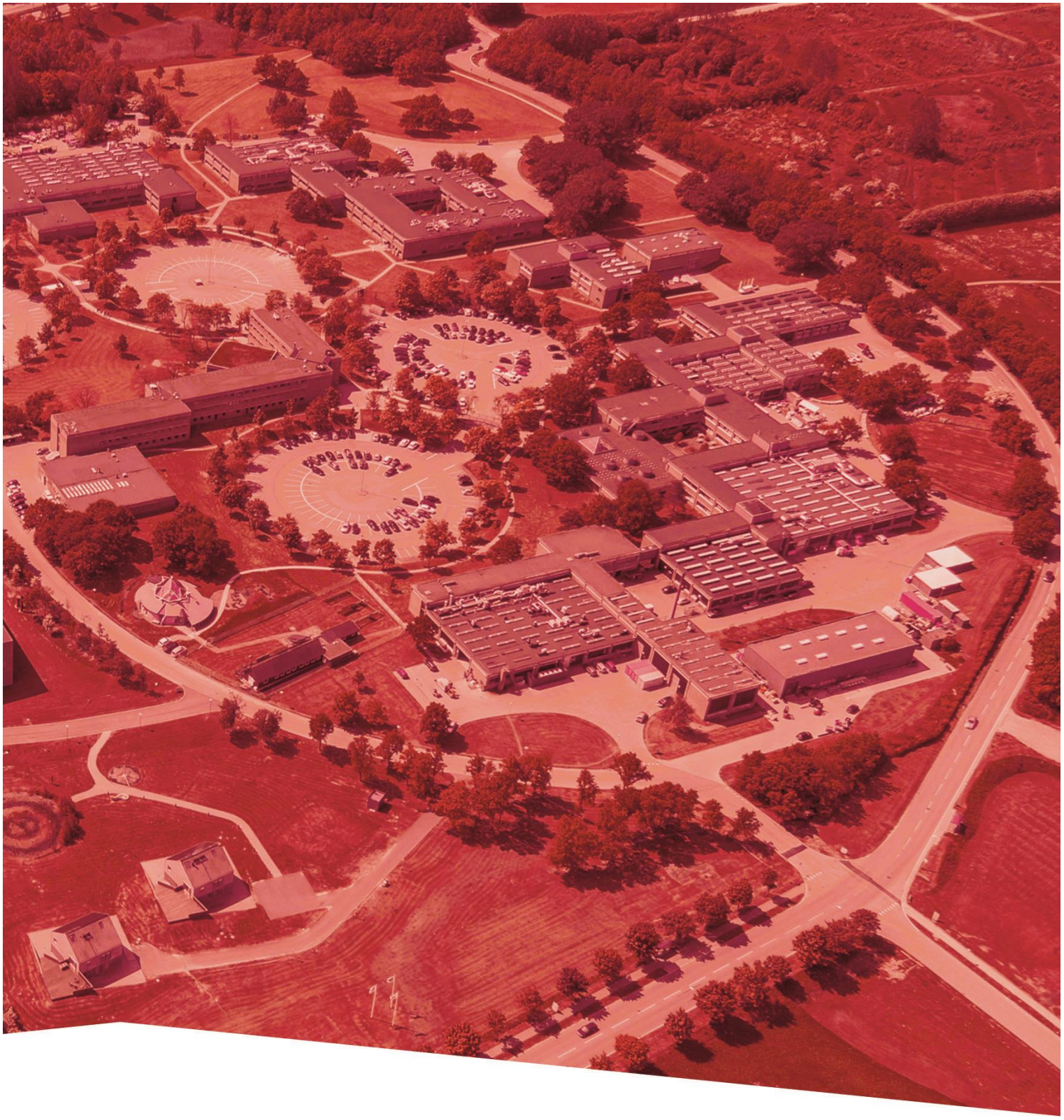

Test of Face Mask

DANISH
TECHNOLOGICAL
INSTITUTE

DANISH
TECHNOLOGICAL
INSTITUTE

Test of Face Mask

Report 952149_2

Prepared for:
RFX + Care International A/S
Bakkegårdsvej 408
3050 Humlebæk

Performed by:
Danish Technological Institute
Kongsvang Allé 29
8000 Aarhus C

February 2021

Author: Stig Koust Hansen, PhD Nanoscience, Consultant,
+45 7220 1151, stko@teknologisk.dk

Quality Assurance: Søren Legarth Brødsgaard, M.Sc., Senior Consultant,
+45 7220 1431 slb@teknologisk.dk

1. Assignment

RFX + Care International A/S (RFX+) has requested the Danish Technological Institute (DTI) to test their reusable face covering in accordance with CEN's guidelines for testing and requirements for Community Face Coverings (CWA17553:2020[1]). The CEN guide prescribe testing for the ability to retain droplet particles (aerosols) and breathability, as well as visual inspection and head harness strength. The tests are performed as described below:

1) Visual inspection – Performed in accordance with section 6.2 in CWA17553:2020

2) Filtration Efficiency - Performed in accordance with instructions in Annex D in CWA17553:2020

3) Breathing Resistance - Performed in accordance with EN13274-3:2002, which is one of the possible test standards referred to in CWA17553: 2020

4) Head Harness Strength - Performed in accordance with section 6.3 in CWA17553:2020

Measurements on 5 identical specimens of two different types are performed.

The above test is performed on the masks as supplied by RFX+ ("as-received"), as well as after 25 and 60 cleaning cycles at 60 degrees washing and hang-drying.

Both types of face masks have a pocket for an external filter and both face masks are tested with and without an external filter. RFX+ have delivered an external filter.

The measurements were performed on in the period 11th of November 2020 to the 25th of February 2021 at the Danish Technological Institute, Aarhus.

1.1. Disclaimer:

The report does not conclude on the filtration of viruses and bacteria, but rather on the filtration of aerosols of comparable sizes through the fabric material.

The method aims to assess the permeability of the material. This is a test that provides indicative results for the ability of the face mask to retain airborne particles (aerosols), and not a test of the finished face mask on a face.

This report supersedes report 952149.

[1] https://www.cencenelec.eu/research/CWA/Documents/CWA17553_2020.pdf

2. Conclusion

The overall result for the test of "IKA" is presented in Table 1 and for "TIG" in Table 2.
The suggested minimum requirements from CWA17553:2020 is presented in Table 3.

The face mask "IKA" thus complies with the requirements for a filtration ability of at least 90% with and without the external filter. However, the requirement for breathability is not fulfilled. These conclusions also apply following 25 and 60 cleaning cycles.

The face mask "TIG" thus complies with the requirements for a filtration ability of at least 70% with and without the external filter. This conclusion also applies following 25 and 60 cleaning cycles. The requirement for breathability is not fulfilled for the face mask "as-received". Following 25 cleaning cycles the breathability requirement for exhalation is fulfilled for the face mask without filter, but not after 60 cleaning cycles.

Table 1: Results for Face Mask "IKA" of test according to CWA17553:2020. Standard deviation in parenthesis.

Test	Breathing Resistance (at 95 L/min) [mbar]		Particle Filtration Efficiency (for 3 µm ± 0,5 µm)	Visual Inspection	Head Harness Strength
	Inhalation	Exhalation			
As-received*	3.4	3.4	92%	No defects Observed	No damage observed
As-received (with filter)	5.1 (±0.3)	5.1 (±0.6)	95% (±3%)	No defects Observed	No damage observed
After 25x Cleaning	6.2 (±0.3)	6.2 (±0.1)	96% (±3%)	No defects Observed	No damage observed
After 25x cleaning (with filter)	7.8 (±0.3)	7.9 (±0.4)	98% (±2%)	No defects Observed	No damage observed
After 60x cleaning	7.6 (±0.2)	7.5 (±0.1)	99% (±0%)	No defects Observed	No damage observed
After 60x cleaning (with filter)	9.4 (±0.8)	9.6 (±0.4)	> 99% (±0%)	No defects Observed	No damage observed

* Only 1 specimen tested

Table 2. Results for Face Mask "TIG" of test according to CWA17553:2020. Standard deviation in parenthesis.

Test	Breathing Resistance (at 95 L/min) [mbar]		Particle Filtration Efficiency (for 3 µm ± 0,5 µm)	Visual Inspection	Head Harness Strength
	Inhalation	Exhalation			
As-received*	3.4	3.5	73%	No defects Observed	No damage observed
As-received (with filter)	4.7 (±0.7)	4.4 (±0.3)	90% (±6%)	No defects Observed	No damage observed
After 25x cleaning	2.7 (±0.4)	2.7 (±0.3)	78% (±1%)	No defects Observed	No damage observed
After 25x cleaning (with filter)	4.6 (±0.3)	4.8 (±0.4)	89% (±5%)	No defects Observed	No damage observed
After 60x cleaning	2.9 (±0.4)	3.2 (±0.4)	79% (±2%)	No defects Observed	No damage observed
After 60x cleaning (with filter)	4.5 (±0.2)	4.9 (±0.8)	94% (±5%)	No defects Observed	No damage observed

* Only 1 specimen tested

Table 3: Minimum requirements as stated in CWA17553:2020.

	Breathing Resistance (at 95 L/min) [mbar]		Particle Filtration Efficiency (for 3 µm ± 0,5 µm)	Visual Inspection	Head Harness Strength
	Inhalation	Exhalation			
Requirement	Max. 2.4	Max. 3.0	Level 70%: Min. 70% Level 90%: Min. 90%	No visible defects	Withstand 5 cycles of being put on and removing (donning and doffing)

3. Samples

5 specimens of each type of the two face masks were delivered to the Danish Technological Institute (DTI). The types are denoted "IKA" and "TIG", respectively, and labelled 1-5 directly on the specimen.

The face mask is categorized as reusable face covering and consists of 100% cotton. Both types have a pocket for an external filter. External filters to fit in the face masks were delivered by RFX+ (Figure 1).

For the "as-received" sample tested without filter, a single specimen of each type was received and tested.

The external filter is fitted into the pocket in face mask by the test responsible from DTI to the best of his capability (Figure 2). However, it should be noted that a perfect fit into the pocket was difficult. Hence, various bends and folds was unavoidable for the external filter. Most likely this gives rise to variations in the results. New external filters were used for each test.

Figure 1: External Filters delivered by RFX+

Figure 2: Face Masks delivered by RFX+. "IKA" shown on the left and "TIG" shown on the right. The bottom images show the face mask fitted with the external filter.

4. Methodology and Equipment

The ability of the face mask to retain aerosols was tested in an experimental setup consisting of a specially designed tube assembly with an inner diameter of 8 cm (Figure 3). In the setup, flow is generated with a fan at the end of the test tube and controlled with a flow regulator and anemometer

(Testo 405i Smart Probe). A constant flow rate of approximately 6 cm/s was used as filtration velocity across the face mask, as defined in CWA17553: 2020, Annex D. This results in a flow of approximately 18 L/min

The face mask was unfolded and mounted in the setup in a leak-tight manner by clamping between two rubber O-rings in an adjustable closing mechanism. The inner side of the face mask is turned towards the incoming aerosols, hence simulating protection against spreading of droplets *from* the carrier.

Test aerosols were generated with a Palas AGK 2000 aerosol generator using a 3% potassium chloride (KCl) solution. This aerosol consists of solid particles in water droplets with a wide particle size distribution, where a significant fraction has a particle size around and smaller than 1µm, but at the same time a sufficiently high concentration of aerosols with a size of 3 µm (± 0.5 µm). This is comparable to droplet particles derived from speech, coughing and exhalation.

Particle number concentration was measured with an Optical Particle Sizer (OPS, TSI Model 3330) in the size range 0.3 µm to 10 µm. This instrument measures the particle size distribution in 16 fractions. The measurement is performed by alternately measuring the concentration on the front ("downstream") and back ("upstream") (point 2 and 3, respectively, in Figure 2) of the fabric material for a period of at least 2 minutes. Prior to each test, a stable concentration of aerosols in the setup is ensured.

The filtration efficiency reported here is calculated as described in Annex D of CWA17553:2020.

$$E(\%) = \frac{C_{upstream} - C_{downstream}}{C_{upstrean}} \times 100$$

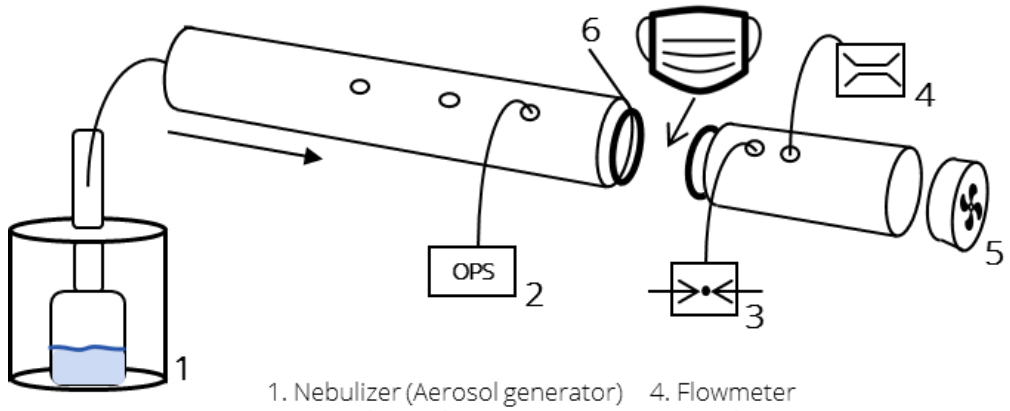

Figure 3: Schematic overview of test setup

The pressure difference (for determining breathing resistance) is measured in the same setup as described above, with no aerosols added. A constant flow of 95 L / min is used over the face mask. Air is drawn through the face mask and the pressure drop is measured between the ambient air and a measuring port on the suction side of the face mask (point 3 in Figure 2). The pressure difference is

measured with a manometer (Testo 435). The test is performed according to the procedure for "Static Breathing Resistance" described in EN13274-3: 2001.

Washing of the face masks was performed at 60 °C ("Normal 60", 55 minutes) on a washing machine of the brand Electrolux W555H. Then the masks were hung for hanging drying until all the masks were completely dry.

5. Results

5.1. Visual Inspection

The face masks were thoroughly inspected visually after receiving the samples and prior to test. No visual defects were observed on the face masks, neither "as-received" or following 25 cleaning cycles.

5.2. Filtration Efficiency

The filtration efficiency for each specimen based of particle number concentration is shown for "IKA" and "TIG" in Table 4 and Table 5, respectively.

In addition, the external filter was tested without being equipped in a face mask. The filtration efficiency was found to be 98%.

Table 4: Particle Filtration Efficiency for each of the 5 specimen of face mask "IKA"

Particle Filtration Efficiency (for 3 µm ± 0,5 µm)	IKA 1	IKA 2	IKA 3	IKA 4	IKA 5	Average
As-received*	92%*	-	-	-	-	92%
As-received (with filter)	91%	> 99%	93%	97%	95%	95% (±3%)
After 25x Cleaning	93%	98%	97%	92%	97%	96% (±3%)
After 25x cleaning (with filter)	98%	99%	> 99%	97%	95%	98% (±2%)
After 60x Cleaning	99%	> 99%	99%	99%	> 99%	99% (±0%)
After 60x cleaning (with filter)	> 99%	> 99%	> 99%	> 99%	> 99%	99% (±0%)

Table 5: Particle Filtration Efficiency for each of the 5 specimen of face mask "TIG"

Particle Filtration Efficiency (for 3 µm ± 0,5 µm)	TIG 1	TIG 2	TIG 3	TIG 4	TIG 5	Average
As-received*	73%*	-	-	-	-	73%
As-received (with filter)	98%	93%	91%	85%	82%	90% (±6%)
After 25x Cleaning	77%	79%	78%	77%	77%	78% (±1%)
After 25x cleaning (with filter)	95%	80%	93%	87%	92%	89% (±5%)
After 60x Cleaning	82%	80%	79%	77%	79%	79% (±2%)
After 60x cleaning (with filter)	92%	> 99%	88%	> 99%	93%	94% (±5%)

The total concentration of particles on the upstream side of the face mask was 4000 (± 100) particles per cm^3, of which there were a minimum of 100 particles with a size of 3 µm (± 0.5 µm).
In CWA17553:2020 two levels of community face coverings are considered according to their filtration efficiency to particles around 3 (± 0.5) µm:
- Level 90%: greater than or equal to 90%
- Level 70%: greater than or equal to 70%

5.3. Breathing Resistance

The breathing resistance for each specimen based on the pressure drop across the speciment is shown for "IKA" and "TIG" in Table 6 and Table 7, respectively.
In addition, the external filter was tested without being equipped in a face mask. The breathing resistance was found to be 1.8 mbar.

Table 6: Breathing Resistance for each of the 5 specimen of face mask "IKA"

Breathing Resistance (at 95 L/min) [mbar]		IKA 1	IKA 2	IKA 3	IKA 4	IKA 5	Average
As-received	Inhalation	3.4	-	-	-	-	3.4
	Exhalation	3.4	-	-	-	-	3.4
As-received (with filter)	Inhalation	4.7	5.4	4.7	5.5	5.0	5.1 (±0.3)
	Exhalation	4.3	4.3	5.3	5.8	5.6	5.1 (±0.6)
After 25x Cleaning	Inhalation	6.6	6.4	5.9	6.4	5.9	6.2 (±0.3)
	Exhalation	6.3	6.1	6.3	6.3	6.0	6.2 (±0.1)
After 25x cleaning (with filter)	Inhalation	7.4	8.3	7.6	7.5	8.0	7.8 (±0.3)
	Exhalation	7.5	8.6	7.7	7.8	7.8	7.9 (±0.4)
After 60x cleaning	Inhalation	7.7	7.2	7.2	7.8	7.5	7.6 (±0.2)
	Exhalation	7.5	7.5	7.4	7.7	7.7	7.5 (±0.1)
After 60x cleaning (with filter)	Inhalation	9.2	9.6	10.5	8.6	9.0	9.4 (±0.7)
	Exhalation	9.5	9.7	8.9	9.9	10.0	9.6 (±0.4)

Table 7: Breathing Resistance for each of the 5 specimen of face mask "TIG"

Breathing Resistance (at 95 L/min) [mbar]		TIG 1	TIG 2	TIG 3	TIG 4	TIG 5	Average
As-received	Inhalation	3.5	-	-	-	-	3.5
	Exhalation	3.4	-	-	-	-	3.4
As-received (with filter)	Inhalation	4.5	4.7	4.4	5.9	4.0	4.7 (±0.7)
	Exhalation	4.7	4.4	4.2	4.6	3.9	4.4 (±0.3)
After 25x Cleaning	Inhalation	2.4	2.5	2.5	3.4	2.7	2.7 (±0.4)
	Exhalation	2.5	2.4	2.6	3.2	2.7	2.7 (±0.3)
After 25x cleaning (with filter)	Inhalation	4.5	4.5	4.6	5.1	4.2	4.6 (±0.3)
	Exhalation	4.7	4.3	4.8	5.4	4.5	4.8 (±0.4)
After 60x Cleaning	Inhalation	2.7	2.8	2.7	3.7	2.7	2.9 (±0.4)
	Exhalation	3.0	3.1	2.9	4.1	3.1	3.2 (±0.4)
After 60x cleaning (with filter)	Inhalation	4.7	4.2	4.3	4.8	4.6	4.5 (±0.2)
	Exhalation	4.4	5.0	4.5	6.3	4.2	4.9 (±0.8)

5.4. Head Harness Strength

Head harness strength is tested by putting on and removing (donning and doffing) each mask 5 times. While wearing the mask a small sequence of moving the head (up & down. side to side) and moving the mouth was performed.

No damage to the head harness was observed for the five tested face masks. neither "as-received" or following 25 and 60 cleaning cycles.