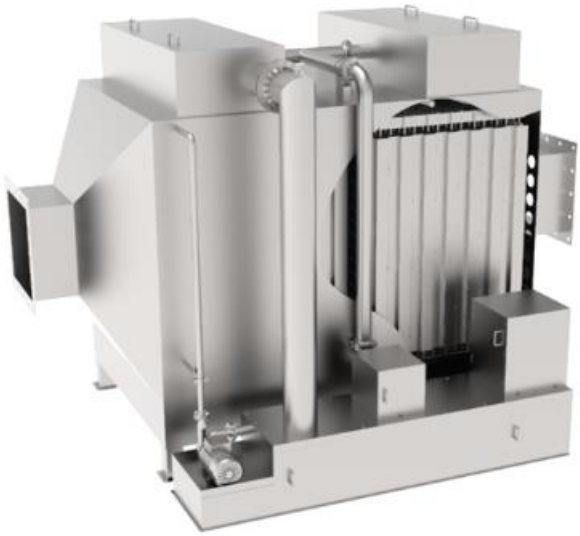
PLASMA GUARD™



TEST REPORTS

PLASMAGUARD TEST REPORTS

Significant testing has been performed during the invention, production, and commercialization of the PlasmaGuard technologies. During this process, we began operating under the trademark "PlasmaGuard" which we continue to use today. You will see in many of our test results, the name "IONaer" is utilized which is the original name under which the technology was invented. The IONaer 7000 Ion Generator has since been transformed and the latest and most advanced version of our technology – PlasmaGuard Pro.

Enclosed you will find various reports supporting the efficiency and performance of the PlasmaGuard units including:

- **Surrogate Aerosol Test**: The goal of this test was to access the efficiency of the unit for its ability to inactivate or neutralize viruses within indoor air under ambient conditions. In order to achieve this, the test was performed in two different manors. The first half of the test, a surrogate virus was introduced into the room at the same time the PlasmaGuard unit was turned on. The results showed a *99.82% reduction in 33 minutes***.** In the second half of the test, the PlasmaGuard unit was ran for 10 minutes before the surrogate virus was introduced into the room. This resulted in a *99.994% reduction within 10 minutes.*
    - Ultimately, the "Surrogate Aerosal Test" results prove how efficient the PlasmaGuard units are in combating viruses introduced into the air such as vegetative bacteria (staphylococci and legionellae), fungi (Aspergillus, Penicillium, and Cladosporium spp. and Stachybotrys chartarum), enteric viruses (noro- and rotaviruses), respiratory viruses (influenza and coronaviruses), mycobacteria (tuberculous and nontuberculous), and bacterial spore-formers (Clostrioides difficile and Bacillus anthracis).The simulation is representative of the way the units will combat viruses that enter a room through human transmission such as coughing or sneezing.

- **Surrogate Surface Test:** Like the surrogate aerosol test, the goal of this test was to determine the efficiency of the PlasmaGuard Unit in reducing pathogen levels on hard surfaces. This test was done utilizing *Human Respiratory Coronavirus 229 E(ATCC VR-740).*
    - The results of this test show the PlasmaGuard unit was able to reduce the presence of the Human Respiratory Coronavirus 229 E(ATCC VR-740) by *85.2% within 30 minutes.*

- **EPA Aerobiology Testing Room:** This report was published to indicate the size of the room in which testing was performed. The size is similar to a typical hospital room. Competitors tend to utilize a 1-meter square box which does not allow for an accurate representative of an entire room.

- **University of Arizona Testing**: This test is another test providing information on how PlasmaGuard units combat pathogens on a hard surface. Testing was done on bacteria E. Coli, A. baummanii, S. aureus and non-enveloped viral surrogate. *Results show our unit eliminated on average 99.02% of these organisms and improved airflow by 94%.*

- **Particulate Decay Rates and Agglomeration:** The purpose of this test was to show how PlasmaGuard units increase the rate at which particulates reduce in indoor air. Particulates natural decay or reduce, but this test shows that *PlasmaGuard units increase the rate of decay by 260%.*

- **Samples of Live Data:** This is a sample of the information you will receive from your PlasmaGuard unit in terms of active monitoring. It shows the number of particulates in the air at certain times.

- **UL Ozone Test – 300 CFM:** This test was performed in order to determine the amount of ozone produced in a 300 CFM HVAC duct while utilizing the PlasmaGuard units. Test results show our units reduced the ambient ozone *from 15 ppb to 5 ppb after 8 hours.*

- **UL Ozone Test – 1500 CFM:** Identical to the 300 CFM test, this test was performed in order to determine the amount of ozone produced in a 1500 CFM HVAC duct while utilizing the PlasmaGuard units. Test results show our units reduced the ambient ozone from *12 ppb to 8 ppb after 8 hours.*

- **UL Test Apparatus:** This diagram illustrates the testing unit used during the UL testing.

- **UL 2043 Test and Listing Report:** This test was performed to determine UL Standard 2043 regarding building and electrical codes. Results determined that PlasmaGuard units are *compliant with standards and requirements.*

- **FCC Compliance Test:** Similar to the UL Testing, these tests determined that PlasmaGuard units *pass compliance for Conducted Emissions and Radiated Emissions.*

As you can see, our units have passed compliance and performance testing and are not only efficient but meet all standards for building and safety. We are actively conducting additional testing to provide results for new virus strains, such as COVID-19 and continue to monitor and comply with safety regulations. PlasmaGuard provides the most efficient and effective indoor air pollution elimination technology on the market.

STUDY TITLE

Assessment of IONaer 7000 Ion Generator to reduce airborne pathogens: Testing with Cystovirus Phi6 (ATCC 21781-B1) as the challenge

TEST ORGANISM

Cystovirus Phi6 (ATCC 21781-B1):
Host:
Pseudomonas syringae (ATCC 19310).

TEST PRODUCT IDENTITY

IONaer 7000 Ion Generator Carrier

TEST Method

Air Decontamination Protocol based on US EPA Guidelines OCSPP 810.2500 for Efficacy Test Recommendations on Air Sanitizers

AUTHOR

Bahram Zargar, PhD

STUDY COMPLETION DATE

April/14/20

PERFORMING LABORATORY

CREM Co. Labs. Units 1-2, 3403 American Dr., Mississauga, Ontario, Canada L4V 1T4

SPONSOR

Clean Air EXP

STUDY NUMBER

CAE200306-01

STUDY PERSONNEL

STUDY DIRECTOR: Bahram. Zargar, PhD

PROFESSIONAL PERSONNEL INVOLVED: Sepideh Khoshnevis, MSc

STUDY REPORT

GENERAL STUDY INFORMATION

Study Title:	Assessment of IONaer 7000 Ion Generator to reduce airborne pathogens: Testing with Cystovirus Phi6 (ATCC 21781-B1) as the challenge
Study Number:	CAE200306-01
Sponsor	Clean Air EXP
Testing Facility	CREM Co Labs Units 1-2, 3403 American Drive, Mississauga, ON, Canada

TEST SUBSTANCE IDENTITY

Test Substance Name: IONaer 7000 Ion Generator

STUDY DATES

Date Device Received:
Study initiation date: March/03/06
Experimental Start Date: March/03/20
Experimental End Date: April/02/20
Study Completion Date: April/14/20

I. BACKGROUND AND INTRODUCTION

Indoor air is well-recognized as a vehicle for the direct and indirect spread of a wide variety of human pathogens, and many technologies are used to remove/inactivate such airborne pathogens in healthcare and other settings. In this study, IONaer 7000 Ion Generator was tested to quantitatively assess if it could reduce the contamination of the air by an enveloped bacteriophage (Phi6) as a surrogate for enveloped viruses such as influenza- and coronaviruses. The technology tested is based on the generation of cold plasma to charge indoor air. The device itself is mounted on the HVAC system to take advantage of the air movements in it.

II. RATIONALE

Indoor air can be an important vehicle for a variety of human pathogens and airborne pathogens can contaminate other parts of the environment to give rise to secondary vehicles leading to an air-surface-air nexus with possible transmission to susceptible hosts. Various groups of human pathogens with potential airborne spread include: vegetative bacteria (staphylococci and legionellae), fungi (*Aspergillus, Penicillium*, and *Cladosporium* spp. and *Stachybotrys chartarum*), enteric viruses (noro- and rotaviruses), respiratory viruses (influenza and coronaviruses), mycobacteria (tuberculous and nontuberculous), and bacterial spore-formers (*Clostrioides difficile* and *Bacillus anthracis*). Many technologies have been developed to decontaminate indoor air under field-relevant conditions. Furthermore, air decontamination may play a role in reducing the contamination of environmental surfaces and have an impact on interrupting the risk of pathogen spread.

OBJECTIVE

To assess the efficacy of IONaer 7000 Ion Generator for its ability to inactivate enveloped virus (*Cystovirus Phi6 (ATCC 21781-B1)*) in indoor air under ambient conditions.

Test Device:	IONaer 7000 Ion Generator
Room Temperature	Ambient temperature (22±2ºC)
Relative Humidity (RH):	50±10%

MATERIAL AND METHODS

1. **The aerobiology chamber**

   The details of our aerobiology chamber have been published before (Sattar et al., 2016). Briefly, the chamber (26 m^3) was built to comply with the guidelines from the U.S. Environmental Agency (U.S. EPA 2012). A PVC pipe connected to a nebulizer introduced microbial aerosols into the center of the chamber and another PVC pipe connected to an air sampler collected the airborne microbes directly onto nutrient agar plates inside the sampler. The nebulizer was operated for the desired length of time with air pressure (25 psi) from a compressed air cylinder. A glove-box on one side of the chamber permitted the handling of the required items without breaching the containment barrier. A muffin fan (Nidec Alpha V, TA300, Model AF31022-20; 80 mm X 80 mm, with an output of 0.17 cubic meters/minute) inside the chamber enabled the uniform mixing of the air inside it. Between uses, fresh air was used to flush out the chamber of any residual airborne microbes.

2. **Environmental monitoring:** The air temperature (22±2°C) and RH (50±10%) inside the chamber were measured and recorded using a remote-sensing device (RTR-500 Datalogger).

3. **The air sampler**

   A programmable slit-to-agar (STA) sampler (Particle Measuring Systems, Boulder, CO; http://www.pmeasuring.com/home) was used to collect air samples from the aerobiology chamber at the rate of 28.3 L (1 ft^3)/min. The sampler was placed outside the chamber and the sampler's inlet was connected via a PVC pipe to withdraw air from the aerobiology chamber. A fresh plate (150 mm diameter) with a suitable nutrient agar was used to collect an air sample and the plates incubated for the development of PFU of the test microbes. When collecting airborne phages, the recovery plate was first inoculated with a suspension of their respective bacterial host and placed in the sampler. The air sample collection time varied from 2 to 60 minutes depending on the nature of the experiment.

4. **Collison nebulizer**

   A six-jet Collison nebulizer (CH Tech., Westwood, NJ; www.inhalation.org) was used to generate the aerosols of the test microbe for ten minutes. Air from a compressed air cylinder at ~172 kPa (25 psi) was used to operate the nebulizer. The fluid to be nebulized consisted of a suspension of the test microbe in PBS.

5. **Test Pathogen**

   Phage Cystovirus Phi6 (ATCC 21781-B1) was grown in its bacterial host *P. syringae*

(ATCC 19310). This phage is a relatively large (about 100 nm in diam.), enveloped virus that is frequently used as a surrogate for human pathogenic viruses. This virus was a gift from the Laval University, Laval, Quebec, Canada.

6. Test Medium

The vegetative microbial growth and recovery media in this study were Luria Broth (LB) and Luria Broth Agar (LBA).

7. Preparation of Test Pathogen Suspension

To prepare a broth culture of *P. syringae,* a loopful of the stock culture was streaked on a LB agar and was incubated for 18±2 h at 28±1°C. A colony was inoculated in 25 mL of LB broth and incubated in at 28±1°C. When the optical density (OD) reached around 0.7, the bacterial suspension was used for the test.

8. Preparation of Phage Inocula for aerosolization

The test phage suspended in saline and nebulized into the aerobiology chamber (Sattar et al., 2016) using a six-jet Collison nebulizer.

TEST METHOD

1. Experimental setup

Flowchart 1 provides the sequence of steps in a typical experiment for testing the air-decontamination device. As control, the study included testing the natural decay of the test organism over time while the fan of the device was on without turning on the device. Table 1 and Table 2 list the times at which the air samples from the chamber were collected and the duration of sampling for each in control and efficacy test, respectively.

Flowchart 1. **Sequence of steps in a typical experiment.**

Air decontamination

Turn on muffin fan in aerobiology chamber at least 10 min before testing and placing 10-150 mm plates on the floors in five different locations

Nebulize test microorganism for 10 minutes

Allow 5 minutes for uniform distribution of aerosols

Collect a two-minute air sample

Turning on the device (in control test no action is required)

Collect an air sample based on Tables 1 and Table 2

Count PFU on plates after 24 hour of incubation

Calculate reduction in the level of viable microbes in air and surface

Table 1: **Time interval of air sampling for control test**

Sampling point (min)	Sampling duration (min)
0 (Baseline)	2
15	2
30	6
45	10
60	20
70-100	30
100-160	60
160-220	60

Table 2: **Time interval of air sampling for efficacy test**

Sampling point (min)	Sampling duration (min)
0 (Baseline)	2
15 (0-30)	30
45 (30-60)	30
67.5 (60-75)	15
82.5 (75-90)	15
105 (90-120)	30

In efficacy, all plates were divided to the sections with 7.5 min sampling period and the PFU in each area was counted and used for calculating the concentration of the bacteriophage in the chamber at the median of that interval.

Experimental Design

Three control tests were performed, with the device OFF, and the muffin fan ON. 150 mm plates with agar and host bacteria were placed in in the STA machine to sample the air. Two multi-challenge efficacy tests were performed. In efficacy test after sampling the baseline, the device turned ON and kept ON until the end of the test.

STUDY ACCEPTANCE CRITERIA

No product acceptance criterion was specified for this range-finding study.

RESULTS

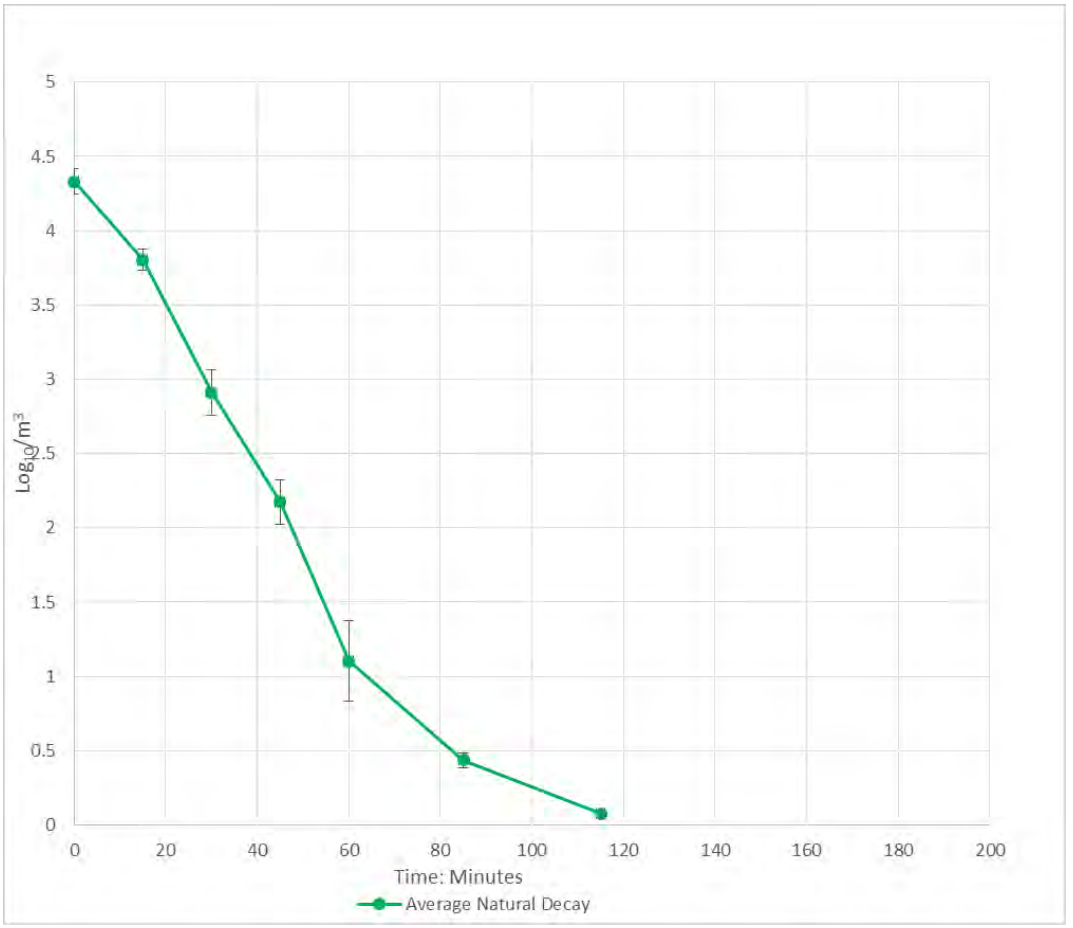
Testing phage survival: Any meaningful assessment of air decontamination requires that the aerosolized challenge microorganisms remain viable in the experimentally-contaminated air long enough to allow for proper differentiation between biological decay and inactivation/removal by the technology being tested. Such airborne viability of the microorganism used in this study was tested in the aerobiology chamber with three control tests without turning on the device while muffin fan was ON. The average of the three control tests was used to calculate the efficacy of IONaer 7000 Ion Generator Carrier.

Efficacy test of the IONaer 7000 Ion Generator against *Cystovirus* Phi6:

This part of the report represents data from the efficacy experiments on the IONaer 7000 Ion Generator against Phi6 at two different RH: 45% and 55%. The raw data are tabulated in Appendix A.

Figure 1 shows the average $\log_{10}$ PFU/m^3 recoveries for the three control tests (biological decay) with the corresponding standard deviation at each sampling interval. The concentration of Phage becomes undetectable after 2 hours.

Fig. 1. The average of three Stability-in-air tests (natural decay) against Phi6 phage with the standard deviation at each sampling point.



Two multi-challenge efficacy tests were performed on the device at two different relative humidity levels. Figure 2 shows the humidity of the chamber during the test. The average relative humidity in Test #1 was 53.5 % and in test #2 was 44%.

Fig. 2. The relative humidity in the two efficacy tests against Phi6

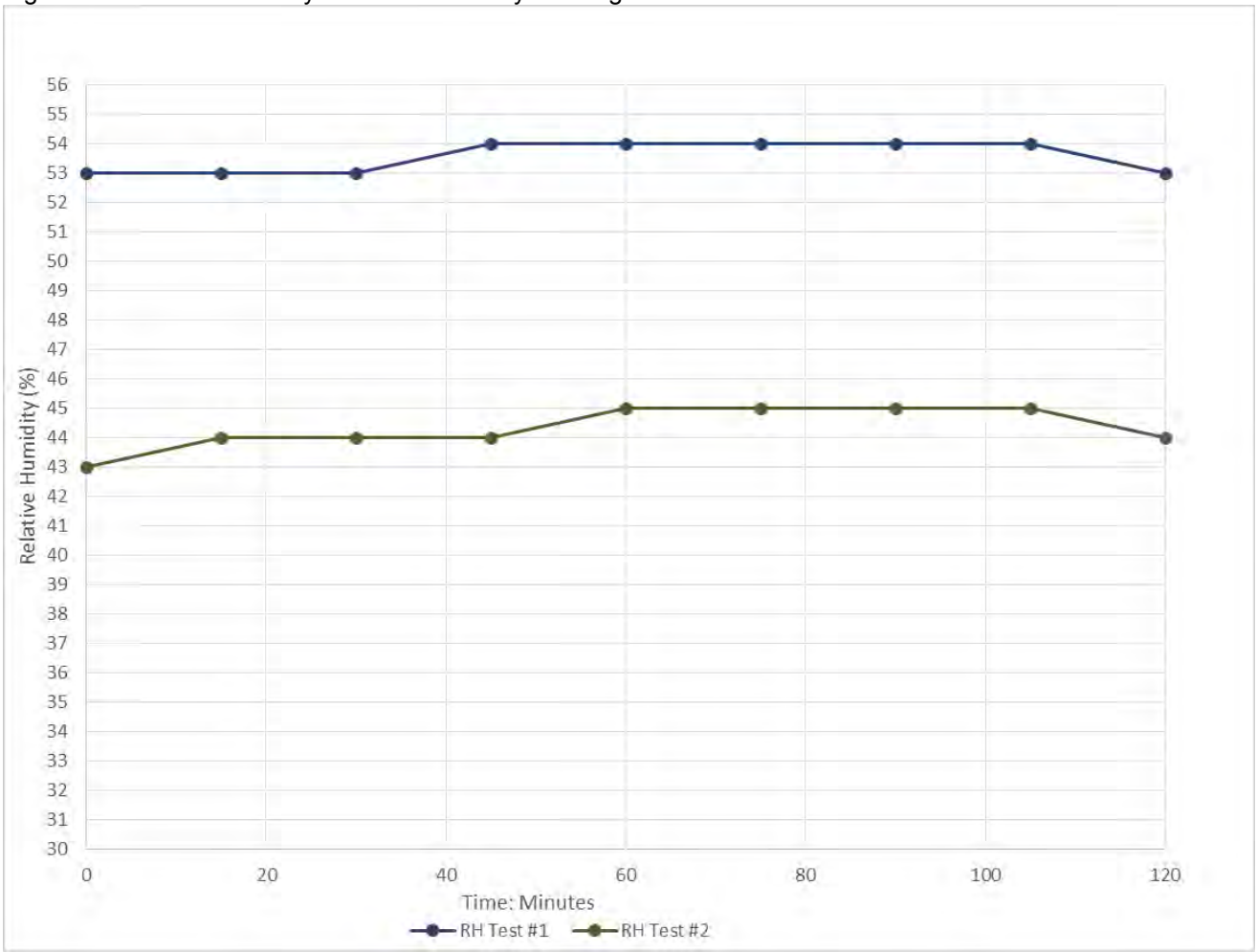


Figure 3 and 4 compares the average log_{10} PFU/m^3 recoveries for the two tests. The average of log_{10} PFU/m^3 recoveries of the transformed control of the three control tests are also shown. 'Transformed control' is the curve generated when the log_{10} PFU data for biological decay were transformed to be compared to the data for the efficacy experiment.

In test #1(Average RH of 53.5%) , the device demonstrate 2.75 Log_{10} reduction (99.82% reduction) after 33 minutes of introducing the first challenge and demonstrate 4.2 Log_{10} (99.994% reduction) reduction in 10 minutes after introducing of the second challenge. In the second test (RH of 44%) the device demonstrate 2.6 Log_{10} reduction (99.75% reduction) after 33 minutes of introducing the first challenge and demonstrate 3 Log_{10} reduction (99.90% reduction) in 30 minutes after introducing of the second challenge.

Fig. 3. The average of three Stability-in-air tests and the first multi-challenge efficacy experiment on IONaer 7000 Ion Generator device against Phi6 phage with the average RH of 53.5 %

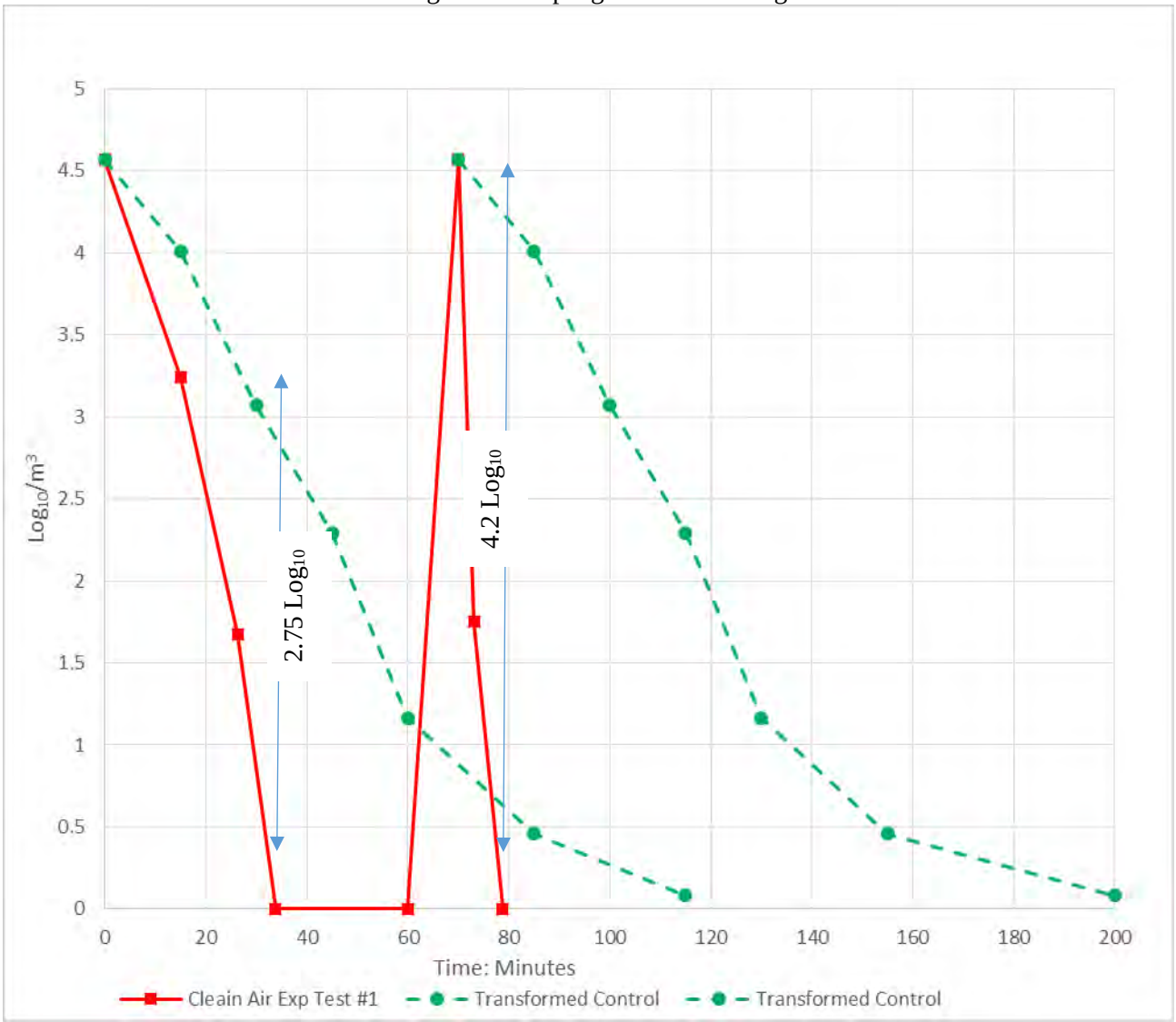
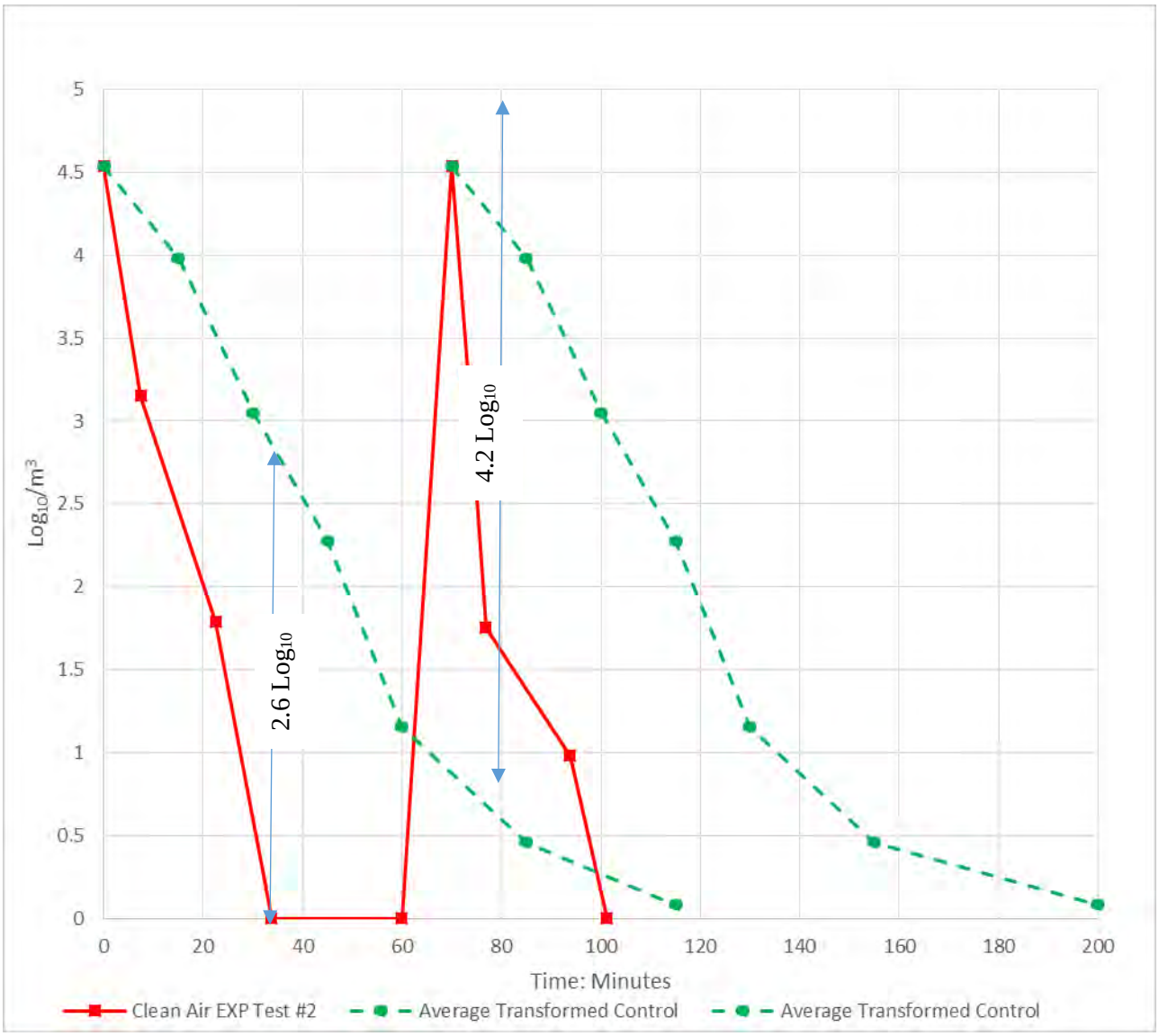


Fig. 3. The average of three Stability-in-air tests and the second multi-challenge efficacy experiment on IONaer 7000 Ion Generator device against Phi6 phage with the average RH of 44 %



Appendix A:

Table 4. Natural decay of bacteriophage *Phi6* without soil load, Reductions were calculated using the % recovery formula for the determination of the biological decay with log_{10} and % reductions at each time point for *Phi6*.

			Sampling Time Points (minutes)						
Sampling Time Points (minutes)			0	15	30	45	60	85	115
Sampling Period (minutes)			2	2	6	10	20	30	60
Total Colony in the room	PFU	**Control #1**	21431	6357	716	89	5	2	1
		Control #2	32067	8819	1727	327	53	2	1
		Control #3	14417	4622	438	114	7	4	1
Recovered on Plates	PFU	**Control #1**	1213	359	121	25	3	2	1
		Control #2	1815	498	292	92	30	2	1
		Control #3	816	261	74	32	4	3	1
log_{10} reduction**	log_{10}	**Control #1**	4.33	3.80	2.85	1.95	0.73	0.38	0.077
		Control #2	4.51	3.94 992	3.24	2.52	1.73	0.38	0.077
		Control #3	4.16	3.66	2.64	2.06	0.85	0.55	0.0771

Table 5. Efficacy of IONaer 7000 Ion Generator when used with a fogger in reducing microbial contamination of air. Reductions were calculated using the % recovery formula for the determination of the biological decay with $\log_{10}$ and % reductions at each time point for *Phi6*.

IONaer 7000 Ion Generator			Sampling Time Points (minutes)										
Sampling Time Points (minutes)			0	7.5	22.5	33.75	60	71	73.125	76.875	93.75	101.25	110
Sampling Period (minutes)			2	15	15	7.5	20	2	3.75	3.75	7.5	3.75	17.5
Total Colony in the room	PFU	**Test #1**	36961	1759	47	0	0	37308	56	0	0	0	36961
		Test #2	34399	1421	62	0	0	34722	2002	56	10	0	34399
Recovered on Plates	PFU	**Test #1**	2092	745	10	0	0	2092	11	0	0	0	2092
		Test #2	1947	602	26	0	0	1947	210	11	2	0	1947
$\log_{10}$ reduction**	$\log_{10}$	**Test #1**	4.57	3.25	1.68	0	0	4.57	1.75	0	0	0	0
		Test #2	4.54	3.15	1.79	0	0	4.54	3.30	1.75	0.98	0	4.53

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STUDY TITLE

Assessment of IONaer 7000 Ion Generator to reduce Pathogen Levels on Hard, Non-porous Environmental Surfaces: Testing with Human Respiratory Coronavirus 229E (ATCC VR-740)

TEST ORGANISM

Coronavirus 229E (ATCC VR-740):
Host:
L-132 cells

TEST PRODUCT IDENTITY

IONaer 7000 Ion Generator Carrier

TEST Method

Modified Quantitative Disk Carrier Test Method (ASTM 2197)

AUTHOR

Bahram Zargar, PhD

STUDY COMPLETION DATE

April/14/20

PERFORMING LABORATORY

CREM Co. Labs. Units 1-2, 3403 American Dr., Mississauga, Ontario, Canada L4V 1T4

SPONSOR

Clean Air EXP

STUDY NUMBER

CAE200306-02

STUDY PERSONNEL

STUDY DIRECTOR: Bahram. Zargar, PhD

PROFESSIONAL PERSONNEL INVOLVED: Sepideh Khoshnevis, MSc

STUDY REPORT

GENERAL STUDY INFORMATION

Study Title:	Assessment of IONaer 7000 Ion Generator to reduce Pathogen levels on Hard, Non-porous Environmental Surfaces: Testing with Human Respiratory Coronavirus 229 E(ATCC VR-740)
Study Number:	CAE200306-02
Sponsor	Clean Air EXP
Testing Facility	CREM Co Labs Units 1-2, 3403 American Drive, Mississauga, ON, Canada

TEST SUBSTANCE IDENTITY

Test Substance Name: IONaer 7000 Ion Generator

STUDY DATES

Date Device Received:
Study initiation date: March/03/06
Experimental Start Date: March/03/20
Experimental End Date: April/15/20
Study Completion Date: April/19/20

TEST SYSTEM

1. Test Microorganism

Coronavirus 229E (ATCC VR-740): Coronavirus 229E is an enveloped virus in the genus Coronavirus. Members of this genus can cause acute and potentially fatal respiratory infections such as SARS-1, SARS-2 (19-nCOV) and the Middle-East Respiratory Syndrome (MERS). Unlike coronavirus 229E, handling of SARS-1, SARS-2 and MERS requires Biosafety Level 3 facilities. Therefore, Coronavirus 229E is frequently used as a surrogate for them to assess the activity of different technologies for infection prevention and control (IPAC).

2. Host Cell Line

L-132 cells were used as hosts to support the replication and quantitation of 229E.

The cells were seeded into 12-well multi-well cell culture plates containing modified Eagle's medium (MEM) supplemented with 10% fetal bovine serum (FBS) and maintained at 36±1°C in a humidified atmosphere of 5% CO_2. Efficacy test was performed when the cell monolayer reached >90% confluency.

Preparation of Test Inocula
To prepare the virus for inoculation, the virus stock was mixed directly with the soil load (5% FBS). Dilution of the mixture was prepared using normal Saline.

The aerobiology chamber

The details of our aerobiology chamber have been published before (Sattar et al., 2016). Briefly, the chamber (26 m^3) was built to comply with the guidelines from the U.S. Environmental Agency (U.S. EPA 2012). A glove-box on one side of the chamber permitted the handling of the required items without breaching the containment barrier. A muffin fan (Nidec Alpha V, TA300, Model AF31022-20; 80 mm X 80 mm, with an output of 0.17 cubic meters/minute) inside the chamber enabled the uniform mixing of the air inside it. Between uses, fresh air was used to flush out the chamber of any residual airborne microbes.

Environmental monitoring: The air temperature (22±2°C) and RH (50±5%) inside the chamber were measured and recorded using a remote-sensing device (RTR-500 Datalogger).

TEST METHOD

1. **Preparation of Test Substance**
   1-cm diameter disks of brushed stainless steel 304 (AISI SS304) were used as the carriers in this test.

2. **Test Procedure**

A quantitative test system to closely simulate the field-application of the environmental surface decontamination process (modified quantitative carrier test – Tier 2 or QCT-2 (ASTM 2197)) was applied. The protocol was adapted to assess IONaer 7000 Ion Generator for surface decontamination.

Each disk received 10 uL of virus inoculum with a soil load (5% FBS). The disks were left inside an operating biosafety cabinet (BSC) for one hour to dry. The control disks for 30 min contact time were placed in a separate Petri dish and the Petri dishes were sealed with M3 tape. The Petri dishes containing test carriers and control carrier were placed on the floor of a sealed aerobiology chamber (26 m^3) in front of the access gloves. The IONaer 7000 Ion Generator was already installed in the chamber close to the access gloves. The fan of aerobiology chamber was turned on 30 minutes before testing and humidity was set to 50±5%. The exposure time was calculated from the moment that the test machine was turned on. Two test carriers and two control carriers were then removed from aerobiology chamber using the transport chamber (without breaking the sealing) and eluted at the contact time (30 min). The eluates were assayed for viable virus.

OBJECTIVE

To assess the ability of the IONaer 7000 Ion Generator to inactivate coronavirus 229E (ATCC VR-740) on the hard, non-porous surfaces.

Test Device:	IONaer 7000 Ion Generator
Room Temperature	Ambient temperature (22±2ºC)
Relative Humidity (RH):	50±5%

DATA ANALYSIS

Calculation of Log_{10} Reduction

Log_{10} Reduction = Log_{10} of average PFU from control carriers – log_{10} of average PFU the test carriers.

STUDY ACCEPTANCE CRITERIA

No product acceptance criterion was specified for this range-finding study.

TEST RESULTS

The initial challenge on each carrier was 5.18 log_{10} PFU. Table 1 show the result of log_{10} reduction for 30 min contact times. In this test, one hour drying time was considered. There is no significant difference between the log reductions in the exposure times (30 min). The device demonstrate 0.83 Log_{10} reduction (85.2% reduction).

Table 1: Virucidal Efficacy of polymer coating technology against Human Respiratory Coronavirus 229E (ATCC VR-740) at 30 min contact time

Log_{10} Reductions in PFU	**Percent Reduction**
0.83	85.2

APPENDIX

Result of efficacy test on polymer coating technology at 30 min contact time against *Human Respiratory Coronavirus 229E (ATCC VR-740)*.

Contact Time	30 minutes					
Dilution	C1	C2	C3	T1	T2	T3
10^{-0}	TNTC	TNTC	TNTC	40,39,38	25,25,19	34,30,37
10^{-1}	10,17,13	14,11,11	14,19,19	4,3,3	2,2,1	4,3,4
10^{-2}	1,1,1	1,1,1	1,1,1	0,0,0	0,0,0	0,0,0
10^{-3}	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0	0,0,0

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Major Article

Mathematical modeling and simulation of bacterial distribution in an aerobiology chamber using computational fluid dynamics

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Key Words:
Airborne spread of infectious agents
Distribution of particles in indoor air
Sampling air for infectious agents
Predictive modeling of bacterial distribution in an aerobiology chamber

Background: Computer-aided design and draft, along with computer-aided engineering software, are used widely in different fields to create, modify, analyze, and optimize designs.
Methods: We used computer-aided design and draft software to create a 3-dimensional model of an aerobiology chamber built in accordance with the specifications of the 2012 guideline from the Environmental Protection Agency for studies on survival and inactivation of microbial pathogens in indoor air. The model was used to optimize the chamber's airflow design and the distribution of aerosolized bacteria inside it.
Results: The findings led to the identification of an appropriate fan and its location inside the chamber for uniform distribution of microbes introduced into the air, suitability of air sample collection from the center of the chamber alone as representative of its bacterial content, and determination of the influence of room furnishings on airflow patterns inside the chamber.
Conclusions: The incorporation of this modeling study's findings could further improve the design of the chamber and the predictive value of the experimental data using it. Further, it could make data generation faster and more economical by eliminating the need for collecting air samples from multiple sites in the chamber.

INTRODUCTION

Prediction of particle transport in turbulent flow is essential in different fields, such as dispersion of passive or reactive particles in turbulent media and in studying air pollution.[1] For example, we are exposed to airborne particulates in workplaces, homes, and other indoor settings.[2] The fate and deposition of such particulates indoors have substantial implications for human and animal health, clean rooms, and air decontamination.[3-5] Therefore, a good understanding of the particle-laden turbulent flow is important in addressing indoor air quality issues and in controlling particle dispersion.

Mitigating the spread of microbial contaminants by indoor air is an essential design consideration for homes, biomedical and health care facilities, and other public settings. Once airborne, the movement of microbes is difficult to control because they may become rapidly dispersed by air movement or adhere to other surfaces for travel with them.[6,7] Ventilation, either natural or mechanical, can provide adequate air exchanges to reduce the risk for airborne microbial spread; however, mechanical ventilation, particularly with conditioning, can be expensive.[8] According to the *Guidelines for Design and Construction of Hospital and Health Care Facilities*,[9] 6-15 air changes per hour are needed to maintain a healthful environment while reducing exposure to harmful chemicals and microbes. This

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requires ventilation system engineers to understand microbial behavior in air to design more efficient and economical means of treating and supplying indoor air.[10]

In general, particles with a mass median aerodynamic diameter of 10 μm or less can remain airborne.[11] Memarzadeh and Xu[12] emphasized the importance of particle size in the airborne transmission of infections by transport of pathogen-laden particles to the mucosal surface of a susceptible host.[12]

Available information shows that ventilation systems can influence the spread of airborne pathogens indoors,[13,14] airflow patterns may contribute directly to such spread,[15] and airflow rates can influence the transport and removal of human expiratory droplets.[5,16-18] Assessing the risk of transmission of infections via air is more difficult than predicting reductions in concentrations of harmful gases with ventilation. Also, and unlike inhaled gases, it may take only a few infectious units of a given pathogen to infect a susceptible host, which, in turn, can amplify the level of the pathogen many-fold for further dissemination.

Increasing the air exchange rate alone is often inadequate for reducing the risk of spread of airborne infections everywhere within a given room. For optimal safety, the entire ventilation system should be analyzed to determine the likely path of pathogen-laden particulates within the occupied zones and the required corrective action.[19]

The 2 major approaches to study of the dispersion of particles in indoor air are physical modeling and numerical simulation with computational fluid dynamics (CFD). Empirical data are useful for CFD validation of air and movement of particulates in indoor environments and health care facilities. CFD modeling is also much more economical to perform than full-scale experimentation with actual pathogens or their surrogates.[20] Thus, with the ready availability and greater sophistication of CFD, it is increasingly being applied to predict room air movement in various types of health care settings.[21] However, this approach has not been adequately applied to other types of indoor settings and validated with experimental data[22]; when applied to predict airflow patterns in buildings, it was a flexible alternative to physical models.[22-24]

This study applies CFD to optimize and validate the performance of an aerobiology chamber that was designed based on Environmental Protection Agency guidelines.[25] The best location, angle, and speed of a muffin fan for producing uniform bacterial distribution were determined. The number of air sampling sites required for characterizing the distribution of the nebulized bacteria in the chamber was investigated. The stabilization time required to produce a uniform distribution of the bacteria was determined, and the effect of furniture on bacterial distribution also was studied.

METHODS

The dimensions of the studied aerobiology chamber were 320 cm × 360 cm × 210 cm.[26] The chamber was designed based on Environmental Protection Agency guidelines[25] and then used to study bacteria survival in air (Fig 1).[26] A 6-jet nebulizer was used to aerosolize bacterial suspensions into the chamber through a pipe with a 3.8-cm diameter. The air was sampled from the center of the chamber using a slit-to-agar machine via a 5.0-cm pipe. A muffin fan (Nidec Alpha V, TA300, Model A31022-20, P/N: 933314 3.0-inch/7.62-cm diameter; output 30 CFM; Nidec Corp., Braintree, MA) placed on the floor of the chamber directly beneath the nebulizer inlet pipe was actuated from the outside for continuous operation during nebulization and testing to ensure uniform distribution of the aerosolized particles and/or any treatment introduced. The procedure of the experiment was as follows:

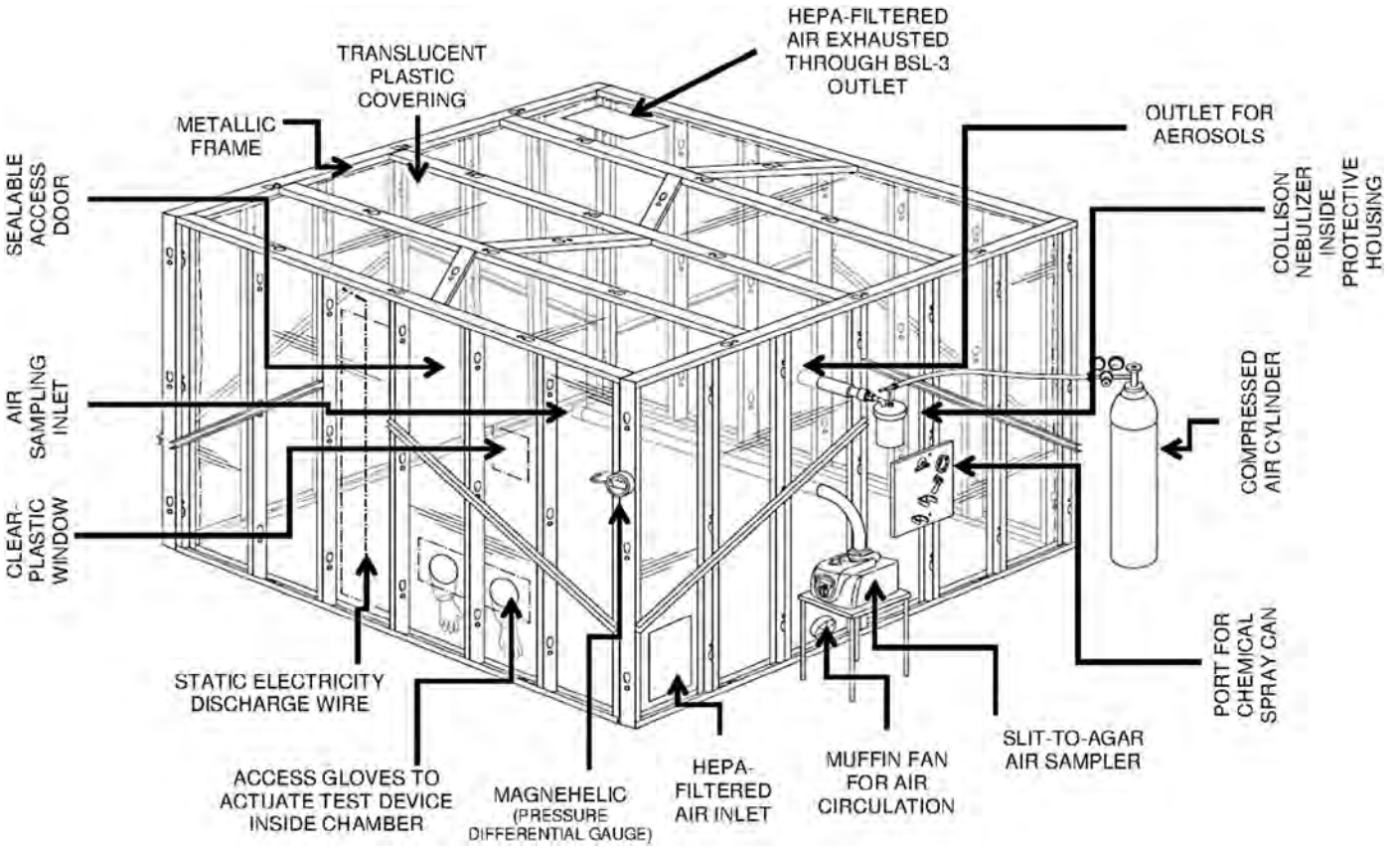


Fig 1. Aerobiology chamber designed based on Environmental Protection Agency guidelines.[25] Reprinted with permission.

- The fan was activated at least 300 seconds before the experiment to circulate the air inside the chamber;
- The test bacterial suspension was nebulized into the chamber for 10 minutes using a 6-jet collison nebulizer; and
- Before sampling, the air in the chamber was allowed to circulate for 300 seconds following the nebulization process.

MATHEMATICAL MODELING, MATERIALS, AND NUMERIC METHODOLOGIES

Theoretical background

The Eulerian-Lagrangian approach was implemented directly using the discrete phase model. In this approach, the fluid phase is treated as a continuum material by solving the time-averaged Navier-Stokes equations, and the dispersed phase is solved by tracking a large number of particles through the calculated flow field.[27] The governing equations are itemized in the following sections.

Governing equations for the continuous phase

The continuous gas-flow phase is governed by the following equations for unsteady compressible flow:[4]

- Continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0 \tag{1}$$

- Momentum equation:

$$\frac{D(\rho \vec{u})}{Dt} = -\vec{\nabla} p + \nabla \cdot \tau \tag{2}$$

- Energy equation:

$$\frac{\partial (\rho E)}{\partial x} + \nabla \cdot (\vec{u}(\rho E + p)) = \nabla \cdot (k_{eff} \nabla T + (\vec{\tau}_{eff} \cdot \vec{u})) \tag{3}$$

Where ρ, t, u, r, p, τ, E, T, k_{eff}, and τ_{eff} are fluid density, time, fluid phase velocity, thermodynamic pressure, stress tensor, energy, temperature, effective conductivity, and effective stress tensor, respectively.

One of the most common turbulence models, the k-ε Realizable turbulence model, was used for turbulence modeling. The turbulence kinetic energy, k, and its rate of dissipation, ε, are obtained from the following transport equations:[27,28]

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_j) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k \tag{4}$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_j}(\rho \varepsilon u_j) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + \rho C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k + \sqrt{\upsilon \varepsilon}} + C_{1\varepsilon}\frac{\varepsilon}{k} C_{3\varepsilon} G_b + S_\varepsilon \tag{5}$$

Where G_k and G_b represent the generation of k due to the mean velocity gradients and buoyancy, respectively; Y_M represents the contribution of the fluctuating dilation in compressible turbulence to the overall dissipation rate; σ_k and σ_ε are the turbulent Prandtl numbers for k and ε, respectively; and S_k and S_ε are user-defined source terms for k and ε, respectively.

The turbulent (or eddy) viscosity, μ_t, is computed by combining k and ε as follows:[27,28]

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \tag{6}$$

The model constants $C_{1\varepsilon}$, $C_{2\varepsilon}$, C_μ, σ_k, and σ_ε have the following values: $C_{1\varepsilon} = 1.44$, $C_{2\varepsilon} = 1.92$, $C_\mu = 0.09$, $\sigma_k = 1.0$, and $\sigma_\varepsilon = 1.3$.[27,28]

The rotating reference frame was applied only in the rotational region by assuming that the region was in a quasisteady state. This method does not explicitly generate model rotation; instead, it generates a constant grid flux in the appropriate conservation equations by automatically adding the source terms with respect to the Coriolis force and centrifugal force, which are calculated with equation 7 based on the properties of the reference frame.[27] Although this method underestimates the weak effect, it is appropriate for the flow, which is most likely to be influenced by time-averaged properties.[27] A significant amount of simulation time can be saved with this method, when compared with simulating the axial flow fan's rotation in a transient state.[27]

$$F_r = \rho \omega \times v \tag{7}$$

Where F_r is the body force term due to fan rotation (kg/m^2/s^2), ρ is the air density (kg/m^3), ω is the rotational speed (rad/s), and v is the linear velocity (m/s).

Governing equations for the discrete phase

The trajectory of the discrete phase is determined by integrating the force balance on the particle, which equates the particle inertia with forces acting on the particle, and can be written as:[27]

$$\frac{du_p}{dt} = F_D(u - u_p) + \frac{g_x(\rho_p - \rho)}{\rho_p} + F_x \tag{8}$$

Where u, u_p, g_x, ρ_p, ρ, and F_x are the fluid phase velocity, particle velocity, gravitational acceleration, particle density, fluid density, and an additional acceleration (force per unit particle mass), respectively. The drag force per unit particle mass (F_D) is equal to:

$$F_D = \frac{18\mu}{\rho_P d_p^2}\frac{C_D Re}{24} \tag{9}$$

$$Re \equiv \frac{\rho d_p |u_p - u|}{\mu} \tag{10}$$

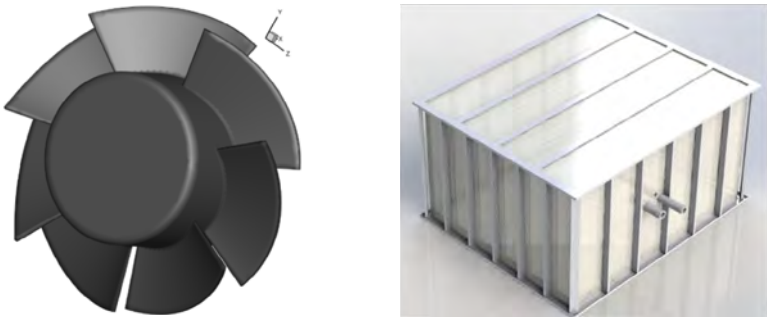
Where μ, d_p, C_D, and Re are the molecular viscosity of the fluid, particle diameter, drag coefficient, and Reynolds number, respectively. The location of each particle, x, is tracked with the following equation:

$$\frac{dx}{dt} = u_p \tag{11}$$

The air velocity, u, in equation 8 is composed of the time-averaged component, $\bar{u}$, and the instantaneous or fluctuating velocity component, $u'(t)$:[4,27]

$$u = \bar{u} + u'(t) \tag{12}$$

The u component is computed using the Reynolds-averaged Navier-Stokes equations with the k-ε Realizable turbulence model. The u′(t) component is computed using a stochastic approach, such as the discrete random walk model or eddy lifetime model.[4] Its value prevails during the lifetime of the turbulent eddy influencing the particle and is assumed to obey the Gaussian probability distribution.[4] Using the discrete random walk model to calculate u′(t), the particle turbulent dispersion is correlated to the flow k:[4,27]



(a) Axial flow fan model (b) Computational domain (aerobiology chamber) model

Fig 2. Three-dimensional model of the axial flow fan and computational domain.

$$u'(t) = \zeta\sqrt{\frac{2k}{3}} \quad (13)$$

Where the variable ζ is a Gaussian random number.

CFD procedure

Generally, flow simulations in CFD take place in 3 main stages. The first step is preprocessing, which includes geometric modeling, production of computational domain, and grid generation. The second is the processing step or flow solution with CFD. In the final step, called postprocessing, the results are displayed.

Geometric modeling

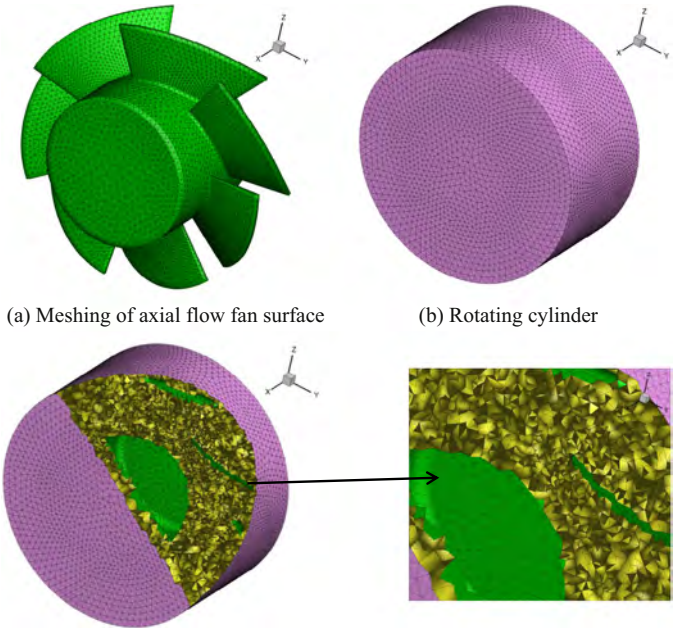
The geometry of the aerobiology chamber consists of several components, such as axial flow fan, fan housing, air sampler inlet pipe, outlet pipe for aerosol sampling, and aerobiology chamber walls. Each of these geometries is modeled separately, and eventually, with superposition of the modeled geometries, the final complex geometry is generated. The computer-aided design and draft model of the flow region is built based on the computer-aided design and draft model of the aerobiology chamber.

The muffin fan, which is an axial flow fan, presents the most complex geometry in the system. The axial flow fan is a tube-axial device with 7 forward-swept blades. The dimension of the fan housing is 80 mm × 80 mm × 40 mm. The tip diameter of fan blades, hub-to-tip ratio, and tip clearance are 76 mm, 0.566 mm, and 1 mm, respectively. Figure 2a presents a 3-dimensional model of the fan.

The whole computational model is shown in Figure 2b. To achieve a reasonable numeric accuracy, it is divided into its different parts. The computational domain is composed of the axial flow fan, fan housing, air sampler inlet pipe, outlet pipe for aerosols, and aerobiology chamber, as shown in Figure 2b.

Grid generation

The physical model of the aerobiology chamber comprises several components with very different geometries. Because of the complicated geometry, unstructured tetrahedral grids were adopted for the whole computational domain. Grids of different sizes were generated for different components and then connected to form the whole geometry. The computational meshes of the aerobiology chamber were divided into 2 zones: rotating zone and stationary zone. Special attention was paid to the geometry and meshing of the fan, with the greatest emphasis on the blades and root of the blades. The rotating zone was a cylindric mesh with 531,218 cells, as shown in Figure 3. Meshes of the surfaces of the axial flow fan



(a) Meshing of axial flow fan surface (b) Rotating cylinder

(c) Cut view of the volume meshing in rotating cylinder

Fig 3. Grid generation in rotating volume.

are also shown in Figure 3. The stationary zone contained 1,125,612 cells.

Several versions of the computational mesh were generated to test the grid independence. Results of this study of the grid are shown in Figure 4. The volume flow rates for cases 3-6 were almost the same. Because case 3 had the lowest computational costs, it was considered the optimum grid number. For a mesh with 1.04 million cells, the maximum cell skewness was 162, and with mesh size of 1.65 million cells, the maximum cell skewness decreased to 154. Thus, the mesh density had an effect on the results for the control simulation case.

Solver

Steady and unsteady simulations

Considering the rotating speed of the axial fan, the airflow was assumed incompressible.[27] The 3-dimensional incompressible Navier-Stokes equations and the k–ε Realizable model were used to model the effects of turbulence on the flow field. The enhanced wall function was used for boundary layer calculation. The second-order upwind differencing format for the convection terms of each

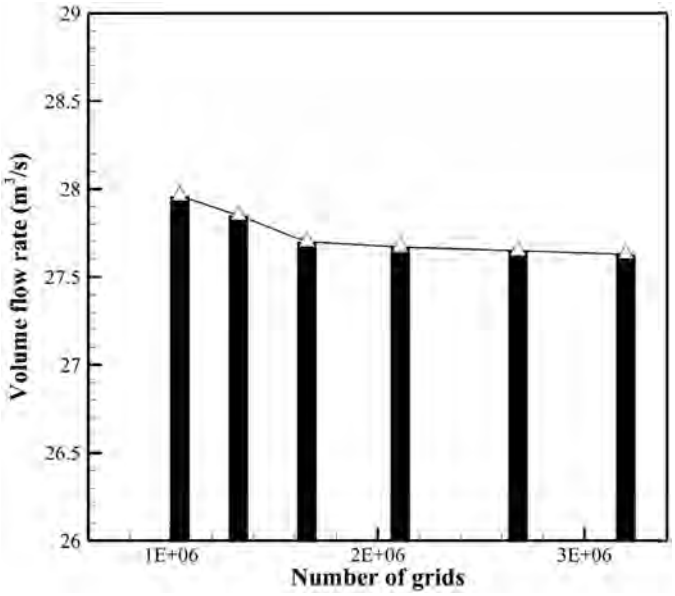


Fig 4. Mesh independency of aerobiology chamber with fan working at 2,500 rpm.

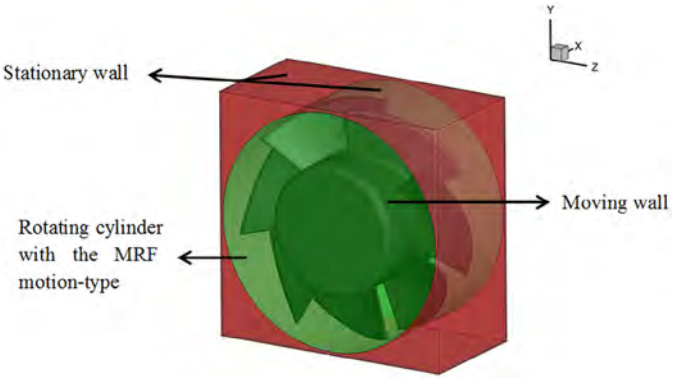


Fig 5. Boundary conditions of fan and its housing. *MRF*, multiple rotating reference frames.

governing equation was adopted, and the second-order accuracy was maintained for the viscous terms. The pressure-velocity coupling was handled by the SIMPLE algorithm for steady solutions and SIMPLEC for unsteady solutions. Because of the large number of computational cells and the possible presence of dynamic effects due to fan rotation, the convergence was satisfied with the criterion of 1×10^{-5} and, in some cases, with the criterion of 5×10^{-6}.

Boundary conditions

The inlet and outlet faces of the fan were set to the interior. No-slip condition was applied on the solid walls. In this simulation, it was assumed that the walls had zero velocity relative to the adjacent fluid. The flowing domain was divided into 2 parts: rotating body and flowing channel. A rotating reference frame was applied to the rotating region around the propeller fan. Different angular velocities were assigned to the rotary zone in the multiple rotating reference frames. A fixed reference frame was applied to the static regions. The conformal interfaces were used for rotor–stator interfaces to accelerate computation speed and improve accuracy. Figure 5 illustrates the boundary conditions of the fan and its housing. Also, the walls of the aerobiology chamber were regarded as stationary.

Turbulence models

Reynolds number was defined based on the fan radius and rotational speed as:[27]

$$\mathrm{Re} = \frac{R^2\omega}{\nu} \tag{14}$$

Where R, ω, and ν are fan radius, rotational speed, and kinematic viscosity, respectively. The Reynolds number of the airflow at a rotational speed of 2,500 rpm was 60,136, which represented a turbulent flow. That is, the existence of the fan as a rotating machine caused a turbulent flow in the chamber. In such a flow, the terms representing turbulence stress should be modeled and added to Navier-Stokes equations. A turbulence model of k–ε Realizable was used to analyze the flow disturbance in the aerobiology chamber. When the fan is operating, its induced momentum is crucial to the airflow and turbulence predictions. Therefore, a low Reynolds number variation of the k–ε Realizable model was used. Flow was solved in 3 rotational fan speeds to select the best velocity for producing uniform flow. The turbulence effects on the particles were accounted for using the discrete random walk model.[27] In addition, it was assumed in the simulations that the particles would rebound to the air after collision with any solid surface.

Postprocessing of the simulation results

The particle trajectories were tracked at different times after particle injection. The nature of the Eulerian-Lagrangian simulation provided for tracking every particle parcel in the flow field at any time.[4] Each parcel that contained a large number of particles was mathematically symbolized as a point in the Eulerian-Lagrangian simulation and represented as a dot in the postprocessed results.[4]

Five different planes passing through the center of the chamber were considered in calculating the area-weighted average velocity magnitude (Fig 6). In a state of uniform flow, the average velocity magnitude in different planes should not be significantly different.

To evaluate bacteria distribution inside the chamber, 5 different control volumes were considered. Each volume was a cube with the dimensions 1 m × 1 m × 1 m (Fig 7). The mass concentrations of particles and the number concentration of particles were calculated. In this study, the number of parcels within the control volume was counted manually. Then, based on the number of parcels, the particle concentrations (number and mass) were determined.

Simulation cases

Twelve configurations of fan position, angle, and velocity were considered (Table 1). The fluid flow was studied in each case with and without injection of aerosolized bacteria. The bacteria distribution and airflow were compared to find the case that could best produce uniformity. To study the effect of furniture on the airflow and bacteria distribution, basic bedroom furniture (ie, a bed, a chair, and a desk) was added to the chamber. The bacteria distribution was then compared with that in an empty room.

RESULTS AND DISCUSSION

Figure 8 compares the 3-dimensional pathlines of the aerobiology chamber for cases 3 and 12. Figures 8a, 8c, and 8d show a vortex, which is not desirable for uniform airflow, whereas Figure 8b is the only case showing no vortex. Such a comparison made between the 3-dimensional pathlines of all cases defined in Table 1 found state 1 (cases 1, 2, and 3) to be the only state with no vortices. This implied that there was uniform airflow when the fan was sitting at a 45° angle in the middle of 1 side of the chamber.

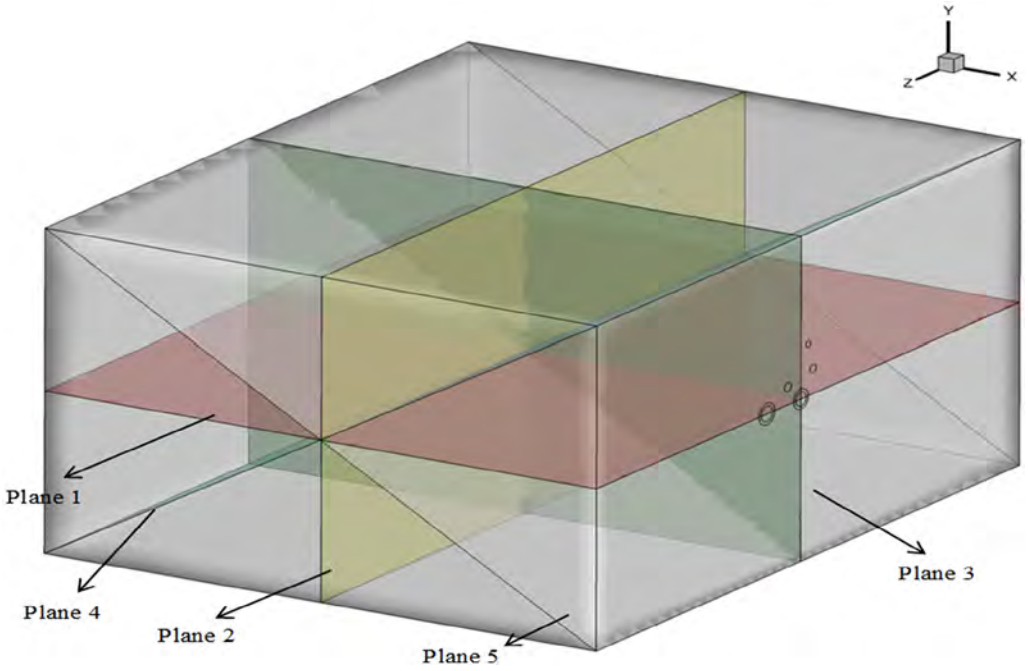


Fig 6. Locations of 5 different planes passing through the center of the aerobiology chamber.

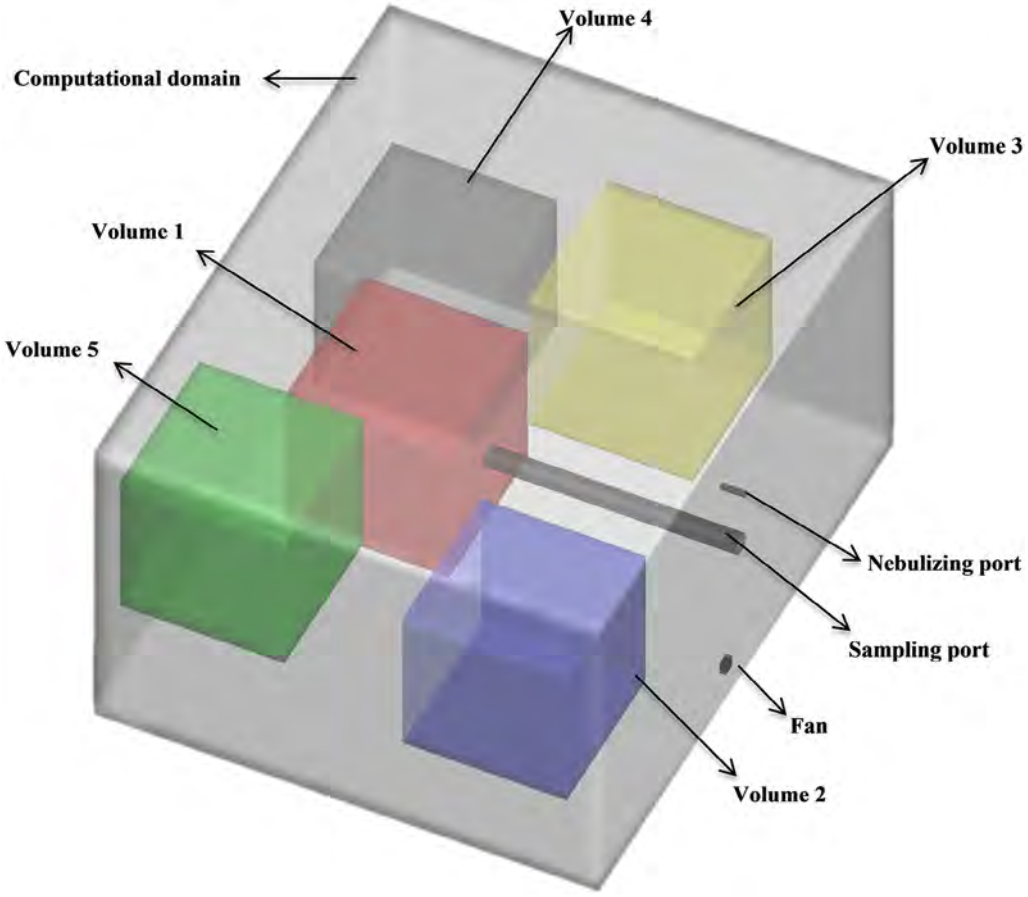
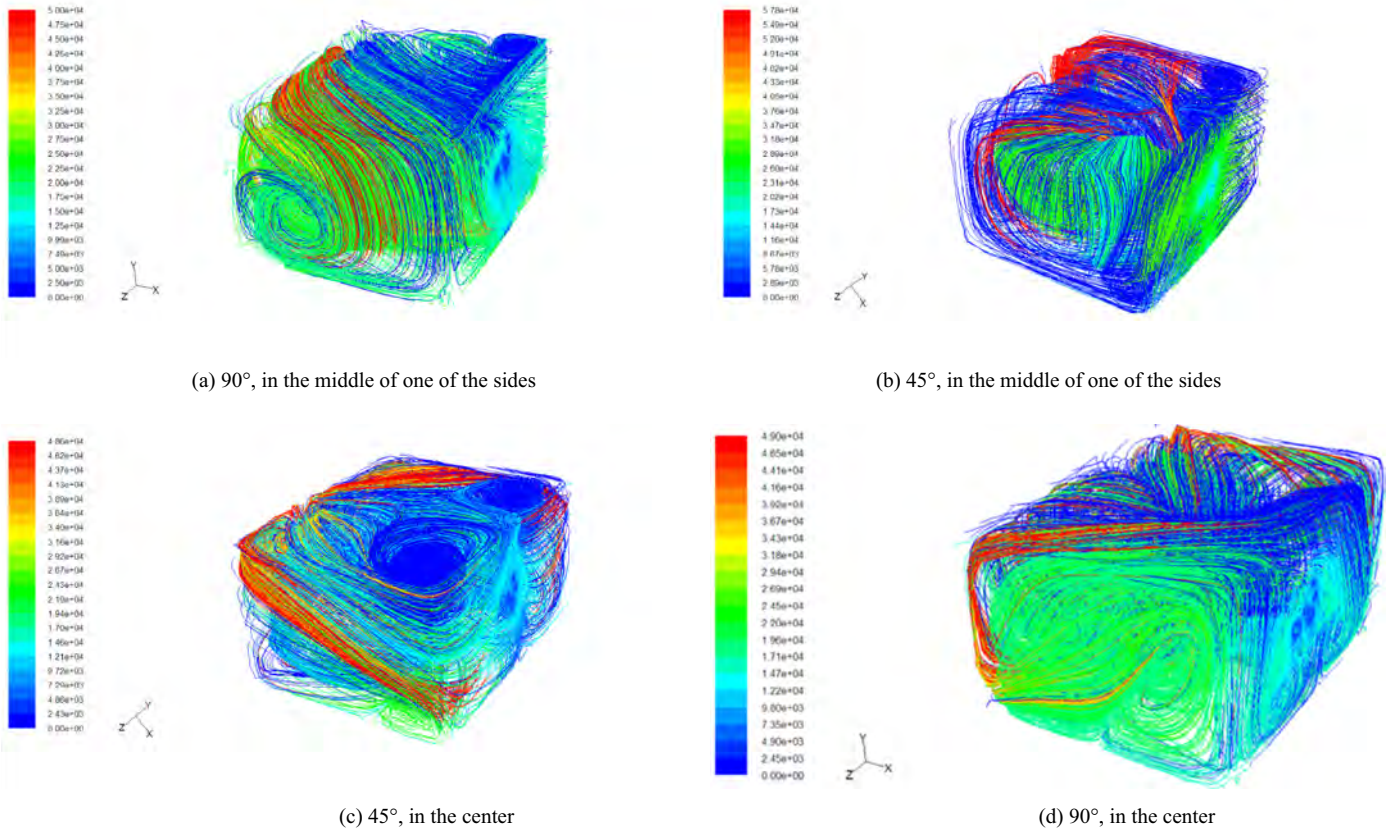


Fig 7. Computational domain and 5 volumes that were considered as samples.



(a) 90°, in the middle of one of the sides

(b) 45°, in the middle of one of the sides

(c) 45°, in the center

(d) 90°, in the center

Fig 8. The pathlines of the aerobiology chamber for the velocity of 2,800 rpm.

Table 1
Different combinations (cases) of position, angle, and speed of the muffin fan

State	Case	Rotational speed (rpm)	Angle	Position
1	1	2,300	45°	In the middle of 1 of the sides
	2	2,500		
	3	2,800		
2	4	2,300	45°	In the center of the chamber
	5	2,500		
	6	2,800		
3	7	2,300	90°	In the center of the chamber
	8	2,500		
	9	2,800		
4	10	2,300	90°	In the middle of 1 of the sides
	11	2,500		
	12	2,800		

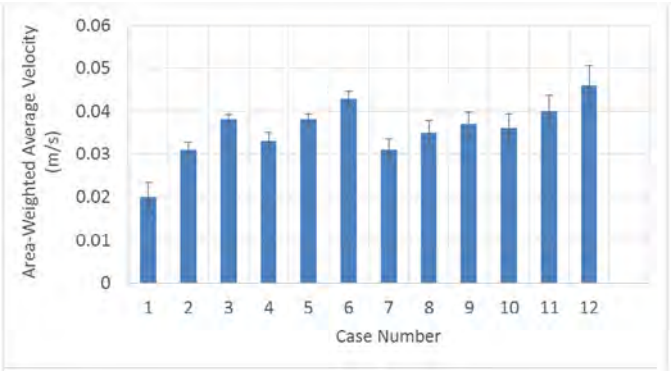


Fig 9. Average and standard variation of area-weighted average velocities on 5 different planes for 12 cases.

To have a better quantitative comparison between states, area-weighted average velocities were calculated on 5 different planes (Fig 9). The average and coefficient of variation (CV) of area-weighted velocities on 5 planes were calculated for each case and are reported in Table 2. Case 3 of state 1 had the smallest CV (6.5%), implying that the fan created the most uniform airflow when positioned in the middle of 1 side of the chamber at an angle of 45° and a speed of 2,800 rpm.

Bacteria were nebulized into the chamber through a port for 600 seconds at a rate of 5,000 CFU/min. For each of the 12 cases, the average of particle concentration in 5 volumes and its CV were calculated 600 seconds after completing the nebulization process (Table 3). Figure 10 shows the average particle concentration in the 5 volumes analyzed and the corresponding standard deviation. Case 3 had the lowest CV, implying that the bacterial distribution in this case was the most uniform. This is in line with our finding from analysis of the area-weighted average velocities. The small standard deviation and CV between the 5 volumes implies that, after 900 seconds, bacteria would be distributed uniformly inside the chamber,

Table 2
Area-weighted average velocity magnitude on 5 different planes for different cases

	State 1			State 2			State 3			State 4		
Case	1	2	3	4	5	6	7	8	9	10	11	12
Speed (rpm)	2,300	2,500	2,800	2,300	2,500	2,800	2,300	2,500	2,800	2,300	2,500	2,800
Plane 1	0.015	0.026	0.036	0.032	0.038	0.043	0.029	0.032	0.035	0.031	0.034	0.039
Plane 2	0.017	0.029	0.036	0.033	0.039	0.043	0.035	0.039	0.039	0.041	0.045	0.052
Plane 3	0.025	0.034	0.041	0.03	0.037	0.047	0.035	0.038	0.042	0.045	0.050	0.059
Plane 4	0.012	0.030	0.036	0.03	0.034	0.038	0.035	0.039	0.040	0.029	0.032	0.037
Plane 5	0.028	0.034	0.040	0.040	0.042	0.044	0.024	0.026	0.028	0.034	0.037	0.043
Mean	0.020	0.031	0.038	0.033	0.038	0.043	0.031	0.035	0.037	0.036	0.040	0.046
CV (%)	34.02	11.08	6.55	12.49	7.67	7.54	16.06	16.34	14.97	18.84	19.09	20.16

CV, coefficient of variation.

Table 3
Log_{10} colony forming units per meters^3 in 5 different volumes at 900 seconds for 12 cases

State	Case	Speed (rpm)	Volume 1	Volume 2	Volume 3	Volume 4	Volume 5	Average	CV (%)
1	1	2,300	4.685	4.565	4.636	4.562	4.679	4.626	0.64
	2	2,500	4.674	4.568	4.620	4.601	4.688	4.630	0.54
	3	2,800	4.662	4.597	4.630	4.631	4.700	4.644	0.42
2	4	2,300	4.678	4.592	4.661	4.541	4.685	4.631	0.67
	5	2,500	4.663	4.570	4.687	4.555	4.692	4.633	0.71
	6	2,800	4.639	4.566	4.725	4.590	4.709	4.646	0.76
3	7	2,300	4.722	4.551	4.664	4.522	4.676	4.627	0.93
	8	2,500	4.713	4.542	4.706	4.556	4.683	4.640	0.90
	9	2,800	4.692	4.497	4.718	4.575	4.697	4.636	1.03
4	10	2,300	4.747	4.564	4.668	4.544	4.692	4.643	0.93
	11	2,500	4.724	4.536	4.674	4.570	4.6988	4.640	0.89
	12	2,800	4.685	4.528	4.695	4.610	4.715	4.647	0.83

CV, coefficient of variation.

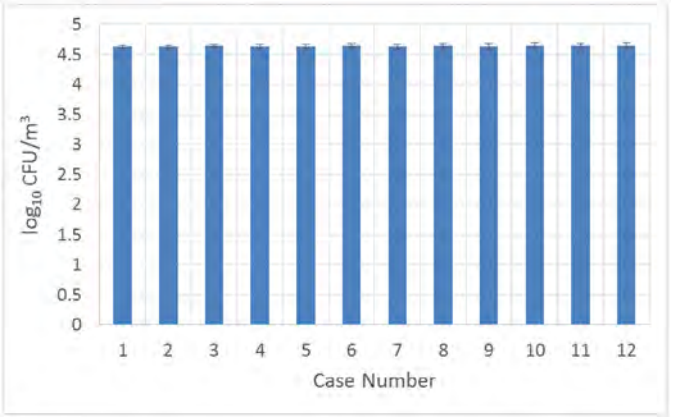


Fig 10. Average and standard variation of bacterial concentration in the 5 volumes analyzed after 900 seconds for 12 cases.

and there may not be any significant difference among the bacteria concentrations in the 5 different volumes analyzed.

The concentration of aerosolized bacteria in each volume was calculated over time for the optimum case (case 3). Table 4 summarizes the results. Figure 11 shows log_{10} colony forming units per meters^3 of samples over the 900 seconds of nebulization of the bacterial suspension into the chamber. The bacteria concentrations in the 5 volumes analyzed were different at the beginning of the process, but the curve of the 5 volumes converged after finishing the nebulization at 600 seconds and reached steady state at 900 seconds. This implies that 300 seconds (5 minutes) of stabilization time after completion of the nebulizing process will result in a uniform distribution of bacteria inside the chamber. That is, the bacteria are uniformly distributed, their concentration has reached a plateau, and the air sampling process can start.

Table 4
Bacteria concentration (CFU/m^3) in 5 volumes

Time (s)	Volume 1	Volume 2	Volume 3	Volume 4	Volume 5
100	1,925	6,865	6,055	2,160	3,195
200	4,315	11,795	10,310	4,965	7,275
300	12,270	21,850	17,405	10,160	16,380
400	21,575	26,960	19,855	17,725	26,120
500	29,475	31,570	33,435	28,430	35,605
600	36,710	40,685	39,695	35,110	41,815
700	48,330	42,740	41,115	38,585	49,575
800	41,860	40,105	43,320	41,010	48,660
900	45,955	39,530	42,655	42,745	50,115

Analysis of variance was performed to determine whether the bacteria concentrations in the 5 volumes analyzed over the time were significantly different. The results showed that the bacteria concentrations were the same at a 99% confidence level ($F_{4,40} = 0.29$; $P = .88$), implying that each of these 5 volumes could be used as a sampling site to calculate the airborne bacteria concentration inside the chamber.

To study the influence of the furniture on bacteria distribution in the chamber, the fan was positioned at the optimum location at a 45° angle at 2,800 rpm (state 1, case 3). Figure 12 shows the schematics of the room with the furniture.

As with the room without furniture, 600 seconds nebulizing time and 300 seconds stabilizing time were considered, and the bacteria concentrations in the 5 volumes were analyzed. The results are summarized in Table 5.

Figure 13 shows log_{10} colony forming units per meters^3 for 900 seconds after initiating bacterial nebulization into the chamber. The concentrations were different at the beginning of the nebulization process but converged during the stabilization time and reached a plateau at the end of the stabilization time.

The bacteria concentrations in the 5 volumes during the nebulization and stabilization processes in the chamber with furniture

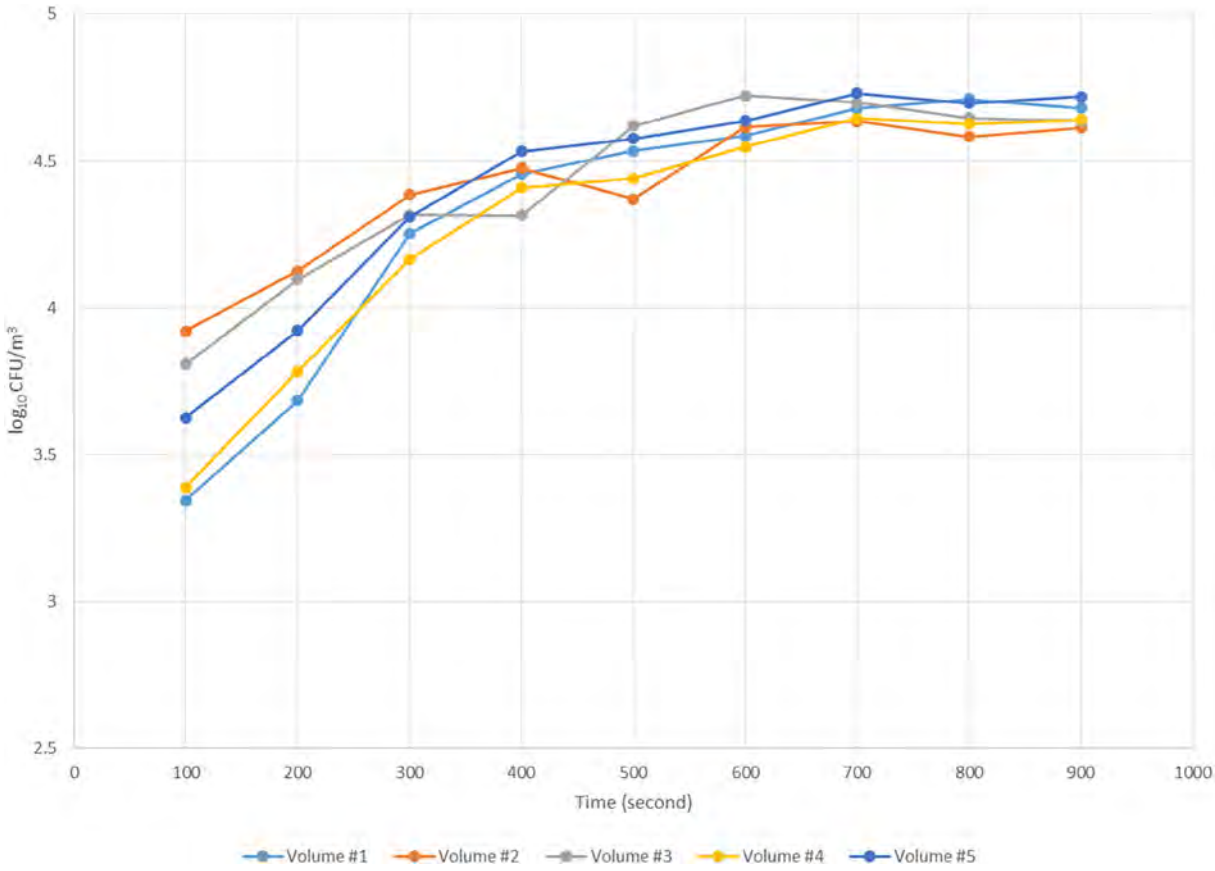


Fig 11. Log_{10} colony forming units per meters^3 in 5 volumes during nebulization and stabilization process. *CFU*, colony-forming units.

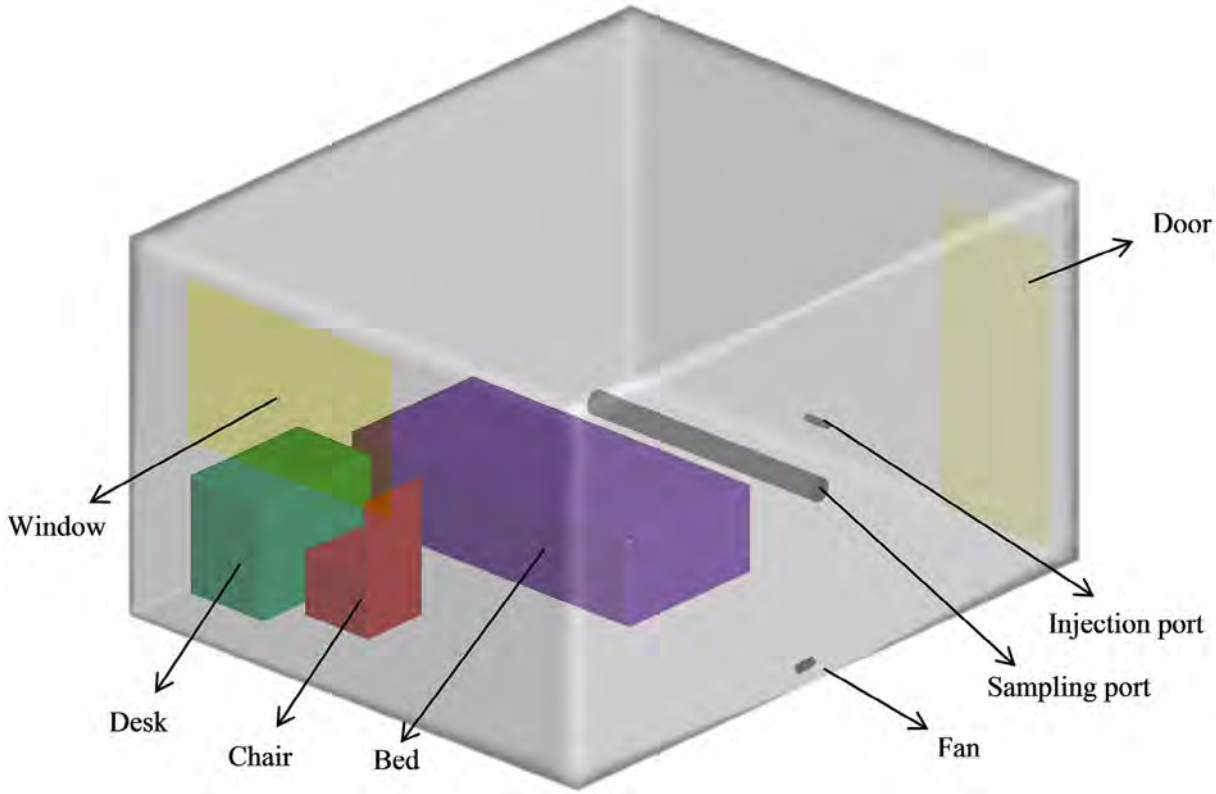


Fig 12. Aerobiology chamber with furniture.

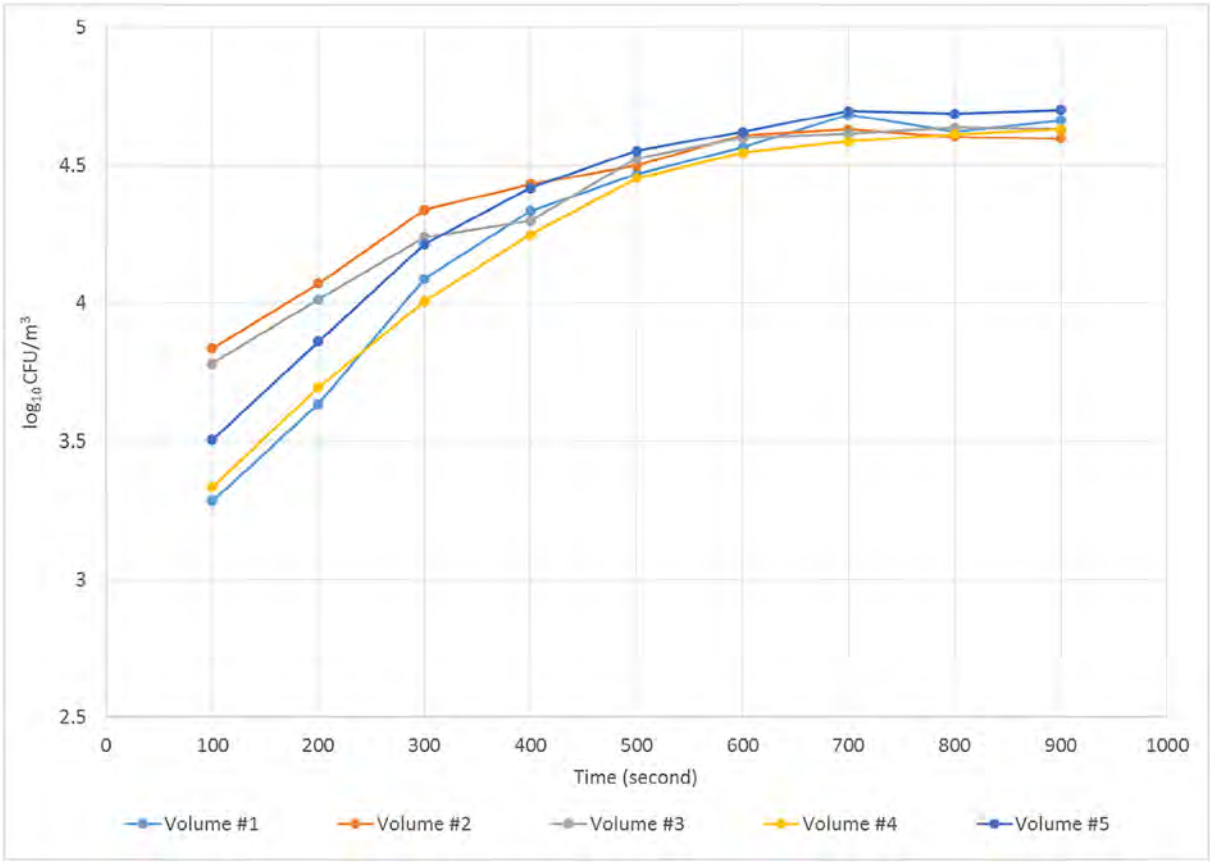


Fig 13. Bacterial concentration in the 5 different volumes analyzed during nebulization and stabilizing times in a chamber with furniture.

Table 5
Bacterial concentration (CFU/m^3) in the 5 different volumes analyzed with room furniture

Time (s)	Volume 1	Volume 2	Volume 3	Volume 4	Volume 5
100	2,215	8,340	6,455	2,445	4,235
200	4,850	13,355	12,530	6,070	8,390
300	17,945	24,250	20,705	14,650	20,445
400	28,550	29,960	20,645	25,685	34,080
500	34,210	23,470	41,645	27,590	37,745
600	38,480	41,280	52,695	35,280	43,415
700	47,730	43,240	49,915	44,230	53,715
800	51,460	38,300	44,310	42,280	49,810
900	47,980	41,005	43,210	43,695	52,430

were compared using analysis of variance. The bacteria concentrations in the 5 volumes were the same at the 99% confidence level ($F_{4,40} = 0.23$; $P = .99$). This implies that, in the presence of the furniture, a single sampling site is sufficient to represent the bacteria distribution inside the chamber.

CONCLUSIONS

Environmental Protection Agency guidelines simply recommend the use of a sealed and empty 800-ft^3 chamber for testing indoor air decontamination technologies, without further specifications on design or operation. However, we considered additional details, such as the time needed for producing a uniform distribution of test bacteria in the chamber with and without basic furniture and the position and number of sites for sampling air from within the chamber. This modeling study, based on CFD, was undertaken to address those issues. Our main conclusions are as follows:

- A muffin fan placed at a 45° angle at the bottom of 1 side of a chamber and operating at 2,800 rpm can provide sufficient air turbulence for uniform bacteria distribution throughout, even in the presence of basic room furniture.
- A 5-minute postnebulization time is sufficient to distribute introduced bacteria aerosols uniformly throughout a chamber.
- Simulating the collection of airborne bacteria from 5 different locations in the chamber indicated that a single site at the center of the chamber was sufficient to provide a representative profile of the concentration of the airborne bacteria.

This information should contribute to further standardization of the design and operation of aerobiology chambers for data generation on the airborne survival of human pathogens, as well as technologies for decontamination of indoor air.

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Surface Time-Kill Study to Evaluate the Antimicrobial Efficacy of the IONaer 7000 Ion Generator against Three Microorganisms

Study Sponsor

IONaer International

Study Personnel

Luisa Ikner, Ph.D.

Charles Gerba, Ph.D.

Report Delivery Date

25 June 2017

THE UNIVERSITY OF ARIZONA®
WEST CENTER
WATER & ENERGY SUSTAINABLE TECHNOLOGY

Study Objective

To evaluate the antimicrobial properties of the IONaer 7000 Ion Generator following 1-hour (for *E. Coli* and *A. baummanii*) or 24-hour (for *S. aureus* and non-enveloped viral surrogate) exposure time against four test organisms inoculated and dried onto hard, nonporous surfaces.

Study Methods

1. Glass slide carriers (1"x 3") were washed in mild soap, double-rinsed in tap water and DI-water, and then autoclaved prior to testing.
2. For *E. coli* and *S. aureus*, bacterial cultures were initiated 22 ± 2 hours prior to testing by inoculating 10 ml of tryptic soy broth (TSB) with one colony of the respective bacteria. On the day of testing, bacterial cells were pelleted by centrifugation (4,000 x g for 10 minutes), and washed twice using 0.01M PBS with successive rounds of centrifugation. For MS2, a pre-titered stock culture (5 x 1011 PFU/ml) was used for the testing.
3. On the day of testing, carrier inoculum cultures were prepared by diluting each of the bacterial cultures and viral stock to achieve target inocula of 7.5 x 105 organisms per 0.020 ml. The carrier inoculum cultures were then amended using fetal bovine serum to achieve a soil load of 2.5%.
4. Clean, dried glass slide carriers were mounted in sterile Petri dishes, and inoculated with 0.02 ml of the test cultures in replicates of two (2) according to the following:
    - Two (2) Time Zero Control Carriers (to be harvested for enumeration immediately upon drying)
    - Two (2) Timed Control Carriers (to be held separately from the exposed test carriers under laminar flow conditions for the study exposure time)
    - Two (2) Test Carriers (to be exposed to the IONaer 7000 Ion Generator for the study exposure time)
5. Inoculated carriers were dried under laminar flow with the Petri dish lids slightly ajar. Drying time for the carriers was approximately 10 minutes.
6. The IONaer 7000 device was placed into a biosafety cabinet chamber, with the laminar flow turned off, for testing. Upon drying, two carriers per organism were placed directly below the device's aluminum enclosure, downstream of the ionizing current, for exposure. The device and fan were powered "on" by plugging in both plugs. The exposure time was initiated when the blue indicator light for ionization glowed steadily (within 30 seconds to 1 minutes of plugging in the device). The biosafety cabinet sash was lowered and closed for the duration of the test.

7. A second set of two dried carriers were held separately in a different biosafety cabinet located in another lab room, and exposed to full laminar flow conditions (i.e. Petri dish lids removed) for the exposure time. These were designated as the Timed Control Carriers.
8. The third set of two dried carriers were harvested immediately into 20 ml of Dey/Engley (D/E) Broth upon drying, and served as the Time Zero controls. Following a 15 second vortex, the detached organisms were diluted 10-fold. Bacterial cultures were plated onto tryptic soy agar (TSA), and MS2 was plated using the double-layer agar overlay technique in combination with an *E. coli* 15597 bacterial host.
9. After the one hour exposure period, the Timed Control and exposed Test Carriers were harvested and plated in the same manner as the Time Zero carriers.
10. All platings were incubated for ~24 hours at 37 °C. Bacterial colony-forming units (CFUs) and viral plaque-forming units (PFUs) were then enumerated, and the reductions calculated.

Study Specifications

Test Organisms (4 total)	Bacteria: *Escheria coli* 25922 *Staphylococcus aureus* 6583 *Acinetobacter baummanii* 19606 Viral Surrogate: MS2 15597
Exposure Time	1 hour (*E. coli*, *A. baummanii*) 24 hours (*S. aureus*, MS2)
Exposure Conditions	22.4°C, 18% R.H.
No. of Replicates	Duplicate

Pathogen	**Total Elimination Percentage**	**Improvement Over Untreated Airflow**
E. coli	99.5%	95.7%
A. baummanii	97.4%	51.4%
S. aureus (staph infection)	99.2%	90.4%
Non-Enveloped Viral Surrogate MS2 (e.g., Norovirus)	99.998%	96%

Blue Heaven Technologies

2820 S. English Station Road - Louisville, KY 40299

TEST NO. 19-626-3 Rev. 1

Portable Room Air Cleaner Test Report

ANSI/AHAM AC-2019

Clean Air Delivery Rate (CADR) Test Method

Test Description

The sample was tested for Particulate(ISO Fine Dust) challenge. Two Grams of dust was injected into the room with stirring fan and circulating fan on. After a 5 minute mixing period the stirring fan and circulating fan were turned off followed by a 20 minute test period.
Unit was mounted in the duct behind a MERV 8 Filter. Duct loop was ran at 600 CFM

Test Lab Information

Testing Organization	Blue Heaven Technologies, Inc. Building 1
Laboratory Facility	994.5 ft^3 (28.2 m^3) Clean Room
Date of Testing	12/3/2019
Test Operators	Tyler Shoulders CAFS

Device Identification

Device Manufacturer	IONAER
Model Number	717023
Description	EXP Purification Unit
Included Technologies	Ionization
Dimensions	13.75" x 7"

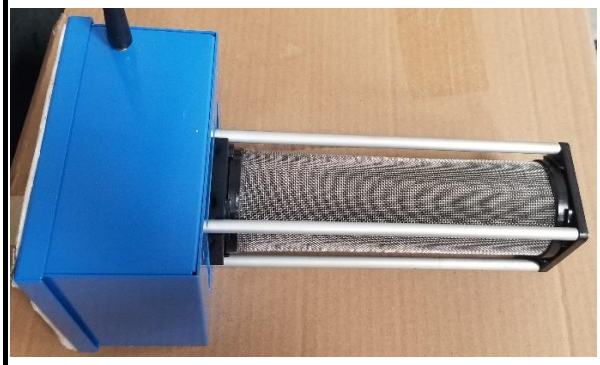
Test Room Conditions

Room Air Temperature	Test Start	69.6	Test End	69.8	Deg F
Room Air Humidity	Test Start	29.9	Test End	30	%
Test Time Start / End	1:57 P.M. - 2:22 P.M.				
Chamber Mixing	5 Minutes				

Test Equipment Information

Particle Measurement	Door Counter: TSI Model S/N: 174301
	Measured Particles Range: 0.3 -10 µm 12 Channels
	TSI Electrostatic Classifier and CPC S/N:3080112/3772123
	Measuring at 200 nm
Humidity Probe	Extech SD700 CP123843 Calibrated 1/22/2019
Temperature Probe	Extech SD700 CP123843 Calibrated 1/22/2019
Barometer	Extech SD700 CP123843 Calibrated 1/22/2019
Additional Information	Second Ion unit was added to the room next to the circulating fan and was on during cleaning periods.

Photos



Requestor Information

Test Requestor	Todd Simpson	Phone Number	480-465-1504
Company Name	IONAER	Email	jtsimpson@ionaer.com
Company Address		Date Requested	11/5/2019

Test Operator Information

Test Performed by:	Tyler Shoulders CAFS	Completion Date	12/6/2019

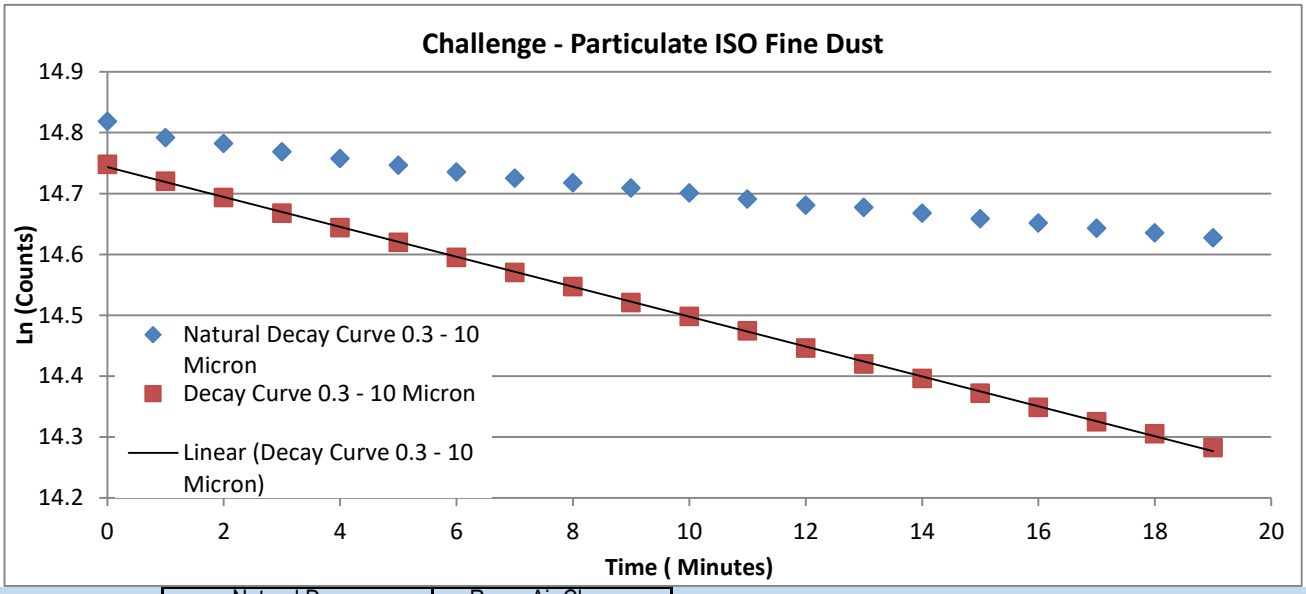
Blue Heaven Technologies
2820 S. English Station Road - Louisville, KY 40299

TEST NO. 19-626-3 Rev. 1

Portable Room Air Cleaner Test Report

ANSI/AHAM AC-2019

Clean Air Delivery Rate (CADR) Test Method



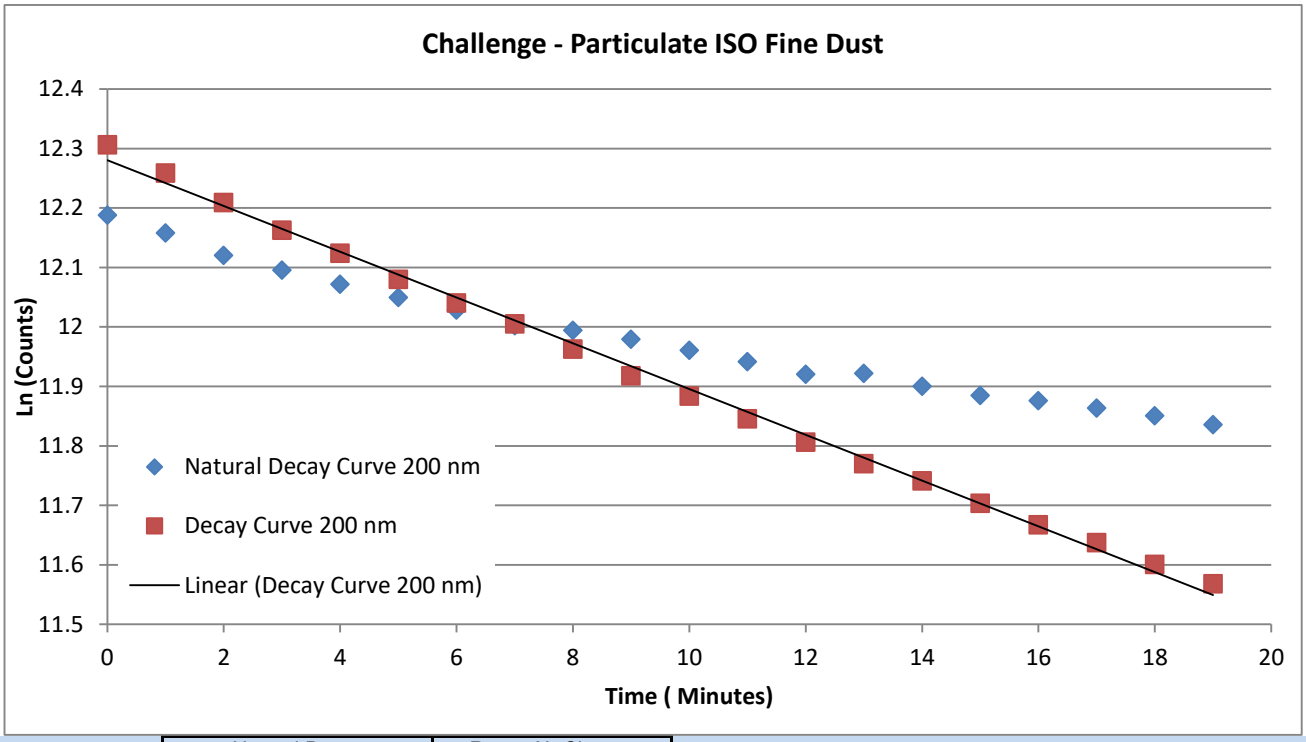
Time (min)	Natural Decay Counts	Natural Decay Ln(Ct)	Room Air Cleaner Counts	Room Air Cleaner Ln(Ct)
0.00	2727537	14.819	2541742	14.748
1.00	2654833	14.792	2472050	14.721
2.00	2630058	14.783	2406941	14.694
3.00	2594447	14.769	2346011	14.668
4.00	2566213	14.758	2290855	14.644
5.00	2537109	14.747	2236130	14.620
6.00	2509207	14.735	2181601	14.596
7.00	2484679	14.726	2127631	14.571
8.00	2465411	14.718	2079347	14.548
9.00	2445126	14.710	2025568	14.521
10.00	2424830	14.701	1979914	14.499
11.00	2400815	14.691	1932987	14.475
12.00	2376716	14.681	1879272	14.446
13.00	2367862	14.677	1830768	14.420
14.00	2345634	14.668	1788062	14.397
15.00	2324435	14.659	1744989	14.372
16.00	2307420	14.652	1705122	14.349
17.00	2288738	14.644	1665138	14.325
18.00	2271333	14.636	1632228	14.305
19.00	2252659	14.628	1595829	14.283

Quantity	Measured
Natural Decay Constant	0.009328
Room Air Cleaner Decay Constant	0.024565
Data Points used	20
Clean Room Volume (ft³)	994.5
Average Room Temperature (Deg F)	69.7
Average Room Humidity (%)	30.0
Smoke Challenge Clean Air Delivery Rate (CADR) 0.3 - 10 Micron	**15.15**

Requestor Information	Test Requestor	Todd Simpson	Phone Number	480-465-1504
	Company Name	IONAER	Email	jtsimpson@ionaer.com
	Company Address	0	Date Requested	11/5/2019
Test Operator Information	Test Performed by:	Tyler Shoulders CAFS	Completion Date	12/6/2019

Portable Room Air Cleaner Test Report

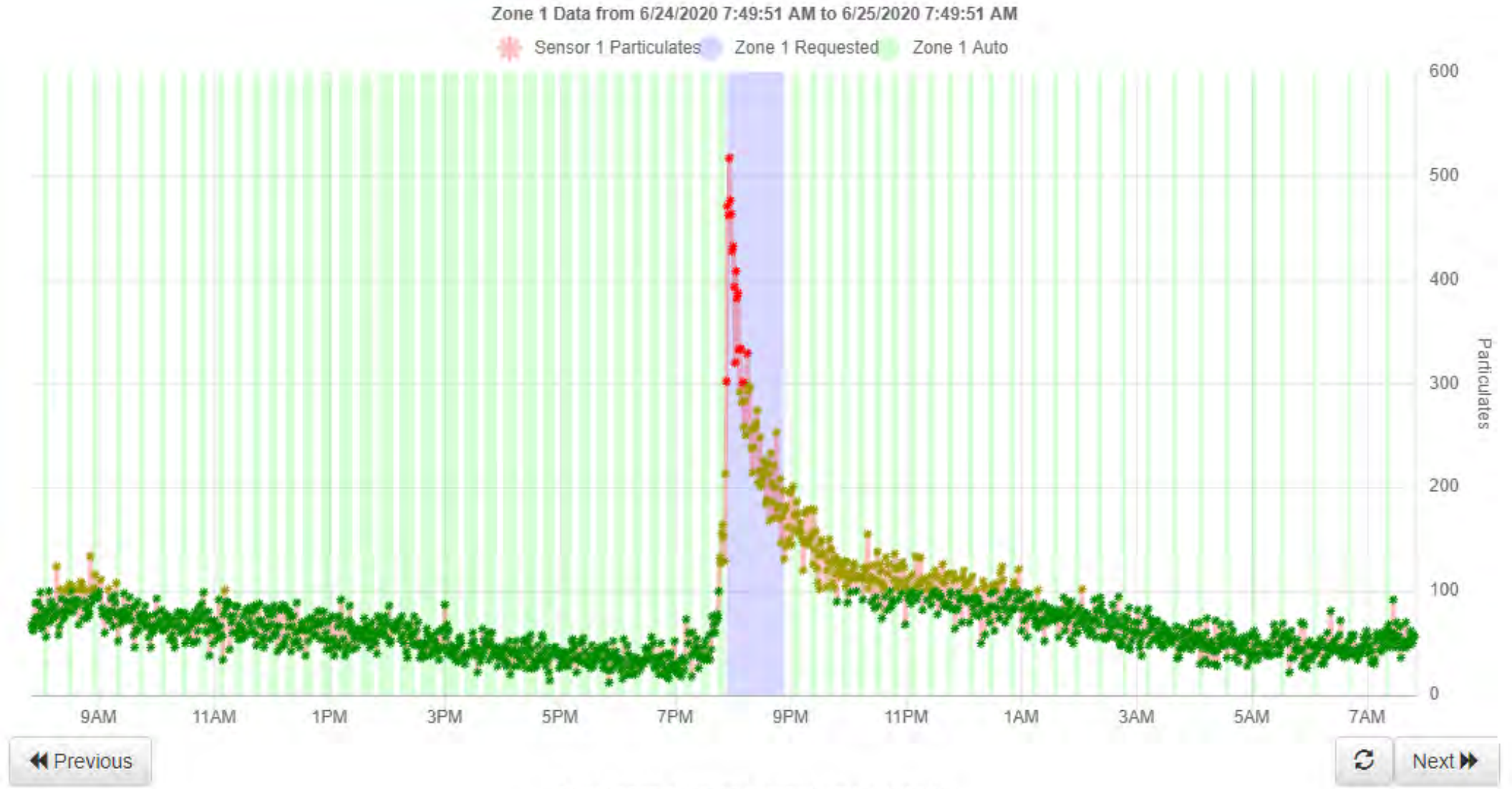
Clean Air Delivery Rate (CADR) Test Method



Time (min)	Natural Decay Counts	Natural Decay Ln(Ct)	Room Air Cleaner Counts	Room Air Cleaner Ln(Ct)
0.00	196486	12.188	221120	12.306
1.00	190692	12.158	210865	12.259
2.00	183635	12.121	200647	12.209
3.00	179078	12.096	191525	12.163
4.00	174927	12.072	184290	12.124
5.00	171087	12.050	176360	12.080
6.00	167496	12.029	169500	12.041
7.00	163113	12.002	163646	12.005
8.00	161828	11.994	156877	11.963
9.00	159429	11.979	149925	11.918
10.00	156557	11.961	144889	11.884
11.00	153535	11.942	139490	11.846
12.00	150300	11.920	134151	11.807
13.00	150541	11.922	129329	11.770
14.00	147375	11.901	125650	11.741
15.00	145043	11.885	120988	11.703
16.00	143798	11.876	116736	11.668
17.00	142049	11.864	113292	11.638
18.00	140181	11.851	109197	11.601
19.00	138108	11.836	105702	11.568

Quantity	Measured
Natural Decay Constant	0.017571
Room Air Cleaner Decay Constant	0.038477
Data Points used	20
Clean Room Volume (ft^3)	994.5
Average Room Temperature (Deg F)	69.7
Average Room Humidity (%)	30.0
Smoke Challenge Clean Air Delivery Rate (CADR) 200 nm	**20.79**

Requestor Information	Test Requestor	Todd Simpson	Phone Number	480-465-1504
	Company Name	IONAER	Email	jtsimpson@ionaer.com
	Company Address	0	Date Requested	11/5/2019
Test Operator Information	Test Performed by:	Tyler Shoulders CAFS	Completion Date	12/6/2019



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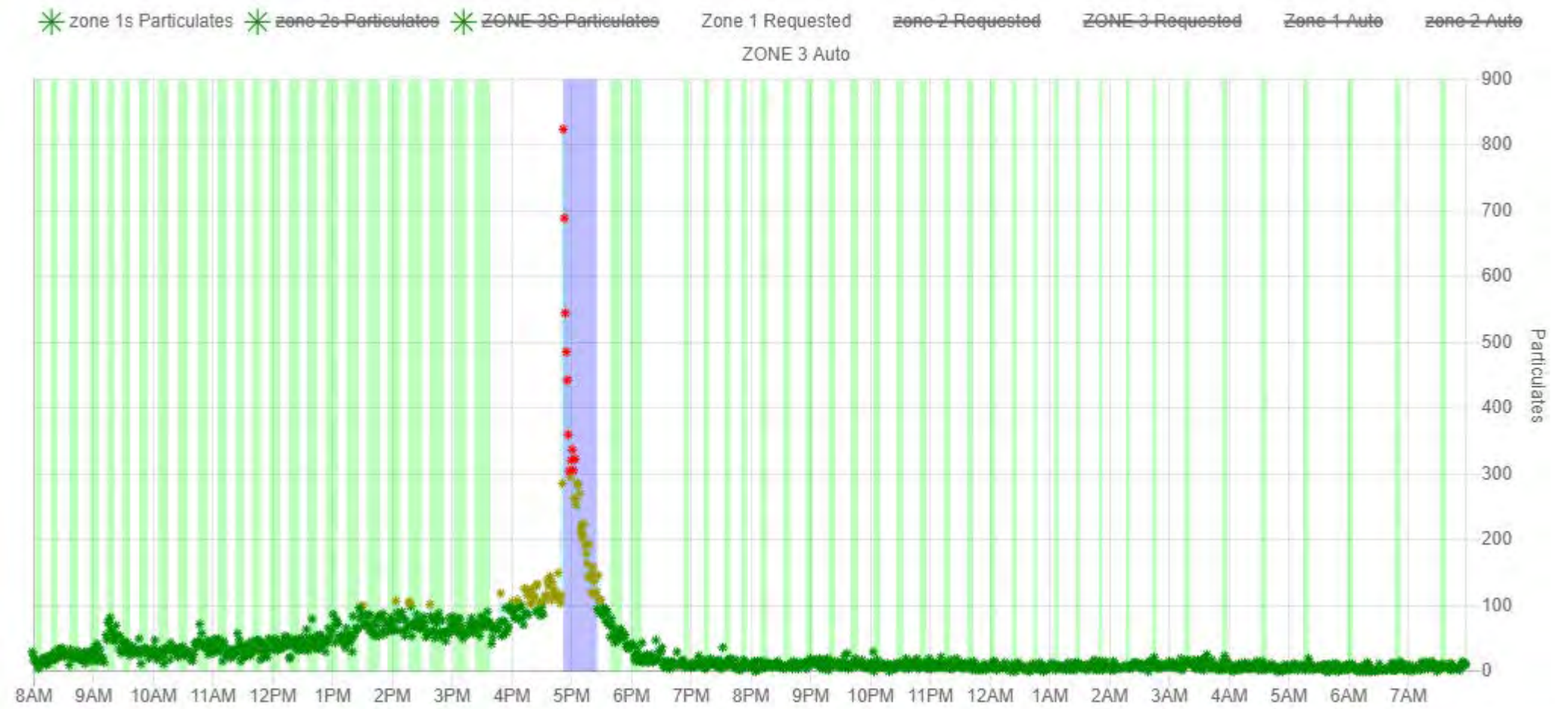
IONaer Data from 6/18/2020 7:58 am to 6/19/2020 7:58 am



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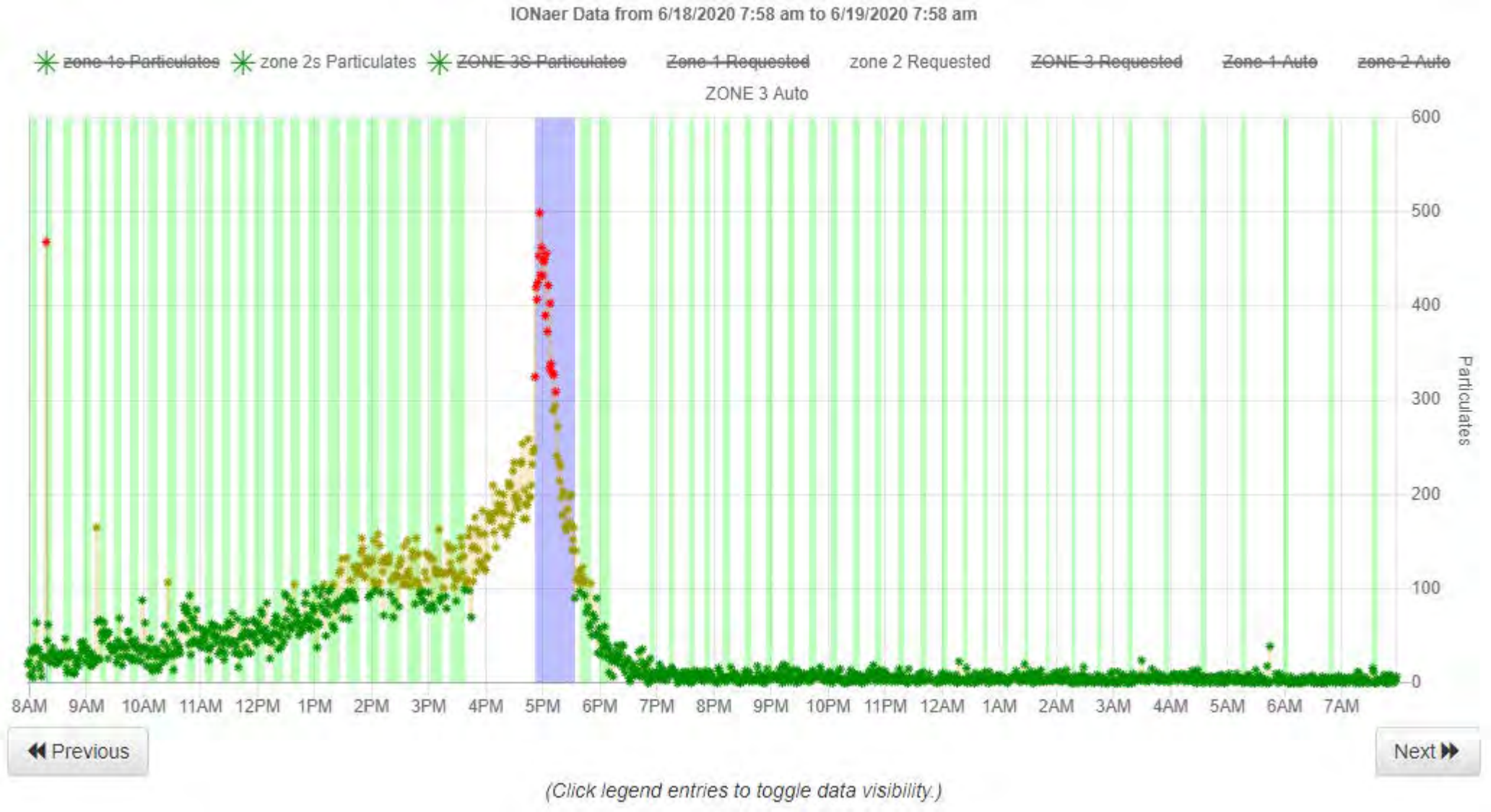
IONaer Data from 6/18/2020 7:58 am to 6/19/2020 7:58 am
zone 1s Particulates
zone 2s Particulates
ZONE 3S Particulates
Zone 1 Requested
zone 2 Requested
ZONE 3 Requested
Zone 1 Auto
zone 2 Auto
ZONE 3 Auto
600
500
400
300
200
100
0
Particulates
8AM
9AM
10AM
11AM
12PM
1PM
2PM
3PM
4PM
5PM
6PM
7PM
8PM
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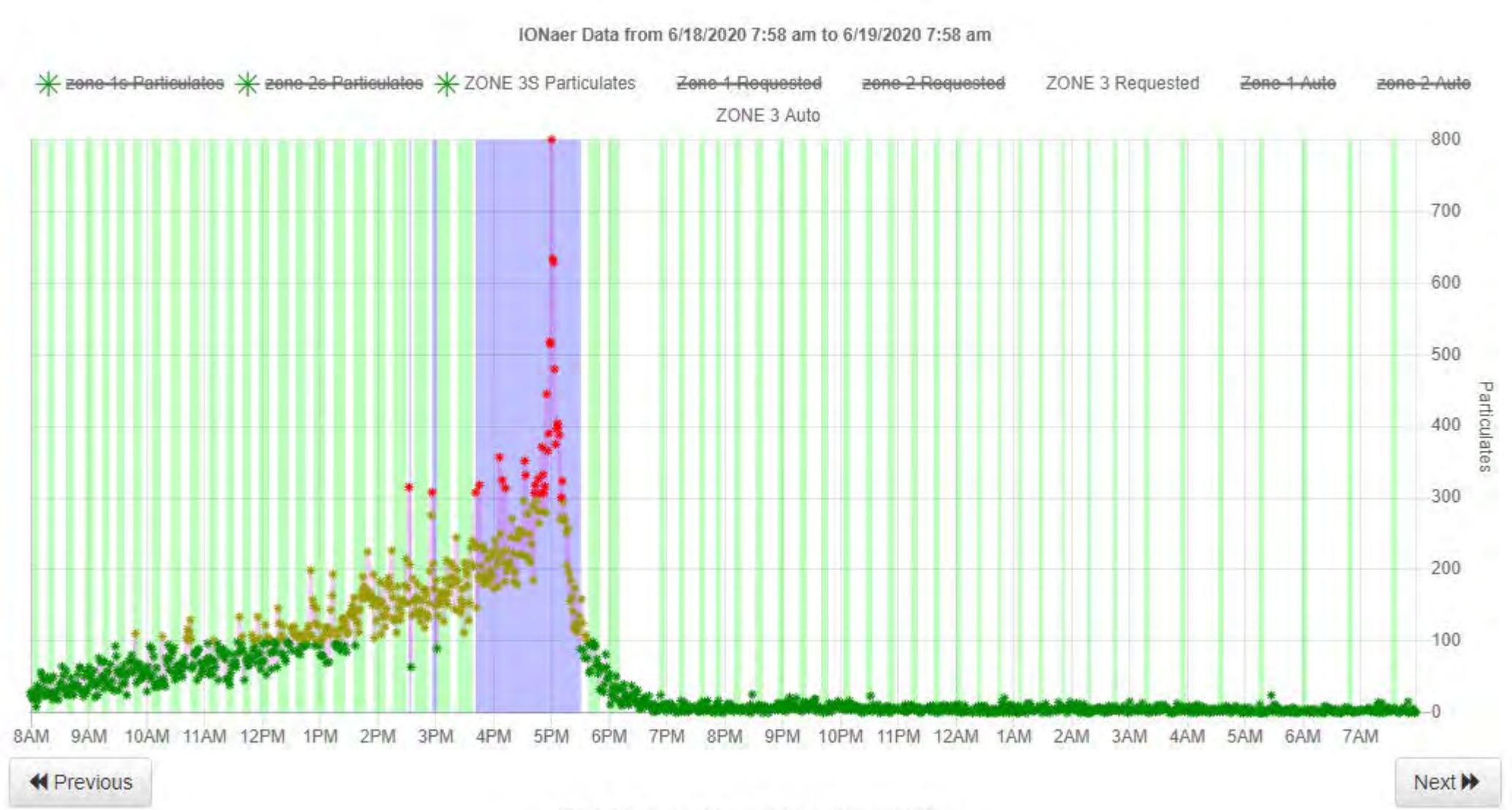
6AM
7AM
Previous
Next
(Click legend entries to toggle data visibility.)



Previous

Next

(Click legend entries to toggle data visibility.)

November 22, 2017

Ionaer International Inc.
Mr. Perry Pauley
4848 E Cactus Road, 505-103
Scottsdale, AZ 85254

Dear Mr. Pauley:

Thank you for choosing UL Environment and its ISO 17025 accredited testing laboratories for your analytical needs. Attached is the final report, which presents the test protocols and resulting data.

We appreciate this opportunity to assist you. If you have any questions or wish to discuss your results, please feel free to contact us at (888) 485-4733.

Sincerely,

W. Elliott Horner, PhD, LEED®AP
Lead Scientist

Attachment: Report: 18762-01

UL Environment, Inc.
2211 Newmarket Parkway, Marietta, GA 30067-9399 USA
T: 888.485.4733 / F: 770.980.0072 / W: UL.com/environment

PROJECT SUMMARY

UL Environment is pleased to present the test results for the unit identified as “Ionaer 7000” model, as submitted by Ionaer International Inc. The requested test protocol for this project was to measure ozone emissions in a duct with an airflow of 300 cubic feet per minute (CFM).

Ozone levels in the duct were measured with a Thermo Electron Corporation, 49i model ozone analyzer. Air from the duct was transferred through non-reactive (Teflon) tubing to the ozone analyzer.

Test conditions and results are presented below in Table 1 and charted in Figure 1.

UL Environment did not select the samples from an inventory listing. UL Environment did not determine whether the samples were representative of production samples, witness the production of the test samples, nor were we provided with information relative to the formulation or identification of component materials used in the test samples. The test results apply only to the actual samples tested.

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UL Environment, Inc.
2211 Newmarket Parkway, Marietta, GA 30067-9399 USA
T: 888.485.4733 / F: 770.980.0072 / W: UL.com/environment

Released by UL Environment
Date Reported: November 22, 2017
Project #: 18762-010AA
Report #: 18762-01

TABLE 1

ENVIRONMENTAL TEST REPORT FOR OZONE EMISSIONS TESTING

Maximum Measured Ozone Emission Concentration (ppm)
0.015

Customer: Ionaer International Inc.

Sample Identification: 18762-010AA

Product Description: AIR CLEANER; Ionaer 7000

Product Loading: 1 unit

Test Conditions: 300 CFM airflow
50% RH ± 5% RH
25°C ± 2°C

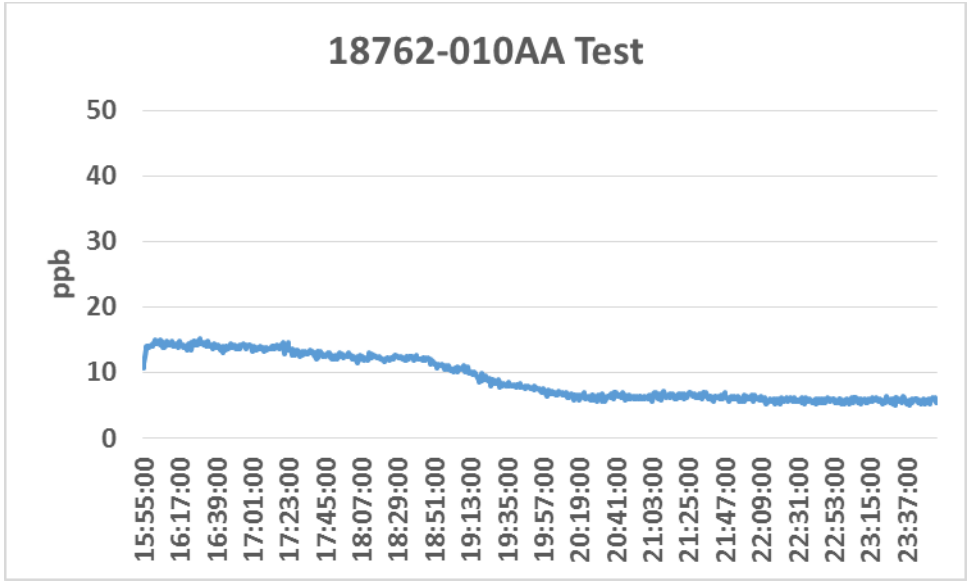
Test Period: 11/17/2017 – 11/18/2017

Test Description: The product was received by UL Environment as packaged and shipped by the customer. The package was visually inspected and stored in a controlled environment. Prior to loading, the product was unpackaged and subjected to a 48-hour run in period. The product was then loaded into an air duct with a blower set at 300 cfm. The device was then monitored for ozone emissions over an 8-hour period.

Ozone analysis conducted using a TEI Model 49i UV-absorbance based analyzer with a detection limit of 0.5 ppb (0.0005 ppm).

FIGURE 1

OZONE LEVELS DURING 8 HOURS IN A TEST DUCT WITH 300 CFM AIRFLOW



Released by UL Environment
Date Reported: November 22, 2017
Project #: 18762-010AA
Report #: 18762-01

November 22, 2017

Ionaer International Inc.
Mr. Perry Pauley
4848 E Cactus Road, 505-103
Scottsdale, AZ 85254

Dear Mr. Pauley:

Thank you for choosing UL Environment and its ISO 17025 accredited testing laboratories for your analytical needs. Attached is the final report, which presents the test protocols and resulting data.

We appreciate this opportunity to assist you. If you have any questions or wish to discuss your results, please feel free to contact us at (888) 485-4733.

Sincerely,

W. Elliott Horner, PhD, LEED®AP
Lead Scientist

Attachment: Report: 18762-02

UL Environment, Inc.
2211 Newmarket Parkway, Marietta, GA 30067-9399 USA
T: 888.485.4733 / F: 770.980.0072 / W: UL.com/environment

PROJECT SUMMARY

UL Environment is pleased to present the test results for the unit identified as “Ionaer 7000” model, as submitted by Ionaer International Inc. The requested test protocol for this project was to measure ozone emissions in a duct with an airflow of 1,500 cubic feet per minute (CFM).

Ozone levels in the duct were measured with a Thermo Electron Corporation, 49i model ozone analyzer. Air from the duct was transferred through non-reactive (Teflon) tubing to the ozone analyzer.

Test conditions and results are presented below in Table 1 and charted in Figure 1.

UL Environment did not select the samples from an inventory listing. UL Environment did not determine whether the samples were representative of production samples, witness the production of the test samples, nor were we provided with information relative to the formulation or identification of component materials used in the test samples. The test results apply only to the actual samples tested.

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UL Environment, Inc.
2211 Newmarket Parkway, Marietta, GA 30067-9399 USA
T: 888.485.4733 / F: 770.980.0072 / W: UL.com/environment

Released by UL Environment
Date Reported: November 22, 2017
Project #: 18762-020AA
Report #: 18762-02

TABLE 1

ENVIRONMENTAL TEST REPORT FOR OZONE EMISSIONS TESTING

Maximum Measured Ozone Emission Concentration (ppm)
0.012

Customer: Ionaer International Inc.

Sample Identification: 18762-020AA

Product Description: AIR CLEANER; Ionaer 7000

Product Loading: 1 unit

Test Conditions: 1500 CFM airflow
50% RH ± 5% RH
25°C ± 2°C

Test Period: 11/20/2017 – 11/21/2017

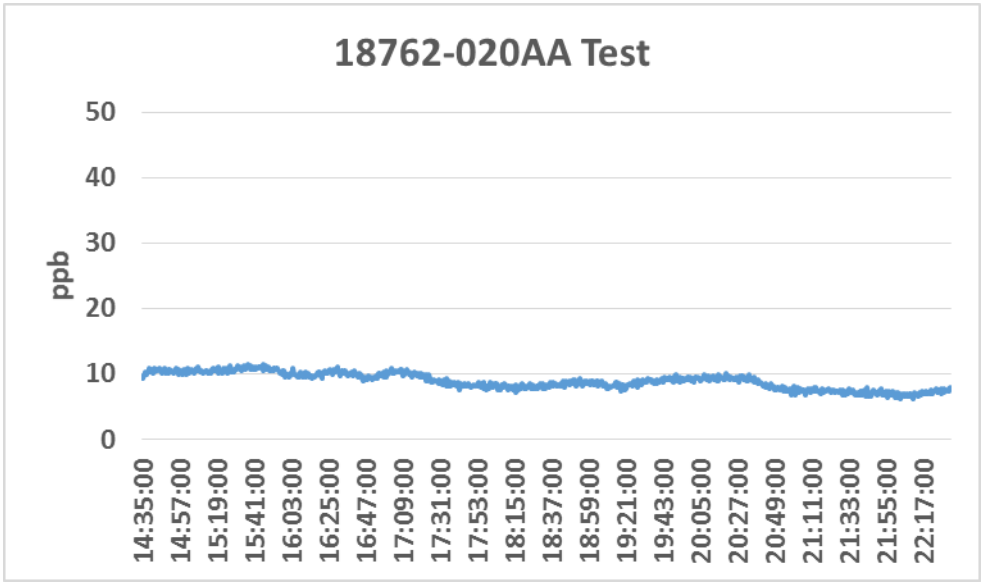
Test Description: The product was received by UL Environment as packaged and shipped by the customer. The package was visually inspected and stored in a controlled environment. Prior to loading, the product was unpackaged and subjected to a 48-hour run in period. The product was then loaded into an air duct with a blower set at 1500 cfm. The device was then monitored for ozone emissions over an 8-hour period.

Ozone analysis conducted using a TEI Model 49i UV-absorbance based analyzer with a detection limit of 0.5 ppb (0.0005 ppm).

Released by UL Environment
Date Reported: November 22, 2017
Project #: 18762-020AA
Report #: 18762-02

FIGURE 1

OZONE LEVELS DURING 8 HOURS IN A TEST DUCT WITH 1,500 CFM AIRFLOW

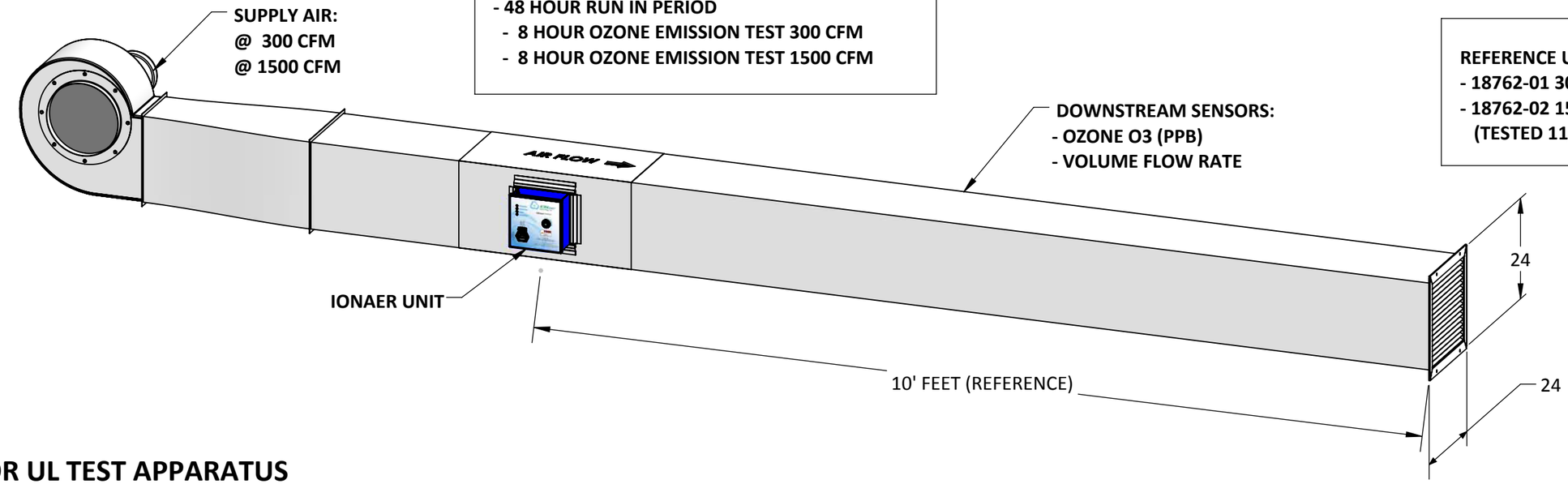


Released by UL Environment
Date Reported: November 22, 2017
Project #: 18762-020AA
Report #: 18762-02

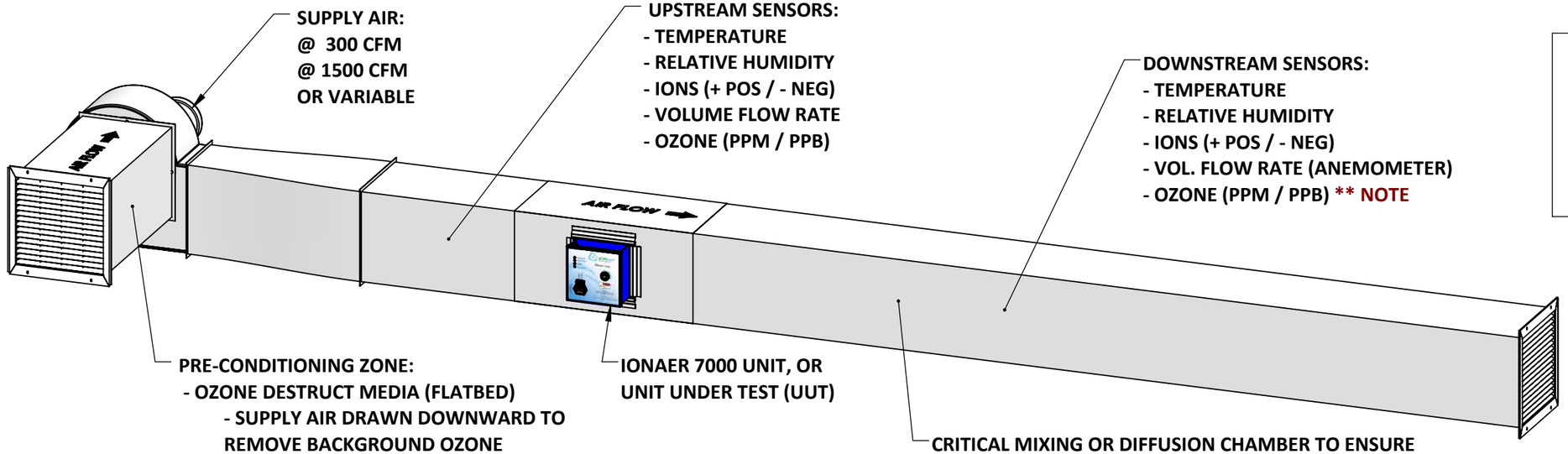
REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED
1	ORIGINAL RELEASE	07/02/19	

- 48 HOUR RUN IN PERIOD
  - 8 HOUR OZONE EMISSION TEST 300 CFM
  - 8 HOUR OZONE EMISSION TEST 1500 CFM

REFERENCE UL DOCUMENTS:
- 18762-01 300 CFM 0.015 PPM
- 18762-02 1500 CFM 0.012 PPM
  (TESTED 11/17-11/18-2017)



PRIOR UL TEST APPARATUS



PROPOSED UL / CARB TEST APPARATUS

NOTE THE GOAL OF THIS TEST IS TO OBTAIN AN ACCURATE OZONE COUNT MEASURED IN PPM, PPB, AND MG/H. THIS LAST VARIABLE, MG/H, CAN BE USED TO EXTRAPOLATE OZONE EFFECTS IN A NORMAL LIVING SPACE ENVIRONMENT (REFERENCE STUDY *"IN-DUCT AIR CLEANING DEVICES: OZONE EMISSION RATES AND TEST METHODOLOGY"* MORRISON ET AL, CARB PROJECT #09-342). THIS TESTING METHOD CAN USE THE MG/H VARIABLE TO MOST CLOSELY SIMULATE ACTUAL OZONE DECAY RATES IN LIVING ENVIRONMENTS.

IONAER INTERNATIONAL, INC.
PHOENIX, ARIZONA, USA

DRAWING NAME
IONAER TEST APPARATUS
(UL / CSA / CARB / OSHA)

SIZE	DWG. NO.	REV.
B		1

SCALE	CAD FILE	SHEET
1/1	CADFILE	1 OF 1

August 14, 2017

IONAER INTERNATIONAL INC.
4848 E Cactus Rd 505-103
Scottsdale, AZ, 85254

Our Reference: File R38991 / Project 4787673266

Subject: UL Standard 2043, Fourth Edition, dated October 2, 2013.
"Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces".

Dear Mr. PERRY PAULEY:

This Report summarizes the data developed on the samples you provided which were subjected to the flame test described in UL Standard 2043, Fourth Edition, dated October 2, 2013. Testing was conducted at UL LLC (UL) on July 19, 2017 at our Northbrook testing facility.

GENERAL:

It should be understood that these results apply only to the particular sample submitted for testing. The test results indicated in this Report are not intended to imply Listing, Classification or Recognition of any product or materials.

It is important to understand that authorities having jurisdiction may require that products such as covered by this report, intended for installation in a building plenum, be listed and labeled for such use in accordance with UL2043, based on current model building and electrical codes. Accordingly, you may wish to consider undergoing a Listing program with UL on your product(s) to address this possible need.

The Classification Marking or Listing Mark of UL on the product is the only method provided by UL to identify products that have been produced under its Classification or Listing and Follow-Up Service.

In no event shall UL be responsible to anyone for whatever use or nonuse is made of the information contained in this Report and in no event shall UL, its employees, or its agents incur any obligation or liability for damages, including, but not limited to, consequential damages, arising out of or in connection with the use, or inability to use, the information contained in this Report.

T E S T R E C O R D

SAMPLES:

The product evaluated is described in Table 1. UL did not witness the production of the test sample nor were we provided with information relative to the formulation or identification of component materials used in the manufacture of the test samples.

Table 1 - Sample Description

Sample Reference	Description
A	IONaer 7000

METHOD:

The tests were conducted in accordance with the test procedure described in UL Standard 2043, Fourth Edition, dated October 2, 2013. ("Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces"), dated October 02, 2013. This test method is used to determine the heat release rate, smoke release and optical density of the samples. The test samples were positioned and installed in the test enclosure as described in Appendix A.

ACCEPTANCE CRITERIA:

Each product specimen shall have the following properties when tested as described herein:

a) The peak rate of heat release measured during each test shall be 100 kilowatts or less, HRRs.
b) The peak smoke release rate measured during each test shall be 0.21 m^2/s or less, SRRs.
c) The total smoke released (10 minute test duration) shall be 75 m^2 or less, TSR.

Note: The above criteria do not include the contribution of the propane ignition burner.

RESULTS:

The summary of test results is tabulated in Table 2 below. Graphs of heat release rate, smoke release rate, and normalized optical density are given in Appendix B. Pre and post-test photographs for each test are given in Appendix A. In addition, a videotape of each test was made and provided.

Table 2 - Test Results

Sample - Test Ref.	Peak Heat Release Rate (kW)	Peak Normalized Optical Density	Average Normalized Optical Density	Peak Smoke Release Rate (m^2/s)	Total Smoke Released (m^2)
A-1	7	0.17	0.02	0.07	12.2
A-2	19	0.23	0.04	0.10	21.2
A-3	27	0.39	0.08	0.16	39.4

Please note that the values in Table 2 above as well as the graphs in Appendix B omit the heat and smoke contribution from the propane ignition burner.

CONCLUSION:

The product, identified by the test sponsor as shown in Table 1 - Sample Description, in the form it was submitted to UL LLC, was evaluated in accordance with UL2043 standard and it was found compliant with standard's requirements.

COMPLETION OF INVESTIGATION

Since this completes the anticipated work, we have instructed our Accounting Department to terminate the investigation and invoice you for the charges incurred to date.

If you have any questions, please do not hesitate to contact the undersigned.

Very truly yours

DAN BOGDAN (847)-664-1229
Building Materials & Systems
Daniel.Bogdan@ul.com

Reviewed by:

ANISH CHACKO (847)-664-1273
Building Materials & Systems
Anish.Chacko@ul.com

A P P E N D I X A

TEST NOTES:

File R38991, Project 4787673266

TEST A-1

07191703

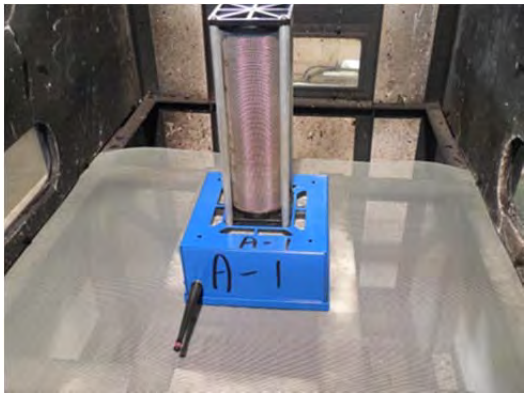
Sample Description: IONaer 7000

Test Notes: The sample was positioned on fine wire mesh and situated above the center of the test burner. The sample was placed face down.

Post Test Observations: No sample burning only light smoke at the conclusion of the test.

Photos:

Pre-Test



Post-Test

TEST A-2

07191704

Sample Description: IONaer 7000

Test Notes: The sample was positioned on fine wire mesh and situated above the center of the test burner. The sample was placed Hoizontal.

Post Test Observations: The sample was still burning with light smoke at the conclusion of the test.

Photos:

Pre-Test **Post-Test**

TEST A-3

07191705

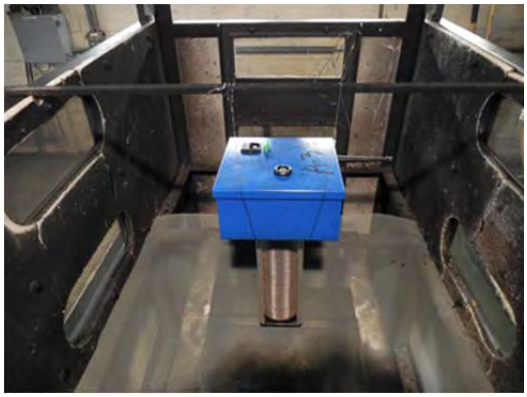
Sample Description: IONaer 7000

Test Notes: The sample was positioned on fine wire mesh and situated above the center of the test burner. The sample was placed Vertical.

Post Test Observations: The sample was still burning with medium smoke at the conclusion of the test.

Photos:

Pre-Test

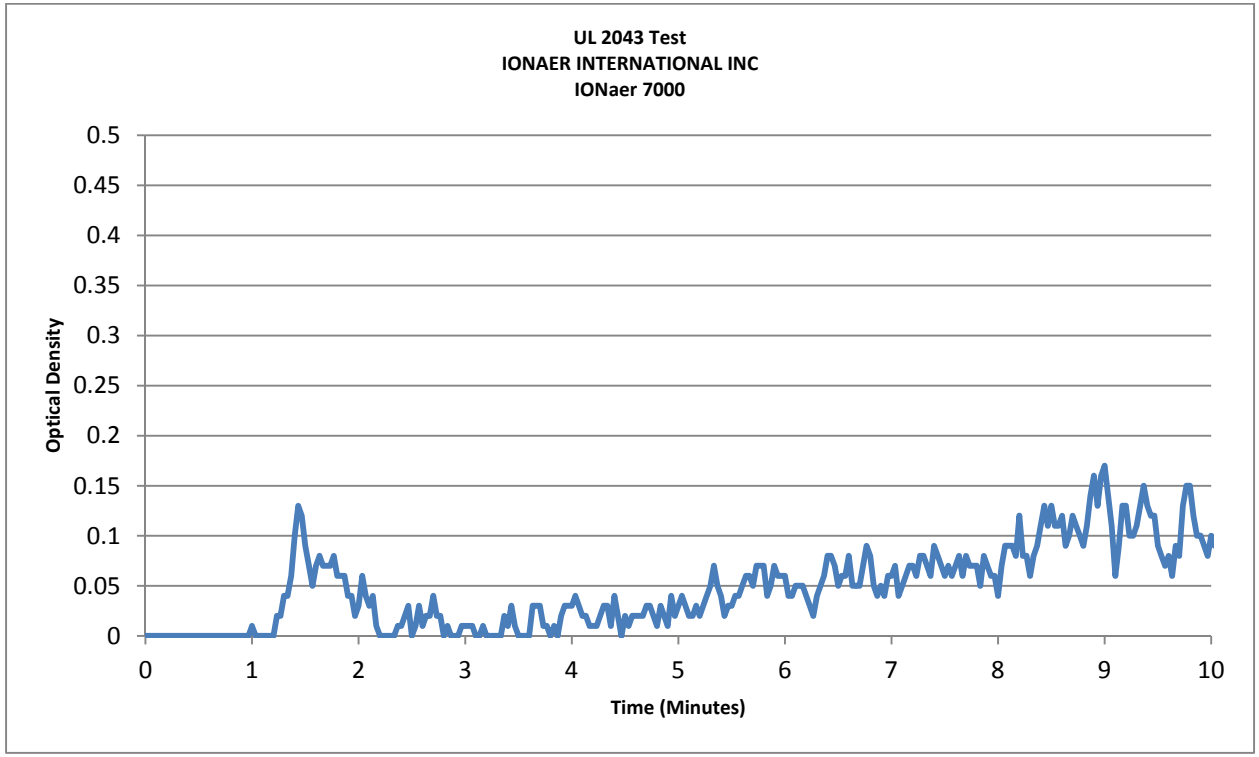


Post-Test

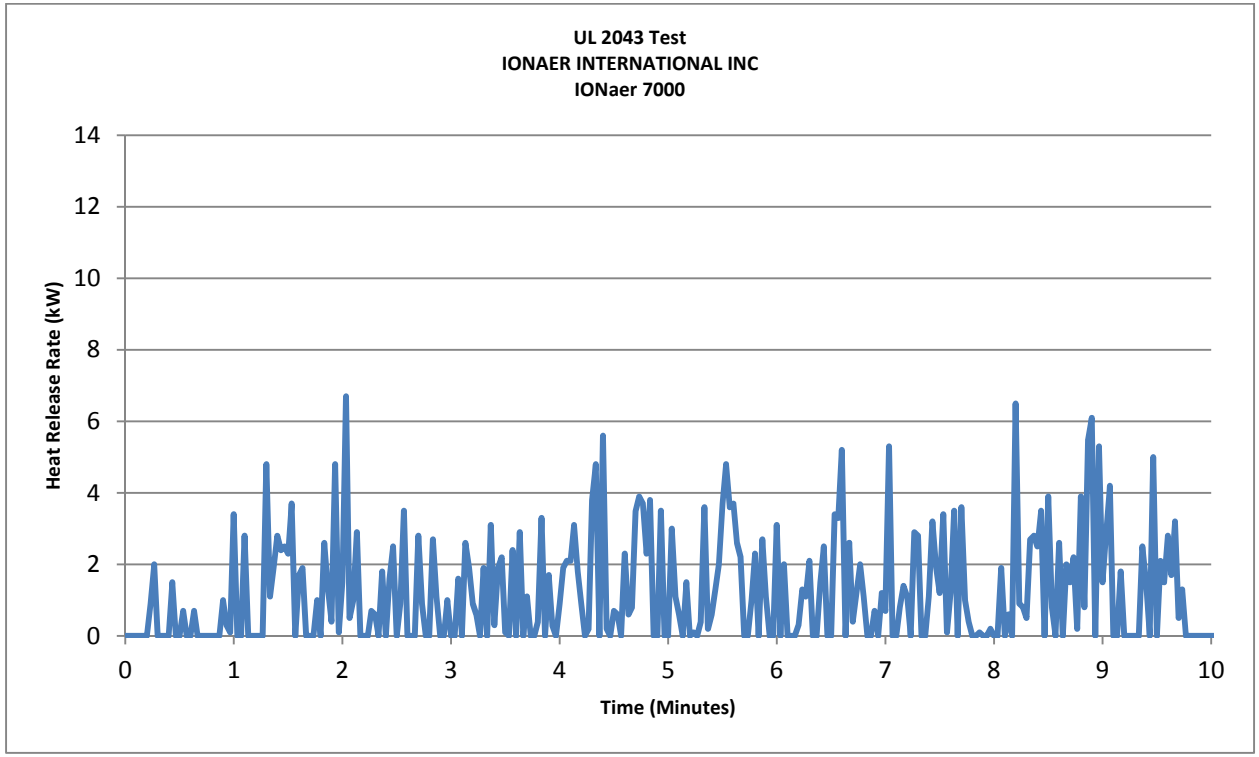
A P P E N D I X B

GRAPHICAL DATA

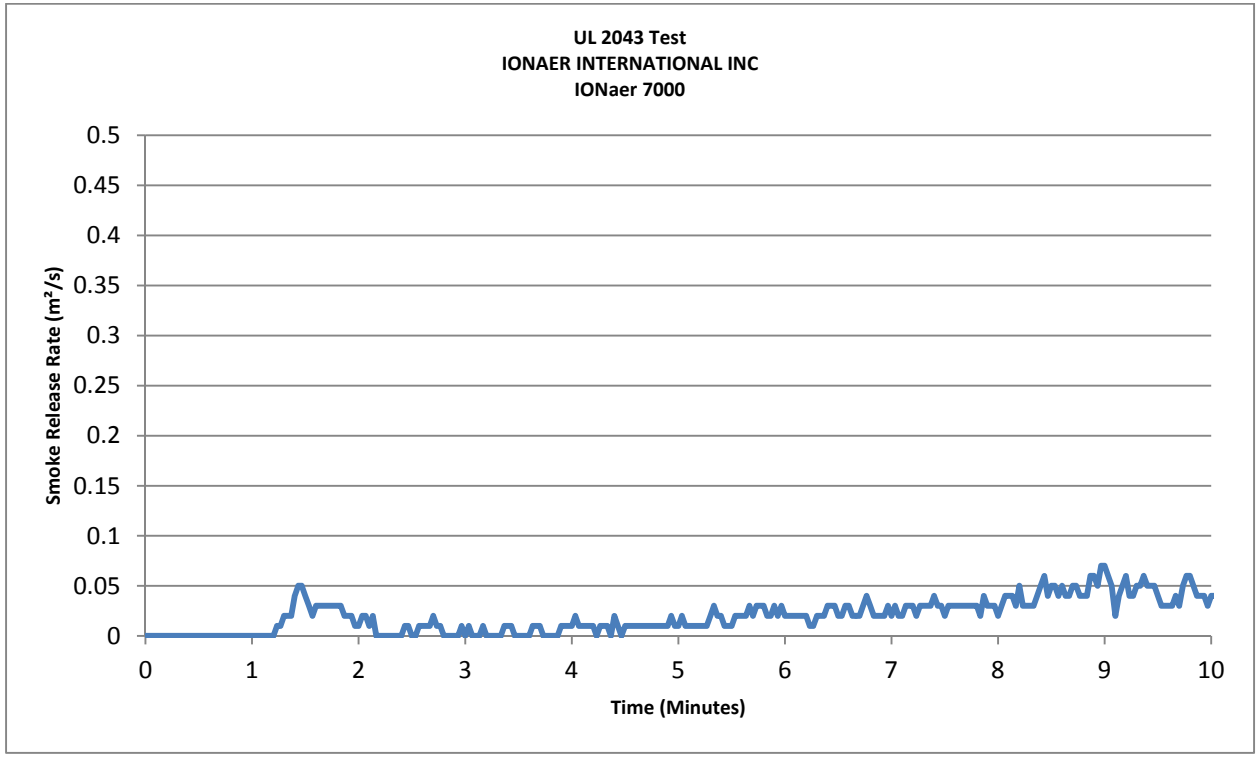
File R38991, Project 4787673266



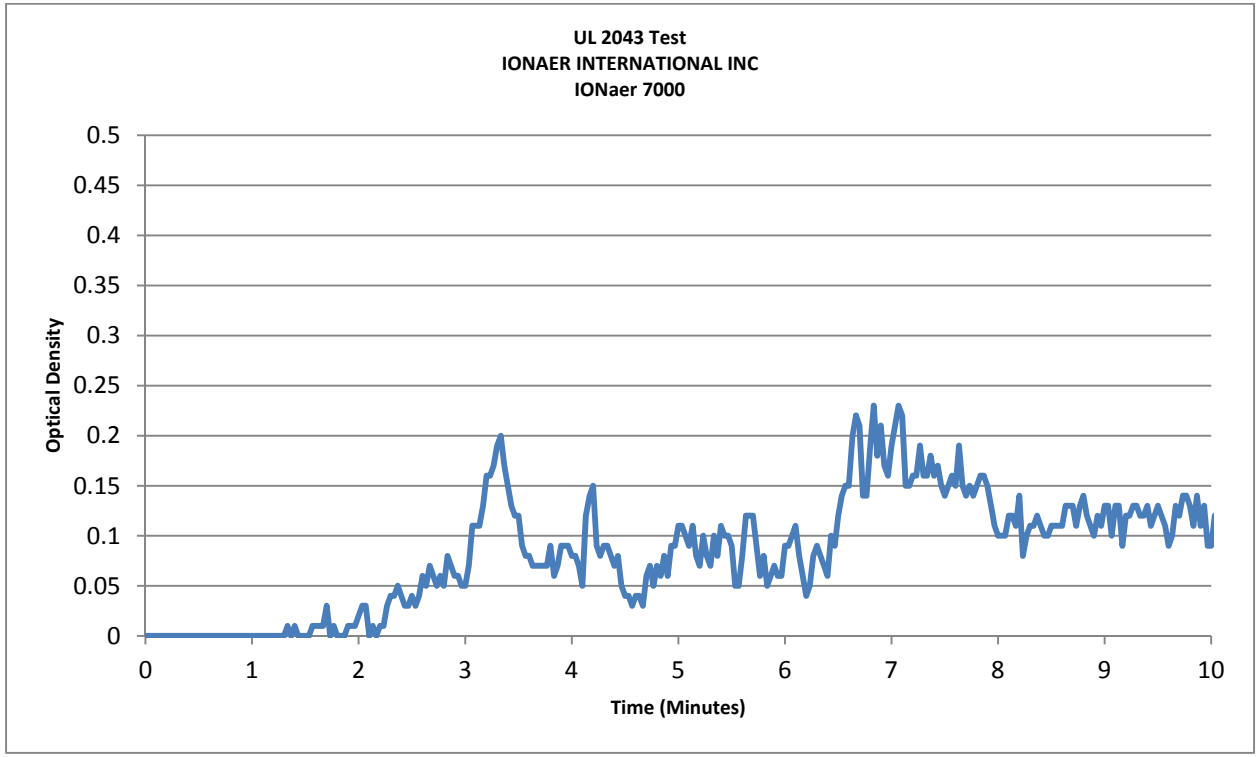
Test Number	Test Code	Description	Peak Normalized Optical Density	Average Normalized Optical Density
A-1	07191703	IONaer 7000	0.17	0.02



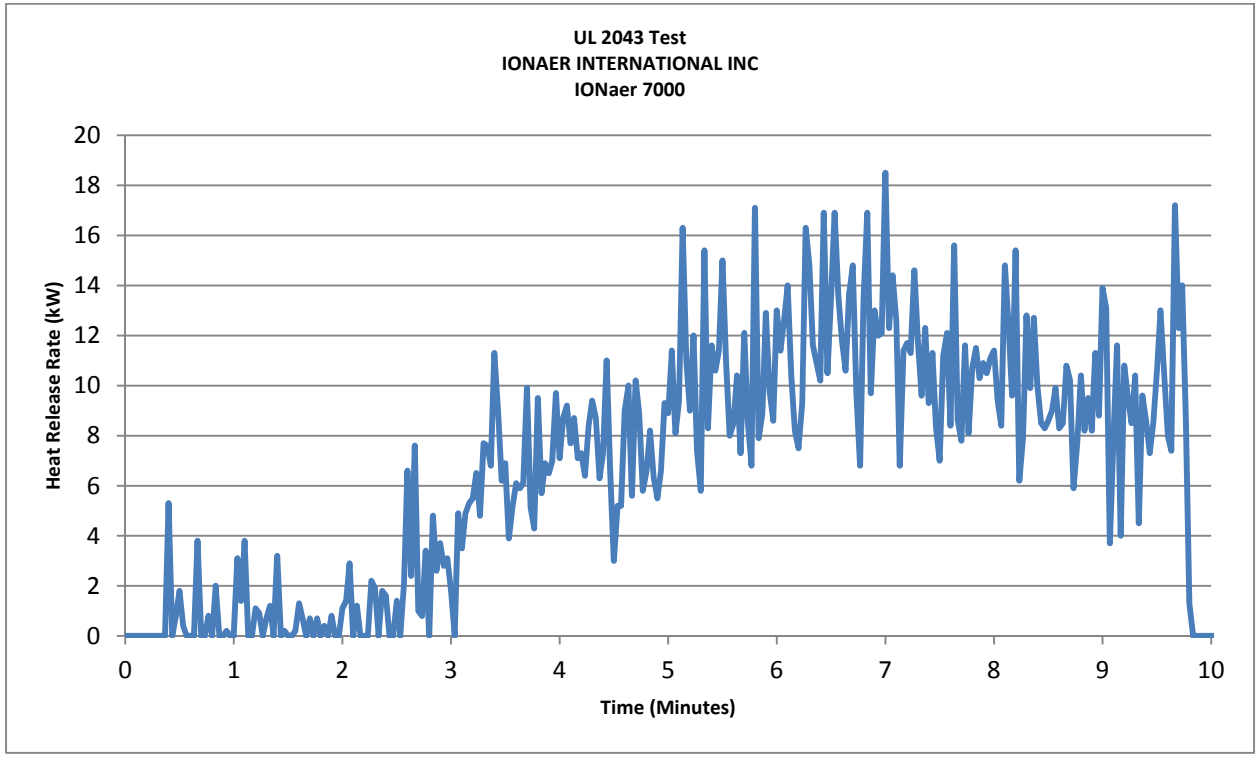
Test Number	Test Code	Description	Peak Heat Release Rate (kW)
A-1	07191703	IONaer 7000	7



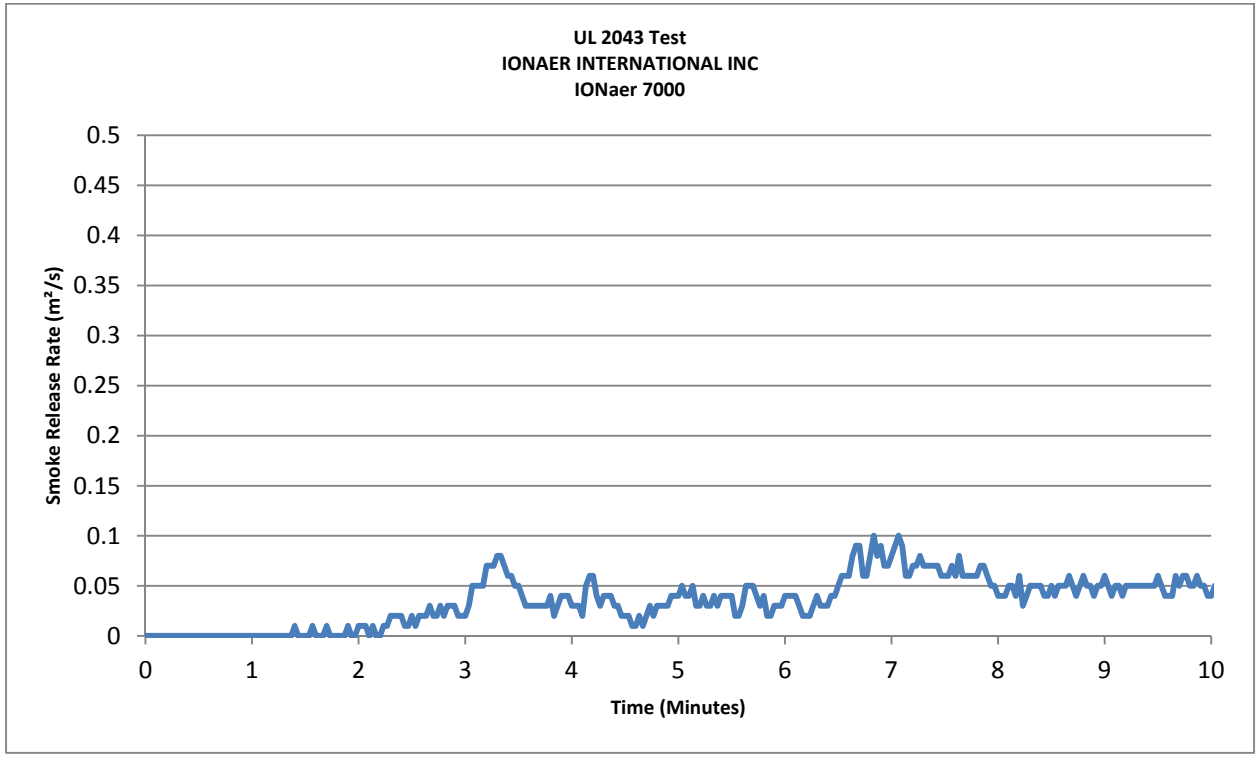
Test Number	Test Code	Description	Peak Smoke Release Rate (m^2/s)	Total Smoke Released (m^2)
A-1	07191703	IONaer 7000	0.07	12.2



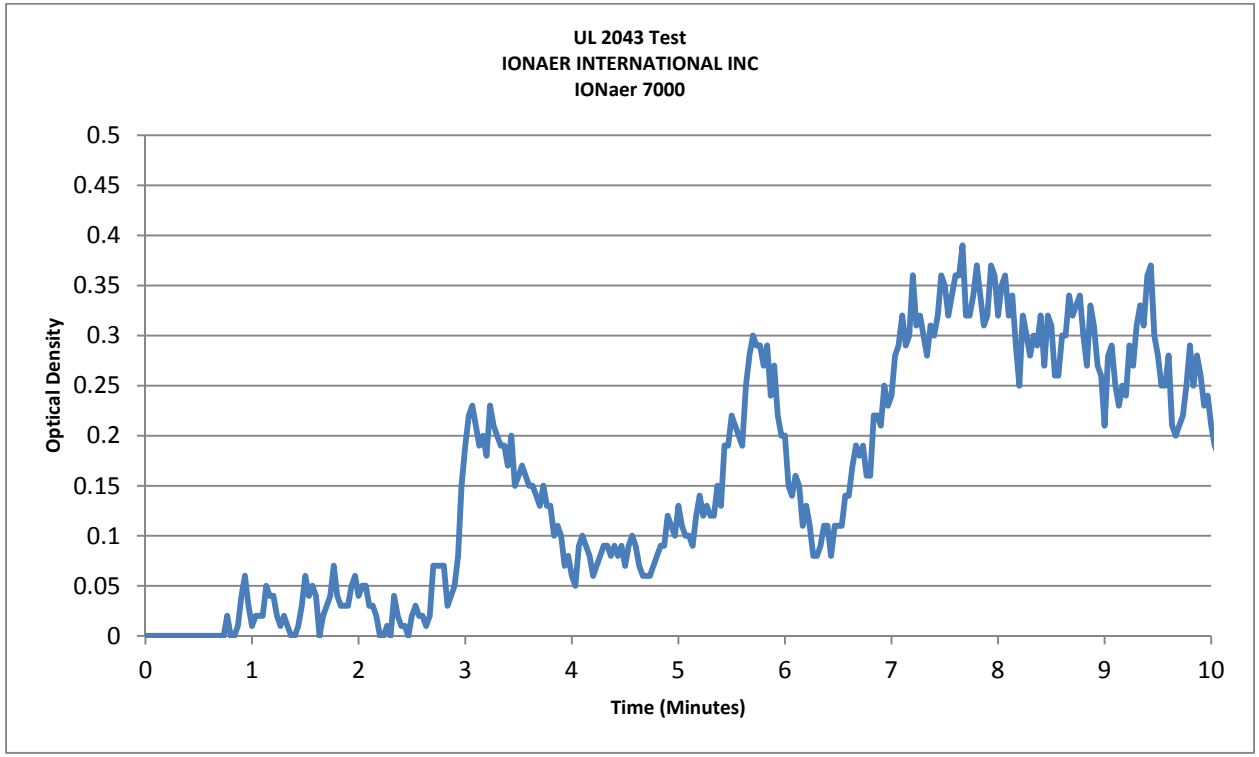
Test Number	Test Code	Description	Peak Normalized Optical Density	Average Normalized Optical Density
A-2	07191704	IONaer 7000	0.23	0.04



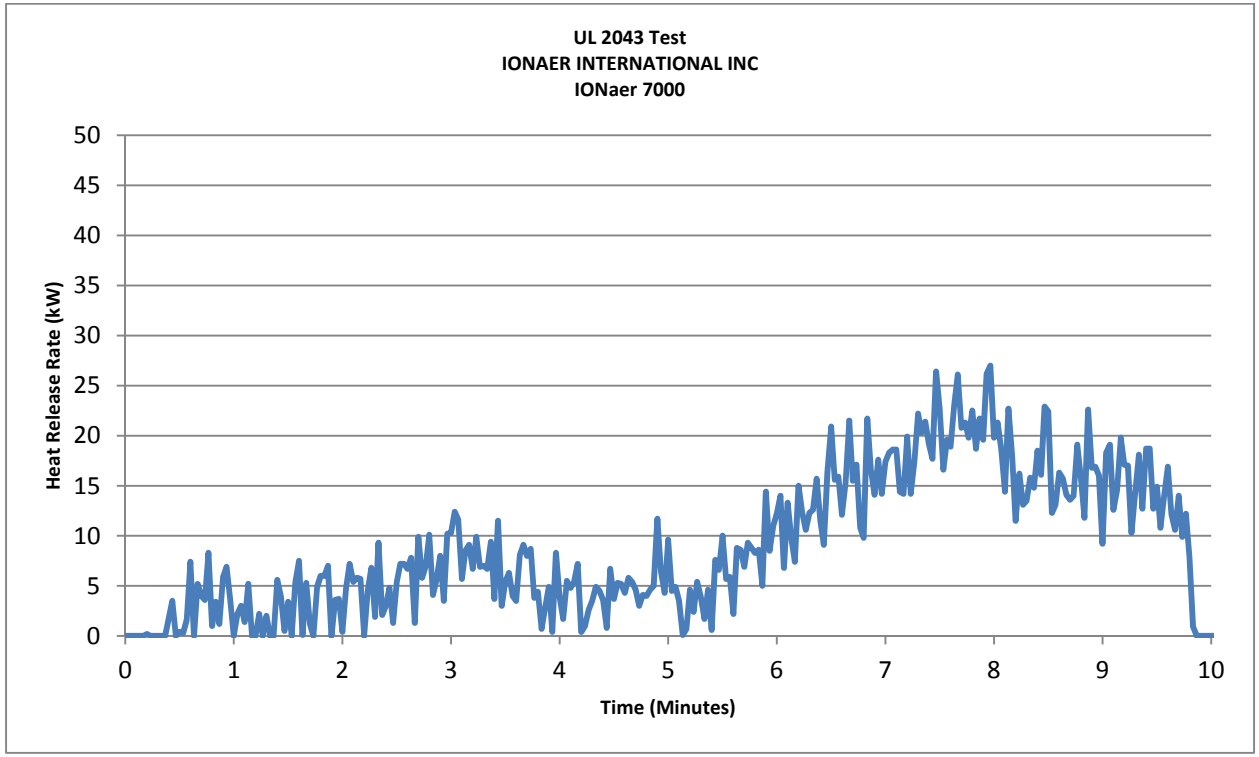
Test Number	Test Code	Description	Peak Heat Release Rate (kW)
A-2	07191704	IONaer 7000	19



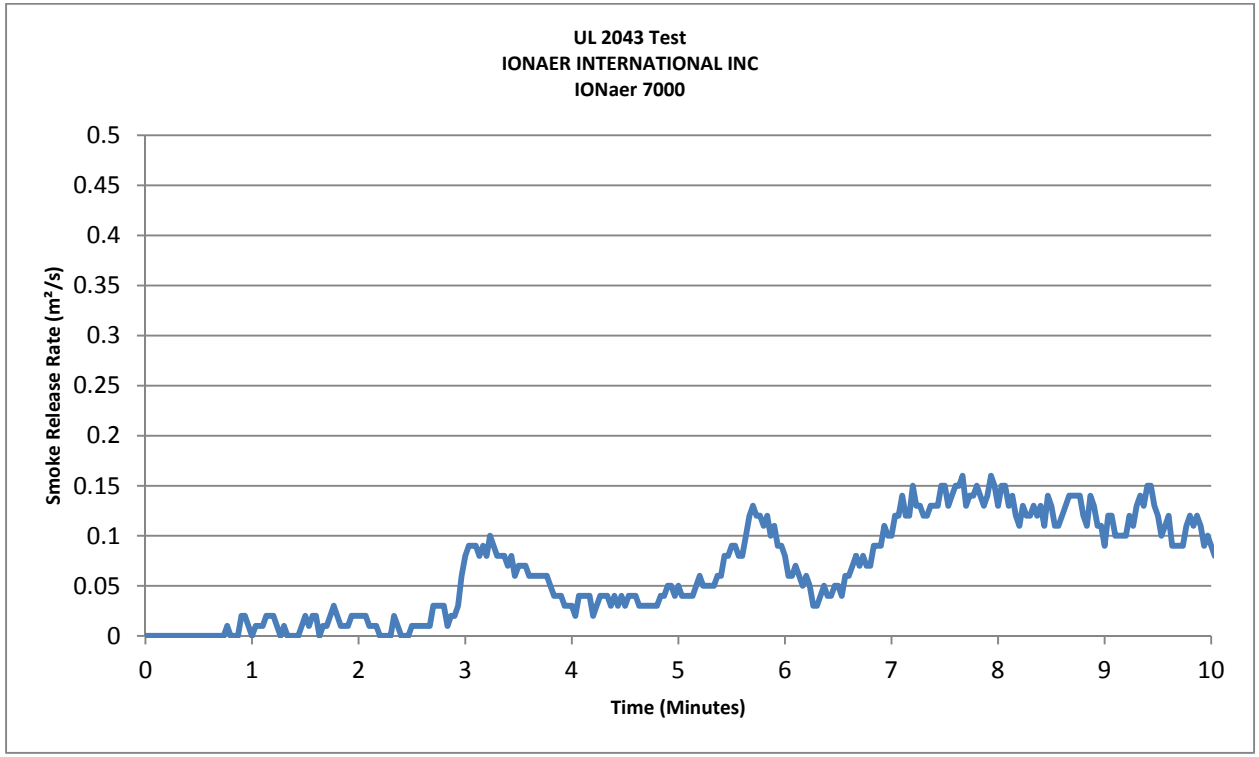
Test Number	Test Code	Description	Peak Smoke Release Rate (m^2/s)	Total Smoke Released (m^2)
A-2	07191704	IONaer 7000	0.10	21.2



Test Number	Test Code	Description	Peak Normalized Optical Density	Average Normalized Optical Density
A-3	07191705	IONaer 7000	0.39	0.08



Test Number	Test Code	Description	Peak Heat Release Rate (kW)
A-3	07191705	IONaer 7000	27



Test Number	Test Code	Description	Peak Smoke Release Rate (m^2/s)	Total Smoke Released (m^2)
A-3	07191705	IONaer 7000	0.16	39.4

H.B. Compliance Solutions

Un-Intentional Radiator Test Report

For the

Integrated Solutions, Inc.

IONaer 7000 Generator & Display Unit

Tested under

The FCC Rules contained in Title 47 of the CFR, Part 15 Subpart B

For Class B Digital Device

November 9, 2016

Prepared for:

Integrated Solutions, Inc.

16602 North 23rd Avenue, Suite 109

Phoenix, AZ 85023-3200

Prepared By:

H.B. Compliance Solutions

5005 S. Ash Avenue, Suite # A-10

Tempe, Arizona 85282

Reviewed By:

Hoosamuddin Bandukwala

Cert # ATL-0062-E

Engineering Statement: The measurements shown in this report were made in accordance with the procedure indicated, and the emissions from this equipment were found to be within the limits applicable. I assume full responsibility for the accuracy and completeness of these measurements, and for the qualifications of all persons taking them. All results contained herein relate only to the sample tested.

Report Status Sheet

Revision #	Report Date	Reason for Revision
Ø	November 9, 2016	Initial Issue

Table of Contents

EXECUTIVE SUMMARY

1. Testing Summary

These tests were conducted on a sample of the equipment for the purpose of demonstrating compliance with Part 15. All tests were conducted using measurement procedure from ANSI ANSI C.63.4 2014 as appropriate.

Test Name	Test Method/Standard	Result	Comments
Conducted Emissions	15.107	Pass	Device power up with 120VAC
Radiated Emissions	15.109	Pass	Emissions within applicable limits

EQUIPMENT CONFIGURATION

1. Overview

H.B Compliance Solutions was contracted by Integrated Solutions, Inc. to perform testing on the IONaer 7000 under the purchase order number 7493.

This document describes the test setups, test methods, required test equipment, and the test limit criteria used to perform compliance testing of the Integrated Solutions, Inc., IONaer 7000.

The tests were based on FCC Part 15 Subpart B Rules. The tests described in this document were formal tests as described with the objective of the testing was to evaluate compliance of the Equipment Under Test (EUT) to the requirements of the aforementioned specifications. Integrated Solutions, Inc. should retain a copy of this document and it should be kept on file for at least five years after the manufacturing of the EUT has been permanently discontinued. The results obtained relate only to the item(s) tested.

Product Name:	IONaer 7000
Model(s) Tested:	N/A
Supply Voltage Input:	Primary Power : 120VAC
Test Item:	Pre-Production
Environmental Test Conditions:	Temperature: 15-35°C Humidity: 30-60% Barometric Pressure: 860-1060 mbar
Modification to the EUT:	None
Evaluated By:	Staff at H.B. Compliance Solutions
Test Date(s):	11/07/2016 till 11/08/2016

2. Test Facility

All testing was performed at H.B. Compliance Solutions. This facility is located at 5005 S. Ash Avenue, Suite # A-10, Tempe AZ-85282. All equipment used in making physical determination is accurate and bears recent traceability to the National Institute of Standards and Technology.

Radiated Emissions measurements were performed in a GTEM chamber (equivalent to an Open Area Test Site). In accordance with §2.948(a)(3), a complete site description is contained at H.B. Compliance Solutions.

Test facility H.B. Compliance Solutions is an L-A-B accredited test site. The L-A-B certificate number is L2458. The scope of accreditation can be found on L-A-B website www.l-a-b.com

3. Description of Test Sample

The Integrated Solutions, Inc. IONaer 7000, is an electronic air purification unit that generates negative ions – and was specifically designed for use in residential, commercial and industrial applications. Unit is intended to be installed in duct systems, air handling units or furnace plenums.

4. Equipment Configuration

Ref. ID	Name / Description	Model Number	Serial Number
# 1	IONaer 7000 Generator	None	None
# 2	IONaer 7000 – Display Unit	None	None

Table 1. Equipment Configuration

5. Support Equipment

All support equipment supplied is listed in the following Support Equipment List.

Ref ID	Name / Description	Manufacturer	Model #	Serial #
# 2	IONaer 7000	Integrated Solutions Inc.	None	None

Table 2. Support Equipment

6. Ports and Cabling Information

Ref ID	Port name on the EUT	Cable Description	Qty.	Length (m)	Shielded? (Y/N)	Termination Box ID & Port ID
# 4	Power	3 wire	1	1	N	AC Mains

Table 3. Ports and Cabling Information

7. Method of Monitoring EUT Operation

Customer provided with instruction to monitor the device. For Generator connect the AC Power. Unit will operate and a Blue solid light will indicated full power. For the Display unit plug the A/C adaptor. Check the "Pairing" screen which shows the MAD IDs of the generator. A sensor unit was also provided to monitor the ION levels. LED were observed to show all other digital circuit were operating.

8. Mode of Operation

The EUT will be configured in its normal operating mode.

9. Modifications

9.1 Modifications to EUT

No modifications were made to the EUT

9.2 Modifications to Test Standard

No Modifications were made to the test standard.

10. Disposition of EUT

The test sample including all support equipment submitted to H.B Compliance Solutions for testing will be returned to Integrated Solutions, Inc. upon completion of testing & certification

Criteria for Un-Intentional Radiators

1. Conducted Emissions

Test Requirement(s):	§15.107	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	Nov/07/2016

Test Procedures: The EUT was placed on a non-metallic table, 80cm above the ground plane inside a shielded enclosure. The EUT was powered through a 50Ω/50µH LISN. The conducted emissions tests were performed using the mode of operation and configuration noted within this report. The frequency range investigated (scanned), is also noted in this report. Conducted power line measurements are made, unless otherwise specified, over the frequency range from 150 kHz to 30 MHz to determine the line-to-ground radio-noise voltage that is conducted from the EUT power-input terminals that are directly (or indirectly via separate transformer or power supplies) connected to a public power network. Equipment is tested with power cords that are the same as those cords normally used or that have electrical or shielding characteristics that are the same as those cords normally used. Typically those measurements are made using a LISN (Line Impedance Stabilization Network). All 50 Ohm measuring ports of the LISN are terminated by 50 Ohms, either by the 50 Ohm EMI receiver or a 50 Ohm resistive load.

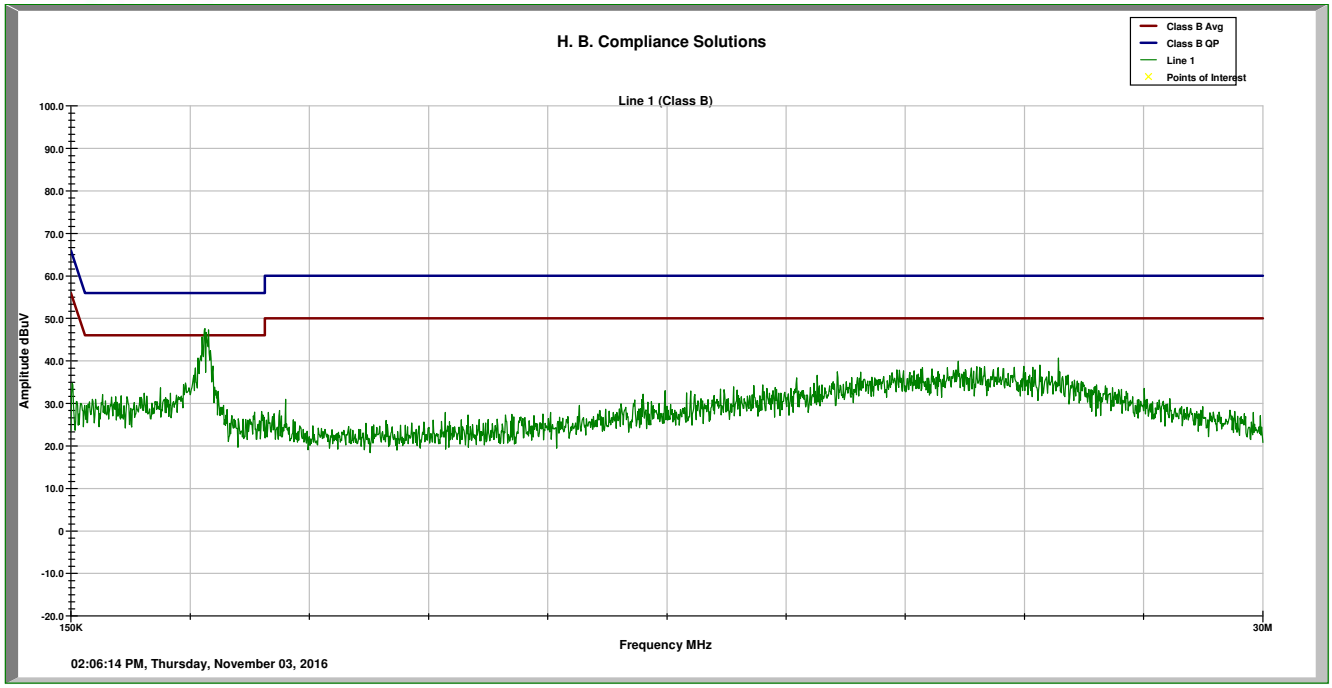
Refer to the Emissions Tests Calculations section in the Radiated Emissions section for sample calculations. For the purposes of the conducted emissions test, the Antenna Factor (AF) is replaced by the LISN correction factor.

Frequency Range (MHz)	Peak Data (kHz)	Quasi-Peak Data (kHz)	Average Data (kHz)
0.150 - 30	9.0	9.0	9.0
Measurements were made using the bandwidths and detectors specified. No video filter was used.			

Table 1.Conducted Emissions – Measurement Bandwidth

Frequency Range (MHz)	15.107(b), Class A Limits (dBuV)		15.107(a), Class B Limits (dBuV)	
	Quasi-Peak	Average	Quasi Peak	Average
0.15 – 0.5	79	66	66 - 56	56 - 46
0.5 – 5.0	73	60	56	46
5.0 – 30	73	60	60	50
Note 1 – The lower limit shall apply at the transition frequencies.				

Table 2. Conducted Emissions Limits – FCC Limits from Section 15.107(a)(b)



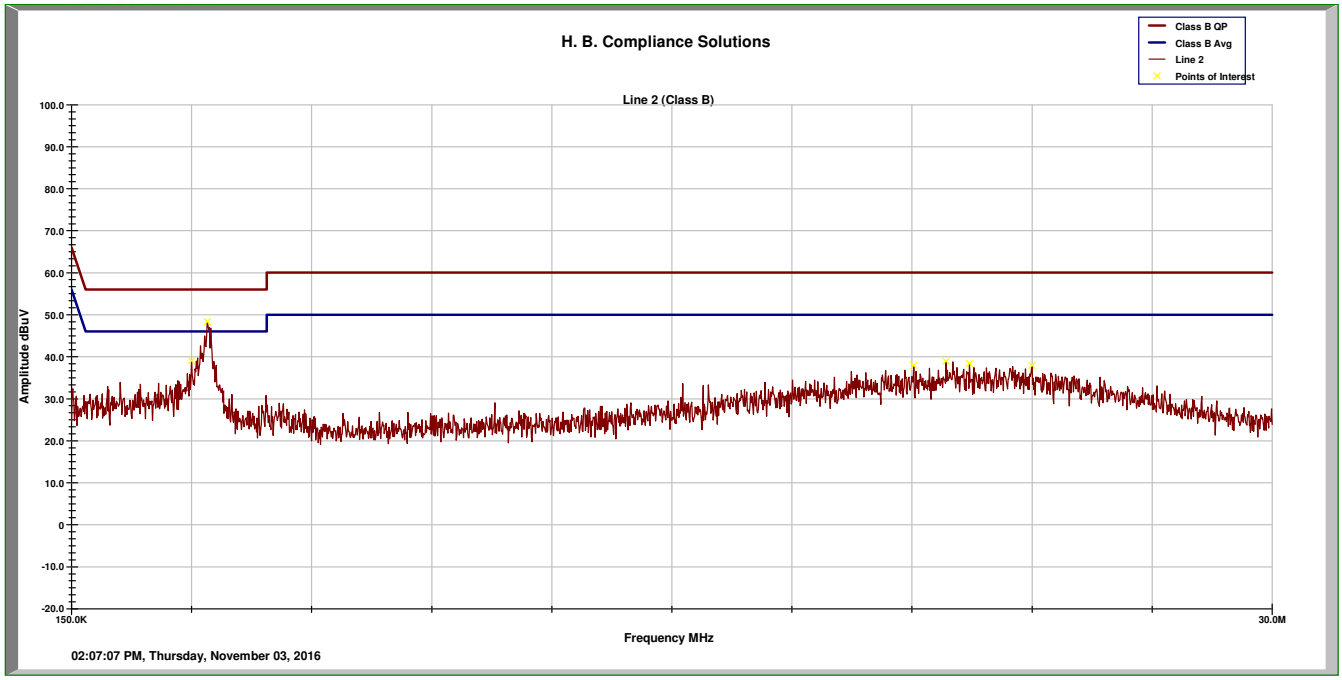
Plot 1 – Conducted Emission Plot – Line Side (Class B) – Generator Unit

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
3.14	38.47	56	-17.53
3.55	50.63	56	-5.37
3.72	38.88	56	-17.12
18.97	33.99	60	-26.01
21.20	35.62	60	-24.38
21.34	35.25	60	-24.75

Table 3. Measurement Results for QP

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
3.14	24.51	46	-21.48
3.55	34.76	46	-11.23
3.72	24.13	46	-21.86
18.97	20.43	50	-29.56
21.20	21.95	50	-28.04
21.34	22.02	50	-27.98

Table 4. Measurement Results for Average



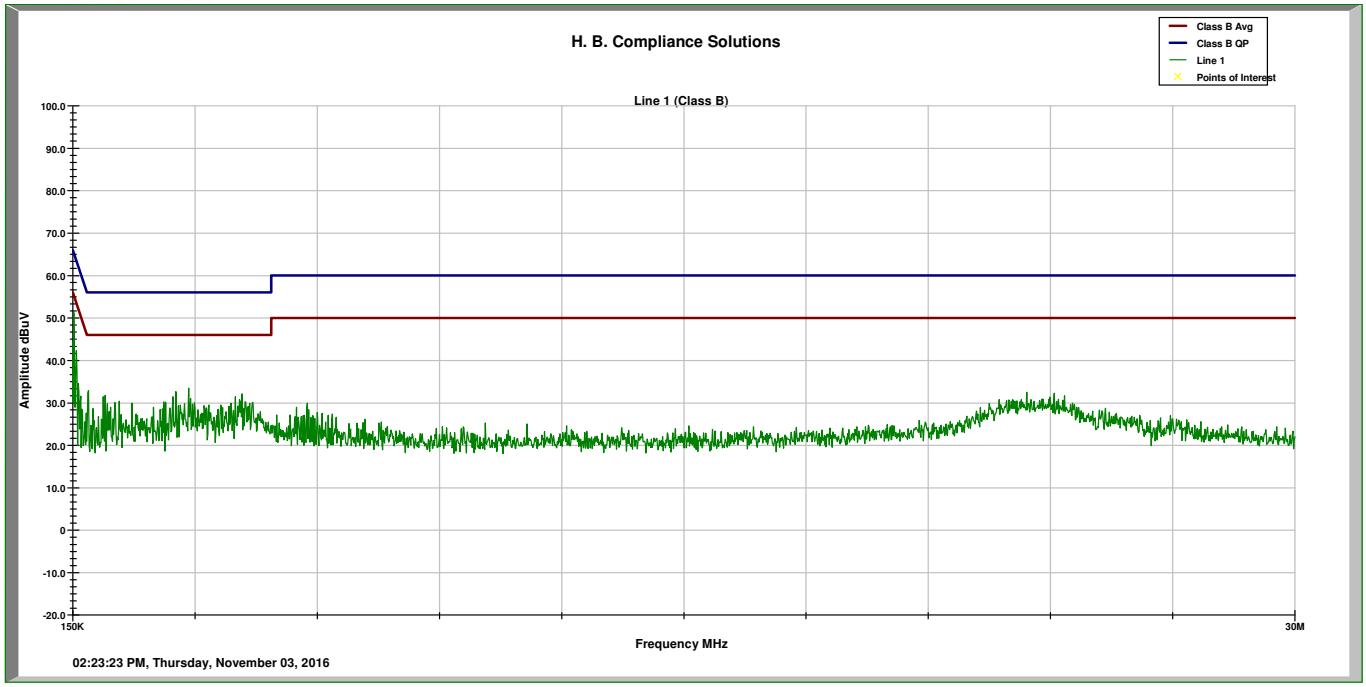
Plot 2 – Conducted Emissions – Neutral Side (Class B) – Generator Unit

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
3.139	31.77	56	-24.23
3.525	44.34	56	-11.66
21.08	30.77	60	-29.23
21.89	31.42	60	-28.58
22.47	31.54	60	-28.46
24.04	31.13	60	-28.87

Table 5. Measurement Results for Quasi Peak

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
3.139	18.355	46	-27.64
3.525	29.65	46	-16.35
21.08	18.508	50	-31.49
21.89	18.682	50	-31.31
22.47	19.085	50	-30.91
24.04	18.587	50	-31.41

Table 6. Measurement Results for Average



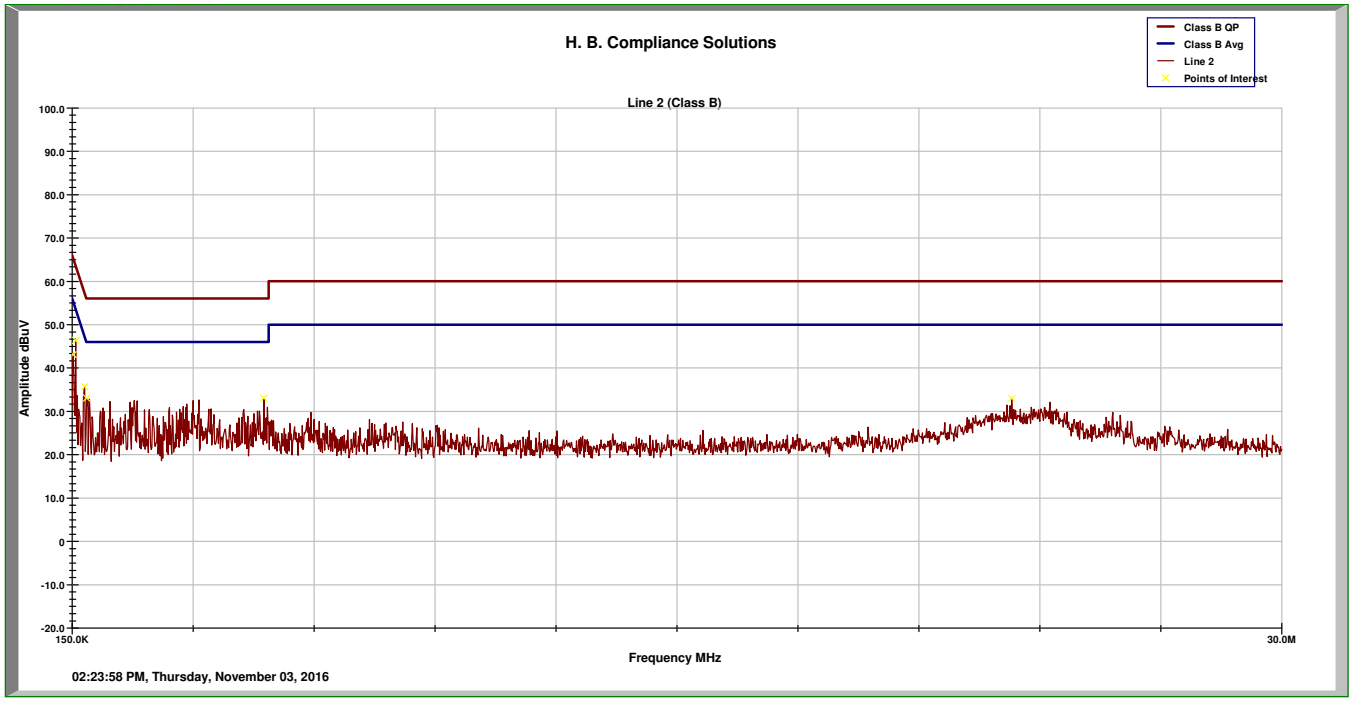
Plot 3 – Conducted Emission Plot – Line Side (Class B) – Display Unit

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
0.201	50.77	64.51	-13.74
0.269	44.53	62.59	-18.06
0.468	36.57	56.91	-20.341
0.550	37.31	56	-18.69
1.683	30.48	56	-25.52
1.751	30.06	56	-25.94

Table 7. Measurement Results for QP

Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
0.201	37.93	54.51	-16.584
0.269	36.05	52.59	-16.545
0.468	26.51	46.91	-20.399
0.550	25.20	46	-20.793
1.683	14.24	46	-31.752
1.751	13.42	46	-32.58

Table 8. Measurement Results for Average



Plot 4 – Conducted Emissions – Neutral Side (Class B) – Display Unit

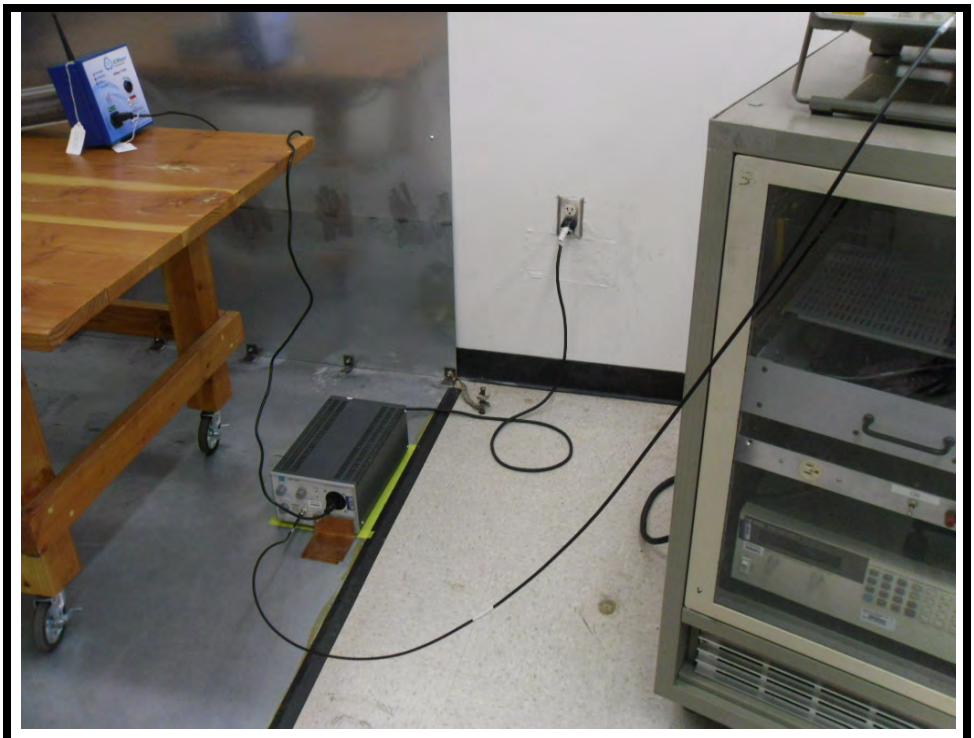
Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
0.163	40.72	65.61	-24.891
0.233	25.09	63.60	-38.513
0.477	35.99	56.65	-20.666
0.490	35.58	56.28	-20.703
4.87	25.03	56	-30.97
23.35	26.29	60	-33.71

Table 9. Measurement Results for Quasi Peak

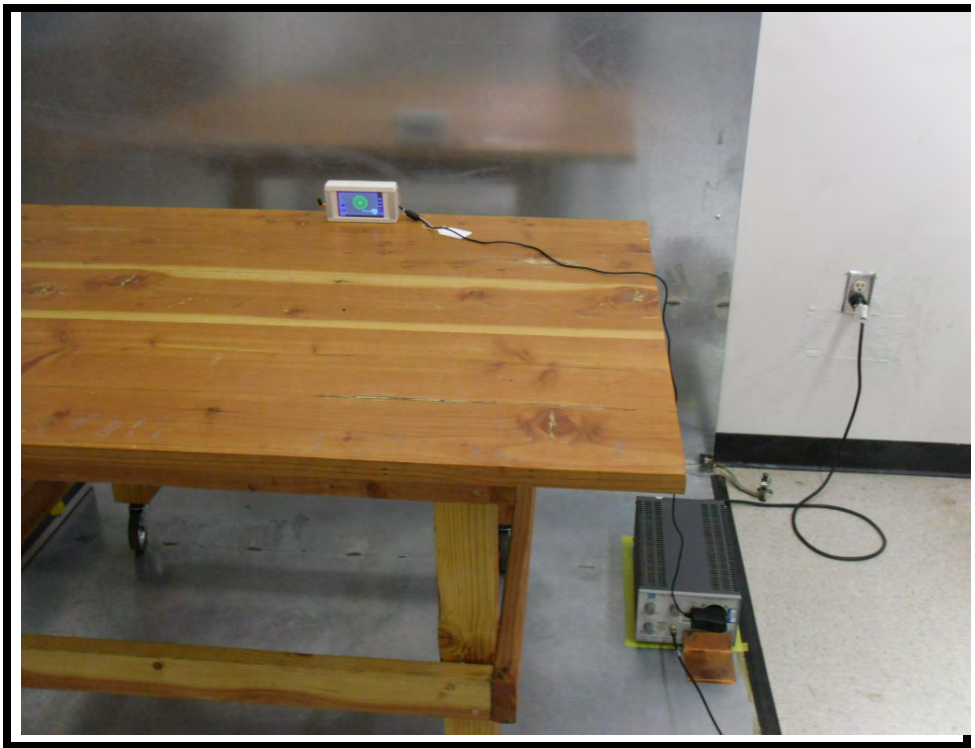
Frequency (MHz)	Measured Level (dBuV)	Limit (dBuV)	Margin (dB)
0.163	14.76	55.61	-40.84
0.233	25.69	53.60	-27.91
0.477	26.40	46.65	-20.24
0.490	20.8	46.28	-25.48
4.87	14.37	46	-31.62
23.35	20.53	50	-29.47

Table 10. Measurement Results for Average

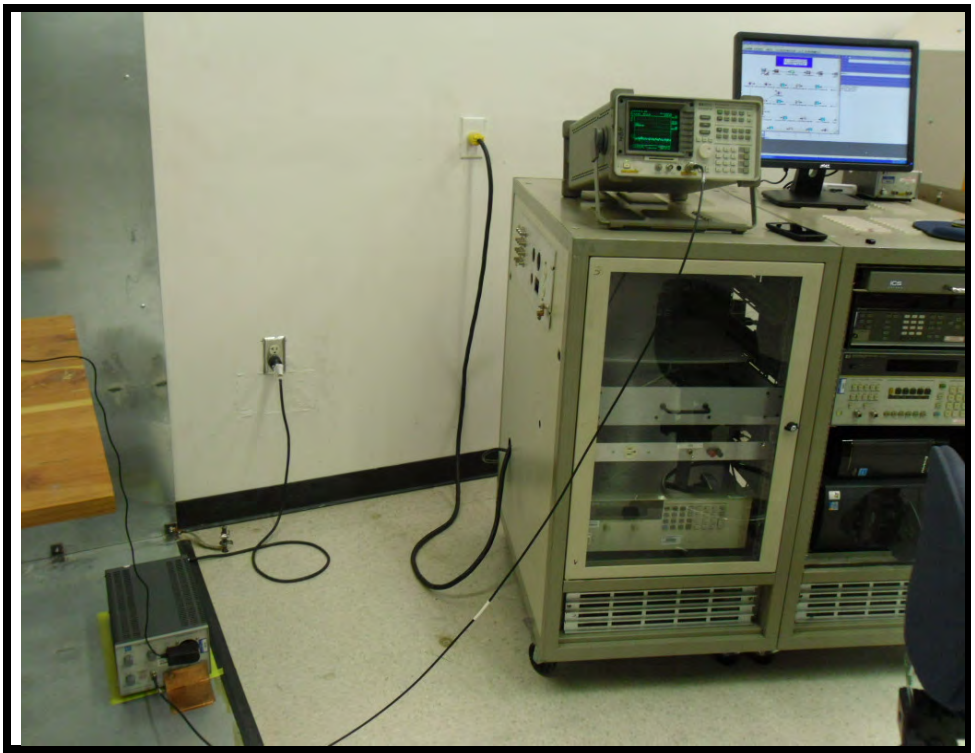
Test Setup Photo 1 – Conducted Emissions – Generator



Test Setup Photo 2 – Conducted Emissions - Generator



Test Setup Photo 3 – Conducted Emissions – Display Unit



Test Setup Photo 4 – Conducted Emissions – Display Unit

2. Radiated Emissions

Test Requirement(s):	§15.109	**Test Engineer(s):**	Keith T.
Test Results:	Pass	**Test Date(s):**	Nov/07/2016

Test Procedures:

The final radiated emissions test was performed using the parameters described above as worst case. That final test was conducted at a facility that meets the ANSI C63.4 TEM waveguides requirements. The frequency range noted in the data sheets was scanned/tested at that facility. Emissions were maximized as specified, by varying table azimuth and manipulating cables.

Using the mode of operation and configuration noted within this report, a final radiated emissions test was performed. The frequency range investigated (scanned), is also noted in this report. Radiated emissions measurements were made at the EUT azimuth such that the maximum radiated emissions level will be detected. This requires the use of a manipulator.

Tests were made with the EUT rotated on X,Y,Z planes to obtain the maximum signal strength. Though specified in the report, the measurement distance shall be 3 meters.

Frequency Range (MHz)	Peak Data (kHz)	Quasi-Peak Data (kHz)	Average Data (kHz)
30 MHz to 1 GHz	120 kHz	120 kHz	N/A
1 GHz to 11 GHz	1MHz	N/A	1MHz
Measurements were made using the bandwidths and detectors specified. The video filter was at least as wide as the IF bandwidth of the measuring receiver.			

Table 11. Radiated Emissions – Measurement Bandwidth

Emissions Tests Calculations

In the case of indoor measurements, radiated emissions measurements are made by the manipulation of correction factors using TILE software. This is done automatically by the software during the final measurement process.

In both cases, the level of the Field Strength of the interfering signal is calculated by adding the Antenna Factor, Cable Factor and by subtracting the Amplifier Gain from the measured reading. The basic equation is as follows:

FS = RA + AF + (CF –AG)

Where: FS = Field Strength

RA = Receiver (indicated) Amplitude

AF = Antenna Factor (GTEM Correlation)

CF = Cable Attenuation Factor

AG = Amplifier Gain

This laboratory uses an approach of combining the CF and AG using an end-to-end measurement of the entire cabling system, including the test cable, any in-line amplifiers, attenuators, or transient protection networks, all measured in-situ.

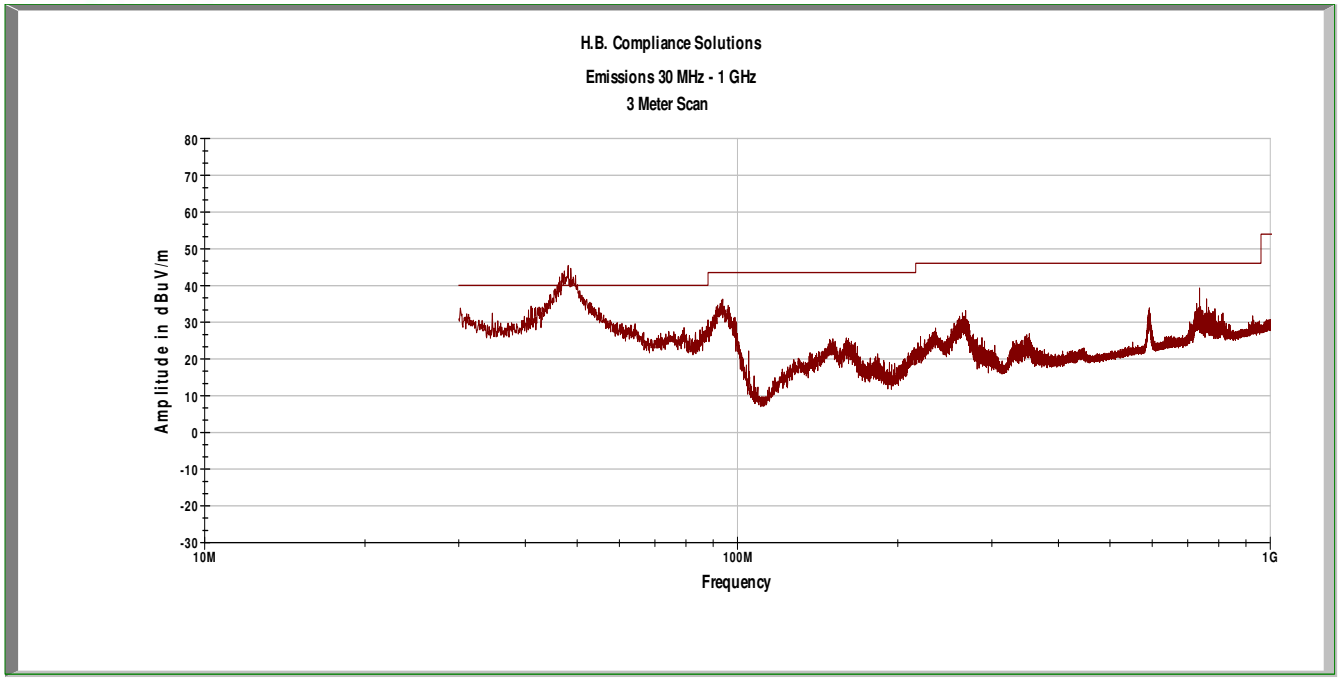
For a sample calculation, assume a receiver reading of 52.5 dBuV is obtained. With an antenna factor of 7.4 and a combined cable factor (CF + AG) of -27.9:

FS = 52.5 + 7.4 + (-27.9) = 32 dBuV/m

FS = 32 dBuV/m

If desired, this can be converted into its corresponding level in uV/m:

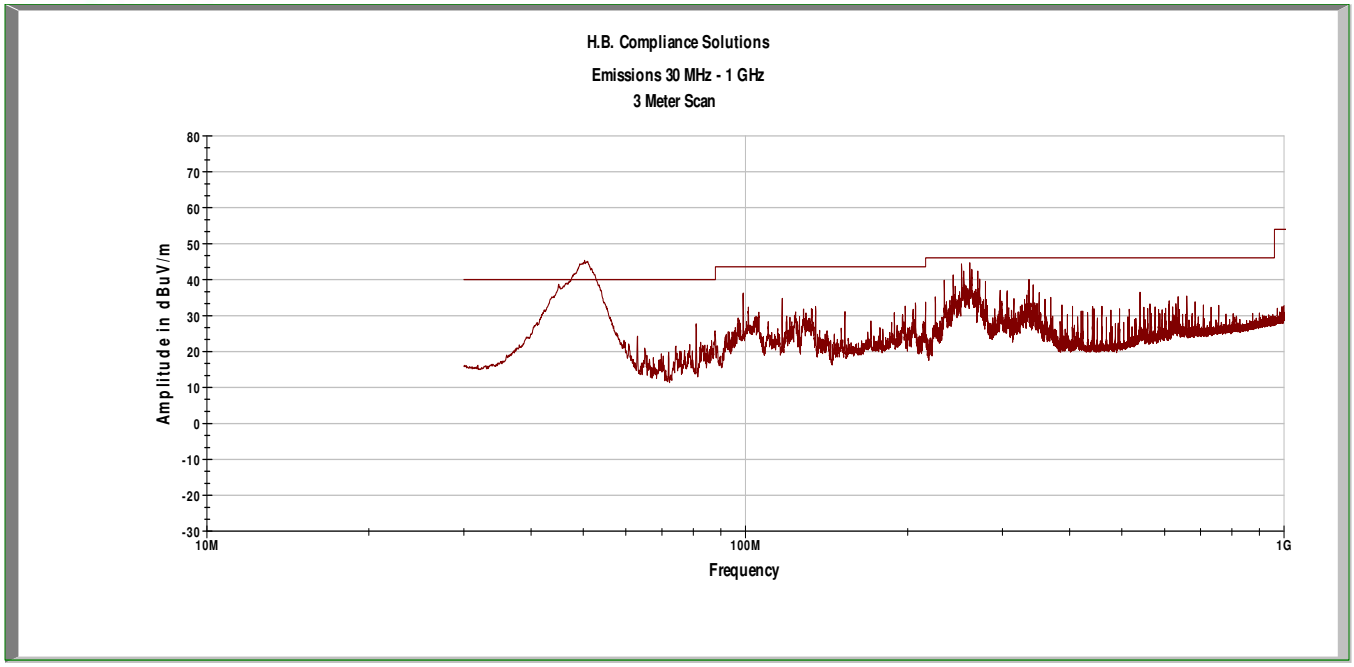
FS = 10^((32 dBuV/m)/20) = 39.8 uV/m



Plot 5 – Radiated Emissions – 30MHz to 1GHz (Class B) – Generator

Frequency (MHz)	Detector Used	Measured Level (dBuV/m)	Limit (dBuV)	Margin (dB)
48.10	QP	36.43	40.0	-3.57
93.30	Peak	36.04	40.0	-3.96
268.03	Peak	33.13	46.0	-12.87
592.72	Peak	33.78	46.0	-12.22
736.93	Peak	39.25	46.0	-6.75

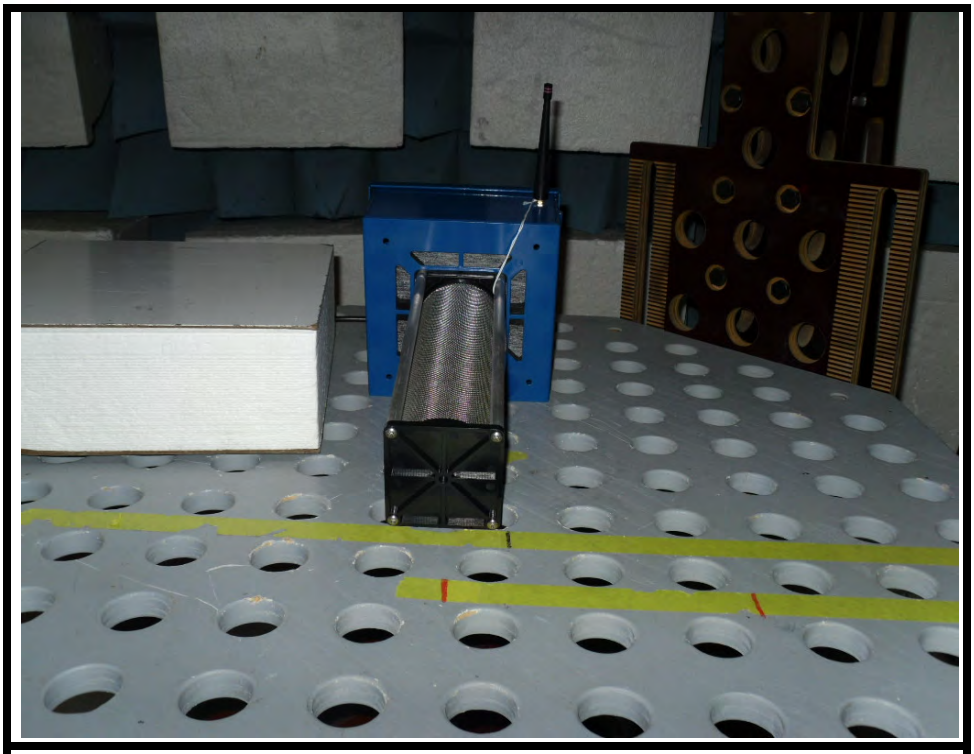
Table 12. Final Measurement Results for Radiated Emissions



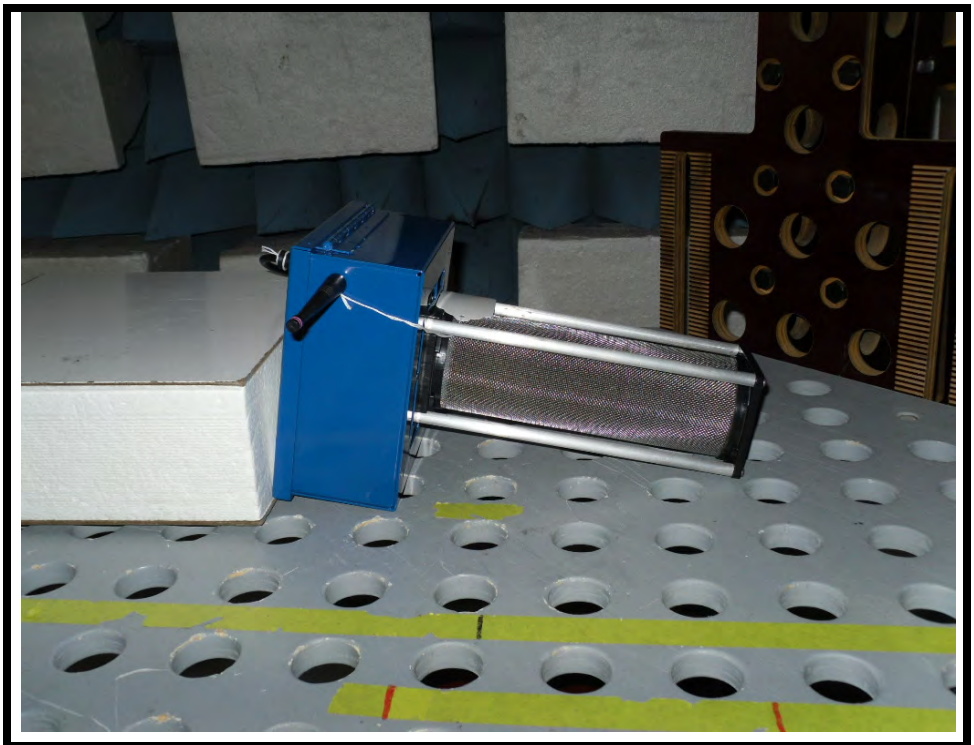
Plot 6 – Radiated Emissions – 30MHz to 1GHz (Class B) – Display Unit

Frequency (MHz)	Detector Used	Measured Level (dBuV/m)	Limit (dBuV)	Margin (dB)
50.24	QP	36.52	40.0	-3.48
99.06	Peak	36.23	40.0	-3.77
252.0	Peak	44.37	46.0	-1.63
260.98	Peak	44.61	46.0	-1.39
342.06	Peak	38.42	46.0	-7.58
540.02	Peak	36.47	46.0	-9.53

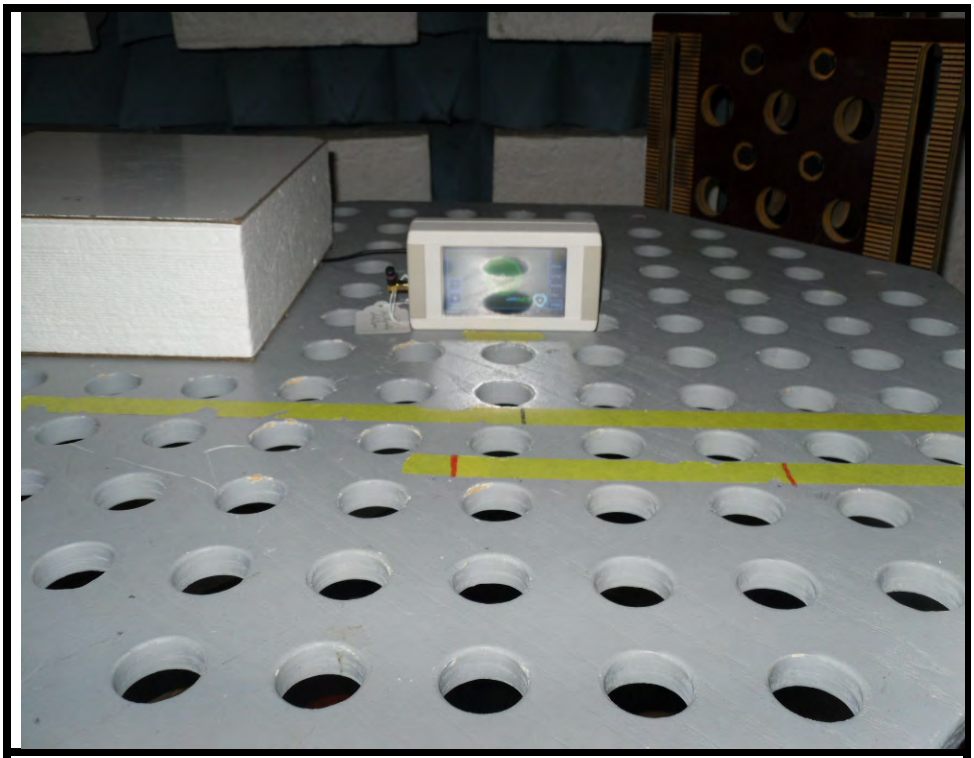
Table 13. Final Measurement Results for Radiated Emissions



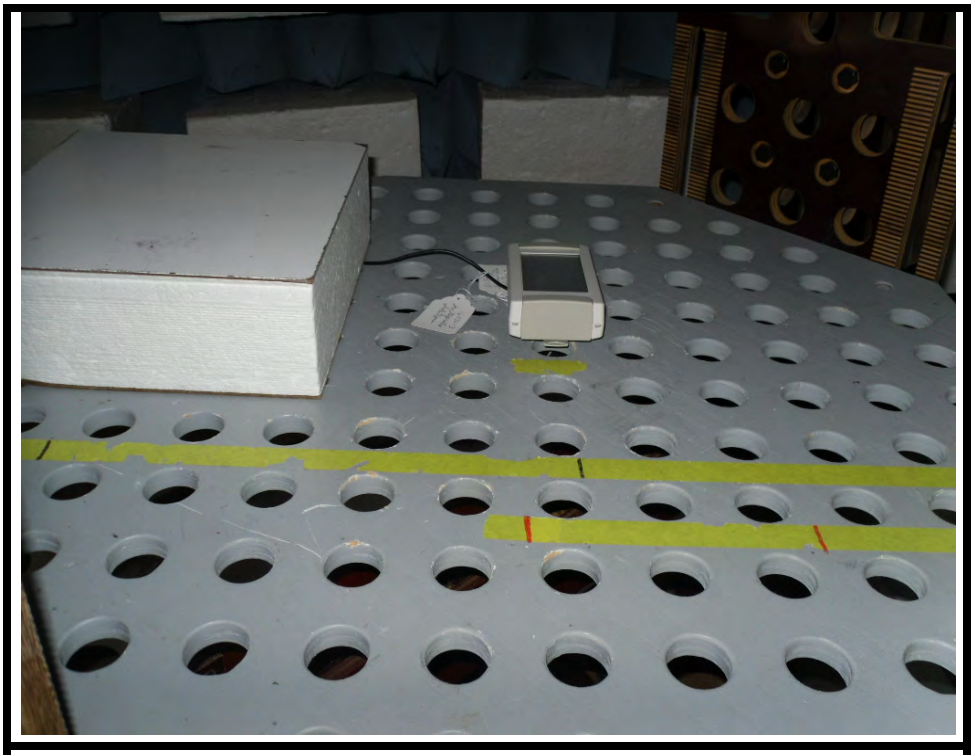
Test Setup Photo 5 – Radiated Emissions - Generator



Test Setup Photo 6 – Radiated Emissions - Generator



Test Setup Photo 7 – Radiated Emissions – Display Unit



Test Setup Photo 8 – Radiated Emissions – Display Unit

3. Test Equipment

Equipment	Manufacturer	Model	Serial #	Last Cal Date	Cal Due Date
EMI Receiver	Hewlett Packard	8568B	2314A02642	27-Apr-16	27-Apr-17
Spectrum Analyzer	Hewlett Packard	8595EM	3801A00177	21-Dec-15	21-Dec-16
Antenna	EMCO	GTEM 5417	1063	Verified	N/A
LISN	Laplace Instruments	LISN 1600	152946	19-Dec-15	19-Dec-16

Table 14 – Test Equipment List

***Statement of Traceability:** Test equipment is maintained and calibrated on a regular basis. All calibrations have been performed by a 17025 accredited test facility, traceable to National Institute of Standards and Technology (NIST)

15.105(b) Information to the User

(For Class B equipment only)

For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location **in the text of the manual**:

NOTE: This equipment has been tested and found to comply with the limits of Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.

- Increase the separation between the equipment and receiver.

- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

- Consult the dealer or an experienced radio/TV technician for help.

The applicant has been cautioned as to the following:

15.27(a) Special Accessories.

Equipment marketed to a consumer must be capable of complying with the necessary regulations in the configuration in which the equipment is marketed. Where special accessories, such as shielded cables and/or special connectors are required to enable an unintentional or intentional radiator to comply with the emission limits in this part, the equipment must be marketed with, i.e. shipped and sold with, those special accessories. However, in lieu of shipping or packaging the special accessories with the unintentional or intentional radiator, the responsible party may employ other methods of ensuring that the special accessories are provided to the consumer, without additional charge.

Information detailing any alternative method used to supply the special accessories for a grant of equipment authorization or retained in the verification records, as appropriate. The party responsible for the equipment, as detailed in § 2.909 of this chapter, shall ensure that these special accessories are provided with the equipment. The instruction manual for such devices shall include appropriate instructions on the first page of text concerned with the installation of the device that these special accessories must be used with the device. It is the responsibility of the user to use the needed special accessories supplied with the equipment.

47 CFR 15.19 Labeling requirements.

(b) Products subject to authorization under a Declaration of Conformity shall be labeled as follows:

(1) The label shall be located in a conspicuous location on the device and shall contain the unique identification described in §2.1074 of this chapter and the following logo:

(i) If the product is authorized based on testing of the product or system; or

Trade Name Model Number

Tested To Comply

With FCC Standards

FOR HOME OR OFFICE USE

(ii) If a personal computer is authorized based on assembly using separately authorized components, in accordance with §15.101(c)(2) or (c)(3) and the resulting product is not separately tested:

Trade Name Model Number

Assembled From

Tested Components

(Complete system not tested)

FOR HOME OR OFFICE USE

(2) Label text and information should be in a size of type large enough to be readily legible, consistent with the dimensions of the equipment and the label. However, the type size for the text is not required to be larger than eight point.

(3) When the device is so small to for such use that it is not practicable to place the statement specified under paragraph (b)(1) of this section on it, such as for CPU board or plug-in circuit board peripheral device, the text associated with the logo may be placed in a prominent location in the instruction manual or pamphlet supplied to the user. However, the unique identification (trade name and model number) and the logo must be displayed on the device.

(4) The Label shall not be a stick-on, paper label. The label shall be permanently affixed to the product and shall be readily visible to the purchaser at the time of purchase, as described in §2.2925(d) of this chapter. "Permanently affixed" means that the label is etched, engraved, stamped, silk-screened, indelibly printed, or otherwise permanently marked on a permanently attached part of the equipment or on a nameplate of metal, plastic, or other material fastened to the equipment by welding, riveting, or permanent adhesive. The label must be designed to last the expected lifetime of the equipment in the environment in which the equipment may be operated and must not be readily detachable.

END OF TEST REPORT

Perry Pauley
IONaer International
2021 W. Adobe Drive
Phoenix AZ 85027

Date: 2017/11/20
Subscriber: None
PartySite: 1823640
File No: R38991
Project No: 17SR4440098
PD No: 17M44471
Type: R
PO Number:

Subject: **Procedure And/Or Report Material**

The following material resulting from the investigation under the above numbers is enclosed.

Issue Date	Vol	Sec	Pages	Revised Date
	1		Revised Authorization Page(s)	2017/11/20
	1		Index Page(s)	
2017/10/31	1	1	Description Page(s)	

Resending revised Report/Procedure material to correct Issue Date for Documents of Project 4787673266.

MIGUEL HIDALGO, UL INSPECTION CENTER SOUTHWEST/PR AREA OFFICE, UL LLC, PO BOX 960367, EL PASO, TX, United States, 79996., PHONE: 1-915-449-1113, FAX: 847-513-7790, EMAIL: Miguel.Hidalgo@ul.com

Please file revised pages and illustrations in place of material of like identity. New material should be filed in its proper numerical order.

NOTE: Follow-Up Service Procedure revisions DO NOT include Cover Pages, Test Records and Conclusion Pages. Report revisions DO NOT include Authorization Pages, Indices, Section General Pages and Appendixes.

Please review this material and report any inaccuracies to UL's Customer Service Professionals. Contact information for all of UL's global offices can be found at http://ul.com/aboutul/locations.

If you'd like to receive updated materials FASTER, UL offers electronic access and/or delivery of this material. For more details, contact UL's Customer Service Professionals as shown above.

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NBK File

UL INSPECTION CENTER 812

FOLLOW-UP SERVICE PROCEDURE
(TYPE R)

ACCESSORIES, AIR-DUCT MOUNTED
(ABQK,ABQK7)

Manufacturer: SEE ADDENDUM FOR MANUFACTURER LOCATIONS

Applicant: 1613910 (Party Site)
IONAER INTERNATIONAL INC
4848 E Cactus Rd 505-103
Scottsdale AZ 85254

Listee/Classified Co.: 1613910 (Party Site)
SAME AS APPLICANT

This Follow-Up Service Procedure authorizes the above Manufacturer(s) to use the marking specified by UL LLC, or any authorized licensee of UL LLC, including the UL Contracting Party, only on products when constructed, tested and found to be in compliance with the requirements of this Follow-Up Service Procedure and in accordance with the terms of the applicable service agreement with UL Contracting Party and any applicable Service Terms. The UL Contracting Party for Follow-Up Services is listed on addendum to this Follow-Up Service Procedure ("UL Contracting Party"). UL Contracting Party and UL LLC are referred to jointly herein as "UL."

UL further defines responsibilities, duties and requirements for both Manufacturers and UL representatives in the document titled, "UL Mark Surveillance Requirements" that can be located at the following web-site: http://www.ul.com/fus and in the document titled "UL and Subscriber Responsibilities" that can be located at the following website: http://www.ul.com/responsibilities. Manufacturers without Internet access may obtain the current version of these documents from their local UL customer service representative or UL field representative. For assistance, or to obtain a paper copy of these documents or the applicable Service Terms, please contact UL's Customer Service at http://ul.com/aboutul/locations/, select a location and enter your request, or call the number listed for that location.

The Applicant, the specified Manufacturer(s) and any Listee/Classified Co. in this Follow-Up Service Procedure must agree to receive Follow-Up Services from UL Contracting Party. If your applicable agreement is a Global Services Agreement ("GSA") with an effective date of January 1, 2012 or later and this Follow-Up Service Procedure is issued on or after that effective date, the Applicant, the specified Manufacturer(s) and any Listee/Classified Co. will be bound to a Service Agreement for Follow-Up Services upon the earliest by any Subscriber of use of the prescribed UL Mark, acceptance of the factory inspection, or payment of the Follow-Up Service fees which will incorporate such GSA, this Follow-Up Service Procedure and the Follow-Up Service Terms which can be accessed by clicking here: http://www.ul.com/contracts/Terms-After-12-31-2011. In all other events, Follow-Up Services will be governed by and incorporate the terms of your applicable service agreement and this Follow-Up Service Procedure.

It is the responsibility of the Listee/Classified Co. to make sure that only the products meeting the aforementioned requirements bear the authorized Marks of UL LLC, or any authorized licensee of UL LLC.

This Follow-Up Service Procedure contains information for the use of the above Manufacturer(s) and representatives of UL and is not to be used for any other purpose. It is provided to the Manufacturer with the understanding that it will be returned upon request and is not to be copied in whole or in part.

This Follow-Up Service Procedure, and any subsequent revisions, is the property of UL and is not transferable. This Follow-Up Service Procedure contains confidential information for use only by the above named Manufacturer(s) and representatives of UL and is not to be used for any other purpose. It is provided to the Subscribers with the understanding that it is not to be copied, either wholly or in part unless specifically allowed, and that it will be returned to UL, upon request.

Capitalized terms used but not defined herein have the meanings set forth in the GSA and the applicable Service Terms or any other applicable UL service agreement.

UL shall not incur any obligation or liability for any loss, expense or damages, including incidental, consequential or punitive damages arising out of or in connection with the use or reliance upon this Follow-Up Service Procedure to anyone other than the above Manufacturer(s) as provided in the agreement between UL LLC or an authorized licensee of UL LLC, including UL Contracting Party, and the Manufacturer(s).

UL LLC has signed below solely in its capacity as the accredited entity to indicate that this Follow-Up Service Procedure is in compliance with the accreditation requirements.

Bruce A. Mahrenholz
Director
North American Certification Program

LOCATION

1823640 (Party Site)
IONaer International
2021 W. Adobe Drive
Phoenix AZ 85027

Factory ID: None

UL Contracting Party for above site is: UL LLC

DESCRIPTION

PRODUCT COVERED:

USL, CNL - Duct-Mounted Ionizing Air Cleaner, Models Ionaer 7000.

TECHNICAL CONSIDERATIONS (NOT FOR FIELD REPRESENTATIVE'S USE):

This equipment has been investigated from the standpoint of electrical, fire and casualty hazards only. Physiological nor health effects, beneficial or otherwise associated with the use of this product and its ability to aid in disinfection of environmental air have not been investigated by UL.

USL indicates investigation to the US standard for Heating and Cooling equipment UL 1995, and the US standard for Electrostatic Air Cleaners UL 867.

CNL indicates investigation to the Canadian standard for Heating and Cooling Equipment CSA C22.2 No. 236And the Canadian Standard for Electrostatic Air Cleaners, CSA C22.2 no. 187.

ELECTRICAL RATINGS:

120VAC, 0.25A, 60Hz
GENERAL CHARACTER AND USAGE:
The units described by this report are air ionization type devices intended for duct mounting in air conditioning plenum or duct systems in home and commercial facilities. The main purpose of the unit is for air purification and odor neutralization. The products include a High voltage power supply connected to an ionizing tube mounted to end up in the air stream. These units are cord connected and intended for indoor use only.
CONSTRUCTION DETAILS:

Nameplate Markings -

Each product is permanently and legibly marked on the outer enclosure by a Recognized(PGDQ2) or Recognized(PGJI2) adhesive label(s) suitable for the mounting surface with the following information:

1. The manufacturer's name or file number and Model designation.

2. Electrical ratings including voltage, current and frequency.

3. Date code or similar marking identifying at least the year and quarter of manufacture.
The month and year as the date code: 032017 as an example for March 2017.

4. Disclaimer Wording - "The health aspects associated with the use of this product and its ability to aid in disinfection of environmental air have not been investigated by UL LLC.". Located on the product and in the instruction manual.

Cautionary Markings- Printed on the same marking materials as the unit nameplate markings.

"CAUTION," And "WARNING" shall be in letters not less than 1/8 inch (3.2 mm) high. The remainder of the marking shall be in letters not less than 1/16 inch (1.6 mm) high.

The following Cautionary markings are required:

"Caution – High Voltage".

"WARNING: Risk Of Electric Shock. Can Cause Injury Or Death: Disconnect All Remote Electric Power Supplies Before Servicing".

Installation Instructions -

Installation Instructions shall be provided with each product and shall include the following wording grouped under the heading Safety Instructions:

> **"Caution: This product shall not be installed behind a suspended floor/ceiling or a structural wall, ceiling, or floor."**
> **"Caution: This product is suitable for mounting to duct of metallic construction only. Installation must be such that the structural integrity of the ducting is not compromised."**

Additionally the Installation instructions shall include the following wording:

> **Use Temperature - Maximum Ambient temperature in which unit shall be used: 180 degree F/ 82.2°C**

OUTER ENCLOSURE; MODEL Ionaer 7000, Figure 1 and 2

1. **Enclosure – Bent aluminum sheet metal approximately 0.08″ thick. Overall dimensions shown in ILL. 1.**

2. **Door - Bent aluminum sheet metal approximately 0.08″ thick. Fixed to the enclosure with a piano hinge spot welded to the door and enclosure. The door and enclosure are tied together by a green wire for grounding purposes.**

3. **Supply Cord Set - Listed (ELBZ) UL/CUL Type SJT min. no 18AWG, terminated in a molded 15A, 250V mounted plug. Between 6 and 10 feet long.**

4. **HVAC Relay Connector – Part of the low voltage, energy limiting communication circuit. A 4 pin Molex connector is used on the front of the unit. This unit is designed to generate ions only when the duct circulating fan is on. This connector receives a 24VDC signal to operate the duct fan.**

5. **Keyed Lock – This unit utilizes a keyed latch to provide protection against accessing the machine compartment.**

6. **LED indicators – 4 low voltage LED lights are located on the front panel door of the unit to indicate unit status. A status light diagnostic chart can be found in Ill. 2 within the unit manual.**

7. **Antenna – Unit utilizes a 2.4GHz antenna used to relay unit information to an outside source. (This unit has not been evaluated for EMC compatibility)**

8. **Media Filter – A steel mesh filter containing carbon granules is fitted around the ionizing assembly. This carbon filter is meant to limit the amount of ozone reaching downstream of the system. The filter is held in place by four stand-offs that are secured to the enclosure by bolts. A molded plastic end cap keeps the filter from sliding laterally and vertically out of place.**

IONIZING TUBE ASSEMBLY; MODEL Ionaer 7000, Figure 3 and 4

1. **Ionizer Tube – Glass tube 38mm x 200mm containing a perforated stainless steel sheet that is connected to the high voltage supply via a conducting coupler.**

2. **Mesh Screen – a stainless steel mesh screen is cut and wrapped around the Ionizer tube. A metal arm makes contact with the mesh screen which is connected to a ground pin on the PCB.**

3. **Plastic Coupler – R/C (QMFC2/8) Chi Mei Corp. PA-765. Approximately 1.75″ in diameter and 1/8″ thickness, rated 94-5V. The ionizer tube is attached to a plastic coupler that has a threaded connection in the base. The plastic coupler can be attached to the plastic base and high voltage current can be sent to the ionizer tube.**

4. **Plastic Base - R/C (QMFC2/8) Chi Mei Corp. PA-765 min. 5VA rated. Plastic base is 5″ x 5″ and approx. 5/16″ thick. The plastic base allows the ionizer tube and plastic coupler to be secured to the final assembly. High voltage connection is passed over the plastic base with stainless steel conductors and reaches the ionizer tube through a threaded connection.**

5. **End Cap - R/C (QMFC2/8) Chi Mei Corp. PA-765 min. 5VA rated. 3.25″ x 3.25″ and 0.25″ thick. This end cap is secured to the plastic base by metal standoffs and holds the media filter in place.**

   Engineering Note – All plastics in the Ionizing tube assembly tested per High Voltage Insulated Material Test.

INSIDE MACHINE COMPARTMENT; MODEL Ionaer 7000, Figure 5

This product utilizes a PCB that controls the ionizing function, powers the fan, displays unit status via LEDs and provides an on/off door switch. The Ionizing Tube assembly as described on page 4 is meant to be serviceable when the unit door is open. Four bolts secure the Ionizing Tube assembly to the frame of the Ionaer 7000 unit. A small DC muffin fan is secured to the Ionizing Tube assembly to provide circulation in the filter assembly.

1. **Circuit Board – R/C (ZPMV2) E321638, ETeknet ETK-1 PCB rated 94V-0, 130°C. Secured within the housing by standoffs. The measures 3 5/8″ in. wide by 5 7/8″ in. long. See Ill 2 for control board wiring diagram. Board is grounded by a bolt through the enclosure. Consists of the following high voltage components:**

   a. **Inlet Voltage Regulators – R/C (QQGQ2) E183223. PCB has 2 Mean Well SELV Switching Mode Power Supplies, Model IRM-20-12 rated 100-240Vac, 50/60hz input, 12Vdc, 1.8A, 21.6VA output, converts the line power into 12V 1.8A, and Model IRM-05-3.3 rated 100-240Vac, 50/60hz input, 3.3Vdc, 1.25A, 4.125VA output, converts into 3.3V 1.25A.**

   b. **Filter – R/C Epcos filter rated 250V 0.5A.**

   See Ill 3 for a full component list for this board.

2. **DC Fan Motor – R/C (GPWV2/8) Delta Electronics Inc. model QFR0812SH, thermally protected rated 12VDC, 0.50A. Fan is secured to the Ionizing Tube Assembly by 4 bolts. Wiring to the fan is routed to the control board and is held in place by tie downs to protect the wires from stress when opening and closing the door.**

3. **Appliance Inlet – This unit utilizes a R/C (AYVZ2/8) Schurter AG model 6200-23 grounding type attachment plug rated 250V, 10A that the power supply cord connects too. The attachment plug is secured to the enclosure by screws and the output leads connect to the circuit board by wires. The grounding lead is wired directly to the PCB board directly to a grounding stud.**

4. **Step Up Transformer – This transformer is rated 12VDC input, 6000V output. This transformer is driven by a pulse wave created by the circuit board. The transformer is mounted to the inside door of the unit adjacent to the PCB by a bolt. The output of this transformer is wired to the Ionizing Tube Assembly by means of a snap connector which allows it to generate ions to distribute to the airstream. See Figure 6 and Illustration 4. Consists of the following components:**

   a. **Magnet Wire – R/C (OBMW2/8) Shanghai Zhong Dian Enamelled Wire Co LTD Model UEW.**
   b. **Plastic Case Resin (acts as bobbin) – R/C (QMFZ2/8) BASF SE model B4406 G6 (o) Q113(1) rated for 23kV/mm minimum 94V-0 rated.**
   c. **Molded Case - R/C (QMFZ2/8) BASF SE model B4406 G6 (o) Q798**

   Engineering Note – This transformer acts like an ignition coil and requires a high frequency pulse to properly function.

Figures and Illustrations