A Bipolar Ionization Primer for HVAC Professionals

BY DAVID N. SCHURK, MEMBER ASHRAE

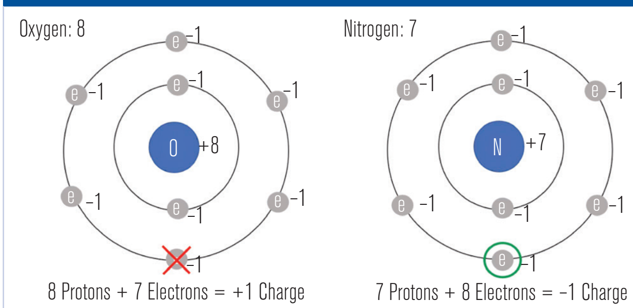
Ionization of the air through artificial means is rooted some 150 years in the past and may not be a new concept to many HVAC engineering professionals. This article reviews what ions and ionization are and provides a primer on bipolar ionization for HVAC professionals.

What is an Ion?

An ion is a charged atom or molecule in which the number of the atom's or molecule's electrons do not equal the number of its protons. An atom can acquire a positive charge or a negative charge depending on whether the number of electrons is greater than or less than the number of protons (*Figure 1*). When an atom is attracted to another atom because it possesses an unequal number of electrons and protons, that atom is called an ion (ION). If the atom has more electrons than protons, it is a negative ion (ANION). If it has more protons than electrons, it is a positive ion (CATION). Because these atoms and molecules have energy potential, they have the innate ability to physically interact with various constituents and compounds in the air.

Ionization of the air through artificial means is rooted some 150 years in the past and may not be a new concept to many HVAC engineering professionals. In his 1966 *ASHRAE Journal* article, "Distribution of Ions by Air for Effectual Control of Electrostatic Charges," Duane D. Pearsall,[1] Member ASHRAE, described the ionization process as multiple collisions of electrons with atoms or molecules of air, explaining that for a single moving electron to ionize an atom or molecule, the electron must possess a certain minimum kinetic energy. The

FIGURE 1 Examples of positive and negative atom or ions.



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History of Ionization

Ionization (plasma) was identified and researched by Sir William Crookes between 1869 and 1875. With his invention of the Crookes tube, cathode rays were first observed. Cathode rays are streams of electrons, which appear when an evacuated glass tube is equipped with two electrodes and a voltage is applied. Glass behind the positive electrode is observed to glow, due to electrons emitted from the cathode. In 1897, British physicist J. J. Thompson showed that cathode rays were composed of a previously unknown negatively charged particle, which was named the electron. Later called cathode-ray tubes (CRTs), this invention was first used to focus beams of electrons deflected by electric or magnetic fields to render an image on a screen.[5] Crookes discovered that these rays move in a straight line, cause glass to glow, carry negative charges and can cause a pinwheel in their path to spin, indicating they have mass.[6]

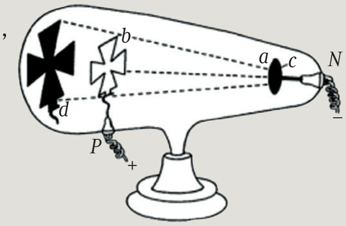


Figure 2. Crooks tube. Electrons (cathode rays) travel in straight lines from the cathode (right) as shown by the shadow cast by the metal maltese cross on the left-hand glass wall of the tube.

level of this energy is referred to as the ionization potential, measured in electron volts (eV). Electrons can be accelerated by an electric field, creating an ionization coefficient sufficiently high enough to ionize the air moving in the immediate field.

With a collision of sufficient intensity by an electron or another ion, the molecule or atom is excited to the point of ionization where the energy absorbed by the atom allows an electron to leave the atom against the force which tends to hold it. An atom that has lost or gained one or more electrons is said to be ionized. In general, an ion is an elementary particle of matter or a small group of such particles having a net positive or negative charge.

Ions in the Atmosphere

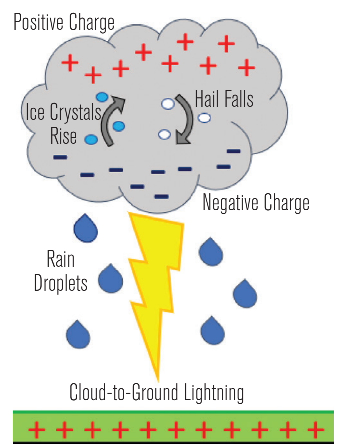
Ions occur naturally outdoors and are prevalent in the air we breathe. Atmospheric air ions are generated from natural sources, such as changes in atmospheric and weather conditions including lightning, sunlight, rain, wind, waterfalls and snow, as well as from plants, natural radioactivity in geological formations, cosmic radiation and combustion processes.[2]

According to Walter Lewin, Professor of Physics Emeritus at Massachusetts Institute of Technology, each day there are thousands of thunderstorms accompanied by hundreds of lightning flashes every second. Falling water (raindrops) can become charged through friction (Lenard effect) and along with other naturally occurring phenomena contribute to the ionization of clean outdoor air.[3] See "Science of Thunderstorms and Ionization From Lightning Strikes and Rain on Earth."

Science of Thunderstorms and Ionization From Lightning Strikes and Rain on Earth

Waterfall

Lenard (aka waterfall) effect is just one of the many ways nature imparts ionization to the clean outdoor air we breathe. It describes the separation of charge by water droplets that "splash," perhaps like they do at the base of a waterfall or during a rainstorm. Smaller drops that have a net negative charge are created, which then ionize the air, while larger drops and/or the bulk remaining maintain an overall charge neutrality or a net-positive charge.



Lightning

Lighting ionizes the air as updrafts in storm clouds carry small water droplets and ice crystals up, while denser soft hail falls. When they collide, ice crystals become positively charged and soft hail becomes negatively charged. Consequently, the clouds' top becomes positively charged, with its base becoming negatively charged. The clouds' negatively charged base repels electrons on the ground. Cloud-to-ground lightning is one type of lightning—others also result from the charge difference in clouds.

Ions and the Air We Breathe

Scientists and meteorologists have measured variations of the electrical charge in the air for more than 100 years.[4] Naturally occurring levels of outdoor ions are greatest where the air is the cleanest, for example at a beach near the ocean, or on a mountaintop (*Figure 3*). Ion counts at these locations may measure anywhere from 3,000 to 21,000 ions per cubic centimeter (ions/cc)

ASHRAE and Ionization

In the Sept. 1966 *ASHRAE Journal*, a peer-reviewed article, "Distribution of Ions by Air for Effectual Control of Electrostatic Charges,"[1] by Duane D. Pearsall, Member ASHRAE, introduced ionization as a method to control static potential indoors by creating an atmosphere essentially saturated with ions of positive and negative polarity (bipolar). This controlled the precipitation of infinitely small particles within industrial cleanrooms, particulate which could, otherwise, seriously interfere with the cleanliness of both process and product.

The article noted how important it was to use electric ionization that incorporated relatively low voltage levels to create a maximum ionization potential without the generation of ozone, a known toxic gas.[11] Pearsall concluded his article by stating that at the time there were no fewer than 300 technical papers relating to the physiological effects of ionization, that most suggested some value in the generation or control of ionization, and that "we have found no information to suggest that ionization is unhealthy to the human environment."

Another ASHRAE article "Reduced Outdoor Air for Auditorium," appeared in the May 2006 *ASHRAE Journal*, authored by Peter F. Johnson, P.E., Member ASHRAE.[12] Johnson discussed a project he designed using bipolar ionization in combination with ANSI/ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality*, using the Indoor Air Quality Procedure (IAQP), which allowed for combining bipolar ionization and high-efficiency particulate filters (MERV 11) to reduce outdoor air ventilation rates. The project was considered an architectural showcase for the Brunswick School of Performing Arts Center in Brunswick, Ohio. With more than a 50% reduction in outdoor air for ventilation achieved, it was also awarded a 2006 ASHRAE Technology Award.

The author noted that with bipolar ionization the site benefited from better indoor air quality along with a $60,000 savings in initial cost through reductions in HVAC equipment size. Substantial lifetime energy savings by reducing the need to heat and cool large quantities of ventilation air was another contributing factor that would be an added benefit over the life of the system.

in both polarities.[7] When ions are measured in more polluted environments, such as inner cities, naturally occurring ion levels become depleted and may measure considerably less.[8] Inside buildings these levels may be diminished even further as any remaining ions are depleted during their interaction with more heavily contaminated air.[8]

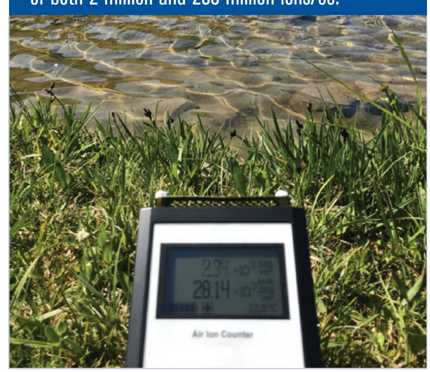
Various pollutants have the effect of reducing the amount of naturally available ionization in ambient air. The concept of artificially ionizing the indoor air has been recognized to replenish the concentration of ions to a level more consistent with that of the outdoors, where the air may be considered cleanest.[9]

Ions and Humans

Ions occur naturally and in abundance in the air around us.[7] While a variety of physiological or health effects in relation to exposure to air ions have been reported through the years, more recent research has posed doubt to these claims. The *Journal of Negative Results in Biomedicine* published a study[10] in which the authors stated that from a mechanistic or physical perspective there is no basis to suspect that electric charges on clusters of air molecules (ions) would have beneficial or deleterious effects on respiratory or biological function.

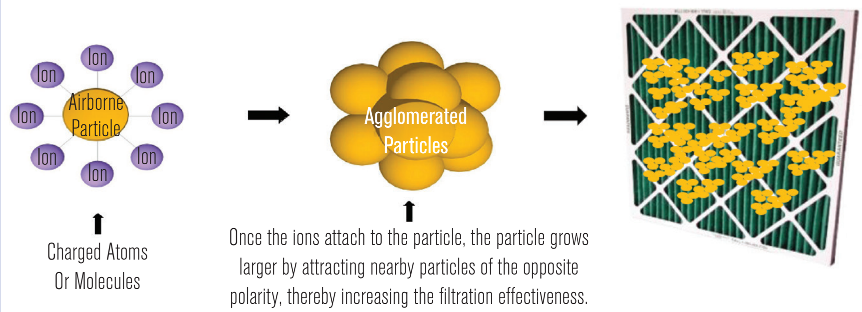
Their conclusion upon review of 80 years' worth of scientific literature, all of which had asserted the impact of human exposure to air ions and their effect on respiratory and other biological effects, was as follows: "Despite numerous experimental and analytical differences across studies, the literature does not clearly support a beneficial role

FIGURE 3 The author's (David Schurk's) handheld ion counter. Peak positive ion concentration 28,140 ions/cc. Reading taken at 12,240 ft (3731 m) elevation on mountaintop in Colorado. The ion counter has selectable maximum ranges of both 2 million and 200 million ions/cc.



in exposure to negative air ions and respiratory function or asthmatic symptom alleviation. Further, collectively, the human experimental studies do not indicate a significant detrimental effect of exposure to positive air ions on respiratory measures. Exposure to negative or positive air ions does not appear to play an appreciable role in respiratory function."[10]

FIGURE 4 Agglomeration of fine particles by electrostatic attraction as applied in cleanrooms.



Power of Ions

The U.S. Environmental Protection Agency (EPA) has identified indoor air quality as one of the environmental risks to public health.[13] The air we breathe may contain a variety of contaminants such as viruses, bacteria, pollen, dust, smoke and volatile organic compounds (VOCs). An extensive body of scientific evidence demonstrates that short- and long-term exposure to particle and gas pollution negatively affects our health and well-being. The world's leading health-related organizations consider fine particulate matter (2.5 micrometers in diameter and smaller) the most dangerous for humans because they penetrate deep into the lungs and bloodstream where they pose a threat to human health.[14]

Fine particulate existing within the indoor air may be too small or lightweight to easily be removed from the occupied space by the influence of air motion alone, particularly at the relatively low air change per hour (ach) rates typical of many residential and commercial HVAC systems. These contaminants, therefore, can remain suspended in the air for long periods.[15] It may include viral material and other pathogens as a part of these airborne particles, which are the transport mechanism for the transmission of respiratory infection between individuals breathing this air. Traditional HVAC ventilation and filtration strategies may have a reduced impact on cleaning the indoor environment.[16]

Technologies that help remediate this problem, like those used in cleanroom applications, may, therefore, be worth consideration.

A simple concept is that if the harmful particles and gases in the space can be removed, they are no longer of concern to human occupants. Ionized air has been demonstrated to be efficient at removing aerosol particles from indoor environments. Studies have found a significant reduction in concentrations of airborne particles due to the presence of ions.[17] Ions, like those already abundant in outdoor air, are artificially generated within the HVAC system so that when released and distributed throughout the building can mix with room air and attach (electrostatically) to airborne particles.

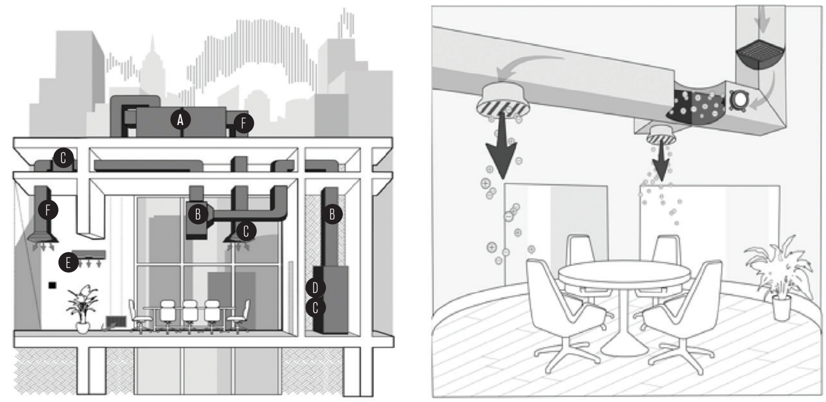
As these charged particles are increasingly attracted and joined to one another, their size and weight is increased to the point where they are larger and heavy enough to be more easily and quickly moved with the HVAC system's airflow (*Figure 4*). They can now be more effectively removed from the space to be exhausted, filtered or treated. Air filters are more successful at removing these larger particles from the air, while internally mounted HVAC air purification devices can now address the pollutants they have been tasked with remediating, those which before had remained in the space.[18]

Bipolar ionization of the air has been used in cleanroom applications to help reduce airborne particle counts and create the clean indoor environments for critical pharmaceutical, health-care, semiconductor, food processing and manufacturing processes.[19] Studies[20] have demonstrated that air ionization is effective at removing aerosols and particles from the environment, providing significant reductions in particulate concentrations. Bipolar ionization has also been studied and shown to be effective at both increasing the filtering rate of aerosolized pathogens as well as effectively increasing the decay of certain viruses and pathogens in testing.[18–23]

Ions in Buildings

On Nov. 11, 2020, Purdue University College of Engineering hosted a webinar[24] in which experts in the built environment addressed a variety of issues relevant to virus transmission and mitigation in buildings specific to SARS-CoV-2. Discussed was the issue that viruses

FIGURE 5 Various mounting locations for bipolar ionization devices in traditional building HVAC systems.



A. Rooftop Unit B. Ductwork C. Terminal Unit
D. Fan Coil Unit E. Mini-Split A/C F. Zone Diffuser

Ion Delivery
In-room ion density is dependent on a variety of factors, including proximity of the ionizing equipment to the occupied space, airflow rates and path of ductwork within the building.

can spread readily in buildings, especially in office or other commercial/institutional buildings that have high occupant density, many shared spaces and surfaces and significant recirculation of indoor air. Dr. Qingyan Chen, Professor of Mechanical Engineering at Purdue, presented his finding on how wearing masks indoors may reduce infection risk by 50%, and that by implementing bipolar ionization in the space it may be possible to reduce transmission rates an additional 20% to 30%.[24]

Modern bipolar ionization devices have been designed to be applicable and affordable for use in more traditional HVAC systems serving residential and commercial buildings. They are no longer only for industrial use. The two predominant technologies used today broadly include needlepoint bipolar ionization, which includes both metal needle points or carbon fiber brush needlepoint emitters, and corona discharge bipolar ionization using an array of tubes. With various HVAC mounting options (*Figure 5*), the system fan and ionization device should be left on to continuously recirculate space air and optimize the distribution of ions within the environment served. Increasing space air exchange rates and upgrading filter efficiency can be a factor contributing to the overall ionization of the indoor environment.

Ions and Ozone

An important concern with any electrically powered air cleaning device is that of ozone production. The U.S. Environmental Protection Agency says that when inhaled, ozone at high concentrations can damage the lungs, causing chest pain, coughing, shortness of breath and throat irritation. Ozone may also worsen chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections.[25] The Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have both provided guidance on recommended exposure limits for ozone.[26,27]

When the energy potential produced through the ionization process is limited to 12 eV or less, ozone will not be produced.[28] Oxygen (O_2) has an ionization energy of 12.07; therefore, ionization of the air at lesser potential will not break oxygen's bonds, which otherwise would lead to the formation of ozone (O_3). It is important to understand that ionization above this threshold will create ozone as a by-product. ASHRAE has issued guidance for the allowable limits of ozone production deemed appropriate for HVAC systems serving occupants within the built environment. ASHRAE Standard 62.1-2019, *Ventilation for Acceptable Indoor Air Quality*, details these restrictions with stringent requirements stating that air cleaning devices shall be labeled and listed in accordance with UL 2998 for zero ozone production.[29]

Conclusion

ASHRAE consulted with the Centers for Disease Control and Prevention (CDC) regarding the use of bipolar ionization and other emerging technologies and received the following guidance: "CDC does not provide recommendations for, or against, any manufacturer or manufacturer's product. While bi-polar ionization has been around for decades, the technology has matured and many of the earlier potential safety concerns are reportedly now resolved. If you are considering the acquisition of bi-polar ionization equipment, you will want to be sure that the equipment meets UL 2998 standard certification (Environmental Claim Validation Procedure [ECVP] for Zero Ozone Emissions from Air Cleaners), which is intended to validate that no harmful levels of ozone are produced."[30]

Although there are still many air cleaning technologies that produce ozone, several bipolar ionization products have been validated to UL 2998 for zero ozone emissions and comply with ASHRAE Standard 62.1-2019.

Bipolar ionization may still be considered by some as an emerging technology, so the CDC says: "As with all emerging technologies, consumers are encouraged to exercise caution and to do their homework. Consumers should research the technology, attempting to match any specific claims against the consumer's intended use. Consumers should request efficacy performance data that quantitatively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology. Preferably, the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources."[30]

This is recommended when selecting any air-cleaning technology or device tasked with remediating specific issues or concerns, or simply helping to create safer and healthier indoor environments for occupants inside buildings of all types.

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