THE CAMFIL GROUP

ASHRAE 241 - impact on air filtration recommendations

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CLEAN AIR SOLUTIONS

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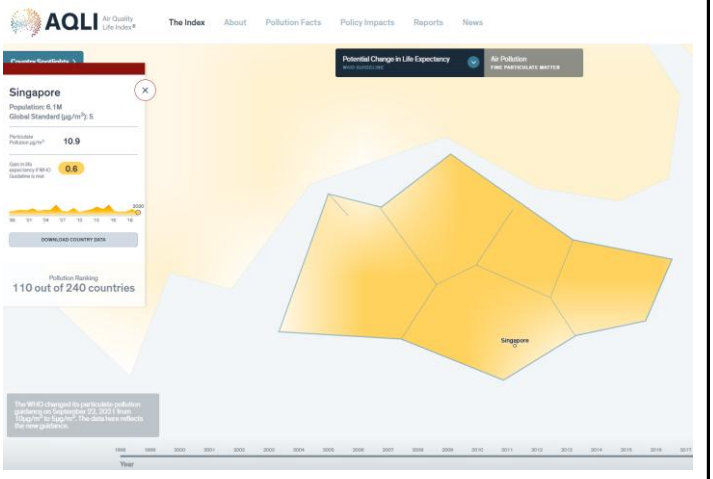
OUTDOOR AIR QUALITY IN SINGAPORE

- Annual average PM2.5: 10,9 µg/m³
- **PM2.5 levels are more than two times above WHO limits of 5µg/m³**
- During Haze the PM2.5 concentrations are significantly higher
- **AQLI - Air Quality Life Index for Singapore**: Reducing PM2.5 annual average concentration to WHO limits would increase life expectancy in Singapore by 0,6 years



https://aqli.epic.uchicago.edu/the-index/

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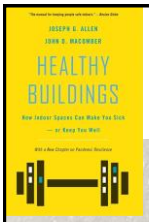


THE IMPORTANCE OF INDOOR AIR QUALITY (IAQ)

TABLE 3.1 The dirty secret of outdoor air pollution.

	Outdoor Air Pollution	Breathing Rate	Time Spent Indoors	Total *Outdoor* Air Pollution Breathed per Day
Outdoors	20 µg/m³	0.625 m³/hour	2.4 hours (10% of 24 hours)	**30 µg/day**
Indoors	10 µg/m³	0.625 m³/hour	21.6 hours (90% of 24 hours)	**135 µg/day**

*Healthy buildings –How indoor spaces can make you sick – or keep you well, Joseph G. Allen & John D. Macomber, Harvard University Press, 2022

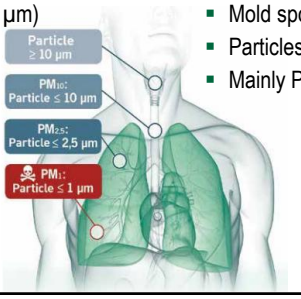
INDOOR AIR QUALITY (IAQ) - AIR FILTRATION & POLLUTANTS

Outdoor Air (supply air)

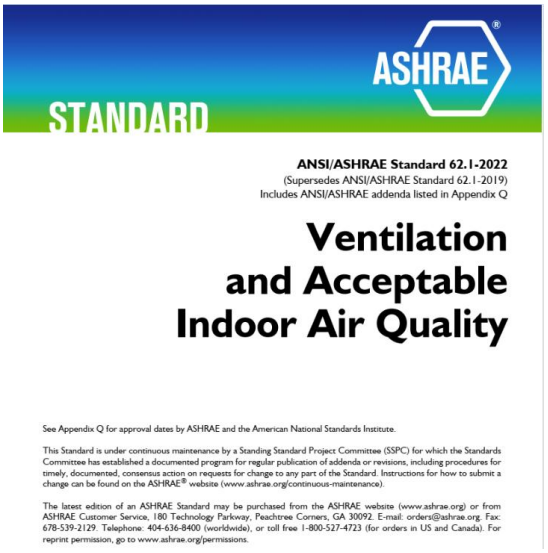
- **Hygiene:**
  - Coarse dust & PM10 (particles ≤ 10µm)
  - Organic particles, sand
- **Health & Productivity**
  - Pollen
  - Combustion particles (mainly PM1 ≤ 1µm)
    - Traffic & industry exhausts
    - Haze / wildfires

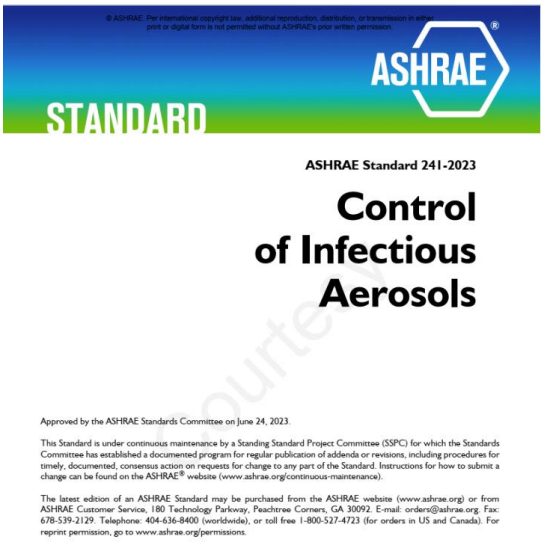
Indoor Air (recirculated air, secondary air)

- **Hygiene:**
  - Coarse dust (organic + fabrics)
  - PM10 (particles ≤ 10µm)
- **Health & Productivity**
  - Pathogen containing aerosols (viruses, bacteria)
  - Mold spores
  - Particles from printers
  - Mainly PM1 & PM2.5



TWO NEW ASHRAE STANDARDS ON INDOOR AIR QUALITY (IAQ)





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ASHRAE 62.1-2022 – VENTILATION AND ACCEPTABLE INDOOR AIR QUALITY

<u>Acceptable</u> Indoor Air Quality (the bare minimum):

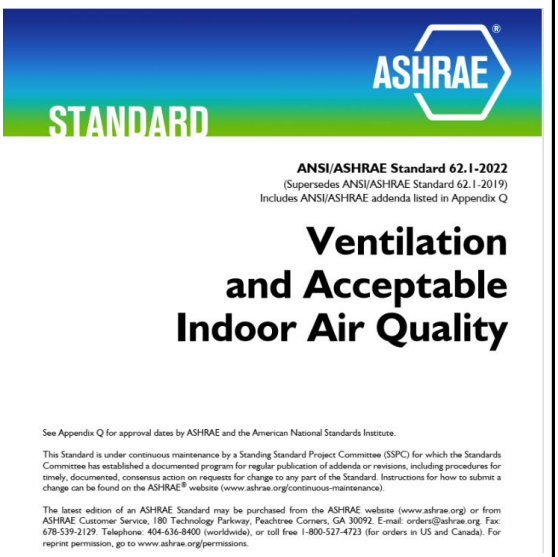
- No known contaminants at harmful concentrations
- Majority of people do not express dissatisfaction

What is missing:

- **Health** – properly defined
- **Productivity**
- **Resilience** – airborne díseases, haze/wildfires…

Minimum Filter Requirements:

- General Minimum: MERV 8 / ePM10 50%
- If PM2,5 values above national limits: MERV 11 / ePM2,5 50%



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ASHRAE 241:2023 - CONTROL OF INFECTIOUS AEROSOLS

"It is one of the most important public health interventions I have seen in years, if not decades."
– Ashish Jha, Coordinator, White House Covid-19 Response Team

- Developed on request of the White House
- Target: Reduce the airborne infection risks
- Groundbreaking in terms of approach to IAQ & Filtration
- First standard to request MERV-A ratings for mechanical filters (or alternatively ISO 16890 ratings)

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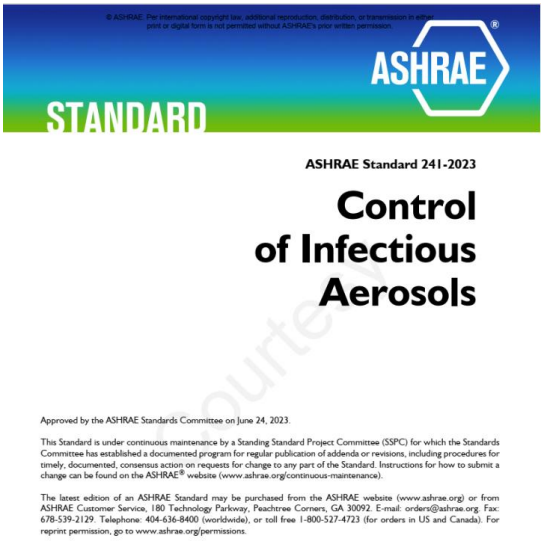
ASHRAE 241:2023 - CONTROL OF INFECTIOUS AEROSOLS



The concept in a nutshell:

- Ventilate optimally with (clean) outdoor air
- Emphasizes alternatives to outdoor air:
  - ECAi (Equivalent Clean Airflow)
  - High efficiency filtration (PM, incl. bioaerosol control)
- Introduces the concept of resilience into IAQ:
  - IRMM (Infection Risk Management Mode)
  - Similar concept can be applied to haze/wildfires

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ASHRAE 241:2023 – INFECTIOUS AEROSOL REMOVAL EFFICIENCY

7.3.1 Infectious Aerosol Removal Efficiency for Mechanical Fibrous Filters Installed In-Duct. The infectious aerosol removal efficiency (ε_{PR}) of mechanical fibrous filters installed within AHUs, ductwork, or plenums shall be determined in accordance with Equation 7-3 or Table 7-1.

$$\varepsilon_{PR} = W_{E1}\varepsilon_{E1} + W_{E2}\varepsilon_{E2} + W_{E3}\varepsilon_{E3} \quad (7\text{-}3)$$

where

ε_{PR} = infectious aerosol removal efficiency, %
W_{E1} = fraction of the infectious aerosol in the 0.3 to 1.0 micrometer (µm) particle size range, dimensionless
W_{E2} = fraction of the infectious aerosol in the 1.0 to 3.0 µm particle size range, dimensionless
W_{E3} = fraction of the infectious aerosol in the 3.0 to 10.0 µm particle size range, dimensionless
ε_{E1} = particle removal efficiency in the 0.3 to 1.0 µm particle size range, %
ε_{E2} = particle removal efficiency in the 1.0 to 3.0 µm particle size range, %
ε_{E3} = particle removal efficiency in the 3.0 to 10.0 µm particle size range, %

The weighting fractions for use in Equation 7-3 shall be $W_{E1} = 0.30$, $W_{E2} = 0.30$, and $W_{E3} = 0.40$.

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ASHRAE 52.2-2017 – SIZE RANGES & FILTER CLASSES

Table 10-2 Size Range Groups

Average Minimum PSE Designator	Corresponding Size Range Group, µm
E_1	0.30 to 1.0
E_2	1.0 to 3.0
E_3	3.0 to 10

- ASHRAE 52.2- 2017 - Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
- Defines particle size ranges E_1 , E_2 , E_3
- MERV filter classes based on efficiencies against the different particle size ranges

Table 12-1 Minimum Efficiency Reporting Value (MERV) Parameters

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0	Average Arrestance, %
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg}$
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg}$
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$
5	N/A	N/A	$20 \le E_3$	N/A
6	N/A	N/A	$35 \le E_3$	N/A
7	N/A	N/A	$50 \le E_3$	N/A
8	N/A	$20 \le E_2$	$70 \le E_3$	N/A
9	N/A	$35 \le E_2$	$75 \le E_3$	N/A
10	N/A	$50 \le E_2$	$80 \le E_3$	N/A
11	$20 \le E_1$	$65 \le E_2$	$85 \le E_3$	N/A
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	N/A
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	N/A
14	$75 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
15	$85 \le E_1$	$90 \le E_2$	$95 \le E_3$	N/A
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A

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ASHRAE 241:2023 – FILTER REQUIREMENTS

- **Required Minimum: MERV 11 / ePM2.5 50%**
- **Any lower MERV Rating gives 0% pathogen removal efficiency**
- The higher the filter class, the higher the pathogen removal efficiency (infectious aerosol removal efficiency) & the higher the ECAi (Equivalent Clean Airflow)
- Example:
  - 10.000 m³/h recirculated air
  - Filtered by a MERV 15-A / ePM1 85% air filter
  - Pathogen Removal Efficiency 91%
  - Equivalent to 9.100 m³/h outdoor air
- **From 2025 MERV-A Ratings (or ISO 16890 class) required!**

Table A-1 Pathogen Removal Efficiency for Air Filter Elements

ASHRAE 52.2 MERV (Prior to 1/1/2025) MERV-A (After 1/1/2025)	ISO16890 ePM	Weighted ε_{PR}
<11		0%
11	ePM2.5 50%	60%
12	ePM2.5 65%	71%
13	ePM1 50%	77%
14	ePM1 70%	88%
15	ePM1 85%	91%
16	ePM1 95%	95%

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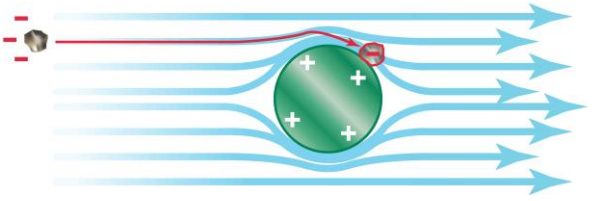
MERV & MERV-A ACC. ASHRAE 52.2- WHAT IS THE DIFFERENCE?

- The **MERV Rating** gives the **initial** particle removal efficiency of an air filter **incl. electrostatic charge**
- Many air filters come with an **electrostatic charge**, that initially increase the efficiency, but disapears over time (often within weeks)
- The **MERV-A Rating** gives the **mechanical** particle removal efficiency of an air filter **after discharging** acc. App. J of ASHRAE 52.2



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MERV gives you the performance of an air filter on its best day, MERV-A gives you the performance on its worst day!

In relation to pathogens, fine dust and health, you should plan for the worst and hope for the best, not vice versa!

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ASHRAE® 52.2-2012 Test Results w/Appendix J Results

Filter Description

Manufacturer	Filter Model	Filter Part Number
	Multi-Sak S22 M14-6	209-106-122

Filter Type	Media Type	Media Color	Media Area (ft²)
Pocket Filter	Synthetic/Charged	Yellow	51

Nominal Size	Actual Size						
HxWxD	Hgt (in)	Wid (in)	Dep (in)	Pleats/Pockets	UL Rating	LabFile	CrRef
24x24x22	23 3/8	23 3/8	22	6	Yes	1460	1420

ASHRAE® 52.2-2012

Time: 15:21:01 Date: Feb 25, 2016
Test Number: 1657-001_00003661.047.aec

Test Data	Test Results	Rated Values	
AirFlow (cfm)	1968	1970	
Nominal Vel (fpm)	495	495	
Initial ΔP (inWG)	0.52	0.52	
MERV	14	14	@1968cfm
E_1 (0.3-1.0μm), (%)	78	≥ 75	
E_2 (1.0-3.0μm), (%)	97	≥ 90	
E_3 (3.0-10μm), (%)	99	≥ 90	
Final DP, (inWG)	1.5	1.5	
Arrestance, (%)	96	None	
DHC, (g)	101		

Temp, (C)	24	Test Aerosol	KCl
RH, (%)	40	Loading Dust	ASHRAE

ASHRAE® 52.2-2012 w/App J

Time: 10:33:06 Date: Mar 09, 2016
Test Number: 1657-002_00003684.047.aec

Test Data	Test Results	Rated Values	
AirFlow (cfm)	1970	3347	
Nominal Vel (fpm)	495	495	
Initial ΔP (inWG)	0.51	0.52	
MERV-A	12A	14A	@1970cfm
E_1-A (0.3-1.0μm), (%)	26	≥ 75	
E_2-A (1.0-3.0μm), (%)	73	≥ 90	
E_3-A (3.0-10μm), (%)	98	≥ 90	
Final DP, (inWG)	1.5	1.5	
Arrestance-A, (%)	98	None	
DHC-A, (g)	114		

Temp, (C)	23	Test Aerosol	KCl
RH, (%)	45	Loading Dust	ASHRAE

Pathogen Removal Efficiency acc ASHRAE 241: 71%

Certified Test Per ASHRAE 52.2-2012	Operator	Particle Counter	Model
Approval: Don Thornburg, Electronic Signature, Original on file	AA	TSI	OPS 3330
	Camfil Permission Required for Distribution		

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ASHRAE 52.2-2017 Test Results w/Appendix J Results

Filter Description

Manufacturer	Filter Model	Filter Part Number
Camfil Corcoran	DU4V-ES3-2424-MV14	855081-021

Filter Type	Media Type	Media Color
V-Bed	Fiberglass/Wet Laid	White

Nominal Size	Actual Size					
HxWxD	Hgt (in)	Wid (in)	Dep (in)	Pleats/Pockets	Media Area (ft²)	UL Rating
24x24x12	23.31	23.31	11.75	4	200.0	Yes

ASHRAE 52.2-2017

Test Report: 230822_4931
Time: 13:51:44 Date: Aug 22, 2023

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2001	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.33	0.31	
MERV	14	14	@2001cfm
E_1 (0.3-1.0μm), (%)	78	≥ 75	
E_2 (1.0-3.0μm), (%)	96	≥ 90	
E_3 (3.0-10μm), (%)	100	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance, (%)	100	99	
DHC, (g)	639		

Temp, (F)	71	Test Aerosol	KCL
RH, (%)	49	Loading Dust	ASHRAE

ASHRAE 52.2-2017 w/App J

Test Report: 230815_4932
Time: 14:07:18 Date: Aug 15, 2023

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2001	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.33	0.31	
MERV-A	14A	14A	@2001cfm
E_1-A (0.3-1.0μm), (%)	78	≥ 75	
E_2-A (1.0-3.0μm), (%)	96	≥ 90	
E_3-A (3.0-10μm), (%)	100	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance-A, (%)	100	99	
DHC-A, (g)	676		

Temp, (F)	71	Test Aerosol	KCL
RH, (%)	49	Loading Dust	ASHRAE

Pathogen Removal Efficiency acc ASHRAE 241: **88%**

Certified Test Per ASHRAE 52.2-2017	Operator	Particle Counter	Model
Approval: Michael Krause, Laboratories and Materials R&D Manager	Mirna Montoya	TSI	OPS-3330

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ASHRAE 52.2-2017 Test Results w/Appendix J Results

Filter Description

Manufacturer	Filter Model	Filter Part Number
[redacted]	SFV95	SFV954412
Filter Type	**Media Type**	**Media Color**
V-Bed	Synthetic/Charged	White

Nominal Size HxWxD	Actual Size Hgt (in)	Wid (in)	Dep (in)	Pleats/Pockets	Media Area (ft²)	UL Rating
24x24x12	23.38	23.38	11.25	4	190.0	Yes

ASHRAE 52.2-2017

Test Report: 230606_4672 | Time: 14:29:34 | Date: Jun 06, 2023

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2001	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.26	0.28	
MERV	15	15	@2001cfm
E_1 (0.3-1.0μm), (%)	92	≥ 85	
E_2 (1.0-3.0μm), (%)	98	≥ 90	
E_3 (3.0-10μm), (%)	100	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance, (%)	91	99	
DHC, (g)	483		

Temp, (F)	72	Test Aerosol	KCL
RH, (%)	48	Loading Dust	ASHRAE

ASHRAE 52.2-2017 w/App J

Test Report: 230710_4673 | Time: 14:08:58 | Date: Jul 10, 2023

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2001	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.25	0.28	
MERV-A	10A	15A	@2001cfm
E_1-A (0.3-1.0μm), (%)	26	≥ 85	
E_2-A (1.0-3.0μm), (%)	57	≥ 90	
E_3-A (3.0-10μm), (%)	94	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance-A, (%)	100	99	
DHC-A, (g)	499		

Temp, (F)	73	Test Aerosol	KCL
RH, (%)	46	Loading Dust	ASHRAE

Pathogen Removal Efficiency acc ASHRAE 241: **0%**

Certified Test Per ASHRAE 52.2-2017	Operator	Particle Counter	Model
Approval: Michael Krause, Laboratories and Materials R&D Manager	Mirna Montoya	TSI	OPS-3330

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ASHRAE 52.2-2017 Test Results w/Appendix J Results

Filter Description

Manufacturer	Filter Model	Filter Part Number
Camfil USA	HFESMV15/24/24/15/10	405620-A15
Filter Type	**Media Type**	**Media Color**
Pocket	Fiberglass/Air Laid	Green

Nominal Size HxWxD	Actual Size Hgt (in)	Wid (in)	Dep (in)	Pleats/Pockets	Media Area (ft²)	UL Rating
24x24x15	23.38	23.38	15.00	10	48.7	Yes

ASHRAE 52.2-2017

Test Report: 220627_3582 | Time: 12:43:46 | Date: Jun 27, 2022

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2001	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.76	0.81	
MERV	15	15	@2001cfm
E_1 (0.3-1.0μm), (%)	87	≥ 85	
E_2 (1.0-3.0μm), (%)	100	≥ 90	
E_3 (3.0-10μm), (%)	100	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance, (%)	100	99	
DHC, (g)	206		

Temp, (F)	76	Test Aerosol	KCL
RH, (%)	48	Loading Dust	ASHRAE

ASHRAE 52.2-2017 w/App J

Test Report: 230314_3581 | Time: 10:43:54 | Date: Mar 14, 2023

Test Data	Test Results	Rated Values	
AirFlow (cfm)	2000	2001	
Nominal Vel (fpm)	500	501	
Initial ΔP (inWG)	0.78	0.81	
MERV-A	15A	15A	@2000cfm
E_1-A (0.3-1.0μm), (%)	86	≥ 85	
E_2-A (1.0-3.0μm), (%)	100	≥ 90	
E_3-A (3.0-10μm), (%)	100	≥ 95	
Final DP, (inWG)	1.5	1.5	
Arrestance-A, (%)	100	99	
DHC-A, (g)	217		

Temp, (F)	77	Test Aerosol	KCL
RH, (%)	44	Loading Dust	ASHRAE

Pathogen Removal Efficiency acc ASHRAE 241: **91%**

Certified Test Per ASHRAE 52.2-2017	Operator	Particle Counter	Model
Approval: Michael Krause, Laboratories and Materials R&D Manager	Mirna Montoya	TSI	OPS-3330

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BETTER AIR FILTRATION - IMPACT ON ENERGY CONSUMPTION

- New guidelines suggest a higher level of air filtration for general ventilation than applied in most buildings today
- How will that affect the energy consumption and is it even possible from a technical perspective?
- By selecting energy efficient air filters, you can often improve indoor air quality, without increases of energy consumption
- The Eurovent Energy Rating for air filters gives a good indication on the energy consumptions and upgrade potentials

Air Filter A
MERV 11
ePM 2.5 50%
120 Pa
Energy Class E
>1900 kWh

Air Filter C
MERV 15A
ePM1 80%
90 Pa
Energy Class A
1212 kWh

A good air filter saves more energy costs, than the whole air filter actually costs

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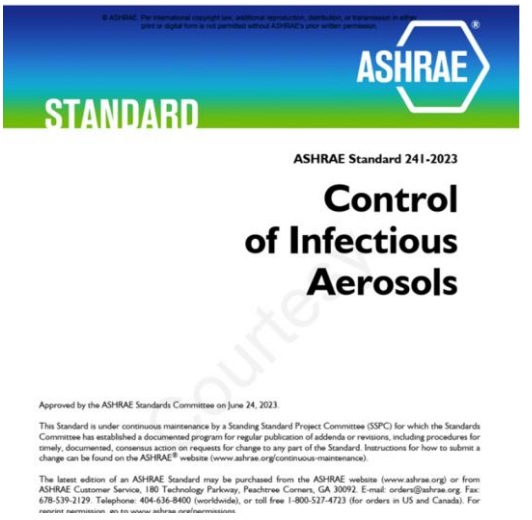
SUMMARY

- Indoor Air Quality is a key foundation for healthy buildings
- Main airborne health risks are very small particles - PM1
- ASHRAE 62.1 defines only the bare minimum, as it does not fully consider health, productivity and resilience
- ASHRAE 241 is groundbreaking in terms of IAQ and air filtration requirements
- First standard to request MERV-A ratings for mechanical filters (or alternatively ISO 16890 ratings)
- Eurovent Energy Rating for air filters allows easy selection of energy efficient air filters
- By selecting energy efficient air filters with high filtration efficiency, you can improve your indoor air quality and reduce your energy costs and CO2 footprint at the same time



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FOR YOUR ATTENTION

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