

Tank Purging Studies at FNAL

Air to Argon without Vacuum



Purpose of Tank Purging R&D

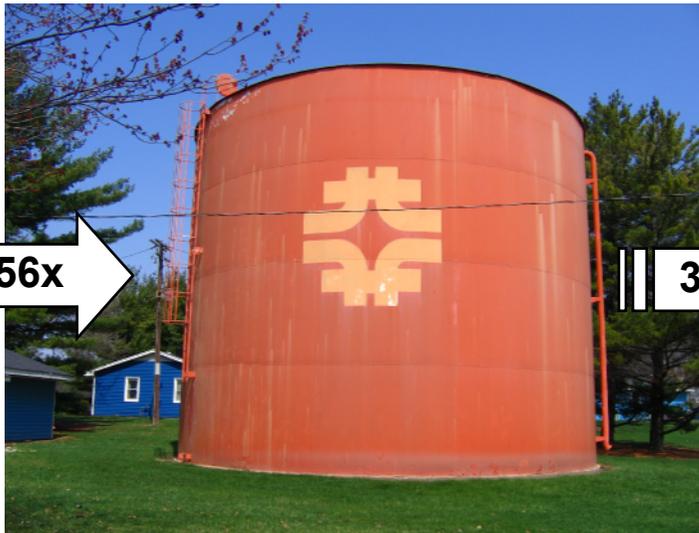
- *In a large tank the majority of oxygen, nitrogen, and water vapor must be removed before liquid argon is introduced into tank*
 - *Must reach a yet to be determined contaminant spec before liquid phase filtration begins*
- *Use low velocity injection of heavier than air argon at tank bottom to act like a piston and push air out*
- *This requires fewer volume changes than “perfect” mixing*

Small, Big, Huge



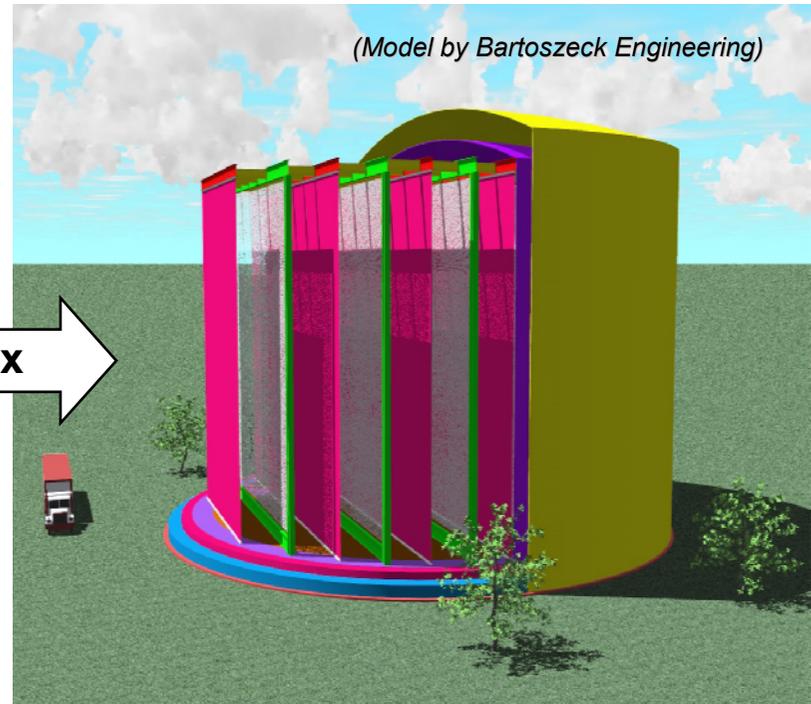
156 ft³

PAB tank
test



40,000 ft³

FNAL Village Water Tank



1,500,000 ft³

50 kton LAr tank

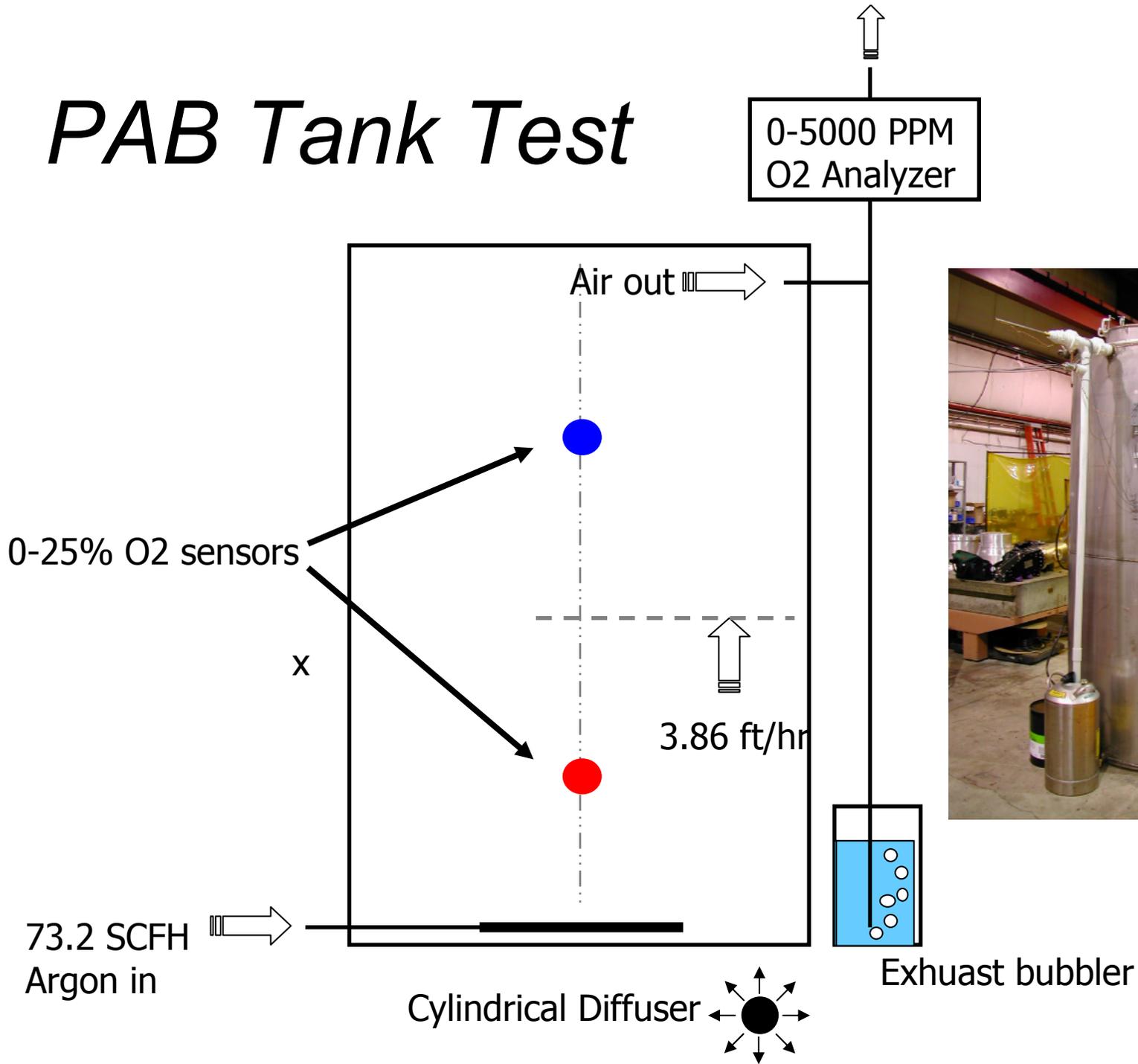
256x

38x

PAB Tank Test

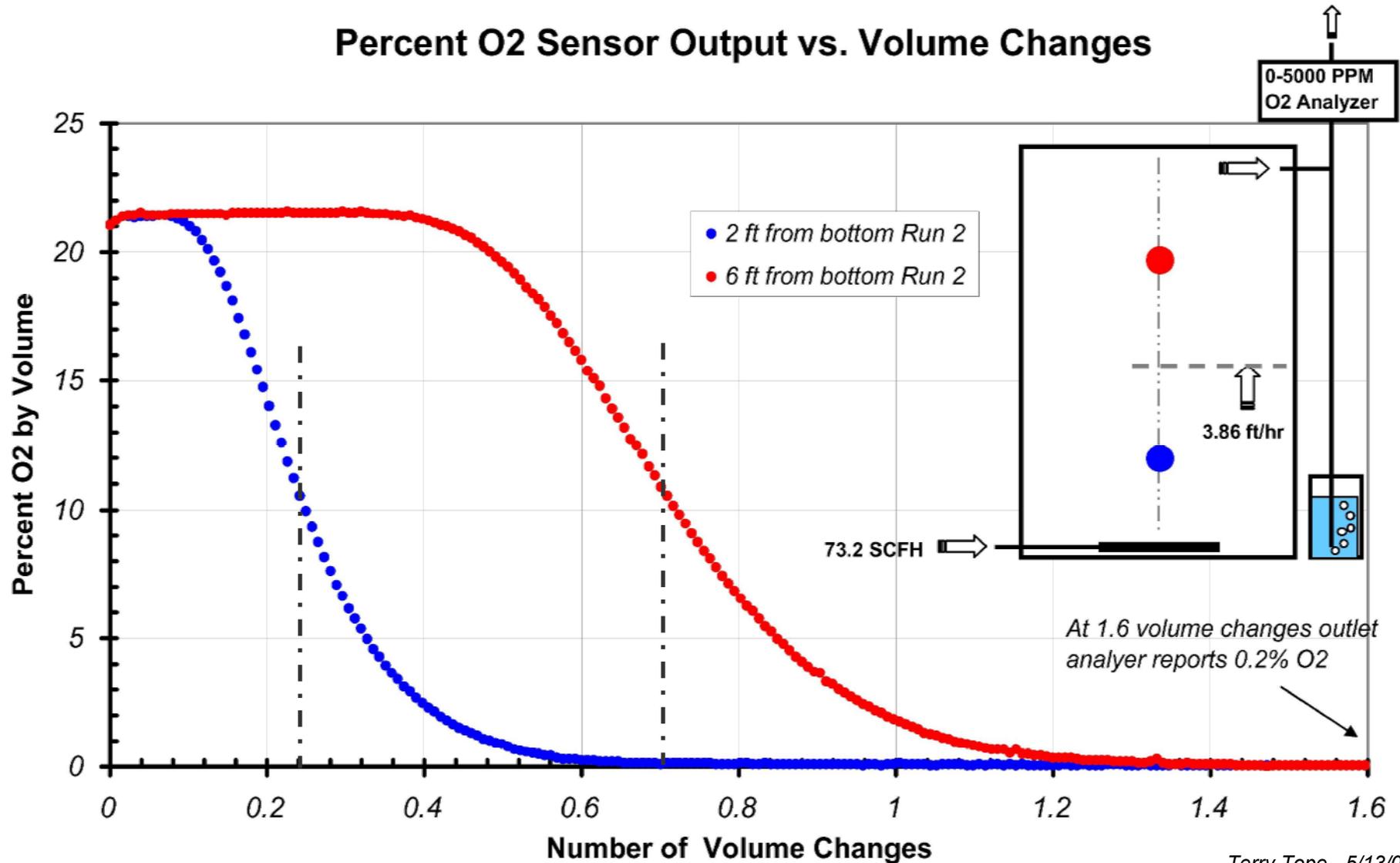
- *Small 156 ft³ Tank inside large building*
- *Isothermal test conditions*
- *Argon introduced thru a diffuser in tank bottom*
- *Experimental O₂ data from air to 15 ppm obtained and compared to*
 - *ANSYS CFD model by Zhijing Tang*
 - *Analytical diffusion model*

PAB Tank Test

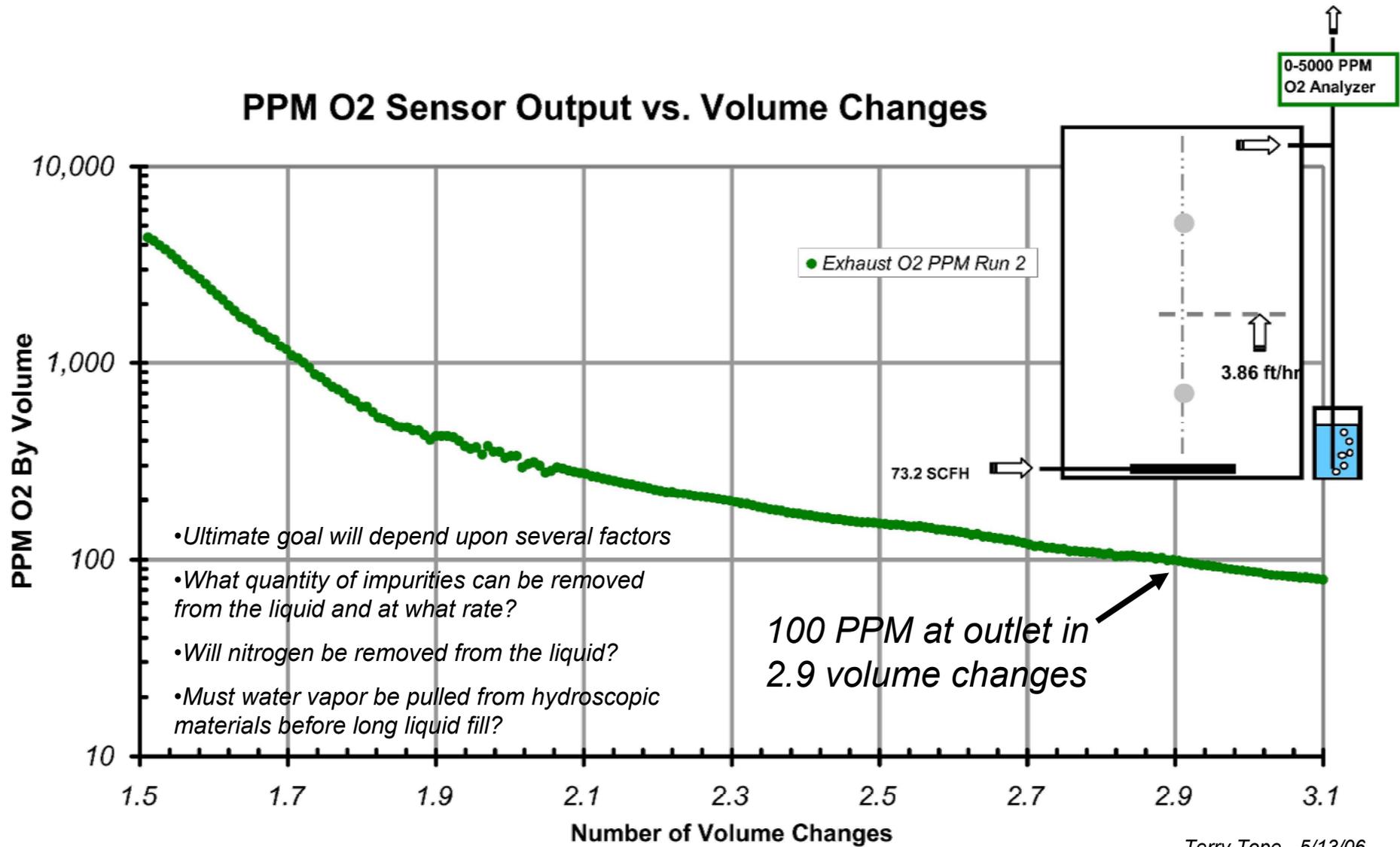


PAB Tank Experimental Results

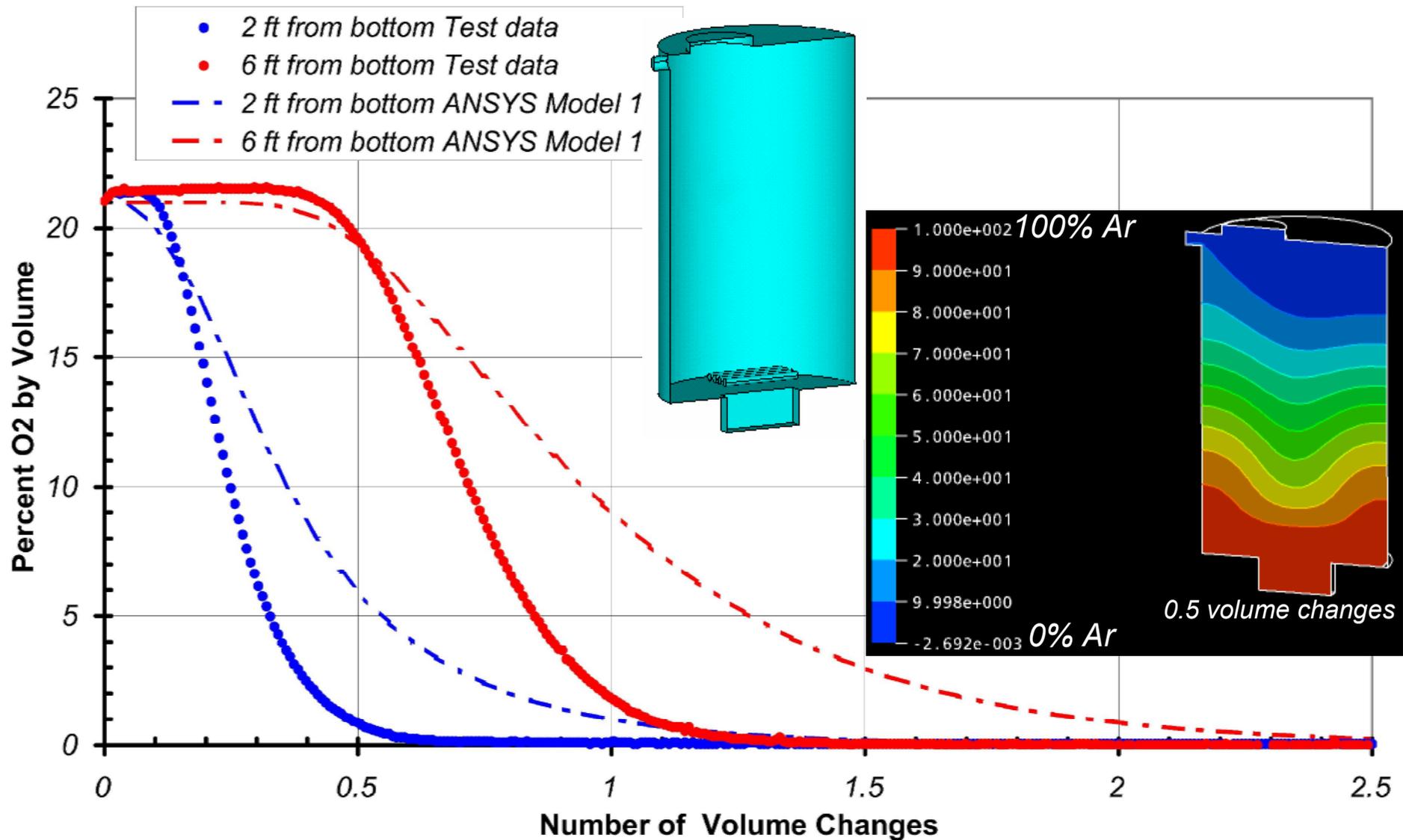
Percent O2 Sensor Output vs. Volume Changes



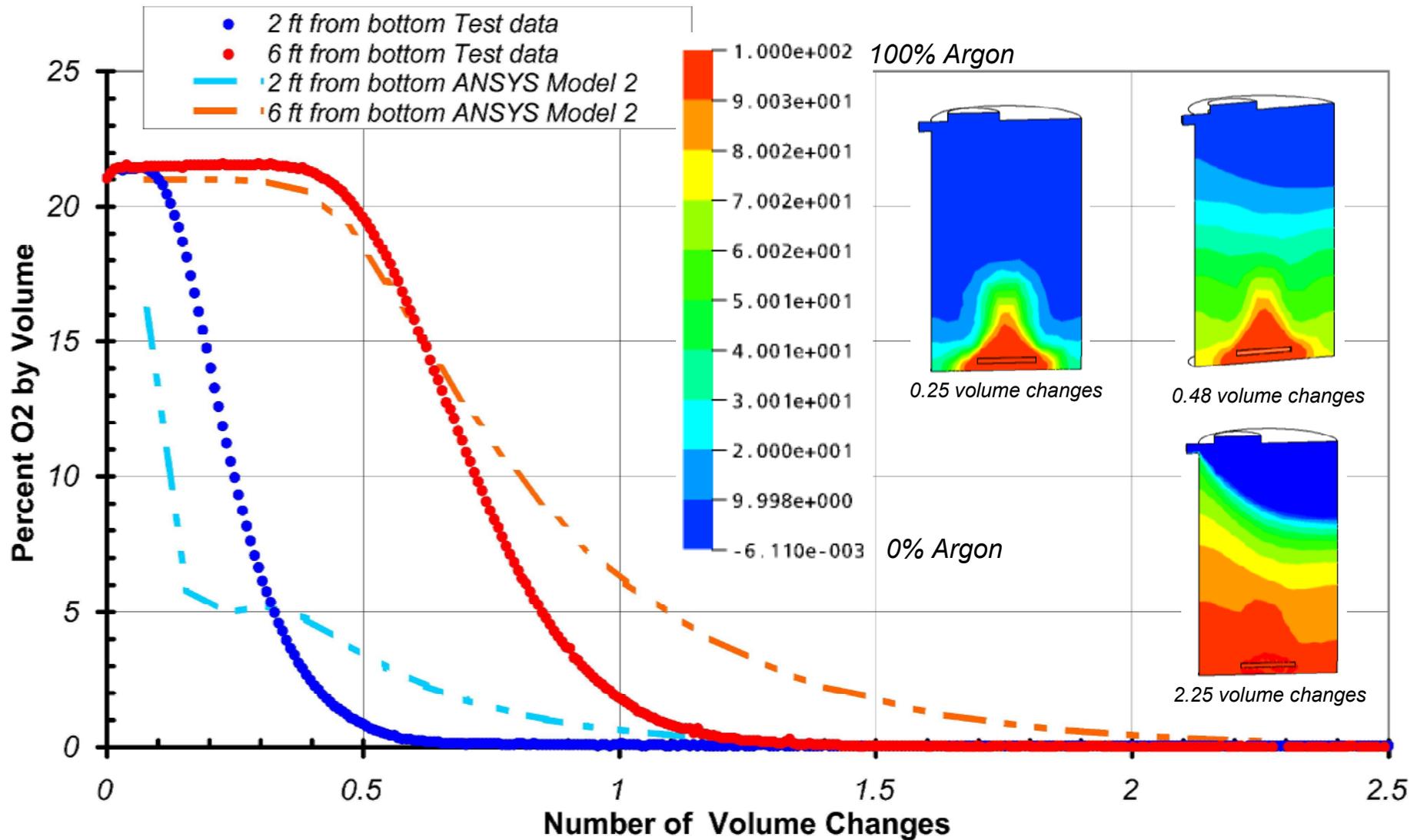
PAB Tank Experimental Results



PAB Tank ANSYS Results – 1st Model



PAB Tank ANSYS Results – 2nd Model



Analytical Diffusion Model

- For 1D species diffusion in x

$$D_{AB} \frac{\partial^2 C_A}{\partial x^2} = \frac{\partial C_A}{\partial t}$$

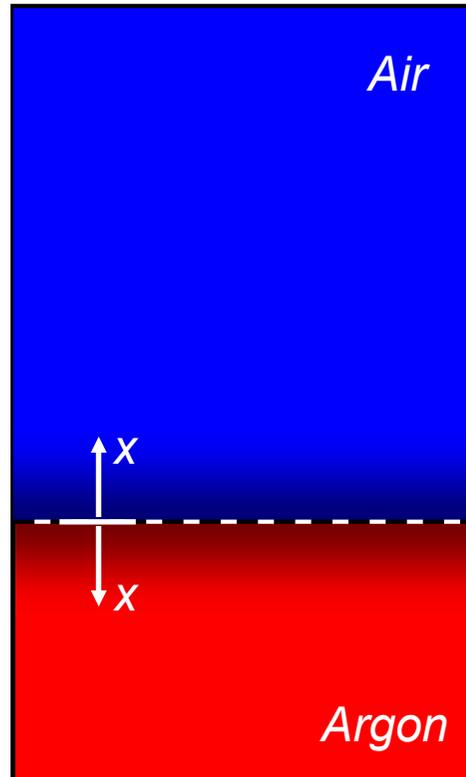
C_A = molar concentration

D_{AB} = mass diffusion coefficient

$D_{AB} = 1.9E-5 \text{ m}^2 \text{ s}^{-1}$ for Ar-Air

Boundary between Air and Argon is always 50% Argon and 50% Air, $x = 0$ at boundary

$$C_A(x, t) = \frac{1}{2} C_{A,s} \left\{ 1 - \operatorname{erf} \left[\frac{x}{2(D_{AB}t)^{1/2}} \right] \right\}$$



IC and BC's

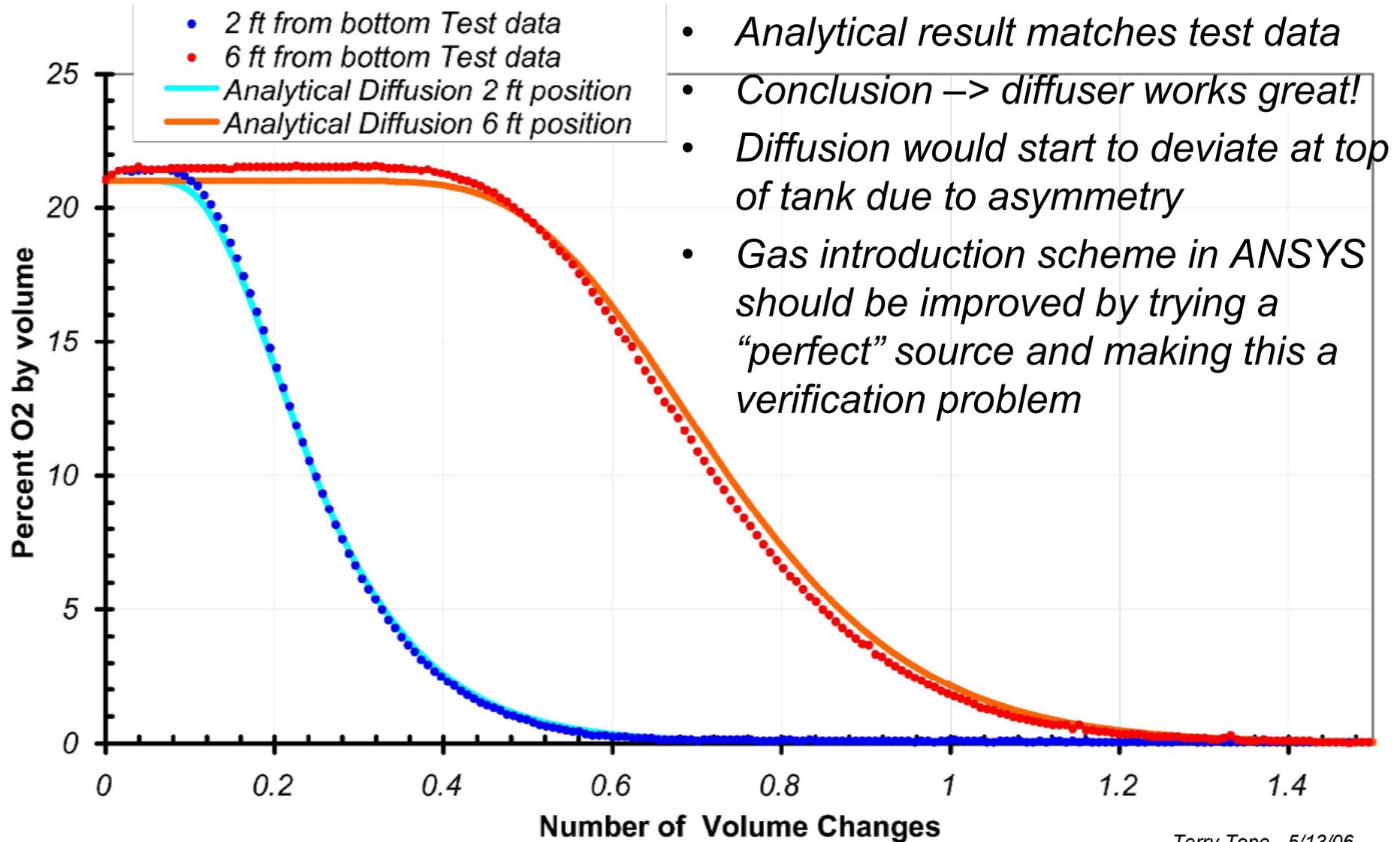
$$C_A(x, 0) = C_{A,i} = 0$$

$$C_A(\infty, t) = C_{A,i} = 0$$

$$C_A(0, t) = \frac{1}{2} C_{A,s}$$

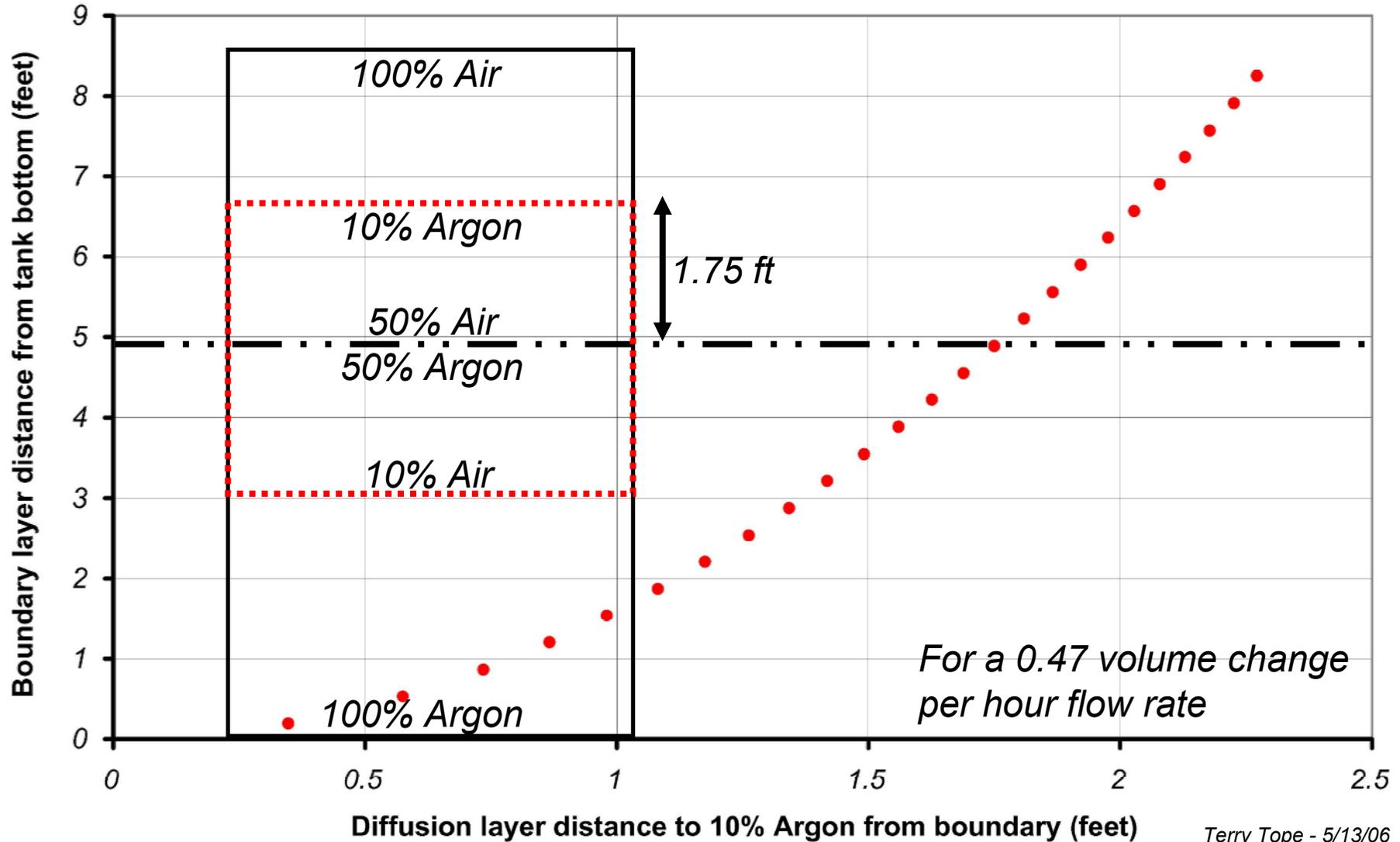
Boundary moves upward at a constant known speed

Analytical Diffusion Model



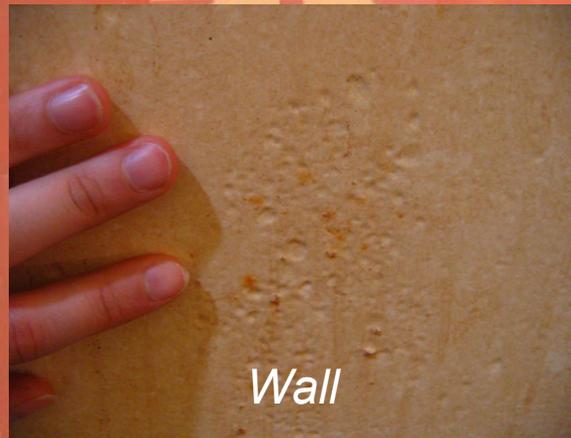
- Analytical result matches test data
- Conclusion → diffuser works great!
- Diffusion would start to deviate at top of tank due to asymmetry
- Gas introduction scheme in ANSYS should be improved by trying a “perfect” source and making this a verification problem

Analytical Diffusion Model



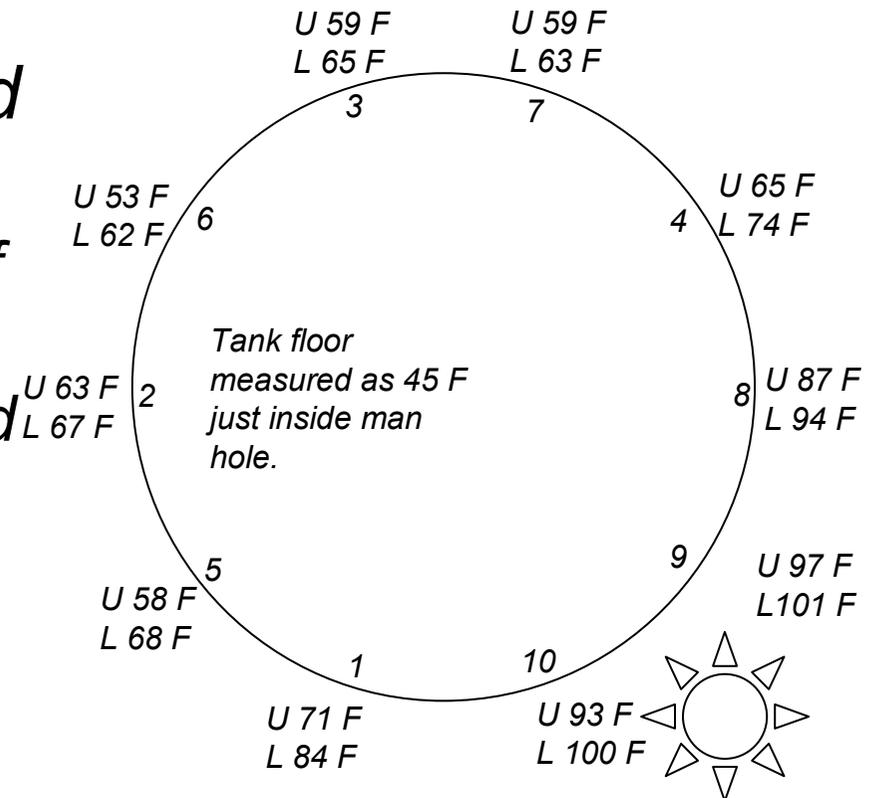
Village Tank

- 40,000 ft³ decommissioned water tank
- Current condition....



Village Tank

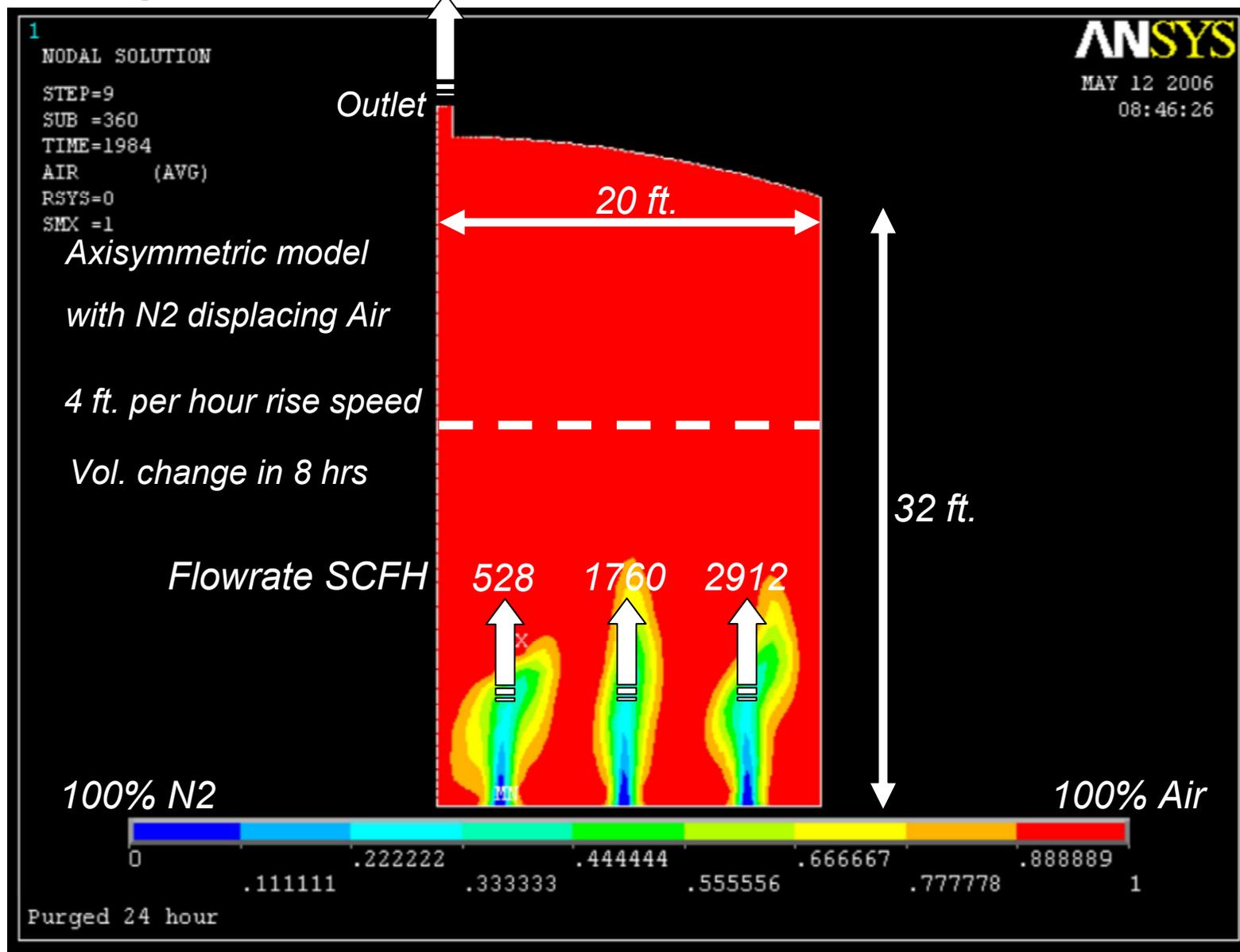
- *Constructed of 1/4 steel*
 - *Walls and roof are thin and poor thermal conductors*
 - *Large temperature gradient measured on sunny day*
- *Large cryogenic tank would be well insulated*
 - *Need to understand effect of thermal gradient on test*
 - *Do convection cells form and cause mixing?*
- *Possible solutions*
 - *Introduce cold gas*
 - *Cool tank walls with water*



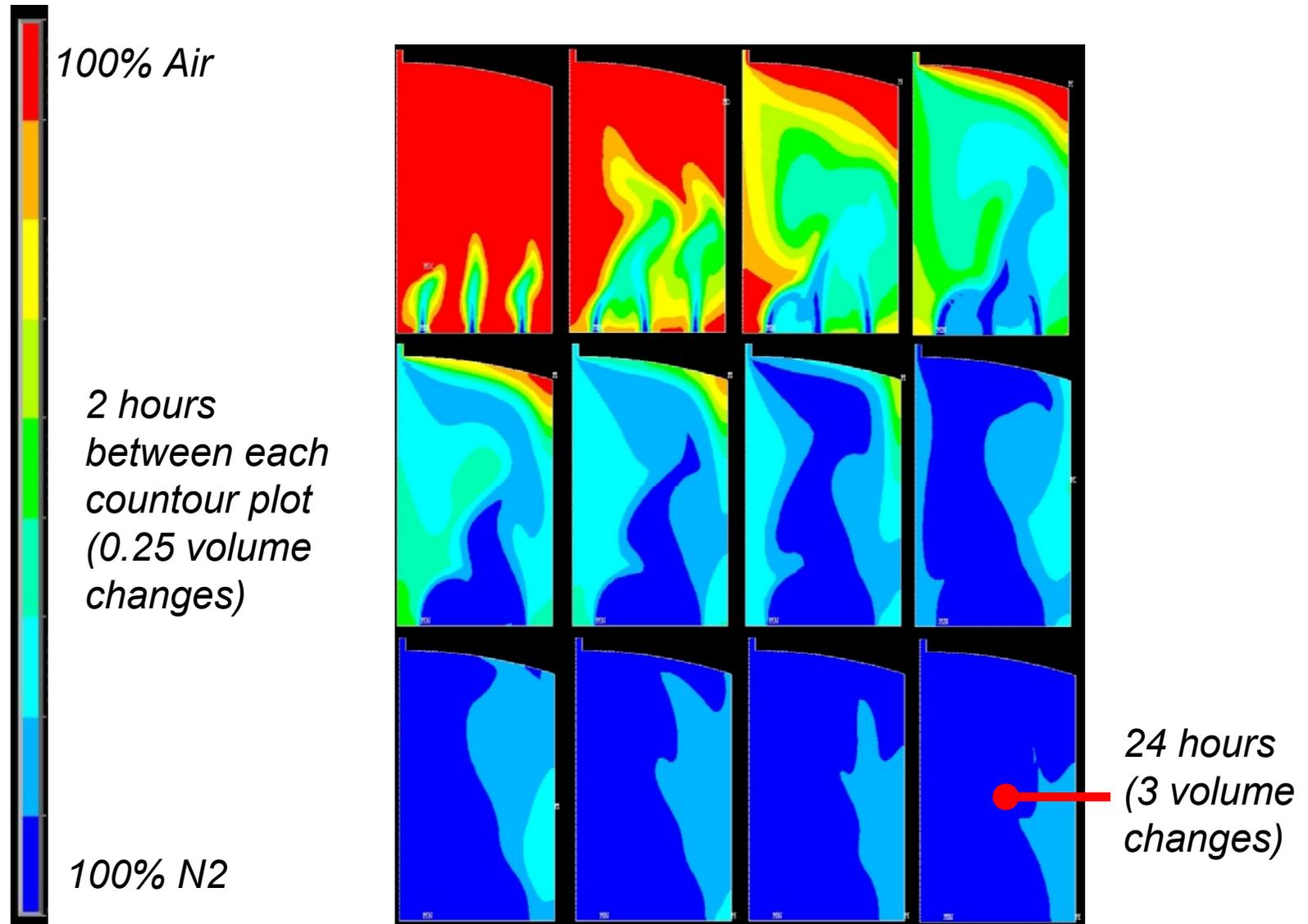
Village Tank

- *Village tank purge testing will allow*
 - *Development of practical scheme for diffusing the gas introduced into a large cryogenic tank*
 - *Development of computer model*
 - *Characterization of the level of tank cleanliness needed to reach the purge spec*
 - *Purity test station at PAB will help develop spec for N₂, H₂O, etc.*
- *As a 1st step an axisymmetric CFD model of the village tank has been solved with N₂ displacing air*
 - *Tests will be performed 1st with N₂ because Argon is much more expensive (~7x)*

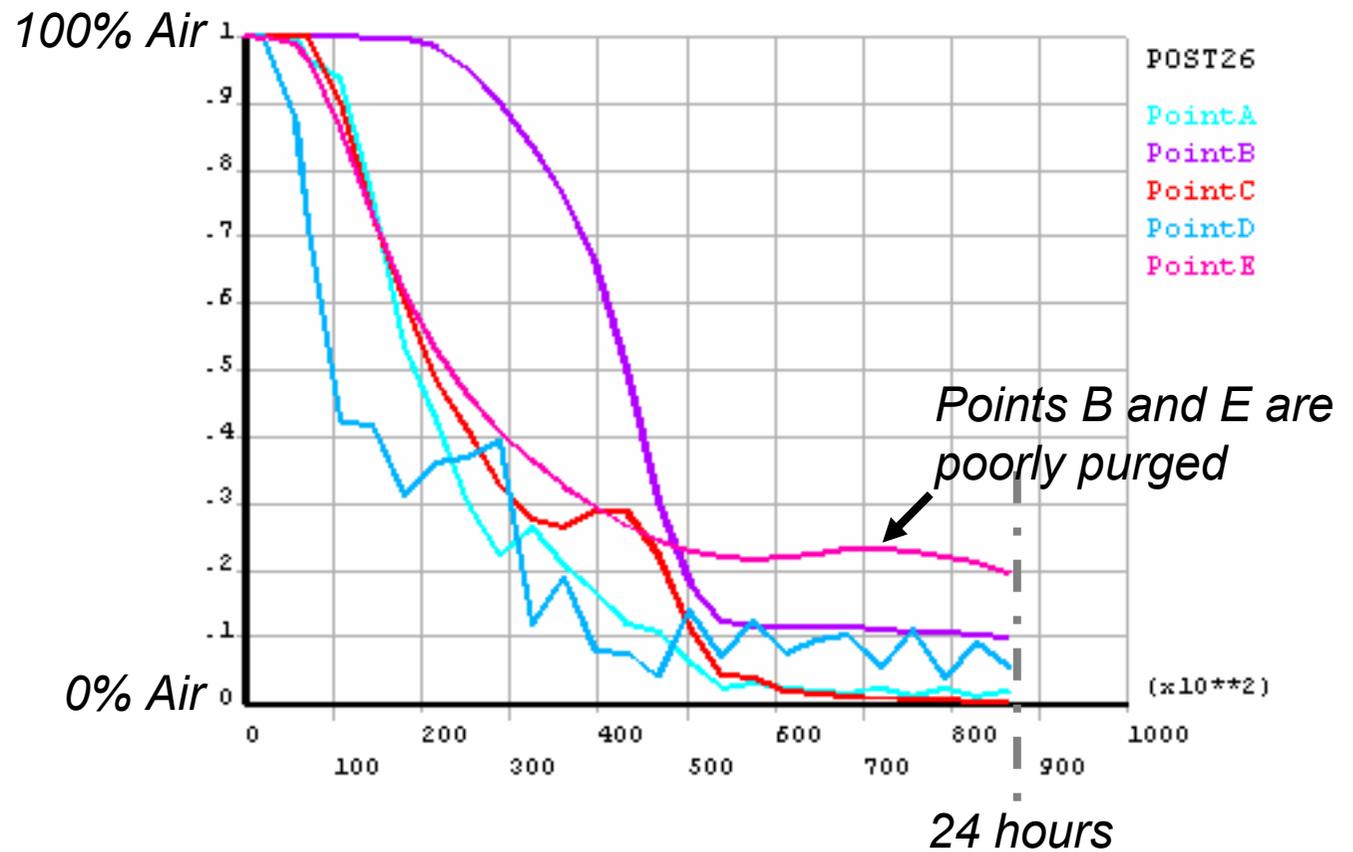
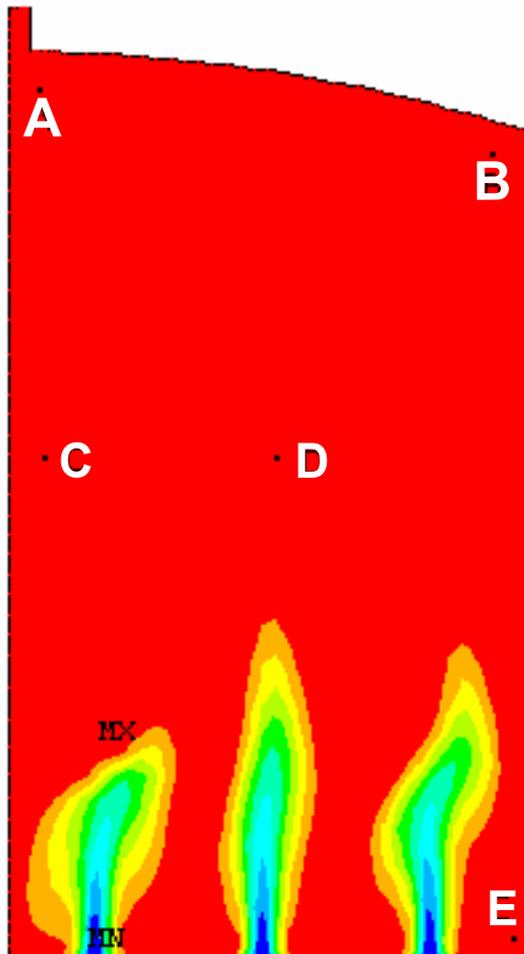
Village Tank – 1st ANSYS Model



Village Tank – 1st ANSYS Model



Village Tank – 1st ANSYS Model



Village Tank – Future Work

- *Plan for village tank*
 - *Improve ANSYS model with PAB setup*
 - *Run test with Nitrogen*
 - *Run test with applied temperature gradient*
 - *Use ANSYS to develop tank purge test*
 - *Determine village tank diffuser locations*
 - *Understand effect of wall temperature gradient*

Village Tank – Future Work

- *Task list*
 - *Remove muck from tank floor and pressure wash walls*
 - *Instrument tank with O₂ and temperature sensors*
 - *Fabricate internal argon manifold*
 - *Prepare site to produce gas from a liquid cryogenic trailers*
- *Future-Future*
 - *Purge microTPC or materials test cryostat and reach high purity liquid using internal liquid filter without evacuation as a first test of the complete cycle*