Test of Purging a small tank with Argon

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Introduction

One of the challenges facing our large liquid argon TPC is to remove the atmosphere of air to the point where the remaining oxygen can be removed by chemical or filtration techniques economically and in a reasonable time. This note describes a simple demonstration of purging the tank with argon gas inserted smoothly at the bottom of the tank to achieve concentrations of oxygen in the few 10's of ppm level. The purging is well described by an analytic diffusion model. The number of volume changes required to reach 100 ppm is a factor of 3 fewer than predicted in a perfect mixing model.

A stainless steel tank of diameter 5 ft and height 8.25 ft, previously used to store oil for the Miniboone experiment, was power washed and the hatch sealed. Two oxygen sensors of the type used in the Tevatron oxygen monitoring system [1] were hung at heights of 2ft and 6ft inside the tank, and a 0 - 5000 ppm oxygen analyser [2] sampled the outlet gas from the top of the tank. The first figure is a photograph of the tank and a schematic showing the location of the oxygen sensors. The dashed boxes are intended to suggest the diffusion of the boundary between argon and air as the purge develops. The inlet diffuser was made from four 3 inch OD, 6 inch long cartridge air-filters stuck end to end. The flow was set to produce a vertical rate of 3.68 ft/hr, a rate considered appropriate for a large tank.

The next figure shows an overview of the data from the two oxygen sensors and the oxygen analyser. Note that the analyser data refer to the right hand scale. Each sensor sees a well defined transition from air to argon and after 6 hrs or 2.7 volume changes the oxygen concentration at the top of the tank has fallen to 100 ppm. This is a reduction in oxygen concentration by a factor of 2000; in a perfect mixing model this would require 7.6 volume changes.

The third figure shows a comparison of an analytic calculation (the formula is in the figure) of perfect flow accompanied by diffusion - the diffusion coefficient is given in [3]. The agreement is quite satisfactory.

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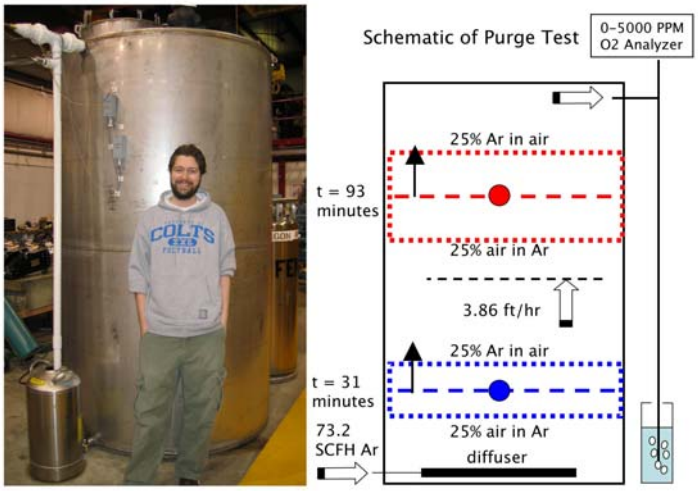
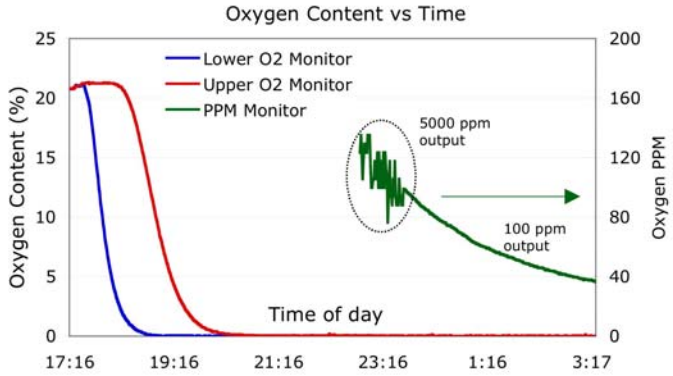
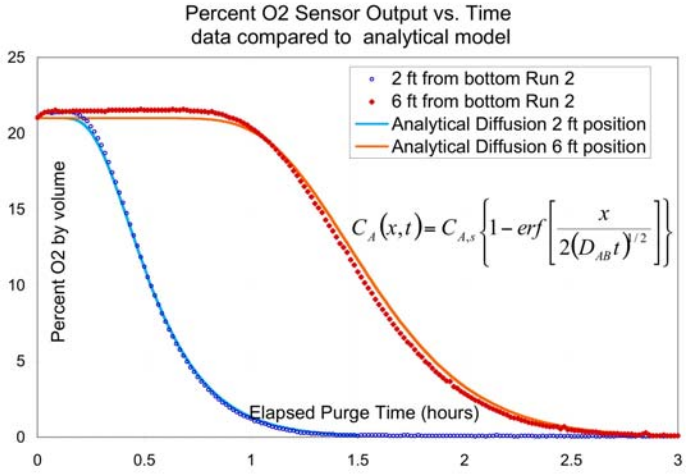
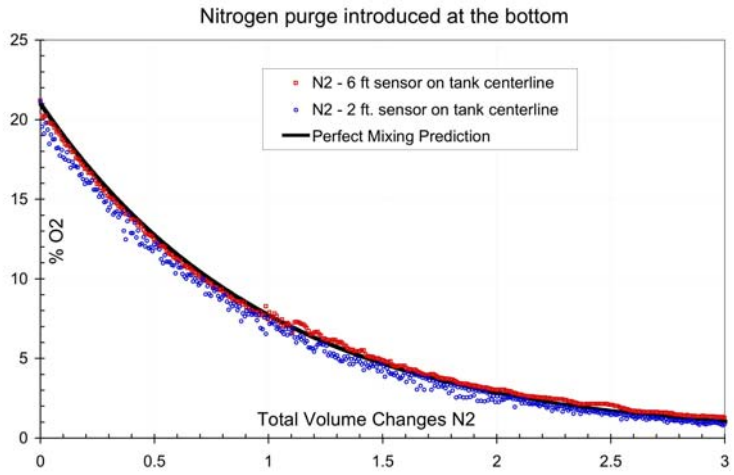

Schematic of Purge Test
0-5000 PPM
O2 Analyzer
25% Ar in air
t = 93
minutes
25% air in Ar
3.86 ft/hr
25% Ar in air
t = 31
minutes
73.2
SCFH Ar
25% air in Ar
diffuser


Oxygen Content vs Time
Lower O2 Monitor
Upper O2 Monitor
PPM Monitor
5000 ppm
output
100 ppm
output
Oxygen Content (%)
Oxygen PPM
Time of day
25
20
15
10
5
0
200
160
120
80
40
0
17:16
19:16
21:16
23:16
1:16
3:17


Percent O2 Sensor Output vs. Time
data compared to analytical model
2 ft from bottom Run 2
6 ft from bottom Run 2
Analytical Diffusion 2 ft position
Analytical Diffusion 6 ft position
$C_A(x,t) = C_{A,s}\left\{1 - erf\left[\frac{x}{2(D_{AB}t)^{1/2}}\right]\right\}$
Percent O2 by volume
Elapsed Purge Time (hours)
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3

The final figure shows what happens when Nitrogen is introduced at the bottom of the tank. As can be seen, the sensors at different levels have similar readings and the mixing is indeed close to perfect.



References

[1] See 'Electrical schematic for AD O2 cell preamp' in http://lartpc-docdb.fnal.gov/cgi-bin/ShowDocument?docid=88

[2] Delta F 310, Delta F Corporation, Woburn, MA.

[3] Table 40 "Experimental Gas Ordinary Diffusion Coefficients at One Atmosphere" for Nitrogen-Argon on page 2-94 of the "Handbook of Heat Transfer" Edited by Warren M. Rohsenow and James P. Hartnett.