High Heat Flux Thermoelectric Module Using Standard Bulk Material

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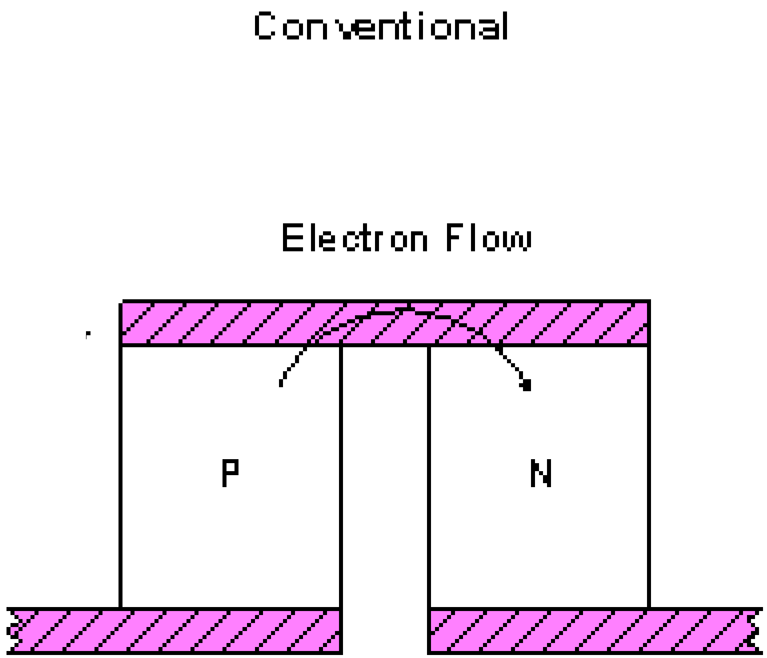
Conventional (Stonehenge) Design

Design has been in production for both military and commercial TE devices over the past 50 years.



Motivations for Change

Parasitic electrical and thermal losses reduce thermoelectric (TE) module performance by 30%-50%.

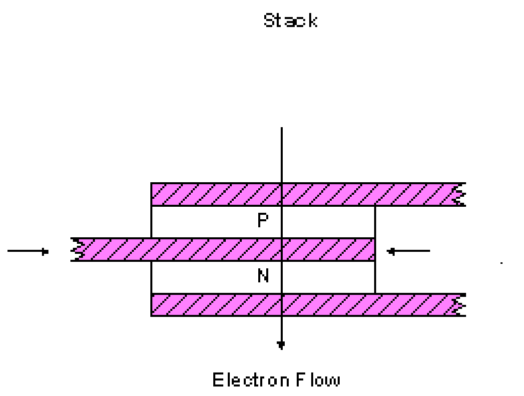
TE heat pumping capacity is a function of material properties as well as aspect ratio (A/L) and fill factor. Fill factor, the fraction of module cross sectional area occupied by TE elements, is often a limiting factor.

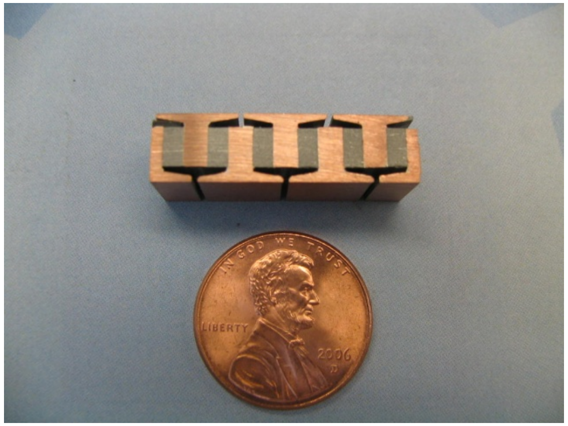
Stack (T or Y Shunt) Design

Amerigon stack design minimizes electrical parasitic resistances by creating the lowest possible electrical resistance (minimum L/A ratio) thus minimizing parasitic electrical resistances.

The design also allows practical fill factors from 1.0 to 2.0, factors not otherwise achievable.

The design allows independent optimization of compressive loading of the TE material and compressive force for optimal thermal contact to external heat sources and sinks.



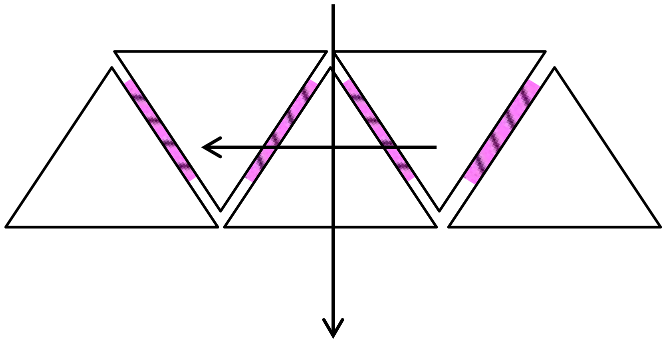


V Shunt Design

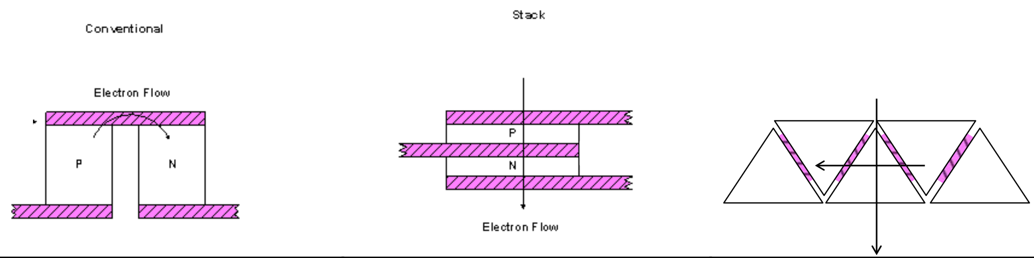
V Shunt design has been developed to provide TE cooling/heating modules with a combination of high fill factors (1.0 to 1.6) and low loss thermal flux and electrical current paths.

Joule heating in the shunt is reduced by increasing current flow cross section.

Shape and aspect ratios can be varied to optimize power density and maximize COP.



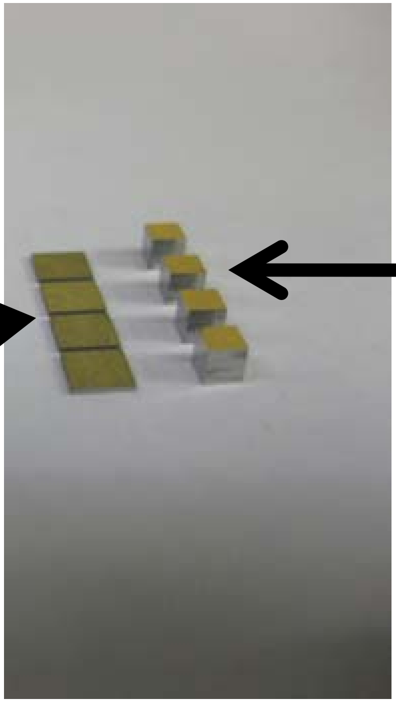
Design Concepts



Electrical Path	Long	Very Short	Short
Thermal Path	Short	Moderate	Short
Parasitic Losses	Relatively High	Very Low	Low
TE Surface to Module Surface Area Ratio Fill Factor	0.6 to 0.8	1.0 to 2.0	1.0 to 1.6

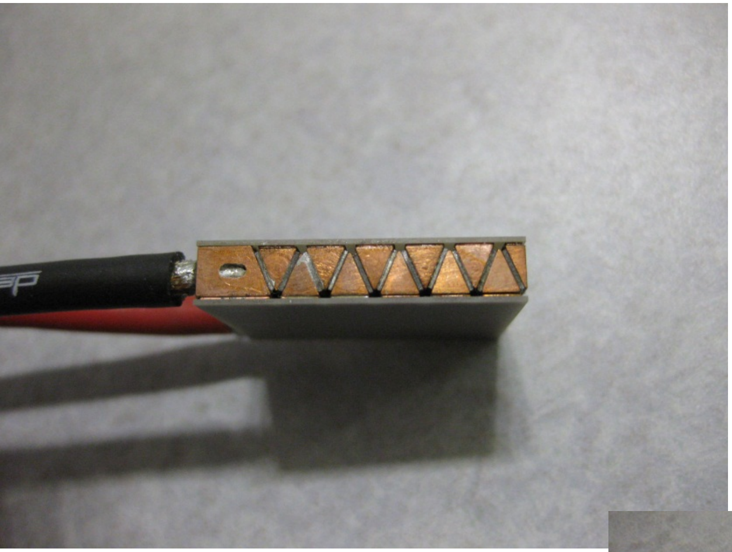
TE Element Comparison

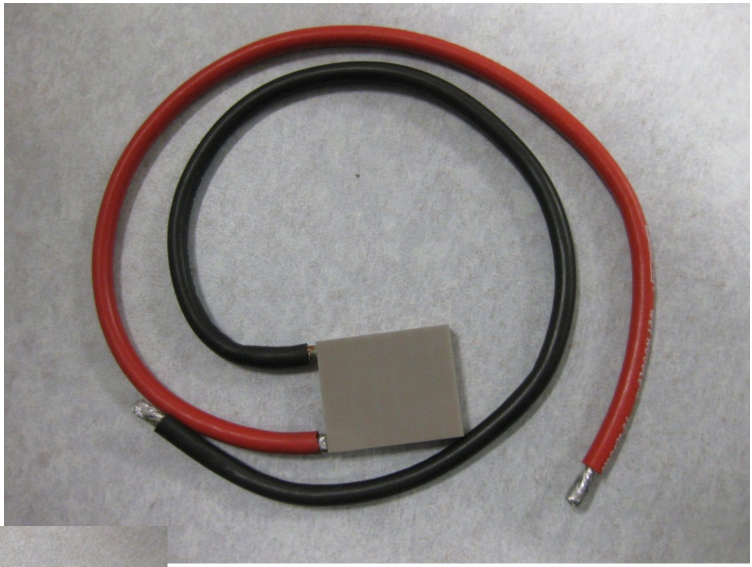
TE elements to be used for V shunt module

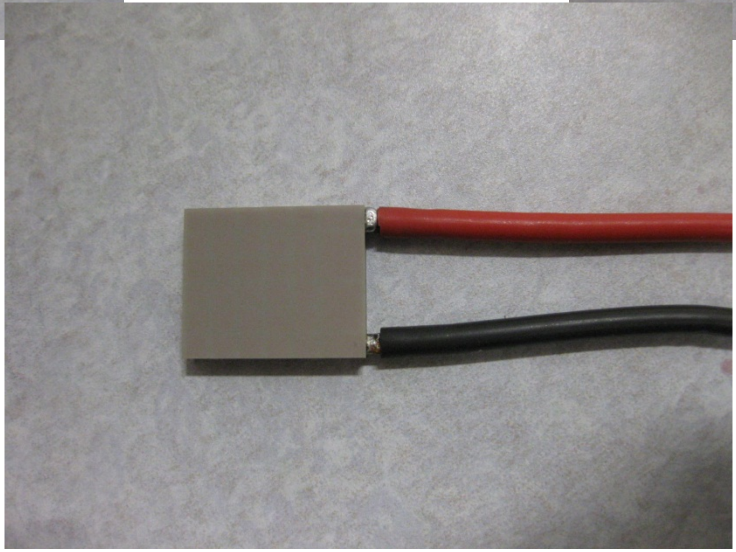


TE elements for a traditional module

V Shunt Module







Harman Test Data

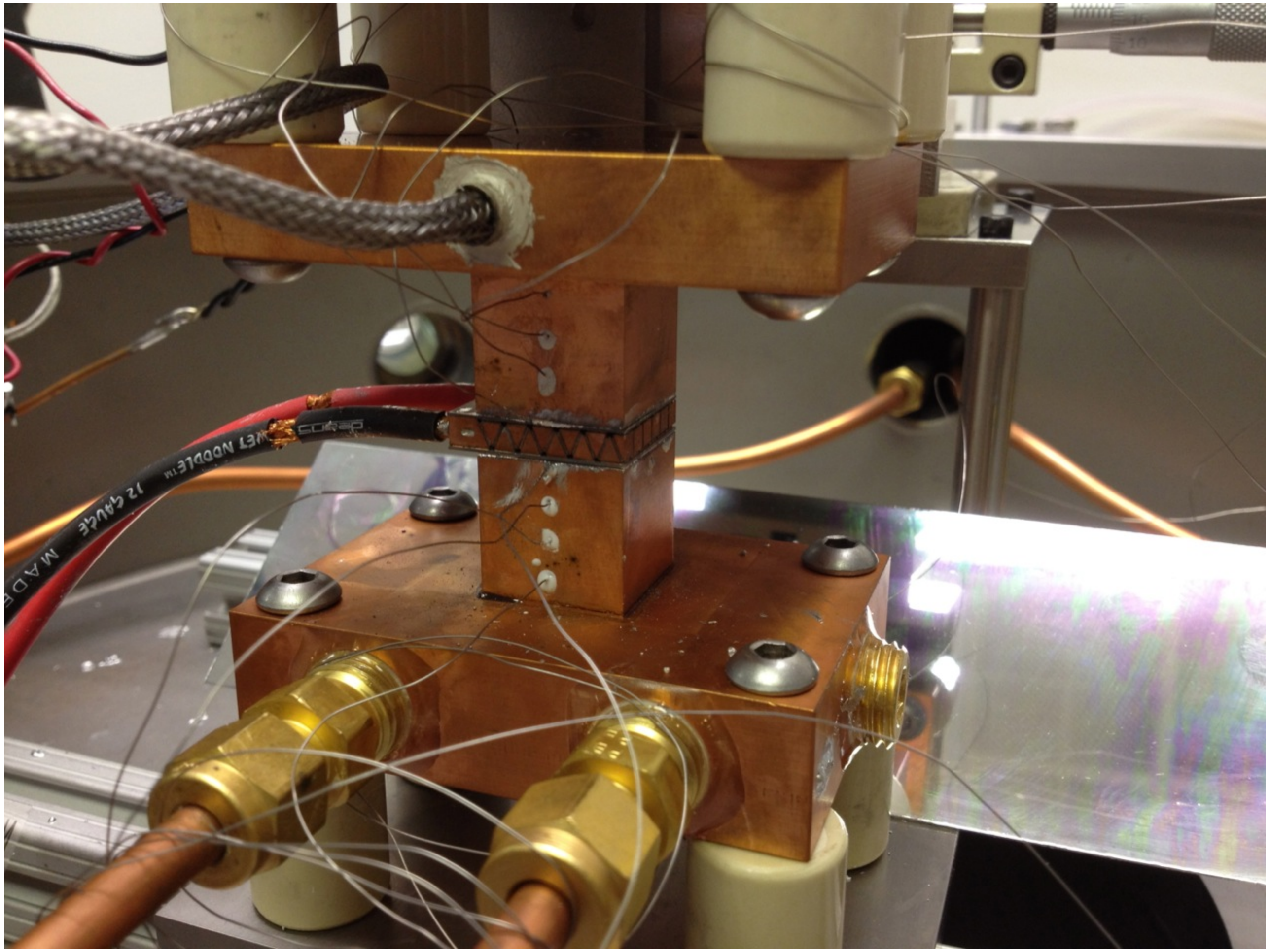
$$ZT_{avg} = \frac{R_{DC}}{R_{AC}} - 1$$

At room temperature:

Module 1 - ZTavg = 0.57

Module 2 - ZTavg = 0.56

V Shunt Module Under Test



Q Meter Test Estimates

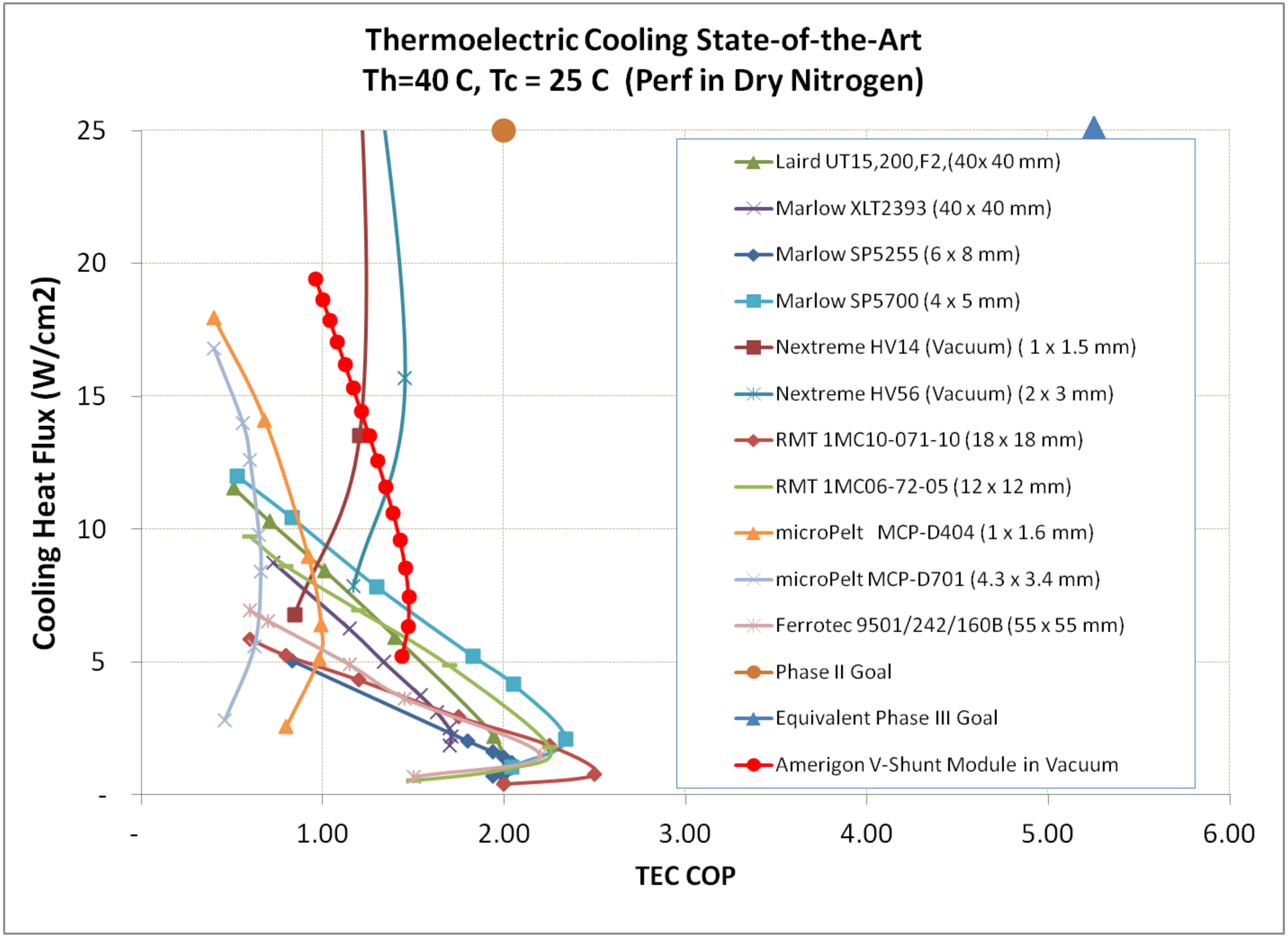
Tc=25C, Th=40C, in Vacuum

Current (A)	20	25	30	35	40	45	50
Expected V (V)	0.7	0.9	1.0	1.2	1.3	1.5	1.6
Expected Qc(W)	20.8	31.9	42.4	52.2	61.3	69.8	77.6
Expected COP	1.4	1.5	1.4	1.3	1.2	1.1	1.0

Tc=80C, Th=95C, in Vacuum

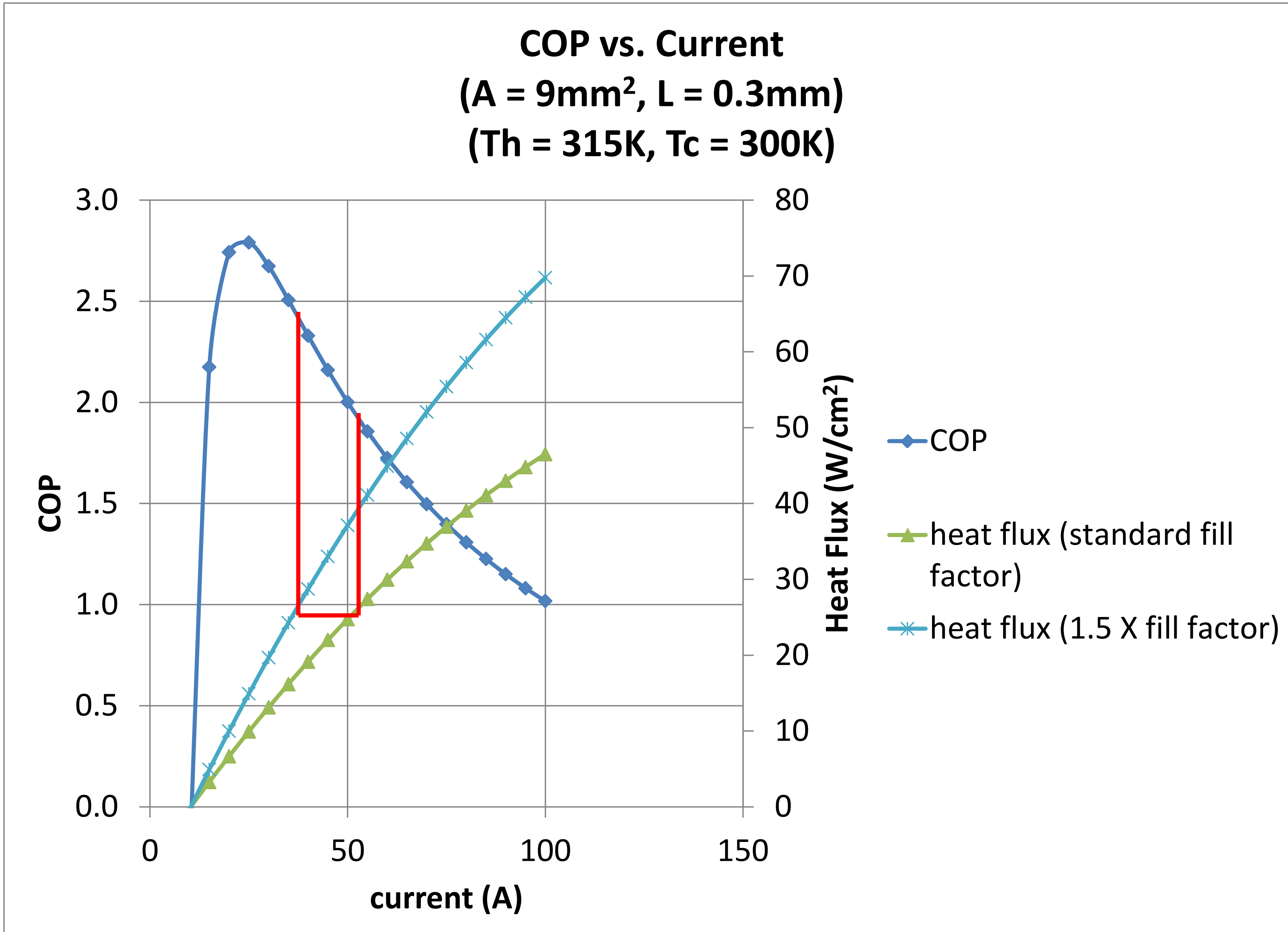
Current (A)	20	25	30	35	40	45	50
Expected V (V)	0.9	1.1	1.3	1.5	1.6	1.8	2.0
Expected Qc(W)	29.2	42.4	54.7	66.1	76.5	86.0	94.6
Expected COP	1.6	1.6	1.4	1.3	1.2	1.0	0.9

Qc vs COP Estimate



SOA data provided by Jim Bierschenk from Marlow Industries

V Shunt Performance Improvement Example



Applications

- Applications where high heat pumping capacity is necessary
- Applications where improved heat pumping capacity for off-peak performance can help improve COP at the same level of heat pumping
- Examples
  - High power electronics
  - Lasers

Next Steps

- Continued build, test, and characterization of V shunt modules
- Initial modules have been made of commercially available materials with future modules using advanced materials.
- Further assembly and manufacturing development to maximize performance and minimize cost
- Application development

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