SNS-OPM-ATT 2.B-10.a.
Unreviewed Safety Issue (USI) Evaluation Form

I. Title of USI Evaluation:

USI Evaluation of Cryogenic Test Facility (CTF) Helium Dewar System

II. Description of Proposed Activity (or discovered condition) (use attachments if necessary):

This USI Evaluation assesses the operation of the new Cryogenic Test Facility (CTF) Helium Dewar System located in the CHL compressor room. The CTF Helium Dewar System primary components include a Cold Box, Helium Distribution Box and a Helium Dewar (see Photo 1). The CTF Helium Dewar System will supply liquid helium to the RFTF Test Cave and VTA test facilities located on the other side of the wall separating the CHL warm compressor room from the RFTF building.

The FSAD-PF addresses oxygen deficiency hazards associated with the operation of the helium compressors located in the room and shows that 1) credited passive ventilation features of the room (open vents on the sides and roof) and 2) *see and flee* training are adequate to ensure personnel safety from ODH hazards associated with helium releases within the facility. Operation of the CTF Helium Dewar System will involve up to 3000 liters of 4 K liquid helium. The analysis below shows that ODH hazards associated with the CTF Helium Dewar System are well within the magnitude and types of ODH hazards evaluated within the FSAD-PF analysis and that the same controls (i.e. passive ventilation features and *see and flee* training) are adequate to mitigate oxygen deficiency hazards associated with the system. Because the CTF and helium compressors are separate systems and are physically separated, there is no common mode failure and as such it is beyond credible to assume both systems would fail simultaneously.

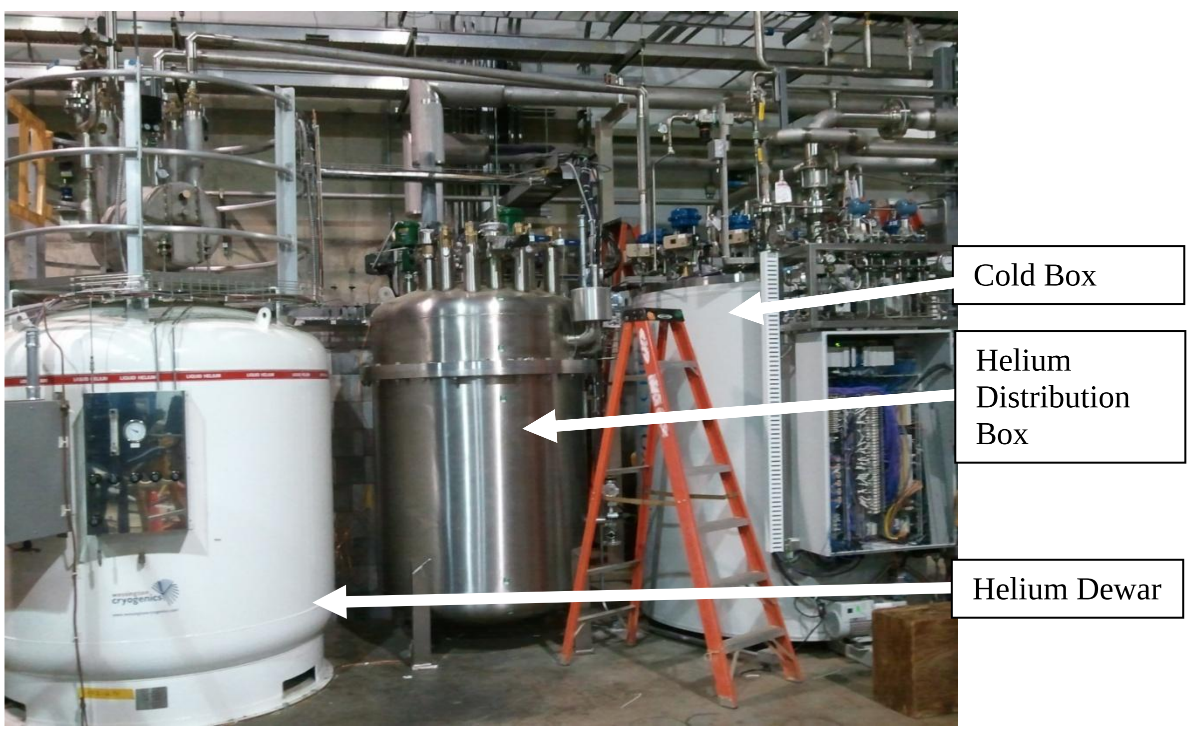


Photo 1. CTF Helium Dewar System

The CHL compressor room is equipped with six 12.5ft x 6ft open louvers on the sides of the building[1] and six 50" x 50" open vents[2] on the roof. Each roof vent is equipped with a fan rated[3] at 25,000 cfm which is used as desired for climate control. The FSAD-PF shows that the passive ventilation achieved by the open side and roof vents is adequate to mitigate the worst case sustained (infinite duration) release within the warm compressor system of 1,000 g helium/second. The passive ventilation features are designated as Credited Controls.

The warm compressor room is also equipped with an non-credited ODH instrumented safety system that conforms to the same specifications as the credited ODH system used in the LINAC tunnel. The CHL ODH system includes multiple ODH sensors near ceiling level, one at a height of about 5 ft (human breathing level) and one at an intermediate height. The lower sensor is mounted on the wall directly adjacent to the CTF Helium Dewar System. Any helium release would rise to the ceiling due to the buoyancy associated with its low density. Once at the ceiling, the helium would continue to rise and passively flow thru the roof vents. By intuition, the limited amount of helium associated with the new CTF Helium Dewar System would flow through the passive roof vents and would not cause oxygen deficiency levels of concern at the ground (breathing) level. However, detailed quantitative modeling of natural convection phenomena is complex and has not been attempted here. Instead, very conservative quantitative evaluations that neglect the significant helium buoyancy effect have been used that show that hazards associated with the CTF Helium Dewar System are safely mitigated by the existing controls (i.e. passive ventilation features and *see and flee* training). The ODH instrumented safety system adds a non-credited layer of safety.

The amount of cryogenic (4K) helium associated with the CTF Helium Dewar System is limited to about 3,000 Liters. Assuming an expansion factor of 757 (per SBMS on *Cryogenic Liquids and Related Components*), the corresponding volume of helium can be calculated at standard temperature and pressure (STP) as follows:

$$3{,}000\ Liter\ He \cdot \frac{1ft^3}{28.3L} \cdot 757 = 8.02x10^4 ft^3\ at\ STP$$

The volume of the warm compressor room can be estimated based on SNS drawings. The floor area can be estimated based on SNS Drawing A2.01.78, Rev1, *CHL Floor Plan* by adding the floor area of the two rectangular sections as follows:

120 ft x 57 ft =	6840 ft^2
60 ft x 23 ft =	1380 ft^2
Total	8220 ft^2

Drawing S5.20.60, Rev 1, Section 1 shows the average building height (roof sloops at ¼ inch/ft) of ~ 32 ft., therefore the total compressor room volume can be estimated at 8,220 ft^2 x 32 ft = 2.63 $x10^5$ ft^3. If we assume a free volume of ~90% (based on visual inspection), then the free volume of the building is ~ 2.37 x 10^5 ft^3.

A very simple estimate of the volume averaged oxygen concentrations within the warm compressor room building for a full release of the 3,000 liter helium inventory can be calculated assuming the building has no in leakage or other ventilation flow using the following expression provided in the SBSM *Guidelines for Evaluating Oxygen Deficiency Hazards from a Cryogen Release* (Worker Safety and Health Management System):

1 SNS Drawing A7.10.60 Rev1, CHL/RF Door, Window & Louver Schedule and Details.
2 SNS Drawing H5.20.61 Rev1, CHL Compressor Room Cross Section
3 SNS Drawing H9.10.60 Rev1, CHL/RF Mechanical Equipment Schedules

$$O_2 = 21\% \cdot \frac{V_{Bldg} - V_{release}}{V_{Bldg}} = 21\% \cdot \frac{2.37x10^5 ft^3 - 8.02x10^4 ft^3 - He}{2.37x10^5 ft^3} = 13.9\% O_2$$

This level of O_2 is classified as "Low Consequence Severity" in the FSAD-PF Appendix D *Safety for Cryogenic Operations* and is above the threshold value of 12.5% that would require a Credited Control per the SNS selection criteria for credited controls (Section 4.4 of the FSAD-NF).

A significant release of cryogenic helium creates loud pressure venting noise and is accompanied by a rapidly growing condensing moisture cloud and would be rapidly identified by personnel in the immediate area. Consistent with the approach used in the FSAD-PF, see and flee training of personnel is relied on to ensure safety of personnel in the immediate area of a release.

The average oxygen concentration calculated above is acceptable but is excessively conservative. A conservative but more refined estimate can be made assuming that the release occurs over a given time frame and assuming some building leakage. An air infiltration rate of 2 building volumes per hour has conservatively been assumed; it is conservative because the warm compressor room has more ventilation flow than the standard flow recommended for warehouses in the air change rate table provided at www.engineering toolbox.com. The SNS Source Term analysis[4] assumes an air infiltration rate of 0.5 building volumes per hour for a secondary confinement (closed room without windows or exterior doors). Because the warm compressor room has open louvers on the sides and roof of the building, the actual air turnover rate would be much greater and the value of 2 is reasonable.

The SBSM *Guidelines for Evaluating Oxygen Deficiency Hazards from a Cryogen Release* recommends a 30 minute release time for cryogens consistent with NFPA-55[5] . The associated release rate would then be 8.02×10^4 ft^3-He/30 min = 2.67×10^3 cfm. The analysis provided in SNS 102030103-CA0003-R00[6] shows that the credited passive ventilation features of the WARM COMPRESSOR ROOM are adequate to mitigate a long term (infinite) helium release rate of 12,000 cfm which is a factor of about 4 times higher than that assumed for the CTF Helium Dewar System. Therefore, the existing passive ventilation features of the building are deemed adequate to mitigate such a release.

The SBSM *Guidelines for Evaluating Oxygen Deficiency Hazards from a Cryogen Release* recommends the following expression to account for the time dependent behavior based on assumed release rate and building leakage. The expression neglects helium buoyancy effects.

$$C_2 = G \cdot \frac{1 - e^{\frac{-Q \cdot t}{V_{Bldg}}}}{Q}$$

and

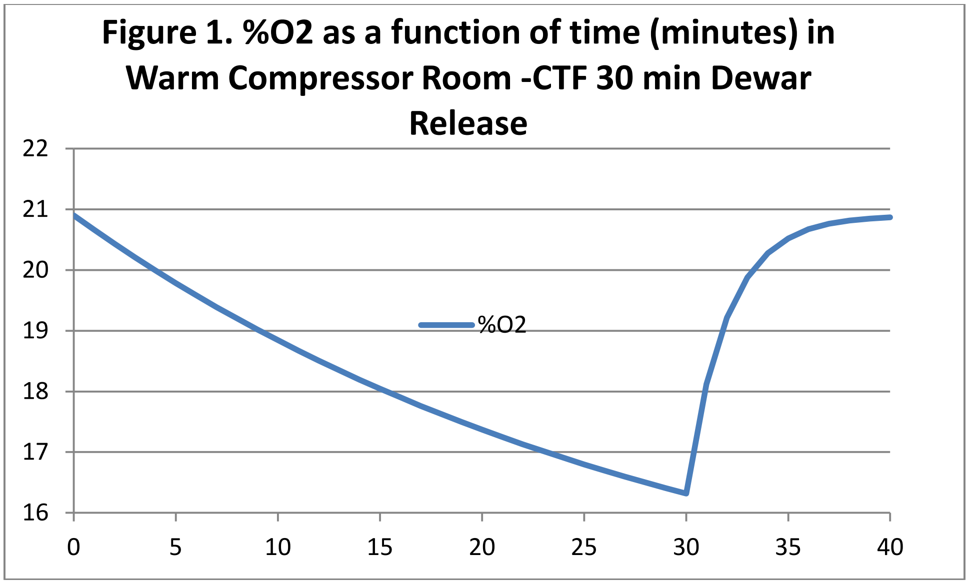
$$\% O2 = (1 - C_2) \cdot 20.9\%$$

Where:

[4] SNS Document 102030102-CA0020-R01, Source Term Analyses for the Target Building Safety Assessment Document, April 2006.
[5] NFPA 55 Compressed Gases and Cryogenic Fluids Code 2013 Edition
[6] Jankovic, et. al., CHL Facility Oxygen Deficiency Hazard Analysis and SIL Level Determination, SNS 102030103CA0002R00, December 2, 2002.

C_2 = Buildup concentration of Helium in building
G = Release Rate = 8.02 x 10^4 ft^3-He/30 min = 2.67 x 10^3 cfm
Q = 2 bldg volumes per hour = 2 x 2.37 x 10^5 ft^3/hr = 7.89x10^3cfm

Using the above expression, the time dependent oxygen concentration can be calculated as shown in Figure1 below. The minimum oxygen concentration of 16.4 % occurs at t = 30 minutes (end of release). Oxygen levels above 16% are classified as "Extremely Low Consequence Severity" and "no escape impairment" in the FSAD-PF Appendix D *Safety for Cryogenic Operations at SNS*.



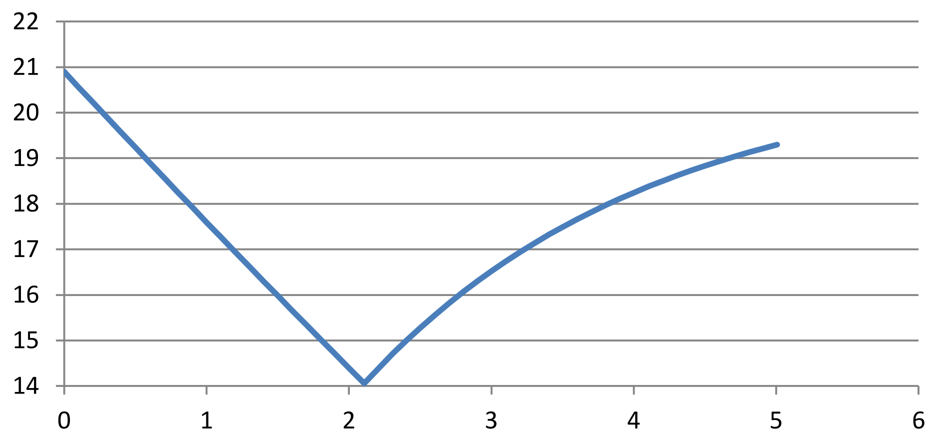
For minimum concentrations above 17.5%, the SBSM *Guidelines for Evaluating Oxygen Deficiency Hazards from a Cryogen Release* states that no controls are warranted because O2 concentrations are sufficient to prevent personnel from experiencing ODH symptoms. It should be noted that calculated oxygen levels only drop below 17.5 % for 11 minutes. It could be argued that because the conservative calculations show average oxygen levels dipping only marginally below 17.5% for only 11 minutes that no controls are warranted, especially since the minimum concentration of 16.3% is not immediately harmful. It can further be argued that because the calculation neglects He buoyancy and the fact that the building is protected by a passive Credited Control of open air louvers on the sides and roof of the building that average oxygen concentrations will never reach 17.5% .

SBSM *Guidelines for Evaluating Oxygen Deficiency Hazards from a Cryogen Release*, recommends controls such as administrative requirements for evacuation upon a release and/or fixed alarming oxygen monitors. As described earlier, the CHL compressor room is equipped with fixed alarming oxygen monitors and personnel with unescorted access receive ODH training that emphasizes *see and flee* and prompt evacuation upon alarm training.

The SNS Superconducting LINAC Systems Group performed a maximum release rate calculation for the CTF Helium Dewar System that effectively assumed that the insulating vacuum vessel disappears leaving the helium vessel in direct contact with room temperature air. As pressure builds up the dewar would discharge to the warm compressor room through the dewar relief valve. Under such a scenario, heat transfer of 6 kW/m^2 is assumed with a corresponding boil off rate of 3368 gram-He/sec. Even assuming such an unlikely loss of vacuum, the vessel surface would quickly build up an ice layer from freezing air which would serve as an insulator thus reducing the heat loading and the release rate. Because such a scenario is difficult to model, an analysis was performed assuming a constant release rate of 3368 gram per second. Because the volume of helium is limited to 3000 Liter, the entire inventory is assumed to evaporate within 2.1 minutes.

Such a scenario is not realistic and is overly conservative, but is provided to show even in the extreme case, the building volume averaged oxygen concentration only reaches a minimum of 14.1% (at t = 2.1 minutes) which is classified as “Low Consequence Severity” in the FSAD-PF Appendix D Safety for Cryogenic Operations at SNS. The analysis used the same methodology presented above for the 30 minute release rate. Results are shown in Figure 2. Even under such an unlikely scenario, workers would *see and flee* based on training. FSAD-PF Appendix D assumes no escape impairment of individuals in oxygen atmospheres above 16%. For oxygen levels between 8.5% and 16%, an escape time of > 5minutes is assumed. For the 2.1 minute release scenario, oxygen levels only dip below 16% for ~ 1.3 minutes.

Figure 2. %O2 as function of time (minutes) in warm compressor room - 2.1 minute release



The analysis provided in SNS 102030103-CA0003-R00 shows that the credited passive ventilation features of the warm compressor room are adequate to mitigate a long term (infinite) continuous helium release rate of 12,000 cfm which is only about a factor of 3 lower than that associated with the 2.1 minute release scenario. Because the 2.1 minute release time is unrealistically short because it neglects the insulating effect of ice condensation on the cold surfaces scenario and because of the very short release duration (2.1 minutes), the existing passive design features of the building designed to mitigate a long term continuous release of 12,000 cfm helium are deemed adequate to mitigate even such an incredible release. During a leak, it is possible that the local oxygen concentration could dip below the average concentration, but the workers are protected against this by their see and flee training based on the visible fog seen when cryogenic helium mixes with ambient air.

Conclusions

The analysis above shows a minimum average oxygen level of 16.4% associated with a credible release from the 3000 liter liquid helium dewar system calculated per SBMS recommended methodology. This value is conservative in that it neglects the buoyancy effect of helium that would drive helium out of the roof vents. Oxygen levels above 16% are classified as “Extremely Low Consequence Severity” with “no escape impairment” in the FSAD-PF Appendix D Safety for Cryogenic Operations at SNS.

The credited passive ventilation features of the warm compressor room and see and flee training already in place for existing ODH hazards within the building have been determined to be adequate to protect individuals from releases associated with the dewar. Additionally, the warm compressor room is equipped with an instrumented ODH system that provides alarms on indication of low oxygen levels.

The CTF Helium Dewar System provides helium to the RFTF and VTA test facilities and is separate from the cryogenic systems that support the proton beam accelerator. ODH hazards associated with the CTF Helium Dewar System are typical of those associated with large dewars and can be considered a standard industrial hazard. The ODH hazards associated with the CTF Helium Dewar System are adequately managed by the existing ORNL SBMS on Worker Safety and Health that addresses ODH for cryogenic releases.

III. Does the proposed activity or discovered condition affect information presented in the FSAD-NF or FSAD-PF, e.g. regarding equipment, administrative controls, or safety analyses. If so specify the applicable FSAD and relevant sections.

Oxygen deficiency hazards in the CHL compressor room are addressed in the following sections of the FSAD-PF:

- Section 5.2.4 CHL Compressor Room Passive Ventilation Features
- Section 3.2.1.4 Support Facilities: CHL and RF Test Facility
- Section 3.2.3.1 Overall Scope of PPS and ODH Systems
- Section 3.2.3.11 Oxygen Deficiency Hazard (ODH) Alarm System
- Section 3.2.4.14 Building 8310 – Central Helium Liquefier Facility
- Table 4.0-1 Summary of Proton Facility CECs
- Section 4.3.1.5 Oxygen deficiency hazard (ODH)
- Section 4.4.2 SNS Approach to ODH Safety and Hazard Analysis

The FSAD-PF should be updated during the next regular update to include a description of the CTF Helium Dewar System and its location within the CHL compressor room.

IV. Does the proposed activity or discovered condition affect any of the requirements of the ASE. If so, list the affected sections

Oxygen deficiency hazards in the CHL compressor room are addressed in the following sections of the ASE:

- Section 3.3 ODH System

No changes to the ASE are required to accommodate operation of the CTF Helium Dewar System

V. USI Evaluation Criteria:

1. Could the change significantly increase the probability of occurrence of an accident previously evaluated in the FSADs? Yes __ No_x_

Justification:

The probability of occurrence of accidents previously evaluated in the FSAD-PF are not increased by the operation of the CTF Helium Dewar System. The design, type and construction is consistent with the other cryogenic systems at SNS. Cryo-release accidents analyzed in the FSAD-PF for massive releases of Helium bound the hazards associated with the limited helium associated with the CTF.

2. Could the change significantly increase the consequences of an accident previously evaluated in the FSADs? Yes__ No _x_
   Justification:

   Cryo-release accidents analyzed in the FSAD-PF for massive releases of Helium bound the hazards associated with the limited helium associated with the CTF Helium Dewar System. The consequences associated with an inadvertent helium release from the CFT do not significantly increase the consequences of accidents evaluated in the FSAD-PF.

3. Could the change significantly increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No x_
   Justification:

   Operation of the CTF Helium Dewar System with the CHL compressor room will not increase the probability of occurrence of a malfunction of equipment important to safety as evaluated in the FSAD-PF. The CTF Helium Dewar System is independent of and physically separated from the helium compressor system housed in the CHL compressor room that provides helium to the LINAC in support of proton beam operations.

4. Could the change significantly increase the consequences of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No _x_
   Justification:

   The consequences of a malfunction of safety equipment remains unchanged. The FSAD-PF shows that a worst case helium release from the warm compressor system can be safely mitigated by *see and flee* personnel training and by passive features of the building which has open louvers on the sides and top of the building. The conservative analysis provided in this document shows that even with an incredible release associated with the system, acceptable helium levels are maintained within the building.

5. Could the change create the possibility of a different type of accident than any previously evaluated in the FSADs that would have potentially significant safety consequences?

   Yes__ No _x_
   Justification:

   Cryo-release accidents analyzed in the FSAD-PF for massive releases of Helium bound the hazards associated with the limited helium associated with the CTF Helium Dewar System. No new type of accident is introduced. Additionally, the worst case consequences severity is classified as “low” in accordance with methodology presented in Appendix D of the FSAD-PF.

6. Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the FSADs?

   Yes__ No _x_
   Justification:

   The possibility of a new or different type of malfunction of equipment is not increased by operation of the CTF Helium Dewar System. The design, type and construction of the CTF Helium Dewar System is consistent with the other cryogenic systems at SNS. The accident analyses assume a component failure that releases helium – no new type of equipment malfunction is created.

VI. USI Determination: A USI is determined to exist if the answer to any of the 6 questions above (Section V) is "Yes." If the answer to all 6 questions is "No", then no USI exists.

a. Does the proposed activity (or discovered condition) constitute a USI?

__ Yes – DOE approval required prior to implementing

_x_ No – Proposed activity may be implemented with appropriate internal review.

David Freeman, Qualified Preparer	7/18/2013 Date
Mike Harrington, Qualified Reviewer	7/18/2013 Date
Paul Abston, SNS ES&H	7/19/2013 Date
Sang-Ho Kim, Superconducting Linac Systems Group Leader	7/18/2013 Date
Glen Johns, Accelerator Operations Group Leader	7-18-13 Date

Approvals:

Signature of SNS Operations Manager or Designee	07.19.2013 Date