Nozzle Development for Heat Transfer Tests and Li Flow through Moderate Magnetic Fields

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Heat Transfer in Liquid Surface PFCs

Nearly all our applications for liquid PFCs involve flow from jets.

Analysis of heat transfer (and fluid flow) is hampered by several factors:

1. **Liquid PFC divertors will have not have fully developed flow. This makes the analysis more complicated.**

*2. **In liquid metals, the MHD effects in complicated flows (e.g., divertor) cannot yet be modeled well.**

For liquid metals, (a) slug flow is still the best approximation, (b) 2-D turbulence is not likely to increase thermal conductivity.

past conclusions from APEX Task 2-3 conference call

Some analyses of MHD in jet flows done by Reed and Molokov

3. **In fast (10m/s) turbulent flows, such as molten salts in B field, Li with no B field, the inherent vorticity creates instability that eventually break up the jets. So "wavy" surfaces from "bulk" vorticity and edge effects from the nozzle boundary layers must be expected.**

Turbulent jets tend to be "globular" within the stream envelope.

Work on nozzles for Li flow loop

Sandia plans to do two types of testing with the Li flow loop.

1. Li jet projected through a magnetic field (various configurations).

2. Heat transfer tests on a <u>flat Li stream</u> without a magnetic field.

Water surrogate for Li jet

Li/H_2O: 1/2 density, 1.15X dyn. visc., 5X surface tension

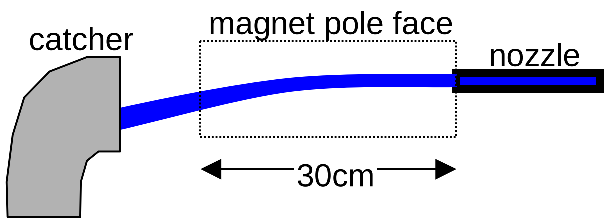
For the Li test, we will observe the trajectory of a "simple" round stream. The stream must traverse the magnet pole face (~30cm).

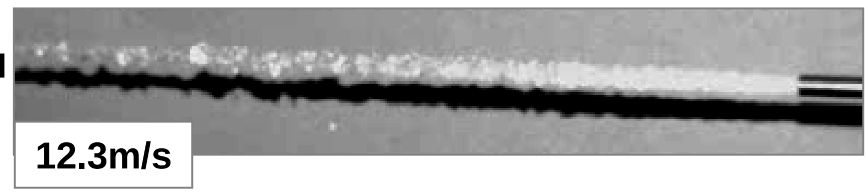
In a water test, a simple pipe nozzle can project a stream over 0.5m with very little dispersion.

The higher surface tension of Li will promote faster jet breakup. However, the presence of the magnetic field will likely stabilize the surface structure of the stream.

Work on nozzles for Li flow loop

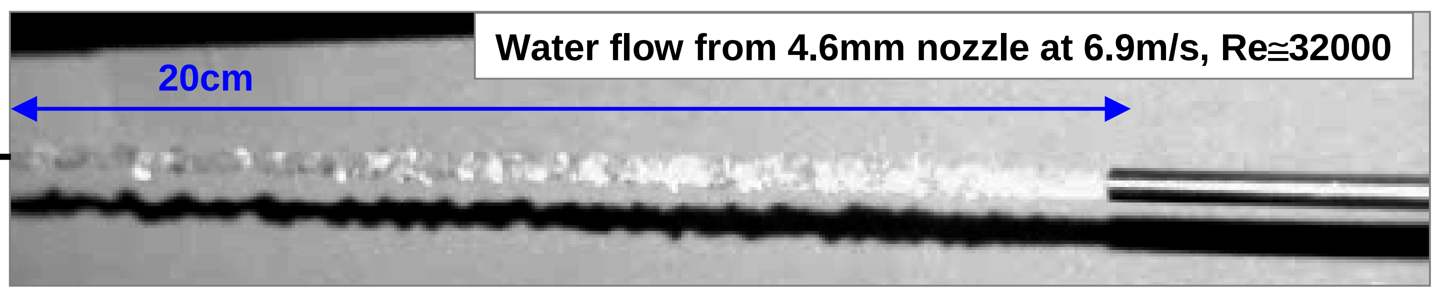
Round Stream Test - first trial, simple tube - 4.6mm ID (1/4” SS)





A straight nozzle projects a water stream over 0.5m with very little dispersion.

to catcher .54m from nozzle



Wavy shadow shows “globular” nature of stream.

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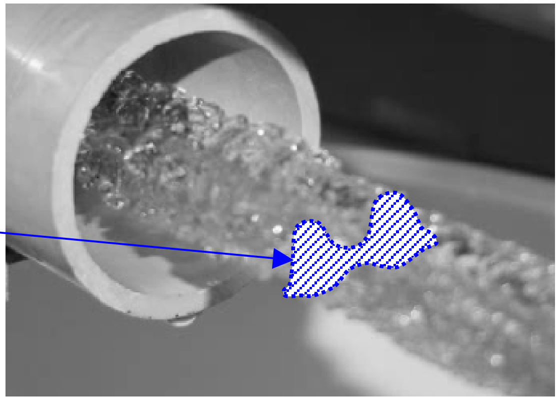
Work on nozzles for Li flow loop

For heat transfer tests (no B field) we plan to use a <u>flat Li stream</u>.

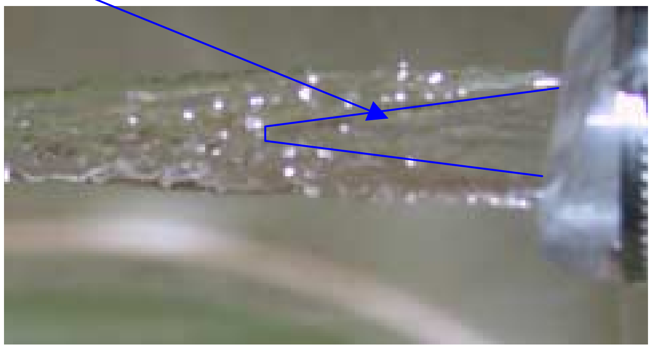
In our "flat stream" tests with water at flow velocities from 3-10m/s, the stream "dog bones" excessively.

At low velocities (<1m/s, Re<~5000), the area just downstream of the nozzle remains smooth and transparent.

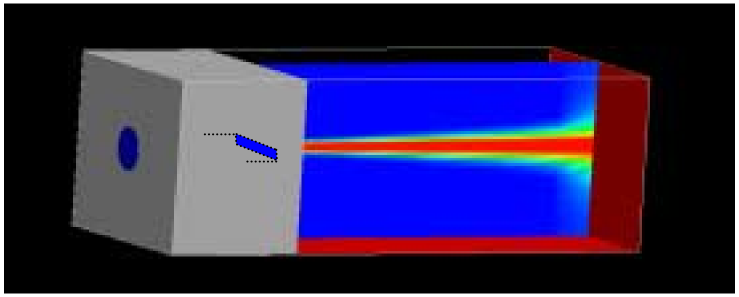
CFD2000 has not given satisfactory results for these problems.



0.3m downstream, v=10m/s



4x25mm outlet, 3.3:1 compression



water flow leaving 4x25mm outlet at 10m/s in air, CFD2000 case for rectangular nozzle

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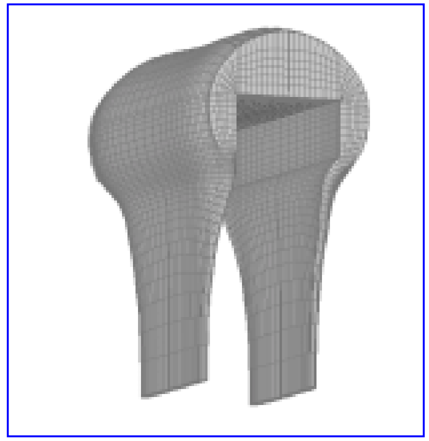
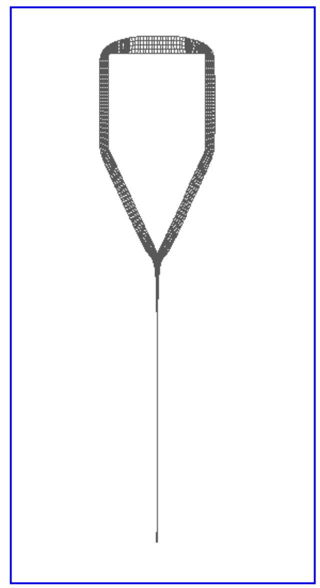
Work on nozzles for Li flow loop

To produce a flat Li stream,
we are investigating the use of a lower velocity, laminar flow, such as flow on ramps or from weirs, to produce a smooth film for heat transfer tests.

This may best simulate (MHD) "slug" flow of liquid metals in magnetic fields.



Model 1 results for GOMA of double film weir overflow



Model 2 results for GOMA 2D film joining and gravity drawdown

Broad film flows are used commercially.

The examples here are from Sandia's Multiphase Transport Processes Dept. They work with industrial partners to develop weir applications in coating and related manufacturing industries.

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Heat Transfer in Liquid Surface PFCs

comments by Richard E. Nygren

1. We probably need more work on jet formation in molten salts if this liquid surface technology is pursued (in APEX).

2. In reactors with high power density, high divertor power is an issue.

Radiation of ~90% of {P_α+$P_{injected}$} is needed in APEX/CLIFF (3.9GW, ARIES-RS) to reduce the power load into the divertor below 100MW.

With 80MW to the divertor, the q''_{peak} >100MW/m^2 for an orthogonal target. *[Rognlien analysis for single null divertor for 2.2GW CLIFF.]*

For high power density fusion reactors,
maybe we need to move the 50MW/m^2 bar even higher.

In APEX Task III, we have suspended work on Sn while we study a Flinabe system, so there is no current ongoing work on a Sn divertor. We hope to restart this work in Task III in late FY2002 or in FY2003.

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