

AEIRO RESEARCH & TECHNOLOGY

From Needlepoint Bipolar Ionization to Targeted Bipolar Pulsed Ionization

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Executive summary

Needlepoint bipolar ionization uses emitters to generate positive and negative ions in an airstream. Manufacturer literature describes charge-related particle interactions and potential applications for indoor air treatment [1]. Product designs vary, so safety, emissions and treatment results should be evaluated at the model and application level rather than inferred from the needlepoint label.

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.

TBPI introduces a delay between positive and negative output periods; the described control strategy may use a delay of approximately one second, subject to the product's available settings. The purpose is to reduce immediate ion-to-ion recombination. The

extent of any improvement depends on geometry, airflow, humidity, output and residence time. The internal comparison referenced in earlier material lacks the protocol and raw data needed to support a generalized cancellation percentage [7].

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.

Ionization technologies are marketed for particle capture, filtration enhancement, VOC/odor reduction and biological outcomes. GPS Air’s public materials describe particle agglomeration and related applications [1]. These are manufacturer descriptions. Their existence does not establish the same performance for every ionizer or for an AEIRO product.

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 [2]. 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 [2, 3].

Ionization technologies can differ in emitter geometry, electrical input, control strategy and emissions. Some ion-generating devices may produce ozone or other byproducts unless appropriate design and maintenance measures are taken [3]. A soft-ionization description is a design distinction; it is not proof that a model cannot transform VOCs or generate any secondary product.

2. Original Needlepoint Bipolar Ionization Technology

2.1 What Needlepoint Bipolar Ionization Was Designed to Do

Needlepoint designs use emitters to release ions into a moving airstream. TBPI adds a controllable polarity and timing strategy. These mechanism descriptions should be separated from product-specific emissions and efficacy results.

UL 2998 is an ozone-emissions validation with a quantification threshold of 0.005 ppm (5 ppb) [4]. Any AEIRO compliance statement should refer to the specific model and its current supporting documentation. A technology-wide label does not establish UL 2998 status for every implementation. Ozone validation alone does not establish biological efficacy, VOC removal or the absence of all other byproducts.

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].

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 [5, 6]. This supports the broader technical premise that electrostatic forces can influence airborne biological particles.

VOCs and odors. Gas-phase contaminants should not be assumed to behave like particles. AEIRO has proposed that ion-influenced interactions with airborne particles, followed by filtration, may contribute to VOC/odor removal. The material supporting this paper does not establish that pathway or quantify its performance for TBPI. An applicable test should identify the compound or odor, particle/filter conditions, operating settings, method and measured reduction.

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.

Recombination is a potential loss pathway for free ions. The useful question is whether a different output strategy changes downstream ion availability and the treatment endpoint under matched conditions.

Simultaneous production can result in ion recombination in ductwork, with the extent 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.

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 [5, 6].

Viral surfaces can have nonuniform electrostatic properties. Fedorov and colleagues modeled the SARS-CoV-2 virion [8], while Lauster and colleagues discuss electrostatics

in virus-cell interactions [9]. A molecular model or cell-binding mechanism does not establish the charge distribution of a respiratory aerosol or the best TBPI setting for it.

Electrostatic-collection research shows that charging and collection conditions can affect bioaerosol removal [10, 11]. Those studies used their own devices and settings, including a livestock application. They are proof-of-principle evidence, not direct validation of an AEIRO installation.

These observations support testing adjustable ion strategies. They do not mean that one polarity will universally capture or inactivate a contaminant, or that programmable output necessarily outperforms a particular simultaneous-output product.

4. Targeted Bipolar Pulsed Ionization: TBPI

4.1 Definition

Targeted Bipolar Pulsed Ionization, or TBPI, is described by AEIRO as polarity-controlled ionization. Depending on the product and software version, the system can use positive, negative, alternating or timed output based on a selected operating mode. A selected mode describes a control strategy, not a verified treatment outcome.

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

Available manual controls may include positive and negative output periods, electrode settings and delay between pulses. Follow the supported ranges in the applicable product and software documentation; this paper does not establish a universal setting for every application.

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.

The delay is intended to let one polarity move away from the source before the opposite polarity is released. Whether this improves useful downstream ion delivery, and by how much, should be established in a controlled comparison with matched total output and installation conditions.

4.3 Why the Delay Matters

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

Separating opposite-polarity output in time may change recombination and attachment near the emitter. Transport depends on airflow, ion density, humidity, geometry and surfaces, so the timing strategy should be evaluated against the actual treatment objective.

This may improve useful ion delivery in three ways:

Reduced emitter-zone recombination. This is an intended effect of time separation; quantify it under the specified output and airflow conditions.

Downstream ion availability. Measure ion concentration and polarity at relevant downstream locations rather than assuming a longer ion lifetime.

Contaminant-specific charge conditioning. A selected mode can emphasize a polarity strategy. Its relevance to the actual aerosol and its effect on treatment need verification.

GPS Air's FAQ describes small-ion lifetimes of up to approximately 60 seconds [12]. This is a manufacturer statement, not a measured TBPI ion lifetime or a universal design allowance. Actual ion transport and loss depend on the environment and installation.

5. TBPI Operating Modes

The modes below describe proposed control logic. Claims of particle removal, biological reduction, VOC/odor treatment, coil effects or static neutralization require testing appropriate to that endpoint. A mode name alone does not demonstrate efficacy.

5.1 Virus Mode

Virus mode may use a polarity or alternating sequence intended to influence charged aerosol carriers. Published molecular and surface-interaction research provides background [8, 9, 13], but does not identify a universally effective ion polarity for infectious respiratory aerosols. Verify the selected strategy using an appropriate aerosol and biological endpoint.

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 [5, 6].

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 is intended to influence particle charging and possible agglomeration. Manufacturer literature describes these mechanisms [1], but a TBPI performance claim should identify particle size, concentration, airflow, filter, settings and measured removal relative to a control.

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 [5, 6]. 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 may use timed alternating output. TBPI is not designed as an intentional VOC-oxidation reactor, but that design description does not establish removal or absence of byproducts. The proposed particle-association and filtration pathway requires supporting tests for the specific compound or odor and installation conditions.

5.6 Static Electricity Mode

Static-control mode is intended to address excess charge through an appropriate polarity balance. Verify ion balance and charge-decay time at the target under the relevant conditions.

6. TBPI Compared With Traditional Needlepoint Bipolar Ionization

Feature	Simultaneous bipolar output	TBPI control approach
Ion output	Positive and negative ions emitted together in the compared configuration.	Selectable polarity or timed output, where supported by the model.
User selection	Capabilities depend on the specific product and controller.	Contaminant-category modes and available manual controls.
Timing	Simultaneous output in the defined comparison.	A delay between opposite-polarity output periods.
Recombination	May occur near the source or downstream.	Time separation is intended to reduce immediate recombination; measure the effect.
Treatment strategy	Product-specific mechanisms and claimed endpoints.	Programmed control logic; verify the relevant contaminant endpoint.
Interface	Model-specific on/off, output or other controls.	Software controls and integrations depend on product/version.

Feature	Simultaneous bipolar output	TBPI control approach
Application fit	Use documented emissions and performance for the application.	Use documented emissions and performance for the application.

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

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. The AEIRO Sense S100 can document the IAQ parameters listed in its current data sheet: temperature, humidity, CO₂, total VOCs, and formaldehyde. Those measurements can describe monitored conditions and trends, but they do not by themselves verify every treatment outcome. Particle, biological, odor, or other efficacy claims require outcome-appropriate measurement or testing.

TBPI's design provides several control features that can be evaluated against the needs of a project:

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. System sizing should be based on the specific application and documented performance rather than assuming a fixed ion-cancellation allowance.

Contaminant matching. Charge distributions and environmental conditions vary; the selected polarity strategy requires a documented basis and measured outcome.

Software integration. Available interfaces, schedules and sensor connections depend on the specific product and software version. Monitoring a parameter does not establish removal of a different contaminant.

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

The proposed distinction is control over polarity and timing. Its value should be expressed through supported capabilities and measured outcomes rather than a broad promise that one technology is always safer or more effective.

8. Conclusion

Needlepoint ionization and TBPI are approaches to delivering ions into air. Manufacturer materials describe potential charge-related applications [1]. Neither a technology label nor an operating mode establishes a particular model's emissions or treatment performance.

TBPI adds selectable polarity and pulse timing with the aim of managing immediate recombination and downstream ion delivery. Demonstrating an advantage requires a documented comparison that controls the installation and measures the relevant endpoint.

The central design difference is adjustable ion output. Its practical benefit should be established for the stated application.

For project evaluation, distinguish supported product controls, measured IAQ parameters and independently tested treatment outcomes. General electrostatic research, manufacturer literature, guidance and internal tests are different forms of evidence and should be identified as such.

References and source types

Research citations provide background for the stated mechanisms and tested systems. They do not automatically validate AEIRO product performance. Manufacturer literature, public guidance and internal references are labeled separately. Product claims require evidence for the relevant model, endpoint and operating conditions.

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