



# Helium-Cooled Porous Media Micro-modeling and applications to PFCs

## *PFC/ALPS Meeting*

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*Sandia National Laboratories*

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# Helium-cooled PFCs

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## **I. Potential applications of porous media to actively cooled pfc's**

- **helium-cooled divertors**
- **helium-cooled solid breeder blankets**
- **helium-cooled diagnostics & shields**

## **II. CFD conjugate heat transfer in porous media on the micro-scale**

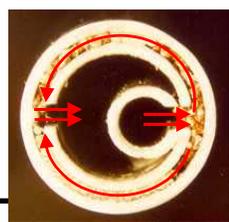
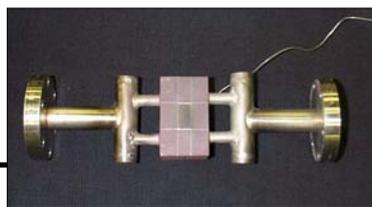
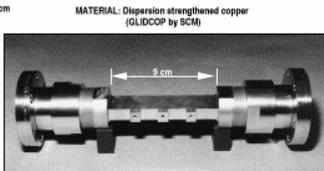
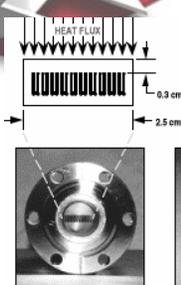


# Progress in helium cooling

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In the last ten years significant progress was made in the development of helium-cooled porous media heat sinks for plasma facing components.

- Before 1999 funded by DOE SBIR/STTR program
- After 1999 funded by industry and other federal agencies
  
- New interest by Europeans for DEMO divertor (FZK, Efremov)



## Tremendous progress in helium cooling

world record heat fluxes absorbed!

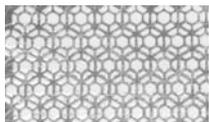
year      Type of Test Article

1993      Micro-channel HX (~100μ channel size)  
 Divertor mockup A (0.46mm channels)  
 Porous (40%) metal HX (0.43mm dia.)



1994      Dual channel porous metal HX  
 Div. mockup A retest, higher heat loads

1996      Phase-II porous metal HX  
 Vanadium HX (9 MW/m<sup>2</sup>)



1997      Faraday shield A (108 MW/m<sup>2</sup>)  
 Divertor mockup B

1998      Faraday 2<sup>nd</sup> shield B  
 Divertor 2<sup>nd</sup> mockup C



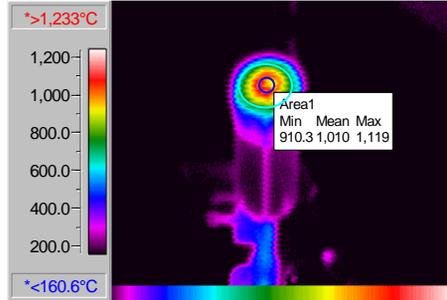
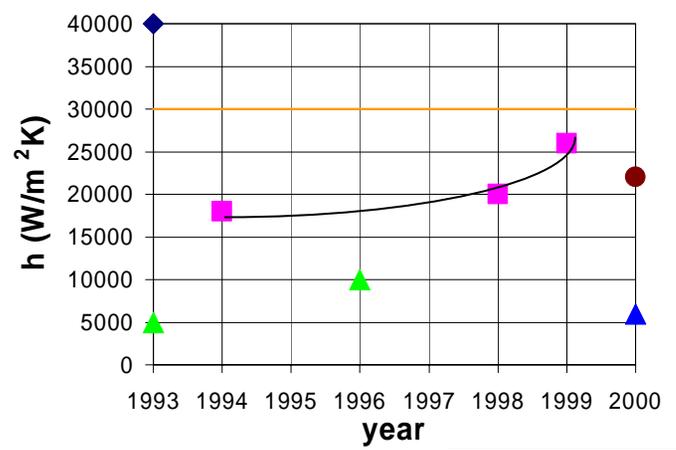
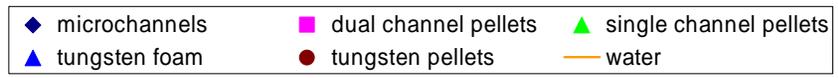
1999      Div. mockup B retest, added diagnostics

a) 2000      W tubes with porous W medium

b) 2000      W first wall module with W porous medium (6 MW/m<sup>2</sup>)

2003      Carbide foam prototypes and CFD modeling

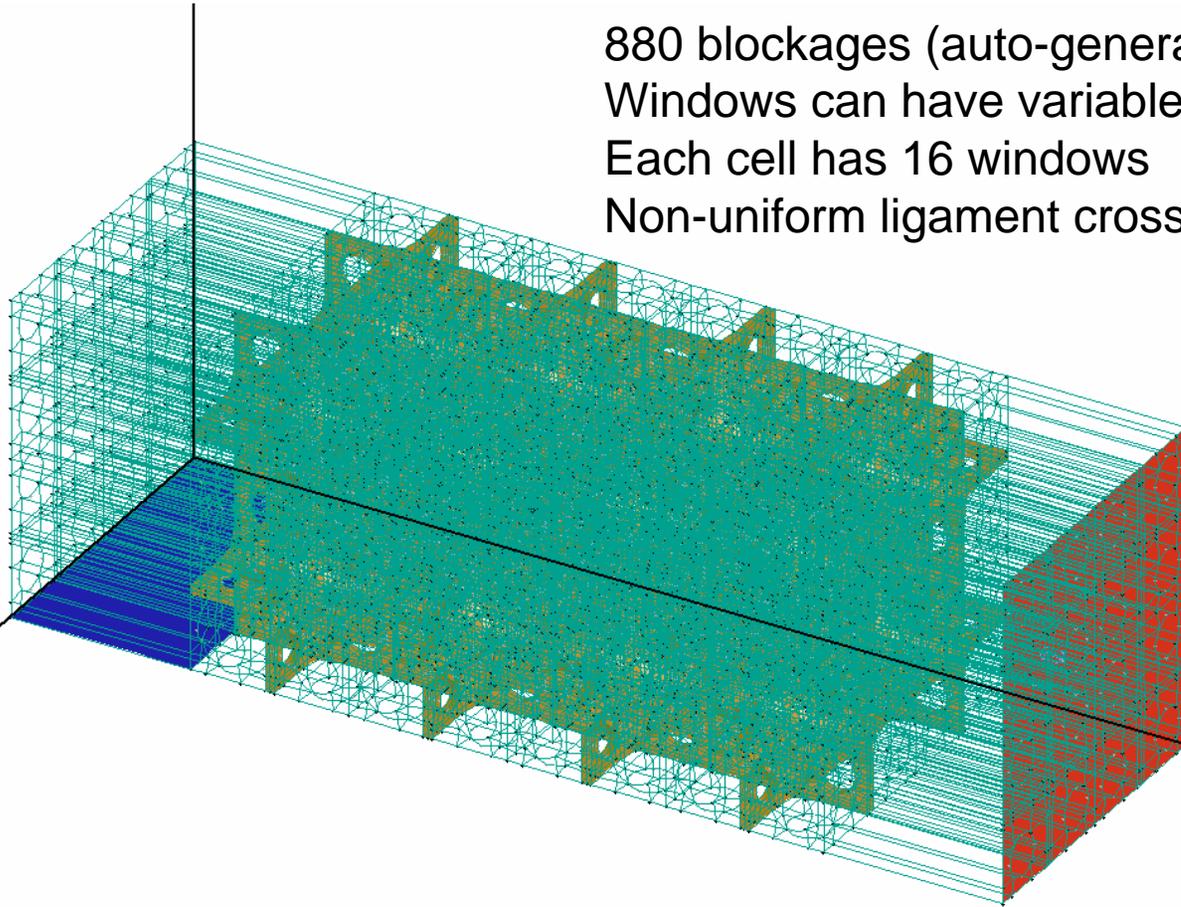
Progress in helium cooling



2x2x4 small porous foam model has structured mesh.



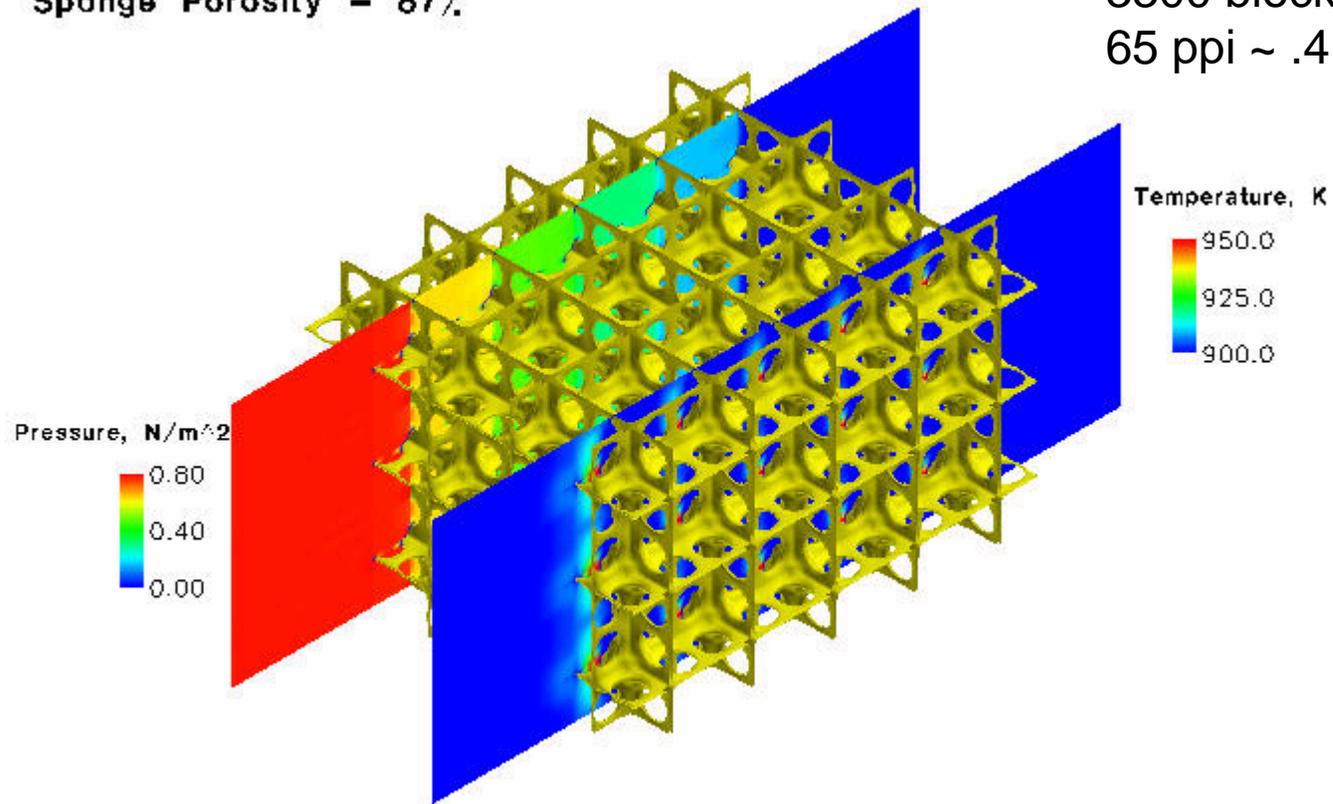
880 blockages (auto-generated)  
Windows can have variable porosity  
Each cell has 16 windows  
Non-uniform ligament cross sections



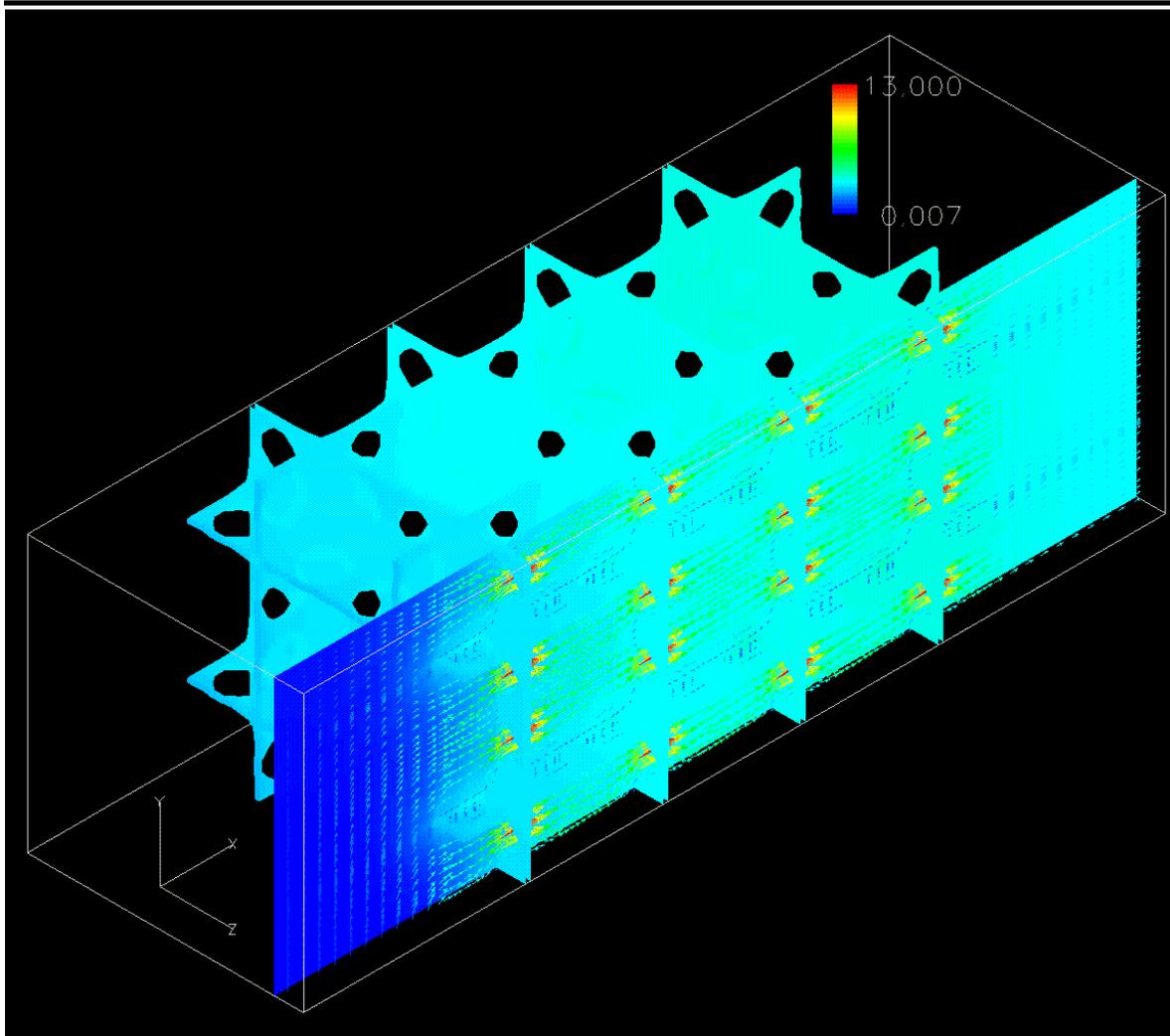
# 4x3x5 medium foam model

Sponge Porosity - 87%

3300 blockages  
65 ppi ~ .4 mm/cell



Conjugate heat transfer in porous media is now easier.



0.1 m/s He, 4 MPa  
 $Q=10$  W/cc

Micro-model

Auto generation

Periodic cells

Variable porosity  
windows

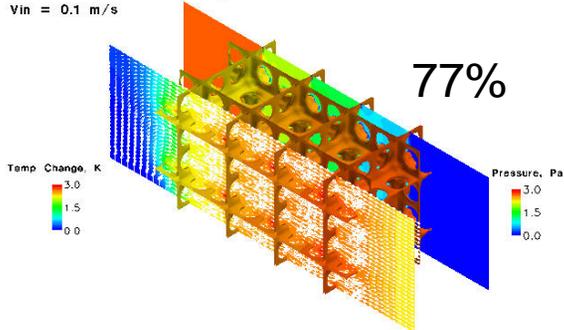
Variable ligament sizes

Variable cell sizes

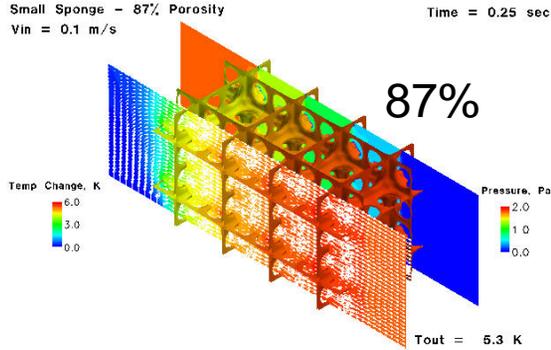
Random cells, MP  
next year

# Thermal optimization studies are currently underway.

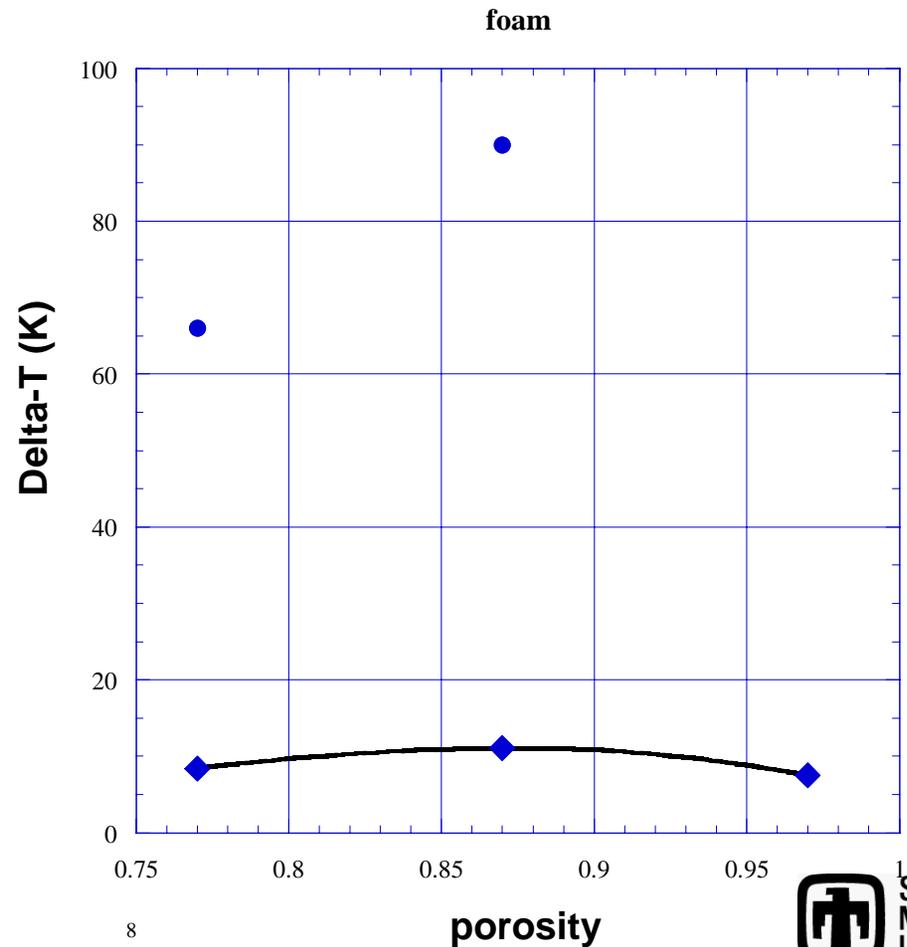
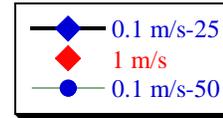
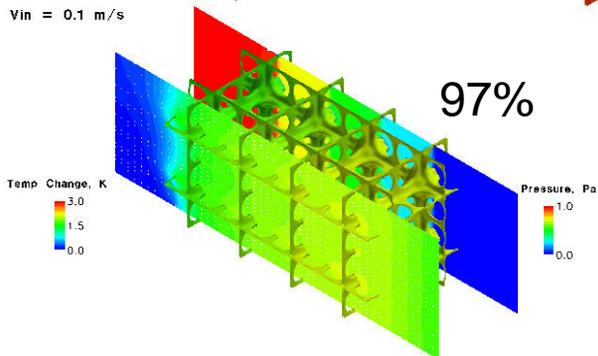
Small Sponge - 77% Porosity  
Vin = 0.1 m/s



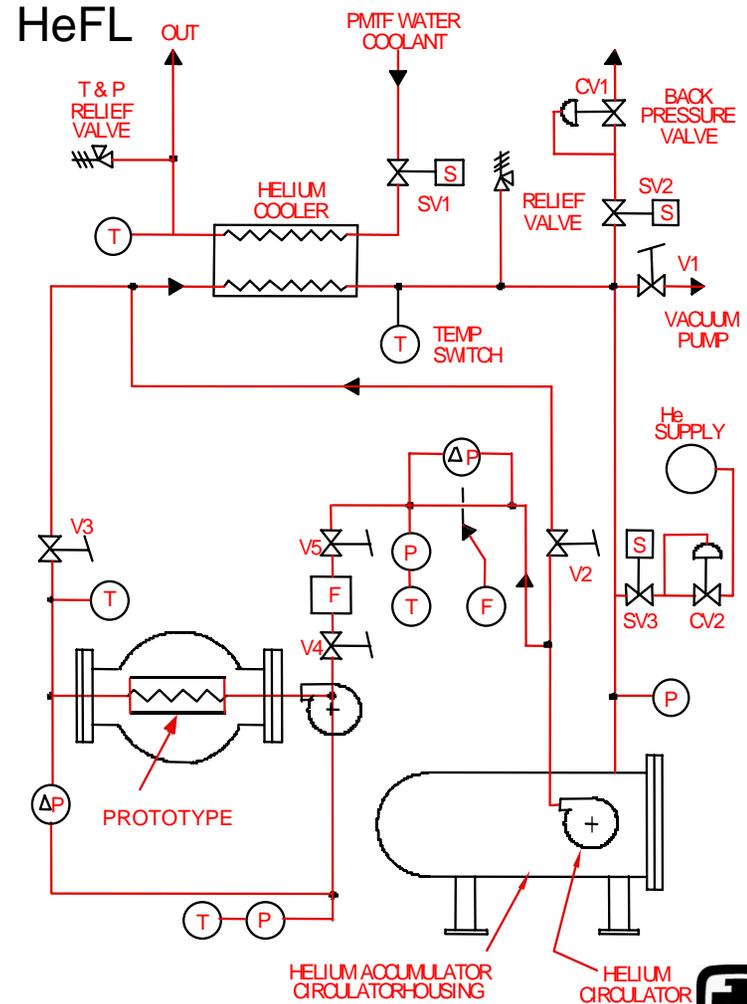
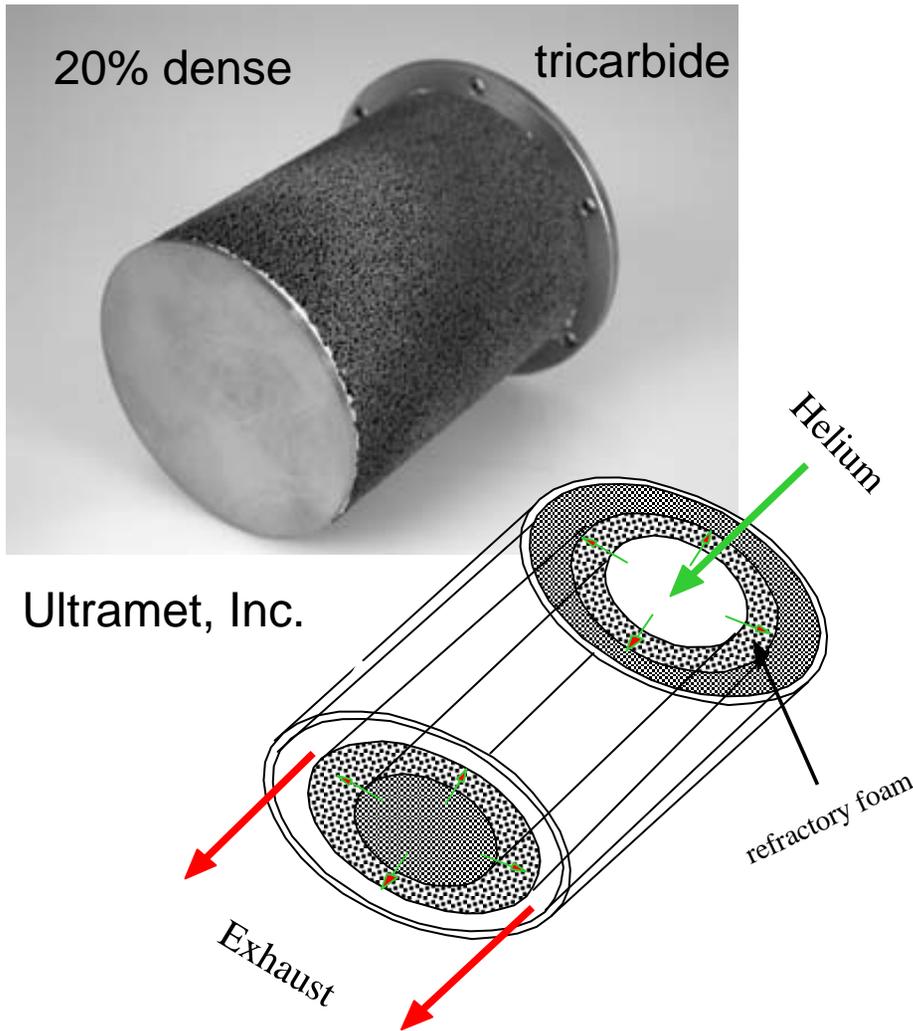
Small Sponge - 87% Porosity  
Vin = 0.1 m/s



Small Sponge - 97% Porosity  
Vin = 0.1 m/s



# Prototypes have just arrived for thermal testing.





# Future

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- MP computations with solver on supercomputer - JANUS

## DEMO, ITER

- Helium-cooled refractory heatsinks for divertors
- Helium-cooled diagnostics, mirrors and shields
- Helium-cooled solid breeder blankets