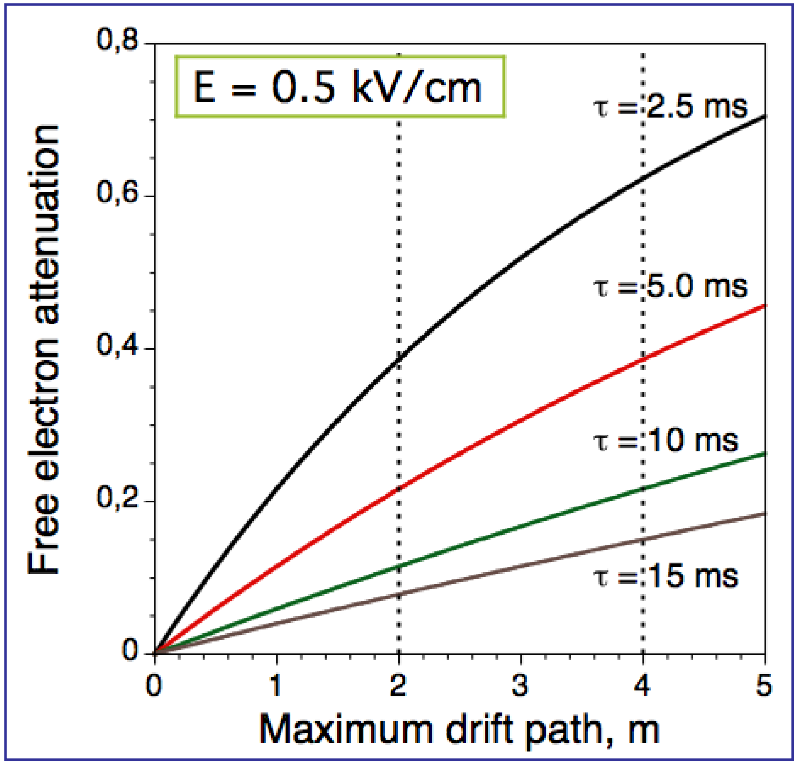
Twenty Ton LAPD
Liquid Argon R&D Workshop
1/26/2009

Rob Plunkett

Issue for any Liquid Argon Device is absence of electronegative contaminants, achieved at low cost



Gradual, staged approach solves scalability problems at every point.

Successful systems have been built on both sides of the Atlantic, but with critical differences in terms of very large detectors.

Fermilab has successful small-scale program, discussed in other talks.

From C. Montanari, June 2007

Required Lifetime for 4m drift ≈ 10 ms ➔➔ ≈0.03 ppb (O2 equiv)
Required Lifetime for 2m drift ≈ 5 ms ➔➔ ≈0.06 ppb (O2 equiv)

The Standard Icarus Procedure (from C. Montanari, June 2007)

- The “standard” Icarus procedure for purification and handling LAr consists of 5 steps:
  1. Use ultra high vacuum standards for detector components design, construction, cleaning and assembly;
  2. Removal of air and outgassing of surfaces by evacuating the argon container volume to the molecular vacuum level (< 10^{-3} mbar);
  3. Fast cooling (to reduce pollution from outgassing) and filling with argon ultra-purified by means of chemical filters and molecular sieves;
  4. Recirculation of the gas phase to block the diffusion of the impurities coming from the hot parts of the detector and from micro-leaks on the openings (typically located on the top of the device) in the bulk liquid;
  5. Recirculation of the bulk liquid volume to further reduce the impurities concentration up to the required level.

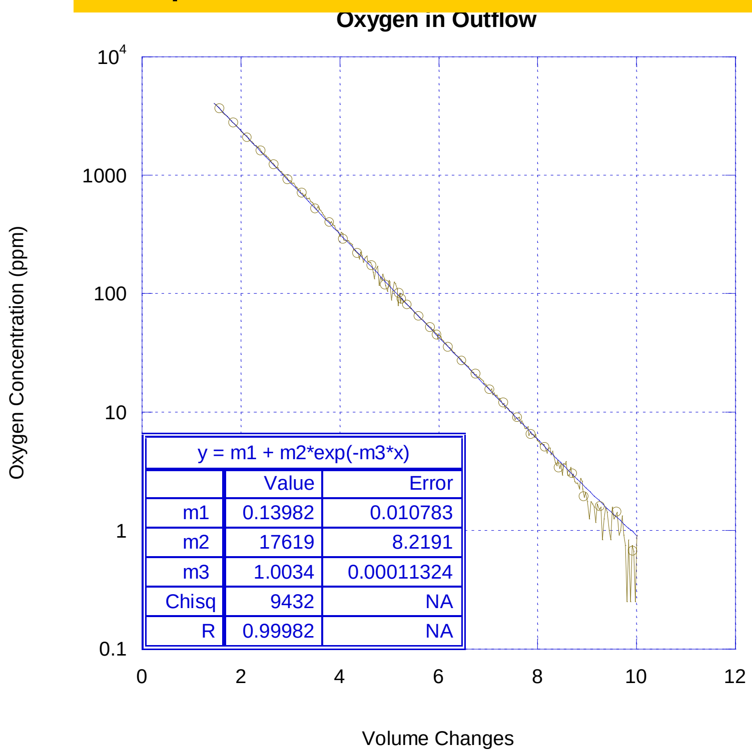
This is not scalable

Motivation for Large Test System

- Current systems use vacuum evacuation as a preliminary cleaning step
- This is extremely difficult to scale to very large volumes – especially mechanically.
- Physics requirements for Liquid Argon detectors are showing that large volumes are required. (5 kTon minimum)
- Hence we must study alternative filling schemes.

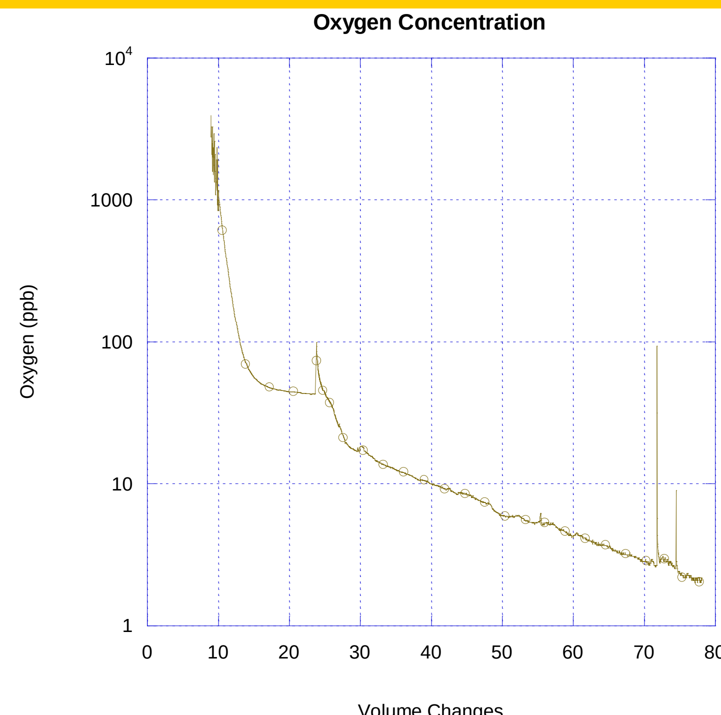
Results of previous tests

Required Lifetime for 4m drift ≈ 10 ms ➔➔ ≈0.03 ppb (O2 equiv)
Required Lifetime for 2m drift ≈ 5 ms ➔➔ ≈0.06 ppb (O2 equiv)



y = m1 + m2*exp(-m3*x)		
	Value	Error
m1	0.13982	0.010783
m2	17619	8.2191
m3	1.0034	0.00011324
Chisq	9432	NA
R	0.99982	NA

Low sensitivity monitor



High sensitivity monitor

Results obtained in test tank by Ar purge, followed by flushing with recycled purified gas

O2 is unlikely to be principal residual contaminant

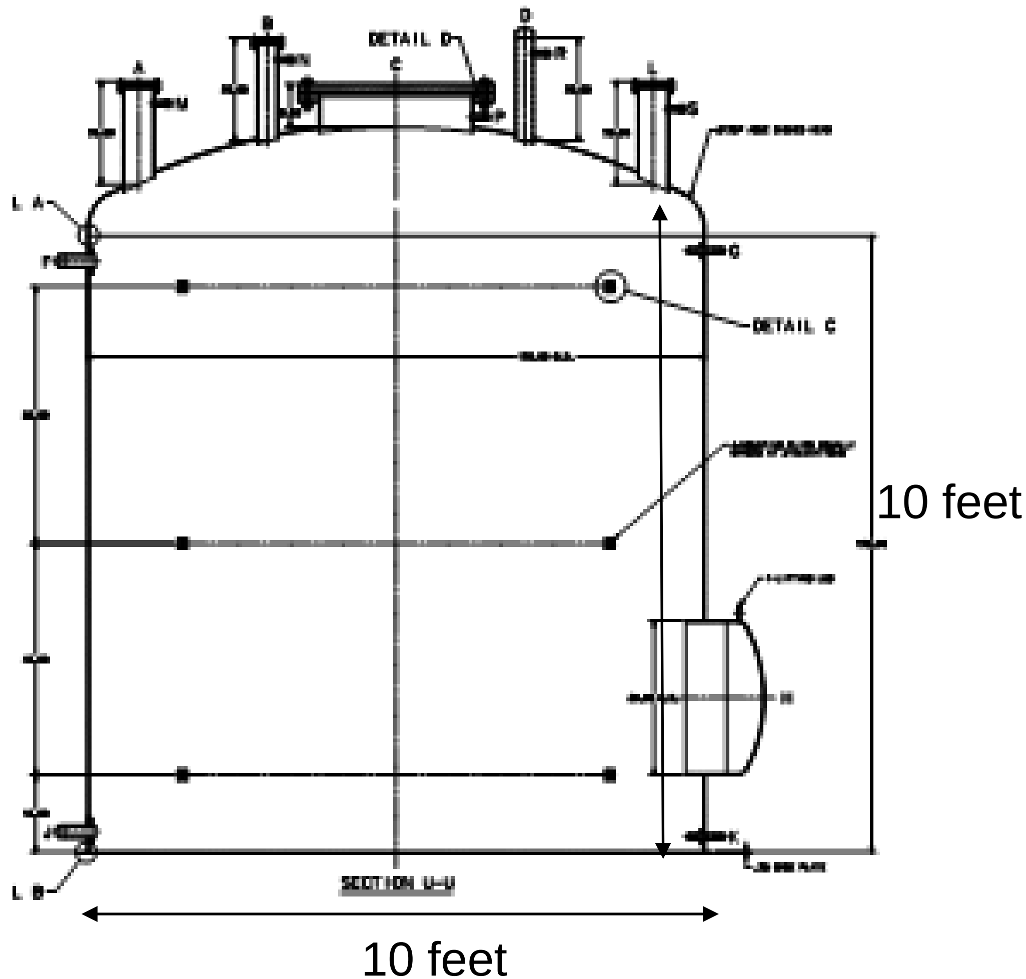
Twenty-ton purity test (LAPD)

3/16” Stainless Steel

Fermilab will add foam insulation (about 1 ft.)

Detailed cleaning procedure specified

Mounted on insulated cribbing.

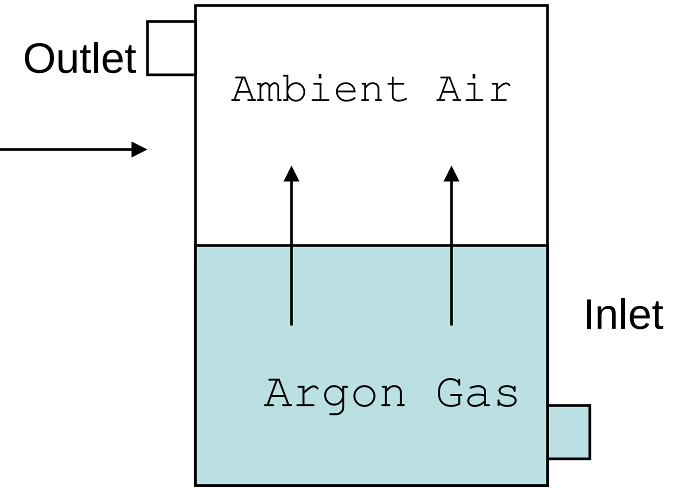


Summary of Basic Process

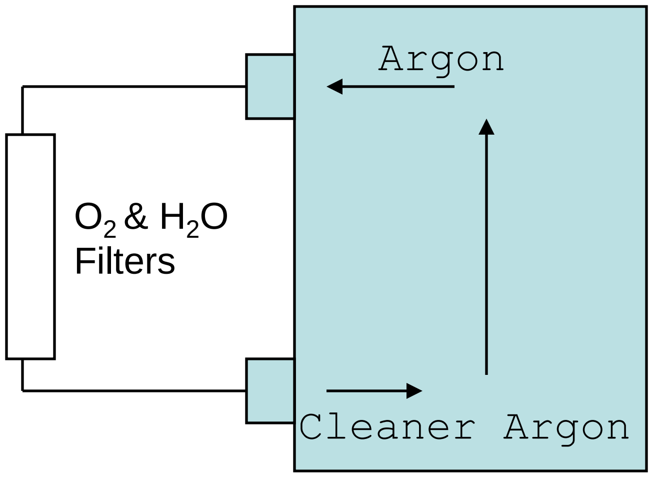
- Initial purge with gaseous Ar from bottom
  - Heavier than air, forms a seal and gradually displaces air through top
- Recycle Ar gas for numerous volume changes, purifying each cycle.
- Fill with filtered Ar liquid.
- Recycle Ar liquid and recondensed gas from ullage, filtering each pass.

Visualization of Process

- Argon Piston

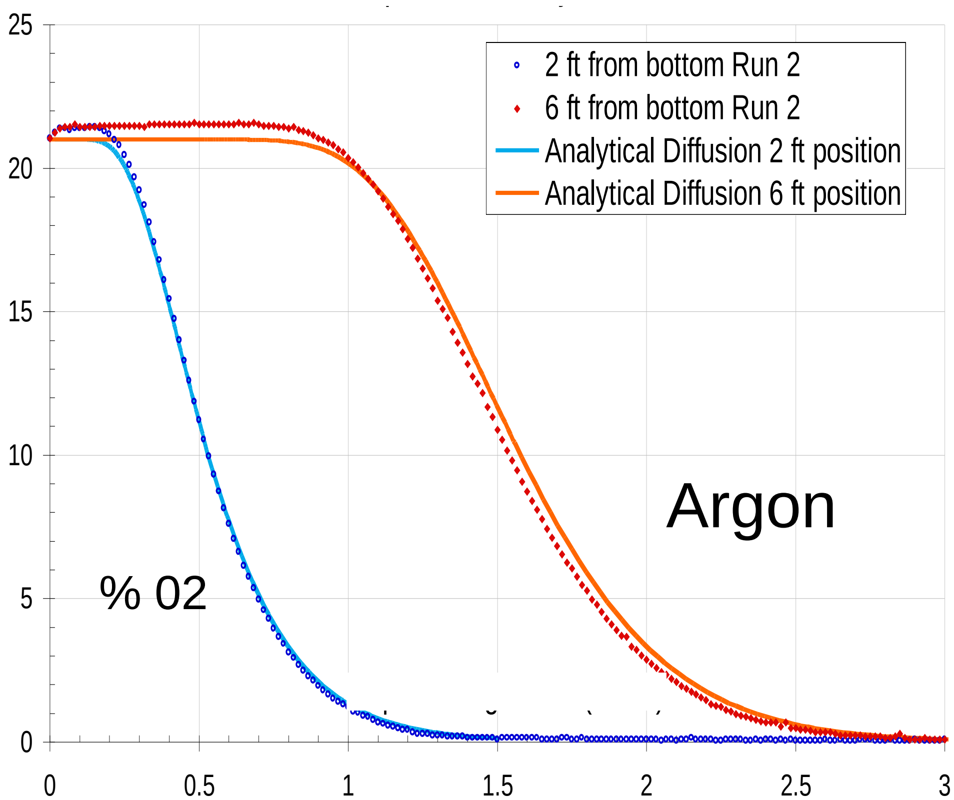


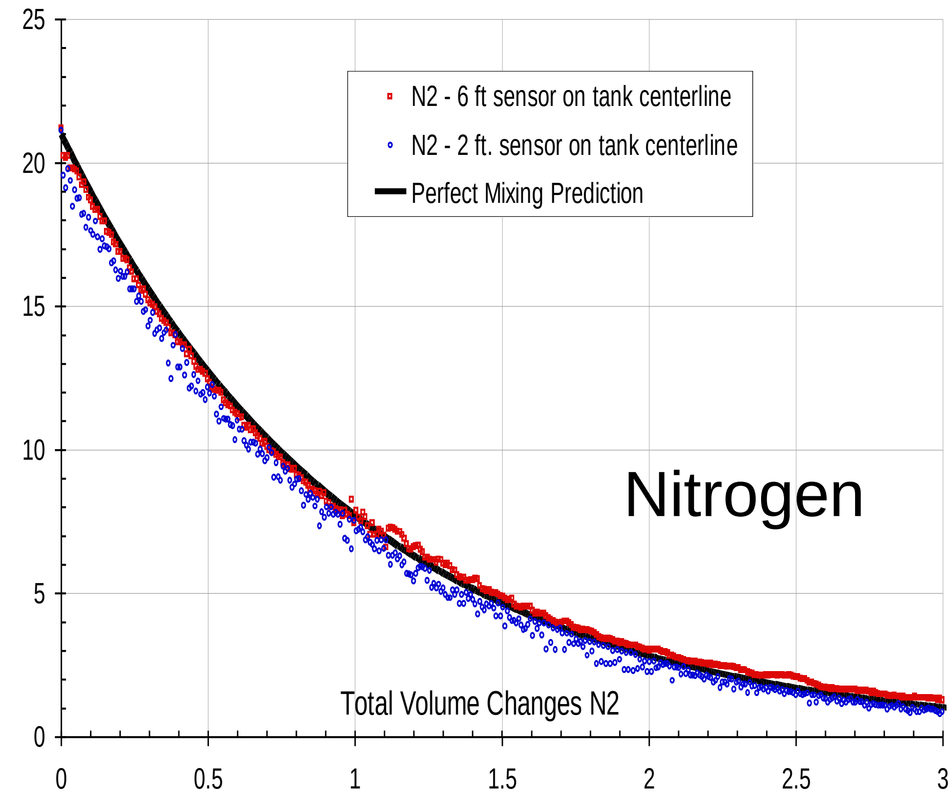
- Exchange a few Volumes
- Recirculate and Filter to <10 ppb



After Reed Andrews

Comparison of Oxygen displacement by Argon and by Nitrogen (Argon Piston)

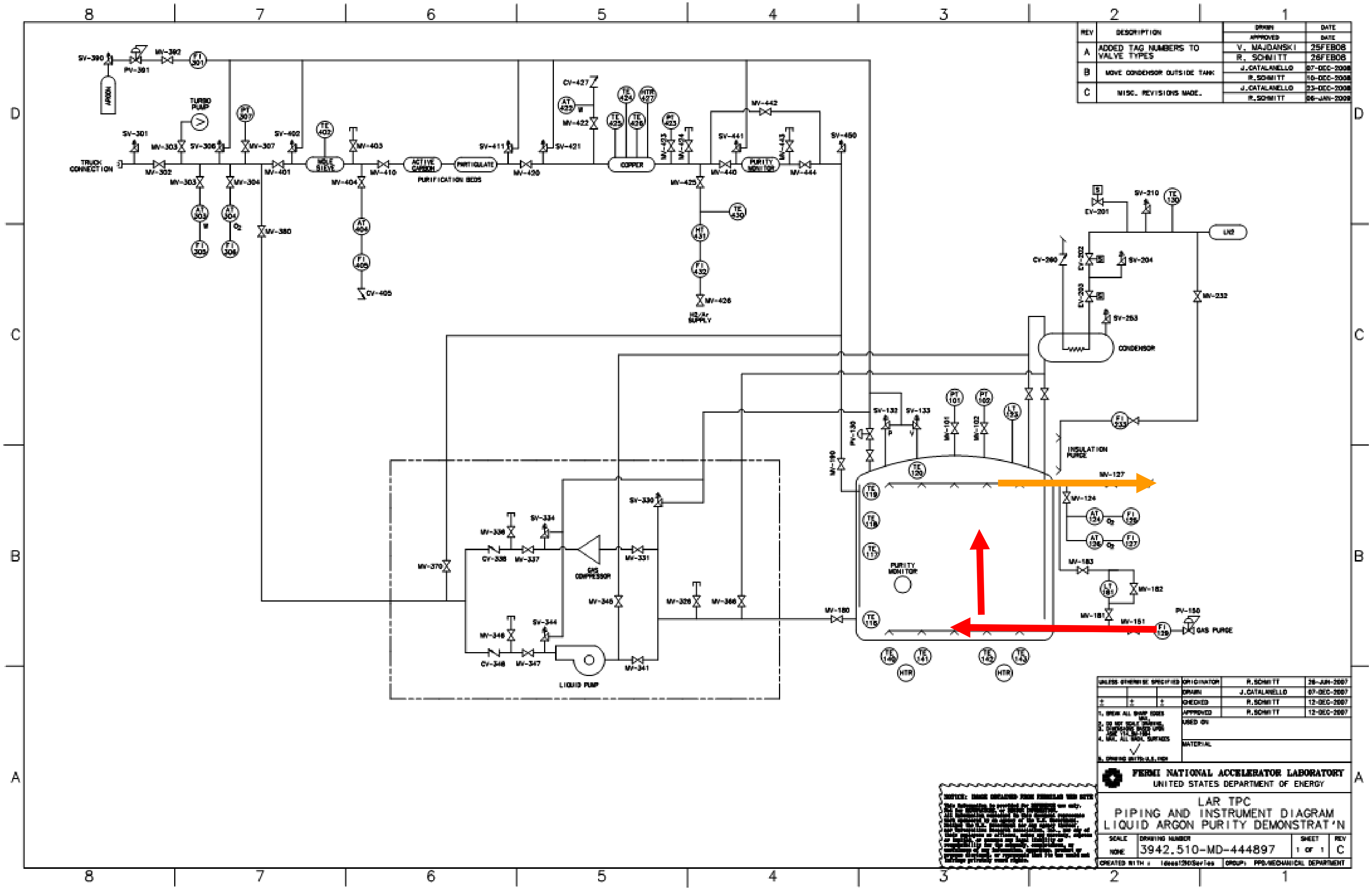




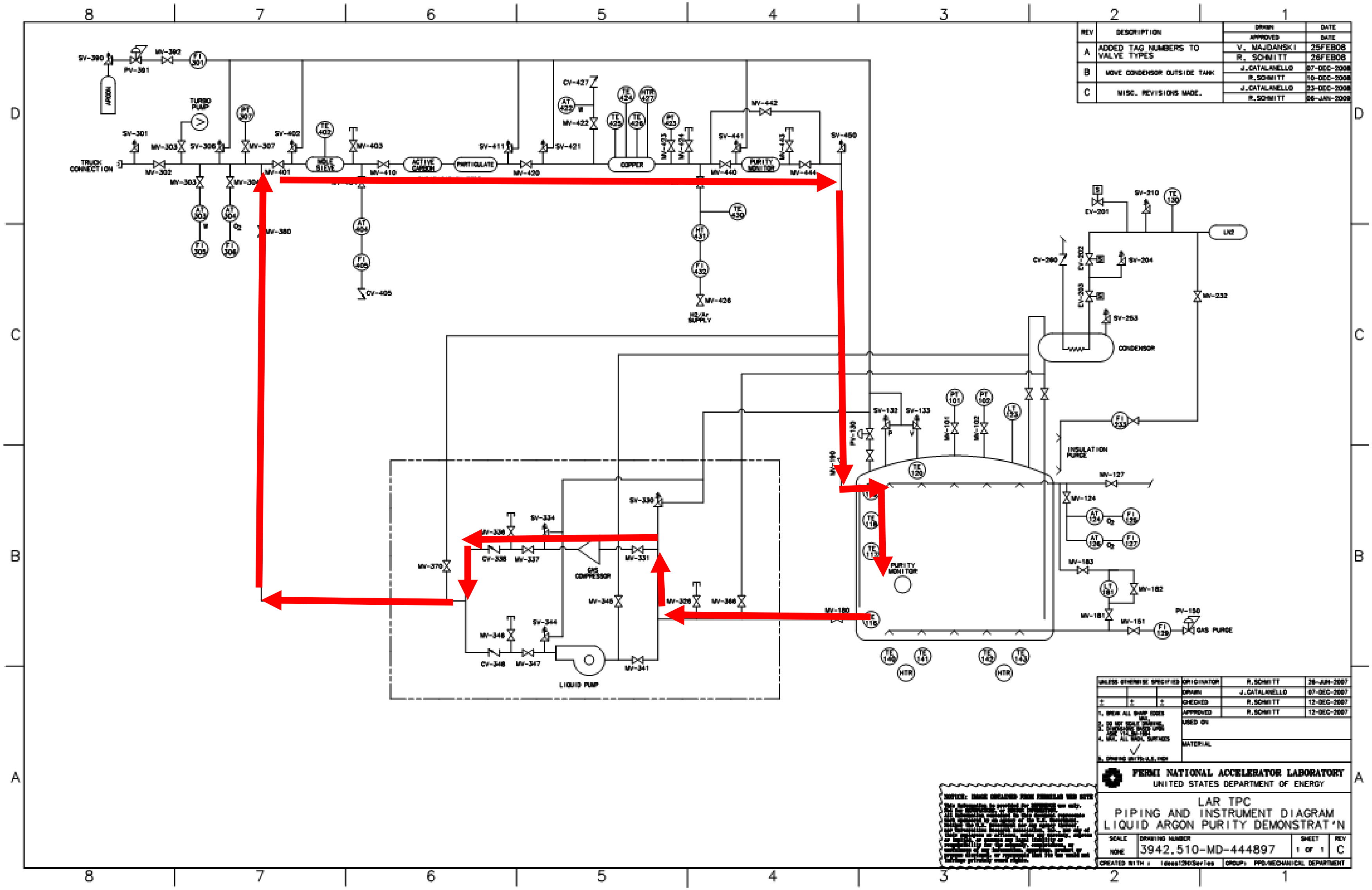
T. Tope

- to 100 ppm (reduction of 2,000) takes 2.6 volume changes
(cf simple mixing, which predicts ln(2000) = 7.6 volume changes)

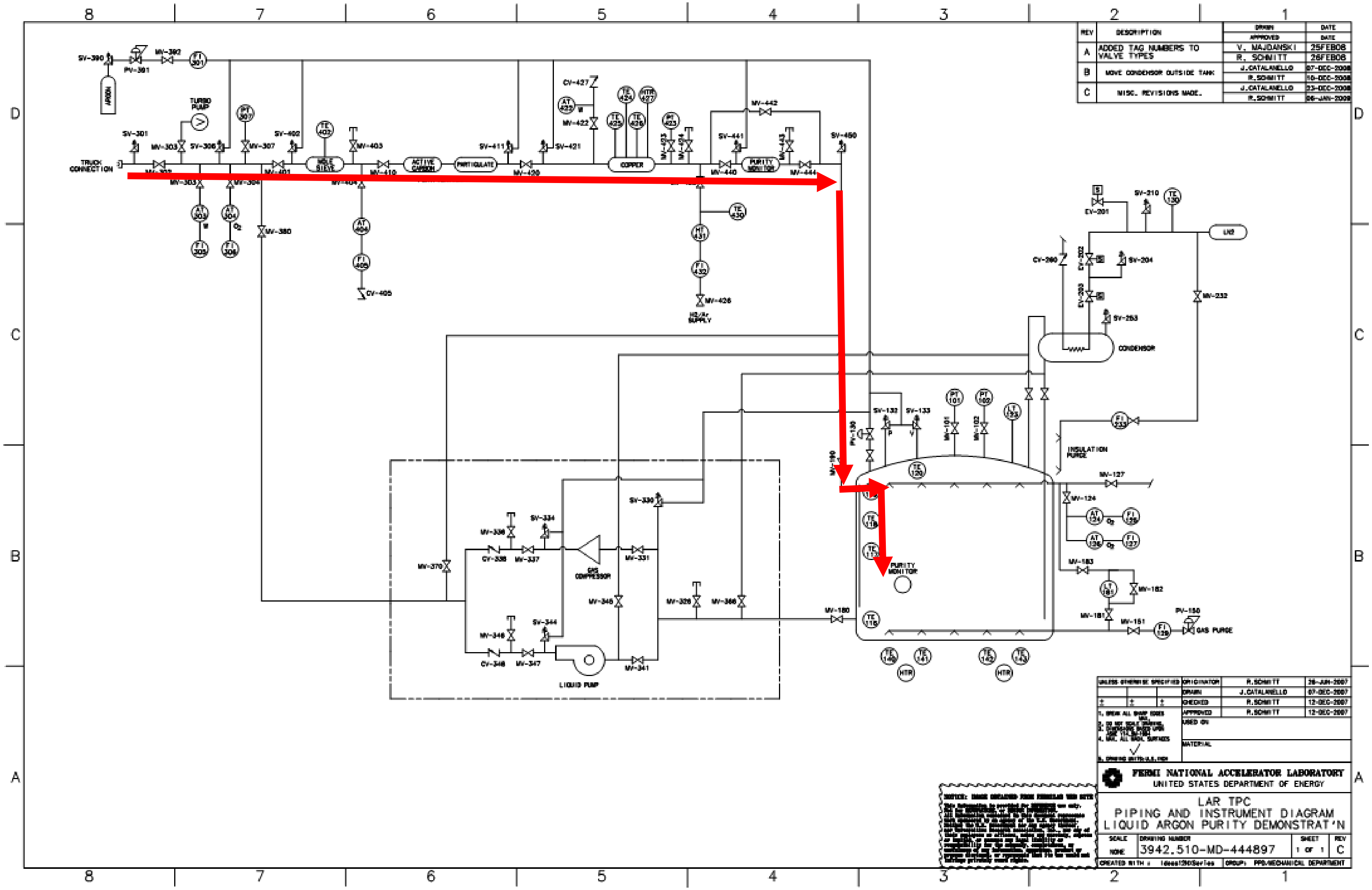
Work by T. Tope



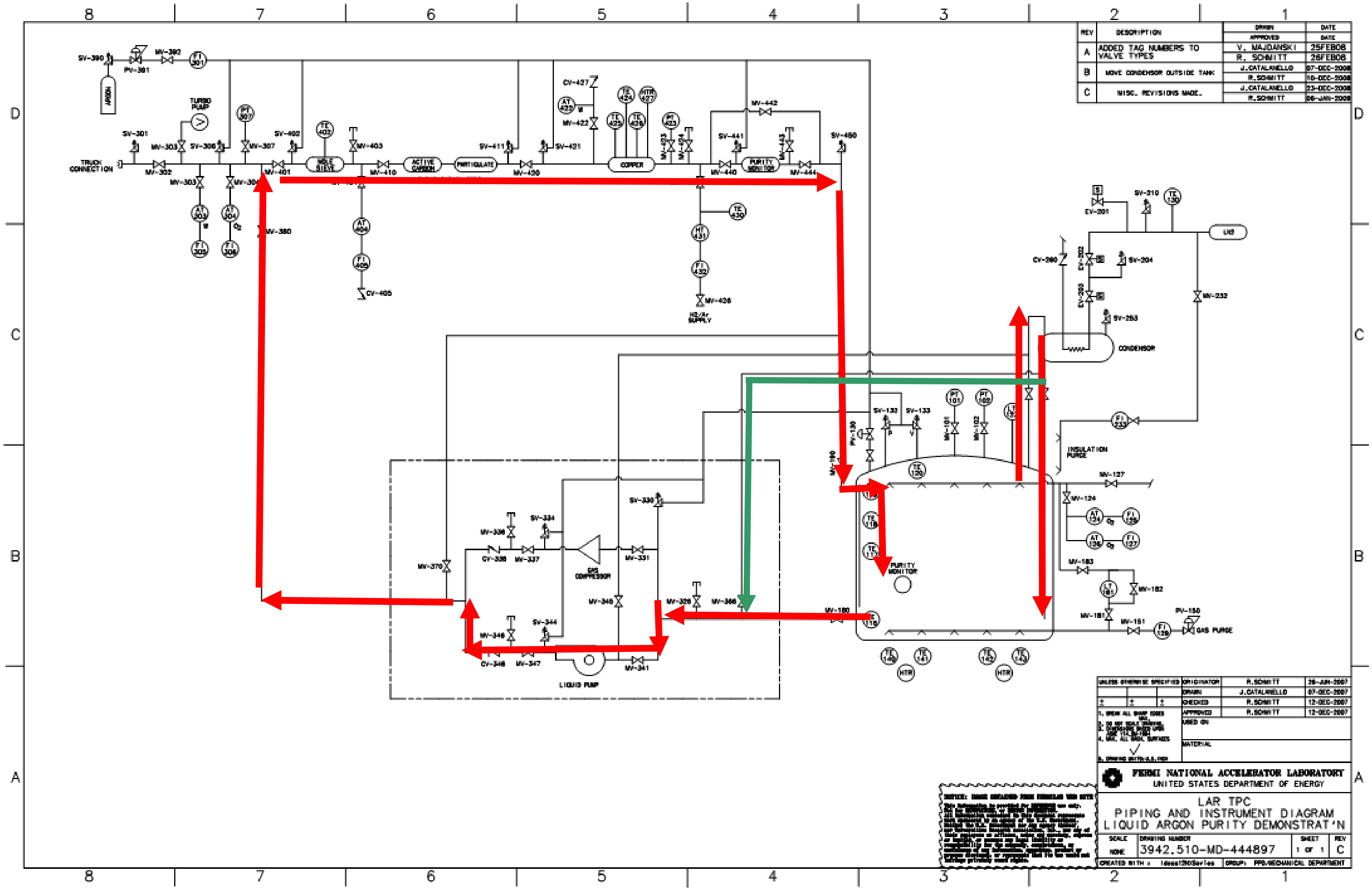
(1) LAPD “Argon Piston” Initial Purge



(2) LAPD Argon gas circulation and filtration



(3) LAPD Argon liquid initial filtration and fill



(4) LAPD Steady State liquid circulation and gas condensation

Purification System

- Filtering for Oxygen and water primarily (N2 shown to be unimportant for electron drift).
- Use sequence of filters as tested successfully for several years at PAB
  - Molecular Sieve for H20
  - Copper/Alumina filter for O2
- Activated Carbon filter possibly added as well
- In-line purity monitoring
- Sintered metal at liquid entrances, including direct recondensate (this as concluded from PAB studies)
- Fabrication (hopefully) in one vacuum vessel for convenience.

Cost and Technical Effort Estimates

- Current Engineering estimates for Design Engineering, and Installation Technical
  - 43 Person-Weeks remaining in design/eng.
  - 53 Person-Weeks for Installation Tech.

- Current M&S cost estimate $367K
  - Includes 40% contingency
  - $206K after subtract things already bought
  - FY2009 Budget request was $400K. Would like to spend all of it in FY2009.
- Purity monitor and DAQ additional
  - Expect ~ $35 K from previous experience.
  - Approximately 3 months required.

Engineering and Tech effort estimates by R. Schmitt

Procurement and Fabrication Status

- Tank ordered, construction drawings approved..
- Argon liquid pump ordered, (custom fabrication).
  - Should be delivered in March.
- Designers working on skids and vessels for pump and for filtration system
- Expect to fabricate purity monitors, other misc. equipment at PAB

Schedule Considerations

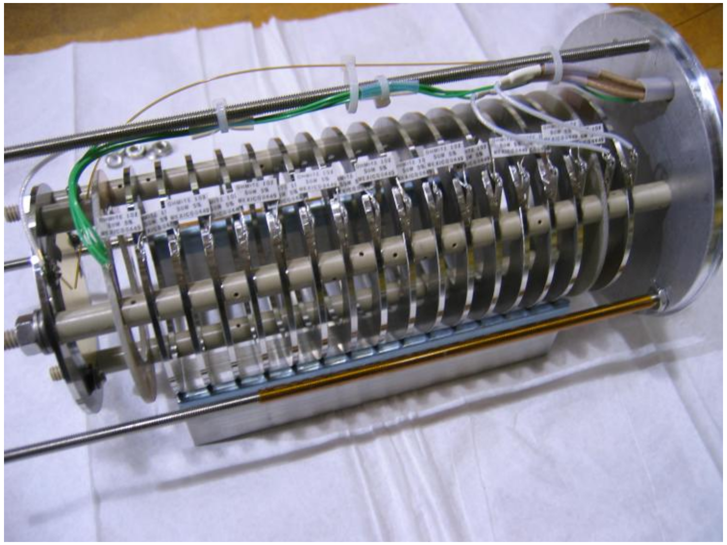
- Tank delivery may happen as early as 1 March. Goal should be to have data within one year.
- Six to nine months engineering effort required, for design with all safety reports, etc.
- Technical work should proceed in parallel.
- Schedule will likely be resource limited.
- There is reason to proceed quickly to coordinate with overall Fermilab effort
  - Information gained (immediately positive or requiring changes) will be a step in the direction of success for using these techniques for Microboone

Location Issue

- Not all locations will be convenient because of ODH Class I requirements.
  - Shouldn't be around offices
  - Best in separate building with adequate exits, etc.
- Plan has been to locate tank in KTeV building, upstream of old EmCal drybox.
  - Area cleared out
  - Excellent loading dock, crane
  - Can work around MICE solenoids
- Problem with E906 beginning to work this summer on pre-installation.
  - Hopefully can be solved or worked around. Need detailed schedule from experiment.
- SciBoone hole proposed
  - Space marginal, probably becomes confined space, maybe ODH 2
  - Not very realistic solution (in my opinion).

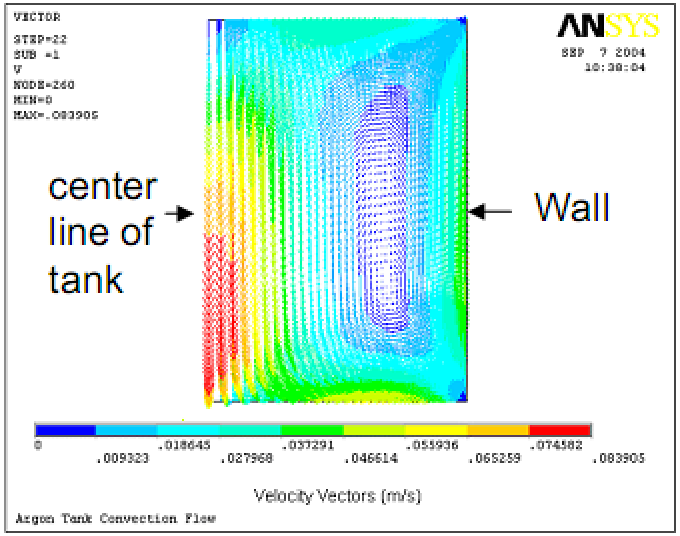
Instrumentation

- Build entirely on results from PAB/European previous work
- At least two purity monitors (one external) of standard design, with DAQ directly cloned from PAB setup.
- Controls similarly cloned from Luke/Bo control system.
- Adequate temperature monitoring.

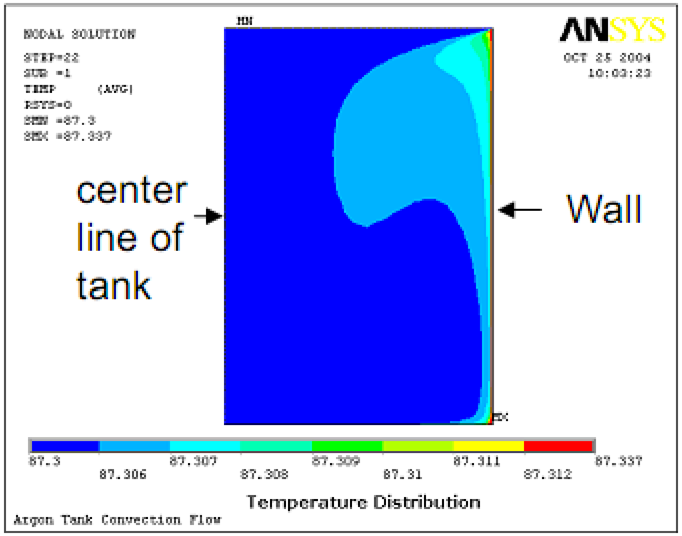


Temperature and Flow Modeling

- Additional goal to compare T distributions with FEA calculations
- Enables prediction of convective motion, important for TPC.
- Flow meters more difficult, perhaps second stage?
  - Very slow flow for a tank of this size
  - Materials compatibility (for purity requirement).



Liquid flow



Temperature

From Z. Tang, as shown by Pordes, NuFact 05

Summary

- Knowledge from PAB work leaves us ready to build a 20 Ton purity demonstration.
- A success here would be a major boost for worldwide Liquid Argon projects, which are all coping with same issues of scalability.
- At this scale, begins to impact laboratory via budget, schedule, location, and effort
- Schedule will be resource-limited. Should receive adequate priority.