

## OXYGEN REDUCTION SYSTEMS

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## 1.0 SCOPE

This data sheet contains recommendations related to the installation and use of FM Approved oxygen reduction systems, which use nitrogen to continuously reduce the oxygen content in rooms, buildings, and equipment enclosures. Guidelines for their design, installation, acceptance testing, inspection, and maintenance are provided.

Oxygen reduction systems are not intended to extinguish fires. Rather, they are designed to limit fires (i.e., they can prevent significant fire spread, depending on the fuel and oxygen concentration). These systems cannot prevent ignition because they do not create the very low oxygen concentrations necessary to accomplish that goal.

This type of system could be used in very high-value occupancies that are susceptible to nonthermal damage, or where the use of sprinklers would be very challenging and expensive, or that lack an available sprinkler protection design.

This data sheet does not apply to the following:

- Inerting systems for fire and explosion protection (see Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*)
- Explosion suppression systems (see Data Sheet 7-17, *Explosion Protection Systems*)
- Fire extinguishing systems
- Oxygen reduction systems using anything other than nitrogen.

Operation of this system necessarily creates and maintains a space in which the oxygen concentration is substantially reduced. This poses health and safety issues for unprotected individuals within the space.

- A. Operation potentially establishes an environment hazardous for human occupancy subject to occupational health, safety, and environmental requirements specified by the relevant jurisdictional authority. The oxygen levels recommended in this data sheet may produce conditions that meet the definition of a confined space (a substantially enclosed space in which serious injury can occur from hazardous substances or conditions within the space, such as a lack of oxygen).
- B. All safety measures and operating procedures must be followed in accordance with the manufacturer's instructions or the relevant jurisdictional authority's safety regulations.

## 1.1 Hazard

The approach used by oxygen reduction systems to control fire hazards involves creating an atmosphere with a reduced oxygen concentration that will have an impact on a potential fire. The challenge is in defining the oxygen concentration. The easiest approach is to use an oxygen concentration that will prevent any combustion (i.e., limiting oxygen concentration). This approach is commonly used to eliminate explosion hazards in vessels, where the oxygen level is kept very low; typically 10% or less oxygen. In a large building, using nitrogen to maintain this level would be prohibitively expensive, and, in reality, unnecessary. Storage arrangements for many occupancies can tolerate ignition and very limited fire spread.

The challenge of defining an oxygen level that allows ignition and some limited fire spread is driven by the physics of how ignition and fire spread occur. It is critical to replicate the commodity and storage arrangement during testing to determine the acceptable oxygen concentration, "**limiting oxygen concentration for fire propagation ( $LOC_{FP}$ )**." Beyond that, it is also important to recognize the tolerances in the oxygen measurement system to ensure the oxygen concentration is maintained at the correct level. The "oxygen concentration design point" uses the  $LOC_{FP}$  minus the error associated with the measurement equipment. Failure to maintain a correct oxygen concentration will result in a spreading fire that will threaten the building.

## 1.2 Changes

**July 2023.** Interim revision. The following changes were made:

- A. Provided other options to maintaining the needed nitrogen concentration for 12 hours within a room/building/equipment enclosure due to loss of power.
- B. Clarified how to handle  $O_2$  sensor uncertainty when calculating the oxygen design point.
- C. Provided additional options for achieving N+1 nitrogen generator designs.

- D. Provided additional information on where to provide O<sub>2</sub> sensors and how many sensors are needed for much larger building volumes.
- E. Provided additional information on O<sub>2</sub> sensor maintenance and replacement schedules.
- F. Provided guidance for protecting ASRS storage arrays.
- G. Provided guidance for protecting frozen foods.

## 2.0 LOSS PREVENTION RECOMMENDATIONS

### 2.1 Introduction

2.1.1 Provide FM Approved systems, equipment, materials, and services whenever they are applicable. For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals.

2.1.2 Design and install oxygen reduction systems in accordance with the following:

- A. Their listing in the *Approval Guide* and this data sheet.
- B. The manufacturer's design, installation, operation, and maintenance manual as identified as part of the FM Approval by document identification number and revision level.
- C. The relevant occupancy- or hazard-specific data sheet.
- D. Applicable jurisdictional requirements.

### 2.2 Construction and Location

2.2.1 Use noncombustible or Class 1 construction for the room/building/equipment enclosure that will contain the reduced oxygen environment.

2.2.2 Design and construct the room/building/equipment enclosure to maintain the oxygen design concentration for twelve (12) hours with all operations shut down and no operation of the nitrogen generator.

2.2.2.1 An alternative in cases where a building design cannot maintain the needed oxygen design concentration is to provide emergency backup power capable of running the nitrogen generators for a minimum of 12 hours.

2.2.2.1.1 Conduct the tightness test in accordance with NFPA 2001, ISO 14520, EN 15004, or other applicable code or standard. Do not obstruct any non-closable openings during the testing.

2.2.2.1.2 Maintain the tightness test results for future reference.

2.2.2.2 Provide a means (e.g., oxygen vs time charts or tests) to determine if leakage rates increase over time.

2.2.3 Protect the exterior walls of the room/building/equipment enclosure containing the reduced oxygen environment from physical damage from vehicle or debris impact.

2.2.4 Do not install heat or smoke vents in the room/building/equipment enclosure containing the reduced oxygen environment.

2.2.5 Design all points of entry to the room/building/equipment enclosure as follows:

- A. Arrange all openings in the room/building/equipment enclosure to minimize the loss of the low oxygen environment. Providing airlock arrangements at openings is one means of achieving this.
- B. Ensure openings are normally closed except when normal operations need them to be open. Arrange doors to fail closed.
- C. Arrange all maintenance access or emergency access openings to be normally closed, with self-closing equipment provided.

2.2.6 Locate the nitrogen generation system and control system in a noncombustible room (equipment room) outside of the room/building/equipment enclosure containing the reduced oxygen environment.

2.2.6.1 Ensure the equipment room is accessible for response to alarms.

2.2.6.2 Limit access to the equipment room to authorized persons only.

2.2.6.3 Ensure the equipment room cannot be exposed to the environment in the building/room/equipment enclosure that contains the reduced oxygen environment, and has a normal air oxygen level.

2.2.6.4 Locate all equipment so it is not subject to mechanical, chemical, climatic, or other conditions that can render it inoperative or susceptible to accidental damage or operation.

2.2.6.5 Locate all equipment so it is fully accessible for inspection, testing, maintenance, and removal or replacement.

## 2.3 Occupancy

### 2.3.1 Sensors and Interlocks

2.3.1.1 Provide interlocks to shut down all operations within the building/room/equipment enclosure when smoke/fire (see 2.4.1.5.1) or an oxygen concentration above set limits (see 2.5.2.2) is detected.

- A. Deenergize all electrical equipment except lighting within the building/room/equipment enclosure.
- B. Shut down all load/unload operations.
- C. Close all exit/entrance doors.

2.3.1.2 Do not return to normal operations until the source of the alarm has been cleared.

2.3.1.3 Provide sensors on all doorways and access openings to show their status (open/closed).

2.3.1.3.1 Arrange for the sensor notifications to go to a remote location that can be accessed by facility personnel or the fire service in normal or upset conditions.

2.3.1.3.2 Arrange maintenance access openings to produce an audible alarm if left open.

2.3.1.4 Provide oxygen sensors in accordance with Section 2.5 throughout the building/room/equipment enclosure that contains the reduced oxygen environment and the nitrogen generator room.

### 2.3.2 System Identification

2.3.2.1 Clearly label any equipment, room, or building, that has a reduced oxygen environment with a placard at the doorway.

2.3.2.1.1 Provide the oxygen concentration and clear entry instructions on the placard.

2.3.2.2 Provide a placard on the doorway to the equipment room.

2.3.2.2.1 Identify the equipment in the room, entry instructions, and contact information.

2.3.2.3 Provide a placard that identifies the key system design parameters in the nitrogen generator room.

2.3.2.3.1 Include the targeted oxygen concentration and the allowable maximum and minimum concentrations.

2.3.2.3.2 Include the last room integrity test date and the identified leakage rate.

## 2.4 Protection

### 2.4.1 General

2.4.1.1 Use FM Approved oxygen reduction systems in accordance with their listings in the *Approval Guide* and this data sheet.

2.4.1.2 Provide the oxygen concentration design point that uses the  $LOC_{FP}$  listed in Table 2.4.1.2 and any needed adjustments covered by 2.4.1.2.1 in the room/building/equipment enclosure. The listed concentrations are based on real-scale fire tests that used the listed material and storage arrangement.

The listed concentrations are based on real-scale fire tests that used the listed material and storage arrangement.

Table 2.4.1.2.  $LOC_{FP}$  for Specific Commodity Storage

Storage Arrangement	Commodity	$LOC_{FP}$
Single, double and multi-row racks; palletized; solid pile	Cartoned (Class 1-3, CUP and CEP)	11.1%
	Uncartoned (UUP, UEP)	13%
	Frozen Food (Cartoned or Uncartoned)	12.5%
Mini-Load Automatic Storage and Retrieval System (ASRS) <sup>1</sup>	Non-Combustible Contents	14.5%
	Uncartoned Plastic Contents	13%
	Cartoned Contents	11%
Top-Load Automatic Storage and Retrieval System (TL-ASRS) <sup>Notes 1,2</sup>	Non-Combustible Contents	15%
	Uncartoned Plastic Contents	13%
	Cartoned Contents	11%

Note 1. Mini-Load ASRS and TL-ASRS testing used plastic containers.

Note 2. There is no difference in  $LOC_{FP}$  between solid walled and non-solid walled TL-ASRS containers.

2.4.1.2.1 To calculate the oxygen concentration design point, subtract any system measurement uncertainty. Many oxygen sensors are only able to provide values that are good to  $\pm 1\%$ . Use the actual sensor uncertainty, validated by FM Approvals, for the calculation.

Example Calculation: Class 3 commodity:  $LOC_{FP}$  (11.1%) –  $O_2$  sensor uncertainty (1%) = 10.1%.

2.4.1.3 Base the nitrogen volume flow during normal operation of the system on the following:

- A. Design concentration within the volume
- B. Air leakage rates within the controlled volume
- C. Air losses driven by normal operations (e.g., loading and unloading operations)
- D. Maximum design wind load on enclosures with exterior walls

2.4.1.4 Provide automatic sprinkler protection for the gas generation room designed for the combustible load in the room.

2.4.1.5 Install an FM Approved very early warning fire detection (VEWFD) system within the room/building/equipment enclosure in accordance with Data Sheet 5-48, *Automatic Fire Detection*.

2.4.1.5.1 Arrange the system to provide the following two alarm points:

- A. Trouble alarm. Provides an alert to a potential problem (incipient combustion: no visible smoke).
- B. Fire alarm. Provides a signal to automatically shut down all operations within the building/room/equipment in accordance with 2.3.1.1 (visible smoke).

## 2.5 Equipment and Processes

### 2.5.1 Gas Generation Equipment

2.5.1.1 Size the nitrogen generation system to meet expected peak nitrogen flow requirements generated by normal operations in the building/room/equipment enclosure.

2.5.1.1.1 Provide N+1 nitrogen generators and vacuum pumps in the design.

2.5.1.1.1.1 For systems protecting equipment, backup nitrogen tanks are acceptable if sized to ensure the oxygen concentration is maintained until repairs to a generator can be completed.

2.5.1.1.2 Provide a means of monitoring the status of the nitrogen generators. Arrange for the system status notifications to go to a normally occupied location. Include system running, system idle, and system trouble indications.

2.5.1.2 Arrange the oxygen-enriched exhaust from the nitrogen generation system to vent outside the building to well-ventilated areas.

2.5.1.3 Provide oxygen sensors in the gas generator room set to alarm if oxygen levels drop below 19.5% or increase above 23.5%. These values are meant to define an environment that can be accessed by a person without any special considerations or equipment.

2.5.1.4 Only provide valves in the nitrogen distribution piping network that are necessary for the proper operation of the nitrogen generation system.

2.5.1.5 Design and support the nitrogen distribution piping and discharge ports for the expected pressure and flow forces.

2.5.1.6 Distribute nitrogen discharge ports throughout the room/building/equipment enclosure in a way that ensures a consistent distribution of the oxygen concentration within the enclosure.

2.5.1.6.1 Provide at least one discharge port every 1600 ft<sup>2</sup> (150 m<sup>2</sup>).

2.5.1.6.2 Provide discharge ports in any concealed spaces.

2.5.1.6.3 Maintain the differences in oxygen concentration throughout the enclosure within 0.25% by volume.

## 2.5.2 Control Systems

2.5.2.1 Monitor the oxygen level within the room/building/equipment enclosure that contains the reduced oxygen environment.

2.5.2.1.1 Use FM Approved oxygen sensors that will provide resolution over the oxygen design range in the enclosure. Connect the sensors to an FM Approved control panel.

2.5.2.1.2 At a minimum, install a sensor within 90% of the roof/ceiling height, and at the floor level within 10% of the roof/ceiling height.

2.5.2.1.3 Arrange sensors evenly throughout the volume of the building/room/equipment enclosure.

2.5.2.1.3.1 Provide a maximum vertical distance of 30 ft (9.1 m) between sensors and a maximum horizontal distance of 98 ft (30 m) between sensors.

2.5.2.1.3.2 Arrange the sensor along the wall and ceiling. Provide at least one sensor at mid building height in the center of the storage array.

2.5.2.1.4 Provide a minimum of three oxygen sensors within the enclosure regardless of size. Use Table 2.5.2.1.4 to determine the minimum number of oxygen sensors needed as the enclosure volume increases.

Table 2.5.2.1.4. Minimum Number of Oxygen Sensors

Enclosure Volume Range, ft <sup>3</sup> (m <sup>3</sup> ) <sup>Note 1</sup>	Minimum Number of Oxygen Sensors
0 < by ≤ 1800 (500)	3
1800 (500) < X ≤ 140,000 (4,000)	4
140,000 (4000) < X ≤ 350,000 (10,000)	6
350,000 (10,000) < X ≤ 880,000 (25,000)	8
880,000 (25,000) < X ≤ 1,880,000 (50,000)	10
1,880,000 (50,000) < X ≤ 3,500,000 (100,000)	12
3,500,000 (100,000) < X ≤ 7,100,000 (200,000)	14
7,100,000 (200,000) < X ≤ 14,000,000 (400,000)	18
X > 14,000,000 (400,000)	Engineering Analysis Needed

Note 1. X = enclosure volume.

2.5.2.2 Design the oxygen control system so the oxygen concentration within the building/room/equipment volume never exceeds the oxygen design point.

2.5.2.2.1 Use the arithmetic mean calculated from all of the oxygen sensors to determine the value for the enclosure. Calculate the mean value at intervals of less than or equal to 10 seconds.

2.5.2.2.2 Arrange the system to produce a trouble alarm when two sensors or the calculated mean value exceed the design concentration.

2.5.2.2.3 Arrange the system to shut down operations and electrical feeds to the enclosure when two sensors or the calculated mean value reach 0.5% above the design concentration.

2.5.2.2.4 Provide a backup power supply for the oxygen sensor network that can provide 24 hours of operation if primary power is lost.

## 2.6 Operation and Maintenance

2.6.1 Once the installation of an oxygen reduction system is complete, develop system documentation that contains the following:

- Building/room/equipment volume
- Building/room/equipment occupancy
- Oxygen concentration design point
- Oxygen leakage rate during normal operation
- Oxygen leakage rate during shutdown
- Nitrogen generation system overview
- Volume map with all openings labeled as operational or normally closed

2.6.2 Do not introduce any combustible loading into the room/building/equipment enclosure until the oxygen design point is reached throughout the volume.

2.6.3 Provide manufacturer recommended scheduled maintenance for all components of the system.

2.6.3.1 Replace oxygen sensors every two years.

2.6.3.2 Remove oxygen sensors for calibration at an approved service location.

2.6.3.3 If an oxygen sensor cannot meet the needed calibration, replace it with a new one.

2.6.4 Develop detailed procedures for resolving operational issues (e.g., dropped containers, electrical equipment breakdown) that may occur in the building/room/equipment enclosure.

2.6.5 Develop detailed procedures for responding to all potential alarms (e.g., smoke detection alarm, oxygen concentration alarm).

## 2.7 Training

2.7.1 Develop a site personnel training program that covers the following:

- A. All required safety information related to the reduced oxygen environment
- B. Operational issue procedures
- C. Emergency response procedures

## 2.8 Human Factor

2.8.1 Treat any situation in which the oxygen concentration in the building/room/equipment is raised above the design concentration as a system impairment.

2.8.1.1 Use Data Sheet 10-7, *Fire Protection Impairment Management*, to manage the lack of fire prevention until the oxygen concentration can be returned to the design concentration.

## 3.0 SUPPORT FOR RECOMMENDATIONS

### 3.1 System Description

Commercial oxygen reduction systems are designed to maintain a reduced oxygen concentration in a building/room/equipment enclosure to limit propagation of a fire. The system could be designed to prevent ignition, but it would not be practical to maintain the oxygen concentration within a large volume. Some systems are designed to keep the building at some reduced oxygen level and, upon detection of smoke, discharge more nitrogen into the building to reduce the oxygen concentration (like a clean agent system).

These systems have been used to eliminate the need for automatic sprinkler protection. In Europe, since code allows the use of these systems, companies have started installing them in warehouses. There are a couple



of reported installations in North America. However, codes in the USA and Canada do not currently recognize the systems, and employee safety laws place limits on the minimum oxygen concentration in spaces that are continuously or occasionally occupied.

Occupancies for which oxygen reduction systems might be considered include the following:

- High-value occupancies [museums, galleries, libraries, archives]
- High-bay warehouses
- Cold storage (freezers)
- Data centers

The main components of an oxygen reduction system are as follows (also see Figure 3.1):

- Nitrogen generation system
- Electronic control device and alarms
- Oxygen sensors

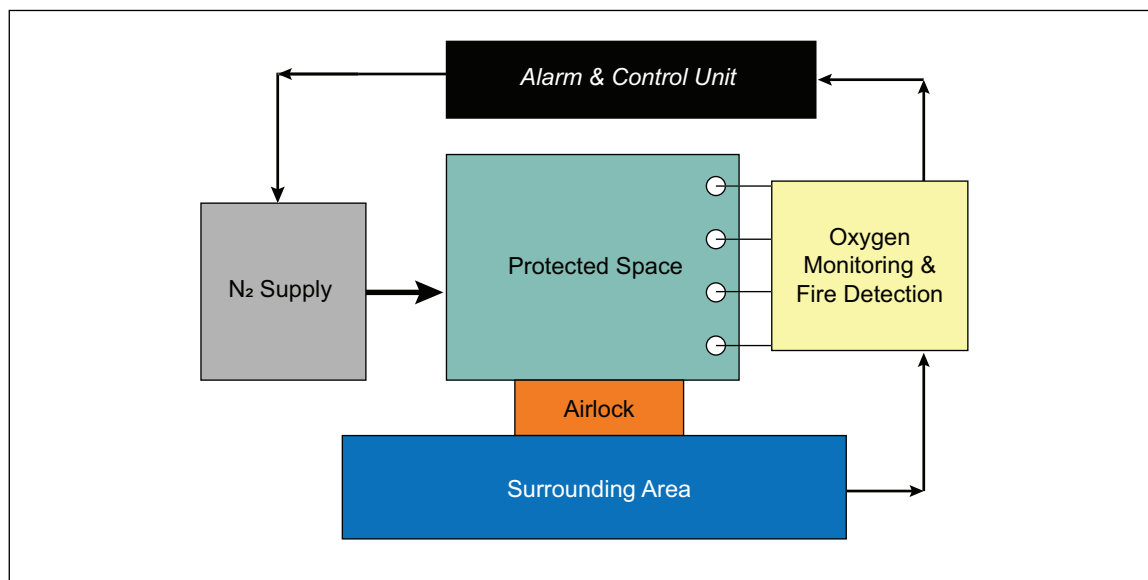


Fig. 3.1. Generic oxygen reduction system

Nitrogen is produced as required and stored temporarily, if necessary. This may involve central nitrogen supply facilities. The storage quantities may be either liquid or gaseous.

The release of nitrogen into the building/room/equipment enclosure is strictly gaseous. An oxygen reduction system monitors the oxygen concentration in the building/room/equipment enclosure by means of suitable oxygen measurement technology. The limitations of the oxygen sensors need to be considered when determining the oxygen concentration design point. During normal operation, the nitrogen is added to the enclosure automatically when the control system reaches the set point oxygen limit.

This system is recognized by various codes and standards around the world, although almost all are based on VdS 3527, *Oxygen Reduction Systems: Planning and Installation*. The systems are designed to maintain an oxygen concentration in the protected space from 17% down to 13%, depending on the type of material being stored.

### 3.2 Determining Oxygen Concentration Limits

FM has completed two studies aimed at defining the oxygen limits for various solid fuels. The first test series used the Fire Propagation Apparatus (small scale). The second test series used a two-tier rack located inside an enclosure that was arranged to permit full control of the oxygen concentration during the test (see Figures 3.2.A and 3.2.B).



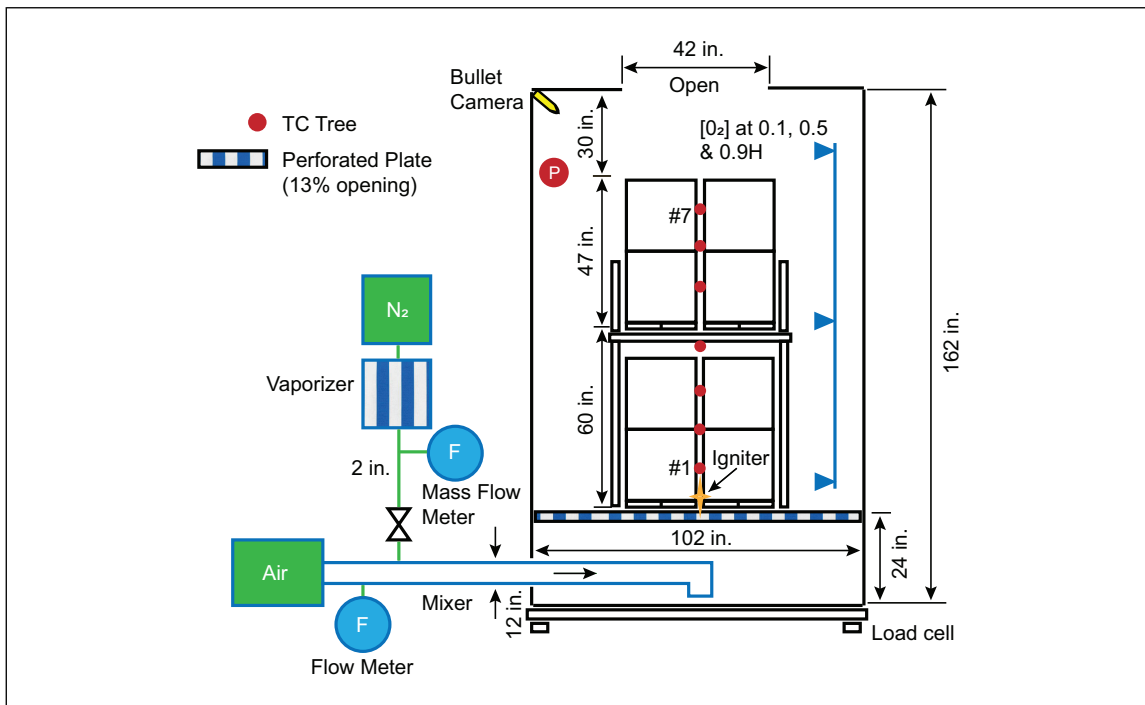


Fig. 3.2.A. Elevation view of FM oxygen concentration test method

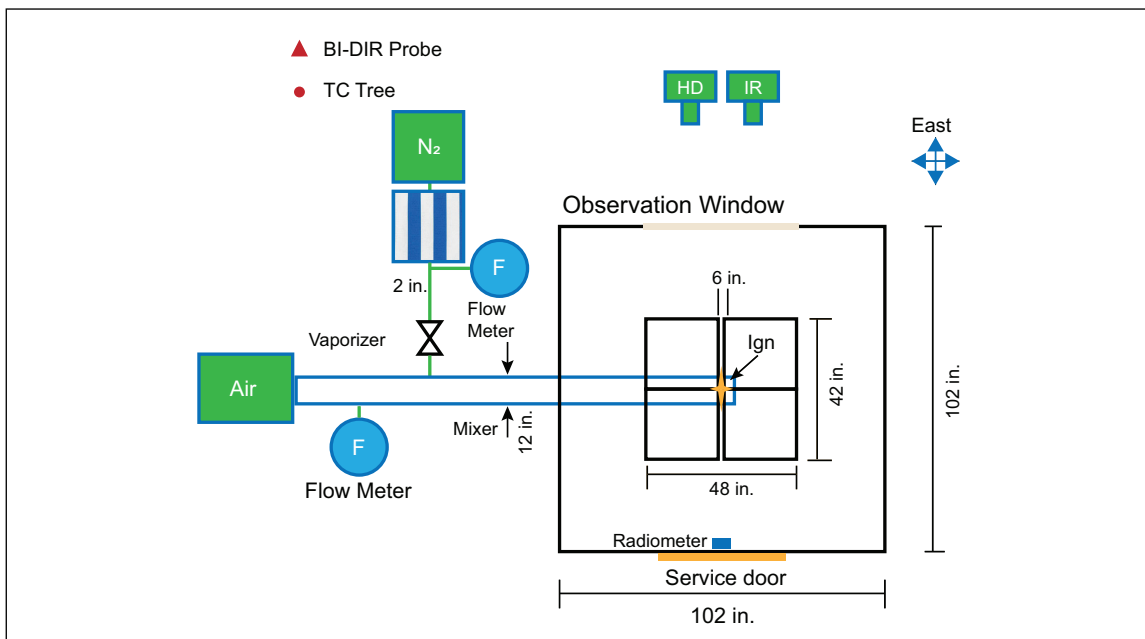


Fig. 3.2.B. Plan view of FM oxygen concentration test method

The research identified oxygen concentration targets that could limit flame propagation in a warehouse. The oxygen concentration ranged from 11.1% to 13% for the various common commodities investigated. These values are not affected by ignition source duration.

Fire testing intended to determine the oxygen limit for a volume that will impact a fire must consider many issues that can influence the measured value. These include the following:

- A. The goal of the design. Is the goal to prevent any ignition, allow ignition but prevent spread, prevent ignition for a limited duration, or prevent ignition from a certain size ignition source? Oxygen concentrations that would prevent ignition (i.e., inerting concentrations) are impractical for large volumes.
- B. The occupancy of the building/room/equipment enclosure. The configuration of the combustibles in the volume are used to determine what oxygen level is needed. Parallel surfaces, enclosed volumes (i.e., boxes or totes that were filled in a standard air atmosphere), storage heights, commodity types, commodity moisture content, etc. can all affect the oxygen design concentration.

Both issues are extremely difficult if not impossible to address with small-scale testing. The goal is to use the minimum oxygen level necessary to prevent significant fire spread, and not require levels that prevent all combustion. The lower the oxygen level goes, the higher the cost to maintain it.

It is important to know how the oxygen concentration design value was generated. The currently accepted small-scale test for setting oxygen concentrations can show plywood won't burn in a standard air atmosphere. Using limiting oxygen values developed for inerting may be lower than what is needed in a large building because that testing is aimed at preventing any ignition, not just preventing spread.

FM designed a larger scale fire test that can determine the needed  $LOC_{FP}$  for rack storage arrays (see Figures 3.2.A and 3.2.B). This test method allows replication of storage geometries, testing of real commodities, and measurement of oxygen concentrations that prevent significant fire spread that are independent of ignition source duration.

### 3.3 Evaluating System Availability

In addition to the work aimed at defining oxygen design limits, a full availability study is needed for these systems. The goal is to define the availability of an oxygen reduction system for comparison to an automatic sprinkler system. Since these systems are active systems (i.e., in operation at all times), the ability to know their availability is easier to determine than an automatic sprinkler system, which requires regular inspections to determine its availability. An evaluation of one system demonstrated that this type of system can have availabilities equivalent to or better than automatic sprinkler systems.

One critical element that was identified was the availability of replacement parts, and personnel qualified to repair the equipment. If a system fault occurs that disables all of the nitrogen generators, the building/room/equipment enclosure needs to be isolated (i.e., all openings closed and operations stopped). A properly designed enclosure will be able to maintain the reduced oxygen concentration for some time, possibly over 24 hours. Repairs need to be completed before the oxygen concentration is elevated above allowable limits.

### 3.4 Potential System Applications

Oxygen reduction systems are not fire protection systems. They are fire prevention systems or fire limiting systems (i.e., they can prevent ignition or limit fire spread, depending on the fuel and oxygen concentration). From a property loss prevention standpoint, it may be beneficial to use this type of system in very high-value occupancies that are susceptible to nonthermal damage, or occupancies where the use of sprinklers is either very challenging and expensive, or for which there is no available design.

Long-term energy costs for oxygen reduction systems are high because the system is normally in operation. Automatic sprinklers, on the other hand, present limited long-term costs (i.e., periodic inspection and maintenance).

In addition, due to the required oxygen concentrations, these systems should only be used in a space that is not normally occupied. Various codes and regulations define "normally occupied" differently. The simplest way to define this targeted type of enclosure is as a confined space.

#### 3.4.1 Storage Enclosures Inside Protected Buildings

The easiest application for these systems is to protect enclosures inside sprinklered buildings. There are storage units for extremely high-value molecular samples, product samples, rare books/documents, and computer tapes, which would all be lost if a fire grew to the point that it operated an automatic sprinkler. Even the use of a clean agent system creates challenges in these enclosures due to over-pressurization concerns and potential damage due to the decibel level associated with the gas discharge. This type of scenario lends

itself to strong prevention efforts to achieve a good level of property protection. These systems can easily be applied to these types of scenarios, and automatic sprinklers could still be provided in these enclosures as a last line of defense.

### 3.4.2 Automatic Storage and Retrieval System (ASRS) Warehouses

ASRS warehouses rely on robotic retrieval of stored commodity. These warehouses typically use open top combustible containers to hold the commodity to ensure consistent robot functioning. These spaces are commonly unoccupied due to the electrical and physical hazards associated with the robots that operate in the aisles between the racks. In many cases, the roof height is in excess of 40 ft (12 m). The use of open top containers makes using ceiling-only sprinkler protection impossible and instead requires numerous levels of in-rack sprinklers. The extreme storage heights also severely challenge ceiling-only sprinkler designs, as well as final extinguishment of the fire. Manual firefighting efforts are unable to extinguish a fire at high elevations within the racks, and the robots make accessing even the lower levels of the racks challenging.

### 3.4.3 Deep Freezer Buildings

These occupancies are challenging to provide automatic sprinkler protection for because, even with specially designed water control valves, an accidental system trip will require the removal of all of the sprinkler pipe so it can thaw out. Additionally, failure to control the moisture levels in the piping can produce ice plugs that are difficult to identify.

### 3.4.4 RP 1 (Tissue) Paper Storage Warehouses

RP 1 paper is typically stored in an open array due to handling practices. Full-scale sprinkler testing has demonstrated that open array storage of RP 1 cannot be protected using automatic sprinklers. Data Sheet 8-21, *Roll Paper Storage*, doesn't currently have any protection options for open array storage of RP 1. More work is needed to define the required oxygen level for this type of storage.

### 3.4.5 Rooms and Buildings with High-Voltage Electrical Equipment

One example of this type of occupancy is high voltage direct current (HVDC) converter stations. The valve hall normally has plastics, and older halls can have large quantities of mineral seal oil. Getting automatic sprinklers in this type of occupancy is very challenging due to the severe electrical hazards in the space. Oxygen values for mineral seal oil still need to be developed, but if a value is not available, using the limiting oxygen concentration for mineral seal oil will work.

## 3.5 Challenges in Using This System as Building Protection

Beyond knowing the oxygen concentration to limit fire propagation, there are several other issues to address with the installation of this type of system in a building/room/equipment enclosure that does not have automatic sprinklers.

A. How to facilitate building access for repairs or maintenance needs to be determined. Sprinkler system shutdown is not something that is frequently needed unless work is required on the sprinkler system itself. Raising the oxygen levels for regular maintenance should not be a normal procedure. When the oxygen levels are increased above the oxygen design point, the system should be considered impaired.

B. Fire service response will need to be clearly defined. Fire service personnel enter buildings to fight and extinguish fires, or at least confirm the lack of a fire. Allowing air into a building with an oxygen reduction system could initiate regrowth of the fire without any fire protection in the volume. Sites with building/room/equipment enclosures that have reduced oxygen environments will need to work with their fire service to develop a plan for responding to a fire that maintains the oxygen design point in the volume.

## 4.0 REFERENCES

### 4.1 FM

Data Sheet 5-48, *Automatic Fire Detection*

Data Sheet 7-17, *Explosion Protection Systems*

Data Sheet 7-59, *Inerting and Purging Vessels and Equipment*

Data Sheet 8-21, *Roll Paper Storage*

Data Sheet 10-7, *Fire Protection Impairment Management*

The *Approval Guide*, an online resource of FM Approvals ([www.fmaprovals.com/approval-guide](http://www.fmaprovals.com/approval-guide))

#### 4.2 Other

European Standards (EN). EN 15004, *Fixed Firefighting Systems. Gas Extinguishing Systems. Part 1: Design, Installation and Maintenance*.

International Organization for Standardization (ISO). ISO 14520-1, *Gaseous Fire-Extinguishing Systems: Physical Properties and System Design: General Requirements*.

National Fire Protection Association (NFPA). NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

VdS Schadenverhütung GmbH (VdS). VdS 3527, *Oxygen Reduction Systems: Planning and Installation*.

#### APPENDIX A GLOSSARY OF TERMS

**Confined space:** A space with substantially limited entry and egress and not normally occupied. OSHA in the US and the HSE in the UK define “confined space” as follows:

OSHA:

1. A space large enough for an employee to enter and perform work;
2. A space that has limited or restricted means for entry or exit; and
3. A space that is not designed for continuous occupancy.

HSE:

1. A place which is substantially enclosed (though not always entirely), and
2. A place where serious injury can occur from hazardous substances or conditions within the space or nearby (e.g., lack of oxygen).

**Limiting oxygen concentration for fire propagation (LOC<sub>FP</sub>):** The concentration of oxygen determined by an adequately scaled test to successfully limit fire spread within a storage array or occupancy.

**Oxygen design point:** The concentration of oxygen in a building/room/equipment enclosure to successfully limit fire spread, accounting for the accuracy of the sensors used to measure the oxygen concentration and any other factors that can create uncertainty in the measured value.

**Oxygen reduced space:** Space in which the oxygen concentration of the atmosphere is reduced by technical means for the purposes of fire protection.

#### APPENDIX B DOCUMENT REVISION HISTORY

**July 2023.** Interim revision. The following changes were made:

- A. Provided other options to maintaining the needed nitrogen concentration for 12 hours within a room/building/equipment enclosure due to loss of power.
- B. Clarified how to handle O<sub>2</sub> sensor uncertainty when calculating the oxygen design point.
- C. Provided additional options for achieving N+1 nitrogen generator designs.
- D. Provided additional information on where to provide O<sub>2</sub> sensors and how many sensors are needed for much larger building volumes.
- E. Provided additional information on O<sub>2</sub> sensor maintenance and replacement schedules.
- F. Provided guidance for protecting ASRS storage arrays.
- G. Provided guidance for protecting frozen foods.

**October 2021.** This is the first publication of this document.