# Simulating a Peltier Cooler

A Peltier cooler, or thermoelectric cooler (TEC), serves the same cooling function as a mechanical refrigeration system. In both devices, thermal energy is extracted from one region to cool it, and exhausted to another region, typically the environment. However, rather than mechanical parts, the Peltier cooler uses solid state thermocouple materials.

The Peltier cooler boundary condition defines the sum of the heat loads produced at hot plate and cold plate elements representing the TEC device. In a TEC device the hot and cold plates are separated by a thin, parallel array of semi-conductor thermocouples. Each thermocouple has an n-type element and a p-type element, and the array is electrically connected in series such that a positive current flowing through it causes Peltier heat to be absorbed at the cold plate junctions and released at the hot plate junctions. This process is reversed with a negative current. Joule heating and conduction heat flow also occur in the semi-conductor material. The sum of the heat loads generated at each set of plate elements and the voltage required to drive the device are given by the equations:

$$Q_{cold} = -2N\left(aIT_{cold} - \left(\frac{I^2\rho}{2G}\right) - k\Delta TG\right)$$

$$Q_{hot} = 2N\left(aIT_{hot} + \frac{I^2\rho}{2G} - k\Delta TG\right)$$

$$V = 2N\left(\frac{I\rho}{G} + a\Delta T\right)$$

Where:

$T_{hot}$ = Hot plate temperature (Kelvin)

$T_{cold}$ = Cold plate temperature (Kelvin)

$\Delta T = T_{hot} - T_{cold}$ (Kelvin)

$G$ = Geometrical factor, calculated as Area/length of one p-type or n-type element of a thermocouple (m)

$N$ = Number of thermocouples in device

$I$ = Current (Amps)

$V$ = Voltage (Volts)

$a$ = Seebeck coefficient (Volts/Kelvin)

$\rho$= Resisitivity (Ohm-m)

$k$ = Thermal conductivity ($W/m^2$ K)

The semi-conductor material properties can be defined as constants, but they are in fact temperature dependent. Equations for them as a function of temperature can be found on some TEC manufacturer's web sites or in textbooks on thermo-electrics. The temperature

dependent properties are evaluated at the average of the cold and hot plate temperatures.

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