This chapter was last reviewed for currency 5/29/2020.
The next thorough review is due 5/29/2023.

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

Quick Start Summary

Product ID: 667 | Revision ID: 2474 | Date published: 7 February 2022 | Date effective: 7 February 2022
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsQuickstart.pdf

1 Who needs to know about these requirements

The requirements of Cryogenic and Oxygen Deficiency Hazard Safety apply to workers, supervisors, responsible persons, line management, and ESH coordinators involved with cryogenic systems or oxygen deficiency hazards, and the cryogenic and oxygen deficiency hazard safety program manager.

2 Why

SLAC is committed to meeting safety requirements for cryogenic systems and oxygen deficiency hazards. Failure to meet them may result in an explosion, injury, or death, and/or release of hazardous materials into the environment.

3 What do I need to know

Before introducing oxygen-displacing gases, including cryogens, into a work area or changing the existing use of such gases (for example, by adding or modifying systems, changing operations, or changing the quantity of gases used), a quantitative, documented safety review must be performed by the responsible person, reviewed by his or her ESH coordinator, and approved by the cryogenic and oxygen deficiency hazard safety program manager. The results of the initial safety review may require performance of a more detailed risk assessment.

The review results in a hazard classification that is then used to determine required controls. The review must be completed and controls implemented before operations begin.

Workers in the area and visitors must observe the boundaries defined in the safety review and comply with controls and training dictated by the ODH classification.

There is a de minimis exemption from all requirements related to hazard classification and posting for certain minimal quantities of oxygen-displacing gases or cryogenic fluids in an open lab of sufficient size and ventilation.

4 When

These requirements take effect 7 February 2022.

5 Where do I find more information

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 36, “Cryogenic and Oxygen Deficiency Hazard Safety”

Or contact the program manager.

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 36

Cryogenic and Oxygen Deficiency Hazard Safety

Product ID: 22 | Revision ID: 2473 | Date published: 7 February 2022 | Date effective: 7 February 2022
URL: https://www-group.slac.stanford.edu/esh/eshmanual/pdfs/ESHch36.pdf

1 Purpose

The purpose of this program is to ensure that work involving *cryogens* and other *oxygen-displacing gases* is performed safely, avoiding such hazards as asphyxiation, pressure explosions, and cold burns. It covers the approval, use, and handling of such substances, including the setting up of new operations and modification of existing operations involving these substances. It applies to workers, supervisors, responsible persons, line management, ESH coordinators, and the cryogenic and oxygen deficiency hazard safety program manager.

Additional requirements for cryogenic systems are covered in Chapter 14, "Pressure Systems". Work in confined spaces is covered in Chapter 6, "Confined Space", with hazardous substances in general in Chapter 53, "Chemical Safety", and with hazardous substances in a laboratory setting in Chapter 58, "Laboratory Safety".

2 Roles and Responsibilities

Functional roles and general responsibilities for each under this program are listed below. More detailed responsibilities and when they apply are provided in the procedures and requirements.

The roles may be performed by one or more individuals and one individual may play more than one role, depending on the structure of the organizations involved. Responsibilities may be delegated.

2.1 Worker

- Observes and follows all posted restrictions, including training and personal protective equipment (PPE) requirements

2.2 Supervisor

- Ensures that workers are appropriately trained and qualified before performing operations with cryogens or oxygen-displacing gases
- Ensures that operations do not exceed any limits contained in operating approvals

2.3 Responsible Person

- Completes an *oxygen deficiency hazard (ODH)* safety review whenever planning to supply a space with cryogens or oxygen-displacing gases; documents review by completing an ODH safety review form, reviewing with his or her ESH coordinator and then submitting it to program manager for approval
- If the initial calculated oxygen level is below specified limits, completes a more detailed ODH risk assessment and submits with safety review form
- Ensures cryogenic or ODH-related activities do not begin before ODH safety review form approval is received from the program manager
- Ensures operations do not exceed any limits contained in ODH safety review form approvals
- Ensures that ODH-related administrative controls (required training, placarding, procedures) are utilized
- Submits revised safety review form for review if additional cryogens or oxygen-displacing gases are introduced into the space or other modifications in operations are planned that could affect the hazard level
- Ensures visitors to ODH classified areas are briefed and escorted as required

2.4 Line Management

- Ensures that an ODH safety review form, and risk assessment if needed, is submitted to and approved by the program manager before the introduction of cryogens or oxygen-displacing gases into a work space
- Is responsible for the maintenance, calibration, and configuration control of all oxygen deficiency controls installed in its work spaces
- Ensures that calibrations of oxygen deficiency monitors are performed according to the manufacturer's recommendations
- Provides appropriate PPE to workers

2.5 ESH Coordinator

- Reviews ODH safety review forms and risk assessments before they are submitted to program manager
- Provides guidance and recommendations on PPE to be used at specific cryogen dispensing facilities and for cryogen usage in general

2.6 Cryogenic and Oxygen Deficiency Hazard Safety Program Manager

- Approves ODH safety review forms and risk assessments for new and modified cryogenic or oxygen-displacing installations
- Assigns an ODH hazard classification and associated controls based on ODH risk assessments
- Approves placard content

- Maintains an inventory of ODH classified areas and fixed oxygen deficiency monitors
- Develops cryogenic and ODH safety training
- Performs audits of ODH classified areas to ensure compliance with this chapter

3 Procedures, Processes, and Requirements

These documents describe the detailed requirements for this program and how to implement them:

- Cryogenic and Oxygen Deficiency Hazard Safety: Cryogenic Requirements (SLAC-I-730-0A06S-008). Describes hazards and controls specific to cryogens but excluding ODH hazards
- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements (SLAC-I-730-0A06S-002). Describes hazards and controls general to oxygen-displacing gases
- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Procedure (SLAC-I-730-0A06C-001). Describes process for safety review and approval of the introduction and use of oxygen-displacing gases, including cryogens, in work areas

These are the forms and tools for this program:

- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Form (SLAC-I-730-0A06J-001). Form for documenting the safety review required before introducing oxygen-displacing gases, including cryogens, into a work area or changing the existing use of such gases
- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Hazard Classification Sign Templates (SLAC-I-730-0A06S-003). Recommended templates for creating ODH warning signs

These are other program documents and resources:

- Cryogenic and Oxygen Deficiency Hazard Safety Program Site (SharePoint)

4 Training

4.1 Worker

Personnel who

- Work with cryogenic liquids or use systems/equipment that involve cryogenic liquids or
- Have managerial control over areas and personnel who use these materials

are required to complete the following:

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)

Personnel who work in areas with an ODH 1 classification (areas with oxygen deficiency monitors) or higher, but not directly with the liquids or systems, may complete the following instead of ESH Course 175:

- ESH Course 176, Oxygen Deficiency Safety Training (ESH Course 176)

Some areas at SLAC have area-specific access training programs that include applicable aspects of ESH Course 176. Access to these areas is permitted upon completion of the area-specific training in lieu of ESH Course 176, for example Course AD118, Cryogenic Accelerator Access Training (Course AD118). Those who work directly with the liquids or systems must still take ESH Course 175.

4.2 Visitor

Visitors who will only be entering areas classified as ODH 1 must be given a hazard awareness briefing by the responsible person before entry. The briefing must include the location of potential oxygen deficiency sources, alarms, and the protocol for responding to off-normal events.

Any visitor who will be entering an area classified as ODH 2 must meet the requirements described above and also have a one-to-one escort in the ODH 2 area. Other restrictions also apply as dictated by approved risk assessment and line management requirements.

5 Definitions

cryogen. Any fluid that operates at cryogenic temperatures (below roughly 150 K)

cryostat. A device designed to maintain cryogenic temperatures

dewar. A double-walled flask of metal or silvered glass with a vacuum between the walls, used to hold liquids at well below ambient temperature

monitor, oxygen deficiency (ODM). A device, usually permanently attached to a structure, that monitors the concentration of oxygen and alarms at a set value.

monitor, personal oxygen. A device carried by an individual that monitors the concentration of oxygen and alarms at a set value

oxygen deficiency area. Any area known to have an oxygen deficiency

oxygen deficiency hazard (ODH). An oxygen concentration equal to 19.5 percent or less (by volume) of dry air

oxygen-displacing gas. A non-toxic or minimally toxic gas that reduces or displaces the normal oxygen concentration in breathing air

ODH hazard classification. Classification system that defines access restrictions and required controls based upon hazards of operations performed in a space:

- *ODH 0.* Hazard classification for areas with a calculated ODH fatality risk of less than 10^{-7}/hr
- *ODH 1.* Hazard classification for areas with a calculated ODH fatality risk of 10^{-7}/hr to 10^{-5}/hr
- *ODH 2.* Hazard classification for areas with a calculated ODH fatality risk of 10^{-5}/hr to 10^{-3}/hr
- *ODH 3.* Hazard classification for areas with a calculated ODH fatality risk of 10^{-3}/hr to 10^{-1}/hr
- *ODH 4.* Hazard classification for areas with a calculated ODH fatality risk of greater than 10^{-1}/hr

pressure relief device. An automatic device used to relieve pressure in a pressure system. For example, a spring loaded pressure relief valve or rupture disk

responsible person. A system owner, scientist, researcher, or project manager, who wants to introduce cryogens or oxygen-displacing gas into a space

6 References

6.1 External Requirements

The following are the external requirements that apply to this program:

- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 7, "General Industry Safety Orders", Group 16, "Control of Hazardous Substances, "Article 107, "Dusts, Fumes, Mists, Vapors and Gases", Section 5149, "Oxygen Deficiency" (8 CCR 5149)
- American Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)* (ACGIH TLVs and BEIs)
- National Fire Protection Association (NFPA) 55, *Compressed Gases and Cryogenic Fluids Code* (NFPA 55)

6.2 Related Documents

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 6, "Confined Space"
- Chapter 14, "Pressure Systems"
- Chapter 40, "Chemical Lifecycle Management"
- Chapter 53, "Chemical Safety"
- Chapter 58, "Laboratory Safety"

Other Documents

- Fermi National Accelerator Laboratory. *Fermilab Environment, Safety, and Health Manual*, Chapter 4240, "Oxygen Deficiency Hazards (ODH)" (FESHM 4240)

Cryogenic Requirements

Product ID: 668 | Revision ID: 2476 | Date published: 7 February 2022 | Date effective: 7 February 2022
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsReqCryogenic.pdf

1 Purpose

The purpose of these requirements is to protect workers from hazards associated with working with cryogens. They cover the introduction and use of cryogens in work areas. They apply to workers, supervisors, and responsible persons.

The following hazards and controls are specific to cryogens. For hazards and controls related to oxygen deficiency hazards, including those caused by cryogens, see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements.

1.1 Hazards

Cryogens are extremely cold (roughly below 150 K) substances, typically stored in liquid form, used to cool other materials to extremely low temperatures. Cryogens used at SLAC include liquid nitrogen, liquid helium, liquid argon, and liquid hydrogen.

Cryogenic hazards fall into these general categories:

- Cold burns (frostbite)
- Pressure explosions
- Chemical explosions or exposures (when hydrogen is present)
- Oxygen deficiency, which can lead to asphyxiation

1.1.1 Cold Burns

The most likely cause of cold burns to the hands and body is contact with metal surfaces at extremely cold temperatures. Cold burns can occur within a few seconds, especially when the skin is moist.

The damage from cold burns occurs as the affected tissue thaws. Water expands as it freezes, and this expansion breaks cell membranes and allows body fluids to accumulate in intercellular spaces. Intense hyperemia (abnormal accumulation of blood) usually takes place in the affected areas. Additionally, a blood clot may form along with an accumulation of body fluids, which decreases the local circulation of blood. If the consequent deficiency of blood supply to the affected cells is extreme, tissue decay may result.

Although not a burn per se, cooling of the internal organs of the body can disturb normal functioning, producing a dangerous condition known as hypothermia.

1.1.2 Pressure Explosions

A pressure explosion can be caused by cryogenic temperatures either through material degradation or inadequate pressure relief.

Because material cracks can more easily develop at cryogenic temperatures, any volume cooled externally by a cryogen or any vacuum space in contact with a cryogen must have the ability to relieve pressure. The cryogen or air may leak into a sealed space through such cracks. Some atmospheric gases will condense under such conditions and exist as a cryogen in the sealed space. Upon warming, these cracks may be too small to vent the gas, and the contained, expanding fluid can shatter the vessel.

Cryogenic liquids allowed to heat above their boiling points undergo a phase change which drives large volume and/or pressure increases. When liquid cryogens warm to room temperature there is a volumetric change on the order of 700 to 900 times. Therefore, systems must be designed to contain the increased pressure in a closed system or relieve it through proper pressure relieving devices.

Certain cryogens, such as helium and hydrogen, are cold enough to solidify atmospheric air. Entry of air into cryostats containing these cryogens can be prevented by pressurizing the system. If openings to the atmosphere exist in an unpressurized system, they are likely to become plugged by solidified moisture from the air, leading to overpressure and vessel failure. Such conditions will also result in hazardous contamination of the fluid.

1.1.3 Chemical Explosions

The chemical properties and reaction rates of substances are influenced by cryogenic conditions. Condensing a cryogen from a pure gas at room temperature will concentrate the material typically 700 to 900 times its room temperature density. Oxygen-enriched air produced by either liquid helium or nitrogen has many of the same properties as liquid oxygen, which can react explosively with materials usually considered to be noncombustible. (Atmospheric oxygen concentrations above 23.5 percent pose a significant hazard.)

Cryogenic fluids with a boiling point below that of liquid oxygen have the ability to condense oxygen out of the air if exposed to the atmosphere. This is particularly troublesome if a stable system is replenished repeatedly to make up for evaporation losses as oxygen may accumulate as an unwanted contaminant. Violent reactions (for example, rapid combustion or explosion) may occur if the material is not compatible with liquid oxygen. An example of this could include a cryogenic fluid spill onto asphalt during a transfer between a tanker and a storage vessel.

Oxygen enrichment will also occur if liquefied air is permitted to evaporate (oxygen evaporates less rapidly than nitrogen). Oxygen concentrations of 50 percent may be reached near evaporating liquid air. Condensed air dripping from the exterior of cryogenic piping will be rich in oxygen.

1.1.4 Oxygen Deficiency or Asphyxiation Hazard

At temperatures above their boiling points, some cryogens can expand in volume 700 to 900 times. The resulting large volume of gas can displace part or all of the air in an unventilated enclosure, creating a potential for asphyxiation. This asphyxiation hazard, also known as an *oxygen deficiency hazard (ODH)*, is particularly serious in enclosed volumes that have no vents or ventilation systems.

2 Requirements

2.1 Environmental and Engineering Controls

2.1.1 Insulation

Surfaces at cryogenic temperatures must be protected to prevent contact with skin. This may be accomplished by means of vacuum jacketing, insulation, or location. Insulation systems must be specially engineered to prevent air penetration, or the insulation must have sufficiently low strength that it will yield at low gas pressure.

2.1.2 Pressure Relief

Adequate pressure relief devices must be provided to vent all gas that could be produced during a theoretical maximum heat flux into the system. The system configuration must ensure that any air that enters the cryostat and freezes cannot prevent proper functioning of pressure relief devices.

Heat flux into the cryogen is unavoidable regardless of the quality of the insulation installed. Pressure relief must be provided to permit routine release of gas vapors generated by this heat input. Typically such relief is best provided by rated spring-loaded relief devices or an open passage to the atmosphere with a check valve.

Additional relief devices should be provided as backup to the operational relief when the capacity of the operational relief device is not adequate to take care of unusual or accidental conditions. This may be the case if the insulation is dependent on the maintenance of a vacuum in any part of the system (this includes permanently sealed dewars), if the system may be subject to an external fire, or if rapid exothermic (heat releasing) reactions are possible in the cryogen or a container cooled by the cryogen. In each case, relief devices capable of handling the maximum volume of gas that could be produced under the most adverse conditions must be provided.

Each and every portion of the cryogenic system must have uninterruptible pressure relief. Any part of the system that can be valved-off from the remainder must have separate and adequate provisions for pressure relief.

Examples of parts that usually require separate relief systems:

- Pressurized supply dewars
- Piping (except ambient) and manifolds
- Tubing and hoses used to transfer a cryogen, unless an air gap is provided
- Bath space surrounding experimental volume
- Any volume cooled externally by a cryogen
- Vacuum spaces in contact with cryogen

See Chapter 14, “Pressure Systems”, for detailed requirements for design, installation, maintenance, and inspection of pressure relief devices.

2.2 Personnel Controls

2.2.1 Personal Protective Equipment

Eye, hand, and body protection must be provided to prevent potential cold burns when handling cryogens.

Eye protection is required at all times when handling cryogenic fluids. When pouring a cryogen or when working with a wide-mouth dewar (that is, open flow delivery), goggles or a full-face shield over safety glasses must be used. A face shield by itself does not provide adequate splash protection; safety glasses or goggles must be worn underneath as well. The only exceptions are for transporting cryogens in closed dewars or portable tanks and disposing of very small quantities (less than 0.5 liter) by evaporation.

For hand protection, it is best to wear loose, insulating gloves, which can be tossed off readily if they become soaked with cryogens. For tasks requiring a high degree of dexterity that are difficult or impossible to perform while wearing insulating gloves, such as manipulating samples in small cryovials, a better solution is the use of insulated hand tools.

Never use clean room gloves, which are absorbent (cotton) or porous (nylon), for hand protection.

Required body protection when working with large (multi-liter) quantities of cryogenic fluids includes

- Cuff-less trousers extended over work boots
- Leather or cryogenic material apron

2.2.2 Training

Personnel who

- Work directly with cryogenic liquids or use systems/equipment that involve cryogenic liquid or
- Have managerial control over areas and personnel who use these materials

are required to complete the following:

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)

2.3 Emergency Controls

2.3.1 Response to Uncontrolled Cryogen Release

In the case of an uncontrolled cryogen release:

- Leave the area immediately.
- Never exit the area through a vapor cloud. If you find yourself in a vapor cloud, hold your breath until you are out of the cloud.

Do not attempt to rescue an injured or unconscious person. Only those who are trained and qualified are authorized to perform rescue operations.

The following may be signs of an uncontrolled release of a cryogen:

- A sudden drop in temperature
- A visible water-vapor plume until the gas warms
- A hissing or whooshing sound associated with rushing gas

3 Forms

The following forms and systems are required by these requirements:

- None

4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- None

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 36, "Cryogenic and Oxygen Deficiency Hazard Safety"
  - Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements (SLAC-I-730-0A06S-002)
  - Cryogenic and Oxygen Deficiency Hazard Safety Program Site (SharePoint)
- Chapter 14, "Pressure Systems"

Other SLAC Documents

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

ODH Requirements

Product ID: 424 | Revision ID: 2475 | Date published: 7 February 2022 | Date effective: 7 February 2022
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsReqODH.pdf

1 Purpose

The purpose of these requirements is to protect workers from the *oxygen deficiency hazard (ODH)* associated with working with oxygen-displacing gases. They cover the introduction and use of oxygen-displacing gases, including cryogens, in work areas. They apply to workers, supervisors, responsible persons, line management, ESH coordinators, and the cryogenic and oxygen deficiency hazard safety program manager.

The following hazards and controls are general to oxygen-displacing gases. For hazards and controls specific to cryogens, see Cryogenic and Oxygen Deficiency Hazard Safety: Cryogenic Requirements.

1.1 Hazards

An *oxygen deficiency hazard (ODH)* exists when the concentration of oxygen is 19.5 percent or less by volume. Individuals exposed to reduced oxygen atmospheres may suffer a variety of harmful effects. Potential consequences increase as the oxygen levels decline. As oxygen levels decrease physiological responses by the human body become more detrimental. When oxygen levels drop into single digits, a person can lose consciousness in a few seconds and die of asphyxiation in a few minutes. At sufficiently low levels of oxygen there is no warning sign before unconsciousness, so it is especially important to be aware of potential hazards before beginning work in a potentially oxygen-deficient area.

Liquefied gases can easily and quickly create an ODH. When expelled to the atmosphere at room temperature, liquefied gases evaporate and expand 700 to 900 times their liquid volume. Consequently, leaks of even small quantities of liquefied gas can displace large amounts of oxygen-containing air, and render an atmosphere lethal.

Dense gases (those with densities significantly greater the atmospheric air) will fill pits and other low areas. Examples of dense gases include various freons, sulfur hexafluoride, and certain cold cryogens. Dense vapors will not readily mix with air and can “layer” and accumulate in depressions.

Air dense gases (those with densities approximating atmospheric air) are used at SLAC in sufficient quantities that they could dilute the available oxygen in a room/enclosed work area. Examples of air dense gas include nitrogen and argon. As an example, one activity where this hazard is present is in laboratories where continuous flow nitrogen is used as a vacuum system purge. Failure of the HVAC system normally in use in such locations (due to maintenance shutdown or power outage) can result in accumulation of inert gas sufficient to create a hazard, even without any failure of any part of the gas handling system. Also, cryogen spills out-of-doors can also result in localized ODH if there is insufficient air movement to dissipate the vapor.

Light gases (those with densities significantly lesser than atmospheric air) can affect the areas above a cryogen spill. Examples of light gases include helium and hydrogen. Experience has shown that with a connecting shaft of only a few square inches, an ODH condition can be present in spaces above the release location.

Users of oxygen-displacing gases should always be aware of the possibility that localized ODH conditions can exist. For example,

- Welding purge gas can accumulate behind the welder's helmet, creating an oxygen deficiency in the breathing space.
- Continuously flowing inert gas can accumulate underneath a fabric shroud on a laser table.

2 Requirements

2.1 Hazard Assessment

Before introducing oxygen-displacing gases, including cryogens, into a work area or changing the existing use of such gases (for example, by adding or modifying systems, changing operations, or changing the quantity of gases used), a quantitative, documented safety review must be performed by the responsible person, reviewed by his or her ESH coordinator, and approved by the cryogenic and oxygen deficiency hazard safety program manager. This safety review consists of an initial preliminary calculation of the oxygen level after a complete release of all cryogens and oxygen-displacing gases (at room temperature and pressure) into the room. If the resulting calculated oxygen level is less than 18 percent, a detailed risk assessment is required.

Note *There is a de minimis exemption from this requirement where the work area has at least one air change per hour of fresh air ventilation and an open floor plan for uses involving 1) a lecture bottle of compressed inert gas per 1,000 cubic feet of open lab space; 2) a standard K-bottle (200–300 cubic feet) of compressed inert gas per 3,000 cubic feet of open lab space; or 3) two liters of liquid nitrogen per 1,000 cubic feet of open lab space. Multiple, individual, bottles listed above are acceptable providing they are not connected together in a common system.*

The risk assessment results in a calculated risk of fatality from the ODH. Based upon the calculated fatality risk, an ODH hazard classification from ODH 0 to ODH 4 (see below) is assigned that is then used to determine required controls. The review must be completed and controls implemented before operations begin. (See Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Procedure.)

2.2 Hazard Classification

All work areas in which cryogens or other oxygen-displacing gases are stored and/or used will be classified as follows.

- ODH 0. Hazard classification for areas with an estimated ODH fatality risk of less than 10^{-7} per hour
- ODH 1. Hazard classification for areas with an estimated ODH fatality risk of 10^{-7} to 10^{-5} per hour
- ODH 2. Hazard classification for areas with an ODH fatality risk of 10^{-5} to 10^{-3} per hour
- ODH 3. Hazard classification for areas with an ODH fatality risk of 10^{-3} to 10^{-1} per hour

- ODH 4. Hazard classification for areas with an ODH fatality risk of greater than 10^{-1} per hour

2.3 Controls

When ODH fatality risk exceeds 10^{-7} per hour (ODH 0), controls must be used to reduce the risk to as low as feasible. The minimum control measures required for each ODH classification are shown in Table 1. Control practices appropriate to the degree of hazard will be required. These control practices fall into the following categories:

- Environmental and engineering controls
- Personnel controls
- Emergency controls

Control requirements tailored to the ODH hazard classification of the work area and any engineering controls specified by the pre-operating approval must be implemented before starting operations.

Table 1 Minimum Required Controls by ODH Classification

ODH Classification	0[4]	1	2[5]	3[5]	4[5]
Environmental and Engineering Controls					
1. Warning signs		X	X	X	X
2. Installed oxygen monitor		X	X	X	X
3. Ventilation		X	X	X	N/A
4. Relief valves and piping arrangements	As required by Chapter 14, "Pressure Systems", or the cryogenic and ODH safety program manager				
Personnel Controls					
Routine					
5. ESH Course 176, Oxygen Deficiency Safety Training (or area-specific training that includes applicable aspects of ESH Course 176, for example Course AD118) or ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training, if also working with cryogenic liquids or using systems/equipment that involve cryogenic liquids		X	X	X	X
6. Personal oxygen monitor			X	X	X
7. Multiple-person team (two-person rule)[1]			X	X	X
8. Unexposed observer (three-person rule)[2]				X	X
9. Self-contained breathing apparatus[3]					X
10. Medical approval as SCBA-qualified[3]					X
Non-routine / visitors					
11. ODH hazard awareness briefing for visitors		X	X	N/A	N/A
12. One-to-one escort by ODH trained personnel			X	N/A	N/A

1. More than one individual must be present at any one time in any work area classified as ODH 2 or higher, and all of these individuals must be appropriately qualified (two-person rule) and within line-of-sight communication with each other.

2. All personnel working in areas classified as ODH 3 or 4 must be in continuous communication with an observer who is not physically present in the work area. The purpose of the observer is to summon help in the case of an ODH emergency (three-person rule). Remote monitoring via surveillance camera and communication via walkie-talkies is acceptable.

3. SLAC at present has no self-contained breathing apparatus (SCBA) or SCBA-qualified personnel.

4. No placarding or training requirements are triggered by a classification of ODH 0.

5. SLAC currently only has ODH 0 and 1 areas. Post 2020, there may be limited maintenance activities related to the cryoplant that are assessed to be ODH 2 or 3 operations, with controls appropriate to those classes used. SLAC does not have any ODH 4 areas or operations.

2.3.1 Environmental and Engineering Controls

2.3.1.1 Signs

Appropriate ODH warning signs, specific to the ODH classification, must be posted at all entrances of ODH 1 or higher work areas. (See Figure 1 for examples.) (For sign templates, see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Hazard Classification Sign Templates.)

Figure 1 Sample ODH Signs

2.3.1.2 Oxygen Deficiency Monitors

A properly operating oxygen deficiency monitor (ODM) must be used by persons participating in operations areas categorized as ODH 1 or greater. An installed monitor is by itself sufficient for ODH 1 areas, while for ODH 2 and higher areas the use of a personal monitor by each individual is also required.

Installed ODMs

Monitors and alarm readouts should be placed so that they can be read and operated from outside of the potential ODH area. Oxygen deficiency monitor units must provide an oxygen readout and a local audible and visible alarm when the oxygen level falls below 19.5 percent. All installed ODMs must be registered with the cryogenic and ODH safety program manager. Oxygen deficiency monitors must be maintained according to the specifications of their manufacturer.

Figure 2 Non-personal oxygen deficiency monitor

Personal ODMs

Personal oxygen meters or portable oxygen deficiency meters may be required for certain tasks or situations as defined in the work planning and control documents. The units are available from many manufacturers. Prior to use the user must review and understand the manufacturer's owner's manual or be trained by a knowledgeable supervisor or ESH coordinator.

Warning Personal oxygen meters have expiration dates for their oxygen sensors and most require a periodic "bump test" in normal outdoor air to maintain their proper function. In all cases refer to the owner's manual for specific instructions. If in doubt, ask for help from your supervisor or ESH coordinator.

Warning Special note regarding the use of personal oxygen meters in a potentially helium-rich environment (such as the B905 Cryoplant or LCLS-II accelerator housing). Monitors intended for such spaces must be tested in a helium-enriched reduced-oxygen environment to establish their performance (once per model) as some models fail to alarm properly in the presence of helium. Do not depend on vendor literature because experience has shown that it is often unclear on this topic. Contact the cryogenic and ODH safety program manager for guidance.

2.3.1.3 Ventilation

The minimum ventilation rate during occupancy must be established during the ODH safety review.

2.3.1.4 Pressure Relief Devices and Vent Piping

Pressure relief devices e and vent piping are designed according to the following requirements and others as dictated by Chapter 14, "Pressure Systems":

- Generally, relief device that may vent a quantity of gas large enough to reduce the oxygen concentration to < 19.5 percent inside of the space due to normal operation, quench, operator error, freezing, or control system failure should be exhausted to a safe location outside of the building.
- Trapped volume reliefs that cannot vent a quantity of gas large enough to reduce the oxygen concentration to < 19.5 percent inside of the space may be vented into the building.
- In some cases, a supplemental relief device, such as a burst disc, may be permitted to vent into a building, irrespective of the volume of gas it can release. The risk assessment of the cryogenic system and space shall account for each failure mechanism and associated risk to determine the correct ODH classification.

2.3.1.5 Optional Controls for Consideration

Restrictive Flow Orifices

In certain situations, restrictive flow orifices in oxygen-displacing gas supply lines, solenoid valves in gas or cryogenic fluid delivery lines interfaced with the local ventilation supplies, and other engineered solutions are preferable to an oxygen deficiency monitor that reacts to an ODH situation.

A *restrictive flow orifice (RFO)* is a passive device that limits the uncontrolled flow from a compressed gas source. While not designed to be a modulator or control valve, an RFO will substantially reduce the flow rate under a specific set of pressure and temperature conditions for a given gas. An RFO has no moving parts and can be inserted into a plumbed compressed gas line outside of a laboratory to reduce the flow of oxygen-displacing gas into the room. RFOs can also be used with compressed gas cylinders. A good rule in properly sizing an RFO is to choose an RFO diameter that permits a flow rate two or three times above the flow rate desired in current applications to allow flexibility in future operations.

Flow Interlocks

Flow interlocks are used to either prevent entry or shut off gas or cryogen flow when undesired operating conditions exist. Examples include the following:

- HVAC interlocked with a (fail-closed) solenoid valve located in the supply line of oxygen-displacing gas or liquid cryogen. Once the volumetric flow rate of supplied air within the duct drops below a set point, a signal is sent from the differential pressure switch to a solenoid valve in the supply line to shut off the flow of gas or cryogenic liquid.
- A fixed oxygen deficiency monitor alarm interlocked in a feedback loop to the supply valve and shuts off the flow of gas in the system if the oxygen level in the room is below a set point.

Each cryogenic system is unique and the use of interlocks should be considered whenever feasible based on the inherent value of preventing accidents as opposed to mitigating their effects.

Controls for Stratification of Oxygen-displacing Gases

The physical properties of oxygen-displacing gases must be taken into consideration when designing appropriate hazard controls configurations. For example, if large volumes of helium are used as a cryogen in an accelerator tunnel then oxygen sensors need to be located where the gas would tend to accumulate during a release. Fixed oxygen monitors sensors should be located at ceiling height because helium is lighter than air.

Lintels and helium removal systems are engineering controls to be considered if large volumes of helium are used in underground tunnels. The lintels should be located to control helium from entering the exit paths, which allows sufficient time for staff to evacuate safely. (See Figure 3 below for an example.)

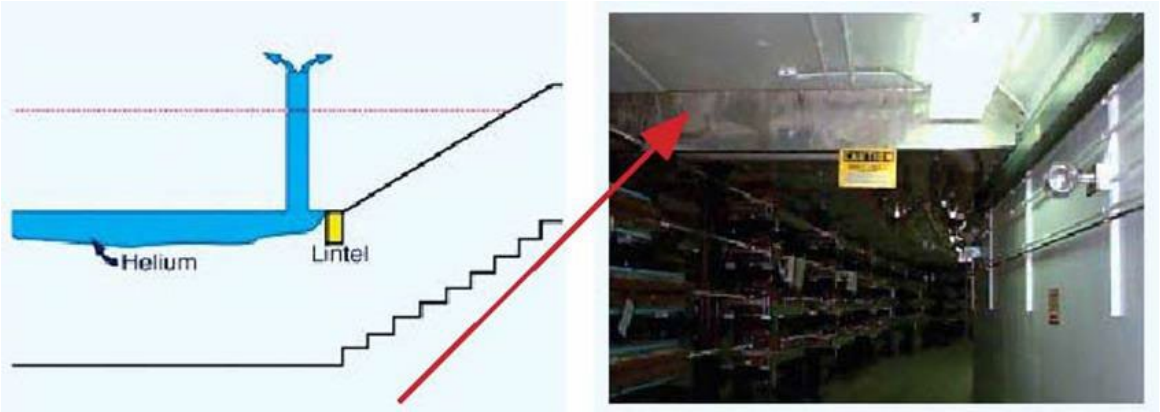

Figure 3 Lintel configuration at Thomas Jefferson National Laboratory

Service buildings located above such a tunnel that have ceiling to floor penetrations connecting an accelerator tunnel to service buildings require special attention to prevent an ODH situation in the above-ground buildings. Such penetrations must be identified and plugged to keep helium out of these buildings. Temporary changes in the ODH classification created by maintenance or shutdown work that displaces these plugs requires the reposting of the service buildings to a higher ODH classification during the work.

2.3.2 Personnel Controls

The following practices are mandatory under the conditions indicated in Table 2 above:

1. Individuals who work in ODH 1 or higher areas must first complete ESH Course 176, Oxygen Deficiency Safety Training (ESH Course 176) (or area-specific training that includes applicable aspects of ESH Course 176, for example Course AD118) or ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175), if they are also working directly with cryogenic liquids or using systems/equipment that involve cryogenic liquids.
2. Individuals working in any work area classified as ODH 2 or higher must be equipped with a personal oxygen monitor. Area oxygen monitors are sufficient in and of themselves for work areas classified as ODH 1.
3. More than one individual must be present at any one time in any work area classified as ODH 2, and all of these individuals must be appropriately qualified (*two-person rule*) and within line-of-sight communication with each other.
4. All personnel working in areas classified as ODH 3 or 4 must be in continuous communication with an observer who is not physically present in the work area. The purpose of the observer is to summon help in the case of an ODH emergency (*three-person rule*). Remote monitoring via surveillance camera and communication via walkie-talkies is acceptable.
5. Individuals must wear a *self-contained breathing apparatus (SCBA)* during any operation in an ODH 4 area. (SLAC does not have any areas classified as ODH 4.)

6. Before entering any ODH 1 or higher area, an untrained visitor must be given an ODH hazard awareness briefing by the responsible person of the classified area.
7. Following the hazard awareness briefing, untrained visitors may enter ODH 1 areas without an escort. However, all entries of untrained visitors to ODH 2 areas will require a one-on-one escort within defined boundaries by trained personnel if permitted by approved ODH risk assessment. All entries of untrained visitors to ODH 3 and higher areas are forbidden.

2.3.3 Emergency Controls

2.3.3.1 Response to an Oxygen Deficiency Monitor Alarm

If an oxygen deficiency monitor alarm sounds

1. Immediately evacuate the ODH area
2. Do not re-enter the area until
   - The reason for the ODH alarm has been determined and corrected and
   - The oxygen deficiency monitor reads atmospheric oxygen greater than 19.5 percent.
3. Never attempt to reenter an ODH area while an alarm is sounding, even to rescue someone. All rescues must be carried out by properly equipped and trained emergency responders. (These would be non-SLAC, professional emergency responders from the local fire department.)
4. In all cases, never enter a space while the oxygen deficiency monitor alarm is indicating a hazard or malfunction condition. Refer to local ODM placard for definition of ODM status indicators and respond accordingly.

3 Forms

The following forms and systems are required by these requirements:

- None

The following are recommended templates. Equivalent forms may be used:

- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Hazard Classification Sign Templates (SLAC-I-730-0A06S-003). Recommended templates for creating signs

4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- None

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 36, "Cryogenic and Oxygen Deficiency Hazard Safety"
  - Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Procedure (SLAC-I-730-0A06C-001)
  - Cryogenic and Oxygen Deficiency Hazard Safety: Cryogenic Requirements (SLAC-I-730-0A06S-008)
  - Cryogenic and Oxygen Deficiency Hazard Safety Program Site (SharePoint)
- Chapter 14, "Pressure Systems"

Other SLAC Documents

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)
- ESH Course 176, Oxygen Deficiency Safety Training (ESH Course 176)
- Course AD118, Cryogenic Accelerator Area Access Training (Course AD118)

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

ODH Hazard Classification Sign Templates

Product ID: 416 | Revision ID: 2264 | Date Published: 29 May 2020 | Date Effective: 29 May 2020
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsTemplateSigns.pdf

These sign templates meet California Department of Occupational Safety and Health (Cal/OSHA) requirements (8 CCR 3340). For additional information on sign requirements, see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements (SLAC-I-730-0A06S-002).

CAUTION

OXYGEN DEFICIENCY HAZARD

1

PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:

- OXYGEN DEFICIENCY HAZARD TRAINING

CAUTION

OXYGEN DEFICIENCY HAZARD

2

PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:

- PERSONAL OXYGEN MONITOR
- OXYGEN DEFICIENCY HAZARD TRAINING

DANGER

OXYGEN DEFICIENCY HAZARD

3

PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:

- MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION ($2^{nd}/3^{rd}$ person rules)
- PERSONAL OXYGEN MONITOR
- OXYGEN DEFICIENCY HAZARD TRAINING

DANGER

OXYGEN DEFICIENCY HAZARD

4

PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:

- **30-MINUTE SELF-CONTAINED BREATHING APPARATUS (SCBA)**
- **MEDICAL CLEARANCE FOR ODH WORK**
- **MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION (2nd/3rd person rules)**
- **PERSONAL OXYGEN MONITOR**
- **OXYGEN DEFICIENCY HAZARD TRAINING**

ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

ODH Safety Review Procedure

Product ID: 415 | Revision ID: 2240 | Date published: 29 May 2020 | Date effective: 29 May 2020
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsProcedODHReview.pdf

1 Purpose

The purpose of this procedure is to protect workers from the *oxygen deficiency hazard (ODH)* associated with working with oxygen-displacing gases. It covers review and approval of the introduction and use of oxygen-displacing gases, including cryogens, in work areas. It applies to responsible persons, ESH coordinators, and the cryogenic and oxygen deficiency hazard safety program manager.

1.1 Exemption

Where the work area has at least one air change per hour of fresh air ventilation and an open floor plan, there is a de minimis exemption from all requirements related to hazard classification and posting for uses involving

- A lecture bottle of compressed inert gas per 1,000 cubic feet of open lab space
- A standard K-bottle (200–300 cubic feet) of compressed inert gas per 3,000 cubic feet of open lab space
- Two liters of liquid nitrogen per 1,000 cubic feet of open lab space

Note *Multiple, individual, bottles listed above are acceptable providing they are not connected together in a common system.*

Line management must still ensure that any exempted cryogen quantity is used prudently with appropriate personal protective equipment.

2 Procedure

Before introducing oxygen-displacing gases, including cryogens, into a work area or changing the existing use of such gases (for example, by adding or modifying systems, changing operations, or changing the quantity of gases used), a safety review must be performed by the responsible person, reviewed by his or her ESH coordinator, and approved by the cryogenic and oxygen deficiency hazard safety program manager.

The initial review consists of calculating the oxygen level after a complete release of all cryogens and oxygen-displacing gases (at room temperature and pressure) into the room. If the resulting calculated oxygen level is less than 18 percent, a more detailed risk assessment is required (see Section 2.2).

2.1 Safety Review

Step	Person	Action
1.	Responsible person	Completes an ODH Safety Review Form ▪ Describes location, gas to be used, source, and delivery system ▪ Determines volume (or flow rate) of gas and of room ▪ Calculates the oxygen level after a complete release of all cryogens and oxygen-displacing gases (at room temperature and pressure) into the room
2.	Responsible person	If the resulting calculated oxygen level is ▪ 18 percent or more, goes to Step 5 ▪ Less than 18 percent, goes to Step 3 *Note: if an oxygen-displacing gas is plumbed-in from outside the work space, then engineered controls such as restrictive flow orifices and/or solenoid valve/HVAC differential pressure circuits may be mandated irrespective of oxygen level calculated with ventilation.*
3.	Responsible person	Lists all existing and planned controls
4.	Responsible person	Conducts a more detailed risk assessment, using the recommend method or an acceptable alternative (see Section 2.2)
5.	Responsible person	Submits form and additional information as needed to ESH coordinator
6.	ESH coordinator	Reviews form and additional information
7.	Responsible person	Submits form and additional information as needed to program manager
8.	Cryogenic and oxygen deficiency hazard safety program manager	Reviews and approves: ▪ Assigns ODH hazard classification to area (see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements) ▪ Adds additional engineering controls, if needed
9.	Responsible person	Implements control requirements tailored to the ODH hazard classification and any engineering controls specified by the pre-operating approval before starting operations.

2.2 Detailed Risk Assessment Method

If a more detailed risk assessment is required after the initial safety review, then the following method, based on that used at Fermilab, is the default to be employed. However, professional judgment may be substituted for the method described below to tailor a more appropriate approach provided that the alternative approach, and the rationale for using it, is documented in the assessment and approved by the program manager.

2.2.1 Estimation of ODH Fatality Rate

The goal of an ODH risk assessment is to estimate the rate increase in the occurrence of fatalities as a result of exposure to an oxygen-reduced atmosphere.

Since the level of risk is directly related to the nature of the operation, the excess fatality rate must be determined on an operation-by-operation basis. For a given operation, several events may cause an oxygen deficiency. Each event has an expected rate of occurrence and each occurrence has an expected probability of fatality. The ODH fatality rate is defined as

$$\phi = \sum_{i=1}^{n} P_i F_i$$

where

ϕ = the ODH fatality rate (per hour)

P_i = the expected rate of the i type of event (per hour)

F_i = the fatality factor for the i type event

The summation must include all types of events that may cause an ODH and result in a fatality.

The risk assessment must also consider the benefit of existing and planned active control systems such as forced ventilation or any supply shut-off valves that are automatically activated by area monitor readings or system failure indicators. These systems must be designed to be activated before the area drops below 18 percent oxygen concentration. Although such systems or any forced ventilation system reduces overall risk, they are also subject to failure (for example, a fan triggered by a low oxygen monitor reading may not function properly because of a power failure, inadequate maintenance, or the monitor's calibration drifting) and this must be factored into the risk assessment. This is accomplished by summing the expected failure rate of all systems and the corresponding fatality factors for when those systems have failed.

2.2.2 Estimation of the Event Rate, P_i

When possible, the value of P_i should be based on operating experience at SLAC; otherwise, data from similar systems elsewhere or other relevant values may be used. (*Fermilab Environment, Safety, and Health Manual*, Chapter 4240, "Oxygen Deficiency Hazards (ODH)" [FESHM 4240] is one source.)

2.2.3 Estimation of the Fatality Factor, F_i

The value of F_i is the probability that a person will die if the i event occurs. This value depends on the oxygen concentration, the duration of exposure, and the difficulty of escape. For convenience of calculation, a relationship between the value of F_i and the lowest attainable oxygen concentration is displayed in Figure 1. The lowest concentration is used rather than an average as the minimum value is conservative and not enough is understood to allow the definition of an averaging period. If the lowest oxygen concentration is greater than 18 percent, then the value of F_i is zero. In other words, all exposures to oxygen levels greater than 18 percent do not contribute to the fatality rate. The value of F_i is designed to reflect this threshold of oxygen concentration. (See FESHM 4240 for methods for calculating oxygen concentration.)

If the lowest attainable oxygen concentration is 18 percent, then the value of F_i is 10^{-7}. This value would cause the ODH fatality rate, ϕ, to be 10^{-7} per hour if the expected occurrence rate of the event was one per hour. As oxygen concentrations decrease, the value of F_i should increase until the probability of a fatality

occurring is 1. That fatality point was defined as an oxygen concentration of 8.8 percent, which is the point at which one minute of consciousness is expected.

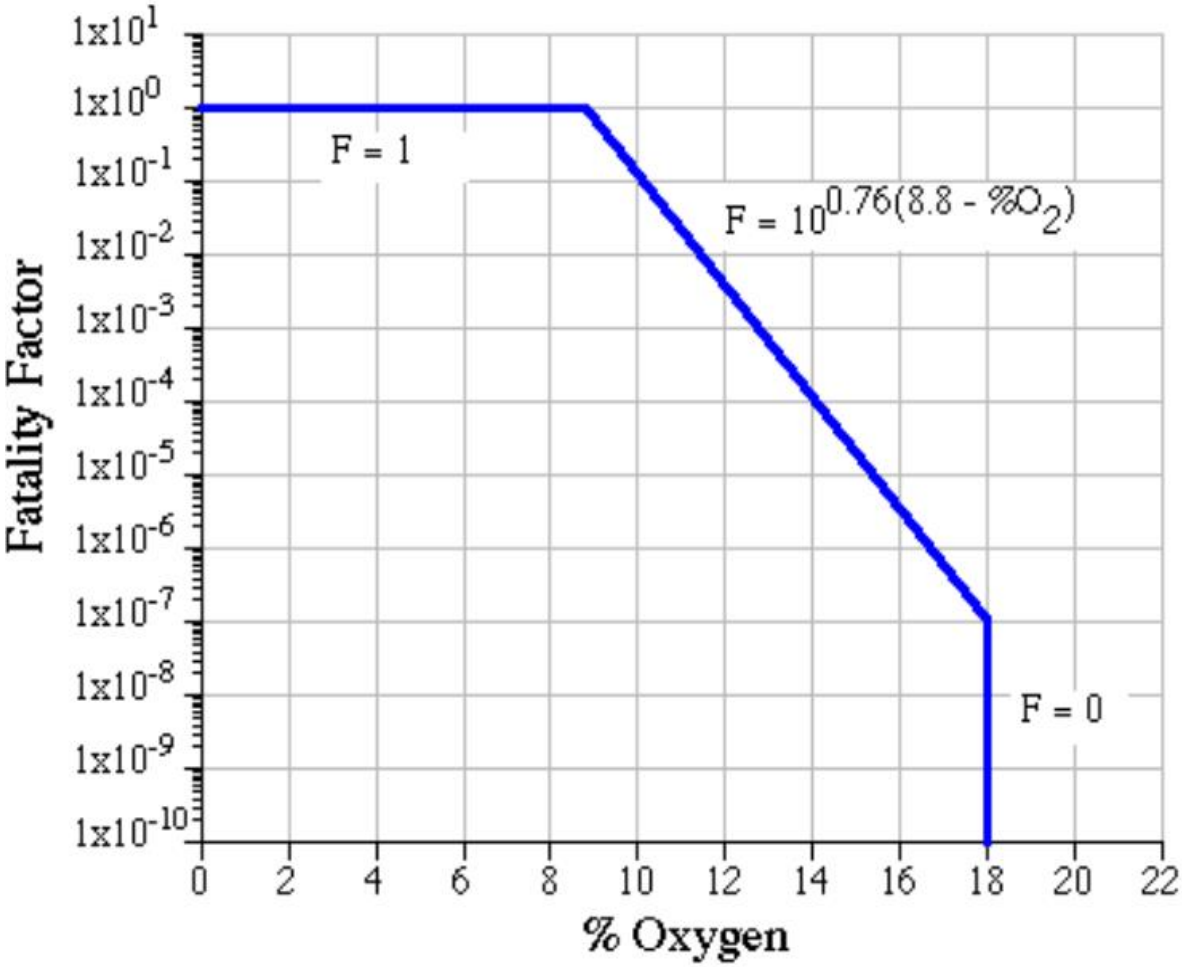

Figure 1 Fatality factor F_i versus the lowest attainable oxygen concentration that can result from a given event (derived from *Fermilab Environment, Safety, and Health Manual*, Chapter 4240, "Oxygen Deficiency Hazards [ODH]" [FESHM 4240])

2.2.4 ODH Fatality Rate and ODH Classifications

Once the ODH fatality rate, ϕ, has been determined, the operation can then be assigned an ODH classification according to the criteria outlined in Table 1.

Table 1 ODH Fatality Rates and Classifications

ODH Fatality Rate, ϕ, per hour	ODH Hazard Classification
$< 10^{-7}$	0
$> 10^{-7}$ but $< 10^{-5}$	1
$> 10^{-5}$ but $< 10^{-3}$	2
$> 10^{-3}$ but $< 10^{-1}$	3
$> 10^{-1}$	4

3 Forms

The following forms are required by this procedure:

- Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Form (SLAC-I-730-0A06J-001)

4 Recordkeeping

The following recordkeeping requirements apply for this procedure:

- The completed ODH safety review form is to be maintained by the program manager and a copy kept by the responsible person

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 36, "Cryogenic and Oxygen Deficiency Hazard Safety"
  - Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements (SLAC-I-730-0A06S-002)

Other SLAC Documents

- Cryogenic and Oxygen Deficiency Hazard Safety Program Site (SharePoint)

Other Documents

- Fermi National Accelerator Laboratory. *Fermilab Environment, Safety, and Health Manual*, Chapter 4240, "Oxygen Deficiency Hazards (ODH)" (FESHM 4240)

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

ODH Safety Review Form

Product ID: 669 | Revision ID: 2241 | Date Published: 29 May 2020 | Date Effective: 29 May 2020
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/cryogenicsFormODHReview.pdf | docx

This form is used to document the safety review required before introducing oxygen-displacing gases, including cryogens, into a work area or changing the existing use of such gases (for example, by adding or modifying systems, changing operations, or changing the quantity of gases used). The form is to be completed by the responsible person for the activity, reviewed by his or her ESH coordinator, and approved by the cryogenic and oxygen deficiency hazard (ODH) safety program manager. The completed form is to be maintained by the program manager and a copy kept by the responsible person (see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Safety Review Procedure [SLAC-I-730-0A06C-001]).

1 General Information

Preparer		Location (bldg/rm/area)	
Responsible person		Directorate	
Description of system			
Gas to be introduced		Type of hazard	
Gas source		Additional comments *(see back for add. space)*	
Attachments	☐ Room floor plan showing location of ODH (required)	☐ Risk assessment (if required, see below)	

2 Preliminary ODH Calculation

If source is INSIDE proposed ODH area (e.g., dewar, tank)		If source is OUTSIDE proposed ODH area (e.g., from a compressor, pump)	
Total volume of room [a], V_R(ft³) =		Total volume of room, V_R(ft³) =	
Volume of gas at room temperature and pressure, V_G(ft³) =		Volume of flow rate of gas into room at room temperature and pressure, Q(ft³/h) =	
Calculate oxygen level, $\frac{21\,(V_R - V_G)}{V_R}$ =		Calculate oxygen level [b], $\frac{21\,(V_R - Q)}{V_R}$ =	
		Will ventilation be maintained during building power failure?[c]	☐ Yes ☐ No

a Room volume is calculated as length x width x ceiling height. Do not reduce room volume to account for room contents (cabinetry, machinery).

b This calculation assumes one air change per hour into the space.

c If there is no positive ventilation during a power failure, further evaluation is required to show that the area has sufficient passive ventilation or other mitigations are in place to assign an ODH 0 classification to the space.

If resulting oxygen level is ≥ 19.5% normal ops or ≥ 18% during system upset	Sign form and submit for approval
If resulting oxygen level is < 19.5% normal ops or < 18% during system upset	Conduct a risk assessment (see ODH Safety Review Procedure, Section 2.2) and complete Part 4, "Additional Information", then sign form and submit for approval

3 Approvals

Person	Name	Signature	Date
Responsible person			
ESH coordinator			
Cryogenic and ODH safety program manager			
ODH classification			
Comments			

4 Additional Information for Risk Assessment

To be completed by responsible person. List all that apply and be as specific as possible; indicate whether controls are existing or planned.	
Engineering Controls *Example:* *Mechanical ventilation* *Fume hoods* *Valves* *Critical orifices*	
Administrative Controls *Example:* *Training required* *Standard protective measures* *Work control documents*	
Attachments *List all that apply:* *Communications* *Risk assessment* *Hazard analysis*	

5 Additional Comments

General Information	
Approval	
Risk Assessment	