Fermilab

Particle Physics Division

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Project: LAPD

Title: LAPD Gas Shed ODH Assessment

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Abstract Summary:

This is the ODH assessment for the LAPD gas shed.

Applicable Codes:

1. *Fermilab Oxygen Deficiency Hazards (ODH), FESHM Chapter 5064, May 7, 2009*

I. INTRODUCTION

This ODH risk assessment is for the gas shed used for the Liquid Argon Purification Demonstration (LAPD) facility located in PC4. The gas shed is a separate building located just North of PC4. A Fatality Rate is computed to determine the ODH Classification. The ODH risk severity is computed from cryogen release probabilities and the associated impact on the gas shed's oxygen content. This gas shed is located at FERMI and FESHM 5064 fatality factors are used. These fatality factors combined with the cryogen release potentials are used to express the ODH risk as a total fatality rate with its associated ODH Class.

The LAPD gas shed contains argon gas cylinders that supply low pressure argon gas to the LAPD equipment in PC4. The gas shed is also supplied with argon gas by capillary tubing from four outdoor argon Dewars and a gas tube trailer.

II. SIZES AND VOLUMES

The enclosed gas shed is approximately 1,600 ft3.

III. VENTILATION

The gas shed has vent panels open to the outside to provide passive ventilation. There are 8" by 15" wall vents on the North and South walls. The two doors on the East side, each have an 18" by 12" vent.

The gas shed's passive (natural) ventilation is primary from buoyancy due to the heavier than air properties of argon gas. Lesser passive ventilation sources such as wind and solar are ignored in for the purposes of this assessment.

The arrangement of shed vents creates a height difference between the low door vents and the high wall vents. An argon release that can lower the oxygen content in the gas shed also creates the buoyancy effect that provides fresh air. At 18% O_2 due to an argon release, the heavier 18% O_2 (14.3% Argon) gas flows out the bottom door vent drawing the lighter outside fresh air. For ODH assessment, only 50% of the buoyancy ventilation is used to be conservative. The calculations and details are in the appendix.

The gas shed has a left over intake fan from a previous experiment. The fan can be manually activated. The intake for the fan is near the ceiling of PC4. Even if this fan is on, the heavier than air cryogens from the floor level of PC4 do not pose a hazard to the gas shed.

IV. SIGNIFICANT SOURCES OF CRYOGENS

The following are the significant sources of cryogens and gases which could produce ODH conditions in the gas shed during LAPD work. These are the sources considered in the analysis of component failures or ruptures. The potential leak rates for argon are estimated.

ARGON GAS CYLINDERS

The gas shed holds 8 bottles of argon, each containing 248 SCF gas.

LIQUID ARGON DEWARS

The 4 outside argon Dewars sum to approximately 10,000 SCF of argon gas. The argon from the dears goes through 10 feet of 0.01” ID capillary tubing, into the gas shed.

ARGON TUBE TRAILER

The outside gas tube trailer holds 40,000 SCF. The argon goes through 50 feet of 0.01” ID capillary tubing.

V. FAILURES CONTRIBUTING TO ODH

A. Gas Cylinder – Leak and Failure

The argon gas cylinders are to Department of Transportation (DOT) specifications. Under DOT standards the cylinders are visually inspected for damage before each filling and any visual defects trigger a recertification. Visual damage includes leaks, bulging, defective valves or safety devices, evidence of physical abuse, fire or heat damage, or detrimental rusting or corrosion. Recertification is also required on a periodic basis by DOT.

The gas cylinder is not an ASME pressure vessel by design. Gas cylinder specific failure rate data was not found. Since the gas cylinder has the characteristics of a closed section of high pressure piping, piping failure rates have been applied.

The gas cylinder is treated as a 6 foot section of piping with a resulting leak failure rate of $1.83\text{x}10^{-09}$ per hour and a failure rate of $1.83\text{x}10^{-10}$ per hour.

B. Tubing – Leak and Failure

Tubing can fail by leaking or breaking. The leak failure can be further broken down into a small leak and a large leak. For this analysis leak rates of 5 ft3/min, 10 ft3/min and 20 ft3/min are used. At 20 ft3/min a gas cylinder empties in less than 15 minutes and at 10 ft3/min a cylinder empties in less than 30 minutes. The small leak risk rate is 3.05×10^{-10} per foot per hour and the large leak risk rate is 3.05×10^{-11} per foot per hour. The pipe break risk is 9.14×10^{-12} per foot per hour. The use of these factors provided additional clarity over the basic per section risk factor listed in FESHM 5064.

C. Human Error – Leak and Failure

During gas cylinder replacement, human error could result in an argon gas leak. An argon gas leak would occur if an operator fails to tighten the CGA fitting while installing a replacement cylinder. After opening the cylinder valve, the escaping gas would provide audible feedback. If the operator fails to close the valve to stop then a sustained leak occurs. With a maximum of 1 cylinder replacement per day, the resulting failure rate is 3.75×10^{-7} per hour for the whole bank of cylinders. The detailed error rate calculation is in the appendix.

VI. ODH CALCULATIONS

Oxygen concentrations are calculated using FESHM, 5064, equation 4 at time equal to infinity.

$$C = 0.21 \cdot \left(1 - \frac{R}{Q}\right)$$

- Q is the rate the ventilation is drawing out the contaminated atmosphere.
- R is the spill rate of the air displacing gas.
- C is the concentration of oxygen assuming perfect mixing.

It is assumed that any leak occurring during calm conditions (no wind) will drive the oxygen concentration to 0%, as time approaches infinity.

The fatality factor is per the graph in figure 1, FESHM 5064. An equation was used to represent the graph in the ODH analysis, detailed in Table 1.

VII. PC4 GAS SHED ODH FINDINGS

The total fatality risk rate for the PC4 gas shed is 3.78×10^{-14} per hour which is ODH class 0. This is for the gas shed with only passive ventilation. The detailed tabulation is in Table 1.

VIII. REFERENCES

1. ***FESHM 5064, May 7, 2009***
2. ***Risk Analysis for Process Plant, Pipelines and Transport, 1st ed, 1994***

TABLE 1: LAPD Gas Shed Oxygen Deficiency Hazard Analysis

PC4 Gas Shed:	1,600	cu. ft. (based on 6ft height for people space)			
ODH Exhaust:	0	cu. ft./min	PoweredVentilation	0	cu. ft./min
Total Exhaust Affecting ODH	0	(vent. + ODH exhaust)		rev.	09/08/11
Ventilation Failure Rate:	0.0000	/hr there is no powered ventilation			
Bouyancy ventilation rate:	156	cu. ft./min	**Bouyancy ventilation taken into account for @ infinity C(O2) for small leaks.**		
small leak limit for bouy.:	50	cu. ft./min	**If a leak exceeds this small leak limit then bouyancy effect is ignored.**		

	Failure Type	# of	Individual Failure Rate (/hr)	SOURCE	Total Failure Rate for Item	Leak rate, into people space (CFM)	C(O2) at infinity	Fatality Factor	PC4 Fatality Rate	ODH CLASS	Notes
EQUIPMENT											
Gas Cylinder[i]											
Cylinder (eqv to 6 ft piping)	leak	8	1.83E-09	1	1.46E-08	5.0	20.33%	0.00E+00	0	0	
Cylinder (eqv to 6 ft piping)	failure	8	1.83E-10	1	1.46E-09	200	18.00%	1.00E-07	1.46E-16	0	C(O2) for full cylinder leaking out
human error - tighting fitting	leak	1	3.75E-07	1	3.75E-07	200	18.00%	1.00E-07	3.75E-14	0	1 cyl change per day / C(O2) for full cylinder leaking out
PIPING											
Sample Tubing											
Tubing	leak, small	30	3.05E-10	B	9.15E-09	5.0	20.33%	0.00E+00	0	0	
Tubing	leak, large	30	3.05E-11	B	9.15E-10	10.0	19.65%	0.00E+00	0	0	
Tubing	break	30	9.14E-12	B	2.74E-10	30.0	16.96%	6.17E-07	1.69E-16	0	
VALVE	leak	10	1.00E-08	A	1.00E-07	10.0	19.65%	0.00E+00	0	0	
regulator	leak	2	1.00E-08	A	2.00E-08	10.0	19.65%	0.00E+00	0	0	

Gas Shed		
	Total Fatality Rate:	**3.782E-14**
	Overall ODH Class:	**0**

SOURCES

A FESHM Chapter 5064, rev. 05/2009
B Risk Analysis for Process Plant, Pipelines and Transport, 1994.

NOTES

i Gas cylinder failure rate is estimated as a 6 foot section of pipe, using the failure data from source B.

Passive Ventilation

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These calculations provide a conservative estimate of the passive (natural) ventilation rate for the PC4 gas shed.

Density Driven Air Flow

Any significant argon release in the gas shed will create density (buoyancy) driven ventilation. The bouyancy is evaluated for an 18% oxygen condition caused by an argon release.

The resulting gas components are determined for the 18% O2 case and used to get the mixture density from REFPROP.

Concentration of Oxygen in air

$$X_o := 0.21 \cdot X_{air}$$

Relationship between inert gas and air

$$X_{air} := 1 - X_{inert}$$

Substituting in the inert conc.

$$X_o := 0.21 \cdot (1 - X_{inert})$$

Rearranged to solve for inert conc.

$$X_{inert} := 1 - \frac{X_o}{0.21}$$

Case 1: Evaluate at 18% O2

$$X_o := 18 \cdot \% \qquad X_{inert} := 1 - \frac{X_o}{0.21} \qquad X_{inert} = 14.3 \cdot \%$$

Resulting "Air" Makeup for Density Determination

$$O2_{conc} := X_o = 18 \cdot \% \qquad N2_{conc} := (1 - X_{inert}) \cdot 0.79 = 67.7 \cdot \% \qquad X_{inert} = 14.3 \cdot \%$$

Density of the reduced O2 (18% O2) air with argon as the added inert gas, as calculated above. ref: REFPROP V9.0

$$\rho_{mix} := 1.2610 \cdot \frac{kg}{m^3}$$ @ 70 F

Density of air

$$\rho_{air} := 1.1997 \cdot \frac{kg}{m^3}$$ air @ 70 F

Area of smallest Vent

$A_{vent} := 8 \cdot in \cdot 15in$ $\qquad A_{vent} = 0.83 \cdot ft^2$

Note that the gas shed has 2 wall vents @ 8" x 15" and 2 door vents @ 18" x 12". The wall vent area is smaller and therefore it determines the air flow. Only 1 wall vent is counted which reduces the available flow by 50% for a conservative basis.

Height between Inlet / Outlet

$h := 2 \cdot ft$

This is the height difference between the top of the door vent and bottom of the wall vents.

Pressure Difference Due - Between Warm Argon / Cold Air

$\Delta P := h \cdot g \cdot (\rho_{mix} - \rho_{air}) = 0.001 \cdot in\_H2O$

Density Air STP

$\rho_{airSTD} := 1.2229 \cdot \frac{kg}{m^3}$

For converting air flow to standard temperature and pressure.

@60 F (Refprop 9)

Orifice Flow Coefficient (square edged orifice)

$C := 0.62$

Area for Air flow

$A_{Induced} := 2 \cdot A_{vent}$

The area for density induced air flow limited by the two small vent area from the previous page.

Density Induced Air Flow

$$Induced_{AirFlow} := \frac{\left(C \cdot A_{Induced} \cdot \sqrt{\frac{2 \cdot g \cdot \Delta P \cdot 1 \frac{lbm}{lbf}}{\rho_{air}}} \cdot \rho_{air} \right)}{\rho_{airSTD}} \qquad Induced_{AirFlow} = 156.0 \frac{ft^3}{min}$$

This above flow is a conservative since only one wall vent area was counted for bouyancy driven ventilation.

Leak Due to Human Error

An Argon release would occur if an operator fails to tighten the CGA fitting, error of commission.

After opening the cylinder valve, the escaping gas can be heard.

At this point the operator can fail to close the valve, error of commission.

A gas cylinder is assumed to be replaced everyday.

Failure rate data from FESHM 5064, Table 3.

Human Error of Commission

$Err_{Human} := 3 \cdot 10^{-3}$ per demand

Rate of Cylinder changes

$$Cyl_{change} := \frac{1}{24 \cdot hr} = 4.17 \times 10^{-2} \cdot \frac{1}{hr}$$

Gas Cylinder Hookup Failure

A hookup failure is when an operator
fails to tighten the CGA fitting
and fails to identify the sound of escaping gas.

Using the per demand failure rate is used with the rate of cylinder changes to reflect the hookup failure rate on a per hour basis.

$$Hookup_{failure} := Err_{Human} \cdot Err_{Human} \cdot Cyl_{change}$$

$$Hookup_{failure} = 3.75 \times 10^{-7} \cdot \frac{1}{hr}$$

For 1 cylinder change per day.

O2 Impact of Leaking out a Cylinder

Cylinder Volume (SCF)

$GasCyl_V := 248 \cdot ft^3$

Shed Volume (up to 6 ft only)

$V_{shed} := 1600 \cdot ft^3$

Cylinder Leak Rate

$R := 200 \cdot \frac{ft^3}{min}$

Time to empty Cylinder (assuming leak rate is constant)

$t_{empty} := \frac{GasCyl_V}{R} = 1.24\,min$

Room O2 concentration at time of leaking cylinder being empty

$t := t_{empty}$ Set time to time of cylinder just emptying from above

$C_t := 21 \cdot \% \cdot e^{-\left(\frac{R}{V_{shed}}\right) \cdot t}$

$C_t = 18.0\,\%$

This is the limit of how low the O2 concentration will go for a cylinder leaking out due to its limited inventory of crygen.