Understanding Oxygen in Your Atmosphere

by Captain Carlos Vazquez

Recently on a trip to Colorado Springs, the author had an opportunity to visit Pikes Peak. At 14,110 feet above sea level, it is the 31st tallest mountain in Colorado. In comparison, many parts of Manhattan are only about five feet above sea level. The tallest building, the soon-to-be-completed 1 World Trade Center (the Freedom Tower), will stand at only 1368 feet above sea level.

When the author arrived at Colorado Springs, he was curious about the "thin air" he would encounter at the higher altitude and how it would affect him. In the past, he has run at altitudes up to 5000 feet and didn't believe the Colorado atmospheric change would have any effect on him. Unfortunately, he discovered that he was wrong. As he rushed off the top of Pikes Peak, he found himself lightheaded and made his way to safer ground. He was embarrassed and, as most Firefighters, probably would rather fall flat on his face unconscious, than to admit there was a problem.

Oxygen, as he learned during his misadventure, is something that cannot be taken for granted. Thus, the objective of this article is to help Firefighters better understand oxygen in their atmosphere, especially during emergency situations. Additionally, the use of a basic oxygen-sensing meter (such as the MSA Altair), in conjunction with self-contained breathing apparatus (SCBA), can be used to better protect Firefighters in these kinds of situations.

In the past, with little or no warning, members on the New York City Fire Department have been incapacitated or even killed by toxic gases. These deaths and injuries have occurred at fires, as well as emergencies, above and below street level, such as subway incidents when members become incapacitated due to elevated levels of carbon monoxide. Without oxygen, a Firefighter will be in plenty of trouble.

FDNY members should be careful not to become complacent or give in to peer pressure when investigating odors, gases and vapors (known or unknown). Respirator protection (SCBA) should always be used or at the ready by Firefighters at an emergency.

In the military, members are taught that when toxic gases are encountered, they should:

- Hold their breath.
- Don their protective mask.
- Clear the mask to get any residue contamination out of the facepiece.
- Alert others and then continue the mission.

The author (a veteran of the U.S. Army) is not advocating waiting for an emergency situation to don the facepiece. However, there are times when Firefighters must have their facepiece in a standby position and be able to don it quickly and efficiently when alerted by monitoring meters or coming across any biological indicators, such as incapacitated animals/people. Always follow proper FDNY Mask standard operating procedures (SOPs).

This is the air we breathe

Air contains roughly:

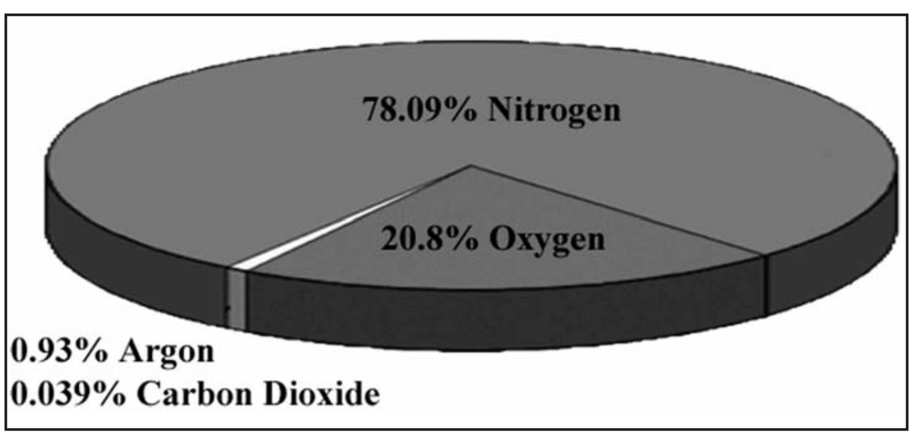
- 78.09 percent nitrogen
- 20.95 percent oxygen
- 0.93 percent argon
- 0.039 percent carbon dioxide
- small amounts of other gases

The 20.95 percent oxygen figure is based on the assumption that the air contains no moisture. Air contains a variable amount of water vapor (humidity), which averages approximately one percent. This is why a value of about 20.8 percent oxygen may be more appropriate (as indicated in the chart below) than 20.9 percent, because it takes humidity into account.

OSHA's Title 29 Code of Federal Regulations 1910.146(b) defines a hazardous atmosphere as one "[...] that may expose employees to the risk of death, incapacitation, impairment, or ability to self-rescue, injury or acute illness from one or more of the following causes [...]." The standard then goes on to list five causes, one of which is "[...] atmospheric oxygen concentration below 19.5 percent [...]." All FDNY oxygen-sensing meters are set to alarm when an oxygen level of 19.5 percent is reached.

Under pressure

Key to understanding the human body's interaction with oxygen is atmospheric or barometric pressure. Normal atmospheric air is calculated at 68 degrees Fahrenheit at sea level and has a pressure of 760 millimeters of mercury (mmHg). Because the atmosphere contains approximately 20.8 percent oxygen, the oxygen contributes to only about 21 percent of the total atmospheric pressure



of the 760 mmHg, which is roughly a partial pressure of 159 mmHg. When we breathe in air, it enters our body and is further humidified, thus lowering that pressure even more.

Oxygen diffuses to the capillaries of the alveoli in the lungs, while the carbon dioxide is expelled from the body through the capillaries. The driving force for the gas exchange is the pressure difference. Higher oxygen pressure outside the body allows oxygen to flow from the lungs into the blood. If the outside oxygen pressure is lower, the pressure of oxygen in the lungs also will be lower and will not enter the body properly.

At higher altitudes, such as Pikes Peak, the same percentages of oxygen and nitrogen are present as at sea level. However, because the pressure outside the body is less at higher altitudes than that found at sea level, the oxygen has difficulty diffusing into the capillaries of the lungs. In turn, this causes dizziness and eventually loss of consciousness.

Left to right are the meters carried by FDNY Firefighters: MSA Altair Meter, BW Technologies GasAlert Extreme CO Meter and the TIF 8800 Combustible Gas Detector. For detailed information regarding these individual meters, members are urged to review "Introducing the MSA Altair Multigas Meter," by Captain Carlos Vazquez, in the 1st/2009 issue of *WNYF*.

The barometric pressure normally drops about three percent for each 1000 feet above sea level. (Barometric pressure is atmospheric pressure as indicated by a barometer. As we go up, the pressure around us drops, just as gravity drops as we become weightless in higher atmospheres. Because this pressure drops, the force that is needed to allow oxygen into our blood stream is diminished, thus causing lightheadedness.) For example, the barometric pressure at the top of 1 World Trade Center (1368 feet) would drop to approximately 719 mmHg from 760 mmHg at sea level. If the author had brought an oxygen meter with him to Pikes Peak, it would have shown an oxygen level at 20.8 percent, which is considered normal. But the lower pressure surrounding him prevented the oxygen from properly entering his body, which is what caused his lightheadedness.

This may appear to be insignificant since FDNY members work in New York City. However, factors such as these must be taken into consideration, especially during emergency situations when there is unusual humidity, temperature or other gases present that can displace oxygen, causing similar effects.

Oxygen displacement

Oxygen-sensing meters, such as the MSA Altair, are intended to detect situations where atmospheric oxygen has been displaced by other gases. Using round numbers, the air consists of 21 percent oxygen and 79 percent nitrogen. That makes the ratio of nitrogen to oxygen about four to one. This means that as atmospheric air is displaced, every one-percent change in the oxygen level on the meter will be accompanied by a four-percent change in the nitrogen level. This occurs because both gases are displaced at the same rate. If carbon monoxide enters the room, it doesn't just push out the oxygen alone; it pushes out both oxygen and nitrogen in the same proportions.

Firefighters need to be vigilant of changes in the atmosphere during an emergency situation. This is especially true of oxygen levels, not simply because Firefighters need to breathe, but because changes in oxygen levels are a true indicator, presenting a possible greater danger at the scene.

For example, if the oxygen levels drop one percent from 20.8 percent to 19.8 percent, the meter will not alarm. But members should be alerted because a one-percent drop in oxygen translates to a total of five percent of the total atmosphere or 50,000 parts per million of "something" else, which is displacing the oxygen and nitrogen in the area. The "something" could be an inert gas, something dangerous such as ammonia or a low flammable range gas.

However, members should understand that not just the oxygen percentage goes down. As the percentage lowers, so does the pressure of the oxygen, producing effects similar to that of a higher altitude, which may cause dizziness, unconsciousness or even death.

Summary

Whether above or below ground during an emergency situation, when the environment changes, so can the oxygen content. This can be in percentage, which can affect the pressure, which can affect Firefighters' breathing.

If entering a known or suspected toxic or oxygen-deprived area, SCBA must be worn.

Even if the oxygen readings are above 19.5 percent, hazardous concentrations of gases and vapors may still be present. Some gases and vapors may be present at concentrations that are toxic, while simultaneously below a combustible gas meter's limit of detection.

No one meter can provide all information. Members should use all available meters when investigating odors, fumes, gases and vapors. Meters available to the majority of ladder companies are the TIF 8800 Combustible Gas Detector, MSA Altair and the BW GasAlert Extreme CO Meter. SOC Support Ladder Companies do not carry the MSA Altair Meter.

If the oxygen level in an area is anything other than 20.8 percent, Firefighters should ask themselves, *Why?* If an answer is not forthcoming, request a Haz-Mat specialized unit via the dispatcher.

About the Author...
Captain Carlos Vazquez a 27-year veteran of the FDNY. He is assigned to Ladder 46. Prior assignments include Ladder 51, Engine 33 and Haz-Mat Operations. He is trained to the Haz-Mat Specialist level. This is his third article for WNYF.