Campervan Thermoelectric Air Conditioner

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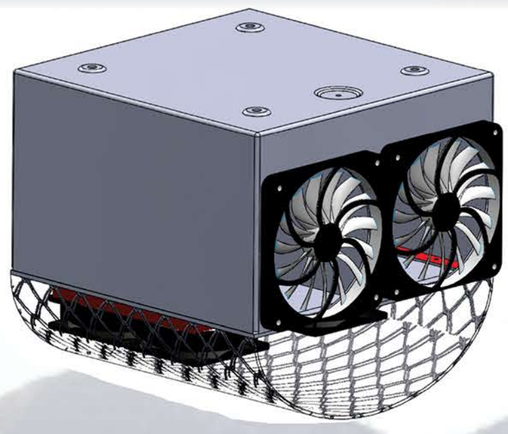
Problem Description

Air conditioners that are installed in the campervan industry are expensive, inefficient, and push the limits of legal road clearance. There is a growing market of young campervan enthusiasts who are looking for an air conditioner with easy off-grid access.



Technical Summary

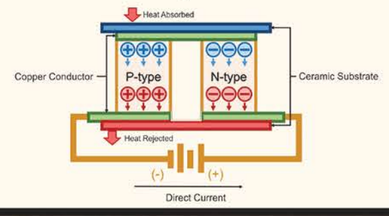
The design makes use of four thermoelectric cells to cool the air inside of the van by forced convection. The air inside the campervan recirculates through the air conditioner and is cooled by the cells, and the heat that is removed is vented out through the floor.

Benefits

- Dual action thermoelectric cells can provide heating or cooling, removing the need for two separate and expensive systems.
- Design does not include moving parts or CFC coolant, drastically reducing maintenance requirements and environmental impact.
- Compact and modular design allows for off-grid use and implementation in various system sizes or as a standalone product.

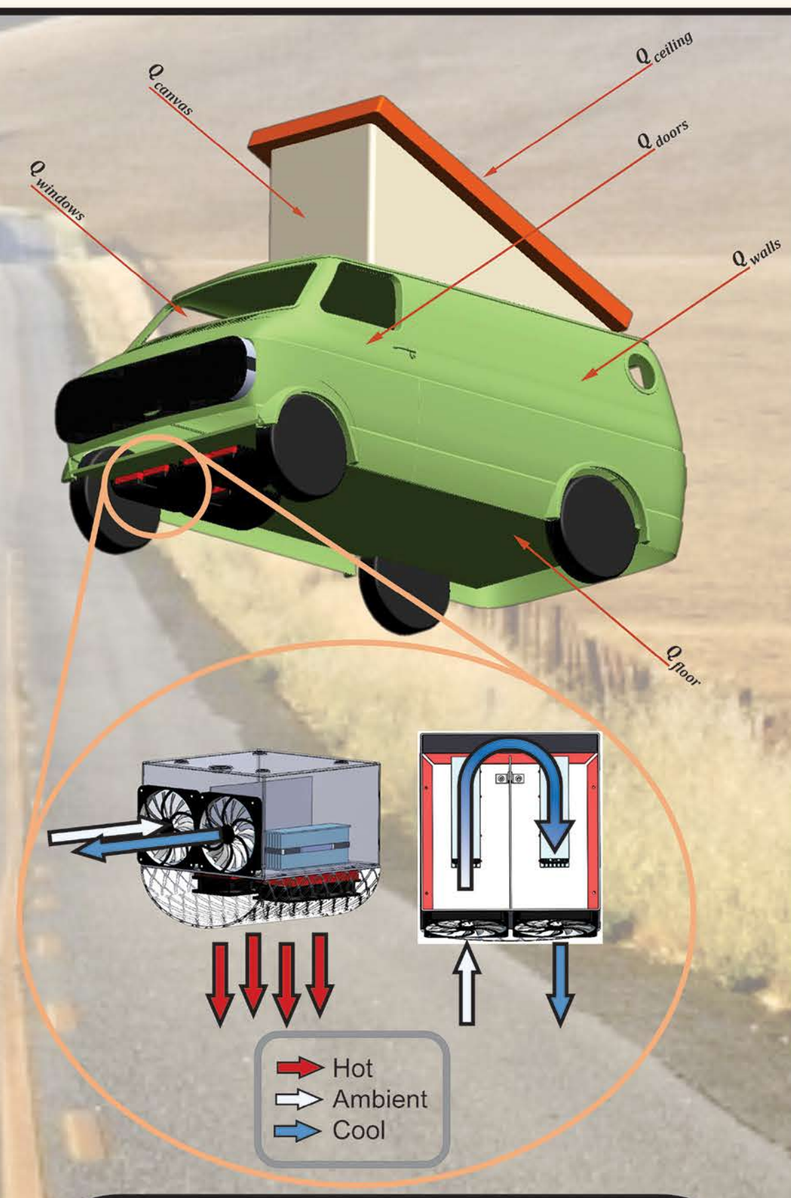
Design Principle

- Thermoelectric cells operate on the principles of the Peltier effect: *As current is passed through the junction of two dissimilar materials, the junction will be cooled.*
- When powered, one side of the cell will heat up and one will cool down.
- Low power consumption relative to mass.
- When the current direction is reversed, so are the hot and cold sides of the cell, so no physical changes are required to transform the design from an air conditioner into a space heater.



Power Requirements

The total power consumption of a 4-cell unit is 280W. This includes operating the thermoelectric cells at 12 Volts and 5 Amps each, as well as minimal additional power to run the fans. Using three units to reach a heat removal rate of 1,500W, the total electrical power consumption is 840W.



$$\sum Q_{in} = Q_{walls} + Q_{floor} + Q_{ceiling} + Q_{canvas} + Q_{windows} + Q_{door} \approx 1{,}250W$$

$$Q_{removed} = 500W / Unit \times 3Units = 1{,}500W$$

$$Q_{removed} - \sum Q_{in} = 250W$$

With three units the heat is removed from the campervan at a rate of 250 W.

Heat Gain

In all campervans, heat is constantly being transferred between the interior space and the outside world through the vehicle's walls, floor, ceiling, canvas, windows, and door. For a standard mid-sized campervan on a summer day, the approximate heat transfer from the outdoor air to the air-conditioned space is 1,250W.

Cooling Rate

- An effective air conditioning system seeks to exceed the transfer of heat from the outside air into the campervan.
- One thermoelectric cell can remove 125W of heat from the air. This provides a heat removal rate of 500W per 4-cell air conditioning unit.
- Due to the compact and modular nature of the design, additional units can be added as desired to reach a specific heat removal rate.
- Three units would be necessary to cool a standard campervan effectively.

Comparison to Standard Air Conditioning Units

In mid-range campervans, standard air conditioners consume approximately 2,500W of electrical power and remove about 2,000W of heat from the interior space. In a space where only 1,250W of heat removal is required, this design choice is relatively inefficient. Three thermoelectric air conditioning units (with four thermoelectric cells each) require less than half of the electrical power the standard unit does while providing ¾ of its heat removal rate, which still exceeds the required rate to overcome the heat transfer into the van from the outside air. Additionally, the leading under mount air conditioner for campervans costs $2,500 and the proposed design prototype only cost $1,000 per unit. Under mass manufacturing conditions, the overall cost would be greatly lower than the industry leader.

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