Gas and Vapor Detection Instruments for Industrial Health and Safety Applications
680 Fairfield Court, P.O. Box 979, Ann Arbor, MI 48106-0979, Phone 734-761-1270, Fax 734-761-3220
web: www.enmet.com e-mail: info@enmet.com

TECHNICAL ADVISORY
Helium Enhanced Oxygen Monitoring Aberration Phenomena
July 20, 2001

1. Introduction

In recent weeks an awareness has developed within the high tech community of erroneous behavior of certain oxygen monitors due to the presence of Helium gas in the ambient atmosphere. Aerospace research, medical diagnostics, particle physics, and semiconductor processing sites have reported oxygen concentration readings of significant error when the atmosphere under test is not just "air" (20.9% O_2/78.1% N_2), but air with moderately higher level of Helium gas co-existent. The phenomenon normally occurs when a routine safety monitor alarm for oxygen is challenged by an atmosphere of decreasing oxygen levels due to increasing Helium gas levels (often as a result of a leak or spill of liquid Helium in use for cryogenic cooling). By contrast, increasing levels of Nitrogen, CO_2, Freon, Argon, etc. seem not to cause the observed aberrant oxygen readings. Furthermore, the Helium-Enhanced Oxygen Aberration (here after referred to as "HEOA") is apparently unique to capillary diffusion barrier type oxygen sensors and not the oxygen micro fuel cell type, otherwise known as the partial pressure or galvanic cell. Capillary diffusion barrier style oxygen sensors have historically been manufactured by a United Kingdom sensor maker, but newer vendors have appeared as various sensor patents expire. The capillary diffusion barrier sensor is used by dozens of instrument designer/marketer firms around the globe.

2. Scenarios

Three possible scenarios might occur in an R&D lab using liquid nitrogen and liquid Helium:

- Ambient air: free of contaminants (O_2=20.9% by volume/N_2=78.1% by volume) and the monitor/alarm reads correctly 20.9% O_2.
- A leak of the nitrogen cryogen occurs such that after equilibrium a supplemental 10% by volume nitrogen diluent level occurs and the monitor alarm correctly reads 18.8% by volume O_2.
- A substantial leak of liquid Helium occurs resulting in an ambient air diluent concentration of 20% by volume Helium. The monitor/alarm reads 19.5% by volume oxygen even though the true level of oxygen is as low as 16.6% by volume. Should the leak continue and the level of Helium diluent reach 50% by volume, the O_2 monitor would eventually read 15.6% O_2 rather then the true life threatening level of 10.5% by volume O_2. This scenario is a real world example of the non fail-safe "HEOA" effect induced by elevated Helium gas levels.

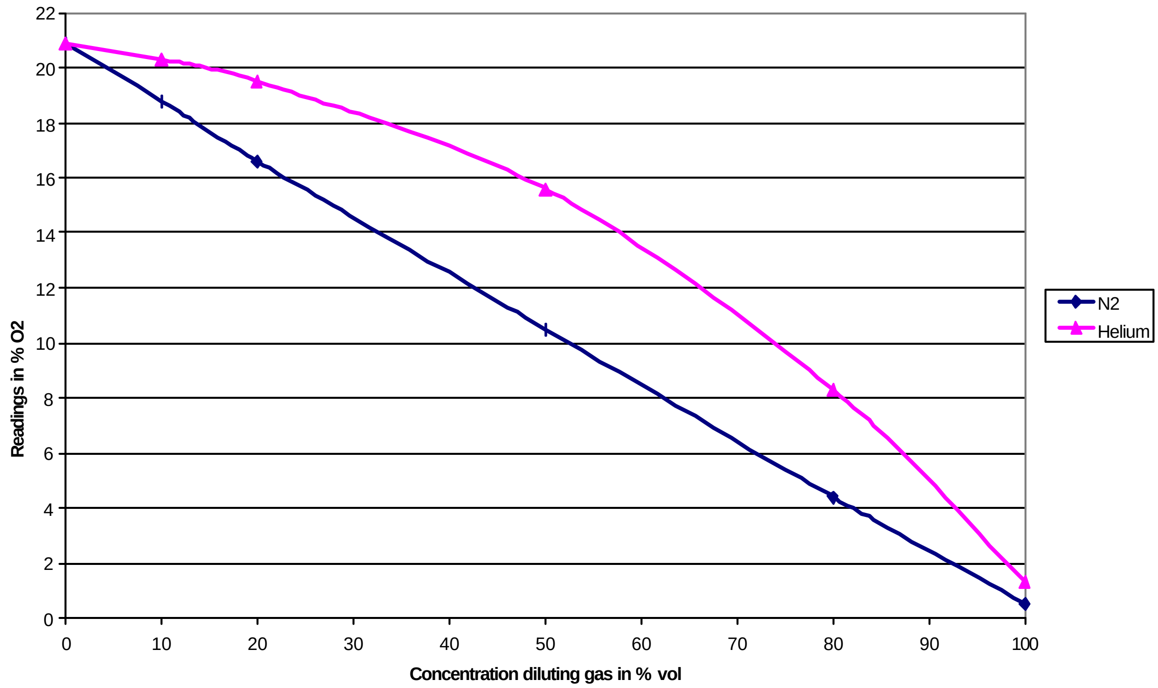
3. Significance and Solutions

3.1 The apparent basis for the incorrectly high reading of oxygen is that Helium gas favors the enhanced transport of oxygen molecules through the capillary diffusion barrier membrane. Although the sensor is not actually detecting Helium, it sees an artificially high level of O_2 due to Helium enhancement (i.e. "facilitation") of the available oxygen molecules for transport to the interior electrodes of the cell. Errors apparently as high as 5.0% by volume of oxygen have been reported when the Helium diluent level approaches 50% by volume. This non-fail safe "HEOA" effect can present a significant health and safety risk to personnel in liquid Helium spill environments.
[The above discussion is developed from curve 4.1 and its associated data table.]

3.2 Oxygen sensor modifications have been achieved that can minimize the "HEOA" effect, although not totally eliminating the phenomena. The sensor modification appears to have at the worst case, an error in the observed oxygen level of about 1.4% by volume and it now is the "fail safe" direction. For example, a 20% by volume Helium diluent level may cause an observed reading of 16.0% by volume oxygen, when the true level is 17.3% by volume oxygen, as can be seen in curve #2. One such location employing the modified oxygen sensor is in an accelerator lab in Cern, Switzerland. The attached curve #4.2 and its data table shows the improvement which may be achieved using the modified oxygen sensors over a broad range of Helium diluent levels. The curve 4.3 and 4.4 which follow the oxygen sensor response as a function of time to step function levels of 10% and 20% by volume Helium to an uncompensated sensor (Type A). Curve 4.5 shows 10% by volume Helium step function exposure to a modified oxygen sensor (Type B).

4. Results

4.1. Response Curves as a Function of He and N2 Concentrations Sensor Type A

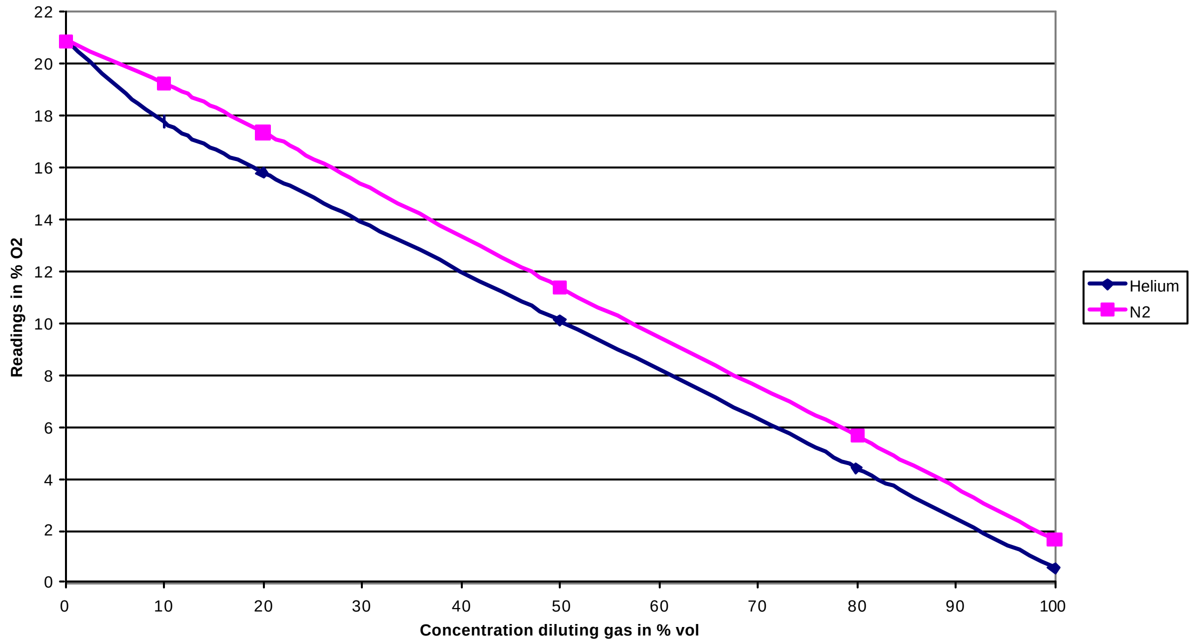


Note that the sensor readings show a false positive concentration of oxygen when the background gas is Helium. When Nitrogen is background gas, the readings are very close to the theoretical values in the table below.

Data Table for O2 sensor type A, mixtures of air with Nitrogen and Helium

	Helium	**Nitrogen**	**Theoretical**
Concentration Gas diluent (% vol)	Reading (% vol O2)	Reading (% vol O2)	Reading (% vol O2)
0	20.9	20.9	20.9
10	20.3	18.8	18.8
20	19.5	16.6	16.7
50	15.6	10.5	10.5
80	8.3	4.4	4.2
100	1.3	0.5	0

4.2. Response Curves as a Function of He and N2 Concentrations Sensor Type B

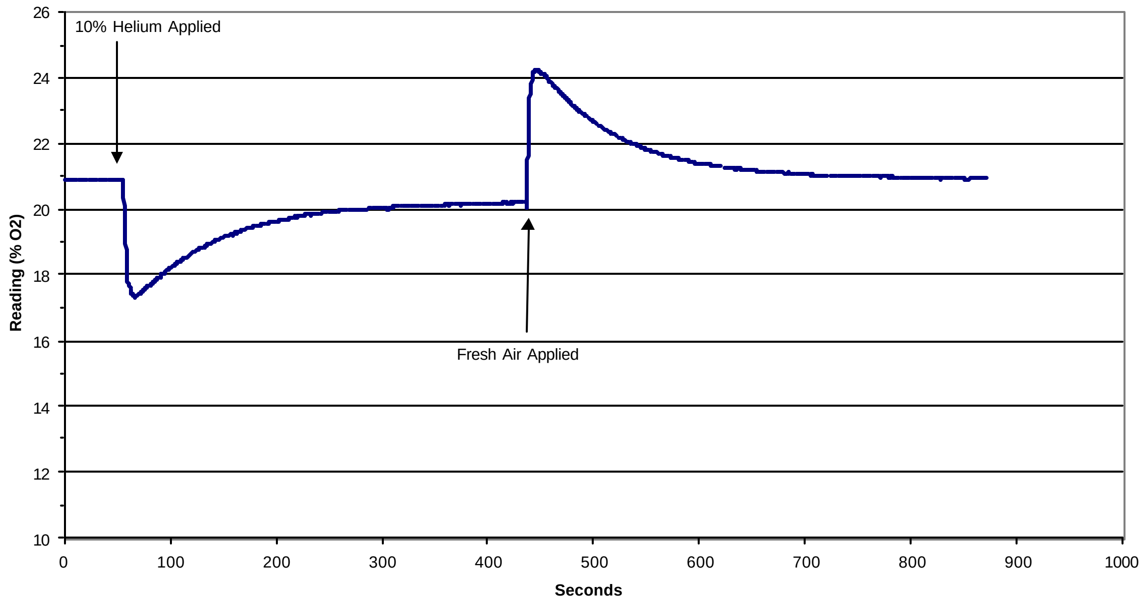


For Sensor type B, note the much more accurate readings from the oxygen sensor in the presence of helium. Note also that the readings for Helium are slightly below expected values, a failure in the safe direction. Nitrogen diluent causes readings only slightly above the theoretical values.

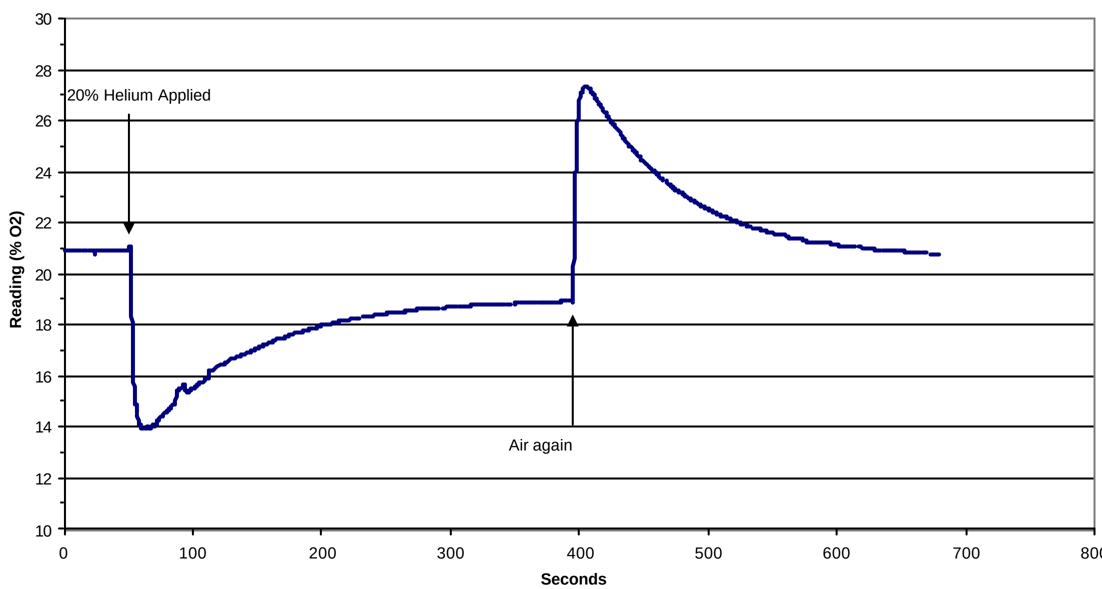
Data Table for O2 sensor type B, mixtures of air with Nitrogen and Helium

	Helium	Nitrogen	Theoretical
Concentration Gas diluent (% vol)	Reading (% vol O2)	Reading (% vol O2)	Reading (% vol O2)
0	20.9	20.9	20.9
10	17.8	19.3	18.8
20	15.8	17.4	16.7
50	10.1	11.4	10.5
80	4.4	5.6	4.2
100	0.5	1.6	0

4.3. Step Change Response Curve to 10% Helium and Fresh Air - O2 Sensor Type A

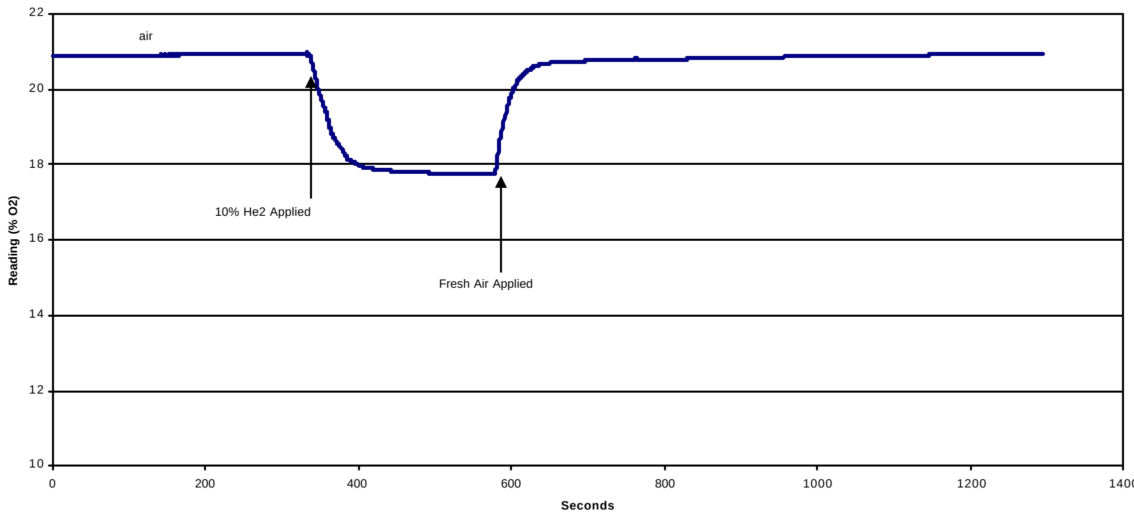


4.4. Step Change Response Curve to 20% Helium and Fresh Air - O2 Sensor Type A



In the previous graph, note the quick initial responses to the Helium shown as decreased O2 readings, followed by upward drift to a false “safe” condition. Once the Helium is removed, a substantial false positive over-recovery, then drift down towards proper levels.

4.5. Step Change Response Curve to 10% Helium and Fresh Air - O2 Sensor Type B



The step change response to 10% Helium and back to fresh air is normal for the Sensor Type B.

5. Conclusion

We can conclude from the results that O2 sensor Type A can detect the initial presence of Helium, but is not reliable for monitoring oxygen concentration accurately in a sustained Helium environment.

Oxygen sensor Type B is less affected by the presence of Helium and can be used to provide much more accurate readings of oxygen readings in moderate helium atmospheres of 10% to 25% by volume.

For more information and availability of oxygen monitors using this modified sensor technology, please contact ENMET Corporation at 1.800.521.2978 or at www.enmet.com.