Predicted Air Disinfection Performance of Air Wave™: Analysis of Performance Characteristics and Effectiveness in a Model Room

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This report summarizes the results of modeling and analysis of the UVC Air Wave™ UVGI unit. This unit is based on a proprietary design by UVC and design specifications are as provided in the UVC reference drawings. Table 1 summarizes specifications for the unit that are used as input to the model of the UV irradiance field. The single biaxial lamp has been modeled as two UV lamps at half power each, in order to achieve better realism.

Table 1: Input Data

Number of Lamps			2	
UV Power	16	Watts		
Arclength:	49	cm	19.2913	in
Radius:	0.9	cm	0.354331	in
x1 coordinate	15.19	cm	5.98031	in
y1 coordinate	3.721	cm	1.46496	in
z1 coordinate	2.97	cm	1.16929	in
x2 coordinate	15.19	cm	5.98031	in
y2 coordinate	3.721	cm	1.46496	in
z2 coordinate	51.97	cm	20.4606	in
UV Power	16	Watts		
Arclength:	49	cm	19.2913	in
Radius:	0.9	cm	0.354331	in
x1 coordinate	17.19	cm	6.76772	in
y1 coordinate	3.721	cm	1.46496	in
z1 coordinate	2.97	cm	1.16929	in
x2 coordinate	17.19	cm	6.76772	in
y2 coordinate	3.721	cm	1.46496	in
z2 coordinate	51.97	cm	20.4606	in
Reflectivity:	5	% or	50%	%
Width:	32.38	cm	12.748	in
Height:	7.442	cm	2.92992	in
Length:	54.94	cm	21.6299	in
Airflow:	2.832	cu.m/min.	100.012	cfm

Results of the analysis are shown in Table 2. Six cases were analyzed, 2 reflectivities and 3 airflows. The 5 % reflectivity model represents internal surfaces that are not coated with any specific reflective material. The 50% reflectivity model represents surfaces partially coated with reflective aluminum or similar material. The first two airflows, 50 cfm and 100 cfm, are the original design parameters. The third airflow, 200 cfm, is a suggested design parameter based on the fact that the levels of UV irradiance are so high in the unit that it may be over-powered (in terms of UV) for the given design airflows. By operating at higher airflow (i.e. 200 cfm) improved performance in an actual room conditions may be obtained, as will be shown later.

Table 2: UVGI Analysis Results

5% Reflectivity	50 cfm			100 cfm			200 cfm		
	Dose	**Ir**	**Et**	**Dose**	**Ir**	**Et**	**Dose**	**Ir**	**Et**
	μJ/cm2	μW/cm2	s	μJ/cm2	μW/cm2	s	μJ/cm2	μW/cm2	s
Top Section	4608	8298	0.5552	2304	8298	0.2776	1152	8298	0.1388
Mid Section	9476	16894	0.561	4738	16894	0.2805	2369	16894	0.14025
Bottom Section	4608	8298	0.5552	2304	8298	0.2776	1152	8298	0.1388
Total Et, s	1.6714			0.8357			0.41785		
Total Dose	18692			9346			4673		
URV	19			18			15		

50% Reflectivity	50 cfm			100 cfm			200 cfm		
	Dose	**Ir**	**Et**	**Dose**	**Ir**	**Et**	**Dose**	**Ir**	**Et**
	μJ/cm2	μW/cm2	s	μJ/cm2	μW/cm2	s	μJ/cm2	μW/cm2	s
Top Section	7008.852	12621.41	0.5552	3504.426	12621.41	0.2776	1752.213	12621.41	0.1388
Mid Section	14413.17	25696.08	0.561	7206.585	25696.08	0.2805	3603.292	25696.08	0.14025
Bottom Section	7008.852	12621.41	0.5552	3504.426	12621.41	0.2776	1752.213	12621.41	0.1388
Total Et, s	1.6714			0.8357			0.41785		
Total Dose	28431			14215			7108		
URV	20			19			17		

It can be observed in Table 2 that very high URV ratings are obtained. As per the previous paragraph, this suggests the unit is over-powered in terms of UV. At the suggested flowrate of 200 cfm, an URV 15 is achieved, which is a respectable value for any UV system. With 50% reflectivity, the URV goes to 17 for the 200 cfm airflow.

Some attempt was made to evaluate the existing UV system against an ordinary system without internal baffling. Unfortunately, the current computer model assumes complete mixing and the subject comparison would not show any significant differences. Because the unique design of the Air Wave system enhances mixing and assures high levels of UV exposure to the entire airflow, it can be assumed that complete mixing will be obtained, and therefore the present model is an accurate depiction of the system performance. However, incomplete mixing cannot be modeled and therefore this comparison cannot be made in any other way than in a laboratory test. It could be expected that this unit would perform according to predictions and that performance would be reliable and repeatable. In these regards, this unit should prove superior to units in which mixing is uncontrolled or incomplete.

Table 3 shows the predicted kill rates for a variety of microorganisms. These microbes include viruses and bacteria, which are the intended targets, and also fungal and bacterial spores. High kill rates are obtained against the viruses and bacteria. High kill rates are not obtained against the spores but spores are preferably removed by filters, not UV systems. If this unit is paired with any filter, it can be re-analyzed for its performance against spores.

Table 3: Kill Rates for Various Microbes

Microorganism	Type	Rate Constant k ($cm^2/\mu J$)	5% Reflectivity 50 cfm Kill %	5% Reflectivity 100 cfm Kill %	5% Reflectivity 200 cfm Kill %	50% Reflectivity 50 cfm Kill %	50% Reflectivity 100 cfm Kill %	50% Reflectivity 200 cfm Kill %
Legionella pneumophila	Bacteria	0.002681702	100.000000	100.000	100.000	100.000	100.000	100.000
Echovirus	Virus	0.002169828	100.000	100.000	99.996	100.000	100.000	100.000
Streptococcus pyogenes	Bacteria	0.001818732	100.000	100.000	99.980	100.000	100.000	100.000
Vaccinia	Virus	0.001527717	100.000	100.000	99.921	100.000	100.000	99.998
Reovirus Type 1	Virus	0.001323276	100.000	100.000	99.794	100.000	100.000	99.992
Influenza A	Virus	0.001186764	100.000	99.998	99.610	100.000	100.000	99.978
Avian Influenza	Virus	0.001186764	100.000	99.998	99.610	100.000	100.000	99.978
SARS virus	Virus	0.001186764	100.000	99.998	99.610	100.000	100.000	99.978
Coxsackievirus B-1	Virus	0.001108138	100.000	99.997	99.436	100.000	100.000	99.962
Staphylococcus aureus	Bacteria	0.000854669	100.000	99.966	98.157	100.000	99.999	99.770
Corynebacterium diptheriae	Bacteria	0.000783129	100.000	99.934	97.426	100.000	99.999	99.618
E. coli	Bacteria	0.000767528	100.000	99.923	97.231	100.000	99.998	99.573
Serratia marcescens	Bacteria	0.000718	100.000	99.878	96.510	100.000	99.996	99.392
Mycobacterium tuberculosis	Bacteria	0.000647696	99.999	99.765	95.152	100.000	99.990	98.998
Haemophilus influenzae	Bacteria	0.00059906	99.999	99.630	93.915	100.000	99.980	98.585
Adenovirus	Virus	0.000545742	99.996	99.391	92.194	100.000	99.957	97.933
Mycobacterium kansasii	Bacteria	0.000370741	99.902	96.873	82.315	99.997	99.486	92.829
Mycobacterium avium-intra.	Bacteria	0.00032375	99.765	95.148	77.973	99.990	98.997	89.985
Pseudomonas aeruginosa	Bacteria	0.000277775	99.444	92.544	72.693	99.963	98.072	86.115
Bacillus Subtilis spores	Spores	0.000192	97.237	83.378	59.230	99.574	93.474	74.454
Penicillium expensum spores	Spores	0.000177	96.343	80.876	56.269	99.348	91.923	71.580
Cryptococcus neoformans	Spores	0.0001666	95.558	78.924	54.092	99.123	90.636	69.399
Mucor racemosus spores	Spores	0.000135	91.982	71.683	46.786	97.847	85.326	61.693
Penicillium italicum	Spores	0.000125882	90.492	69.164	44.470	97.209	83.295	59.128
Fusarium oxysporum	Spores	0.000112353	87.756	65.008	40.846	95.900	79.753	55.003
Penicillium digitatum	Spores	7.17647E-05	73.853	48.866	28.492	87.001	63.947	39.955
Fusarium solani	Spores	7.05882E-05	73.271	48.300	28.097	86.559	63.338	39.451
Aspergillus glaucus spores	Spores	0.0000523	62.378	38.664	21.682	77.394	52.454	31.046
Aspergillus flavus spores	Spores	0.0000384	51.216	30.155	16.426	66.437	42.066	23.886
Cladosporium	Spores	0.0000384	51.216	30.155	16.426	66.437	42.066	23.886
Scopulariopsis	Spores	0.0000288	41.628	23.598	12.592	55.904	33.595	18.511
Moraxella-Acinetobacter	Bacteria	1.77136E-05	28.187	15.257	7.944	39.566	22.261	11.830
Rhizopus nigricans spores	Spores	0.00001047	17.775	9.322	4.775	25.745	13.829	7.172
Aspergillus niger spores	Spores	0.000006978	12.228	6.314	3.208	17.995	9.443	4.839

The previous model evaluated the once-through or single-pass efficiency of the Air wave unit. In order to determine its actual performance characteristics, it is necessary to place it in a model room. In this case, the unit is modeled inside a 250 ft2 classroom with 15% outside air. It is assumed that two Air wave units are placed in the room and operated at 50-200 cfm. The performance, in terms of reducing airborne concentrations of three microbes, TB bacilli, Influenza, and SARS virus, are compared between the three airflow rates. The results of these airborne concentrations are also shown in terms of predicted infections. It can be observed in Table 4 that performance is similar for all three microbes – this is because such high kill rates are obtained against all three. It can also be observed that the highest reduction in infections occurs when the units are operated at 200 cfm. This is due to the fact, as mentioned before, that the unit is over-powered in the 50-100 cfm operating condition. The best in-room performance occurs with the higher airflow due to the fact that the UV dose is more effectively delivered at the higher volume of airflow. An alternative explanation is that the over-concentration of UV in the smaller airflows is an inefficient use of the energy (i.e. energy wasted).

Table 4: % Infections in Model Room

50% Reflectivity	no UV	50 cfm	100 cfm	200 cfm
TB bacilli	99	89	43	9
Influenza	99	89	43	9
SARS	99	89	42	9

Figure 1 shows an example of the airborne concentrations of TB bacilli in the model classroom. The TB is released at a constant rate (assumed to be from an occupant) and gradually accumulates in the classroom in the absence of any air treatment other than 15% outside air. When the room is equipped with two Air Wave units, the airborne concentrations drop significantly, as shown in the graph.

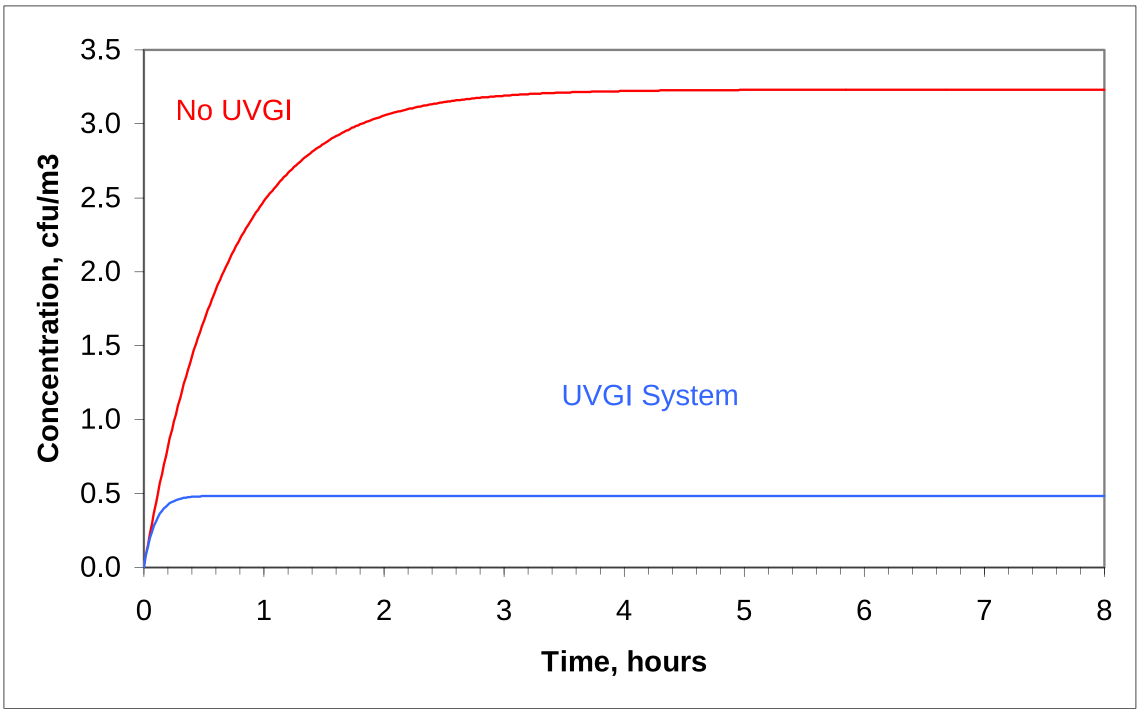

Figure 1: Concentration reduction of TB bacilli in a model classroom with an Air wave unit installed.

Figure 2 shows the reduction in predicted infections from TB bacilli in them model classroom. It can be observed that levels are significantly reduced by the unit, operated at 200 cfm.

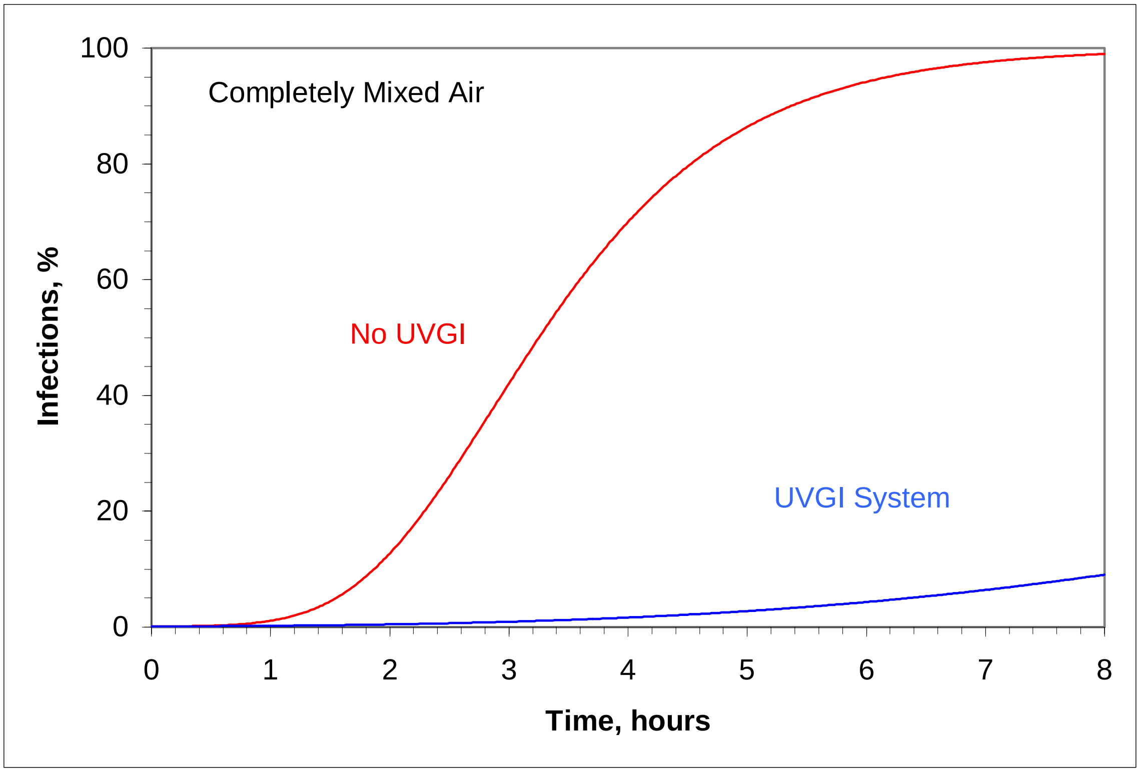

Figure 1: TB Infection reduction in a model classroom with airborne levels as shown in Figure 1. In this model two Air wave units are operating at 200 cfm.

SUMMARY

The preceding analysis has shown that the Air Wave™ unit can effectively control levels of viable airborne microorganisms. The unit will produce high internal irradiance levels that allow it to perform at or above the URV 15 level. It is suggested herein that the airflow could be doubled to maximize efficient use of the UV irradiance field in actual applications. The performance of the unit at the 200 cfm flowrate has been evaluated in a model classroom where it has been predicted to effectively reduce airborne concentrations of TB, influenza, SARS virus, and other health threats. Predicted infections with these microbes have likewise been shown to be reduced when the Air wave unit has been installed. This unit should be effective in controlling levels of airborne microbes that may contribute to respiratory infections, allergies, asthma, and airborne nosocomial and operating room infections. Suitable applications of this unit would include commercial and residential applications, schools, hospital general areas, isolation rooms, and operating rooms, shelters, and prison isolation wards. Unit may also be suitable for controlling some food pathogens that contaminate foods by the airborne route including Listeria, and may also be useful in controlling Norwalk virus on ships.

References

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