Thermoelectric Modules
Introduction
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1 THERMOELECTRIC COOLING
Thermoelectric cooling provides an alternative solution to the common compressor and absorber cooler. Thermoelectric coolers are used especially if small cooling power is needed (up to 500 W)

Benefits of thermoelectric coolers:
- small size
- no fluid
- exact temperature control
- heating by changing the direction of the current

2 APPLICATIONS
The operational area of the thermoelectric cooling is very extensive. Therefore here only a small selection of applications:
- x-ray units
- medical equipment and analyzers
- gas analyzers
- laser cooling
- food cooling

3 WHAT IS A THERMOELECTRIC MODUL
A thermoelectric module is an electrical module, which produces a temperature difference with current flow. The emergence of the temperature difference is based on the Peltier effect designated after Jean Peltier. The thermoelectric module is a heat pump and has the same function as a refrigerator. It gets along however without mechanically mobile construction units (pump, compressor) and without cooling fluids. The heat flow can be turned by reversal of the direction of current.

4 THERMOELECTRIC EFFECT
If one connects 2 wires of differently electrically leading materials at the 2 ends and if one applies additionally a voltage, a current flows, which transports heat of one junction point to the other. In the consequence one junction point becomes cold and the other one warm.

For thermoelectric modules materials are applicable with a high electrical conductivity and a small thermal conductivity. Unfortunately good electrical conductors are also good heat conductors. One obtains the best efficiency with semiconductors.
5 PRINCIPLE STRUCTURE

Thermoelectric modules consist of 2 different electrically leading materials. These are alternating electrically interconnected and mechanically arranged in such a manner that the junction points are alternating on one level.

6 THERMAL FLOWS

6.1 Thermal balance

On the hot side the net heat from the cold side and the power required to pump this heat must be transferred to the environment.

\[ Q_h = P_{el} + Q_c \]
6.2 Single Thermal Flows

The cooling capacity ($Q_c$) can be expressed in the following formula:

$$Q_c = Q - Q_J - Q_{\Delta T}$$

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Formula</th>
<th>Explanation / remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_c$</td>
<td>W</td>
<td>$Q = I \cdot \alpha \cdot T_c$</td>
<td>heat transported from the cold side.</td>
</tr>
<tr>
<td>$Q$</td>
<td>W</td>
<td>$Q = I \cdot \alpha \cdot T_c$</td>
<td>heat pumped through the Peltier effect</td>
</tr>
<tr>
<td>$Q_J$</td>
<td>W</td>
<td>$Q_J = \frac{1}{2} \cdot I^2 \cdot R$</td>
<td>Joule heat, caused by the current flow, arises ever to the half on both sides</td>
</tr>
<tr>
<td>$Q_{\Delta T}$</td>
<td>W</td>
<td>$Q_{\Delta T} = C \cdot \Delta T$</td>
<td>heat flow between 2 points with different temperatures</td>
</tr>
<tr>
<td>$I$</td>
<td>A</td>
<td>#</td>
<td>electric current</td>
</tr>
<tr>
<td>$R$</td>
<td>Ω</td>
<td>#</td>
<td>electric resistance</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>V/K</td>
<td>#</td>
<td>material-dependent &quot;thermal strength&quot;</td>
</tr>
<tr>
<td>$C$</td>
<td>W/K</td>
<td>#</td>
<td>Thermal conductance between the cold and hot side</td>
</tr>
<tr>
<td>$T_c$</td>
<td>K</td>
<td>#</td>
<td>temperature on the cold side</td>
</tr>
<tr>
<td>$\Delta T$</td>
<td>K</td>
<td>$T_h - T_c$</td>
<td>temperature difference between the cold and hot side</td>
</tr>
</tbody>
</table>

The heat transport by the Peltier effect is proportional to the current. The electrical loss is proportional to the current in the square. Hence it follows that with increasing current the electrical loss grows faster than the heat transport by the Peltier effect. In consequence, from a certain amperage the cooling capacity does not continue to rise despite of the increase in current, but even decreases!
7 CHARACTERISTIC VALUES

In the data sheets apart from the mechanical dimensions the following parameters are shown:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{\text{max}}$</td>
<td>0.7 ... 78 A</td>
</tr>
<tr>
<td>$U_{\text{max}}$</td>
<td>1 ... 24 V</td>
</tr>
<tr>
<td>$Q_{\text{max}}$</td>
<td>0.4 ... 180 W</td>
</tr>
<tr>
<td>$\Delta T_{\text{max}}$</td>
<td>67 ... 74 K</td>
</tr>
</tbody>
</table>

One pay attention, that the above values apply to a certain temperature. Normally the temperature of the hot side of the thermoelectric module is given. This must be indicated in the data sheet (e.g. $T_h = 300K$). The data of different thermoelectric modules may only be compared 1:1, if the reference temperature is the same.

7.1 Interpretation of the parameters:
- The values are measured in vacuum.
- On the hot side there is applied the reference temperature.
- If the current $I_{\text{max}}$ flows and there is no cooling ($Q_c = 0$), there will be the maximum achievable temperature difference $\Delta T_{\text{max}}$ between the hot and cold side. The voltage on the thermoelectric module contact is $U_{\text{max}}$.
- If the current $I_{\text{max}}$ flows and the temperature difference is 0 ($\Delta T = 0$), there will be the maximum cooling capacity $Q_{\text{max}}$.
  **Attention:** The voltage is smaller than $U_{\text{max}}$!
7.2 Relation between $\Delta T$ and $Q_c$

$\Delta T$ and $Q_c$ work against each other. With increasing temperature difference the cooling capacity decreases. For this reason in the development must be paid attention to the temperature difference as small as possible. One reaches this, by realizing good heat transfers.

![Relation between Qc and dT](image)

Example FROST-74

8 WHERE THERMOELECTRIC MODULES ARE USED

Thermoelectric modules are particularly suitable for applications with the following conditions:

- small cooling capacity
- low weight
- high reliability
- small sizes
- exact temperature control
- Low cost
- no liquid

9 SELECTION OF A SUITABLE THERMOELECTRIC MODULE

9.1 Parameters

For the determination of the optimal thermoelectric module the following values must be given:

- $T_c$ (temperature on the cold side)
- $T_h$ (temperature on hot side)
- $Q_c$ (cooling capacity)

The above values often cannot be simply determined. Then one must assume values, which must be examined for their correctness in experiments.
9.2 Utilities
For the selection of a suitable thermoelectric module is a software tool available:

Selection of the thermoelectric module

Diagrams of thermoelectric modules

Calculation of a cooling unit

Deltron AG will be glad to help you with the selection of the thermoelectric modules. Please contact us.