protoDUNE – single-phase Instrumentation - Gas Analyzers

Stephen Pordes, Fermilab

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Motivation:

- Check the quality of the argon delivered for water, oxygen and nitrogen content
- Monitor the progress of the purging of the cryostat atmosphere
- Look for the existence/appearance of leaks during the gas phase of recirculation and purification
- Ensure that the ultimate level of atmospheric contamination is low enough not to be a significant load on the purification system
- Monitor the effectiveness of the liquid purification in its early stages before the purity monitors come on line.
- Help diagnose problems should they occur during operation, including assessing contamination introduced in case of emergency removal/replacement of equipment.

This list may not be complete but is based on our experience at Fermilab. The first use was motivated by trying to understand the purging process for removing the atmosphere from a cryostat.

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Experience

- Have (1 in ~10) rejected trailer-load of argon for high oxygen (7 ppm vs 5 of spec; company initially denied and then agreed)
- Have detected leaks during purging and recirculation process
- Have used to understand major sources that affect electron drift-lifetime
- Have used to monitor purification process in cryostat before purity monitors are sensitive
- Have used to compare contaminants in ullage with electron drift-lifetime to understand contaminant flow in ullage.
- Have used as diagnostic when incidents (e.g., pump restart) have affected electron drift-lifetime.

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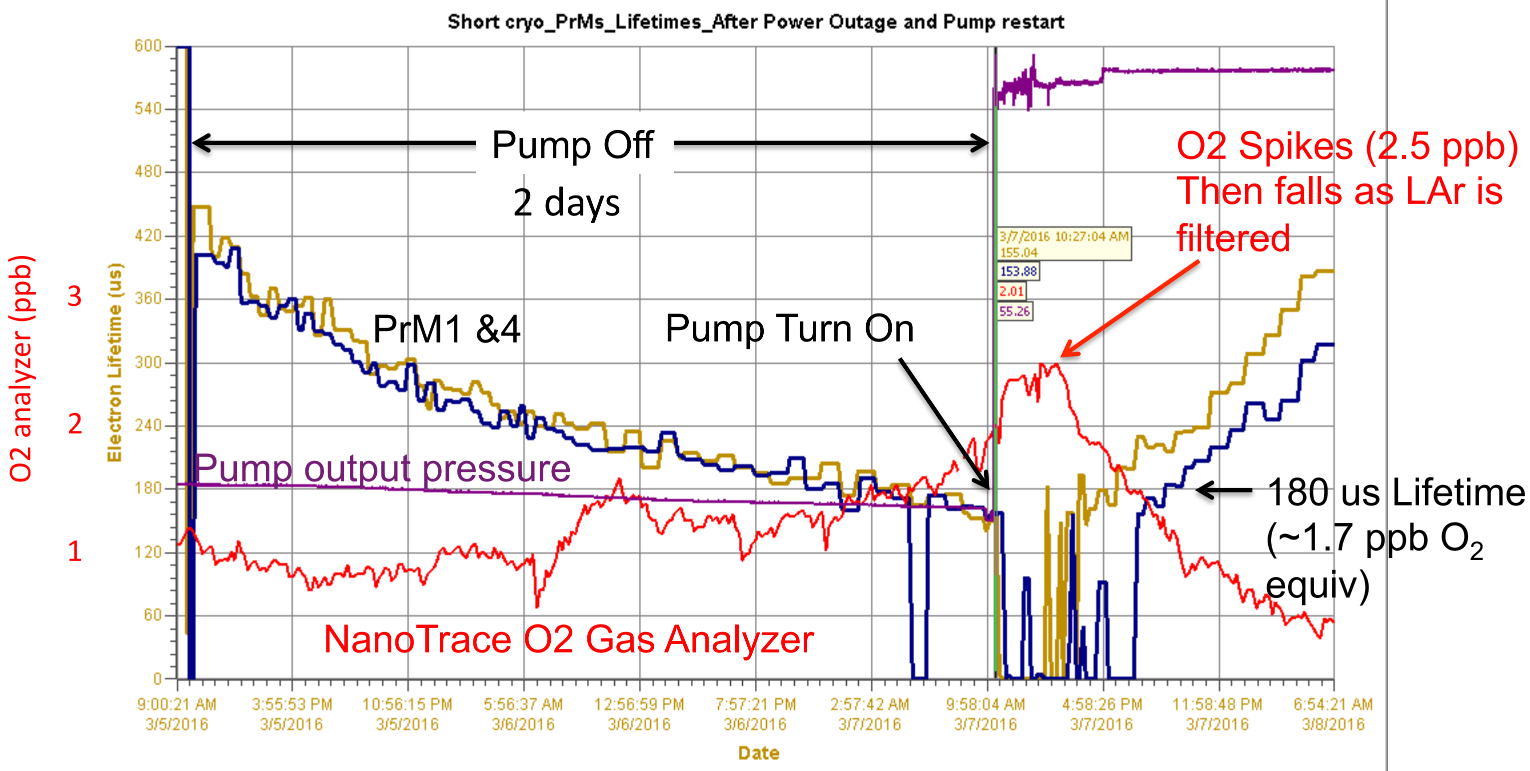
Example

Pump turn on produces a spike in Oxygen

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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Performance:

- Measure one type of contaminant only and over limited range
- Sensitivities for oxygen and water range down to fractions of a ppb
- Nitrogen devices are less sensitive and in our experience much less stable – they require weekly calibration to operate at the ~ 0.3 ppm accuracy and should be calibrated before any crucial test
- Need a switchyard to allow sampling from multiple sources

Moderate and high sensitivity analyzers available to the first atmosphere-to-purity experience at Fermilab

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**
Budget price	**$35k**	**$80k**		**$5k**	**$10k**	**$25k**	**$25k**
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.

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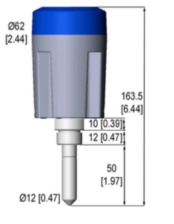
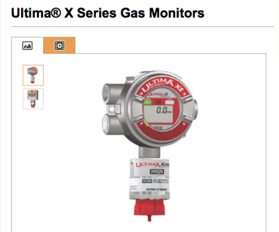
Various H_2O, N_2 and O_2 Gas Analyzers

H_2O

N_2

Vaisala Dew Point Meter



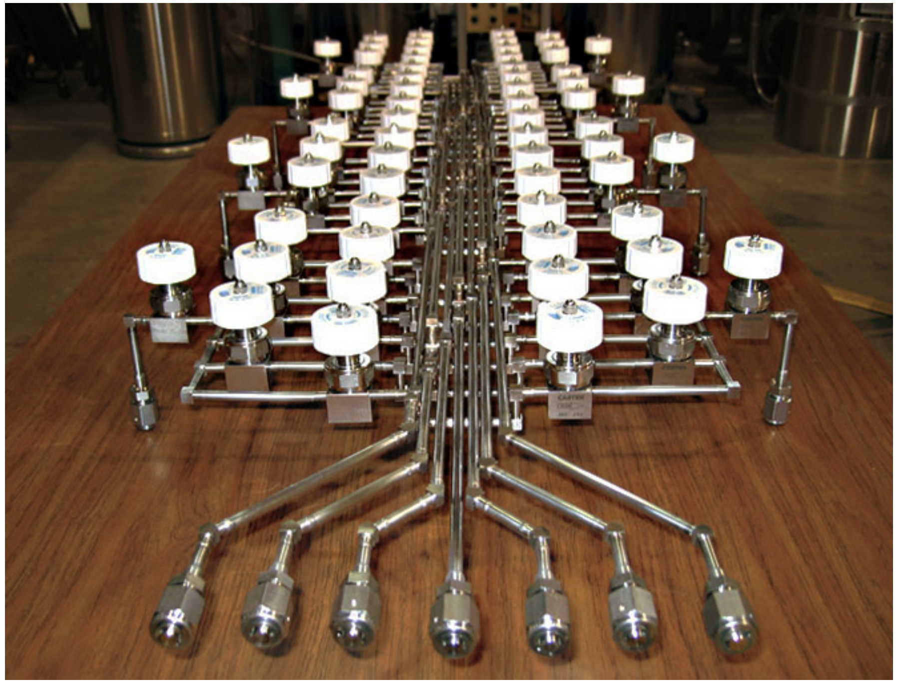


O_2 (0->25%) Monitor

O_2

from Alan Hahn

The Menorah switchyard (7 in, 8 out)



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Proposal – top of range:

- Vaisala or equivalent Dew Point Monitor
- Medium range (DF310E) and high sensitivity (DF550) oxygen analyzers
- Nitrogen analyzer (Servomex Servopro or LDetek8000)
- High sensitivity (0.6 ppb) (but not highest sensitivity) H20 analyzer (Tiger Optics Halo 3)

Modest proposal

- Omit the H20 analyzer

Input	Output to
Received liquid	Halo, DF310E, Servopro N2, fast purge
Cryostat during purge	DF310E, Servopro N2, Vaisala, Halo, fast purge
Cryostat Liquid	Halo, DF 550, Servopro N2, fast purge
Cryostat Ullage	Halo, DF 550, Servopro N2, fast purge
Feedthrough flow	Halo, fast purge
Nitrogen Calibration	Servopro N2, fast purge

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Response to charge:

In response to the charge:

1. The set of instrumentation proposed will cover the needs for gas analysis from delivery to purge to operations
2. It is envisaged that the same type of instrumentation is appropriate for DUNE. The length of DUNE may require several sets of instrumentation distributed along the length of the cryostat.
3. The major item that is not a stock commercial device is the valve switchyard. There is experience both in building such a device in-house and in purchasing one so the times to procure or construct are known. The analyzers come with commercial warranties and the switchyard can be constructed and qualified at Fermilaband checked at CERN. The items can be shipped to CERN as ordinary commercial objects. Calibration/span gases will be ordered and used for initial commissioning. It is assumed that installation of the piping to the analyzer rack will be done by the Neutrino Platform.
4. There is no installation plan as yet. (April 2017). This clearly needs to be resolved with the Neutrino platform.
5. The connections to the cryogenics system are defined in the Piping and Instrumentation Diagram (EDMS). The location of the analyzer rack and switchyard are yet to be determined.
6. The slow control system needs to record the readings from these devices and possibly exercise a calibration cycle. It is expected that the measurements from the analyzers will be recorded in a data-base and accessible in some historian. The readout interfaces have not been discussed with the slow control system and this needs to be understood and agreed in the next 6 months.

Response to charge (2)

7. We expect that the electrical grounding issues presented by the external piping used for sampling will be resolved by the electrical engineers when they define the grounding for the external piping in general.
8. The equipment is all external to the cryostat and is not expected to interfere with detector operations. We will check if the pump which may be used to boost the sample line pressures produces any electrical noise that affects the detector readout. The system needs to be operating particularly during the gas purge and recirculation phases.
9. safety of installation and operation The analytic instrumentation carries electrical certification. Installation of the switchyard and the instrumentation requires careful leak-checking but is otherwise straight forward. Once installed and commissioned, the operations burden is limited to setting the appropriate sources on the appropriate devices and so recording, and periodic calibrations of the N2 sensor. When vacuum pumps are used, procedures will be followed to ensure that we do not pull a vacuum where it is not wanted.
10. The proposal is based on experience at Fermilab where these instruments have been used extensively. We have consulted the people who built the systems at Fermilab and intend to continue this consultation and to incorporate the results of their and local (CERN) experience.