Gas Analyzers

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Gas Analyzers

- O_2, N_2, H_2O gas analyzers
  - Various sensitivities-see table below
- Extensively used during Ar Gas Purge and recirculation period to monitor progress
- Sample either liquid or gas depending on location of pickoff tubing in cryostat.
- During LAr Phase of running, can be useful to look at outgassing/ contamination
  - Highest sensitivity O_2 analyzer ($\leq$ 1ppb) is useful for e^- lifetimes < 2 ms
- See LArTPC DocDB 406 for manuals, documentation….

From T. Tope

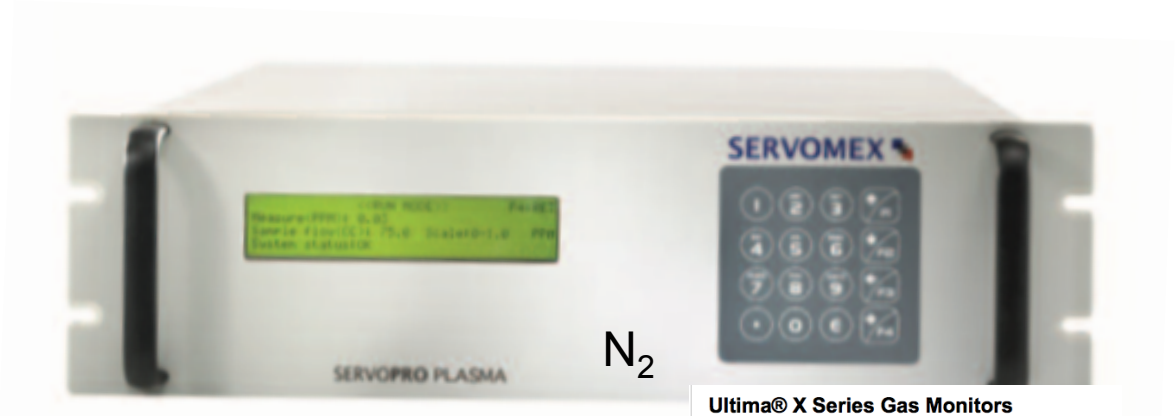
PC4 Gas Analyzers

Manufacturer	**Delta-F**	**Tiger Optics - one unit**		**Delta-F**	**Delta-F**	**Servomex/Kontrol Analytik**	**Tiger Optics**	
Model	**NanoTrace II DF-560**	**LaserTrace O2**	**LaserTrace H20**	**DF-310**	**DF-310*E***	**K2001^{ns}**	**HALO H20**	**Sum**
Budget price	**$35k**	**$80k**		**$5k**	**$10k**	**$25k**	**$25k**	**$180k**
Species analyzed	Oxygen	Oxygen	Water	Oxygen	Oxygen	Nitrogen	Water	
Ranges of operation	0-20 ppm	0-1.25 ppm	0-2.5 ppm	0-5,000 ppm	0-50 ppm	0 - 100 ppm	0-20 ppm	
LDL (experience based)	1 ppb	1 ppb	1 ppb	1 ppm	100 ppb	100 ppb	4 ppb	
Comments	The only high sensitivity oxygen meter in this set that is reliable. Used to monitor tank liquid purification and oxygen filter saturation. Long recovery time from oxygen upsets, typically use DF-310E above 1 ppm to protect it and prevent long recovery times.	These two analyzers are one unit that can't be separated. The oxygen analyzer is difficult to operate and at the moment is compromised. The water analyzer is the most sensitive water analyzer in the system. The water analyzer is used to check for water filter saturation and other careful measurements. The water analyzers take a long time to come to equilibrium because the water in the gas stream must come to equilibrium with the tubing along its entire length. Thus a water analyzer can't be switched between sources on a short time scale. It can often take days to reach a stable reading		High range of this oxygen meter is necessary for tank purge from air and to monitor tank vapor space during any tank extraction or insertion type repairs that introduce gross amounts of contamination.	Mid range oxygen analyzer. Used during the purge from air and gas recirculation phases until the NanoTrace can be brought online or any time the contamination is above 1 ppm to protect the NanoTrace.	Only N2 analyzer, necessary for light collection	Typically this analyzer monitors the tank vapor space so the water outgassing can be integrated over the entire run. The other water analyzer is then used to sample from other points in the system.	

Various H_2O, N_2 and O_2 Gas Analyzers

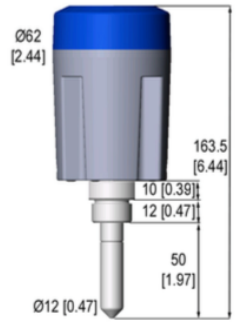
H_2O

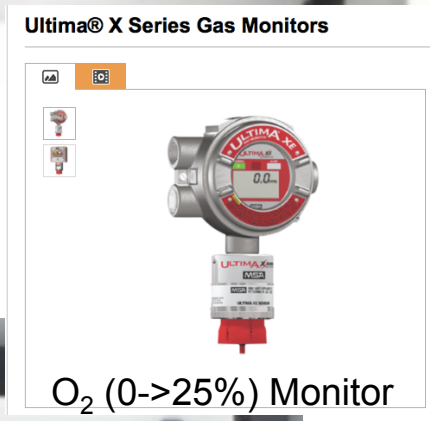
O_2



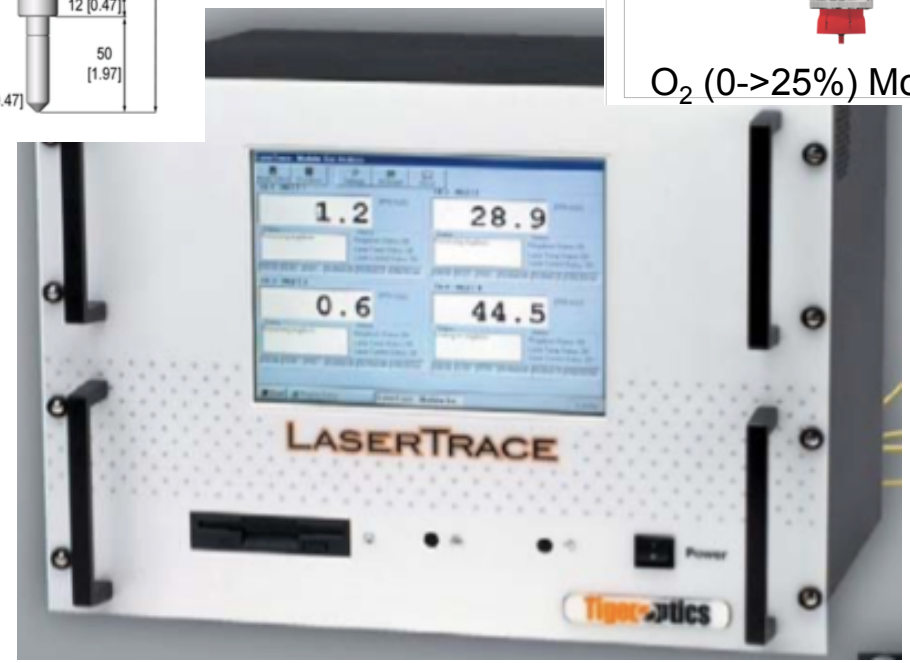
N_2

Vaisala Dew Point Meter





O_2 (0->25%) Monitor



Functionality

- Units measure trace contaminants in a sample gas (Ar in our case)
  - O_2, H_20, and N_2 are our major concerns that impact electron lifetime and photon yields
- Any one unit is specialized for one contaminant and generally only over a limited range of contamination.
- Use the Gas Analyzers to:
  - Check LAr deliveries
  - Monitor Gas Phase of Cryostat
  - Correlate LAr Phase operation with Purity Monitors, or other Lifetime monitors.

Membrane Cryostat:
Air -> ms lifetimes without evacuating

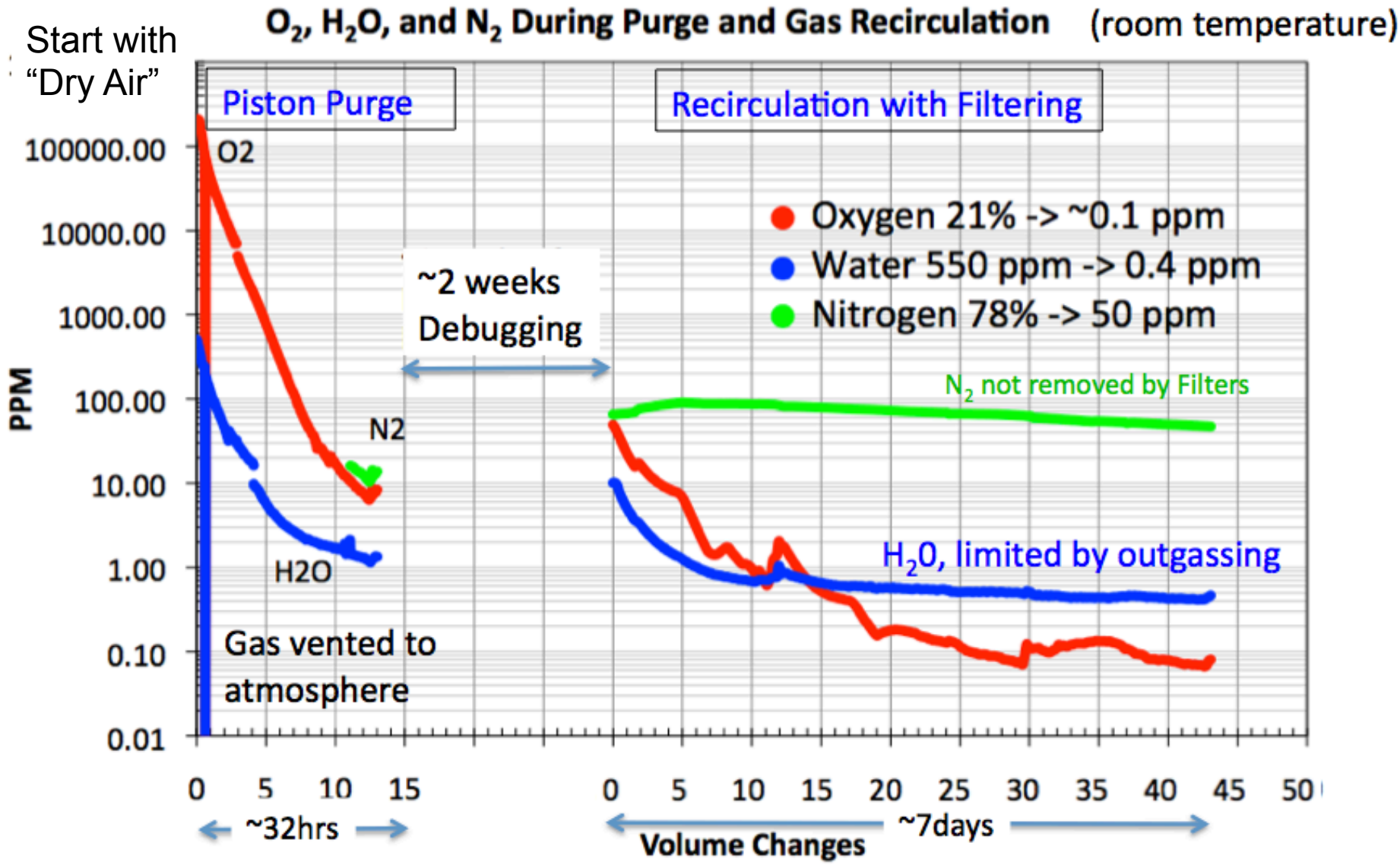
- Phases
  - Piston Purge/Vent Cryostat with Gaseous Argon
  - Gas Recirculation through the Filtration System
  - Cooldown with cooled Argon Gas
  - Fill Cryostat with filtered LAr.
  - Start Liquid Recirculation

Air -> ms lifetimes without evacuating:
Piston Purge and venting

- Piston Purge flows a high flow of Ar gas into bottom of cryostat, while we vent the outflow to atmosphere.
  - No filtering!
  - Goal would be O2, N2 levels at the ~<100 ppm level in the volume of cryostat
    - Equivalent to LAr contaminations at 0.1ppm level (liquid # density)/(gas # density) ~1000
- Context: LAPD and 35T Cryostats
  - Filtration system can handle ~2 ppm of O2 in 30-35T of LAr before need of regeneration
  - LAr Delivery—actual specs/and as delivered
  - Filling cryostat would use ~0.5 ppm of filter capacity (25%)
  - Would prefer that Gas Phase of purification contributes less than this to filter capacity.
    - Prefer a lot less!
    - Plot next page shows we do quite well

Component	Specification	Analytical Result	Analytical Method
Moisture	<= 4 PPM	0.63 PPM	Analyzer
Nitrogen	<= 15 PPM	0.32 PPM	Analyzer
Oxygen	<= 5 PPM	0.33 PPM	Analyzer

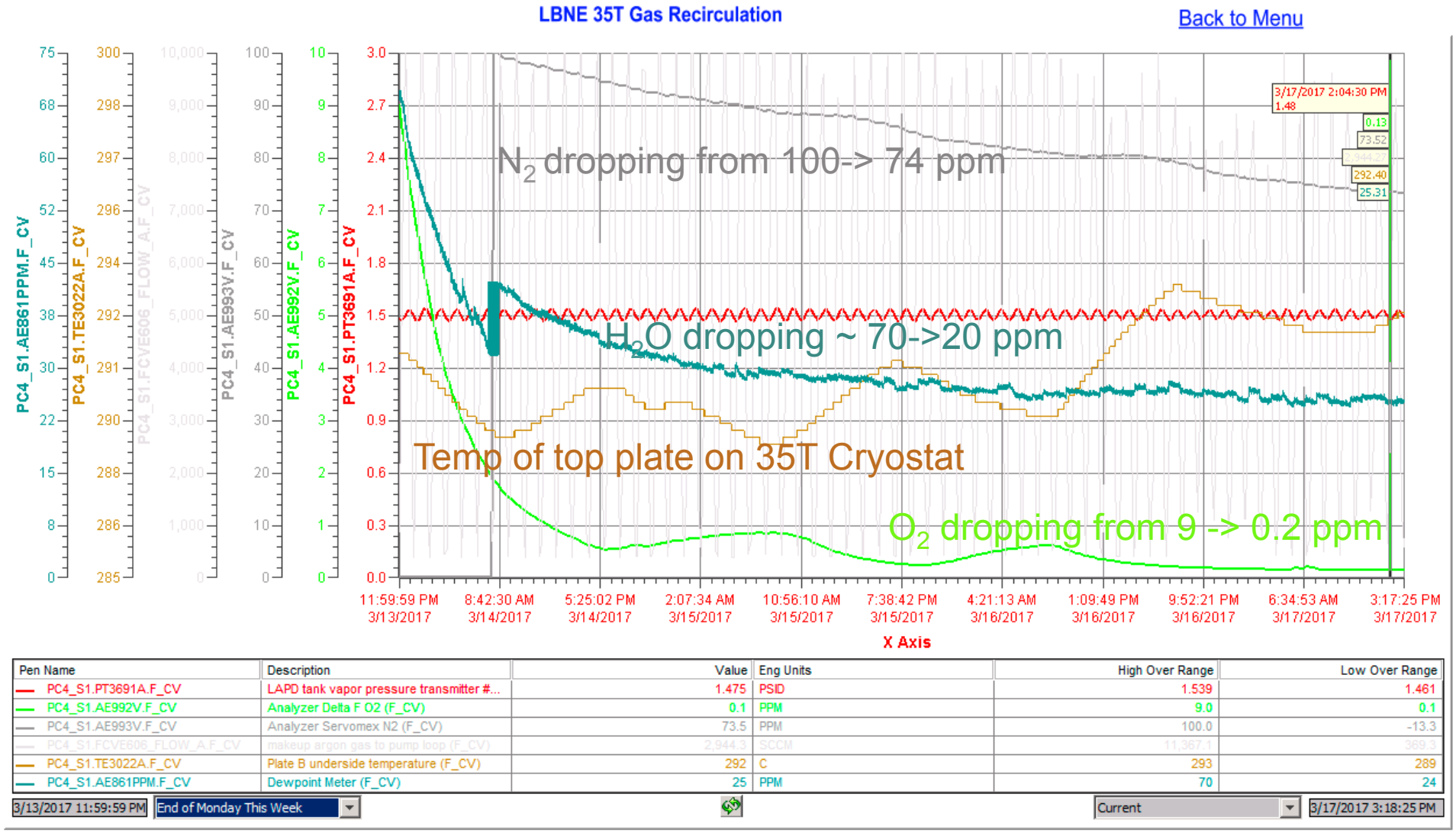
Gas Analyzers Measurements



Air -> ms lifetimes without evacuating: Gas Recirculation

- Ar gas is recirculated through the purification filters to remove O_2 and H_2O in the cryostat volume
  - Cryostat is still at room temperature
  - Useful to check for leaks
- Typically looking at N_2 and O_2 analyzers to see how they behave during this phase
  - An air leak would tend to increase N_2 and O_2
    - Or limit the level O_2 will drop to.
- N_2 not filtered, but usually drops since we are adding Ar makeup gas to cryostat to replace that being sent to analyzers and to other devices.
  - As long as N_2 is in the <1000 ppm range, equates to ~ 1 ppm range if completely absorbed in liquid.
- O_2 should be in the ~0.2 ppm range which means our filtering and/or leak rate is adequate.
- H_2O is outgassing and typically stays in the 10s of ppm range.

Gas Recirculation in HV Test (35T Cryostat)



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
PC4_S1.PT3691A.F_CV	LAPD tank vapor pressure transmitter #...	1.475	PSID	1.539	1.461
PC4_S1.AE992V.F_CV	Analyzer Delta F O2 (F_CV)	0.1	PPM	9.0	0.1
PC4_S1.AE993V.F_CV	Analyzer Servomex N2 (F_CV)	73.5	PPM	100.0	-13.3
PC4_S1.FCVE606_FLOW_A.F_CV	makeup argon gas to pump loop (F_CV)	2,944.3	SCCM	11,367.1	369.3
PC4_S1.TE3022A.F_CV	Plate B underside temperature (F_CV)	292	C	293	289
PC4_S1.AE861PPM.F_CV	Dewpoint Meter (F_CV)	25	PPM	70	24

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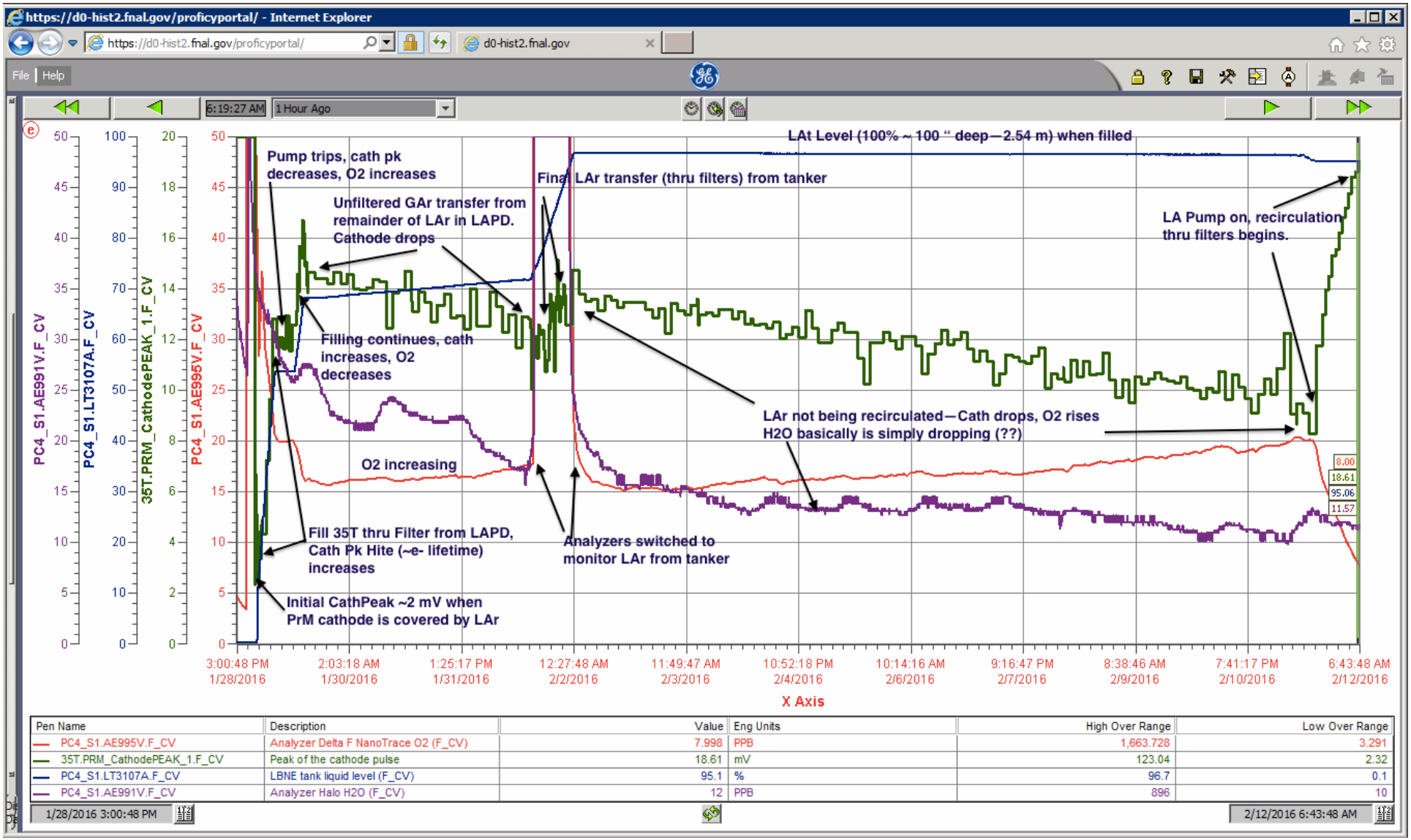
O_2 & N_2 Oscillations due to heating and cooling of top SS Plate on 35T

Air -> ms lifetimes without evacuating: Liquid Filling and start recirculating

- This sends the Ar gas through the recirculation filters in order to check for leaks
- Typically looking at N_2 and O_2 analyzers to see how they behave during this phase
  - An air leak would tend to increase N_2 and O_2
    - Or limit the level O_2 will drop to.
- N_2 not filtered, but usually drops since we are adding Ar makeup gas to cryostat
  - As long as it is in the <1000 ppm range, the LAr equivalent would be ~ 1 ppm range
- O_2 should be in the ~0.2 ppm range which means we are filtering should be adequate.
- H_2O is outgassing and typically stays in the 10s of ppm range.

O_2 and H_2O Gas Analyzer during Phase 2 fill sampling from LAr.



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
PC4_S1.AE995V.F_CV	Analyzer Delta F NanoTrace O2 (F_CV)	7.998	PPB	1,663.728	3.291
35T.PRM_CathodePEAK_1.F_CV	Peak of the cathode pulse	18.61	mV	123.04	2.32
PC4_S1.LT3107A.F_CV	LBNE tank liquid level (F_CV)	95.1	%	96.7	0.1
PC4_S1.AE991V.F_CV	Analyzer Halo H2O (F_CV)	12	PPB	896	10

Miscellaneous Details

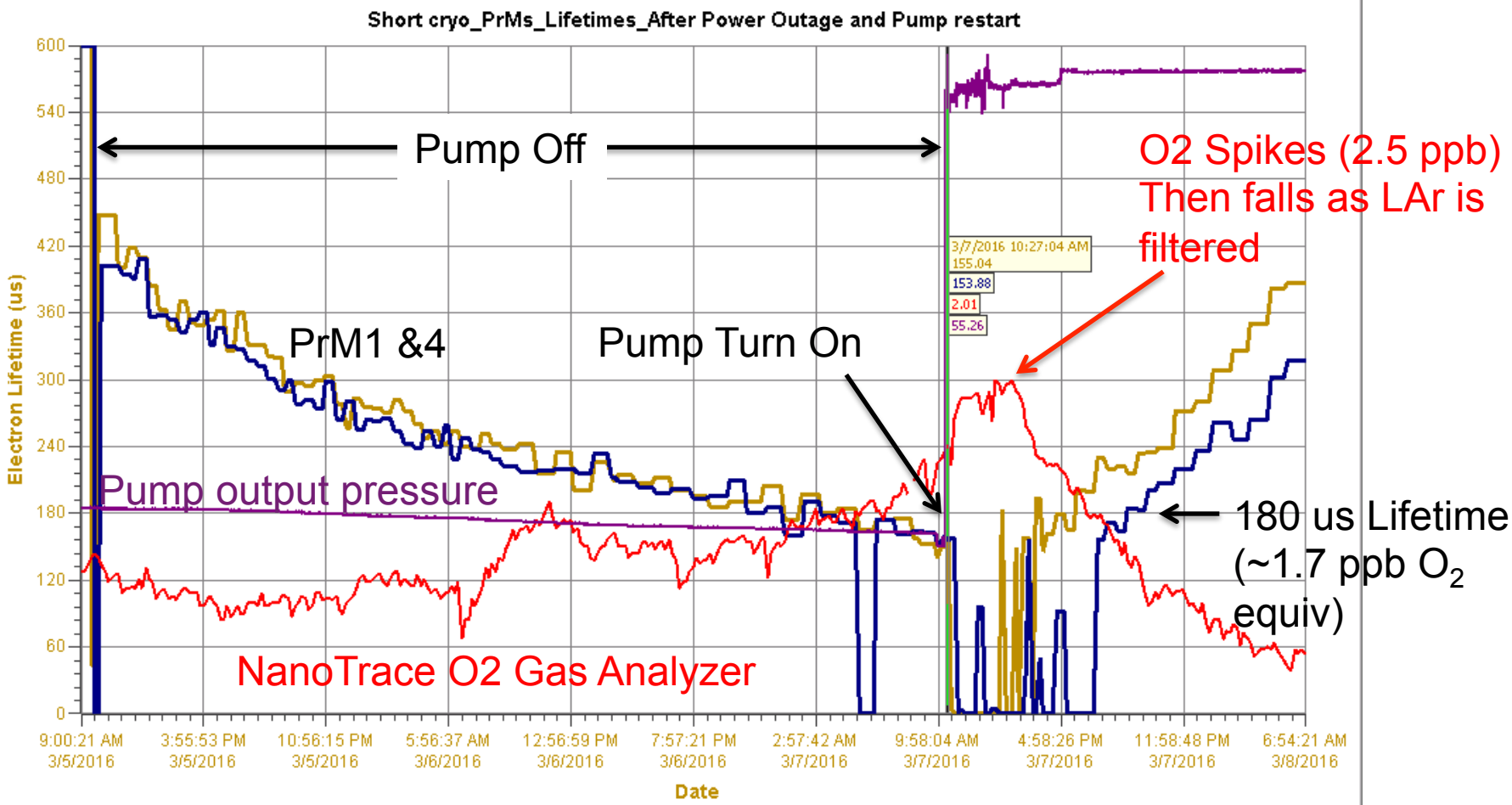
- Technologies
  - H_2O
    - Standard Humidity/Dew Point sensors-
      - organic film capacitor that absorbs water vapor, C changes (100%->10's of ppms)
    - Laser
      - Use H_2O vapor to absorb IR laser in cavity, measure exponential decay of intensity – (20 ppm ->2 ppb) or 5 ppm->100 ppt) depending on model.
  - O_2 range from
    - ODH type sensors 20% (air) down to sub %
    - KOH charge exchange devices- 1000 ppm (0.1%) to 100 ppt
      - Not all in same module! We use 3 to cover this range
    - Conversion of O_2 to H_2O, then see H_2O Laser description (1.6 ppm->100 ppt)
  - N_2
    - range from 100 -> 0.1 ppm
    - Use plasma to produce spectral lines and measure intensity
- These units need care and often "feeding"- not always set and forget
  - Some turn off if contaminants are off scale and might damage the sensors, some don't.
    - Some do not automatically turn back on
  - Need to periodically check the liquids if that is the technology

More Miscellaneous

- Sampling can be from Liquid or Vapor spaces depending on where end of tubes are located
  - H_2O measurements from liquid are problematical
    - Vapor pressure is just too low
    - Tubing runs from Cryostat to Gas Analyzers are often long, so must contend with changing H_2O outgassing from inner walls of tubing due to room environmental temperature changes.
- Connection to Slow Controls
  - At FNAL, we use the analog outputs to connect to SCADA nodes
    - Often need some digital connections to indicate scale the unit is using
      - Some ranges over 10^4 so scaling is important with analog outputs.
  - Most Units have (often optional) digital readout capability
    - Ranging from serial, GPIB, Ethernet
    - I prefer personally these since often there is more info available from the unit

XTRA slides

Expanded region around Pump Restart after Power Outage



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
35T.PRM_Lifetime_1.F_CV	Lifetime calculated from Anod...	155.0	us	5,746.9	0.0
35T.PRM_Lifetime_4.F_CV	Lifetime calculated from Anod...	153.9	us	2,539.9	0.0
PC4_S1.AE995V.F_CV	Analyzer Delta F NanoTrace O...	2.011	PPB	2.488	0.311
PC4_S1.PT3102A.F_CV	LBNE pump discharge (F_CV)	55.3	PSIG	59.2	15.0

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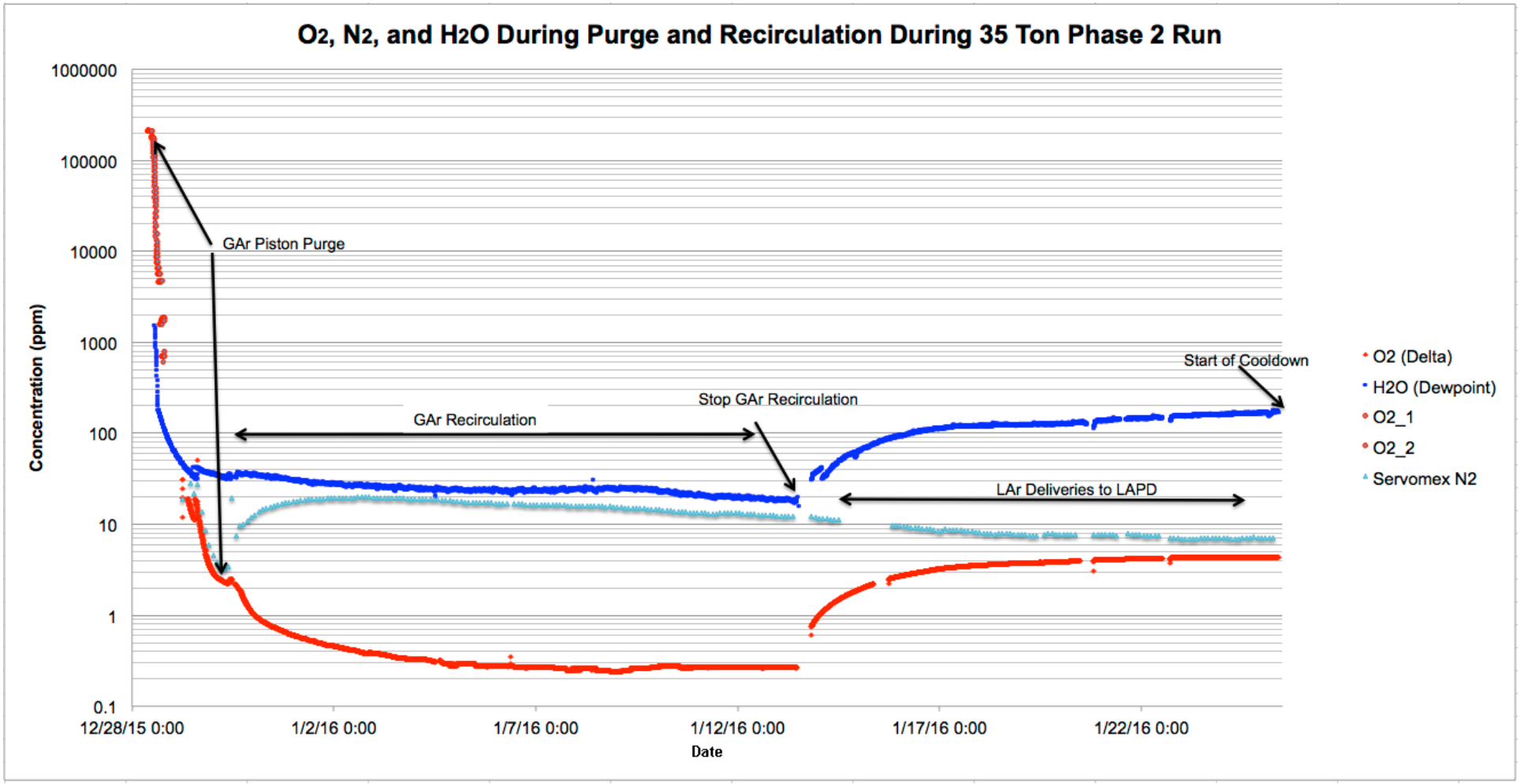
O2, N2, and H2O During Purge and Recirculation During 35 Ton Phase 2 Run
Concentration (ppm)
1000000
100000
10000
1000
100
10
1
0.1
12/28/15 0:00
1/2/16 0:00
1/7/16 0:00
1/12/16 0:00
1/17/16 0:00
1/22/16 0:00
Date
GAr Piston Purge
GAr Recirculation
Stop GAr Recirculation
Start of Cooldown
LAr Deliveries to LAPD
O2 (Delta)
H2O (Dewpoint)
O2_1
O2_2
Servomex N2