SUBJECT AREA CONTENT

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Management System: Worker Safety and Health

Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls

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Effective Date: **Feb 27, 2017** (Rev 3.5) Periodic Review Due: **Oct 15, 2019**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak	Management System Steward: Gail Mattson

Introduction

The Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard (29CFR1910.134) defines an oxygen-deficient atmosphere as an atmosphere with an oxygen content below 19.5% by volume.

Staff must not be exposed to an oxygen-deficient atmosphere under normal working conditions. If work needs to be performed in an oxygen-deficient atmosphere, specific work planning needs to be conducted to ensure compliance with OSHA requirements (see the Work Planning and Control for Experiments and Operations Subject Area).

Persons exposed to reduced-oxygen atmospheres may experience adverse health consequences, including unconsciousness, or death. The purpose of this subject area is to describe the methodology for assessing and classifying workplaces where abnormal conditions have the potential for producing an oxygen-deficient environment and controlling the associated hazards.

The use of compressed gases, liquefied gases, and volatile liquids is commonplace at Brookhaven National Laboratory (BNL). Introduction of these materials to the atmosphere can present a hazard. In particular, oxygen deficiency is important for those materials, which are neither acutely toxic nor flammable. Air normally contains about 21% oxygen with the remainder consisting mostly of nitrogen. Individuals exposed to reduced-oxygen atmospheres may suffer a variety of harmful effects. The Effects Thresholds for Exposure to Reduced Oxygen page on the ESH Guide: Oxygen Deficiency Hazard on the Safety and Health Services Web Site list some effects on humans in oxygen deficiency atmospheres and the sea level oxygen concentration at which they occur.

If exposure to reduced oxygen is terminated early enough, effects are generally reversible. If not, permanent central nervous system damage or lethality results. Major effects hindering escape from the vicinity of an oxygen deficiency are disorientation and unconsciousness. If it is possible for staff to be exposed in the event of equipment failure/human error to an atmosphere containing less than 19.5%

oxygen, then the hazard is to be evaluated and assessed, and control measures implemented to minimize the risk.

This subject area is not applicable to areas defined as confined spaces. See the Confined Spaces Subject Area.

Contents

Section	Overview of Content (see section for full process)
1. ODH Evaluations and Calculations	• Conduct quantitative assessment of fatality risk potential. • Calculate ◦ fatality factor based on the lowest oxygen concentration ◦ probability of event using equipment failure rates ◦ fatality rate • Ensure that the risk assessment is conducted. • Determine ODH Class by the predicted fatality rate. • Ensure that ODH control measures are implemented. • Update building's FUA and emergency run cards.
2. Implementing ODH Control Measures	• Establish and maintain controls required based on ODH Classification and lowest oxygen levels. • Ensure controls are implemented.
3. Emergency Evacuation and Rescue	• Obtain PPE. • Prepare to evacuate. • Don SRSAR, if applicable, then check that no one is trapped. • Evacuate area, if no one is trapped. • Ensure that victims don their own SRSARs, if trapped, and if possible. • Evacuate area, then dial 911 or 2222. • Wait to assist Emergency Services.
4. Reentry into ODH Areas after Alarm	

- SCBA-qualified Staff enter ODH Area after alarm/indication using SCBA.
- Check for staff needing rescue/assistance.
- Determine oxygen concentration, cause, and initiate corrective actions, if appropriate.
- If oxygen levels remain less than 19.5%, use work planning to restore system.
- Resume normal operation, if cause is found and oxygen levels are greater than 19.5% and rising.

5. Escorted Access into ODH Areas

- Inform person entering the ODH area of hazards.
- Review alarms and evacuation routes.
- Instruct those entering ODH 1 areas on use of POMs and SRSARs.

Definitions

Exhibits

ODH Control Measures

Forms

None

Training Requirements and Reporting Obligations

This subject area contains the following training requirements (see the BNL Training and Qualifications website):

- Oxygen Deficiency Hazard - Class 0 (TQ-ODH)
- Oxygen Deficiency Hazard - Class 1 (TQ-ODH1).

This subject area does not contain reporting obligations.

External/Internal Requirements

Requirement Number	Requirement Title
29 CFR 1910	Labor/Occupational Safety and Health Standards
BSA Contract No. DE-SC0012704 - Clause C.4	Statement Of Work

BSA Contract No. DE-SC0012704 - Clause H.27 (ACT)	Non-Federal Agreements for Commercializing Technology (Pilot) (ACT)

References

29 CFR 1910.134, OSHA Respiratory Protection Standard

Confined Spaces Subject Area

Cryogenics Safety Subject Area

Emergency Preparedness Subject Area

ESH Guide: Oxygen Deficiency Hazard, Safety and Health Services Web Site

Facility Hazard Analysis and Risk Assessment Subject Area

Hazard Evaluation Tools, Safety Engineering Group Web Site

OSHA Standard Interpretation: "03/08/1999 - Medical evaluation not required for the use of escape only respirators"

Training and Qualifications Web Site

Work Planning and Control for Experiments and Operations Subject Area

Standards of Performance

Managers shall analyze work for hazards, authorize work to proceed, and ensure that work is performed within established controls.

All staff and users shall identify, evaluate, and control hazards in order to ensure that work is conducted safely and in a manner that protects the environment and the public.

All staff and users shall ensure that they are trained and qualified to carry out their assigned responsibilities, and shall inform their supervisor if they are assigned to perform work for which they are not properly trained or qualified.

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PROCEDURE: ODH EVALUATIONS AND CALCULATIONS

Management System: Worker Safety and Health

Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls

1. ODH Evaluations and Calculations

Effective Date: **Feb 27, 2017**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to all Department Chairs/Division Managers or designees who are responsible for operations or equipment that have the potential of producing an oxygen-deficient atmosphere in an occupied workspace. If under normal conditions, oxygen concentrations can fall below 19.5% (i.e., normal venting of gases), then controls must be used as required by Respiratory Protection Standard (29 CFR 1910.134), and this procedure does not apply. This procedure is not applicable to confined spaces. See the Confined Spaces Subject Area.

Required Procedure

If a worst case accident caused by equipment failure or human error occurs (i.e., without dilution from ventilation, the entire contents of the cryogenic dewar, refrigerator, target, or compressed gas cylinder is released into the workspace), and oxygen concentrations do not fall below 19.5%, then there is no ODH situation and no further analysis or controls are required.

No assessment is required for areas temporarily used during transport of cryogenic dewars or compressed gases, or if the space is not designed for human occupancy (i.e., storage closets).

Note: The displaced oxygen may be in an area different than where the cryogen or compressed gas is stored due to configuration/venting. Ensure that all affected areas are reviewed.

Step 1	The Department Chair/Division Manager or designee evaluates the operation to determine if an oxygen-deficient atmosphere (i.e., cryogenic or compressed gas use) can occur. See the Facility Hazard Analysis and Risk Assessment or Work Planning and Control for Experiments and Operations Subject Areas. The evaluation is performed in two parts by: 1. Determining the minimum oxygen concentration that staff may be exposed to and establishing controls based on hazardous threshold levels. 2. Performing a quantitative assessment of the stochastic effects to humans exposed to oxygen-deficient atmospheres that determines the ODH Classification. ODH Class is based on the calculated probability of a fatality. This is the product of the

	fatality factor due to the total oxygen concentration and the failure rate of equipment. See the Hazard Evaluation Tools on the Safety Engineering Group Web Site for ODH assessments due to either cryogenics or compressed gas use. See the ESH Guide: Oxygen Deficiency Hazard on the Safety and Health Services Web Site for information on the effects on humans in oxygen deficiency atmospheres. **Note:** High concentrations of Carbon Dioxide (CO_2) and Carbon Monoxide (CO) can have lethal effect even when oxygen concentrations are above 19.5%.
Step 2	The Department Chair/Division Manager or designee determines the lowest concentration due to equipment failure/human error and calculates the fatality factor based on the lowest oxygen concentration using the following formula: $F = \mathbf{10}^{\left(6.5 - \frac{PO_2}{10}\right)}$ Where: PO_2 = Partial Pressure of Oxygen = % Oxygen Concentration x Atmospheric Pressure (in mm Hg) (typical atmospheric pressure at sea level is 760 mm Hg). See the ESH Guide: Oxygen Deficiency Hazard on the Safety and Health Services Web Site for additional information on ODH Fatality Factor and Fatality Rate, and for methods to calculate oxygen concentrations in ventilated spaces. **Note:** If oxygen concentrations do not fall below 18%, then there is no harmful physiologic effect and no ODH classification is required.
Step 3	The Department Chair /Division Manager or designee calculates the probability of the event using equipment failure rates. See the ESH Guide: Oxygen Deficiency Hazard on the Safety and Health Services Web Site for examples of Failure Rates/Human Error to use to determine failure rates/probability of occurrence. If area monitoring or ventilation is used as part of the determination of probability/likelihood, then the systems are required to be part of a preventive maintenance or alarm program.
Step 4	Once the fatality factor and the probability are known, the Department/Division or project calculates the fatality rate using the following formula: $\mathbf{\Phi = \sum P_i F_i}$ Where: • **Φ** = The ODH Fatality Rate (per hour), • $\mathbf{P_i}$ = The expected rate of the i^{th}event (per hour), • $\mathbf{F_i}$ = The Fatality Factor for the i^{th}event. The summation shall be taken over all events that may cause oxygen deficiency and result in fatality. See the ESH Guide: Oxygen Deficiency Hazard on the Safety and Health Services Web Site for additional information on ODH Fatality Factor and Fatality Rate.
Step 5	The Department/Division or project determines the ODH Class by the predicted fatality rate in step 4. The following are ODH Classes:

PROCEDURE: IMPLEMENTING ODH CONTROL MEASURES

Management System: Worker Safety and Health

Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls

2. Implementing ODH Control Measures

Effective Date: **Feb 27, 2017**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to all staff where ODH classification of 0 or greater has been established. This information does not apply to Confined Spaces or when staff can be exposed to oxygen concentrations less that 19.5% under normal operations.

Required Procedure

The Department Chair /Division Manager or designee determines if the affected area requires an ODH Classification using the processing in the section ODH Evaluations and Calculations. If the area is classified as ODH 0 or greater, then the following controls, based on classification, are as a minimum required to be implemented.

Step 1

Based on the minimum oxygen concentration, the Department Chair /Division Manager or designee establishes and maintains the minimum controls required as follows:

Oxygen Concentration	Controls
≥14%	Controls Required by ODH Classification (step 2).
≥10%<14%	Controls Required by ODH Classification (step 2) plus ODH Monitoring (either fixed area or POM) that alarms locally.
<10%	Controls Required by ODH Classification (step 2) plus ODH Monitoring that

	provides alarms/indication both locally and before entering the area.

Alarms must be perceptible in the environment used (e.g., visual or vibration in high noise areas).

Note: Ensure to incorporate the impact from added monitoring to the ODH Classification process.

Step 2

Based on the ODH Classification, the Department Chair /Division Manager or designee establishes and maintains the minimum controls required as follows:

ODH Classification	Controls
0	Postings Training
1	Postings Training (including practical demonstration of personal protective equipment [PPE]) PPE: • Personal Oxygen Monitor • Self-Rescue Respirator (Supplied Atmosphere)
2	Ventilation Multiple Personnel in Communication ("2-Staff Rule") Postings Training (including practical demonstration of PPE) PPE: • Personal Oxygen Monitor • Self-Rescue Respirator (Supplied Atmosphere)
3	Ventilation Unexposed Safety Monitor/Observer Postings Training (including practical demonstration of PPE) PPE: • Personal Oxygen Monitor • Self-Rescue Respirator (Supplied Atmosphere)

PROCEDURE: EMERGENCY EVACUATION AND RESCUE

Management System: Worker Safety and Health
Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls
3. Emergency Evacuation and Rescue

Effective Date: **Oct 15, 2014**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to all staff authorized to be in an ODH Classified area. This procedure does not apply to entry into a space that is possible oxygen deficient.

Required Procedure

The Department Chair/Division Manager or designee ensures the following process is incorporated into the Building's Local Emergency Plan per the Emergency Preparedness Subject Area.

Step 1	The Department Chair/Division Manager or designee ensures that all personnel authorized to be in an ODH Classified space obtain personal protective equipment (PPE) as defined by work planning. **Note:** Supervisors must arrange for ODH training for BNL staff through the Training Coordinator who has jurisdiction over the ODH operation(s) of interest. For non-BNL staff, the BNL representative for the non-BNL staff member arranges training. For training in oxygen hazards and associated safety measures, see the Training and Qualifications Web Site.
Step 2	Upon indication of a failure that can cause an ODH area (such as a cryogen leak or an area ODH alarm alert), or personal oxygen monitor (POM) alarms, all staff prepare to evacuate the area.
Step 3	Don the Self-Rescue Supplied Atmosphere Respirator (SRSAR), if applicable (i.e., areas classified as ODH Class 1 or higher). **Note:** An SRSAR contains approximately 5 minutes of air supply.
Step 4	Check if anyone is trapped or needs assistance in the area.

Step 5	If no one is trapped or needs assistance, evacuate the area immediately. If someone is trapped, ensure that the victim donned his/her own SRSAR (if applicable), then evacuate the area and notify the Fire Rescue Group immediately by dialing 2222 or 911. **Do not try to move the victim.** **Note:** If it will take longer than one minute to assist the victim with the SRSAR, or if someone is unaccounted for, then evacuate the area immediately and contact the Fire Rescue Group.
Step 6	Contact the appropriate Department/Division personnel per the Local Emergency Plan. After evacuating, wait to assist the Fire Rescue Group, if called. See the section Reentry into ODH Areas after Alarm for reentry requirements.

Guidelines

Be aware as much as practical of the total number of employees entering or working in an ODH Class 1 or greater area so to assist the Fire Rescue Group in an emergency.

References

Emergency Preparedness Subject Area

Training and Qualifications Web Site

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PROCEDURE: REENTRY INTO ODH AREAS AFTER ALARM

Management System: Worker Safety and Health

Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls

4. Reentry into ODH Areas after Alarm

Effective Date: **Oct 15, 2014**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to the safe reentry into ODH Classified areas after a low-oxygen alarm. It applies to supervisors and other staff required to enter the ODH area for repair, diagnosis, and/or mitigation of hazards. This information does not apply to the Fire Rescue Group staff. Staff are not authorized to be in atmosphere less than 19.5% oxygen concentration without approved Self-Contained Breathing Apparatus (SCBA) and the associated medical approval and training.

Required Procedure

ODH alarms can be cause by monitor failures or by localized leaks. Use the following procedure to facilitate returning systems to normal operation. If possible, secure the source of the cryogen or gas from outside the area. If applicable, staff authorized to operate equipment in the area may provide additional ventilation as long as they do not expose themselves to a potentially oxygen deficient atmosphere (e.g., by switching on exhaust fans).

Step 1	Staff (entrants) wearing self-contained breathing apparatus (SCBA) and calibrated oxygen monitoring equipment initially enter into any area that has fixed oxygen monitors alarming, or which has been evacuated because of a Personal Oxygen Monitor (POM) alarm. A Self-Rescue Supplied Atmosphere Respirator (SRSAR) and a POM are not to be used.
Step 2	The entrant verifies that no staff are in the area that need assistance. If personnel require assistance, notify Fire Rescue immediately (dial x2222 or 911). Follow any instructions provided by the Fire Rescue Group.
Step 3	After the area has been verified free of personnel requiring assistance, the entrant determines if area oxygen concentrations are 19.5% or greater. **Note:** If the entrants discover the cause of the oxygen deficient and are qualified to operate the system, they may attempt corrective actions (e.g., close a valve, open a vent).

Step 4	If oxygen levels remain less than 19.5%, or if the cause can not be determined or corrected, then further reentries will require specific work planning. See the Work Planning and Control for Experiments and Operations Subject Area.
Step 5	If oxygen levels are 19.5% or greater, then the entrant may remove the SCBA.
Step 6	If oxygen levels are 19.5% or greater and rising, and the cause of the oxygen deficient atmosphere is known and corrected (or determined to be caused by a faulty detector), then staff may reenter the area as normal.

References

Work Planning and Control for Experiments and Operations Subject Area

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Questions/Comments Disclaimer

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PROCEDURE: ESCORTED ACCESS INTO ODH AREAS

Management System: Worker Safety and Health
Subject Area: Oxygen Deficiency Hazards (ODH), System Classification and Controls
5. Escorted Access into ODH Areas

Effective Date: **Oct 15, 2014**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to escorts and to BNL staff and non-BNL staff escorted into ODH Class 0 and 1 Areas.

Required Procedure

Untrained staff may access ODH Class 0 Areas with a trained escort, but only for short-term operational needs and informational tours. An escort is not to be used as a substitute for training.

Untrained staff are one-to-one escorted by an ODH-qualified person into ODH Class 1 Areas.

Step 1	Escorts brief personnel before entering the ODH area on • The hazards of oxygen deficiency; • Alarms and indications in the area; • Evacuation routes.
Step 2	**If entering an ODH Class 1 Area:** Escorts instruct personnel before entering the ODH area on the use of a Self-Rescue Supplied Atmosphere Respirator (SRSAR) and Personal Oxygen Monitor (POM). All personnel must carry their own SRSAR and POM.

Guidelines

ODH Class 0 Areas

- Persons with frequent escorted accesses to ODH Class 0 Areas should be reported to the Environmental Safety and Health Coordinator.
- No more than two persons per escort should be escorted into an area for short-term work.
- Up to six persons may be escorted for an informational tour. Tours of more than six persons should be pre-approved by the Department/Division.

ODH Class 1 Areas

- Informational tours are permissible; a tour route, which minimizes the risk to staff, should be established and approved by the Department/Division.

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DEFINITIONS

Definition: Oxygen Deficiency Hazards (ODH), System Classification and Controls

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>entrant</td><td>Staff authorized to enter an ODH classified area after either an ODH alarm or other indication (cryogenic leak) that there may be an oxygen deficient atmosphere. Must be qualified to used the required personal protective equipment (Self-Contained Breathing Apparatus [SCBA] and oxygen monitor).</td></tr>
<tr><td>mm Hg</td><td>Millimeters of mercury representing or measuring a pressure by relating it to the weight of a liquid mercury column (1 mm Hg = 1 Torr).</td></tr>
<tr><td>multiple personnel in communication</td><td>Required more than one individual to enter an ODH 2 Classified Area. All individuals must be ODH trained and use the required personal protective equipment (Self-Rescue Supplied Atmosphere Respirator [SRSAR] and personal oxygen monitor [POM]).</td></tr>
<tr><td>oxygen concentration</td><td>The molar fraction of a gaseous mixture represented by oxygen. It is also equal to the ratio of the partial pressure of oxygen to the total mixture pressure.</td></tr>
<tr><td>oxygen deficiency hazard (ODH)</td><td>The condition where the body does not absorb sufficient oxygen from the atmosphere to support the biochemical activity of the brain and other vital organs. This is typically recognized when the partial pressure of atmospheric oxygen is less than 110 mm Hg (represents an altitude of 10,000 feet).</td></tr>
<tr><td>oxygen deficiency hazard class</td><td>
<table>
<tr><th>ODH Class</th><th>Fatalities/Hr</th></tr>
<tr><td>No Classification Required</td><td>0 (Oxygen concentration not less than 18%)</td></tr>
<tr><td>0</td><td>$<10^{-7}$note 1</td></tr>
<tr><td>1</td><td>$>=10^{-7}$ but $<10^{-5}$</td></tr>
<tr><td>2</td><td>$>=10^{-5}$ but $<10^{-3}$</td></tr>
<tr><td>3</td><td>$>=10^{-3}$ but $<10^{-1}$</td></tr>
</table>
</td></tr>
</table>

	4 | $>=10^{-1}$ Note 1: Areas that have Departmental/Divisional controls established that can demonstrate the fatality rate is less than 10^{-9} by engineering/safety analysis, may not have to have an ODH classification (SME concurrence required).
oxygen-deficient atmosphere	An atmosphere with an oxygen content below 19.5% by volume (as defined by the OSHA Respiratory Protection Regulation, 29CFR1910.134).
parts per million (ppm)	The number of parts of a particular gas in a million parts of air. Use of ppm as a volumetric measurement (not a weight measurement) avoids the use of awkward decimals required to express low concentrations.
personal oxygen monitor (POM)	A direct-reading alarming monitor that measures the oxygen concentration as a percentage of air.
personal protective equipment (PPE)	Devices used by staff to control or mitigate a hazard, including gas concentration self-monitors (such as POM or Bacharach Oxygen Monitor) and Self-Rescue Supplied Atmosphere Respirators.
Self-Rescue Supplied Atmosphere Respirator (SRSAR)	A device containing breathing air to be used for escape during an ODH event.
Torr	A unit of pressure equal to 1 mm Hg; 760 Torr = 29.92 in of Hg (normal atmospheric pressure at sea level).
unrestricted	Areas that have been evaluated for ODH but have a fatality rate of less than 10^{-7} per hour.
volume concentration	The ratio of the volume of a specific gas to the total volume occupied by a mixture of gases at any temperature and pressure. It is used when the volume parameter has definite physical significance. In the case of explosive or oxygen-enriched atmospheres, volume concentration serves as a useful criterion for evaluating a potentially hazardous condition. Volume concentration is calculated as follows: Volume concentration (in percent) = {(Partial Pressure/Total Pressure) x 100}.

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