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Airflow and UV properties of the halō™ Model 5R/M

Summary

LUV Systems seek to create a sterilizing device using ultraviolet light. One of the primary goals of EP is to evaluate the efficacy of using UVGI light to kill or weaken SARS-CoV-2, the virus that causes illness and death from the COVID-19 disease. Knowing exactly which types of UV light kills and at what dose is of great interest to the world and EP. In this report we present airflow measurements and UV flux measurements of the LUV's the halō™ Model 5R/M.

Inside the halō™ Model 5R/M cowling, the highest flux measured was between 1.6 mW/cm^2, between bulbs, and 3.7 mW/cm^2 in the center of the bulb holders. Three volumetric flow rates were determined to be 1600 cfm, 1900 cfm, and 2400 cfm at each fan speed, #3, #4, #5 respectfully. At these speeds, the delivered dose to particles traveling through the fan would receive between 2 mJ/cm^2 and 7 mJ/cm^2 depending on fan speed and the exact path taken. Ambient dose, away from the fan (six feet) at a height of six feet, the dose was quite low, at 0.055 μW/cm^2, much lower than the dose given to the air pulled through the device. The highest measured background dose at a height of six feet below the fan representing someone looking directly up at the halō™ under the fan center was 0.35 μW/cm^2. A more typical dose under the fan, two feet off center was lower at 0.25 μW/cm^2.

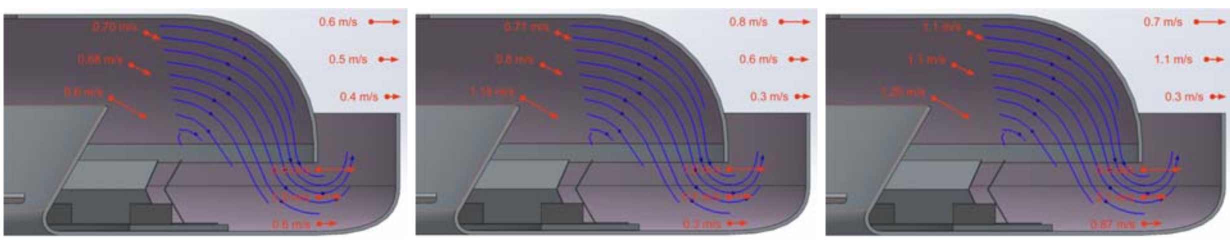
This work was performed by Dr. Kevin Hickerson, founder of The Earthineering Company and flow simulations were performed by subcontractor Dylan Owens at both the Earthineering and LUV Systems locations..

Airflow Measurements

Airflow measurements are shown using previous CAD models (see Earthineering report of March 29, 2021) of the cowlings, and were imported from previous OnShape optical models. They show the radially projected airflow measurements made using an air flow measurement device provided by LUV Systems.

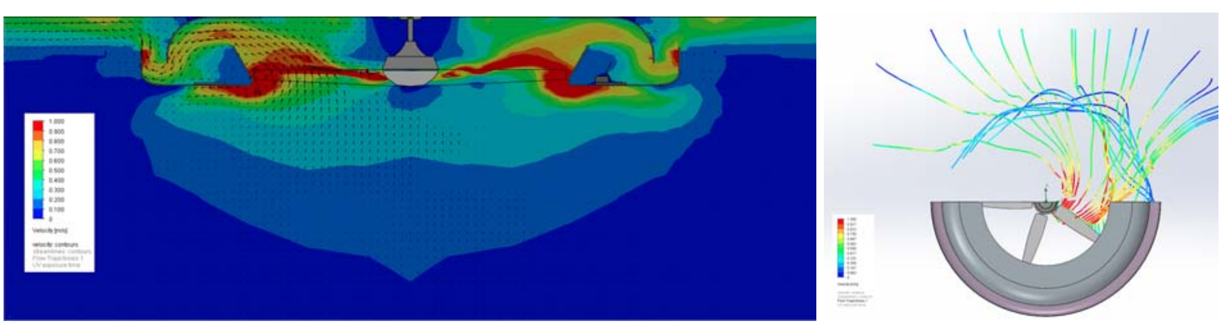
Compared to previous Computational Fluid Dynamics (CFD) simulations of airflow, these measurements allowed us to show fairly close agreement with previous estimates of the time spent in the illuminated region. The following figures are visualizations of the simulation results, showing the airflow at fan speed designated #3, #4, and #5 on the fan control system, respectively.

Radial airflow measurements at different fan speeds



The volumetric flow rate was determined to be 1600 cfm, 1900 cfm, and 2400 cfm at each fan speed, #3, #4, #5 respectfully. The air flow measurements, combined with geometric calculations of the cross sectional areas of airflow apertures, allow us to compute an approximation of the total airflow through the cowling at each section, and thus estimate the airflow passing through the UV-C irradiated section of the colwing. The calculation of these flow rates are shown in the following tables.

Predictive CFD modeling of typical airflow with similar design



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Speed 3	Diameter [in]	Height [in]	Area [sqm]	F1 [m/s]	F2 [m/s]	F3 [m/s]	Flow [m3/s]	Flow [cfm]
Inlet	76.748	5.343	0.83110	0.7	0.88	0.6	0.60	1280
Midlet	94.19	5.151	0.98336	0.4	1.2	0.6	0.72	1528
Outlet	105.993	8.65	1.85828	0.6	0.5	0.4	0.93	1969

Speed 4	Diameter [in]	Height [in]	Area [sqm]	F1 [m/s]	F2 [m/s]	F3 [m/s]	Flow [m3/s]	Flow [cf/s]
Inlet	76.748	5.343	0.83110	0.71	1	0.8	0.70	1473
Midlet	94.19	5.151	0.98336	0.8	0.7	0.6	0.69	1459
Outlet	105.993	8.65	1.85828	1.51	0.3	0.3	1.31	2769

Speed 5	Diameter [in]	Height [in]	Area [sqm]	F1 [m/s]	F2 [m/s]	F3 [m/s]	Flow [m3/s]	Flow [cf/s]
Inlet	76.748	5.343	0.83110	1.1	1.1	1.25	0.96	2025
Midlet	94.19	5.151	0.98336	0.4	2.1	0.87	1.10	2341
Outlet	105.993	8.65	1.85828	0.7	1.1	0.3	1.30	2756

UV-C Irradiation Measurements

Measurements of the UV-C intensity were performed using three measurement techniques and two devices. We used both a ILT2400 NIST Traceable optical meter from International Light Technologies, and a UV/VIS/IR spectrometer from Thorlabs, the CCS200. Because the ILT2400 could not be used at full intensity, a third method of using the ILT2400 with a UV-C reduction filter was also used and extrapolated and compared with the measurements from the CCS200.

UV/VIS/IR Spectrometer

The spectrometer chosen was the economic fiber-coupled CCD based CCS200 from Thorlabs. However, this spectrometer and coupled fiber system are not explicitly calibrated to measure optical power. This was used with a Earthineering Company proprietary cos diffuser as an angle-desensitized fiber coupler. This diffuser, coupling fiber optic cable, and integrated 254 nm Hg line were calibrated to the ITL2400 using a special Hg bulb calibration setup fixing the distance and light collection geometry of the two sensors.

UVGI Light Measurement System

To measure UV-C dose appropriate for deactivating virions, we used the ITL2400 to give the equivalent UVGI (Ultraviolet Germicidal Irradiation) dose in mW/cm^2. It's important to note that the ITL2400 is calibrated to only measure UVGI dose. The energy calibration is the energy deposited along the UGVI sensitivity curve for this detector, and not necessarily the exact radiological energy deposited at the important 254 nm line radiated by Hg bulbs. This correction is about 20%.

Halo dose measurements

Several measurements were taken in, around, and far away from, the cowling of the Halo prototype while running in the LUV Systems office.

Because some of these measurements saturated the ITL2400 detector, a filter was used to suppress some of the flux that reached the detector. This filter was calibrated back in the Earthineering Company lab to suppress the signal by 300x. Unfortunately, this filter has some calibration error of about 30%. This uncertainty is caused by both the non-linearity and the electronic instability of the ILT2400. Future work may want to see this high flux measurement system further refined and stabilized.

Inside the cowling, at the highest flux portion of the air passing through the cowling, the flux was measured to be between 1.6 mW/cm^2 at the lowest point between bulbs and 3.7 mW/cm^2 in the center of the bulb holders. At the measured airflow rates, and estimating the average path length of a particle that passes through this air-flow region to be about one meter long, this corresponds to an average dose of between 2 mJ/cm^2 and 7 mJ/cm^2 depending on fan speed. The pathlength of travel from a particle is based on simulations, and is longer than direct perpendicular flow due to angular flow from the fan.

Ambient dose measurements

To evaluate the safety of users standing near or around the Halo, ambient measurements were also taken. No filter was used, because the doses were far lower in these areas and did not require them. This means these measurements have less intrinsic uncertainty because they simply rely on the NIST calibration of the device as-is. The dose looking directly up at a height of six feet, the maximum dose found, under the fan center was 0.35 μW/cm^2. This was the highest measured dose at a location that was consistent with a normal user not deliberately trying to get close to the lamp area. By contrast, if a user got on a ladder and deliberately looked into the top of the cowling, they would receive an eye dose of 1.7 μW/cm^2. A more typical dose under the fan, two feet off center was lower at 0.25 μW/cm^2.

Ambient dose farther away from the fan (six feet) at a height of six feet, the dose was lower still at 0.055 μW/cm^2.

Prepared by

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Dr. Hickerson received his doctorate in experimental nuclear physics from Caltech in 2013. He has been working with x-rays, UV/VIS optics, neutrons, neutron optics, optomechanics, solar power optics, and spectroscopy for over 20 years, in industry, national and international laboratories. He has authored more than 10 patents and his work has been cited over 2500 times in other patents and peer reviewed articles.

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Consultant for The Earthineering Company, LLC

Dyan is an engineer with extensive experience developing novel robotic systems, with a background in mechanical, electrical, software, and controls system design. He holds a B.S. in mechanical engineering degree from Caltech and a M.S. in mechanical engineering from MIT. The Office of Naval Research sponsored his work on robotic systems for use in harsh saltwater environments.