From Needlepoint Bipolar Ionization to Targeted Bipolar Pulsed Ionization: A Next-Generation Approach to Contaminant-Specific Air Treatment

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Executive Summary

Needlepoint bipolar ionization represented a major advancement over earlier corona-discharge air ionization technologies. Rather than relying on high-energy plasma tubes or dielectric-barrier corona systems, needlepoint bipolar ionization uses controlled electrical energy at needlepoint emitters to generate both positive and negative ions. The intent was to reproduce the beneficial effects of naturally occurring ionized air while preventing ozone and byproducts. Needlepoint ionization technology simultaneously produces positive and negative ions that travel through the HVAC system and into the occupied space, where they interact with airborne particles, microorganisms, and some gaseous contaminants [1][2].

Since the original development of needlepoint bipolar ionization, the indoor air quality market has significantly matured. Engineers, building owners, healthcare facilities, schools, and regulators have increasingly asked more specific questions: What contaminant is being targeted? What polarity is most effective? How long do ions survive in the duct or occupied zone? How can unnecessary ion recombination be reduced? And how can an air-cleaning system adjust to different threats such as viruses, bacteria, mold, particles, VOCs, cooling coil cleaning and static electricity?

Targeted Bipolar Pulsed Ionization, or TBPI™, is designed to answer those questions. TBPI™ builds on the foundation of bipolar ionization but introduces active polarity control and a delay between ion pulses. Instead of producing positive and negative ions simultaneously at all times, TBPI™ allows the system to change the ionization output profile based on a user-selected contaminant. The user may select from a list such as bacteria, virus, particles, mold, VOCs, or static electricity. The system then adjusts the polarity output and timing sequence to emphasize the ion polarity or polarity pattern believed to be most useful for that target. Users can also select manual mode and set the available variables to their desired levels.

A key distinction is that TBPI™ introduces a short delay, approximately one second, between positive and negative ion output changes. This delay is intended to reduce immediate ion-to-ion recombination in the ductwork. Traditional simultaneous-output bipolar ionizers release both polarities at the same time, which leads to partial cancellation before ions reach the intended treatment zone. This recombination can represent roughly 30–40% of the ion output in some duct configurations. TBPI™ is intended to reduce that loss by separating polarity events in time, allowing one ion polarity to propagate before the opposite polarity is released.

The result is a more controllable, contaminant-specific ionization platform. TBPI™ does not merely ask, "How many ions can be produced?" It asks, "Which ions should be produced, when should they be produced, and what contaminant are they intended to influence?"

1. Background: The Evolution of Air Ionization

Air ionization has been studied and applied for more than a century. In general terms, an ion is an atom or molecule that has gained or lost electrons and therefore carries a net electrical charge. Positive ions have a net positive charge; negative ions have a net negative charge. In air-cleaning applications, these ions can interact with airborne particles, biological aerosols, and some gaseous compounds through electrostatic attraction, charge transfer, agglomeration, and oxidative or reactive chemistry pathways.

Modern HVAC ionization technologies are typically promoted for several mechanisms: particle agglomeration, enhancement of filtration, odor and VOC reduction, and biological contaminant reduction. Needlepoint bipolar ionization produces positive and negative ions that attach to particles, causing them to combine and become larger so they can be more easily filtered from the air [1]. Needlepoint bipolar ionization is used for particle reduction, odor mitigation, and in-space microbe control [2].

ASHRAE has recognized that filtration and air cleaning can improve indoor air quality by physically removing contaminants, inactivating viable biological agents, or addressing contaminants from indoor and outdoor sources [3]. However, ASHRAE and EPA also caution that air-cleaning technologies using electricity must be evaluated carefully for ozone, byproducts, effectiveness, and suitability for the intended application [3][4].

Ionization is not a single technology. Older corona-discharge systems, dielectric-barrier systems, plasma systems, needlepoint systems, unipolar systems, and newer controlled bipolar systems can have very different output characteristics, energy levels, byproduct profiles, and control strategies. It is well known that older corona-discharge systems produce ozone and will produce ultrafine particles when the ozone contacts limonene and other VOCs. The older systems are known as hard ionization and are known to fragment molecules leading to byproduct formation. Newer ionization systems like needlepoint bipolar ionization and TBPI™ are soft ionization systems with much lower energy levels that cannot fragment molecules.

2. Original Needlepoint Bipolar Ionization Technology

2.1 What Needlepoint Bipolar Ionization Was Designed to Do

Needlepoint bipolar ionization was developed as a lower-energy alternative to traditional corona-discharge ionization. The core concept was to use needlepoint emitters to generate ions in the moving airstream without requiring a dielectric tube or high-energy plasma field. The technology was intended to produce both positive and negative ions and deliver those ions through the HVAC system.

Needlepoint bipolar ionization is a “soft ionization” method that produces positive and negative ions for contaminant reduction in commercial HVAC applications [2]. Needlepoint bipolar ionization is third-party tested and UL 2998 certified as ozone-free [2][5]. UL describes UL 2998 as a Zero Ozone Emissions validation program for air cleaners, with ozone levels required to remain below the quantifiable limit of detection of 0.005 ppm, or 5 ppb [6].

2.2 How Needlepoint Bipolar Ionization Interacts with Contaminants

Needlepoint bipolar ionization has generally been described around three major contaminant categories:

Particles. Ions attach to airborne particles, changing their charge state and encouraging agglomeration. As particles combine into larger clusters and gain surface area, they may be more readily captured by HVAC filters or removed from the breathing zone. One air ionization manufacturer describes this particle-agglomeration mechanism in public materials [1][7].

Microorganisms. Biological aerosols such as bacteria, viruses, and mold spores can carry electrical charge. Research on airborne microorganisms has shown that charge magnitude and polarity are relevant to collection behavior and that bacteria and fungal spores can carry measurable electrical charges in airborne states [8][9]. This supports the broader technical premise that electrostatic forces can influence airborne biological particles.

VOCs and Odors. Odors and VOCs are controlled like particles via agglomeration. The low energy, soft ionization output cannot fragment VOCs to reduce odors; therefore, for a system to control odors using needlepoint bipolar ionization, there must be a particle filter and particles in the air for the gases to adsorb and then be removed by the filter.

2.3 The Limitation of Simultaneous Bipolar Output

Traditional needlepoint bipolar ionization and other simultaneous-output bipolar ionizers generally produce positive and negative ions at the same time. This approach has an advantage: both polarities are continuously available in the airstream. However, it also creates an inherent inefficiency. Opposite polarity ions attract one another. When positive and negative ions are produced simultaneously in close proximity, some portion of the ion population can recombine before reaching the intended target.

In simple terms, simultaneous bipolar output creates its own loss mechanism. Some ions clean the air; some ions cancel each other.

Simultaneous production can result in approximately 30–40% ion cancellation in ductwork **[10]**, depending on emitter geometry, airflow velocity, duct length, turbulence, humidity, ion density, and distance to the occupied zone. The underlying physics is straightforward: opposite charges attract, and recombination reduces the number of free ions available downstream.

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3. The Need for a More Targeted System

Indoor air challenges are not all the same. A classroom with high particle load, a healthcare space concerned with airborne pathogens, a brewery concerned with odors, a clean manufacturing area concerned with static electricity, and a commercial building concerned with mold spores may each benefit from a different ionization strategy.

Traditional bipolar systems generally operate with a fixed output pattern. They may vary total ion concentration, but they do not typically allow the user to select a contaminant and automatically shift the polarity profile to match that contaminant. TBPI™ is based on the idea that ionization should become more intelligent, more programmable, and more contaminant specific.

Several scientific observations support this direction:

First, airborne particles and microorganisms can carry electrical charges, and those charges can affect how they are transported, collected, and deposited [8][9].

Second, viral surfaces can have nonuniform electrostatic properties. For example, a 2022 study modeling the SARS-CoV-2 virion reported that the viral envelope possesses a positive net charge, largely influenced by positively charged spike proteins [11]. Other research has emphasized that electrostatic interactions play a role in viral attachment and surface interactions [12].

Third, electrostatic collection methods have long used charge manipulation to improve particle and bioaerosol removal. Studies of electrostatic precipitation and bioaerosol collection show that charging airborne microorganisms can significantly improve collection efficiency [13][14].

These findings do not mean that one polarity setting will universally “kill” or “capture” every contaminant. That would be an overstatement. But they do support the more careful proposition that charge matters, and that an air-cleaning platform capable of controlling polarity will have practical advantages over a fixed simultaneous-output system.

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4. Targeted Bipolar Pulsed Ionization: TBPI™

4.1 Definition

Targeted Bipolar Pulsed Ionization, or TBPI™™™, is a polarity-controlled ionization technology that adjusts ion output based on the contaminant selected by the user rather than producing positive and negative ions simultaneously at all times, TBPI™ uses programmed output sequences to emphasize positive ions, negative ions, alternating polarity, or timed bipolar patterns depending on the selected contaminant category.

A typical TBPI™ user interface may include selectable contaminant modes such as:

- Virus
- Bacteria
- Particles
- Mold
- VOCs / odors
- Static electricity
- Cooling Coil Cleaning
- General IAQ / auto mode

The system then applies a programmed polarity strategy for that target. For users that like to take control themselves, TBPI™ can be set to manual mode, allowing the user to define all system variables including time positive, time negative, electrode voltage and the time delay between pulses.

4.2 Core Innovation: Time-Separated Polarity Output

The defining technical difference between TBPI™ and conventional needlepoint bipolar ionization is the introduction of time-separated polarity control.

In a conventional simultaneous bipolar system, positive and negative ions are produced at the same time. In a TBPI™ system, the system may produce one polarity, pause briefly, then produce the opposite polarity. The delay between polarity changes may be approximately one second, although the exact delay can be adjustable based on airflow, duct geometry, target contaminant, and desired ion travel distance.

This delay is intended to allow the first polarity ion wave to move downstream before the opposite polarity ions are released. By reducing immediate ion-to-ion recombination near the emitter, TBPI™ will increase the useful ion population available for interaction with airborne contaminants with minimal cancelation.

4.3 Why the Delay Matters

The delay is not just a control feature; it is central to the TBPI™ concept.

If positive and negative ions are released simultaneously, the strongest electrostatic attraction may occur between the ions themselves. If the system releases negative ions first, waits approximately one second, and then releases positive ions, the first ion population has more opportunity to attach to particles, microorganisms, VOCs or static charges before the opposite polarity is introduced.

This may improve useful ion delivery in three ways:

Reduced emitter-zone recombination. Less immediate cancellation near the ion source.

Improved downstream ion availability. Ions will survive longer, allowing them to enter the occupied space or target zone.

Contaminant-specific charge conditioning. A selected ion polarity can be emphasized based on the expected charge characteristics of the target contaminant. Defaults for each contaminant are already coded in the software when in auto mode, but the user may select manual mode for custom input.

Small ions typically have a life expectancy of up to 60 seconds before touching a surface or particle and discharging [15]. That published ion-lifetime claim supports the practical possibility of time-separated polarity strategies, although actual ion life will vary by airflow, humidity, particle concentration, surfaces, and space geometry.

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5. TBPI™ Operating Modes

The following examples describe how TBPI™ may be positioned. These should be treated as design logic and a proposed operating strategy unless third-party testing confirms an alternative setting may be more effective.

5.1 Virus Mode

Virus mode may emphasize the polarity most likely to create electrostatic attraction with the target viral aerosol or viral surface structure. Research has shown that viral particles and viral proteins can have important electrostatic characteristics. A SARS-CoV-2 electrostatic mapping study reported a positive net charge for the modeled virion envelope [11]. Other studies have discussed electrostatic interaction between SARS-CoV-2 and charged surfaces or biological receptors [12][16].

For virus-targeting applications, TBPI™ may therefore emphasize negative ion output, alternate polarity with delay, or use a sequence designed to increase electrostatic interaction with positively biased viral aerosols. The purpose is not to claim that polarity alone guarantees viral inactivation, but to use electrostatic forces as part of a broader airborne contaminant reduction strategy.

5.2 Bacteria Mode

Bacteria and bacterial aerosols can carry positive, negative, or mixed charge distributions depending on organism type, growth conditions, aerosolization method, humidity, and surrounding particles. Studies of airborne microorganisms show that charge is a relevant parameter for biological aerosol collection [8][9].

TBPI™ bacteria mode may use alternating polarity sequences to charge or destabilize bacterial aerosols, increase agglomeration, and improve removal by filtration. In HVAC systems, this may be especially useful when paired with appropriate particulate filtration.

5.3 Particle Mode

Particle mode may be optimized for agglomeration. Ions attach to particles and cause them to cluster into larger particles that are easier to filter [1][7]. TBPI™ can build on this mechanism by using programmed polarity patterns that reduce ion cancellation and increase the likelihood that ions attach to particles rather than recombining with each other.

For particulate reduction, TBPI™ may use alternating positive and negative output with a delay, rather than simultaneous output, to encourage charge transfer and particle-to-particle attraction while preserving ion density downstream.

5.4 Mold Mode

Mold spores are biological particles, and studies of airborne microorganisms include fungal spores among charge-carrying bioaerosols [8][9]. TBPI™ mold mode may therefore emphasize particle charging, agglomeration, and filtration enhancement. TBPI™ is designed to influence airborne mold spores through electrostatic charging and improved removal pathways.

5.5 VOC / Odor Mode

VOC/Odor mode pulses between both polarities with a fixed delay. Please note, TBPI™ is a soft ionization device and VOC and odor control through oxidation, like older dielectric barrier systems, will not happen. Soft ionization requires the presence of particles in the air so the ions can help attract the VOCs to the particles and then a particle filter can remove both.

5.6 Static Electricity Mode

Static electricity is inherently charge-based. TBPI™ static mode will neutralize static charge by selecting the appropriate polarity output or alternating sequence. Unlike biological or VOC applications, static control may be one of the most straightforward uses of polarity-selectable ionization because the target condition is explicitly electrostatic.

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6. TBPI™ Compared With Traditional Needlepoint Bipolar Ionization

Feature	Traditional Needlepoint Bipolar Ionization	TBPI™
Ion output	Positive and negative ions produced simultaneously	Positive, negative, alternating, or timed output
User contaminant selection	Generally fixed-output or broad IAQ mode	User selects virus, bacteria, particles, mold, VOCs, static, etc.
Polarity control	Limited or not user-targeted	Central feature
Delay between polarity shifts	Typically none	Approx. one-second delay or programmable delay
Ion recombination management	Positive and negative ions recombine near emitter & duct	Time separation intended to reduce cancellation
Targeting strategy	General contaminant reduction	Contaminant-specific electrostatic strategy
Control interface	Typically on/off or output level	Software-driven contaminant selection
Best use case	General IAQ enhancement	Adaptive IAQ, targeted pathogen/particle/static control

The key distinction is that TBPI™ changes ionization from a fixed-output device into a programmable contaminant-response platform.

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7. Market Significance

TBPI™ arrives at a time when the indoor air quality market is moving from generic air-cleaning claims toward measurable, application-specific performance. Building owners increasingly want technologies that can be explained, controlled, monitored, and validated. One of Aeiro's S100 IAQ monitors may be used in conjunction with a TPBI system to confirm system effectiveness.

TBPI™ offers several advantages to traditional simultaneous output systems:

More intelligent control. The system can respond to user-selected contaminant categories rather than running one fixed ionization profile.

Reduced ion waste. The delayed polarity shift is intended to reduce ion recombination and preserve useful ion density. A TBPI™ system without ion cancellation can be smaller than a simultaneous output ionizer that must account for ion recombination loses.

Better contaminant matching. Different contaminants may respond differently to positive ions, negative ions, alternating polarity, or static neutralization.

Software-defined IAQ. TBPI™ can be integrated into smart building platforms, sensors, schedules, and contaminant-response modes.

Clear differentiation. TBPI™ creates a meaningful technical distinction from traditional needlepoint bipolar ionization and other fixed-output ionizers.

In the original "soft" needlepoint bipolar ionization era, the industry message was largely, "We produce bipolar ions safely." In the TBPI™ era, the message becomes, "We control ion polarity and timing to target the contaminant of concern."

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8. Conclusion

Needlepoint bipolar ionization was an important step forward in HVAC-based air treatment. It moved the market away from older, higher-energy corona systems and introduced a practical way to generate positive and negative ions in an airstream safely without ozone or byproducts. Publicly available materials describe benefits including particle agglomeration, filtration enhancement, odor mitigation, and biological contaminant reduction [1][2][7].

Targeted bipolar pulsed ionization represents the next logical step. TBPI™ keeps the useful foundation of bipolar ionization but adds contaminant-specific control, polarity selection, and delayed polarity switching. By separating positive and negative ion output in time, TBPI™ is designed to reduce immediate recombination and improve the useful delivery of ions to the target zone.

The central innovation is not simply more ion output; it is smarter ion output.

TBPI™ reframes bipolar ionization as a programmable, targeted air-treatment platform—one that can be adapted for viruses, bacteria, particles, mold, VOCs, odors, cooling coil maintenance and static electricity control.

References

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[2] GPS Air, "Needlepoint Bipolar Ionization / Soft Ionization" public technology page, describing needlepoint bipolar ionization for particle, microbe, and odor reduction and noting third-party testing and UL 2998 certification.

[3] ASHRAE, *Position Document on Filtration and Air Cleaning*, 2024, discussing filtration and air-cleaning technologies for contaminant removal and biological inactivation.

[4] U.S. Environmental Protection Agency, guidance on air cleaners, HVAC filters, and coronavirus, noting bipolar ionization as an emerging technology with limited field evidence and potential ozone/byproduct concerns if not properly designed and maintained.

[5] GPS Air, "How Ionization Works," describing needlepoint bipolar ionization as soft ionization and stating GPS products are UL 2998 certified as ozone-free.

[6] UL Solutions, "Zero Ozone Emissions Validation," describing UL 2998 and its 0.005 ppm / 5 ppb ozone detection threshold.

[7] GPS Air, "Indoor Air Quality & Particle Pollution," describing particle reduction through agglomeration.

[8] Lee et al., "Assessment of electrical charge on airborne microorganisms," PubMed abstract, describing charge as an important parameter affecting collection of airborne microorganisms.

[9] CDC/NIOSH archive, Baron et al., "Electrical charges on airborne microorganisms," describing parameters affecting magnitude and polarity of charges carried by airborne biological particles.

[10] Testing conducted in a 30' long duct comparing dual polarity output versus pulsed ionization output. Measurements were taken at the supply diffuser 30' from the TBPI™ device.

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[13] Mainelis et al., "Collection of airborne microorganisms by a new electrostatic precipitator," reporting improved bioaerosol collection when particles were electrically charged.

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[16] Javidpour et al., “Electrostatic interaction between SARS-CoV-2 virus and charged electret fibre,” exploring electrostatic interaction between charged surfaces and a SARS-CoV-2 model.

[17] ASHRAE filtration/disinfection technical resources and EPA guidance referencing UL 2998 for air-cleaning devices using bipolar ionization.