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Oxygen Deficiency Hazard

Safety Booklet

Preamble to ODH

Many work areas store or use compressed gasses, liquefied gasses, and volatile liquids. The uncontrolled release of these gasses and liquids could lead to a reduction in the amount of available oxygen in the work area. There are serious health effects associated with exposure to decreased oxygen levels. If oxygen levels drop significantly, unconsciousness or even death may occur.

Since the liquid to gas expansion ratio of nitrogen is 1:694 at 20 °C, a tremendous amount of force can be generated if liquid nitrogen is rapidly vaporized. In an incident in 2006 at Texas A&M University, the pressure-relief devices of a tank of liquid nitrogen were malfunctioning and later sealed. As a result of the subsequent pressure build-up, the tank failed catastrophically and exploded. The force of the explosion was sufficient to propel the tank through the ceiling immediately above it.[8]

Because of its extremely low temperature, careless handling of liquid nitrogen may result in cold burns.

As liquid nitrogen evaporates it will reduce the oxygen concentration in the air and might act as an asphyxiant, especially in confined spaces. Nitrogen is odourless, colourless and tasteless, and may produce asphyxia without any sensation or prior warning.[9] A laboratory assistant died in Scotland in 1999, apparently from asphyxiation caused by liquid nitrogen spilled in a basement storage room.[10]

This booklet provides information on how to recognize and protect yourself from cryogenic hazards. It also explains control measures used to reduce these hazards. After reading this booklet, you should be able to work safely in Oxygen Deficiency Hazard (ODH) 0 and ODH 1 areas.

Zone 0

Zone 0 is an area in which an explosive atmosphere is present continuously for long periods of time or will frequently occur.

Zone 1

Zone 1 is an area in which an explosive atmosphere is likely to occur occasionally in normal operation. It may exist because of repair, maintenance operations, or leakage.

Zone 2

Zone 2 is a place in which an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only. These areas only become hazardous in case of an accident or some unusual operating condition.

Worker Requirements for Entry into ODH 0 and 1 Areas

Any personnel who need to enter ODH 0 and 1 areas without a qualified escort should either attend ODH training or pass an ODH proficiency test.

Visitor Requirements

Visitors who have not had ODH training may enter an ODH 0 or 1 area ONLY after the ODH hazard has been explained to them or accompanied by an ODH qualified escort.

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Hazards of Cryogens & Mitigation

The principle hazards of cryogens are (in increasing order):

1 Risk of explosion: exposure to flying debris caused by over-pressurisation of a cryogenic device.
2 Risk of cryogenic burns to skin and eyes while dispensing cryogens.
3 Oxygen Deficiency Hazard (ODH).

Mitigation of Cryogenic Hazards

1. Risk of explosion:

In order to mitigate the risk of explosion, careful engineering design is required. Critical considerations include the selection of suitable materials for cryogenic fabrications, and the installation of appropriate pressure relief devices in any volume that could become isolated in the system (for example by valve closures).

The design of experimental apparatus may include cryogenic devices. Examples include but are not limited to connection to dewars, feeds of cryogenic fluids to vacuum vessels. **Any such design requires the review and approval of a cryogenic expert**.

2. Personal Protective Equipment (PPE):

For dispensing cryogens required personal protective equipment required includes: Eye protection: safety glasses and face shield; goggles for amounts under 1 litre. Hand protection: loose-fitting insulating cryogenic use gloves. Body protection: long pants, no open toed shoes.

3. Oxygen Deficiency Hazards (ODH):

The appropriate mitigation of the oxygen deficiency hazard associated with cryogen transport and use is achieved by a combination of engineering, administrative, and personal protective equipment controls. The discussion of the use of cryogens and ODH Controls constitutes the remainder of this booklet.

NORMAL vs. OXYGEN DEFICIENT ATMOSPHERE

Normal Atmosphere

GAS	VOLUME
nitrogen	78%
oxygen	21%
argon/other	1%
TOTAL	**100%**

19.5% Oxygen atmosphere is considered to be hazardous Oxygen Deficient Atmosphere.

Health Effects of Reduced Oxygen

Normal air is approximately 21% oxygen and 78% nitrogen. The remaining 1% is mostly argon. Health effects begin at an oxygen concentration of 17%. Oxygen monitors are set to alarm at 19.5%. This advance warning should give ample time to escape the hazard area. The early health effects are difficult to detect so the oxygen monitors are relied upon to give early warning:

Percent Oxygen	Health Effects
17	Night vision reduced Increased breathing volume Accelerated heartbeat
16	Dizziness Reaction time for new tasks is doubled
15	Poor judgment Poor coordination Abnormal fatigue upon exertion Loss of muscle control
10-12	Very faulty judgment Very poor muscular coordination Loss of consciousness
8-10	Nausea Vomiting Coma
< 8	Permanent brain damage
< 6	Spasmodic breathing Convulsive movements Death in 5-8 minutes

NOTE: Individuals with lung disorders or other health problems may experience health effects sooner than healthy individuals.

CAUTION: Oxygen levels of less than 12% can cause unconsciousness suddenly and without warning. In such a low oxygen concentration the lungs see the environment as oxygen poor and will actually give up oxygen rather than take it in. Do not assume that if you are in an oxygen deficient atmosphere that you will be all right if you take a deep breath and hold it.

Oxygen Deficiency: The Cryogen Connection

Oxygen deficiency hazards are associated with standard industrial work, including the use of inert gases and refrigerants. However, the most significant oxygen deficiency hazard is associated with the use of the cryogen's helium and nitrogen. Even temporary enclosures (i.e. temporary cleanroom) that have inert gas connections can become an ODH area. A hazard assessment must be conducted for such areas.

GAS	TEMPERATURE	LIGHTER OR HEAVIER THAN AIR	MONITOR PLACEMENT
helium	any	lighter	ceiling
nitrogen	cold warm	heavier lighter	floor ceiling
argon	any	heavier	floor
hydrogen	any	lighter	***

Properties of Cryogens

The term cryogenic is applied to very cold temperatures. Cryogenic fluids are extremely cold when in a liquid state. At normal temperatures they are gases. Gases that can exist as cryogens are: helium, nitrogen, argon, and hydrogen. The temperature of the liquid nitrogen is about -200 ^{o}C.

All cryogens expand when evaporating from liquid to gas. The expansion ratio can be estimated at 1000:1. This means that when a litre of liquid cryogen evaporates 1,000 litres of gas will form. When there is a release of liquid the liquid will evaporate rapidly and the percentage of other gases, most notably oxygen, will decrease in the area of the release. This high expansion ratio is the cause of the oxygen deficiency hazard.

Cryogens expand greatly. In the event of a release they can displace breathing air. Leaks in small spaces can also reduce oxygen levels over time.

NOTE: The cryogens used are odourless and tasteless. Because we cannot sense them, their presence is monitored by the use of oxygen monitors. When a cryogen is released it will displace air as it rapidly evaporates and expands. The oxygen monitors will normally alarm when oxygen concentration drops to 19.5%

NOTE: Wear loose fitting non-absorbent gloves so that in the event that the gloves are wetted with liquid they can be easily removed. Whether cryogen gases are lighter or heavier than air depends on gas density. This is important in determining where a released cryogen will accumulate. For example: monitors are at floor level to detect cryogenic plumes heavier than air and near the ceiling to detect cryogenic plumes lighter than air.

***Hydrogen is a flammable cryogen. The flammability hazard is more important than the oxygen deficiency hazard and becomes significant at low concentrations, so flammable gas detectors would be installed at ceiling level instead of oxygen monitors.

Oxygen Deficiency Hazard Risk Assessment - Work Area Classification

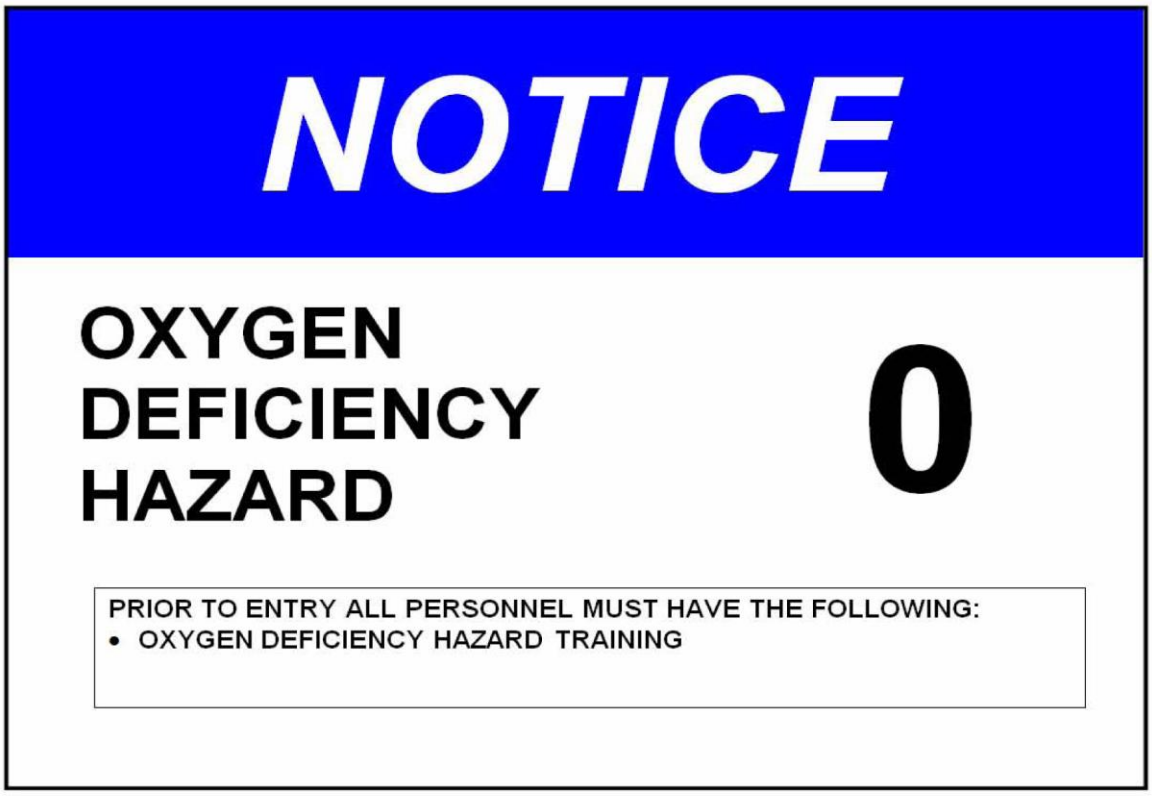
The goal of ODH risk assessment is to estimate the increase in the rate at which fatalities will occur in a given area. Controls are then designed to prevent those fatalities. The level of risk is based on the type of work that will be done in a given area. The level of risk is also based on expected component failure rates for the cryogenic or other equipment that presents an oxygen deficiency hazard.

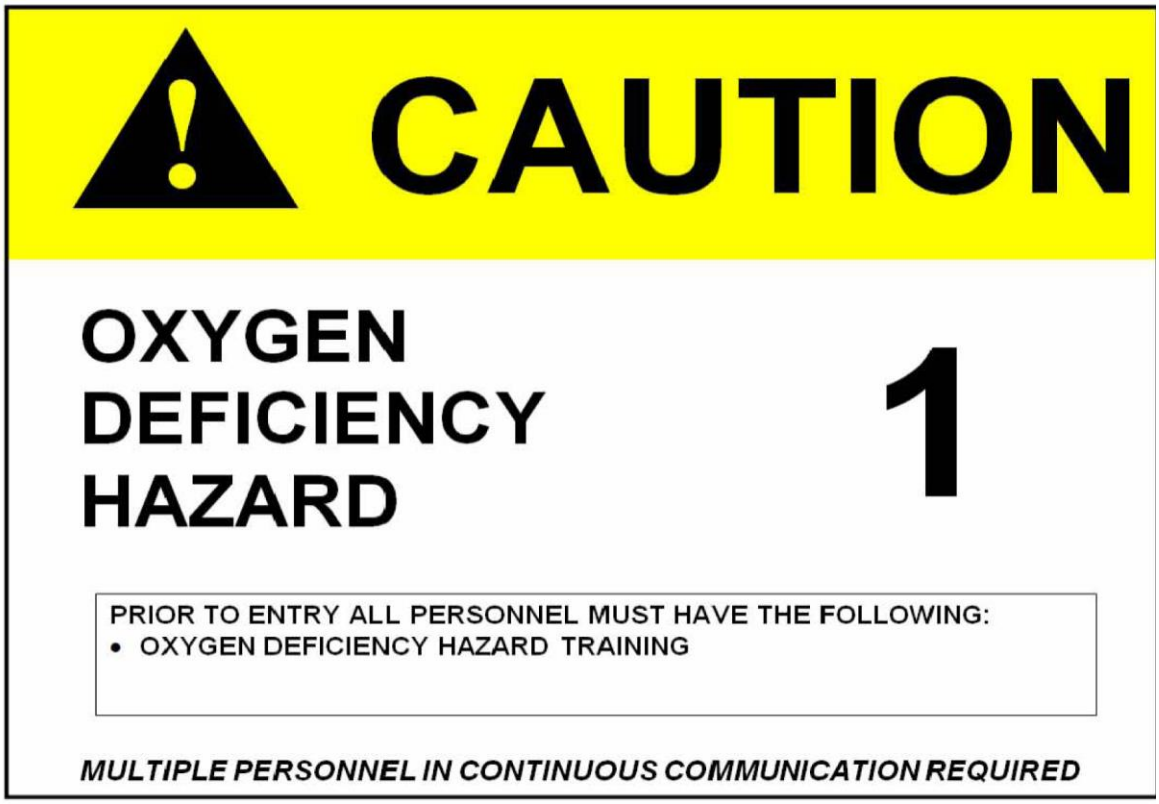
There are 5 ODH hazard levels. They are noted ODH 0 through 4. The hazard increases as the number increases. Work areas are classified assuming that there are NO CONTROLS, not even training. Dividing lines are based on the statistical probability of one worker fatality occurring in a specified number of worker-hours:

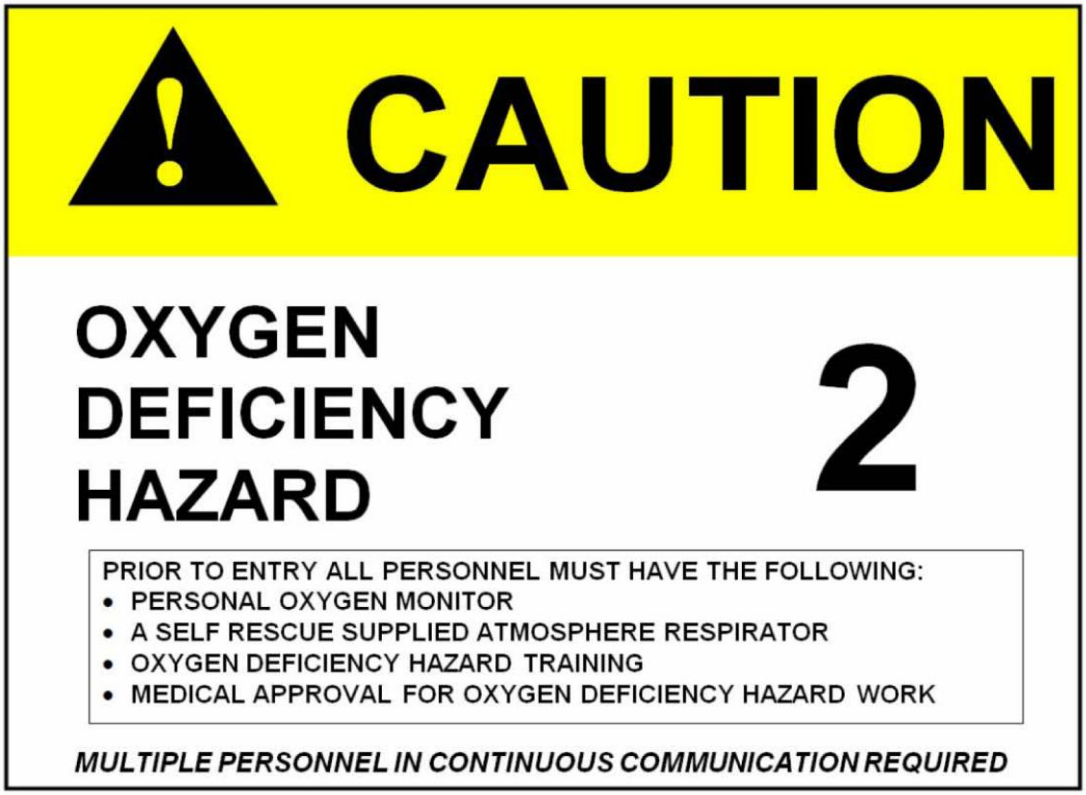
*10 million hours equates to over 5,000 worker years. ODH classification is not necessary in work areas where compressed gases, liquefied gases, and volatile liquids are not stored or used.

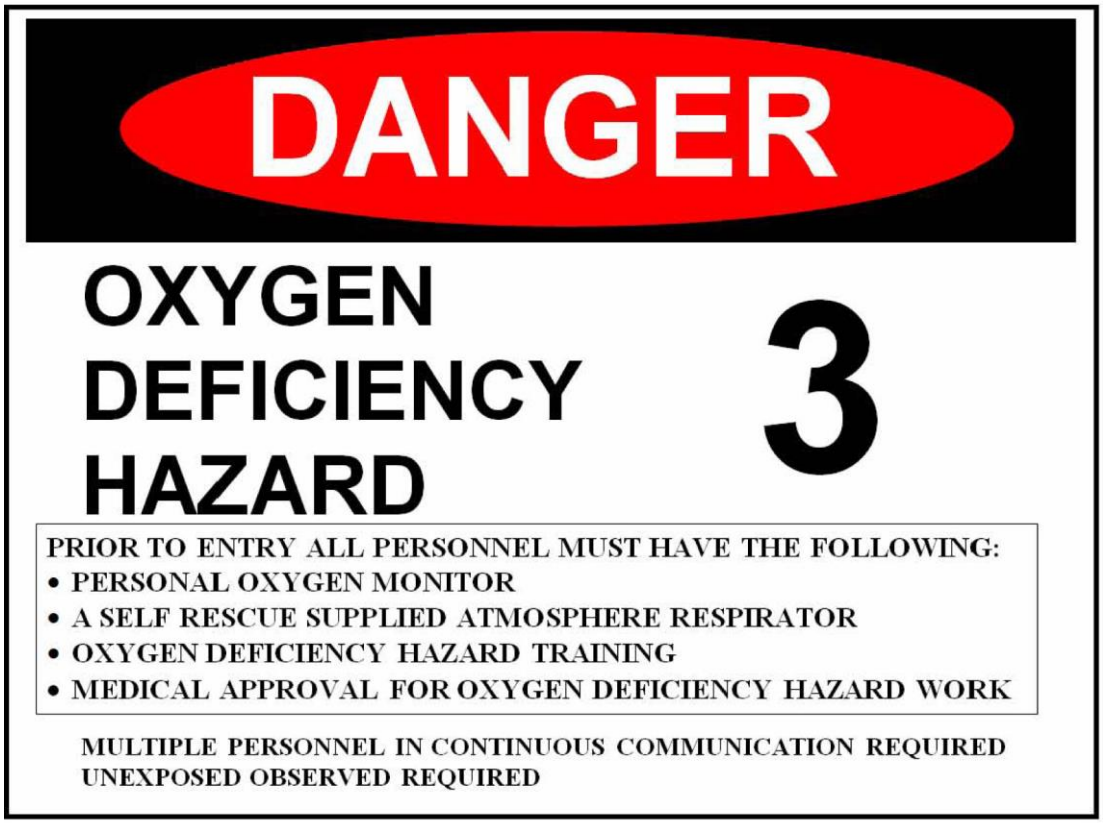
ODH Class	**# of worker-hours before a fatality is expected**
0	Greater than 10 million *
1	from 100,000 hours to 10 million hours
2	from 1,000 to 100,000 hours
3	from 10 to 1,000 hours
4	less than 10 hours

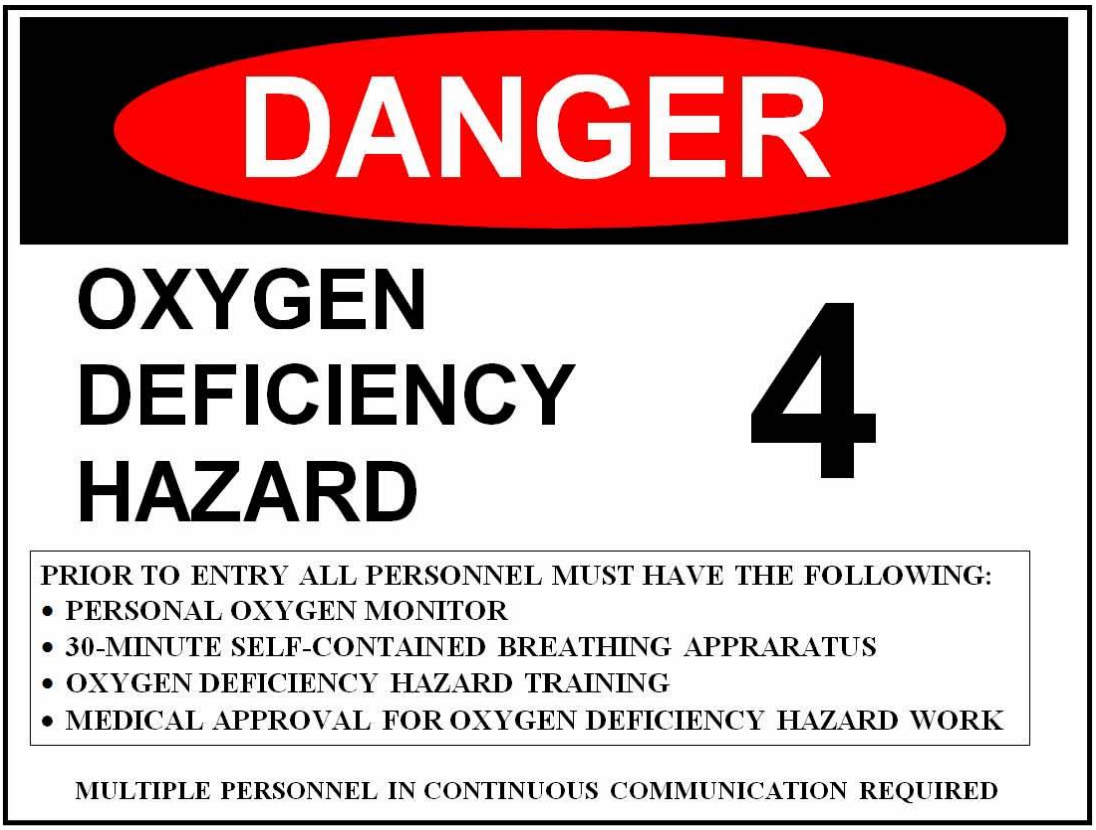
LOOK FOR AND OBEY REQUIREMENTS ON SIGNS
POSTED AT ODH WORK AREAS!

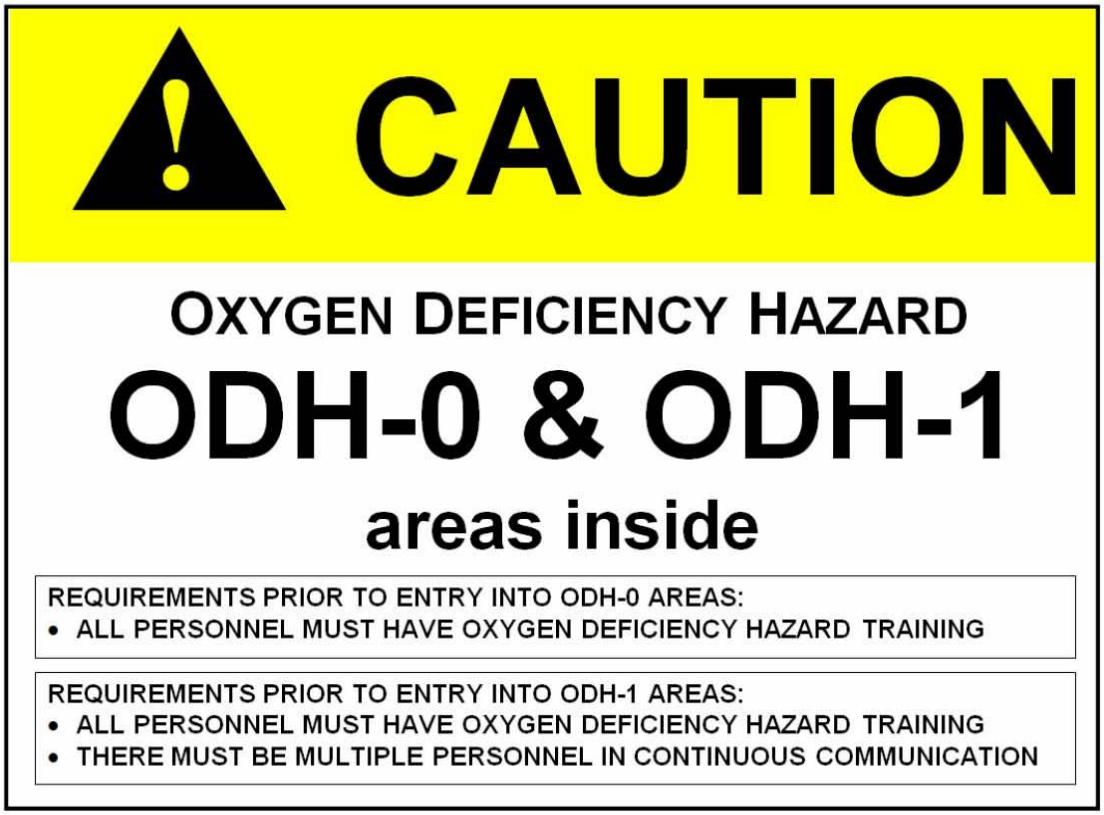





CAUTION
OXYGEN DEFICIENCY HAZARD
2
PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:
• PERSONAL OXYGEN MONITOR
• A SELF RESCUE SUPPLIED ATMOSPHERE RESPIRATOR
• OXYGEN DEFICIENCY HAZARD TRAINING
• MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK
MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION REQUIRED


DANGER
OXYGEN DEFICIENCY HAZARD
3
PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:
• PERSONAL OXYGEN MONITOR
• A SELF RESCUE SUPPLIED ATMOSPHERE RESPIRATOR
• OXYGEN DEFICIENCY HAZARD TRAINING
• MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK
MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION REQUIRED
UNEXPOSED OBSERVED REQUIRED

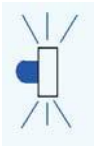

DANGER
OXYGEN DEFICIENCY HAZARD
4
PRIOR TO ENTRY ALL PERSONNEL MUST HAVE THE FOLLOWING:
• PERSONAL OXYGEN MONITOR
• 30-MINUTE SELF-CONTAINED BREATHING APPRARATUS
• OXYGEN DEFICIENCY HAZARD TRAINING
• MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK
MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION REQUIRED


CAUTION
OXYGEN DEFICIENCY HAZARD
ODH-0 & ODH-1
areas inside
REQUIREMENTS PRIOR TO ENTRY INTO ODH-0 AREAS:
• ALL PERSONNEL MUST HAVE OXYGEN DEFICIENCY HAZARD TRAINING
REQUIREMENTS PRIOR TO ENTRY INTO ODH-1 AREAS:
• ALL PERSONNEL MUST HAVE OXYGEN DEFICIENCY HAZARD TRAINING
• THERE MUST BE MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION

ODH Hazard Avoidance

Follow all instructions on posted ODH signs:

ODH 0/1 workers: Stay out of ODH 2, 3, 4 work areas. NO EXCEPTIONS! Observe the buddy rule for ODH 1 or greater.



INDICATIONS OF AN ODH INCIDENT

When you hear an alarm EVACUATE the work areas immediately. Red flashing light and/or buzzer means ODH alarm.

Pay attention to local indications such as the sound of rushing gas, which indicates a leak.

In case of an uncontrolled release of cryogens NEVER walk into a vapor cloud. Why? Extremely cold vapours, if inhaled, will damage lung tissue. Visibility will also be limited, increasing the chance of fall. Take an alternate exit.

ODH Assessments
An ODH assessment must be conducted whenever an ODH area is established or modified, and whenever cryogens are used, stored or dispensed. Contact EHS staff for assistance

ODH Control Measures
Once an ODH area has been identified, specific control measures must be followed to enter that area. These controls are designed to make the risks of ODH 2, 3, and 4 areas comparable to the risk of an ODH 0 area.

These are three types of controls:

1. **Engineering controls consist of:**

- Fixed oxygen monitors in designated ODH 1-4 areas
- Complete filling and sealing of all penetrations leading from storage or lab area.
- Helium removal systems in the storage or lab area.

Both fixed and portable oxygen monitors will alarm at 19.5% oxygen.

The ODH alarm indicator is a flashing red light and/or a high-pitched buzzer.

2. **Administrative control:**

- ODH signs.
- ODH training.
- Buddy Rule: In order to enter a work area, there must be at least 2 workers who stay together and in constant communication.

3. **Personal protective equipment and personal alarm devices are required for work in areas classified ODH 2 or greater. Personal protective equipment includes:**

- Personal oxygen monitors.
- 5-minute supplied air escape packs.
- Self-contained breathing apparatus (SCBA)

All personnel entering an ODH 2 or 3 areas are required to carry a personal oxygen monitor and a five-minute supplied air escape pack.

Emergency Escape Packs

For ODH 2 and 3 areas, each person is required to carry their own five-minute escape pack. The MSA pack supplies five minutes of air. This section outlines the proper procedures for checking, activating, and donning the pack.

General Information

The cylinder contains a **five**-minute supply of compressed air.

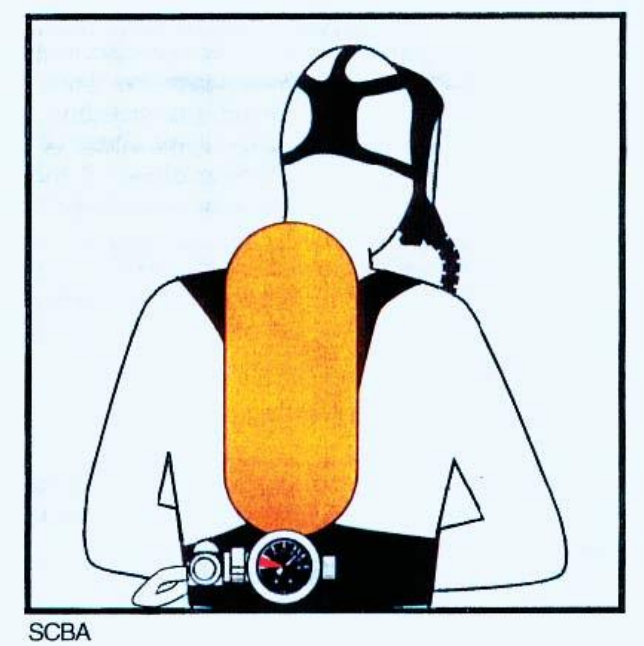
Note: The escape pack may be carried into the ODH area with a personal oxygen monitor as part of a written standard operating procedure for response to ODH alarms. However, once it is donned, the only allowable option is immediate evacuation. The escape pack is to be used for ESCAPE ONLY.

Self-Contained Breathing Apparatus (SCBA)

The SCBA is used only for planned work and emergency response.

Planned work - The SCBA is to be used only for entry into ODH 4 areas. The SCBA provides an air supply that lasts approximately 30 minutes.

Emergency Response - SCBA's are used for both rescue and for entry into hazardous atmospheres.



SCBA

KNOW THE REQUIRED CONTROLS FOR ENTRY INTO ODH 0 THROUGH ODH 4 AREAS

They are outlined in the following table. If at any time you are unsure of the classification of your work area, contact your supervisor and make sure you determine the classification before you enter the area and begin work.

ODH Control Measures Hazard Class

Engineering Controls	**0**	**1**	**2**	**3**	**4**
Ventilation - One air change per hour		X	X	X	X
Fixed oxygen monitor		X	X	X	X
Administrative Controls					
ODH Signs	X	X	X	X	X
ODH Training	X	X	X	X	X
Buddy Rule: In order to enter the work area there must be at least two workers who stay together. This is referred to as multiple personnel in continuous communication.		X	X		X
Three-man rule/Unexposed Observer l				X	
Personal protective Equipment					
Personal oxygen meter			X	X	X
5 minute escape pack			X	X	
Self-contained breathing apparatus					X

NOTE: Be aware that certain work or temporary conditions may render a work area temporarily ODH 2 or above.

Any work under ODH3 or 4 conditions must be pre-planned and coordinated. A cryogenic expert will then be assigned for planning ODH3 or ODH4 work.

The Three-Man Rule/Unexposed Observer: An unexposed observer is required for ODH 3 work. An unexposed observer is an ODH-qualified worker who is physically removed from an ODH 3 area and can monitor work activities. In case of an ODH incident the unexposed observer can summon help.

EMERGENCY PROCEDURES

PROBLEM	RESPONSE
Installed oxygen monitor alarms	• **EVACUATE** • notify supervisor • do not enter work area until problem has been solved
Any indication of possible gas leak, such as: vapour cloud or sound of rushing gas	• **EVACUATE** the work area • notify supervisor
Any indication of an ODH situation and a worker is DOWN	• **EVACUATE** • call 911 • notify supervisor
Personal oxygen monitor alarms	• don escape pack and **EVACUATE** the area (ODH 2) • Troubleshoot monitor to verify monitor is responding properly • notify supervisor of potential ODH problem if monitor has not malfunctioned*
Not enough oxygen monitors for all members of work group to enter an ODH 2 or greater area	• DO NOT ENTER area until each member has a personal oxygen monitor
Work group enters an ODH 2 area with personal monitors. One monitor is dropped and malfunctions.	• due to the buddy rule, two workers will have to exit together
Workers experiences health effects associated with ODH.	• **EVACUATE** the work area • call 911 • notify supervisor

Estimating Oxygen Concentration

The equation for estimating oxygen concentration in the work area if the contents of a compressed gas cylinder are released.

Resulting % oxygen = $\frac{21 (Vr-Vg)}{Vr}$

Where: Vr = volume of the room Vg = volume of the gas.

Resulting oxygen concentration percentage must be at least 19.5%.

*For compressed gas bottles Vg can range from 7-13 cubic meters, depending on the gas and the type of cylinder. Check with the gas supplier. Use room volume in cubic meters.

**For a cryogenic container, Vg is number of liquid litres x expansion ratio (700-1000)/1000 litres per cubic meter. Convert the room volume to cubic meters.