First Test Set

Five cotton batting cloth masks were tested in May 2020 by Ken Sasaki of Levitt Safety, a professional fit tester in Vancouver, Canada following the methodology of CSA Standard Z94.4.[i]

The quantitative fit tests of the masks included seven exercises each lasting 30 seconds: normal breathing, deep breathing, turning head side-to-side, nodding head up and down, talking out loud, bending over, and normal breathing again. In quantitative fit testing, Fit Factor is defined as the ratio of the concentration of particles outside the mask to the concentration in the space between the inside of the mask and the wearer. Since the results of quantitative fit tests depend on both the filtering efficiency of the mask materials and the fit of the mask, the results are shown here as filtering effectiveness. The relationship between Fit Factor and filtering effectiveness is:

Equation 1. Filtering Effectiveness

$$Filtering\ Effectiveness = 1 - \frac{1}{Fit\ Factor}$$

An Accufit9000 (AccuTec.IHS) particle counter (capable of measuring particles of 0.02 µm to 1 µm) was used for the testing. The ambient particle count during the fit testing was approximately 7,000 particles per cm^3. For comparison, an N95 respirator (Moldex 2212) was tested at the same time. The average fit factor for the N95 respirator was 911.

Five different configurations of masks were tested, and the results are shown in Table 1.

Table 1. Fit Test Results: First Set

Mask	**Gasket**	**Batting Thickness** (mm)	**Basis Weight** (grams.m^{-2})	**Fit Factors for Seven Exercises**	**Filtering Effectiveness**
1	Yes	Double Layer: 5 mm	2 x 150	6,6,10,10,6,11,12	88.5%
2	Yes	Single Layer: 3.5 mm	1 x 200	9,10,12,7,12,11,8	89.9%
3	Yes	Double Layer: 7 mm	2 x 200	17,14,13,13,12,10,18	92.8%
				Average of Masks with Gaskets	**90.4%**
4	No	Double Layer: 5 mm	2 x 150	11,12,15,14,8,12,13	91.8%
5	No	Double Layer: 5 mm	2 x 150	7,7,11,7,7,10,10	88.1%
				Average of Masks Without Gaskets	**90.0%**

A gasket made of 3 mm thick ethylene-vinyl acetate foam was sewn into Masks 1 through 3, to see if this material would improve the seal between the mask and the face. In Masks 1 through 4, the nose wire was embedded in cotton batting. Mask 5 was made without batting around the nose wire to see if this would improve the seal between the mask and the nose and cheeks.

The tests showed that the filtering effectiveness for masks with gaskets was not significantly higher than for masks without gaskets, which suggests that the added cost and time needed to add a polymer gasket would not be worthwhile. The tests also showed it is possible to make cloth masks with a filtering effectiveness that is both higher than average for cloth masks, and that is also consistent. The average filtering effectiveness was 90.2% (95% CI 88.4% to 92%).

Second Test Set

A second set of three cotton batting cloth masks were tested in May, 2020 by Rachel Baaske of Link2Life Emergency Training, a professional fit tester in Vancouver, Canada also following the methodology of CSA Standard Z94.4. The quantitative fit tests of the masks included seven exercises each lasting 30 seconds: normal breathing, deep breathing, turning head side to side, nodding head up and down, talking out loud, bending over, and again normal breathing. An Accufit9000 (AccuTec.IHS) particle counter (capable of measuring particles of 0.02 µm to 1 µm) was used for the testing.

A gasket made of 3 mm thick ethylene-vinyl acetate foam was sewn into the inside edge of all three masks. Three different configurations of masks were tested, and the results are shown in Table 2 below.

Table 2. Fit Test Results: Second Set

Mask	**Batting Thickness** (mm)	**Basis Weight** (grams.m^{-2})	**Fit Factors for Seven Exercises**	**Filtering Effectiveness**
1	Double Layer: 5mm	2 x 150	4,6,5,4,3,3,3	75.0%
2	Single Layer: 3.5mm	1 x 200	9,7,4,3,3,4,4	79.4%
3	Double Layer: 7mm	2 x 200	5,7,4,5,4,4,2	77.4%
			Average of Masks with Gaskets	**77.3%**

The average filtering effectiveness of all masks in the second test set was 77.3% (95% CI 75.1% to 79.4%)

Third Test Set

A third set of cotton batting cloth masks was tested by Dr. Amy Mueller, Assistant Professor, Civil and Environmental Engineering, Northeastern University in Boston. In early 2020, Dr. Mueller and her colleagues tested a wide range of hand sewn and commercial facemasks, and the results of their work are described in their paper, *Quantitative Method for Comparative Assessment of Particle Filtration Efficiency of Fabric Masks as Alternatives to Standard Surgical Masks for PPE*. Dr. Mueller kindly agreed to include three copies of each cotton batting mask in a further round of testing in May and June 2020. Each mask copy was tested three times using a particle generator to produce 0.04 µm NaCl particles and PortaCount 8020 respirator fit testers. The test results are shown in Table 3 below.

Table 3. Fit Test Results: Third Set

Mask	Batting Thickness (mm)	Basis Weight (grams.m^{-2})	Filtering Effectiveness			Filtering Effectiveness
1a	Double Layer: 5mm	2 x 150	84.9%	87.8%	87.3%	**80.7%**
1b			80.0%	79.3%	79.3%	
1c			77.8%	75.9%	74.1%	
2a	Single Layer: 3.5mm	1 x 200	60.6%	62.3%	71.5%	**69.2%**
2b			64.5%	66.3%	62.7%	
2c			75.0%	80.1%	80.1%	
3a	Double Layer: 7mm	2 x 200	55.7%	61.4%	62.8%	**79.4%**
3b			88.3%	88.5%	88.6%	
3c			89.3%	91.2%	89.2%	
Average of Masks with Gaskets						**76.5%**

Mueller et al report that the test methodology included testing masks with and without a nylon layer over the mask. The reported intention of the nylon layer was to see its presence improved the filtering efficiency, which would indicate that the fit of the mask can be improved. The average filtering effectiveness of all masks without the nylon layer was 76.5% (95% CI 72.3% to 80.6%) and the average filtering effectiveness of all masks with the nylon layer was 83.7% (95% CI 80.9% to 86.4%). The higher average and smaller variation of test results with the nylon layer indicate that the fit of the mask needs improvement. The variability in results (for example between masks 3a and 3c) indicates that the consistency of hand-sewn masks also needs improvement.

The thickness of cotton batting used in the tested masks varied from 3.5 mm to 7mm, but the results did not show a strong correlation between effectiveness and thickness. The tests also showed that the design of the mask needs improvement to give a better fit, and that variability among masks needs to be reduced.

The value of loose-fitting masks in reducing emissions of respiratory droplets from the wearer has been acknowledged. The test results here show that cloth masks can also reduce the amount of small particles that the wearer inhales. The three sets of tests show that even with different testers, test methodologies, and mask designs, filtering effectiveness against incoming particles of 76.5%, 77.3%, and 90.2% was achieved. These results were achieved by novices, and the performance of factory-made cloth masks would likely be better.

[i] Canadian Standards Association. CSA Standard Z94.4-18 - Selection, use, and care of respirators.