# 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 cryogens is the high bay area. The Pump room will have no cryogens 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 Fi versus the lowest attainable oxygen concentration which can result from a given event.

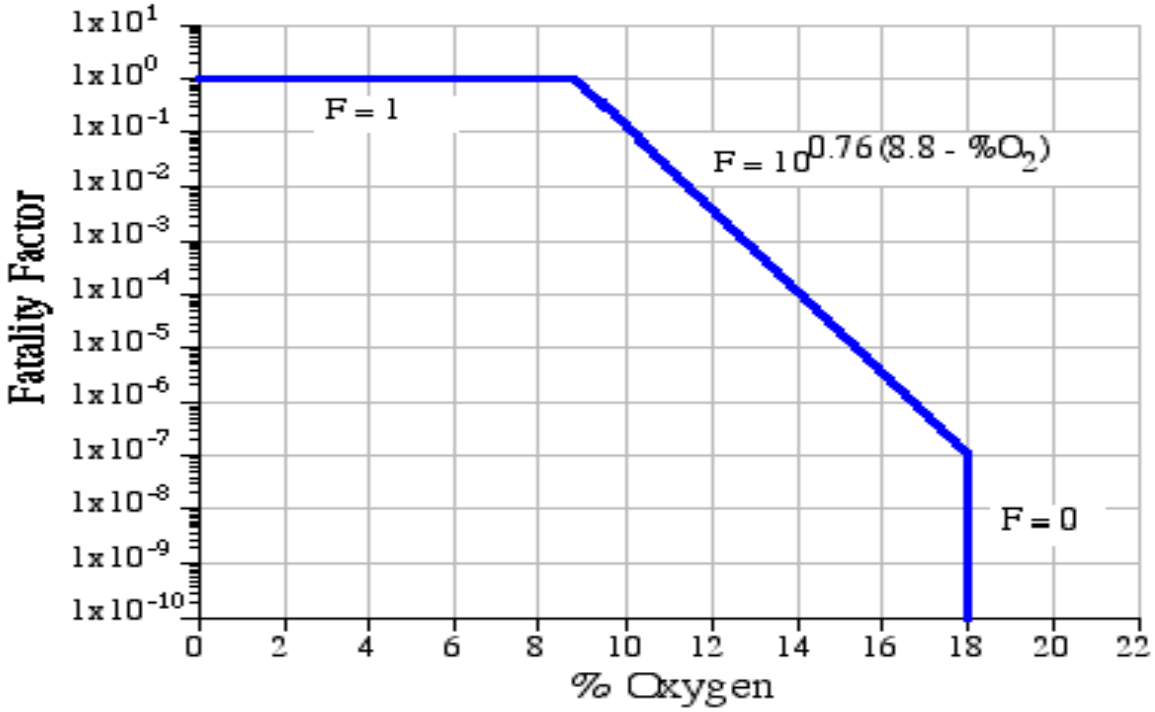


Chart 1. Fatality factor Chart from the EH&S manual.

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.

| | | |
|---|---|---|
| Valves (relief) | Premature open | $1 \times 10^{-5}$ /hr |
| Control Valve leak | Leak (JLab data) | $1 \times 10^{-5}$ /hr |
| Magnet (cryogenic) | Leak or rupture | $1 \times 10^{-6}$ /hr |
| Fluid line (cryogenic) | Leak or rupture | $3 \times 10^{-6}$ /hr |
| U-tube change release (cryogenic) | Large Event | $4 \times 10^{-5}$ /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:
$\varphi$ = 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 $\Psi$ ($hr^{-1}$) |
| 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 $0_2$ concentration for each 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.

| Instantaenous 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 | 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 | %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 | 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 |
| LN2 Dewar | 160 | 111040 | 18.51% | 0.00E+00 | 1.00E-06 | 0.00E+00 |
| LN2 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 $O_2$ 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 | | | %O2 | 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 %O2 | | | 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** |
|---|---|---|

**<u>Conclusion</u>**

**The rating for the HDIce lab is ODH 0**