B2 Filter Technology Review

Summary

Every B2 Mask contains two filters that filter out particles down to 0.1μm in size with an efficiency between 99.6%-98.3% for light breathing, and between 99.0%-94.7% for heavy breathing. Industry-standard NaCl particle testing was performed at the University of Minnesota Department of Mechanical Engineering, as well as with Breathe99's filter manufacturer, to study particle filtration efficiency, performance over time, and breathability. Extended use simulation indicates that the filtration efficiency does not drop as the filters load with particles. Measurements of pressure differentials indicate that B2 Filters are well within FDA-mandated requirements for breathability. We hope that individuals and organizations looking for a high-performance respirator will be able to use this test data to determine if B2 Mask suits their needs.

I. Introduction

This review focuses on performance testing for the B2 Filters, an important aspect of B2 Mask's superior protection and comfort. B2 Mask features a flexible facepiece that creates an airtight seal on the face, which directs all breathing in and out of two circular B2 Filters. An adjustable fabric overlay securely holds the facepiece on the face. For more information about B2 Mask, see www.breathe99.com.

B2 Mask is designed for everyday use at home and in the workplace. Although it is not a medical device, it was designed according to medical N-series respirator requirements[1]. The primary design criteria for B2 Filters are: filtration efficiency, duration of protection, and breathability. Although we are in the process of pursuing all relevant certifications, please note that B2 Mask and B2 Filters are not yet NIOSH- or FDA-approved. By sharing B2 Filter test data, we hope that readers can make an informed decision about whether B2 Mask offers the protection and breathability they need for their specific use case.

II. B2 Filter Technology Overview

B2 Filters are composed of 4 layers, shown in Figure 1. The outer two layers are polypropylene coverwebs for protection, while the two inner layers perform the filtering. One filtering layer is electrostatically charged spunbond polypropylene, which attracts and traps small particles. The other filtering layer is meltblown polypropylene, a super-fine mesh that mechanically traps particles.

B2 Filters are designed to filter out particles 0.1 μm (equivalent to 100 nm) in diameter and larger. Figure 2 shows the relative sizes of common environmental contaminants.

Figure 1. B2 Filter Layers

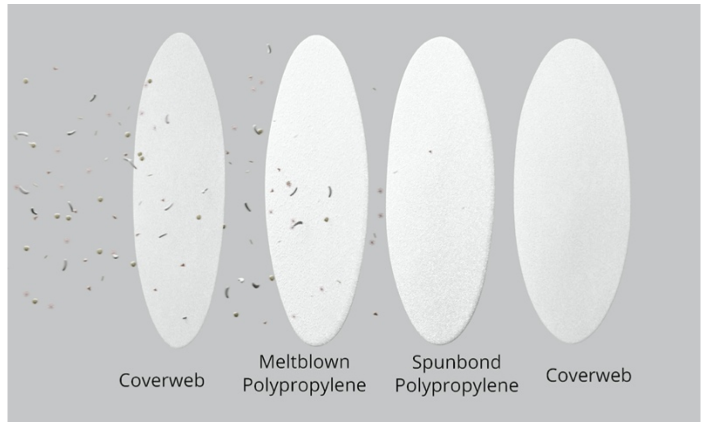
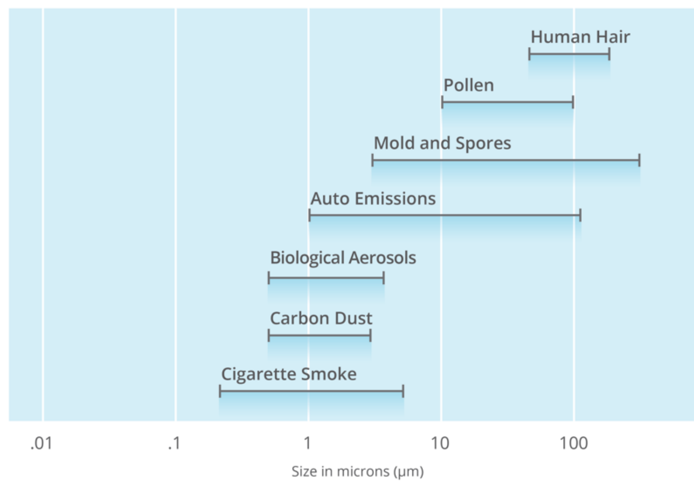


Figure 2. Sizes of Common Environmental Contaminants[2]



III. Test Setup

Electrostatically neutralized NaCl nanoparticles in the size range of 30-300 nm were generated using a Collision-type atomizer followed by a diffusion dryer and a neutralizer. The particle size distributions both upstream and downstream of the test filter were measured by a Scanning Mobility Particle Sizer (SMPS 3936; TSI Inc.) to calculate the Particle Filtration Efficiency (PFE) per each particle size. The pressure drop across the test filter was measured for the designated test flow rates. Instruments were calibrated with NIST-calibrated test particles to ensure accuracy.

When interpreting the test data, it is important to remember that NIOSH respirator standards measure particles down to 0.075 ± 0.020 μm count median diameter[3] (equivalent to 0.3 um mass median aerodynamic diameter (MMAD) in test procedures[4]). Out of scientific interest and because of the available test setup, the testing included smaller particles.

IV. Particle Filtration Efficiency

Instantaneous Particle Filtration Efficiency (PFE) of B2 Filters was tested at two flow rates, representing light breathing[5] at 32 L/min and heavy breathing[6] at 85 L/min. Because B2 Mask uses two filters, while the fixture only held one filter, the testing flow rates were halved to 16 L/min and 42.5 L/min, respectively. Four filters were tested at each flow rate. The face velocity of one B2 Filter at a flow rate of 42.5 L/min is 18.9 cm/s, and for a flow rate of 16 L/min the face velocity is 7.1 cm/s.

The test data in Figures 3 and 4 show that for light breathing and 0.1 μm particles, the samples performed between 99.6% and 97.9% efficiency, with an average of 98.9%. For 0.3 μm particles, the samples performed between 100% and 98.9% efficiency, with an average of 99.6%.

For heavy breathing and 0.1 μm particles, the samples performed between 99.0% and 94.7% efficiency, with an average of 97.6%. For 0.3 μm particles, the samples performed between 100% and 95.8% efficiency, with an average of 98.1% (note some erratic measurements in the 0.3 μm size range visible in Figure 4).

Figure 3. PFE for Light Breathing, 4 samples.

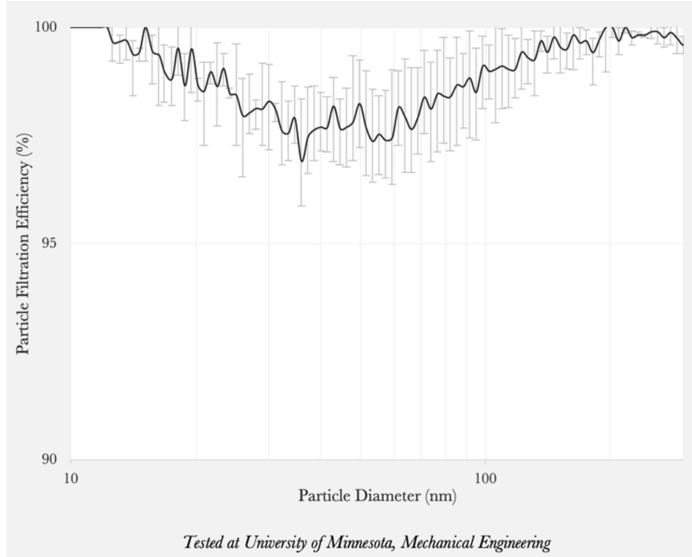
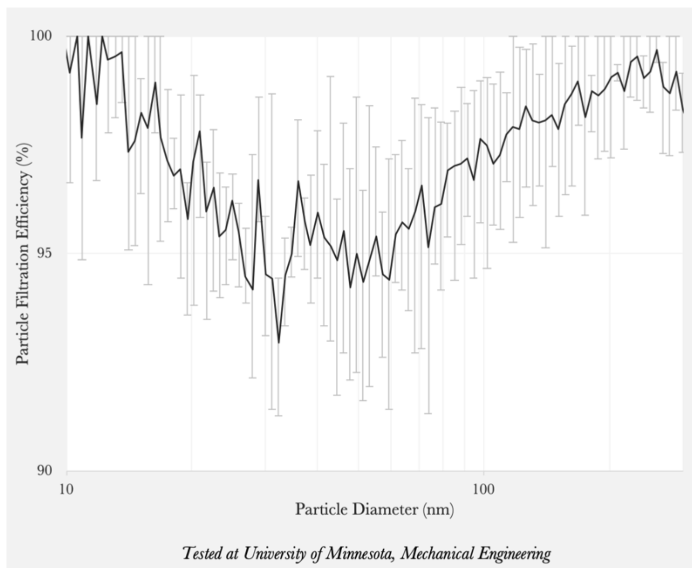


Figure 4. PFE for Heavy Breathing, 4 samples.



V. Breathability

Breathability is measured during the PFE test by reading the air pressure in the chambers before and after the filter, as air flows through the filter at a constant rate. The average airflow resistance for light breathing was 6.75 mmH2O, and for heavy breathing it was 15.48 mmH2O (see Table 1). The maximum allowable airflow resistance for non-powered respirators specified by NIOSH is 25 mmH2O exhalation and 35 mmH2O inhalation[7]. Especially at light breathing, such as a seated indoor job, the data show that B2 Filters are very breathable. One area noted for future improvement is the fairly large deviation between samples.

Table 1. Airflow Resistance During PFE Tests.

	Mean Airflow Resistance (mmH2O)	Standard Deviation
Light Breathing	**6.75**	2.35
Heavy Breathing	**15.48**	5.33

VI. Extended Use Simulation

As air passes through a filter over time, its filtration properties can change. To simulate use over an extended period of time, NaCl particles ranging from 30-300 nm were flowed over the filter at a constant rate of 42.5 L/min (half of 85 L/min because one filter was used). The heavy breathing rate is considered to be a worst-case scenario. The particle filtration efficiency was measured every 5 or 10 minutes, as was the pressure differential.

Figure 5 shows that the PFE was the lowest at the beginning of the test, and increased until the test was stopped at 110 min. Some time interval measurements are not shown in Figure 5 in order to reduce crowding, but they all followed the trend of increasing PFE over time. Figure 6 shows that the airflow resistance consistently increased over time as well.

Unfortunately, it is hard to accurately correlate test minutes with real-world hours of use. This is because the particle loading over time depends heavily on situational parameters, such as how many particles are in the environment where the user is and their breathing rate. We leave it up to the reader to draw conclusions about their particular use cases.

This test was performed during the development stage of B2 Filters before production began, so the test sample consisted of stacked layers of raw material in the design described in Section II, cut to size. They were the same materials used in production B2 Filters. Breathe99 intends to verify these results by testing a final-production B2 Filter. However these results provide reasonable confidence that, as a B2 Filter is used over time the protection does not deteriorate. It is the breathability that decreases over time as particle loading increases, which serves as a natural indicator to the user to change their filter.

Figure 5. Extended Use Simulation with Heavy Breathing, PFE.

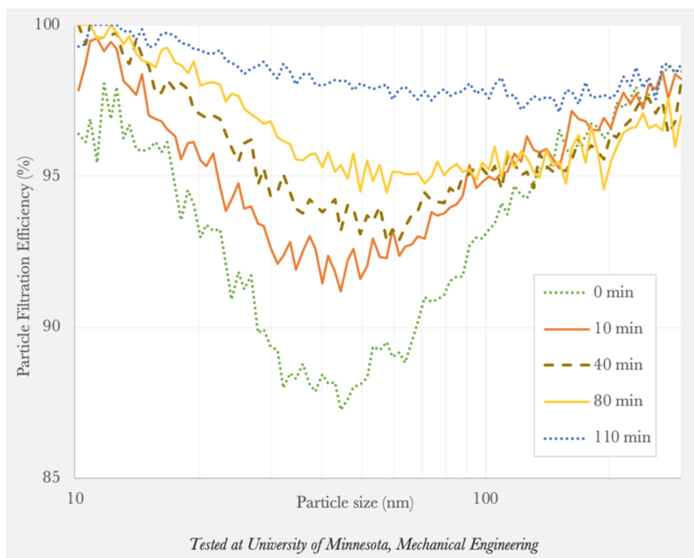
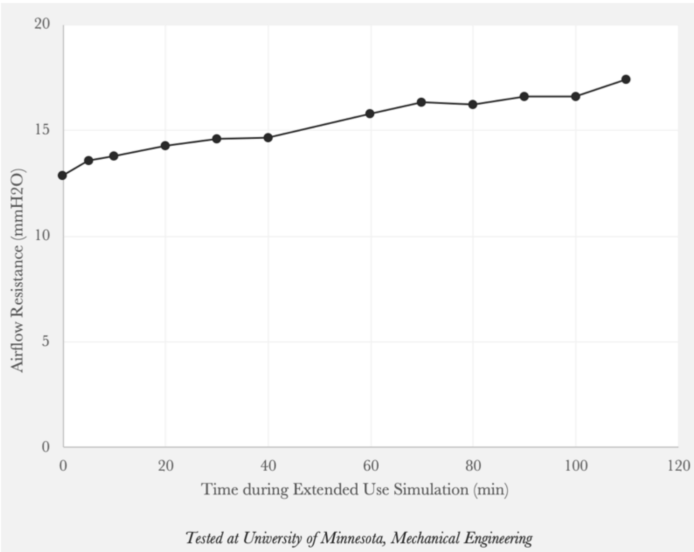


Figure 6. Extended Use Simulation with Heavy Breathing, Airflow Resistance.



VII. Bacterial and Viral Filtration

It is widely accepted that when it comes to particle filtration, it is the size of the particle that matters and not its composition[8]. It is also widely accepted that respiratory disease transmission occurs through human aerosol droplets as opposed to individual aerosolized pathogens[9]. Finally, it has been shown that both the FDA-recognized ASTM F2101 test for Bacterial Filtration Efficiency (BFE) and similar Viral Filtration Efficiency (VFE) test do not improvefilter certification over the more conservative NIOSH 42 CFR Part 84 respirator tests[10].

With this in mind, BFE and VFE tests are still of value in providing the public with peace of mind when it comes to disease control. The ASTM F2101 test method uses aerosol droplets of 3.0 ± 0.3 μm diameter, which is 10X larger than the largest particle size tested with B2 Filters. For 0.3 μm particles, B2 Filters showed an average 99.6% filtration efficiency for light breathing and 98.1% for heavy breathing (again, note that there appear to be some erratic measurements in the 0.3 μm size range visible in Figure 4).

A B2 Filter manufacturer has also previously contracted Nelson Labs to perform the ASTM 2101 BFE test on one of the B2 Filter materials. The report was confidentially shared with Breathe99 and showed over 99.9% BFE. Breathe99 plans to have the ASTM F2101 BFE and VFE tests performed on production B2 Filters at Nelson Labs in the near future.

VIII. Final Remarks

B2 Filters have been shown to provide excellent protection against environmental contaminants with good breathability. The other factor contributing to the overall protection of B2 Mask is the fit and airtight seal of the soft molded facepiece. Further fit testing is planned for B2 Mask, the likely subject of another Breathe99 publication. Breathe99 will continue to gather feedback and explore available filter materials that meet user needs in terms of protection and comfort. Breathe99 is in the process of arranging NIOSH pre-certification testing at Nelson Laboratories. However, we also continue to focus on non-medical use cases for which there is a need for high-quality protection.

We would like to thank our partner at the University of Minnesota Department of Mechanical Engineering for making reliable scientific testing possible during our rapid journey to produce B2 Filters.

References

[1] (Title 42 Public Health Code of Federal Regulations (CFR) Part 84 Respiratory Protective Devices)

[2] Owen, M., Ensor, D., & Sparks, LE. (1992). Airborne Particle Sizes and Sources Found in Indoor Air. Atmospheric Environment Part A-General Topics, 26(12), 2149-2162.

[3] Title 42 Public Health Code of Federal Regulations (CFR) Part 84 Respiratory Protective Devices, Subsection 174 Filter efficiency level determination test—non-powered series N, R, and P filtration.

[4] Eninger, R. M., Honda, T., Reponen, T., McKay, R., & Grinshpun, S. A. (2008). What does respirator certification tell us about filtration of ultrafine particles?. Journal of occupational and environmental hygiene, 5(5), 286–295. https://doi.org/10.1080/15459620801960153

[5] Common industry flow rate used filtration testing with the TSI 8130 filter tester, within ranges stated in Janssen, LL., Anderson, NJ., Cassidy, PE., Weber, RA., & Nelson, TJ. (2005), Interpretation of Inhalation Airflow Measurements for Respirator Design and Testing, Journal of the International Society for Respiratory Protections, Vol. 22, 122-141.

[6] See [3]

[7] Title 42 Public Health Code of Federal Regulations (CFR) Part 84 Respiratory Protective Devices, Subsection 172 Airflow Resistance Test.

[8] National Institute for Occupational Safety and Health. (2018, January 31). A Particle is a Particle. National Personal Protective Technology Laboratory (NPPTL).

[9] Atkinson J, Chartier Y, Pessoa-Silva CL, et al., editors. (2009) Natural Ventilation for Infection Control in Health-Care Settings. Geneva: World Health Organization. Annex C, Respiratory droplets. https://www.ncbi.nlm.nih.gov/books/NBK143281/

[10] Samy Rengasamy, Ronald Shaffer, Brandon Williams & Sarah Smit. (2017) A comparison of facemask and respirator filtration test methods, Journal of Occupational and Environmental Hygiene, 14:2, 92-103