ALL YOU NEED IS LUV!
(Idaho Mountain Express, 1/20/23)

introducing

the halō™

breathe clean and healthy indoor air

LUV Systems Inc.

- Continuously protect all your occupants from **airborne germs and allergens** all day long
- Enhance your ESG metrics - energy efficiency, indoor air security, carbon footprint, labor relations, health and wellness, inclusiveness for the vulnerable and responsible governance
- Show your affirmative commitment to the safety, health, and well-being of customers and staff
- **10X** better than any other approach to reduce health risk from infectious airborne pathogens
- The only proactive solution, with state-of-the-art directional airflow and rapid disinfection
- Proven SARS-CoV-2 99.9% kill rate by Boston University Medical BSL3/4 infectious disease lab, effective for ALL known respiratory pathogens
- Upper-air UVGI technology endorsed by The White House and leading infection control experts
- Airflow and spectrometry independently verified by Caltech/MIT physicists and engineers
- Proprietary aerospace-grade materials and coating; custom exterior colors/designs available
- Whisper-quiet and unobtrusive, aesthetic design
- Designed and manufactured locally, ships direct from our Gardena, California distribution center
- *Coverage:* up to 4,500 SF (> **20** ACH_e)
- *Warranty:* 5-year limited, excludes bulbs
- *Bulbs:* 254 nm, ~9,000 hour rated
- *O&M:* < $5/day, 500-650 W/120 V
- *Compliance:* Seismic Zone IV • UL 507 • FCC 47 • CSA 22.2#113-10 • ICES-005 • 2022 ACGIH TLVs

Breathe free!

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844-THE-HALŌ (844-843-4256) | https://www.luvsystems.com | backtobusiness@luvsystems.com

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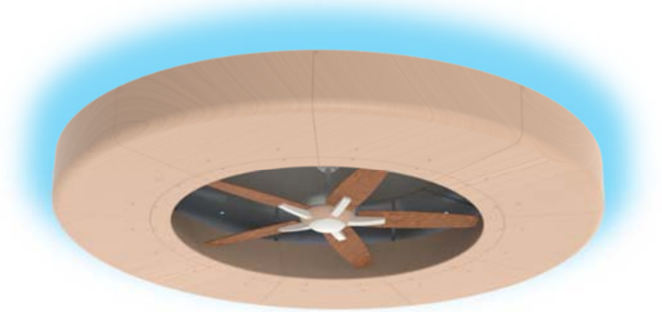

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Selected Literature


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EPC Western Plaza
18726 S. Western Avenue, Suite 407
Gardena, California 90248
844-THE-HALŌ (844-843-4256)
www.luvsystems.com
Systems Inc.
Anu Sood PE CPP
Founder & CEO
m 310-803-7280
anu@luvsystems.com
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best-in-class air disinfection system

CONTENTS

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THE WHITE HOUSE

BRIEFING ROOM

Let's Clear The Air On COVID

[and all respiratory pathogens!]

March 23, 2022 • OSTP BLOG

By Dr. Alondra Nelson, head of the White House Office of Science and Technology Policy and Deputy Assistant to the President

The most common way COVID-19 is transmitted from one person to another is through tiny airborne particles of the virus hanging in indoor air for minutes or hours after an infected person has been there. While there are various strategies for avoiding breathing that air – from remote work to masking – we can and should talk more about how to make indoor environments safer by filtering or cleaning air.

In fact, research shows changing the air in a room multiple times an hour with filtered or clean outdoor air – using a window fan, by using higher MERV filters in an Heating, Ventilation, and Air Conditioning (HVAC) system, using portable air cleaning devices, and even just opening a window – can reduce the risk of COVID-19 transmission – with studies showing five air changes an hour reduce transmission risk by 50 percent. [1,2] And, improving indoor air has benefits beyond COVID-19: it will reduce the risk of getting the flu, a common cold, or other diseases spread by air, and lead to better overall health outcomes.

The Biden-Harris Administration identified improved indoor air quality as an important tool to fight the spread of airborne diseases in the American Pandemic Preparedness Plan last September – and the National COVID-19 Preparedness Plan prioritized it again earlier this month. A number of Federal departments and agencies – including the White House Office of Science and Technology Policy (OSTP) – have worked together to launch the Clean Air in Buildings Challenge, a call to action for anyone who manages or maintains a building. As part of the launch, the Environmental Protection Agency released a practical guide for building managers, contractors, homeowners, and business owners to create an action plan for cleaner indoor air.

Now, we all need to work collectively to make our friends, family, neighbors, and coworkers aware of what we can do or ask for to make being indoors together safer. Each of us has a set of simple but powerful actions we can use to bring clean air into the rooms we're in and clean the air already in the room.

Here are the basics:

- Ventilation: Bringing in clean outdoor air is key. Indoor air moves less than outdoor air, so virus particles hang in the air in greater concentrations. Ventilation strategies that bring in more outdoor air can disperse viral particles and lower the risk of people inhaling them or getting infected through their eyes, nose, or mouth. Fans and HVAC systems can help make open windows more effective by pulling in clean outdoor air, and can send clean air into rooms without windows or good ventilation. New buildings are often constructed to seal air in for energy efficiency, so their HVAC systems must be on or their windows opened to clear the air. Older buildings may be less well sealed, but have outdated air handling systems or lack them altogether. An HVAC expert can help with this; more resources are available here.
- Air filtration: Using high-quality air filters like HEPA or MERV-13 – connected to capable HVAC systems or portable air purifiers – to remove virus particles from indoor air is also important. Filtration is a great tool to supplement ventilation or to use if adequate ventilation isn't possible – for example, if extreme temperatures, wildfire smoke, or outdoor pollution make you not want to open a window. And we need filtration equipment more than we might think: many schools, workplaces, hotels, and homes have windows that do not open at all. Many Americans and small businesses cannot afford major HVAC upgrades. While all of us can benefit, many Americans have health vulnerabilities and need the extra protection of having cleaner air. In all these cases, portable air cleaning devices with powerful fans – as powerful as a box fan you could buy at a store – can make a big difference in reducing virus particles in the air. HEPA filters, for instance, are at least 99.97% efficient at capturing human-generated viral particles associated with COVID-19. As a temporary measure, there are affordable and effective DIY options, including the four-filter-plus-box-fan cube called the Corsi-Rosenthal box.
- Air disinfection: By inactivating ("killing") airborne virus through methods like ultraviolet germicidal irradiation (UVGI) systems, we can add another layer of protection in indoor spaces. The latest technology in these UV lights is particularly useful in crowded areas with poor airflow, in healthcare settings with vulnerable populations (such as hospitals or nursing homes), or in areas like restaurants where people aren't wearing masks because they're eating and drinking. For instance, one study demonstrated that when used with proper ventilation, UVGI is about 80% effective against the spread of airborne tuberculosis, equivalent to replacing the air in an indoor room up to 24 times in an hour. [3] However, there are some challenges to doing this widely, and more research and innovation is needed to develop UVGI systems that are more affordable, standardized, and consume less energy.

Used along with layered prevention strategies recommended by Centers for Disease Control and Prevention and others, improving indoor air quality is a critical part of a plan to better protect us all. But it will not by itself eliminate the risk of infection: the best way to protect yourself against COVID-19 is to get vaccinated and boosted.

For decades, Americans have demanded that clean water flow from our taps and pollution limits be placed on our smokestacks and tailpipes. It is time for healthy and clean indoor air to also become an expectation for us all. Clean and healthy indoor air is a fundamental commitment we must make to our children, to workers, to those who are medically vulnerable, and to every person in the country.

Now we're making it possible: Federal funds and resources are available to support improvements in ventilation, filtration, and clean indoor air – the American Rescue Plan has $122 billion for schools and $350 billion for state, local, and Tribal governments, which can support upgrades to their local businesses, nonprofits, community centers, and other commercial and public establishments. Additionally, the Bipartisan Infrastructure Law provides billions of dollars to our communities to support people's health and safety in new or upgraded airports, transportation hubs, low-income housing, schools, and other buildings.

I am pleased to announce next we will be bringing experts from the fields of public health, the social sciences, engineering, and journalism together at a virtual White House event to learn more. Register here to join Let's Clear the Air on COVID, which will kick off at 12:30pm on March 29th.

Scientific and public health evidence supports practical, actionable solutions for cleaner indoor air. It is time for a national conversation on how better indoor air quality can help us all live healthier lives.

[1] Rothamer, D.A., et al. Strategies to minimize SARS-CoV-2 transmission in classroom settings: combined impacts of ventilation and mask effective filtration efficiency. *Science and Technology for the Built Environment*, 27:9, 1181-1203 (2021). https://www.tandfonline.com/doi/full/10.1080/23744731.2021.1944665

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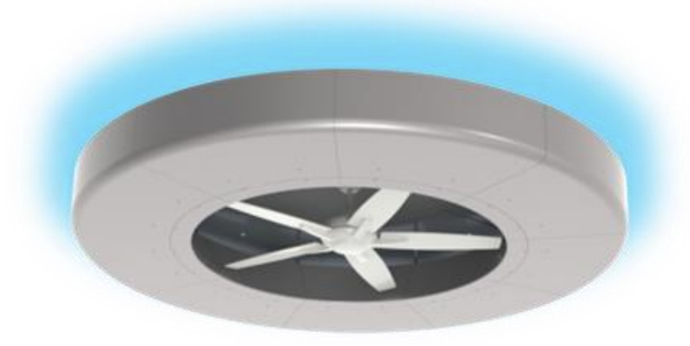

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Technical Specifications

Model: 5R/M

Safety & Efficacy

- Close-range (< 6 ft) and long-term (> 8 hr) protection, effective for ALL known respiratory pathogens
- Proven 99.9% SARS-CoV-2 kill rate by Boston University Medical infectious disease laboratory
- Verified > 2,000+ CFM for breathing zone control
- Average germicidal dose (per pass): > 2.0 mJ/cm^2 in air
- Airborne Pathogen Mitigation Index (APMI): [1] > 9.5/10
- Equivalent Air Changes/Hour (ACH_e): > 20
- Safety compliance with UL 507/Clause 223.2 and CSA 22.2#113-18; FCC 47 and ICES-005; 2022 ACGIH TLVs

Capacity

- Coverage area: 800 to 4,500 sq ft
- Multiple units for larger spaces
- Ceiling height: 9 ft minimum, no maximum
- Lateral room dimensions: 15 ft minimum

Power

- On/off: Wall switch, optional motion detection for automatic operation
- Total consumption: 500-650 W
- Supply: 120 V, standard 15 A breaker

[1] The dimensionless APMI, or Airborne Pathogen Mitigation Index ranges from 0 to 10, with 0 representing the least protection (e.g., no mitigation) and 10 representing the highest protection from cross-transmission risk of respiratory infection. For more information and a comparison to other mitigation measures, please see the LUV Systems' paper, *Preventing Respiratory Infections: A unified dose model and IAQ risk assessment tool*.

Lights

- 254 nm fluorescent/germicidal (Low-UVC) bulbs
- Certified ozone-free
- Low-UVC flux (combined): 97-153 W, contained
- Rated bulb life: 9,000 hr

Upflow Fan

- Brushless DC motor
- Blade color: White [2]
- Programmed fan modulation
- Air dynamics optimized for maximum breathing zone control and effective halō residence time
- Gentle airflow < 1 ft/sec in occupied areas
- Whisper-quiet operation
- Blade diameter: 60 in

Construction

- Fabricated to aerospace-grade specifications
- Proprietary low-UVC absorbing internal coating
- Exterior colors: [2] Alabaster | Angelic White | Taupe | Ash
- Exterior finish: Satin
- Overall dimensions: 8.8 ft diameter x 1.6 ft height
- Weight: 350 lb
- Warranty: 5-year limited, excludes bulbs

Mounting

- Compatible with wood frame, concrete, and drop ceilings
- Complies with California building code, Seismic Zone IV

[2] Please inquire for custom colors/designs.

230216

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US011305031B2

(12) **United States Patent**
Sood et al.

(10) **Patent No.: US 11,305,031 B2**
(45) **Date of Patent: Apr. 19, 2022**

(54) **ULTRAVIOLET PATHOGEN DISINFECTION SYSTEM**

(71) Applicant: **Sood, Seth, Khatri & Chaudhary LLC**, Rancho Palos Verdes, CA (US)

(72) Inventors: **Anurag Sood**, Rancho Palos Verdes, CA (US); **Neeraj R. Chaudhary**, Fremont, CA (US); **Sandeep Seth**, Houston, TX (US); **Danish S. Khatri**, Redondo Beach, CA (US)

(73) Assignee: **Sood, Seth, Khatri & Chaudhary LLC**, Rancho Palos Verdes, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/240,953**

(22) Filed: **Apr. 26, 2021**

(65) **Prior Publication Data**

US 2022/0008596 A1 Jan. 13, 2022

Related U.S. Application Data

(63) Continuation of application No. 17/164,605, filed on Feb. 1, 2021, which is a continuation-in-part of (Continued)

(51) **Int. Cl.**
A61L 9/20 (2006.01)
A61L 9/03 (2006.01)

(52) **U.S. Cl.**
CPC ***A61L 9/032*** (2013.01); ***A61L 9/20*** (2013.01); *A61L 2209/111* (2013.01); *A61L 2209/14* (2013.01); *A61L 2209/15* (2013.01)

(58) **Field of Classification Search**
CPC . A61L 9/015; A61L 9/032; A61L 9/12; A61L 9/112; A61L 9/16; A61L 9/18;
(Continued)

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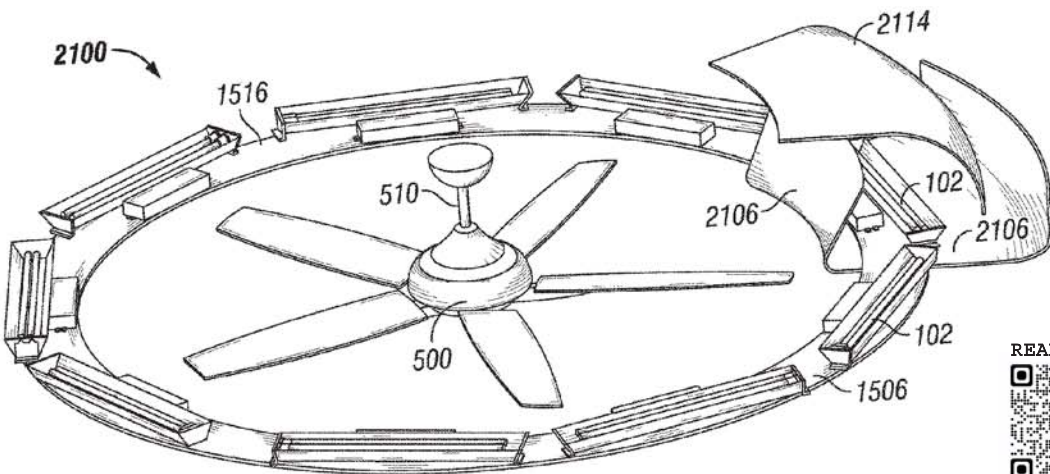
Primary Examiner — Timothy C Cleveland
(74) *Attorney, Agent, or Firm* — C. Tumey Law Group PLLC

(57) **ABSTRACT**

An air treatment system includes a lower cowling configured to be suspended from a ceiling, the lower cowling defining an interior lower cowling surface and configured to be disposable radially outward from and around a fan configured to induce airflow. Further, the air treatment system includes an upper cowling configured to be disposed vertically above the lower cowling and define an interior upper cowling surface. A gap between the interior upper cowling surface and the interior lower cowling surface forms a fluid passageway comprising an intake opening, an exhaust opening, and a chamber. The fluid passageway is contoured to receive airflow from the fan via the intake opening and direct the airflow through the chamber to exit the exhaust opening. Moreover, the air treatment system includes at least one air treatment device secured within the chamber, the air treatment device configured to treat air passing through the chamber.

29 Claims, 30 Drawing Sheets



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Statement 24H. The system of claim 23H, wherein the ceiling plate is secured to the airflow redirector.

Statement 25H. The system of claim 22H, wherein the fan is configured to automatically modulate between a lower fan speed and an upper fan speed.

In the above description of various embodiments of present inventive concepts, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of present inventive concepts. Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which present inventive concepts belong. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

When an element is referred to as being "connected", "coupled", "responsive", or variants thereof to another element, it can be directly connected, coupled, or responsive to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected", "directly coupled", "directly responsive", or variants thereof to another element, there are no intervening elements present. Like numbers refer to like elements throughout. Furthermore, "coupled", "connected", "responsive", or variants thereof as used herein may include wirelessly coupled, connected, or responsive. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Well-known functions or constructions may not be described in detail for brevity and/or clarity. The term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that although the terms first, second, third, etc. may be used herein to describe various elements/operations, these elements/operations should not be limited by these terms. These terms are only used to distinguish one element/operation from another element/operation. Thus, a first element/operation in some embodiments could be termed a second element/operation in other embodiments without departing from the teachings of present inventive concepts. The same reference numerals or the same reference designators denote the same or similar elements throughout the specification.

As used herein, the terms "comprise", "comprising", "comprises", "include", "including", "includes", "have", "has", "having", or variants thereof are open-ended, and include one or more stated features, integers, elements, steps, components or functions but does not preclude the presence or addition of one or more other features, integers, elements, steps, components, functions or groups thereof.

Although several embodiments of inventive concepts have been disclosed in the foregoing specification, it is understood that many modifications and other embodiments of inventive concepts will come to mind to which inventive concepts pertain, having the benefit of teachings presented in the foregoing description and associated drawings. It is thus understood that inventive concepts are not limited to the specific embodiments disclosed hereinabove, and that many modifications and other embodiments are intended to be included within the scope of the appended claims. It is further envisioned that features from one embodiment may be combined or used with the features from a different embodiment(s) described herein. Moreover, although specific terms are employed herein, as well as in the claims which follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described inventive concepts, nor the claims which follow. The entire disclosure of each patent and patent publication cited herein is incorporated by reference herein in its entirety, as if each such patent or publication were individually incorporated by reference herein. Various features and/or potential advantages of inventive concepts are set forth in the following claims.

What is claimed is:

1. An air treatment system, comprising:

a lower cowling configured to be suspended from a ceiling, the lower cowling defining an interior lower cowling surface and configured to be disposable radially outward from and around a fan suspended from the ceiling that is configured to induce airflow in an upward direction toward the ceiling, in a radially outward direction, or some combination thereof;

an upper cowling configured to be disposed vertically above the lower cowling and define an interior upper cowling surface, wherein a gap between the interior upper cowling surface and the interior lower cowling surface forms a fluid passageway comprising an intake opening, an exhaust opening, and a chamber, and wherein the fluid passageway is contoured to receive airflow from the fan via the intake opening and direct the airflow through the chamber to exit the exhaust opening, wherein the exhaust opening is disposed radially outward from a blade of the fan; and

at least one air treatment device secured within the chamber, the air treatment device configured to treat air passing through the chamber.

2. The system of claim **1**, wherein the air treatment device comprises a plurality of UV light sources arranged inside the chamber at spaced apart positions around the fan.

3. The system of claim **1**, wherein the air treatment device comprises a pathogen disinfection system, a heating system, a cooling system, an ionization system, a filtration system, a humidity control system, an ozone control system, or some combination thereof.

4. The system of claim **1**, further comprising a base configured to be suspended from a ceiling via at least one connection element, wherein a first side of the base is disposable radially outward from the fan, wherein the base comprises a plurality of base segments, wherein adjacent base segments are joined via mounting plates to form a contiguous support around the fan, and wherein the base supports the at least one air treatment device.

5. The system of claim **4**, further comprising at least one stabilizing rod configured to secure the upper cowling to the base, wherein the at least one stabilizing rod comprises a first end connected to the base and a second end connected to the upper cowling.

6. The system of claim **1**, wherein the lower cowling comprises:

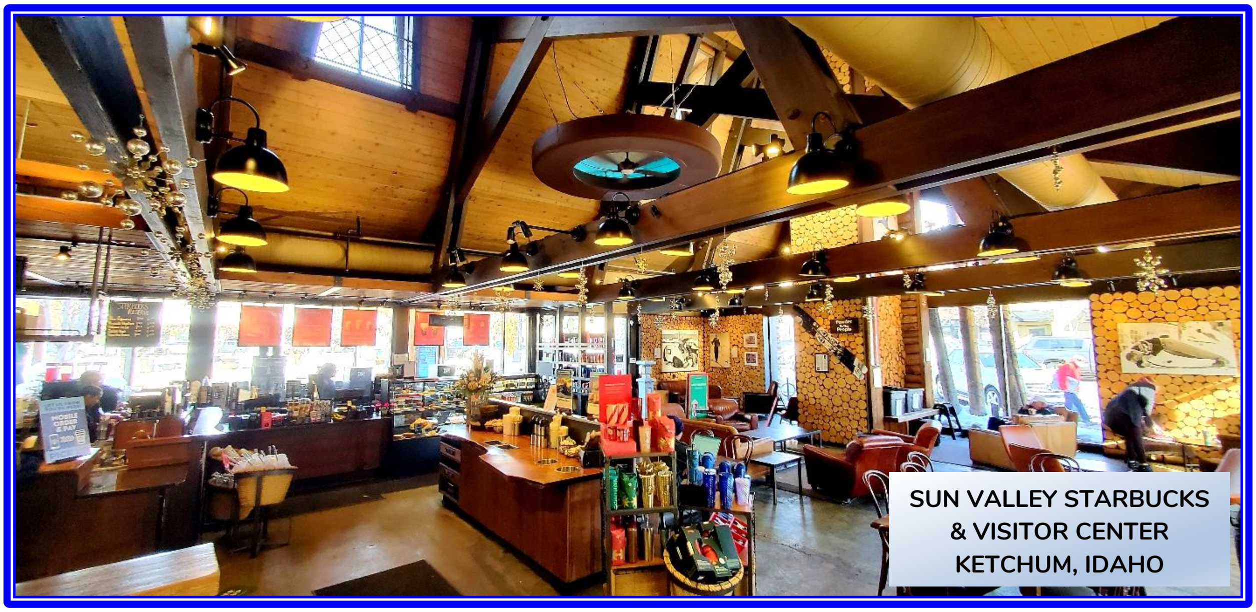
a middle portion;

an inner lip positioned radially inward from the middle portion and extending upward from the middle portion; and

an outer lip positioned radially outward from the middle portion and extending upward from the middle portion.

7. The system of claim **6**, wherein the inner lip extends upward from the middle portion by an amount at least two times greater than an amount that the outer lip extends vertically upward from the middle portion, and wherein the

Preventing respiratory infections:
A unified dose model and IAQ risk assessment tool



by Anu Sood, PE, CPP
Founder and CEO

LUV Systems, Inc.
EPC Western Plaza
18726 South Western Avenue #407
Gardena, CA 90248
LuvSystems.com
844-THE-HALŌ (844-843-4256)

Issue Date: February 22, 2022

TRANSPARENCY NOTICE: This document and supporting research are wholly funded by LUV Systems, Inc., which is presently designing low-UVC consumer and commercial disinfection products. If there is any concern that this could be a potential financial or other conflict-of-interest, please be assured that our primary objective in these efforts is to develop and introduce safe, effective, and reliable disinfection products to the marketplace.

LUV Systems, Inc.

EPC Western Plaza
18726 South Western Avenue, Suite 407
Gardena, California 90248
844-THE-HALŌ (844-843-4256)
www.luvsystems.com

MICROORGANISM LOW-UVC SUSCEPTIBILITY FACTORS

Ultraviolet light from the sun is the primary germicide in the outdoor environment. [1] For healthy indoor air quality, active airflow and circulation may be combined with an effective dose of low-UVC disinfection. The effective dose is based on microorganism susceptibility to low-UVC. Assuming first-order rate constant and kinetics: [2]

$$C(t) = C_0 e^{-Kd(t)}$$

where $C(t)$ is the concentration of active microorganisms surviving after low-UVC exposure, C_0 is the initial concentration, K is the microorganism susceptibility factor (m^2/J), and d(t) is the delivered low-UVC dose (J/m^2; light intensity multiplied by exposure time t). Various documented 254 nm low-UVC K factors are provided below:

Microorganism *	Type	K, m^2/J
SARS-CoV-2 (COVID-19) (agar)	**Virus**	**0.098-0.23**
MS2 (agar/aerosol)	**Virus**	**0.099-0.56**
phi X174 (agar/aerosol)	**Virus**	**0.099-0.56**
Influenza A (aerosol)	**Virus**	**0.26**
H1N1 (aerosol)	**Virus**	**0.26**
phi 6 (aerosol)	**Virus**	**0.31**
T7 (aerosol)	**Virus**	**0.31**
Adenovirus (aerosol) [3]	Virus	0.18-0.25
Coxsackie B-1 (aerosol) [3]	Virus	0.38-0.39
Influenza A (aerosol) [3]	Virus	0.36-0.68
Sindbis (aerosol) [3]	Virus	0.28-0.35
Vaccinia (aerosol; pox surrogate) [3]	Virus	0.47-0.81
Measles [4]	Virus	0.11
Vaccinia (pox surrogate) [4]	Virus	0.003-0.3
Smallpox (predicted) [4]	Virus	0.1
Monkeypox (predicted) [4]	Virus	0.1
Rhinovirus B/C (predicted) [4]	Virus	0.04-0.05
Hepatitis A	Virus	0.032
Polio virus	Virus	0.040
Rotavirus	Virus	0.028
Bacillus anthracis	Bacteria	0.051
B. megatherium sp. (spores)	Bacteria	0.084
B. megatherium sp. (veg)	Bacteria	0.178
Campylobacter jeluni	Bacteria	0.209
Clostridlum tetani	Bacteria	0.019
Corynebacterium diphteriae	Bacteria	0.069
Dysentery bacilli	Bacteria	0.105
Eberthella typhosa	Bacteria	0.108
Escherichia coli	Bacteria	0.077
Klebsiella terrifani	Bacteria	0.089
Legionella pneumophila	Bacteria	0.256

Microorganism *	Type	K, m^2/J
Mycrobacterium tuberculosis	Bacteria	0.038
Neisseria catarrhalis	Bacteria	0.053
Phytomonas tumefaciens	Bacteria	0.053
Pseudomonas aerugionosa	Bacteria	0.042
Pseudomonas flourescens	Bacteria	0.065
Proteus vulgaris	Bacteria	0.086
Salmonella enteritidis	Bacteria	0.058
Salmonella paratyphi	Bacteria	0.072
Salmonella typhimurium	Bacteria	0.029
Sarcina lutea	Bacteria	0.012
Seratia marcescens	Bacteria	0.095
Shigella paradysenteriae	Bacteria	0.141
Staphylococcus albus	Bacteria	0.126
Staphylococcus aureus	Bacteria	0.086
Streptococcus faecalis	Bacteria	0.052
Streptococcus hemoluticus	Bacteria	0.106
Streptococcus lactus	Bacteria	0.037
Streptococcus viridans	Bacteria	0.115
Yersinia enterocolitica	Bacteria	0.209
Bakers' yeast	Yeast	0.060
Brewers' yeast	Yeast	0.070
Common yeast cake	Yeast	0.038
Saccharomyces sp.	Yeast	0.029
Aspergillus glaucus	Mold	0.004
Mucor racemosus A	Mold	0.013
Oospora lactis	Mold	0.046
Penicillium expansum	Mold	0.018
Penicillium roqueford	Mold	0.018
Rhizopus nigricans	Mold	0.002
Cryptosporidium parvum	Protozoa	0.092
Giardia lamblia	Protozoa	0.209

* Higher K values mean more susceptible. **Bold entries with shaded cells** are from Table 6 in *Preventing respiratory infections: A unified dose model and IAQ risk assessment tool* by LUV Systems, Inc. (February 2022). Except for those notated with footnotes [3] and [4], all others are from Section 2.2 in *Ultraviolet purification application information* by Koninklijke Philips Electronics N.V. (November 2006). K values that are provided as ranges represent different doses or substrates including aerosols or various surfaces. As the substrate can significantly affect microorganism susceptibility to low-UVC light (due to shielding), it is noted the Philips reference does not identify the substrate associated with each K value. This is an important qualifier as the measured dose is not necessarily the same as the dose physically received by a given pathogen.

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scientific reports

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Rapid and complete inactivation of SARS-CoV-2 by ultraviolet-C irradiation

Nadia Storm[1,4], Lindsay G. A. McKay[1,4], Sierra N. Downs[1], Rebecca I. Johnson[1], Dagnachew Birru[2], Marc de Samber[3], Walter Willaert[3], Giovanni Cennini[3] & Anthony Griffiths[1]✉

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has devastated global public health systems and economies, with over 52 million people infected, millions of jobs and businesses lost, and more than 1 million deaths recorded to date. Contact with surfaces contaminated with droplets generated by infected persons through exhaling, talking, coughing and sneezing is a major driver of SARS-CoV-2 transmission, with the virus being able to survive on surfaces for extended periods of time. To interrupt these chains of transmission, there is an urgent need for devices that can be deployed to inactivate the virus on both recently and existing contaminated surfaces. Here, we describe the inactivation of SARS-CoV-2 in both wet and dry format using radiation generated by a commercially available Signify ultraviolet (UV)-C light source at 254 nm. We show that for contaminated surfaces, only seconds of exposure is required for complete inactivation, allowing for easy implementation in decontamination workflows.

Towards the end of 2019, an outbreak of life-threatening pneumonia caused by a novel betacoronavirus occurred in the Hubei Province of China[1]. The virus, named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has since spread across the world at an alarming rate to cause a debilitating and ongoing pandemic, with only a few islands not reporting any cases to date. While SARS-CoV-2 is thought to be of zoonotic origin[2], intense and extensive human-to-human transmission has mainly been driven by the inhalation of respiratory droplets and virus-bearing particles spread through the air[3], or by contact with surfaces contaminated with settled droplets[4]. Although academic institutions and pharmaceutical organizations worldwide have banded together to develop countermeasures against the virus, there are still no licensed vaccines or therapeutics available. The disruption of transmission chains is therefore crucial for managing the outbreak and preventing additional infections.

Ultraviolet (UV) irradiation is an extensively tested, widely used and effective no-contact method for inactivating viral pathogens[5–7]. There are three types of UV, including UV-A (315–400 nm), UV-B (280–315 nm) and UV-C (100–280 nm), of which UV-C is most commonly employed in germicidal applications. At a wavelength of 254 nm, viral inactivation can be attributed to direct UV-C light absorption and photochemical damage to nucleic acid, leading to the disruption of viral replication[8]. Despite its wide use, limited data exists on the effectiveness of UV-C on inactivating wet and dried SARS-CoV-2 on contaminated surfaces. In particular, the efficacy of UV-C for inactivating SARS-CoV-2 in fluids needs to be determined, as the UV absorbance characteristics of fluid constituents may influence the dose required to achieve complete viral inactivation.

In this paper, we describe the complete and rapid inactivation of SARS-CoV-2 in both wet and dried droplets using 254 nm UV-C irradiation. Our results suggest that UV-C is an affordable and effective tool for preventing SARS-CoV-2 contact transmission that can easily be deployed to manage the coronavirus disease outbreak.

Results and discussion

Estimation of viral decay time. To examine the inactivation efficacy of UV-C on SARS-CoV-2, virus was applied to plastic tissue culture dishes and exposed to UV radiation as either wet or dried droplets for varying amounts of time ranging from 0.8 to 120 s. Under a UV-C irradiance of 0.849 mW/cm^2, partial inactivation

[1]National Emerging Infectious Diseases Laboratories, Boston University School of Medicine, 620 Albany Street, Boston, MA 02118, USA. [2]Signify Research, 1 Charles Park, 2nd Fl, Cambridge, MA 02142, USA. [3]Signify Research, High Tech Campus 7, 5656 AE Eindhoven, the Netherlands. [4]These authors contributed equally: Nadia Storm and Lindsay G. A. McKay. ✉email: ahgriff@bu.edu

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Photochemistry and Photobiology, 20**, **: *–*

Special Issue Invited Review

Air Disinfection for Airborne Infection Control with a Focus on COVID-19: Why Germicidal UV is Essential†

Edward A. Nardell*

Division of Global Health Equity, Brigham & Women's Hospital, Harvard Medical School, Boston, MA,

Received 7 January 2021, accepted 16 March 2021, DOI: 10.1111/php.13421

ABSTRACT

Aerosol transmission is now widely accepted as the principal way that COVID-19 is spread, as has the importance of ventilation—natural and mechanical. But in other than healthcare facilities, mechanical ventilation is designed for comfort, not airborne infection control, and cannot achieve the 6 to 12 room air changes per hour recommended for airborne infection control. More efficient air filters have been recommended in ventilation ducts despite a lack of convincing evidence that SARS-CoV-2 virus spreads through ventilation systems. Most transmission appears to occur in rooms where both an infectious source COVID-19 case and other susceptible occupants share the same air. Only two established room-based technologies are available to supplement mechanical ventilation: portable room air cleaners and upper room germicidal UV air disinfection. Portable room air cleaners can be effective, but performance is limited by their clean air delivery rate relative to room volume. SARS-CoV-2 is highly susceptible to GUV, an 80-year-old technology that has been shown to safely, quietly, effectively and economically produce the equivalent of 10 to 20 or more air changes per hour under real life conditions. For these reasons, upper room GUV is the essential engineering intervention for reducing COVID-19 spread.

INTRODUCTION

It is not an exaggeration to claim that the most effective, evidence-based, cost-effective, safe and available engineering intervention to disinfect air is being largely ignored during a lethal viral pandemic spread predominantly by the airborne route. That intervention is germicidal ultraviolet (GUV) air disinfection (1).

Given the current COVID-19 pandemic, this perspective will focus on SARS-CoV-2 virus transmission, but GUV is effective against all known microbial pathogens (2). GUV is widely used for potable water disinfection where its efficacy against a wide range of water-borne pathogens is well established (3). Because GUV works primarily by causing damage to nucleic acids (DNA or RNA), universally present in pathogenic microbes, its efficacy against protozoa, fungi, bacteria and viruses is assured, with some variability in the dose required (4). Fungal spores are among the hardest pathogens to inactivate, but GUV is effective in reducing mold growth in air conditioning coils and drip pan surfaces (5). Although there is some potential among microbes to repair nucleic acid UV damage (photoreactivation), tests in biological test chambers and field studies shows no significant resistance to GUV microbial inactivation (6). Drug resistant pathogens, such as multidrug resistant tuberculosis, are fully UV susceptible (1).

AIRBORNE TRANSMISSION AND THE ROLE FOR IN-ROOM AIR DISINFECTION

For many months early in the pandemic, the predominant transmission pathways of COVID-19 were unclear and largely attributed to large droplets and surface contact spread (7). Determining exactly how respiratory viruses transmit from person to person is challenging. The mode of spread of common upper respiratory viral infections and seasonal influenza have long been controversial—large respiratory droplets and surface contact spread versus airborne spread by minute respiratory droplets (8). Not only is the distinction blurred in most cases, many respiratory infections spread by all 3 pathways. Now, well into the epidemic, the evidence suggests less transmission by large (ballistic) droplets and surfaces, and more by the airborne route. The Washington State Chorus transmission event has proven informative (9). Careful interviews with members showed that social distancing and contact precautions largely precluded significant large droplet and surface contact spread, and that the extensive transmission of COVID-19 and 2 deaths were almost certainly the result primarily of airborne transmission. Likewise, Jones has attributed only 8% of transmission among healthcare workers to surface contact—initially said to be a major pathway of transmission (10). The great seasonal changes in transmission between warmer and colder months is largely attributable to indoor airborne transmission, although proximity indoors also favors large droplet and surface contact spread (11).

For airborne infections, the most common way to reduce risk indoors is dilution and removal of infectious particles in room air through ventilation (12). Very large rooms (an auditorium or sports arena) reduce airborne infection risk indoors in the short

*Corresponding author email: enardell@gmail.com (Edward A. Nardell)

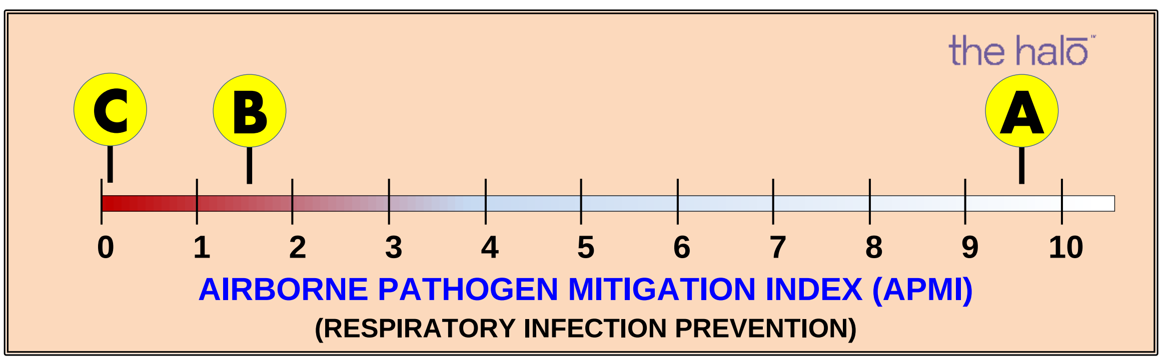
†This article is part of a Special Issue dedicated to the topics of Germicidal Photobiology and Infection Control

SAMPLE INTAKE REPORT FROM IAQ RISK MODEL

SUN VALLEY STARBUCKS & VISITOR CENTER
KETCHUM, IDAHO

- the halō™ Model 5R/M – 1 unit
- Coverage area – 1,800 sq ft
- Install height – 13.5 ft (cathedral ceiling)
- Positioning – ceiling-centered
- Finish – Mahogany Brown

PARAMETER [1]	SCENARIO: full operation		
	Baseline (no masks) C	Cloth masks enforced [2] B	Baseline plus the halō™ A
Inputs			
Room size, ft^2 [A]	1,800	1,800	1,800
Ventilation flowrate (makeup air), CFM [$\dot{v}_E$] [3]	270	270	270
HVAC air flowrate, CFM [$\dot{v}_F$] [4]	1,500	1,500	1,500
HVAC filtration/treatment	None	None	None
Lateral air velocity, ft/min [$v_{H,A}$]	49	49	10
Maximum occupancy, people [p] [5]	90	90	90
Proximal receptors [q_R]	6	6	6
Minimum distancing, ft [x]	4.5	4.5	4.5
Mask efficiency, % [f_{M-E} or f_{M-I}]	0	0	0
Other mitigation	None	None	the halō
Results			
Time to infection/SARS-CoV-2 wild type [t_{INF}], hr	0.28	1.6	8.7
Equivalent air changes per hour [ACH_e], hr^{-1}	0.77	0.77	16
Source/sink ratio, PPQ [α/β]	60,700	31,800	5,500
APMI, dimensionless	**0.037**	**1.5**	**9.6**



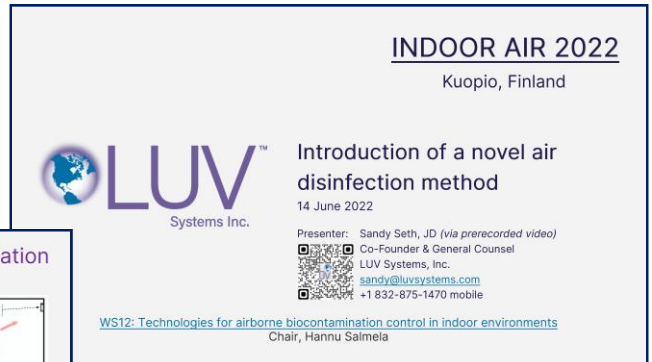
[1] Symbols in brackets indicate the term used for the given parameter in the reference paper and simulation model.
[2] This option assumes cloth masks enforced for all occupants, with 50% filtration efficiency for PPQ upon inhalation and exhalation.
[3] Ventilation is assumed at 0.15 CFM/sq ft, a nominal rate per California building energy standards, with windows/doors/natural draft openings closed.
[4] HVAC capacity is assumed at 25 BTU/sq ft and airflow at 400 CFM/ton. See https://learnmetrics.com/ac-tonnage-calculator/ and https://learnmetrics.com/how-many-cfm-per-ton/.
[5] Assumed capacity at 1 person per 20 sq ft.

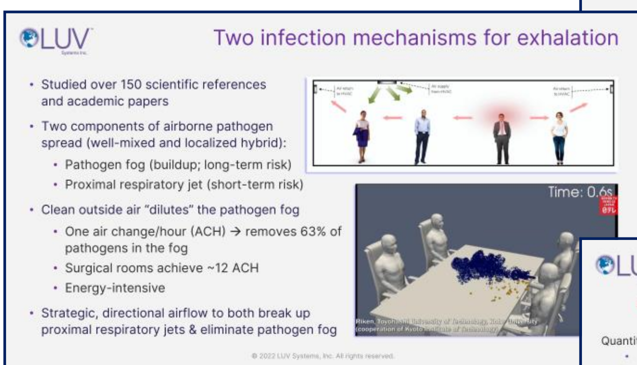
LUV Systems, Inc.

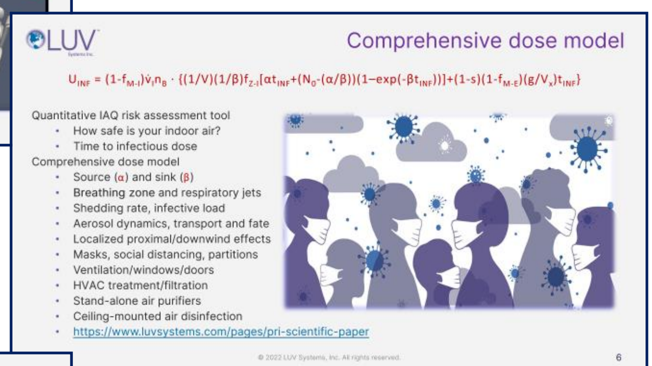
EPC Western Plaza
18726 South Western Avenue, Suite 407
Gardena, California 90248
844-THE-HALŌ (844-843-4256)
www.luvsystems.com

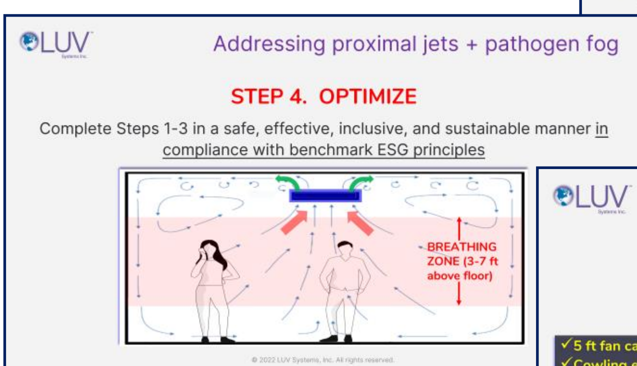
INDOOR AIR 2022 – KUOPIO, FINLAND

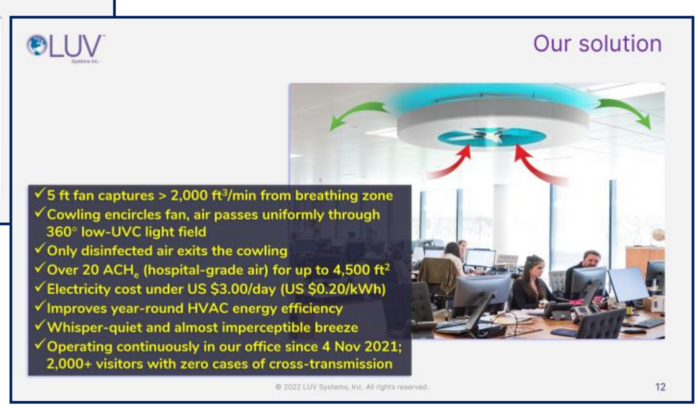
In coordination with VTT Technical Research Centre of Finland Ltd, LUV Systems recently co-chaired a workshop and presented at the Indoor Air 2022 conference in Kuopio, Finland. Highlights from our presentation are provided below, please contact us for more information including the video presentation and technical papers:











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LUV Systems, Inc.

EPC Western Plaza
18726 South Western Avenue, Suite 407
Gardena, California 90248
844-THE-HALŌ (844-843-4256)
www.luvsystems.com

UL CERTIFICATION

Intertek (Lake Forest, California) has successfully tested **the halō™ Model 5R/M** and verified full compliance with applicable safety, operational, and functional standards per Underwriter Laboratories UL 507 (Electric Fans, 10th edition; 2017). Excerpts from the draft listing report are provided below. Listing with Electrical Testing Laboratories (ETL) is forthcoming, pending an Intertek/ETL field audit of **the halō™** manufacturing site. In addition to UL 507, **the halō™ Model 5R/M** has been tested and meets applicable provisions of the following standards:

- 2022 Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs), published by the American Conference of Governmental Industrial Hygienists (2021), with updated ambient UV exposure standards
- US Federal Communications Commission FCC 47 pertaining to electromagnetic interference for industrial, scientific, and medical equipment (please note **the halō™** is not a medical device)
- Canadian Standards Association CSA 22.2#113-18 (Fans and Ventilators, 11th edition; 2018)
- Canadian standard ICES-005 pertaining to electromagnetic interference for lighting equipment

intertek
Total Quality. Assured.

Listing Constructional Data Report (CDR)

1.0 Reference and Address			
Report Number	105098099LAX-001	DRAFT Issued: 28-Oct-2022	For Review and Comment
Standard(s)	Electric Fans [UL 507:2017 Ed.10+R:27May2020] Fans and Ventilators [CSA C22.2#113:2018 Ed.11]		
Applicant	LUV SYSTEMS, INC.	Manufacturer	**LUV Systems,**
Address	18726 South Western Avenue Suite 407 Gardena, CA 90248	Address	18726 South W Suite 407 Gardena, CA 9
Country	USA	Country	USA
Contact	Sandeep Seth Anu Sood	Contact	Sandeep Seth Anu Sood
Phone	(832) 875-1470 (310) 803-7280	Phone	(832) 875-147 (310) 803-728
FAX	NA	FAX	NA
Email	sandy@luvsystems.com anu@luvsystems.com	Email	sandy@luvsyst anu@luvsyster

Report No. 105098099LAX-001 Page 2 of 25 DRAFT Issued: 28-Oct-2022
LUV SYSTEMS, INC. For Review and Comment

2.0 Product Description	
Product	Air Disinfection System Using Upflow Ceiling Fan
Brand name	the halō
Description	The product covered by this report uses a ceiling fan in an upflow mode. The product is intended to be installed in commercial building and to disinfect the air in the room. The fan has UV lamps rated 254nm contained in a circular duct system surrounding the fan. The air is directed through the ductwork & disinfected. Unit is indoor use and permanently connected.
Models	5R/M
Model Similarity	NA
Ratings	110-125 Vac, 50/60 Hz, 1 Φ, 5.4 FLA
Other Ratings	Minimum distance from floor to fan blades: 8.6 ft. Receptacle: 110-125 VAC, 50/60Hz, 1Φ, 7A, 650W.

Report No. 105098099LAX-001 Page 3 of 25 DRAFT Issued: 28-Oct-2022
LUV SYSTEMS, INC. For Review and Comment

3.0 Product Photographs

Photo 1 - Side View of the 5RM

Photo 2 - Underside View of the 5RM with Lower Cowling Removed

Report No. 105098099LAX-001 Page 19 of 25 DRAFT Issued: 28-Oct-2022
LUV SYSTEMS, INC. For Review and Comment

8.0 Test Summary					
Evaluation Period	1-Sep-2022 to			Project No.	G105098099
Sample Rec. Date	30-Sep-2022	Condition	Production	Sample ID.	LAN2209301400-001
Test Location	25800 Commercentre Drive Lake Forest, California 92630 USA				
Test Procedure	Testing Lab				
Determination of the result includes consideration of measurement uncertainty from the test equipment and methods. The product was tested as indicated below with results in conformance to the relevant test criteria.					
The following tests were performed:					

Test Description	UL 507:2017 Ed.10+R:27May2020 Clause	CSA C22.2#113:2018 Ed.11 Clause	
Continuity of Grounding Circuit Test	42	5.18	
Starting Current Test	44	6.1	
Input Test	45	6.3	
Temperature Test	46	6.4	
Dielectric Voltage Withstand Test	47	6.5	
Locked Rotor Cycling	50	6.11	
Humidity Conditioning Test	53	6.26	
Static Load Test for Mounting Means	60, 91.1	--	
UV Radiation Test	223.2	--	
Impact Test	--	6.25	

8.1 Signatures			
A representative sample of the product covered by this report has been evaluated and found to comply with the applicable requirements of the standards indicated in Section 1.0.			
Completed by:	Randy Chau	Reviewed by:	Michael Brousseau
Title:	Project Engineer	Title:	Reviewer
Signature:	*Signature on file*	Signature:	*Signature on file*

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

Mar 10, 2021

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

Sandeep Seth
LUV Systems, Inc.
18726 South Western Avenue
Suite 407
Gardena, CA 90248

Subject: Assignment of New EPA Company Number

Dear Registrant:

The Office of Pesticide Programs received your request for a company/distributor number. The company number assigned to you is 100000.

You are required to notify the Agency of any change in name or address. All requests for change of company name and/or address, appointment of agent or withdrawal of an agent's appointment, must be sent to the following address:

Document Processing Desk(COADR)
Office of Pesticide Programs(7504P)
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

All products must be registered with the Agency prior to shipment and/or sale. Information on registering pesticide products can be obtained by calling the Registration Division Ombudsperson at (703) 308-8893. Requests for a Pesticide Registration Kit can be obtained via e-mail to: Hobgood.Sherada@epa.gov If you are only distributing a product you must complete the Notice of Supplemental Registration of Distributor (EPA form 8570-5). This form can also be obtained by calling the number listed above or can be downloaded at: https://www.epa.gov/pesticide-registration/pesticide-registration-manual-blank-forms.

Any production of pesticides, active ingredients or devices, including companies or establishments that import into the United States, must be conducted in a registered pesticide-producing or device-producing establishment. Information on registering an establishment can be downloaded at: https://www.epa.gov/compliance/epa-form-3540-8-application-registration-pesticide-producing-and-device-producing.

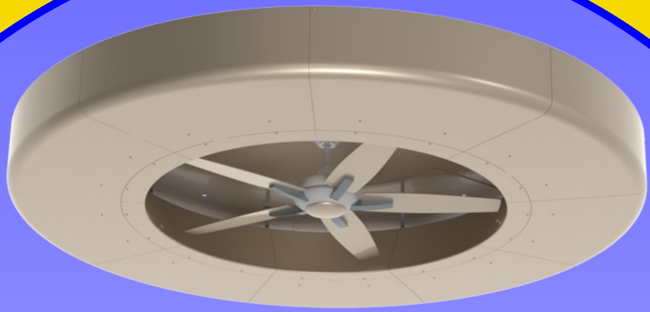
Sincerely,

Shirley A Burgess

Front End Processing Staff
Information Services Branch
Information Technology & Resources Management Division

TREATED WITH LUV

LUV™ Systems Inc.



This facility is equipped with

the halō™

Continuously treating airborne germs and allergens to provide you healthy indoor air

www.luvsystems.com

230216

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