ODH Assessment

DATE: 9/1/2015\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

DIVISION: \_\_\_ Accelerator Division\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

LOCATION: \_\_\_Upgrade Injector Test Facility (UITF) at Building 58\_\_\_\_\_\_\_\_

ASSESSMENT AUTHOR: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

APPROVAL: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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cc:  
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*ODH Risk Assessment, UITF*

*September 1, 2015*

**Introduction**

**This assessment addresses the risk of oxygen deficiency hazard for the Upgrade Injector Test Facility (UITF). The assessment is conducted in accordance with the requirements specified in** Jefferson Lab's ODH Risk Assessment Process (ODHRAP). **This assessment addresses the helium ODH hazards associated with the facility. These are sources of helium gas which can dilute the normal oxygen content with health effects as outlined in** Jefferson Lab's ODH Risk Assessment Process (ODHRAP).

**The following sections cover the modeling scope and methodology for the cryogen dispersion release, a description of the work space, operational modes which affect the risk factors, failure rates of the components, the resultant area classification, and self-rescue-atmosphere respirators.**

**Model for Cryogen Dispersion Release**

**The building description is depicted on Figures 1 - 3, shown below. The work areas covered in this analysis include the UITF enclosure, composed of an existing work space called Cave 1, and a recently constructed addition called Cave2. There are no boundaries between Cave1 and Cave2, although ceiling height varies between 12 and 15 feet. An elevation view is shown in Figure 4. Within Cave1, there are two 30” diameter ventilation tubes on the east wall approximately 7’ above the floor: one tube vents to the exterior of the building, and the other vents to the high bay region. In addition, there are six 10” diameter ceiling penetrations for routing cables to the electronics racks above. Within Cave2, there are umpteen 6” diameter vent stacks on the east wall, approximately 12’ above the floor. These openings vent into the Test Lab high bay. The main entry/exit to UITF is through a labyrinth with chain-link fence gate, approximately 6’ wide and 8’ tall, which also provides an escape path for helium gas. The vent tubes, penetrations and chain-link fence gate allow lighter than air mixtures of ODH gases to leave the enclosure, vented to the high bay and the outdoors.**

**Helium spill tests within the JLab accelerator tunnel and the CHL vent stack test apparatus have shown that rising helium gas interacts with the surrounding air, mixing with it as it rises. Once combined with air, the helium does not readily separate out of the air/helium mixtures thus is not reversible. It will retain the same helium to air percentages as long as it does not further interact with additional sources of air (dilution) or high concentrations of helium (enrichment). Since the helium/air gas mixture is “lighter than air”, the mixture rises but at a substantially smaller rate than pure helium gas since the mixture is heavier. When natural convection ventilation (in the form of vertical vent tubes) is provided, both oxygen and helium are purged from the enclosure area. The helium/air mixture will displace more of the confined space in a vertical downward direction from the ceiling if no additional sources of air are provided to mix with the escaping helium/air mixture.**

**The UITF Model for Cryogen Dispersion Release is based on a fully operational cryogenic quarter-cryomodule with 400 L of liquid helium capacity and cryogenic distribution system at 2K located within the UITF accelerator enclosure. Liquid helium is supplied to the quarter-cryomodule from the Cryomodule Test Facility (CTF) refrigerator located adjacent to building 58. The UITF ODH sources of pressurized helium gas are a cryogen distribution 3.5 atm, 35K shield supply line, a 3.0 atm shield return process line, a 3 atm 4k supply line, a 4K .031/1 atm return line, a warm (300K) 3 atmosphere helium supply line and the component failures associated with the quarter-cryomodule. The cryogen transfer line relief valves are located outdoors of the UITF facility and do not contribute as a source for ODH for the UITF accelerator enclosure. (From Kelly Dixon:** There are 2 reliefs for the 1/4 CM, the secondary will vent into the room during a very rare event. I'm not sure where the primary relieves but it may be possible to send this through our guard vacuum header--I have not seen any routing plan for this to date. HD Ice has it's own relief device(s) and I'm guessing that they are planning to vent this into the room. We don't need our own relief valve for HDIce within the room.)

**In addition to the quarter-cryomodule, this ODH assessment considers a fully functional HDIce target attached to a 500 L LHe buffer dewar, and a 1000 L LHe supply dewar. The helium gas boil off from the HDIce target is captured and returned to the CTF refrigerator, using a return line attached to the exhaust port of vacuum pumps used to cool the helium within the HDIce target. Here we need to say: where is the relief valve for the HDice stuff?**

**Each of the cryogenic helium supply lines within the UITF enclosure are identified by** Jefferson Lab's ODH Risk Assessment Process (ODHRAP)**, Table 2 as having a rupture probability of 2x10-8 hours each. The estimated spill amount of pure helium from the supply lines would be approximately 15,000 SCF with a duration of 20 minutes. This amount of liquid evaporating to gas would fill a volume that exceeds the entire UITF accelerator enclosure in accordance with Figure 3 of Appendix 6500-TE would result in a fatality factor of 1 for each of the lines. The total contribution to the analysis for the transfer line supply lines in the enclosure would be 1x10-7 hrs-1.**

**The quarter cryomodule is equipped with a primary and secondary helium process relief valves. The primary reliefs are designed for a cryomodule blocked flow failure mode and is limited by the cryomodule inlet JT valves size to 15 g/s (187 scfm) ODH source availability. Please refer to attached “HELIUM SPILL” DIAGRAM. Primary cryomodule relief valve exhausts are set at 1.16 atm differential (17 PSID) and are manifolded to a guard vacuum relief header system which has its own relief valves set at 1.4 PSIG to the outdoors. This cryomodule blocked flow relief failure mode is not considered a source of helium gas source into the accelerator enclosure. Relief valve failure rate (1x10-5 per day) per Table 3 of the Appendix does not contribute to the analysis for the number of system relief valves.**

**Because the Test Lab high bay volume is so large (roughly 2.35 million cubic feet), the high bay is considered to be equivalent to the outdoors. The combined area of the above-head-height penetrations listed above is 14.7 ft2, providing up to 37.5 g/s helium (470 SCFM) natural vent capacity for minor cryomodule or cryogen transfer line leaks at 17% oxygen level with a helium/air mixture. The resultant sum fatality factor for leaks (JT valve failure), etc. of a single component is 0 (19.5% O2) with an individual probability of 1.1x10-4 hours. Clearly the product/sum (10-10) of all individual devices under a small leak failure mode is <10-7 under Table 6 of ODH Classification Appendix and does not substantially contribute to the ODH analysis for leaks.**

**The quarter cryomodule secondary relief valve is a parallel plate relief with a setting of 3.4-4 atm (35-45 PSIG) that can relieve into the accelerator enclosure. However this is unlikely since an instantaneous vaporization of the liquid inventory of a single cryomodule (1600 liquid liters, 49,000 SCF from 2K liquid) would expand directly into the sub atmospheric return header. The return header is amply sized to limit the pressure to 15 PSIG for beam line or insulating vacuum failure within the cryomodule under 2K or 4K operation. Again, consideration of a faulty relief valve as the mode of failure does not contribute to the analysis for the number of relief within the enclosure.**

**To ensure the 2K return header is never isolated from a cryomodule, the cryomodule RT (return valve) must be administratively locked open by a JLAB Standard Operations Procedure (TSOP or SOP using the JLAB administrative “Danger” lock system) any time a cryomodule is connected to the 2K return header and is assumed in effect for this analysis. Other operational, maintenance, or repair process connection configurations must be considered separately under additional JLAB TSOPs or SOPs whenever the cryomodule is disconnected from the 2K return header and is cold with liquid inventory. Such special procedures should be considered separately and is not part of this assessment.**

**From Kelly Dixon:** There are 2 reliefs for the 1/4 CM, the secondary will vent into the room during a very rare event. I'm not sure where the primary relieves but it may be possible to send this through our guard vacuum header--I have not seen any routing plan for this to date. HD Ice has it's own relief device(s) and I'm guessing that they are planning to vent this into the room. We don't need our own relief valve for HDIce within the room.

**We need to discuss how HDIce stuff is vented. Relief valves? Where are they, at what point do they open up. Where does vented gas go?**

**The model for a helium release rate is based on the worst release cases listed under the Operational Modes below. Failure rate estimates (Pi) are based JLAB listed equipment rates under** Jefferson Lab's ODH Risk Assessment Process (ODHRAP). **The sum of the failure product of the Fi and Pi for each of the operational modes determined the area classification in accordance with Table 6 of Section 6500 of the EH&S manual.**

**Description of Work Space:**

Existing test cave, Cave1: 9,140 cubic feet

New cave extension, Cave2: 16,564 cubic feet

Total UITF volume: 25,704 cubic feet

The Test Lab building is 297’x 132’ x 60’ for a total of 2.35 million cubic feet of space.

To justify the assumption that the high bay volume is large enough to be considered equivalent to the outdoors, consider the improbable circumstance of 1,900 L of LHe released simultaneously from the quarter cryomodule (400L) and from the HDIce target (500 L buffer dewar and 1000 L fill dewar). This amount of LHe would expand to 52,315 cubic feet of gas, representing 2.2% of the total Test Lab high bay volume.

**ODH RISK ASSESSMENT**

**The following are a set of events and the associated probability and fatality factors.**

**Cryomodule and TL (Accelerator Enclosure) (normal ops, small natural vent)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EVENT** | **SPILL RATE, cfm** | **SPILL, scfm** | **%02** | **Pi** | **Fi** |
| **Small Leak** | **12.5** | **22500** | **19.5(1)** | **1.1x10-4** | **0** |
| **4K Line Rupture, 2** | **6250** | **125,000** | **<9(2)** | **4x10-8** | **1** |
| **Shield Line Rupture, 2** | **6250** | **125,000** | **<9(2)** | **4x10-8** | **1** |
| **Power Outage** | **0** | **0** | **21** | **2x10-4** | **0** |
| **Relief Failure** | **42500** | **48000** | **<9** | **12x10-10** | **1** |
| **Blocked Shield Rtn** | **188** | **3760** | **17(2)** | **1x10-7** | **0** |
| **Blocked 2K return** | **188** | **125000** | **21(2)** | **1x10-6** | **0** |
| **Insul Vac Loss** | **10625** | **48000** | **<9(3)** | **4x10-6** | **0** |
| **Beam Line Vac Loss** | **42500** | **48000** | **<9(3)** | **4x10-6** | **0** |
| **Waveguide Vac Loss** | **10625** | **48000** | **<9(3)** | **4x10-6** | **0** |

**Superscript Notes:**

**Note 1: Not detectable by upper ceiling ODH sensors**

**Note 2: Relieve Valve to Guard Vacuum Header System, out-of-doors**

**Note 3: Absorbed by 2K return line header, limited to 2 atm pressure**

**UITF Accelerator Enclosure U-Tube Operation (per demand):**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EVENT** | **SPILL RATE, cfm** | **SPILL, scfm** | **%02** | **Pi** | **Fi** |
| **U-Tube** | **6250** | **125,000** | **<9(-1)** | **4x10-4** | **1** |

**Superscript Note:**

**Note 1: Flex line 4K supply connection sting, no isolation valving on 4K supply**

**ODH Analysis Results**

1. **Steady-State 2K and 4K operations with 3-1/4 cryomodules, sealed floor penetrations to the second floor, and SOP controlled locked open 2K cryomodule return valves into the 2K return header….Rating ODH-0 (<10-7) for the UITF enclosure, behind and in front of the quarter-cryomodule per TABLE6 of the JLab EH&S manual, Appendix 6500-T3.**
2. **Cryomodule U-Tube Change-out Procedure…..ODH-2 (<10-4) per TABLE 6 of the JLAB EH&S manual, Appendix 6500-T3.**









