The effect of thermal cycling on prototype graphite foam heat exchangers

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Introduction

- **ORNL graphite foam exhibits highly graphitic ligaments**
  - **High k, E**
  - **Low CTE**
  - **Open porosity**
- **Excellent thermal management material**

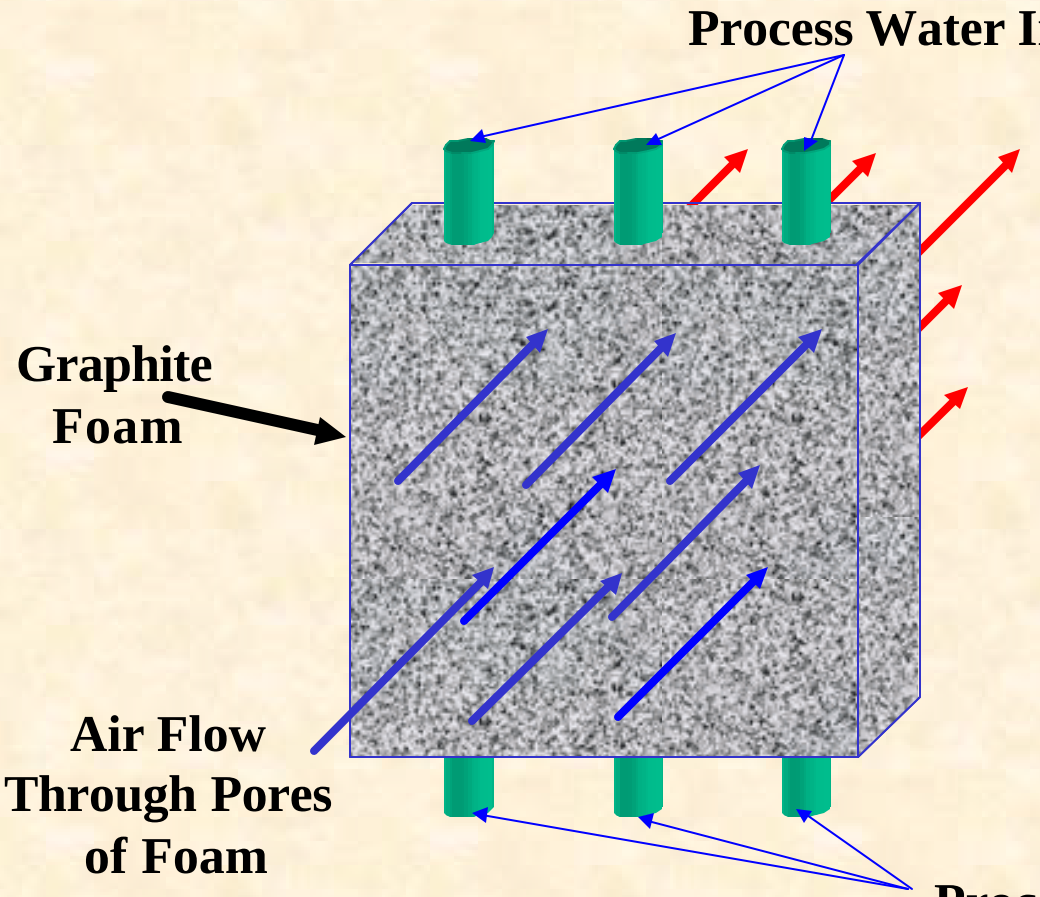
Why Graphite Foam Heat Exchangers?

- **Fuel celled vehicles generate heat which is difficult to dissipate due to the low operating temperatures**
- **Heavy vehicles are soon going to be required to utilize EGR, resulting in a radiator size increase of ~30-40%**
- **Smaller, lighter weight efficient heat exchangers are needed**
  - **Graphite foam is an ideal heat transfer material**

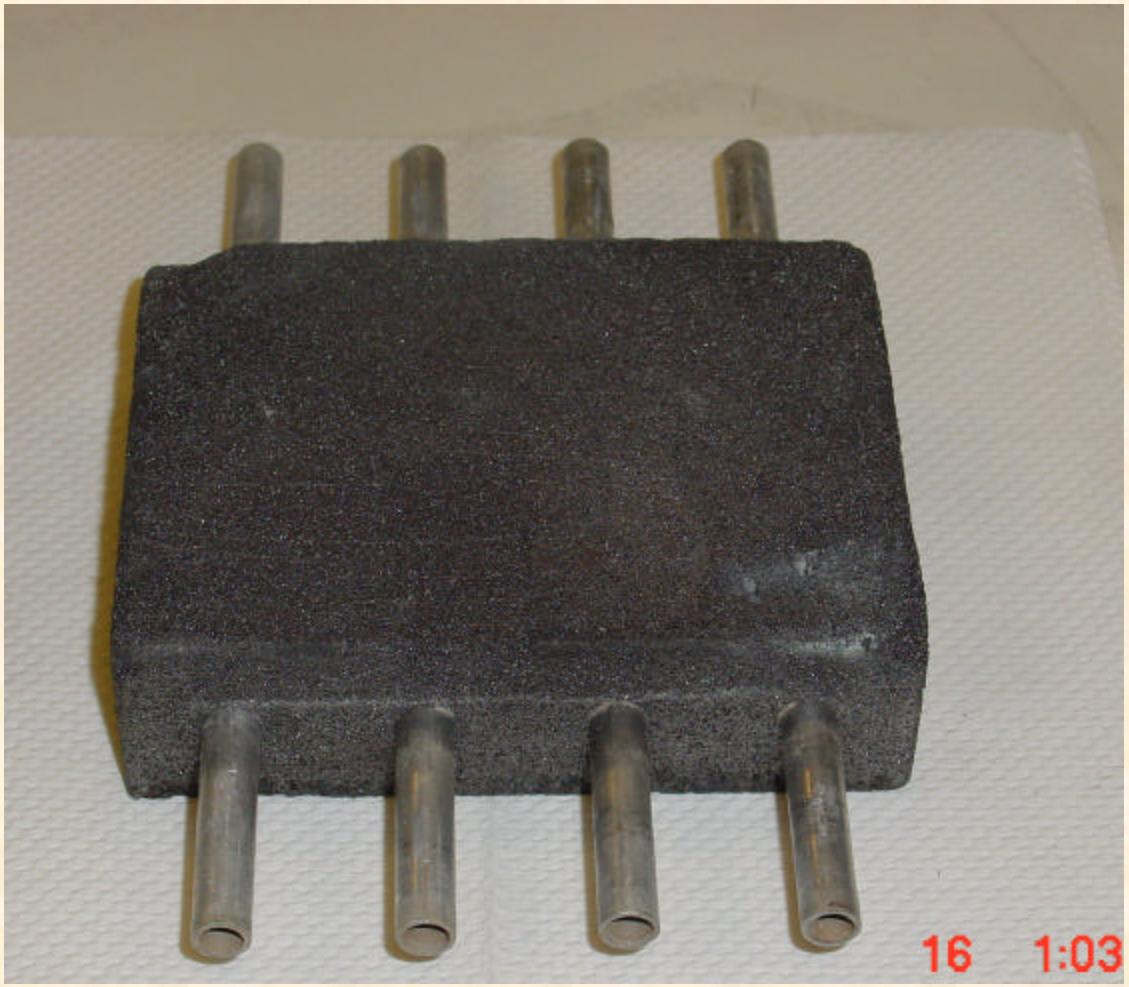
Thermal Cycling Testing

- **Measure heat flow and heat transfer coefficient as a function of cycles**
- **Compare various tube materials and their effect on tube/foam interface**

Thermal Cycling Sample Design



Foam with Press Fit Tubes

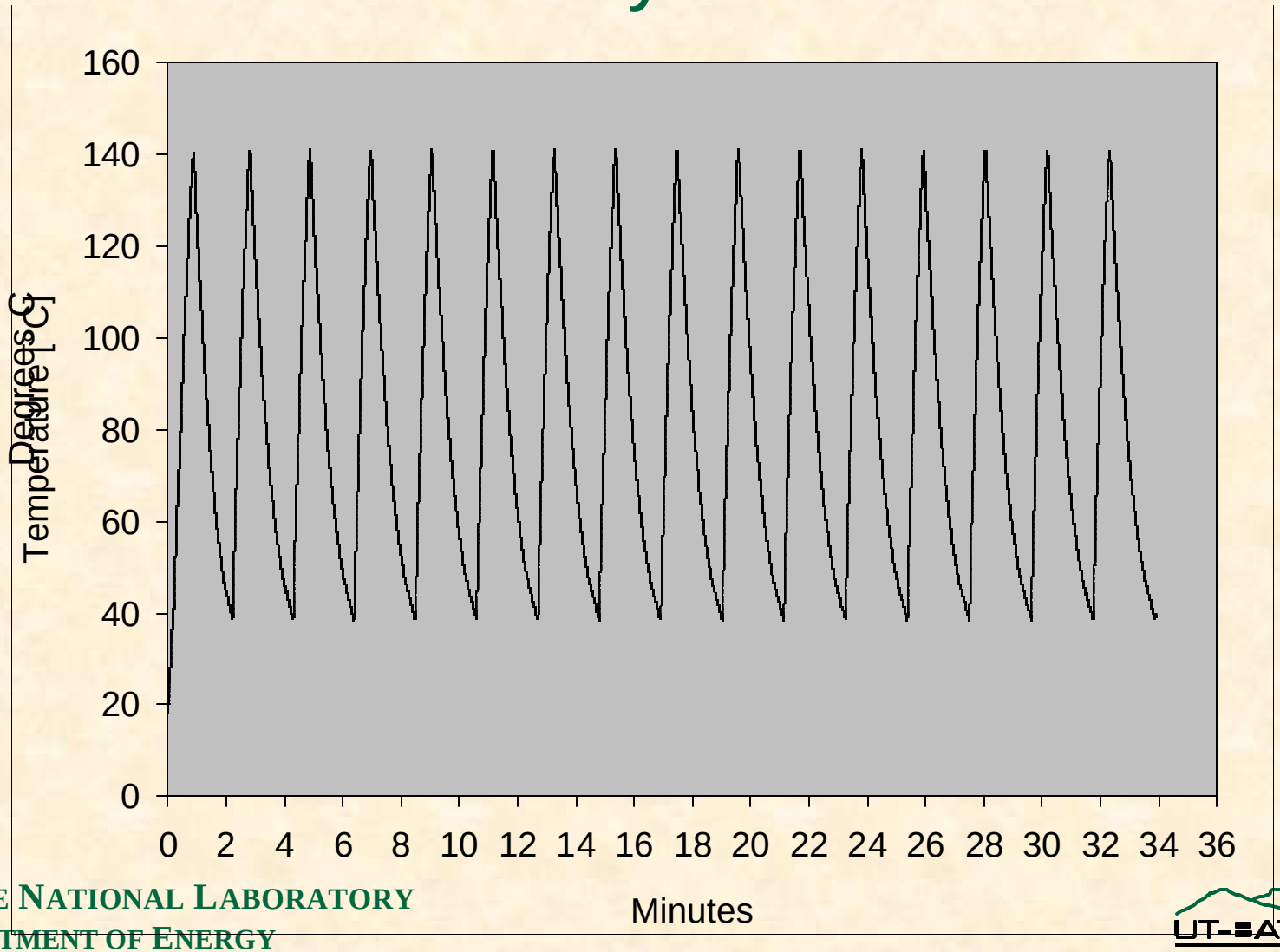


Infrared Thermal Cycling Furnace

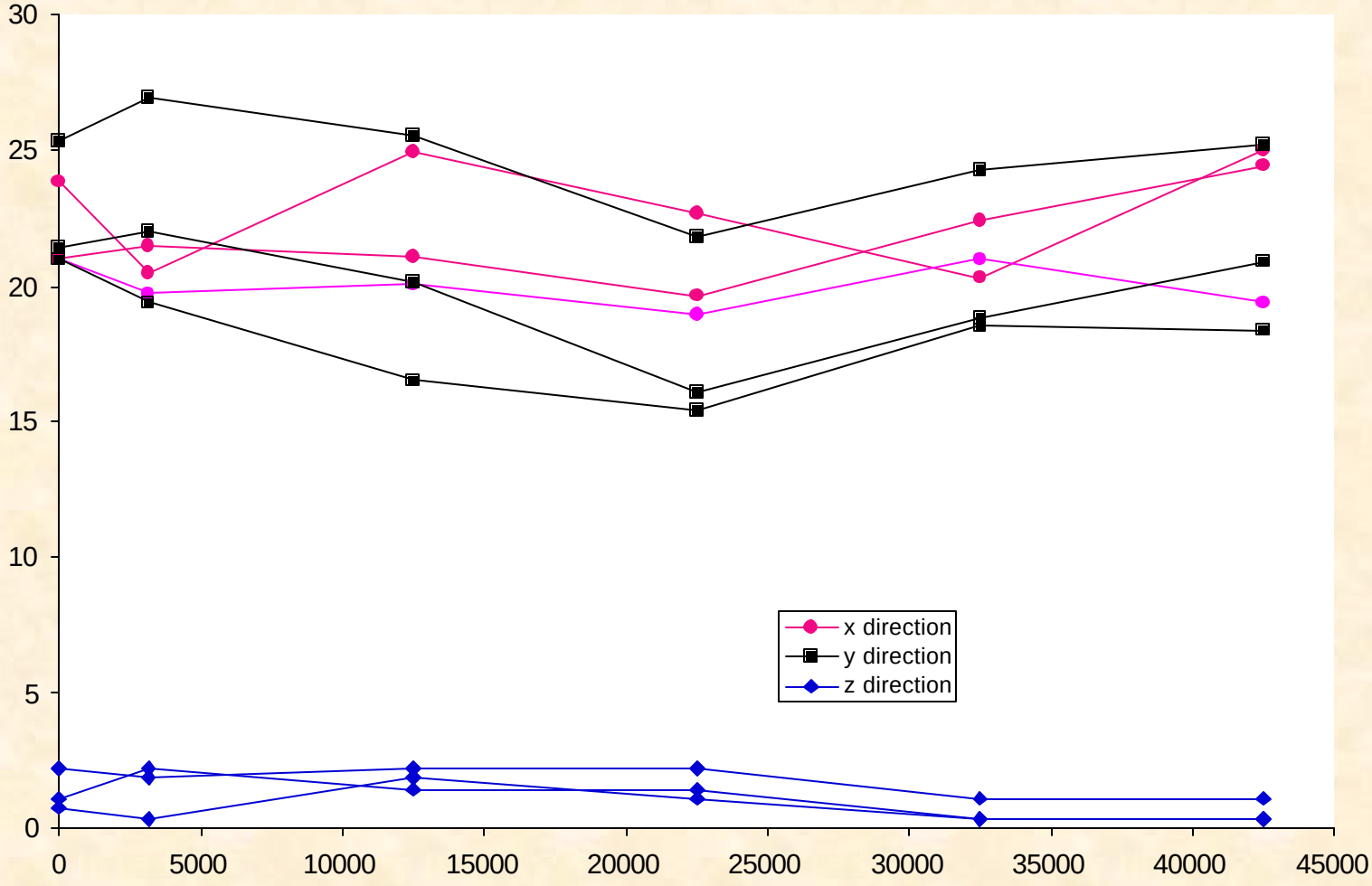
Infrared Heating Cycle

Cooling Cycle

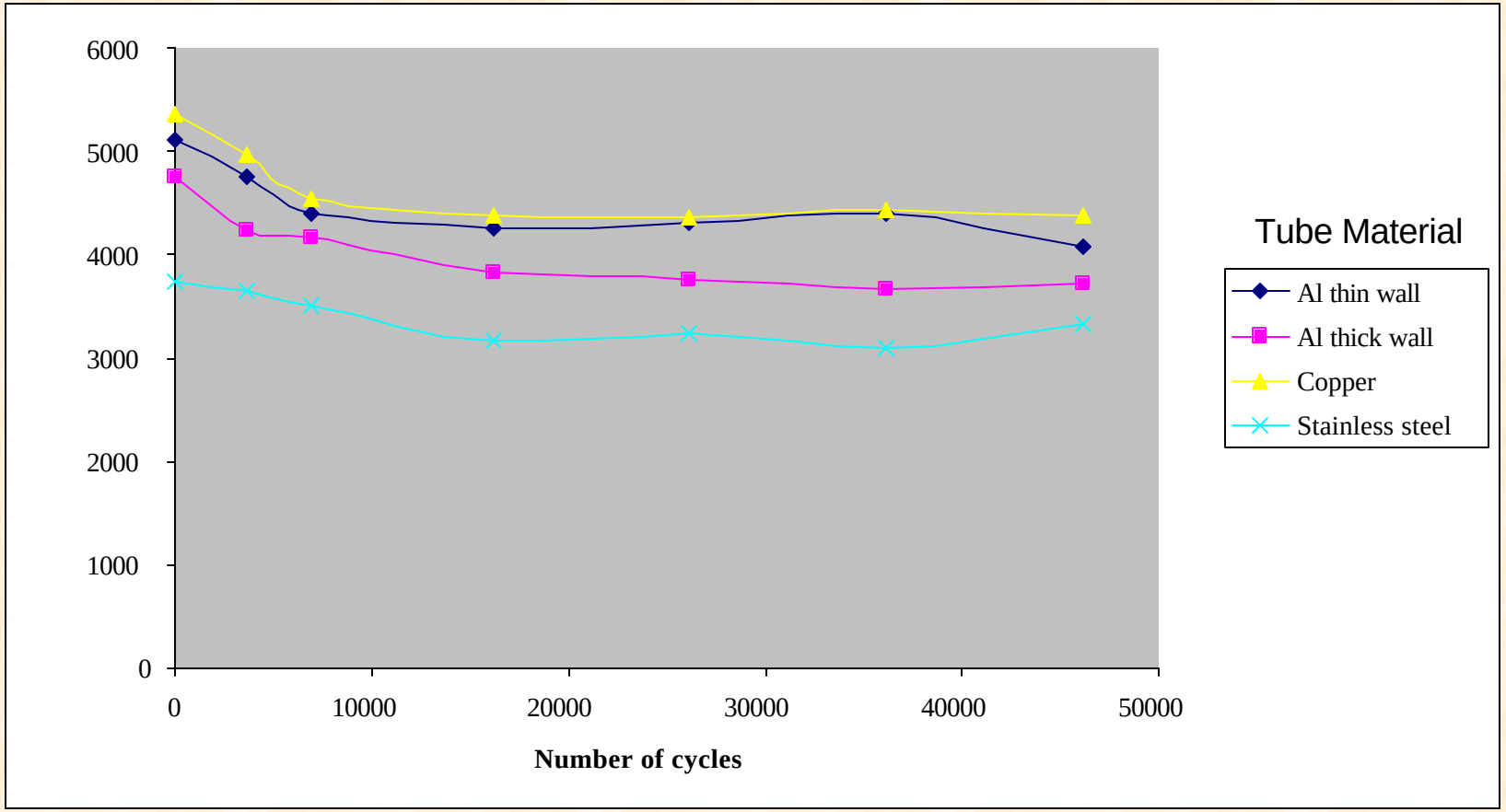
Plot of Thermal Cycles



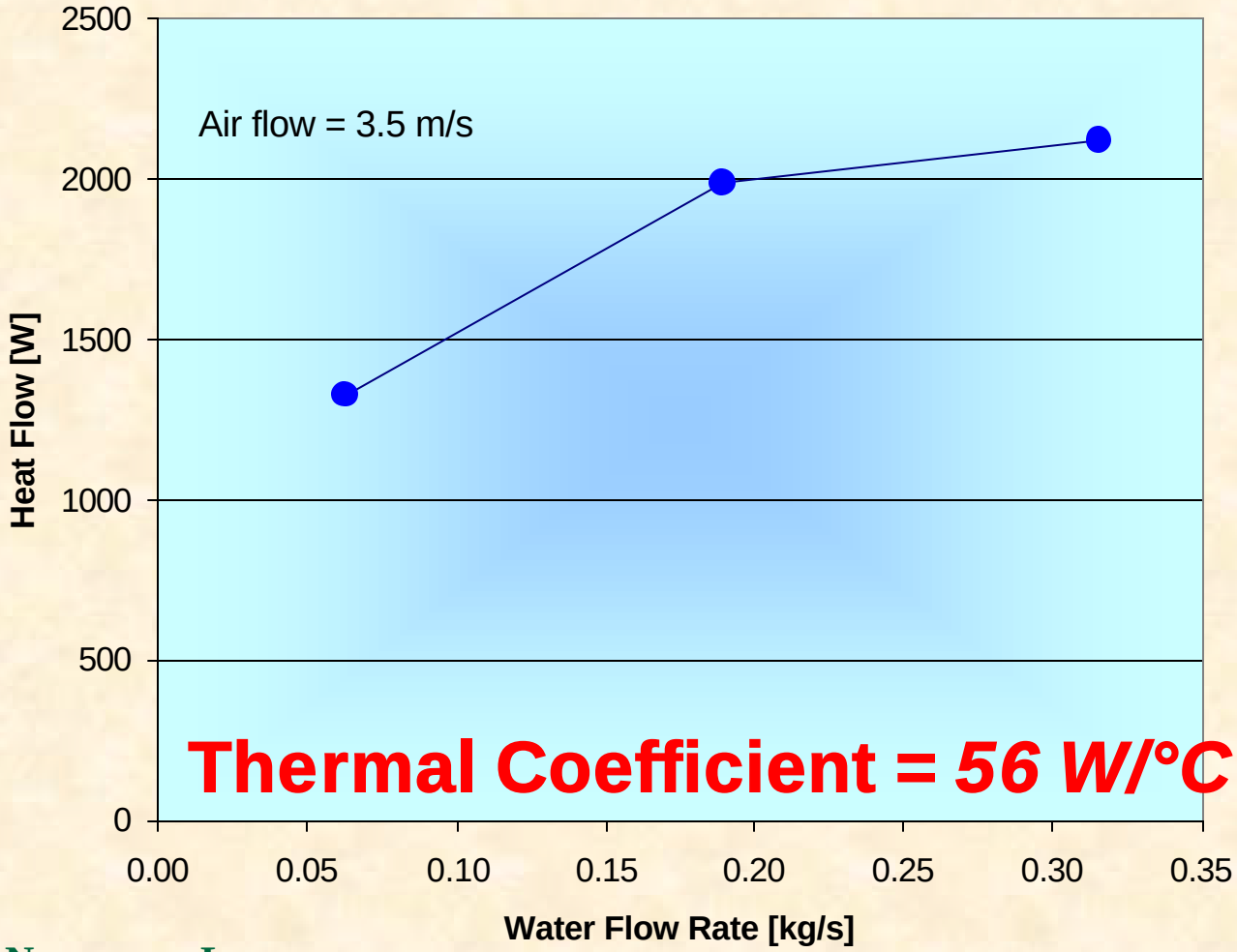
Electrical Resistivity



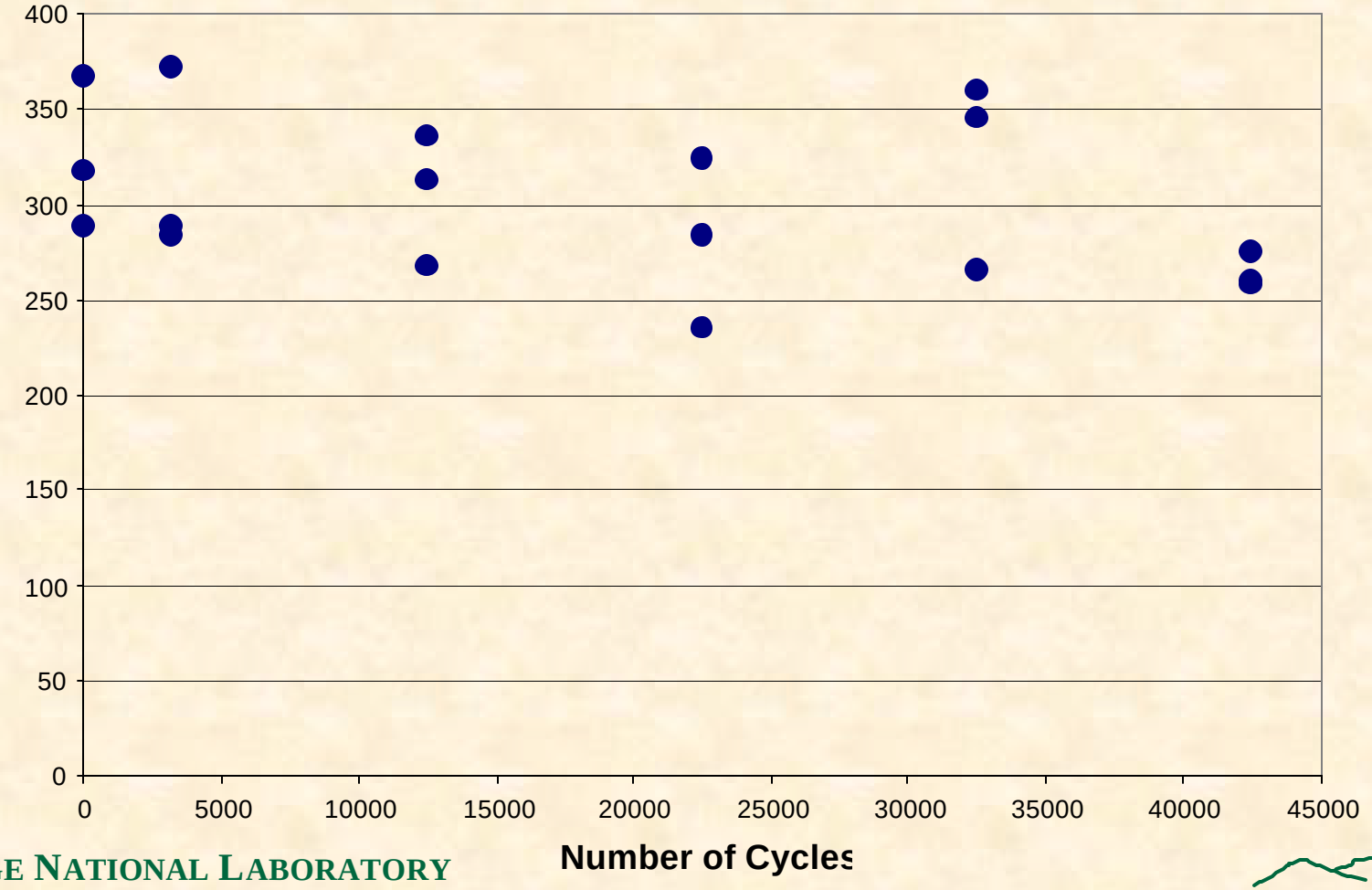
Heat Transfer Coefficient vs Cycle



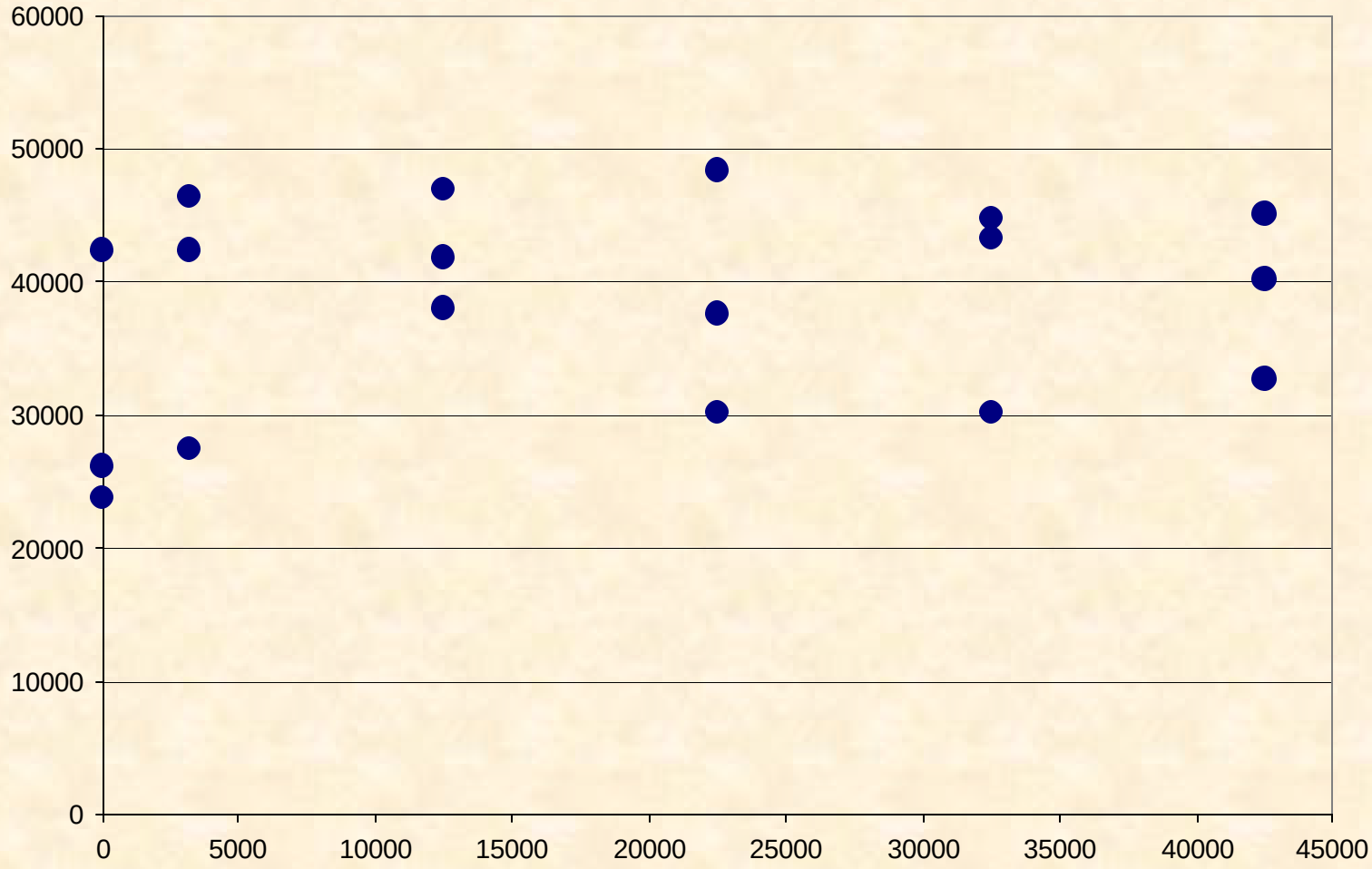
Heat Flow vs Flow Rate



Compression Stress vs. Cycle



Compression Modulus vs. Cycle



Discussion

- **Higher pressure drop can be overcome by:**
  - **Removal of fan (resulting in higher horsepower)**
  - **Redesign of heat exchanger**
- **Although higher pressure drops are experienced by forcing air through the foam, heat transfer is greatly increased**

Heat Exchanger Comparison

Carbon Foam Core

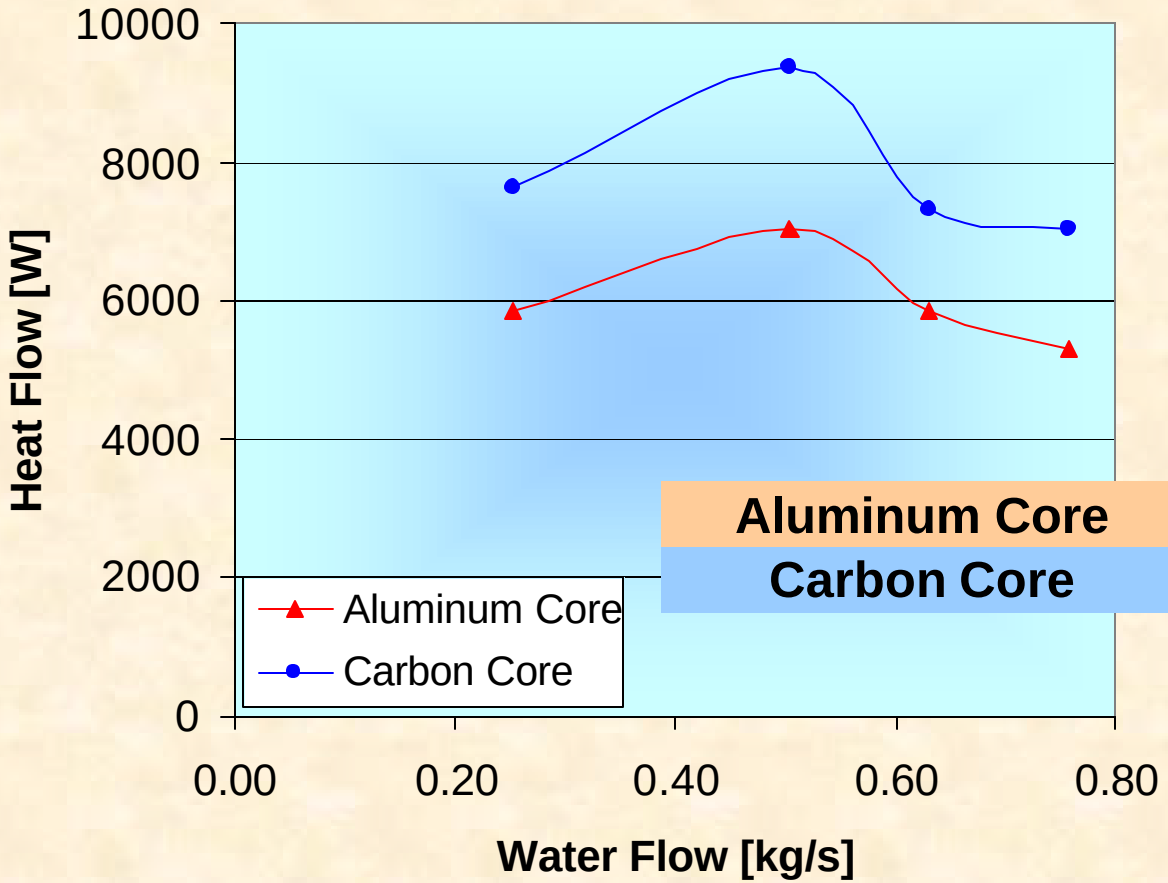
Machined Carbon Foam Fins
Core size = 30.5 cm x 7.6 cm x 3.8 cm
Overall Fin Surface Area = 0.42 m^2

C&R Aluminum Core

Louvered Aluminum Fins
Core size = 30.5 cm x 7.6 cm x 3.8 cm
Overall Fin Surface Area = 0.71 m^2

Heat Dissipation of Foam vs. Al

Air Flow of 12 m/s

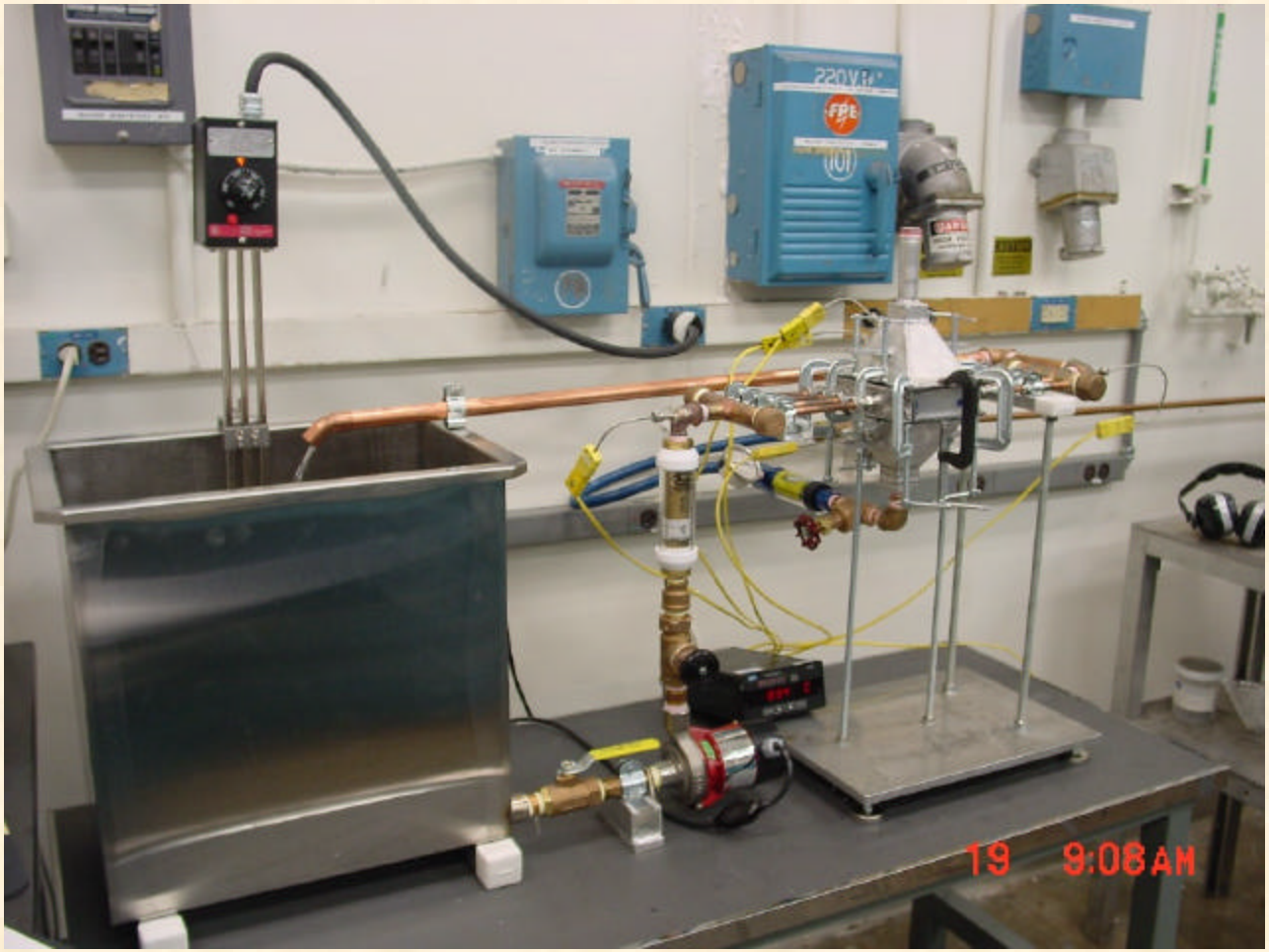


	Thermal Coefficient W/°C
Aluminum Core	0.15
Carbon Core	0.21

Discussion

- **30% improvement in heat transfer with approx. 40% less surface area and equivalent pressure drop**
- **Alternative placement on vehicle**
- **New methods to join foam and substrate**

Ongoing Durability Testing



Summary

- **Graphite foam is an excellent thermal management material**
- **Foam heat exchangers can be smaller, lighter, and more efficient**
- **New joining techniques may allow for even better heat transfer**
- **Further testing is ongoing**
  - **Vibration**
  - **Corrosion**
  - **Full scale prototype**
  - **Further reduction of pressure drop**

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