Changes in IAQ Caused By Corona Discharge Air Cleaner

BY TODD CRAWFORD; PATRICIA FRITZ, MEMBER ASHRAE; THOMAS WAINMAN

ASHRAE Standard 62.1 has long established that an occupied space requires an adequate supply of clean air to maintain acceptable indoor air quality (IAQ). The most common source of clean air—outside air—must be conditioned at a price; fans, filters, heating, cooling, and tempering are major capital, maintenance and operating expenses in buildings. Consequently, ventilation systems are designed to preserve as much of the conditioned air as possible by cleaning and recirculation. ASHRAE's IAQ Procedure[1] describes a method to reduce the proportion of outside air supply by treating (cleaning) and recirculating air. ASHRAE's IAQ Procedure is akin to the Exception in International Mechanical Code §403.2 (2010):

"Where the registered design professional demonstrates that an engineered ventilation system design will prevent the maximum concentration of contaminants from exceeding that obtainable by the rate of outdoor air ventilation...the minimum required rate of outdoor air shall be reduced in accordance with such engineered system design."

Corona discharge (sometimes labeled: ionizing, negative ion, bipolar ionizing, activated oxygen, mountain fresh air, etc.) often is a proposed air cleaning technology to remove airborne contaminants. Corona discharge ionizes oxygen in air and generates an electrostatic field. The design of the corona discharge system can be modified to create mixtures of reactive oxygen species (ROS): ozone, hydroxyl radicals, and superoxide anions.[2] Ozone emissions from air cleaners are regulated in California[3] and are generally discouraged in many states' guidance documents (see, for example: Connecticut, New York[4]); the manufacturer's marketing materials claim this air cleaner does not produce ozone. ROS initiate radical reactions that rapidly decay unsaturated volatile organic compounds (VOC) and generate particles. The radical reactions propagate, creating and destroying radicals and ROS until the reactants are transformed and the products do not react further.[5] For "air cleaning" the final reaction products would be carbon dioxide and water but in practice, corona discharge transforms airborne contaminants into myriad products that are not well-characterized for their chemical identities, yields or toxicities. We designed this study to evaluate the changes in IAQ caused by a corona

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discharge air cleaner installed in a classroom ventilation system.

This study was performed in an unoccupied high school classroom in upstate New York during the winter vacation. The classroom's unit ventilator can circulate room air at 1,000 cfm (472 L/s) and supply 15 cfm (7 L/s) outdoor air per person, which complies with the applicable mechanical code. For this study, a corona discharge air cleaner was installed and connected to operate synchronously with the ventilator fan. The outdoor air supply was adjusted in four phases:

- Phase 1: corona discharge OFF; outdoor air supplied at 450 cfm (212 L/s).
- Phase 2: corona discharge ON; outdoor air supplied at 450 cfm (212 L/s).
- Phase 3: corona discharge ON; outdoor air supplied at 250 cfm (118 L/s).
- Phase 4: corona discharge OFF; integrated economizing outdoor air supply controlled by the building ventilation management software (ASHRAE Cycle II).

Indoor temperature, relative humidity and carbon dioxide concentrations (parts per million, ppm) were logged throughout the study with a datalogger and carbon dioxide meter. The concentration of ozone (parts per billion, ppb) was logged with a UV absorbance photometer. The concentration of VOC (ppb) was logged using photoionization detectors. The concentration of ultrafine particles (UFP, counts per cubic meter) was logged with a scanning mobility particle sizer. Air samples were collected on sorbent cartridges (silica treated with 2,4-dinitrophenylhydrazine, DNPH) for analysis of aldehydes and acetone (ppb) by HPLC (NYS Method DOH-LOAC-616 SOP). The aldehyde and acetone concentrations are "time weighted averages," based on the total air volume collected during the sampling time—short-term fluctuations in concentrations are not captured by this method. To simulate students' exhaled breath in the vacant classroom, a piece of dry ice (approximately 400 grams of carbon dioxide) was set out to sublime in the classroom during each phase. Lemon essence (one milliliter, containing limonene) was evaporated during Phases 2, 3 and 4 to simulate the presence of VOC when students are present in a classroom—limonene was deployed during Phase 1 but no data was acquired due to an instrument error. The phases of the study and IAQ measurements are summarized in *Table 1*.

TABLE 1 Summary of data.

	PHASE 1	PHASE 2	PHASE 3	PHASE 4
Corona Discharge Air Cleaner	OFF	ON	ON	OFF
Initial Outdoor Air Supply (cfm)	450	450	250	450
Air Change Rate[1] (hour^{-1})	2.7	2.7	1.2	0.7
Average Outdoor Temperature[2] (°F)	27	21	21	21
Average Outdoor Relative Humidity[2] (%)	58	58	51	74
Average Classroom Temperature (°F)	70	68	73	69
Average Classroom Relative Humidity (%)	15	14	10	12
Average Classroom Ozone (ppb)	16.3	34.7	34.8	15.0
Average Classroom Formaldehyde (ppb)	2.42	3.05	3.74	1.87
Average Classroom Acetaldehyde (ppb)	1.21	1.71	1.56	0.68
Average Classroom Propionaldehyde (ppb)	0.24	0.44	0.25	0.16
Average Classroom Butyraldehyde (ppb)	0.20	0.31	0.25	0.16
Average Classroom Valeraldehyde (ppb)	0.10	0.27	0.23	0.15
Average Classroom Hexaldehyde (ppb)	0.21	0.37	0.37	0.19
Average Classroom Acetone (ppb)	3.06	6.11	8.22	2.58

[1] Estimated from rate of change of carbon dioxide concentrations.[6]
[2] Outdoor temperature and relative humidity were obtained from local weather data accessed on http://www.wunderground.com.
Note: Increased levels of pollutants indicates worse IAQ.

FIGURE 1 Ozone concentrations in classroom seating area. Yellow shading indicates period when corona discharge air cleaner is switched on.

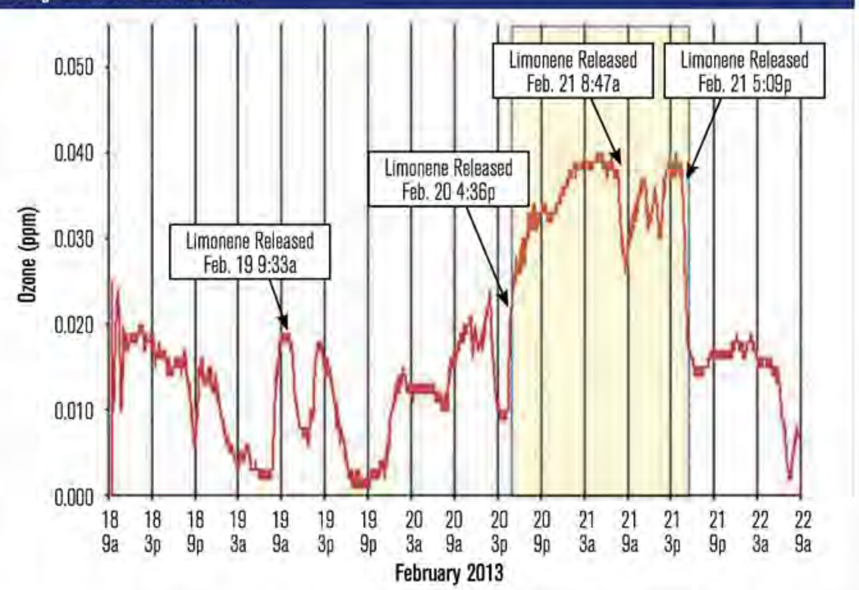
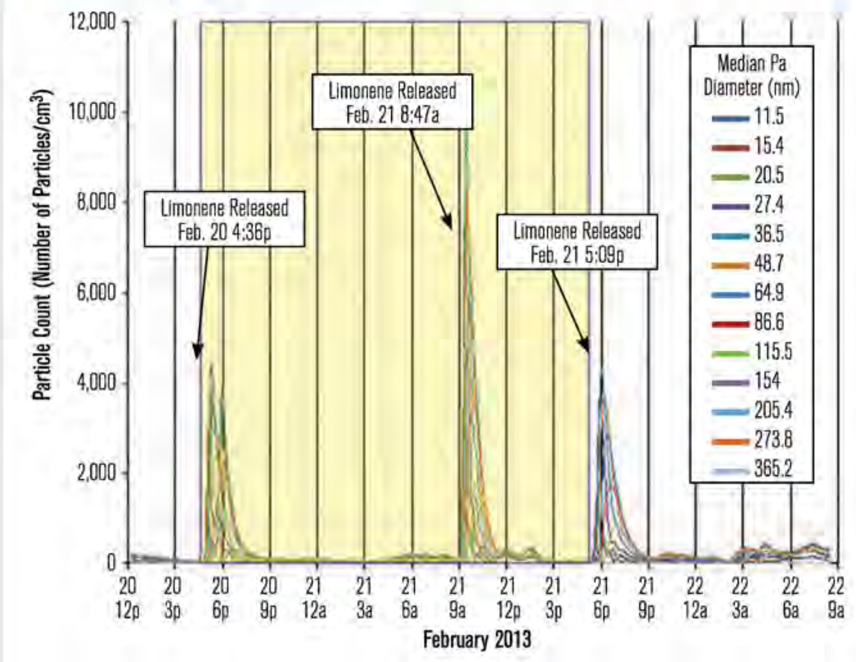


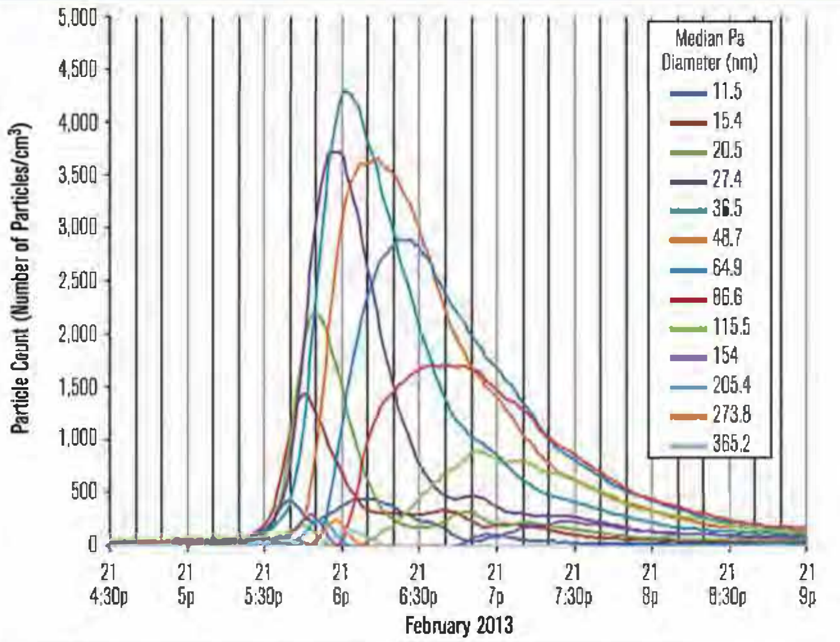
FIGURE 2 Ultrafine particle counts by median particle diameter in classroom seating area. Yellow shading indicates period when corona discharge is switched on. No data was acquired during Phase 1 due to an instrument error.



The average classroom temperature and relative humidity remained within normal indoor ranges during the study; the low indoor relative humidity is typical for winter in upstate New York (*Table 1*). The average indoor ozone concentrations more than doubled when the corona discharge was on, with little change from reducing the outside air supply (*Figure 1*, Page 65). There was a sustained increase in indoor ozone concentrations while the corona discharge air cleaner was operating. The concentrations of the aldehydes and acetone increased when the corona discharge was operating (Phase 1 versus Phase 2; *Table 1*). Decreasing the outdoor air supply further increased the concentrations of formaldehyde and acetone (Phase 3). UFP counts increased following the deployment of limonene in the classroom (*Figure 2*). Smaller diameter particles (<36.5 nm) were generated first, with larger diameter particles (>48.7 nm) appearing as time passed, likely due to agglomeration of the smaller particles (*Figure 3* shows detail). UFP formed whether the corona discharge was ON or OFF but the counts were highest when the corona discharge was switched ON and the outdoor air supply rate was decreased (Phase 3).

This study showed that operating the corona discharge air cleaner in the ventilation unit of the classroom caused an increase of the indoor ozone concentration, and correspondingly, turning off the air cleaner coincided with a decrease in indoor ozone concentrations. The release of limonene in the classroom was rapidly followed by the formation of UFP; the particle count was highest when the corona discharge was ON and the outdoor air supply rate was decreased. The time-weighted average concentrations of aldehydes and acetone were elevated when the corona discharge air cleaner was operating, but time-resolved changes in concentrations could not be observed by this method. The increased concentrations of ozone, UFP, aldehydes and acetone indicated IAQ degraded when the corona discharge air cleaner was operating. Our study showed the corona discharge air cleaner did not meet the requirements of the Exception in Mechanical Code Section 403.2. Based on these findings, New York State Education Department determined that corona discharge air cleaner systems cannot be used in schools in New York State.

FIGURE 3 Detail of ultrafine particle counts by selected median particle diameter in classroom seating area.



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Changes in IAQ Caused By Corona Discharge Air Cleaner

The IEQ Applications column entitled "Changes in IAQ Caused By Corona Discharge Air Cleaner," published in the December 2018 *ASHRAE Journal*, in my opinion has multiple challenges with the test methods employed, presentation of results, and conclusions reached by the New York State Department of Education.

First, there are multiple means of generating ions that result in varying levels of ozone. Most manufacturers can provide documentation regarding the level of ozone their particular technology generates. The authors of this article do not mention which manufacturer's product they tested or the level of ozone the device generates.

Second, the authors do not state whether they collected data for ozone, relative humidity, temperature, VOCs, aldehydes, and acetone from the outdoor air during the testing. For this reason, it is impossible to determine whether outdoor pollutant sources active during the testing time period could have impacted the results.

Third, technology exists that would allow for counting of ion levels in the space. Manufacturers of these devices typically will indicate what the ion level needs to be to have a meaningful impact on contaminants. Ion levels were not measured before or during the test, in the space or outdoors, and the authors appear to have assumed the corona device tested was creating a level of ions that could impact the contaminants being monitored. Without this information it is impossible to determine if the device was operating as intended by the manufacturer.

Fourth, most of the technologies used to generate ions are not known for creating any contaminants other than ozone. The authors do not state this fact, and yet contaminants other than ozone were measured to have increased when the device was turned on. Assuming the device did not generate those other contaminants, what caused them to increase? This is an unanswered question.

Finally, CARB has two standards: a one-hour average of 0.09 ppm (90 ppb) and an annual average of 0.07 ppm (70 ppb). The ozone levels reported during all test conditions are below these levels (maximum of 34.8 ppb and minimum of 15 ppb). However, the authors left readers with the impression that the device had created unacceptable levels of ozone in the space.

Having implemented bipolar ionization in multiple facilities throughout my career and having been involved in pre- and post-installation IAQ testing, I can attest to the effectiveness of bipolar ionization when properly designed and implemented. In my opinion, ASHRAE and the authors have done a disservice by reporting on a poorly designed and executed test. There are multiple manufacturers and industry experts who could have assisted and supported the authors in their pursuit of trying to understand this type of technology and the meaningful benefits it can provide.

Ellis G. Guiles, P.E., Member ASHRAE, Wayne, Pa.

The Authors Respond

We thank Mr. Guiles for his comments. Our article describes a method of measuring the changes in indoor air quality caused by corona discharge. The study was designed and executed in collaboration with the manufacturer of the air cleaner. New York State Education Department (NYSED) requested the study and New York State Department of Health (NYSDOH) executed the air monitoring, sampling and analysis of the indoor air quality. The vendor and manufacturer installed the corona discharge air cleaner in the classroom unit ventilator and made all the adjustments for each phase of the study.

Mr. Guiles argues the configuration of the corona discharge affects the emission of ozone. Ozone is one of the reactive oxygen species (ROS) that may be formed by corona discharge in air; other ROS include hydroxyl radical and superoxide anion. The relative proportions of the different ROS may be varied by changing the configuration of the corona discharge, but we leave it to others to demonstrate a corona discharge that won't form any ROS in air. As noted in our article, the manufacturer's marketing literature stated this system does not form ozone.

Mr. Guiles questions whether the outdoor air conditions influenced the indoor air quality (IAQ).

There are no significant sources of aldehydes or acetone in this suburban location. Winter concentrations of ozone are very low and daytime levels may increase when ozone is formed by sunlight, but Figure 1 shows the concentration of indoor ozone rose during the nighttime period when the corona discharge was turned on. This study was internally controlled so that we compared the IAQ when the air cleaner was operating against conditions when it was turned off. Table 1 and Figure 1 clearly show that indoor air contamination increased when the air cleaner was operating compared to when it was turned off.

Mr. Guiles suggests that ion levels should have been monitored to validate the operation of the corona discharge system. The manufacturer and vendor were engaged throughout this study and at no time did they suggest their air cleaner was faulty, nor did they recommend measuring the ion levels.

However, if ion levels were elevated when the corona discharge was operating that would have been interpreted as another increase in the indoor air contamination.

We are dismayed by Mr. Guiles' assertions that: 1) corona discharge doesn't create any contaminants other than ozone, and 2) there are no mechanisms for the formation of indoor air contaminants. We cited two papers to provide readers with excellent summaries of corona discharge and indoor ozone chemistry (Goldman at al. 1985 and Weschler 2000). Those two papers reference some of the many scientific and technical publications that describe in detail corona discharge and reactions in indoor air. This column described the methods that we designed to measure the contaminants that are well-known to form during these processes.

Mr. Guiles refers to the California Air Resources Board (CARB) Ambient Air Quality Standards for ozone, which is an outdoor air standard, not an indoor air standard. The more applicable CARB regulations, those for ozone emissions for portable indoor air cleaning devices, were not relevant to our evaluation of the corona discharge air cleaner. The vendor claimed their system would satisfy the requirements for the Exception in Mechanical Code 403.2. No numerical standards for any specific air contaminant apply in the Exception. Our study demonstrated that indoor air contaminants increase when the corona discharge is operating in the ventilation system. NYSED used this data to respond to the vendor's claims. This air cleaner system, installed and operated by the manufacturer in a classroom, does not comply with the requirements of Mechanical Code 403.2.

Finally, Mr. Guiles attests "to the effectiveness of bipolar ionization when properly designed and implemented," but did not share the IAQ parameters upon which this experience is based. In broad terms, we concur that properly designed, installed and operated corona discharge air cleaners may be appropriate in some settings. This study describes a method for evaluating air cleaning systems when they are installed in ventilation systems to establish whether they meet indoor air quality requirements for specific settings, in this case a school.

Todd Crawford, Patricia Fritz, Member ASHRAE, and Thomas Wainman, New York State Department of Health, Albany, N.Y.

LETTERS

Changes in IAQ Caused By Corona Discharge Air Cleaner

With 18 patents granted and 14 more pending, Global Plasma Solutions (GPS) is the leading manufacturer of needlepoint bipolar ionization (NPBI) systems designed for indoor air purification. As a result of the column entitled "Changes in IAQ Caused by Corona Discharge Air Cleaner," (December 2018) we have received numerous phone calls, emails and direct inquiries challenging the efficacy and viability of NPBI technology for treating indoor air. In short, the column has had the negative effect of incorrectly associating GPS' NPBI technology with all corona discharge and other ionization products. The column states "Corona discharge (sometimes labeled: ionizing, negative ion, activated oxygen, mountain fresh air, etc.) ..." The readers of *ASHRAE Journal*, and the market in general, deserve to be made aware that NPBI does not produce ozone or other listed contaminants, and that NPBI technology should not be associated with corona discharge.

NPBI is not a corona discharge technology. It should not be categorized in this manner, nor should it be associated with corona discharge and its negative side-effects. On the contrary, GPS' NPBI technology has been certified by UL 867 and UL 2998 as an ozone free technology. That is, ozone, aldehydes and ultrafine particles are not created by the application of NPBI. GPS or NPBI technology is rightfully not listed on the CARB website of Potentially Hazardous Ozone Generators Sold as Air Purifiers (https://www.arb.ca.gov/research/indoor/o3g-list.htm). In fact, NPBI is used by many cleanroom manufacturers to reduce ultra-fine particles. NPBI is successfully used in hospitals, offices, airports, schools, arenas, airplanes, veterinary offices and vivariums, to name a few applications. GPS has many third party IAQ studies proving that NPBI does not produce undesirable by-products. On the contrary, the studies show that the use of NPBI technology in conjunction with the IAQ procedure produces exceptional air quality and substantial energy savings.

Figure 1. Corona discharge tube.

While the authors highlighted several good technical points on the specific technology utilized in the testing, it does not provide sufficient detail on the differences between corona discharge and NPBI technologies. The technology and subsequent product used in the tests in the New York study are listed as a known ozone generator by the State of California. Furthermore, the same product was removed from the FEMA Trailer Study for Formaldehyde Reduction due to their high ozone output. Publishing a study from 2013 based on a known ozone producing technology does not reflect the current state of the art. The column fails to detail the differences between the technologies which has caused a lot of confusion, skepticism and concerns in the market. The column has done a great disservice to all that are dedicated to promoting the use of proven new technologies to deliver clean indoor air while delivering energy and cost savings.

Corona discharge systems have been operating since the late 1800s and were developed by Sir William Crooks. At the time they were called the "Crooks Tube," as well as cathode ray tubes. Around 1928 William Langmuir changed the name to "plasma tube." They are marketed as corona discharge tubes (CDT), or dielectric barrier discharge (DBD) systems. Many companies use CDT/DBD to generate ozone for odor control in unoccupied spaces. In short, there will be ozone when using corona CDT/DBD technology.`

Figure 1 shows an example of a CDT. There is an inner filament, a glass tube, and an outer filament,

CHEMICAL	FORMULA	Electron Volt
Xylene*	C_8H_{10}	7.89
Styrene*	C_8H_8	8.46
Methyl Ethyl Ketone*	C_3H_8O	9.52
Ammonia*	NH_3	10.07
Acetaldehyde*	CH_3CHO	10.23
Ethyl Alcohol*	C_2H_5OH	10.48
Formaldehyde*	CH_2O	10.88
Oxygen	O_3	12.07

Glass tubes require >12.07 to break down the dielectric

* Typical contaminants of concern as contained within ASHRAE 62.1
• Electron Volt Energy greater than 12Ev, creates ozone (O_3)

CORONA DISCHARGE TUBE

Figure 2. A sample of eV potential for several compounds.

very similar to the product used in the New York classroom study. The glass is the "dielectric," or resistance to the voltage path to ground. The dielectric can be glass, quartz, mica, ceramic, or any material that has a high insulating value. For a corona discharge system to operate, the voltage and current must be high enough to breakdown the dielectric material to complete the electrical path to ground. When the power output is high enough, and the path to ground is achieved due to the dielectric breakdown, a corona discharge is formed. The corona discharge is easiest seen in darkness. It appears as a purple glow down the entire tube.

The power required to breakdown most dielectrics exceeds 12.07eV (electron volts). Every gas has an electron volt potential. Figure 2 shows a sample of eV potential for several compounds. Oxygen has a potential of 12.07eV. When the power input is greater than 12.07eV, ozone is created as oxygen is ionized. Understanding the relationship of power to eV is critical when designing air purification systems to produce the desired effect, while avoiding the formation of ozone and

Figure 3. NPBI electrode.

other by-products. NPBI is uniquely different from corona discharge systems. NPBI does not use a dielectric. It does not produce ozone. The power output is controlled to less than 12.07eV.

NPBI electrodes, or "needles," are made from carbon fiber (Figure 3), titanium, silver, gold, stainless steel, and other corrosion resistant conductive materials. As you can see from the Figure 3, the electrodes are attached to the flexible circuit and there is no dielectric.

NPBI has been used for particle reduction, odor control, pathogen control and static electricity control for more than 10 years. The production of unwanted by-products, including ozone, associated with corona discharge air cleaners are avoided when using NPBI. The newer NPBI technology should NOT be associated with corona discharge. This should be made clear to all, especially the readers of the *ASHRAE Journal.*

Charlie Waddell, Associate Member ASHRAE, Chief Technology Officer, Global Plasma Solutions, Savannah, Ga.

Editor's Note: The authors of the column responded after print deadlines. Their response is below.

The Authors Respond

Mr. Waddell, Global Plasma Solutions, Inc., (GPS) asks New York State Department of Health (Department) to distinguish needlepoint bipolar ionization (NPBI) from corona discharge air cleaners. The letter suggests that GPS customers have negatively and incorrectly associated NPBI with corona discharge and ionization.

Mr. Waddell offers GPS patents, UL certifications and general information to support his assertions that NPBI does not produce ozone or other contaminants and should not be associated with corona discharge.

The Department's column described the methods used to measure the changes in indoor air quality caused by operating a corona discharge air cleaner in a classroom ventilation unit. The study demonstrated that the air cleaner failed to meet the requirements of International Mechanical Code Section 403.2 (2010) because the study measured increased indoor ozone levels, ultra-fine particle counts and aldehyde concentrations.

For the purposes of this study, the Department designed an approach to evaluate regulatory compliance in New York. However, the Department's approach could be adapted by others to compare different air cleaner technologies and devices. Mr. Waddell's assertions about NPBI air cleaners could be tested and compared against other ionization air cleaners following the methods described in the column.

Mr. Waddell asserts that NPBI should not be associated with ionization products. However, patents for Global Plasma Solutions include patents for "ion generation devices." No differentiation between NPBI and ion generation can occur when their patents don't make that distinction.

Mr. Waddell offers that NPBI technology has been certified by UL 867, *Standard for Electrostatic Air Cleaners* and UL 2998, *Environmental Claim Procedure for Zero Ozone Emissions from Air Cleaners*. Ozone is one component of the mixture of reactive oxygen species (ROS) formed by ionization in air. Our study design measured ozone concentrations, but the scientific literature clearly establishes that a mixture of ROS is formed by ionization in air. GPS manufactures ion generation devices, which must form ROS to perform "air purification": ROS react with volatile organic chemicals, forming ultra-fine particles and aldehydes, as was shown in our study.

Mr. Waddell states their units are used for particle reduction, without mention of what metric (particle, count, size or mass) or what test was used to establish that. The UL 867 standard was referenced in the letter, but that standard addresses electrical issues, and it is the Department's understanding from the UL website, that it is not for air cleaners to remove particles other than dust. The Department's study did not measure dust, it measured ultra-fine particles. Ultra-fine particles are not in the particle fraction designated as dust.

The Department acknowledges that "clean air" is a subjective assessment. However, the study demonstrated increases in the concentrations of the analytes measured when the air cleaner was operating.Further increases occurred when the outdoor air supply rate was reduced below that required by the mechanical code. The Department's interpretation of the observed increases in the analytes measured when the unit was operated, and a decrease in those concentrations when the unit was off, is that, rather than removing pollutants, air quality was degraded when it operated, and it worsened when there was a reduction in the outdoor air delivery rate.

Advances in outdoor and indoor air cleaning technology to mitigate known and emerging contaminants of concern is a shared challenge for industry, academia and health agencies. It requires careful attention to all potential air quality impacts, and recognition of conditions outside of the laboratory to achieve methods which deliver a healthful indoor environment and protect public health.

There are no industry standards or guidelines to distinguish NPBI from other corona discharge air cleaners. Any comparisons of the effects on indoor air quality of different air-cleaning technologies should be based on data collected following the methods used in our study. The Department hopes manufacturers and researchers will reference our column in the Journal when they are tasked with evaluating changes in indoor air quality caused by ionizing air cleaners.

Todd Crawford, Patricia Fritz, Member ASHRAE, and Thomas Wainman, New York State Department of Health, Albany, N.Y.

Changes in IAQ Caused By Corona Discharge Air Cleaner

In the December 2018 column "Changes in IAQ Caused By Corona Discharge Air Cleaner," an in situ test done in a high school classroom formed the basis for the column. On reviewing this column, AtmosAir saw several inconsistencies and data presented in such a way that could bias the reader into an uninformed conclusion. This letter is written to help readers of this column better understand those inconsistencies and better educate the reader.

The column concludes that operation of the corona discharge air cleaner degraded air quality as there were increased levels of ozone, aldehydes and ultra-fine particles on days when the air cleaner was in operation. In the testing described, lemon essence, containing d-limonene, was evaporated into the subject classroom during the four separate phases of tests, as described in the column. It is well known that limonene when introduced to an environment with any ozone level, regardless of the source of the ozone, will precipitate an increase to aldehydes and ultra-fine particles. Many studies have concluded this (Weschler, C. J., and Shields, H. C. 1999. "Indoor Ozone/Terpene Reactions as a Source of Indoor Particles." *Atmos. Environ.* 33(15):2301–2312). The column would seem to suggest that the corona discharge air cleaner operation was solely responsible for these increases, but in fact ambient ozone levels in the classroom, which cannot be definitively traced to solely the operation of the air cleaner, were a causal link to any levels of aldehydes and ultra-fine particles measured.

Also as we well know, ozone is a natural element of air and can be found in varying levels in both outdoor and indoor air. Indoor ozone levels have been found to track to outdoor ozone levels closely (Weschler, C.J. 2001. "Ozone in Indoor Environments: Concentration and Chemistry." *Indoor Air* 10(4):269–288). The measured increases in indoor ozone the test cites had no corresponding outdoor ozone measurements taken, so the increase in any indoor ozone level cannot be definitively traced to solely an indoor source or the corona discharge air cleaner.

Average outdoor ozone levels for the upstate New York region in 2013 averaged 64 ppb (New York State Department of Environmental Conservation). The testing cites indoor levels ranging from 16.3 ppb to 34.8 ppb. Since ambient indoor ozone levels can be 10% to 50% of outdoor levels (*Estimating Mortality Risk Reduction and Economic Benefit From Controlling Ozone Air Pollution*. 2008. The National Academies Press, Washington D.C.), it stands to reason indoor levels in the ranges measured could be attributed to the concentrations found outdoors.

The column makes reference to various measured levels of contaminants sampled in the space. However, the column does not reference what the acceptable exposure limits are for the various compounds measured. See *Table 1* for a comparison.

TABLE 1 Comparison of contaminant levels.

CONTAMINANT	HIGH MEASURED VALUE	STANDARD	OTHER GUIDELINE
Ozone	34.8 ppb	100 ppb (NIOSH)	50 ppb (CARB)
Formaldehyde	3.74 ppb	16 ppb (NIOSH)	27 ppb (USGBC)
Acetaldehyde	1.71 ppb	200,000 ppb (OSHA)	25,000 ppb (ACGIH)
Propionaldehyde	.44 ppb	N/A	20,000 ppb (ACGIH)
Butyraldehyde	.31 ppb	N/A	N/A
Valeraldehyde	.27 ppb	N/A	N/A
Hexaldehyde	.37 ppb	N/A	N/A
Acetone	8.22 ppb	250,000 ppb (NIOSH)	250,000 ppb (ACGIH)

NIOSH = National Institute for Occupational Safety and Health
OSHA = Occupational Safety and Health Administration
USGBC = United States Green Building Council
ACGIH = American Conference of Governmental Industrial Hygienists
CARB = California Air Resources Board

As you can see the contaminant levels measured were significantly lower than any published standard or guideline, and some contaminants were so obscure that no published permissible exposure limits could be found. These levels do not show that bad air quality was found in the tested space in any of the test conditions.

The same can be attributed to the measurements of ultra-fine particles. Since no baseline was established nor outdoor levels measured, they cannot be definitively traced to an indoor source or the corona discharge air cleaner. Ultra-fine particles lack any indoor standards or guidelines or permissible exposure limits, so a comparison table cannot be provided.

The column also implies that the findings of this test were a factor in the New York State Education Department determining corona discharge air cleaner systems cannot be used to apply the 403.2 exception, which allows for reduction of outside air from standard ventilation rates. The fact is prior to and subsequent to this testing; the 403.2 exception has not been allowed in New York State Education Department.

Corona discharge is just one form of an ionization process and one type of an electronic air cleaner. There are many types of these technologies, and they have been used in literally 10,000-plus applications in schools across the U.S. over the past 20 where the 403.2 exception was applied. No IAQ issues have ever been reported from any of these applications, and these schools have benefitted from lower HVAC equipment and conditioning costs plus good IAQ in those treated spaces. Many studies with findings of improved IAQ using electronic air cleaning products have been done.

It is our position that the testing the column was based on was poorly constructed. It lacked an adequate baseline and an outdoor air comparison. The column then makes statements based on this flawed test. This column would leave the reader with more questions than answers.

Anthony M. Abate, Member ASHRAE, Fairfield, Conn.

The Authors Respond

Thank you for asking New York State Department of Health (Department) to respond to the most recent letter regarding our column in the December 2018 issue of *ASHRAE Journal*.

The Department determined that increases in concentrations of aldehydes and ultra-fine particles resulted from operating the corona discharge air cleaner in the classroom by comparing the concentrations during periods when the corona discharge was turned on to periods when it was turned off. The data, summarized in Table 1 and Figure 2 in the column, show that the concentrations of aldehydes and ultra-fine particles were consistently higher when the corona discharge was operating.

Data collected by the New York State Department of Environmental Conservation (data available upon request) shows hourly, average ozone concentrations ranged from 21 to 38 parts per billion (ppb) at the outdoor ozone monitor nearest the school during the study period, Feb. 18–22, 2013, considerably lower than the 64 ppb concentration cited in the letter. In fact, that value was the fourth highest eight-hour average ozone concentration in 2013 and was recorded on May 2, 2013, during the ozone season.

As shown in Figure 1 of the column, the indoor ozone concentrations fluctuated between 2 and 25 ppb when the corona discharge was turned off and 25 to 40 ppb when it was turned on. The observed changes in indoor ozone were clearly associated with operating the corona discharge air cleaner.

The measurements were made in an unoccupied classroom during the school winter vacation, and the normal ventilation cycles were modified to maintain uniform outdoor air supply rates during the study. There were no interferences from changes in room or building occupancy, outside traffic patterns or from cleaning or maintenance activities in the classroom during the study.

The study was designed to evaluate changes in the indoor air quality of a classroom while operating a corona discharge air cleaner with a reduced fresh air flow rate provided by the ventilation system. The Department found that the concentrations of ozone, ultra-fine particles and aldehydes increased under these conditions. The study was not designed to determine the health effects of these air pollutants, but instead was intended to test the claims that the amount of fresh air brought into a classroom can be reduced without adverse impacts on air quality. Since corona discharge air cleaners are marketed as potentially beneficial to health, it is appropriate to investigate those claims.

Todd Crawford, Patricia Fritz, Member ASHRAE, and Thomas Wainman, New York State Department of Health, Albany, N.Y.

Editor's Note: The authors' response to a June 2019 letter regarding this column can be found at www.ashrae.org/June2019Letters.

Improving the Performance of Steam Turbine Chiller Plants

"Saving Energy: Improving the Performance of Steam Turbine Chiller Plants" by Charles G. Copeland in August 2019 highlights the importance of combined heat and power-based steam power plants, which could provide an economical electrical energy source as well as thermal energy for cooling/heating for an overall efficient solution.

There are two factors which further need the author's attention and comments:

1. Fuel Options. The advantages of a steam system-based energy solution should be highlighted in terms

of fuel options, especially because oil and natural gas are becoming more expensive in developing countries, increasing costs of operating such plants substantially. Biomass options should be highlighted, as in Pakistan and other agro-based economies a large number of high-pressure steam boilers are fired by biomass (mostly bagasse, sugarcane waste) in combined heat and power mode, providing both economical process steam and electrical energy, some even exporting to the national grid and making good money.

2. Solar Option. There is a big opportunity for concentrated solar power (CSP)-based thermal energy to supplement boiler feed water heating, which could considerably reduce boiler fuel costs. I am not aware of any industrial or large commercial installation of this option, but technically this is feasible if roof or open space allows this.

Mr. Copeland's comments could clear the above options for possible implementation.

Ainul Abedin, P.E., Fellow ASHRAE, Karachi, Pakistan

The Author Responds

Comments as follows:

1. Biomass is certainly an option as the primary form of heating for boilers where oil and gas in parts of the world are becoming more expensive.

2. I'm not familiar with concentrated solar power (CSP) to produce heat; usually solar panels these days produce electricity. In the 1970s we worked on an early thermal solar collector on New York's lower east side to heat domestic hot water. The building later installed a windmill on the roof, which produced electricity, exporting some of it to the grid. When the local utility objected, the former attorney general Ramsey Clark defended it with the Public Service Commission, which gave rise to the Public Utilities Regulation Policies Act, which recently celebrated its 40th anniversary. This permits the export of electricity from localized generation such as cogeneration along with proper safeguards to be exported into the grid.

Charles C Copeland, P.E., Fellow/Life Member ASHRAE, New York, N.Y.

Desiccant Dehumidification Process for Energy Efficient AC

The August 2019 article "Desiccant Dehumidification Process For Energy Efficient Air Conditioning" details a first-generation device consisting of a desiccant belt, aimed at reducing energy consumption for HVAC. Though the article is well-written and well-presented, it represents a substantial "step backward" in desiccant technology, using a methodology of a poorly sealed desiccant laden belt, and insufficient desiccant mass for the application.

In comparison, multiple manufacturers use a similar, though patented and proven, approach in this very same application—minimizing HVAC energy consumption using desiccant technology. I am baffled as to why *ASHRAE Journal* would publish an article on an unproven, "step backward," single example of a technology which is already sold commercially and is already saving energy cost in use.

I request that *ASHRAE Journal* clarify for its readers that the method presented in the article is a single example experimental device, and that there are multiple equipment offerings incorporating desiccant technology that are currently used to reduce HVAC energy consumption.

Spencer Goland, Baton Rouge, La.

The Authors Respond

Thank you to Mr. Goland for the interest taken in our article. We fully acknowledge that desiccant is widely used and effective in commercially packaged and well-proven desiccant systems, such as the desiccant wheel discussed in the article. The belt design from our article is absolutely a first-generation experimental model. That being said, we saw design benefits in the belt that are not present in other commercially available desiccant technologies, including the use of low-cost silica beads and operation at low regeneration temperatures.

Our article illustrated a limited example including application of a relatively small system (i.e., not much desiccant) to a building with low outdoor airflow located in a climate with comparatively low humidity, and yet potential for energy savings was still observed.

Using a commercial product with optimized design and size, being in high humidity climate, and/or requiring a higher amount of outdoor air would greatly increase the potential of the desiccant technology for energy saving. We recommend that anyone interested in reducing system latent loads contact a local commercial HVAC supplier or representative to see all the options and have them assist in the selection.

Tom B. Cremonte, Associate Member ASHRAE, Troy, Mich., and Jonathan Maisonneuve, Ph.D., Auburn Hills, Mich.