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Defend 400: Particulate Matter Reduction and CADR (ARE Labs)

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Revision	Date	Description
1	11-May-21	Intial Release
2	26-May-21	Updated to include eCADR of PM1 and PM2.5 data.

1. Introduction

Particulate matter reduction and equivalent clean air delivery rates (CADR) for the Defend 400 device are reported here.

Testing was conducted at ARE Labs, Kansas, USA in an environmental test chamber (approximately 16 m^3) with polystyrene latex microspheres (0.5 to 5.0 um in diameter) and an aerodynamic particle sizer (APS).

2. Test Setup

Details of the environmental test chamber, the polystyrene latex micropheres can be found in reference [1].

A TSI Aerodynamic Particle Sizer model 3321 (TSI Inc., Shoreview, MN) was used to measure particle size and concentration of PSL microspheres. The APS provides real-time aerodynamic particle characterization with a size range from 0.54-20.0 µm with 52 size bins of resolution. Sampling is continuous with a data export interval of 1 second. The APS has a continuous flow rate of 1 LPM. The APS was connected to a splitter with on/off valves in order to sample inhaled aerosols as well as ambient aerosols within the chamber.

PLS microspheres were nebulized into the test environment and one control and one test run were completed. Data were collected in March and April 2021.

The test air cleaner device evaluated is the Defend 400 which is equiped with a HEPA 13 filter by Camfil.

3. Results

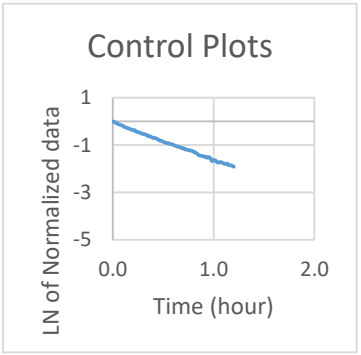
The particulate matter counts for each particle size bin are normalized by the initial concentration after nebulization. A natural logarithm function is applied to the normalized data; LN(normalized data). This operation is applied to both, control and test runs. The slope of data pairs of time (in hour) and natural logarithm of the normalized data for each particle bin size is calculated. This is done for both, control and test data. Finally, the difference between the control and the test data slopes is taken and multiplied by the volume of the chamber to get the estimated clean air delivery rate (CADR) for each particulate size bin.

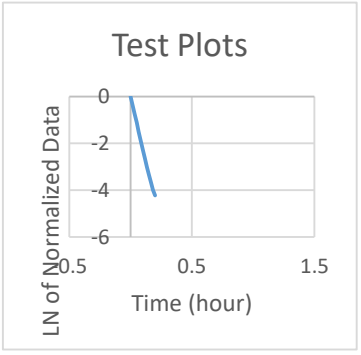
Data for particulates diameter 2.5 um and greater was excluded from the calculation due to noise observed in the data resulting from low counts.

The data is summarized in table below. The average and median CADR are **355** and **358 m^3/h** respectively.

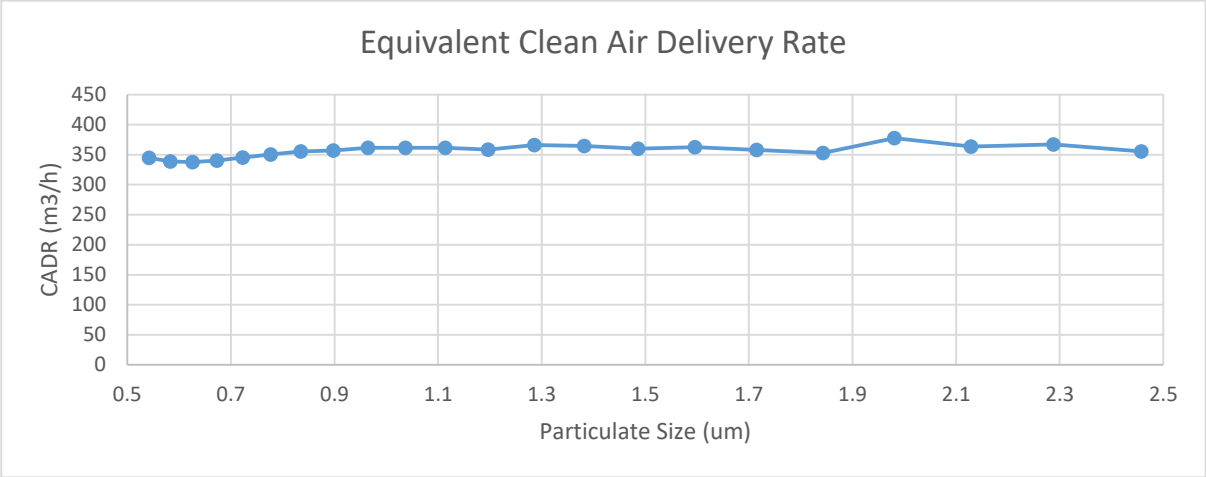
PM size (um)	Control Slope (1/hour)	Test Slope (1/hour)	Volume (m^3)	eCARD (m^3/h)
<0.523	-0.94102	-21.6723	16	331.7
0.542	-0.72041	-22.2846		345.0
0.583	-0.76086	-21.9296		338.7
0.626	-0.80646	-21.9079		337.6
0.673	-0.85633	-22.1153		340.1
0.723	-0.90798	-22.4807		345.2
0.777	-0.95534	-22.8681		350.6
0.835	-0.9912	-23.2107		355.5
0.898	-1.02018	-23.3415		357.1
0.965	-1.05572	-23.6511		361.5
1.037	-1.09498	-23.6983		361.7
1.114	-1.13138	-23.7402		361.7
1.197	-1.17403	-23.5888		358.6
1.286	-1.21308	-24.0994		366.2
1.382	-1.25458	-24.023		364.3
1.486	-1.31215	-23.8069		359.9
1.596	-1.36542	-24.0076		362.3
1.715	-1.42299	-23.7931		357.9
1.843	-1.49262	-23.5342		352.7
1.981	-1.57415	-25.1741		377.6
2.129	-1.67248	-24.4075		363.8
2.288	-1.80967	-24.7603		367.2
2.458	-1.96648	-24.196		355.7

Defend 400





The data of the table above are plotted in the figure below. The CADR is reasonably flat across the range of particulate sizes reported here (0.5 to 2.5 um).



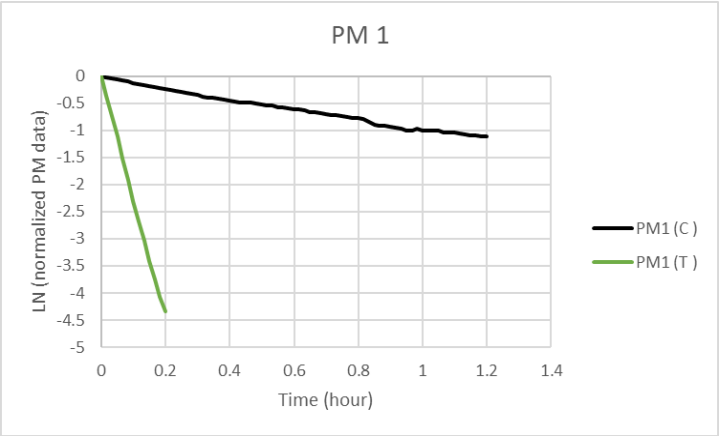
Clean Air Delivery Rate of PM1 and PM2.5 particulate

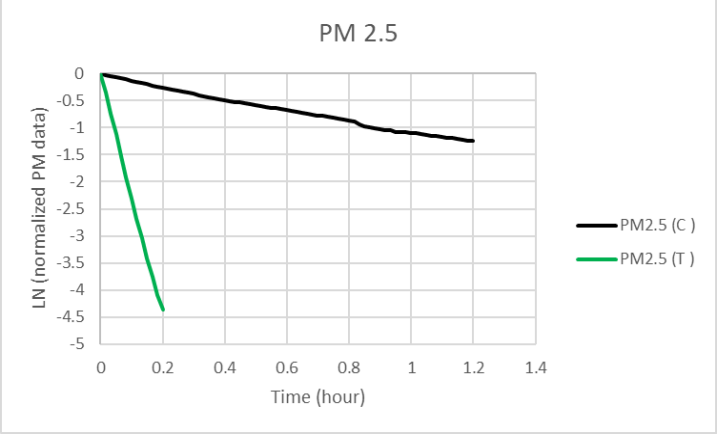
Particulate matter counts for particles with diameter 1 um or less are aggregated to estimate the PM1 reduction. Similarly, counts for particles with diameter 2.5 um or less are aggregated to estimate the PM2.5 reduction. The table below summarizes the PM1 and PM2.5 equivalent Clean Air Delivery Rates.

PM size (um)	Control Slope (1/hour)	Test Slope (1/hour)	Volume (m^3)	eCARD (m^3/ hour)
PM1	-0.93426	-22.2305	16	**340.7**
PM2.5	-1.04029	-22.3533		**341.0**

The graphs below show the PM1 and PM2.5 control and test data. The horizontal axis in these plots is time in hours and the vertical axis is the natural logarithm of the normalized PM1 and PM2.5 particulate matter counts. The slope of these curves is calculated by a linear regression and tabulated in the table above. The slopes and the volume of the test chamber are combined to estimate the equivalent CADR.

Note that the eCADR of PM1 and PM2 are lower than the average and median eCADR of all particulate sizes. When estimated, the PM1 and PM2 eCADR, are weighed down by the particulate counts of smaller size particles. This is due to the fact there are more particulate of smaller sizes than those of larger diameters in the air.





4. Conclusion

The equivalent CADR of the Defend 400 (with HEPA 13 filter) for PM1 and PM2.5 are estimated. At the estimated PM1 and PM2.5 CADRs, it takes **26 min** to reduce PM by 99.99% in a 16 m^3 chamber.

	Time (min)	**Volume (m^3)**	**eCADR (m^3/h)**	**Red. (%)**
PM1	26.0	16	**340.7**	99.99
PM2.5	25.9	16	**341.0**	99.99

Formula applied to get time in minutes

$$t[cadr\_, Red\_, Vol\_] := -\frac{Vol}{cadr} * Log[(100 - Red)/100] \times 60$$

5. References

[1] ARE Labs - Novaerus - Efficacy of Novaerus Defend 400 Against Aerosolized Virus and Bacterial Spores - Final Report V1.0, 2021

6. Appendix

Test equipment: TSI Aerodynamic Particle Sizer model 3321 (TSI Inc., Shoreview, MN). Next calibration due in August 2021.

7. Approvals

Author(s) Print Name	Signature	Date
Felipe Soberon	Felipe Soberon	11-May-21