Status of EVOLVE boiling flow regime experiments

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APEX TASK IV

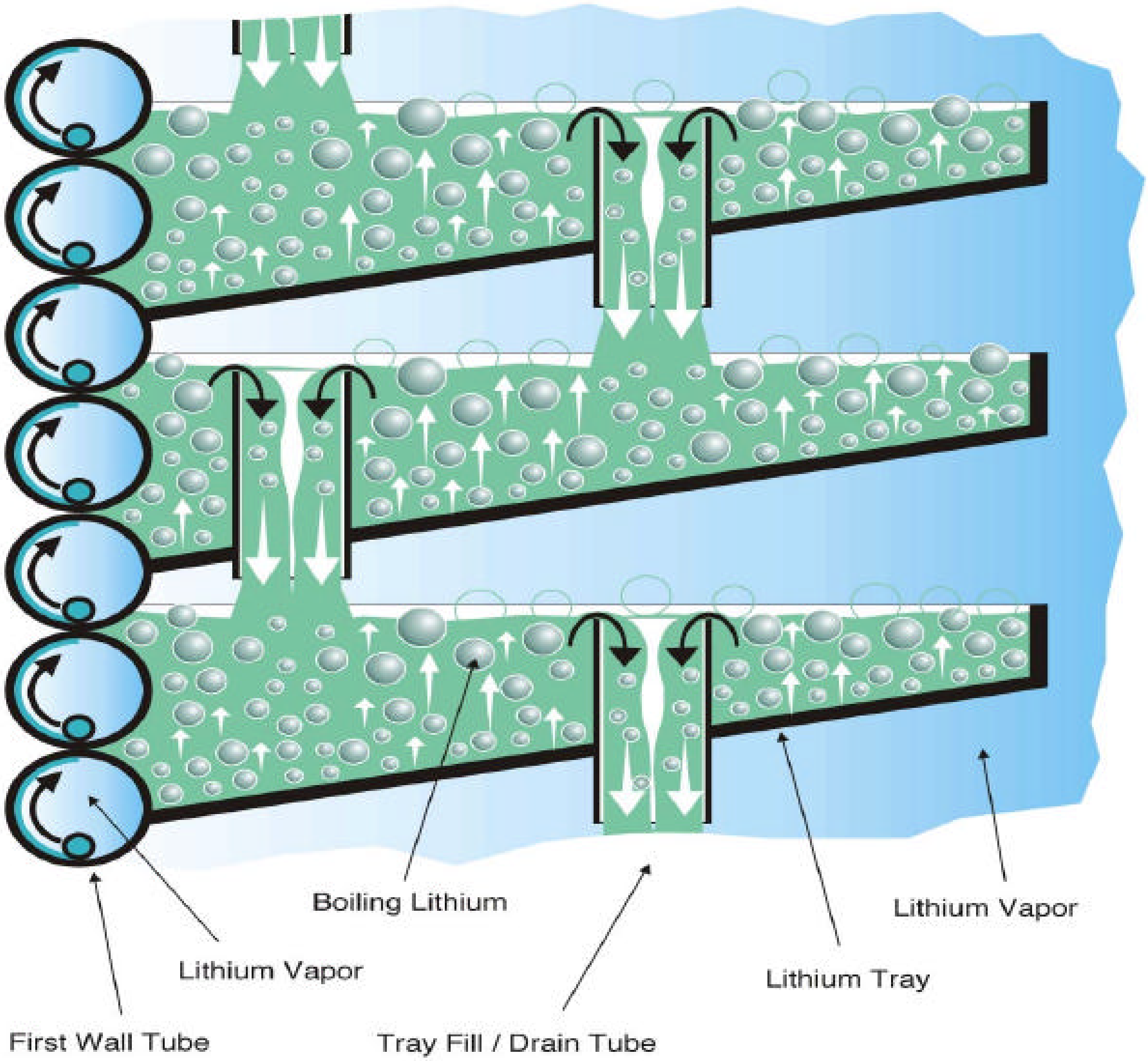
APEX NOVEMBER MEETING

Nov. 7, 2001

Outline

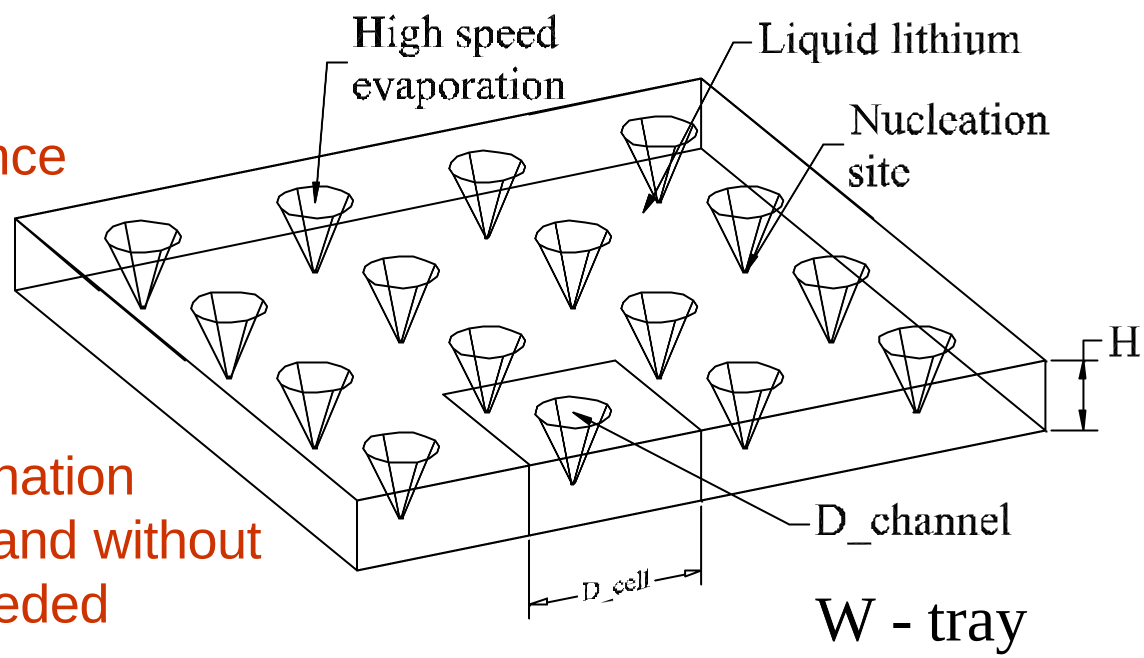
- Motivation for experiment
- Fundamental questions concerning the Evolve boiling concept.
- Scaling Considerations.
- Test section
- N_2- He/NaK experiments
- Experimental results (Void fraction distributions)
- Cryostat design and progress
- Time line of progress
- Summary

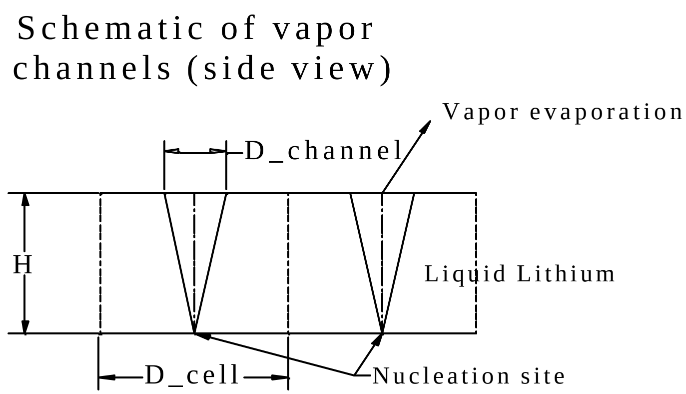
EVOLVE boiling concept

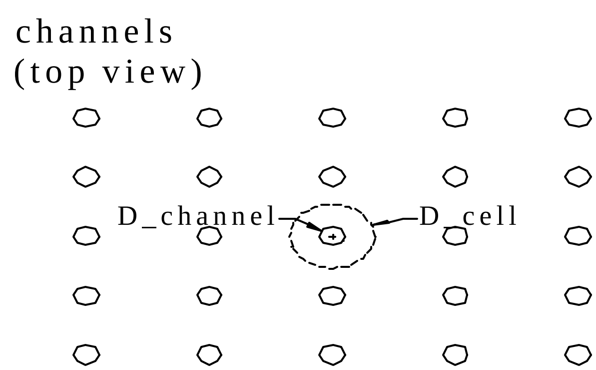


Vapor produced in discrete channels

High vapor generation coupled with the presence of a high magnetic field may result in discrete channels of vapor to be formed by the evaporation. Examination of the flow regime with and without the magnetic field is needed







Questions the experiment will answer.

1. What is the integral vapor fraction and vapor distribution within the pool?

2. Do we produce a stable nucleate boiling regime (simulated by gas injection) and form vapor channels in the conductive pool?

3. What are the effects of the Magnetic field on the void fraction distribution and flow regime.

   - Does the B field result in a gas layer between the pool and bottom plate.

4. How do experimental results compare to analytical theory and numerical results.

How do we answer these questions:

- From previous data magnetic field does not seem to inhibit formation of vapor. This suggests the ability to do “Cold” experiments assuming selective boiling sites for vapor formation.

- Initial “Cold” Experiments with gas injection:
  - Perform tests to visualize fluid mechanics: i.e., flow regimes and CHF within a magnetic field
    - This can be done with bubbling a light gas through a pool of molten metal, while preserving Jg*, density ratio, electrical conductivity, Re and Ha of lithium vaporization.
    - Investigate the effects of the magnetic field on the flow regime and whether it promotes film boiling.
    - Compare flow regime in pool with and without MHD.
- Investigate initiation of channel flow with a porous plate.

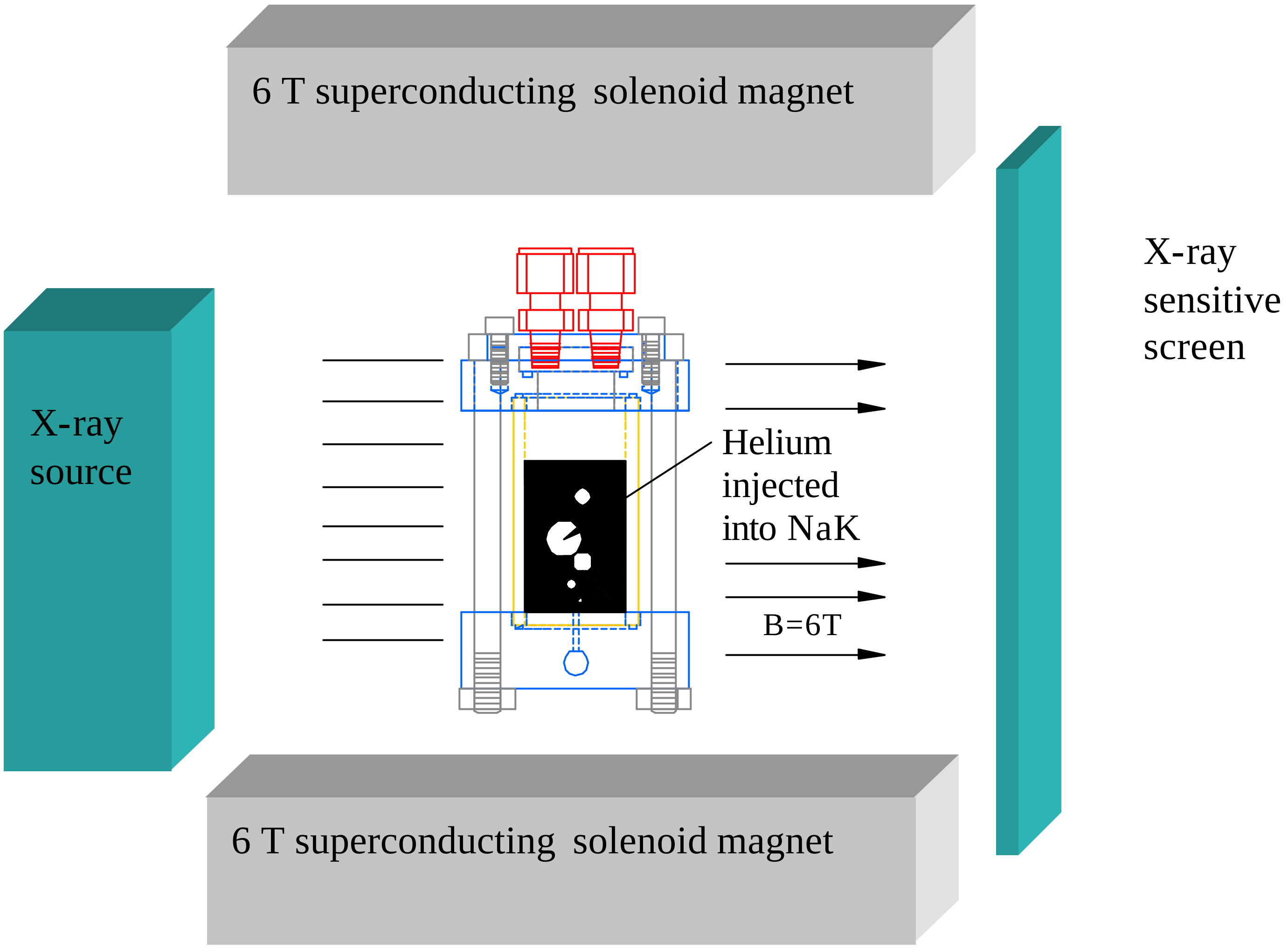
Scaling Considerations

- Based on the neutronic heat loading information given below the vapor production and superficial velocity can be obtained.
- Assuming an average volumetric heating and assuming a volume of 2.54 cm^3 for a single cell, $Jg^{*} \sim 4.5$, $Jg^{*} = [Jg/((\sigma(\rho_l-\rho_g)g/\rho_l^2)^{0.25}]$
- This corresponds to a volumetric flow rate of V = 550 cm^3/s of vapor produced in the the channel.
- Density ratio of vapor/gas to liquid consistent

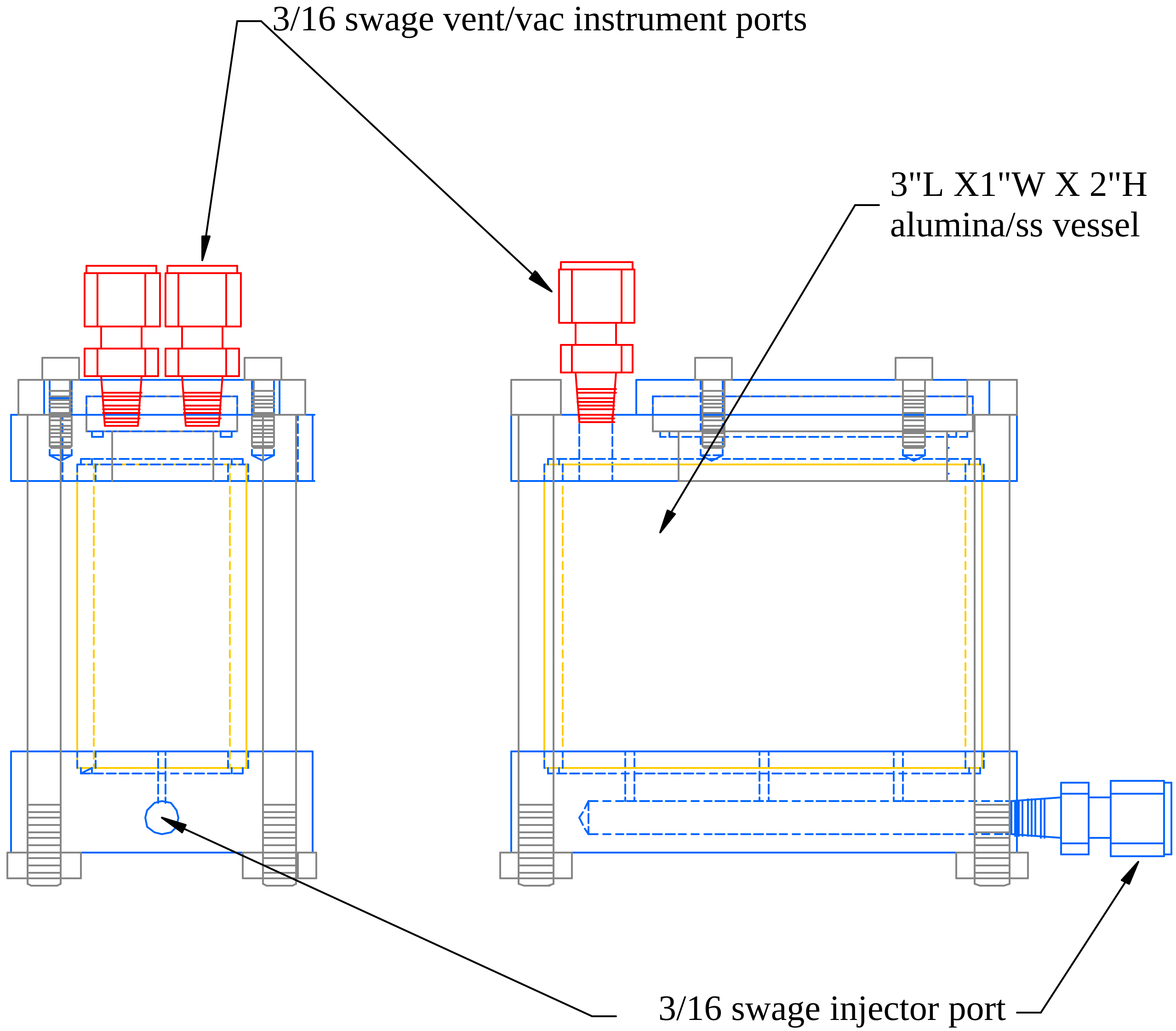
Nuclear Heating (W/cm^3) Distribution in OB Tray
Using Third Iteration Vapor Fraction Distribution

104.4						
104.5	13.5	11.9	10.4	9.3	8.4	56.7
105.5	13.7	12.1	10.6	9.5	8.5	55.8
106.4	14.1	12.3	10.9	9.8	8.8	54.8
107.2	14.6	12.6	11.5	10.3	9.3	53.8
109.0	27.0	23.1	20.0	17.7	16.0	52.7
109.0	98.0	84.2	72.9	64.1	56.8	50.5
110.0						

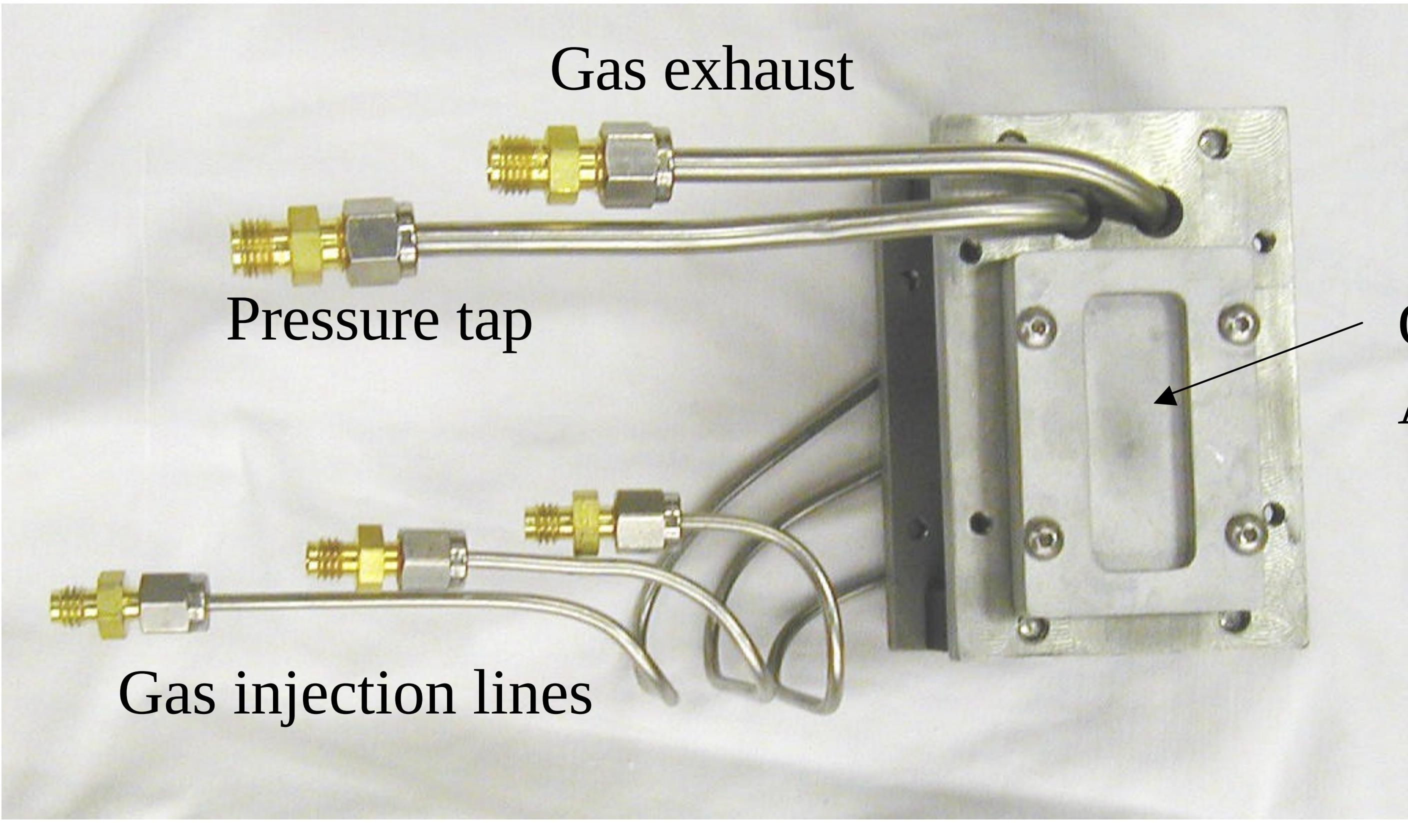
Conceptual picture of experimental system



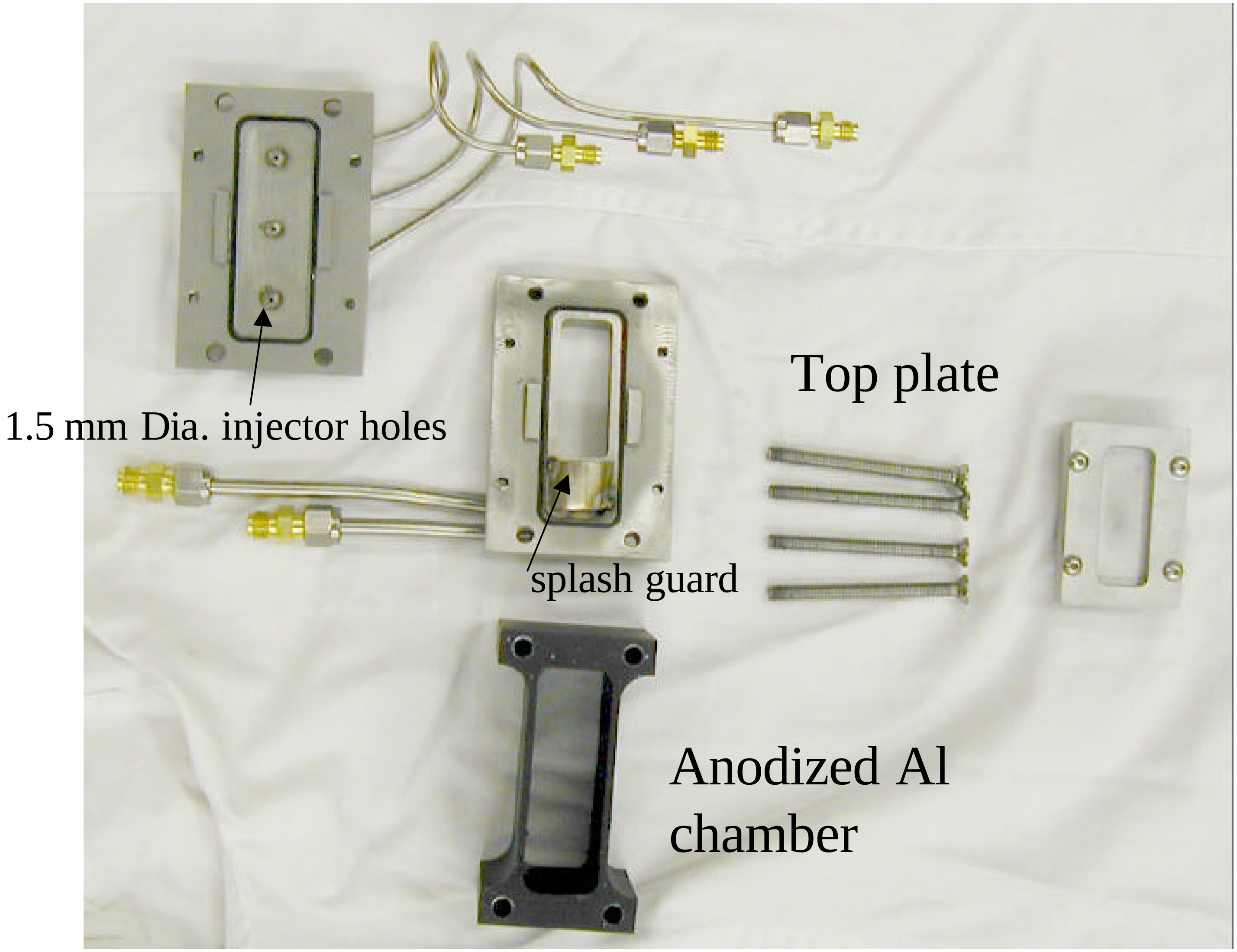
Schematic Diagram of test section



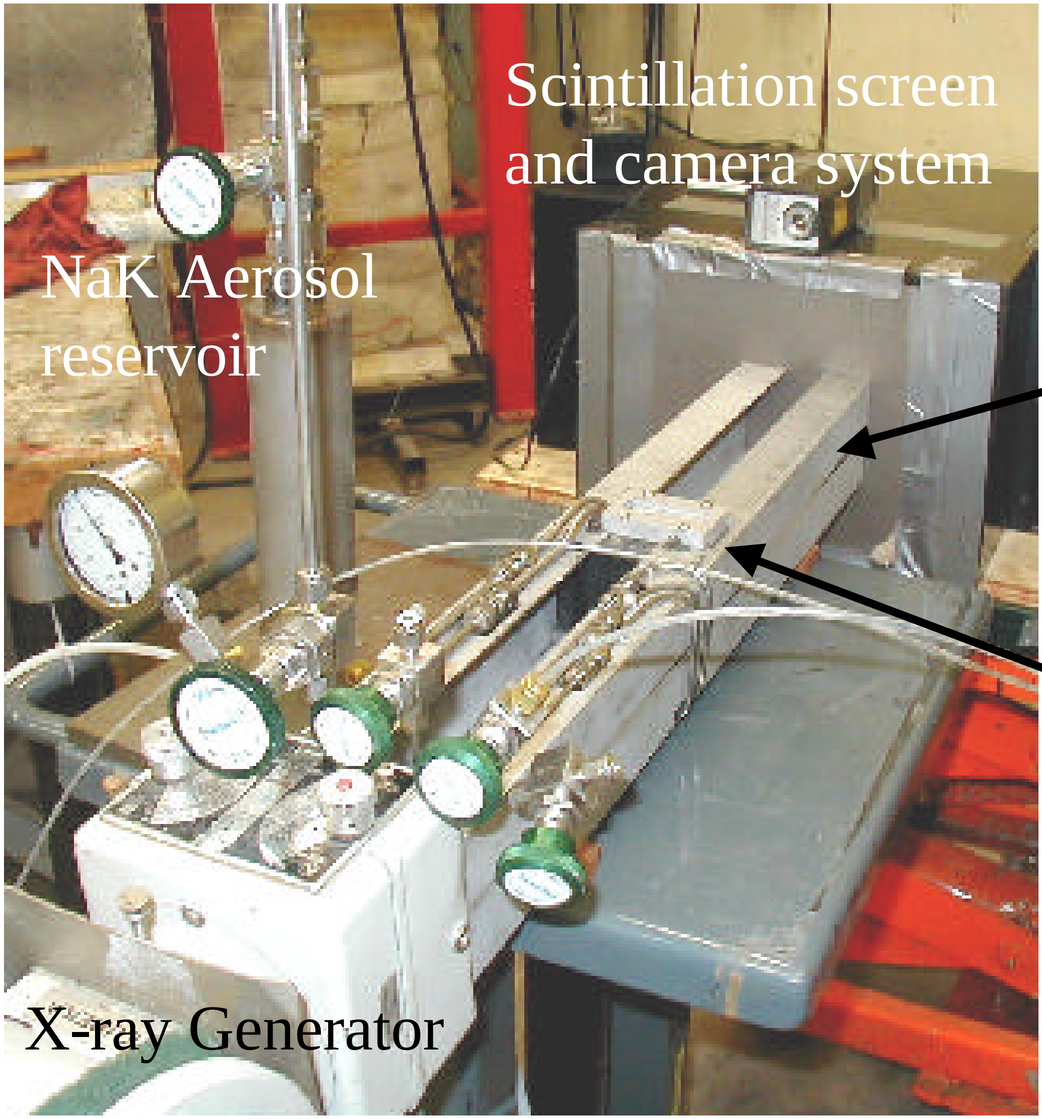
Top View of test section



Individual Parts



X-ray Imaging setup

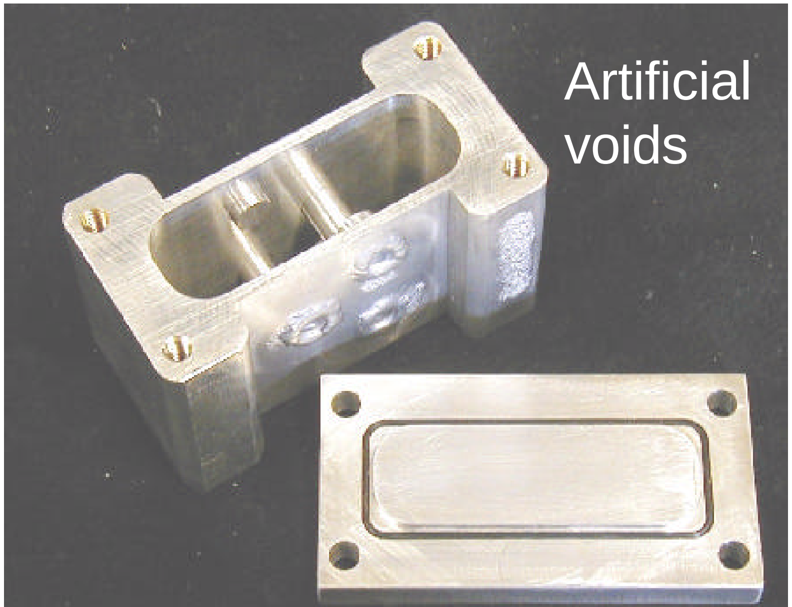


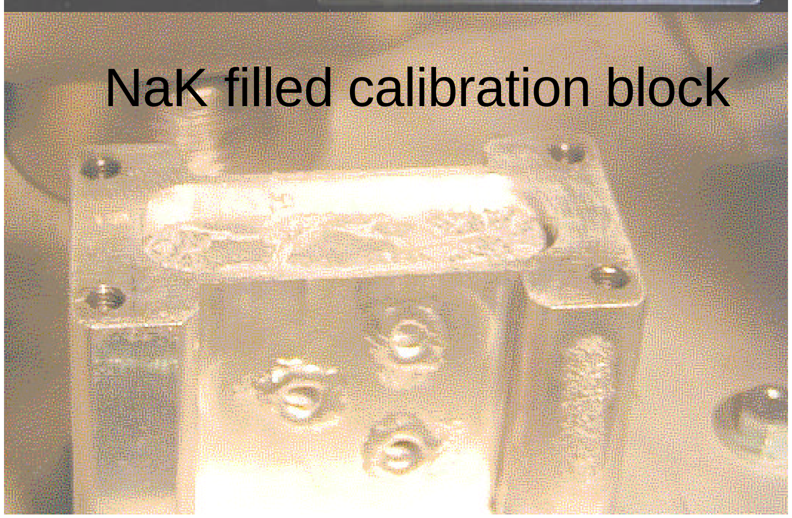
Support Rails for cryogenic chamber

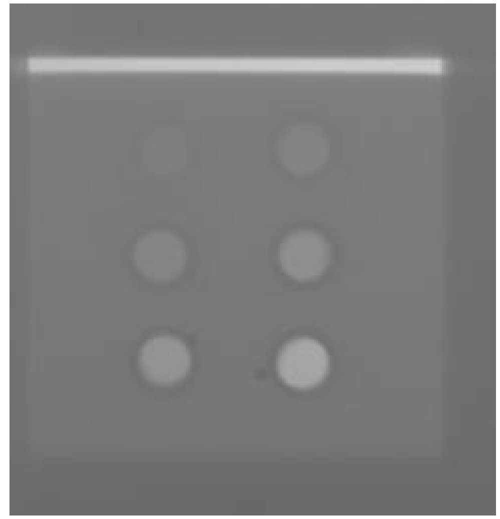
Test section

Injection valves

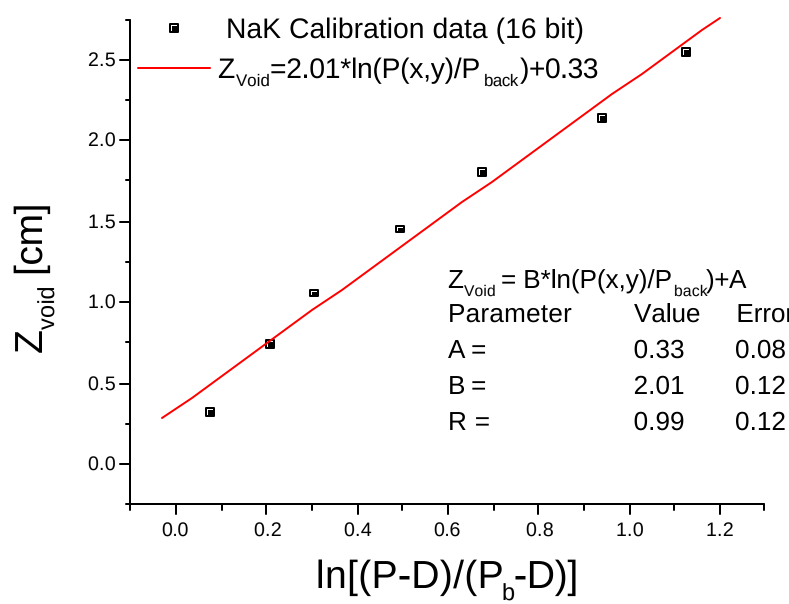
X-ray void calibration





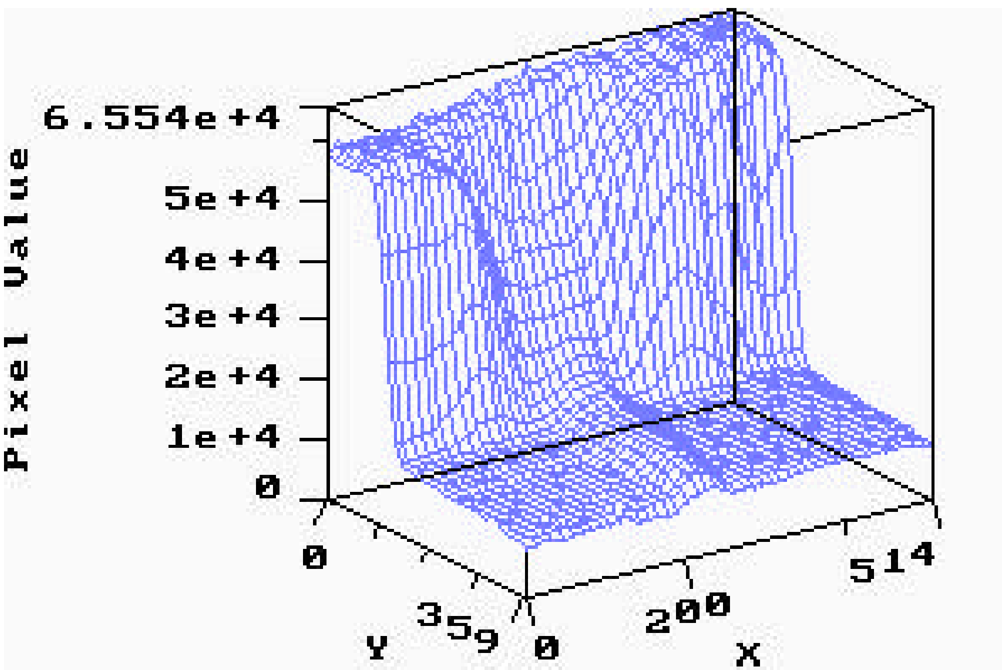


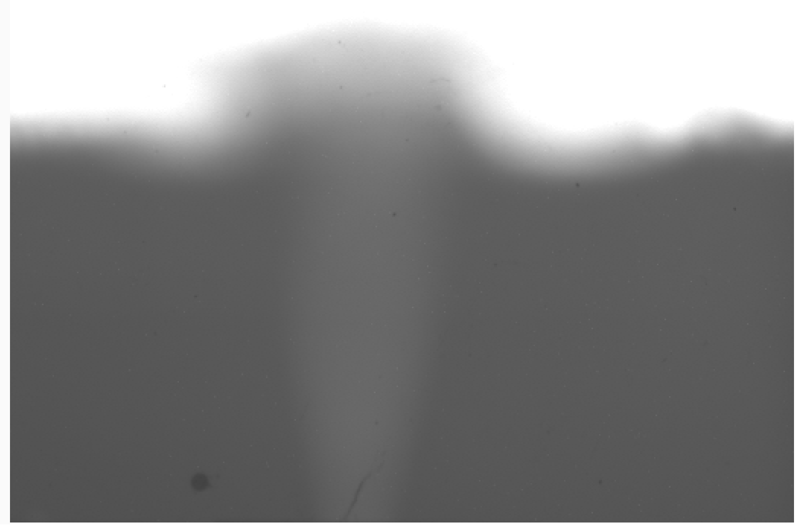
X-ray image of calibration block used to generate the curve below



He/NaK experiments

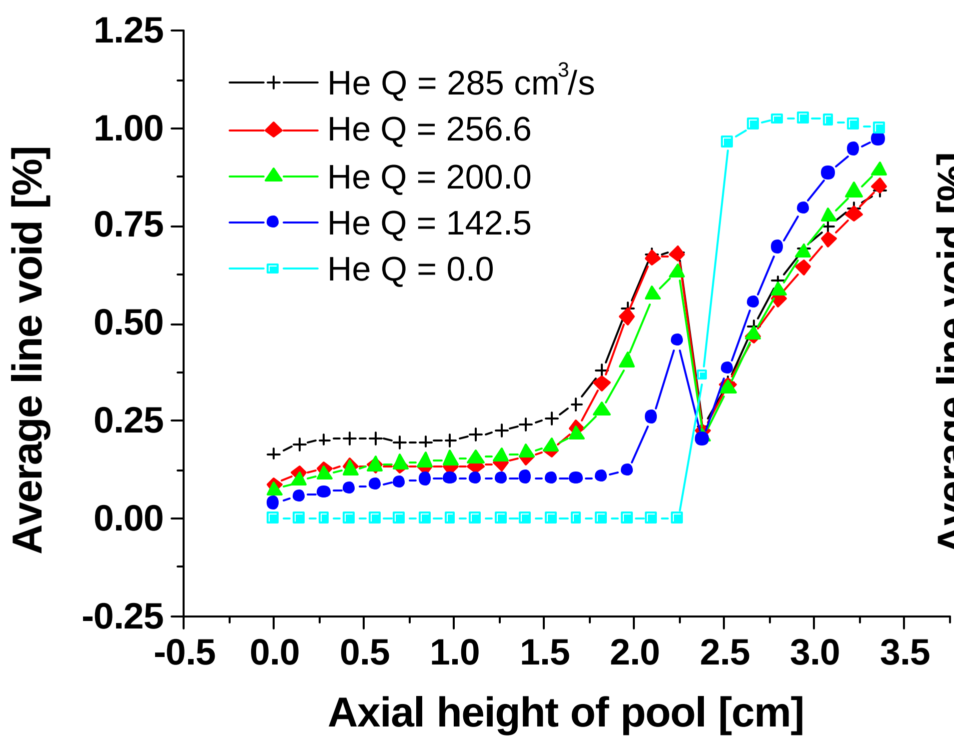
Average void distribution of Helium injected into NaK at 85 cm^3/s.
The pixel value is proportional to the void.

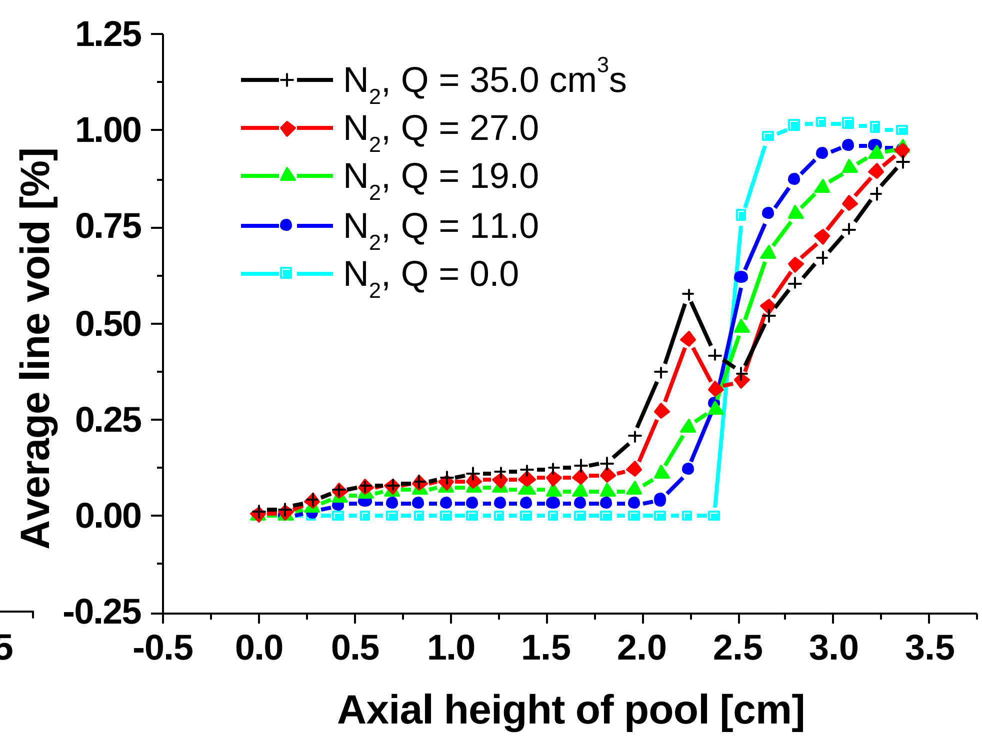




Average void distribution in the NaK pool

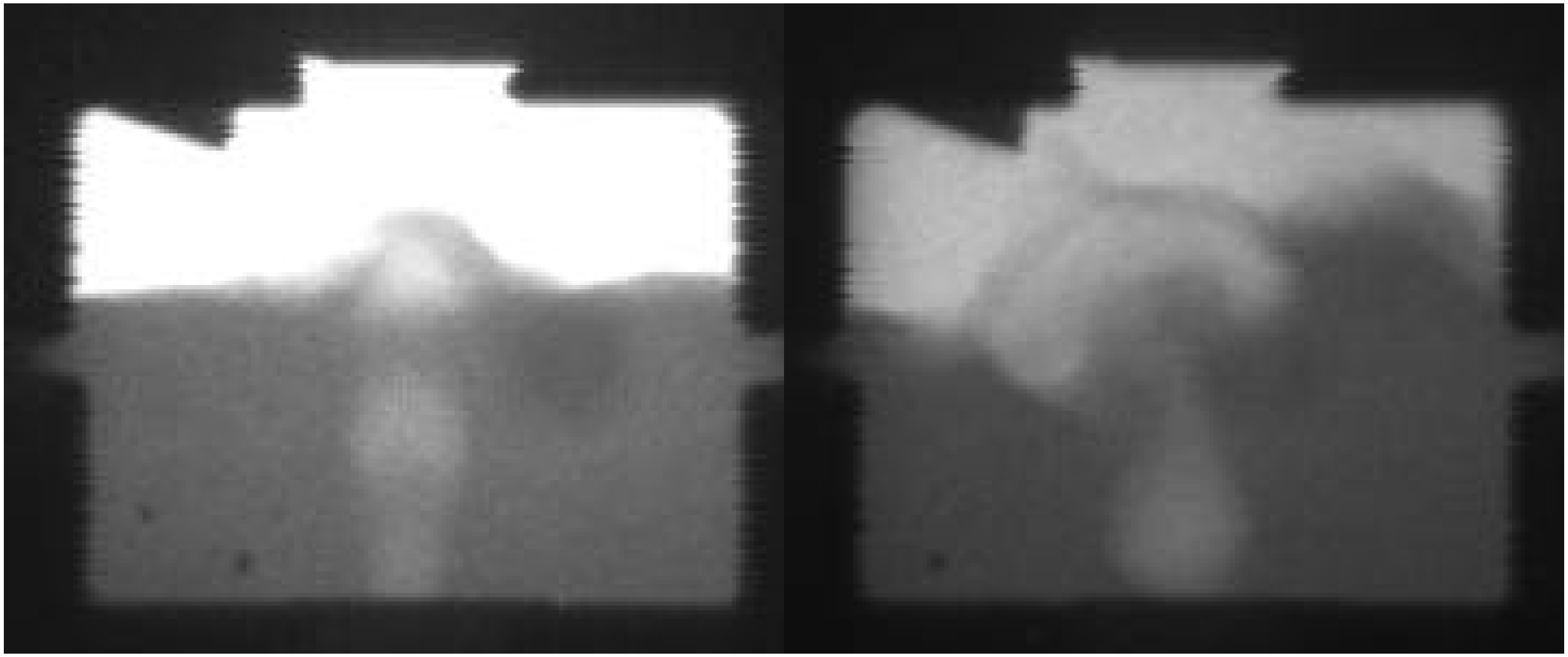
Plots show the average void produced for different volumetric flow rates. As the flow increases the amount of liquid metal lifted by the jet increases.





N_2 - He/NaK experiments:

200 frames taken at 136 fps movie shown at 10 fps



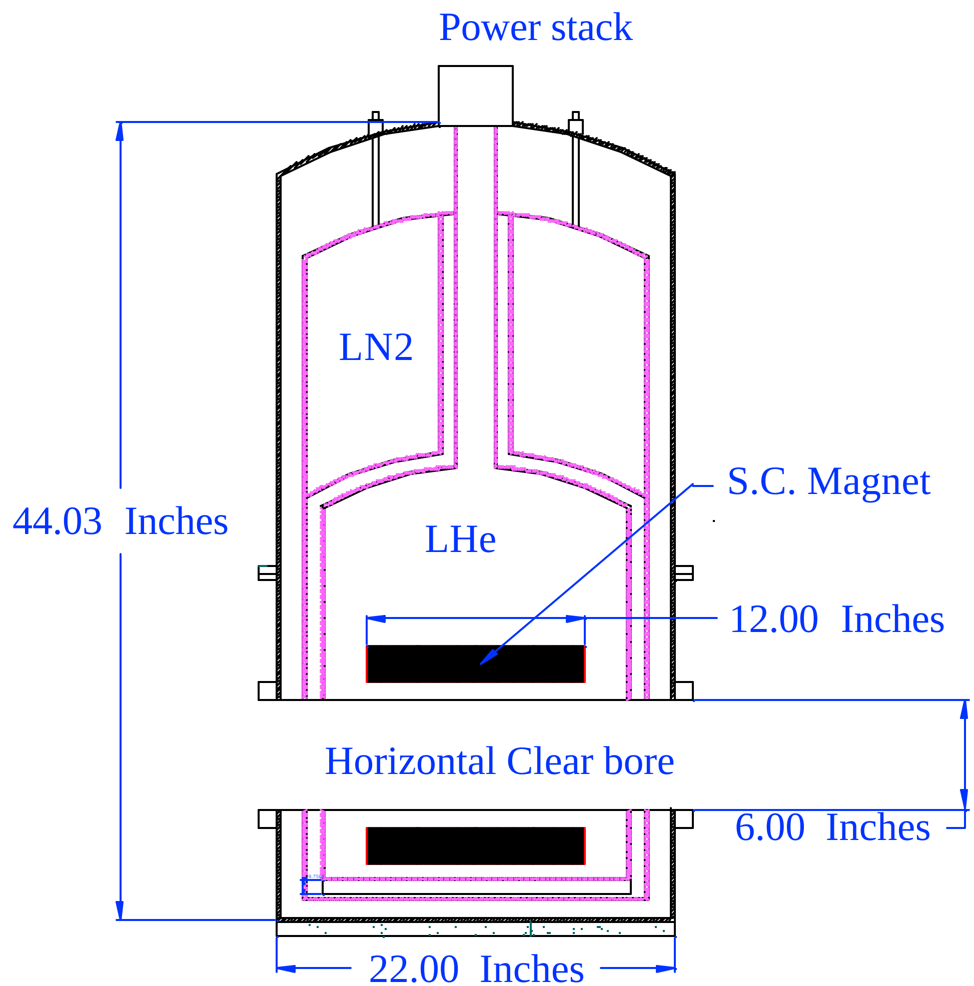
19 cm^3/s N2

285 cm^3/s He

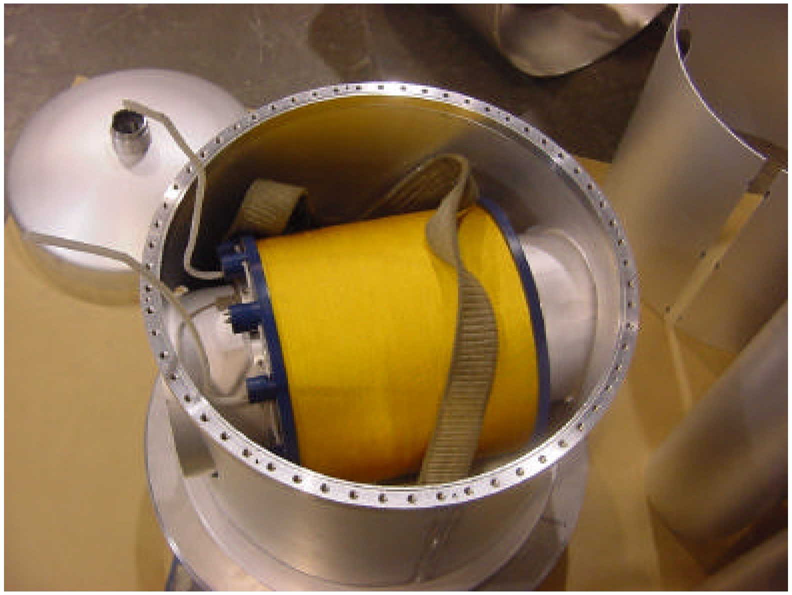
Horizontal 6” clear bore cryo-vessel and magnet

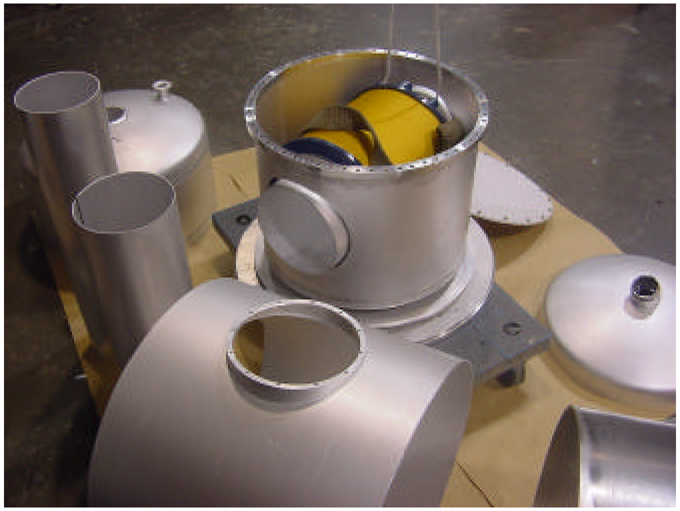
This facility will allow several MHD studies at high field strengths

American Magnetics A6080-3	
Central field	60KG
Clear bore	8.0 inches
Overall Length	12 inches



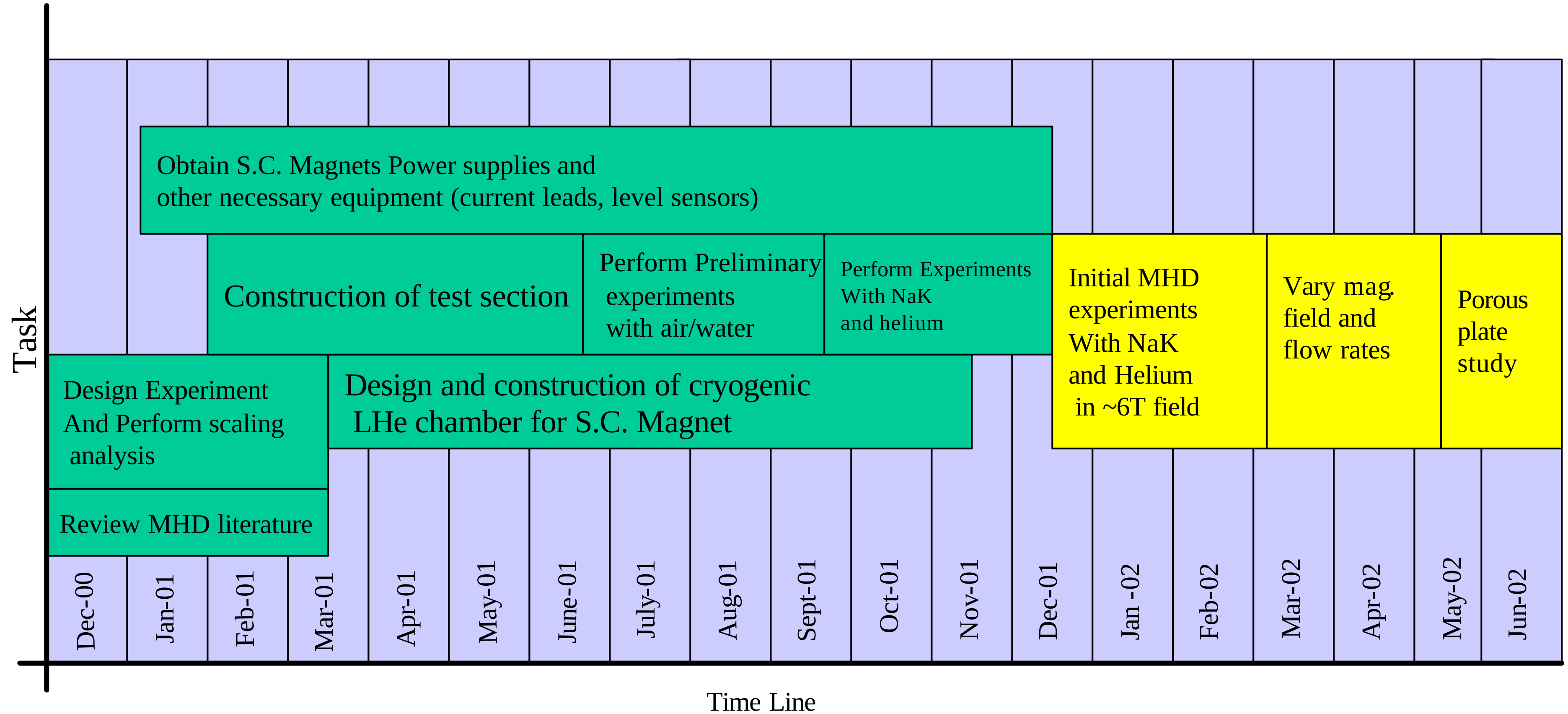
Progress on LHe Cryo- Stat





Schedule of experimental activity

We have completed the tasks shown in the green and are at the stage of preliminary experiments with NaK and helium injection.
The cryogenic system has been designed and is under construction and scheduled for completion sometime this month.



Summary:

Experimental test section and X-ray calibration block have been constructed and instrumentation and control systems for gas injection and magnet operation are in place.

NaK handling system to control O_2 and H_2O during transfer and gas injection is in place.

X-ray image experiments have been conducted for air/water and for N_2 – He/NaK and void –vs- position was obtained for several flow rates. Air/water experiments result in high liquid entrainment and significant decrease in pool volume for low flow rates. He/Nak experiments had little liquid metal entrainment however very violent interactions on the surface of the liquid metal.

The horizontal clear bore cryogenic chamber has been designed and is under construction at Precision Cryogenics Inc. and is expected this month. (this will allow MHD studies for the EVOLVE concept and other APEX MHD design questions)

MHD experiments will be conducted as soon as the cryostat arrives to investigate the flow regimes in the presence of high magnetic fields. These results will then be compared to theory and models.