Nathan Wong

Abstract

During my working term at NASA Glenn my main responsibility was to test and determine the long-term stability of a CO2 sensor that would be used in the new space suit. My work consisted of two experiments that would test for short duration and long duration stability. The status of the project is incomplete, but based on the work that I have completed the CO2 sensor has been stable throughout the fourteen weeks that I have been working on it.

Background

Carbon Dioxide is a product of human metabolism. In the earth environment the air is approximately 21% oxygen and 79% nitrogen. Exhaled air is 16% oxygen, 5% carbon dioxide, and 79% nitrogen. Exhaled Carbon Dioxide mixes with atmospheric air to dilute it to approximately 300-600 ppm. At 2% inhaled CO2 most people experience adverse effects such as nausea and headaches. 5% CO2 is the toxic level for CO2. When working outdoors in or a well-ventilated area the CO2 level is of low concern, but in a confined space such as an Extra Vehicular Activity (EVA) it is important to have a close monitor of the CO2 levels (Dietrich, 2008).

Current Solution

The current EVA suit monitors the CO2 level just as it enters the helmet to make sure the CO2 level is below a critical threshold. The current CO2 sensor utilizes the high absorption of infrared light at approximately 4.3um to determine the concentration of CO2 going through the sensor (Hamilton Sundstrand, 1997).

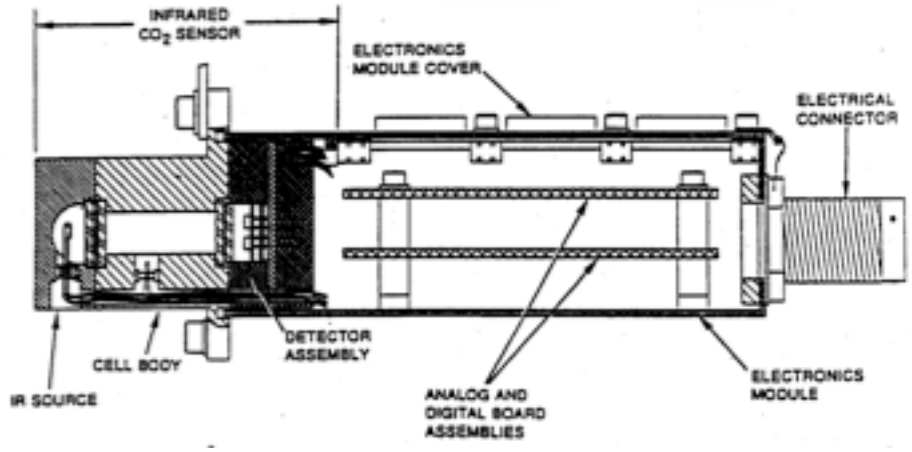

Figure 1: Current CO2 sensor

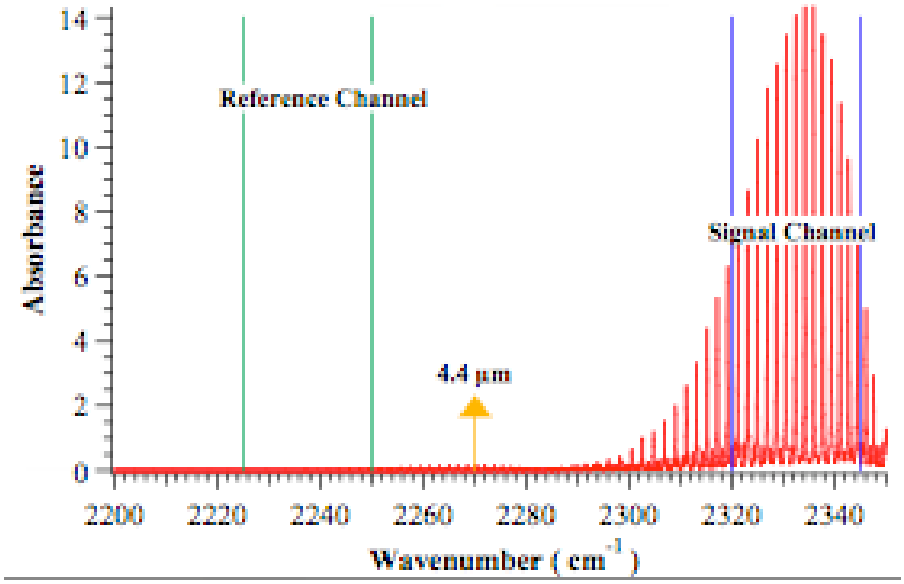

Figure 2: CO2 absorbance as a function of wavenumber

Tests

One of the tests that was completed was a short duration reading that would test for known concentrations of CO2 in 11 partial pressure increments (i.e 0, 11, 22, …) up to 77. Every 7.6 partial pressure is equal to 1% CO2 so partial pressure 77 is equal to approximately 10% CO2. These numbers were chosen because they closely represent what would be seen on a real mission. Particular interest was taking in the values that ranged from 0-22 because they most closely correspond to the values we would see during normal human breath. This test was performed once or twice daily using a mass flow controller to adjust the flow rates of a carbon dioxide, nitrogen, and a 25/75 oxygen/nitrogen gas tank. The flow rates needed for each partial pressure was already calculated and was put in a book. Readings would be taken for each partial pressure and recorded.

The second test that was completed was a long duration test. For this test the concentration of CO2 was kept at partial pressure 11 for the whole test. The test lasted one hour and readings were taken every tenth of a second for that time. This test was done to see if the CO2 sensor could maintain stable readings for an extended period of time. After both of these tests the total amount of time that the CO2 sensor was running what calculated and added to a spreadsheet to keep a total time log. This log would be used to measure the accuracy of the sensor vs. time used.

Results

For the first test the average and standard deviation was calculated for each of the partial pressures.

Partial Pressure	CO2 (V)	Standard Deviation (V)
0	.701468	.00800446
11	.57969	.0052955
22	.511647	.00344505
33	.46725	.00257029
44	.430596	.0025186
55	.403448	.00205323
66	.382052	.00270353
77	.367075	.0031434

Table 1: Results of short duration testing

These results show that the readings were not deviating significantly from reading to reading. In most cases the standard deviation is within 1%. Results of partial pressures 0-22, which are closest to human breath, were graphed to see if there was any noticeable drift.

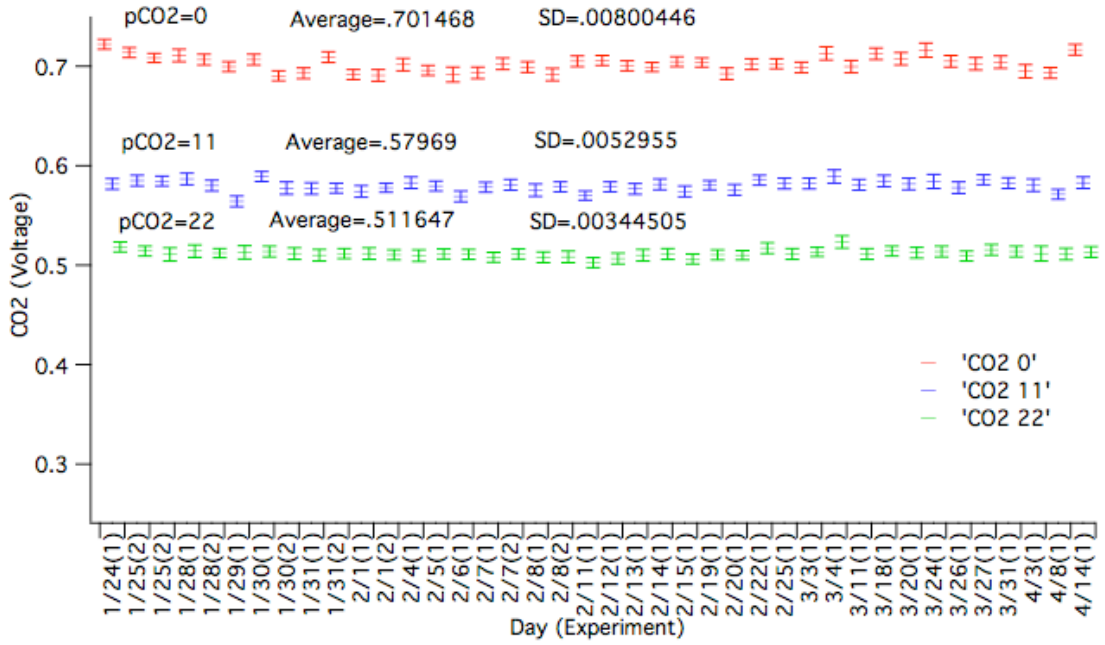

Figure 3: Graph of partial pressures 0-22 CO2 voltage vs. date of the expiriment.

From the graph it can be seen that there is no significant drift in either direction.

Sources of Error

Some sources of error could come from the fact that the numbers used in the mass flow controller to regulate the concentrations of gas is based on barometric pressure. If the pressure shifts enough during the course of a test the numbers could shift for that test. Over a long period of time these shifts would go both up and down canceling each other out. This could account for some of the jumps in the graph, but you can see that the jumps go both ways. This effect would have the most influence on the long duration test.

Future Work

More work is needed on this project. The sensor needs to have an operation life of 16,800 hours and a calibration time of 6 months. The amount of testing that has so far been done is not equal to that. Continued testing in the methods described earlier would be advisable.

Also two commercial sensors were purchased. One was an infrared sensor like the one in use currently and another was an electrochemical cell. Tests should be performed on both of these sensors and compared to the current tests.

In the lab there is a Servo Ventilator unit, which is used for life support. Through use of its control panel a method for simulating human breathing patterns could be used to test the sensors in a changing concentration environment.

A final test that should be performed is the evaluation of the sensor in a near vacuum environment. This test is important because of the environment that the sensor will operate in. If the sensor is not able to perform at very low pressures it would not be of much use in a mission.

Conclusion

The testing that has been completed so far on the CO2 sensor shows good reliability in the sensor with little drift. This is the main focus of the work so far. More of the same testing should be done to continue to monitor the accuracy of the sensor. Also some simulated use tests such as vacuum and breathing tests should be conducted, along with similar tests using different types of CO2 sensor technologies.

Sources

Dietrich, D.L, Paul, H., Conger, B., "Carbon Dioxide Sensors for EVA suits- Current Status and Trade Study, 2008

Hamilton Sundstrand (1997). Design specification for transducer, carbon dioxide, infrared. Design Specification SVHS13466, Hamilton Sundstrand - A United Technologies Company, Windsor Locks, Connecticut.