IEC/TS 62610-3

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TECHNICAL SPECIFICATION

colour inside

Mechanical structures for electronic equipment – Thermal management for cabinets in accordance with IEC 60297 and IEC 60917 series –

Part 3: Design guide: Evaluation method for thermoelectrical cooling systems (Peltier effect)

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Mechanical structures for electronic equipment – Thermal management for cabinets in accordance with IEC 60297 and IEC 60917 series –
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MECHANICAL STRUCTURES FOR ELECTRONIC EQUIPMENT – THERMAL MANAGEMENT FOR CABINETS IN ACCORDANCE WITH IEC 60297 AND IEC 60917 SERIES –

Part 3: Design guide: Evaluation method for thermoelectrical cooling systems (Peltier effect)

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62610-3, which is a technical specification, has been prepared by subcommittee 48D: Mechanical structures for electronic equipment, of IEC technical committee 48: Electromechanical components and mechanical structures for electronic equipment.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
48D/401/DTS	48D/414/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62610 series can be found, under the general title *Mechanical structures for electronic equipment – Thermal management for cabinets in accordance with IEC 60297 and IEC 60917 series*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
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INTRODUCTION

Besides the conventional compressor cooling there are several alternatives for cooling, for example: absorption cooling, thermoelectric cooling (Peltier), magneto caloric cooling, CO_2 cooling and others.

For the design of thermoelectrical cooling systems, values of the dissipation loss depending on the ambient temperature and internal temperature are necessary.

Thermoelectrical cooling systems performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, of the design of the Peltier device and of Peltier electrical parameters.

Therefore an evaluation method has to be developed. This design guide allows a comparison of thermoelectrical cooling systems.

MECHANICAL STRUCTURES FOR ELECTRONIC EQUIPMENT – THERMAL MANAGEMENT FOR CABINETS IN ACCORDANCE WITH IEC 60297 AND IEC 60917 SERIES –

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1 Scope and object

This part of IEC 62610 provides an evaluation method for thermoelectrical cooling systems (Peltier effect).With this design guide it is possible to calculate the efficiency of the thermoelectrical cooling system (Peltier effect) and its cooling power depending on the ambient temperature and internal temperature. This design guide can also be used to appraise thermoelectrical cooling systems by its efficiency.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62194:2005, *Method of evaluating the thermal performance of enclosures*

3 Abbreviations, symbols and indices

For the purposes of this document, the following abbreviations, symbols and indices apply.

3.1 Abbreviations

COP	coefficient of performance [-]
c_P	heat capacity [W/kgK]
D	pipe diameter [m]
I	current [A]
k	overall heat transfer coefficient k [W/ m^{2}K]
n	total number of Peltier devices [-]
Δp	pressures difference [Pa]
Q	energy flow (thermal, electrical, conductivity) [W]
Q_C	effective cooling power of the thermoelectrical cooling system (Peltier) [W]
Q_{cPe}	cooling power of a Peltier device at operating conditions [W]
Q_D	total dissipated heat flow on the hot side [W]
Q_H	heating power inside the cabinet [W]
R_{Pe}	electrical resistance of the Peltier device [V/A]
R_i	thermal resistance [K/W]
S	surface [m^2]
T	temperature [K]
V	voltage [V]

$\dot{V}$	volume flow [m^3/s]
ZT	Figure of Merit [-]

3.2 Symbols

α	Seebeck coefficient [V/K]
ρ	density [kg/m³]
λ	thermal conductivity [W/m^{2}K]
σ	electrical conductivity [S/m = A/V]
φ	relative humidity

3.3 Indices

1-7	position marks
A	related to an air flow
a	ambient
C	effective cooling power
c	cold side
D	total dissipated and removed heat on the hot side
E	electrical power applied to the thermoelectrical cooling system
F	Fan
H	heating inside the cabinet
h	hotside
i	internal, inside the cabinet
L	heat loss
m	average
Pe	related to the Peltier device
R	reverse
S	related to the whole thermoelectrical cooling system

4 Theory of the thermoelectrical cooling system

4.1 The Peltier element

The Peltier effect is the direct conversion of electric voltage to temperature differences and the reverse process is called Seebeck effect.

Therefore a thermoelectrical cooling system (Peltier effect) transfers heat from one side of the device to the other side against the temperature gradient, with consumption of electrical energy.

This Peltier effect is described by the following equation:

$$Q_{cPe} = \alpha \cdot I \cdot T_c - \frac{1}{2} \cdot I^2 \cdot R_{Pe} - \left(\frac{\lambda_{Pe} \cdot S_{Pe}}{x_{Pe}} \right) \cdot \left(T_{4h} - T_{4c} \right) \quad [W] \qquad [1]$$

The cooling power of one Peltier element Q_{cPe} depends on different phenomena.

The term $\alpha \cdot I \cdot T_c$ is the maximum cooling power based on the Peltier effect, whereas α represents the Seebeck coefficient.

The term $\frac{1}{2} \cdot I^2 \cdot R_{Pe}$ represents the Joule heating, the term $\left(\frac{\lambda_{Pe} \cdot A_{Pe}}{x_{Pe}}\right) \cdot (T_{4h} - T_{4c})$ is the heat conduction between the hot and the cold side through the Peltier element.

According to Equation 1 it is a requirement to minimize the terms of the Joule heating and the heat conduction.

For the evaluation of a Peltier element the coefficient Figure of Merit ZT was defined as shown in Equation 2.

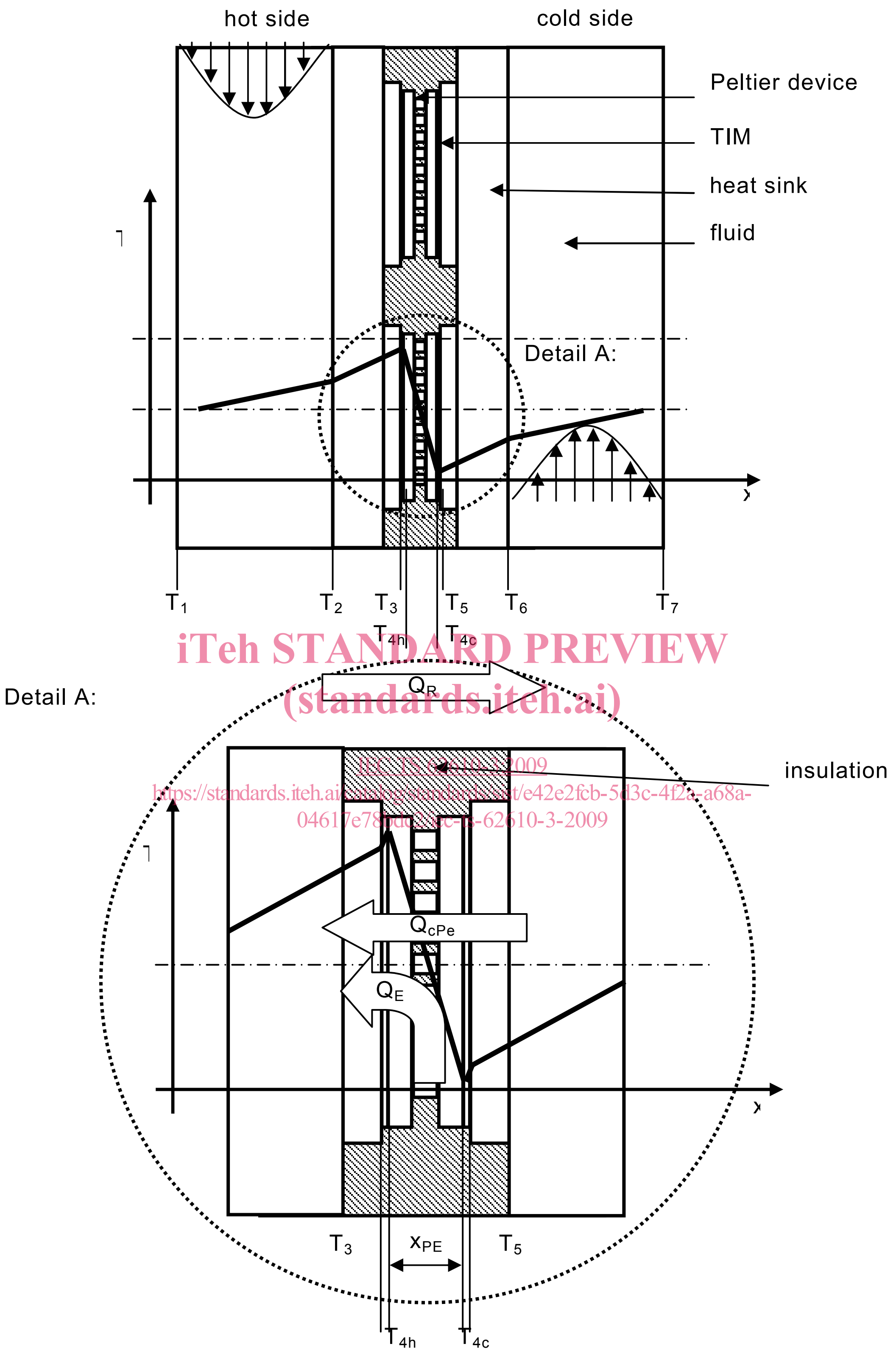
$$ZT = \frac{\alpha^2 \cdot \sigma}{\lambda} \cdot T \quad [-] \tag{2}$$

which represents the ratio between the electrical conduction σ to the heat conduction λ at a given temperature T.

ZT is therefore a very convenient figure for comparing the potential efficiency of devices using different materials. Values of ZT=1 are considered good, and values of at least the 1–3 range are considered to be essential for thermoelectrics to compete with mechanical generation and refrigeration in efficiency.

4.2 Thermoelectrical cooling systems

The thermoelectrical cooling systems (see Figure 1) transport heat Q_c from one medium to another whereas these media can be either gas or liquid. For a better heat transfer, heat sinks are connected to each side of the Peltier device. The material between the Peltier device and the heat sink is called Thermal Interface Material (TIM).



IEC 2351/09

Figure 1 – Principles of the thermoelectrical cooling system

The medium at temperature T_7 passes the heat sink of the thermoelectrical cooling system (Peltier) which has a temperature of T_6 and is cooled by convection. The heat is transferred through the heat sink by conduction at the given temperature gradient between T_6 and T_5. Then the heat flux is transferred through the Thermal Interface Material (TIM) by conduction. The Peltier device is responsible for the main temperature gradient.

On the hot side of the Peltier device the heat flux passes the TIM and the heat sink due to conduction and finally the heat is removed by the medium on the hot side by convection.

The total thermal resistance limiting the total heat flux is a sum of every resistance of each described process (see Figure 2).

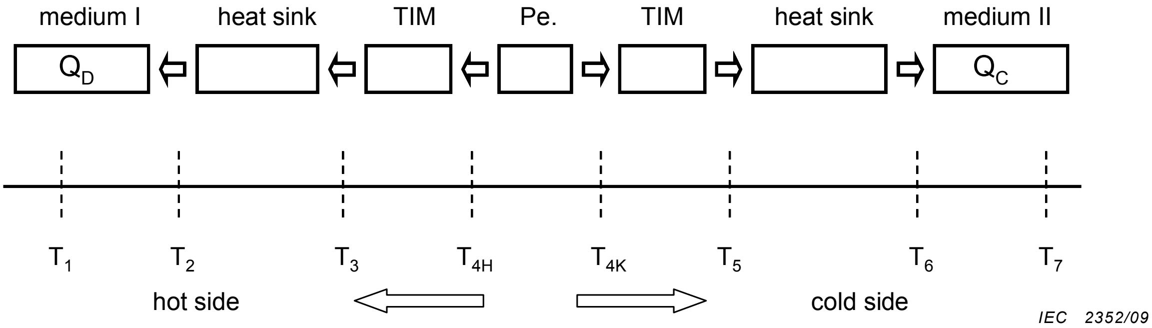


Figure 2 – Thermal resistances

The thermal resistances can be expressed as followed:

$$R_1 = \frac{T_2 - T_1}{Q_D} \quad [K/W] \qquad R_5 = \frac{T_5 - T_{4K}}{Q_C} \quad [K/W]$$

$$R_2 = \frac{T_3 - T_2}{Q_D} \quad [K/W] \qquad R_6 = \frac{T_6 - T_5}{Q_C} \quad [K/W]$$

$$R_3 = \frac{T_{4H} - T_3}{Q_D} \quad [K/W] \qquad R_7 = \frac{T_7 - T_6}{Q_C} \quad [K/W]$$

$$R_{total} = \sum_{i=1}^{7} R_i \qquad [3]$$

Minimizing each resistance is necessary for designing an efficient thermoelectrical cooling system.

As shown in Figure 1 the empty space between the two heat sinks and the Peltier devices is filled with insulation materials to avoid a reverse heat flux Q_R from the hot heat sink to the cold one due to conduction. For an efficient working thermoelectrical cooling system this reverse heat flux through the insulation is to be minimized at all costs. Therefore in further calculation this heat flow Q_R is assumed to be zero.