Demand Controlled Ventilation using CO_2 Sensors in a Wireless Sensor Network

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Abstract

The focus of this research project was to investigate Indoor Air Quality (IAQ) monitoring technologies, government regulations and policies, and best practices to improve IAQ. The goal was to minimize the adverse effect of poor IAQ in direct relation to CO_2, by designing and testing demand controlled ventilation applications. The investigation involved: development of a cost effective indoor air quality prototype sensor unit for CO_2 levels; the testing of the unit in a simulated room environment; and collection of the data from testing. The data from the simulations was then compiled and analyzed. Additionally, literature review was instrumental in determining testing parameters and conducting experiments. This provided valuable experiences which will be shared with the educational community.

Background

With the heightened concern over indoor air quality (IAQ), the interest in monitoring the air quality and the cost of those monitoring systems has drastically increased. The most common types of inside monitoring are done with individually purchased units for the home (i.e. carbon monoxide and smoke detectors). Typically, professional gas sensor units cover a wide variety of gasses and measure them to very sensitive concentrations. The use of these units is constrained by high cost and they are generally used only when a problem has been reported. In order to have a more comprehensive picture of what is happening with IAQ, a more cost effective; early warning and ventilation system needs to be developed.

Professional grade monitoring systems researched included PPM technologies wireless IAQ profile monitor. Each of these units can monitor 3 to 7 parameters via a wireless network. The manager PC connects to a mesh network via a special node which is capable of receiving and transmitting information to the IAQ profile monitors. The manager PC can view, run, and control the real time monitoring and data logging of air quality in a building at the click of a button. The PPM monitoring software enables the data gathered to be viewed graphically, produce reports with statistical data, and run schedules as well as alarm functions and notifications for more effective and economical building management.

Although the PPM monitoring system is a good idea, its major limiting factor is cost. This reduces expansion of the PPM monitoring system for the general public. Each network setup has to have a controller equipped with a zigbee wireless module antenna, and mounting stand which only comes configured for temperature and relative humidity (RH). The base model costs $856.62 and each additional sensor function plus the installation is an additional cost. The maximum number of parameters is 6. The remote sensors which communicate with the controller unit are the same scenario. The remote sensor comes equipped for temperature and humidity and can be configured for up to 8 sensor functions. The base remote sensor costs $779.61 and can function as a stand-alone unit. It is said that “Having a product giving real time monitoring will give immediate warning of over exposure to toxic or harmful gases [1]. For maximum efficiency a network of these sensors would provide a more comprehensive picture of a large building’s air quality, but the cost of such a venture could also be astronomical. Additionally, this product would not be compatible or cost effective for use with “demand controlled ventilation” applications.

The primary professional grade monitoring system researched is the Gray Wolf Direct Sense IQ 610 monitoring system. This system is also the professional system which was available for comparison testing with our prototype sensor assembly.

The IQ610 monitoring system offers several mobile computing platforms making it relatively easy to use. This unit came equipped to measure TVOC, CO2, CO, Ozone, Temperature, %RH, and Dew Point for an initial cost of $7449, and the option for adding additional parameters are available. Customers have the option of buying their computing platform (i.e. pocket PC, ruggedized pocket PC or tablet PC) from Gray Wolf or provide their own laptop. Software to run the sensor is provided when purchased.

The Wolf Sense PC data transfer software allows readings logged on a mobile PC to be reviewed on desktop models. Readings can be easily exported to Excel. The other option is to use the Wolf Sense software to produce graphs from data with all pertinent documentation to produce a highly professional presentation directly from the monitoring system. Photos, graphs, and other files may be attached for additional documentation. The system is also available with an optional advanced report generator which eliminates the need for additional software and produces professional presentations of the data gathered.

The Gray Wolf IAQ 610 monitors make proactive IAQ surveys to be efficient and easy to conduct. It enables the user to optimize the balance between facility energy efficiency and occupant health and comfort. It also enables the user to identify potential IAQ issues before they become problems and allows for immediate response to complaints with high accuracy testing capabilities. The Gray Wolf IAQ610 is designed for both walk-thru and long term testing needs and is one of the most intuitive IAQ meters available on the market [2]. As with the previous commercial grade IAQ sensor, this product would not be compatible or cost effective for use with “demand controlled ventilation” applications.

There is one company that manufactures commercial grade IAQ monitoring devices that are intended for use with demand controlled ventilation (DCV) applications, and are less expensive than the previous models reviewed. The Vaisala CARBOCAP® carbon dioxide (CO_2) transmitter GMD/W20 series was manufactured specifically for building DCV applications. They are easy to install and require no maintenance.

The GMD/W20 series transmitters are manufactured using a silicon-based Vaisala CARBOCAP® sensor and has a simple structure. Reliability is not affected by dust, water vapor, and most chemicals.

The GMD/W20 series CO_2 transmitter measures 0 to 5000 ppm CO_2 (dependent on part number ordered) with an accuracy of +/- 2%. This unit also offers long-term stability of +/- 5% for 5 years. The operating voltage is 24V AC/DC and the power consumption is < 2W, which makes it economical to operate.

The GMD/W20 series has two mounting capabilities. It can be mounted in the ducts for the HVAC, or it can be mounted in a room. The duct mount unit requires a small hole which. This minimizes leakage risks, which in turn alleviates measurement errors. The wall-mount series are easily installed using standard electrical junction boxes. The wall-mount series also comes with or without display and provides excellent control of IAQ and appreciable savings in maintenance, recalibration, and energy consumption costs. At a projected cost of $410 per HVAC zone, the GMD/W20 series monitoring devices are a reasonably cost effective option for CO_2 DCV applications [3].

Related Works

With the rapid development of wireless communication systems in all aspects of our lives, incorporating wireless sensor networks (WSN) for monitoring conditions in many applications has become an acceptable practice. The development and implementation of wireless sensor network (WSN) has increased interest because it offers a wide range of applications. These applications include: monitoring energy usage, monitoring air quality conditions, monitoring health conditions, national security applications, detecting weather conditions, monitoring agriculture environments, assessing water quality parameters, and many other industrial settings [4].

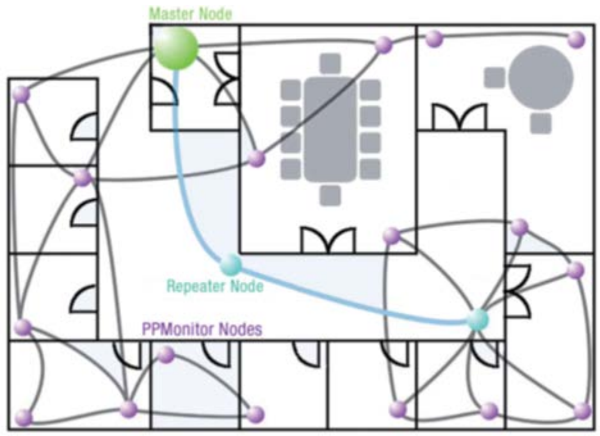

Figure 1 – How wireless units can be placed building wide to monitor CO2/IAQ

Wireless Sensor Networks

Wireless sensor network technology promises a wide range of applications from research to our daily lives. The benefits include reduced installation and system costs, increased flexibility, and simplification of deployment. Additional benefits include minimizing the need for battery replacement, adding weather proof containers which reduce maintenance, and enlarging coverage of large spatial areas [6].

The challenges involved in monitoring natural, in-situ environmental systems have resulted in an increase interest in WSN's. It would allow the monitoring of remote or dangerous environments as well a s providing hazard warnings for situations such as floods, earthquakes and inclement weather.

This project used an Arduino board in combination with an Xbee shield which allows the Arduino board to communicate wirelessly using Zigbee for our wireless sensor network (WSN). The WSN consists of three components: gateway, nodes, and software. The nodes interface with an indoor air quality (IAQ) CO2 sensor board that was specifically designed interface through Arduino. These IAQ CO2 sensor boards are capable of gathering data and transmitting information to the host assembly. The gateway Arduino/Zigbee board gets its power through the USB connection to the host controller and sends information directly to this computer and also allows for programming access. The IAQ monitor nodes transmit gathered information wirelessly through Zigbee to the host (in this case the fan controller), but require an external power source (i.e. battery) due to the lack of USB connectivity when deployed.

The IAQ sensor assembly and wireless transmission is based on the compatibility of the Arduino with the Xbee modules either from Max Stream or Digi, depending on which shield you incorporate into the design. The module can communicate up to 100 feet indoors or 300 feet outdoors (with line of sight). Possibilities for usage include using it as a serial/USB replacement or put it into a command mode and configure it for a variety of broadcast and mesh networking options. Xbee products are easy to use. They require no configuration or additional development and allow networks to be enabled in a minimum time frame. Programmable versions allow for further customization without the need of a separate processor. These modules do not form a risk to RF performance or security.

Figure 2 Arduino Xbee Shield Adaptor, Arduino Xbee Shield Assembled, Xbee with Antenna

Introduction

In recent decades much research has gone into the concept of improving indoor air quality, specifically its importance as a public health issue. Research has shown that both short term and long term health conditions can be linked to the indoor characteristics of buildings. According to ASHRAE, “providing superior IAQ can improve health, work performance and school performance, as well as reduce health care costs, and consequently be a source of substantial economic benefit” [7].

In the 1970’s, new building designs put emphasis on becoming more energy efficient. Buildings were designed and constructed to be air tight, meaning windows were sealed and ventilation units were turned down to minimal levels. This was done to reduce the energy used to cool or heat the air used in the building. While that was a useful concept for energy efficiency it had adverse effects on the indoor air quality. This issue has been remedied as of late, with a push for buildings to be energy efficient and maintain proper indoor air quality. It is stated that “While some see energy efficiency and IAQ as contradictory goals, an integrated design can lead to high performing buildings that are both energy efficient and have good IAQ….Furthermore, as the world moves rapidly toward constructing high performance and sustainable buildings , it should be recognized that sustainable/net zero energy efforts will fail if they achieve energy targets but cause significant health or comfort problems for occupants or imped occupant performance in ways that inhibit the building from attaining the goals for with it was built” [7].

The procedure of monitoring indoor air quality was another aspect that we wanted to investigate. Most buildings have an established ventilation rate that the HVAC unit is expected to execute. This ventilation rate is based upon building size and the expected number of building occupants. Because of this stagnant monitoring technique the concept of carbon dioxide based demand controlled ventilation was introduced. “CO2 demand controlled ventilation is a real-time, occupancy-based ventilation approach that can offer significant energy savings over traditional fixed ventilation approaches, particularly where occupancy is intermittent or variable from design conditions” [8]. This concept could potentially save companies significant amounts of money in energy costs, while increasing the health of the buildings occupants. “Excessive over-ventilation is avoided while still maintaining good IAQ and providing the required cfm-per-person outside air requirement specified by codes and standards. The authors have observed operational energy savings of $0.05 to $0.15 per square foot annually [8]. This monitoring technique is a monumental change from the previous method of using a fixed ventilation system and then taking IAQ measurement’s after a problem has been reported. This sort of technique has led to the development of the condition known as sick building syndrome.

Sick building syndrome was introduced in the late 1980’s, and was directly caused by poor indoor air quality. Sick building syndrome (SBS) can affect people in different ways, but should not be confused with specific building related illnesses. SBS symptoms will usually resolve themselves after the person leaves the room or building. Symptoms of SBS include fatigue, headaches, shortness of breath, loss of concentration, eye and throat irritation, and nausea, which are coincidently many of the same symptoms of CO2 exposure. Common factors that lead to SBS are poor ventilation, airborne pollutants (dust and fungal spores), chemical pollutants, ozone, and high concentration of VOC’s, and CO2. It is said that “CO2 levels can be used as a good indicator of human bioeffluent concentration and/or occupancy” [15]. Demand controlled ventilation (DCV) work is being done to develop automated systems to monitor IAQ in relation to CO2 levels emitted by building occupants. “CO2 based DCV systems can use CO2 as an occupancy indicator to modulate ventilation below the maximum total outdoor sir intake rate while still maintaining the required ventilation rate per person, providing certain conditions are met” [14]. This in turn, can assist in preventing SBS from becoming a factor in buildings.

An extension of this project was to examine the role that IAQ, specifically CO2, plays in educational environments. Several studies have researched the IAQ of schools, and the possible health effects it has on students. “The elevated indoor PM2.5 and BTEX concentrations in primary school classrooms, exceeding the ambient concentrations, raise concerns about possible adverse health effects on susceptible children” [9]. Before acceptable levels can be established for classroom, certain values must be determined for the levels at which parameter can become detrimental to student health. “In order to set adequate threshold values and guidelines, detailed information on the health impact of specific PM2.5 composites is needed. The results suggest that local outdoor air concentration measurements do not provide an accurate estimation of children’s exposures to the identified air pollutants inside classrooms” [9].

Once all of the factors that influence indoor air quality have been considered, we can begin to look into their effects on student attendance and performance in schools. To better determine what effects poor IAQ and CO2 levels have on students in schools, we must first examine what poor air quality in general can have on children. “Relatively little is known about the exact mechanisms underlying any health effects, although most pollutants affect the respiratory and cardiovascular systems. Even less is known about the effects of pollutants on children, although it is thought that children are more susceptible to the effects of pollution than adults because their bodies are developing and they have higher metabolic rates. For example, a child exposed to the same air pollution source as an adult would breathe in proportionately more air and suffer proportionately greater exposure" [10].

After determining the possible health effects that poor indoor air quality can have on student health, we can begin to think about its effect on student performance. It is difficult to determine the relationship between poor IAQ and student performance unless we can narrow it down to certain indicators. One such indicator that is referenced in research is absenteeism. Leaky roofs, problems with heating, ventilation and air conditioning systems, insufficient cleaning or excessive use of cleaning chemicals and other maintenance issues can trigger a host of health problems, including asthma and allergies, which increase absenteeism and reduce academic performance [10]. The Centers for Disease Control, or CDC, backs up this idea in a 2003 journal which states Asthma is a leading chronic illness among children and adolescents in the United States. It is also one of the leading causes of school absenteeism. On average, in a classroom of 30 children, about 3 are likely to have asthma [11].

When it comes to improving indoor air quality, solutions can often be found by determining and treating the source. A good example is the effect high concentrations of CO2 in an occupied room without proper ventilation effects concentration and comfort. "Several studies noted a feeling of increased warmth with elevated CO2 concentration despite the fact that the measured indoor temperatures were no higher." [16]. Another example would be the airborne bacterial contamination that occurs when large groups of students congregate. Research has shown that the application of a pulsed UV-rich light system to disinfect the contaminated air will cause a significant reduction in the levels of airborne bacterial population [12].

The EPA has developed an IAQ Tools for Schools program which helps schools organize and implement a specific IAQ program. The program implements strategies including moisture management, integrated pest management, cleaning and maintenance, material selection and adequate ventilation, which all help control environmental triggers in building occupants [13]. This program offers a cycle of continuous assessment, planning, and evaluation to help deliver positive indoor air quality results. The main idea being that if a proactive approach is taken vs. a retroactive approach, most issues can be avoided before any symptoms are felt by building occupants.

Design Challenges

- CO sensor required a filter/amplifier board to function correctly
- Preheat time for CO2 sensor was 96 hours
- Accuracy of our design versus Grey Wolf

- Developing testing criteria
- Stability of calibration

The Arduino compatible board that was ordered for assembly purposes is 2 inches by 2.25 inches, and is compatible with the Zigbee wireless card. We were unable to mount the filter/amplifier board needed for the CO2 sensor to the Arduino, so both boards were mounted to a 4" square piece of wood for stability. Another issue is warm up periods; the CO2 sensor needs a minimum of 96 hours.

This current mounting solution seems to have solved the issue of wires coming lose during testing. To add the wireless ability an Xbee shield was added along with a module to allow communication between both Arduino boards. The module then sends the gathered information from the CO2 sensor to another Xbee module that is programmed as a gateway device and controls the ventilation fan for the demand controlled ventilation (DCV) purpose.

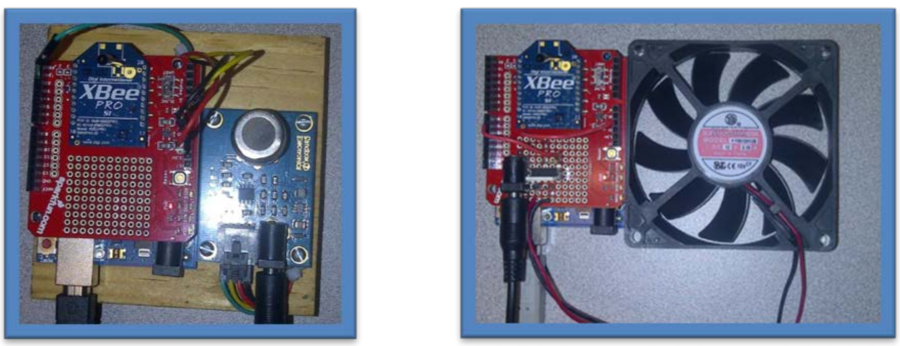

Figure 3 –IAQ CO2 prototype and IAQ DCV prototype

Materials and Methods

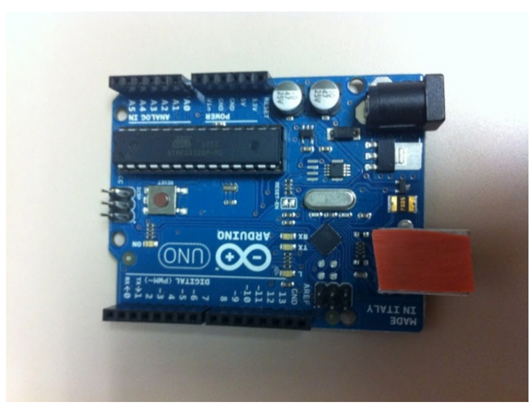

Figure 4-Arduino Board

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as Pulse Width Modualation outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable of power it with an AC-to-DC adapter or battery to get started. In layman's terms: The Arduino Uno acts like the mother board of a computer for our project sensor board.

Figure 5 – CO2 Sensor

The MG811 CO_2 Sensor has Output Signal of 100-600 mV or 350-10,000 ppm CO_2 and requires a heating Voltage of 6.0 +/- 0.1 V AC or DC.

Lab Experiments

To show the necessity of adequate ventilation, a Grey Wolf sensor was placed in a library computer lab thirty minutes prior to 17 people entering the room. CO_2 was measured and is displayed in Figure 6.

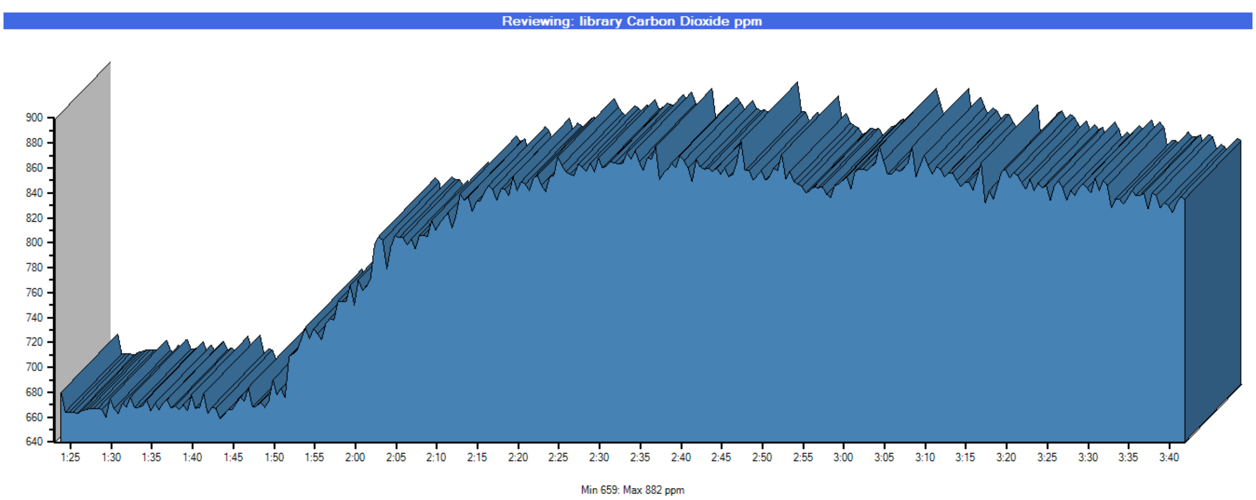

Figure 6 - The y-axis is the ppm CO_2, and the x-axis is the time of day

It can be seen that in a relatively short amount of time, the CO_2 level rose by 200ppm. In a classroom setting, where 30 students are not uncommon, the CO_2 level can quickly rise to levels sufficient to cause problems.

Part 1

Several problems were encountered dealing with the discrepancy between a part and the spec sheet. One of those parts was the exhaust fan. CFM and fan speed at specific voltages needed to be determined so that we could determine a mathematical relationship.

Fan Speed: Method 1: Initially, a photogate was used with the fan operating at voltages between 12.00 and 5.00. 5 or 6 measurements were made at each voltage starting at 12.01V and dropping by .50V each trial.

Figure 7- Photogate and fan

A photogate was placed across the 7 bladed fan, the fan was turned on, and the photogate measured the time between the front of a fan blade to the front of the next fan blade, or about 51°. The fan was rated at 2600rpm at 12V, so the expected time value was .0033s. At 12.01V, the photogate gave an average time of .0093s. The voltage was decremented, and problems began to arise. The photogate started to give several values that were multiples of each other. It appeared that the photogate could not keep up with the speed of the fan. Perhaps there was a minimum time required to take the measurement. The experiment was abandoned.

Fan Speed: Method 2: The fan emits a tone when running due to the fan blades cutting through the air. By using a tone generator on a computer, and a good musician's ear, the frequency of the fan was found at different voltages. The frequency emitted by the fan was divided by the number of blades (7) and multiplied by 60 to get rotations per minute. (Table 1).

Table 1 Voltage and frequency

Voltage (V)	Frequency (Hz)

12.80	303
12.02	288
10.92	266
10.00	244
9.09	222
8.28	202
7.20	170
6.12	140
5.23	110
5.00	105

The fan speed was measured at 2470rpm at 12.02V which is relatively close to the spec sheet. Since most continuous sounds have higher harmonics, which are at whole number multiples of the fundamental frequency, to insure the listener was hearing the correct frequency, a strobe was used to measure the fan speed.

Fan Speed: Method 3: An Arduino was used to make an LED blink at a frequency of 45.45 Hz, and the fan was turned on and adjusted to about 13V. It appeared motionless, which indicated that the frequency of the fan was a multiple of 45.45Hz. The LED rate was doubled, and a doubled image was seen, indicating that the 45.45Hz value was good. This kind of check is similar to the Nyquist criterion in electrical engineering. This confirmed that the frequency measurements were good.

Part 2

Fan Airflow: Method 1: To determine the flow rate created by the fan, it was decided that Bernoulli's fluid flow equation would be used. Measuring the cross sectional area of the tube and the pressure drop relative to the room would be sufficient to find the speed of the fluid. A small pressure tap was put into the hose connecting the fan to the enclosure. Fig. 8.

Figure 8 Pressure tap on hose

With the fan at 12V, a Pasco absolute pressure and temperature sensor was to read the pressure. It would then be compared to the pressure in the room. Unfortunately, the pressure drop was smaller than the background noise. The accuracy of the sensor from the spec sheet was +/- 2kPa. The speed of the air in the tube would need to be 58m/s to create a 2kPa change. This method was abandoned.

Fan Airflow: Method 2: With a lack of equipment, it was decided that a garbage bag would be used to determine the flow rate. It was taped to the intake for the enclosure and filled with air. The fan was turned on with 12.00V and the time for the bag to void itself of air was determined. It took 2 minutes and 36 seconds. It was decided that the measurement of the capacity of the garbage bag did not need to be extraordinarily precise. With the top of the bag closed, it was squashed into a pumpkin shape. Approximating it to a cylinder, it was determined to be approximately .9 (+/-.2) cubic feet. This gives the airflow measurement a value of .34CFM (cubic feet per minute). The spec sheet says 34CFM. Since the fan is being used for a different purpose than what it was intended for, and the airflow is somewhat constricted, the measurements taken appear to be accurate, although not precise.

Part 3

The behavior of the injected CO2 in the container would determine how to proceed with testing. Expectations were that the CO2 in a closed container would pool at the bottom. Three tests were conducted to ascertain the nature of how the CO2 distributed itself.

The sensor was placed on the floor of the enclosure, allowed to reach equilibrium, and then CO2 was injected into the enclosure. Fig.9

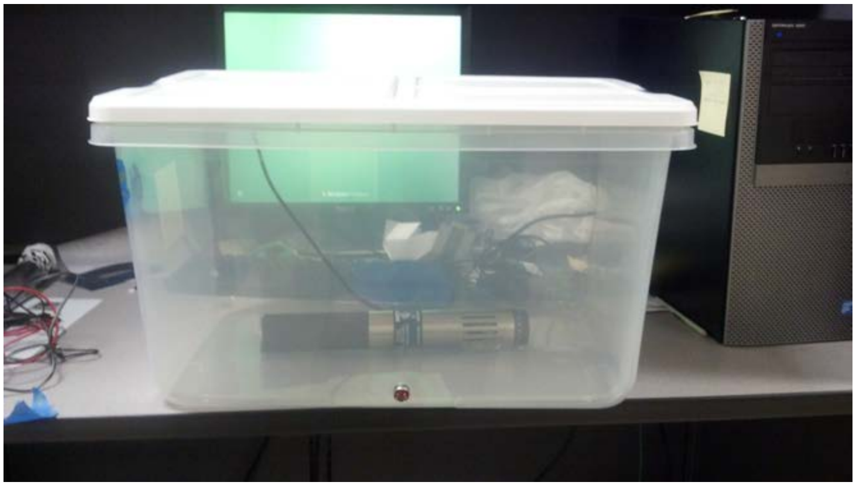

Figure 9 Sensor on bottom

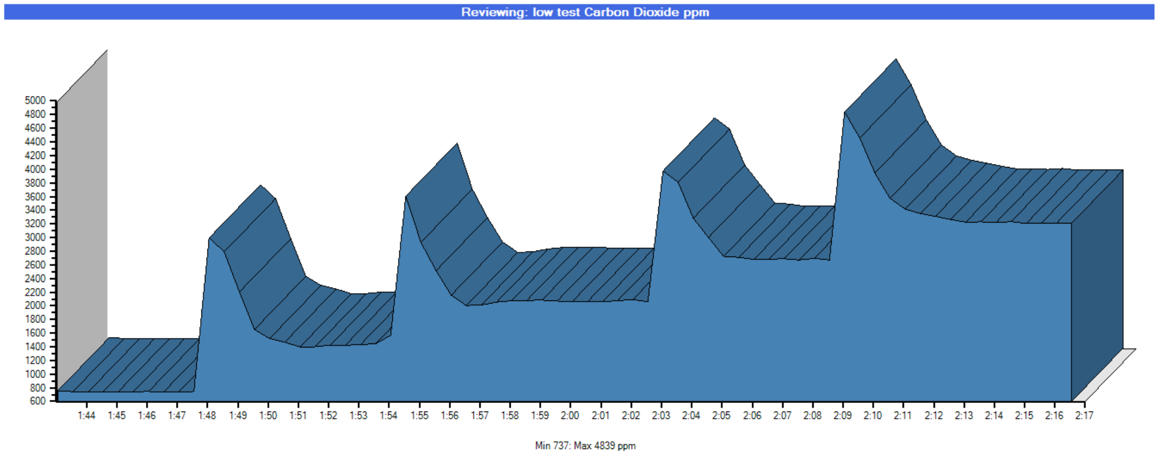

Figure 10. The y-axis is the ppm CO2, and the x-axis is the time of day

Each injection of CO2 into the container was 50.0mL, or approximately 800ppm. It can be noticed that there is an initial spike in the measurement as the heavier CO2 sinks down toward the sensor. After about 3 minutes the gas distributes itself throughout the cage, but the increase from each 800ppm injection shows up on average as an increase of 620 ppm. Next, the sensor was placed in the middle of the enclosure. Fig. 11.

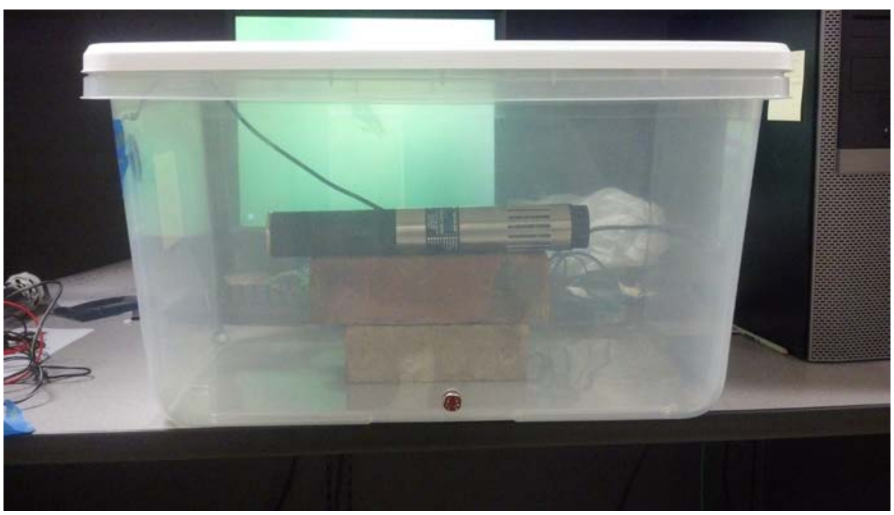

Figure 11 Sensor in the middle

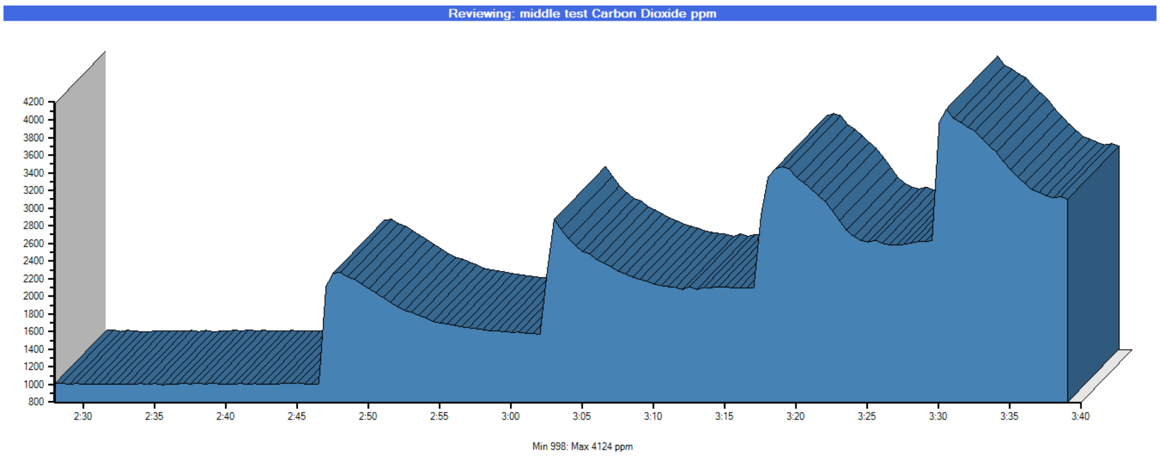

Figure 12. The y-axis is the ppm CO2, and the x-axis is the time of day

Again 800ppm was injected several times, but the average increase was only 531ppm. The time was vastly increased for the system to reach equilibrium, about 15 minutes. Lastly, the sensor was placed high in the container. Fig. 13

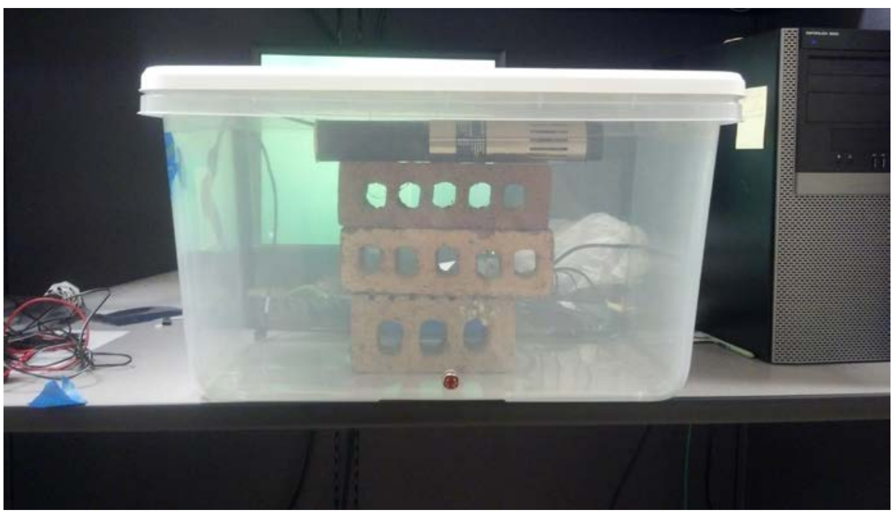

Figure 13 Sensor near the top

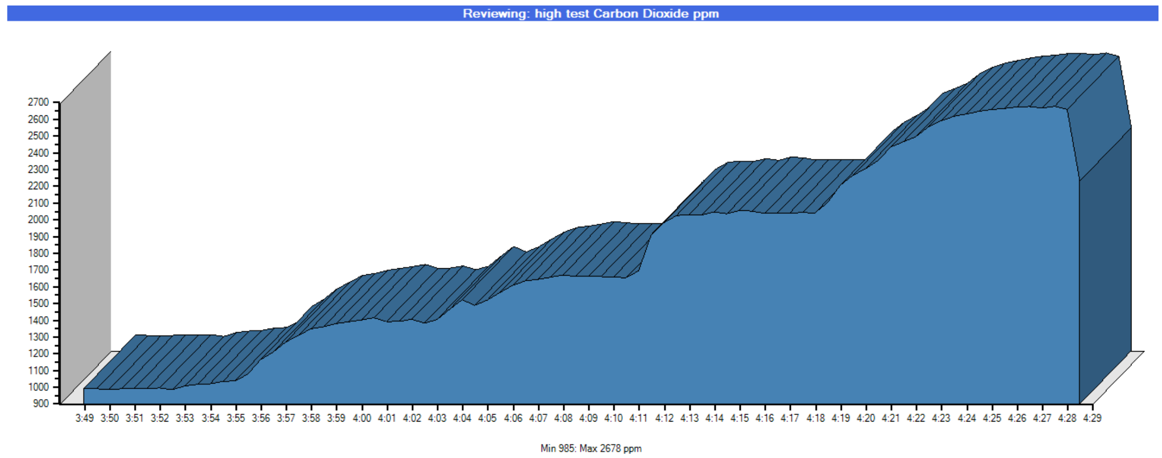

Figure 14. The y-axis is the ppm CO2, and the x-axis is the time of day

Again 800ppm was injected several times, but the average increase was only 424ppm. As the CO2 distributes itself in the container, the data suggests that the CO2 is setting up in a sort of density gradient, with the higher concentration towards the bottom of the container. This suggests an explanation for the "loss" of CO2 in each test. When 800ppm is added to the container, the higher the sensor is in the container, the lower the CO2 concentration observed.

Part 4

Do building materials have an effect on CO2 concentration in a room? Several tests were done to see if the presence of CO2 either promoted CO2 release or was absorbed by carpet, sheet rock, cinder blocks, ceiling tiles, bricks, and plants. The sensor was placed low in the container with the material to be tested. Some of the graphs are coming down from the initial spike of CO2 as in the previous low sensor test.

Test 1: Linoleum floor tile (adhesive bottom still covered)

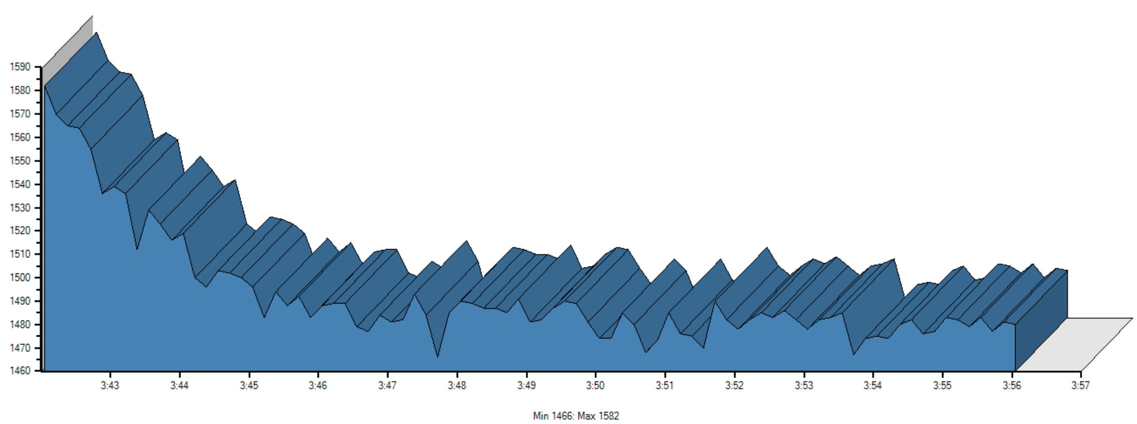

Figure 15. Linoleum floor tile- The y-axis is the ppm CO2, and the x-axis is the time of day.

No appreciable increase or decrease.

Test 2: Ceiling Tile

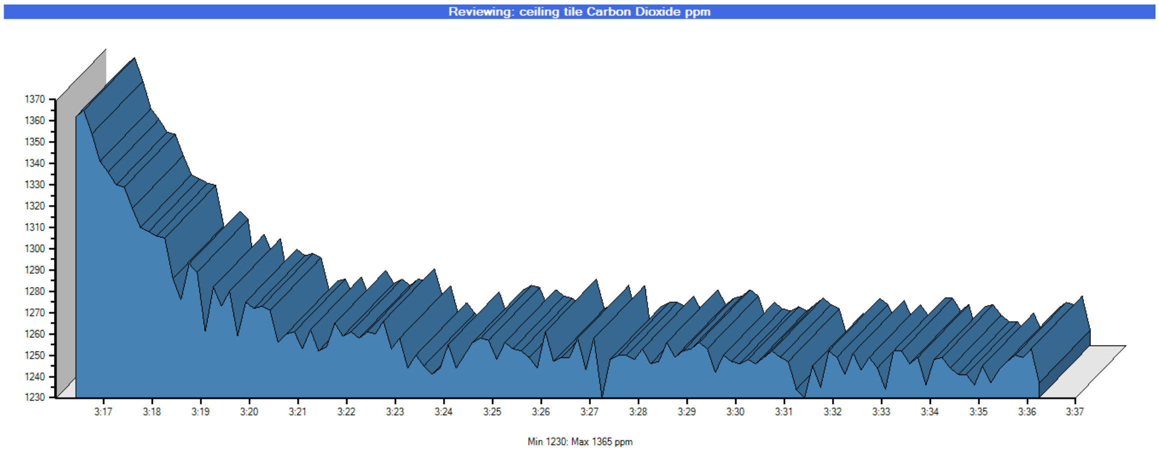

Figure 16. Ceiling Tile -The y-axis is the ppm CO2, and the x-axis is the time of day

No appreciable increase or decrease.

Test 3: Bricks (at least 10 yr. old)

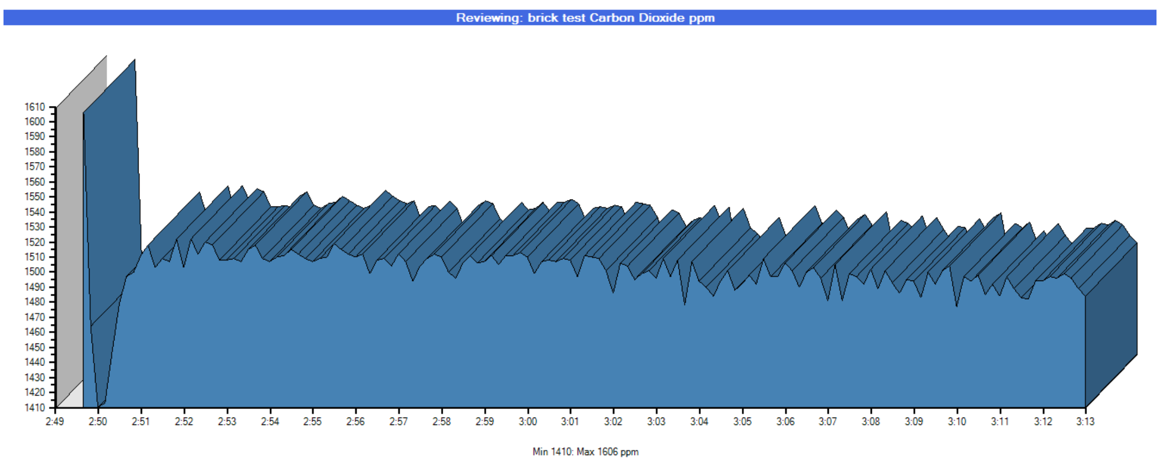

Figure 17. The y-axis is the ppm CO2, and the x-axis is the time of day

In approximately 20 minutes, the level of CO2 had dropped by 20ppm.

Test 4: Dry wall

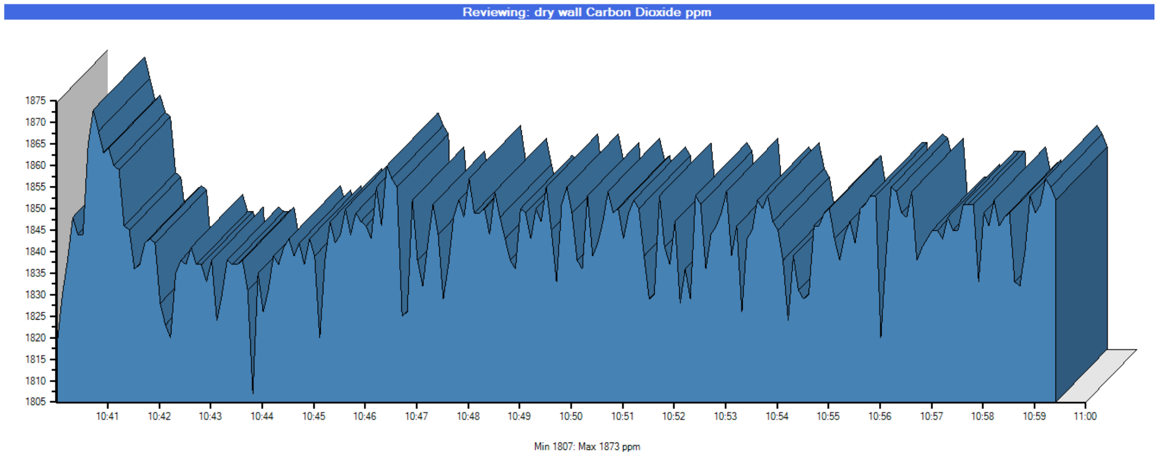

Figure 18. The y-axis is the ppm CO2, and the x-axis is the time of day

No appreciable increase or decrease.

Test 5: Plants (a fern and a small caladium)

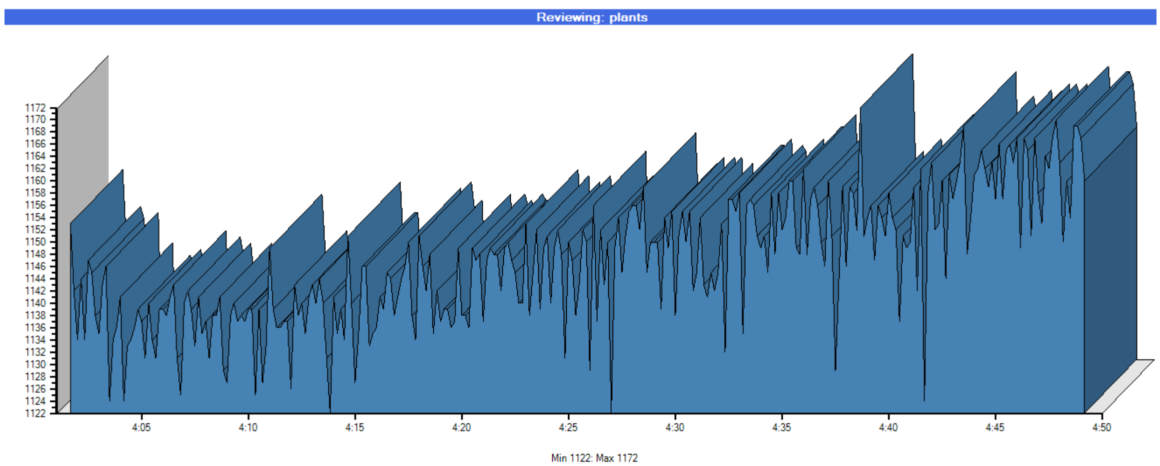

Figure 19. The y-axis is the ppm CO2, and the x-axis is the time of day

In 40 minutes, the CO2 rose by 26ppm. The plants were in the shade at the time of the test.

Test 6: cinder block (new)

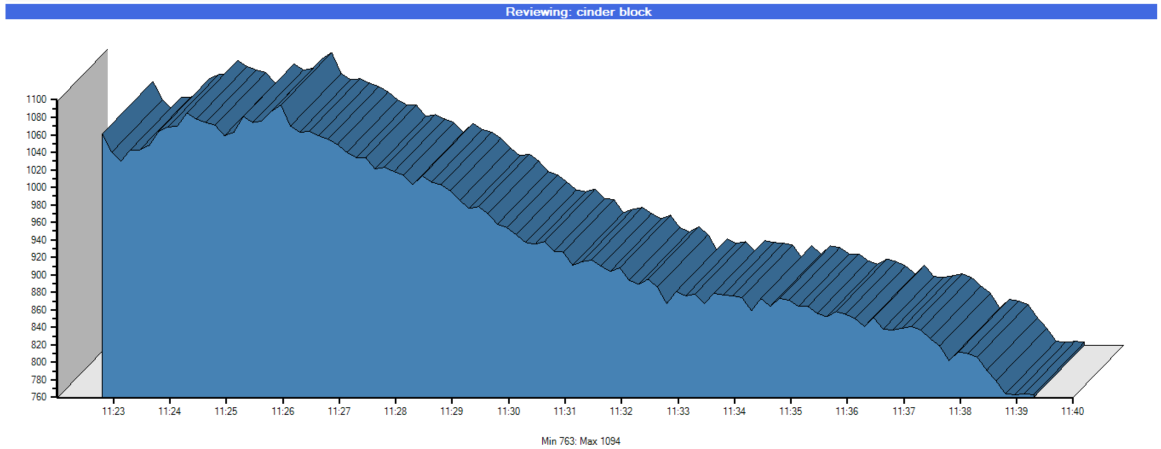

Figure 20. The y-axis is the ppm CO2, and the x-axis is the time of day

The change was so significant and unexpected, that more experimentation was necessary. For the next test, every possible seal was taped shut, and the chamber was allowed to drop to 305ppm, which was 500ppm below the room the experiment took place in.

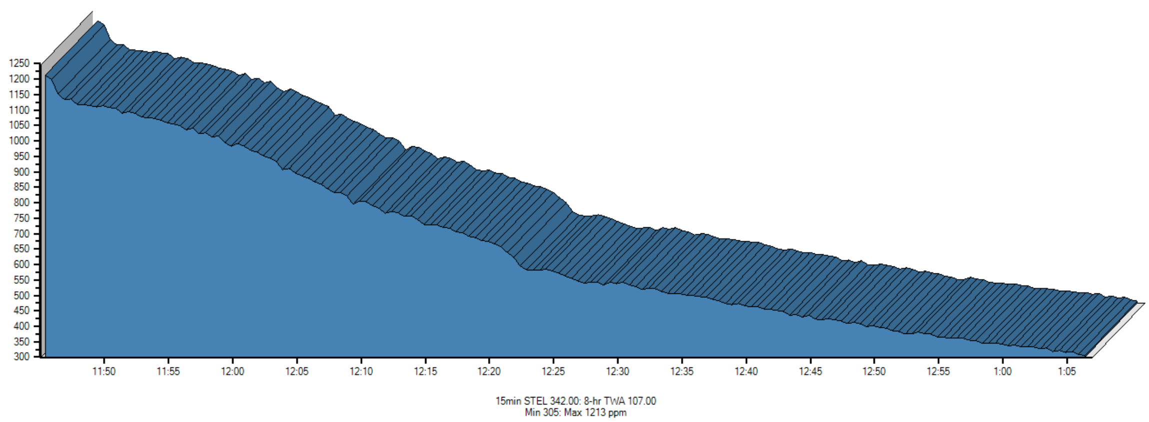

Figure 21. The y-axis is the ppm CO2, and the x-axis is the time of day

A third test was performed the following day starting at 28500ppm and dropping to 174ppm in 4 hours and 34 minutes. A large percentage of the cinder block is di- and tri-calcium silicate, or $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$, respectively. CaO is formed by the following reaction:

$$CaCO_3\ (s) \rightarrow CaO(s) + CO_2\ (g)$$

This is usually accomplished at 500-600°C. However, the reaction is reversible and is the suspected mechanism for what is taking place. More experiments need to be done, but equipment and time limitations constrained the team.

Part 5

The main objective of this project was to variably power an exhaust fan dependent upon the concentration of CO2 in an enclosure. Figure 22 shows how fast the CO2 naturally dissipates with only a 4.0cm diameter hole cut near the bottom of the chamber. The CO2 level dropped by 50000ppm in approximately 3 minutes for an average rate of 17000ppm per minute. Figure 23 shows the rate at which the fan dissipated the CO2. The fan was attached to the hole. With the fan on, the average drop rate was 39000ppm per minute.

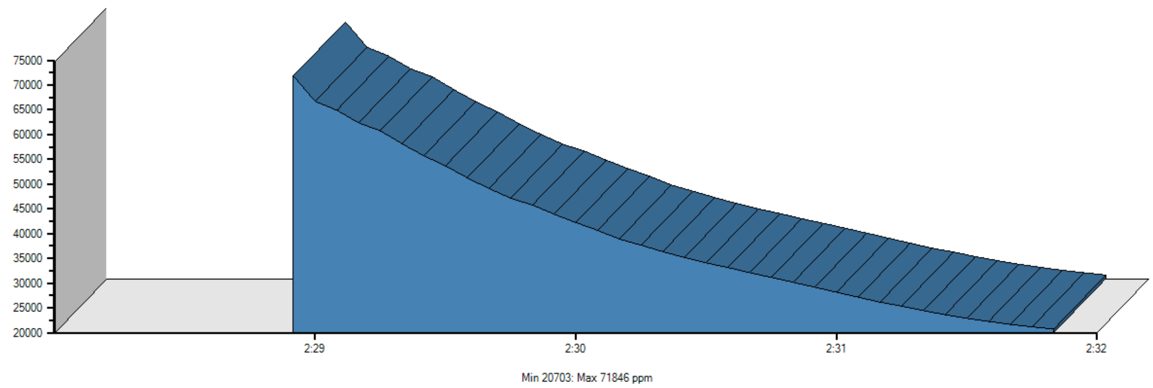

Figure 22. Dissipation of CO2. The y-axis is the ppm CO2, and the x-axis is the time of day

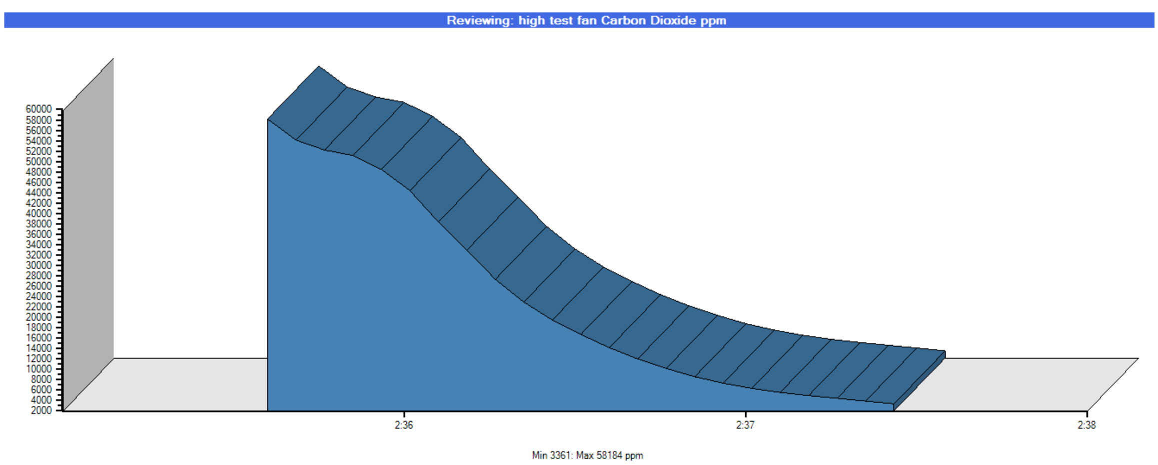

Figure 23. Fan driven dissipation of CO2. The y-axis is the ppm CO2, and the x-axis is the time of day

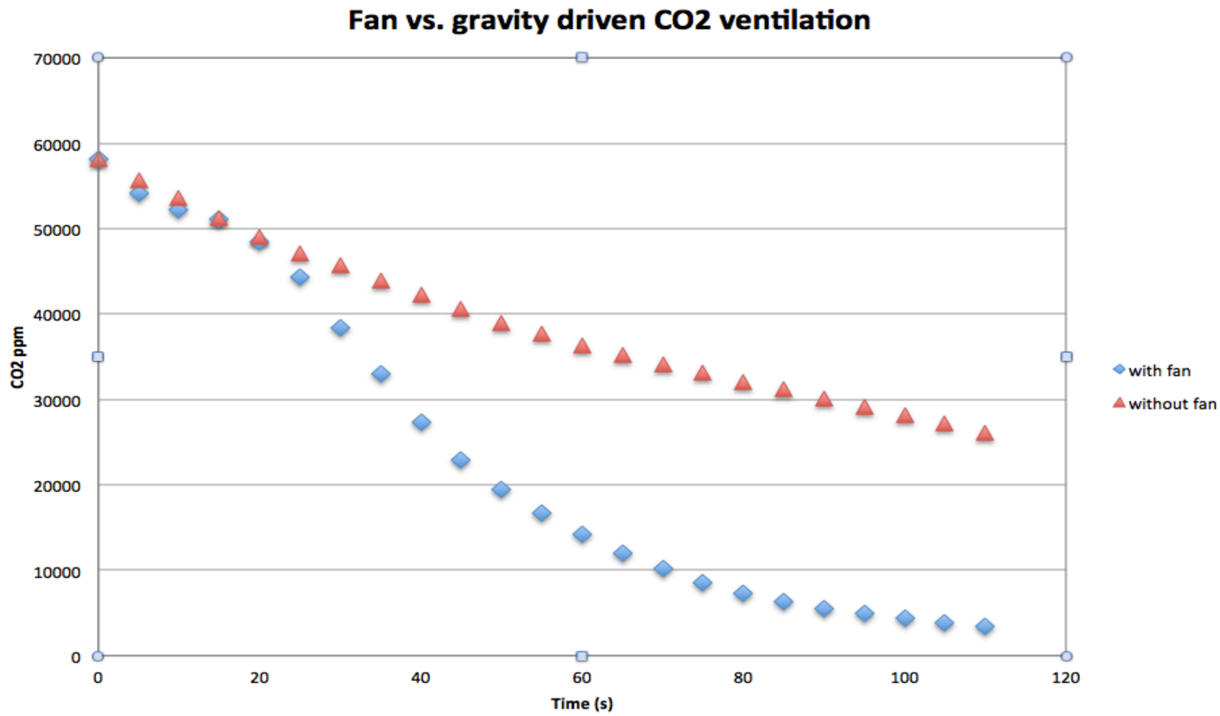

Figure 24- Comparison of fan vs. no fan

Conclusion

Potential hazardous gases in the work place are a critical issue. Too often, these gases are undetected until the employee becomes ill or a foul odor is reported by building occupants. By the time this occurs, occupants will have suffered exposure to poor air quality. The next step is to test the building with an expensive sensor unit to determine the source of the problem. With an on-demand venting system in place, IAQ issues could be dealt with immediately.

While running the Grey Wolf and the prototype board, there seemed to be a lag in the data acquisition for the prototype. As far as room ventilation is concerned, a few seconds shouldn't matter at all, so this doesn't seem to be a concern. The prototype reading seemed more stable while the Grey Wolf readings were "noisier." This could be due to the fact that the prototype simply doesn't have the resolution capability of the Grey Wolf. This is potentially a benefit, as a noisy signal near the fan activation criterion could cause the fan to stop and start at small intervals. This could be mitigated with proper coding.

Further Work

One of the chief concerns is how well the CO_2 sensor can be calibrated. On numerous occasions, the reading given from the prototype was fairly far off from what it read previously. Temperature and humidity were cited on the spec sheet to have an effect on the sensor, but to include those factors in the CO_2 reading was beyond our control, assuming that those were the culprits. If the purchased CO_2 sensor is to be used in a device, more controlled experiments must be done.

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