

## Test by

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## Executive Summary

The model 2000 air disinfection unit consists of a charcoal filter, a HEGA, (High Efficiency Gas Adsorbers) Military Carbon Cloth Prefilter, a 0.1 HEPA filter and a UV lamp through which air is driven at airflows between 50 cfm and 340 cfm. Computer modeling and analysis of the UV disinfection unit indicates that it will remove pathogens from the air at high rates that approach 100%.

The UV Dose produced by the unit at the operating airflow of 50 cfm is 35.5 J/m<sup>2</sup> and the UV Dose produced at 340 cfm is 5.22 J/m<sup>2</sup>. Eight bioweapon agents have been evaluated, these being TB bacilli (*Mycobacterium tuberculosis*), anthrax (*Bacillus anthracis* spores), smallpox (*Variola virus*), botulinum toxin, Influenza A virus, SARS virus, Ebola virus, and *Yersinia pestis* (plague), and high removal rates were found for all agents, these having an average removal rate of 99.999% at the operating airflow of 50 cfm, and 99.998% removal at the operating airflow of 340 cfm. Analysis of several hundred pathogens including bacteria, viruses, fungal spores and protozoa indicates that the net average removal rate for all pathogens exceeds 99.99%. Modeling of the Model 2000 unit in a 400 ft<sup>2</sup> room indicates it will rapidly draw down the airborne concentrations of pathogens to harmless levels within a few hours.

## Description of the System

The Model 2000 air disinfection system consists of an ultraviolet light in a cylindrical chamber into which air flows into the unit through a carbon filter and a HEPA filter before reaching the UV irradiation chamber. The UV lamp is a U-tube type lamp 7" long, Model GUPH22-212T5L/4P, with 19 W of power input and 6 W of UV output. It has a diameter of 15 mm (1.5 cm), or a radius of 7.5 mm (0.75 cm). Based on the vendor drawing (Light Sources GU22-212T5L) the arclength scales to approximately 29.2 cm. In the case of U-tube type lamps the arclength is not the length of the lamp body but about twice the body length plus the tip portion (the curved bend). The lamp rating is stated as 55 microW/cm<sup>2</sup>. The lamp has a 1" (2.54 cm) base and sits 1.25" (3.175 cm) below the top of the chamber. The UV chamber has an inside diameter of 7.25" (18.415 cm) and is 13" high (33.02 cm). The nominal flow rate through the chamber is 50 cfm and the highest flowrate is 300 cfm. The HEPA filter is a custom filter model 20510. The face area through which the airflow enters the UV chamber is  $\pi(7.25)(13) = 296 \text{ in}^2$  or 1910 cm<sup>2</sup>.

Table 1 summarizes the UV chamber dimensions and operating parameters. The Exposure Time at the lower airflow of 50 cfm is 0.373 seconds and this is within the minimum recommendation of 0.25 seconds per IUVA (2005). The Exposure Time at the higher airflow of 340 cfm is 0.055 seconds and this does not meet the minimum recommendation of 0.25 seconds. It can be seen in Table 1 that the air velocity through the HEPA filter is between 24 fpm (at 50 cfm) and 165 fpm (at 340 cfm). Since these face velocities are well within the minimum recommended face velocity of 250 fpm (ASHRAE) the HEPA filters will perform at least as well as their rating at 250 fpm.

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**Table 1: UV Chamber Parameters**

Height	13	in	33.02	cm
	1.083333	ft	0.3302	m
Diameter	7.25	in	18.415	cm
	0.604167	ft	0.18415	m
Base Area	41.28249	in <sup>2</sup>	266.3381	cm <sup>2</sup>
	0.286684	ft <sup>2</sup>	0.026634	m <sup>2</sup>
Equivalent side	6.425145	in	16.31987	cm
HEPA Face Area	296.0951	in <sup>2</sup>	1910.287	cm <sup>2</sup>
	2.056216	ft <sup>2</sup>	0.191029	m <sup>2</sup>
Airflow 1	50	cfm	1.41585	m <sup>3</sup> /min
Velocity 1	174.4081	fpm	53.15987	m/min
	2.906801	fps	0.885998	m/s
Exposure Time 1	0.372689	sec	0.372687	sec
HEPA Velocity 1	24.31651	fpm	7.411713	m/min
Airflow 2	340	cfm	9.62778	m <sup>3</sup> /min
Velocity 2	1185.975	fpm	361.4871	m/min
	19.76625	fps	6.024785	m/s
Exposure Time 2	0.054807	sec	0.054807	sec
HEPA Velocity 2	165.3523	fpm	50.39965	m/min

**Analysis Results**

Two conditions were analyzed, an airflow of 50 cfm and an airflow of 340 cfm. Table 4 summarizes the results for both cases. At 50 cfm the UV Dose is 35.5 J/m<sup>2</sup> which rates an URV 14. At 340 cfm the UV Dose is 5.22 J/m<sup>2</sup> which rates an URV 10.

**Table 4: Analysis Results**

Airflow	50	cfm	340	cfm
Irradiance	95.256	W/m <sup>2</sup>	95.256	W/m <sup>2</sup>
Exposure Time	0.372689155	sec	0.054807229	sec
UV Dose	35.5008781	J/m <sup>2</sup>	5.220717368	J/m <sup>2</sup>
URV	14		10	

For this unit, the microbes and agents of most interest include TB bacilli, Anthrax, smallpox, and botulinum toxin. The removal rates of these agents are summarized in Table 5. The HEPA removal rates will be at least the rates shown in Table 5 because the air velocity through the HEPA filter is well below the minimum recommended for such filters. Also, the HEPA removal rates will be the same for both cases, 50 cfm and 340 cfm, although it is likely that slightly higher HEPA removal rates will occur at 50 cfm. Botulinum toxin is not susceptible to breakdown under UV exposure but it is removable by filtration. The carbon filter will also have some effect on removal of botulinum toxin (Gomez 1995) Toxins used as bioweapons are typically ground to a particle size of about 1-6 microns and a logmean diameter of 1.5 microns is used to assess the removal rates of this toxin by the HEPA filter.

**Table 5: Removal Rates of Bioweapon Agents**

Microbe/Agent	UV D90 J/m <sup>2</sup>	UV k m <sup>2</sup> /J	UV Kill Rate %	Diameter microns	HEPA Removal %	Total Removal %
<b>Design Airflow 50 cfm</b>						
Mycobacterium tuberculosis	5	0.4271	100.00	0.637	100.0000	100.0000
Bacillus anthrax	85	0.02702	61.68	1.118	100.0000	100.0000
Variola (smallpox)*	26	0.088561	95.69	0.224	99.9516	99.9979
Botulinum toxin	0	0	0.00	1.5	100.0000	100.0000
Influenza A	23	0.010103	30.14	0.098	99.9934	99.9954
SARS virus*	7	0.3289	100.00	0.113	99.9893	100.0000
Ebola virus	28.4	0.081	94.36	0.09	99.9950	99.9997
Yersinia pestis*	24	0.095941	96.68	0.7	100.0000	100.0000
<b>Design Airflow 340 cfm</b>						
Mycobacterium tuberculosis	5	0.4271	89.24	0.637	100.0000	100.0000
Bacillus anthrax	85	0.02702	13.16	1.118	100.0000	100.0000
Variola (smallpox)*	26	0.088561	37.02	0.224	99.9516	99.9979
Botulinum toxin	0	0	0.00	1.5	100.0000	100.0000
Influenza A	23	0.010103	5.14	0.098	99.9934	99.9937
SARS virus	7	0.3289	82.04	0.113	99.9893	99.9981
Ebola virus	28.4	0.081	34.48	0.09	99.9950	99.9967
Yersinia pestis	24	0.095941	39.40	0.7	100.0000	100.0000

NOTE: Asterisk indicates the UV rate constant is predicted genomically.