



Site preparation

- Prepare the lab one day before the ventilation test.
- Inform facility coordinator, DSR, and lab users about the time and scope of test, see email template below:

Dear Professor XXX,

This Monday 10th December we will conduct a ventilation effectiveness test in B5 L2 A6 from 9am to 11:30am.

The testing method involves discharging the content of carbon dioxide fire extinguishers into the room to reach concentrations above 10,000 ppm throughout the room. The decay rate is determined in multiple locations in the room through the parallel measurement of the decay of CO₂ concentrations using between three and six data-logging CO₂ sensors. The findings are then compared with the air exchange rate calculated from the flow rate measured in the ventilation ductwork for possible changes in the ventilation system.

During this period of time the lab requires to be vacated.

Smoke detectors will be isolated for the test and sensitive equipment will be covered with plastic by Campus and Technology Park Operations.

We kindly ask for your cooperation and support for this important test, a team will be ready from 8am to cover equipment and prepare for the test.

Let me know if you have any questions.

Thanks for your support.

- Make sure of availability of fire extinguisher for the test, contact T&I group in FS one week in advance to order more if necessary.
- Get a floor plan for the room and gather control system prior to testing.
- Liaise with the facility coordinator to prepare the room for the test.
- Get worker support to transport fire extinguishers and conduct the test.
- Cover sensitive equipment with plastic sheets, no need to cover all benches, we want the lab condition as is.
- For big labs (neighborhoods), cover middle corridor with a plastic curtain to segregate small rooms.
- Cover with plastic sheets, gaps on top of fume hoods for labs with this condition.

Egg distribution

Distribute eggs at bench level, assume quadrant display and in places of interest (dead spots, chemical bench, ventilated enclosure, exhaust vents, etc.)

Number of eggs to be used	Room Size	Number of Fire Extinguishers
10	200 m ²	4-5
8	100 m ²	4
6	50 m ²	3
4	25 m ²	2
3	Less than 25m ²	1

- Take notes of the location and pictures of each Air Quality Egg. This will help with analyzing the data. Items to note:
 - Mark this on the floor plan;
 - Location of fire extinguishers;
 - Location of exhaust and supply diffusers;
 - Time- start and end of each test run.
- Avoid placing eggs in locations blocked by lab furniture or big equipment.
- Plug the batteries 2-3 minutes before the release of fire extinguisher in the first run. There is no need to disconnect before the second run of for more testing in the same test period.

Safety Considerations

- Electrostatic discharge: Put the extinguisher on the floor and do not touch metal parts of it.
- CO₂ exposure: Size the extinguishers to fill the room without overfilling:
 - NIOSH Exposure Limits:
 - 15 minute Short Term Exposure Limit (STEL) is 30,000 ppm
 - 8 hour TLV-TWA (exposure averaged out over 8 hours) is 5,000ppm
 - Revised NIOSH Immediate Dangerous to Life (IDLH) is 40,000 for a 30 minute exposure (<https://www.cdc.gov/niosh/idlh/124389.html>).
- Ergonomics: Extinguishers are heavy even when empty; use carts to move them.
- Noise: Wear hearing protection when extinguishers are being released
- Eye protection: Dry ice flakes shoot out of the horn. Also wear a lab coat.
- Computer protection: Cover computers and sensitive electronics to prevent dry ice from landing on them

Test Duration

- Normally 2 runs per room, each run takes 20-30 minutes by room plus setup.
- Releasing fire extinguishers will only take 30-50 seconds, after the fire extinguishers are emptied make sure all people is out the lab and avoid entering the lab in the next 20-30 minutes.
- Take some pictures and videos to document the test and observe the cloud behavior, stagnation or dead spots in the lab.
- After 20 to 30 minutes have passed, one person from the testing team enters the lab and verifies that the concentration of CO₂ have dropped under 2,500 ppm, (Average in all eggs)
 - If the concentration is still high, wait for another 10 minutes.
- Once the concentration is under 2,500 as an average for all the eggs in the test, conduct a second run for the same room. Take note is there is any changes for the second run such as change in the location of the sensor, open sash in fume hoods, open valves for snorkels or open ventilated enclosures.
- After the second run is completed, disconnect the batteries from the eggs and move to next room or download the data the same day of the test.

Message before releasing Fire Extinguishers

Brief the team about the objective of the test, the number of tests to be conducted during the day and the rooms to be tested.

Make sure everyone is wearing safety glasses and earplugs.

One person per Fire Extinguisher.

Remind everyone to remove the pin and hold the fire extinguisher between the discharge hose and discharge nozzle. To avoid static electricity, place one knee on the floor while discharging the Fire Extinguisher.

The technique is to sweep the nozzle left and right, aiming to the middle of the room and with the objective to fill the room with CO₂.

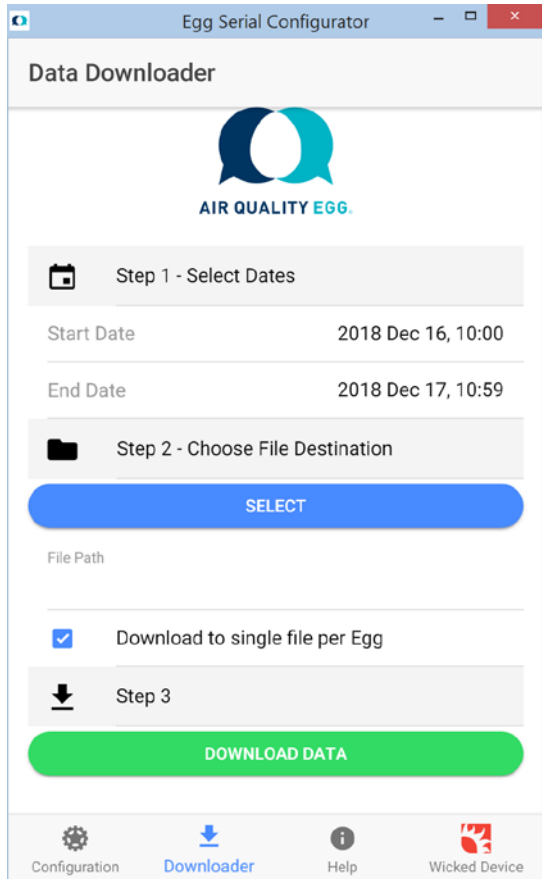
Show everyone the exit and possible tripping hazards. The visibility might be limited during the egress.

Fire extinguisher needs to be completely discharged.

After the fire extinguisher is emptied, leave the room and wait until the concentration of CO₂ is near 2,000 ppm as an average for all eggs.

Download Data

- 1- Connect the eggs to the computer.
- 2- [Go to https://shop.wickeddevice.com/resources/installation-setup-software/](https://shop.wickeddevice.com/resources/installation-setup-software/) and download the egg configuration.
- 3- Select file and create a folder where to save the data.
- 4- Go to downloader



- 5- Check the time stamp of the test time
- 6- Save file as a **CSV** file, not excel spreadsheet
- 7- Predetermine folder where files will be saved and naming convention
- 8- Save raw data set in a separate file. This will not be uploaded to the Wicked Device site. But, may be needed in the future and will unrecoverable from the Egg from which is was downloaded after subsequent test runs are conducted and data is overwritten on the SD card in the Egg. Use the raw data folder and save the file.
- 9- Save each run separately

NOTE: The eggs will store data and continue recording without overwriting; however it is highly recommended to download the data as soon as possible to avoid overlapping files from other rooms or dates.

Data Scrubbing

- 1- Columns will include a timestamp with recorded readings every 5 seconds and measurements for temperature, CO₂, relative humidity and others.

	1	2	3	4	5	6	7	8
1	Timestamp	Temperature[degC]	Humidity[percent]	CO2[ppm]	Pressure[Pa]	Latitude[deg]	Longitude[deg]	Altitude[m]
00	12/10/2018 13:30	19.56	61.63	450	101433.4	---	---	---
01	12/10/2018 13:30	19.58	61.61	450	101434.5	---	---	---
02	12/10/2018 13:30	19.38	59.37	1929	101438.5	---	---	---
03	12/10/2018 13:30	19.12	57.99	5470	101439.4	---	---	---
04	12/10/2018 13:30	19	57.97	10000	101439.1	---	---	---
05	12/10/2018 13:30	18.81	59.21	10000	101435	---	---	---
06	12/10/2018 13:30	18.73	60.42	10000	101441.2	---	---	---
07	12/10/2018 13:30	18.67	61.64	10000	101438.5	---	---	---
08	12/10/2018 13:30	18.64	62.1	10000	101435.3	---	---	---
09	12/10/2018 13:31	18.62	62.42	10000	101435.7	---	---	---
10	12/10/2018 13:31	18.6	62.65	10000	101433.8	---	---	---
11	12/10/2018 13:31	18.6	62.65	10000	101436.1	---	---	---

2- Delete unneeded columns including:

Pressure[Pa] Latitude[deg] Longitude[deg] Altitude[m]

3- Columns needed for measuring air exchanges per hour (ACH) are time and CO₂. Normal background levels of CO₂ are typically less than 500ppm. However, inside of a building these can be slightly higher. Select rows that represent one run. When the fire extinguishers are released. The room must fill with the gas to levels exceeding 10,000ppm. The meters cannot report-out levels higher than this, although they may be much higher. The raw data will show levels that rise rapidly and then remain at 10,000 for a time and then begin to drop down. The ACH measurement is this backside of the curve. Capture this by deleting the background levels and those at the tail end of the test.

*Note: For this step, use as a reference the time stamp when the test started, peak concentration at 10,000 and when the Field test was declared completed. (Typically after 20 or 30 minutes depending on the room size)
Using CO₂ values after the test was completed or when someone entered the room to verify sensors will stir concentrations up and produce skewed results and graphs not representing the measured ACH value.*

Data Test Example:

09:27 beginning of the test, release of fire extinguisher and reaching max value of 10,000 ppm.

Timestamp	CO2[ppm]
1/30/2019 9:27	485
1/30/2019 9:27	485
1/30/2019 9:27	485
1/30/2019 9:27	486
1/30/2019 9:27	487
1/30/2019 9:27	866
1/30/2019 9:27	3279
1/30/2019 9:27	9528
1/30/2019 9:27	10000

9:46 end of the test

1/30/2019 9:46	1788
1/30/2019 9:46	1744
1/30/2019 9:46	1722
1/30/2019 9:46	1691
1/30/2019 9:46	1674
1/30/2019 9:46	1658

Total time: 19min.

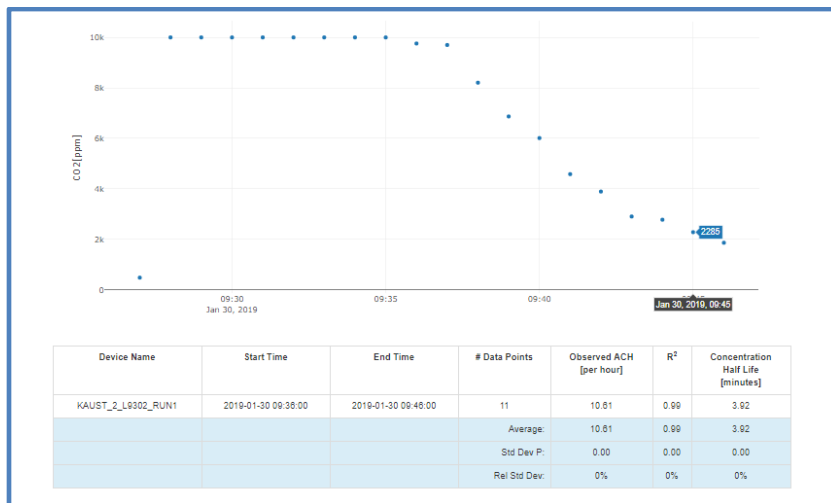
4- Using the Chrome browser:

<https://airqualityegg.wickeddevice.com/co2/>

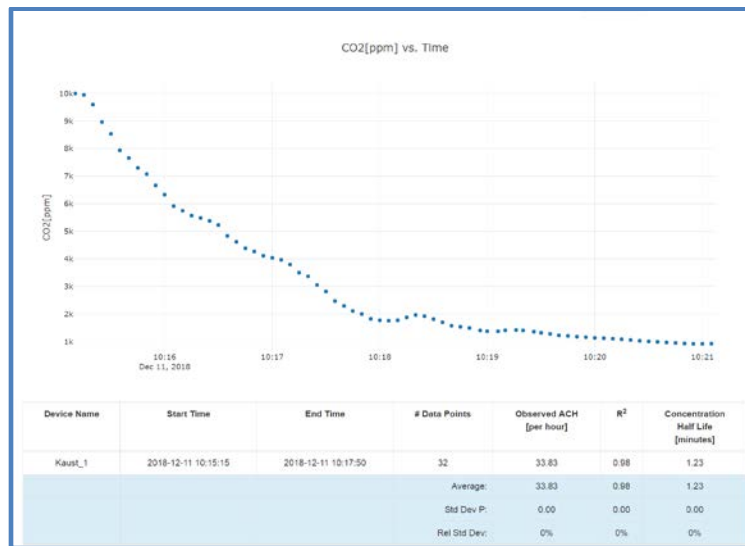
5- Select file or drop the CSV file and upload.

6- In the Field dropdown list, choose CO₂ and click "Add to Plot". If temperature and humidity are in the file, these will also appear in the dropdown.

7- Drag the cursor from the last 10K to the lowest value to generate a curve representing the time of the test.

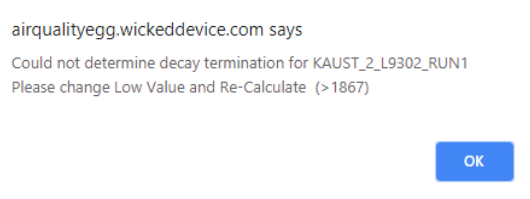


Example Graph before Step 15



Example Graph after Step 15

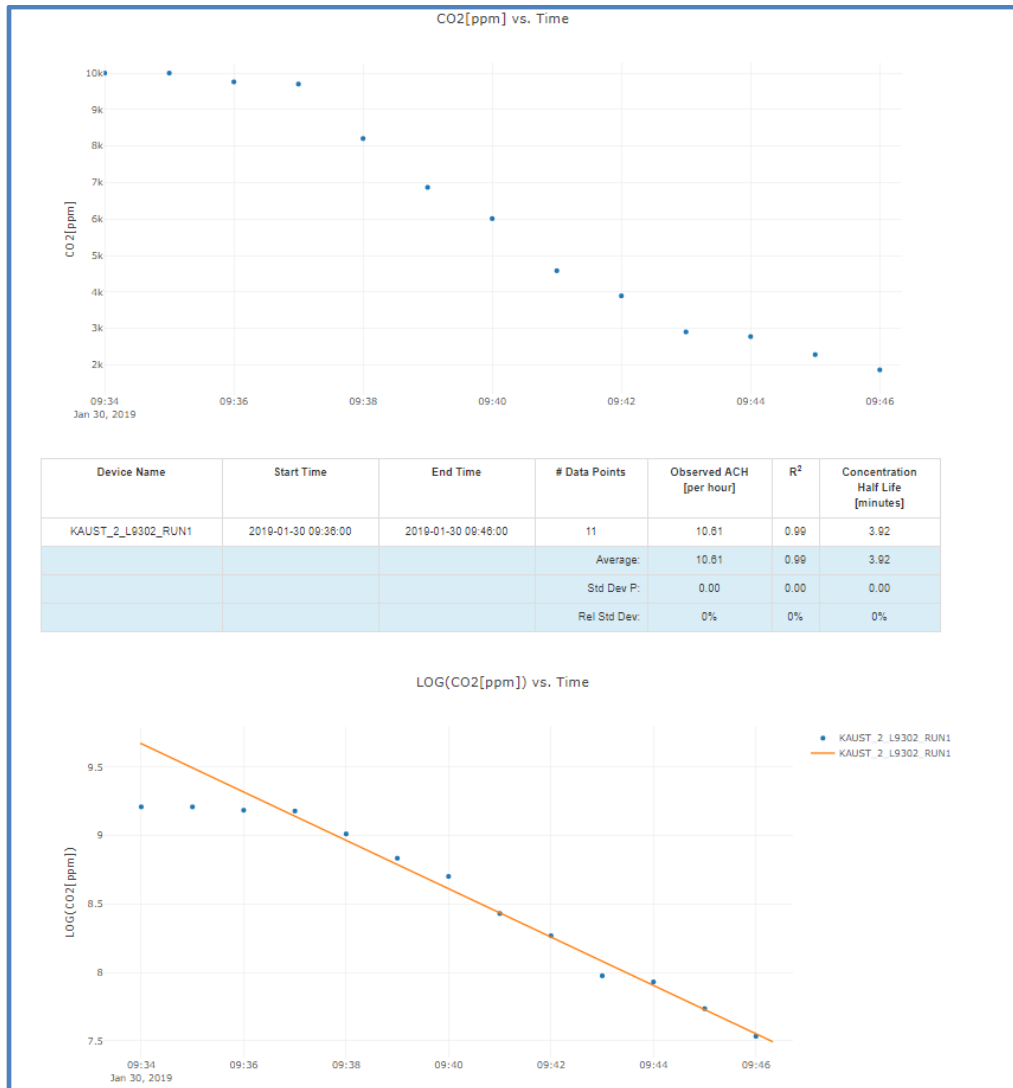
Note: Adjust High and Low Values to correspond to the actual readings. A popup window will indicate when this needs to be done and what values must be used.



Typically use the lowest value in the graph and avoid using CO2 values after bumps. (Need example and better description of this part)

- 8- Remove any extra data points in order to capture the best ACH rate.
- 9- For a good ventilation reading, R² should be 0.9 and above. The second graph will have a confidence line laid over the curve. It should be over the backside of the curve. The closer the points fall near the line, the higher the confidence level and the smoothness of the curve.
 - a. Explanation: The correlation coefficient represents the smoothness of the curve as the tracer gas is removed from the room. A perfect R² is equal to 1. If the R² is low then there is further investigation required that should include not using this data set.

See example graph with correlation 0.99 and linear LOG graph for CO₂ concentration in time, representing a smooth decay.



Data Interpretation

1. Decay rate \approx Building Control System supplied decay rate:

Explanation:

- The room was effectively filled with CO₂ and that location was seeing what the building is providing.
- There is laminar sweeping throughout the lab that properly serves to remove air contaminants.
- The tracer gas measured by an Egg is not blocked from diluting with the air in the room and then being removed by exhaust.

2. Decay rate $>$ the building rate:

Explanation:

- The room was not filled, so the decay rate was impacted by expansion of gas away from the source.
- The Egg is near an exhaust point.
- There is mechanical equipment failure or need for calibration.

3. Decay rate < the building rate:

Explanation:

- Dilution of tracer gas near Egg is not occurring causing the gas to linger and lengthening the decay rate.
- The monitor was located in a dead spot in the room.

4. When to dismiss a data set

- Not a significant number of data points to give an accurate calculation.
- “Bumps” the curve. These may be cut out and recalculation done. These are due to someone entering the room while the test in progress, there is stagnation and the tracer gas remains at the floor level, there is an extremely long time for the gas to be removed, etc.
- There are gaps in data.
- The time of decay for one Egg is different from the others.
- If there is no decay curve from 10,000 ppm, the peak CO₂ concentration is reported. This can occur if the room was overfill or the ACH rate is significantly lower than expected.

Approved by: Revised by: Ellen Sweet Revision Date: 6/17/2019	CO2 Test Page 1 of 3
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