Confined Space Overview

Confined Spaces Overview

- **Confined Space**: A space that:
  1. Is large enough and so configured that an employee can bodily enter and perform assigned work; and
  2. Has limited or restricted means for entry or exit; and
  3. Is not designed for continuous occupancy

- **Permit-Required Confined Space**: A space that meets all three of the above criteria and has one or more of the following characteristics:
  1. Contains, or has a potential to contain, a hazardous atmosphere;
  2. Contains a material that has the potential for engulfing an entrant;
  3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or
  4. Contains any other recognized serious safety or health hazard

Confined Spaces at Fermilab

Pump Vaults

Lift Stations

F2/F3 Enclosures

Ultrasonic Cleaning Tanks

Manholes

Ovens/Autoclaves

Cryostats

Sump Pits

Vaults

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Confined Spaces at Fermilab Cont.

- ESH at work Confined Spaces page: Confined Spaces | ESH at work
  - Review links under “Confined Spaces Resources”
- Confined Spaces Program: FESHM 4230

HAVE YOU CHECKED THE CONFINED SPACES DATABASE?

LINK: Confined Spaces

- Use the search bar or filter by location to find confined spaces in your Division
- Review the information and hazards listed for each space
  - Is the space Permit Required or Non-Permit Required? Are additional requirements listed?
  - If you cannot find a particular confined space or if edits are needed for an existing confined space, contact: Mitch Lindgren

Entry Procedure – Entry Permit or Reclassification?

- Review "FESHM 4230.03 – Confined Space Flow Chart"
- If atmospheric monitoring with the multi-gas meter shows that no atmospheric hazard is present, there is no possibility for a hazardous atmosphere to arise, and no physical hazards exist within the space or can be eliminated prior to entry – the permit-required confined space can be temporarily reclassified to a non-permit required confined space using the Reclassification Form. The Reclassification Form should be used whenever possible.
- If an atmospheric hazard is present or has the potential to arise, or if an identified hazard within the space can not be eliminated and will remain during entry, the space must be entered under a full Confined Space Entry Permit.

Confined Space Entry Permit	Reclassification Form
• High risk operation • Roles of Entry Supervisor, Attendant, and Entrant must be identified and constant communication with entrant must be maintained • Full-body harness must be worn by entrants and a rescue retrieval system must be present, with limited exceptions • Continuous atmospheric monitoring is required and forced-air ventilation may be necessary • Pipelines or similar conveyances carrying hazardous liquid/gas between the confined space and point(s) of isolation must be isolated. All significant identifiable hazards and precautions taken must be listed on permit.	• All hazards eliminated prior to entry so less risk involved vs. full permit entry • Entry Supervisor, Attendant, and Entrant roles not required • Full-body harness and retrieval system not required • Atmosphere must be monitored prior to entry, but continuous monitoring is not required • NOTE: Introducing a hazard (e.g., welding, painting, chemical use, etc.) into a non-permit confined space may cause the space to become a permit-required confined space

Rescue Retrieval Equipment

- What type(s) does your Division have available?

Tripod/Winch

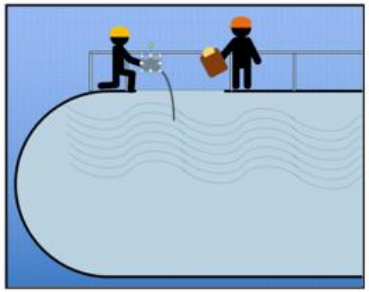
Davit Arm

Fall Protection Harness

- Other equipment is available such as vehicle hitch mounted retrieval systems
- Have you been trained on how to operate the equipment?
- How is it stored? Is it in good working order?

Atmospheric Monitoring with Multi-Gas Meter

- Stratified atmospheres: due to varying vapor densities of gasses, the atmosphere in a confined space must be monitored vertically every 4 feet:



Methane Combustible Gas

(Lighter than air)

Hydrogen Sulfide (H_2S)

(Slightly heavier than air)

Carbon Monoxide (CO)

(Slightly lighter than air)

- The MSA Altair 5X multi-gas meters sample air at one foot/second, and the sensors recognize a hazardous atmosphere within 15 seconds. Therefore, conservatively, the instruments response time using a 10-foot hose is 25 seconds per sampling location.
- Review "FESHM 4230.06 – Confined Space Atmospheric Testing Information"

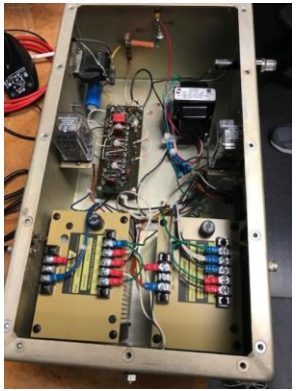
Field Work for Trained Individuals

- Find and assess a confined space within your Division:
  - Is it Permit-Required? Identify all present or potential hazards.
  - How is the space isolated? How are hazards eliminated or controlled?
  - Can the space be Reclassified to a non-permit confined space? (i.e., no actual or potential atmospheric hazard exists and all other hazards can be eliminated without entering the space)
  - Does the confined space have the correct signage?
- Perform a “mock entry” - go through the process of filling out a Confined Space Entry Permit and/or a Reclassification Form for the space. Ensure all fields on each form are filled out. Perform pre-entry atmospheric monitoring and record results but do not actually enter the space. Notifications to FFD and DSO are not required for this exercise.
- For assistance, contact: Mitch Lindgren

Hazardous Energy Control

Recent Fermilab Events Involving Electrical work

1. April 2024: MI-40 sump pump controller
    1. Reached into an energized controller with unguarded parts to test pump operation.
2. May 2024: Linac crowbar assembly
    1. Contacted energized part inside enclosure while removing mounting bolt
3. January 2025: IB1 LCW pump coupling
    1. Reversed rotation to test pump
    2. Pump seized, coupling shattered



Safe conduct of electrical work

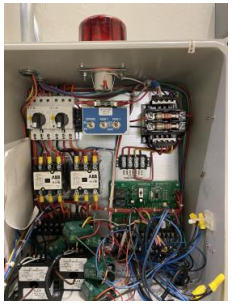
Why did these happen?

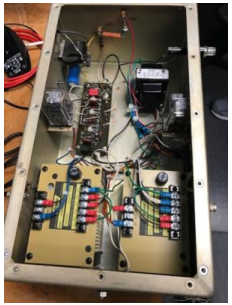
In all in the new scope three cases workers were troubleshooting equipment that wasn't working correctly.

In each case the troubleshooting process pointed to a further test or component replacement that was not identified in the original planned scope.

No work pause was taken to determine the hazards and how to mitigate them.

Scope creep can find new hazards. Scope creep is particularly common during troubleshooting.





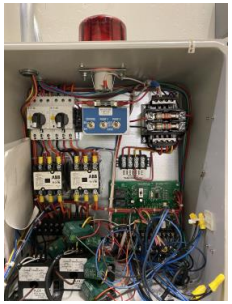
Safe conduct of electrical work

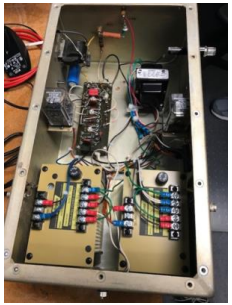
Action items:

Is troubleshooting part of the work done by your group? If so, what kinds of equipment does your group troubleshoot?

Is the scope of work clearly defined before work starts? Does work get paused when conditions suggest additional, non-scoped, tasks or steps?

Are there equipment or systems you work on or with that expose workers to electrical, mechanical, pressure, falling or ergonomic hazards? Could changes or improvements be made to prevent or minimize those exposures?





LOTO is not just for electrical hazards

In the third case the new hazard was mechanical, not electrical. When the motor was started, the coupling between a motor and pump cracked in two pieces landed about 10 feet away.

While coupling guards are primarily intended to prevent contact between people and their clothing with rotating equipment, the guard would likely have contained the parts if it had been put back in place before starting the motor.

LOTO is not just for electrical hazards

Los Alamos National Laboratory recently reported this incident:

“On January 9, 2025, a [subcontact] employee (C1) … fractured their right middle finger, and severed the tips of their right middle and ring fingers while performing preventative maintenance on computer room air handlers …. C1 and two other [subcontractor technicians (C2 and C3) electrically locked and tagged out the involved air handler motor local disconnect switch and verified zero energy power being supplied to the equipment. The fan assembly continued to free spin at a rapid rate due to the operation of adjacent air handlers sharing a common plenum, with which the isolation dampers of the involved air handler were not working properly to prevent the rapid free spinning. C1 entered the air handler plenum attempting to slow down a free spinning fan belt with the palms of their hands, when the belt caught their glove and pulled their hand into the fan belt pulley. C1 notified C2. C2 notified C3 and C3 transported C1 to Occupational Medicine for evaluation. Due to the extent of C1's injury, C3 transported C1 to the Los Alamos Medical Center further evaluation.”

- No LOTO was done on the dampers to remove the energy
- No work pause was taken to figure out how to stop the rotation without a worker getting into the “line of fire.”

LOTO is not just for electrical hazards

Action items:

What tasks or activities expose you to hazards other than electricity? What measures are taken to mitigate those hazards?

Are there more effective ways to protect workers from these hazards than are currently used? What could be done to implement them?

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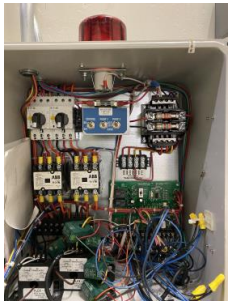
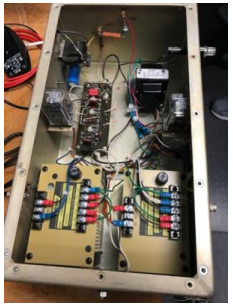
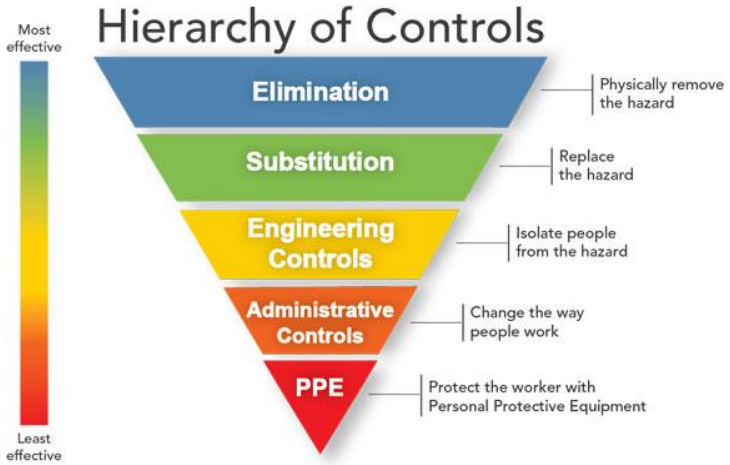
Prevention by design, a.k.a. Safety by Design

In the first two instances, workers reached into an enclosure with exposed conductors to do a task (manually operate a pump or remove a mounting bolt) that should not have required exposure to hazardous energy.





Personnel designing and selecting equipment ought to incorporate features that minimize the exposure of workers to hazards as outlined in NIOSH's Hierarchy of Controls.



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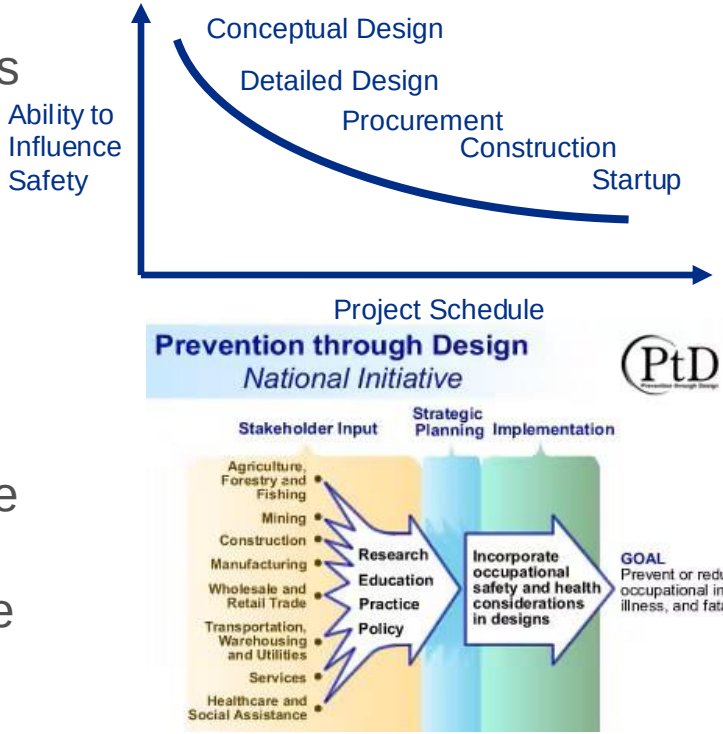
Prevention by design, a.k.a. Safety by Design

Action items:

Are you working on designs or installations that might expose workers to hazards?

Have you identified the Energy Isolating Devices that workers will need to use to apply LOTO? Will they accept padlocks without using adapters?

Can expected service and maintenance be done without the use or ladders or lifts, or taking awkward positions like laying on the floor?



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Safety in troubleshooting

Troubleshooting is a risky activity.

- Broken equipment may present hazards that are not found when the equipment is a normal condition.
- It is difficult and labor intensive to develop a thorough troubleshooting work plan that will identify most failures.
- Without a thorough work plan, the troubleshooter essentially develops that work plan “on the fly” as each troubleshooting step is identified and then performed.
- Safe troubleshooting demands the work pause to identify hazards and develop mitigations at each step in the process.
- Time pressure often compounds the high mental demands of troubleshooting with pressure to work hastily.

Safety in troubleshooting

Action items:

If your group does troubleshooting:

- Identify equipment that can present unexpected hazards when it is broken. How can those potential hazards be safely approached?
- Do you work on equipment or systems that are so critical, expensive, or hazardous that developing a thorough troubleshooting work plan is a worthwhile investment?
- Do you implement work pauses for planning at each step when you are troubleshooting without a previously developed thorough work plan?
- Are you and your line management committed to defending the need to troubleshoot carefully and deliberately even when others desire quick results?

Safety Pause - Oxygen Deficiency Hazard (ODH)

Mike Zuckerbrot and CSS Expert ODH Panel→

Fermilab Safety Pause

23 January 2025

ODH
(Kintner)
Geynisman
White
Voirin
Overhage
Zifko
Bushek (ESH)
Medina (ESH)

Agenda

- ODH General - See FESHM 4240 for full scope of requirements
  - Basic information on ODH
  - ODH Classifications
    - Specific areas within groups/departments and their requirements
  - Requirements for different classifications
  - Procedures and control measures
  - Alarm response
    - Personal O2 monitors
    - Fixed/in-place O2 monitors
- Recent incidents
  - IB1 alarm response
  - Release of N2 gas due to improper portable dewar usage
- Recommendations

Basic Information on ODH

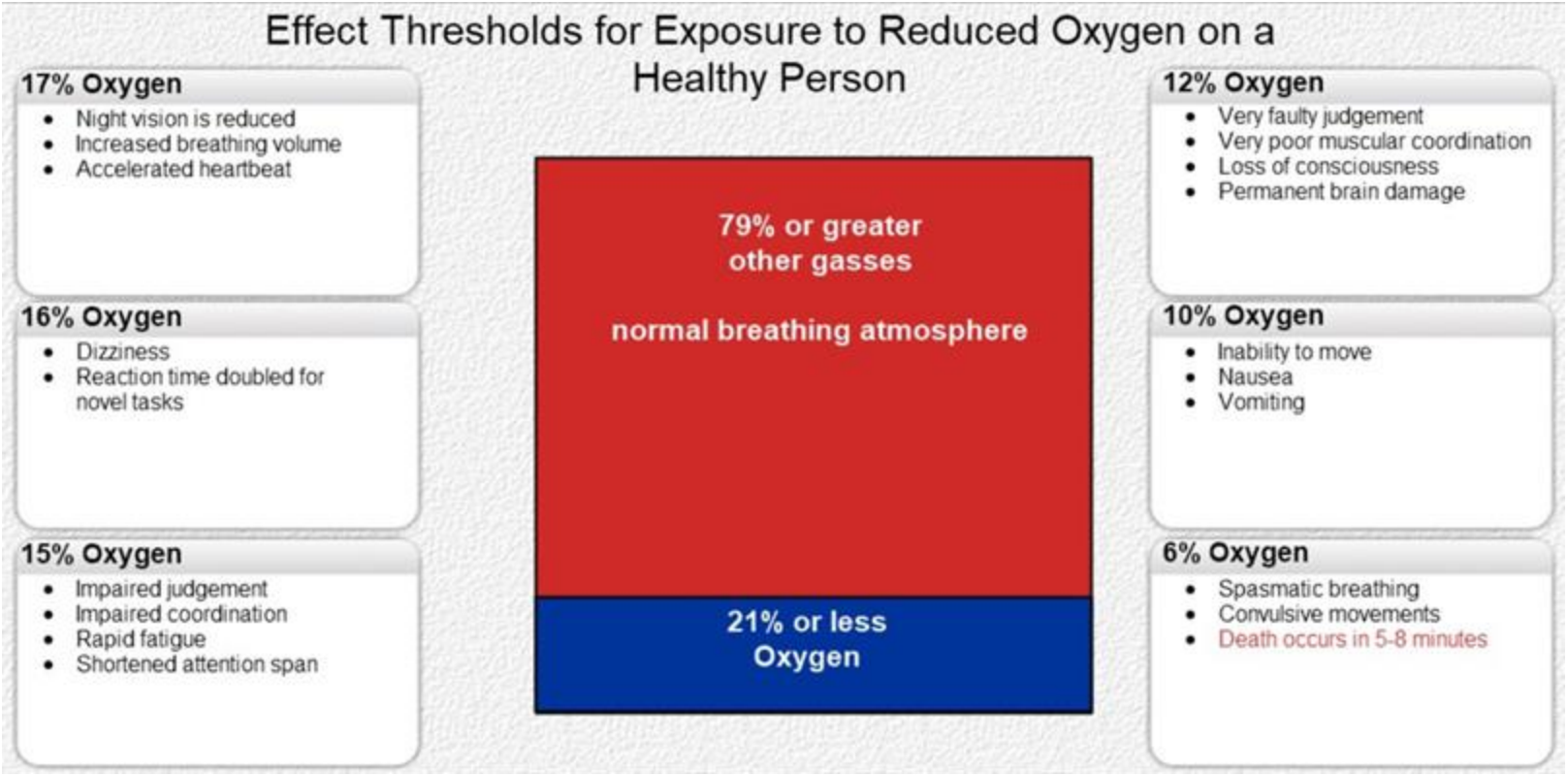
Our normal breathing atmosphere consists of 3 gases:

- Nitrogen (N_2), 78%
- Oxygen (O_2), 21%
- Argon (Ar), 1%

An **Oxygen Deficient Atmosphere** is defined as any time the oxygen concentration drops below 19.5%

This oxygen level is defined by OSHA and defines the alarm set point for fixed/in-place as well as personal oxygen monitors used at Fermilab

Basic Information on ODH



Basic Information on ODH

- FESHM 4240
  - ESH-doc-387-v19: FESHM Chapter 4240 - Oxygen Deficiency Hazards (ODH) FINAL
- Hazards of Nitrogen Asphyxiation
  - https://www.csb.gov/videos/hazards-of-nitrogen-asphyxiation/
- ODH siren sound

ODH Classifications

- ODH 0 (least hazardous) - Two types
  - True ODH 0
  - Engineered ODH 0
    - Relies on active control measures (i.e. on-demand ventilation, isolation of gas/cryogenic sources - based on O2 concentration)

- ODH 1

- ODH 2 (most hazardous)

- See following slides for specific requirements pertaining to each type of classification

Specific ODH areas within Groups/Departments

- Presenters should discuss areas controlled or frequented by their groups/departments
  - Specific ODH classifications
  - Any unique requirements
  - Any unique hazards
  - Cryo investigations after ODH alarms
  - Power outage response
  - Out-of-service policy

ODH Classifications Requirements

See Table 5 of the ODH 4240 chapter

Table 5, ODH Control Measures

ODH HAZARD CLASS	Engineered 0	1	2
Environmental Controls			
1. Warning signs	X	X	X
2. Ventilation	X(note 6, 7)	X	X
3. Area (Fixed) Oxygen Monitoring	X(note 2, 6, 7)	X (note 1, 2,6)	X (note 1,2,6)
4. Siren / strobe light alarms	X(note 2)	X(note 2)	X(note 2)
ODH-Qualified Personnel Controls			
4. Medical approval as ODH qualified		X	X
5. ODH training		X	X
6. Personal oxygen monitor		X (note 3)	X (note 3)
7. Self-rescue supplied atmosphere respirator (escape pack)		X (note 4)	X (note 4)
8. Multiple personnel in communication			X
ODH-Restricted Personnel Controls			
9. Must not be ODH-excluded		X	X
10. ODH briefing or training		X	X
11. Personal Oxygen Monitor		X (note 3)	X (note 3)
12. Self-rescue supplied atmosphere respirator (escape pack)		X (note 4)	X (note 4)
13. One-to-one escort by ODH qualified personnel		X (note 5)	X (note 5)
14. At least two ODH qualified personnel			X
X = Required.			

ODH Procedures and Control measures - Basic Requirements

- All personnel entering ODH posted areas must be aware of the hazards, know how to recognize ODH alarm (siren, strobe), and how to recognize cryo / ODH hazards, how to safely exit the area and how to call x3131.

- All personnel entering ODH 1 or ODH 2 posted areas must be additionally medically qualified, trained and supplied with ODH equipment, e.g. personal monitors or escape packs, if required per ODH Assessment.

- All personnel must be aware that rescue must be conducted by emergency (Fire Department) personnel.

ODH Training and Medical Qualifications

- Individuals engaged in ODH class 1 or greater operations shall receive training in oxygen deficiency hazards and associated safety measures as outlined below. Annual retraining shall be required.
- The Occupational Medical Office is responsible for reviewing the medical fitness of persons who participate in ODH operations.
  - Medical surveillance shall be required to assure that persons engaged in ODH operations are adequately fit to escape from an oxygen deficient situation when properly warned.
  - Hearing, vision, cardiopulmonary function, ambulatory abilities and mental stability shall all be considered in this respect.
  - A three level system of medical approval shall be used which gives the greatest operational freedom to those who are most fit

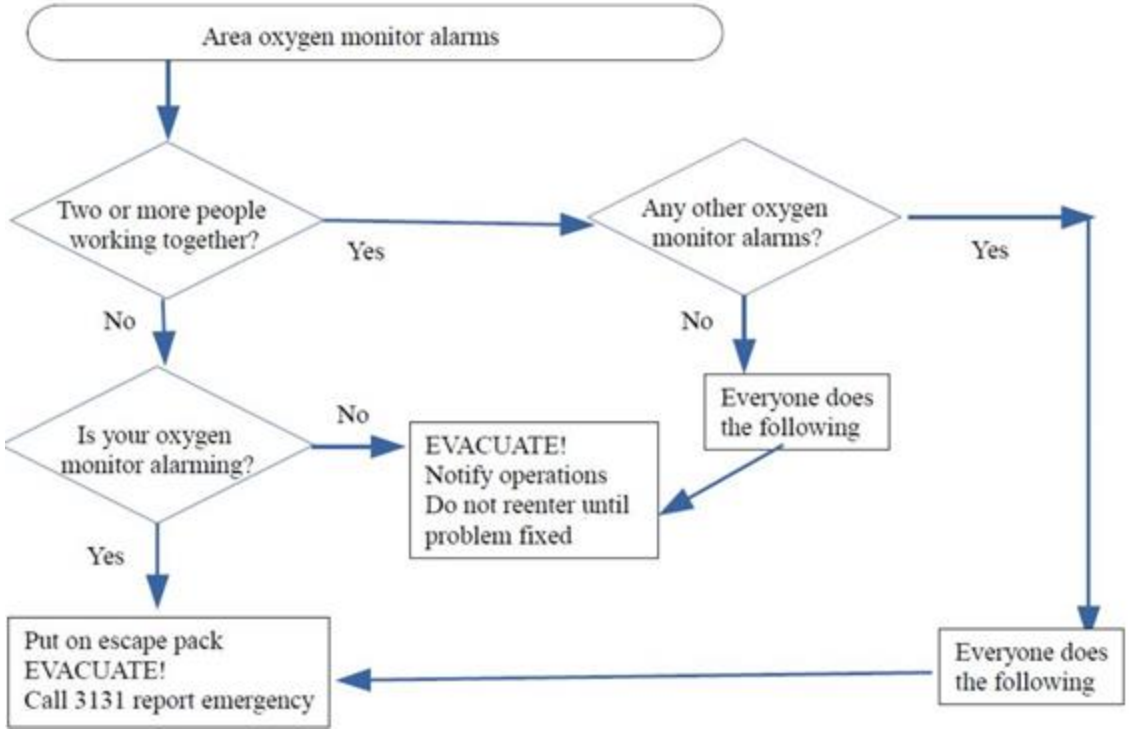
Level	Meaning	Duration of Approval
ODH Qualified	Medically qualified to enter ODH Class 1 and 2 areas.	Typically 1-2 years based on the age and health status of the worker.
ODH Restricted	Medically qualified to enter ODH Class 1 and 2 areas when escorted by an ODH Qualified person.	Typically 1-2 years based on the age and health status of the worker.
ODH Excluded	Prohibited from entering any ODH Class 1 or 2 areas.	Excluded until reclassified by the Medical Office.

Rules for non-qualified or non-trained personnel and escorts

- Be aware that access to Engineered ODH 0 areas is allowed for non-qualified and non-trained personnel.
- These areas still contain cryogenic and pressurized gas sources that can displace oxygen.
- Therefore, such personnel should only enter Engineered ODH 0 areas if informed of the dangers, alarm response and evacuation routes.

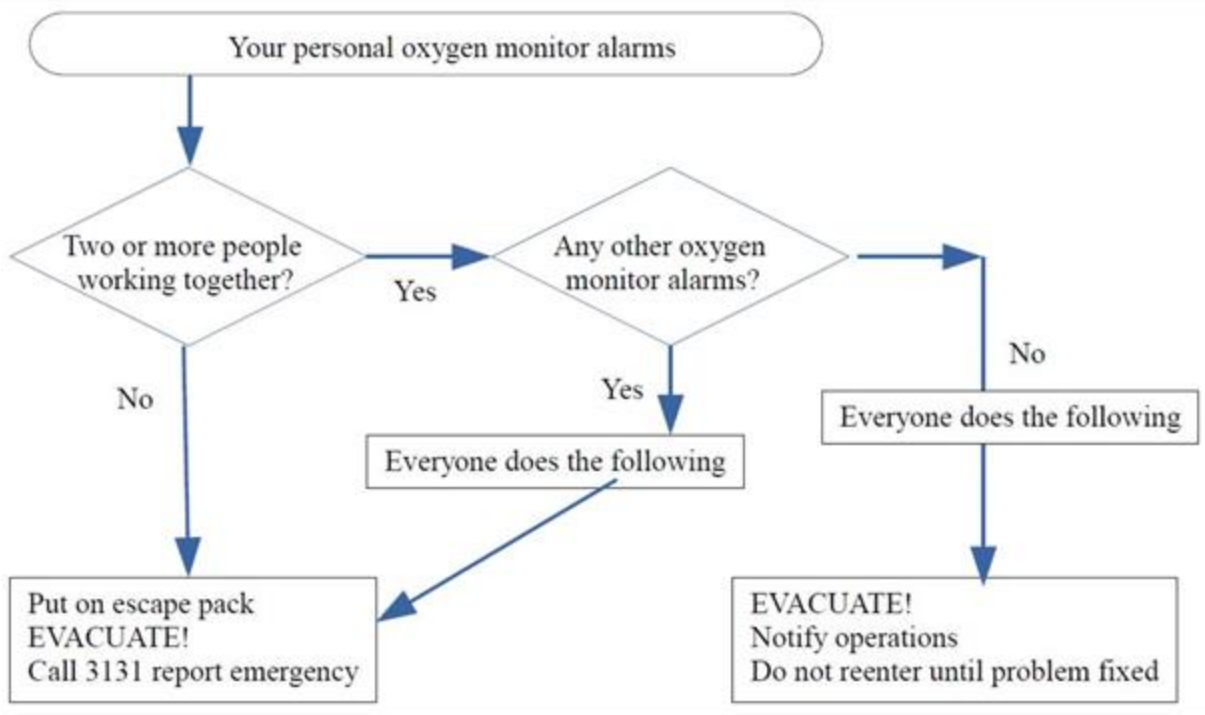
Alarm Response

- Fixed/in-place area O2 monitors



Alarm Response

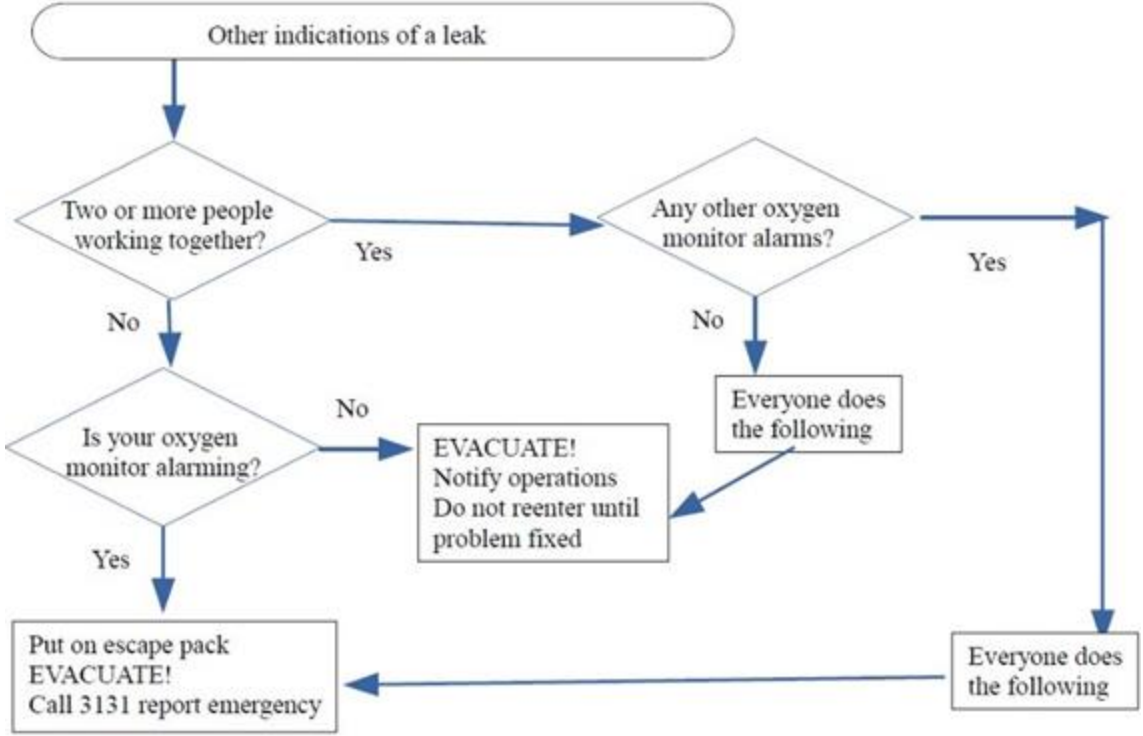
- Personal O2 Monitors



Commercial model *OX-03 Series* manufactured by RKI Inc.

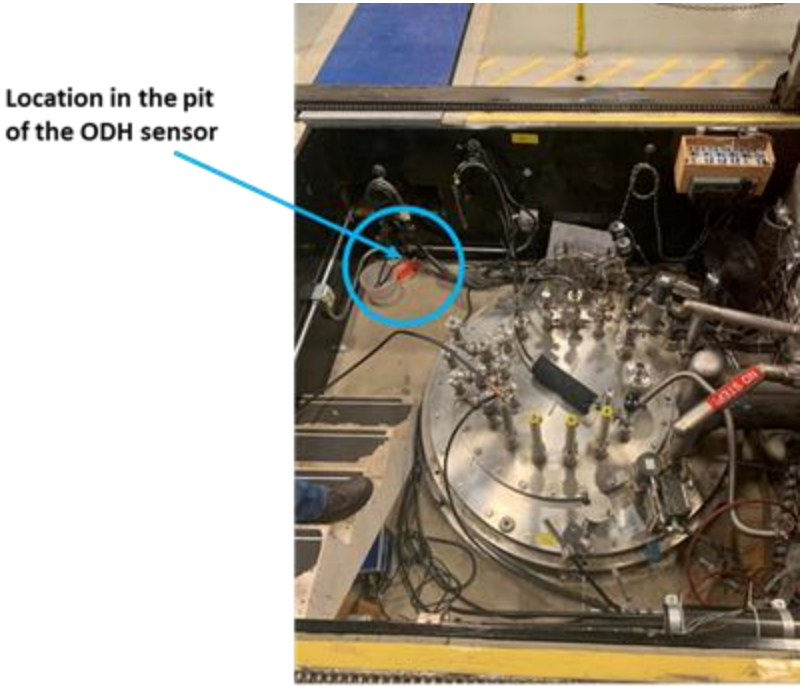
Alarm Response

- Indications of a leak (vapor plume, audible sound, etc.)



Recent Incidents: IB1 Alarm Response

- Cryostat top flange bolts were not tightened, but elog entry posted for cryo to proceed
- Initial vacuum leak test did not reveal loose bolts
- IB1 operator opened valve to bring cryostat to positive pressure while sitting in the control room
- Shortly thereafter IB1 Hi-Bay ODH alarm activated. The IB1 control room is on a separate ventilation system and did not require evacuation
- IB1 Operator isolated cryostat from the control room. Approximately 40 seconds later the ODH alarm cleared.
- ODH sensor was directly in path of leaking helium. Measured O_2 dropped close to 14%, but ODH condition was highly localized to VTS3 Pit
- The IB1 operator did not call ext. 3131, but for Engineered ODH 0 areas without FIRUS connections the Fire Dept. must be notified via 3131 for $O_2 < 18.0\%$



VTS3 pit

Recent Incidents: IB1 Alarm Response Follow-up

- IB1 ODH monitoring system upgraded to PureAire sensors using the ES&H Interlocks XP chassis

- IB1 Hi-Bay ODH system now connected to FIRUS
  - FIRUS Trouble Alarm automatically leads to notification for Cryo Expert to begin investigation when any O_2 reading < 19.5%
  - FIRUS Emergency Alarm automatically leads to dispatch of Fire Dept. when any O_2 reading < 18.0%

- IB1 Hazard Awareness Training class now required for entry to IB1

- A major focus of upcoming FESHM 4240 revision is on expanding and clarifying ODH event response and re-entry procedures

Recent Incidents: Uncontrolled Release of N2 Gas at ICBA

- Employees were conducting a hipot test which involved cooling a system down to test a hypothesis there was moisture trapped with the assembly
- Components were mechanically fastened (tape, clamps, etc.) and connected to a portable dewar, when the dewar was opened a pop was heard as a component failed and the dewar was closed – no one was injured
- Employees were unfamiliar with working with dewars/cryogens and had never taken the training or took it many years ago
  - i.e. unfamiliar with low vs. high pressure dewars, liquid vs. gas withdrawal ports, etc..
- Cryogenic safety training did not specifically cover some details of portable dewars and was not required at a regular interval
  - Training has been updated with some extra specifics on portable dewars and is now required bi-yearly
- Reminder that employees unfamiliar/untrained in working with cryogens should not be performing the work without work planning, proper review and input from SME's

Recommendations

- Action Item
  - Signage
    - Signage for all cryogenic systems should be verified to be within compliance by DSO's responsible for areas
- General recommendations
  - Equipment testing
    - Verify responsible parties (i.e. Interlocks, controls groups) have tested systems at required intervals
  - Personal monitors
    - Verify personal monitors are in working order and properly calibrated. Contact Industrial Hygiene group with any issues.
  - General walkthroughs
    - Cryogenic systems owners should regularly conduct walkthroughs to inspect for abnormalities (i.e. ice balls, vapor clouds, odd noises)

Backup Slides

ODH Control Measures

1. Engineered ODH 0- an area relying on active monitoring and ventilation to achieve the ODH Class 0 classification.
2. Warning signs - ODH signs shall be posted where they best serve to warn potentially exposed individuals. ODH signs are available from the ESH&Q Section
3. Ventilation - The minimum ventilation rate during occupancy should be established during the ODH risk assessment. This may be accomplished by any reliable means.
4. Medical approval as ODH qualified - This block of precautions shall only apply to individuals who have been classified as ODH-qualified by the Fermilab Occupational Medical Office.
5. ODH Training - Individuals shall receive training in oxygen deficiency hazards and safety measures associated with the operation. Annual retraining shall be required. Training is coordinated by the ESH&Q Section. Successful completion of an online challenge exam may be used to substitute for the annual retraining requirement.
6. Personal oxygen monitor - Individuals shall be equipped with a functioning calibrated personal oxygen monitor. Prior to each use they shall check that the displayed concentration is 21% in a normal atmosphere and the monitor is not past due for calibration. Personal oxygen monitors shall not be used beyond the last day of the month indicated on the calibration sticker. All personal oxygen monitors used at Fermilab are set to alarm at the mandatory confined space limit of 19.5% (see Chapter 4230). This eliminates the need to maintain two "types" of personal oxygen monitors (one for ODH and one for confined spaces) as well as the associated potential for mismatching monitor and application. Area oxygen monitors may be used in place of personal oxygen monitors where it has been demonstrated that they provide an equal or superior level of safety (e.g., where a high background noise level makes the personal oxygen monitor alarm imperceptible). Area ODH monitors are set to alarm at the ODH limit of 19.5% oxygen.

ODH Control Measures

7. Self-rescue supplied atmosphere respirator (escape pack) - All individuals present shall have ready access to self- rescue supplied atmosphere respirators (escape packs) during the operation unless it has been demonstrated that they do not improve the probability of surviving an oxygen deficient atmosphere (e.g., when it takes longer to put on and activate the respirator than it does to escape the oxygen deficient environment).
8. Multiple personnel in communication - More than one individual shall be present; all of whom shall meet requirements (4), (5), and (6) above.
9. Must not be ODH-excluded - This block of precautions shall only apply to individuals who have not been classified as ODH-excluded by the Occupational Medical Office (such individuals are classified as ODH-restricted). Individuals classified as ODH-excluded shall not participate in any ODH Class 1 or greater operation.
10. ODH briefing - Individuals shall be briefed in oxygen deficiency hazards and safety measures of the operation prior to making entry into an ODH area.
11. One-to-one escort by ODH-qualified personnel - An escort can be provided in special cases when the persons entering an area do not meet requirements (4) and (5). Individuals shall be under the direct continuous supervision of individuals who meet (4), (5), and (6) above. Note that escorted persons shall not have been designated as ODH-excluded by the Occupational Medical Office. If not evaluated by the Medical Department, the escort assumes responsibility for judging whether or not they believe the fitness of the escorted individual would significantly impede escape from the ODH operation in the event of an alarm. The rules for tour groups are listed below under “ODH Area Tour Requirements”, which are an exception to the one-to-one escort requirement.
12. At least two ODH-qualified personnel - Both (8) and (11) shall be followed when making entry into an ODH area.

ODH Procedures and Control measures

Response to an alarm from a personal oxygen monitor:

- If one person is working alone in an area and his/her personal oxygen monitor alarms, the person must immediately don a self-rescue supplied atmosphere respirator (escape pack), evacuate the area, and dial 3131 to report an emergency.
- If two or more people are working together in an area and a personal oxygen monitor alarms, they should compare readings. If other monitors read OK, then everyone must evacuate the area and solve the problem with the personal oxygen monitor before re-entering. If other monitors confirm low oxygen levels, then everyone must don an escape pack, evacuate the area, and then dial 3131 to report an emergency.

ODH Procedures and Control measures

Response to an alarm from a personal oxygen monitor:

- If one person is working alone in an area and an in-place oxygen monitor alarms, and his/her personal oxygen monitor reads greater than 19.5%, the person should evacuate the area going away from the assumed source of the alarm. After exiting, he/she should notify the operations department responsible for the area of the problem. He/she should not re-enter until the problem has been solved.
- If two or more people are working together, they should compare readings of personal oxygen monitors. If all personal oxygen monitors read OK, everyone should evacuate the area going away from the assumed source of the alarm. After evacuating, they should notify the operations department responsible for the area of the problem. They should not re-enter the area until the problem has been solved. If a personal oxygen monitor confirms low oxygen levels, everyone should don an escape pack, evacuate the area, and then dial 3131 to report an emergency.

ODH Procedures and Control measures

Response to other indications of a possible cryogen or gas leak:

- If one person is working alone and his/her personal oxygen monitor reads greater than 19.5%, he/she should evacuate the area going away from the assumed source of the problem. After exiting, he/she should notify the operations department responsible for the area of the problem. If a personal oxygen monitor has alarmed, he/she must immediately don a self-rescue supplied atmosphere respirator (escape pack), evacuate the area, and dial 3131 to report an emergency.
- If two or more people are working together, they should compare personal oxygen monitor readings. If all are OK, they should all evacuate the area going away from the assumed source of the problem. After exiting, they should notify the operations department responsible for the area of the problem. If a personal oxygen monitor has alarmed, they must immediately don self-rescue supplied atmosphere respirators (escape packs), evacuate the area, and dial 3131 to report an emergency.

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