Heat Exchangers/Radiators Utilizing Graphite Foams

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Challage of Power Electronics

Newsletter from USCAR

Problem

"One challenge faced by engineers planning to use power electronics in hybrid-electric vehicles is managing the tremendous amount of heat these devices generate. Power electronics can only withstand limited amounts of heat before they begin to deteriorate and fail."

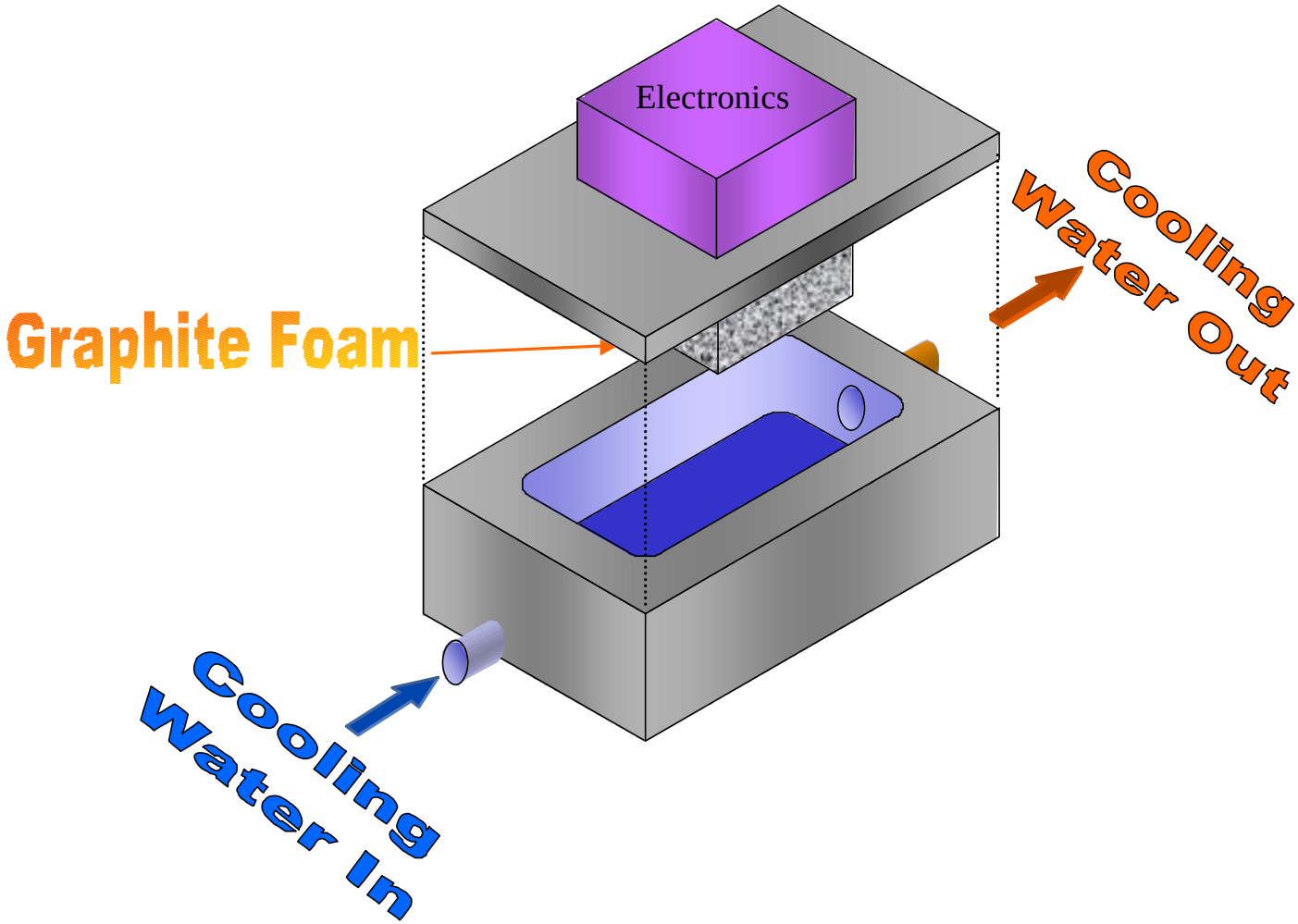
Solution

"Using carbon foam as the core material for these heat exchangers, the effective transfer of heat can be significantly increased while reducing the size and weight of the heat exchanger."

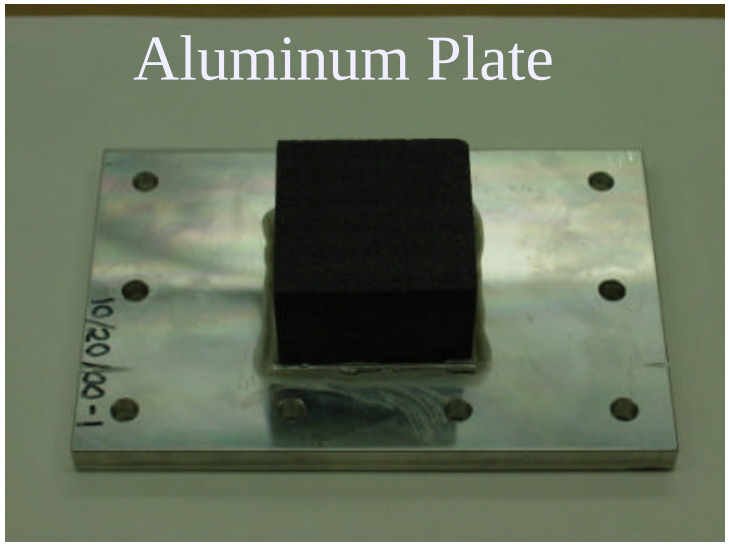
DOE objectives

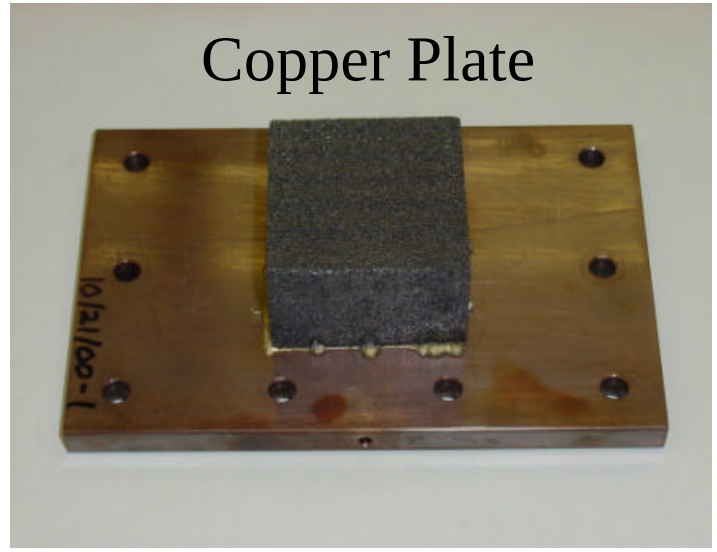
Perform above while reducing cost, weight, size, an emissions.

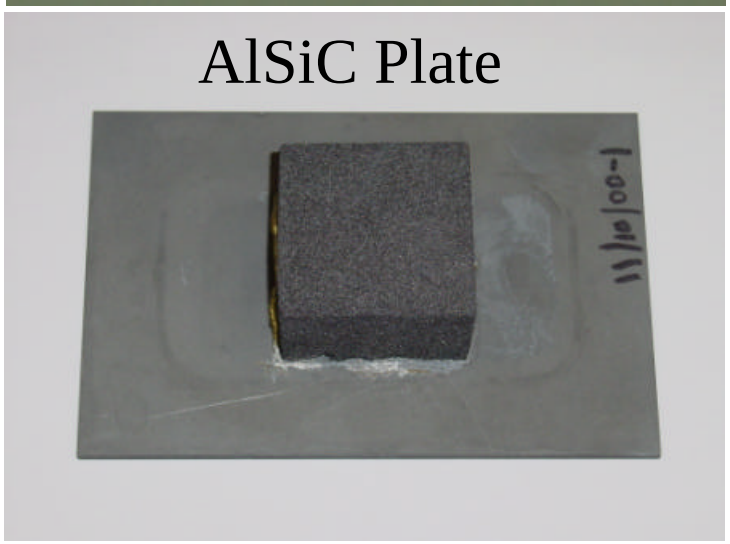
Model Heat Sink

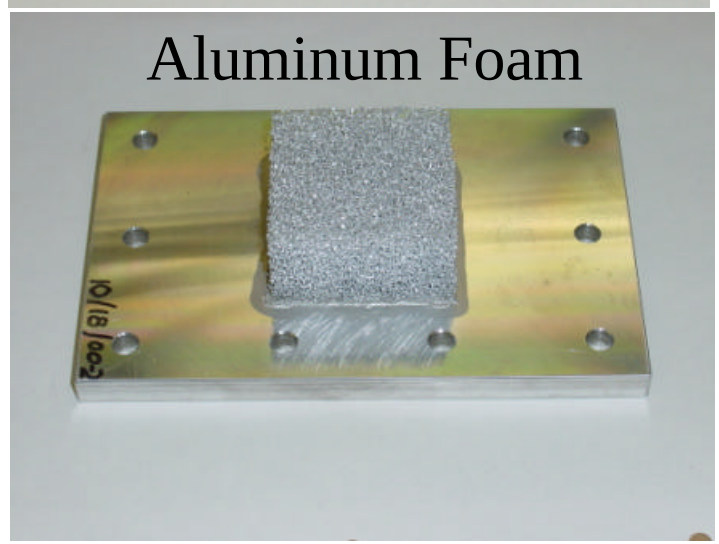


Test Heat Sinks



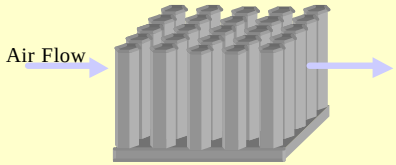




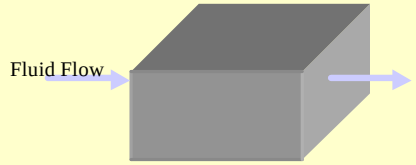
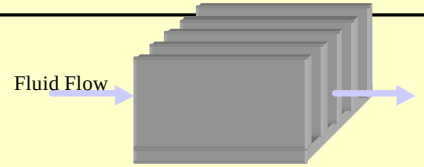
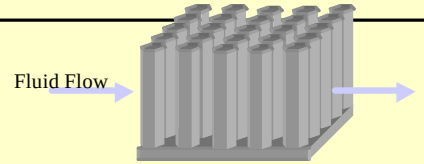
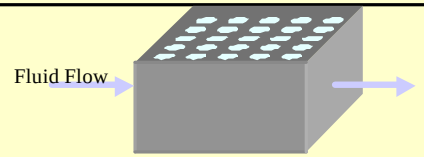
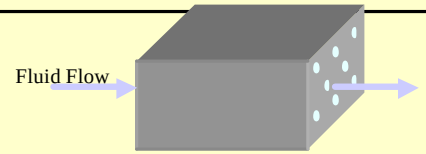


Heat Transfer of Metallic Heat Sinks

Air Cooling

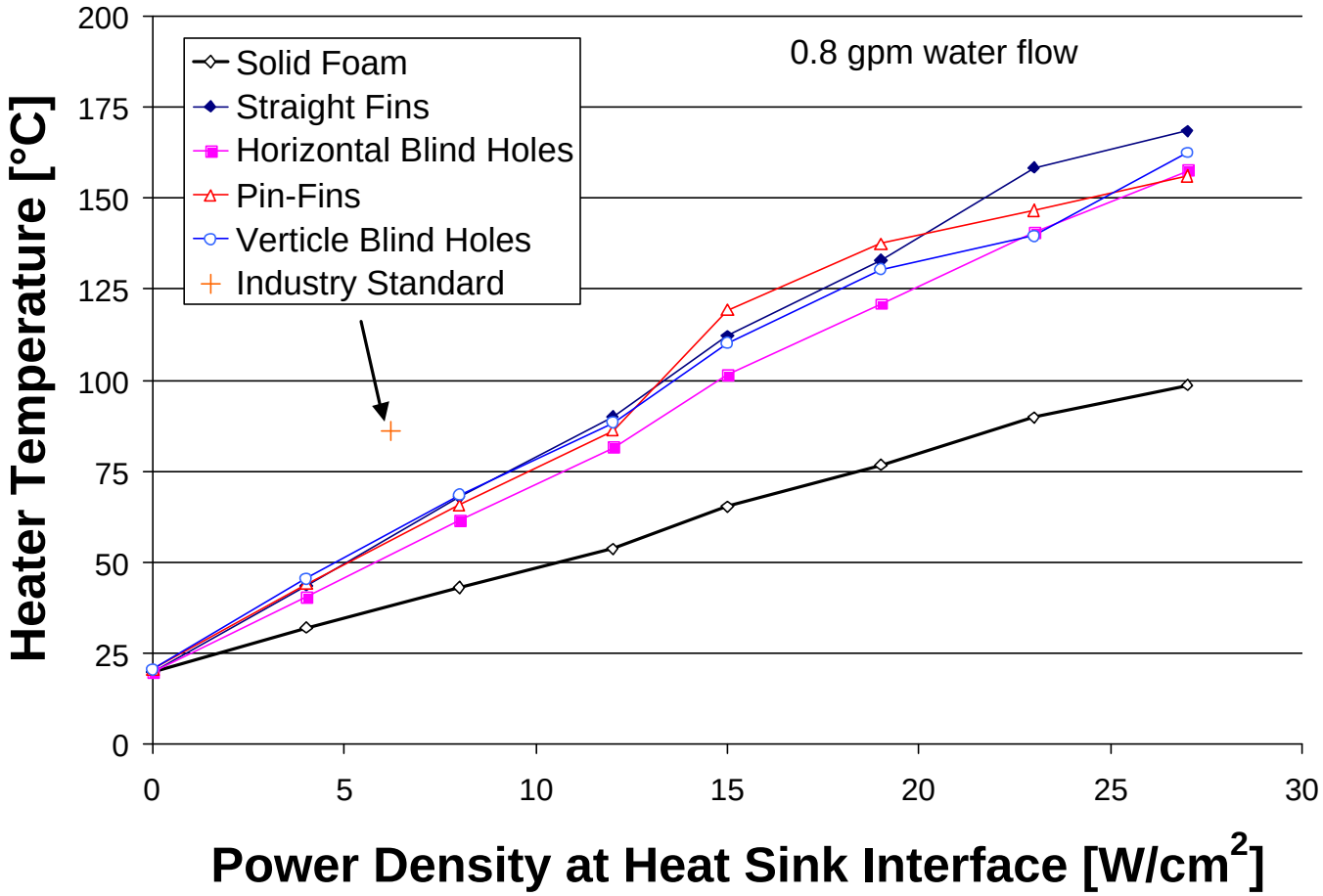
	Heat Transfer Coefficient h, (W/m^2·K)	ΔP/L (psi/in)	Thermal Resistance °C/W
Aluminum Finned	70	<0.05	1-5
Aluminum Pin-Finned 	550	<0.05	0.7
Aluminum Foam	250	<0.05	1.3

Heat Transfer for Foam Heat Sink

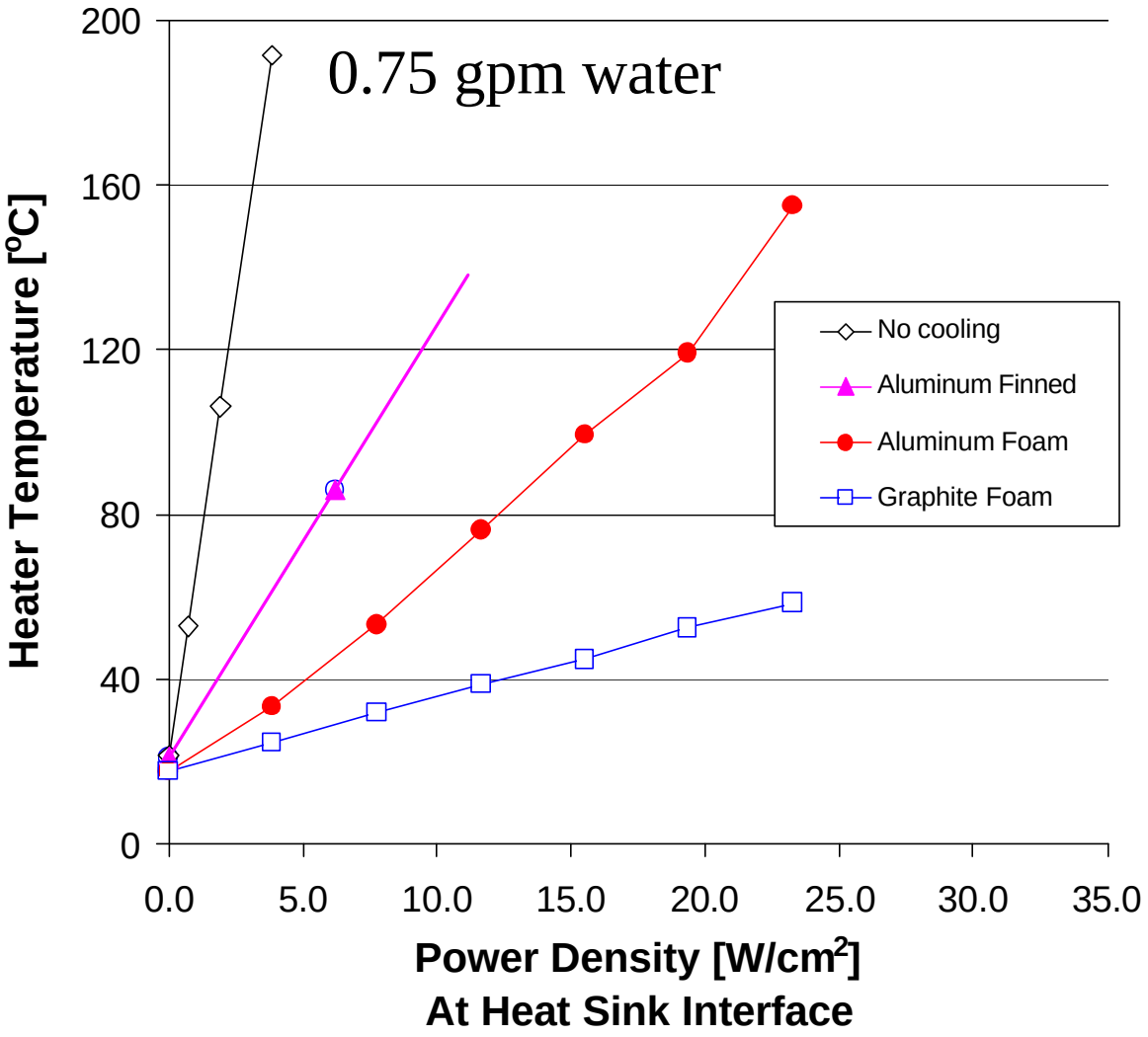
		Heat Transfer Coefficient h, (W/m^2·K)		ΔP/L (psi/in)	Thermal Resistance °C/W
Solid Foam		Air	2600	2	0.13*
		Water	Up to 23000	1	0.02
Finned		Air	1000	<0.05	0.38*
		Water	2100	0.5	0.19
Pin-Fin		Air	1500	0.05	0.26*
		Water	2500	0.5	0.15
Blind-holes (pin fin negative)		Air	2000	1	0.19*
		Water	4600	0.5	0.09
Blind-holes (parallel to air flow)		Air	3100	0.35	0.13*
		Water	4500	0.5	0.09

Heater Temperatures vs Power Density

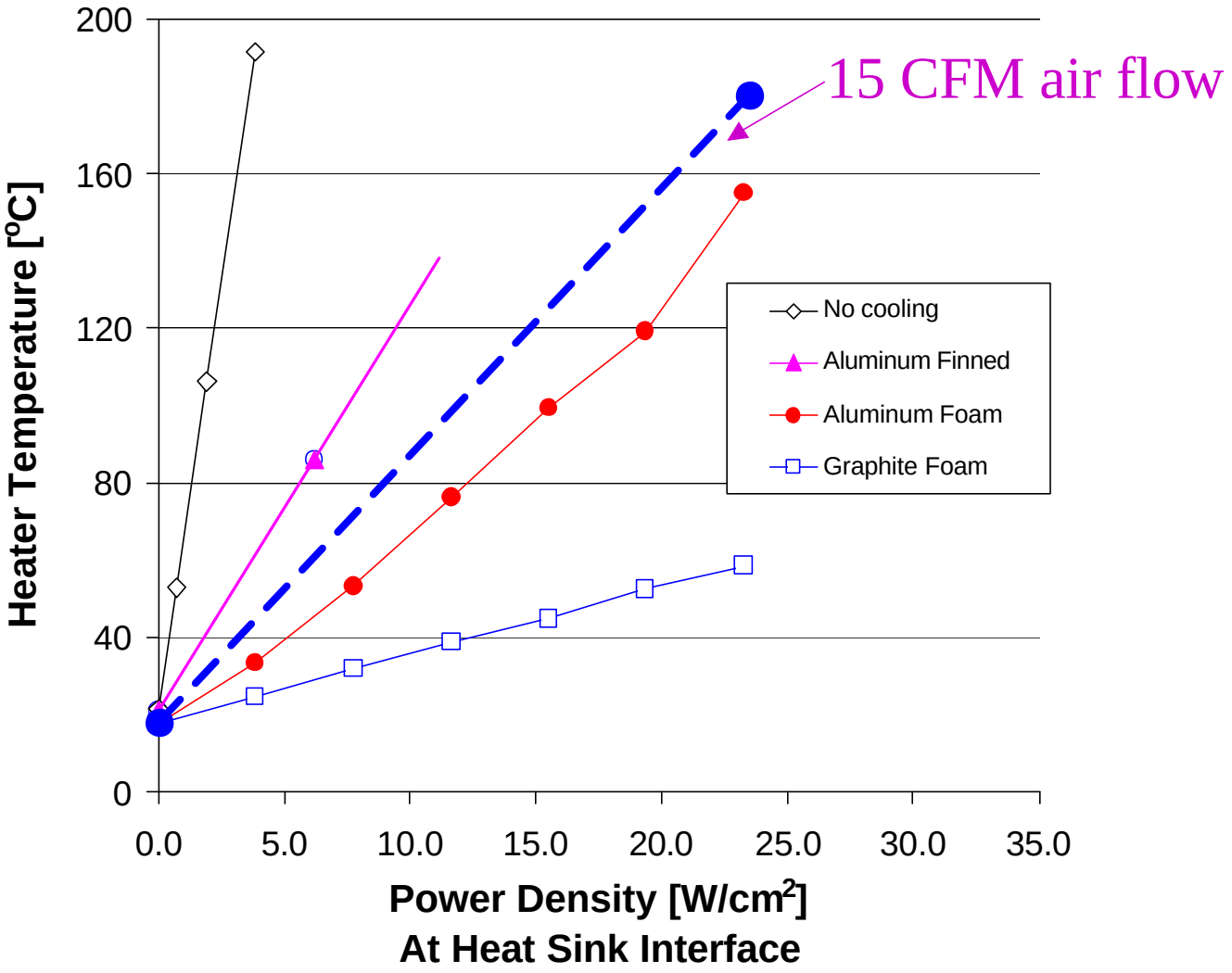
Water Flow



Electronic Temperatures vs. Power Density



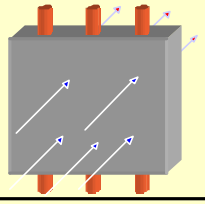
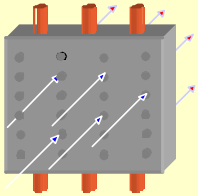
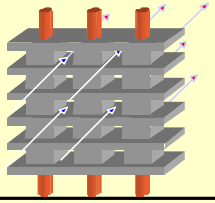
Air cooling with graphite foams



Heat Exchanger Needs for Heavy Vehicles

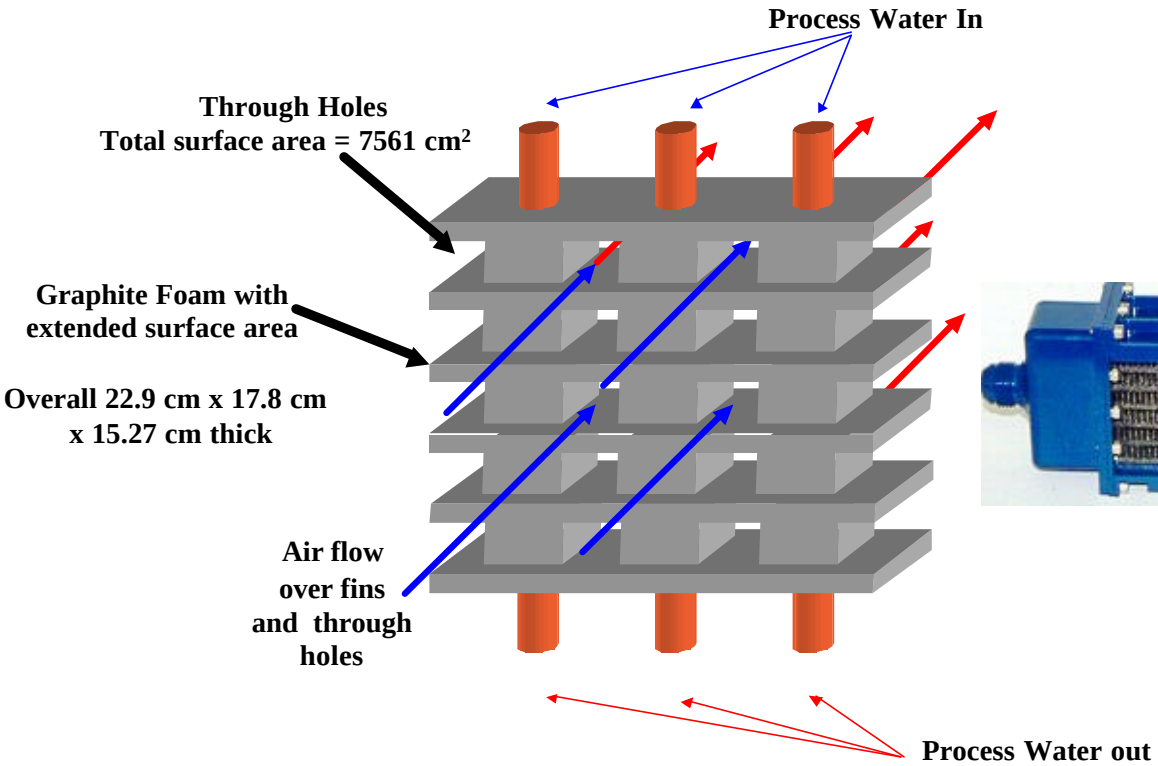
- The large size and up-front location of radiators greatly increases the aerodynamic drag of most vehicles.
- This can account for nearly 25% of the fuel use in a heavy vehicle at 60 mph.
- The need for EGR cooling is expected to increase radiator size by up to 30-40% in some cases.
- Thus, development of smaller, lighter, and more efficient radiators and EGR coolers will impact the **styling**, driver visibility, and the fuel economy of a wide variety of trucks.

Heat Transfer as a Radiator

		Heat Transfer Coefficient h, ($W/m^2 \cdot K$)	$\Delta P/L$ (psi/in)
Solid Foam		10,000*	2
Through-holes		1,000*	0.1
Finned		1,000*	0.05
Current Radiator		30-200	<0.05

* Based on tube surface area

Prototype Radiator Demonstrated



Prototype Radiator

Measured U_o **= 1000 W/m² ·K depending on air humidity**

Similar design tested successfully for 800 hp Winston Cup racing engine
9”x7”x6” - ~2500 CFM - 33.5 kW dissipation

Conclusions

- Graphite foams can be used for significant improvements in heat transfer in many types of cooling applications
- Heat transfer coefficients up to two orders of magnitude greater than existing designs have been demonstrated
- Heat exchangers utilizing air can be utilized to replace designs currently using water
- Most applications of graphite foams will not be a one-to-one replacement of current designs

Special Thanks

Joyce LeTondre, Paul Beaudreaux – NSA

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