Tank Purging Studies at FNAL

Air to Argon without Vacuum

Terry Tope

FLARE Meeting 5/13/06

Purpose of Tank Purging R&D

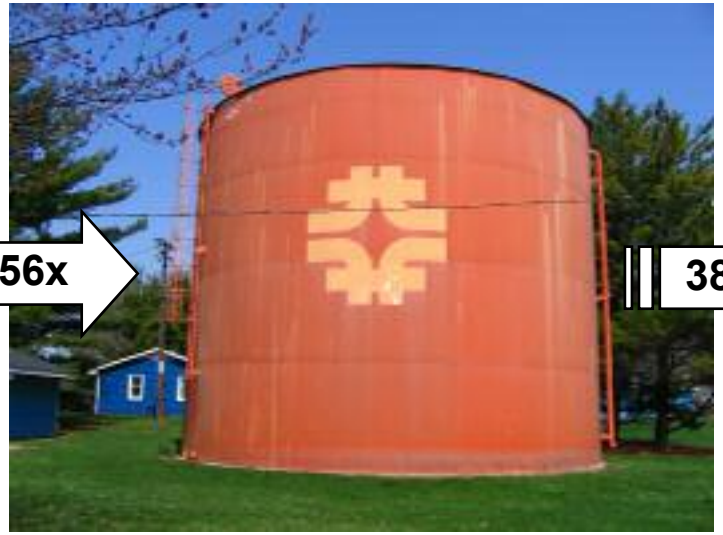
- *In a large tank the majority of oxygen, nitrogen, and water vapor must be removed before liquid argon is introduced into tank*
  - *Must reach a yet to be determined contaminant spec before liquid phase filtration begins*
- *Use low velocity injection of heavier than air argon at tank bottom to act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

Small, Big, Huge

156 ft³

PAB tank test

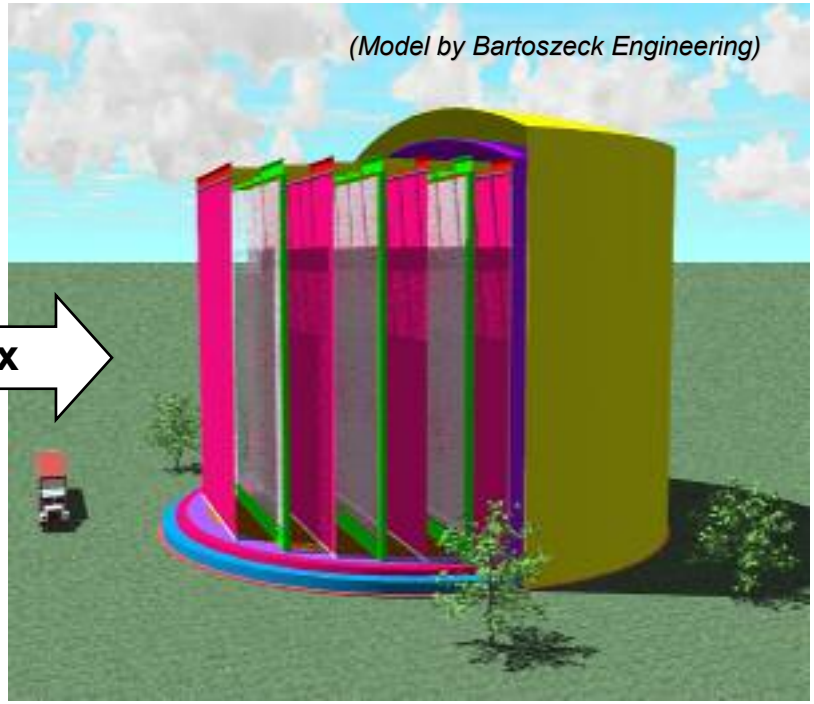
256x



40,000 ft³

FNAL Village Water Tank

38x



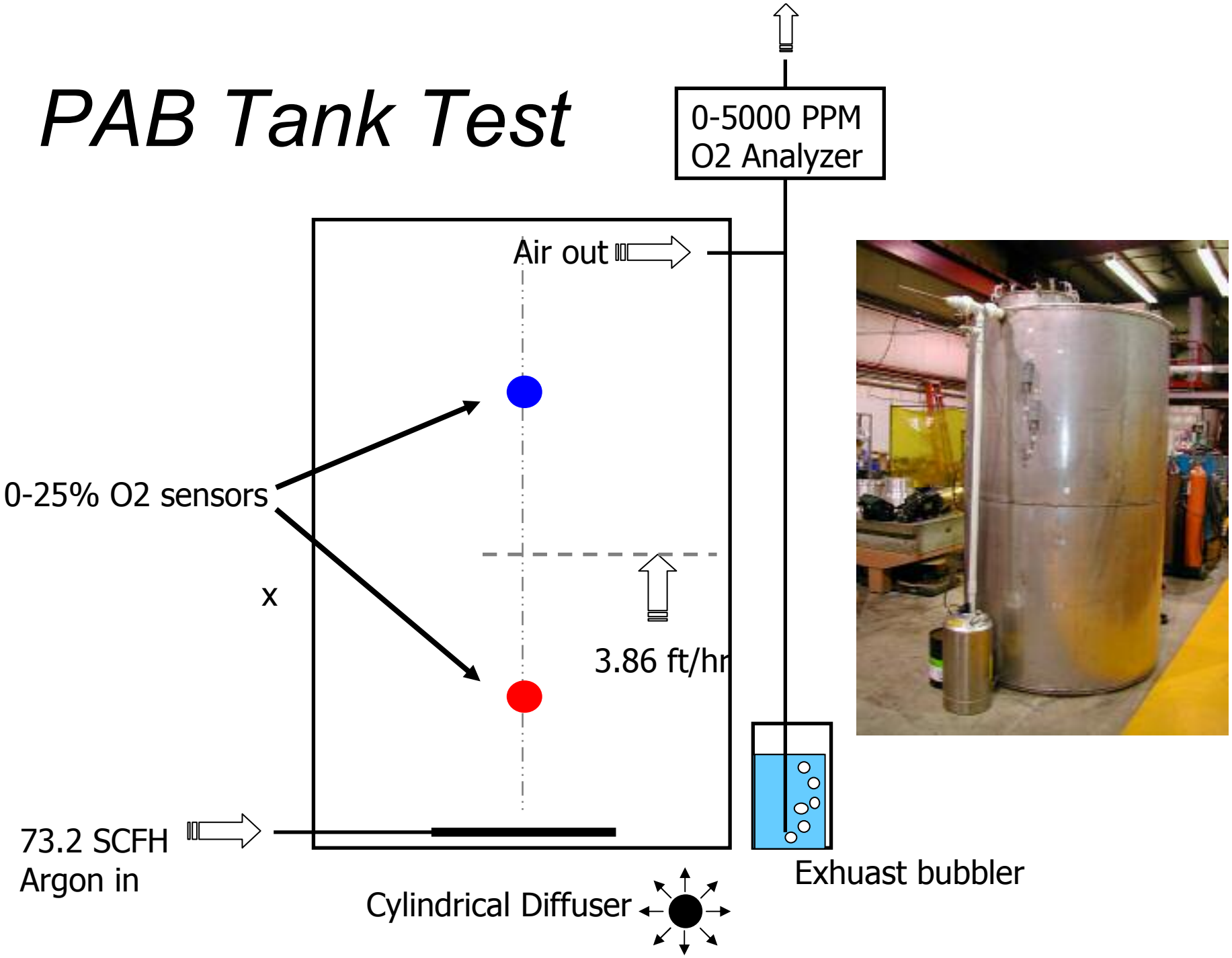
1,500,000 ft³

50 kton LAr tank

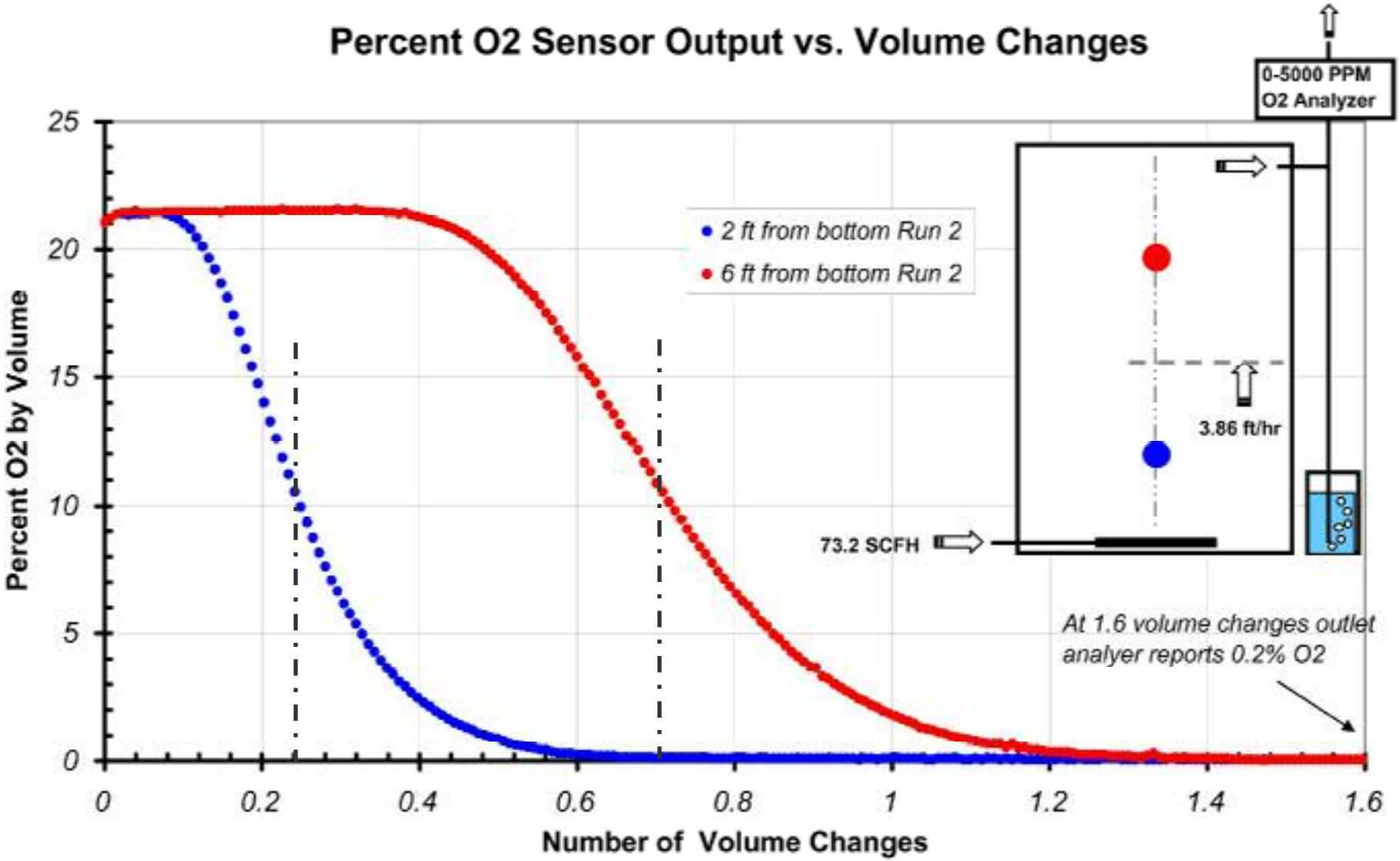
PAB Tank Test

- *Small 156 ft^3 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*

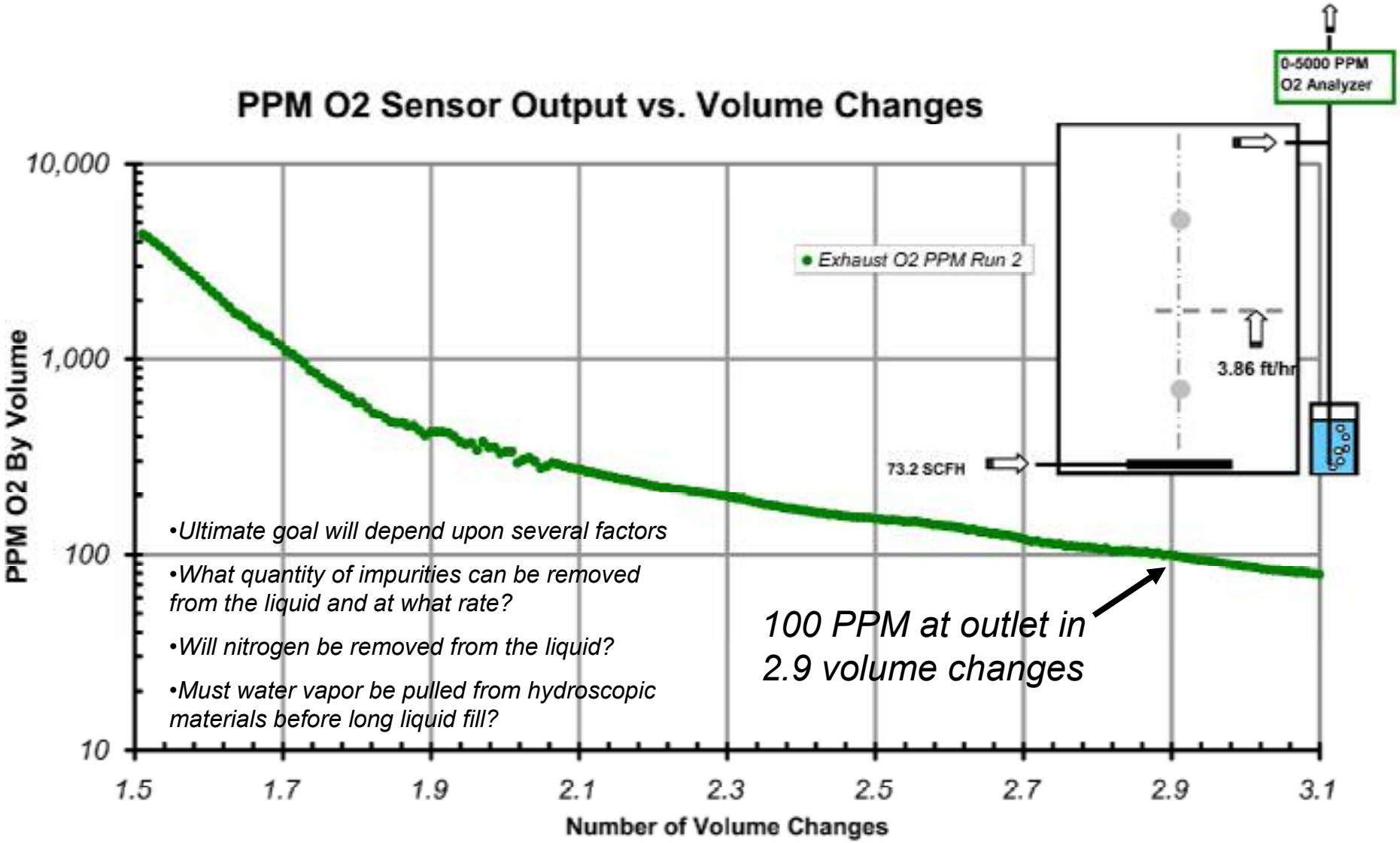
PAB Tank Test



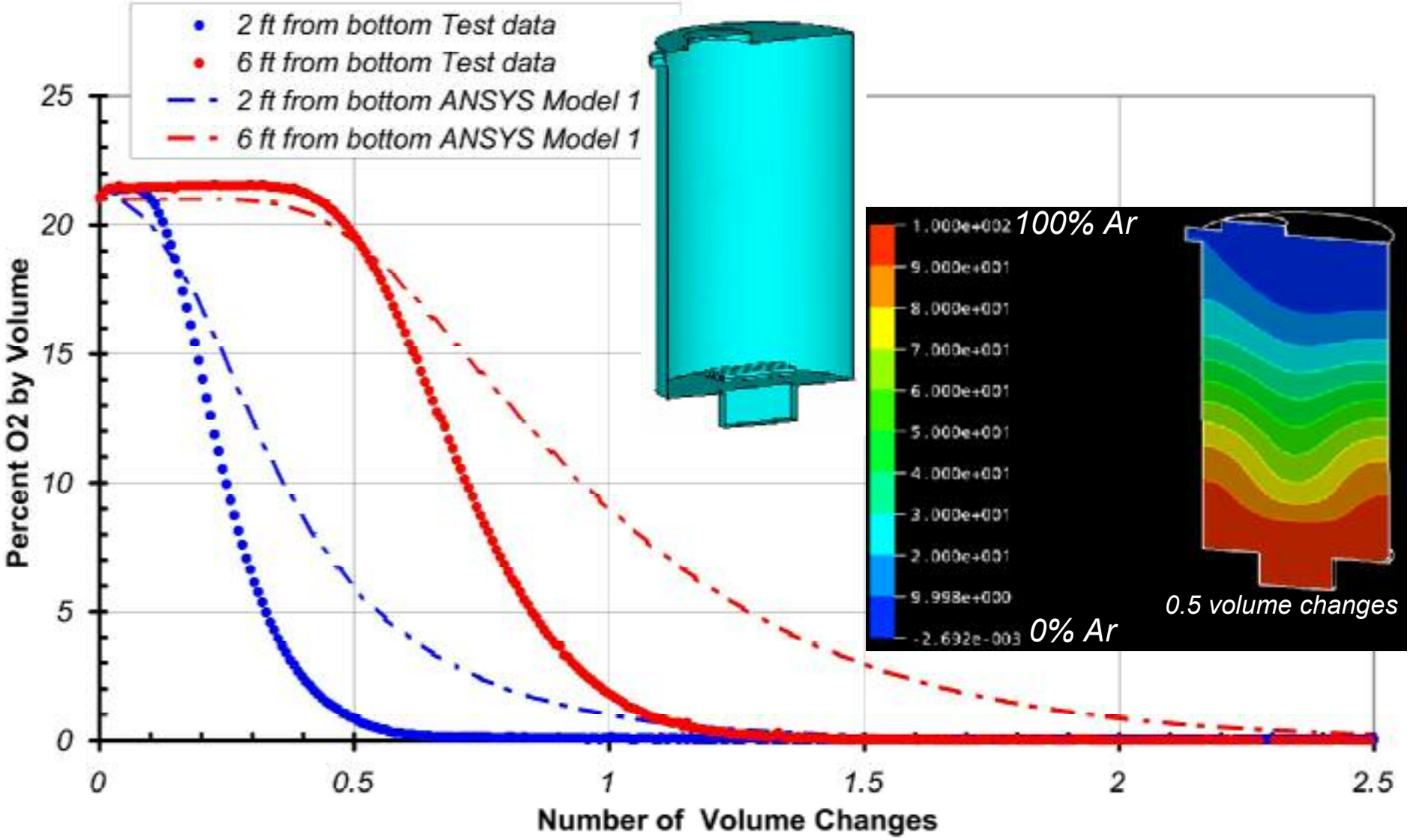
PAB Tank Experimental Results



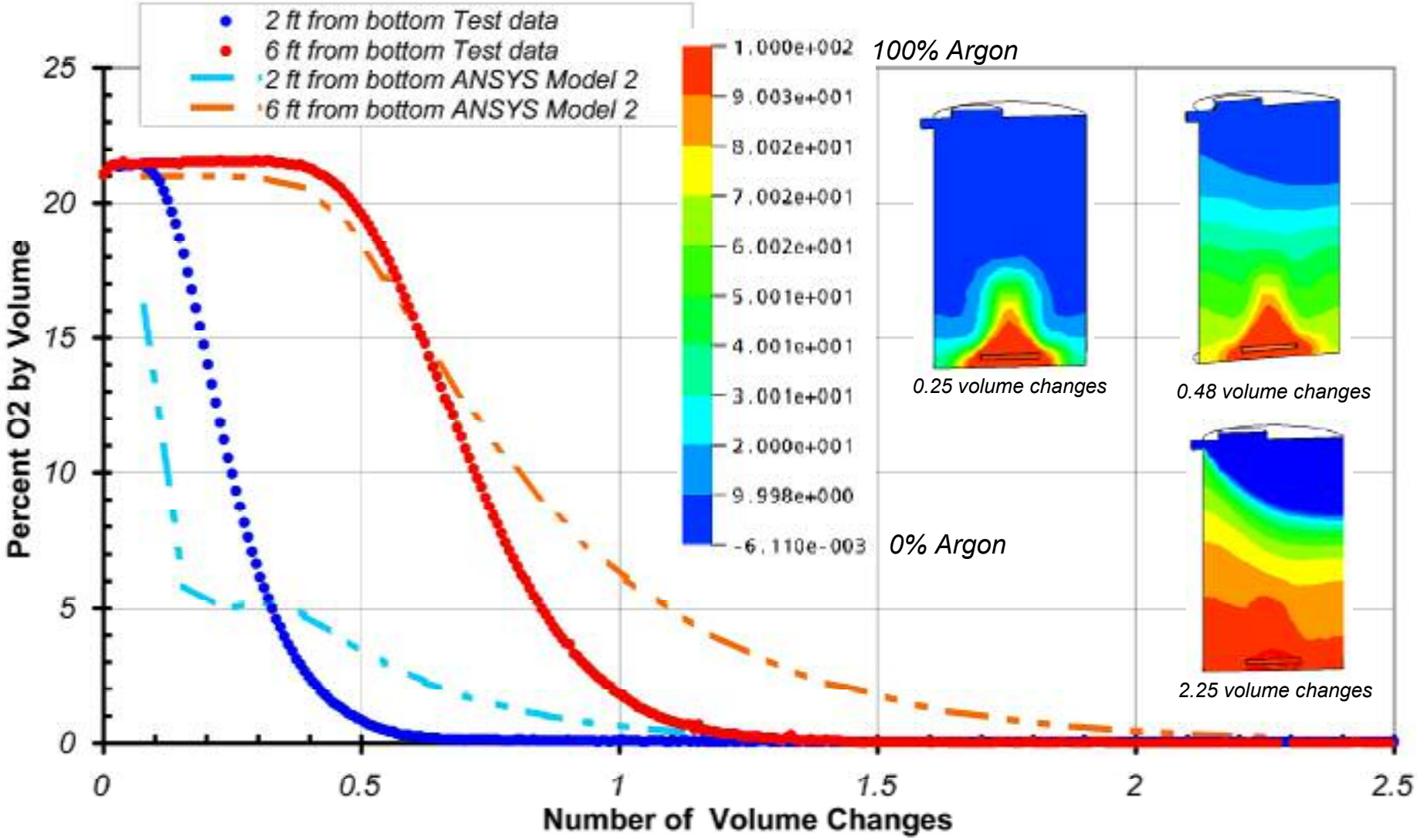
PAB Tank Experimental Results



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 m^2 s^{-1} for Ar-Air

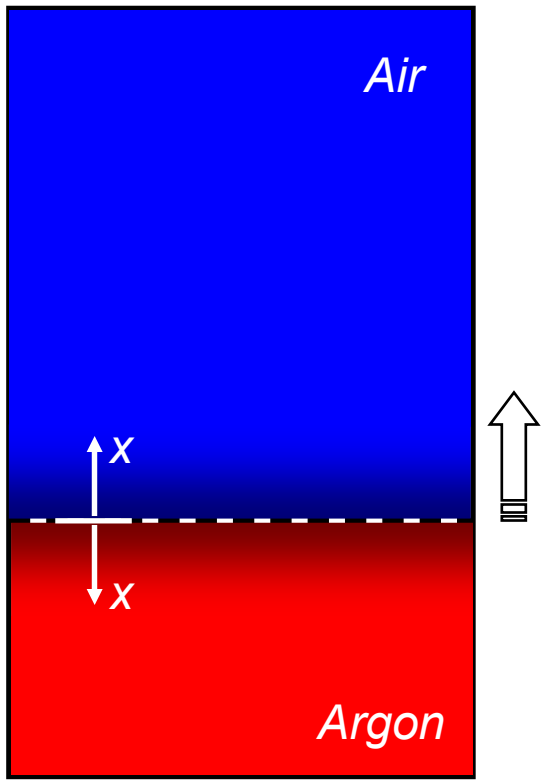
IC and BC's

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

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

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

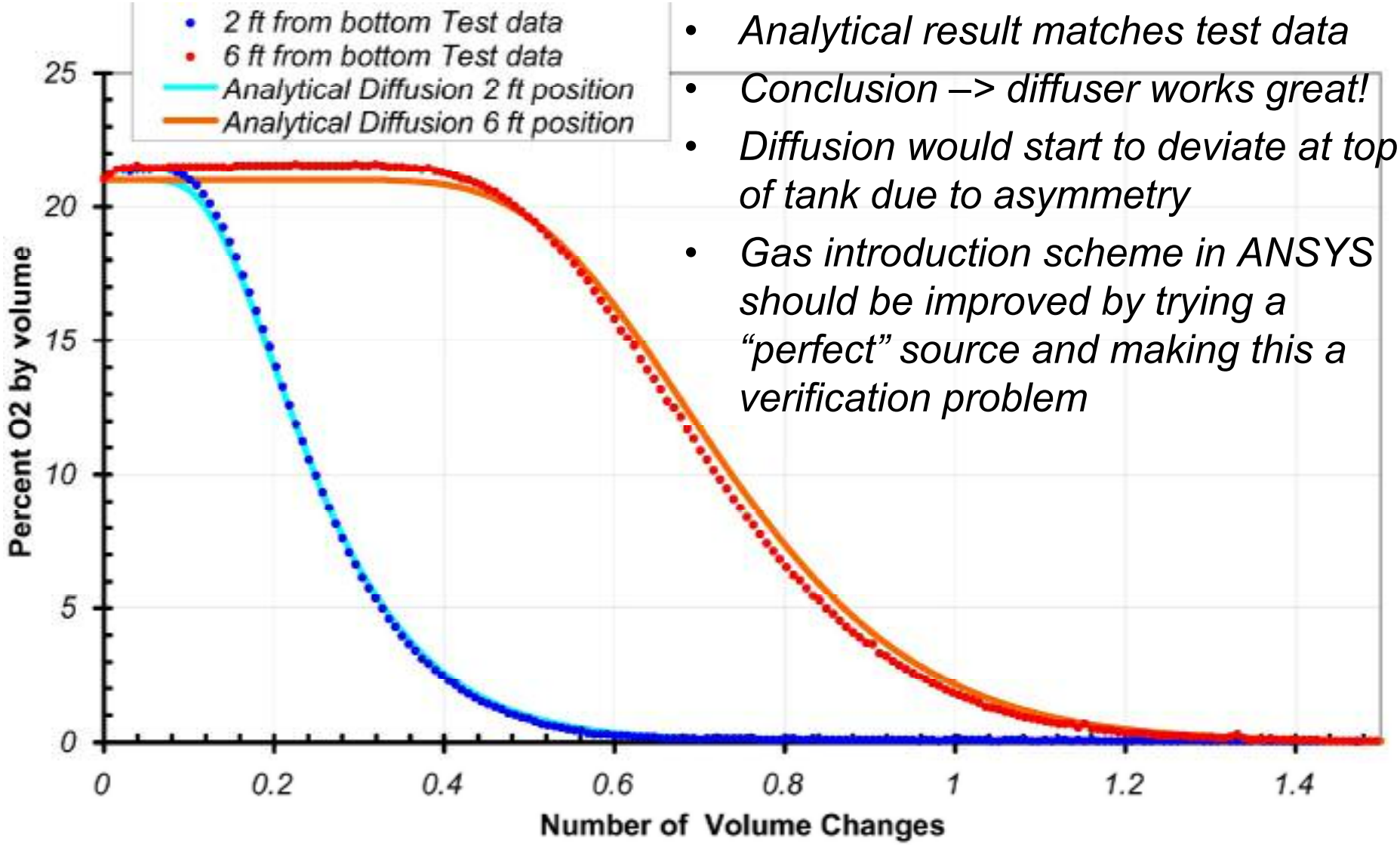
Boundary between Air and Argon is always 50% Argon and 50% Air, x = 0 at boundary



Boundary moves upward at a constant known speed

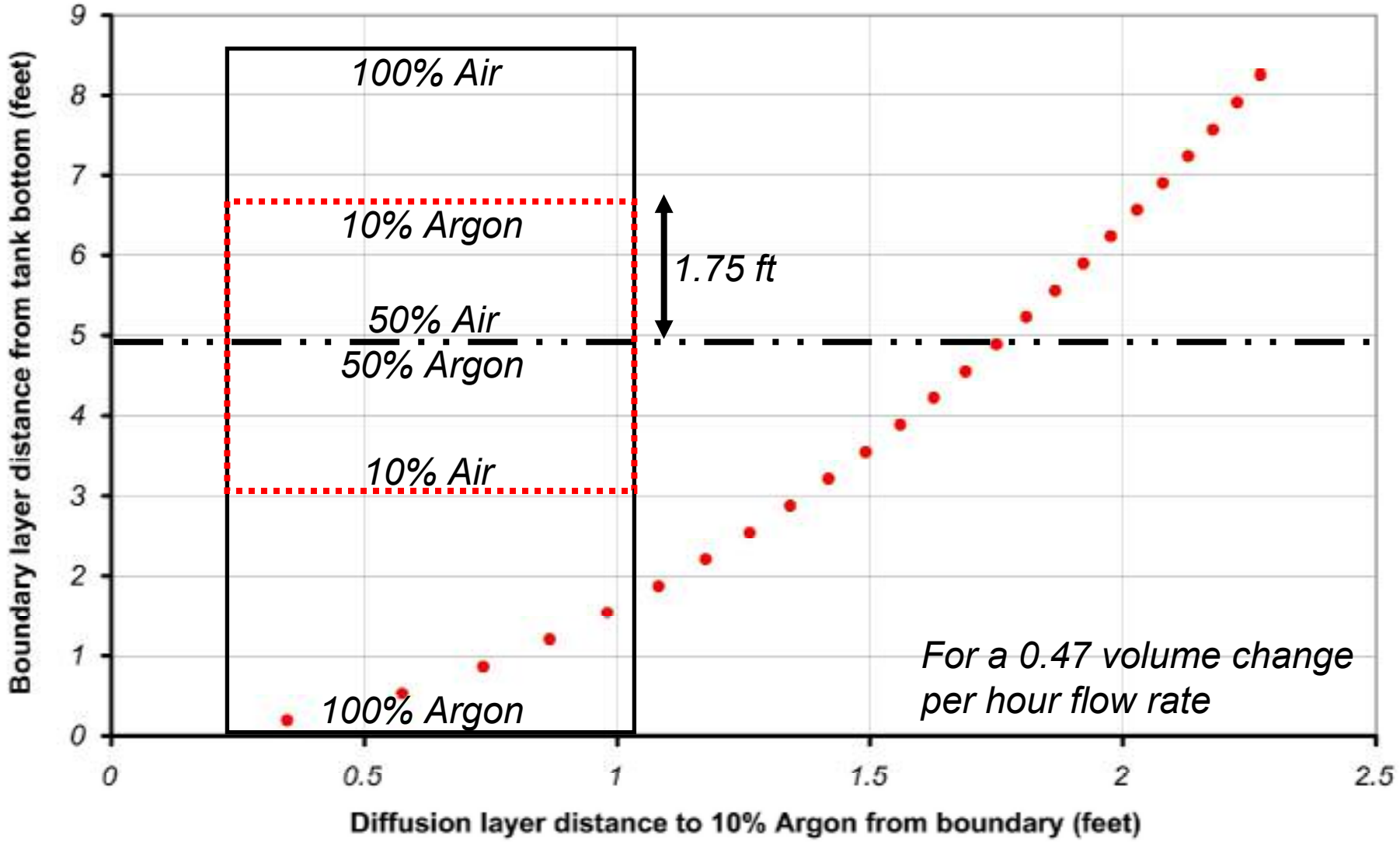
$$C_A(x,t)=\frac{1}{2}C_{A,s}\left\{1-erf\left[\frac{x}{2(D_{AB}t)^{1/2}}\right]\right\}$$

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

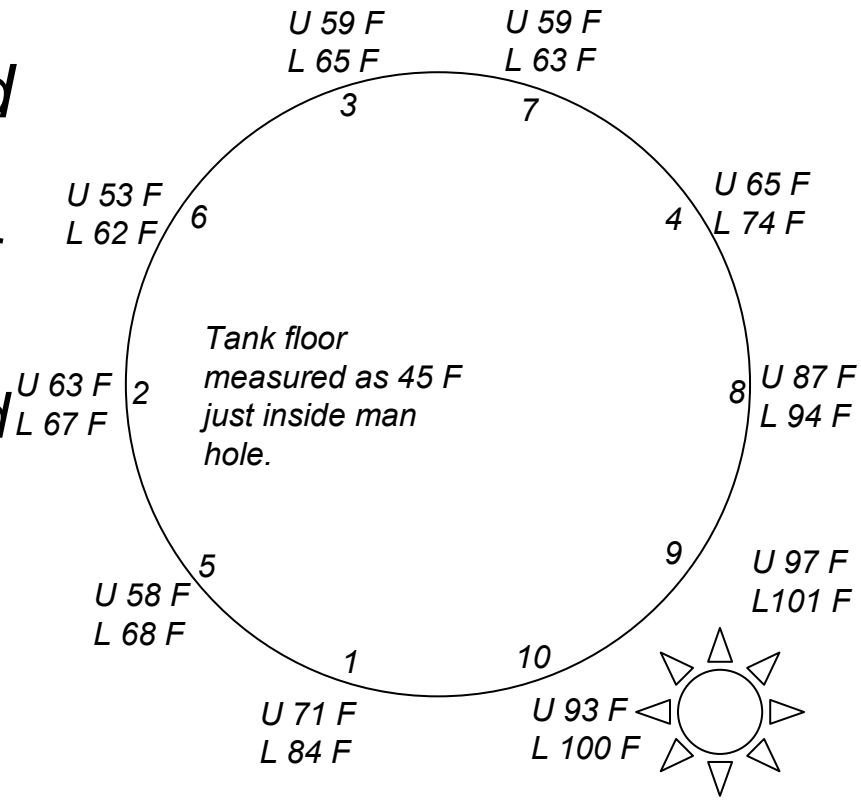


Village Tank

- 40,000 ft^3 decommissioned water tank
- Current condition….

Village Tank

- Constructed of ¼ 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

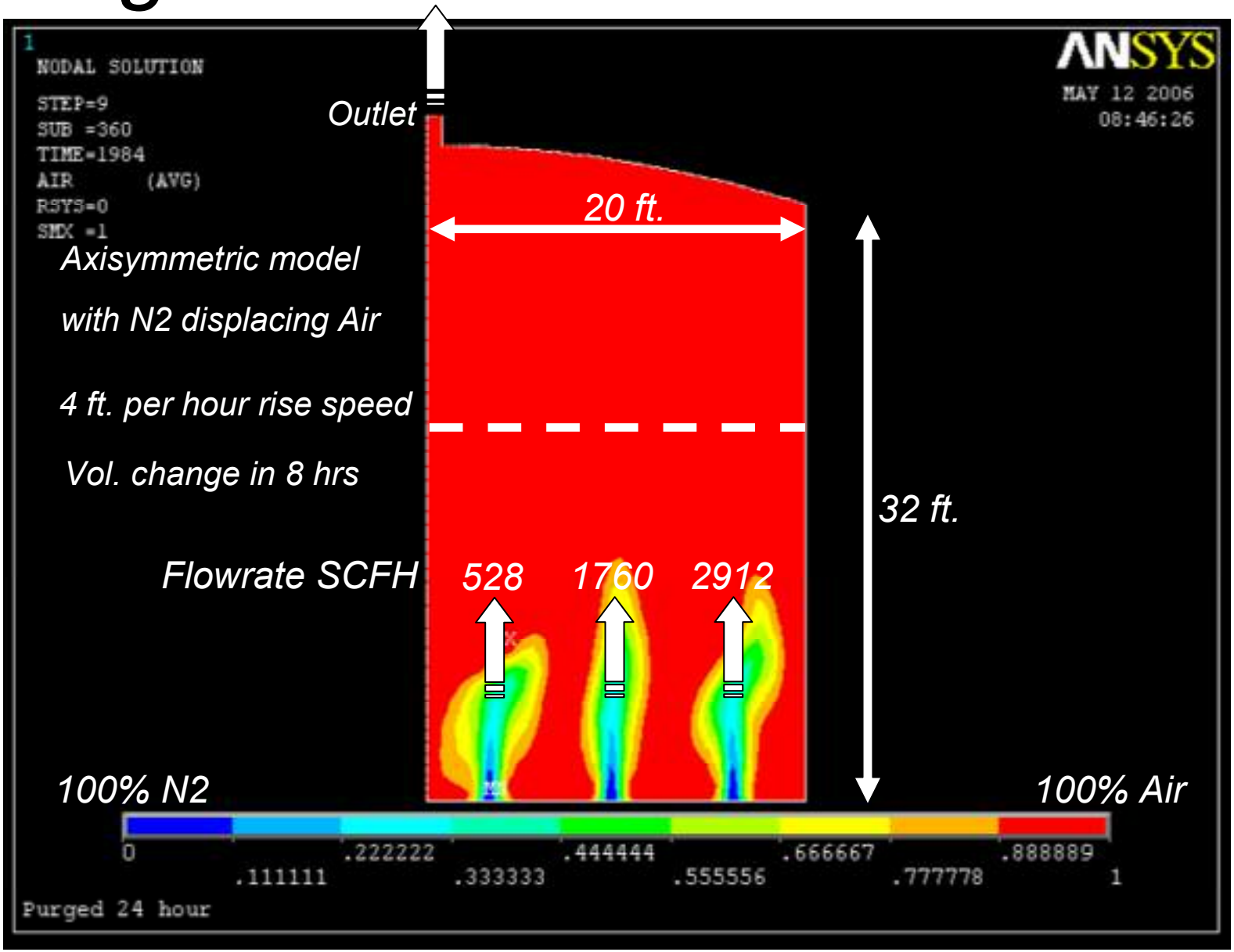


Sun position relative to tank.

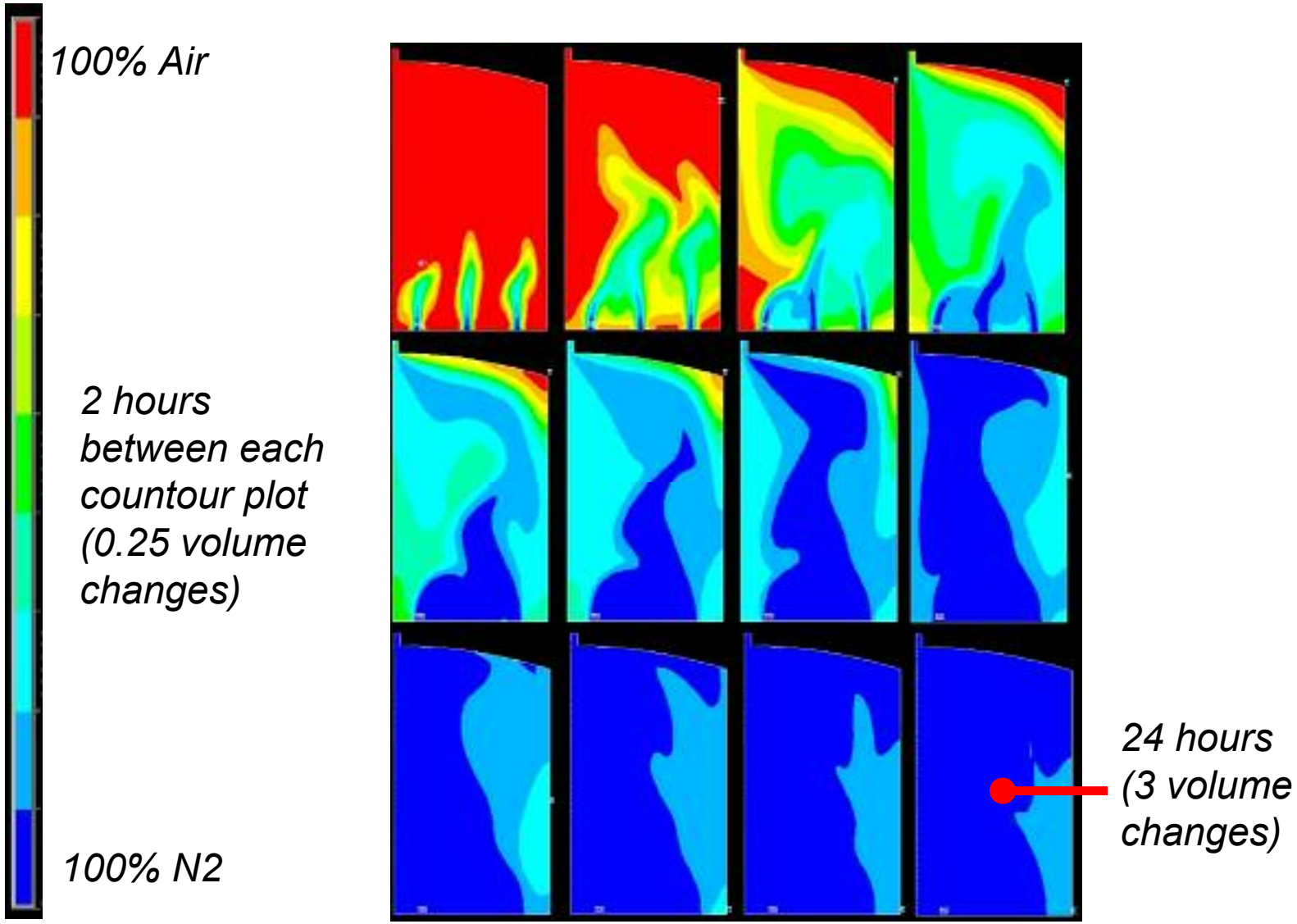
Village Tank

- *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)*

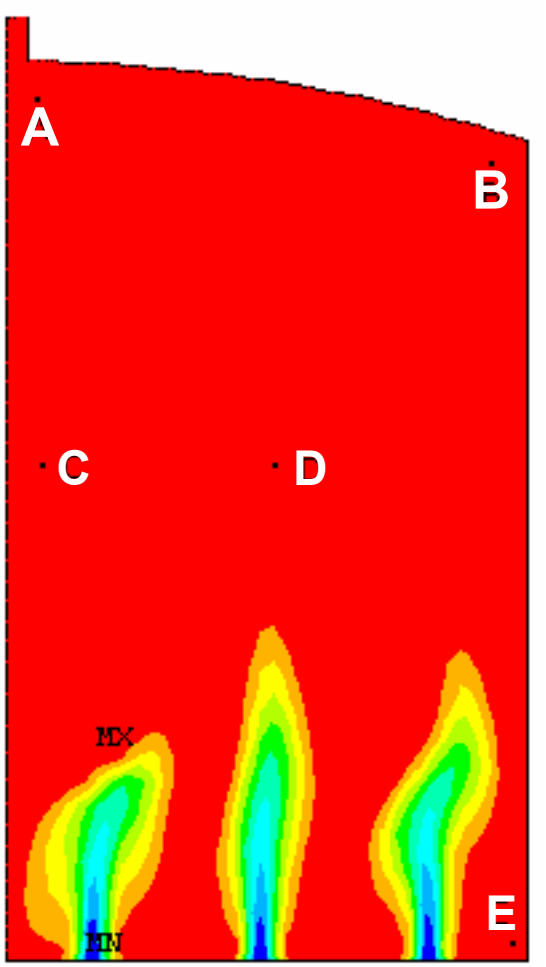
Village Tank – 1st ANSYS Model

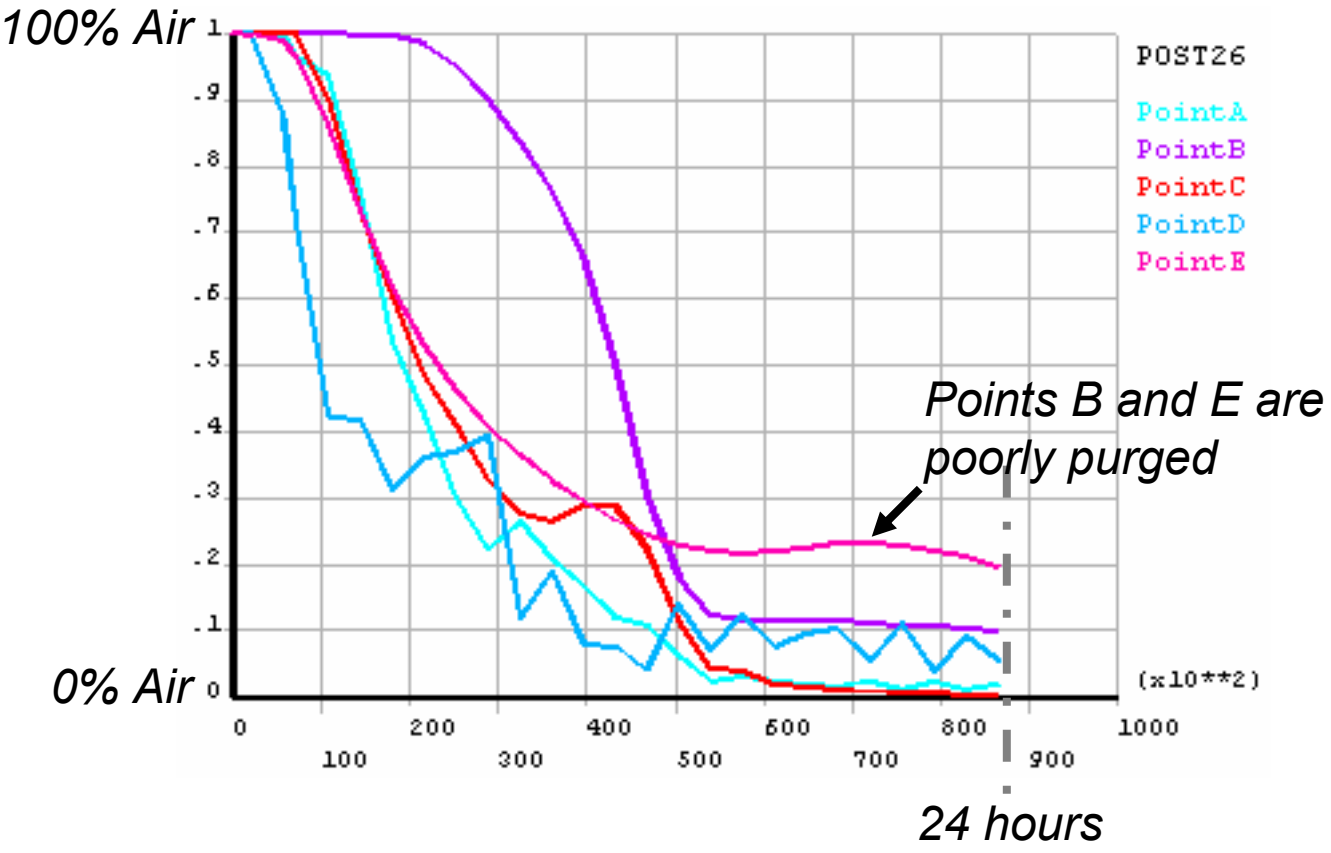


Village Tank – 1st ANSYS Model



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*