DEVICE FOR HEATING OR COOLING AIR

Field of Invention

This invention relates to a device for heating or cooling air.

Background

Air-conditioners have become indispensable to most people. According to Black principles, the amount of thermal energy absorbed is equal to the amount of thermal energy released. Thus, the heat transferred to another element and dissipated to the surroundings compensates for the cold air released. The heat has to be transferred outside the control volume so that it does not affect the inside temperature. For cooling devices such as air conditioners, CFC is used as a refrigerant. Through the compression and expansion cycle, the refrigerant changes phases between liquid and gas. However, air-conditioners consume high amounts of energy and result in hefty electricity costs.

Another device that can provide cooling is a portable air cooler. The air cooler includes a water tank that contains cold water. A porous evaporative pad is attached to a roller located inside the cooler. This evaporative pad absorbs water from the water tank. When the motor inside the cooler is turned on, air is drawn into the cooler, and as the air passes through the evaporative pad, a heat exchange occurs between the air and the water on the filter pad, and cooling of the air takes place. The cooled air is then blown out to the surroundings by the motor. For better cooling, ice cubes are placed in the water tank so that the water on the filter pad is of lower temperature and thus cools the air drawn in to a lower temperature.

A disadvantage of air coolers is the inconvenience of having to constantly place ice or cold water in the water tank. Moreover, even before the water is used up, the water warms easily to room temperature. In a hot and tropical climate such as Singapore, the water at room temperature may be too warm to provide adequate cooling.

A thermoelectric module is a heat transfer device that converts electrical energy into thermal energy. It makes use of electric current to carry the thermal energy from one point to another point. This differs from an air conditioner which converts the potential energy of fluid into thermal energy.

Thermoelectric modules as the heat transfer device of the air cooler do not need servicing for a long period of time, unlike air conditioners that require regular maintenance. Furthermore, thermoelectric modules can be used for non-humid air cooling. However, a conventional air cooler activates and deactivates the thermoelectric module as the air cooler is turned on and off, which may not make the best use of the thermoelectric module or provide efficient thermal exchange for rapid heating or cooling.

There is, therefore, a need for an improved air cooler that overcomes the above problems. Also, there is a need for a device that can heat or cool air.

Summary of Invention

In accordance with a preferred aspect of the invention, a device for heating or cooling air comprises (1) a first thermoelectric module for heating or cooling the air in response to a first electric current, wherein the first thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements, (2) a second thermoelectric module for heating or cooling the air in response to a second electric current, wherein the second thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements, (3) a heat sink sandwiched between the thermoelectric modules, (4) a controller that activates the first thermoelectric module, thereby heating or cooling the second thermoelectric module by thermal conduction through the heat sink, and then activates the second thermoelectric module a predetermined time period after activating the first thermoelectric module, and (5) a blower that dispenses the air that is heated or cooled by the thermoelectric modules.

Preferably, the thermoelectric modules heat the air and the blower dispenses the heated air. Alternatively, the thermoelectric modules cool the air and the blower dispenses the cooled air. The thermoelectric modules heat the air in response to the electric currents

flowing in a first direction and the blower dispenses the heated air, and the thermoelectric modules cool the air in response to the electric currents flowing in a second direction opposite the first direction and the blower dispenses the cooled air.

Preferably, the thermoelectric modules are spaced from one another and removably secured to the heat sink.

Preferably, the first thermoelectric module includes an upper ceramic surface that faces towards the second thermoelectric module, the second thermoelectric module includes a lower ceramic surface that faces towards the first thermoelectric module, and the heat sink is metal and contacts and is sandwiched between the ceramic surfaces.

Preferably, the first thermoelectric module has greater heating or cooling capacity than the second thermoelectric module. More preferably, the first thermoelectric module has at least 50% greater heating or cooling capacity than the second thermoelectric module.

Preferably, the semiconductor elements are bismuth telluride.

Preferably, the controller activates the second thermoelectric module after the first thermoelectric module reaches at least 50% of its maximum heating or cooling capacity. More preferably, the controller activates the second thermoelectric module after the first thermoelectric module reaches 50 to 80% of its maximum heating or cooling capacity.

Preferably, the predetermined time period whereby the second thermoelectric module is activated after the first thermoelectric module is at least 20 seconds. More preferably, the predetermined time period is 20 to 30 seconds.

Preferably, the thermoelectric modules cool the air using only the electric currents, the blower dispenses the cooled air that is cooled only by the thermoelectric modules, and the device is devoid of a refrigerant.

Preferably, the device includes a reservoir for receiving and storing a liquid and a liquid transfer element in fluid communication with the reservoir, wherein the liquid transfer element contacts the liquid in the reservoir and heats or cools the air outside the

reservoir using the liquid received from the reservoir, the first thermoelectric module is spaced from the liquid, the second thermoelectric module contacts the liquid in the reservoir, and the blower dispenses the air that is heated or cooled by the liquid transfer element.

Preferably, the thermoelectric modules heat the liquid in the reservoir, the liquid transfer element heats the air using the heated liquid, and the blower dispenses the heated air. Alternatively, the thermoelectric modules cool the liquid in the reservoir, the liquid transfer element cools the air using the cooled liquid, and the blower dispenses the cooled liquid.

Preferably, the thermoelectric modules heat the liquid in the reservoir in response to the electric currents flowing in a first direction, the liquid transfer element heats the air using the heated liquid, and the blower dispenses the heated air, and the thermoelectric modules cool the liquid in the reservoir in response to the electric currents flowing in a second direction opposite the first direction, the liquid transfer element cools the air using the cooled liquid, and the blower dispenses the cooled air.

Preferably, the second thermoelectric module is fixedly secured to the reservoir and is adjacent to and exposed by a slot in the reservoir.

Preferably, the thermoelectric modules are spaced from one another and removably secured to the heat sink.

Preferably, the first thermoelectric module includes an upper ceramic surface that faces towards the second thermoelectric module, the second thermoelectric module includes an upper ceramic surface that faces away from the first thermoelectric module and contacts the liquid in the reservoir and a lower ceramic surface that faces towards the first thermoelectric module and is spaced from the liquid, and the heat sink is metal and contacts and is sandwiched between the upper ceramic surface of the first thermoelectric module and the lower ceramic surface of the second thermoelectric module.

Preferably, the reservoir includes an aluminium tank.

Preferably, the reservoir is positioned between the second thermoelectric module and the blower.

Preferably, the liquid includes water. The liquid may essentially be water but may include fragrances, such as essential oils. More preferably, the liquid consists of water.

Preferably, the liquid transfer element includes a porous evaporative pad that is continuously wetted by and absorbs the liquid in the reservoir and evaporates the absorbed liquid at the blower, and a motor that rotates the evaporative pad. Alternatively, the liquid transfer element includes a conduit that circulates the liquid from the reservoir to the blower and then recirculates the liquid from the blower to the reservoir, and a pump that pumps the liquid through the conduit. The conduit heats or cools the air at inlet and outlet ends of the blower.

Preferably, the thermoelectric modules cool the liquid in the reservoir using only the electric currents, the liquid transfer element cools the air using only the cooled liquid from the reservoir, the blower dispenses the cooled air that is cooled only by the liquid transfer element, and the device is devoid of a refrigerant.

As another alternative, the device includes the reservoir, the liquid transfer element and a second blower. The liquid transfer element is in fluid communication with the reservoir and contacts the liquid in the reservoir. However, the liquid transfer element heats or cools exhaust air outside the reservoir using the liquid received from the reservoir, and the second blower dispenses the exhaust air.

The thermoelectric modules heat the air and cool the liquid in the reservoir, the liquid transfer element cools the exhaust air using the cooled liquid received from the reservoir, the second blower dispenses the cooled exhaust air, and the liquid transfer element recirculates the liquid to the reservoir, thereby supplying heat to the thermoelectric modules, or the thermoelectric modules cool the air and heat the liquid in the reservoir, the liquid transfer element heats the exhaust air using the heated liquid received from the reservoir, the second blower dispenses the heated exhaust air, and

the liquid transfer element recirculates the liquid to the reservoir, thereby removing heat from the thermoelectric modules.

Preferably, the first thermoelectric module includes an upper surface that faces towards the second thermoelectric module and a lower that faces away from the second thermoelectric module, the second thermoelectric module includes an upper surface that faces away from the first thermoelectric module and a lower surface that faces towards the first thermoelectric module, the upper surfaces generate heat and the lower surfaces absorb heat if the thermoelectric modules heat the air and cool the liquid and the exhaust air, and the upper surfaces absorb heat and the lower surfaces generate heat if the thermoelectric modules cool the air and heat the liquid and the exhaust air.

Preferably, the first thermoelectric module is closer than the second thermoelectric module is to the reservoir, the second thermoelectric module is closer than the first thermoelectric module is to the blower. More preferably, the thermoelectric modules are proximate to the blower and the reservoir and are not proximate to the second blower.

Preferably, the blower dispenses the air without using any liquid transfer element, and the second blower dispenses the exhaust air independently of the blower.

Preferably, the device includes a first outer casing and a second outer casing that are spaced from one another, wherein the thermoelectric modules, the heat sink and the blower are located in and the air is dispensed from the first outer casing, the second blower is located in and the exhaust air is dispensed from the second outer casing, and the liquid transfer element extends into and between and the liquid circulates into and between the outer casings. More preferably, the outer casings are separately moveable, the liquid transfer element includes a flexible host between the outer casings, and the blowers include inlet ends that draw in the air and the exhaust air from a separation between the outer casings.

Advantageously, the device is portable, user friendly, and provides efficient operation of the thermoelectric modules. Another advantage is that the device can be used for non-humid air cooling. Also, the device does not use a refrigerant, such as Freon, which is detrimental to the environment.

Brief Description of Drawings

In order that the present invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative examples only preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

In the drawings:

Figure 1 shows a cross-sectional view of a device according to a first embodiment of the invention;

Figure 2 shows a cross-sectional view of a device according to a second embodiment of the invention;

Figure 3 shows a cross-sectional view of a device according to a third embodiment of the invention;

Figure 4 shows a cross-sectional view of a device according to a fourth embodiment of the invention;

Figure 5 shows a cross-sectional view of a thermoelectric module stack in the device according to the first embodiment of the invention;

Figure 6 shows a cross-sectional view of a thermoelectric module stack in the device according to the second and third embodiments of the invention;

Figure 7 shows a cross-sectional view of a thermoelectric module stack in the device according to the fourth embodiment of the invention;

Figure 8 shows an operational diagram of the thermoelectric stack;

Figures 9 and 10 show electrical circuits for the device according to the first embodiment of the invention;

Figures 11 and 12 show electrical circuits for the device according to the second embodiment of the invention;

Figures 13 and 14 show the electrical circuits for the device according to the third embodiment of the invention; and

Figures 15 and 16 show the electrical circuits for the device according to the fourth embodiment of the invention.

Detailed Description of The Preferred Embodiments

Generally speaking, a "blower" is a device that produces a current of air. This includes electric fans and the like.

Generally speaking, a "thermoelectric module" is a semiconductor module that converts electrical energy to thermal energy for heating or cooling. The thermoelectric module can include bismuth telluride (Bi_2Te_3) as the semiconductor elements. When a DC current at low voltage is applied, one thermoelectric module face is cooled while the opposite face is heated. This is due to heat being moved through the thermoelectric module from one face to the other. Heat is moved in the opposite direction when the polarity of the DC current is reversed. Thus, the thermoelectric module pumps heat from one plate to another plate. The potential difference between two plates causes heat transfer to occur. The greater the potential difference between the two plates, the faster the heat pumping capacity. Further, the temperature difference between the two plates gets larger as the heat pumping continues. A larger temperature difference increases the thermal resistance between the two junctions and hence reduces the current flowing between the two junctions. This causes the thermoelectric module to have lower efficiency as the temperature difference increases. An addition, the efficiency of the thermoelectric module typically reaches close to steady state in a matter of seconds, usually less than one minute, after the thermoelectric module is activated.

The semiconductor elements are connected electrically in series and thermally in parallel. The semiconductor elements and their connectors are mounted between two thin wall ceramic substrates. The substrates reinforce the thermoelectric module, provide flat and parallel contact surfaces, and insulate the semiconductor elements from external surfaces.

The semiconductor elements include n-type and p-type materials. The n-type material has excess electrons while the p-type material is electron deficient. Electrons flow from the n-type material to "holes" in the p-type material, hence moving heat through the thermoelectric module. When a DC current passes through the thermoelectric module, one surface is cooled while the other surface is heated.

Generally speaking, a "heat sink" is a device that conducts and dissipates unwanted heat generated by an electronic component. For the thermoelectric modules of the present invention, the external heat sink is typically made of aluminium and contains fins to increase the heat dissipation rate. The absence of a heat sink may cause the thermoelectric modules to transfer insufficient heat.

Figure 1 shows a first embodiment of the invention for heating or cooling air. The device comprises a thermoelectric module stack 2 and a blower 4 that dispenses the air (shown by arrow 6) that is heated or cooled by the thermoelectric module stack 2. A controller 8 controls the activation and deactivation of thermoelectric modules in the thermoelectric module stack 2.

The heating or cooling of the air by the thermoelectric module stack 2 is dependent on the voltage polarity of an electric current supplied to the thermoelectric module stack 2. The thermoelectric module stack 2 heats the air in response to the electric current flowing in a first direction and the heated air is dispensed into the environment surrounding the device as shown by arrow 6. Alternatively, when the electric current flows in a second direction opposite the first direction, the thermoelectric module stack 2 cools the air in response to the reversed electric current and the cooled air is dispensed into the environment surrounding the device as shown by arrow 6.

The thermoelectric module stack 2 is discussed in greater detail below.

Table 1 shows the air temperature surrounding the device in Figure 1 with respect to activation time of the thermoelectric module stack 2. This device is effective in cooling the air by 2 to 3°C below the ambient temperature.

Table 1

Time (sec)	Temperature of Air (°C)
0	23
30	22
60	21.5
90	21
120	20.5
150	20
180	20
210	20
240	20
270	20
300	20

Total resistance: 2,750Ω

Power consumption: 21W

The electrical circuits for the device of the first embodiment of the present invention are shown in Figures 9 and 10.

In a second embodiment of the present invention, as shown in Figure 2, the device for heating or cooling air includes the thermoelectric module 2, the blower 4 and the controller 8. The device further includes a water reservoir such as an aluminium water tank 10 and a liquid transfer element such as an evaporative pad 12. The evaporative pad 12 is in fluid communication with the water 14 in the water tank 10. Roller shafts powered by a motor 16 rotate the evaporative pad 12. As a result, water 14 from the water tank 10 constantly wets the rotating evaporative pad 12. The device also includes

an outer casing 18, a ventilation panel 20 with blades for the directing the dispensed air, and a back cover 22 that allows air surrounding the device to be drawn into the device. The blower 4 blows and dispenses the heated or cooled air out of the device.

The water tank 10 may be any material. Preferably the water tank 10 is aluminium. This allows for minimal corrosion of the water tank 10 after prolonged contact with the water 14.

Generally speaking, the "liquid transfer element" is an element in fluid communication with the reservoir and transfers the heated or cooled liquid from the reservoir to the blower for dispensing the air as heated or cooled by the water in the liquid transfer element.

The reservoir may contain any liquid to heat or cool the liquid transfer element.

The water 14 in the water tank 10 is heated or cooled by the thermoelectric module stack 2. The thermoelectric module stack 2 is connected to a power source. The controller 8 controls the activation and deactivation of the thermoelectric modules in the thermoelectric module stack 2.

The heating or cooling of the water 14 by the thermoelectric module stack 2 is dependent on the voltage polarity of the electric current that is supplied to the thermoelectric module stack 2. The thermoelectric module stack 2 heats or warms the water 14 in response to an electric current flowing in a first direction, the liquid transfer element (in this case, the evaporative pad 12) heats or warms the air using the heated or warmed water 14, and the blower 4 dispenses the heated or warmed air. When the direction of the electric current is reversed (i.e. opposite to the first direction), the thermoelectric module stack 2 cools the water 14 in response to this electric current flowing in a second direction, the liquid transfer element (in this case, the evaporative pad 12) cools the air using the cooled water, and the blower 4 dispenses the cooled air.

In the case where the device provides cooled air, the thermoelectric module stack 2 cools the water 14 in the water tank 10. The cooled water wets the evaporative pad 12. Air is drawn into the device (as shown by arrow 24) by the blower 4 and as it passes

through the wetted evaporative pad 12, there is a heat exchange between the air and the water on the evaporative pad 12, and cooling takes place. The cooled air is then blown out to the surroundings by the blower 4 (as shown by arrow 26).

In the case where the device provides heated air, the thermoelectric module stack 2 heats the water 14 in the water tank 10. Once again, air is drawn into the device (as shown by arrow 24) by the blower 4. As the air passes through the evaporative pad 12 that is wetted by the warm or heated water, there is a heat exchange between the air and the water on the evaporative pad 12, and heating takes places. Thus, the air is heated as it passes through the evaporative pad 12. Warmed or heated air is then blown out of the device (as shown by arrow 26) by the blower 4.

In this embodiment, each heat sink in the thermoelectric module stack 2 may have a case fan attached to it. Case fans may also be attached to one side of the outer casing 18 to suck the warm air out into the surroundings.

The device also includes a water-level indicator 28 that indicates the water level in the water tank 10. The water-level indicator 28 display red, yellow and green and includes one LED of each colour. The red LED will light up if the water tank 10 is almost empty, the red and yellow LEDs will light up when the water tank 10 is half full, and the red, yellow and green LEDs will light up when the water tank 10 is full. The LEDs are soldered to a printed circuit board.

A polarity switch may be fixed on the front panel of the device. It allows a user to select whether the device functions as a heater or a cooler. When the switch is at the "I" position (and the current flows through the thermoelectric module stack 2 in a first direction), cold air will be blown out. When the switch is at the "O" position (and the current flows through the thermoelectric module stack 2 in a second direction), warm air will be blown out.

The device includes a power adaptor that converts AC power from the mains to DC power for use by the thermoelectric module stack 2, case fans and water-level indicator 28. The power adaptor may be placed at the bottom of the device.

The thermoelectric module stack 2 is able to cool the water 14 in the water tank 10 to around 20°C if the thermoelectric module stack 2 is switched on for more than 20 minutes. Table 2 shows the drop in water temperature after 90 minutes.

Table 2

Time (sec)	Temperature of Water (°C)
0	29
30	29
60	28
150	27.5
210	27
510	26.5
12mins	26
16mins	25.5
22mins	25
30mins	24.5
37mins	24
47mins	23.5
After 90mins	23.5

The device according to this second embodiment of the invention may be customised to any size, shape and dimensions depending on the needs of a user. For example, a larger device may be built to heat or cool air in a large room.

The electrical circuits for the device in the second embodiment of the present invention are shown in Figures 11 and 12.

In a third embodiment of the present invention, as shown in Figure 3, the device includes similar elements as the device in the second embodiment, with similar elements having the same reference numerals. Thus, the same description need not be repeated. However, the liquid transfer element in the third embodiment is a system of conduits in

fluid communication with the water 14 in the water tank 10. The system of conduits is in the form of radiators 30.

Generally speaking, the "radiator" is a heat exchanger that heats or cools the air surrounding it. The radiators 30 may also have fins that increase their surface area, allowing for more efficient heat exchange.

In the third embodiment, the device includes two radiators 30; one over the front face of the blower 4 and the other over the rear of the blower 4. The radiators 30 are each connected to a respective water pump 32, with both water pumps 32 located in the water tank 10.

Similar to the second embodiment of the invention, the thermoelectric module stack 2 is fastened to the water tank 10 by any fastening means such as screws and is configured in the similar way as that described for the device shown in Figure 6.

As heated/cooled water flows through the radiators 30 in front and behind the blower 4, the surfaces of the radiators 30 are heated/cooled due to conduction. Air is drawn into the device at inlet 22 by the blower 4 as shown by arrow 34. The temperature of the moving air produced by the blower 4 is raised/lowered as it comes into contact with the inlet radiator 30. Heating or cooling the air is based on the heat transfer through convection theory. The user will then feel warmed or cooled wind blown from the blower 4 (as shown by arrow 36). The ventilation panel 20 may include blades to direct the air dispensed by the blower 4.

The outer casing 18 may be acrylic.

Once again, the water tank 10 is in contact with the thermoelectric module stack 2 and is aluminum since aluminum has good heat transfer performance and exhibits minimal corrosion after prolonged contact with water 14. A removable acrylic cover covers the water tank 10 to minimise evaporation of the water 14. A rubber sheet may be attached to the exterior of the water tank 10 for insulation using black tape. Rubber is used to insulate the outer surface of the water tank 10 to minimise heat gained or lost to the surroundings, hence maintaining the desired temperature.

Aluminium hose connectors may attach hoses from the water pumps 32 to the radiators 30. Hose connectors may also be used to connect to the water inlet of the inlet radiator 30 and the water outlet of the outlet radiator 30, and the water inlet of the inlet radiator 30 and its hose connector may be larger than the water outlet of the outlet radiator 30.

The water pumps 32 pump the water 14 from the tank 10, through the connecting hoses, radiators 30, and back to the water tank 10. Thus, the two radiators 30 in this embodiment serve as the liquid transfer element. Fins provide a larger surface area for the exchange of heat between the surfaces of the radiators 30 and the moving air. The radiators 30 are placed in the front and the back of the blower 4. The radiators 30 may be sprayed black to maximise conduction to the surrounding air. In addition, selected fins may be taken off the radiators 30 to increase the air flow capacity of the blower 4.

The thermoelectric module stack 2 may have a case fan attached to it. Case fans may also be attached to one side of the outer casing 18 to suck the warm air out to the surroundings of the device.

Two water collectors may be placed beneath the radiators 30 to collect water droplets formed on the surfaces of the tubes. The two water collectors are attached to each other using a piece of acrylic. Water may form on the copper tubing due to condensation as the temperature of the water flowing inside the tubing drops as low as 14°C. The tray will hold water that drips down, avoiding accumulation of water at the base of the external casing.

The power adaptor may be secured to a partition placed between the water tank 10 and radiators 30.

Four switches may be fixed on the front panel of the device. One of the switches is used to change the device function between cooling and warming effect. When the switch is at the "I" position, the device functions as a cooling fan. When the switch is at the "O" position, warm air will be blown out. The other three switches turn on and off the pumps, the AC-DC power converter and the blower 4.

The electrical circuits for the device of the third embodiment are shown in Figures 13 and 14.

In a fourth embodiment of the present invention, as shown in Figure 4, the device includes two units 42 and 44. Both units 42 and 44 include an outer casing 18a, 18b, a ventilation panel 20a, 20b and a back cover with air inlets 22a, 22b. The device in this fourth embodiment includes similar elements as the device in the first, second and third embodiments, with similar elements having the same reference numerals. Thus, the same description need not be repeated.

Unit 42 includes the thermoelectric module stack 2 and controller 8. The thermoelectric module stack 2 and the controller 8 are shown in detail in Figure 7 and are discussed in greater detail below. Air surrounding the unit 42 is drawn into the unit via air inlet 22a and the blower 4 dispenses the air (shown by arrow 46) that is heated or cooled by the thermoelectric module stack 2.

Unit 44 includes a second blower 38 and a second water tank 54.

The outer casing 18a of unit 42 and the outer casing 18b of unit 44 are spaced from one another. As described earlier, the thermoelectric module stack 2, heat sink 48 and blower 4 are located in and the air 46 dispensed from the outer casing 18a of unit 42. The second blower 38 is located in and the exhaust air 40 is dispensed from the outer casing 18b of unit 44. The liquid transfer element 30 extends into and between and the liquid water 14 circulates into and between the outer casings 18a, 18b. The liquid transfer element includes a flexible hose 56 between the outer casings 18a, 18b.

As shown in Figure 4, the liquid transfer element 30 is in fluid communication with the tank 10 and contacts the water 14 in the tank 10. The liquid transfer element 30 heats or cools exhaust air 40 outside the tank 10 using the liquid received from the tank 10, and the second blower 38 dispenses the exhaust air 40.

In an exemplary embodiment, a heat sink 48 may be placed on top of the thermoelectric module stack 2 so that the blower 4 will dispense the cool or heated air 46 through the fins of the heat sink 48.

The liquid transfer element 30 is in fluid communication with the tank 10 via insulated pipes connected to inlet and outlet ports 50a, 50b and 52a, 52b respectively of the outer casings 18a, 18b of units 42 and 44. These insulated pipes carry circulating water to and from both units 42 and 44.

The thermoelectric module stack 2 is proximate to the blower 4 and the tank 10 but the thermoelectric module stack 2 is not proximate to the second blower 38. The blower 4 dispenses the air 46 without using any liquid transfer element 30, and the second blower 38 dispenses the exhaust air 40 independently of the blower 4.

In operation, the thermoelectric module stack 2 heats the air and cools the water 14 in the tank 10, the liquid transfer element 30 cools the exhaust air 40 using the cooled water 14 received from the tank 10, the second blower 38 dispenses the cooled exhaust air 40, and the liquid transfer element 30 recirculates the water 14 to the tank 10, thereby supplying heat to the thermoelectric module stack 2. Alternatively, the thermoelectric module stack 2 cools the air and heat the water 14 in the tank 10, the liquid transfer element 30 heats the exhaust air 40 using the heated water 14 received from the tank 10, the second blower 38 dispenses the heated exhaust air 40, and the liquid transfer element 30 recirculates the water 14 to the tank 10, thereby removing heat from the thermoelectric module stack 2.

The water 14 is circulated through the liquid transfer element 30 by water pumps 32 located in the second water tank 54. The second water tank 54 has a water-level indicator 28 that indicates the water level in the second water tank 54.

The outer casings 18a, 18b are separately moveable such that because unit 42 heats or cools the air in the room, it is placed in that room. On the other hand, unit 44 allows the dissipation of heat generated by unit 42 and, as such, is placed outside the room. Heat removal in this embodiment is carried out separate and away from the source of the heat, for example the thermoelectric module 2 in unit 42, so that the immediate surroundings where the unit 42 operates in will not be affected. For example, if the unit is used for cooling, the heat generated by the thermoelectric module 2 will not degrade the cooling effect in the immediate surroundings.

In the first, second, third and fourth embodiments of the present invention, castor wheels may be attached to the bottom of the outer or external casing of the device. The castor wheels allow for easy movement of the device.

Figure 5 shows the thermoelectric module stack 2 used in the device in the first embodiment of the invention. The thermoelectric module stack 2 comprises a first thermoelectric module 58 and a second thermoelectric module 60 for heating or cooling air in response to an electric current. A heat sink 62 is sandwiched between the first 58 and second 60 thermoelectric modules for dissipating heat to enable satisfactory heat pumping capacity to be maintained. The controller 8 that controls the activation and deactivation of the first 58 and second 60 thermoelectric modules in the thermoelectric module stack 2. Optionally, a further heat sink 64 is attached to the first thermoelectric module 58 opposite the heat sink 62.

The first 58 and second 60 thermoelectric modules are spaced from one another and removably secured to the heat sinks 62, 64. The first thermoelectric module 58 includes an upper ceramic surface that faces towards the second thermoelectric module 60. The second thermoelectric module 60 includes a lower ceramic surface that faces towards the first thermoelectric module 58. The heat sinks 62, 64 are metal and contact the ceramic surfaces of the thermoelectric modules 58, 60.

The thermoelectric module stack 2 is fastened to the blower 4 by a plate 66 and screws 68. The screws 68 are spring loaded so that there will not be over-tightening of the thermoelectric module stack 2. This prevents damage to the thermoelectric modules 58, 60.

An additional heat sink may be sandwiched between the second thermoelectric module 60 and the blower 4. When the thermoelectric module stack 2 is turned on or activated and set to provide cool air to the environment, the cool surface of the second thermoelectric module 60 will cool the additional heat sink. The blower will blow air through the cooled fins and blow out the cooled air.

Figure 6 shows the thermoelectric module stack 2 used in the device in the second and third embodiments. The stack is similar to the stack shown in Figure 5.

A slot 70 in the water tank 10 facing the thermoelectric module stack 2 allows a surface of the second thermoelectric module 60 to be in direct contact with the water 14 in the water tank 10. The second thermoelectric module 60 is fixedly secured to the water tank 10 and is adjacent to and exposed by the slot 70 in the water tank 10. This allows the thermoelectric module stack 2 to be in heat exchange connection with the water 14 in the water tank 10. There may be any number of thermoelectric modules that may be added to the device. In other words, there may be any number thermoelectric modules and heat sinks stacked together so long as a heat sink is sandwiched between two thermoelectric modules.

Plate 66 fastens the thermoelectric module stack 2 to the water tank 10 by screws 68. Silicone grease may be provided between the thermoelectric modules 58, 60 and the heat sink 62 to provide better thermal conductivity and avoid drilling the thermoelectric modules 58, 60. Alternatively, an adhesive may attach the thermoelectric modules 58, 60 and heat sink 62 together. Silicon 72 may line the edges where the water tank 10 and the second thermoelectric module 60 meet so that water 14 will not leak from the water tank 10.

Figure 7 shows the thermoelectric module stack 2 used in the device in the fourth embodiment. The stack is similar to the stack shown in Figures 5 and 6.

The first thermoelectric module 58 includes an upper surface that faces towards the second thermoelectric module 60 and a lower surface that faces away from the second thermoelectric module 60. The second thermoelectric module 60 includes an upper surface that faces away from the first thermoelectric module 58 and a lower surface that faces towards the first thermoelectric module 58. The upper surfaces of the thermoelectric modules 58, 60 generate heat and the lower surfaces of the thermoelectric modules 58, 60 absorb heat if the thermoelectric modules 58, 60 heat the air and cool the water 14 and the exhaust air 40. Alternatively, the upper surfaces of the thermoelectric modules 58, 60 absorb heat and the lower surfaces of the thermoelectric

modules 58, 60 generate heat if the thermoelectric modules 58, 60 cool the air and heat the water 14 and the exhaust air 40.

The first thermoelectric module 58 is closer than the second thermoelectric module 60 is to the tank 10. The second thermoelectric module 60 is closer than the first thermoelectric module 58 is to the blower 4.

The electrical circuits for the device of the fourth embodiment are shown in Figures 15 and 16.

In the four embodiments of the invention, and as shown in Figure 8, the controller 8 activates the first thermoelectric module 58 for a predetermined time period before activating the second thermoelectric module 60. In other words, the first thermoelectric module 58 is activated for a selected time until the heat sink 62 and the second thermoelectric module 60 reach a desired temperature. The predetermined time period may be between 20 to 30 seconds. Preferably, the first thermoelectric module 58 reaches between 50 to 80% of its maximum heating or cooling capacity, and more preferably reaches near its maximum heating or cooling capacity, as the second thermoelectric module 60 is activated at and in response to the expiration of the predetermined time period.

Thus, the predetermined time period determines when the first thermoelectric module 58 is sufficiently close to its maximum heating or cooling capacity, thereby operating the second thermoelectric module 60 in a more efficient and effective manner than merely activating the thermoelectric modules 58, 60 simultaneously.

Further, the first thermoelectric module 58 has greater heating or cooling capacity than the second thermoelectric module 60. For example, the first thermoelectric module 58 has 50 to 100% greater heating or cooling capacity than the second thermoelectric module 60.

The combined features of the first thermoelectric module 58 having greater heating or cooling capacity than the second thermoelectric module 60, the first thermoelectric module 58 being activated before the second thermoelectric module 60 is activated in

response to turning on the device, and the first thermoelectric module 58 reaching a predetermined fraction of its maximum heating or cooling capacity upon activating the second thermoelectric module 60 provides efficient operation of the device as heat exchange can more readily take place between the thermoelectric modules 58, 60. The first thermoelectric module 58 aids the removal of heat from or cooling the second thermoelectric module 60.

The heat pumping capacity of a thermoelectric module is influenced by the ambient temperature, heat dissipation rate of the heat sink and the potential difference of the applied voltage. The heat dissipation rate is affected by wind speed, air flow, temperature difference, contact surface area, and properties of the fluid. Therefore, a high heat transfer rate may not be necessary if the heat sink cannot absorb the heat transferred. However, a large surface contact area may then be needed to obtain a high heat dissipation rate. Therefore, advantageously, heat sinks 62, 64 increase the heat transfer rate, taking into consideration that metal has higher thermal conductivity than ceramic. The heat sinks 62, 64 may be painted black to improve heat conductivity.

Once again, the device may include any number of thermoelectric modules, heat sinks and case fans connected in the way described above. The device may also include any number of blowers and heat sinks to achieve the desired heating or cooling.

While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purpose of illustration, it will be apparent to those skilled in the art that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.

CLAIMS

1. A device for heating or cooling air, comprising:

a first thermoelectric module for heating or cooling the air in response to a first electric current, wherein the first thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements;

a second thermoelectric module for heating or cooling the air in response to a second electric current, wherein the second thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements;

a heat sink sandwiched between the thermoelectric modules;

a controller that activates the first thermoelectric module, thereby heating or cooling the second thermoelectric module by thermal conduction through the heat sink, and then activates the second thermoelectric module a predetermined time period after activating the first thermoelectric module; and

a blower that dispenses the air that is heated or cooled by the thermoelectric modules.

2. A device according to claim 1, wherein the thermoelectric modules heat the air and the blower dispenses the heated air.

3. A device according to claim 1, wherein the thermoelectric modules cool the air and the blower dispenses the cooled air.

4. A device according to claim 1, wherein:

the thermoelectric modules heat the air in response to the electric currents flowing in a first direction and the blower dispenses the heated air; and

the thermoelectric modules cool the air in response to the electric currents flowing in a second direction opposite the first direction and the blower dispenses the cooled air.

5. A device according to claim 1, wherein the thermoelectric modules are spaced from one another and removably secured to the heat sink.

6. A device according to claim 5, wherein:

the first thermoelectric module includes an upper ceramic surface that faces towards the second thermoelectric module;

the second thermoelectric module includes a lower ceramic surface that faces towards the first thermoelectric module; and

the heat sink is metal and contacts and is sandwiched between the ceramic surfaces.

7. A device according to claim 1, wherein the first thermoelectric module has greater heating or cooling capacity than the second thermoelectric module.

8. A device according to claim 7, wherein the first thermoelectric module has at least 50% greater heating or cooling capacity than the second thermoelectric module.

9. A device according to claim 1, wherein the semiconductor elements are bismuth telluride.

10. A device according to claim 1, wherein the controller activates the second thermoelectric module after the first thermoelectric module reaches at least 50% of its maximum heating or cooling capacity.

11. A device according to claim 10, wherein the controller activates the second thermoelectric module after the first thermoelectric module reaches 50 to 80% of its maximum heating or cooling capacity.

12. A device according to claim 1, wherein the predetermined time period is at least 20 seconds.

13. A device according to claim 12, wherein the predetermined time period is 20 to 30 seconds.

14. A device according to claim 1, wherein the thermoelectric modules cool the air using only the electric currents, the blower dispenses the cooled air that is cooled only by the thermoelectric modules, and the device is devoid of a refrigerant.

15. A device according to claim 1, including:

a reservoir for receiving and storing a liquid; and

a liquid transfer element in fluid communication with the reservoir, wherein the liquid transfer element contacts the liquid in the reservoir and heats or cools the air outside the reservoir using the liquid received from the reservoir;

wherein the first thermoelectric module is spaced from the liquid, the second thermoelectric module contacts the liquid in the reservoir, and the blower dispenses the air that is heated or cooled by the liquid transfer element.

16. A device according to claim 15, wherein the thermoelectric modules heat the liquid in the reservoir, the liquid transfer element heats the air using the heated liquid, and the blower dispenses the heated air.

17. A device according to claim 15, wherein the thermoelectric modules cool the liquid in the reservoir, the liquid transfer element cools the air using the cooled liquid, and the blower dispenses the cooled liquid.

18. A device according to claim 15, wherein:

the thermoelectric modules heat the liquid in the reservoir in response to the electric currents flowing in a first direction, the liquid transfer element heats the air using the heated liquid, and the blower dispenses the heated air; and

the thermoelectric modules cool the liquid in the reservoir in response to the electric currents flowing in a second direction opposite the first direction, the liquid transfer element cools the air using the cooled liquid, and the blower dispenses the cooled air.

19. A device according to claim 15, wherein the second thermoelectric module is fixedly secured to the reservoir and is adjacent to and exposed by a slot in the reservoir.

20. A device according to claim 19, wherein the thermoelectric modules are spaced from one another and removably secured to the heat sink.

21. A device according to claim 20, wherein:

the first thermoelectric module includes an upper ceramic surface that faces towards the second thermoelectric module;

the second thermoelectric module includes an upper ceramic surface that faces away from the first thermoelectric module and contacts the liquid in the reservoir and a lower ceramic surface that faces towards the first thermoelectric module and is spaced from the liquid; and

the heat sink is metal and contacts and is sandwiched between the upper ceramic surface of the first thermoelectric module and the lower ceramic surface of the second thermoelectric module.

22. A device according to claim 15, wherein the reservoir includes an aluminium tank.

23. A device according to claim 15, wherein the reservoir is positioned between the second thermoelectric module and the blower.

24. A device according to claim 15, wherein the liquid includes water.

25. A device according to claim 15, wherein the liquid consists essentially of water.

26. A device according to claim 15, wherein the liquid consists of water.

27. A device according to claim 15, wherein the liquid transfer element includes:

a porous evaporative pad that is continuously wetted by and absorbs the liquid in the reservoir and evaporates the absorbed liquid at the blower; and

a motor that rotates the evaporative pad.

28. A device according to claim 15, wherein the liquid transfer element includes:

a conduit that circulates the liquid from the reservoir to the blower and then recirculates the liquid from the blower to the reservoir; and

a pump that pumps the liquid through the conduit.

29. A device according to claim 28, wherein the conduit heats or cools the air at inlet and outlet ends of the blower.

30. A device according to claim 1, including:

a reservoir for receiving and storing a liquid;

a liquid transfer element in fluid communication with the reservoir, wherein the liquid transfer element contacts the liquid in the reservoir and heats or cools exhaust air outside the reservoir using the liquid received from the reservoir; and

a second blower that dispenses the exhaust air;

wherein the thermoelectric modules heat the air and cool the liquid in the reservoir, the liquid transfer element cools the exhaust air using the cooled liquid received from the reservoir, the second blower dispenses the cooled exhaust air, and the liquid transfer element recirculates the liquid to the reservoir, thereby supplying heat to the thermoelectric modules, or the thermoelectric modules cool the air and heat the liquid in the reservoir, the liquid transfer element heats the exhaust air using the heated liquid received from the reservoir, the second blower dispenses the heated exhaust air, and the liquid transfer element recirculates the liquid to the reservoir, thereby removing heat from the thermoelectric modules.

31. A device according to claim 30, wherein:

the first thermoelectric module includes an upper surface that faces towards the second thermoelectric module and a lower surface that faces away from the second thermoelectric module;

the second thermoelectric module includes an upper surface that faces away from the first thermoelectric module and a lower surface that faces towards the first thermoelectric module;

the upper surfaces generate heat and the lower surfaces absorb heat if the thermoelectric modules heat the air and cool the liquid and the exhaust air; and

the upper surfaces absorb heat and the lower surfaces generate heat if the thermoelectric modules cool the air and heat the liquid and the exhaust air.

32. A device according to claim 31, wherein:

the first thermoelectric module is closer than the second thermoelectric module is to the reservoir; and

the second thermoelectric module is closer than the first thermoelectric module is to the blower.

33. A device according to claim 31, wherein the thermoelectric modules are proximate to the blower and the reservoir and are not proximate to the second blower.

34. A device according to claim 31, wherein the blower dispenses the air without using any liquid transfer element, and the second blower dispenses the exhaust air independently of the blower.

35. A device according to claim 31, including:

a first outer casing and a second outer casing that are spaced from one another; wherein:

the thermoelectric modules, the heat sink and the blower are located in and the air is dispensed from the first outer casing;

the second blower is located in and the exhaust air is dispensed from the second outer casing; and

the liquid transfer element extends into and between and the liquid circulates into and between the outer casings.

36. A device according to claim 35, wherein the outer casings are separately moveable.

37. A device according to claim 35, wherein the liquid transfer element includes a flexible hose between the outer casings.

38. A device according to claim 35, wherein the blowers include inlet ends that draw in the air and the exhaust air from a separation between the outer casings.

39. A device according to claim 15, wherein the thermoelectric modules cool the liquid in the reservoir using only the electric currents, the liquid transfer element cools the air using only the cooled liquid from the reservoir, the blower dispenses the cooled air that is cooled only by the liquid transfer element, and the device is devoid of a refrigerant.

40. A device for cooling air, comprising:

a first thermoelectric module for cooling the air in response to a first electric current, wherein the first thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements;

a second thermoelectric module for cooling the air in response to a second electric current, wherein the second thermoelectric module is a semiconductor device that operates on the Peltier effect using an array of p-type and n-type semiconductor elements, and the first thermoelectric module has at least 50% greater cooling capacity than the second thermoelectric module;

a heat sink that contacts and is sandwiched between the thermoelectric modules;

a controller that activates the first thermoelectric module, thereby cooling the second thermoelectric module by thermal conduction through the heat sink, and then activates the second thermoelectric module a predetermined time period after activating the first thermoelectric module at which time the first thermoelectric module reaches at least 50% of its maximum cooling capacity; and

a blower that dispenses the air that is cooled by the thermoelectric modules.

41. A device according to claim 40, including:

a reservoir for receiving and storing a liquid; and

a liquid transfer element in fluid communication with the reservoir, wherein the liquid transfer element contacts the liquid in the reservoir and cools the air outside the reservoir using the liquid received from the reservoir;

wherein the first thermoelectric module is spaced from the liquid, the second thermoelectric module contacts the liquid in the reservoir, and the blower dispenses the air that is cooled by the liquid transfer element.

42. A device according to claim 40, wherein:

the thermoelectric modules are spaced from one another and removably secured to the heat sink;

the first thermoelectric module includes an upper ceramic surface that faces towards the second thermoelectric module;

the second thermoelectric module is fixedly secured to the reservoir, extends into a slot in the reservoir and includes an upper ceramic surface that faces away from the first thermoelectric module and contacts the liquid in the reservoir and a lower ceramic surface that faces towards the first thermoelectric module and is spaced from the liquid; and

the heat sink is metal and contacts and is sandwiched between the upper ceramic surface of the first thermoelectric module and the lower ceramic surface of the second thermoelectric module.

43. A device according to claim 40, wherein the liquid consists of water.