Capillary Sampling Tubes for LAPD

Version 3

Hans Jostlein June 2, 2010

Introduction

We propose to install capillary sampling tubes into the LAPD tank to measure purity at several locations, in the liquid and gas spaces.

We propose two sets of sampling tubes:

--a "Purge Monitoring" set of 12 tubes with 1/16" capillaries, flowing 1.3 l / hour each, employing inexpensive oxygen sensors to monitor initial gas purging; and

--a "High Purity Monitoring" set of 6 tubes with 1/8" capillaries, flowing 21 l / hour to the "Menorah" gas switchyard and to the high sensitivity instrumentation

The Purge Monitoring Set

It is desirable to monitor closely the initial gas purge, down to well below 1 % oxygen. This includes the "Argon piston" phase and the subsequent purge/ vent cycles.

We want to know not only the average gas purity, but also gain enough information for comparison to FEA flow models to validate or improve those models. The models will be important for future large detectors such as the LAr20 proposal for LBNE. We will want temporal and spatial information. This will inform about the degree of diffusion and mixing during purges. Sampling close to the walls, top, and bottom will help detect any dead areas, if they exist.

Description of the Purge Monitoring Set

We wish to strike a balance between performance and cost/ effort with this system.

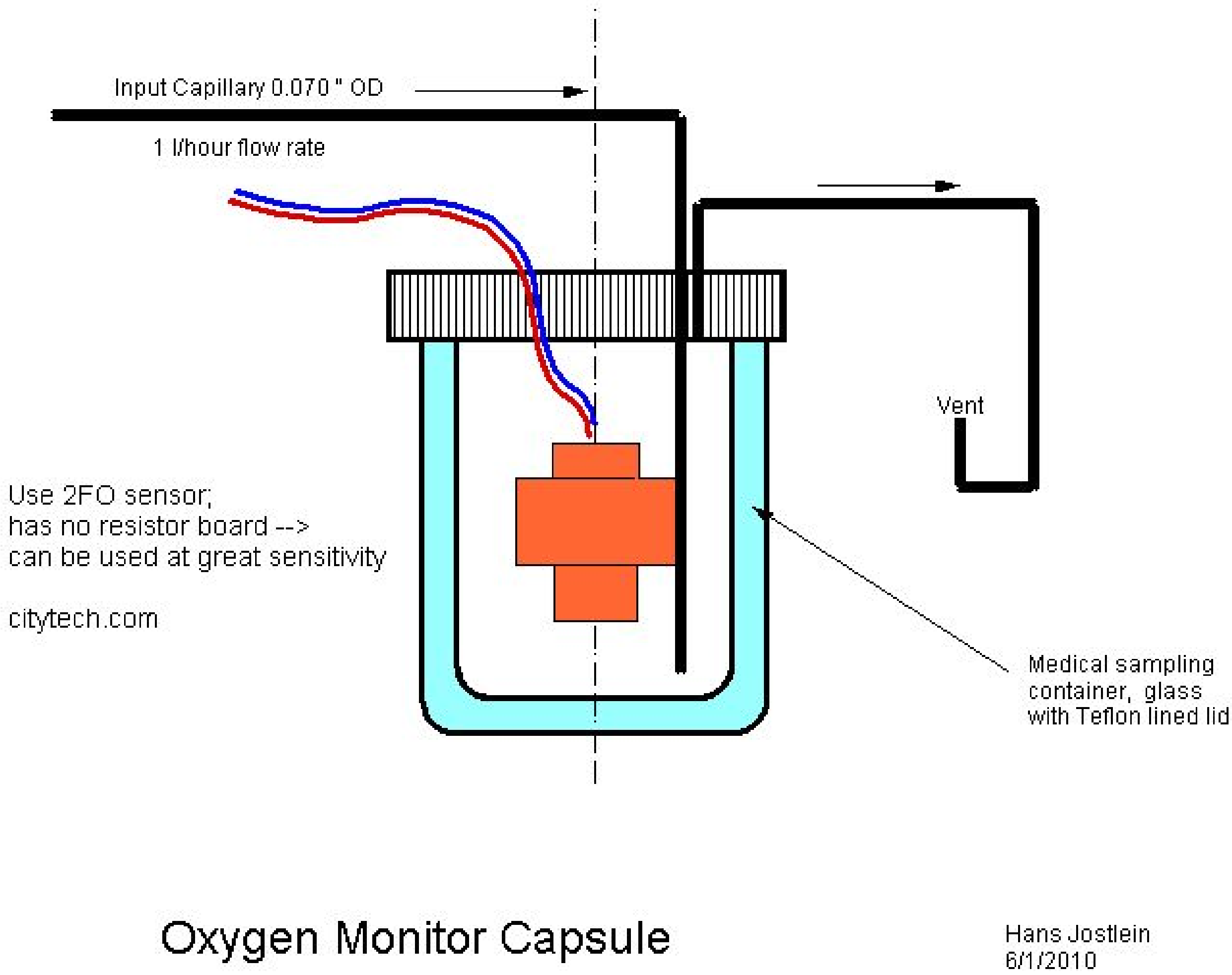
We propose to deploy 12 each industrial type oxygen sensors, similar to those used in the original "Argon Piston" test, but with an extended range of sensitivity. The will be located in two strings of 6 each, one string near a wall, and the other near the tank center. Their vertical spacing will be about 2 ft, similar to the spacing in the original test.

The sensors will be inside glass “sample jars” with Teflon coated lids. The jars are inexpensive and come in many sizes.

The sample tubes will be 0.070” OD capillaries, which run continuously from the intake point through a CF flange to the jars. The jars can be mounted on the platform or near the ground, if convenient.

The sensors will feed into a set of two 10-input, 22 bit resolution, DAQ boxes with USB output.

Here is a picture of an oxygen sampling capsule:



Capillary Performance

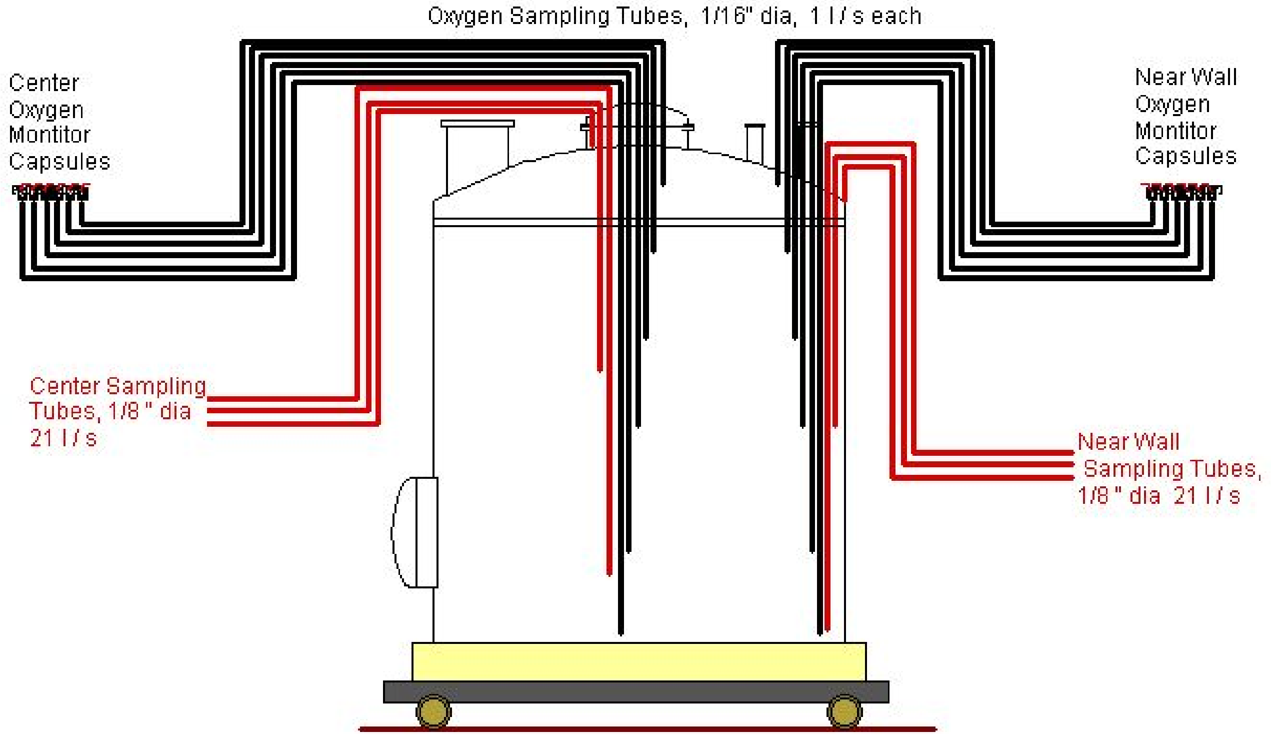
We will use capillaries of 0.070” diameter.

We want to use continuous lengths from the sample inlet point all the way to the valves in front of the analytical instruments. The purpose is to avoid leaks, preserve sample integrity, and to keep it simple. The capillaries would penetrate a CF flange where they will be brazed into drilled holes.

We have calculated the flow rate and average velocity of RT Argon gas under a pressure differential of 1 psi, see the excel sheet below. We find the average velocity to be 2.9 m/s, which guarantees fresh samples and quick response, even for the assumed length of 15 ft. If open to the atmosphere, each capillary will purge out 11 l of G-Ar per hour. If the capsules have a volume of 4 ounces (0.12 l) it will less than a minute to change one volume. The flow can be controlled / reduced by inserting short pieces of wire of appropriate diameter into the exhaust capillaries.

Sampling Capillary Layout

The following picture shows both sampling sets: the Purge sampling in black and the High Purity sampling in red:



Straight Capillary Sampling Tubes in the LAPD Tank
For Oxygen Monitoring during Initial Purge

Hans Jostlein
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There are two sets of capillary bundles, one near the tank center, and one near the tank wall.

Each bundle penetrates a single 2 .75" OD CF flange. The flange contains both the 0.070" OD and the 0.070" OD capillaries.

All sampling tubes go straight down inside the tank and end at the selected elevations.

Outside the tank the 0.070" purge capillaries terminate on platform, where the sensor capsules and DAQ boxes are located. The high purity (1/8") capillaries continue , in single runs, all the way to the Menorah. This will minimize connections, eliminate tube leaks , and help preserve the gas purity.

Oxygen Sensor Electrical Properties

The principle of operation can be found at CitiTech.com

http://www.citytech.com/loader/frame_loader.asp?page=http://www.citytech.com/contact/contact.asp

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For the purge monitoring system we are interested in a system that covers the range from atmospheric air (21% Oxygen) to the smallest oxygen partial pressures that we can reasonably and economically detect.

In the past we used the Citicell sensor model AO2.

I will show that the model 2FO

http://www.citytech.com/PDF-Datasheets/2fo.pdf

can cover a far greater range of Oxygen partial pressures,   and propose that we use this sensor for the new system.

Electrically speaking, O2 sensors are current sources. The current is proportional to the rate of O2 entering the cell.

If the cell contacts are not connected to anything ("open") then the cell reaches its saturation voltage, about 20 mV, not unlike a fully charged battery.

If the contacts are connected to a load resistor, and if the resistor is low enough to keep the sensor below saturation voltage, then the current through the resistor is independent of the resistor. The voltage across the resistor is the product of current x resistance, and is usually the quantity measured.

The model AO2, used in ODH monitoring, needs to cover only a narrow range, about 15% TO 21% oxygen in air. It is optimized for this task by incorporating a fixed load resistor and a thermistor for temperature compensation. The output is about 11 mV at 21% O2. The offset is less than 20 microvolt. We can estimate the lower detection limit, assuming 20 microvolt, and get 21% x 20 microvolt/11 milivolt = 380 ppm.

Preferably one uses a sensor without the fixed load resistor, for much greater sensitivity.

Consider the model 2FO, which puts out 0.41 mA for air.   To stay below 10 mV one would start with a load resistor of 24 ohm. Once the concentration drops below 10 ppm, say, the output voltage has dropped to 0.48 mV, which still can be measured quite accurately.

At that point one switches to a larger load resistor, 512 Ohm, getting a larger output voltage of 10 mV.

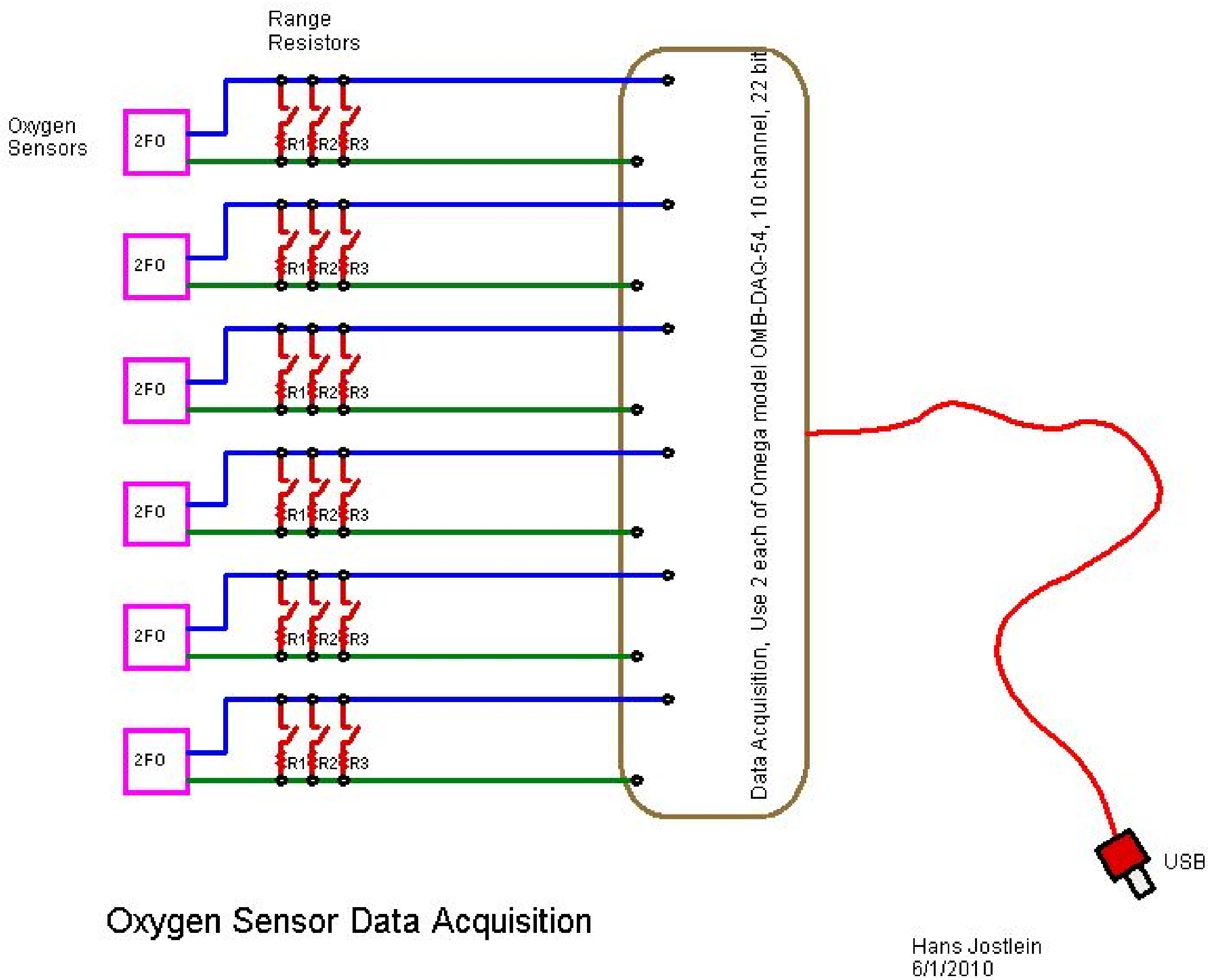
After reaching 0.1 ppm, one switches to a load resistor of 10.2 kOhm, and so on.

At some point the internal leakage of the sensor will prevent further increases in sensitivity. We will find that leakage value by testing a 2FO sensor in rather pure Argon.

Data Acquisition

We will minimize any engineering effort by purchasing a low cost DAQ-in-a-box:

http://www.omega.com/ppt/pptsc.asp?ref=OMB-DAQ55



We propose to use two sets of the OMEGA model OMB-DAQ-54, which is designed for thermocouples.

It has programmable inputs from +- 31 mV to +- 20 V scale. It supports either 5 differential or 10 single ended inputs. Since the sensors have short leads and will be near the inputs, we will use the single ended inputs, set to +- 31 mV full scale. The digital outputs are transmitted to a computer via USB cable.

The DAQ box costs $ 649 each.

Cost of the Purge Monitoring Set

The 2FO sensors cost $ 99.- a piece, and we would use 12 of them.

The two DAQ boxes will cost $ 1298.- total.

The glass jars cost about $ 30.- total.

We have the capillaries at hand.

Cost of the Purge Monitoring Set

We will need 12 each of these items:

--sensor cell $ 50.- each

--PC board—hope to get from AD

--Jars $ 2.- each

--capillary $ 3.- to 5.- per ft $ 100.- each

--Labor: I will do the capsules and capillary preparation, flange drilling, and installation into the flanges (2 each 2.75" OD CF). Installation effort is mostly electrical connection and integration into the process control system.

Total material cost less than $ 150.-per sample point, $ 1800.- total, plus integration labor.

The High Purity Monitoring Set

This set is separate and slightly different from the Purge Monitoring set to meet different instrumentation requirements:

--the high sensitivity instruments require about 1 scfh of gas flow. This calls for 1/8" OD capillaries, and shut-off valves.

--We wish to use the "Menorah" gas switch yard to connect the costly high sensitivity instruments (Oxygen and Water) to various sampling points as needed. Only a limited number of spigots is available for this on the Menorah. We assume (for now) that 6 spigots are available. If the number is smaller, we suggest to install all six capillaries, but to cap the unused ones to make them available later if their location needs to be studied.

The proposed capillaries are shown in red on the above drawing.

Conclusions

We find that a distributed sampling system in the LAPD tank is possible and easy and inexpensive.

We propose two systems, one for detailed studies of the gas purge, and one for high purity monitoring after the initial purge.

The costs are reasonable, and the effort is available in the required short time frame.

1 in=	0.0254	m		
1 Pa=	0.000145	psi		
1 psi=	6894.757	Pa		
1 psi=				
Argon gas density at RT	1.67	kg/m^3		
Ar gas visosity	2.10E-05	Pa s		
Tube diameter	0.0315	in	0.0008	m
Tube open area	0.000779	in^2	5.03E-07	m^2
tube length	30	ft	9.144	m
Pressure	1	psi	6894.757	Pa
dp/32	215.4612	Pa		
d^2/mu L=	3.33E-03	m / (Pa s)		
Flow rate Q=	3.61E-07	m^3/s	1.30E+00	l/hr
Linear velocity, average	7.18E-01	m/s		