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A Test Method for Measuring the Ozone Emission of In-duct Air Cleaners

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A Test Method for Measuring the Ozone Emission of In-duct Air Cleaners

by

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Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Engineering

The University of Texas at Austin

December 2011

Acknowledgements

I would like to thank my mother, father and sister for their never-ending love, support and encouragement. I would like to acknowledge my advisers, Dr. Jeffrey Siegel and Dr. Atila Novoselac, for their guidance and support. I would also like to thank Joshua Rhodes for his design work of the test apparatus. Lastly, I would like to thank the California Air Resources Board for their funding of this research.

December 2011

Abstract

A Test Method for Measuring the Ozone Emission of In-duct Air Cleaners

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There are many U.S. health-related standards for ozone that aim to limit exposure to ozone. The potential for ozone emission from electrically connected air cleaners is well- known and has led to standards and regulations for portable indoor air cleaning devices, which emit ozone at measured rates of 0.056 – 13.4 mg hr^{-1}. However, there is evidence that some in-duct air cleaners may actually emit more ozone than portable air cleaners, despite being exempt from most regulations due to the lack of a suitable test method for measuring ozone generation. To explore if in-duct cleaners actually do emit ozone, I investigated seven commercially available residential in-duct air cleaning devices. These devices used one of two broad technologies as means of air cleaning: UV light or electrical corona. The lowest measured emission rates came from two air cleaners that utilized UV light technology and were 0.309 ± 1.7 mg hr^{-1}, which was likely below the detection limit of the apparatus and method, and 4.29± 1.5 mg hr^{-1}. Three of the air cleaners tested, also with UV lamps, were of the same brand and model yet exhibited differing emission rates, ranging from 7.44± 1.6 mg hr^{-1} to 15.8± 2.6 mg hr^{-1}. These three air cleaners were classified as medium emitters and also utilized UV light technology. The high median measured emission rates were measured from both an air cleaner utilizing electrical corona technology, 30.2 ± 4.0 mg hr^{-1}, and UV light

technology, 29.4 ± 3.9 mg hr^{-1}. These experimental results confirm that some in-duct air cleaners are able to generate more ozone than some portable air cleaners and also suggest potential health risks to the indoor environment.

Table of Contents

List of Tables ix

List of Figures x

Motivation and Background 1

Experimental Methodology 3

- Test Procedure 8
- Quality Assurance 9
- Experimental Matrix 9

Results and Discussion 11

- Measurement Uncertainty and Detection Limit 13
- Emission Rate Variation 16
- Implications of Ozone Emission 18
- Parametric Testing 21

Conclusions 23

Appendix A Extended Test Protocol 24

Appendix B Summary of Experimental Data 31

Appendix C Detailed Data from Test Runs 36

- Air Cleaner 1 36
- Air Cleaner 2 49
- Air Cleaner 3 67
- Air Cleaner 4 78
- Air Cleaner 5 92
- Air Cleaner 6 104
- Air Cleaner 7 118

References..127

Vita 130

List of Tables

Table 1: Instrumentation Used in the Test Apparatus 7

Table 2: Air Cleaners Tested 10

Table 3: Health-Based Standards for Ozone Levels
Established By the U.S. Government 21

List of Figures

Figure 1: Test apparatus 5

Figure 2: Sampling grid configuration 6

Figure 3: Air cleaner emission rates and
coefficients of variation (CV) measured over *n* test runs.................. 12

Figure 4: Emission rates and uncertainties at
ozone concentration differences of 5, 10 and 20 ppb 14

Figure 5: Emission rates of AC5 and AC7 based
upon successive flow variance tests 18

Figure 6: Air cleaner ozone emission rate shown as
equivalent rise in outdoor ozone concentration............................... 20

Motivation and Background

There are multiple health-related standards for ozone established by the U.S. government, such as the National Institute for Occupational Safety and Health, the Occupational Safety and Health Administration, the California Air Resources Board and the Environmental Protection Agency, which place limits on exposure to ozone. Investigations have shown associations between outdoor ozone concentration exposure and morbidity and mortality. Ozone can cause chest pain, coughing, shortness of breath, throat irritation, and exacerbate asthma (e.g. Bell et al., 2004; Hubbell et al., 2005; Ito et al., 2005; Jerrett et al., 2009; Levy et al., 2005). Ozone has also been found to be very chemically reactive (e.g. Weschler, 2000), which can lead to additional exposure to harmful reaction by-products (Weschler, 2006). Although intended for indoor air purification, some in-duct air cleaners may actually produce ozone during operation. (e.g. Viner et al., 1992). This raises concerns about their overall value for improving indoor air quality.

Ozone emission from some air cleaners is a well-known phenomenon. In 2007, the California Air Resources Board adopted a regulation placing a 50 ppb emission concentration limit on portable indoor air cleaning devices, relying on the test method described in Section 37 of Underwriters Laboratory Standard 867 to certify compliance. In-duct air cleaners, which are physically integrated within a central HVAC system, were exempt from the regulation because no suitable test method was available for measuring ozone from such devices. Several investigations demonstrate that some in-duct air cleaners may actually emit much more ozone than portable air cleaners (e.g. Bowser, 1999; Emmerich and Nabinger, 2000; Hanley et al. 1995; Viner et al. 1992). In principal, any electrically connected device may generate ozone. One prominent type of technology used by in-duct air cleaners is the electrical corona, which has been found to generate ozone (e.g., Britigan et al., 2006; Viner et al. 1992; Waring et al., 2008). Another major technology used is ultraviolet light, which uses wavelengths below 253.7 nm for germicidal irradiation yet consequently also leads to ozone generation (Vig, 1985). Most in-duct air cleaning devices integrate one or both of these approaches, often in combination with charged plates, photocatalysts, and other technologies. Because of the diversity in electronic air cleaning, and the evidence that in-duct air cleaners may emit much more ozone than portable air cleaners, there is strong motivation for a test standard for in-duct air cleaning devices.

The primary focus of this study is to develop a test methodology for measuring the ozone emission rate of in-duct air cleaners. Bowser (1999) studied 15 homes with in-duct electrostatic precipitators and approximated emission rates ranging from roughly 15-73 mg h^{-1} based on the rise in indoor concentrations of ozone. Viner et al. (1992) investigated two commercial in-duct electrostatic precipitators in a laboratory test duct and observed ozone emission rates ranging from 18-30 mg h^{-1}, albeit at much lower flow rates than would typically be seen in residential HVAC systems. In this paper, I present a laboratory test method, which reflects residential installation and application for any in-duct electrically connected air cleaner that emits ozone. The purpose of this method is to allow for comparison of ozone emission from different air cleaners.

Experimental Methodology

The ozone emission rate, E (mg h^{-1}), of an air cleaner is shown in Equation 1,

$$E = Q(C_{downstream} - C_{upstream}) \quad (1)$$

where Q (m^3 h^{-1}), is the average volumetric flow rate through the air cleaner and $C_{downstream}$ and $C_{upstream}$ are the average concentrations (μg m^{-3}) of ozone downstream and upstream of the air cleaner, respectively. While this approach may seem very simple, there are several limitations with actually using it to measure the ozone emission rate of air cleaners. The primary limitation is ozone concentration dilution. At typical air flowrates for large residential HVAC systems, the ozone concentration rise across the air cleaner can be much smaller than the measurement uncertainty of an ozone analyzer. To address this limitation, variable speed fans are used in the test method described below to decrease the flow and increase the concentration difference to a value far above the minimum detection limit of the analyzer. This may introduce other concerns if ozone emission rate is dependent on flow and this is addressed in the method described below.

To measure ozone emission rate, the experimental apparatus shown in Figure 1 was developed. The apparatus is a closed loop system, constructed of both stainless and galvanized steel. Stainless steel was used only in the portions of the apparatus where ozone sampling occurred, as it is less reactive with ozone than galvanized steel. The upper portion is a 60 cm x 60 cm square stainless steel duct, 590 cm in length. The curved transition sections from the upper to lower duct are constructed of galvanized steel, with a 60 cm x 60 cm cross section at the junction with the upper and lower ducts and 150 cm in height. The lower portion of the apparatus consists of two Trane Modular Variable Speed Air Handlers (Model No. 4TEE3F65B1000A) joined by a 48 cm x 60 cm galvanized steel duct, 210 cm long. The test section, in the upper portion of the apparatus, is 60 cm length duct segment where the air cleaners are installed. An AEROSTAR High Volume HEPA Filter (Filtration Group Inc. Item No. 40419) and an AEROSTAR Activated Carbon Filter (Filtration Group Inc. HEGA Series 1652, Item No. 17972) are installed within the upper portion, upstream of the test section for particle filtration and to diminish all ozone in the air stream, respectively. The two previously described air handlers, which supply the air flow and pressure distribution through the apparatus, are each controlled by an Evolution Controls Inc. Visual Control Unit (Model No. EVO/ECM-VCU-36-mp). A flow station is located in the lower portion of the apparatus, in the section of duct immediately following air handling unit #2. The flow station (Shortridge Instruments, Inc., VelGrid) is a square, 16 point, face velocity grid. The pressure difference is measured through the velocity grid by using a DG-700 Pressure and Flow Gauge. The flow rate was calculated by converting the flow station pressure measurement to the appropriate flow rate. This calibration method was done using The Energy Conservatory TrueFlow Air Handler Flow Meter and the DG-700 digital pressure gauge. Calibration of the flow meter occurred only once during the course of all air cleaner testing, and happened prior to any air cleaner testing.

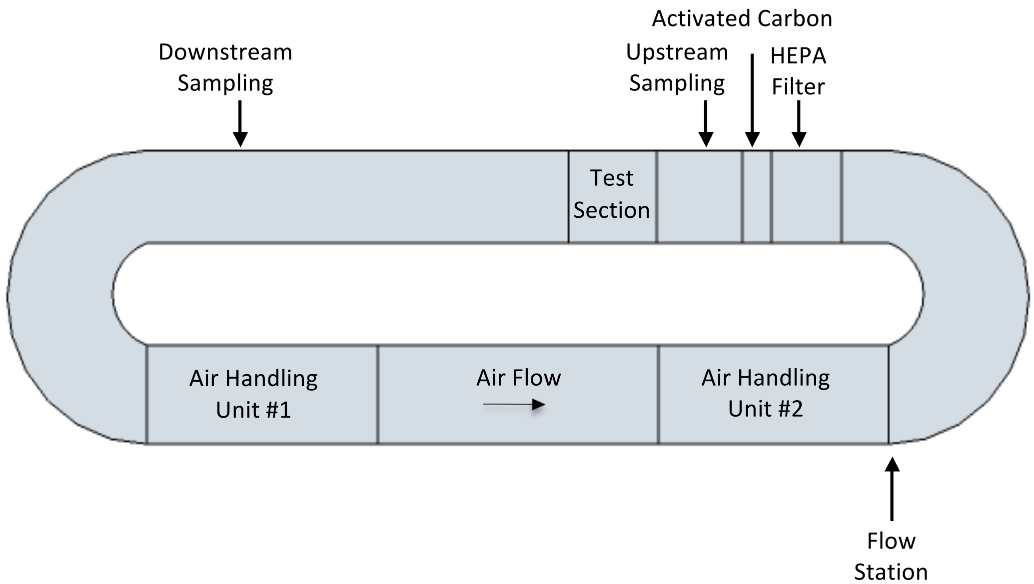

Figure 1. Test apparatus

The air is sampled both upstream and downstream of the test section through a sampling grid. The upstream sampling grid is located 15 cm before the test section and the downstream sampling grid is located 270 cm after the test section. The sampling grid, illustrated in Figure 2, consists of three vertical stainless steel rods, 55 cm in length with a 6 mm outer diameter and 1.5 mm wall thickness. Five 1 mm diameter holes were drilled 12 cm apart on each of the three rods, to measure an average ozone concentration over the entire cross section of the duct. The three rods are spaced evenly across the duct with one inserted at the centerline of the duct and the other two 20 cm on either side of center. A Swagelok cap is attached to each rod on the end inside of the duct. The rods are each held in place within the duct with a Swagelok Bulkhead Union. The segments of the sampling grid outside of the duct are a combination of three short 6 mm vertical stainless steel rods and two horizontal pieces, connected by

Swagelok Unions. From the top of the sampling grid, 6 mm Teflon tubing connects the sampling grid to remainder of the sampling system.

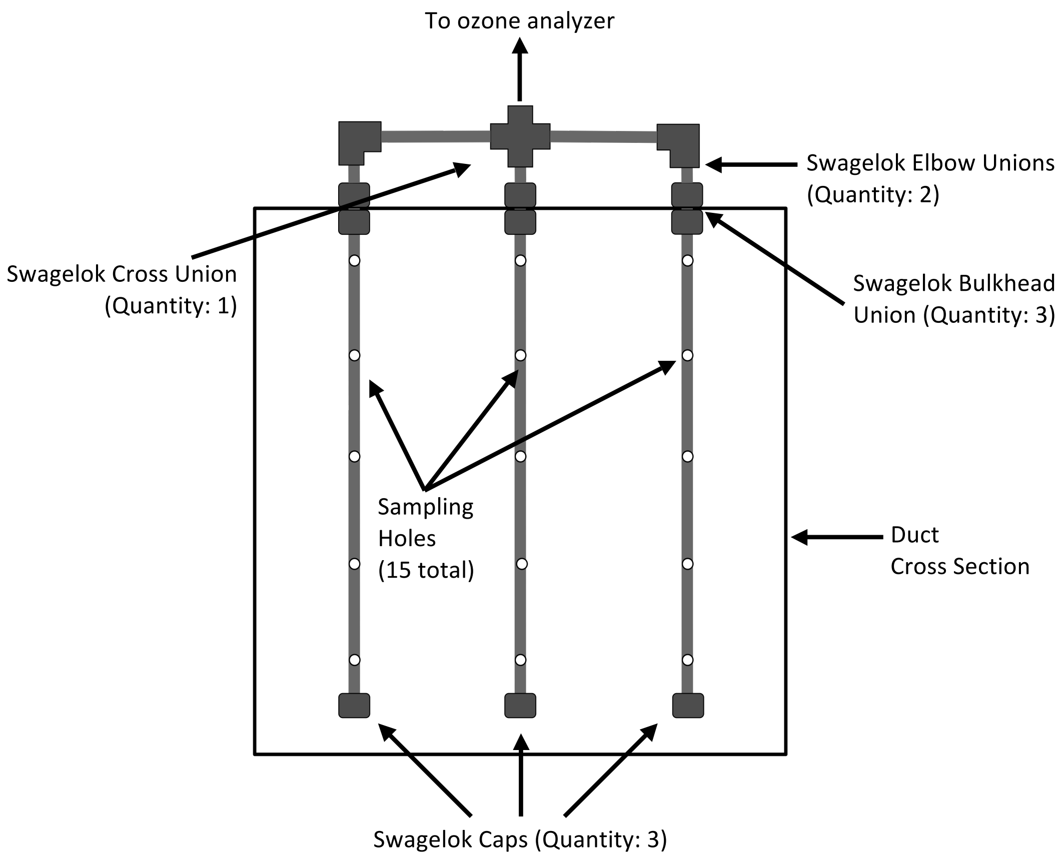

Figure 2. Sampling grid configuration

In order to use a single monitor to analyze both the upstream and downstream ozone concentrations, two Omega 2-way General Purpose Solenoid Valves (Normally Closed Model No. SV125; Normally Open Model No. SV133) were used to enable switching back and forth between upstream and downstream sampling. An Omega Programmable Timing Controller (Model No. PTC-15) controls these valves, controlling whether the ozone monitor is analyzing upstream or downstream concentrations. A 2B Technologies Model 205 Dual Beam Ozone Monitor was used to measure the ozone concentration as measured through the sampling grid.

Additional measurements include temperature (Omega Thermistor, Model No. 44033) and relative humidity (Veris Industries HD Deluxe Humidity Transmitter, Model No.HD2NVSX), which are both located before the upstream sampling grid in the upper portion of the apparatus. The specific measurement devices used in the study are listed in Table 1 and all were connected to an instruNet Analog/Digital, Input/Output System (Model 100) which recorded data every 10 seconds.

Table 1. Instrumentation Used in the Test Apparatus

Measurement	Instrumentation	Accuracy/uncertainty
Ozone concentration	2B Technologies Model 205	Accuracy ±1.0 ppb or 2% Lower limit of detection = 1 ppb
Pressure	DG-700 Pressure and Flow Gauge	Accuracy ±0.15 Pa or 1%
Flow rate	Shortridge Instruments, Inc. VelGrid	Accuracy ±7%[1]
Relative humidity	Veris Industries HD Deluxe Humidity Transmitter	Accuracy at 25ºC from 10-80% RH ±1%
Temperature	Omega Precision Thermistor	Accuracy ±0.10ºC

[1]Based on accuracy of the calibration device (The Energy Conservatory TrueFlow Air Handler Flow Meter)

TEST PROCEDURE

To measure ozone emission rate, an air cleaner was inserted into the test section of the apparatus according to the manufacturer's recommended installation configuration. The variable speed fans were initially set to approximately 500 m^3 hr^{-1}, the lowest constant flow by the apparatus. The fans were initially set at this low speed to ensure the air cleaners could attain an ozone concentration rise of at least 5 ppb. The minimum concentration difference of 5 ppb was chosen based upon the uncertainty assessment, which is discussed below in greater detail. Once the flow rate reached a steady state, the air cleaning device was then turned on and was given five minutes to reach steady state ozone concentration levels as measured by the ozone monitor. At this point sampling began, switching between the upstream and downstream sampling grids. One sampling period consisted of one upstream and one downstream sampling measurement. One full test consisted of two sampling periods. The sampling period lasted four minutes, two minutes of upstream measurement and two minutes of downstream measurement. As previously discussed, data was recorded every 10 seconds, meaning each measurement for a single grid sampling period consisted of 12 data points. The first two points of data were discarded from each set to allow for adequate flush of the sampling system from the previous grid sampling period. An entire test is eight minutes in length. This sampling period length for a single grid was chosen because 10 data points provided a robust average concentration and no variation was seen over the course of 100 seconds. Once a test was run at the lowest flow rate, fan speeds could be increased up until the minimum concentration difference of 5 ppb was reached or until the maximum achievable flow rate, 2200 m^3 hr^{-1}, whichever occurs first.

QUALITY ASSURANCE

Uncertainties in the emission rate were assessed by propagating the uncertainties for each of the parameters in Equation 1, according to ASHRAE Guideline 2-2010. Additional testing was also conducted to determine sampling grid performance, and sampling valve losses. The uniformity of both the upstream and downstream grids was assessed by taking a 9-point measurement over the cross-section of the duct, directly with a short length of Teflon tubing from the ozone analyzer instead of through the sampling grid from Figure 2. The average of the 9–point sample was compared with the sampling grid measurement, which was used to verify both the sampling grid performance as well as losses associated with the longer sampling line length. Sampling valve losses were quantified by taking measurements directly from the grid to the analyzer, bypassing the valves. Again, these measurements were compared to the normal configuration measurements. Preliminary testing showed some variation in the measured emission rate for some air cleaners, and it was not clear if this was due to variation in the test method and apparatus, especially after periods of non-use, or in the air cleaners. This variation is discussed in greater detail below. A low, medium and high emitting air cleaner each repeated 10 identical tests to help assess this issue.

EXPERIMENTAL MATRIX

A summary of the seven air cleaners tested, the technology as specified by the manufacturer, and the broad technology categorization is provided in Table 2. Air cleaner AC1 utilizes UV light technology, consisting of just a single lamp. Air cleaners AC2, AC3 and AC4 are identical units; each of the same brand and model. This air cleaner classifies its unique technology as photohydroionization, which consists of a broad spectrum UV tube in a hydrated catalytic matrix cell and also reports low-level ozone production (10 – 20 ppb). AC5 is an electrostatic precipitator and reports generating very low levels of ozone as well (5-10 ppb) from the use of electrical corona. AC6's broad technology categorization is UV light, but actually utilizes a combination of three UV light bulbs and a titanium dioxide catalyst. This air cleaner was specifically chosen for its claim of zero ozone generation during operation. The final air cleaner tested, AC7, utilizes what the manufacturer classifies as an advanced oxidation process and reports the ozone output as not applicable. This consists of a UV light and a photocatalyst target. These air cleaners were chosen for their diversity in technology used, sizes and configurations, and different ranges of manufacturer reported ozone generation levels.

Table 2. Air Cleaners Tested

Air Cleaner	Manufacturer's Characterization of Technology	Broad Technology Categorization
AC1	Germicidal UV system	UV light
AC2[1]	Photohydroionization	UV light
AC3[1]	Photohydroionization	UV light
AC4[1]	Photohydroionization	UV light
AC5	Electrostatic precipitation	Electrical corona
AC6	Photocatalytic oxidation	UV light
AC7	Advanced Oxidation Process	UV light

[1]Same brand and model air cleaner

Results and Discussion

Figure 3 shows the ozone emission rates measured for the seven air cleaners tested. The boxes show the range from the 25th and 75th percentile of emission rates with the median shown as a horizontal line within the box, while the whiskers illustrate the maximum and minimum emission rates measured for that air cleaner. Also noted in the figure is the number of tests run, *n*, for each air cleaner. A test is defined as an 8-minute sampling period at one consistent flow rate. Three of the air cleaners, AC2 –AC4, are of the same brand and model air cleaner. The lowest median measured emission rate was 0.309 ± 1.7 mg hr^{-1} for AC6 and was likely below the detection limit of the apparatus and method (see below). The high emission rates were 30.2-± 4.0 mg hr^{-1} for AC5 and 29.4 ± 3.9 mg hr^{-1} for AC7. The high emission rates came from both types of air cleaners utilizing either the electrical corona, AC5, or UV light technology, AC7. The low and medium range emission rates were measured only from air cleaners that use UV light technology, including AC1 and AC6 as low emitters, and AC2-4 as medium range emitters.

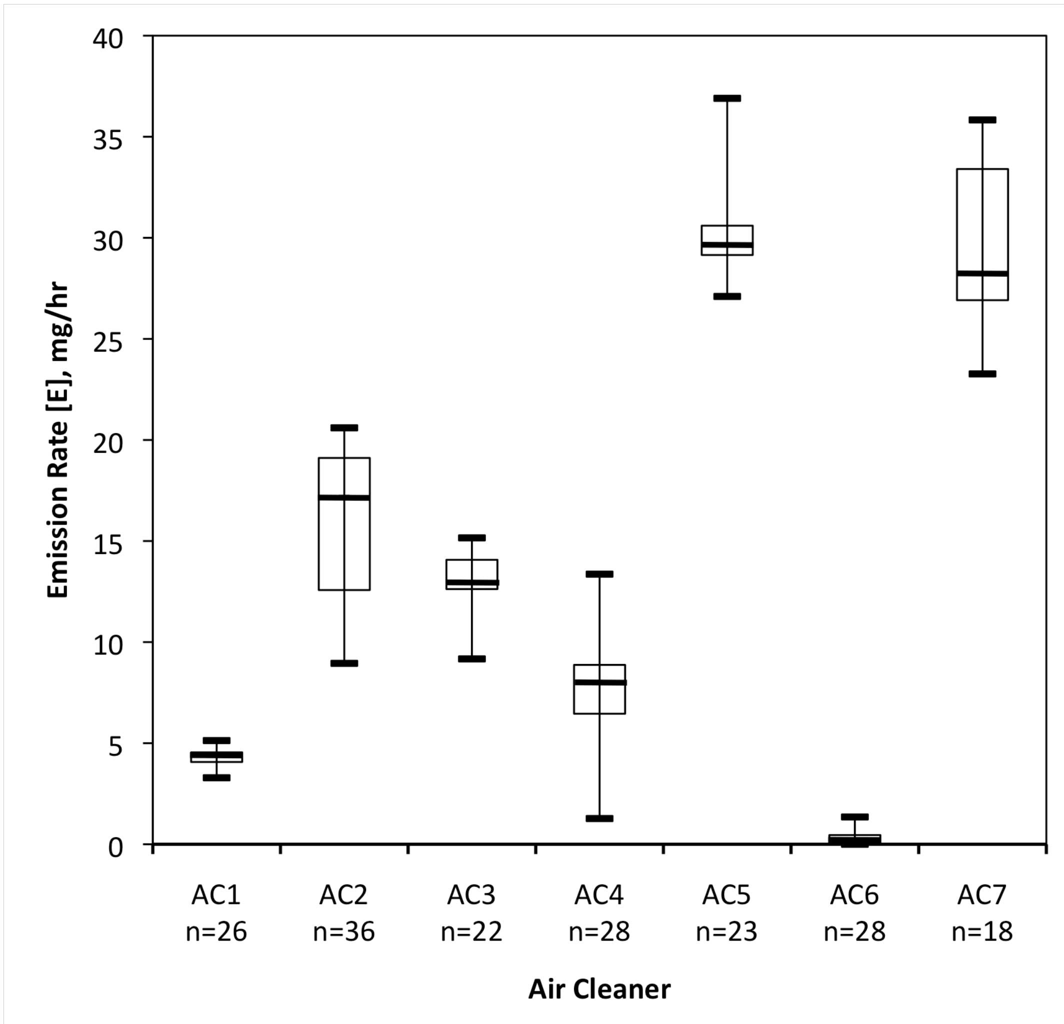

Figure 3. Air cleaner emission rates and coefficients of variation (CV) measured over *n* test runs

Because AC5 is the only device that used an electrical corona, this is the only logical emission rate to be used as a comparison to previously measured emission rates from in-duct air cleaners. The emission rate from AC5 is very comparable with what Viner et al. (1992) measured from two in-duct electrostatic precipitator air cleaners. The larger of the two units Viner et al. that tested was most similar to AC5, consisting of 28 corona wires and 112 plates, and was found to have an ozone generation rate of 21.6 mg hr^{-1}, which is comparable to 30.2-± 4.0 mg hr^{-1} measured of AC5. Bowser (1999) studied 15 homes with in-duct electrostatic precipitators and approximated emission rates ranging from roughly 15-73 mg h^{-1} based on the rise in indoor concentrations of ozone, which AC5 also agrees with as it falls within this range. It is also relevant to compare the measured emission rates from these in-duct air cleaners to measured emission rates from previously measured portable air cleaning devices. Britigan et al. (2006) found portable air purifiers, using an electrical corona to emit 0.16-2.2 mg hr^{-1} and dedicated portable ozone generators to emit as high as 42-220 mg hr^{-1}. They also tested one portable air cleaner using UV light technology and measured an emission rate of 0.74 mg hr^{-1}. The median emission rate of AC7, which utilized UV light technology, was much higher at 29.4-± 3.9 mg hr^{-1}. Some of the in-duct air cleaners tested emit more ozone than portable units, which also may suggests that some in-duct air cleaners emit more ozone than the regulated amounts of portable units.

MEASUREMENT UNCERTAINTY AND DETECTION LIMIT

Figure 3 shows the range of the results, rather than the uncertainty for an individual measurement. The uncertainty in the emission rate is driven by the accuracy of the instruments, namely the measurements of ozone concentration and flow rate as shown in Equation 1 and discussed in the methodology. This presents a limitation to the approach in that for some air cleaners, the concentration difference at a very low air flowrates is still small enough to have substantial uncertainty. Figure 4 illustrates this as it presents emission rates at concentration differences of 5, 10, and 20 ppb measured at flow rates between 500 – 3000 m^3 hr^{-1}. The uncertainty at the same emission rate, such as 20 mg hr^{-1}, is 5.8 mg hr^{-1} with a low concentration difference of 5 ppb as compared to

2.0 mg hr^{-1} at a high concentration of 20 ppb. As the concentration difference increases, the uncertainty of the emission rate decreases. To have reasonable uncertainties for low ozone-emitting devices, the flow has to be reduced below what is practical in the test apparatus and also no longer represents reasonable operating conditions. A reasonable uncertainty for this test method is defined as 30%, which corresponds with the suggested threshold emission rate, described below.

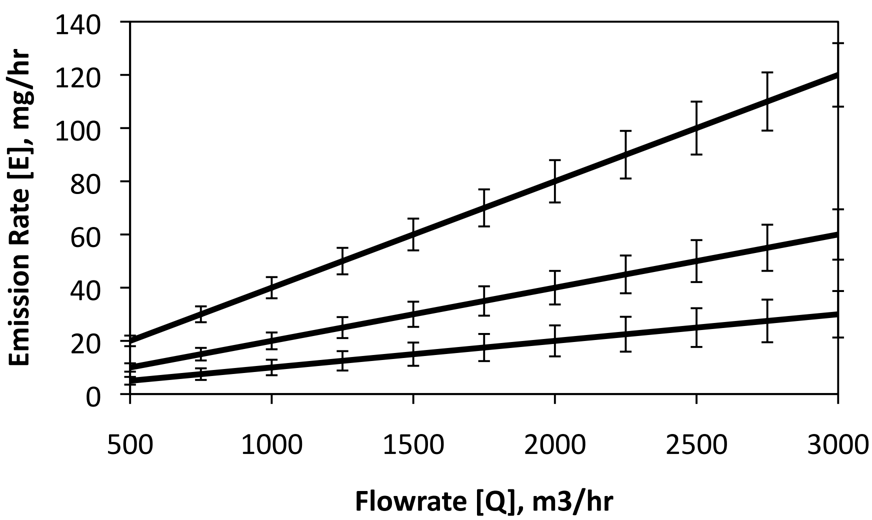

Figure 4. Emission rates and uncertainties at ozone concentration differences of 5, 10 and 20 ppb

At some minimum emission rate a chamber test, much like that of UL 867, should be used to determine ozone emission rate. Such a test has the advantage of much higher accuracy as ozone concentrations are much higher and there is no flow measurement to add to uncertainty. Based on the uncertainty of the devices we used in this investigation (see Table 1), a minimum emission rate of 5 mg hr^{-1}, corresponding to the apparatus's lowest flow of 500 m^3 hr^{-1} and a concentration difference of 5 ppb, is suggested for this threshold. Such an air cleaner would have an uncertainty of 30% or 1.5 mg hr^{-1}. A chamber test would be a reasonable approach to providing greater accuracy at low flows, however it does not reflect actual in-duct installation of the air cleaner.

Another approach to assessing the smallest ozone emission rate that can be measured by the apparatus is to determine a method of quantification limit (MQL). The methods used among programs within the EPA for defining the MQL range from non-specific to very specific. The method used for our purposes, and as defined by the Office of Prevention, Pesticides, and Toxic Substances, involves running the lowest “calibration standard” several times (+7) and multiplying the standard deviation by 6-10 to determine the MQL. In the absence of a true calibration standard, I will instead use the lowest emitting air cleaner tested. To ensure this low emitter is generating an ozone concentration above the noise of the ozone analyzer, a second method based on the Office of Research and Development – National Exposure Laboratory is used, which defines the MQL as the lowest calibration standard that can generate a coefficient of variation <15%. Based on the median emission rates of the air cleaners and coefficients of variation, AC1 is the calibration standard at 4.3 mg hr^{-1}, given a coefficient of variation of 10%. Using the standard deviation of AC1’s emission rate based on all tests run on this device, the method quantitation limit is 2.5 mg hr^{-1}, suggesting that air cleaners with emission rates below this threshold may be detectable but are not quantifiable with the apparatus. An example of an unquantifiable emission rate is AC6, with a measured emission rate of 0.309 ± 1.7 mg hr^{-1}. Turning to a chamber test when the emission rate falls below the MQL has the same benefits and drawbacks of discussed above with determining the threshold.

EMISSION RATE VARIATION

The analysis above ignored any real difference in emission rate that might be caused by test conditions. Viner et al. (1992) and Boelter and Davidson (1997) previously investigated the effect of air flow rate on the ozone generation rate from electrostatic precipitators and both found it to be independent of air flow rate. Because this test method differs from those used in these investigations, and because I also investigate air cleaners utilizing UV light, a flow variance test was run on each air cleaner. This entailed beginning a test at the apparatus's lowest flow rate, 500 m^3 hr^{-1}, and increasing the flow rate over at least three increments until a minimum concentration difference of 5 ppb was achieved or the highest flow rate of the apparatus was achieved, whichever occurred first. At each flow rate a full 8-minute test was run.

Measurements show some evidence of variation in ozone emission rates. This variation may be due to the test method and apparatus or variation in the air cleaner. Figure 3 also displays the coefficient of variation for each air cleaner, based upon all tests run on the device. It is important to highlight the difference in coefficients between AC2, AC3 and AC4. As previously stated, these are all the same brand and model of air cleaner, yet have different measured emission rates and coefficients of variation that range from 0.11 to 0.35. A series of 10 identical tests performed on AC1, AC4 and AC5 were used to further investigate the variance issue, as previously introduced in the methods. The coefficient of variation for AC1, a low emitter, went from 0.10 for all tests to 0.12 for the 10 identical tests. Similarly, the coefficient of variation for AC5 saw very little change, as it was 0.08 overall and 0.07 for the 10 identical tests. The greatest difference in the coefficient of variation was seen in AC4 which was 0.35 overall, but lowered to 0.12 for the 10 identical tests. This evidence lends to contributing the variation to the air cleaner, but certainly does not rule out the test method and apparatus.

Figure 5 shows the average emission rates of AC7 found over two successive flow variation tests, and AC5 emission rates found over three successive flow variation tests. For AC7 it appears that the emission rate at low flow rates, 35.0±2.8 mg hr^{-1} at 500 m^3 hr^{-1}, varies from the emission rate at high flow rates, 25.1±6.5 mg hr^{-1} at 1220 m^3 hr^{-1}. While these results still lie within the bounds of uncertainty, there is still some suggestion that the ozone generation rate may be dependent on flow.

These results again raise the question of whether a chamber test would be a better solution. If a chamber test were used, because there is no flow rate variation, emission rates would actually be higher in a chamber than they would be in a duct. This would result in an over-prediction of ozone emission as compared to typical operation. AC5 presents a stronger case that emission rate is independent of flow, given the results shown in Figure 5. There is less overall variation among the emission rates over a range of flow rates than was seen with AC7.

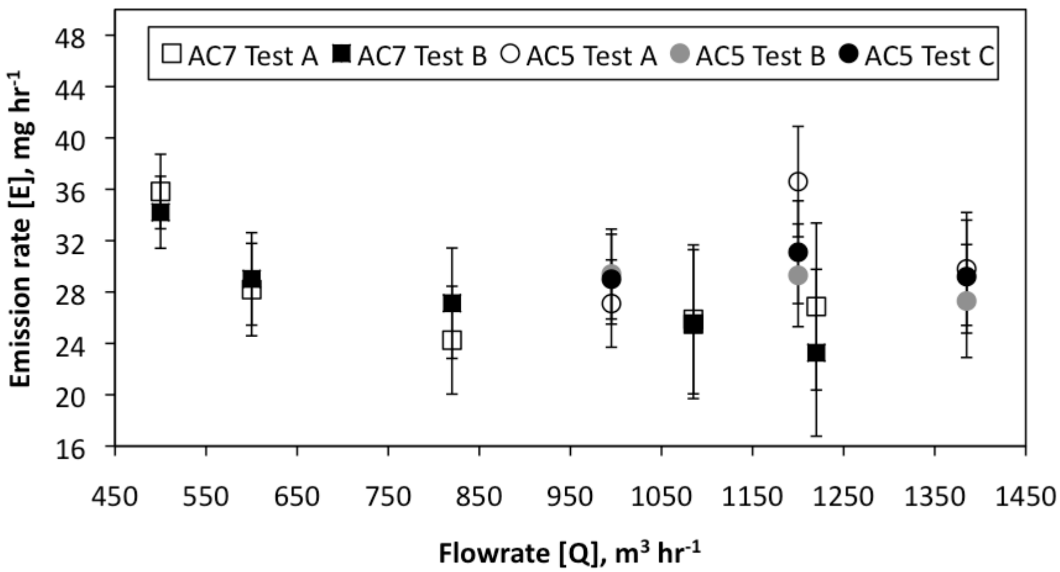

Figure 5. Emission rates of AC5 and AC7 based upon successive flow variance tests

AC2, AC3, and AC4 also exhibited behavior that suggested that emission rate was independent of flow rate. One issue, which is not directly addressed in the testing, is that in residential HVAC systems a consistent flow rate is not continuously being supplied. The HVAC system may cycle between on (flow) and off (no flow) periods, but some air cleaners stay on regardless of the HVAC system cycling. During the periods when no flow is being supplied and the air cleaner is still on, potentially high concentrations of ozone will develop in the duct in the area surrounding the air cleaner.

Implications of Ozone Emission

Thus far, indoor ozone concentrations have been measured and presented and health implications from outdoor ozone exposures have discussed. However, no connection between these two has been made. To put the emission rates measured from the air cleaners into context, Figure 6 shows the equivalent outdoor ozone concentration increase, the amount the outdoor concentration of ozone would need to increase to equal the same indoor concentration increase due to an air cleaner. Following the same approach as Waring et al. (2008), the equivalent outdoor ozone concentration increase, ΔC_{out} is defined as

$$\Delta C_{\text{out}} = \frac{E/V}{p\lambda} \qquad (2)$$

where E, ozone emission rate, was assumed as either 5, 15 or 30 mg hr^{-1}, V, the average volume of a home based upon the American Housing Survey (U.S. Census Bureau, 2011), was assumed as 339 m^3, the ozone penetration factor, p, was assumed as 0.79 (Stephens et al., 2011), and the air exchange rate, λ, was varied between 0.2 and 2.0 hr^{-1}. The solid line represents a low emitting device, 5 mg hr^{-1}, the larger dashed line represents a medium emitter, 15 mg hr^{-1}, and the small dashed line represents a high emitter, 30 mg hr^{-1}.

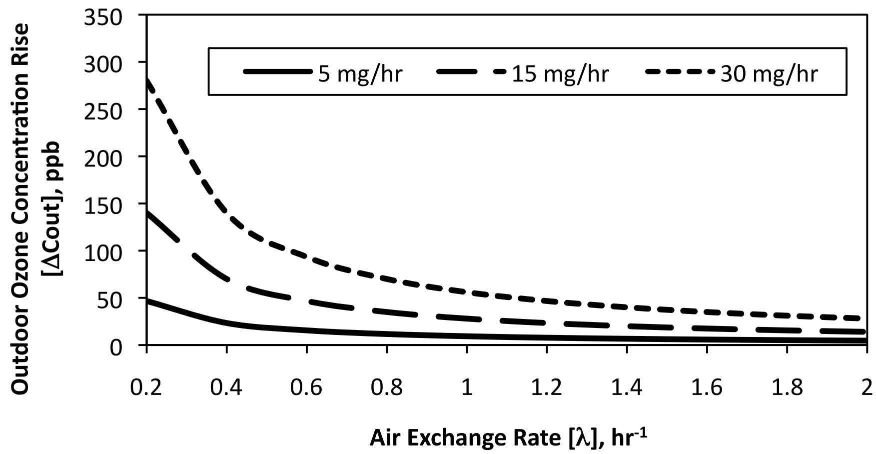

Figure 6. Air cleaner ozone emission rate shown as equivalent rise in outdoor ozone concentration

For a typical residential air exchange rate of 0.5 hr^{-1} (Murray and Burmaster, 1995), the outdoor ozone concentration would need to increase by 19 to 112 ppb in order to achieve a steady-state indoor ozone concentration equivalent to that in the same home with an operating in-duct air cleaner. The effect is greatest for high emitting air cleaners. These predicted increases are significant, based on Bell et al. (2004), which found that a 10 ppb increase in the outdoor ozone concentration from the previous week was associate with a 0.52% increase in daily mortality and a 0.64% increase in cardiovascular and respiratory mortality. Gent et al. (2003) found that a 50 ppb increase in the previous-day, 8-hour ozone level increased the likelihood of chest tightness and shortness of breath by 33% and 30%, respectively. There may be potential for an increase in health problems due to the increased ozone concentrations indoors as the result of operating in-duct air cleaners.

Table 3 is adapted from Britigan et al. (2006) and reviews existing U.S. health-related standards for ozone, which apply to outdoor ozone concentrations. While Figure 6 illustrated outdoor concentration rise, this increase may actually be a high enough levels to be equivalent to overall outdoor concentrations. Again assuming an air exchange rate of 0.5 hr^{-1}, a high ozone emitting air cleaner produces an equivalent outdoor concentration rise over 100 ppb, which exceeds both the EPA NAAQS and California AAQS 8-hr exposure limits. The actual impact on indoor ozone concentrations is complicated by varying deposition loss rates, as well the loss of ozone and the formation of ozone byproducts. However, the results are suggestive that ozone emitting air cleaners can present potential health problems within the indoor environment.

Table 3. Health-Based Standards for Ozone Levels Established By the U.S. Government

Agency	Standard	Exposure Time	Concentration Level (ppb)
EPA[a]	NAAQS[b]	1-hr average	120
EPA	NAAQS	8-hr average	80
OSHA[c]	PEL[d]	8-hr average	100
CARB[e]	California AAQS	1-hr average	90
CARB	California AAQS	8-hr average	70
CARB	Stage 1 smog alert		200
CARB	Stage 2 smog alert		350
CARB	Stage 3 smog alert		500

[a] Environmental Protection Agency
[b] National Ambient Air Quality Standard
[c] Occupational Safety and Health Administration
[d] Permissible Exposure Limit
[e] California Air Resources Board

Parametric Testing

Experimental results demonstrate that some in-duct air cleaners emit enough ozone to raise concern about potential health effects. However, there are parameters that were not investigated during these tests, which may actually cause even greater emission rates. Viner et al. (1992) found that ozone emissions from in-duct electrostatic precipitators were constant at low humidities yet decreased by 25% as humidity rose from 50 to 80% relative humidity. Put into perspective, the EPA recommends that relative humidity be kept below 60% to control mold (EPA Guide to Mold, Moisture, and Your Home). Liu et al. (2000) found that the temperature had a small impact on ozone generation. A temperature increase from 20 to 50 ºC resulted in an ozone concentration rise from 30 to 45 ppb. Potentially, the greatest effect on ozone generation may be due to dust loading, as observed by Dorsey and Davidson (1994). An electronic air cleaner was used to filter Arizona road dust and a 4.6 fold increase in ozone emission rates was observed after the electrical coronas had become soiled over a weeklong period. The accumulation of dust to the corona discharge wire increased the corona current, and as Viner et al. (1992) observed, corona current is linearly proportional to ozone production rates. Additionally, all of the aforementioned conditions relate to ozone generation from electrical coronas but not from UV light. To explore these effects on ozone generation a series of parametric tests should be conducted on the air cleaners to determine this variable dependence. To cover a range of conditions likely to be encountered in a typical residential home, test at both a low (20-30% RH) and high (50-70% RH) relative humidity, at both low (10ºC) and high (50ºC) temperatures, and when the air cleaners have been naturally and artificially loaded with dust should be conducted.

Conclusions

This investigation provides experimental results that demonstrate in-duct air cleaners emit enough ozone to be of concern. Seven air cleaners were investigated to determine their ozone emission rates, while being operated. The lowest measured emission was from a photocatalytic oxidation (PCO) air cleaner containing a UV lamp and was 0.309 ± 1.7 mg hr^{-1}, which was likely below the detection limit of the apparatus and method. The next lowest emission was from a UV lamp and was 4.29± 1.5 mg hr^{-1}. Three of the air cleaners tested, also PCO devices containing UV lamps, were of the same brand and model yet exhibited differing emission rates, ranging from 7.44± 1.6 mg hr^{-1} to 15.8± 2.6 mg hr^{-1}. The highest median measured emission rates were measured from both an air cleaner utilizing electrical corona technology, 30.2 ± 4.0 mg hr^{-1}, and PCO with UV lamp technology, 29.4 ± 3.9 mg hr^{-1}. Regardless of the technology, even low emitting air cleaners result in outdoor equivalent ozone concentration rises which have the potential to lead to adverse health effects. Therefore, this investigation suggests caution in the use of ozone emitting in-duct air cleaners in indoor environments.

Appendix A: Expanded Test Protocol

1. Purpose. This protocol is intended to provide a more complete procedure for evaluating the ozone generation from electrically-connected in-duct air cleaning devices. The test method and data processing procedure are discussed in greater detail below. Emission rate, E, quantified the ozone generation rate of air cleaners in the experiments described in this paper. The emission rate, E, was derived from the airflow rate, Q, and the measured ozone concentration difference, ΔC. The number of tests run, n, run on each air cleaner varied but the same procedure was followed for each test and resulted in a mean emission rate. In addition to the data collected for calculating E, relative humidity and temperature were also recorded during a test. Collection and processing protocol for each of these data sets is described herein.

2. Test Method.

2.1. Airflow Rates for Tests. Tests shall be run for airflow rates as specified in Section 2.1.1 or Section 2.1.2.

2.1.1. The air cleaner shall be first tested at 500 $m^3\ hr^{-1}$ or manufacturers' lowest recommended air flow rate, whichever is higher. In the event that 500 $m^3\ hr^{-1}$ is above the manufacturers' highest recommended air flow rate, the highest recommended air flow rate can be used.

2.1.2. If at 500 $m^3\ hr^{-1}$ the concentration difference between upstream and downstream measurements is greater than 5 ppb, then increase the airflow by 5% and repeat. If a concentration difference greater than 5 ppb is still achieved, increase the airflow in continued 5% increments until a concentration difference of 5 ppb is met. If a concentration difference of 5 ppb is not achieved at lowest airflow, test the device with UL 867.

2.1.3. Test an air cleaner at a minimum of three flows that range from 500 $m^3 hr^{-1}$ or manufacturers' lowest recommended air flow rate, whichever is higher, to the flow rate determined in 2.1.1. Flow rates should be spaced equally over the flow range.

2.2. Test Procedure. The following steps shall be taken to ensure a complete test for one air cleaning device.

a. Insert air cleaning device into the test section of the test apparatus, see Figure 1 of Experimental Methodology. Secure the device and the enclosure of test apparatus.

b. Set the fans of the air handling units to desire flow rate and wait for steady flow to be achieved.

c. Turn on air cleaning device and wait 5 minutes for a steady concentration to be measured downstream by the ozone analyzer. Once achieved, begin sampling ozone concentrations through sampling grids. The automated valves will switch back and forth between upstream and downstream measurements at equal intervals. Intervals shall be two minutes and a sampling period shall consist of at four intervals, two upstream and two downstream. The first 20 seconds of data from each two minute interval shall be discarded before assessment of emission rate.

3. Reporting Results. Airflow rate and ozone concentration measurements are recorded and used to calculate the emission rate of the air cleaner under investigation. The procedure for data collection and processing follows. Additional measurements of temperature and relative humidity are recorded as well.

3.1. Emission Rate Data Collection and Processing.

3.1.1. Components. The components of the emission rate are ozone concentration difference between the downstream and upstream sampling points and the airflow rate across the air cleaner.

3.1.2. Ozone concentration measurements. Begin by turning on and allowing the ozone monitor to stabilize, approximately 20 minutes, prior to collecting measurements. The front menu of the ozone analyzer has four options **Dat, Avg, Cfg,** and **Lmp**. Using the selector knob navigate to **Dat**, which will present a submenu of **Xmt, Log,** and **End.** Navigate to **Log**, where you will be then be asked if you want to overwrite the data stored in the logger. By selecting **Yes** the previously stored data will be discarded, so be sure you have already downloaded this data (instructions follow) before continuing. To begin logging select **Yes**, which will return you to the main. The last step before begin data collection is to select the back arrow, ←, to return to the front menu display. This selection must be done simultaneously with flipping the timer switch on so that concentration measurements and the timer controlling the sampling valves are in sync. Ozone concentration measurements are now being recorded by the ozone analyzer and shall continue for the desired length of testing. Once the desired amount of testing has been completed the, you must now stop data collection. From the front menu of the analyzer, again select **Dat** and then **End**, from the submenu. On the PC the analyzer is connected to via an interface serial cable, open the 2B Technologies – Dual Beam Data Display software, located on the desktop. On the software select the menu option “Start” under the Data Capture menu item. Next, on the ozone monitor front menu select **Dat** and then **Xmt**, which will send the recorded data to the program. Once completed select “Stop” on the software. You will then be prompted to save the data as a text file

(.txt). The file naming convention used is: [Air cleaner number(i.e. AC1)]_[Test type]_[Date].txt. The test type is used to classify what type of test was run. Names used were "Initial", "Full test", and "One Flow". Steps to process the data from the text file follows.

3.1.3. Flow rate measurement. The flow rate measurement, as discussed in Experimental Methodology, is based a pressure measurement which is then converted to an appropriate flow rate. The processing and conversion of this measurement is discussed below in greater detail. For each sampling period, record the pressure measurement to be used to calculate the flow rate.

3.1.4. Raw Data Processing.

3.1.4.1 Ozone Concentration. The text file saved from the ozone monitor needs to be imported into an Excel file to extract the data. In Excel select the menu options DATA > GET EXTERNAL DATA > IMPORT TEXT FILE. You are then prompted with selecting a file, choose the appropriate data to be processed. Next, you are prompted with a 3-step menu. Select in Step 1 that the Data Type is Delimited, in Step 2 that the Delimiter is Comma, and finally that the Column Data Format is General. Selecting Finish will import the data into the Excel file. The first two columns are only of importance, the first being the data point, and the second being the concentration measurement (ppb). Copy these two columns and paste into the Results Template File, in the Data Point and Concentration columns..

3.1.4.2. Flow Measurement. The recorded pressure measurements are next converted to a flow rate. The flow station was calibrated using The Energy Conservatory TrueFlow Air Handler Flow Meter, and from the calibration curve the following conversion was used to calculate flow rate:

Flow rate [Q] =120.12*SQRT(Pressure Measurement [P])

The flow meter pressure is recorded and then the flow rate, Q, is calculated.

3.1.5. Calculations

3.1.5.1. Emission Rate. The emission rate is the product of the ozone concentration difference and the flow rate, both of which have been measured and recorded. The average concentrations for the upstream and downstream measurements are first calculated. Adjacent to the raw concentration data are the calculations for emission rate. The average upstream concentration and average downstream concentration for the sampling period are used to calculate and the difference, DeltaC. Below this calculation is the flow rate measurement, previously introduced, and finally the calculated emission rate following the equation:

Emission Rate [E] = Flow rate [Q] x Concentration Difference [ΔC]

3.1.5.2. Uncertainty. The uncertainty of the emission rate is calculated and recorded. The absolute uncertainty, δC, of the concentration difference, ΔC, is calculated using the following equation:

$$\delta C = \mathrm{SQRT}(c_{up}^2 + c_{down}^2)$$

where c_{up} and c_{down} are the uncertainty of the concentration measurement, which for this test method is the accuracy of the ozone analyzer, 1 ppb. The relative uncertainty is defined as:

Relative Uncertainty = $\delta C/\Delta C$

The relative uncertainty of the flow rate is comes from the accuracy of calibration method and The Energy Conservatory TrueFlow Air Handler Flow Meter, which is defined as:

$$q/Q = 7\%$$

where q is the absolute uncertainty of the flow rate and Q is the flow rate. Finally, the absolute uncertainty of the emission rate, e, is calculated as:

$$e = E \text{ x SQRT}[(q/Q)^2+(\delta C/\Delta C)^2]$$

where E is the emission rate for which the uncertainty is being calculated and q/Q is the relative uncertainty of the flow rate and $\delta C/\Delta C$ is the relative uncertainty of the concentration difference.

3.2. Additional Data Collection. Temperature, relative humidity and the electricity usage of the air cleaner were also recorded during a test. The sensors used for temperature and relative humidity measurements are connect to the instruNet data acquisition system. Following the connection of the sensors to the data acquisition system, the outputs from the sensors are able to be recorded on the connected PC. Each sensor is connected to a designated channel of the data acquisition system. Opening the instruNet software program, located on the PC desktop, allows you to see each channel of the data acquisition system. The appropriate configurations are discussed below to record accurate readings. For this testing data was manually recorded in the laboratory lab notebook. The electricity usage (i.e. Power, voltage and current) was also manually measured during a test.

3.2.1. Temperature. The temperature within the apparatus is measured by a thermistor, which is connected to a data acquisition system. The data acquisition system allows you to configure the corresponding channel of the thermistor as a temperature measurement. By configuring the channel in this manner, you will notice that the real time measurement in the instruNet software is now in ºC.

3.2.2. Relative Humidity. The instruNet data acquisition system does not have a designated relative humidity configuration like it does for temperature. However, for the channel that the relative humidity sensor is connected to a voltage measurement is displayed. This voltage reading ranges from 0-5 V and corresponds linearly with a relative humidity measurement of 0-100%.

3.2.3. Electricity Usage. A Kill A Watt Electricity Usage Monitor was used to measure the voltage, current and watt draw of an air cleaner during a test. These measurements were taken as a way to monitor the performance of the air cleaner, as a fluctuation in one of these may alter the emission rate measurement.

Appendix B: Summary of Experimental Data

Air Cleaner	Date	Type of Test	Flow Rate m^3/hr	Emission Rate mg/hr	Uncertainty mg/hr
AC1	25-Aug-11	Initial Trial	493	3.75	1.4
AC1	12-Oct-11	Full Test - 1	512	4.55	1.5
AC1	12-Oct-11	Full Test - 1	563	4.24	1.6
AC1	12-Oct-11	Full Test - 1	612	4.22	1.8
AC1	12-Oct-11	Full Test - 1	841	4.34	2.4
AC1	12-Oct-11	Full Test - 1	512	4.34	1.5
AC1	12-Oct-11	Full Test - 2	512	4.47	1.5
AC1	12-Oct-11	Full Test - 2	563	4.00	1.6
AC1	12-Oct-11	Full Test - 2	612	4.85	1.8
AC1	12-Oct-11	Full Test - 2	841	4.47	2.4
AC1	12-Oct-11	Full Test - 2	512	3.61	1.5
AC1	12-Oct-11	Full Test - 3	512	3.81	1.5
AC1	12-Oct-11	Full Test - 3	563	4.67	1.6
AC1	12-Oct-11	Full Test - 3	612	4.51	1.8
AC1	12-Oct-11	Full Test - 3	841	4.66	2.4
AC1	12-Oct-11	Full Test - 3	512	4.53	1.5
AC1	12-Oct-11	One Flow Repeat	490	3.82	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.06	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.36	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.49	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.68	1.4
AC1	12-Oct-11	One Flow Repeat	490	5.13	1.4
AC1	12-Oct-11	One Flow Repeat	490	3.29	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.14	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.10	1.4
AC1	12-Oct-11	One Flow Repeat	490	4.56	1.4
AC2	25-Aug-11	Initial Trial	493	8.95	1.5
AC2	1-Sep-11	Full Test - 1	493	11.6	1.6
AC2	1-Sep-11	Full Test - 1	556	11.4	1.8
AC2	1-Sep-11	Full Test - 1	612	11.4	1.9
AC2	1-Sep-11	Full Test - 1	1095	13.2	3.2
AC2	1-Sep-11	Full Test - 1	1224	12.2	3.6
AC2	13-Sep-11	Full Test - 2	490	11.4	1.6
AC2	13-Sep-11	Full Test - 2	490	12.8	1.7
AC2	13-Sep-11	Full Test - 2	610	12.6	1.9
AC2	13-Sep-11	Full Test - 2	1095	12.8	3.2

AC2	13-Sep-11	Full Test - 2	1095	11.7	3.2
AC2	13-Sep-11	Full Test - 2	1120	13.2	3.5
AC2	13-Sep-11	Full Test - 2	1225	12.2	3.6
AC2	13-Sep-11	Full Test - 2	1225	16.0	3.6
AC2	13-Sep-11	Full Test - 2	490	12.5	1.6
AC2	27-Sep-11	Full Test - 3	490	18.3	1.9
AC2	27-Sep-11	Full Test - 3	490	20.2	2.0
AC2	27-Sep-11	Full Test - 3	610	20.6	2.2
AC2	27-Sep-11	Full Test - 3	1095	12.7	3.2
AC2	27-Sep-11	Full Test - 3	1095	13.8	3.2
AC2	27-Sep-11	Full Test - 3	1120	19.7	3.7
AC2	27-Sep-11	Full Test - 3	1225	17.2	3.7
AC2	27-Sep-11	Full Test - 3	1225	19.4	3.7
AC2	27-Sep-11	Full Test - 3	490	17.6	1.9
AC2	27-Sep-11	Full Test – 4	288	18.4	1.9
AC2	27-Sep-11	Full Test – 4	475	18.1	2.6
AC2	27-Sep-11	Full Test – 4	714	18.4	3.7
AC2	27-Sep-11	Full Test – 5	288	18.1	1.9
AC2	27-Sep-11	Full Test – 5	475	19.0	2.6
AC2	27-Sep-11	Full Test – 5	714	19.7	3.7
AC2	27-Sep-11	Full Test – 6	288	19.9	2.0
AC2	27-Sep-11	Full Test – 6	475	19.2	2.6
AC2	27-Sep-11	Full Test – 6	714	19.1	3.7
AC2	27-Sep-11	Full Test – 7	288	19.7	2.0
AC2	27-Sep-11	Full Test – 7	475	17.2	2.6
AC2	27-Sep-11	Full Test – 7	714	19.6	3.7
AC3	1-Sep-11	Initial Trial	493	9.17	1.5
AC3	29-Sep-11	Trial	490	10.4	1.6
AC3	29-Sep-11	Trial	490	12.9	1.7
AC3	29-Sep-11	Trial	490	13.0	1.7
AC3	13-Oct-11	Full Test - 1	512	12.6	1.7
AC3	13-Oct-11	Full Test - 1	598	12.6	1.9
AC3	13-Oct-11	Full Test - 1	821	11.4	2.5
AC3	13-Oct-11	Full Test - 1	1084	12.5	3.2
AC3	13-Oct-11	Full Test - 1	1218	12.8	3.6
AC3	13-Oct-11	Full Test - 1	512	13.7	1.7
AC3	13-Oct-11	Full Test - 2	512	13.1	1.7
AC3	13-Oct-11	Full Test - 2	598	12.9	1.9
AC3	13-Oct-11	Full Test - 2	821	13.1	2.5
AC3	13-Oct-11	Full Test - 2	1084	12.6	3.2
AC3	13-Oct-11	Full Test - 2	1218	13.1	3.6

AC3	13-Oct-11	Full Test - 2	512	14.4	1.8
AC3	13-Oct-11	Full Test - 3	512	15.2	1.8
AC3	13-Oct-11	Full Test - 3	598	14.2	2.0
AC3	13-Oct-11	Full Test - 3	821	14.8	2.5
AC3	13-Oct-11	Full Test - 3	1084	15.0	3.2
AC3	13-Oct-11	Full Test - 3	1218	12.1	3.5
AC3	13-Oct-11	Full Test - 3	512	14.9	1.8
AC4	6-Oct-11	Full Test - 1	489	1.27	1.4
AC4	6-Oct-11	Full Test - 1	614	1.89	1.7
AC4	6-Oct-11	Full Test - 1	827	3.24	2.4
AC4	6-Oct-11	Full Test - 1	1079	4.00	3.1
AC4	6-Oct-11	Full Test - 1	1199	5.02	3.4
AC4	6-Oct-11	Full Test - 1	489	5.40	1.4
AC4	6-Oct-11	Full Test - 2	489	6.53	1.5
AC4	6-Oct-11	Full Test - 2	614	7.61	1.8
AC4	6-Oct-11	Full Test - 2	827	13.36	2.5
AC4	6-Oct-11	Full Test - 2	1079	6.22	3.1
AC4	6-Oct-11	Full Test - 2	1199	6.71	3.4
AC4	6-Oct-11	Full Test - 2	489	7.43	1.5
AC4	6-Oct-11	Full Test - 3	489	8.72	1.5
AC4	6-Oct-11	Full Test - 3	614	9.25	1.9
AC4	6-Oct-11	Full Test - 3	827	8.97	2.4
AC4	6-Oct-11	Full Test - 3	1079	9.78	3.1
AC4	6-Oct-11	Full Test - 3	1199	7.83	3.4
AC4	6-Oct-11	Full Test - 3	489	8.28	1.5
AC4	7-Oct-11	One Flow Repeat	489	7.56	1.5
AC4	7-Oct-11	One Flow Repeat	489	7.36	1.5
AC4	7-Oct-11	One Flow Repeat	489	8.29	1.5
AC4	7-Oct-11	One Flow Repeat	489	8.84	1.5
AC4	7-Oct-11	One Flow Repeat	489	8.11	1.5
AC4	7-Oct-11	One Flow Repeat	489	8.15	1.5
AC4	7-Oct-11	One Flow Repeat	489	10.4	1.6
AC4	7-Oct-11	One Flow Repeat	489	9.33	1.5
AC4	7-Oct-11	One Flow Repeat	489	8.64	1.5
AC4	7-Oct-11	One Flow Repeat	489	10.0	1.6
AC5	30-Sep-11	Initial Trial	1215	28.6	4.0
AC5	30-Sep-11	Initial Trial	1215	30.2	4.0
AC5	4-Oct-11	Full Test - 1	995	27.1	3.4
AC5	4-Oct-11	Full Test - 1	1200	36.6	4.3
AC5	4-Oct-11	Full Test - 1	1385	29.8	4.4
AC5	4-Oct-11	Full Test - 2	995	29.4	3.5

AC5	4-Oct-11	Full Test - 2	1200	29.3	4.0
AC5	4-Oct-11	Full Test - 2	1385	27.3	4.4
AC5	4-Oct-11	Full Test - 2	995	29.6	3.5
AC5	4-Oct-11	Full Test - 3	995	29.0	3.5
AC5	4-Oct-11	Full Test - 3	1200	31.1	4.0
AC5	4-Oct-11	Full Test - 3	1385	29.2	4.4
AC5	4-Oct-11	Full Test - 3	995	29.5	3.5
AC5	4-Oct-11	One Flow Repeat	1185	36.9	4.2
AC5	4-Oct-11	One Flow Repeat	1185	29.1	3.9
AC5	4-Oct-11	One Flow Repeat	1185	30.3	4.0
AC5	4-Oct-11	One Flow Repeat	1185	29.5	3.9
AC5	4-Oct-11	One Flow Repeat	1185	30.9	4.0
AC5	4-Oct-11	One Flow Repeat	1185	32.0	4.0
AC5	4-Oct-11	One Flow Repeat	1185	31.1	4.0
AC5	4-Oct-11	One Flow Repeat	1185	28.9	3.9
AC5	4-Oct-11	One Flow Repeat	1185	30.0	4.0
AC5	4-Oct-11	One Flow Repeat	1185	30.2	4.0
AC6	29-Sep-11	Initial Trial	490	0.543	1.4
AC6	29-Sep-11	Initial Trial	490	0.366	1.4
AC6	29-Sep-11	Initial Trial	490	0.010	1.4
AC6	29-Sep-11	Initial Trial	490	0.147	1.4
AC6	30-Sep-11	Full Test - 1	490	0.636	1.4
AC6	30-Sep-11	Full Test - 1	615	0.940	1.7
AC6	30-Sep-11	Full Test - 1	805	1.03	2.3
AC6	30-Sep-11	Full Test - 1	1095	0.000	3.1
AC6	30-Sep-11	Full Test - 1	1215	0.000	3.4
AC6	30-Sep-11	Full Test - 1	490	0.210	1.4
AC6	13-Sep-11	Full Test - 2	490	0.372	1.4
AC6	13-Sep-11	Full Test - 2	615	0.000	1.7
AC6	13-Sep-11	Full Test - 2	805	1.350	2.3
AC6	13-Sep-11	Full Test - 2	1095	0.000	3.1
AC6	13-Sep-11	Full Test - 2	1215	0.000	3.4
AC6	13-Sep-11	Full Test - 2	490	0.259	1.4
AC6	13-Sep-11	Full Test - 3	490	0.230	1.4
AC6	13-Sep-11	Full Test - 3	615	0.000	1.7
AC6	13-Sep-11	Full Test - 3	805	0.484	2.3
AC6	27-Sep-11	Full Test - 3	1095	0.000	3.1
AC6	27-Sep-11	Full Test - 3	1215	0.000	3.4
AC6	27-Sep-11	Full Test - 3	490	0.000	1.4
AC6	27-Sep-11	Full Test - 4	490	0.444	1.4
AC6	27-Sep-11	Full Test - 4	615	0.117	1.7

AC6	27-Sep-11	Full Test - 4	805	0.234	2.3
AC6	27-Sep-11	Full Test - 4	1095	0.000	3.1
AC6	27-Sep-11	Full Test - 4	1215	0.825	3.4
AC6	27-Sep-11	Full Test - 4	490	0.441	1.4
AC7	13-Oct-11	Full Test - 1	512	35.53	2.9
AC7	13-Oct-11	Full Test - 1	1051	29.17	3.6
AC7	13-Oct-11	Full Test - 1	1354	28.21	4.3
AC7	13-Oct-11	Full Test - 1	1947	27.06	5.8
AC7	13-Oct-11	Full Test - 1	2208	27.31	6.5
AC7	13-Oct-11	Full Test - 1	512	33.47	2.75
AC7	13-Oct-11	Full Test - 2	512	35.83	2.9
AC7	13-Oct-11	Full Test - 2	598	28.19	3.6
AC7	13-Oct-11	Full Test - 2	821	24.25	4.19
AC7	13-Oct-11	Full Test - 2	1084	25.87	5.8
AC7	13-Oct-11	Full Test - 2	1218	26.87	6.5
AC7	13-Oct-11	Full Test - 2	512	34.49	2.8
AC7	13-Oct-11	Full Test - 3	512	34.21	2.80
AC7	13-Oct-11	Full Test - 3	598	29.02	3.6
AC7	13-Oct-11	Full Test - 3	821	27.13	4.27
AC7	13-Oct-11	Full Test - 3	1084	25.50	5.8
AC7	13-Oct-11	Full Test - 3	1218	23.27	6.5
AC7	13-Oct-11	Full Test - 3	512	33.20	2.7

Appendix C: Detailed Data from Test Runs

AIR CLEANER 1

RUN 1 — 4-Oct-11

Sampling Period 1				
Average Upstream	0.59	ppb	0.00118	mg/m3
Average Downstream	4.49	ppb	0.00898	mg/m3
DeltaC	3.90	ppb	0.00780	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	1124	CFMxppb	3.82	mg/hr

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	36%	7.0%	37%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	4.8
2	3.0

RUN 2 — 4-Oct-11

Sampling Period 1				
Average Upstream	1.24	ppb	0.00247	mg/m3
Average Downstream	5.39	ppb	0.01077	mg/m3
DeltaC	4.15	ppb	0.00830	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.06	CFMxppb		mg/hr

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	34%	7.0%	35%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	4.7
2	3.6

RUN 3 — 4-Oct-11

Sampling Period 1				
Average Upstream	0.50	ppb	0.00099	mg/m3
Average Downstream	4.95	ppb	0.00989	mg/m3
DeltaC	4.45	ppb	0.00890	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.36	mg/hr		

Absolute Uncertainty in DC (ppb)	Relative Uncertainty of DC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	32%	7.0%	33%	1.4

Sampling Set (Down & Up)	Delta C ppb
1.0	4.8
2.0	4.1

RUN 4 — 4-Oct-11

Sampling Period 1				
Average Upstream	0.52	ppb	0.00104	mg/m3
Average Downstream	5.11	ppb	0.01021	mg/m3
DeltaC	4.59	ppb	0.00917	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.49	mg/hr		

Absolute Uncertainty in DC	Relative Uncertainty of DC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	31%	7.0%	32%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1.0	4.1
2.0	5.1

RUN 5 — 4-Oct-11

Sampling Period 1				
Average Upstream	0.41	ppb	0.00081	mg/m3
Average Downstream	5.19	ppb	0.01038	mg/m3
DeltaC	4.79	ppb	0.00957	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.68	mg/hr		

Absolute Uncertainty in DC	Relative Uncertainty of DC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	30%	7.0%	30%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1.0	5.2
2.0	4.4

RUN 6 4-Oct-11

Sampling Period 1				
Average Upstream	0.35	ppb	0.00070	mg/m3
Average Downstream	5.59	ppb	0.01118	mg/m3
DeltaC	5.24	ppb	0.01048	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	5.13	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	27%	7.0%	28%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	4.6
2	5.9

RUN 7 4-Oct-11

Sampling Period 1				
Average Upstream	1.56	ppb	0.00313	mg/m3
Average Downstream	4.93	ppb	0.00985	mg/m3
DeltaC	3.36	ppb	0.00672	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	3.29	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	42%	7.0%	43%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	2.7
2	4.0

RUN 8

12-Oct-11

Sampling Period 1				
Average Upstream	0.87	ppb	0.00173	mg/m3
Average Downstream	5.09	ppb	0.01019	mg/m3
DeltaC	4.23	ppb	0.00846	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.14	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	33%	7.0%	34%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	4.9
2	3.6

RUN 9

12-Oct-11

Sampling Period 1				
Average Upstream	0.72	ppb	0.00143	mg/m3
Average Downstream	4.90	ppb	0.00980	mg/m3
DeltaC	4.19	ppb	0.00837	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.10	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	34%	7.0%	35%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	4.0
2	4.4

RUN 10

Sampling Period 1				
Average Upstream	0.67	ppb	0.00134	mg/m3
Average Downstream	5.33	ppb	0.01065	mg/m3
DeltaC	4.66	ppb	0.00931	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	4.56	mg/hr		

12-Oct-11

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	30%	7.0%	31%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	5.0
2	4.4

Initial Test Run

Sampling Period 1				
Average Upstream	0.23	ppb	0.000455	mg/m3
Average Downstream	4.03	ppb	0.008056	mg/m3
DeltaC	3.80	ppb	0.007601	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	3.75	mg/hr		

25-Aug-11

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.414	37%	7.0%	38%	1.4

Full Test Run 1

12-Oct-11

Sampling Period 1				
Average Upstream	0.53	ppb	0.00106	mg/m3
Average Downstream	4.97	ppb	0.00994	mg/m3
DeltaC	4.44	ppb	0.00888	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	4.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	32%	7.0%	33%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	3.9
2	5.0

Sampling Period 2				
Average Upstream	0.40	ppb	0.00080	mg/m3
Average Downstream	4.17	ppb	0.00834	mg/m3
DeltaC	3.77	ppb	0.00754	mg/m3
Flow Meter Pressure	7.6	Pa		
Q	331	CFM	563	m3/hr
E	4.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	38%	7.0%	38%	1.6

Sampling Set	Delta C
(Down & Up)	ppb
1	4.1
2	3.4

Sampling Period 3				
Average Upstream	0.33	ppb	0.00066	mg/m3
Average Downstream	3.78	ppb	0.00755	mg/m3
DeltaC	3.45	ppb	0.00689	mg/m3
Flow Meter Pressure	9	Pa		
Q	360	CFM	612	m3/hr
E	4.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	41%	7.0%	42%	1.8

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 4				
Average Upstream	0.11	ppb	0.00022	mg/m3
Average Downstream	2.69	ppb	0.00538	mg/m3
DeltaC	2.58	ppb	0.00516	mg/m3
Flow Meter Pressure	17	Pa		
Q	495	CFM	841	m3/hr
E	4.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	55%	7.0%	55%	2.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 5				
Average Upstream	0.44	ppb	0.00088	mg/m3
Average Downstream	4.68	ppb	0.00936	mg/m3
DeltaC	4.24	ppb	0.00848	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	4.3	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	33%	7.0%	34%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	0.0
2	0.0

Full Test Run 2

12-Oct-11

Sampling Period 1				
Average Upstream	0.55	ppb	0.00109	mg/m3
Average Downstream	4.91	ppb	0.00981	mg/m3
DeltaC	4.36	ppb	0.00872	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	4.5	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	32%	7.0%	33%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	4.2
2	4.5

Sampling Period 2				
Average Upstream	0.68	ppb	0.00135	mg/m3
Average Downstream	4.23	ppb	0.00846	mg/m3
DeltaC	3.56	ppb	0.00711	mg/m3
Flow Meter Pressure	7.6	Pa		
Q	331	CFM	563	m3/hr
E	4.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	40%	7.0%	40%	1.6

Sampling Set (Down & Up)	Delta C ppb
1	4.1
2	3.0

Sampling Period 3				
Average Upstream	0.09	ppb	0.00017	mg/m3
Average Downstream	4.05	ppb	0.00809	mg/m3
DeltaC	3.96	ppb	0.00792	mg/m3
Flow Meter Pressure	9	Pa		
Q	360	CFM	612	m3/hr
E	4.8	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	36%	7.0%	36%	1.8

Sampling Set (Down & Up)	Delta C ppb
1	0.0
2	0.0

Sampling Period 4				
Average Upstream	0.67	ppb	0.00133	mg/m3
Average Downstream	3.32	ppb	0.00664	mg/m3
DeltaC	2.66	ppb	0.00531	mg/m3
Flow Meter Pressure	17	Pa		
Q	495	CFM	841	m3/hr
E	4.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	53%	7.0%	54%	2.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 5				
Average Upstream	0.77	ppb	0.00153	mg/m3
Average Downstream	4.29	ppb	0.00858	mg/m3
DeltaC	3.53	ppb	0.00705	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	3.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	40%	7.0%	41%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Full Test Run 3 12-Oct-11

Sampling Period 1				
Average Upstream	1.14	ppb	0.00229	mg/m3
Average Downstream	4.86	ppb	0.00972	mg/m3
DeltaC	3.72	ppb	0.00743	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	3.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	38%	7.0%	39%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	3.6
2	3.8

Sampling Period 2				
Average Upstream	0.20	ppb	0.00039	mg/m3
Average Downstream	4.35	ppb	0.00869	mg/m3
DeltaC	4.15	ppb	0.00830	mg/m3
Flow Meter Pressure	7.6	Pa		
Q	331	CFM	563	m3/hr
E	4.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	34%	7.0%	35%	1.6

Sampling Set	Delta C
(Down & Up)	ppb
1	4.3
2	4.0

Sampling Period 3				
Average Upstream	0.40	ppb	0.00081	mg/m3
Average Downstream	4.09	ppb	0.00817	mg/m3
DeltaC	3.68	ppb	0.00736	mg/m3
Flow Meter Pressure	9	Pa		
Q	360	CFM	612	m3/hr
E	4.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	38%	7.0%	39%	1.8

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 4				
Average Upstream	0.06	ppb	0.00012	mg/m3
Average Downstream	2.83	ppb	0.00566	mg/m3
DeltaC	2.77	ppb	0.00554	mg/m3
Flow Meter Pressure	17	Pa		
Q	495	CFM	841	m3/hr
E	4.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	51%	7.0%	52%	2.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 5				
Average Upstream	0.39	ppb	0.00077	mg/m3
Average Downstream	4.81	ppb	0.00962	mg/m3
DeltaC	4.43	ppb	0.00885	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	4.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	32%	7.0%	33%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Air Cleaner 2

Initial Trial 25-Aug-11

Sampling Period 1				
Average Upstream	0.230	ppb	0.00046	mg/m3
Average Downstream	9.31	ppb	0.0186	mg/m3
DeltaC	9.08	ppb	0.0182	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.95	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	15.6%	7.0%	17%	1.5

Full Test 1-Sep-11

Sampling Period 1				
Average Upstream	0.235	ppb	0.00047	mg/m3
Average Downstream	12.0	ppb	0.0240	mg/m3
DeltaC	11.8	ppb	0.0236	mg/m3
Q	290	CFM	493	m3/hr
E	11.6	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	14%	1.6

Sampling Set (Down & Up)	Delta C ppb
1	11.7
2	11.8

Sampling Period 2				
Average Upstream	0.440	ppb	0.00088	mg/m3
Average Downstream	10.7	ppb	0.0214	mg/m3
DeltaC	10.2	ppb	0.0205	mg/m3
Q	327	CFM	556	m3/hr
E	11.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	14%	7.0%	15%	1.8

Sampling Set (Down & Up)	Delta C ppb
1	10.5
2	10.0

Sampling Period 3				
Average Upstream	0.630	ppb	0.00126	mg/m3
Average Downstream	9.93	ppb	0.0199	mg/m3
DeltaC	9.30	ppb	0.0186	mg/m3
Q	360	CFM	612	m3/hr
E	11.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	15%	7.0%	17%	1.9

Sampling Set (Down & Up)	Delta C ppb
1	9.3
2	9.3

Sampling Period 4				
Average Upstream	0.445	ppb	0.00089	mg/m3
Average Downstream	6.46	ppb	0.0129	mg/m3
DeltaC	6.02	ppb	0.0120	mg/m3
Q	645	CFM	1096	m3/hr
E	13.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	24%	7.0%	25%	3.2

Sampling Set (Down & Up)	Delta C ppb
1	5.4
2	6.6

Sampling Period 5				
Average Upstream	0.465	ppb	0.00093	mg/m3
Average Downstream	5.43	ppb	0.0109	mg/m3
DeltaC	4.97	ppb	0.00993	mg/m3
Q	720	CFM	1223	m3/hr
E	12.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	28%	7.0%	29%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	5.5
2	4.5

Full Test 13-Sep-11

Sampling Period 1				
Average Upstream	0.55	ppb	0.00110	mg/m3
Average Downstream	12.1	ppb	0.0243	mg/m3
DeltaC	11.6	ppb	0.0232	mg/m3
Q	290	CFM	493	m3/hr
E	11.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	12%	7.0%	14%	1.6

Sampling Set	Delta C
(Down & Up)	ppb
1	10.6
2	12.6

Sampling Period 2				
Average Upstream	0.32	ppb	0.00065	mg/m3
Average Downstream	13.3	ppb	0.0267	mg/m3
DeltaC	13.0	ppb	0.0260	mg/m3
Q	290	CFM	492.71	m3/hr
E	12.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	12.7
2	13.0

Sampling Period 3				
Average Upstream	0.165	ppb	0.00033	mg/m3
Average Downstream	10.4	ppb	0.0209	mg/m3
DeltaC	10.3	ppb	0.0205	mg/m3
Q	360	CFM	612	m3/hr
E	12.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	14%	7.0%	15%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	9.61
2	10.9

Sampling Period 4				
Average Upstream	0.137	ppb	0.000273	mg/m3
Average Downstream	5.97	ppb	0.0119	mg/m3
DeltaC	5.83	ppb	0.0117	mg/m3
Q	645	CFM	1096	m3/hr
E	12.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	24%	7.0%	25%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	5.51
2	6.01

Sampling Period 5				
Average Upstream	0.980	ppb	0.00196	mg/m3
Average Downstream	6.32	ppb	0.0126	mg/m3
DeltaC	5.34	ppb	0.0107	mg/m3
Q	645	CFM	1096	m3/hr
E	11.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26%	7.0%	27%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	5.42
2	5.26

Sampling Period 6				
Average Upstream	0.825	ppb	0.00165	mg/m3
Average Downstream	6.35	ppb	0.0127	mg/m3
DeltaC	5.52	ppb	0.0110	mg/m3
Q	705	CFM	1198	m3/hr
E	13.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26%	7.0%	27%	3.5

Sampling Set	Delta C
(Down & Up)	ppb
1	5.36
2	5.68

Sampling Period 7				
Average Upstream	1.18	ppb	0.00236	mg/m3
Average Downstream	6.18	ppb	0.0124	mg/m3
DeltaC	5.00	ppb	0.0100	mg/m3
Q	720	CFM	1223	m3/hr
E	12.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	28%	7.0%	29%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	4.44
2	5.56

Sampling Period 8				
Average Upstream	0.0267	ppb	0.0000533	mg/m3
Average Downstream	6.58	ppb	0.0132	mg/m3
DeltaC	6.55	ppb	0.0131	mg/m3
Q	720	CFM	1223.28	m3/hr
E	16.0	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	22%	7.0%	23%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	6.67
2	6.40

Sampling Period 9				
Average Upstream	0.135	ppb	0.00027	mg/m3
Average Downstream	12.8	ppb	0.0257	mg/m3
DeltaC	12.7	ppb	0.0254	mg/m3
Q	290	CFM	493	m3/hr
E	12.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	1.6

Sampling Set	Delta C
(Down & Up)	ppb
1	12.8
2	12.6

Full Test 27-Sep-11

Sampling Period 1				
Average Upstream	1.04	ppb	0.00208	mg/m3
Average Downstream	19.6	ppb	0.0393	mg/m3
DeltaC	18.6	ppb	0.0372	mg/m3
Q	290	CFM	492.71	m3/hr
E	18.3	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	7.6%	7.0%	10%	1.9

Sampling Set (Down & Up)	Delta C ppb
1	17.8
2	19.4

13 Watt
120 Volt
0.2 Amp

Sampling Period 2				
Average Upstream	0.72	ppb	0.00144	mg/m3
Average Downstream	21.2	ppb	0.0424	mg/m3
DeltaC	20.5	ppb	0.0409	mg/m3
Q	290	CFM	493	m3/hr
E	20.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	6.9%	7.0%	9.8%	2.0

Sampling Set (Down & Up)	Delta C ppb
1	20.2
2	20.8

13 Watt
120 Volts
0.2 Amp

Sampling Period 3				
Average Upstream	0.175	ppb	0.00035	mg/m3
Average Downstream	17.0	ppb	0.0340	mg/m3
DeltaC	16.8	ppb	0.0336	mg/m3
Q	360	CFM	612	m3/hr
E	20.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	8.4%	7.0%	11%	2.2

Sampling Set	Delta C
(Down & Up)	ppb
1	17.1
2	16.5

13	Watt
120	Volts
0.21	Amp

Sampling Period 4				
Average Upstream	0.680	ppb	0.00136	mg/m3
Average Downstream	6.47	ppb	0.0129	mg/m3
DeltaC	5.79	ppb	0.0116	mg/m3
Q	645	CFM	1096	m3/hr
E	12.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	24%	7.0%	25%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	10.3
2	8.71

13	Watt
120	Volts
0.21	Amp

Sampling Period 5				
Average Upstream	0.114	ppb	0.000228	mg/m3
Average Downstream	6.42	ppb	0.0128	mg/m3
DeltaC	6.30	ppb	0.0126	mg/m3
Q	645	CFM	1095.855	m3/hr
E	13.8	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	22%	7.0%	24%	3.2

Sampling Set (Down & Up)	Delta C ppb
1	8.93
2	9.11

13	Watt
120	Volts
0.21	Amp

Sampling Period 6				
Average Upstream	1.00	ppb	0.00200	mg/m3
Average Downstream	9.21	ppb	0.0184	mg/m3
DeltaC	8.21	ppb	0.0164	mg/m3
Q	705	CFM	1198	m3/hr
E	19.7	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	17%	7.0%	19%	3.7

Sampling Set (Down & Up)	Delta C ppb
1	7.97
2	8.45

13	Watt
119.8	Volts
0.21	Amp

Sampling Period 7				
Average Upstream	1.70	ppb	0.0034	mg/m3
Average Downstream	8.74	ppb	0.0175	mg/m3
DeltaC	7.04	ppb	0.0141	mg/m3
Q	720	CFM	1223	m3/hr
E	17.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	20%	7.0%	21%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	7.35
2	6.72

13	Watt
121	Volts
0.21	Amp

Sampling Period 8				
Average Upstream	0.960	ppb	0.00192	mg/m3
Average Downstream	8.88	ppb	0.0178	mg/m3
DeltaC	7.92	ppb	0.0158	mg/m3
Q	720	CFM	1223	m3/hr
E	19.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	18%	7.0%	19%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	8.27
2	7.57

13	Watt
121	Volts
0.21	Amp

Sampling Period 9				
Average Upstream	1.03	ppb	0.00206	mg/m3
Average Downstream	18.9	ppb	0.0378	mg/m3
DeltaC	17.9	ppb	0.0357	mg/m3
Q	290	CFM	493	m3/hr
E	17.6	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	7.9%	7.0%	11%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	18.0
2	17.7

13	Watt
120.6	Volts
0.21	Amp

Run 1 27-Sep-11

Sampling Period 1				
Average Upstream	1.47	ppb	0.00294	mg/m3
Average Downstream	20.2	ppb	0.0404	mg/m3
DeltaC	18.7	ppb	0.0375	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	18.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	7.5%	7.0%	10%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	17.9
2	19.6

13	Watt
120.9	Volt
0.19	Amp

Sampling Period 2				
Average Upstream	1.04	ppb	0.00208	mg/m3
Average Downstream	12.3	ppb	0.0246	mg/m3
DeltaC	11.2	ppb	0.0225	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	18.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13%	7.0%	14%	2.6

Sampling Set	Delta C
(Down & Up)	ppb
1	10.5
2	12.0

13	Watt
121.1	Volt
0.19	Amp

Sampling Period 3				
Average Upstream	1.06	ppb	0.00211	mg/m3
Average Downstream	8.64	ppb	0.0173	mg/m3
DeltaC	7.59	ppb	0.0152	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	18.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	19%	7.0%	20%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

13	Watt
121.2	Volt
0.21	Amp

Run 2 27-Sep-11

Sampling Period 1				
Average Upstream	1.12	ppb	0.00224	mg/m3
Average Downstream	19.6	ppb	0.0393	mg/m3
DeltaC	18.5	ppb	0.0370	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	18.1	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	7.6%	7.0%	10%	1.9

Sampling Set (Down & Up)	Delta C ppb
1	17.8
2	19.2

13 Watt
120.7 Volt
0.19 Amp

Sampling Period 2				
Average Upstream	1.26	ppb	0.00251	mg/m3
Average Downstream	13.0	ppb	0.0261	mg/m3
DeltaC	11.8	ppb	0.0235	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	19.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	14%	2.6

Sampling Set (Down & Up)	Delta C ppb
1	11.7
2	11.9

13 Watt
120.9 Volt
0.21 Amp

Sampling Period 3				
Average Upstream	0.66	ppb	0.00131	mg/m3
Average Downstream	8.77	ppb	0.0175	mg/m3
DeltaC	8.12	ppb	0.0162	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	19.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	17%	7.0%	19%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

13	Watt
120.9	Volt
0.21	Amp

Run 3 27-Sep-11

Sampling Period 1				
Average Upstream	1.37	ppb	0.00274	mg/m3
Average Downstream	21.7	ppb	0.0435	mg/m3
DeltaC	20.4	ppb	0.0408	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	19.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	6.9%	7.0%	9.9%	2.0

Sampling Set	Delta C
(Down & Up)	ppb
1	20.5
2	20.2

13	Watt
121	Volt
0.21	Amp

Sampling Period 2				
Average Upstream	1.55	ppb	0.00309	mg/m3
Average Downstream	13.4	ppb	0.0269	mg/m3
DeltaC	11.9	ppb	0.0238	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	19.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	12%	7.0%	14%	2.6

Sampling Set	Delta C
(Down & Up)	ppb
1	12.0
2	11.8

13	Watt
121	Volt
0.21	Amp

Sampling Period 3				
Average Upstream	1.13	ppb	0.00226	mg/m3
Average Downstream	9.00	ppb	0.0180	mg/m3
DeltaC	7.87	ppb	0.0157	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	19.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	18%	7.0%	19%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

13	Watt
121.3	Volt
0.21	Amp

Run 4 27-Sep-11

Sampling Period 1				
Average Upstream	1.80	ppb	0.00360	mg/m3
Average Downstream	21.9	ppb	0.0438	mg/m3
DeltaC	20.1	ppb	0.0402	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	19.7	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	7.0%	7.0%	9.9%	2.0

Sampling Set (Down & Up)	Delta C ppb
1	19.0
2	21.3

13 Watt
120.2 Volt
0.19 Amp

Sampling Period 2				
Average Upstream	2.65	ppb	0.00530	mg/m3
Average Downstream	13.3	ppb	0.0267	mg/m3
DeltaC	10.7	ppb	0.0214	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	17.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	13%	7.0%	15%	2.6

Sampling Set (Down & Up)	Delta C ppb
1	12.3
2	9.0

13 Watt
120.3 Volt
0.19 Amp

Sampling Period 3				
Average Upstream	0.76	ppb	0.00151	mg/m3
Average Downstream	8.84	ppb	0.0177	mg/m3
DeltaC	8.09	ppb	0.0162	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	19.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	17%	7.0%	19%	3.7

Sampling Set	Delta C
(Down & Up)	ppb
1	7.6
2	8.6

13	Watt
120.3	Volt
0.21	Amp

AIR CLEANER 3

Initial Trial 1-Sep-11

Sampling Period 1				
Average Upstream	0.111	ppb	0.000223	mg/m3
Average Downstream	9.42	ppb	0.0188	mg/m3
DeltaC	9.31	ppb	0.0186	mg/m3
FlowPlate Pressure		Pa		
Q	290	CFM	493	m3/hr
E	9.17	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	15%	7.0%	17%	1.5

Run 1 29-Sep-11

Sampling Period 1				
Average Upstream	0.75	ppb	0.00150	mg/m3
Average Downstream	11.3	ppb	0.0227	mg/m3
DeltaC	10.6	ppb	0.0212	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	10.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13%	7.0%	15%	1.6

Sampling Set	Delta C
(Down & Up)	ppb
1	10.5
2	10.7

Run 2 29-Sep-11

Sampling Period 1				
Average Upstream	0.11	ppb	0.00021	mg/m3
Average Downstream	13.3	ppb	0.0265	mg/m3
DeltaC	13.1	ppb	0.0263	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	12.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	13.4
2	12.9

Sampling Period 2				
Average Upstream	1.00	ppb	0.00200	mg/m3
Average Downstream	14.3	ppb	0.0286	mg/m3
DeltaC	13.3	ppb	0.0266	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	13.0	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	12.9
2	13.6

Full Test 1 13-Oct-11

Sampling Period 1				
Average Upstream	1.23	ppb	0.00245	mg/m3
Average Downstream	13.6	ppb	0.0271	mg/m3
DeltaC	12.3	ppb	0.0247	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	12.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11.5%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	11.4
2	13.2

Sampling Period 2				
Average Upstream	0.87	ppb	0.00173	mg/m3
Average Downstream	11.4	ppb	0.0228	mg/m3
DeltaC	10.5	ppb	0.0211	mg/m3
Flow Meter Pressure	8.6	Pa		
Q	352	CFM	598	m3/hr
E	12.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13.4%	7.0%	15%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	9.6
2	11.5

Sampling Period 3				
Average Upstream	1.17	ppb	0.00234	mg/m3
Average Downstream	8.11	ppb	0.0162	mg/m3
DeltaC	6.94	ppb	0.0139	mg/m3
Flow Meter Pressure	16.2	Pa		
Q	483	CFM	821	m3/hr
E	11.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	20.4%	7.0%	22%	2.5

Sampling Set	Delta C
(Down & Up)	ppb
1	7.1
2	6.8

Sampling Period 4				
Average Upstream	0.66	ppb	0.00132	mg/m3
Average Downstream	6.42	ppb	0.0128	mg/m3
DeltaC	5.76	ppb	0.0115	mg/m3
Flow Meter Pressure	28.2	Pa		
Q	638	CFM	1084	m3/hr
E	12.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	24.6%	7.0%	26%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	5.6
2	5.9

Sampling Period 5				
Average Upstream	0.87	ppb	0.00174	mg/m3
Average Downstream	6.14	ppb	0.0123	mg/m3
DeltaC	5.27	ppb	0.0105	mg/m3
Flow Meter Pressure	35.6	Pa		
Q	717	CFM	1218	m3/hr
E	12.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26.9%	7.0%	28%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	5.8
2	4.7

Sampling Period 6				
Average Upstream	0.91	ppb	0.00182	mg/m3
Average Downstream	14.3	ppb	0.0287	mg/m3
DeltaC	13.4	ppb	0.0268	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	13.7	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	10.5%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	13.0
2	13.9

Full Test 2 13-Oct-11

Sampling Period 1				
Average Upstream	1.09	ppb	0.00218	mg/m3
Average Downstream	13.9	ppb	0.0278	mg/m3
DeltaC	12.8	ppb	0.0256	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	13.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	12.5
2	13.2

Sampling Period 2				
Average Upstream	1.16	ppb	0.00231	mg/m3
Average Downstream	12.0	ppb	0.0239	mg/m3
DeltaC	10.8	ppb	0.0216	mg/m3
Flow Meter Pressure	8.6	Pa		
Q	352	CFM	598	m3/hr
E	12.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13%	7.0%	15%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	10.8
2	10.8

Sampling Period 3				
Average Upstream	1.03	ppb	0.00206	mg/m3
Average Downstream	9.02	ppb	0.0180	mg/m3
DeltaC	7.99	ppb	0.0160	mg/m3
Flow Meter Pressure	16.2	Pa		
Q	483	CFM	821	m3/hr
E	13.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	18%	7.0%	19%	2.5

Sampling Set	Delta C
(Down & Up)	ppb
1	7.2
2	8.8

Sampling Period 4				
Average Upstream	1.56	ppb	0.00312	mg/m3
Average Downstream	7.40	ppb	0.0148	mg/m3
DeltaC	5.84	ppb	0.0117	mg/m3
Flow Meter Pressure	28.2	Pa		
Q	638	CFM	1084	m3/hr
E	12.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	24%	7.0%	25%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	6.0
2	5.7

Sampling Period 5				
Average Upstream	1.11	ppb	0.00221	mg/m3
Average Downstream	6.50	ppb	0.0130	mg/m3
DeltaC	5.39	ppb	0.0108	mg/m3
Flow Meter Pressure	35.6	Pa		
Q	717	CFM	1218	m3/hr
E	13.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26%	7.0%	27%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	4.9
2	5.9

Sampling Period 6				
Average Upstream	1.62	ppb	0.00323	mg/m3
Average Downstream	15.7	ppb	0.0313	mg/m3
DeltaC	14.0	ppb	0.0281	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	14.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	10%	7.0%	12%	1.8

Sampling Set	Delta C
(Down & Up)	ppb
1	14.1
2	14.0

Full Test 3

Sampling Period 1				
Average Upstream	1.15	ppb	0.00230	mg/m3
Average Downstream	15.9	ppb	0.0319	mg/m3
DeltaC	14.8	ppb	0.0296	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	15.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	9.6%	7.0%	12%	1.8

Sampling Set	Delta C
(Down & Up)	ppb
1	14.3
2	15.3

Sampling Period 2				
Average Upstream	0.96	ppb	0.00191	mg/m3
Average Downstream	12.8	ppb	0.0256	mg/m3
DeltaC	11.8	ppb	0.0237	mg/m3
Flow Meter Pressure	8.6	Pa		
Q	352	CFM	598	m3/hr
E	14.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	12%	7.0%	14%	2.0

Sampling Set	Delta C
(Down & Up)	ppb
1	10.8
2	12.9

Sampling Period 3				
Average Upstream	1.11	ppb	0.00221	mg/m3
Average Downstream	10.1	ppb	0.0202	mg/m3
DeltaC	9.00	ppb	0.0180	mg/m3
Flow Meter Pressure	16.2	Pa		
Q	483	CFM	821	m3/hr
E	14.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	16%	7.0%	17%	2.5

Sampling Set	Delta C
(Down & Up)	ppb
1	8.0
2	10.0

Sampling Period 4				
Average Upstream	1.01	ppb	0.00202	mg/m3
Average Downstream	7.91	ppb	0.0158	mg/m3
DeltaC	6.90	ppb	0.0138	mg/m3
Flow Meter Pressure	28.2	Pa		
Q	638	CFM	1084	m3/hr
E	15.0	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	20%	7.0%	22%	3.2

Sampling Set	Delta C
(Down & Up)	ppb
1	6.5
2	7.3

Sampling Period 5				
Average Upstream	1.56	ppb	0.00312	mg/m3
Average Downstream	6.53	ppb	0.0131	mg/m3
DeltaC	4.97	ppb	0.00994	mg/m3
Flow Meter Pressure	35.6	Pa		
Q	717	CFM	1218	m3/hr
E	12.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	28%	7.0%	29%	3.5

Sampling Set	Delta C
(Down & Up)	ppb
1	5.5
2	4.5

Sampling Period 6				
Average Upstream	0.90	ppb	0.00180	mg/m3
Average Downstream	15.4	ppb	0.0308	mg/m3
DeltaC	14.5	ppb	0.0290	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	14.9	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	9.8%	7.0%	12%	1.8

Sampling Set (Down & Up)	Delta C ppb
1	13.3
2	15.7

AIR CLEANER 4

Full Test 1 6-Oct-11

Sampling Period 1				
Average Upstream	0.65	ppb	0.00129	mg/m3
Average Downstream	1.95	ppb	0.00389	mg/m3
DeltaC	1.30	ppb	0.00260	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	1.3	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	109%	7.0%	109%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	1.2
2	1.4

Sampling Period 2				
Average Upstream	1.02	ppb	0.00203	mg/m3
Average Downstream	2.56	ppb	0.00511	mg/m3
DeltaC	1.54	ppb	0.00308	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	1.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	92%	7.0%	92%	1.7

Sampling Set	Delta C
(Down & Up)	ppb
1	1.7
2	1.3

Sampling Period 3				
Average Upstream	1.20	ppb	0.00239	mg/m3
Average Downstream	3.16	ppb	0.00631	mg/m3
DeltaC	1.96	ppb	0.00392	mg/m3
FlowPlate Pressure	10	Pa		
Q	487	CFM	827	m3/hr
E	3.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	72%	7.0%	72%	2.4

Sampling Set	Delta C
(Down & Up)	ppb
1	2.0
2	1.9

Sampling Period 4				
Average Upstream	0.550	ppb	0.00110	mg/m3
Average Downstream	2.41	ppb	0.00481	mg/m3
DeltaC	1.86	ppb	0.00371	mg/m3
FlowPlate Pressure	17	Pa		
Q	635	CFM	1079	m3/hr
E	4.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	76%	7.0%	77%	3.1

Sampling Set (Down & Up)	Delta C ppb
1	1.3
2	2.5

Sampling Period 5				
Average Upstream	0.875	ppb	0.00175	mg/m3
Average Downstream	2.97	ppb	0.00594	mg/m3
DeltaC	2.10	ppb	0.00419	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	5.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	68%	7.0%	68%	3.4

Sampling Set (Down & Up)	Delta C ppb
1	2.4
2	1.8

Sampling Period 6				
Average Upstream	0.860	ppb	0.00172	mg/m3
Average Downstream	6.38	ppb	0.0128	mg/m3
DeltaC	5.52	ppb	0.0110	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	5.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26%	7.0%	27%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	4.8
2	6.2

Full Test 2 6-Oct-11

Sampling Period 1				
Average Upstream	0.855	ppb	0.00171	mg/m3
Average Downstream	7.53	ppb	0.0151	mg/m3
DeltaC	6.68	ppb	0.0134	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	6.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	21%	7.0%	22%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	6.5
2	6.9

Sampling Period 2				
Average Upstream	1.18	ppb	0.00235	mg/m3
Average Downstream	7.38	ppb	0.0148	mg/m3
DeltaC	6.20	ppb	0.0124	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	7.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	23%	7.0%	24%	1.8

Sampling Set	Delta C
(Down & Up)	ppb
1	5.9
2	6.5

Sampling Period 3				
Average Upstream	1.20	ppb	0.00240	mg/m3
Average Downstream	9.28	ppb	0.0186	mg/m3
DeltaC	8.08	ppb	0.0162	mg/m3
FlowPlate Pressure	10	Pa		
Q	487	CFM	827	m3/hr
E	13.4	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	18%	7.0%	19%	2.5

Sampling Set	Delta C
(Down & Up)	ppb
1	10.9
2	5.3

Sampling Period 4				
Average Upstream	1.29	ppb	0.00257	mg/m3
Average Downstream	4.17	ppb	0.00834	mg/m3
DeltaC	2.89	ppb	0.00577	mg/m3
FlowPlate Pressure	17	Pa		
Q	635	CFM	1079	m3/hr
E	6.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	49%	7.0%	50%	3.1

Sampling Set (Down & Up)	Delta C ppb
1	2.9
2	2.9

Sampling Period 5				
Average Upstream	1.51	ppb	0.00302	mg/m3
Average Downstream	4.31	ppb	0.00862	mg/m3
DeltaC	2.80	ppb	0.00560	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	6.7	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	51%	7.0%	51%	3.4

Sampling Set (Down & Up)	Delta C ppb
1	3.5
2	2.2

Sampling Period 6				
Average Upstream	1.14	ppb	0.00228	mg/m3
Average Downstream	8.73	ppb	0.0175	mg/m3
DeltaC	7.59	ppb	0.0152	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	7.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	19%	7.0%	20%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	6.6
2	8.5

Full Test 3 6-Oct-11

Sampling Period 1				
Average Upstream	0.410	ppb	0.00082	mg/m3
Average Downstream	9.32	ppb	0.0186	mg/m3
DeltaC	8.91	ppb	0.0178	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.7	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	16%	7.0%	17%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	9.3
2	8.5

Sampling Period 2				
Average Upstream	0.460	ppb	0.00092	mg/m3
Average Downstream	8.00	ppb	0.0160	mg/m3
DeltaC	7.54	ppb	0.0151	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	9.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	19%	7.0%	20%	1.9

Sampling Set	Delta C
(Down & Up)	ppb
1	7.7
2	7.4

Sampling Period 3				
Average Upstream	0.990	ppb	0.00198	mg/m3
Average Downstream	6.41	ppb	0.0128	mg/m3
DeltaC	5.42	ppb	0.0108	mg/m3
FlowPlate Pressure	10	Pa		
Q	487	CFM	827	m3/hr
E	9.0	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	26%	7.0%	27%	2.4

Sampling Set	Delta C
(Down & Up)	ppb
1	5.8
2	5.1

Sampling Period 4				
Average Upstream	0.915	ppb	0.00183	mg/m3
Average Downstream	5.45	ppb	0.0109	mg/m3
DeltaC	4.54	ppb	0.00907	mg/m3
FlowPlate Pressure	17	Pa		
Q	635	CFM	1079	m3/hr
E	9.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	31%	7.0%	32%	3.1

Sampling Set	Delta C
(Down & Up)	ppb
1	5.0
2	4.1

Sampling Period 5				
Average Upstream	1.02	ppb	0.00203	mg/m3
Average Downstream	4.28	ppb	0.00856	mg/m3
DeltaC	3.27	ppb	0.00653	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	7.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	43%	7.0%	44%	3.4

Sampling Set	Delta C
(Down & Up)	ppb
1	3.7
2	2.8

Sampling Period 6				
Average Upstream	1.39	ppb	0.00278	mg/m3
Average Downstream	9.85	ppb	0.0197	mg/m3
DeltaC	8.46	ppb	0.0169	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	17%	7.0%	18%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	9.6
2	7.3

RUN 1 7-Oct-11

Sampling Period 1				
Average Upstream	0.76	ppb	0.00151	mg/m3
Average Downstream	8.49	ppb	0.0170	mg/m3
DeltaC	7.73	ppb	0.0155	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	7.57	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	18%	7.0%	20%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	7.5
2	8.0

RUN 2 7-Oct-11

Sampling Period 1				
Average Upstream	1.26	ppb	0.00252	mg/m3
Average Downstream	8.78	ppb	0.0176	mg/m3
DeltaC	7.52	ppb	0.0150	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	7.36	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	19%	7.0%	20%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	7.2
2	7.9

RUN 3 7-Oct-11

Sampling Period 1				
Average Upstream	0.69	ppb	0.00138	mg/m3
Average Downstream	9.16	ppb	0.0183	mg/m3
DeltaC	8.47	ppb	0.0169	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.29	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	17%	7.0%	18%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	8.3
2	8.7

RUN 4 7-Oct-11

Sampling Period 1				
Average Upstream	1.00	ppb	0.00200	mg/m3
Average Downstream	10.0	ppb	0.0201	mg/m3
DeltaC	9.03	ppb	0.0181	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.84	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	16%	7.0%	17%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	8.9
2	9.2

RUN 5 7-Oct-11

Sampling Period 1				
Average Upstream	1.29	ppb	0.00258	mg/m3
Average Downstream	9.58	ppb	0.0192	mg/m3
DeltaC	8.29	ppb	0.0166	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.11	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	17%	7.0%	18%	1.5

Sampling Set	Delta C
(Down & Up)	ppb
1	7.6
2	9.0

RUN 6 7-Oct-11

Sampling Period 1				
Average Upstream	1.24	ppb	0.00247	mg/m3
Average Downstream	9.56	ppb	0.0191	mg/m3
DeltaC	8.33	ppb	0.0167	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.15	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	17%	7.0%	18%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	7.7
2	8.9

RUN 7 7-Oct-11

Sampling Period 1				
Average Upstream	0.485	ppb	0.00097	mg/m3
Average Downstream	11.1	ppb	0.0222	mg/m3
DeltaC	10.6	ppb	0.0213	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	10.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	13%	7.0%	15%	1.6

Sampling Set (Down & Up)	Delta C ppb
1	10.1
2	11.2

RUN 8 7-Oct-11

Sampling Period 1				
Average Upstream	0.725	ppb	0.00145	mg/m3
Average Downstream	10.3	ppb	0.0205	mg/m3
DeltaC	9.54	ppb	0.0191	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	9.33	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	15%	7.0%	16%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	9.4
2	9.7

RUN 9 7-Oct-11

Sampling Period 1				
Average Upstream	0.973	ppb	0.00195	mg/m3
Average Downstream	9.80	ppb	0.0196	mg/m3
DeltaC	8.83	ppb	0.0177	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	8.64	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	16%	7.0%	17%	1.5

Sampling Set (Down & Up)	Delta C ppb
1	8.5
2	9.1

RUN 10 7-Oct-11

Sampling Period 1				
Average Upstream	0.62	ppb	0.00123	mg/m3
Average Downstream	10.9	ppb	0.0217	mg/m3
DeltaC	10.2	ppb	0.0205	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	10.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	14%	7.0%	15%	1.6

Sampling Set (Down & Up)	Delta C ppb
1	9.9
2	10.6

AIR CLEANER 5

Initial Trial 30-Sep-11

Sampling Period 1				
Average Upstream	1.33	ppb	0.00266	mg/m3
Average Downstream	13.1	ppb	0.0262	mg/m3
DeltaC	11.8	ppb	0.0235	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	28.6	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	14%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	11.0
2	12.6

24	Watt
120.5	Volts
0.31	Amp

Sampling Period 2				
Average Upstream	0.863	ppb	0.001726667	mg/m3
Average Downstream	13.3	ppb	0.0267	mg/m3
DeltaC	12.5	ppb	0.0249	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	30.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set	Delta C
(Down & Up)	ppb
1	13.3
2	11.6

24	Watt
120.5	Volts
0.31	Amp

Full Test 1 4-Oct-11

Sampling Period 1				
Average Upstream	1.38	ppb	0.00276	mg/m3
Average Downstream	15.0	ppb	0.0299	mg/m3
DeltaC	13.6	ppb	0.0272	mg/m3
FlowPlate Pressure	14.5	Pa		
Q	586	CFM	996	m3/hr
E	27.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	10%	7.0%	13%	3.4

Sampling Set	Delta C
(Down & Up)	ppb
1	13.2
2	14.0

Sampling Period 2				
Average Upstream	1.22	ppb	0.00244	mg/m3
Average Downstream	16.5	ppb	0.0330	mg/m3
DeltaC	15.3	ppb	0.0306	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	36.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	9.3%	7.0%	12%	4.3

Sampling Set	Delta C
(Down & Up)	ppb
1	17.9
2	12.6

Sampling Period 3				
Average Upstream	1.30	ppb	0.00260	mg/m3
Average Downstream	12.1	ppb	0.0242	mg/m3
DeltaC	10.8	ppb	0.0216	mg/m3
FlowPlate Pressure	28	Pa		
Q	815	CFM	1385	m3/hr
E	29.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13%	7.0%	15%	4.4

Sampling Set	Delta C
(Down & Up)	ppb
1	10.6
2	11.0

Full Test 2 4-Oct-11

Sampling Period 1				
Average Upstream	0.73	ppb	0.00146	mg/m3
Average Downstream	15.5	ppb	0.0310	mg/m3
DeltaC	14.8	ppb	0.0295	mg/m3
FlowPlate Pressure	14.5	Pa		
Q	586	CFM	996	m3/hr
E	29.4	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	9.6%	7.0%	12%	3.5

Sampling Set (Down & Up)	Delta C ppb
1	14.9
2	14.6

Sampling Period 2				
Average Upstream	1.07	ppb	0.00213	mg/m3
Average Downstream	13.3	ppb	0.0266	mg/m3
DeltaC	12.2	ppb	0.0245	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	29.3	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	14%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	13.3
2	11.2

Sampling Period 3				
Average Upstream	1.27	ppb	0.00253	mg/m3
Average Downstream	11.1	ppb	0.0222	mg/m3
DeltaC	9.85	ppb	0.0197	mg/m3
FlowPlate Pressure	28	Pa		
Q	815	CFM	1385	m3/hr
E	27.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	14%	7.0%	16%	4.4

Sampling Set	Delta C
(Down & Up)	ppb
1	10.3
2	9.4

Sampling Period 4				
Average Upstream	0.73	ppb	0.00145	mg/m3
Average Downstream	15.6	ppb	0.0311	mg/m3
DeltaC	14.8	ppb	0.0297	mg/m3
FlowPlate Pressure	14.5	Pa		
Q	586	CFM	996	m3/hr
E	29.6	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	9.5%	7.0%	12%	3.5

Sampling Set	Delta C
(Down & Up)	ppb
1	14.7
2	15.0

Full Test 3 4-Oct-11

Sampling Period 1				
Average Upstream	1.31	ppb	0.00261	mg/m3
Average Downstream	15.9	ppb	0.0318	mg/m3
DeltaC	14.6	ppb	0.0291	mg/m3
FlowPlate Pressure	14.5	Pa		
Q	586	CFM	996	m3/hr
E	29.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	9.7%	7.0%	12%	3.5

Sampling Set (Down & Up)	Delta C ppb
1	15.1
2	14.1

Sampling Period 2				
Average Upstream	1.10	ppb	0.00220	mg/m3
Average Downstream	14.1	ppb	0.0281	mg/m3
DeltaC	13.0	ppb	0.0259	mg/m3
FlowPlate Pressure	21	Pa		
Q	706	CFM	1199	m3/hr
E	31.1	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	12.6
2	13.3

Sampling Period 3				
Average Upstream	1.71	ppb	0.00342	mg/m3
Average Downstream	12.3	ppb	0.0245	mg/m3
DeltaC	10.6	ppb	0.0211	mg/m3
FlowPlate Pressure	28	Pa		
Q	815	CFM	1385	m3/hr
E	29.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	13%	7.0%	15%	4.4

Sampling Set (Down & Up)	Delta C ppb
1	10.5
2	10.7

Sampling Period 4				
Average Upstream	1.07	ppb	0.00213	mg/m3
Average Downstream	15.9	ppb	0.0317	mg/m3
DeltaC	14.8	ppb	0.0296	mg/m3
FlowPlate Pressure	14.5	Pa		
Q	586	CFM	996	m3/hr
E	29.5	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	9.6%	7.0%	12%	3.5

Sampling Set (Down & Up)	Delta C ppb
1	15.5
2	14.2

RUN 1 4-Oct-11

Sampling Period 1				
Average Upstream	1.14	ppb	0.00227	mg/m3
Average Downstream	16.7	ppb	0.0334	mg/m3
DeltaC	15.6	ppb	0.0312	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	36.9	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	9.1%	7.0%	11%	4.2

Sampling Set (Down & Up)	Delta C ppb
1	15.0
2	16.2

RUN 2 4-Oct-11

Sampling Period 1				
Average Upstream	1.35	ppb	0.00269	mg/m3
Average Downstream	13.6	ppb	0.0273	mg/m3
DeltaC	12.3	ppb	0.0246	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	29.1	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	13%	3.9

Sampling Set (Down & Up)	Delta C ppb
1	12.8
2	11.8

RUN 3 4-Oct-11

Sampling Period 1				
Average Upstream	0.985	ppb	0.00197	mg/m3
Average Downstream	13.8	ppb	0.0276	mg/m3
DeltaC	12.8	ppb	0.0256	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	30.3	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	12.5
2	13.1

RUN 4 4-Oct-11

Sampling Period 1				
Average Upstream	1.56	ppb	0.00312	mg/m3
Average Downstream	14.0	ppb	0.0280	mg/m3
DeltaC	12.5	ppb	0.0249	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	29.5	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	3.9

Sampling Set (Down & Up)	Delta C ppb
1	12.7
2	12.3

RUN 5 4-Oct-11

Sampling Period 1				
Average Upstream	1.09	ppb	0.00218	mg/m3
Average Downstream	14.1	ppb	0.0283	mg/m3
DeltaC	13.0	ppb	0.0261	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	30.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set	Delta C
(Down & Up)	ppb
1	12.7
2	13.4

RUN 6 4-Oct-11

Sampling Period 1				
Average Upstream	0.840	ppb	0.00168	mg/m3
Average Downstream	14.4	ppb	0.0287	mg/m3
DeltaC	13.5	ppb	0.0271	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	32.0	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	10%	7.0%	13%	4.0

Sampling Set	Delta C
(Down & Up)	ppb
1	13.2
2	13.8

RUN 7 4-Oct-11

Sampling Period 1				
Average Upstream	1.29	ppb	0.00258	mg/m3
Average Downstream	14.4	ppb	0.0288	mg/m3
DeltaC	13.1	ppb	0.0262	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	31.1	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	12.7
2	13.6

RUN 8 4-Oct-11

Sampling Period 1				
Average Upstream	1.25	ppb	0.00249	mg/m3
Average Downstream	13.4	ppb	0.0269	mg/m3
DeltaC	12.2	ppb	0.0244	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	28.9	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	12%	7.0%	14%	3.9

Sampling Set (Down & Up)	Delta C ppb
1	11.2
2	13.2

RUN 9 4-Oct-11

Sampling Period 1				
Average Upstream	1.20	ppb	0.00239	mg/m3
Average Downstream	13.9	ppb	0.0277	mg/m3
DeltaC	12.7	ppb	0.0253	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	30.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	12.6
2	12.7

RUN 10 4-Oct-11

Sampling Period 1				
Average Upstream	1.10	ppb	0.00219	mg/m3
Average Downstream	13.8	ppb	0.0277	mg/m3
DeltaC	12.8	ppb	0.0255	mg/m3
FlowPlate Pressure	20.5	Pa		
Q	697	CFM	1185	m3/hr
E	30.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	11%	7.0%	13%	4.0

Sampling Set (Down & Up)	Delta C ppb
1	12.5
2	13.0

AIR CLEANER 6

Initial Trial 1 29-Sep-11

Sampling Period 1				
Average Upstream	0.280	ppb	0.00056	mg/m3
Average Downstream	0.835	ppb	0.00167	mg/m3
DeltaC	0.555	ppb	0.00111	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.543	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	255%	7.0%	255%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.49
2	0.62

Sampling Period 2				
Average Upstream	1.04	ppb	0.00208	mg/m3
Average Downstream	1.41	ppb	0.00283	mg/m3
DeltaC	0.374	ppb	0.00075	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.366	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	378%	7.0%	378%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.64
2	0.11

Initial Trial 2 29-Sep-11

Sampling Period 1				
Average Upstream	0.985	ppb	0.00197	mg/m3
Average Downstream	1.00	ppb	0.00199	mg/m3
DeltaC	0.0102	ppb	0.0000205	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.0100	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	13813%	7.0%	13813%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	-0.263
2	0.283

Sampling Period 2				
Average Upstream	0.585	ppb	0.00117	mg/m3
Average Downstream	0.735	ppb	0.00147	mg/m3
DeltaC	0.150	ppb	0.000300	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.147	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	943%	7.0%	943%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	-0.060
2	0.360

Full Test 1 30-Sep-11

Sampling Period 1				
Average Upstream	0.960	ppb	0.00192	mg/m3
Average Downstream	1.61	ppb	0.00322	mg/m3
DeltaC	0.650	ppb	0.00130	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.636	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	218%	7.0%	218%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	-0.4
2	1.7

Sampling Period 2				
Average Upstream	0.469	ppb	0.000938	mg/m3
Average Downstream	1.24	ppb	0.00247	mg/m3
DeltaC	0.766	ppb	0.00153	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	0.940	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	185%	7.0%	185%	1.7

Sampling Set (Down & Up)	Delta C ppb
1	1.0
2	0.5

Sampling Period 3				
Average Upstream	0.0550	ppb	0.00011	mg/m3
Average Downstream	0.695	ppb	0.00139	mg/m3
DeltaC	0.640	ppb	0.00128	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	1.03	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	221%	7.0%	221%	2.3

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 4				
Average Upstream	0.965	ppb	0.00193	mg/m3
Average Downstream	0.901	ppb	0.00180	mg/m3
DeltaC	-0.0639	ppb	-0.000128	mg/m3
FlowPlate Pressure	17.5	Pa		
Q	644	CFM	1095	m3/hr
E	-0.140	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	-2214%	7.0%	2214%	-3.1

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 5				
Average Upstream	1.01	ppb	0.00201	mg/m3
Average Downstream	0.640	ppb	0.00128	mg/m3
DeltaC	-0.365	ppb	-0.000730	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	-0.886	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	-387%	7.0%	388%	-3.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Sampling Period 6				
Average Upstream	0.655	ppb	0.00131	mg/m3
Average Downstream	0.870	ppb	0.00174	mg/m3
DeltaC	0.215	ppb	0.000430	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.210	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	658%	7.0%	658%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.0
2	0.0

Full Test 2 30-Sep-11

Sampling Period 1				
Average Upstream	0.795	ppb	0.00159	mg/m3
Average Downstream	1.18	ppb	0.00235	mg/m3
DeltaC	0.380	ppb	0.000760	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.372	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	372%	7.0%	372%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	-0.040
2	0.800

Sampling Period 2				
Average Upstream	0.610	ppb	0.00122	mg/m3
Average Downstream	0.510	ppb	0.00102	mg/m3
DeltaC	-0.100	ppb	-0.000200	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	-0.123	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	-1414%	7.0%	1414%	-1.7

Sampling Set (Down & Up)	Delta C ppb
1	0.290
2	-0.490

Sampling Period 3				
Average Upstream	0.595	ppb	0.00119	mg/m3
Average Downstream	1.44	ppb	0.00287	mg/m3
DeltaC	0.840	ppb	0.00168	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	1.35	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	168%	7.0%	169%	2.3

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 4				
Average Upstream	0.680	ppb	0.00136	mg/m3
Average Downstream	0.660	ppb	0.00132	mg/m3
DeltaC	-0.0200	ppb	-0.0000400	mg/m3
FlowPlate Pressure	17.5	Pa		
Q	644	CFM	1095	m3/hr
E	-0.0438	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	-7071%	7.0%	7071%	-3.1

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 5				
Average Upstream	1.03	ppb	0.00206	mg/m3
Average Downstream	0.820	ppb	0.00164	mg/m3
DeltaC	-0.210	ppb	-0.000420	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	-0.510	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	-673%	7.0%	673%	-3.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 6				
Average Upstream	1.06	ppb	0.00211	mg/m3
Average Downstream	1.32	ppb	0.00264	mg/m3
DeltaC	0.265	ppb	0.00053	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.259	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	534%	7.0%	534%	1.4

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Full Test 3 30-Sep-11

Sampling Period 1				
Average Upstream	0.870	ppb	0.00174	mg/m3
Average Downstream	1.11	ppb	0.00221	mg/m3
DeltaC	0.235	ppb	0.000470	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.230	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	602%	7.0%	602%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	0.410
2	0.060

Sampling Period 2				
Average Upstream	0.900	ppb	0.00180	mg/m3
Average Downstream	0.355	ppb	0.000710	mg/m3
DeltaC	-0.545	ppb	-0.00109	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	-0.669	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	-259%	7.0%	260%	-1.7

Sampling Set (Down & Up)	Delta C ppb
1	-1.070
2	-0.020

Sampling Period 3				
Average Upstream	0.585	ppb	0.00117	mg/m3
Average Downstream	0.885	ppb	0.00177	mg/m3
DeltaC	0.300	ppb	0.000600	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	0.484	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	471%	7.0%	471%	2.3

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 4				
Average Upstream	1.00	ppb	0.00200	mg/m3
Average Downstream	0.705	ppb	0.00141	mg/m3
DeltaC	-0.295	ppb	-0.000590	mg/m3
FlowPlate Pressure	17.5	Pa		
Q	644	CFM	1095	m3/hr
E	-0.646	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	-479%	7.0%	479%	-3.1

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 5				
Average Upstream	0.815	ppb	0.00163	mg/m3
Average Downstream	0.655	ppb	0.00131	mg/m3
DeltaC	-0.160	ppb	-0.000320	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	-0.388	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	-884%	7.0%	884%	-3.4

Sampling Set (Down & Up)	Delta C ppb
1	0.000
2	0.000

Sampling Period 6				
Average Upstream	0.825	ppb	0.00165	mg/m3
Average Downstream	0.820	ppb	0.00164	mg/m3
DeltaC	-0.005	ppb	-0.00001	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	- 0.00489	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	-28284%	7.0%	28284%	-1.4

Sampling Set (Down & Up)	Delta C ppb
1	0.0
2	0.0

Full Test 4 - No insert 30-Sep-11

Sampling Period 1				
Average Upstream	1.00	ppb	0.00200	mg/m3
Average Downstream	1.46	ppb	0.00291	mg/m3
DeltaC	0.454	ppb	0.000908	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.444	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	312%	7.0%	312%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	-0.293
2	1.200

Sampling Period 2				
Average Upstream	0.800	ppb	0.00160	mg/m3
Average Downstream	0.895	ppb	0.00179	mg/m3
DeltaC	0.0950	ppb	0.000190	mg/m3
FlowPlate Pressure	5.5	Pa		
Q	361	CFM	614	m3/hr
E	0.117	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	1489%	7.0%	1489%	1.7

Sampling Set (Down & Up)	Delta C ppb
1	0.240
2	-0.050

Sampling Period 3				
Average Upstream	1.08	ppb	0.00216	mg/m3
Average Downstream	1.23	ppb	0.00245	mg/m3
DeltaC	0.145	ppb	0.000290	mg/m3
FlowPlate Pressure	9.5	Pa		
Q	475	CFM	806	m3/hr
E	0.234	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	975%	7.0%	975%	2.3

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 4				
Average Upstream	1.39	ppb	0.00278	mg/m3
Average Downstream	0.955	ppb	0.00191	mg/m3
DeltaC	-0.435	ppb	-0.000870	mg/m3
FlowPlate Pressure	17.5	Pa		
Q	644	CFM	1095	m3/hr
E	-0.952	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	-325%	7.0%	325%	-3.1

Sampling Set	Delta C
(Down & Up)	ppb
1	0.000
2	0.000

Sampling Period 5				
Average Upstream	0.785	ppb	0.00157	mg/m3
Average Downstream	1.13	ppb	0.00225	mg/m3
DeltaC	0.340	ppb	0.000680	mg/m3
FlowPlate Pressure	21.5	Pa		
Q	714	CFM	1213	m3/hr
E	0.825	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	416%	7.0%	416%	3.4

Sampling Set (Down & Up)	Delta C ppb
1	0.000
2	0.000

Sampling Period 6				
Average Upstream	0.795	ppb	0.00159	mg/m3
Average Downstream	1.25	ppb	0.00249	mg/m3
DeltaC	0.450	ppb	0.000900	mg/m3
FlowPlate Pressure	3.5	Pa		
Q	288	CFM	489	m3/hr
E	0.441	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	314%	7.0%	314%	1.4

Sampling Set (Down & Up)	Delta C ppb
1	0.000
2	0.000

AIR CLEANER 7

Full Test 1 17-Oct-11

Sampling Period 1				
Average Upstream	1.23	ppb	0.00246	mg/m3
Average Downstream	35.9	ppb	0.0718	mg/m3
DeltaC	34.7	ppb	0.0694	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	35.5	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	4.1%	7.0%	8.1%	2.9

Sampling Set (Down & Up)	Delta C ppb
1	33.1
2	36.2

Sampling Period 2				
Average Upstream	1.82	ppb	0.00364	mg/m3
Average Downstream	15.7	ppb	0.0314	mg/m3
DeltaC	13.9	ppb	0.0278	mg/m3
Flow Meter Pressure	26.5	Pa		
Q	618	CFM	1051	m3/hr
E	29.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	10%	7.0%	12%	3.6

Sampling Set (Down & Up)	Delta C ppb
1	13.8
2	14.0

Sampling Period 3				
Average Upstream	1.22	ppb	0.00243	mg/m3
Average Downstream	11.6	ppb	0.0233	mg/m3
DeltaC	10.4	ppb	0.0208	mg/m3
Flow Meter Pressure	44	Pa		
Q	797	CFM	1354	m3/hr
E	28.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	14%	7.0%	15%	4.3

Sampling Set	Delta C
(Down & Up)	ppb
1	10.2
2	10.7

Sampling Period 4				
Average Upstream	0.915	ppb	0.00183	mg/m3
Average Downstream	7.87	ppb	0.0157	mg/m3
DeltaC	6.95	ppb	0.0139	mg/m3
Flow Meter Pressure	91	Pa		
Q	1,146	CFM	1947	m3/hr
E	27.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	20%	7.0%	22%	5.8

Sampling Set	Delta C
(Down & Up)	ppb
1	6.6
2	7.3

Sampling Period 5				
Average Upstream	1.08	ppb	0.00215	mg/m3
Average Downstream	7.26	ppb	0.0145	mg/m3
DeltaC	6.19	ppb	0.0124	mg/m3
Flow Meter Pressure	117	Pa		
Q	1,299	CFM	2208	m3/hr
E	27.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	23%	7.0%	24%	6.5

Sampling Set	Delta C
(Down & Up)	ppb
1	6.2
2	6.2

Sampling Period 6				
Average Upstream	1.58	ppb	0.00316	mg/m3
Average Downstream	34.3	ppb	0.0685	mg/m3
DeltaC	32.7	ppb	0.0653	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	33.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	4.3%	7.0%	8.2%	2.8

Sampling Set	Delta C
(Down & Up)	ppb
1	31.9
2	33.5

Full Test 2 17-Oct-11

Sampling Period 1				
Average Upstream	1.47	ppb	0.00294	mg/m3
Average Downstream	36.4	ppb	0.0729	mg/m3
DeltaC	35.0	ppb	0.0700	mg/m3
Flow Meter				
Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	35.8	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	4.0%	7.0%	8.1%	2.9

Sampling Set	Delta C
(Down & Up)	ppb
1	33.7
2	36.3

Sampling Period 2				
Average Upstream	1.17	ppb	0.00233	mg/m3
Average Downstream	14.6	ppb	0.0292	mg/m3
DeltaC	13.4	ppb	0.0268	mg/m3
Flow Meter				
Pressure	26.5	Pa		
Q	618	CFM	1051	m3/hr
E	28.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	11%	7.0%	13%	3.6

Sampling Set	Delta C
(Down & Up)	ppb
1	14.3
2	12.6

Sampling Period 3				
Average Upstream	1.73	ppb	0.00345	mg/m3
Average Downstream	10.7	ppb	0.0214	mg/m3
DeltaC	8.96	ppb	0.0179	mg/m3
Flow Meter Pressure	44	Pa		
Q	797	CFM	1354	m3/hr
E	24.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	16%	7.0%	17%	4.2

Sampling Set	Delta C
(Down & Up)	ppb
1	9.3
2	8.6

Sampling Period 4				
Average Upstream	1.11	ppb	0.00221	mg/m3
Average Downstream	7.75	ppb	0.0155	mg/m3
DeltaC	6.65	ppb	0.0133	mg/m3
Flow Meter Pressure	91	Pa		
Q	1,146	CFM	1947	m3/hr
E	25.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	21%	7.0%	22%	5.8

Sampling Set	Delta C
(Down & Up)	ppb
1	7.2
2	6.1

Sampling Period 5				
Average Upstream	1.37	ppb	0.00273	mg/m3
Average Downstream	7.45	ppb	0.0149	mg/m3
DeltaC	6.09	ppb	0.0122	mg/m3
Flow Meter Pressure	117	Pa		
Q	1,299	CFM	2208	m3/hr
E	26.9	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	23%	7.0%	24%	6.5

Sampling Set	Delta C
(Down & Up)	ppb
1	6.5
2	5.7

Sampling Period 6				
Average Upstream	0.930	ppb	0.00186	mg/m3
Average Downstream	34.6	ppb	0.0692	mg/m3
DeltaC	33.7	ppb	0.0673	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	34.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	4.2%	7.0%	8.2%	2.8

Sampling Set	Delta C
(Down & Up)	ppb
1	33.7
2	33.6

Full Test 3 17-Oct-11

Sampling Period 1				
Average Upstream	1.34	ppb	0.00267	mg/m3
Average Downstream	34.7	ppb	0.0695	mg/m3
DeltaC	33.4	ppb	0.0668	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	34.2	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	4.2%	7.0%	8.2%	2.8

Sampling Set (Down & Up)	Delta C ppb
1	32.6
2	34.2

Sampling Period 2				
Average Upstream	1.08	ppb	0.00215	mg/m3
Average Downstream	14.9	ppb	0.0298	mg/m3
DeltaC	13.8	ppb	0.0276	mg/m3
Flow Meter Pressure	26.5	Pa		
Q	618	CFM	1051	m3/hr
E	29.0	mg/hr		

Absolute Uncertainty in ΔC (ppb)	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E (mg/hr)
1.4	10%	7.0%	12%	3.6

Sampling Set (Down & Up)	Delta C ppb
1	13.9
2	13.7

Sampling Period 3				
Average Upstream	1.15	ppb	0.00229	mg/m3
Average Downstream	11.2	ppb	0.0223	mg/m3
DeltaC	10.0	ppb	0.0200	mg/m3
Flow Meter Pressure	44	Pa		
Q	797	CFM	1354	m3/hr
E	27.1	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	14%	7.0%	16%	4.3

Sampling Set	Delta C
(Down & Up)	ppb
1	9.6
2	10.4

Sampling Period 4				
Average Upstream	0.95	ppb	0.00190	mg/m3
Average Downstream	7.50	ppb	0.0150	mg/m3
DeltaC	6.55	ppb	0.0131	mg/m3
Flow Meter Pressure	91	Pa		
Q	1,146	CFM	1947	m3/hr
E	25.5	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	22%	7.0%	23%	5.8

Sampling Set	Delta C
(Down & Up)	ppb
1	7.2
2	5.9

Sampling Period 5				
Average Upstream	1.20	ppb	0.00239	mg/m3
Average Downstream	6.47	ppb	0.0129	mg/m3
DeltaC	5.27	ppb	0.0105	mg/m3
Flow Meter Pressure	117	Pa		
Q	1,299	CFM	2208	m3/hr
E	23.3	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	27%	7.0%	28%	6.5

Sampling Set	Delta C
(Down & Up)	ppb
1	5.9
2	4.6

Sampling Period 6				
Average Upstream	1.33	ppb	0.00265	mg/m3
Average Downstream	33.7	ppb	0.0675	mg/m3
DeltaC	32.4	ppb	0.0648	mg/m3
Flow Meter Pressure	6.3	Pa		
Q	301	CFM	512	m3/hr
E	33.2	mg/hr		

Absolute Uncertainty in ΔC	Relative Uncertainty of ΔC	Relative Uncertainty of Q	Relative Uncertainty of E	Absolute Uncertainty of E
(ppb)				(mg/hr)
1.4	4.4%	7.0%	8.2%	2.7

Sampling Set	Delta C
(Down & Up)	ppb
1	31.4
2	33.4

References

Bell, M.L., McDermott, A., Zeger, S.L., Samet, J.M., Dominici, F., 2004. Ozone and Short-term Mortality in 95 US Urban Communities, 1987-2000. Journal of the American Medical Association 292, 2372-2378.

Boelter, K.J. & Davidson, J.H., 1997. Ozone Generation by Indoor, Electrostatic Air Cleaners. Aerosol Science and Technology (27)6, 689-708.

Bowser, D., 1999. Evaluation of Residential Furnace Filters. Report prepared for CMHC.

Britigan, N., Alshawa, A., Nizkorodov, S.A., 2006. Quantification of Ozone Levels in Indoor Environments Generated by Ionization and Ozonolysis Air Purifiers. Journal of the Air & Waste Management Association 56(5), 601-610.

Dorsey, J.A. & Davidson, J.H., 1994. Ozone Production in Electrostatic Air Cleaners with Contaminated Electrodes. IEEE Transactions on Industry Applications 30(2), 370-376.

Emmerich, S.J. & Nabinger, S. J., 2000. Measurement and Simulation of the IAQ Impact of Particle Air Cleaners in a Single-Zone Building. NIST Building and Fire Research Laboratory. NISTIR 6461, Gaithersburg, Maryland.

Gent, J.F., Triche, E.W., Holford, T.R., Belanger, K., Bracken, M.B., Beckett, W.S., Leaderer, B.P. 2003. Association of Low-Level Ozone and Fine Particles With Respiratory Symptoms in Children with Asthma. Journal of the American Medical Association 290(14), 1859-1867.

Hanley, J.T., Smith, D.D., Ensor, D.S., 1995. Fractional Aerosol Filtration Efficiency Test Method for Ventilation Air Cleaners. ASHRAE Transactions.

Hubbell, B.J., Hallberg, A., McCubbin, D.R., Post, E., 2005. Health-Related Benefits of Attaining the 8-Hr Ozone Standard. Environmental Health Perspectives 113(1), 73-82.

Ito, K., DeLeon, S.F., Lippmann, M., 2005. Associations Between Ozone and Daily Mortality: Analysis and Meta-Analysis. Epidemiology (16)4, 446-457.

Jerrett, M., Burnett, R.T., Pope III, C.A., Ito, K., Thurston, G., Krewski, D., Shi, Y., Calle, E., Thun, M., 2009. Long-Term Ozone Exposure and Mortality. The New England Journal of Medicine (360)11, 1085-1095.

Levy, J.I., Chemerynski, S.M., Sarnat, J.A., 2005. Ozone Exposure and Mortality: An Empiric Bayes Metaregression Analysis. Epidemiology (16)4, 458-468.

Liu, L., Guo, J., Li, J., Sheng, L., 2000. The Effect of Wire Heating and Configuration on Ozone Emission in a Negative Ion Generator. Journal of Electrostatics 48(2000), 81-91.

Murray, D.M. & Burmaster, D.E., 1995. Residential Air Exchange Rates in the United States: Empirical and Estimated Parametric Distributions by Season and Climatic Region. Risk Analysis 15(4), 459-465.

Stephens, B., Gall, E.T., Siegel, J.A., 2011. Measuring the Penetration of Ambient Ozone into Residential Buildings. Submitted to Environmental Science and Technology August 2011.

U.S. Census Bureau, Current Housing Reports, Series H150/09, American Housing Survey for the United States: 2009. U.S. Government Printing Office, Washington, DC, 20401. Printed 2011.

Vig, J.R., 1985. UV/Ozone Cleaning of Surfaces. Journal of Vacuum Science and Technology A (3)3, 1027- 1034.

Viner, A.S., Lawless, P.A., Ensor, D.S., Sparks, L.E., 1992. Ozone Generation in dc-Energized Electrostatic Precipitators. IEEE Transactions on Industry Applications 28(3), 504-512.

Waring, M.S., Siegel, J.A., Corsi, R.L., 2008. Ultrafine Particle Removal and Generation by Portable Air Cleaners. Atmospheric Environment 42(20), 5003-5014.

Weschler, C.J., 2000. Ozone in Indoor Environments: Concentration and Chemistry. Indoor Air 10, 269-288.

Weschler, C.J., 2006. Ozone's Impact on Public Health: Contributions from Indoor Exposures to Ozone and Products of Ozone-Initiated Chemistry. Environmental Health Perspectives 114(10), 1489-1496.

Vita

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