Selecting a thermoelectric cooler

Understanding how these devices work can put the freeze on overheated systems

BY G. SCOTT MIKALAUSKIS
TECA, Chicago, IL
http://www.thermoelectric.com

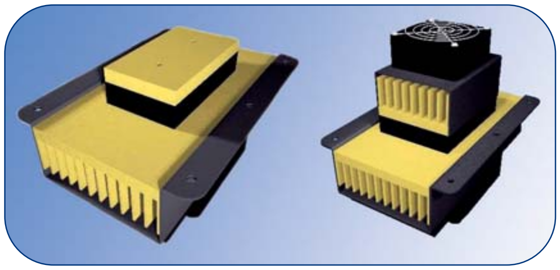

Fig. 1. To suit different applications, thermoelectric coolers can come in the form of a cold plate (left) or an air conditioner with a fan (right).

Although they've been around for a long time, thermoelectric cooling systems still provide a remarkably efficient way to cool today's hottest circuitry without the need for gases or compressors. How do they work? When are they used? How can appropriate thermoelectric devices be selected for a given application?

The Peltier effect

Thermoelectric cooling relies fundamentally on the Peltier effect. Electrons passing through semiconductor materials with alternating conductive properties absorb ambient heat energy in order to travel through one of the materials and expend this energy as they travel through the other material.

Given the proper spatial arrangement, these materials can form a small module (about the size and shape of a saltine cracker) that will get hot on one side and cold on the other. Such thermoelectric modules alone would not be suitable for most cooling applications, but they are at the heart of any thermoelectric cooling system. The addition of heat sinks, fans, fins, cold plates, liquid jackets, and the like allow thermoelectric devices to be built in the form of air conditioners, liquid chillers, and cold plates (see *Fig. 1*).

Comparison: conventional refrigeration

Because thermoelectric cooling is a form of solid-state refrigeration, it has the advantage of being compact and durable. A thermoelectric cooler uses no moving parts (except for some fans), and employs no fluids, eliminating the need for bulky piping and mechanical compressors used in vapor-cycle cooling systems.

Such sturdiness allows thermoelectric cooling to be used where conventional refrigeration would fail. In a current application, a thermoelectric cold plate cools radio equipment mounted in a fighter jet wingtip. The exacting size and weight requirements, as well as the extreme g forces in this unusual environment, rule out the use of conventional refrigeration.

Thermoelectric devices also have the advantage of being able to maintain a much narrower temperature range than conventional refrigeration. They can maintain a target temperature to within ±1° or better, while conventional refrigeration varies over several degrees.

Unfortunately, modules tend to be expensive, limiting their use in applications that call for more than 1 kW/h of cooling power. There are also limits to the maximum temperature differential that can be achieved between one side of a thermoelectric module and the other.

However, in applications requiring a higher ΔT, modules can be cascaded by stacking one module on top of another. When one module's cold side is another's hot side, some unusually cold temperatures can be achieved.

Enclosure cooling

After the modules themselves, most thermoelectric devices made today are probably air conditioners. Thermoelectric air conditioning is used mostly in enclosure cooling applications, especially the cooling of electronic enclosures.

These air conditioners are usually

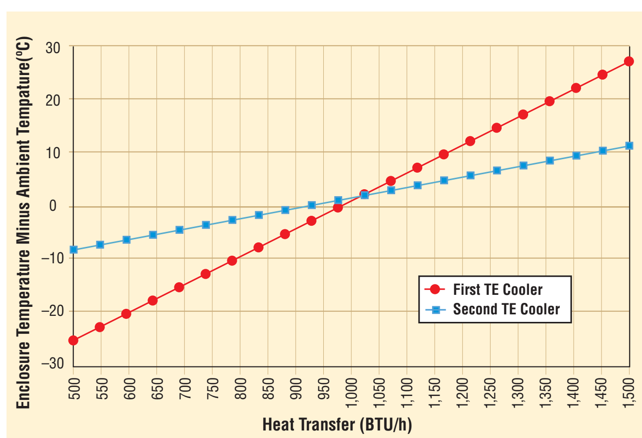

Fig. 2. The first cooler in the graph has a broader heat-pumping capability than the second, although some manufacturers will provide above-0° ratings, which can be misleading.

designed for mounting directly on the enclosure wall, in such a way that forms a tight seal between the air conditioner and the enclosure. Because of the solid-state nature of thermoelectric technology, these air conditioners do not exchange air or any other material between the enclosure and the ambient environment. This can be an important advantage if delicate electronics or special materials must be kept safe in a dirty environment.

Varying greatly in size, heat load, and ambient conditions, enclosures cooled by thermoelectric air conditioners include such diverse applications as environmental test chambers, galley refrigerators, and ATMs. The cooling of computer electronics by this method is especially common, as is the cooling of individual computer chips by direct contact with tiny thermoelectric cold plates.

Thermoelectric air conditioners also suit hazardous environments, up to and including Class 1 Division 1. Such devices must be designed in such a way that they cannot cause an explosion, even when operating in an environment where explosive gases are present. (So, for example, such devices cannot use fans, because the spinning fan blades could build an electric charge.)

Selection parameters

Because thermoelectric coolers are often used to cool enclosures, some selection media are organized around that application. Selection of a thermoelectric cooler depends on certain technical parameters. Specifically, the engineer needs to know the enclosure's surface area, desired enclosure temperature, ambient temperature, amount of insulation around the enclosure, and the active load inside the enclosure.

As a practical matter, selection of a thermoelectric device these days is very simple. Most cooler manufacturers have free downloadable "sizing software" on their Web sites. After prompting the user for all the required data, these programs perform all the necessary calculations and recommend one or more suitable products.

Alternatively, thermoelectric devices can be selected through the use of performance curves. These curves describe heat-pumping capacity at different values of ΔT.

Their use requires that the engineer already have some idea of the amount of heat to be transferred by the cooler. Not all manufacturers measure product performance in the same way, so take care when comparing data from different companies.

Whether selected through sizing software or by comparison of performance curves, the engineer will want to have some idea of where and how the thermoelectric cooler is to be attached to the application. For example, thermoelectric air conditioners mount directly onto an enclosure wall and—depending on the particular air conditioner—it may or may not intrude into the enclosed space.

Also, thermoelectric air conditioners can generally operate in any orientation, so except in the case of some liquid chillers, there is no such thing as upside-down or sideways thermoelectric technology. Because of this, a thermoelectric air conditioner could operate from the top, bottom, or any side of an enclosure.

Power requirements for thermoelectric devices vary greatly. While the modules themselves can only operate on dc, an air conditioner, liquid chiller, or cold plate can be made to use either dc or ac, and operable across a range of voltages and frequencies. Even if an unusual power situation exists, a thermoelectric device can usually be adapted to it.

Watch out for ratings

When comparing thermoelectric devices, it is important to be particularly aware of the desired temperature differential between the enclosure and the ambient temperature. By convention, thermoelectric devices are usually rated at 0° ΔT, where the enclosure temperature is at equilibrium with the ambient temperature.

Actual applications often call for a negative ΔT—an enclosure made cooler than its surroundings. Less common are applications calling for above-ambient cooling, in which the desired enclosure temperature is hotter than the ambient temperature.

Most of the time, this type of cooling is accomplished simply by opening the enclosure to the outside, or by installing a simple fan. However, if an application requires the enclosure remain sealed, and that it also remain above a certain temperature (above a dew point temperature, for example), then above-ambient active cooling may be called for.

When selecting a thermoelectric cooler, engineers need to take care to not be misled by the device's rating. The amount of heat that a cooler removes depends in part on the temperature differential between the enclosure and the ambient environment (see *Fig. 2*)

Any cooler with a performance rating given at 0° ΔT will achieve a higher performance rating at 20° ΔT. So, care must be taken when comparing products to use the same rating point for each unit considered. Being rigorous and consistent will yield the most consistent and reliable results. EP