MEMO:

Research results – Development phase 3DQ.nl Adapter (prototype)

3D Printing Limburg

Date: 14-04-2020
Version: 2.1
By: ing. Ton Scheres, CTO, 3D Printing Limburg BV
Rutger van Knippenberg, Print Operator, 3D Printing Limburg BV

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1.Motivation

We were asked to start developing and testing an adapter to connect various easily available full face snorkel masks to standard P3 filters.

2. Basic principles

i. The prototype has to be made in such a way that it is suitable for industrial production.

ii. The combination 'snorkel mask - adapter – filter' needs to be viewed as a complete safe and robust PPE unit and must conform to the following minimum norms:

> a. Face Fit Test where the combination as a complete unit gives a protection factor of >1000, based on the standards in the following documents:
>
> i. https://www.veiligheidskunde.nl/xu/document/cms/streambin.asp?requestid=5868E144-9EF8-45BC-8AED-A4554C46BE28
>
> ii.https://www.safetysign.nl/userfiles/Gele_Safety_Sign/20170216_Reglement_Erkenningsregeling_Gele_Safety_Sign.pdf
>
> b. We focused only on the combination 'snorkel mask – adapter – filter', even though it is known that in addition to these PPE's, other PPE's such as gloves, disposable overalls category CE3 etc, should be worn in areas where the air could be contaminated with Covid-19 particles or other comparable virus particles.

iii. The adapter, in combination with a snorkel mask and a filter, is to be used in an environment where the air is possibly (highly) contaminated with microorganisms such as Covid-19 particles. Even though a good snorkel mask and a good filter should be used, it cannot be discounted that a (very) limited number of microorganisms could get into the mask. Therefore the adapter should be both designed and produced so that on both the outside and the inside as few microorganisms as possible can remain behind or attach themselves to (miniscule) crevices and/or joints in the adapter. If this were to happen, the virus particles might be able to multiply, and we could then see a so-called hotbed of virus particles. It is known that microorganisms, such as virus particles, can enter the body via the mucous membranes of the eyes

iv. It should be possible to clean, disinfect and/or sterilise effectively both the combination 'snorkel mask - adapter – filter' as a whole, and also as separate parts, so that it can be re-used. Microorganisms should be given as little opportunity as possible to remain behind in crevices and joints of the adapter (or those of the snorkel mask and/or filter).

v. The combination 'snorkel mask - adapter – filter' must not suddenly come loose under normal use.

vi. Preference is given to the use of recognised (screw) connections between filter(s) and (snorkel) masks.

3. PHASE 1: Assessment of existing adapters

During the 1st development phase a number of existing 3D-printed adapters which were provided to us were closely judged and tested (using a certified Face Fit Test and other methods) and analysed.

The tests were carried out on:

i. Decathlon type 1, with Charlotte Valve adapter, linked to breathing apparatus
ii. Atlantis mask in combination with Atlantis V1.1 adapter (FDM/SLA) and HME filter
iii. Uno mask in combination with Uno V1.2 adapter (FDM/SLA) in combination with HME filter
iv. Decathlon version 1 mask in combination with Safety - Ocean Reef adapter (FDM/SLA) in combination with P3 filter screw connection.

In addition to these 4 models, we also carried out continuous shadow tests (such as a certified Face Fit Test) with full face masks used in the asbestos industry, which are used in a similar way in practice. In this case we tested the Scott Vision2 mask, in combination with the matching P3 filter with screw connection (RD=40).

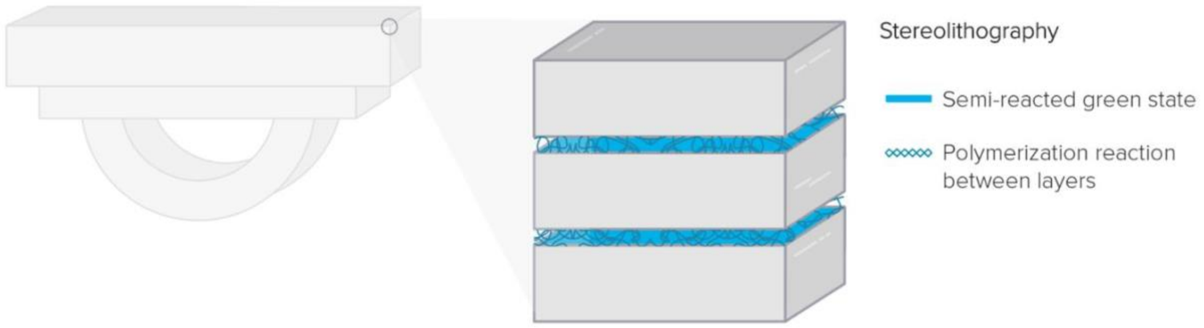
Of these 4 models we had both a variant printed using FDM (without finishing!) and a variant printed using SLA. Our test results show that FDM without a finishing process such as adding a coating is completely unsuitable for this type of use, because:

- We consider that the example printed using FDM can and should be only used as a disposable because the space between the layers is a perfect place for virus particles such as Covid-19 (and bacteria) to multiply (risk of "hotbed")

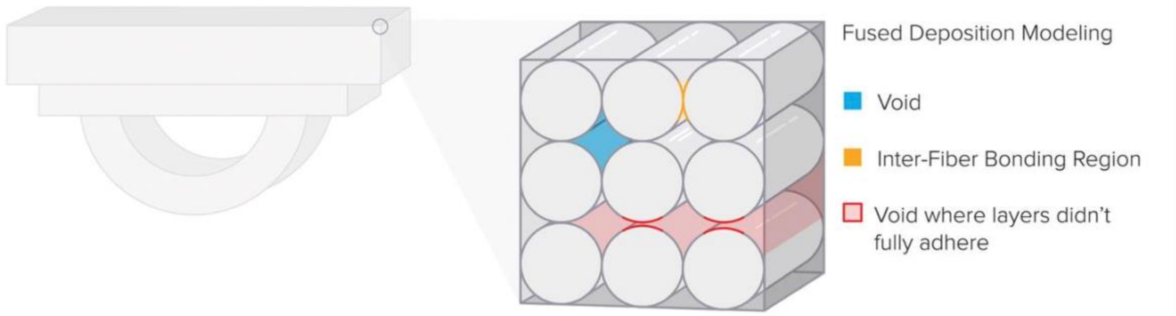
- An FDM printed adapter is absolutely unsuitable for disinfection, which is necessary if these adapters have to be used several times or for a longer period of time.

- FDM models (certainly PLA) are not strong enough to come through a materials stress test, the click system is not suitable for multiple use and in time, will leak.

- See the diagram below for a graphical representation.



In SLA prints, there is no difference between the Z-axis and the XY plane in terms of chemical bonds; each continuous part printed on an SLA machine is a continuous polymer network.



FDM 3D printers form layers by depositing lines of PLA or ABS. This process means that layers are not bonded together as strongly as the lines (filament extrusion) themselves; there are voids in between the rounded lines and it's possible that layers may not fully adhere to one another.

4. Plus factors per model

a. Charlotte Valve

- The only adapter in the test that was focused on active respiration
- As far as we can ascertain, this is the 'first' initiative that is aimed for use with snorkel masks, so it is a source of inspiration for others.
- We did not carry out a Face-Fit test, because we do not have a ventilator machine and we did not want to concentrate on the combination of an adapter and a ventilator in this test process.

b. Atlantis V1.1

- Cheap and easy to produce quickly in large quantities.

c. Uno V1.2

- Cheap and easy to produce quickly in large quantities.

d. Safety - Ocean Reef (Made in Italy)

- The adapater is a good size, so it is a good fit on the adapter of the mask.
- It uses the right filter (the Scott Pro2000) which is safe to use for passive respiration
- Compact and with the filter situated at the top of the head at a spot where as few virus particles as possible are found.

5. Shortcomings per model

a. Charlotte Valve adapter

- Intended for active respiration via breathing apparatus.
- Print orientation - it is impossible to print this model without supports. The places where the supports are later removed and where supports have been situated leave rough patches which, when in use, would provide an ideal growing place for virusses.
- The walls are too thin, there are weak spots in the model that could quickly break.
- Partly because of the thin walls, the model is not sturdy enough, whereby the adapter could leak,
- The tolerances are too great, so it doesn't close closely enough, and leakages could arise.
- Separation of the canals is insufficient, and leaks occur because the distance in the adapter is too great; this must not happen, particularly during active respiration.

b. Atlantis V1.1

- The example printed using FDM can only used as a disposable because the space between the layers is a perfect place for bacteria and virus particles to multiply. An FDM printed adapter cannot be disinfected well enough for repeated use or for use over a longer period of time!

• FDM models (certainly PLA) are not strong enough to come through a materials stress test, the click system is not suitable for multiple use and in time, will leak.

• Tolerances: the model does not fit adequately onto the adapter of the snorkel mask; there are clearly leaks present.

• The clip on the snorkel mask is not used, so it is not fixed in place and during use could start to leak unnoticed, could become loose or even fall off.

• In our view the HME-filter used is not good enough for passive respiration. The suction is too strong and can cause the filter to become loose. (This happened during our Face Fit Test!). The air also has to pass through a relatively narrow tube, whereby resistance is built up. *Considering that air takes the route of least resistance, if this is drawn in, the resistance is too high.*

c. Uno V1.2

• The example printed using FDM can only used as a disposable because the space between the layers is a perfect place for bacteria and virus particles to multiply. An FDM printed adapter cannot be disinfected well enough for repeated use or for use over a longer period of time!

• FDM models (certainly PLA) are not strong enough to come through a materials stress test, the click system is not suitable for multiple use and in time, will leak.

• Tolerances: the model does not fit adequately onto the adapter of the snorkel mask; there are clearly leaks present.

• The clip on the snorkel mask is not used, so it is not fixed in place and during use could start to leak unnoticed, or could become loose or even fall off.

• The filter used (Intersurgical) is not good enough for passive respiration. The suction is too strong, and can cause the filter to become loose. (This happened during our Face Fit Test!).

d. Safety - Ocean Reef (Made in Italy)

• The walls are too thin, there are weak places in the model that could quickly break.

• Partly because of the thin walls, the model is not sturdy enough, and not "stress resistant", whereby the adapter could leak.|

• The screw filter sits 'on 'the adapter instead of 'in' it, which results in a weak spot should the filter receive a knock or a fall which puts stress on the filter. The adapter can even split or break as a result.

• Incorrect / unsatisfactory print-orientation. It is impossible to print this model without supports. The places where the supports are later removed and where supports have been situated leave rough patches in which microorganisms such as virus particles could nestle and multiply (hotbed risk).

6. Face Fit Test resultas per model tested

We submitted the alternative models Atlantis V1.1., Uno V1.2 and Safety - Ocean Reef – Made in Italy to a face fit test. The Charlotte Valve was not submitted to a face fit test because the adapter is only inteded for use with active respiration. These face fit tests were carried out according to the “Yellow Safety Sign” certified test method by a certified Face Fit company. The test norm of a Protection factor of > 1000 was used, which in our view is usual for a full face mask without forced air unit. See: https://www.veiligheidskunde.nl/xu/document/cms/streambin.asp?requestid=5868E14 4-9EF8-45BC-8AED-A4554C46BE28

a.Charlotte Valve:

- Not tested further because this model is intended for active respiration.

b. Atlantis V1.1

- Mask used: Atlantis
- Highest value measured: 15
- Face Fit Test general value: 11
- Test successful: No

c. Uno V1.2

- Mask used: Uno
- Highest value measured: 8
- Face Fit Test general value: 5
- Test successful: No

d. Safety - Ocean Reef (Made in Italy)

- Mask used: Decathlon model 1
- Highest value measured: 1570
- Face Fit Test general value: 1024
- Test successful: Yes

e. Scott-Vision2 (shadow test)

- Mask used: Vision 2 with matching P3-filter
- Highest value measured: >60.000
- Face Fit Test general value: >40.000
- Test successful: Yes

7. Own design 3DQ adapter - Prototype

Based on the experiences and test results of Fase 1 as shown above, we chose to develop our own 3DQ adapter (design – test – adapt design – test etc). In this process the tests were carried out with various materials, various types of filters and various designs. In this phase we designed – tested – redesigned – tested etc – a range of variations.

See the photo below for an impression of the models and filters tested.

8. Final design of 3DQ adapter that fulfills the basic principles (Prototype)

• SLA

We chose to make a 3Dprint using SLA, because it produces a smooth finish which can be cleaned well. This strong material ensures that the model will not split or break.

• Formlabs-resin:

We tested various resins, and chose to use a resin in the "Formlabs" range, a fairly expensive resin, but which definitely conforms to the quality requirements as formulated in the basic principles. This is particularly important because the combination of full face (snorkel) mask – with adaptor – filter needs to be used as PPE in areas where the air could be contaminated with many Covid-19 particles (microorganisms).

• Minimum wall thickness of 2mm

We specifically chose a minimum wall thickness of 2 mm which produces a very robust model which will not easily leak after being knocked or falling.

• P3 filter met RD 40mm en/of RD 50mm

We chose to use the Scotts Pro2000 filter (P3), as this conforms to the correct class of filter to be used with microorganisms such as virus particles including Covid-19 particles

The diameter of the filter is also important. The bigger this diameter, the easier it is to breathe in and out through the filter. In the combinations of mask + adapter + HME filter we tested, we found that none of the combinations passed the face fit test, presumably because the HME filter has too small a diameter, giving a high resistance, whereby, when breathing in, a flow of air is created through a weak spot in the combination. Such a vulnerable spot could be a crevice or hole in the HME filter, that then increases in size, but it could also be a gap or hole in the adapter or a gap in the mask (along a pressure valve at the discharge outlet) or more likely, via a gap between the rubber edge and the face.

• Screw fitting conform EN 148-1

The Scotts Pro2000 filter (P3) has the great advantage that it has a (standard) screw fitting, so leaks can scarcely or never occur when this P3 filter is screwed onto the adapter.

• Seamless connection to the mask

The connection to the mask is seamless and can be fixed using a solid clip, so that the adaptor cannot suddenly fall off during normal movement.

9. Face Fit Test 3DQ adapter

- Mask used: Decathlon model 1
- Highest value measured: 14678
- Face Fit Test general value: 3075
- Test successful: Yes

10. Saturation test 3DQ adapter

This test measures the quantity of oxygen which is taken up by the blood. In the medical world a value of 95% or higher (SpO2) is considered a nomal value for a healthy person. Values of 90% or lower give cause for concern, and immediate contact should be made with a medical specialist.

SP02 value	Heart Rate	Moment	Section
98	70	0:00	Start test
97	76	0:05	Measurement 1
99	86	0:10	Measurement 2
98	73	0:15	Inizio Face Fit Test
98	73	0:15	Phase 1: Normal Breathing
97	71	0:17	Phase 1: Normal Breathing
98	80	0:19	Phase 3: Head side-to-side
97	83	0:21	Phase 4: Head up-and-down
99	82	0:23	Phase 5: Talk out loud
97	81	0:25	Phase 6: Bending over
97	72	0:27	Phase 7: Normal Breathing
98	73	0:29	Phase 8: Fine
98	70	0:30	Measurement 3
99	64	0:45	Measurement 4
99	63	1:00	Measurement 5

11. Other relevant aspects

• Air flows always take the route of least resistance. If there is an "open connection" somewhere in the combination of mask – adapter – filter, this is easy to see in the Face Fit Test. An open connection, or gap can occur in the connection between filter and adapter and/or between adapter and mask and/or between mask and face and/ or via pressure release valves in the mask.

In all the tests of combinations with HME filters the average face fit score test was no higher than 10.

• There are specific norms for different filters: use the correct one. See appendix 2. Norms are written for a specific application. It is incorrect to asssume a particular filter norm for a different application than that to which the filter norm applies. A number of other aspects are important as well as good "air filtering".

o Can the filter cope with large (sudden) differences in air pressure?

o Can the filter cope with high wind pressure? In normal language: the filter should be able to deal with "*steenslag*" if the wind is sucked in at a higher pressure. As an example, when air is blown out by a vacuum cleaner, the filter must not break down immediately if a sharp particle is pushed against the filter at high pressure. Should that happen, a larger hole would develop as the air will take the route of least resistance, mainly by going through the larger "hole". As a result, the "hole" that results from a broken filter could increase in size quite quickly.

o How large is the filter surface area? Filters with a small surface area will become full or blocked more quickly. At that point the resistance of the filter will increase and the air will seek out the route of least resistance.

• Visibility through the mask. An asbestos mask has a convex screen, which gives good visibility, including in the corners. Snorkel masks, intended mainly to be able to see under water usually have flat screens. Above water visibility is reduced by flat screens. The Decathlon-snorkel mask has a flat screen, which limits visibility more than other (snorkel) masks.

• Comfortability of the mask. Asbestos masks are many times more comfortable than snorkel masks. This is because the rubber around the mask is of better quality, which gives it a better fit, and also makes it more comfortable. Also important is the number of straps with which the mask is held in place. An asbestos mask usually has 5 straps, a snorkel mask usually only 2. It is possible that the pressure points could cause irritation after a while. In a mask with more straps the pressure on each strap is less, so irritation will occure less quickly.

• Communication via the mask. A (half) face mask fits better than a traditional medical face mask (*mondkapje*) and provides better noise resistance. Partly because of this, spoken communication can be affected. In the asbestos market there are masks available that reduce noise, but which still allow good spoken communication. Snorkel masks vary in the amount of noise reduction they provide.

• Spectacle wearers. For professional asbestos masks, and a number of snorkel masks suitable accessories are available for people who wear glasses. These can be ordered at different prescription strengths and can be clicked on to the inside of the mask. The Decathlon masks, both model 1 and 2, do not have options for spectacle wearers.

• Sterilisation and cleaning options for the whole set. When choosing the correct method of printing (FDM or SLA) it has already been stated that rough areas should be avoided as much as possible, because virus and other particles and gather or nestle here, which can cause a hotbed risk. This applies also to the mask and the filter, both on the inside and the outside.

• Beard growth. A beard or unshaved face has a negative effect on the Face Fit Test score.

• Match the type of breathing protection to the level of concentration of breathable particles (fine particles and/or microorganisms) in the air / in the area and to the time when breathing protection should be used.

- o In areas with high concentrations, where someone has to work for a long period (>1 hour) we advise using a full face mask with forced air unit.
- o In areas with low concentrations, we consider a half face mask would be sufficient.
- o We have not tested traditional face masks (*mondkapjes*) enough, but our opinion is that the risk of 'open connections' is much greater with a traditional mask than with half face and full face masks. On the other hand, partly because of these open connections, the resistance of the filter is lower in a traditional mask so the lungs do not have to work so hard.

12. Futher development

On the request of several doctors and anesthesiologists we will work to develop and test half face masks. We need to find a solution to the problem that virus particles can enter the body via mucous membranes of the eyes. More information will follow in due course.

Appendix 1: Relevant scientific documents

https://oceanreefgroup.com/covid19/

https://www.veiligheidskunde.nl/xu/document/cms/streambin.asp?requestid=5868E144- 9EF8-45BC-8AED-A4554C46BE28

https://www.safetysign.nl/userfiles/Gele_Safety_Sign/20170216_Reglement_Erkenningsregeling_Gele_Safety_Sign.pdf

https://media.carellurvink.nl/files/item/kcclhoofdstuk/500200.pdf

https://www.vdp.com/resources/338/767.pdf

https://www.koudeenluchtbehandeling.nl/verdieping/corona-voorzorgsmaatregelenventilatie-en-luchtbehandeling-tegen-mogelijke-verspreiding-100019?vakmedianetapprove-cookies=1&_ga=2.45600420.1608767974.1585812997-2046622355.1585812997脊

https://support.blacklinesafety.com/notifications/covid-19-disinfecting-g7

https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

https://www.who.int/medicines/areas/quality_safety/quality_assurance/SupplementaryGMPHeatingVentilationAirconditioningSystemsNonSterilePharmaceuticalDosageFormsTRS961Annex5.pdf?ua=1

Appendix 2: Table showing different filter norms

ASHRAE Standard 52.2				ASHRAE Standard 52.1	Application Guidelines		
MERV	Particle Size Removal Efficiency, Percent in Particle Size Range, µm			Dust-Spot Efficiency Percent	Particle Size and Typical Controlled Contaminant	Typical Applications	Typical Air Filter/Cleaner Type
	0.3 to 1	1 to 3	3 to 10				
20	≥ 99.999	in 0.1 – 0.2 µm particle size		—	< 0.3 µm Virus (unattached) Carbon dust Sea salt All combustion smoke	Electronics manufacturing Pharmaceutical manufacturing Carcinogenic materials	HEPA/ULPA Filters*
19	≥ 99.999	in 0.3 µm particle size		—			
18	≥ 99.99			—			
17	≥ 99.97			—			
16	> 95	> 95	> 95	—	0.3-1 µm All bacteria Droplet nuclei (sneeze) Cooking oil Most smoke Insecticide dust Most face powder Most paint pigments	Superior commercial buildings Hospital inpatient care General surgery	**Bag Filters** – Nonsupported (flexible) microfine fiberglass or synthetic media, 12 to 36 inches deep. **Box Filters** – Rigid style cartridge, 6 to 12 inches deep.
15	85-95	> 90	> 90	> 95			
14	75-85	> 90	> 90	90-95			
13	< 75	> 90	> 90	80-90			
12	—	> 80	> 90	70-75	1-3 µm Legionella Humidifier dust Lead dust Milled flour Auto emission particles Nebulizer drops	Superior residential Better commercial buildings Hospital laboratories	**Pleated filters** –Extended surface with cotton or polyester media or both, 1 to 6 inches thick. **Box Filters** – Rigid style cartridge, 6 to 12 inches deep.
11	—	65-80	> 85	60-65			
10	—	50-65	> 85	50-55			
9	—	< 50	> 85	40-45			
8	—	—	> 70	30-35	3-10 µm Mold Spores Dust mite body parts and droppings Cat and dog dander Hair spray Fabric protector Dusting aids Pudding mix Powdered milk	Better residential Commercial buildings Industrial workplaces	**Pleated filters** –Extended surface with cotton or polyester media or both, 1 to 6 inches thick. **Cartridge filters** –Viscous cube or pocket filters **Throwaway** –Synthetic media panel filters
7	—	—	50-70	25-30			
6**	—	—	35-50	< 20			
5	—	—	20-35	< 20			
4	—	—	< 20	< 20	> 10 µm Pollen Dust mites Cockroach body parts and droppings Spanish moss Sanding dust Spray paint dust Textile fibers Carpet fibers	Minimum filtration Residential window air conditioners	**Throwaway** – Fiberglass or synthetic media panel, 1 inch thick. **Washable** – Aluminum mesh, foam rubber panel **Electrostatic** – Self-charging (passive) woven polycarbonate panel
3	—	—	< 20	< 20			
2	—	—	< 20	< 20			
1	—	—	< 20	< 20			

FILTERS FOR FRESH AIR PRECLEANING SYSTEMS

Fits RESPA Model	Sy-Klone Part No.	Filter Rating at Specified Airflow	Minimum Average Efficiency	Operating Airflow	For Use On	Effective Against	Applications
RESPA-CF Standard Length & RESPA-CF2 Standard Length (Filters with Ejection Ports)	**FEFF108** (replaces FEFF008)	**MERV 16** @ 150 CFM (255 m3/h)	≥95% on particle size 0.3 to 1.0 µm	≤ 150 CFM (255 m3/h)	Fresh Air Filtration	0.3 - 1.0 µm particulate, such as: all bacteria; most tobacco smoke; droplet nuclei (sneeze); respirable crystalline silica (RCS); diesel particulate matter (DPM); and other respirable particulate within the size range.	Mining, Agriculture, Demolition, Construction, Waste, Indoor Recycling, all applications where respirable dust is present.
		F9 @ 150 CFM (255 m3/h)	≥95% on particle size 0.4 µm (Em)				
	FEFF118 (replaces FEFF018)	**HEPA H-13** @ 100 CFM (170 m3/h)	Initial Efficiency ≥99.95%	≤ 100 CFM (170 m3/h)	Fresh Air Filtration	0.3 µm particulate, such as: all combustion smoke; diesel particulate matter (DPM); respirable crystalline silica (RCS); radon progeny; carbon dust; sea salt; and other respirable particulate within the size range.	Nuclear Clean-up, working with friable Asbestos, Carcinogenic Materials.
	FEFF131 (RESPA-CF requires REVA-019 Odor Filter Retrofit Kit)	**HEPA H-13 and Odor Retention** @ 50 CFM (85 m3/h)	Initial Efficiency ≥99.95%	≤ 50 CFM (85 m3/h)	Fresh Air Filtration where Odor Reduction is needed	General odors caused by particulate and non toxic gas contaminates. 0.3 µm particulate, such as: all combustion smoke; diesel particulate matter (DPM);respirable crystalline silica (RCS); radon progeny; carbon dust; sea salt; and other respirable particulate within the size range.	Ag Spraying equipment, waste, recycling facilities, farming. Any application that involves non toxic odors.
RESPA-CF Extended Length* & RESPA-CF2 Extended Length (Filters with Ejection Ports)	**FEFF109** (replaces FEFF009)	**MERV16** @ 150 CFM (255 m3/h)	≥95% on particle size 0.3 to 1.0 µm	≤ 150 CFM (255 m3/h)	Fresh Air Filtration	0.3 - 1.0 µm particulate, such as: all bacteria; most tobacco smoke; droplet nuclei (sneeze); respirable crystalline silica (RCS); diesel particulate matter (DPM); and other respirable particulate within the size range.	Mining, Agriculture, Demolition, Construction, Waste, Indoor Recycling, all applications where respirable dust is present.
		F9 @ 150 CFM (255 m3/h)	≥95% on particle size 0.4 µm (Em)				
	FEFF119 (replaces FEFF019)	**HEPA H-13** @ 100 CFM (170 m3/h)	Initial Efficiency ≥99.95%	≤ 100 CFM (170 m3/h)	Fresh Air Filtration	0.3 µm particulate, such as: all combustion smoke; diesel particulate matter (DPM); respirable crystalline silica (RCS); radon progeny; carbon dust; sea salt; and other respirable particulate within the size range.	Nuclear Clean-up, working with friable Asbestos, Carcinogenic Materials.
	FEFF130 RESPA-CF2 Extended Length Only	**HEPA H-13 and ABEK1 P3** @ 50 CFM (85 m3/h)	Initial Efficiency ≥99.95%	≤ 50 CFM (85 m3/h)	Fresh Air Filtration	For use in known toxic gas environments. As a particulate filter: 0.3 µm particulate, such as: all combustion smoke; diesel particulate matter (DPM); respirable crystalline silica (RCS); radon progeny; carbon dust; sea salt; and other respirable particulate within the size range. Please consult www.sy-klone.com for the list of gases that this filter is effective against	Industrial processing, ore processing, waste, Toxic gas applications Nuclear Clean-up, working with friable Asbestos, Carcinogenic Materials.
	FEFF132(RESPA-CF requires REVA-020 Odor Filter Retrofit Kit)	**HEPA H-13 and Odor Retention** @ 50 CFM (85 m3/h)	Initial Efficiency ≥99.95%	≤ 50 CFM (85 m3/h)	Fresh Air Filtration where odor reduction is needed	General odors caused by particulate and non toxic gas contaminates. 0.3 µm particulate, such as: all combustion smoke; diesel particulate matter (DPM);respirable crystalline silica (RCS); radon progeny; carbon dust; sea salt; and other respirable particulate within the size range.	Ag Spraying equipment, waste, recycling facilities, farming. Any application that involves non toxic odors.

* Standard length can be converted to extended length: RESPA-CF Extend the REVOLUTION Kit (MERV 16 / F9), Part No. REV0006

Comparison between HVAC filter classes and Dust filter classes

Aktuell DIN EN 779	Aktuell DIN EN 779	DIN 24184	BS3928	US Mil.-Std.	Aktuell DIN EN 1822	ZH 1/487	*NEU* DIN EN 60335-2
PREV bstaubfilter scheidegrad A Enddifferenzdruck 250Pa	Feinstaubfilter mittl. Fraktionsabscheidegrad E (0,4 µm) Enddifferenzdruck 450Pa	Schwebstofffilter Anfangs-Abscheidegrad A Parafinölnebel 0,3-0,5 µm	Schwebstofffilter Anfangs-Abscheidegrad A NaCl 0,3(0,6) µm	Schwebstofffilter Anfangs-Abscheidegrad A DOP 0,3 µm	HEPA- und ULPA-Filter Anfangs-Abscheidegrad A DEHS, MPPS, ca. 0,1-0,3µm	Staubbeseitigungsgeräte mittl. Durchlassgrad D Quarzstaub zwischen 0,2-2µm	Staubbeseitigungsgeräte mittl. Durchlassgrad D Quarzstaub zwischen 0,2-2µm
A > 50% G1 A<65%							
A > 65% G2							
A > 80% G3							
A > 90% G 4							
	E > 40% F5					D < 5% U	
	E > 60% F6					D <1% S	D < 1% L
	E > 80% F7						
	E > 90% F8					D < 0,5% G	
	E > 95% F9						D < 0,1% M
		A > 85% Q	A > 95% EU10		A(integr.) > 85% H10	D < 0,1% C	
		A > 98% R	A > 99,9% EU11	95 %	A(integr.) > 95% H11		
			A > 99,97% EU12	99,97%	A(integr.) > 99,5% H12	D < 0,05% Parafinöl ≤ 1µm K1,K2	D < 0,005% Parafinöl ≤ 1µm H
		A > 99,97% S	A > 99,99% EU13	99,99%	A(integr.) > 99,95% H13 A(lokal) > 99,75%%		
			A > 99,999% EU14	99,999%	A(integr.) > 99,995% H14 A(lokal) > 99,975%		
					A(integr.) > 99,9995% U15 A(lokal) > 99,9975%		
					A(integr.) > 99,99995% U16 A(lokal)>99,99975%		
					A(integr.) > 99,999995% U17 A(lokal) > 99,9999%		