ODH

Bob Sanders

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ODH: Oxygen Deficiency Hazard

Gases such as argon or nitrogen displace oxygen in the air we breath, potentially creating life threatening situations by lowering the oxygen concentration.

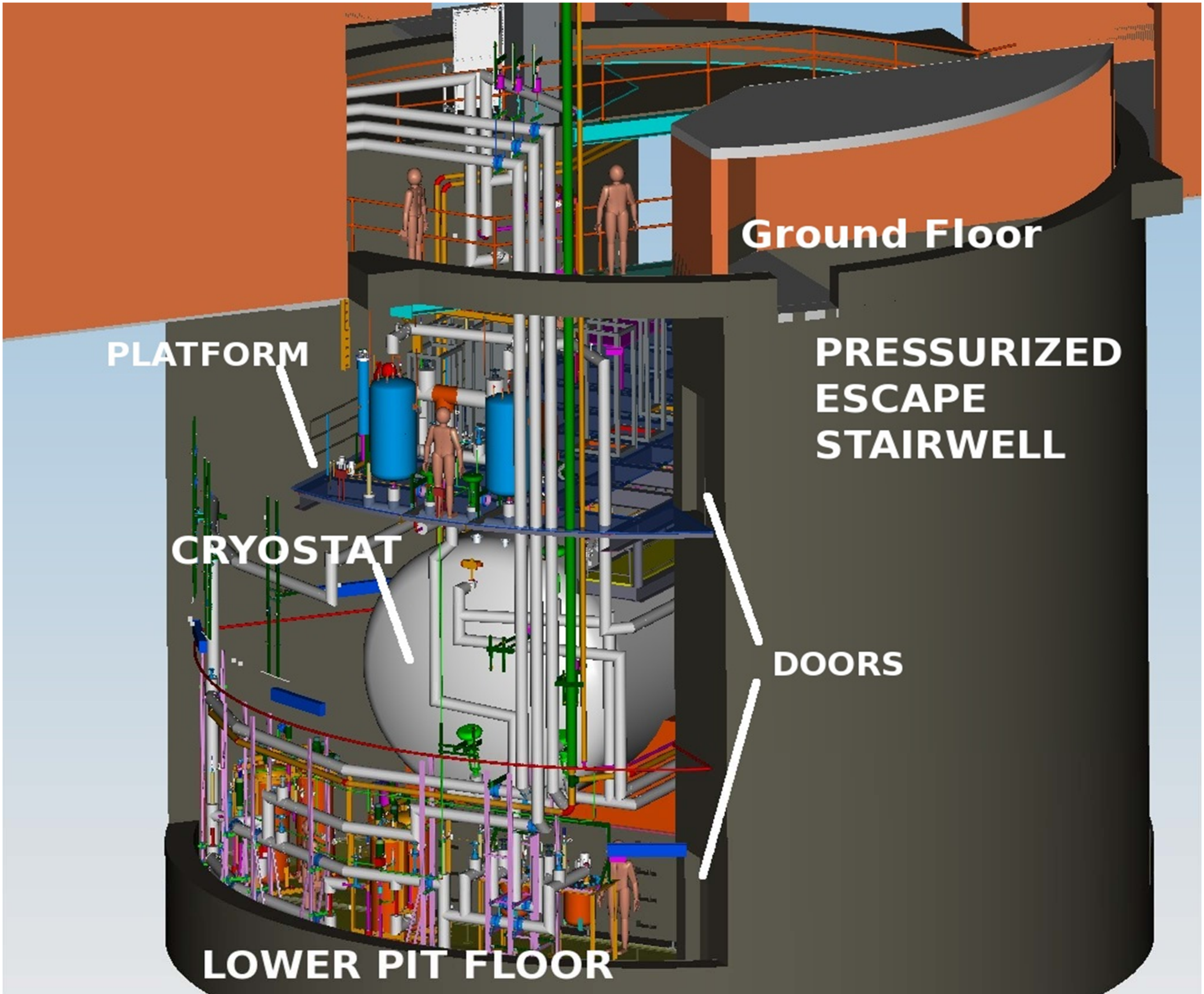
Cryogens used in TPC's:

- Liquid Nitrogen
- Liquid Argon

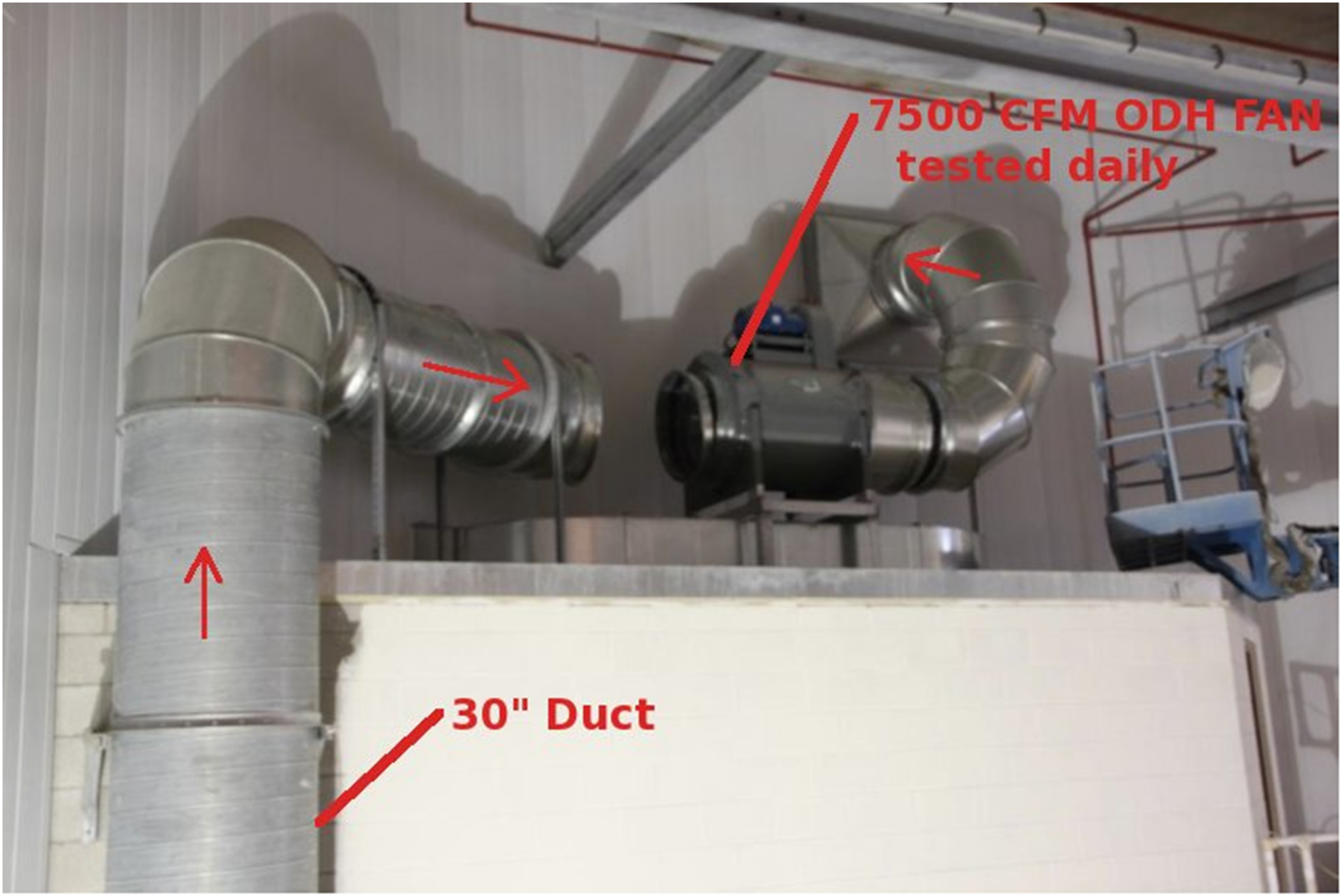
A lot of Cryogens in a Small Place

MicroBooNE Enclosure Air Volume:
8ft above ground floor: 49000 ft^3

MicroBooNE Liquid Argon: ~38000 gallons
If warmed up that becomes 4.2 X 10^6 ft^3 argon gas


Ground Floor
PLATFORM
PRESSURIZED
ESCAPE
STAIRWELL
CRYOSTAT
DOORS
LOWER PIT FLOOR


ODH FAN DUCT
Concrete Floor
will be foam insulated
Deck Grating
~16" above floor


7500 CFM ODH FAN
tested daily
30" Duct

Commercial Oxygen Monitors

- SIL 2 (reliability rating)
- Includes relays
- Self diagnostics
- Local display
- Remote readout

LAPD ODH Similar to MicroBooNE but there are differences

MicroBooNE Enclosure Smaller

- - Release of all liquid argon in filters and piping not a big issue with LAPD

- - Do the same thing with MicroBooNE and the oxygen concentration at the ground floor is ~13%.

- - Its much worse in the pit

LAPD Max Vessel Pressure 3 psig

- MicroBooNE: 30 psig max cryostat pressure
- For the same failure, the MicroBooNE argon release rates are much bigger.
- MicroBooNE ODH fan is less effective for the same failure

FESHM 5064

$$\phi = \sum_{i=1}^{n} P_i F_i$$

where ϕ = the ODH fatality rate (per hour),

P_i = the expected rate of the i^{th} event (per hour), and

F_i = the probability of a fatality due to event i.

- The chapter requires the probability of a fatality due to ODH be calculated. All events that can cause a reduction in the oxygen concentration must be considered.

Example of Industry Failure Data

PIPING	small leak, 10mm^2	$1x10^{-9}$/meter-HR
	pipes>2", large leak, 1000mm^2	$1x10^{-10}$/meter-HR
	Rupture	$3x10^{-11}$/meter-HR
PIPE Welds	small leak, 10mm^2	$2x10^{-11}$*(D/t)/HR
D=Diameter	pipes>2", large leak, 1000mm^2	$2x10^{-12}$*(D/t)/HR
t=wall thickness	Rupture	$6x10^{-13}$*(D/t)/HR

- Sometimes different interpretations of data

- For example, how big is a rupture?

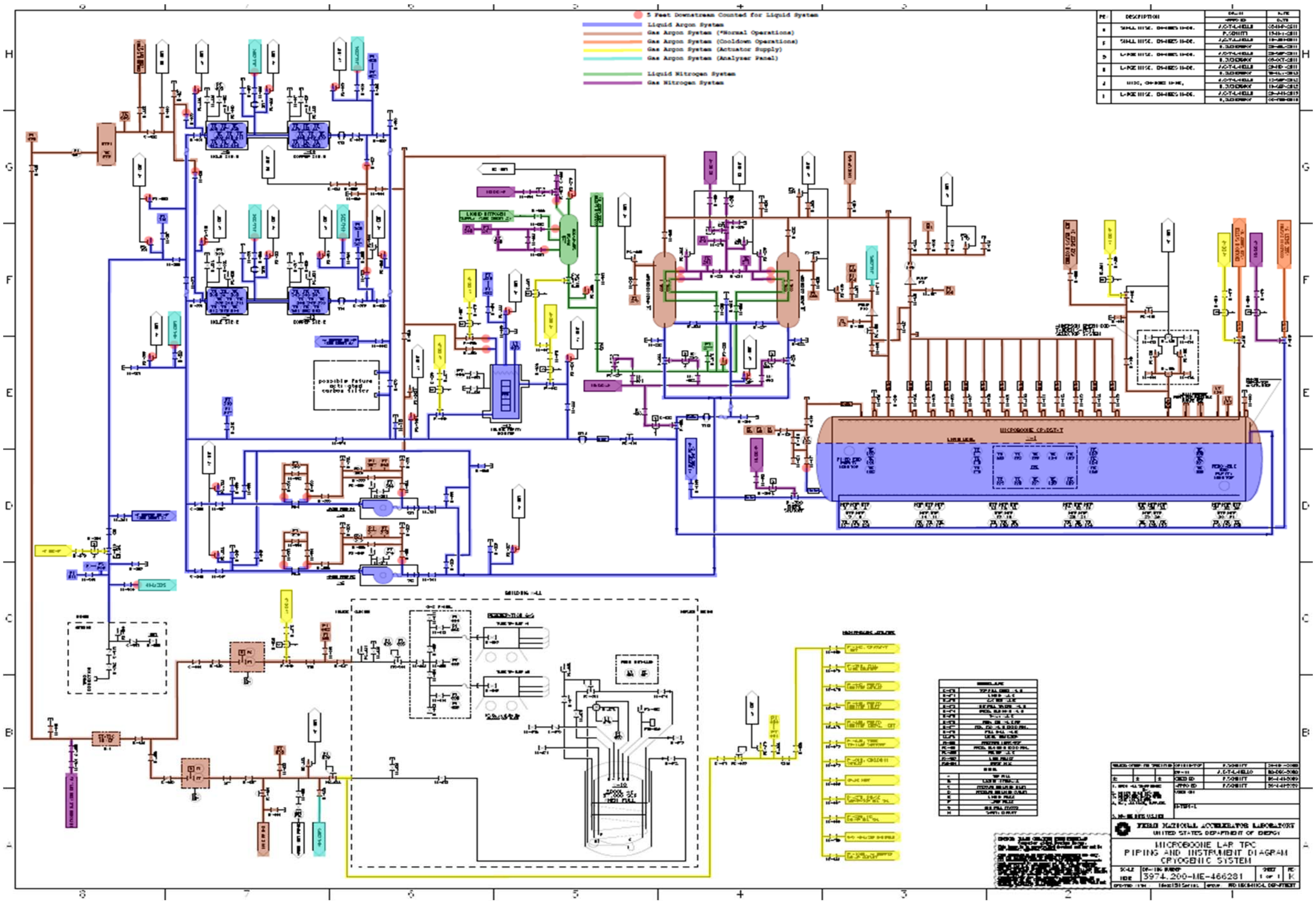
- uB used 3" sch 10 pipe cross section, if D>2"

Example of Interpretation Issue

- We have Industry data for flange failures
- What about VCR's which are not common in industry?
- LAPD ODH analysis teated VCR's as threaded joints
- uB ODH tried to do the same, but had to treat them as flanges

FLANGES			
With Reinforced &	Leak, 10 mm^2 opening	$4x10^{-7}$/HR	c,d
Preformed Gaskets	Rupture	$1x10^{-9}$/HR	c,d

Identify Systems



For Each System Count Number of Components

Liquid Argon System																					
Print #	Welds by Category					Lengths by Category (Feet)					Valves by Category					*Flanges by Category					Desription / Notes
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
493117	0	18	12	0	0	0	8	10	0	0	0	2	2	0	0	2	0	0	0	0	Cond. To Pumps A
493119	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	Cond. To Pumps B
493124	0	0	4	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	Cond. To Pumps C
493139	11	8	12	0	0	12	2	8	0	0	2	1	2	0	0	5	0	0	0	0	Cond. To Vessel A
493217	0	0	4	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	Cond. To Vessel B
493112	0	0	1	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	Cond. To Vessel C

True Totals																			
Welds					Lengths (Feet)					Valves					Flanges				
A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
207	403	328	45	31	194	456	384	29	21	31	32	16	4	0	80	20	9	7	5

Conservative Totals (10% Increase)																			
Welds					Lengths (Feet)					Valves					Flanges				
A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
228	443	361	50	34	213	502	422	32	23	34	35	18	4	0	88	22	10	8	6

For each system calculate the probability of a leak size developing

Calculate probability of a rupture or break. Take into account leaks from welds,pipes and valves. The number of items and lengths of pipes is in subsection 1 above. The probabilities are in section 2.4 and 2.5 . Ruptures of reinforced gaskets are addressed in the next subsection.,

$$\mathbf{P_{rupt}} := \overrightarrow{\left(\mathbf{N_w} \times \mathbf{P_{w\_rupt}} + \mathbf{L_p} \times \mathbf{Pf_{p\_rupt}} + \mathbf{N_v} \times \mathbf{Pf_{v\_rupt}}\right)}$$

$$\mathbf{sizes} = \begin{pmatrix} \text{"<= 1/2 tube"} \\ \text{"<= 1" pipe"} \\ \text{"<= 1 1/2" pipe"} \\ \text{"<= 2" pipe"} \\ \text{"> 2" pipe"} \end{pmatrix} \qquad \mathbf{P_{rupt}} = \begin{pmatrix} 2.09 \times 10^{-8} \\ 2.53 \times 10^{-8} \\ 1.663 \times 10^{-8} \\ 2.946 \times 10^{-9} \\ 8.053 \times 10^{-10} \end{pmatrix} \times \frac{1}{\mathbf{hr}}$$

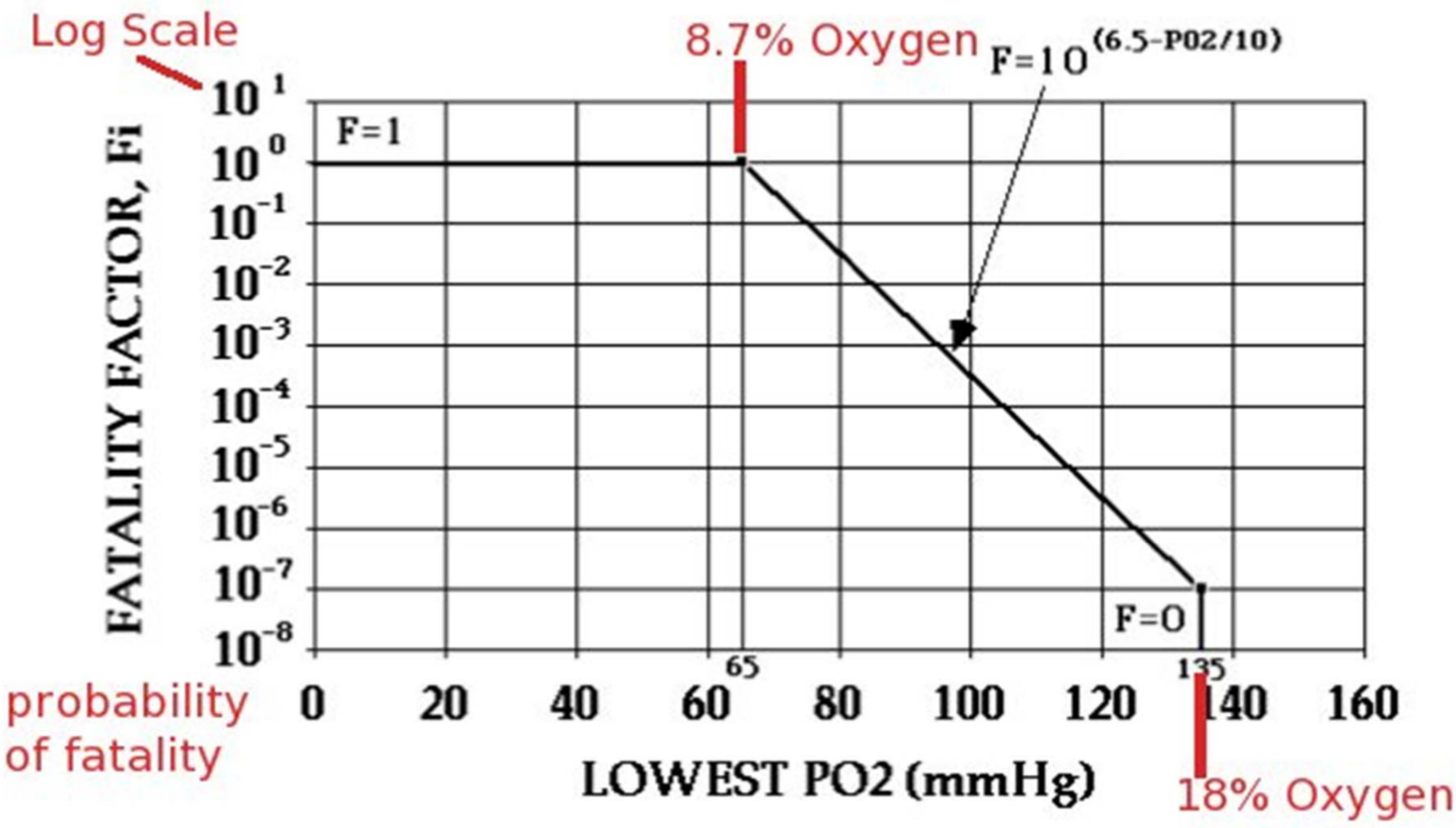
Calculate the release rate of argon or nitrogen for each size leak

Rupture: Repeat calculations for a rupture.

$$R_{rupt} := \frac{\rho_{ar.f} \times A_{rupt} \times Cd \times \sqrt{2 \times g \times h_L}}{\rho_{ar}}$$

$$sizes = \begin{pmatrix} \text{"<= 1/2 tube"} \\ \text{"<= 1\" pipe"} \\ \text{"<= 1 1/2\" pipe"} \\ \text{"<= 2\" pipe"} \\ \text{"> 2\" pipe"} \end{pmatrix} \qquad A_{rupt} = \begin{pmatrix} 0.145 \\ 0.945 \\ 2.222 \\ 3.654 \\ 8.347 \end{pmatrix} \times in^2 \qquad R_{rupt} = \begin{pmatrix} 2.038 \times 10^3 \\ 1.326 \times 10^4 \\ 3.118 \times 10^4 \\ 5.128 \times 10^4 \\ 1.171 \times 10^5 \end{pmatrix} \times \frac{ft^3}{min}$$

For each case, probability of a fatality depends on oxygen concentration



For each case calculate the fatality rate (fatalities/hr)

case 1: Calculate ϕ for the case where the ODH fan is running and all liquid argon shutoff valves are closed. Assume the liquid argon in the piping system and filter skids has been drained through the failed component. At a minimum the fatality rate is always at least $F_{lar.empty}$, calculated in section 2.9 because of the liquid in the piping system and filter skids. With the ODH automatic shut-off valves closed only argon vapor (with fatality rate $F_{rupt.vap}$ from is being released from the failed component. The fatality rate of the argon vapor $F_{rupt.vap}$, was calculated in section 4.4. Use the highest of the two fatality rates.

For ϕ multiply the fatality rate by the probability of a leak.

$$Fmax := MAX(F_{lar.empty}, F_{rupt.vap}) \qquad \phi_{rupt.fan.sh} := \overrightarrow{(P_{rupt} \times Fmax)}$$

$$F_{lar.empty} = 4.573 \times 10^{-4} \times \text{fatality}$$

$$\text{sizes} = \begin{pmatrix} \text{"<= 1/2 tube"} \\ \text{"<= 1" pipe"} \\ \text{"<= 1 1/2" pipe"} \\ \text{"<= 2" pipe"} \\ \text{"> 2" pipe"} \end{pmatrix} \qquad F_{rupt.vap} = \begin{pmatrix} 0 \\ 0 \\ 3.875 \times 10^{-6} \\ 1.154 \times 10^{-3} \\ 1 \end{pmatrix} \times \text{fatality} \qquad Fmax = \begin{pmatrix} 4.573 \times 10^{-4} \\ 4.573 \times 10^{-4} \\ 4.573 \times 10^{-4} \\ 1.154 \times 10^{-3} \\ 1 \end{pmatrix} \times \text{fatality}$$

$$\phi_{rupt.fan.sh} = \begin{pmatrix} 9.558 \times 10^{-12} \\ 1.157 \times 10^{-11} \\ 7.606 \times 10^{-12} \\ 3.4 \times 10^{-12} \\ 8.053 \times 10^{-10} \end{pmatrix} \times \frac{\text{fatality}}{\text{hr}}$$

ODH Class

- - Add up the fatality rates for each case
- - Use Table 4 below to find ODH Class
- - ODH 0 means hazard is same as normal work place

Table 4, Oxygen Deficiency Hazard Class

ODH Class	$[\phi]$ (hr^{-1})	
0		$<10^{-7}$
1	$> 10^{-7}$ but	$<10^{-5}$
2	$> 10^{-5}$ but	$<10^{-3}$