

Current status of heat transfer modeling at SNL SAND2013-5847P

The points regarding Sandia's activities for Task 1 are:

- (1) *SNL will perform thermal and fluid modeling* for heat transfer tests;*
- (2) *Most likely the EB-60 and He Flow Loop will be available some time in 2014 as a (user) facility, and the scope of PHENIX extends several years*

**We have performed CFD analysis on fusion PFCs using CCM+, SC-Tetra, CFdesign, FLUENT and for other applications CFD2000. We combine these results with ABAQUS for modeling thermal stresses and mechanical behavior.*

Nearer Term (US)

- Complete the matrix of modeling efforts in the US (previous action item, SNL)
- Collaborate with GIT on development of tests and US modeling, maybe engage a GIT student to spend time at SNL (SNL-GIT)
- Develop a model of a micro-jet array and identify the manufacturing techniques (e.g., additive manufacturing) for refractory PFCs. (SNL)
- Collaborate on modeling for HHF tests at ORNL (SNL-ORNL-GIT)
- Complete visit to Japan as part of US-J bilateral agreements with focus on PHENIX Task 1 (Nygren visit before Feb2014)

Longer Term (all)

- Continue to refine the best plan for modeling and testing in PHENIX including the considerations below.
 - a. use of HHFF at Sandia when it becomes available
 - b. issues related to flow instabilities and high temperature and He pressure
 - c. development of physics models for near-sonic jet flow of compressible gases such as He
 - d. anticipated progress outside as well as within PHENIX, e.g., useful collaborations for the US and Japan, e.g., Japan-US-Korea and US-PRC

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SNL-GIT
SNL

*matrix of modeling efforts in the US (next slide),
then further comment on task and issues*

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ORNL-GIT-SNL

SNL

SNL

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Table of Modeling and testing of He-cooled PFC test articles

[Our final table should have footnotes to descriptions and papers]

	Builder/designer	B/D	GIT		Sandia		Other		*
			model	test	model	test	model	org	ref
Jet Flow (pseudo)									
HEMJ 9 unit	KIT	B&D			CCM+	?			
HEMJ (W/brass)	GIT/KIT	B/D	FLUENT	2013					
T-tube jet, DMS model	PPI (Plasma Processes)	B&D	FLUENT	?			CFX	UCSD Raffray	3
ARIES Div	ARIES	D	CFX	?			CFX	UCSD Raffray	3
DEMO FW/blanket	?APEX	D	SC-Tetra	?				UCLA	
HEMJ turbulence	KIT/UCLA	D	SC-Tetra	2007?				UCLA	
Porous Media									
T-tube PS media	PPI	B				2001	CFX/Merlot	UCSD Raffray	3
Mo single tube foam	Ultramet	B			CCM+	2008	SC-Tetra	DMS Sharafat	4
W & Mo 4-channel panels, foam	Ultramet	B			CCM+	2010	SC-Tetra	DMS Sharafat`	5
W thimble, sintered media	Thermacore	B				2000	FloWrks		1
Cu dual channel parallel flow, sintered media	Thermacore	B				1998	FloWrks		2
Other									
pin array	GIT	B&D	FLUENT	2007?					3
Cu microfins	Creare, GA	B&D			FLUENT	1993			7
V Swirl tube	GA	B&D			?	1996			6

*references on next page

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**references as noted in last column previous page*

1. Dennis L. Youchison and Mark T. North, "Thermal Performance of a Dual-Channel, Helium-Cooled, Tungsten Heat Exchanger," Proceeding of the 14th ANS-TOFE Conference, Park City, UT, October 19-23, 2000, *Fusion Technol.* **39** 2, 899-904 (2001). also SAND2000-2922C report.
2. Dennis L. Youchison, Mark T. North, James E. Lindemuth, Jimmie M. McDonald and Thomas J. Lutz, "Thermal Performance and Flow Instabilities in a Multi-Channel, Helium-Cooled, Porous Metal Divertor Module, *Fusion Eng. Des.*, **49-50**, 407-415 (2000).
3. M.S. Tillack, A.R. Raffray, X.R. Wang, S. Malang, S. Abdel-Khalik, M. Yoda, D. Youchison, "[Recent US activities on advanced He-cooled W-alloy divertor concepts for fusion power plants](#)" *Fusion Eng. Des.*, **86** 71-98 (2011).
4. S. Sharafat, A. Mills, D. Youchison, R. Nygren, B. Williams, N. Ghoniem, "Ultra low pressure-drop helium-cooled porous-tungsten PFC," *Fusion Science & Technol.* **52** 2, 559-565 (2007).
5. S. Sharafat, A. Aoyama, M. Narula; J. El-Awady, N. Ghoniem, B. Williams, D. Youchison, "Development status of the helium-cooled porous tungsten heat exchanger concept , " Proceedings of the 22nd IEEE/NPSS Symp. on Fusion Engineering – 22nd SOFE, IEEE 07CH37901C, 2007, p.1-4.
6. C.B. Baxi, J. Smith, D. Youchison, "Design, Fabrication and Testing of a Helium-Cooled Module," *Fus. Eng. Des.*, **28** 22-26 (1995).
7. D.L. Youchison, M.G. Izenson, C.B. Baxi, and J.H. Rosenfeld, "High-Heat Flux Testing of Helium-Cooled Heat Exchangers for Fusion Applications," *Fusion Technol.* **29**, 559-570 (1996).

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ORNL-GIT-SNL

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Fusion has not yet investigated micro-jet cooling as is being done in the electronics industry. HEJM has small jets but not micro-jet technology. What are some of the issues?

- 1. The flow of interest pushes sonic velocities for compressible gas (He, or air for electronics)*
- 2. Small jet diameter and spacing strip boundary layers, force rotation and mixing near the cooled surface and should not produce the relatively high local stresses found for the HEMJ.*
- 3. Fabrication for refractory PFCs requires a new approach such as additive manufacturing to develop micro-jet arrays with distribution systems for modular units to cover large areas.*

Some random Google hits on micro-jets

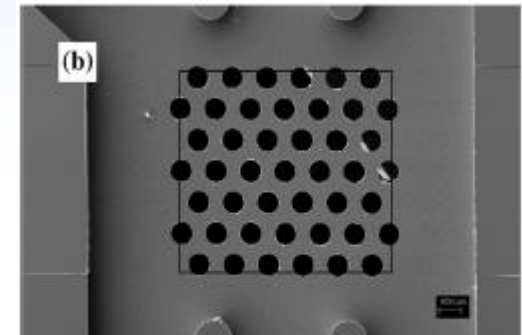


Fig. 5. SEM images of (a) $A_r = 0.089$ and (b) $A_r = 0.354$ (staggered) arrays.

The effect of area ratio on microjet array heat transfer

Gregory J. Michna^{a,*}, Eric A. Browne^b, Yoav Peles^b, Michael K. Jensen^b

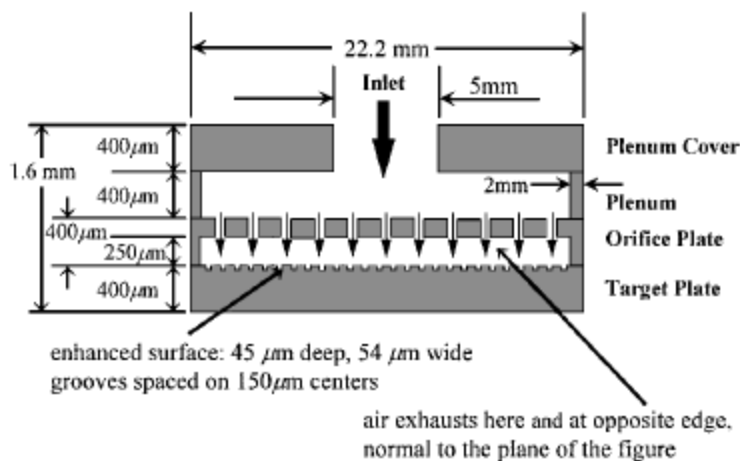
^a Department of Mechanical Engineering, South Dakota State University, Brookings, SD 57007, United States

^b Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180, United States

Table 1

Geometric specifications of the microjet arrays.

Array	Array type	Hole spacing (μm)	Nominal diameter (μm)	Actual diameter (μm)	Area ratio
1	In line	250	50	54	0.036
2	In line	250	100	112	0.159
3	Staggered	360	100	112	0.089
4	Staggered	230	100	112	0.214
5	Staggered	180	100	112	0.354



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Experimental Investigation of an Air Microjet Array Impingement Cooling Device

John E. Leland^{*} and Rengasamy Ponnappan[†]
U.S. Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433-7251

and
Kevin S. Klasing[‡]
Universal Energy Systems, Inc., Dayton, Ohio 45432-1894

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END

Thank you

Domo Arigato Gozaimasu