

Jefferson Lab HDIce Lab - ODH Analysis

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The Thomas Jefferson National Accelerator Facility (JLab) built an extension to our Test Lab to house the HDIce Lab. This analysis covers this new space. There are 3 rooms in the HDIce Lab. The high bay area, the Pump Room and the Liquid Helium Dewar room. The only room with both personal and cryogenics is the high bay area. The Pump room will have no cryogenics and the Liquid Helium Storage room will have no people.

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 F_i versus the lowest attainable oxygen concentration which can result from a given event.

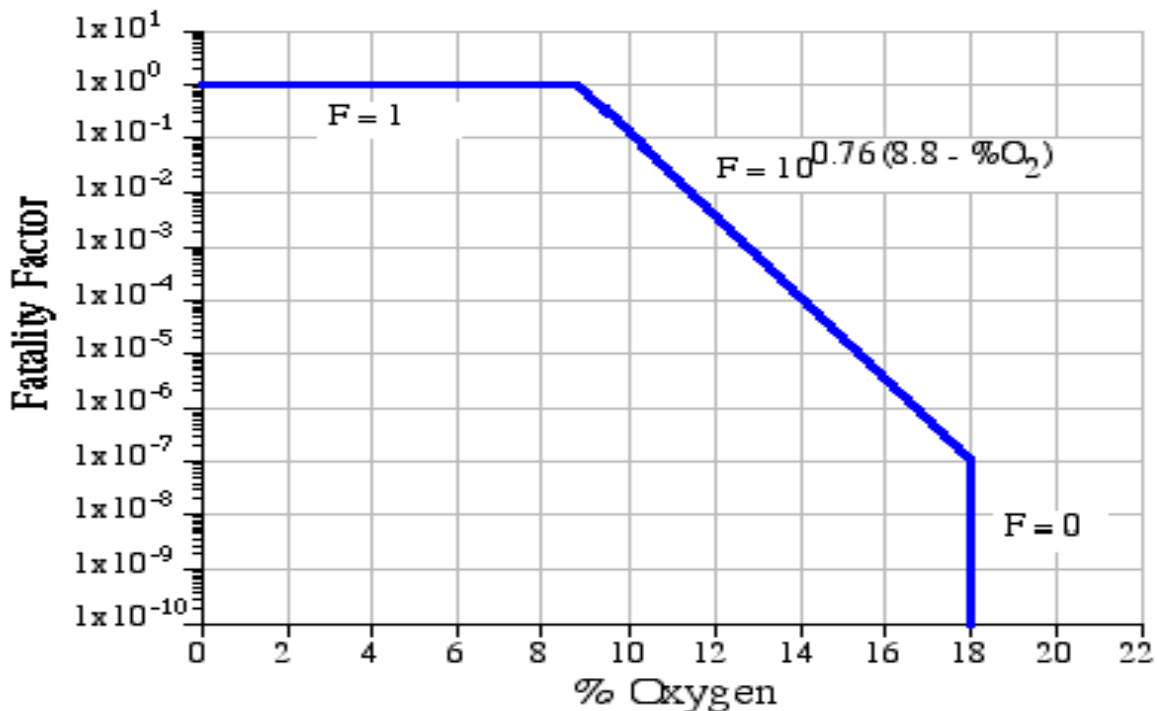


Chart 1. Fatality factor Chart from the EH&S manual.

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.

Valves (relief)	Premature open	1×10^{-5} /hr
Control Valve leak	Leak (JLab data)	1×10^{-5} /hr
Magnet (cryogenic)	Leak or rupture	1×10^{-6} /hr
Fluid line (cryogenic)	Leak or rupture	3×10^{-6} /hr
U-tube change release (cryogenic)	Large Event	4×10^{-5} /hr

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

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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.

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 Volume (l)
Total nitrogen	552
Total helium	856

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 resulting O₂ concentration for each volume of LHe or LN₂ are vented instantaneously. For this calculation I assume that an equivalent volume of normal (21% O₂) 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	%O ₂	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	1.00E-06	0.00E+00
Oxford DF	55	41470	20.07%	0.00E+00	1.00E-06	0.00E+00
Rome DF	200	150800	17.62%	1.99E-07	1.00E-06	1.99E-13
SD	45	33930	20.24%	0.00E+00	1.00E-06	0.00E+00
Emergency helium dewar	500	377000	12.54%	1.44E-03	1.00E-06	1.44E-09
NITROGEN	LL	gas liters	%O ₂	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	0	0	21.00%	0.00E+00	1.00E-06	0.00E+00
Oxford DF	50	34700	20.22%	0.00E+00	1.00E-06	0.00E+00
Rome DF	100	69400	19.44%	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
LN ₂ Dewar	160	111040	18.51%	0.00E+00	1.00E-06	0.00E+00
LN ₂ Dewar	160	111040	18.51%	0.00E+00	1.00E-06	0.00E+00

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

One can see that only two cases provide an O₂ concentration to dip below 18% but the probability of the event is small thus the ODH rating is 0.

There is also a transfer line from the future helium storage dewar. Its flow is limited to 10g/s by a fixed orifice in the line. Using this flow rate and mixing this flow with the continuously running fresh air make up the O₂ concentration can drop low (13.5%) but the likely hood of having the TL left open to air to allow the liquid to continue to vent is small.

HELIUM			%O ₂	Fatality Factor	Probability Factor	F*P
Case of someone leaving a bayonet open						
Helium Dewar Flow Analysis						
Max flow due to DP of TL	g/s	10				
	LL/s	0.08				
	gas L/sec	60.24				
	SCFM	127.7173				
Fresh Air Make up Flow	CFM	231				
Steady State %O ₂			13.52%	2.57E-04	4.00E-05	1.03E-08

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

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

Total Sum	1.17E-08	= ODH 0
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Conclusion

The rating for the HDIce lab is ODH 0