MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Ciclo de Palestras Sobre Controle Térmico de Satélites

Refrigeradores Termo-elétricos (TEC)

Dr. Valeri Vlassov
Divisão de Mecânica Espacial e Controle - DMC

INPE-2003

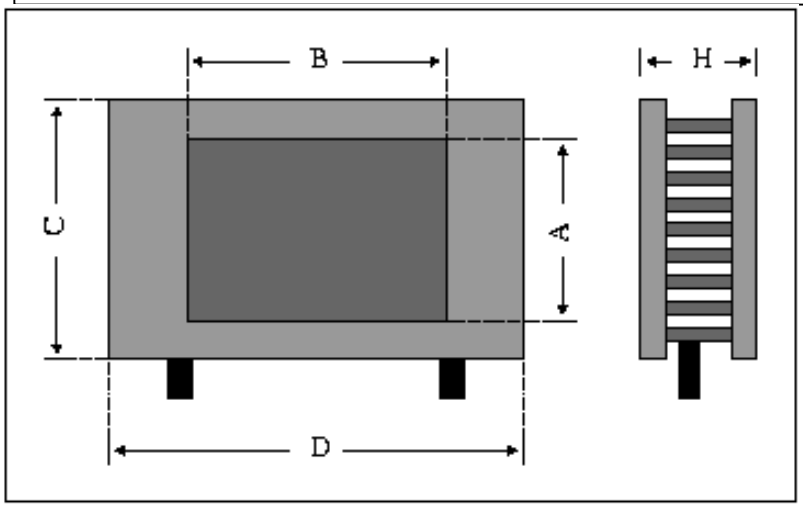
O que é o TEC?

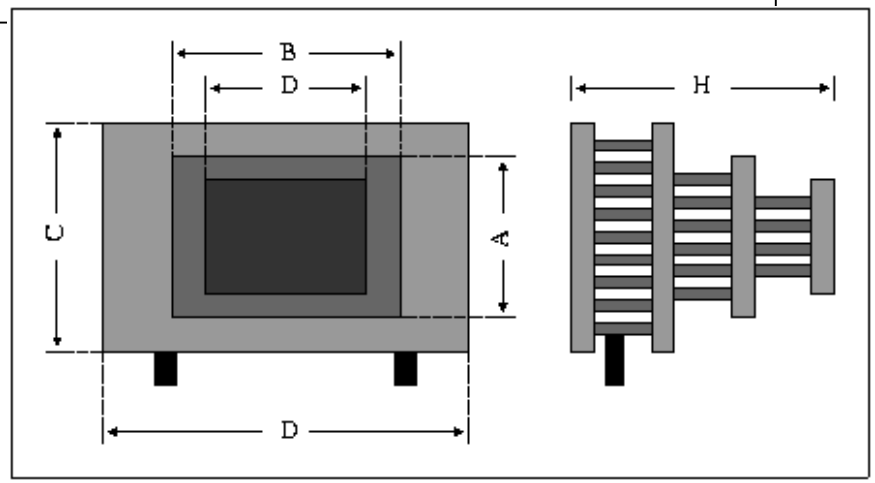
- TEC – "ThermoElectroc Cooler
- Uma bomba de calor sem partes móveis – uso do efeito Peltier para bombear calor.
- Efeito Peltier – Quando corrente elétrica passa através do contato de dois diferentes condutores, uma diferença de temperatura se forma entre eles.

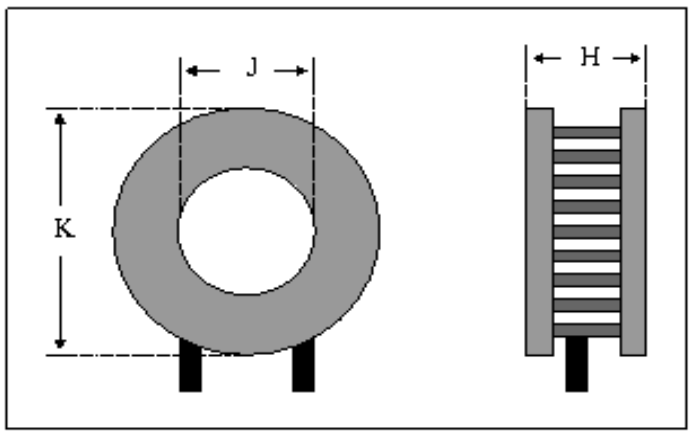
Cronologia do invento

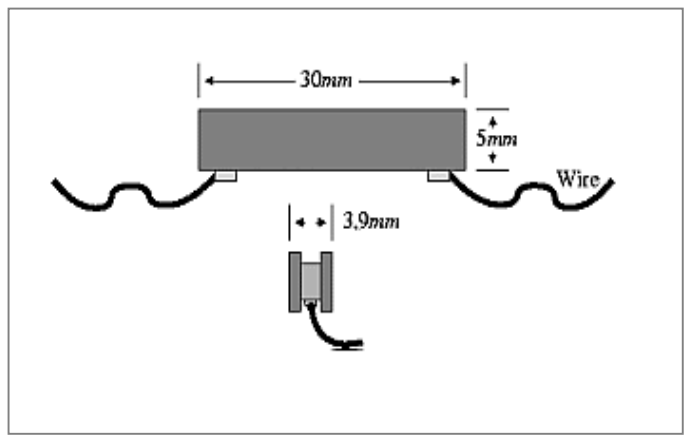
- 1834 – Jean Charles Athanase Peltier (França) descobriu o efeito de mudança de temperatura ao passar corrente através de 2 materiais diferentes. Fez conclusão errada: que a corrente fraca não obedece o lei de Ohm.
- 1838 – Emil Lenz explicou o fenômeno e demonstrou o efeito inverso.
- 1909 – Altenkitch desenvolveu a teoria básica

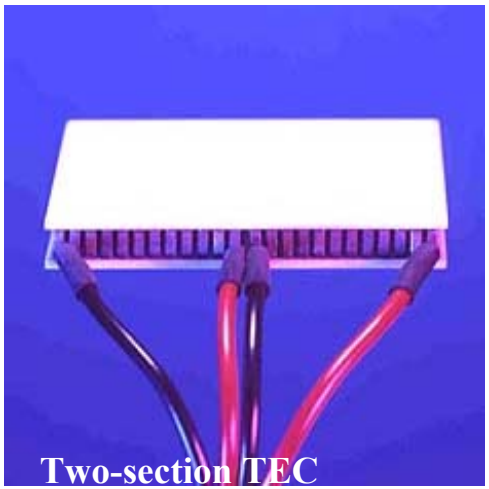
Tipos de TEC

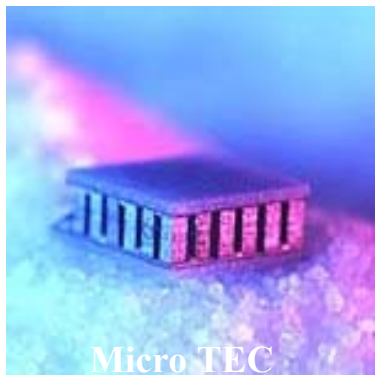


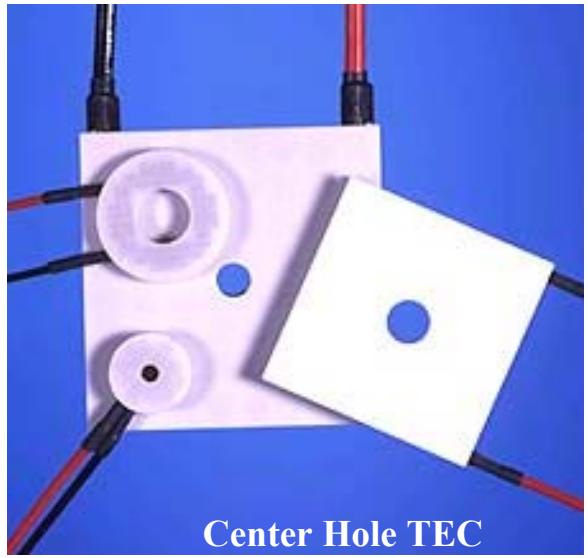


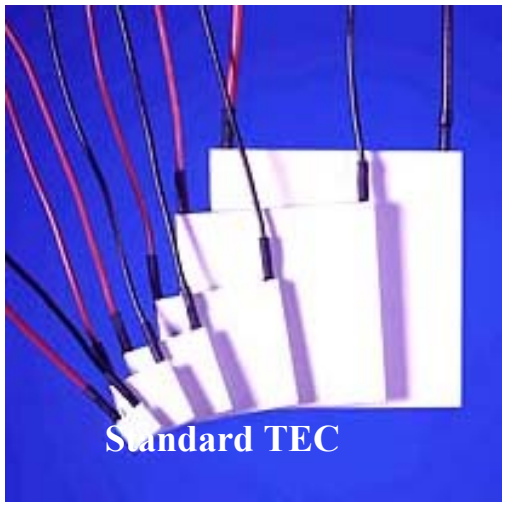


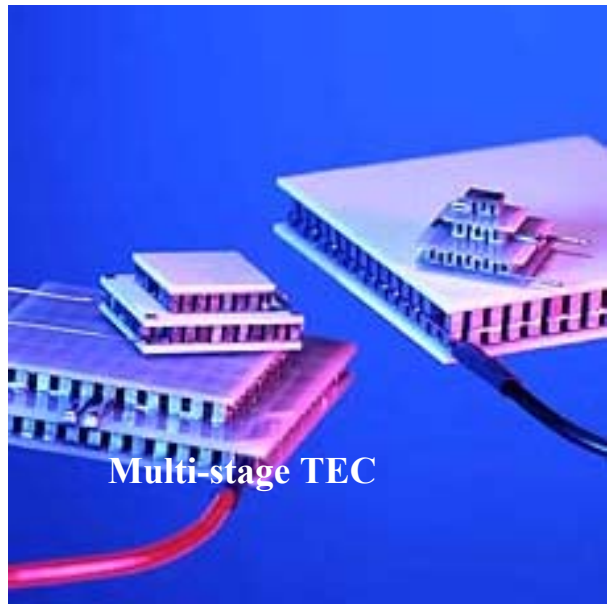


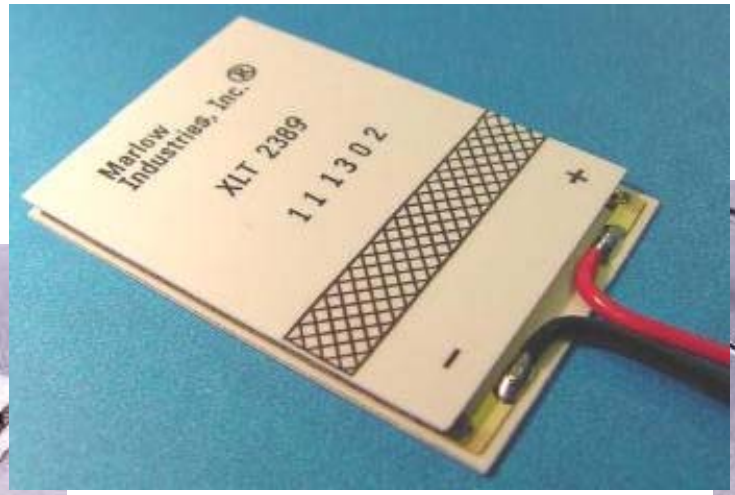

Two-section TEC


Micro TEC


Center Hole TEC


Standard TEC


Multi-stage TEC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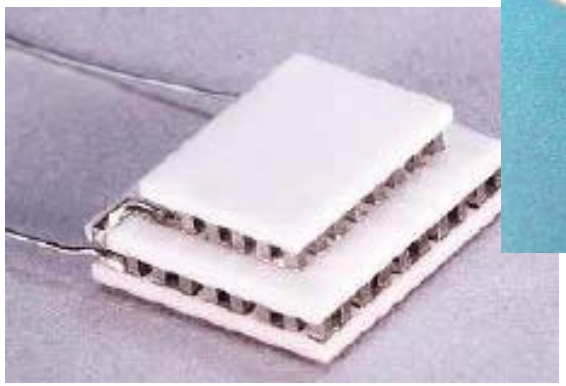
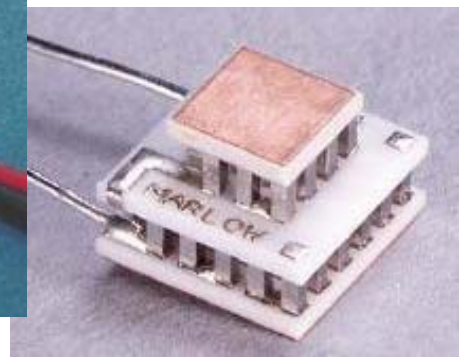
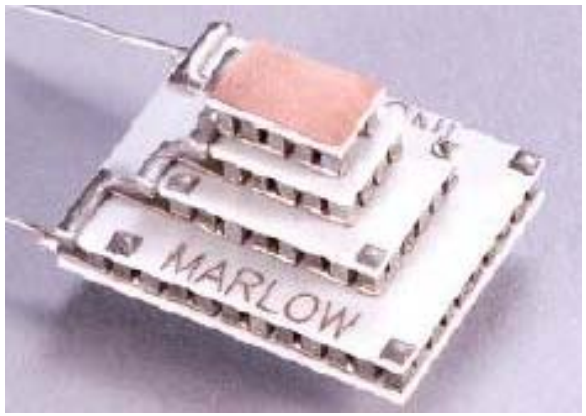
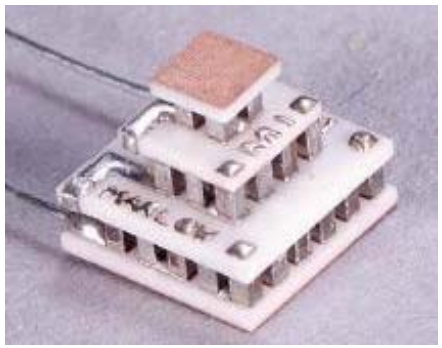



MARLOW


MARLOW


MARLOW

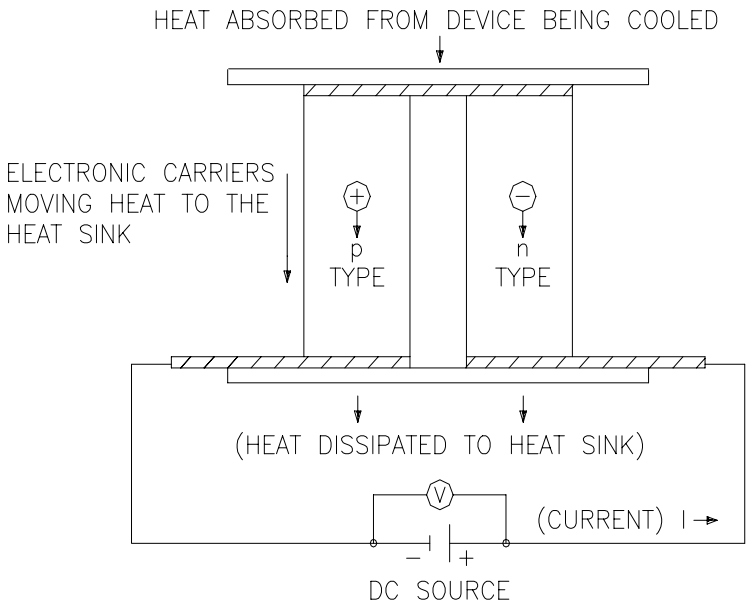
Vantagens

- Não tem partes móveis
- Vida útil de mais de 100,000 horas de operação (>11 anos).
- Não tem líquido.
- Permite controle com alta precisão (de +- 0.05 oC)
- Reversível (aquecimento-resfriamento)

Desvantagens

- Baixa efetividade (COP~ <1) – Uso do TEC é razoável só para fluxos de calor baixos.
- Baixa eficiência em temperaturas baixas
- ΔT ótimo ~ 80..120 ^{o}C
- Umidade pode causar corrosão eletrolítica e então degradação e danificação do TEC.
- Solda nas junções impõe restrições na temperatura (~<120 oC)

Um elemento de TEC



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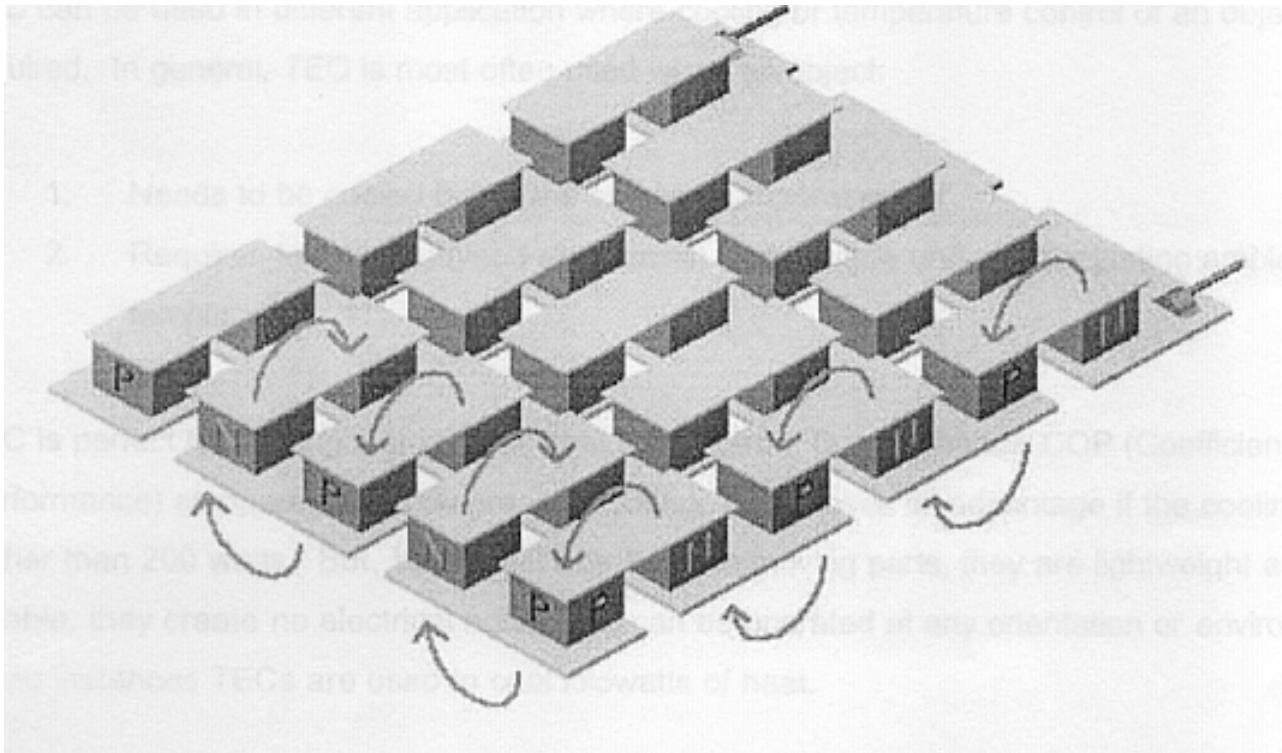
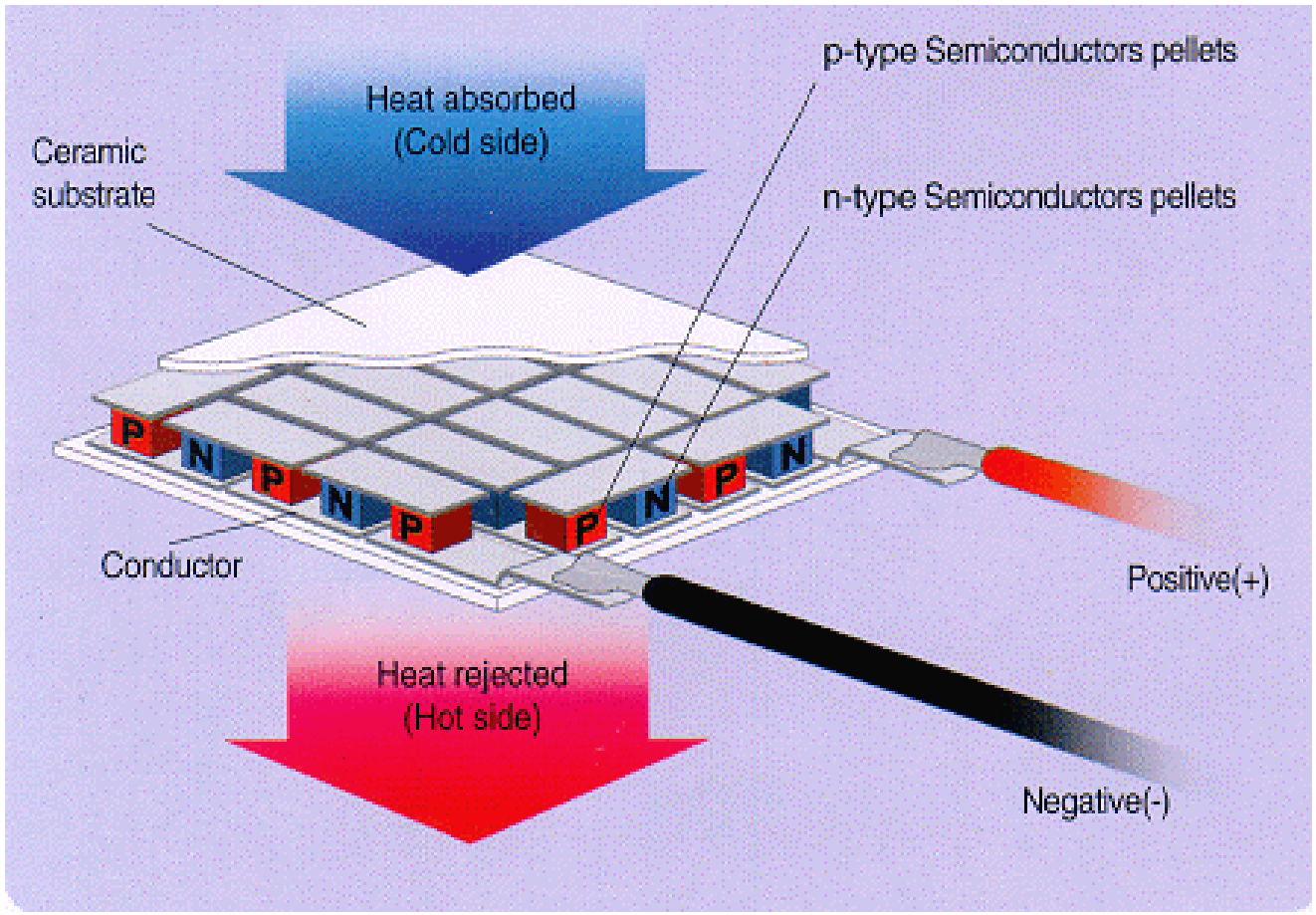
Conexão elétrica dos elementos

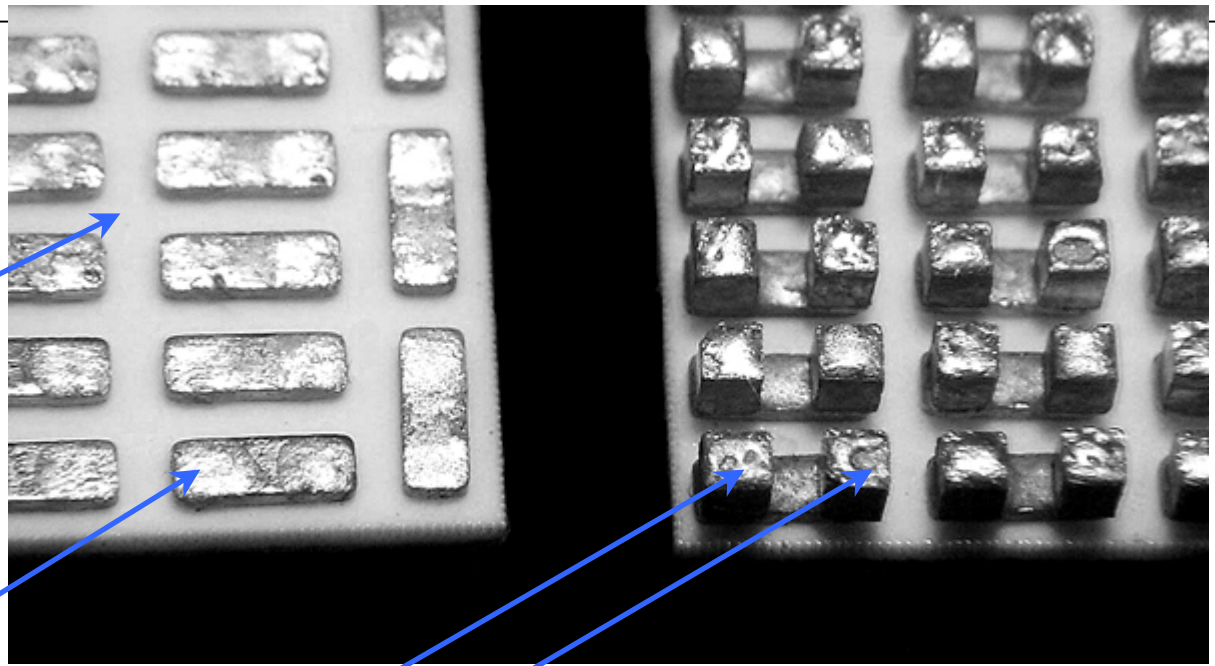


A vista do interior



Materiais

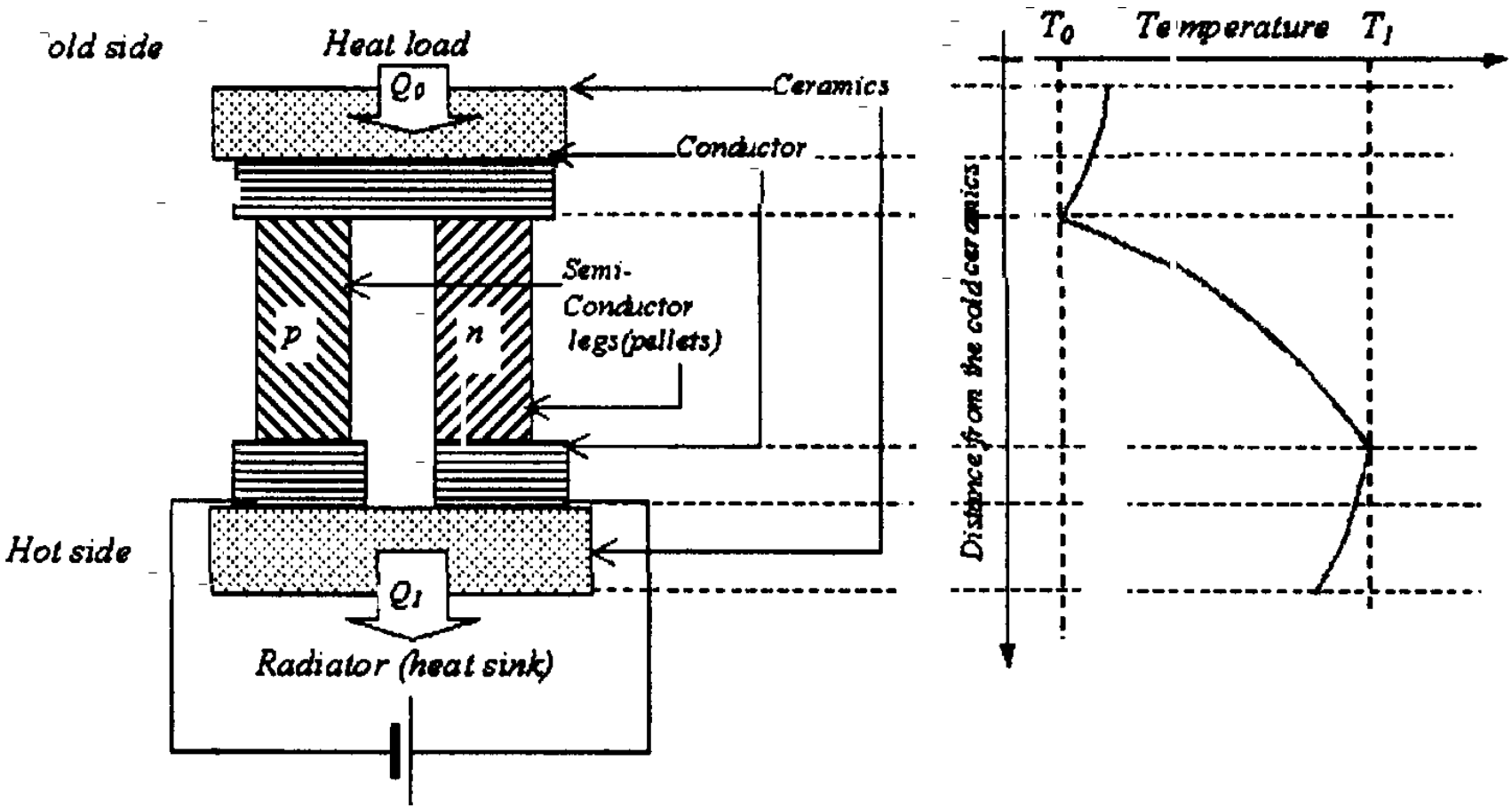
Ceramic plate (Al_2O_3)



Conductor - Copper

Tipo **n**: Bismuth Telluride Selenium (BiTeSe) compound
Tipo **p**: Bismuth Telluride Antimony (BiTeSb) compound

Distribuição de temperatura



COP – "Coefficient Of Performance"

$$Q_c = s \cdot T_c \cdot I - 0.5 I^2 R - K \cdot \Delta T$$

Peltier effect

Flows back to cold junction

Conduction heat due to temp. diff. between junctions

$$P_i = V \cdot I$$

$$C.O.P = Q_c / P_i$$

s – coeficiente de Seebeck

Parâmetros principais de TEC

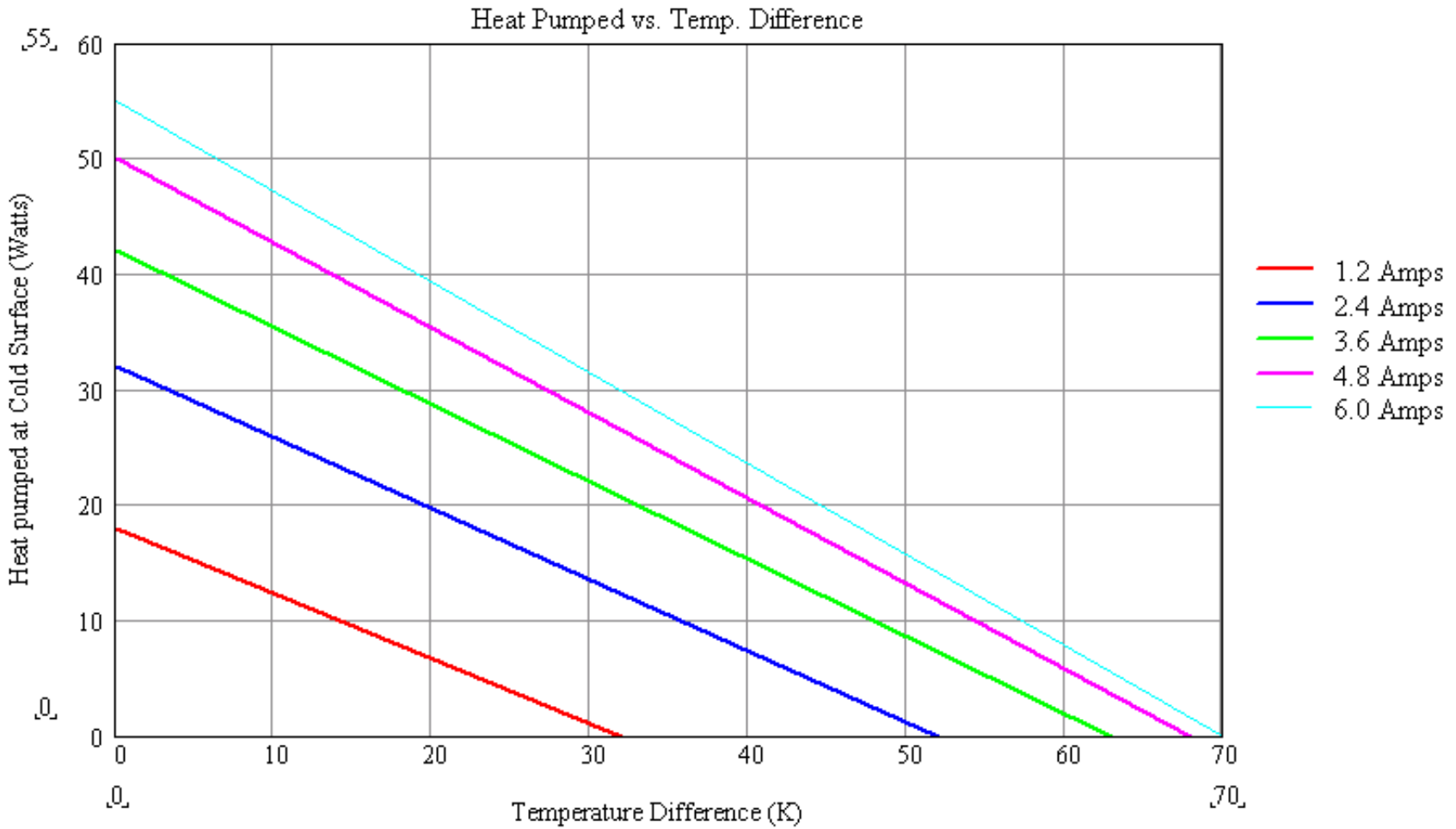
ΔTmax – diferença de temperatura máxima quando Q=0

Qmax – fluxo de calor máximo quando ΔT=0

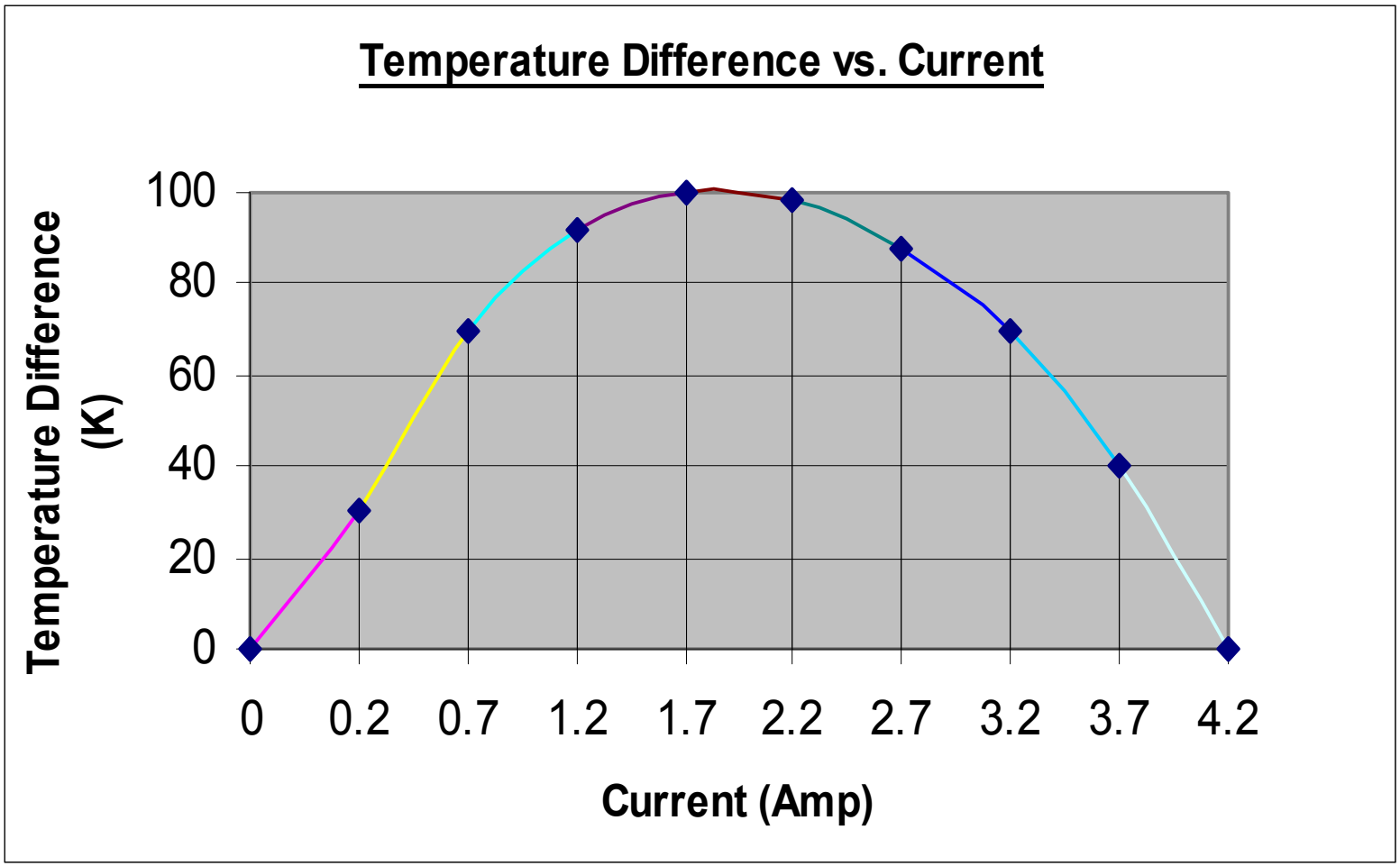
Imax – corrente elétrico quando ΔT= ΔTmax

Vmax – voltagem quando I= Imax e Q=0

Curvas de Performance



Curvas de Performance



Características do TEC de vários estágios

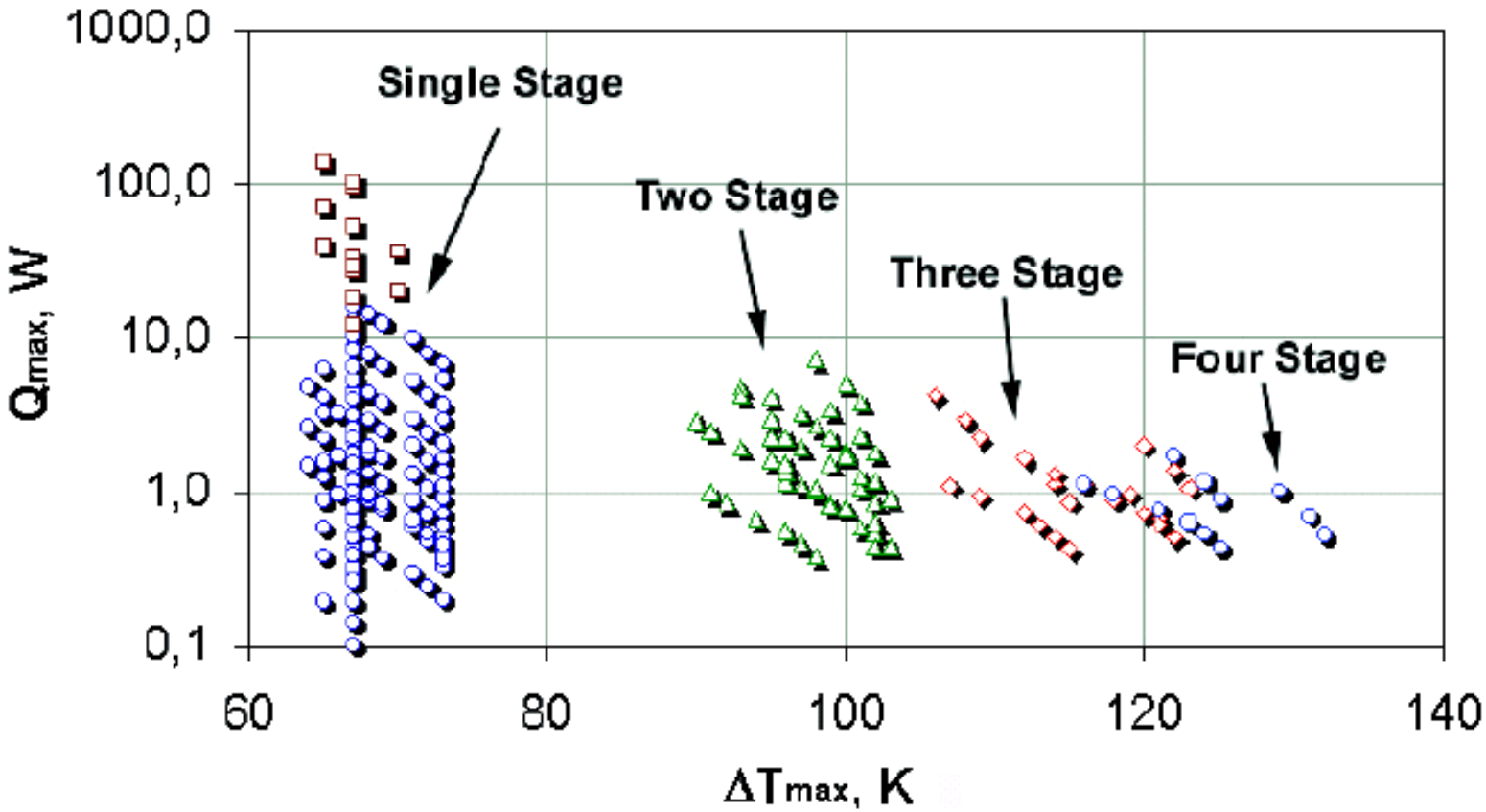


Figura de mérito

$$Z = \frac{\alpha^{2}}{\rho \cdot K}$$

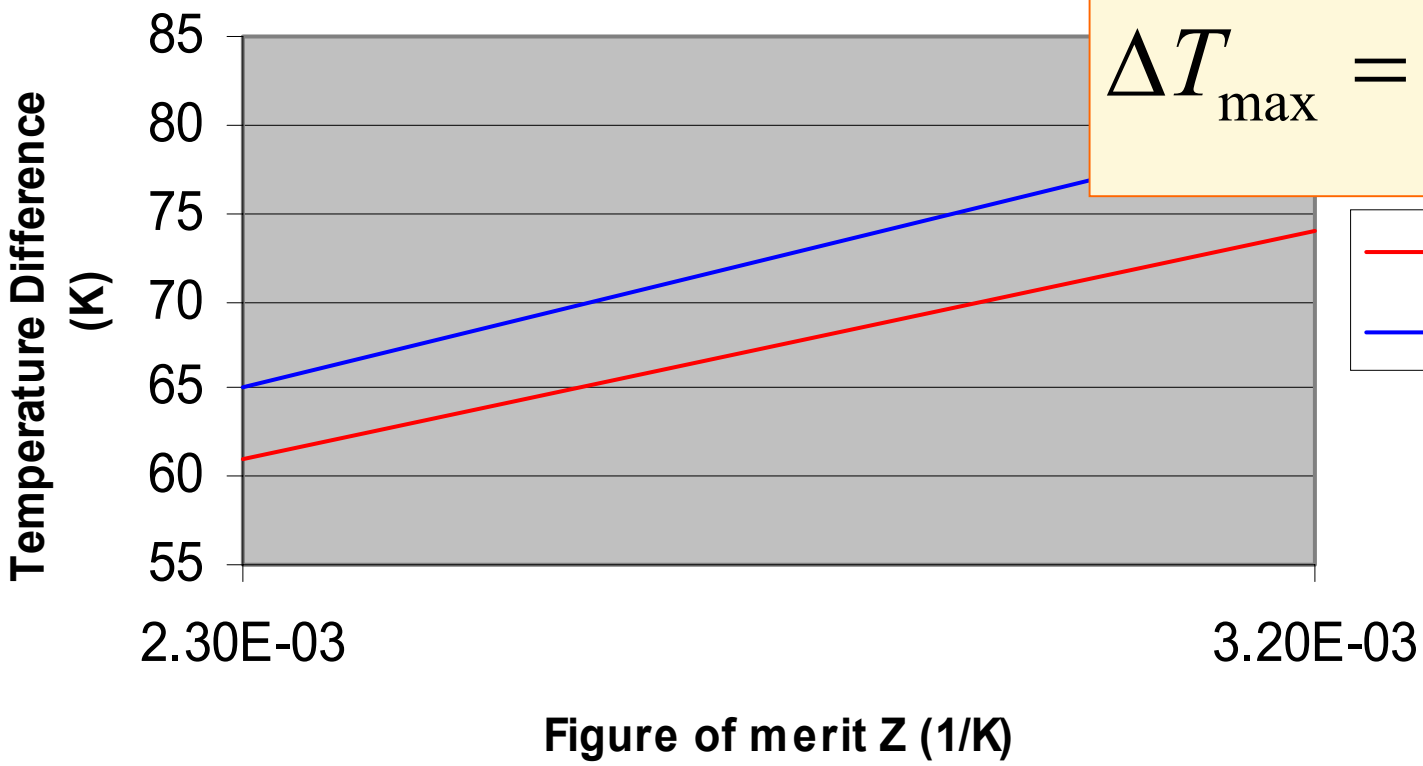
where α = Seebeck coefficient

ρ = Electrical Resistivity

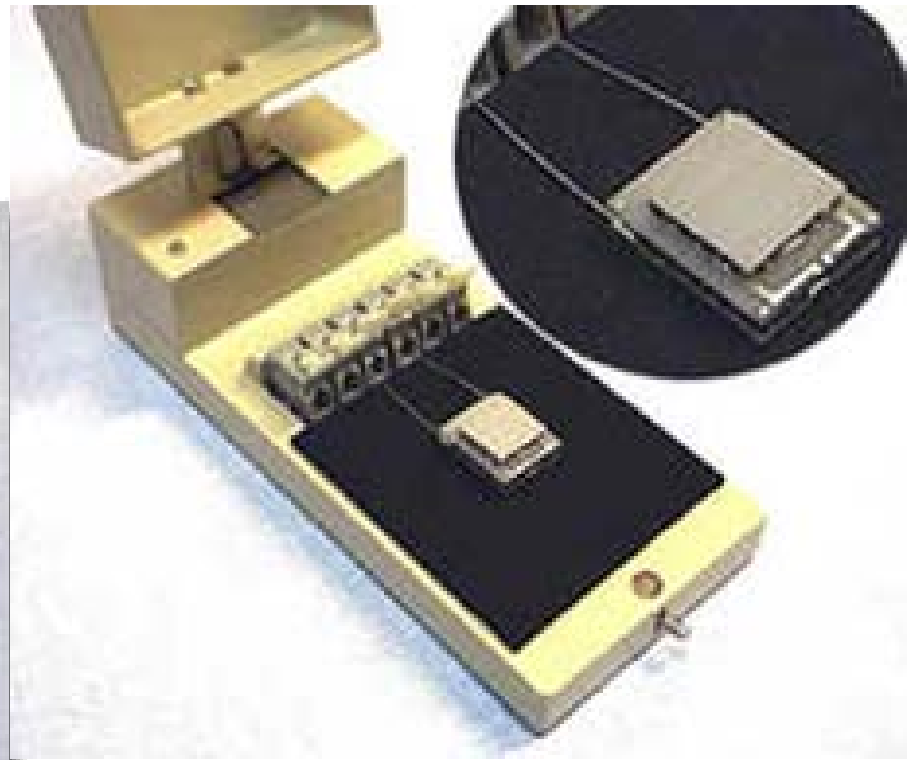
K = Thermal Conductivity

Temperature Difference vs. Figure of Merit

$$\Delta T_{\max} = \frac{1}{2} Z \cdot T_c$$

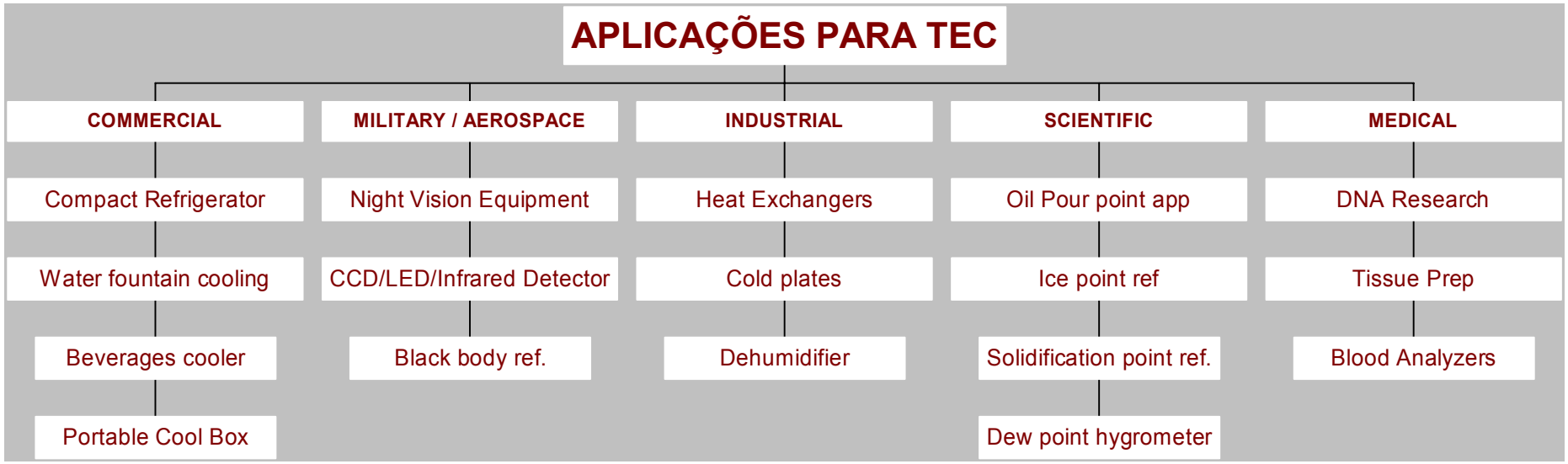


Z-meter



Linhas de aplicação

- Resfriamento abaixo de temperatura de ambiente local
- Controle preciso de temperatura de objeto



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Testes típicos

The minimal set of tests-

- Mechanical Shock test
- Vibration test
- Shear force test
- High temperature storage test
- Temperature cycle endurance test

Failure Criteria-

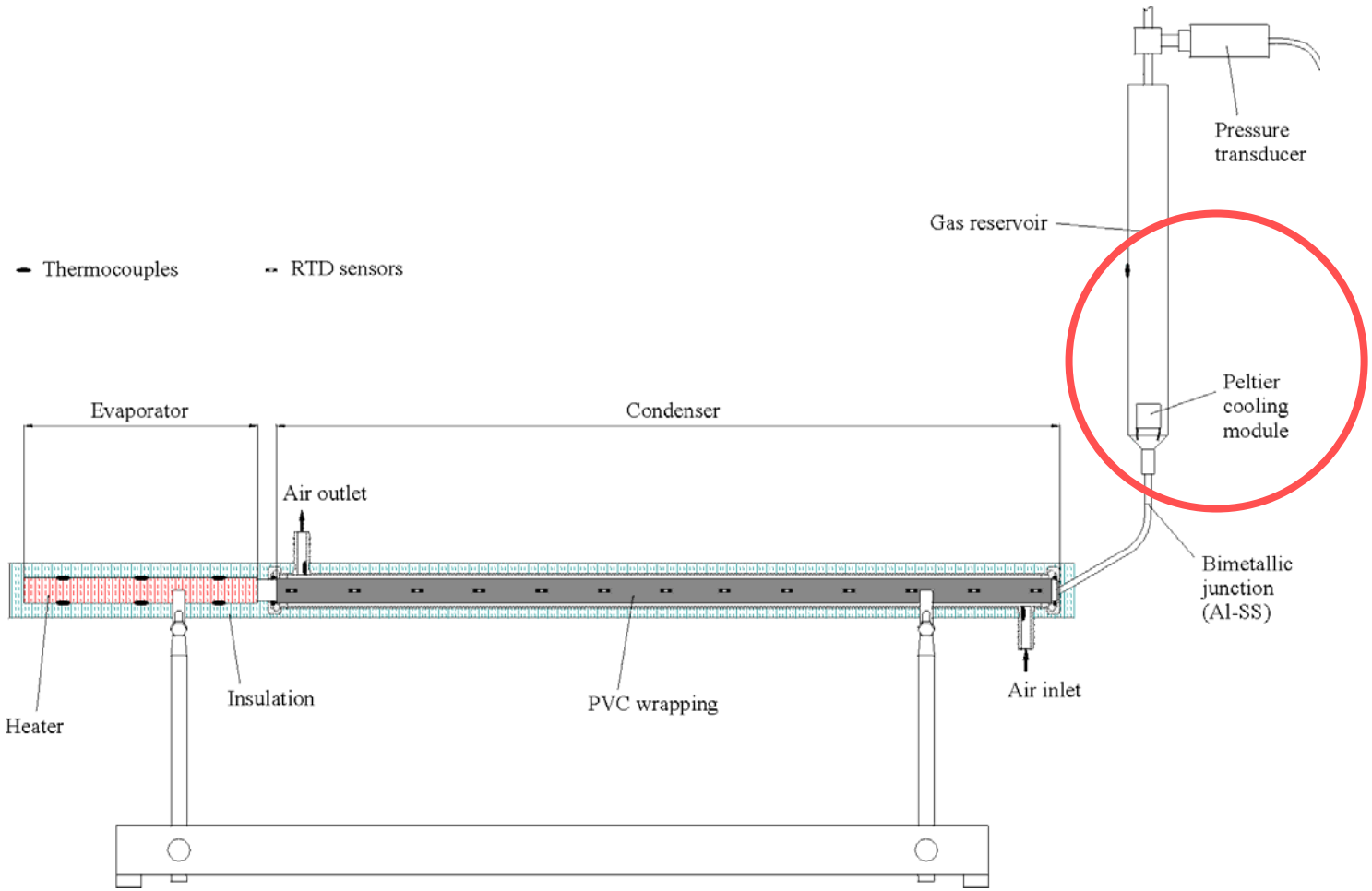
- Drop in TEC maximum cooling capacity below specified rating
- Increase in TEC resistance. (5% or higher)

Aplicações espaciais

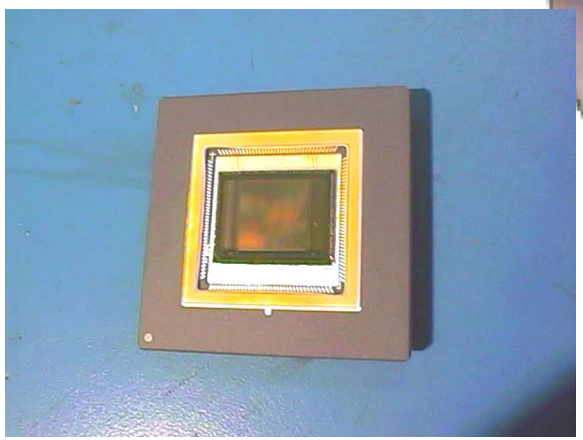
- Visible detector cooling
- CCD cooling
- IR detector cooling
- x-ray detector cooling
- radiation shield cooling
- black-body reference
- UV detector cooling
- laser interferometers
- control element in VCHP e LHP
- thermal cyclers
- blood sample freezing
- food refrigeration

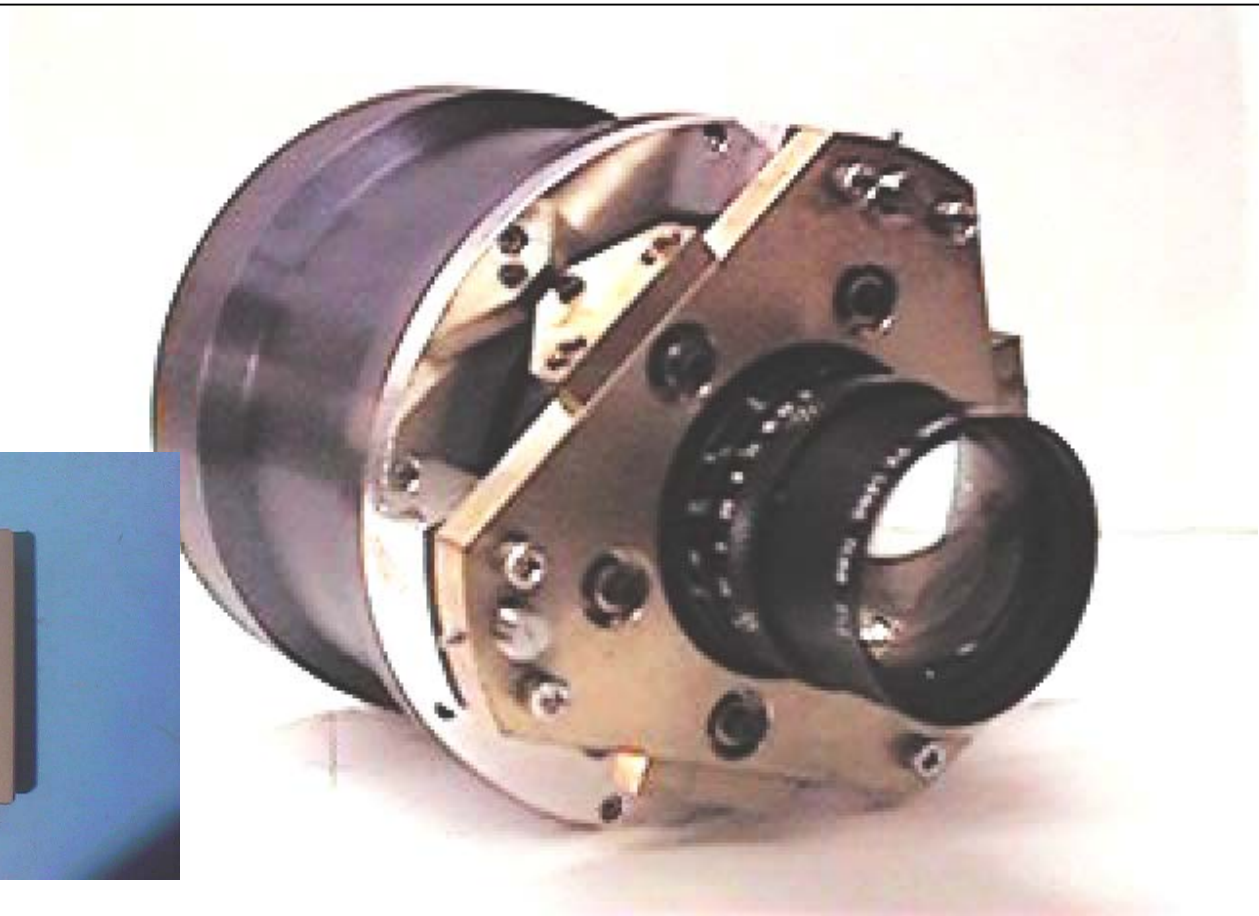
O TEC está sendo usado no Hubble Space Telescope, Space Shuttle, ISS e vários satélites de defesa, meteorologia, ciência e tecnologia

Aplicações no INPE: VCHP



Aplicações no INPE: Experimento Sensor de Estrelas





Fornecedores nos USA

Company	Web-site
Ferrotec America	*www.ferrotec-america.com*
Marlow Industries	*www.marlow.com*
Melcor	*www.melcor.com*
Hitech Technologies	*www.hitech.com*
TE Technology	*www.tetech.com*
Tellurex	*www.tellurex.com*
Thermoelectric Cooling America	*www.thermoelectric.com*
Kryotherm Engineering	*www.kryotherm.ru*

Mais fornecedores

Fandis	Italy	*http://www.fandis-tm.com*
Huayu	China	*http://www.huayutec.com*
Hui Mao Cooling	China	*http://www.huimao.com*
Komatsu Electronics	Japan	*http://www.komatsu-electronics.com*
Kryotherm	Russia	*http://www.kryotherm.spb.ru*
Osterm	Russia	*http://www.zts.com/osterm*
Qinhuangdao Fulianjing	China	*http://www.fulianjing.com*
RMT Ltd	Russia	*http://www.rmtltd.ru*
SCTB NORD	Russia	*http://www.sctbnord.com*
SIREC sri	Italy	*http://www.sirec-it.com*
Supercool AB	Sweden	*http://www.supercool.com*
Taihuaxing Trading	China	
Thermion	Ukraine	*http://www.zts.com/thermion*

Custo de TECs comerciais

N	Type	Cost (in US Dollars)	
		Minimum	Maximum
1	Standard	$ 14.30	$ 52.60
2	Center Hole	$ 18.70	$ 25.10
3	Micro	$ 15.50	$ 39.50
4	Multi-stage	$ 34.50	$ 151.70

PERGUNTAS