Ultra-high Efficiency Filter Tests

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Background

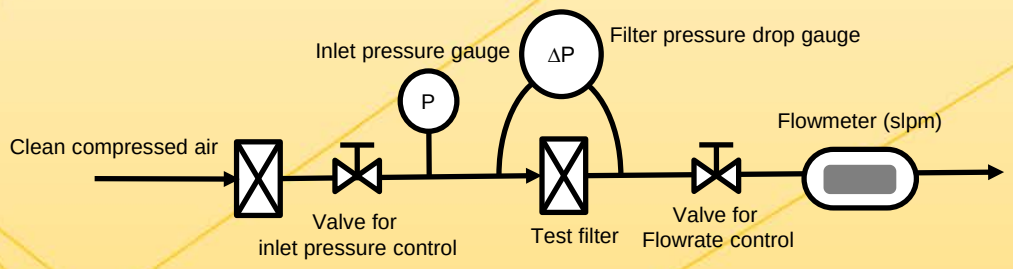
- As ultra-clean environment becomes very critical in more and more industrial applications, ultra-high efficiency (UHE) filters are required in many devices and facilities.

- With this reason, a proper filter test method needs to be developed to measure UHE filter efficiency up to nine-9s (99.9999999%).

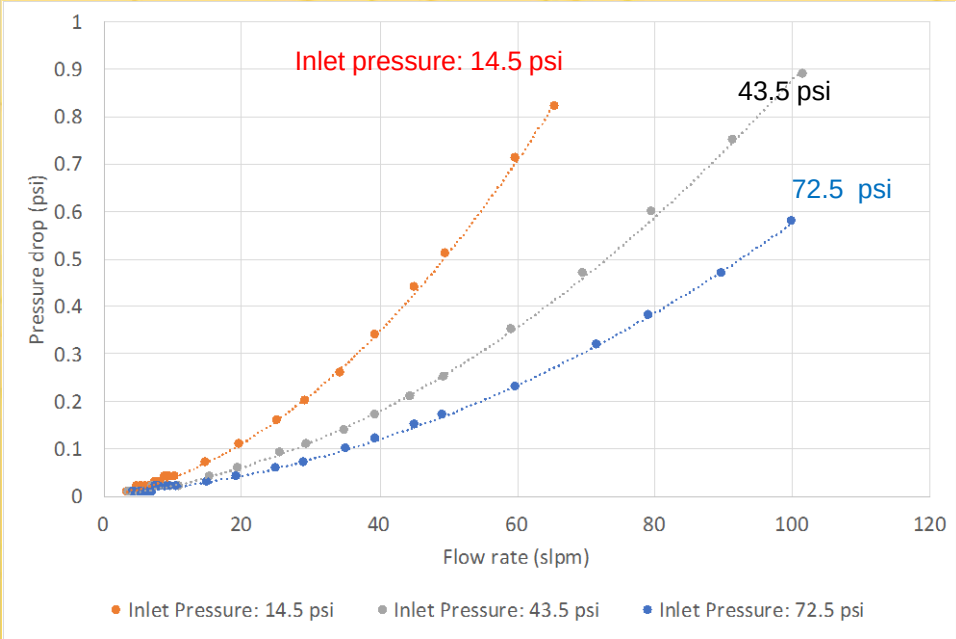
- This study is to establish an UHE filter test setup and provide with a reliable test procedure.

Filter Pressure Drop Test

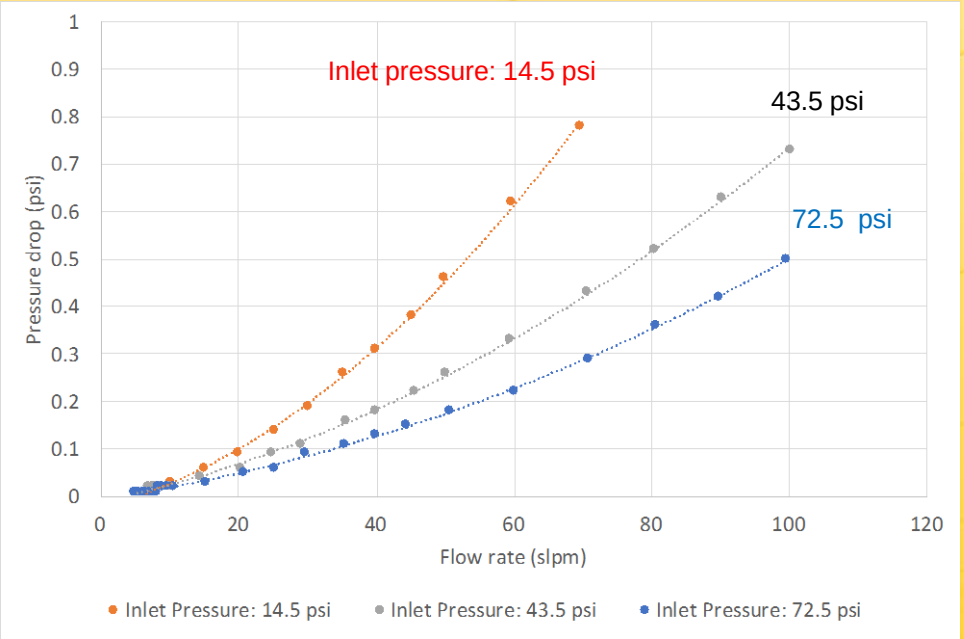
UHE filter pressure drop test setup (SEMI 90120393B-STD)



UHE filter sample A

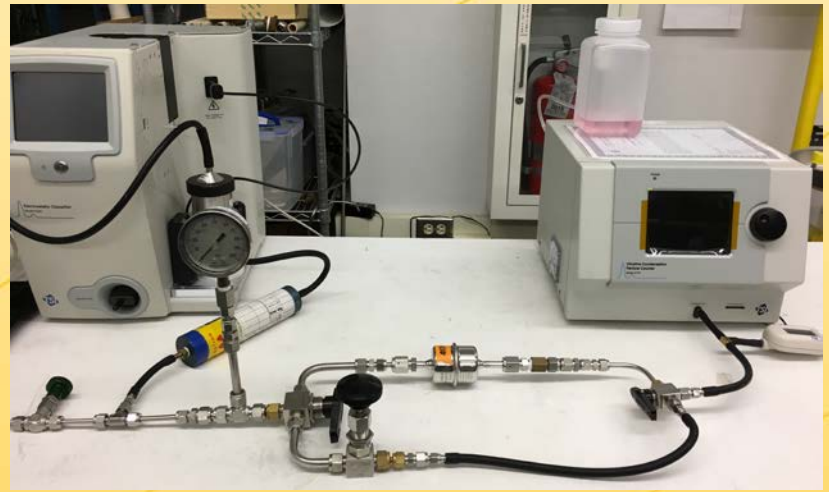


UHE filter sample B

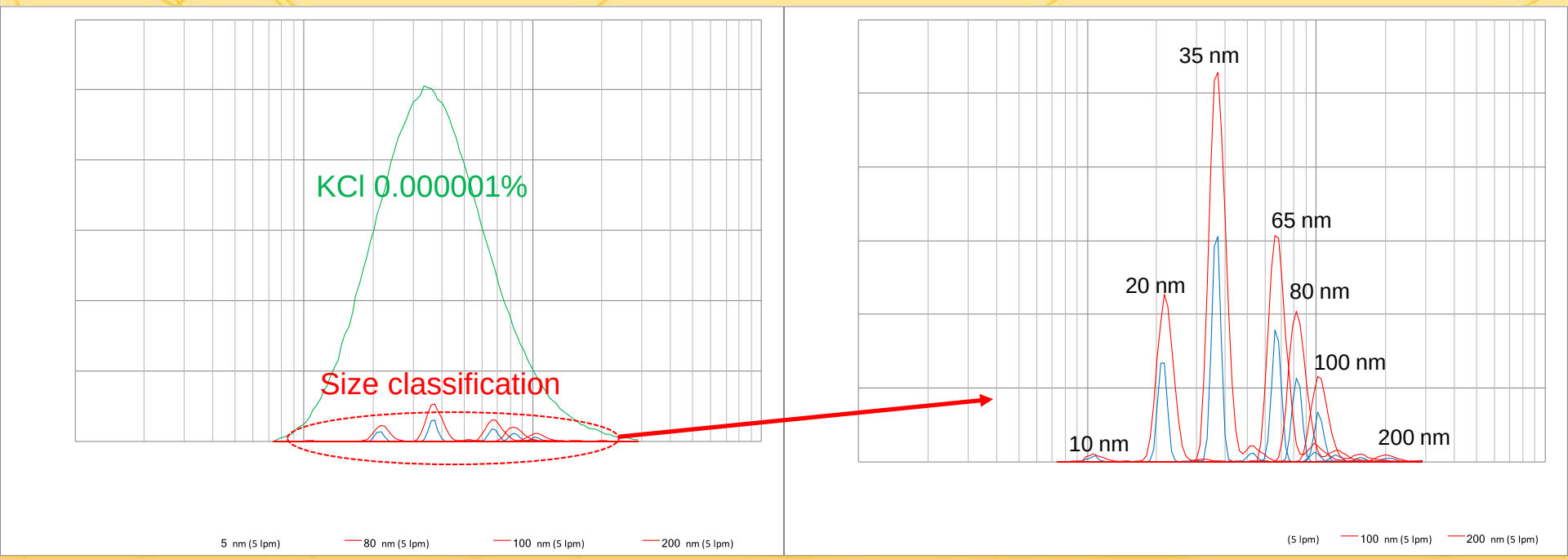


Filtration Efficiency Test

Filtration efficiency test setup



Test particle size distribution



Blue: Aerosol flow 1.5 lpm, DMA sheath flow 15 lpm
Red: Aerosol flow 1.5 lpm, DMA sheath flow 5 lpm

Background particle count

1. Filter test setups always have “background particle counts” due to a particle counter false count, outgassing, a particle resuspension from surface, residual particles in dead space, leakage and etc.

2. Background particle count is critical for UHE filter efficiency test due to extremely low particle penetration.

3. Measured downstream particle counts without particle generation for extended sampling time for background monitoring. 28 particles were detected for 33,377 sec. of monitoring (= 0.0001 #/cc).

4. Background count (0.001 #/cc) is much lower than TSI UCPC 3776 specifications (0.01 #/cc), which means there is no significant error sources in the test setup other than UCPC false count.

Upstream particle count

1. Should be high enough to measure 9-nines efficiency (>10^9 particles), and the sampling time needs to be decided based on the upstream particle concentration.

2. Should be low enough not to have UCPC coincidence error (3x10^5 #/cc) and particle coagulations (10^6 #/cc).

3. *"As a rule of thumb, coagulation is neglected in laboratory experiments and occupational hygiene work if the concentration is lower than $10^9/m^3$ [$10^6/cm^3$]"* , Aerosol Technology by William C. Hinds

Downstream particle count

1. Measured upstream sampling time when the particle count reached 99,999,999 (UCPC max. display) and decided the minimum downstream sampling time 10 times higher than this.

2. After downstream particle counting, measured upstream particle concentration again to make sure the concentration is stable over the sampling time.

3. If downstream particle concentration is lower than background count (0.001 #/cc), the filtration efficiency is considered as higher than 99.9999999%.

UHE filter efficiency test result

UHE filter sample A (Filtration flowrate: 5 slpm)

Size (nm)	Upstream (#/cc)	Downstream			Background (#/cc)	Efficiency (%)
		Time (sec.)	Counts (#)	Concentration (#/cc)		
3.4	2.18×10^{5}	5,500	4	8.73×10^{-4}	0.001	> 99.9999999
10	2.73×10^{5}	4,390	3	8.20×10^{-4}	0.001	> 99.9999999
20	2.85×10^{5}	4,210	2	5.70×10^{-4}	0.001	> 99.9999999

UHE filter sample B (Filtration flowrate: 5 slpm)

Size (nm)	Upstream (#/cc)	Downstream			Background (#/cc)	Efficiency (%)
		Time (sec.)	Counts (#)	Concentration (#/cc)		
3.4	2.50×10^{5}	4,800	4	1.00×10^{-3}	0.001	> 99.9999999
10	2.82×10^{5}	4,250	5	1.41×10^{-3}	0.001	99.9999999
20	2.67×10^{5}	4,500	1	2.67×10^{-4}	0.001	> 99.9999999

Conclusions

- UHE filter test setup and procedure was established to measure filtration efficiency up to nine-9s by
  1. Adjusting DMA sheath flow ratio
  2. Measuring background particle counts
  3. Increasing particle sampling time.

- Sample A and B show filtration efficiencies of higher than nine-9s in diffusion dominant particle size range.

Thank You.