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Application Note

Thermoelectric Assemblies for Food and Beverage Applications

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Thermoelectrics are easy-to-service, cost-effective systems that encompass high cooling capacity in small sizes. With a wide range of small- and medium-sized units, Thermoelectric Assemblies (TEAs) are the only effective thermal management solution for many food and beverage applications.

Many food and beverage applications have tight space constraints and low weight requirements, making thermoelectrics a better choice than compressor-based systems. In addition, the assemblies have fewer moving parts and require less maintenance over the extended product life cycle.

TEAs offer the ability to cool down to well below room temperature, DC operation with reverse polarity to accommodate heating and cooling in one system, and are easily optimized to minimize vibration and noise.

The units can also be customized to accommodate food regulation standards put in place to minimize bacteria and food contamination. All of these factors as well as being environmentally friendly and low-cost make thermoelectrics an excellent choice for food and beverage applications.

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Corporate Contact:
1.636.898.6000

www.lairdtech.com

Thermoelectric Assemblies for Food and Beverage Applications

Thermoelectric Assemblies (TEAs) are cooling and heating systems that utilize Thermoelectric Modules (TEMs) to transfer heat by air, liquid or conduction methods including integrated temperature controls. TEAs remove the passive heat load generated by the ambient environment and active device in order to stabilize the temperature of appliances used in food and beverage applications. TEAs are ideal because passive cooling technologies cannot go below ambient and compressor-based systems are too large to fit into tight geometric constraints.

Thermoelectric Operation

TEAs use TEMs to dissipate heat. TEMs are solid-state heat pumps that require a heat exchanger to dissipate heat utilizing the Peltier Effect. During operation, DC current flows through the TEM to create heat transfer and a temperature differential across the ceramic surfaces, causing one side of the TEM to be cold, while the other side is hot. A single-stage TEM can achieve temperature differentials of up to 70°C and transfer heat at a rate of up to 150 watts. In order to increase the amount of heat pumping capacity, the TEM's modular design allows for the use of multiple TEMs mounted side-by-side, which is called a TE Array.

TEMs are composed of two ceramic substrates that serve as electrically insulating materials and house P-type and N-type semiconductor elements. Heat is absorbed at the cold junction by electrons as they pass from a low-energy level in the P-type element onto a higher energy level in the N-type element. At the hot junction, energy is expelled to a thermal sink as electrons move from a high-energy element to a lower-energy element.

Reversing the polarity changes the direction of heat transfer. TEMs are rated at maximum parameters (ΔT_{max}, I_{max}, V_{max}, and Q_{max}) under no load conditions, with temperature control accuracy achieving ±0.01°C under steady-state conditions. TEMs can be used as power generators and create 1 to 2 watts of energy per TEM. They can cool to -100°C (6-stage) and pump up to 150 watts of heat, with higher heat pumping capacities achieved by wiring TEMs into an array. Their geometry can vary from 2x2mm to 62x62mm and are much more efficient in heating mode than resistant heaters. They also fit into tight geometric space constraints that cannot accommodate a much larger compressor-based system.

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Assembly Transfer Systems

Different TEAs are used to meet the thermal demands for specific applications.

- **Air-to-Air Assemblies** offer dependable, compact performance by cooling objects via convection. Heat is absorbed and dissipated by heat exchangers equipped with fans. Specifications apply to an ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Direct-to-Air Assemblies** offer dependable, compact performance by cooling objects via conduction. Heat is absorbed through a cold plate, pumping the heat through the TEM and dissipating it into the air through a heat sink. Specifications apply to an ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Liquid-to-Air Assemblies** cool or heat liquids that flow through a heat exchanger. The liquid heat exchanger is designed for a re-circulating system, absorbs heat and pumps it through the TEM, where it dissipates into the outside environment through an air heat sink. Specifications apply to an ambient temperature of 32°C and nominal voltage with tolerances ±10%.
- **Direct-to-Liquid Assemblies** cool or heat objects attached directly to the cold plate. Heat is dissipated into a liquid heat exchanger on the hot side. The liquid circuit is normally a re-circulating type that requires a pump and additional liquid heat exchanger that dissipates heat into the ambient environment. Specifications apply to the warm side liquid temperature of 32°C and nominal voltage with tolerances ±10%.
- **Liquid-to-Liquid Assemblies** cool or heat liquids as they pass through a heat exchanger. Heat is then transferred onto another heat exchanger on the hot side. The liquid circuit is normally a re-circulating type that requires a pump and additional liquid heat exchanger that dissipates heat into the ambient environment. Specifications apply to warm side liquid temperature of 32°C and nominal voltage with tolerances ±10%.
- **Re-Circulating Chillers** cool a wide range of liquid circuits and work in “closed loop” systems that contain a liquid-to-air assembly, pump, temperature controller, power supply and reservoir. Outlet temperature can be controlled from 2°C to 40°C to within ± 0.02°C under steady-state conditions using distilled H_2O as coolant.

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Food and Beverage Applications

Many food and beverage applications have size constraints, power consumption requirements, or noise restrictions that make thermal management difficult. TEAs are ideal for these applications by offering highly reliable cooling or heating below or above ambient through solid-state operation, low maintenance and long service life. They also have a low cost of ownership, compact size, and can be installed in any orientation. This cannot be accomplished by any other means without a complex heating and cooling system.

For instance, vending machines utilize TEAs in order to store and dispense beverages in locations with tight space constraints such as retail store counters and public transportation stations. The TEAs cool the beverages from 15°C to 22°C below room temperature. They offer extended benefits through low cost of ownership and long service life with minimal maintenance required throughout the product life cycle.

Likewise, TEAs are used in wine coolers that are available in a variety of sizes from small countertop coolers to commercial wine cooler-dispenser combinations, facilitating outdoor applications such as beach cabanas or poolside bars. In high ambient temperatures, TEAs refrigerate the wine from 1°C to 17°C, dependant on thermal mass or number of bottles stored. The compact size and minimal noise vibration of the TEAs do not agitate the sediments of the wine, which can be very costly with excessive noise vibration, damaging the wine.

Temperature-controlled mobile food trolleys also utilize TEAs in order to store and transport hot or cold food on serving trays for an extended period of time. The heating and cooling zones can be integrated into the same system on the same trolley, providing maximum thermal flexibility with heating and cooling periods increased to minimize food exposure to ambient temperatures. TEAs can act as hot plates and elevate the temperature up to 65°C, or act as cold plates and reduce the temperature to below 8°C. With their compact size, TEAs do not require much space, which allows for more food to be transported on the trolley.

Similarly, TEAs keep coffee fresh in high-end coffee dispensing machines by maintaining the temperature of the coffee concentrate at 4°C in ambient temperatures. Because of tight space constraints, TEAs are an ideal cooling solution due to their compact size and low power consumption, once steady-state is reached.

TEAs are well suited for use by countertop chillers. These chillers keep perishable items such as fruits, vegetables or sliced lemons at a beverage station, cream cheese packets at a self-serve station, or dairy creamers at a coffee station all cold. TEAs keep the perishable items below 5°C in a room temperature environment by providing a cooling source that requires little space, unlike a conventional compressor-based system, which requires a large amount of space.

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In the same way, hotel and dorm room mini-bars use TEAs to cool beverages and perishable items to as low as 5°C in ambient temperatures. TEAs do not use a compressor, so vibration is minimal and fan noise can be suppressed to limit hearing discomfort in such already confined spaces.

A similar application can be found in mini-keg coolers. The coolers, used in the home consumption of draft beer, utilize TEAs to cool the beer from 1°C to 10°C in a room temperature environment. TEAs offer minimal noise and vibration, require minimal space, and make the keg coolers less cumbersome for handling and transport; as opposed to compressor-based systems.

Summary

Thermal management of food and beverage systems is more challenging than ever. Product form factors continue to shrink, increasing the difficulty of incorporating conventional compressor-based solutions into the product design. In today's complex food and beverage operating environment, TEAs are necessary to provide compact, low cost, design-friendly thermal management solutions in a variety of modular platforms.

TEAs combine special benefits that make them the only effective solution for many food and beverage thermal management applications by offering greater performance, higher reliability, and lower cost of ownership. Their advanced capabilities are aided by new materials, technology, temperature control, and automated assembly.

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Laird Technologies designs and manufactures customized, performance-critical products for wireless and other advanced electronics applications.

The company is a global market leader in the design and supply of electromagnetic interference (EMI) shielding, thermal management products, mechanical actuation systems, signal integrity components, and wireless antennae solutions, as well as radio frequency (RF) modules and systems.

Custom products are supplied to all sectors of the electronics industry including the handset, telecommunications, data transfer and information technology, automotive, aerospace, defense, consumer, medical, and industrial markets.

Laird Technologies, a unit of Laird PLC, employs over 10,000 employees in more than 39 facilities located in 13 countries.

Contact Information

For additional information, visit http://www.lairdtech.com or contact us at:

Tel: +1-888-246-9050 option 2
e-mail: CLV-customerservice@lairdtech.com

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