Jefferson Lab HDIce Lab - ODH Analysis

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The HDIce Lab is a facility to build, test and prepare HD polarized targets for use in the experimental Halls at The Thomas Jefferson National Accelerator Facility (JLab). The facility is attached to the Test Lab on its north end. This analysis is a revision of the original analysis of this space. There are 3 rooms in the HDIce Lab. The high bay area, the Pump Room and a storage room which was a liquid storage room (see below for more information). The only room with both personal and liquid cryogens is the high bay area.

Since the original version of this analysis there have been a few changes that require a new ODH analysis. These changes are based on actual operating experience, limits in budget and other factors. In the original plan for this facility the liquid storage room would have liquid storage dewars and from that room a permanent transfer line system would distribute cryogens to the loads. Due to budget considerations, the transfer line system was never built and it has been eliminated from all future plans. The other major change is that at times it became necessary to bring two 500 helium dewars into the high bay. In planning for future operations in the lab it was decided to complete the ODH analysis with as many as three 500liter helium dewars in the high bay, thus increasing the potential inventory by 1000 liquid liters of helium. The final slightly smaller change is that the Rome Dilution Refrigerator has been removed from the facility and will not be used in the future, there are no plans to replace it, thus removing 200liquid liters of helium inventory

An Oxygen Deficiency Hazard (ODH) is identified based on the potential to cause injury or death from an atmosphere that is oxygen depleted. The analysis depends on two factors: probability of a failure and the likelihood of fatality if the failure occurs. Complete detailed calculations for this can require lots of time and effort. As a strategy to simplify the analysis, in this paper I start by assuming worst case scenarios and then analyzing these, if they pass then all other scenarios that are not as bad can be ignored.

The fatality factor is based on oxygen content as shown in Chart 1.

Figure 3: Fatality factor Fi versus the lowest attainable oxygen concentration which can result from a given event.

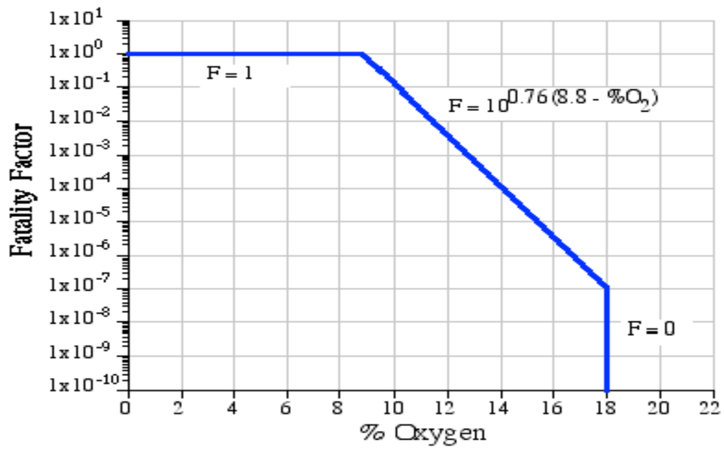

Chart 1. Fatality factor Chart from the EH&S manual.

The probability of occurrence is taken from various sources and is mostly based on acquired data from operating histories. JLab has a significant cryogenic history and some values have been supplemented by JLab data.

Equipment Failure Rate Estimates *

System	Failure Mode	Failure Rate
Compressor (Two-stage Mycom)	Leak Component rupture	5×10^{-6}/hr 3×10^{-7}/hr
Dewar	Loss of vacuum	1×10^{-6}/hr
Electrical Power Failure (unplanned)	Time Rate Demand Rate Time Off	1×10^{-4}/hr 3×10^{-4}/D 1 hr
Fluid Line (Cryogenic)	Leak Rupture	5×10^{-7}/hr 2×10^{-8}/hr
Cryogenic Magnet (Powered, unmanned)	Rupture	2×10^{-7}/hr
Cryogenic Magnet (Not powered, manned)	Rupture	2×10^{-8}/hr
Header Piping Assembly	Rupture	1×10^{-8}/hr
U-Tube Change (Cryogen Release)	Small Event Large Event	3×10^{-2}/D 1×10^{-3}/D
*Median estimates excerpted from FESHM-4240 Technical Appendix, Rev 11/2016		

Table 1. Equipment failure rates from the EH&S manual

The ODH fatality rate comes from the summation formula, equation 1, and the ODH rating comes from table 1b, from the EH&S manual.

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

Equation 1. Summation of the product of probability and fatality for each occurrence

where:
φ = the ODH fatality rate (per hour),
P_i = the expected rate of the i^{th} type of event (per hour)
F_i = the fatality factor for the i^{th} type event.

Table 6: Oxygen Deficiency Hazard Classification	
ODH Class	ODH Fatality rate Ψ (hr^{-1})
0	$<10^{-7}$
1	$>10^{-7}$ but $<10^{-5}$
2	$>10^{-5}$ but $<10^{-3}$
3	$>10^{-3}$ but $<10^{-1}$
4	$>10^{-1}$

Table 1b ODH Classification table from EH&S manual

General Information

In the HD Lab, both nitrogen and helium are used in both gas and liquid forms. The amount of maximum total amount of liquid stored in the high bay listed in table 2

Liquid Inventory totals	Liquid Liters
Liquid Helium	1656
Liquid Nitrogen	436

Table 2. Stored liquid inventory in the high bay including transfer line volumes

High Bay Volume		
Length (L)	ft	51
Height (H)	ft	24
Width (W)	ft	27
Volume	ft^3	33048
	liters	9.36E+05

Table 3. Lab Volume

I calculate the 0_2 concentration in the high bay that results when each liquid volume of LHe or LN_2 are vented instantaneously. For this calculation I assume that an equivalent volume of normal (21% O_2) air is removed from the room as the cryogenic liquid is dumped in. Then after some time the entire volume equilibrates through normal diffusion. Table 4 shows the results.

Instantaneous Release from Cryostat or Dewar Due to Rupture						
HELIUM	LL	gas liters	%O2	Fatality Factor	Probability Factor	F*P
IBC	30	22620	20.49%	0.00E+00	1.00E-06	0.00E+00
PD	25	18850	20.58%	0.00E+00	1.00E-06	0.00E+00
TC	1	754	20.98%	0.00E+00	5.00E-07	0.00E+00
Oxford DF	55	41470	20.07%	0.00E+00	1.00E-06	0.00E+00
SD	45	33930	20.24%	0.00E+00	1.00E-06	0.00E+00
Helium Supply Dewar	500	377000	12.54%	1.44E-03	1.00E-06	1.44E-09
Helium Supply Dewar	500	377000	12.54%	1.44E-03	1.00E-06	1.44E-09
Helium Supply Dewar	500	377000	12.54%	1.44E-03	1.00E-06	1.44E-09
NITROGEN	LL	gas liters	%O2	Fatality Factor	Probability Factor	F*P
IBC	0	0	21.00%	0.00E+00	1.00E-06	0.00E+00
PD	50	34700	20.22%	0.00E+00	1.00E-06	0.00E+00
TC	4	2776	20.94%	0.00E+00	5.00E-07	0.00E+00
Oxford DF	50	34700	20.22%	0.00E+00	1.00E-06	0.00E+00
SD	30	20820	20.53%	0.00E+00	1.00E-06	0.00E+00
Emergency helium dewar	0	0	21.00%	0.00E+00	1.00E-06	0.00E+00
LN2 Dewar	100	69400	19.44%	0.00E+00	1.00E-06	0.00E+00
LN2 Dewar	100	69400	19.44%	0.00E+00	1.00E-06	0.00E+00
LN2 Dewar	100	69400	19.44%	0.00E+00	1.00E-06	0.00E+00

Table 4. Analysis of the dump of any cryogenic liquid volume.

One can see that dumping the helium dewars cause the O_2 concentration to dip below 18% but the probability of those events are small thus the ODH rating is 0.

It is possible for a user to make an error while working on the system. The most likely errors are to either open a helium dewar to air and letting its boil off go into the room. Or even more likely is that the multiple supply dewars are brought into the room and then not used. These will pressurize to their relief pressure due to static heat load and then slowly vent into the high bay.

Case of 3 helium dewars venting due to static heat load			%O2	Fatality Factor	Probability Factor	F*P
Helium Dewar Flow Analysis						
Helium volume in Dewars	LL	1500				
Helium evaporation rate	%/day	0.7				

	LL/day	10.5				
	g/s	0.015190972				
	LL/s	0.000121528				
	gas L/sec	0.091510417				
	SCFM	0.194015018				
Fresh Air Make up Flow	CFM	231				
Steady State %O2			20.98%	0.00E+00	5.00E-01	0.00E+00

Table 5. ODH conditions for continuous flow from the dewars.

The final ODH rating is the sum of all P*F which gives

Total Sum	**4.31E-09**	**= ODH 0**

<u>Conclusion</u>

The rating for the HDIce lab is ODH 0