MedGas Insights
from BeaconMedæs

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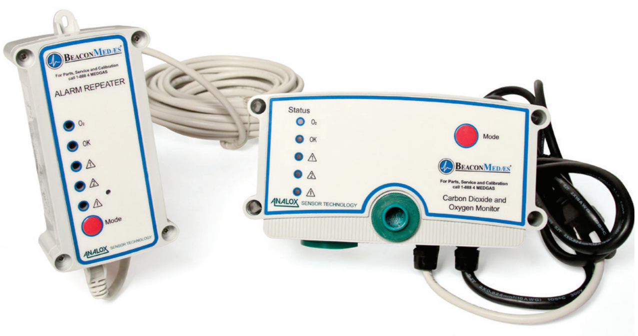
Oxygen Depletion and Med Gas Safety



You are almost certainly aware of the requirement for ventilation in manifold rooms and for specific signage on the manifold room door, and perhaps have seen some of the precautions required for "confined space entry" by OSHA. But you may not have considered why these rules exist.

You can start by demonstrating the problem for yourself. Simply hold your breath as long as you can possibly manage (harder now, that wasn't even trying...) If you're in high training, you might manage to hold it for a minute or two. Most of us wouldn't manage even that. Now recall the panicked feeling you had that last moment before you started breathing again. Think of having that same panic caused not because you're voluntarily holding your breath, (which you can stop any time) but because there simply isn't enough oxygen in the gas you're breathing.

We can't live without oxygen, and the length of time we can live without it is frighteningly short. Most people will be dead after eight minutes. Worse, they may fall unconscious much faster - it's said you get two breaths in an oxygen deficient room before you will not be able to get out of the room unassisted.

It is this hazard more than any other that is relevant in medical gas work. We routinely confine large volumes of gases in small rooms, and these gases (with the obvious exceptions of oxygen and medical air) are considered "primary asphyxiants" which is the fancy way of pointing out that the largest hazard if they get

What Happens?

When the amount of oxygen available to breathe begins to fall, there are specific and well documented physiological effects on the body and equally important, the brain.

Oxygen level	Effect
19.5%	**Minimum permissible oxygen level**
19.5% – 15%	**Decreased ability to work strenuously. May impair coordination and may induce early symptoms in persons with coronary, pulmonary, or circulatory problems**
15% – 12%	**Respiration increases in exertion, pulse up, impaired coordination, perception, judgement.**
12% – 10%	**Respiration further increases in rate and depth, poor judgement, lips blue.**
10% – 8%	**Mental failure, fainting, unconsciousness, ashen face, blueness of lips, nausea, and vomiting.**
8% – 6%	**In 8 minutes, 100% fatal. In 6 minutes, 50% fatal. In 4-5 minutes, recovery with treatment.**
6% – 0% (4%)	**Coma in 40 seconds, convulsions, respiration ceases, death.**

After "The Unseen Menace" © SCOTT INSTRUMENTS loose is that they will dilute the oxygen in the air below the normal 20.9%.

Under NFPA 99, there are several things required to minimize this hazard:

1. Every manifold room must be ventilated. It used to be that only a single opening was required, but now one opening at floor level and one at ceiling level are the minimum requirement. Once the total amount of gas in the room gets beyond 3,000 ft^3,(1) there is an additional requirement for mechanical ventilation adequate for 10 air changes per hour (2).

2. All the relief valves need to be piped to outside, so if the relief valve operates, the gas does not vent into the room. (obviously, one also needs to think about the place where the vent line will terminate, or casual passerby may be in for a surprise !)

3. Signage must be placed on the doors warning workers not to enter without taking care to ventilate the room first.

Is there a problem?

Let's do a little math. A cylinder of nitrogen holds about 230 ft^3 of gas. If the manifold room is say 10 feet deep x 10 feet wide by 8 feet high, it holds 800 ft^3. So if one cylinder empties itself into the room, we are going to dilute the air in the room by about 25%. If we started with 21% oxygen, the oxygen in that room will be dropped to about 15%. Two cylinders would drop us to 11%, three to 5%.

Nitrous oxide and Carbon dioxide are worse, since the contents of a single cylinder is much greater. For Nitrous oxide, the discharge of a single cylinder in that same room would drop the oxygen level to 6%, and the level of nitrous oxide itself would be about 70%. Similarly, a cylinder of carbon dioxide would dilute the oxygen to about 10%, and the carbon dioxide itself would reach about 54%. Obviously, with Nitrous or CO_2 there is the physiological effect of the gas itself to consider. A dentist typically uses a 50-50 mix of oxygen and nitrous to work on your teeth. Under those conditions you are pretty heavily sedated and aren't going to be walking around. At 70% nitrous with no oxygen the effects are likely to be immediate and probably fatal.

The Canadian Center for Occupational Health and Safety says this about exposure to elevated CO_2:

"Concentrations greater than 10% have caused difficulty in breathing, impaired hearing, nausea, vomiting, a strangling sensation, sweating, stupor within several minutes and loss of consciousness within 15 minutes. Exposure to 30% has quickly resulted in unconsciousness and convulsions. Several deaths have been attributed to exposure to concentrations greater than 20%."

Nasty enough for certain, and we have not even discussed really unpleasant gases that can be found in manifold rooms like anaerobic mixtures, nitric oxide or the various research gases and mixtures sometimes used.

Now one would think that the ventilation requirements would protect us from any ill effects, but let's consider that. If I release that cylinder of CO_2 in our example room, and my little ventilation fan is working at the regulation 10 air changes per hour, Detail 2.1 shows roughly how long it takes for the room atmosphere to return to normal.

Detail 2.1

Recovery Following A Single Cylinder Discharge into a 800 ft^3 Manifold Room

	Carbon Dioxide		*Nitrous Oxide*		*Nitrogen*	
Cylinder Contents	434 ft^3		558 ft^3		226 ft^3	
(10 air changes/hr)	O_2 Level	CO_2 Level	O_2 Level	N_2O Level	O_2 Level	N_2 Level
Start	21%	0%	21%	0%	21%	78%
Discharge	10%	54%	6%	70%	15%	83%
5 Minutes	15%	25%	13%	32%	18%	80%
10 Minutes	19%	15%	18%	20%	20%	79%
15 Minutes	20%	11%	20%	14%	21%	79%
20 Minutes	21%	8%	21%	11%	21%	79%
30 Minutes	21%	6%	21%	7%	21%	79%
45 Minutes	21%	4%	21%	5%	21%	78%
1 Hour	21%	3%	21%	4%	21%	78%
2 Hours	21%	1.3%	21%	2%	21%	78%

Even two hours after a single cylinder discharge, detectable levels of nitrous oxide and carbon dioxide would linger in this room. So although our ventilation and air changes will help us prevent accumulation because of small leaks as they are intended to do, they would not prevent a problem with a sudden large scale release of gas such as would follow failure of a pigtail or cylinder relief. For five to 30 minutes or so following a sudden release (depending on the gas involved), the atmosphere in the room would be hazardous to anyone entering the room.

What else is likely to happen when a catastrophic failure occurs? Well, of course it is likely that an alarm will be triggered. The alarm most likely would be changeover (since the manifold is designed to keep supply running as first priority) or a low level alarm. The normal reaction to either of these alarms is of course to go into the manifold room and change cylinders - *exactly what will put the worker at most risk!*

NFPA 99 does not ignore this risk - there is a requirement for signage to warn the worker. Here are the two signs required.

With oxygen and air only:

CAUTION

MEDICAL GASES INSIDE

No Smoking ~ No Open Flames

With other gases and mixtures:

CAUTION

MEDICAL GASES INSIDE

No Smoking ~ No Open Flames

ASPHYXIATION HAZARD

Room may have insufficient oxygen! Open Door and allow room to ventilate before entering

So in summary, NFPA's ventilation requirement helps prevent accumulations from occurring due to ordinary leaks, and signage is used to attempt to compensate for more catastrophic failures. The problem is that gases are odorless, colorless and therefore undetectable without special instruments. The worker does not have these, and of course is used to just going in there and getting the job done. They plough into the room, they take their first breath, and...

Under the OSHA (Occupational Safety and Health Administration) definition, all manifold rooms should be treated as confined spaces :

"A confined space has limited or restricted means for entry or exit, and it is not designed for continuous employee occupancy. Confined spaces include, but are not limited to underground vaults, tanks, storage bins, manholes, pits, silos, process vessels, and pipelines. OSHA uses the term "permit-required confined space" (permit space) to describe a confined space that has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere..."(3)

The OSHA regulations for Confined Space entry are quite detailed. They speak of more than one individual, pre-entry gas testing, defined hierarchy of responsibilities, continuous attendants, and a host of other rules which together are probably more elaborate than required in the average health facility setting.

In the laboratory world, many labs have found a satisfactory middle ground by requiring a monitor for the room air which allows the worker to know if the room is safe before entering. Called Oxygen Depletion monitors, they are a very useful and inexpensive way to ensure the hazard is recognized and mitigated.

Typically the monitors work by installing a simple sensor with an annunciator in the room and a remote annunciator or alarm outside the room (ideally near the door handle). They give a visual indication of the atmosphere in the room (usually a green light) if all is OK, and a red indicator and alarm horn or buzzer if the room oxygen is low. A simple glance will allow the worker to know if entering the room is safe. In the event an accident occurs while the worker is physically in the room, they will also give warning and should allow the worker time to exit the room. They can be obtained with remote contacts for connection to a master alarm as well.

BeaconMedaes is recommending the installation of Oxygen Depletion monitors for any manifold enclosure which is not open air (obviously they would be unnecessary if your manifolds were outdoors and the enclosure was a chain link fence) and which contains asphyxiant or toxic gases. This would include any enclosure, whether provided with natural or mechanical ventilation.

Exceptions would be enclosures which contain ***only*** air, oxygen and/or mixtures with oxygen content equal to or greater than 20% (e.g. Helium-oxygen mixtures, O_2>20%).

This provision has been added to our general guide spec as follows:

Manifold Room Oxygen Depletion Monitors

1. *Furnish each manifold room with an oxygen depletion monitor mounted in the manifold room at 1.2 meters (4 feet) AFF in a protected location where cylinders will not damage the sensor or alarm. Monitors indicate oxygen low level at 19.5% or less and a second indication at 18% or less. Audible and visual indication is provided.*
2. *Provide audible and visual indicator outside door at 1.5 meters (5 feet) AFF to alert operator prior to entry. Label "Atmospheric Oxygen Content Low – Do Not Enter".*
3. *Monitors are provided with volt free contact for connection to master alarm.*

Depending on the gases in the room, different monitors may be required. Carbon Dioxide will produce a false "oxygen" level with many monitors, and a separate CO_2 detection sensor is required by OSHA for rooms which contain CO_2 or mixtures containing CO_2. It is very important to use the correct monitor type.

Some Questions You May Have.

Is the oxygen depletion monitor a requirement of NFPA 99, now or in the proposed 2012 edition?

No. It has been written into some local regulations (for laboratories primarily) and therefore is becoming quite common in the lab world. Some engineering firms who work with both medical and laboratory clients have seen the merit of this and are have been including these devices in their specifications. An interesting example of where these are being recommended is the EIGA IGC 44 specification(3) (which is also an interesting reference document to understand the risks associated with gases).

Is OSHA requiring this or inspecting for it?

Not in medical facilities (that we have heard about). OSHA has apparently been more stringent with laboratories.

Have there been fatalities?

Regrettably, yes. The OSHA web site references several confined space incidents. However, fortunately, we are not aware of any on the medical side.

Is catastrophic release of gas common?

Not at all. Catastrophic failure falls into the "rare but serious" category of the risk analysis matrix.

The biggest problem in manifold rooms by far is small leaks which adequate ventilation should handle. This category typically encompasses normal boiloff from liquid containers too.

Catastrophic release of the type that concerns us here would be most commonly caused by the failure of a pigtail (most hospitals don't pay them much attention until they break) which could in turn empty a whole cylinder or bank of cylinders, most likely while the worker is in the room changing them. Much more rare would be failure of a cylinder relief valve. Most of the other possibilities are adequately covered if the manifold and manifold room is designed and piped per NFPA 99.

Can these devices be retrofit to existing facilities?

Yes, very easily. The sensors are simple wall mounted devices that you would typically place in the manifold room at waist or counter height and would plug into any convenient plug. The repeater or remote annunciator would be mounted on the wall outside the room. A simple cable connects the two. You can get more elaborate, but certainly this simple set up will cover the worker very well.

Should they be?

As with any worker safety initiative, it's up to the facility to decide their tolerance for risk. Naturally, one should begin by examining the enclosure(s) and considering whatever procedures and training is in place for worker safety already (various guidelines exist, for example the DOE-STD-5503-94 *EM HEALTH AND SAFETY PLAN GUIDELINES* issued by the Department of Energy). Certainly a monitor is not the only way to address this hazard.

Should the alarm be repeated at the master?

That's a useful idea but certainly not required to achieve the desired result. The important alarm is the one at the door that warns the worker to stay out of the room and therefore out of harm's way.

Some References.

(1) NFPA 99 2005 5.1.3.3.3, 5.2.3.3 and 5.3.3.6

(2) ASHRAE 170 "Ventilation Requirements for Health care Facilities" - 2008 and AIA "Guidelines for Design and Construction of Health Care Facilities" 2006

(3) http://osha.gov/SLTC/confinedspaces/index.html

(4) European Industrial Gas Association IGC Document 44/09/E