SANFORD UNDERGROUND RESEARCH FACILITY

SOUTH DAKOTA SCIENCE AND TECHNOLOGY AUTHORITY

Oxygen Deficiency Hazards Standard

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Revision History

Rev	Date	Section	Paragraph	Summary of Change	Authorized by
01	6/7/2023	NA	NA	Initial Release	CCR 721
02	5/29/2024	NA	NA	Updated Logo	CCR 946

1.0 Purpose

The purpose of this standard is to provide information on how to safely assess the potential for a possible oxygen deficient environment. This standard outlines the requirements for developing controls to reduce or eliminate oxygen deficient hazards, including providing equipment to monitor air oxygen content.

2.0 Scope

This standard applies to all personnel at Sanford Underground Research Facility (SURF) where any release of a compressed and/or liquefied gas may occur. Emergency response and confined spaces are covered by separate standards.

3.0 Definitions

ALARA (As Low As Reasonably Achievable) – The approach to protection from hazards by managing and controlling exposure to potential hazards (both individual and collective) to the work force and to the general public at levels as low as is reasonable, taking into account social, technical, economic, practical and public policy considerations. ALARA is not a hazard limit but a process which has the objective of reducing hazards as far below the applicable limits as is reasonably achievable.

Fixed Oxygen Monitor – A device usually permanently attached to a structure, which monitors the concentration of oxygen and alarms at a set value. Fixed oxygen monitors must alarm at 19.5% oxygen and lower and trigger a facility-wide alarm at <18% oxygen.

Oxygen Concentration – The molar fraction of a gaseous mixture represented by oxygen. For a mixture of ideal gases, it is also equal to the ratio of the partial pressure of oxygen to the total mixture pressure. The oxygen concentration in normal ambient atmosphere is 20.9% (~21%).

Oxygen Deficiency – Any condition under which the concentration of atmospheric oxygen is less than 19.5% by volume.

Oxygen Deficiency Hazard (ODH) Operation – An operation that exposes personnel to an increased risk of fatality in excess of 10^{-7}/hr due to oxygen deficiency. Unlike confined spaces, ODH work spaces are generally designed for occupancy and provided with normal building type access and egress. In addition, the hazard is primarily limited to oxygen deficiency which is well understood and controlled through quantitative risk assessment.

Personal Oxygen Monitor – A device carried by an individual that monitors the concentration of oxygen and alarms at a set value. All personal oxygen monitors used at Sanford Lab are set to alarm at the mandatory confined space limit of 19.5%.

Safe Area – A known area with oxygen levels above 19.5%.

Self-Contained Self Rescuer (SCSR) – A device capable of supplying oxygen to be used for an escape during an oxygen deficient event.

Quantitative Assessment – Use of a set of methods, principles, or rules for assessing risks based on the use of numbers where the meanings and proportionality of values are maintained inside and outside the context of the assessment.

4.0 Responsibilities

4.1. SURF Laboratory Director

- **4.1.1.** Ensures accountability of the requirements of this document with direct reports.
- **4.1.2.** Authorizes resumption of work activities when required.

4.2. SDSTA Directors

- **4.2.1.** Submit a written exception request to the ESH Director for work in ODH Class 2 areas.

4.3. Science Director

- **4.3.1.** Ensures that the requirements of this standard are implemented for all research projects proposed at SURF.
- **4.3.2.** Ensures that ODH assessment is addressed in Authorization To Proceed as applicable.
- **4.3.3.** Works with Engineering Department to identify resources as required to assist experiment groups lacking expertise in ODH assessments.
- **4.3.4.** Ensures that qualified persons are assigned to review and maintain documentation for ODH risk assessments.
- **4.3.5.** Ensures maintenance of records of reliability of ODH-associated equipment.
- **4.3.6.** Supplements research collaborations as required by performing supplemental ODH assessment calculations.
- **4.3.7.** Develops and ensures training requirements are met.

4.4. Environment, Safety and Health (ESH) Department

- **4.4.1.** Purchases personal oxygen monitors.
- **4.4.2.** Provides training related to ODH.
- **4.4.3.** Provides standardized warning signs where applicable.
- **4.4.4.** Maintains records of incidents which have resulted in an oxygen deficient atmosphere.
- **4.4.5.** Provides oversight and consultation on the technologies and procedures for monitoring oxygen deficient atmospheres.
- **4.4.6.** Approves exception request for work in ODH Class 2 areas.

4.5. SDSTA Occupational Health Nurse

- **4.5.1.** Coordinates medical appointments as applicable.
- **4.5.2.** Reviews medical records associated with fitness of personnel who participate in ODH operations.
- **4.5.3.** Retains medical records.

4.6. QA/QC Department

- **4.6.1.** Ensures calibrations of personal oxygen monitors are completed.
- **4.6.2.** Maintains calibration records.

4.7. Surface Operations and Utilities Department

- **4.7.1.** Calibrates fixed oxygen monitors.

4.8. Cryogen Safety Subcommittee

4.8.1. Consists of:

- ESH Representative
- Engineering Representative
- Science Department representative
- Others as needed.

4.8.2. Consults on all cryogenic system matters and makes recommendations on ODH issues.
4.8.3. Develops the capability for evaluating cryogenic systems.
4.8.4. Proposes appropriate modifications to this standard as necessary.
4.8.5. Develops/updates cryogenic system safety training for personnel.
4.8.6. Performs a technical assessment of any externally generated ODH analysis and provides recommendations.
4.8.7. Reviews and approves all ODH calculations and completes ODH assessments.
4.8.8. Provides support on incidents related to ODH issues.

4.9. Engineering Department

4.9.1. Oversees the design, installation, and maintenance of facility ODH associated equipment.
4.9.2. Performs ODH calculations and assessments for projects that utilize cryogens.

4.10. Laboratory Coordinator/Duty Officer

4.10.1. Executes the following actions in the event of an ODH alarm and re-entry:

- Verifies the explanation of ODH alarms.
- Confirms oxygen level readings.
- Grants permission for re-entry with a portable gas tester when required.
- Coordinates with ESH Department.

5.0 Instructions

Work in ODH areas shall be planned in accordance with the ESH-(2000-S)-73320 Work Planning and Control Standard. Occupancy of areas with ODH shall be limited to the extent practical while still allowing work to be performed. Work Offices shall not be located in areas with oxygen deficiency hazards. In any case, the ALARA principle shall be applied.

5.1. Quantitative Assessments:

- Shall be conducted for all ODH operations that are physically capable of exposing individuals to an oxygen deficiency. This assessment shall assign an ODH Class to each area with potential risk as well as specify any unusual precautionary requirements.
  - ODH Class 0 is the least hazardous and is assigned to areas where there is no probability or a very low probability of an oxygen deficiency hazard.
  - ODH Class 2 is the most hazardous.
  - The classification of an area can change depending on the operations being performed. If conditions and/or activities change in ways that significantly increase the risk, the associated quantitative assessment must be revised. Refer to ESH-(11000-A)-204618 Oxygen Deficiency Hazards Technical Assessment.
- If an area cannot be engineered to satisfy requirements below Class 2, the Director responsible for the area must submit a written exception request to the ESH Director or Director's designee. The request shall include a justification and an evaluation of hazards,

procedures, and safety controls. The request must be approved by the ESH Director or designee before operations contributing to oxygen deficiency hazards are begun.

5.2. Underground Assessments:

- ODH evaluation describes (Oxygen Deficiency Hazard Technical Assessment) and measures the hazards in underground installations, the same as those required for surface installations. However, time of egress may be longer, gases or cryogenic fluids may accumulate, and rescue operations may be more difficult. All of these factors must be taken into account in conducting a hazard analyses.
  - If there are oxygen deficiency hazards and normal entry and egress is by means other than by foot, at least one egress path to a "safe area" which can be reached by foot must be provided. The safe area must be free of oxygen deficiency hazards and remain so during all possible equipment failures. If the safe area relies upon ventilation, emergency power must be provided to its ventilation systems.
  - The path to the safe area must be adequately marked and illuminated and remain free of obstructions. Portable light sources may be required in some cases.

5.3. Control Measures:

- Control measures appropriate to the ODH Class shall be implemented as noted in the table below.

ODH Hazard Class	0	1	2
Required Facility Environment Controls			
1. Warning Signs	X	X	X
2. Ventilation (minimum requirements established)	X	X	X
3. Fixed Oxygen Monitors	X	X	X
Personnel Working with Cryogens in ODH Spaces			
4. ODH Training		X	X
5. Personal Oxygen Monitor		X	X
6. Self-Contained Self-Rescuer Available		X	X
7. Multiple Personnel in Communication			X
8. Medically Qualified			X

5.4. Equipment Engineering:

- Compressed gas equipment at SURF shall be designed and installed to ensure that areas intended for human entry during normal operation will be no greater than ODH Class 2.
- For facilities with deliberate planned ODH potentials, fixed ODH alarms are required to provide adequate warning to the occupants and must be reviewed by the SDSTA Engineering Department.
- Any changes to the configuration or approved intended use of such equipment shall be reviewed for possible impact to previously reviewed ODH Assessments.

5.5. Records:

- Records of reliability of ODH-associated equipment and records of ODH alarms that were the result of an oxygen deficient atmosphere shall be maintained.

5.6. Monitoring for Indication of Oxygen Deficiency

- Indications of a possible oxygen deficiency include:
  - Observations of uncontained cryogens or gases such as vapor clouds, sound of gas leaks, etc.

- Readings or alarms of gas monitoring devices that continuously monitor oxygen concentrations.

- There are two types of oxygen deficiency monitors that should be placed at breathing zone height whenever possible.
  - Fixed oxygen monitors attached to a lab surface (usually wall). Fixed oxygen monitors are set to alarm in the room in which they are situated when the oxygen concentration is below 19.5% (Local Alarm) and set to alarm the facility when the oxygen concentration is below 18.0% (General Facility Alarm).
  - Portable (hand-held) gas monitors intended to be carried by persons are set to alarm when the oxygen concentration is below 19.5%.

5.7. Response to Indication of ODH Condition:

- Indications of uncontained cryogens or gases:
  - Address the issue if within your capability and a gas monitor indicates not less than 19.5%. Otherwise, leave the area, and report the emergency.
- Local alarm or portable gas monitor alarm less than 19.5%:
  - Leave area then determine if the alarm is valid.
- Facility alarm or portable gas monitor alarm less than 18.0%:
  - Evacuate to a safe area. If the safe area cannot be reached within 30-seconds, don an SCSR before escaping.
  - Follow the ESH-(6000-FD)-100304 Emergency Reporting System.

5.8. Re-Entry to Oxygen Deficient Spaces:

- If facility O2 sensors are present and have returned to levels above 19.5% per remote verification, and alarms have been cleared:
  - Portable gas testers shall be utilized as an additional source of monitoring.
  - Plausible explanation provided to Lab Coordinator/Duty Officer about why the local alarm sounded and why the situation is now resolved.
- If oxygen levels are between 18.0% and less than 19.5%:
  - Local alarm, if present, sounds:
    - User is to provide an explanation to the Lab Coordinator/Duty Officer as to why the alarm sounded.
    - The Lab Coordinator/Duty Officer confirms that the O2 sensor is 19.5% or greater.
    - Lab Coordinator/Duty Officer may provide permission for re-entry with a portable gas tester.
      - Additional precautions such as carrying an escape respirator may be required.
- If oxygen levels are unknown or the levels are known to be less than 18.0% by volume, the following is required:
  - Emergency Response Team (ERT) personnel with SCBA equipment.
  - Cryogen systems expertise from technical support staff shall serve as external consultation.

6.0 Documented Information/Related Documents

6.1. ESH-(11000-A)-204618 Oxygen Deficiency Hazards Technical Assessment
6.2. ESH-(6000-FD)-100304 Emergency Reporting System