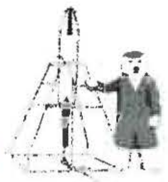

The Total Hemispheric Emissivity of Painted Aluminum Honeycomb at Cryogenic Temperatures

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Introduction

- Very Black, robust surfaces are important for NASA
  - Radiators for space missions: $\varepsilon \approx 1$
  - Absorbers for test facilities: $\alpha \approx 1$

- Options:
  - Most space-flight black paints: ε drops for $T < \sim 100$ K
  - Ball Infrared Black™ (BIRB™): very high performance; proprietary
  - Molded filled-epoxy pyramids: heavy; practical only for small areas
  - Painted aluminum honeycomb core

- James Webb Space Telescope (JWST)
  - Radiators will operate at ~ 35 Kelvin
  - Will use BIRB™ on some radiators
  - Chose to use painted honeycomb on other radiators
  - Minimizing mass extremely important
  - Need to know emissivity accurately to predict JWST performance

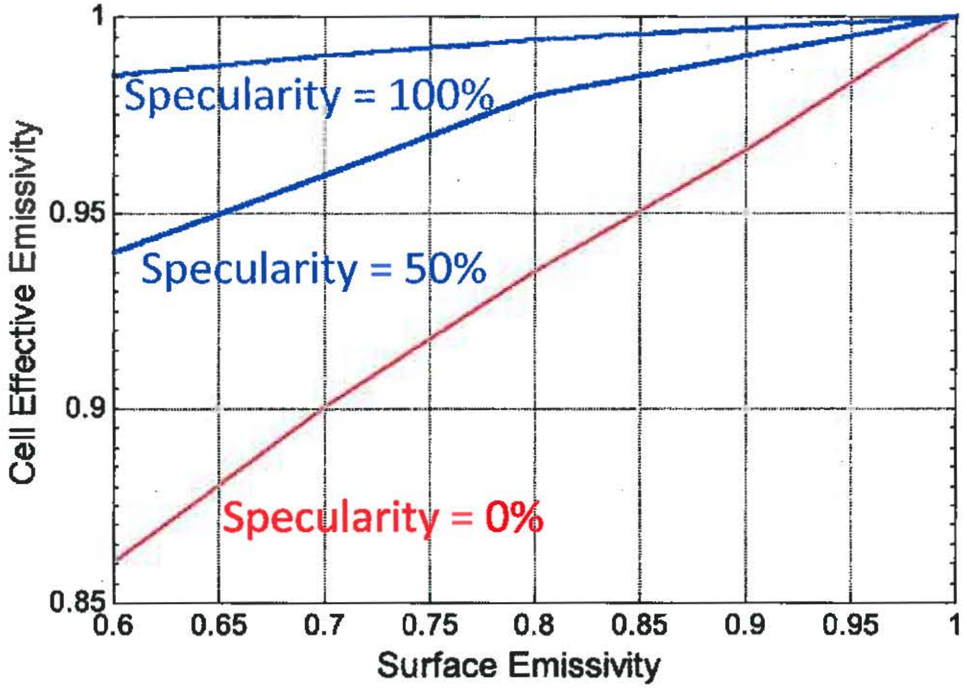
Theory

- Painted honeycomb: convoluted geometry (lots of holes)
  - For radiators, large effective emitting area
  - For absorbers, multiple bounces in cells enhances effective absorptivity

- Sparrow et al. (1964) calculated effective emissivity of cylindrical holes
  - Features that give high effective emissivity:
    - Large aspect ratio (depth/radius)
    - High surface emissivity
    - High % specularity of radiation reflected from surfaces

- We made a thermal desktop model of cylindrical holes
  - Verified that its predictions matched those of Sparrow
  - Made a similar model of hexagonal hole

Honeycomb Thermal Model



- Our Thermal Desktop model of a honeycomb cell
  - Assumes depth/radius = 6
  - Surface emissivity applied to side walls and bottom
  - Results are similar to those for a cylindrical hole

Test Sample Specs

Sample #	Core Thickness	Cell Size	Core Foil Thickness	Avg. Core Coating Thickness
1	12.7 mm	3.175 mm	38.1 μm	16.3 μm
2	9.525 mm	3.175 mm	50.8 μm	17.0 μm
3	9.525 mm	3.175 mm	17.8 μm	8.4 μm

- Coating is Z307 paint
  - Unpublished NASA study showed that emissivity of this paint is independent of thickness from 36 to 117 μm down to 30 Kelvin
  - Published NASA study found that radiation reflected off large Z307-painted wall was > 98% specular
  - Bottom of hole is epoxy, not painted aluminum
    - Model predicts very minor contribution from cell bottom

Infinite Parallel Planes

- Measurement technique assumes radiative heat exchange between infinite parallel plates:

$$\dot{Q} = \frac{\sigma A(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

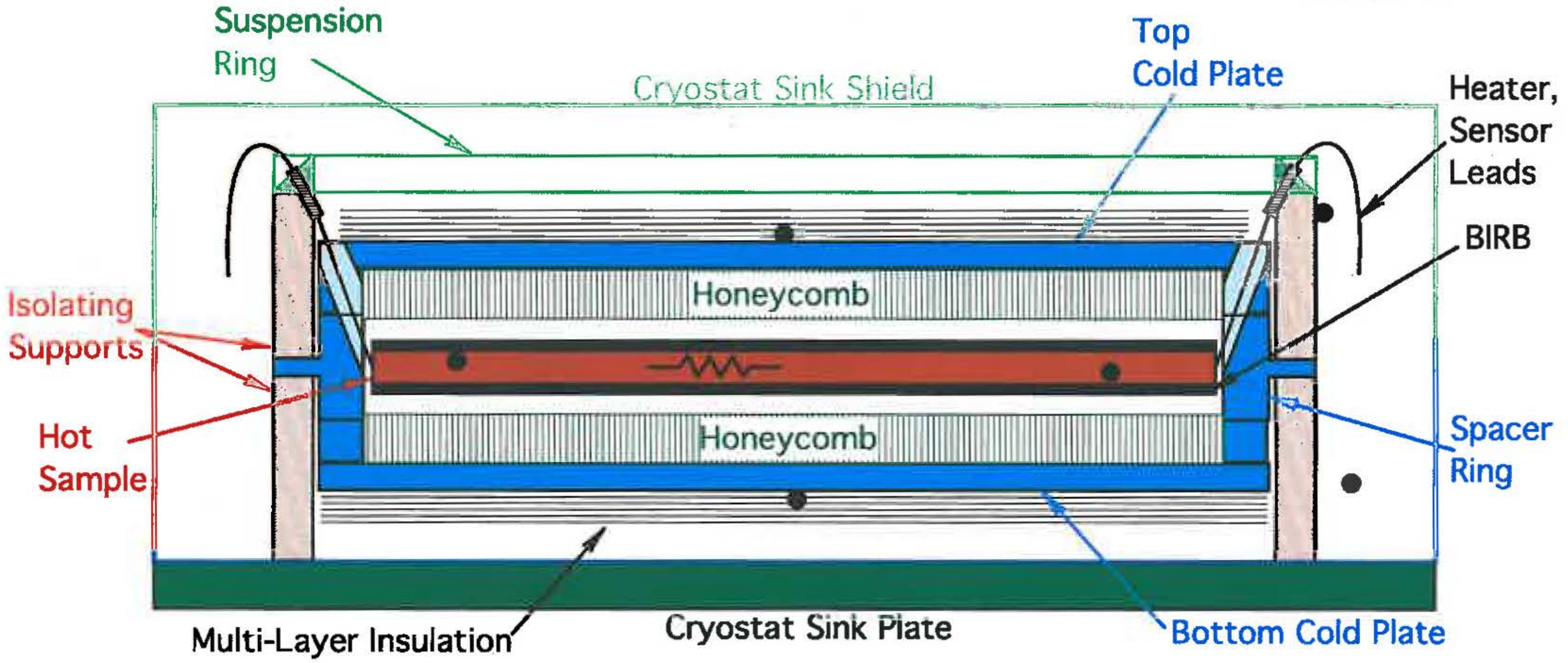
- Correction for edge effect is done via a Thermal Desktop model
- For small ΔT: $\left(T_1^4 - T_2^4\right) \approx 4\overline{T}^3 \Delta T$

(for $\Delta T < (0.06) \times T_{AVG}$, this approximation is accurate to within 0.1%)

For known ε_2:

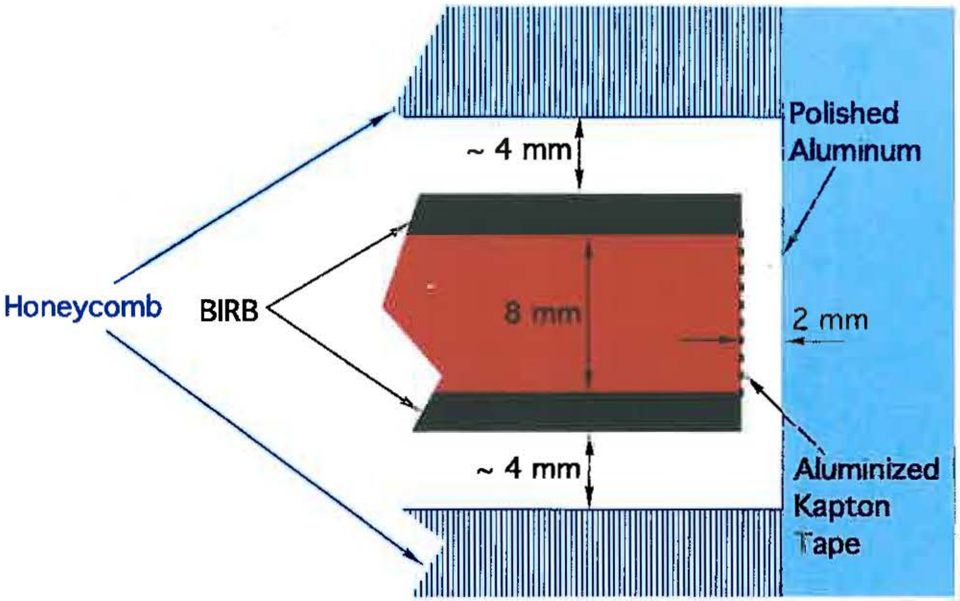
$$\varepsilon_1 = \frac{1}{4\sigma A \overline{T}^3 \left(\frac{d\Delta T}{d\dot{Q}}\right) + 1 - \frac{1}{\varepsilon_2}}$$

Our Apparatus



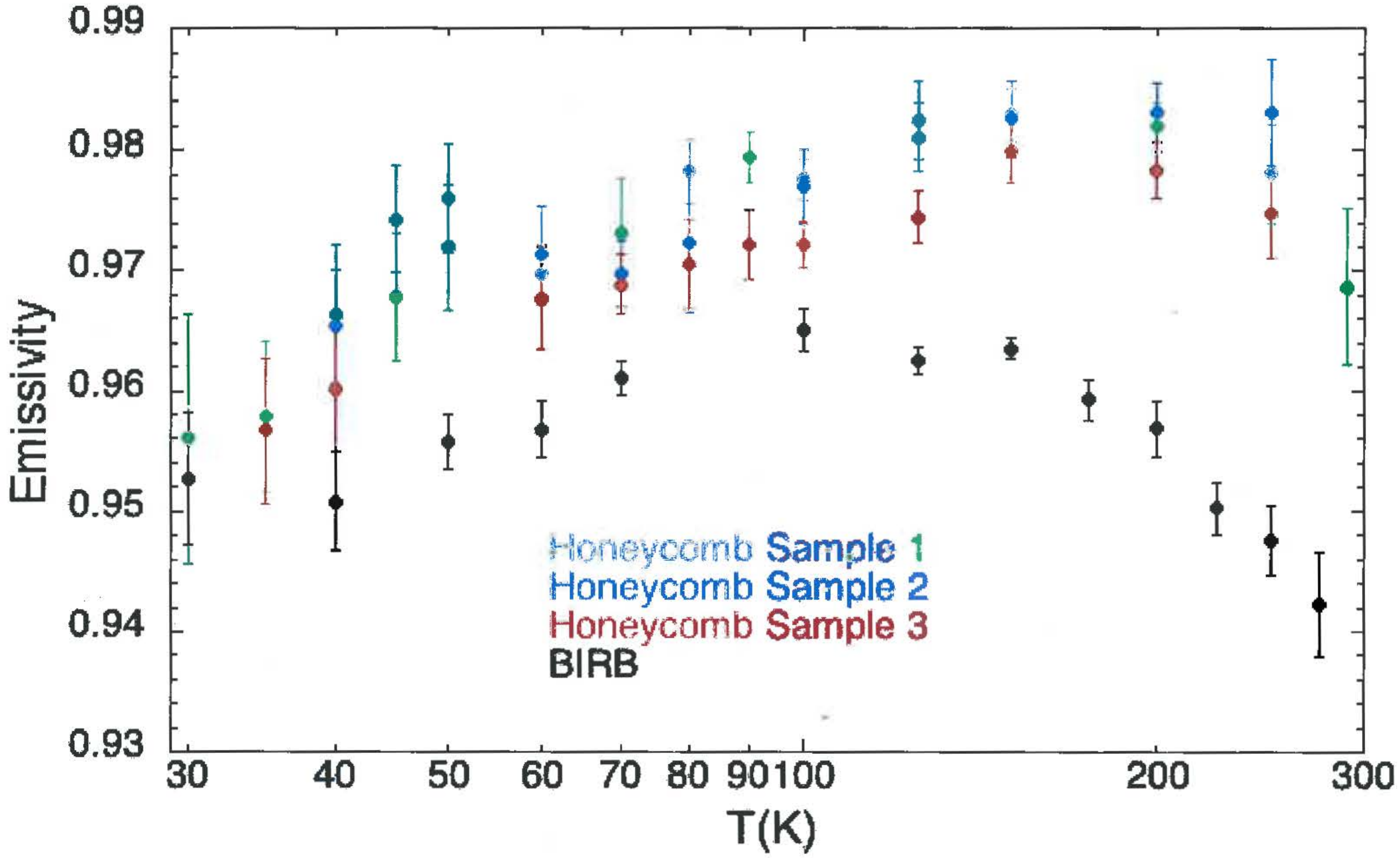
- Hot BIRB™ -coated disk inside cold Honeycomb-lined “can”;
- Sample (disk) suspended by its thermometer, heater leads
- Control: $T_{\text{sample}} = T_{\text{suspension}} = T_{\text{hot}}$
- $T_{\text{can}} = T_{\text{cold}}$
- Measure ΔT vs control power for constant T_{avg}
- Using slope eliminates errors due to sensor calibrations

Edge Effect Correction



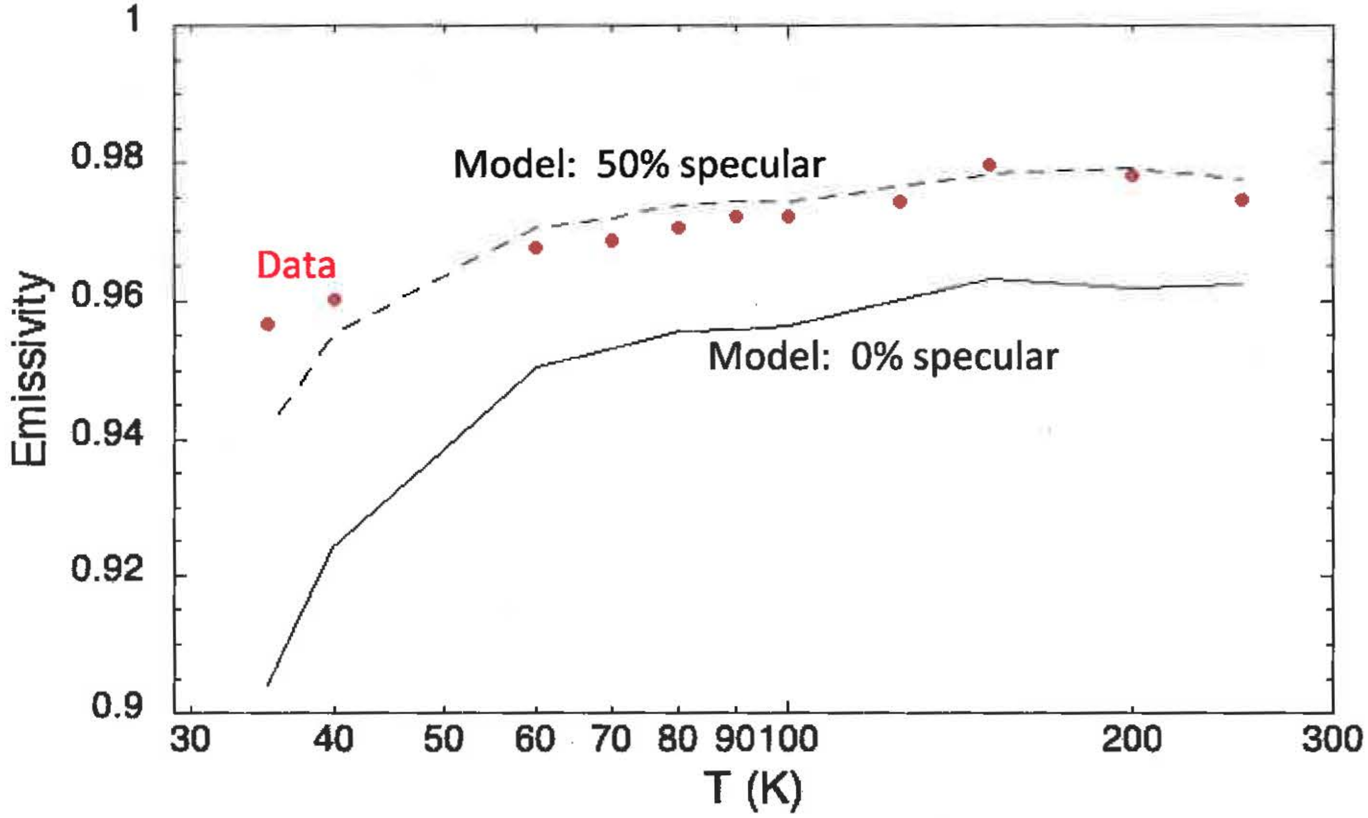
- Edge effect makes our setup different from “infinite planes”
- Cold side (HC) slightly larger than Hot side (BIRB™)
- Thermal Desktop model: use smaller area in “infinite plate” analysis
  - ~1% smaller area than the hot plate gives correct emissivity value

Honeycomb Emissivity Results



- Error bars: 1-σ uncertainty due to slope fit and BIRB™ uncertainty
- BIRB™ data is that of the coating on the Hot plate in this test
- All 3 honeycomb samples show similar very-high emissivity

Data vs. Model



- Data shown are for the thinnest honeycomb (sample 3)
- Model assumes coating emissivity from internal GSFC study
- Best model match assumes 50% specularity
  - Can't explain this, as we expect ~ 100% specularity

Conclusions

- Honeycomb emissivity ~ equal for three samples tested.
- Honeycomb configuration was successfully light-weighted
- Honeycomb has slightly higher ε than original BIRB™
- It’s not clear why model doesn’t match data very well