Properties of thermocouple plates

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A thermocouple plate (TCP) consists of a large number of n- and p-doped BiTe-bits placed between two ceramic plates. Figure 1 shows this arrangement. When designing calorimetric instruments in which TCP:s are used it is importan to know their properties. The three most interesting properties are:

k - the heat conductance of the TCP (W/K) (1)

E - the output voltage per degree temperature difference (V/K) (2)

S - the sensitivity (V/W) (3)

In this report I will give equations for calculating these properties. It should be noted that it is not trivial (or even not possible) to derive these parameters from the producers data sheets. This is because the TCP:s are normally used as cooling or heating devices with large temperature differences and thermal powers. The present calculations only concern the case with very small temperature differences and thermal powers.

Given the thermal properties of the materials and their geometry the total thermal conductance may be calculated by the following equation (the electrical conductors (copper) have a very high thermal conductivity and does not need to be considered when the total heat conductance of the thermocouple plate is calculated):

$$\frac{1}{k_{\mathrm{TCP}}} = \frac{H}{2n\lambda_{\mathrm{TC}}L^2} + \frac{2h}{\lambda_{\mathrm{cer}}\ell^2} \tag{4}$$

The nomenclature is as follows (the values given refer to the Melcor TCP:s I have used):

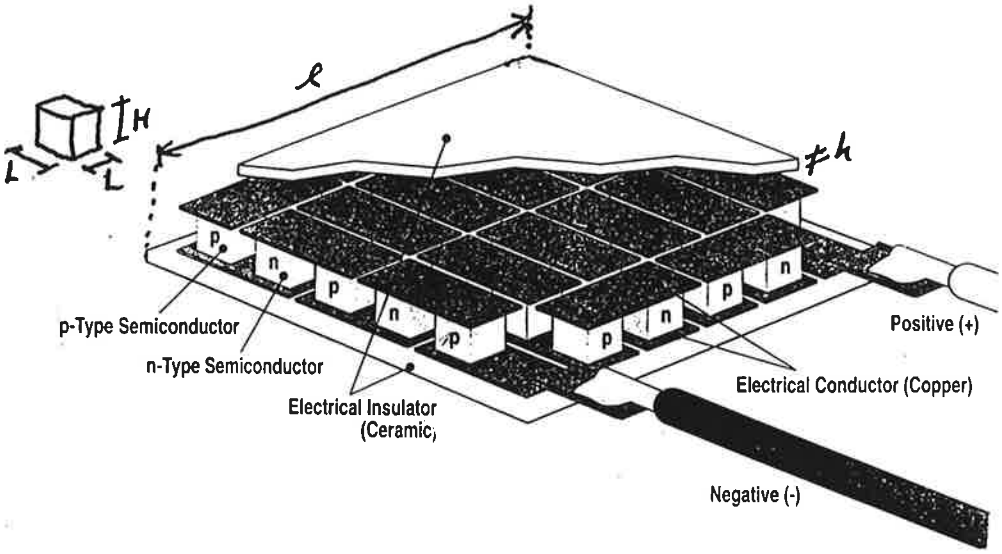

Figure 1: A thermocouple plate (taken from Thermoelectric Handbook, Melcor Thermoelectrics, Trenton, New Jersey, USA, 1995)

k_{TCP}	conductance of thermocouple plate	J/K
H	height of each TC-bit	m
L	width of each TC-bit	m
n	number of thermocouples	-
λ_{TC}	heat conductivity of thermocouple material	1.5 W/m/K
h	height of one ceramic plate	$0.5 \cdot 10^{-3}$ m
ℓ	width of the ceramic plates	m
λ_{cer}	heat conductivity of ceramic (alumina)	35.3 W/mK

The last term in the above equation is usually very small. For the third type of TCP in the table on the next page the last term was less than 1% of the middle term. This is because the alumina has a high heat conductivity compared to the thermocouple material.

The λ_{TC}-value given above is an approx. mean of the values for the n- and p-doped materials (their values are approx. 1.4 and 1.6 W/m/K). The value is taken at 25°C.

The output voltage per degree temperature difference is simply the sum of the electrical output of all thermocouples. An approximate value of the voltage per degree temperature difference over one thermocouple is 0.40 mV (a mean value of the three measured TCP:s in Bäckman et al.(1994) J. Biochem. Biophys. 28 85-100). This gives the following expression for the voltage per degree temperature difference over a TCP:

$$E = 0.40 \cdot 10^{-3} n \tag{5}$$

The sensitivity will then simply be:

$$S = \frac{E}{k} \tag{6}$$

I have looked at the following TCP:s from Melcor (Trentor, New Jersey, USA):

Melcor no.[1]	ℓ / mm	H / mm	L / mm	n	k / W/K	E / V/K	S / V/W
CP1.0-127-05L	30	1.27	1.0	127	0.297	0.0508	0.171
CP1.4-71-06L	30	1.52	1.4	71	0.272	0.0284	0.104
CP1.4-71-045L	30	1.14	1.4	71	0.362	0.0284	0.0785

Note that there are $2n$ thermocouples (all in parallell) and that there are two ceramic plates (in series).

[1]The Melcor numbers CPx.x-yy-zzL give the following information: x.x is the width the BiTe bits of the thermocouples (L), yy is the number of thermocouples (n), and zz is the height of a thermocouple in 1/10th inch (the decimal dot is missing; 05 means 0.5·2.54 mm).