sitting or laying down on the article. Many of the conventional devices that have been used suffer from serious drawbacks. As one example, the resistance heated type prior art mattresses and cushions do not provide for cooling or ventilation, a major disadvantage in many parts of the world that lack adequate air conditioning. Moreover, the conventional devices are very inefficient and lack adequate control to adjust the heating or cooling temperature to satisfy the needs of the user. In addition, because of the believed negative impact on the environment, certain materials, such as Freon used for cooling purposes, are being phased out for use in air conditioning systems in many countries.

Some drivers of semi-tractor trailers use a sleeper cab with a bed inside that enables the driver to sleep when necessary while on the road without incurring hotel bills. Recent legislation has mandated that diesel truck engines cannot be allowed to idle to provide electricity for an on-
board air conditioning system as in the past. Conventional air conditioning space cooling systems use too much energy to run for long periods of time on the vehicle battery or batteries.

In U.S. Patent No. 6,085,369 by Steve Feher there is disclosed a selectively cooled or heated cushion and apparatus therefore and in U.S. Patent Publication No. 2006/0137099, also by Steve Feher, published June 29, 2006, a convective cushion with a positive coefficient of resistance heating mode is disclosed. While each of the Feher '369 patent and the Feher '099 application is a substantial improvement over other known and conventional prior art techniques, there is believed to be room for improvement in apparatus and systems that provide selectively variable temperature air to convective cushions for cooling and/or heating both a seating surface and a sleeping surface with the same air cooling or heating source and in a wide variety of applications, including home, office and in vehicles. Thus, a need exists for improved systems and methods for convective cooling and heating of seats, mattresses, mattress pads and other articles.
SUMMARY OF THE INVENTION

A multiple convective cushion seating and sleeping systems and methods for controlled convective cooling and heating for seats, mattresses, mattress pads and other articles. The invention is intended to be used in many applications, including in vehicles such as tractor trailers and recreational vehicles, and in dwellings such as dorm rooms where a chair and bed can be cooled and heated with a single cooled and/or heated air source, saving the user money and space over having to purchase and set up two separate air sources, one for the chair and one for the bed. In one or more embodiments of the invention, a single source of cooled and/or heated air is used to convectively cool and/or heat multiple surfaces, such as seating surfaces and sleeping surfaces, either individually or simultaneously.

With respect to large trucks, it is known that conventional air conditioning space cooling systems use too much energy to run for eight hours on the vehicle battery or batteries. The invention advantageously uses an air convection cooled and/or heated mattress or mattress pad which is more energy efficient at cooling and eating the sleeper than a space cooling and heating device. The invention is much quieter, enabling a better sleep for light sleepers and, because of much higher efficiency, the invention can be powered by a typical truck electrical system without running the battery down. The invention saves space and weight by utilizing a single air cooling and/or heating source and with respect to use in vehicles, advantageously allows for the simultaneous use of both a convectively cooled or heated seating surface and sleeping surface when two drivers are taking turns driving and sleeping.

In one or more embodiments of the invention, the invention includes a first convective cushion and a second convective cushion, each with a generally permeable top surface, an internal air flow structure and an air inlet in communication with the respective air flow
structure. A power unit including a blower delivers air of selectively variable temperature and quantity to both respective air inlets for the convective cushions and the air then fans out within the respective air flow structure with some of the air permeating up through the convective cushion's top surface to cool or heat the user or users. The power unit includes a thermoelectric heat pump, a Stirling cycle heat pump or other types of heat pumps supplying cooled and/or heated air. Valves are optionally utilized to control the flow of the air from the blower to the air flow structures of the convective cushions.

The air flow structures include the use of tubular spacer fabric, air flow structures such as Muller Textile's 3 Mesh or Strahle and Hess\(^1\) assembled woven fabric and other air flow structures known to persons skilled in the art. In embodiments of the invention, some of the air delivered to the air flow structure of the convective cushion flows toward and out air outlet vents at an end of the cushion. The present invention includes the use of a controller to selectively control the operation of the blower, the use of a remote control signal from a telecommunications unit and use of the invention with the first cushion on a conventional mattress and the second cushion attached to a seat cushion.

Further embodiments of the invention include methods for delivering temperature modified air to convective cushions for convective cooling and/or heating of multiple surfaces. The methods include the steps of providing a first plenum structure, a second plenum structure, and activating a power unit in fluid communication with air flow structures within each plenum structure to deliver temperature modified air to both the first and second plenum structures and provide convective cooling and/or heating to multiple surfaces. Further embodiments include the step of placing the first plenum structure on a conventional mattress and attaching the second
plenum structure to a seat cushion and include the step of installing the first plenum structure, the second plenum structure and the power unit within a vehicle.

Other and further advantages and embodiments will appear to persons skilled in the art from the written description and the drawings herein.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a perspective view of one embodiment of a convective cushion of the present invention.

FIG. 2 is a side elevation and section view of a convective cushion of one embodiment of the present invention.

FIG. 3 is a schematic view of a version of a heat pump in one or more embodiments of the present invention.

FIG. 4 is a front elevation and sectional view showing a pleat in one embodiment of the present invention.

FIG. 5 is a front elevation and partial section view showing the air flow for one embodiment of the present invention.

FIG. 6 is a front elevation and partial section view showing the air flow in a further embodiment of the present invention.

FIG. 7 is a front elevation and partial section view showing the air flow in another embodiment of the present invention.

FIG. 8 is a side elevation and partial section view of one version of a series air flow structure for one embodiment of the present invention.
FIG. 9 is a side elevation and partial section view of one version of a parallel flow structure for one embodiment of the present invention.

FIG. 10 is a front elevation and partial section view illustrating an embodiment of a convective cushion for use in one or more embodiments of the present invention.

FIG. 11 is a side elevation and partial section view of one version of a series air flow structure with headrest for one embodiment of the present invention.

FIG. 12 is a section view of a Stirling cycle device for use in one or more embodiments of the present invention.

FIG. 13 is a side elevation and section view illustrating the piston, the magnetic piston ring and the magnetic bearing permanent magnet and pole assembly in a Stirling cycle device in one or more embodiments of the present invention.

FIG. 14 is a front elevation and section view of the piston, magnetic piston ring and the magnetic bearing permanent magnet and pole assembly in a Stirling cycle device in one or more embodiments of the present invention.

FIG. 15 is a schematic view of a version of a mobile device for use in one or more embodiments of the present invention.

FIG. 16 is a schematic view of a version of a heat pump in one or more embodiments of the present invention.

FIG. 17 is a schematic view of another version of a heat pump in one or more embodiments of the present invention.

FIG. 18 is a perspective view of a further embodiment of a convective cushion in one or more embodiments of the present invention.
FIG. 19 is an end elevation and section view of the convective cushion illustrated in Fig. 18 used in one or more embodiments of the present invention.

FIG. 20 is partial perspective view of one embodiment of the tubular spacer material in one or more embodiments of the present invention.

FIG. 21 is a schematic view of one embodiment of a thermoelectric device in one or more embodiments of the present invention.

FIG. 21a is an end elevation view of one embodiment of a blower for use with one or more embodiments of the thermoelectric device of FIG. 21.

FIG. 22 is a schematic view of one embodiment of a thermoelectric device in one or more embodiments of the present invention.

FIG. 23 is a perspective view of one embodiment of the convective cushion and seating system of the present invention.

FIG. 24 is an end elevation and section view of the convective cushion in one embodiment of the convective cushion and seating system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a perspective view of one embodiment of the convective cushion 10 as applied to a mattress for cooling and heating while a user is resting or sleeping. The convective cushion 10 includes a plenum 12 having a generally air permeable top surface 14 that is secured around a perimeter 16 to a bottom surface 18. The bottom surface 18 is in one or more embodiments generally impermeable to air and as shown in FIGS 1 and 2 can be placed on a mattress 20 to make the bottom surface 18 generally impermeable. In one or more embodiments, the mattress
20 is a foam mattress, but the present invention includes the use of a futon, coil spring mattresses, inflatable mattresses or other structures made of other materials to support the plenum 12.

As shown in FIG. 1, the plenum 12 includes multiple pockets 22 made of a synthetic material woven into a mesh of approximately 4-6 strands per inch x 4-6 strands per inch with each of the pockets 22 separately removable as part of the plenum 12. FIG. 1 shows three pockets 22 but other quantities and sizes of pockets 22 are within the scope of the present invention.

Each of the pockets 22 contains tubular spacer material 30. The present inventor's U.S. Patent Nos. 6,085,369 and 6,263,530 pioneered the use of tubular spacer fabric as an air flow structure for seats, mattresses, mattress pads and other articles of furniture that can be sat on or laid down upon. Although one embodiment of the invention utilizes the same tubular spacer fabric as described in the inventor's issued U.S. Patent Nos. 6,085,369 and 6,263,530, it is within the scope of the present invention to utilize other air flow structures such as Muller Textile's 3 Mesh or Strahle and Hess' assembled woven fabric and other air flow structures, however there may be substantially reduced levels of performance when compared to the tubular spacer fabric disclosed in the above issued U.S. patents.

The pockets 22 secure the multiple sections of the tubular spacer material 30 close together while still allowing air to flow from one end of the plenum 12 to the other end of the plenum 12 through pockets 12 via the tubular spacer material 30. The pockets 22 may be arranged so that the longitudinal axes of the tubular spacer material in the pockets 22 are all aligned to allow substantially uninterrupted flow of air. If the pockets 22 were made of standard cotton sheeting, as the upper and lower layers are made, the pressure drops across the pocket
walls between the tubular spacer material 30 layers would be too high and functional air flow within the plenum 12 would not be possible using a small, light, cost-effective and quiet main blower.

The use of multiple pockets 22 containing tubular spacer material 30 in one or more embodiments instead of one single mattress sized panel allows for the tubular spacer material 30 to be easier to handle in smaller pieces and it is generally not feasible to launder a single mattress size piece of tubular spacer material 30 in a standard washing machine. A single queen size piece of tubular spacer material 30 is not impossible to handle, but is much more difficult to handle than smaller pieces, even if laundering by washing in a shower or bathtub or a large washtub. For larger beds, such as King, California King, and larger, it may be more convenient to divide the plenum 12 into more pockets 22 to facilitate shipping, handling and laundering and these embodiments are within the scope of the present invention also.

As shown in FIG. 1, one or more embodiments include an air inlet nozzle 40 to deliver air to the plenum 12. Air enters the mattress pad through the air inlet nozzle 40 and fans out within the tubular spacer material 30, with some of the air permeating up through the top surface 14 of the plenum 12 as the air flows toward an outlet at the opposite end of the plenum 12, which is shown as air outlet vents 41 in FIG. 1. This air flow surrounds the user underneath and to a lesser extent, on the sides, with an atmosphere or micro-environment of cooled or heated air, depending upon which mode is chosen. The air inlet nozzle 40 in one or more embodiments is removable and may be removed prior to machine washing, by sewing or otherwise attaching a small plastic adaptor to the edge of a cloth cover, allowing the air inlet nozzle 40 to be snapped on and off. Further embodiments of the invention include an extra layer 24 as shown in FIG. 1 which can be placed over a pocket 22 adjacent to the air inlet nozzle 40. The extra layer 24 can
provide temperature control for the space adjacent to the air inlet nozzle 40 by limiting air flow through the top surface 14 in the area of the extra layer 24.

In one or more embodiments, the blower 46 delivers air to the air inlet nozzle 40 which may include a flexible hose portion as shown in FIG. 1, and the air delivered from the blower 46 to the air inlet nozzle 40 is of a selectively variable temperature, a selectively variable quantity or a selectively variable temperature and quantity. In additional embodiments, the blower 46 includes a decorative face plate 48 illustrated in FIG. 1 to display colors and/or designs that a user may select to mask the blower 46, which may be under the bed or at the end of the bed in the event it does not fit under the bed. If under the bed, there needs to be an open path to enable air flow to the blower 46.

In one or more embodiments, the face plate 48 which is removable from the blower 46 and secured to the blower 46 by plastic fittings, snap-on connectors or other securing mechanisms that allow the face plate 48 to be removed, all of which are known to persons skilled in the art and included within the scope of the present invention. The face plate 48 may cover all or as shown merely a portion of the blower 46, and be a single color such as a neutral color or a dark color or may be a combination of colors. The face plate 48 may be made of one or more materials including plastic, wood or a combination of materials. The face plate 48 may also be a design such as a wood appearing veneer as selected by the user to present a more attractive appearing article to persons viewing the blower 46. Embodiments of the present invention allow a user to selectively change the face plate 48 as desired for a variety of color, color combinations and design arrangements that the user may wish to select.

In one or more embodiments shown in FIG. 1 and FIG. 2, a fitted sheet 32 secures the pockets 22 together in a similar way a fitted sheet with an elastic band fits securely onto a
mattress by gripping around the bottom edge. An outer top cover 34 may also be sewn to the 
underlayer around the perimeter at the top of the plenum 12 to further secure the pockets 22.

FIG. 2 shows a closure 36 along a long side edge of the plenum 12. This closure 36 may be 
made of hook and loop fastener or may be a ZIPPER running the length of the edge. The closure 
36 may also be a plastic slide, snaps or buttons. In further embodiments, an elastic band 38 can 
secure the top layer 34 to the mattress 20.

FIG. 2 shows an alternative embodiment with an air inlet duct 42 that is molded into a 
foam mattress 20. The outlet air duct 44 is molded into the foam mattress 20 and allows air that 
does not escape through the top surface 14 of the plenum 12, and which flows longitudinally 
within and through the tubular spacer material 30, to flow out of the cushion 10.

FIG. 3 shows a schematic view of an embodiment of the convective cushion 10 with a 
thermistor or thermocouple 50. As illustrated in FIG. 3, data from the thermistor or 
thermocouple 50 is communicated to a controller 52, which may be either a variable amplitude 
Stirling Cycle cooler piston drive controller or Peltier thermoelectric heat pump control circuit,
to either increase or decrease the amplitude of the Stirling Cycle piston displacement or the 
power level delivered to the thermoelectric heat pump, and hence the cooling power delivered to 
the cushion 10 as a function of a preselected temperature.

In one or more embodiments, the thermistor or thermocouple 50 may be placed on the 
underside of the top cover 34 of the embodiment shown in FIGS. 1 and 2 adjacent to the tubular 
spacer material 30. In other embodiments of the invention, the thermocouple 50 is placed in a 
seat backrest, a seat rest or may be placed anywhere else in the conditioned air stream to provide 
temperature feedback to the controller 52 and use conditioned air temperature at any given point in the stream as a reference temperature for the controller 52.
In further embodiments of the invention, the thermistor or thermocouple 50 is of the miniature type in order to minimize sensor mass and enable more rapid and sensitive reaction to changes in cover cloth temperature.

In cooling mode, if the user is large and hot, it will take longer for the sensor to cool down because the user's body heat will prevent the sensor from cooling down to the temperature of the air flowing by on the inside of the tubular spacer material 30. But if the user is small and relatively cool, or if the user has cooled down after sitting on the seat or lying on the mattress pad, the sensor will begin to read more of the internal air temperature, and this change in value can be interpreted as a signal to reduce cooling power in order to avoid overcooling.

The embedded thermocouple or thermistor 50 is applicable to both cooling and heating modes in the improved Peltier thermoelectric type convective cushion 10 because heating mode is a function of input power to the thermoelectric device and the air flow volume through the heat pump.

Also as shown in FIG. 3, one or more embodiments include a double pole, double throw switch 54 that is arranged to switch a resistor 56 in and out in series with the basic main blower control potentiometer. The basic control potentiometer controls the speed of the main blower, which controls the cooling or heating power delivered to the cushion 10 at a given temperature change. The variable amplitude piston driver controller also controls the power of the Stirling machine, but another method of control, especially in heating mode, is to control the amount of air blown through the cushion 10 regardless of air temperature change using the double pole, double throw switch 54.

It can be appreciated in FIG. 3 that the trim resistor, which drops the speed of the main blower in heating mode, is only switched in circuit for a Stirling Cycle machine when heating
mode is selected. It is then in series with the main blower control potentiometer, in order to maintain user control of main blower speed and air flow within the reduced heating mode blower speed range. Note that the double pole, double throw switch 54 is connected to the main power switch, and that a jumper is used to show that the two poles connect to the main switch. The diagonal line in the double pole, double throw switch 54 in FIG. 3 represents the mechanical connection between the two poles, which are activated by a common solenoid or other actuator.

FIG. 4 shows an embodiment of the convective cushion 10 for use in seats, beds or other articles of furniture having deep lateral and longitudinal styling pleats. Pleats are often used by furniture designers to enhance the appearance of the outside surface of seats and cushions, but present a problem when one is trying to blow air longitudinally within the tubular spacer material 30 located just under a body cloth or leather cover for a seat or cushion.

For example, FIG. 10 shows one of the inventor's previous embodiments of a seat with tubular spacer material. The styling pleat shown in FIG. 10, a surface longitudinal pleat 58, is relatively shallow and is located superficially over the tubular spacer material 30 layer and the depth of the pleat is defined by the thickness of the pad between the outer cloth or leather cover material and the tubular spacer material 30 layer.

FIG. 4 is an illustration of an embodiment of the convective cushion 10 of the present invention in a seat with a deep longitudinal pleat 62 running from the seat bite line, or seat hinge point 64, to the front edge of the seatrest 66. This is accomplished in one embodiment by dividing the tubular spacer material 30 into two halves, with a longitudinal gap running down the middle as shown in FIGS. 4 and 5. The longitudinal gap leaves room for Lister wires 68 and hog rings 70 to assemble the apparatus into a seat. One wire 68 is anchored into the foam base 72, and the other wire is sewn into the seat cover pleat 62 in such a way as to allow the two wires to
be clamped loosely together with the hog ring 70 shown. One or more embodiments include an optional bolster 76 which is shown in FIG. 4.

In one or more embodiments, two or more hog rings 70 are used on each Lister wire assembly 68. The Lister wire assembly 68 pulls a cover 74 down deeply into the gap, creating a deep styling pleat 62 that is securely anchored to the seat base foam 72. Additional hog rings 70 may also be located along the side edges as shown to create deep styling pleats on the sides of the cushion as well.

FIGS. 5 and 6 show additional embodiments of the invention with backrests. FIG. 5 shows a single longitudinal deep styling pleat 80 in the backrest 82 that allows for air flow from the air inlet 84 to the air outlet 86 through the tubular spacer material 30. FIG. 6 shows a multiple styling pleats 80 in the backrest 82 which allows for air flow from the air inlet 84 to the air outlet 86 through the tubular spacer material 30. FIG 6 also illustrates an embodiment with multiple deep pleats 62 in the seatrest 66. Thermal efficiency between the user and the seat 60 or cushion 10 is improved or maintained by creating deep pleats without the need for excessive padding over the tubular spacer material 30.

FIG. 7 shows an embodiment for a convective seat or cushion with a lateral deep styling pleat 90, which cuts across the seat cushion, effectively cutting off longitudinal internal air flow through the tubular spacer material layers in the seat and/or backrest 82 as shown in FIG. 7 with arrows indicating air flow.

FIG. 8 shows an embodiment of the invention with a series panel flow structure 92 where the deep lateral styling pleats 90 define two panels as shown in FIG. 8 but other quantities of lateral pleats 92 with more than two panels are within the scope of the invention. Air from a heat pump such as a Stirling or Peltier system is delivered to backrest air inlet 92a, where the air or a
portion of the air that does not permeate through to the user travels up to the top of the panel through the tubular spacer material 30 and then out the back side into the U shaped duct 92b, where the air enters the upper backrest panel as shown in FIG. 8. This air then flows internally up through the upper panel also containing tubular spacer material 30 to the top of the panel, where the air can exit the back of the seat 60.

FIG. 9 shows one embodiment of the invention with a parallel panel flow structure 94. In this embodiment, air is blown into a manifold 94a that has a number of air outlets equal to the number of air flow panels. Air is blown simultaneously into the lower inlets of the panels, flows up through the panels, and then vents from the upper outlets 94b and 94c of the panels. For further embodiments of the invention, longitudinal air flow is enabled through adjacent panels when separated by deep styling pleats and the invention is not limited to the particular arrangements or number of panels, inlets and outlets shown in the Figures.

Other embodiments of the invention include seat rests that can be configured in the same manner for lateral and longitudinal deep pleats. An advantage of the parallel arrangement is that the air temperature change is substantially the same in all of the panels, whereas in the series arrangement, the temperature change will diminish as the air flows from one panel to the next because heat is absorbed from the user in cooling mode and is transferred to the user in heating mode.

FIG. 11 shows a side elevation of a series type lateral pleat air panel arrangement with a seat headrest 100 included into the top air panel. The present invention includes a parallel arrangement with three or more paths, including two or more lateral pleats and panels in the seat or backrest with an additional parallel panel for the headrest. The above embodiments for
pleated seats can also be used with portable cushions by the use of thinner base foam layers in the cushion.

FIGS. 12-14 show an improved Stirling cycle free-piston device 110 used in one or more embodiments of the invention. The device 110 includes a housing 112 enclosing a sealed chamber 114 that is filed with a gas within which the moving parts are located. The piston 116 is resiliently supported at one end by piston spring 118 for reciprocating movement of the piston 116 toward and away from the orifice 120. The piston spring 118 may be of the helical coil type or of the leaf type and additionally, a lever connected to a torsion bar spring can also be used.

As shown in FIG. 12, the magnet 130 and the coil 132 surround the piston 116 for driving the piston 116 on an electric supply from leads 134 and 136. A displacer 138 is mounted on the opposite side of the orifice 120 that is resiliently mounted by a displacer spring 140 for gas pressure induced movement of the displacer 138 toward and away from the orifice 120. The operation of the Stirling device produces a temperature reduction at the end 142 for cooling air that is delivered to the convective cushion 10 of the invention.

As shown in detail in FIGS. 13 and 14, the cylinder 150 that surrounds the piston 116 includes a magnetic bearing permanent magnet 152 that is sandwiched between pole pieces 154 and 156. The pole pieces 152 and 154 focus and direct the magnetic flux and field into the magnetic piston ring 158 embedded in the piston 116 as shown in FIG. 13. Since the piston 116 is supported at one end, the function of the magnetic bearing is to levitate, or suspend approximately half the total weight of the piston at the cylinder center line and maintain it there during reciprocation.

In one or more embodiments, the piston 116 is made of a lightweight material other than that used for the magnetic ring and known to persons skilled in the art in order to minimize the
magnetic flux, and hence bearing size, required to levitate and maintain the piston 116 and magnetic piston ring 158 on center within the annular structure of the magnetic bearing assembly and the cylinder 150 during reciprocation. The present invention includes the use of such lightweight materials. The piston 116 moves essentially in pure reciprocating motion, with little if any angular moment, which is ideal for a magnetic bearing, particularly of the passive type, as described here, and does not require auxiliary control coils or an active feedback controller to maintain bearing and piston concentricity.

In an embodiment of the invention, a surface coating or treatment resulting in a very low coefficient of friction is used. For example, in the event that the Stirling device 110 is subjected to a sharp bump or high acceleration force and the piston is momentarily displaced within the magnetic bearing and the cylinder bore, low friction surfaces will minimize undesirable wear during a "hard landing" of the piston.

In one or more embodiments, a ferrofluid 160 is placed in the magnetic circuit gap 162 between the stator pole 130 and piston driver coil 132 as shown in FIG. 12. In one or more additional embodiments, ferrofluid 160 is placed in the gap 164 between the magnetic piston ring 158 (and piston 116) and the cylinder 150 with the magnetic bearing permanent magnet 152 and pole pieces 154 and 156 and as shown in FIGS. 13 and 14.

Ferrofluid is a liquid well known to persons skilled in the art that contains ferromagnetic particles in suspension so that the fluid itself acquires magnetic properties and behaves as though it is magnetic. The magnetic field of the stator magnet holds the Ferrofluid in place, while allowing the Ferrofluid to exhibit low viscosity and shear strength for low pumping losses due to the reciprocating motion of the piston driver coil. The Ferrofluid 160 increases the magnetic permeability of the air gap and increases magnetic field strength and efficiency. Another
advantage of the Ferrofluid in the air gap is that heat generated in the piston driver coil is more efficiently conducted across the Ferrofluid to the stator pole and then outward to the ambient environment than it is with a gap of helium separating the piston driver coil from the stator pole. This helps to reduce temperature rise in the piston drive coil, which reduces electrical resistance changes as a function of temperature and makes for increased coil insulation life and greater reliability.

FIG. 15 is a schematic flow chart of one embodiment of the invention to further enhance the performance and convenience of the seat convective cushion 10 used in a vehicle. This embodiment allows the driver, by use of a telecommunications device, such as a telephone, mobile telephone, pager or cellular phone/text messaging type communication system, to activate and, if desired, to select cooling or heating mode from blocks away in order to have the seat(s) cool down or warm up in advance, according to the weather and the preferences of the user(s). In one or more embodiments, a driver of the vehicle controls the cooling and heating of the convective cushion from a much greater distance from the vehicle than conventional "Keyless Entry" systems, which generally only work within a 25 foot radius of the vehicle, and often do not work well from angles approaching the vehicle from behind and to the side.

In further embodiments, the invention allows a user to activate and control a Variable Temperature Steering Wheel, ("VTSW"), which is the subject of the inventor's U.S. Patent No. 5,850,764. In additional embodiments, the VTSW may be energized simultaneously with the vehicle seat using the present invention, in order to provide a steering wheel grip surface temperature that corresponds with the seat mode.

For example, in warm weather, especially with bright sunlight impinging upon the interior surfaces of a vehicle, both the steering wheel grip surface and seat surfaces may become
relatively very hot. It would then be desirable to cool these surfaces down to a pleasant temperature, preferably before entering the vehicle, to avoid heat stress.

In embodiments of the invention, both the steering wheel and the seat can be left in cooling mode while driving in order to maintain vehicle occupant thermal comfort while using little, if any, conventional space air conditioning. This saves on fuel and reduces emissions and improves vehicle performance, as vehicle air conditioning systems typically require approximately 3-5+ horsepower, and the single convective cushion + VTSW combination requires not more than approximately 80 watts total for the Stirling Cycle type convective cushion with VTSW, and approximately 140-160 watts for the Peltier thermoelectric convective cushion with VTSW. Each additional convective cushion requires approximately 20 watts for the Stirling cycle device and approximately 80-100 watts for the Peltier thermoelectric device.

FIG. 16 shows embodiments of an improved heating and cooling source device 170 with an active cooling mode re-heater 172 that regulates the relative humidity of the heat pump output air to the convective cushion 10 (arrows show air flow to a cushion) by raising the temperature of cooling mode conditioned air back to, or above, the dew point. In one embodiment shown in FIG. 16, the device 170 includes a main heat exchanger 171 and an auxiliary heat exchanger 173 and positive temperature coefficient (PTC) heating element 175.

In the embodiments shown schematically in FIG. 16, the device 170 includes a hygrometer 174 to measure relative humidity to provide control input to a controller for controlled operation of the re-heater 172. In further embodiments, an ambient and/or conditioned air temperature sensor 176 is provided, which may be integral with the hygrometer or separate, connected to the master controller in order to provide additional control input for the control operation of the device 170 and re-heater 172.
Cooling air that contains water in vapor form to below the dew point precipitates a percentage of that water vapor as condensate. The amount of condensate depends on how far below the dew point the air is cooled. After cooling down to the dew point, or sub-cooling below the dew point, the air can be said to be saturated with vapor, or at 100% relative humidity, because it is holding all of the water that is theoretically soluble in that volume of air, as vapor, at that temperature and barometric pressure.

The greater the drop in temperature for a given starting water vapor content, or relative humidity, the more condensate will be precipitated out of the air when that air is cooled. The greater the subsequent rise in temperature, (re-heat), the lower the relative humidity of that air will be because some of the water that was originally entrained in the air as water vapor has been removed as condensate, and as the temperature of that air rises it's capacity for holding water vapor increases again. However, since some of the water vapor that was originally entrained in that air has been precipitated out as condensate, the relative humidity of that air is now lower.

One procedure is to first drop the conditioned air temperature enough, if the starting relative humidity is higher than desired, to get rid of some of the water vapor, then raise it enough to reduce its relative humidity, (relative humidity is simply the amount of water vapor contained in a given unit volume of air divided by the theoretical maximum amount of water vapor that can be contained in that volume of air at that given temperature and barometric pressure), without heating it up beyond the ideal or desired comfort temperature. This process is desired to provide true air conditioning, wherein the relative humidity of the environment is controlled in addition to the temperature.

In one or more operating embodiments of the invention, a basic operational logic includes the following:
1. If the hygrometer, (relative humidity gauge or sensor), senses relative humidity below 50%, for example, (or any other desired relative humidity), at any output air temperature, the re-heater is not energized.

2. The re-heater is not energized in heating mode, unless ambient temperature is so low that it is necessary or desirable.

3. If re-heat is necessary in either cooling mode or heating mode, the controller energizes the re-heater on a curve until the desired relative humidity is reached for a given selected air temperature, or until the selected temperature is maintained at a predetermined relative humidity.

   In further embodiments, a condensate trap (not shown) may be provided, however it is in one or more embodiments simply a small volume container with a small aperture that allows condensation produced in the main heat exchanger to drain out without allowing ambient air to leak into the cooling mode air stream. This can be accomplished in one or more embodiments by using a drain hole of approximately 0.10-0.20” diameter plugged with a short length of wicking material (not shown) that blocks air flow while wicking liquid into the condensate trap chamber. The wick can also be extended in length and extended to reach to surface of the auxiliary heat exchanger in order to provide some evaporative cooling to the auxiliary heat exchanger, reducing its temperature and thereby increasing the coefficient of performance ("COP") of the Stirling heat pump device by reducing the overall temperature change between the cold and hot sides.

   In additional embodiments of the invention, the re-heater 172 is configured to provide heated air for a heating mode that delivers heated air to the convective cushion 10 in addition to re-heat in a cooling mode as described above.
FIG. 17 illustrates another embodiment of an improved free piston Stirling cycle heat pump device 170 wherein the auxiliary fan 180 is ducted to provide heated air to the re heater 172 to control the relative humidity of the air to be delivered to a convective cushion 10 (outlet arrows in FIG. 17 show air flow to a cushion).

In cooling mode, the Stirling Cycle heat pump cools air that is drawn through the main heat exchanger 171, (main heat exchanger 171 as also shown in Fig. 16). This cooled air is also blown through the passive cooling mode re-heater central heat exchanger on its way to the cushion. Simultaneously, the auxiliary fan 180 draws ambient air, via the re-heater air duct 182, in the direction of the arrows shown in FIG. 17 through duct 182, through the annular passive re-heater heat exchanger fins. Thus, heat from ambient air is transferred to the cooled air raising the temperature of the cooled air and lowering the relative humidity of the cooled air, while simultaneously lowering the temperature of the ambient air that is then drawn through the auxiliary heat exchanger.

In addition to lowering the relative humidity of the cushion air, other functions that may be provided include:

1. The thermal transfer efficiency of heat from the auxiliary heat exchanger 173 to the ambient air is increased because reducing the temperature of the ambient air increases the temperature change between the auxiliary heat exchanger and the ambient air.

2. Because of increased thermal transfer efficiency, and a lower auxiliary heat exchanger temperature, the total heat pump temperature change from hot side to cold side is reduced, increasing the COP of the Stirling heat pump device, which increases the energy efficiency of the Stirling Cycle heat pump device. In one or more embodiments, a positive temperature coefficient ("PTC") device 175 and heat exchanger 171 shown in Fig. 17 for heating
mode can also be eliminated by attaching positive temperature coefficient elements 175 to the passive cooling mode reheater and energizing these PTC elements 175 when heating mode is desired. The auxiliary fan 180 is not energized during heating mode, so there is no air flow through the outer section of the passive reheater to reduce its efficiency in heating mode.

FIGS. 18 and 19 illustrate another embodiment of the invention that can be used by more than one sleeper or sleepers simultaneously. As shown in FIG. 18, the plenum 12 includes a divider 190 that divides the plenum into sections, which can be two sections as shown in FIG. 18 or more than two sections depending on the needs of the user or users. Each of the sections can have a separate inlet for delivering an air flow to the section and as shown in FIG. 18, a first air inlet nozzle 192 and second inlet nozzle 194 are provided in the embodiment with two sections. In further embodiments, each of the sections includes an outlet vent shown as air outlet vent 196 and air outlet vent 198 in the embodiment illustrated in FIG. 18 to allow air flow out of the sections.

The divider 190 is relatively impermeable to air and extends from the top surface 14 to the bottom surface 18 as shown in FIG. 19 to prevent substantial lateral mingling of separate air streams supplied by a heat pump, which may be a thermoelectric heat pump with two separate cooled or heated air outputs or a Stirling Cycle heat pump with two separate cooled or heated air outputs. These heat pumps with two air outputs are not shown in FIG. 18 because they are well known to persons skilled in the art and are essentially single output devices doubled up to create two independently adjustable heat pumps. A purpose of the dual air flow structure and system is to allow the sleepers to have different temperature settings.

In embodiments of the invention, the divider 190 substantially prevents lateral mixing or mingling of the different air flows, such as from air inlet nozzle 192 and second inlet nozzle 194
as shown in FIG. 18. There is potential for some lateral air mixing between that portion of the air in the air flow structure that percolates up through the bedding top, however most of the air in the tubular spacer material 30 flows through the tubular spacer material 30 and vents out of the outlet vents shown as air outlet vent 196 and air outlet vent 198 in FIG. 18 opposite the air inlets. This means that preventing lateral mixing within the tubular spacer material 30 is an effective way to provide an essentially independent air temperature within, and hence, essentially independent cooling and heating effects on the sections of the convective cushion 10. In one or more embodiments, an extra layer 24 is provided as shown in FIG. 18 and in FIG. 19 which can be placed over a portion of the top surface 14 to provide temperature control for the space adjacent to one or more of the inlet nozzles 192 and 194 by limiting air flow through the top surface 14 in the area of the extra layer 24.

FIG. 20 illustrates a further embodiment of the invention in a perspective view of a solution to unraveling of filaments on the ends of cut pieces of the tubular spacer material 30. Such a solution is applicable to the convective cushion 10 such as described and shown in FIG. 1 and in FIG. 18. Prior to cutting the tubular spacer material 30 to a desired length, with length being along the longitudinal direction or length of the tubes, film 200, such as a flexible plastic film including SARAN Wrap or tape, is affixed to the cut line or end being cut either with adhesive that has already been applied to the film 200 or with spray or brushed adhesive.

After the adhesive has cured, the tubular spacer material 30 is cut down the middle of the tape or film leaving a margin of film 200 on each side of the cut line 202 as shown in FIG. 20. This allows the film 200 to be adhered to the fibers of the tubular spacer material 30 before cutting and remains adhered after cutting which keeps the fibers or filaments from unraveling.
FIG. 21 shows in a schematic illustration an embodiment of an improved Peltier thermoelectric heat pump 210 for use with the present invention. In this embodiment, an auxiliary blower 212 draws air through an auxiliary heat exchanger 214 that has fins in both an outer air stream and an inner air stream. In the cooling mode for this embodiment, the main blower 216 draws, or blows, ambient air through the main heat exchanger 218, cooling the air below ambient temperature. The main blower 216 then blows that cooled air through a heat exchanger that can include inner fins and outer fins. Meanwhile, the auxiliary blower 212 draws air in an opposite direction, pulling ambient air that has been cooled below ambient in the reheater heat exchanger 220 across the auxiliary heat exchanger 214. The thermoelectric device 215 is shown in FIG. 21. FIG. 21a is an end view of the improved Peltier thermoelectric heat pump 210 shown in FIG. 21 and illustrates an end view of the reheater heat exchanger 220.

The cooled air results in a lower auxiliary heat exchanger temperature, which lowers the overall temperature difference between the cold side and the hot side of the Peltier device, increasing its coefficient of performance and energy efficiency. The relative humidity of the cooled air delivered to the convective cushion (as shown in arrow 222) is thereby reduced.

A condensate wick 224 is shown communicating between the main heat exchanger 218 and the auxiliary heat exchanger 214. Condensation produced in the main heat exchanger 218 in cooling mode is drawn to the auxiliary heat exchanger 214 by the wick 224, without allowing the two air streams to co-mingle, providing whatever condensate is available to the auxiliary heat exchanger 214. The condensation evaporates on the relatively warm auxiliary heat exchanger producing an additional cooling effect which increases the COP of the thermoelectric device 210 and improves its energy efficiency further beyond what is provided by the counter-regenerative auxiliary air cooling system.
In further embodiments, if a thermoelectric device has sufficient capability, such as, for example, that described in the inventor's U.S. Patent No. 6,855,880 entitled Modular Thermoelectric Couple and Stack, it is useful to control main blower air relative humidity by using the active re heater to raise cooling air temperature and thereby reduce its relative humidity if desired.

FIG. 22 is a schematic illustration of another embodiment of an improved Peltier thermoelectric heat pump 210 for use with the present invention in a heating mode. In this embodiment, the re-heat heat exchanger 220 becomes regenerative in this mode because it is a form of bottom cycling, in which heat energy is taken from a low point in the cycle to a higher point in the cycle to improve efficiency. By pre-heating auxiliary air, the cold side runs at a higher temperature in heating mode.

Since the main exchanger 218 is hot in heating mode, the warmer the auxiliary heat exchanger 220 is, the lower the overall temperature change, hence the higher the COP, or energy efficiency of the Peltier thermoelectric heat pump. In one embodiment, the device 210 is designed with enough capacity to produce the desired net heating mode air temperature even with a bit of cooling provided by the regenerator.

FIG. 23 illustrates one or more embodiments of the invention for cooling and heating multiple surfaces, such as seating surface and a sleeping surface, with the same air cooling or heating source. The first convective cushion 300 includes a first plenum 302 having a generally air permeable top surface 304 that is secured around a perimeter 306 to a bottom surface 308. The bottom surface 308 is in one or more embodiments generally impermeable to air and can be placed on a mattress 310 as shown in FIG. 23 and FIG. 24 to make the bottom surface 308 generally impermeable. A fitted sheet 318 may be used to secure the first plenum 302 to the
mattress 310 and an elastic band 320 can also be used to secure the first plenum 302 and the mattress 310 together.

The first plenum 302 includes tubular spacer material 312 as an air flow structure which includes the use of tubular spacer fabric, air flow structures such as Muller Textile's 3 Mesh or Strahle and Hess \(^1\) assembled woven fabric and other air flow structures known to persons skilled in the art as previously described herein. As shown in FIG. 23, air enters the first plenum 302 mattress pad through the air inlet nozzle 314, which may be removable, and fans out within the tubular spacer material 312, with some of the air permeating up through the top surface 304 as the air flows toward the air outlet vents 316. The tubular space material 312 is arranged so that the longitudinal axes of the tubular spacer material 312 are all aligned to allow substantially uninterrupted flow of air from the air inlet nozzle 314 to the air outlet vents 316 at an opposite end of the first plenum 302.

The second convective cushion 330 includes a second plenum 332 that in one or more embodiments is formed to fit within a seat or portable seat cushion 334 as shown in FIG. 23. The second plenum 332 includes tubular spacer material 312 as described above for the first plenum 302. Air enters the second plenum 332 through the air inlet 336 and fans out within the tubular spacer material 312, with some of the air permeating through the second plenum as the air flows toward the outlet vents 338. The power unit 340 includes a blower and a heat pump 341 that delivers either heated or cooled air through the first duct or conduit 342 to the air inlet nozzle 314 and to the first plenum 302 while also delivering the same heated or cooled air through the second duct or conduit 344 to the air inlet 336 and to the second plenum 332. The heat pump 341 can be a thermoelectric heat pump, a Stirling cycle heat pump or other type of heat pump that supplies cooled and/or heated air.
As shown in FIG. 23, the first valve 346 can be placed adjacent to or within the first duct or conduit 342 to control the flow of air to the first plenum 302. A second valve 348 can be placed adjacent to or within the second duct or conduit 344 to control the flow of air from the power unit 340 to the second plenum 332. The first valve 346 and the second valve 348 can be adjusted to control the cooling and/or heating of both the first convective cushion 300 and the second convective cushion 330 either individually or simultaneously. The valves 346 and 348 enable the air flow from the power unit 340 to be controlled so that more or less of the temperature modified air can be delivered to one, or both, of the first convective cushion 300 and the second convective cushion 330 which is a cost effective method of enhancing the controllability of convective cooling and/or heating. If most or all of the temperature modified air is directed to the first convective cushion, then the cooling or heating of this cushion will be more pronounced. If most or all of the temperature modified air is directed to the second convective cushion, then the cooling or heating of this cushion will be more pronounced. The valves 346 and 348 can be adjusted manually, by electronic power controls, by a remote control operation or other methods of control known to persons skilled in the art and these are included within the scope of the present invention.

While the present invention has been described with regards to particular embodiments, it is recognized that additional variations of the present invention may be devised without departing from the inventive concepts in the claims and the invention includes the full breadth and scope of the claims including all equivalents.
WHAT IS CLAIMED IS:

1. A multiple convective cushion system comprising:

   a first plenum defined by a first bottom surface secured around a perimeter to a generally air permeable first top surface and containing a first air flow structure therein, said first top surface adapted for convective air flow delivered from the first air flow structure to the first top surface;

   a first air inlet in fluid communication with the first air flow structure;

   a second plenum defined by a second bottom surface secured around a second perimeter to a generally air permeable second top surface and containing a second air flow structure therein, said second top surface adapted for convective air flow delivered from the second air flow structure to the second top surface;

   a second air inlet in fluid communication with the second air flow structure; and

   a power unit having a blower in fluid communication with both the first air inlet and the second air inlet to deliver air of selectively variable temperature and quantity to the first air flow structure through the first air inlet and to the second air flow structure through the second air inlet.

2. The multiple convective cushion system of claim 1 wherein the first air flow structure and the second air flow structure comprise tubular spacer fabric.
3. The multiple convective cushion system of claim 1 further comprising a first valve to selectively control the flow of the selectively variable temperature and quantity air to the first air flow structure.

4. The multiple convective cushion system of claim 3 further comprising a second valve to selectively control the flow of the selectively variable temperature and quantity air to the second air flow structure.

5. The multiple convective cushion system of claim 1 wherein the first plenum and the second plenum comprise air outlet vents for the outlet of at least a portion of the selectively variable temperature and quantity air delivered respectively to the first and second plenums.

6. The multiple convective cushion system of claim 1 wherein the power unit comprises a thermoelectric heat pump.

7. The multiple convective cushion system of claim 1 wherein the power unit comprises a Stirling cycle heat pump.

8. The multiple convective cushion of claim 1 wherein the power unit comprises a controller that selectively controls the operation of the blower to control the delivery of the air from the blower to the first and second air inlets.
9. The multiple convective cushion of claim 8 wherein the controller is operated by a control signal from a telecommunications unit.

10. The multiple convective cushion of claim 1 wherein the first bottom surface of the first plenum is adapted to be placed on a conventional mattress and the second plenum is adapted to be attached to a seat cushion.

11. A method for delivering temperature modified air using convective cushions, comprising the steps of:

   providing a first plenum structure having a generally air permeable first top surface and containing a first air flow structure therein, said first top surface adapted for convective air flow delivered from the first air flow structure to the first top surface;

   providing a second plenum structure having a generally air permeable second top surface and containing a second air flow structure therein, said second top surface adapted for convective air flow delivered from the second air flow structure to the second top surface;

   placing a power unit having a blower in fluid communication with the first air flow structure by a first conduit and in fluid communication with the second air flow structure by a second conduit; and

   activating the power unit to produce air of selectively variable temperature and quantity and to deliver said air to the first conduit for the first air flow structure and substantially simultaneously deliver said air to the second conduit for the second air flow structure, wherein the first plenum structure and the second plenum structure receive air of a desired temperature and quantity.
12. The method of claim 11 wherein the first air flow structure and the second air flow structure comprise tubular spacer fabric.

13. The method of claim 11 further comprising the step of placing a valve within the first conduit to control the flow of the selectively variable temperature and quantity air to the first air flow structure.

14. The method of claim 13 further comprising the step of placing a second valve within the second conduit to control the flow of the selectively variable temperature and quantity air to the second air flow structure.

15. The method of claim 14 further comprising the step of controlling the operation of the first valve and the second valve to adjust the quantity of the air delivered by the power unit to the first air flow structure and the second air flow structure.

16. The method of claim 11 further comprising the step of providing air outlet vents for the first plenum structure and the second plenum structure for the outlet of at least a portion of the selectively variable temperature and quantity air delivered respectively to the first air flow structure and the second air flow structure.

17. The method of claim 11 further comprising the step of providing a thermoelectric heat pump with the power unit.
18. The method of claim 11 further comprising the step of providing a Stirling cycle heat pump with the power unit.

19. The method of claim 11 wherein the power unit comprises a controller and further comprising the step of the controller selectively controls the operation of the blower to control the delivery of the air from the blower to the first and second conduits.

20. The method of claim 19 including the step wherein the controller is operated by a control signal from a telecommunications unit.

21. The method of claim 11 further comprising the step of the first plenum structure is placed on a conventional mattress and the second plenum structure is attached to a seat cushion.

22. The method of claim 11 further comprising the step of installing the first plenum structure, the second plenum structure and the power unit within a vehicle.
INTERNATIONAL SEARCH REPORT

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A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A47C 16/00,20/02; B68G 5/00 (2008.04)
USPC - 5/652.2

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) A47C 16/00,20/02, B68G 5/00 (2008 04)
USPC 5/652 2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC 454/120, 297/180 1,180 11,180 13, 5/652 1,652 2,654

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Electronic Databases Searched PubWEST/PGPB,USPT,USOC,EPAB,IPAB) Google, Google Patents

Search Terms Used convective, cool, heat, mattress, temperature, control, individual, Independent, cushion, second, plenum, valve, seat, vehicle

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
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D Further documents are listed in the continuation of Box C

Date of the actual completion of the international search
27 September 2008 (27 09 2008)

Date of mailing of the international search report

Authorized officer
Lee W Young

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