台灣空氣品質健康安全協會
Taiwan Air Quality Health & Safety Association

2020年冬季專業教育訓練課程

懸浮微粒(氣膠)過濾與呼吸防護技術之應用

新風系統及室內空氣清淨機CADR簡易測試方法建立與應用

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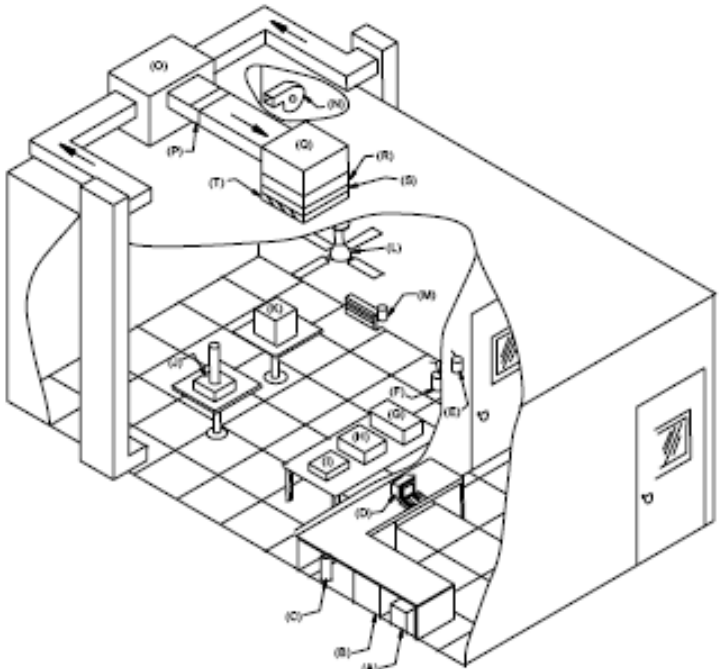
A Study between Methods for Testing Air Cleaners

新風機效能(Q×η)與測試艙CADR相關性研究

(Relationship between filtration performance and CADR measurements)

Introduction

- Clean Air Delivery Rate (CADR) is a certified way to evaluate the performance of indoor air cleaners.
- The standard test procedure for CADR evaluation requires large space and well-regulated conditions.
- Replacing standard CADR test with a more efficient "flow rate (Q) & efficiency (η)" method is a potential alternative.



(ANSI-AHAM AC-1 2020)

Two types of CADR

'Chamber' Clean Air Delivery Rate, $CADR_C$

$$CADR_C = (K_e - K_n) \cdot V$$

$$= \eta_{filter} \cdot Q_{AC} \cdot \varepsilon$$

(Noh and Oh, 2015)

K_e = Measured Decay Rate

K_n = Nature Decay Rate

V: Volume of the test chamber

'Equivalent' Clean Air Delivery Rate, $CADR_E$

$$CADR_E = \eta_{filter} \cdot Q_{AC}$$

η_{filter} = Filtration efficiency

Q_{AC} = Air cleaner flow rate

ANSI/AHAM AC-1-2013測試粒子

測試粒子	粒徑範圍 (μm)	測試初始濃度 particles/cc
粉塵	0.5 ~ 3	200 to 400
香煙	0.10 ~ 1	24,000 to 35,000
花粉	5 ~ 11	4 to 9

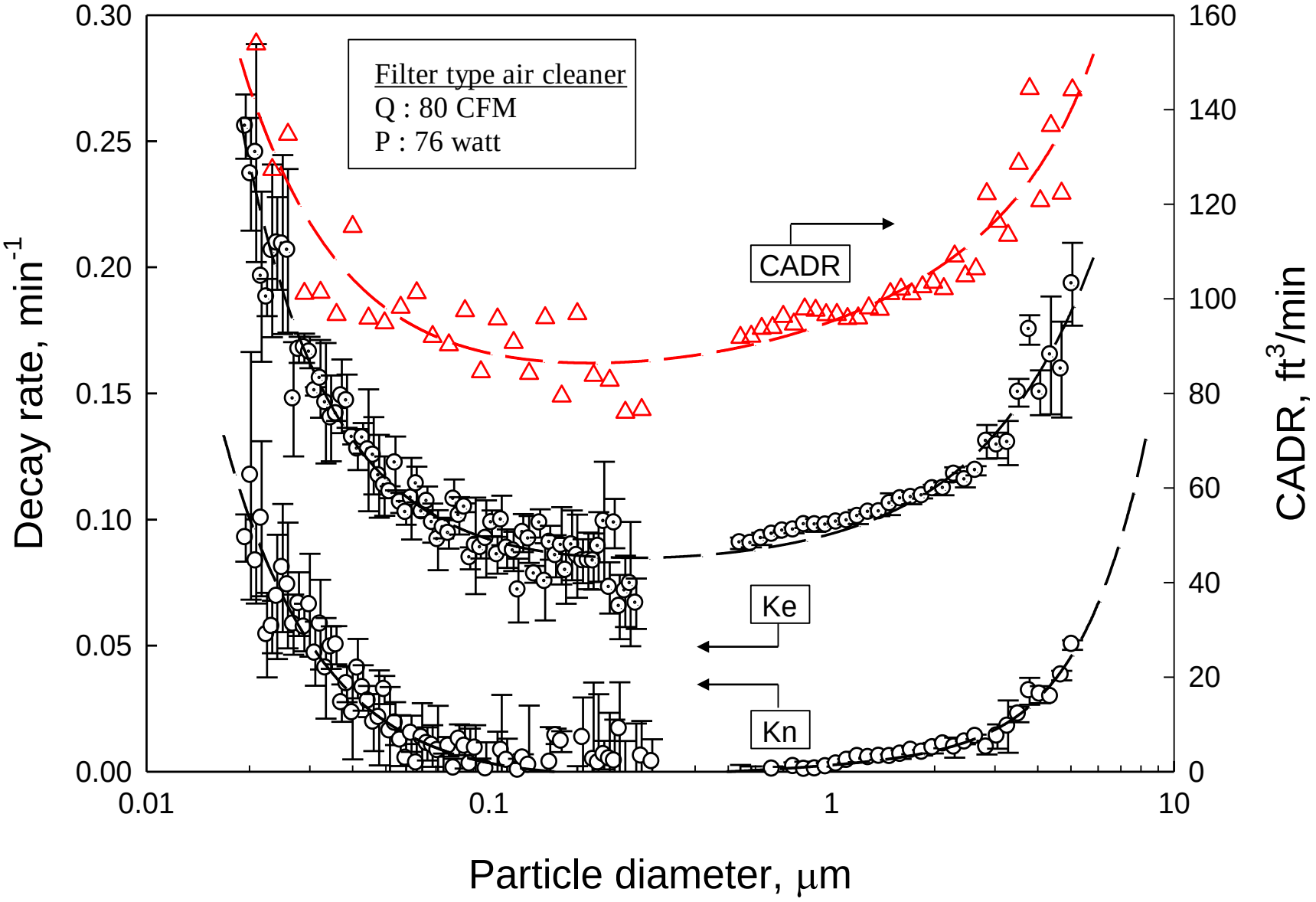


Figure 14. Natural decay rate, measured decay rate and CADR curves of filter type air cleaner.

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ORIGINAL ARTICLE

Effect of filter collection efficiency on the clean air delivery rate in an air cleaner

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Methods

Actual CADR from a chamber test

$$CADR_{\mathrm{A}} = (K_e - K_n) \cdot V$$

K_e = Measured Decay Rate

K_n = Nature Decay Rate

V: Volume of the test chamber

Theoretical CADR

$$CADR_{\mathrm{T}} = \eta \cdot \mathrm{Q}$$

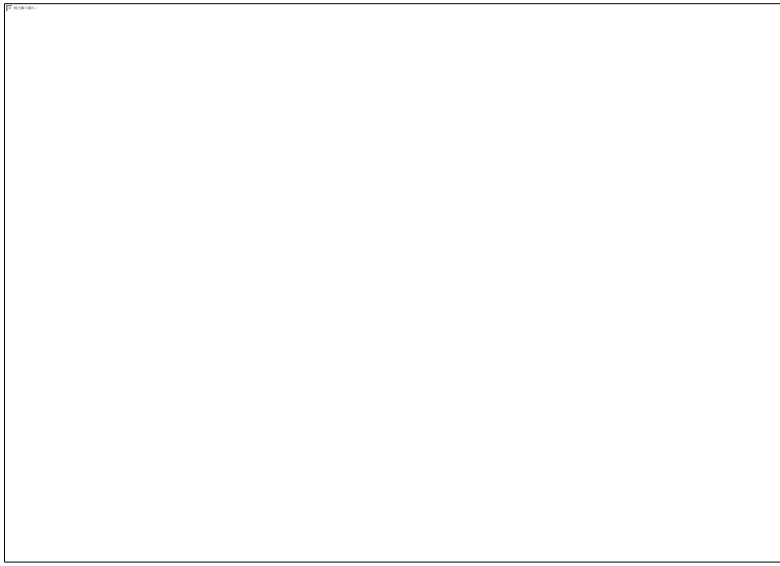
η= Filtration efficiency

Q= Air cleaner flow rate

Methods

Mode

- Weak (W)
- Strong (S)
- The simultaneous operation of two air cleaners in the strong mode (SS)



The air cleaner
(AX20K3020NWD, Samsung)

Methods

TABLE 2 Physical properties of the three tested filters

Filter/ Filter media	Parameters	Filter		
		E11	**E12**	**H13**
Filter	Length, [mm]	318	318	318
	Width, [mm]	278	278	278
	Height, [mm]	28	28	28
	Pleat length, [mm]	28	28	28
	Number of pleats	76	70	76
Filter media	Material	PP	PP	PP
	Fiber diameter, [μm]	2.51	2.22	2.67
	Geometric standard deviation, [-]	1.39	1.75	1.53
	Filter thickness, [mm]	0.50	0.37	0.99
	Solidity, [-]	0.047	0.056	0.036
	Filtration area, [m^2]	1.10	1.05	1.16

Abbreviation: PP, polypropylene fibers.

Methods

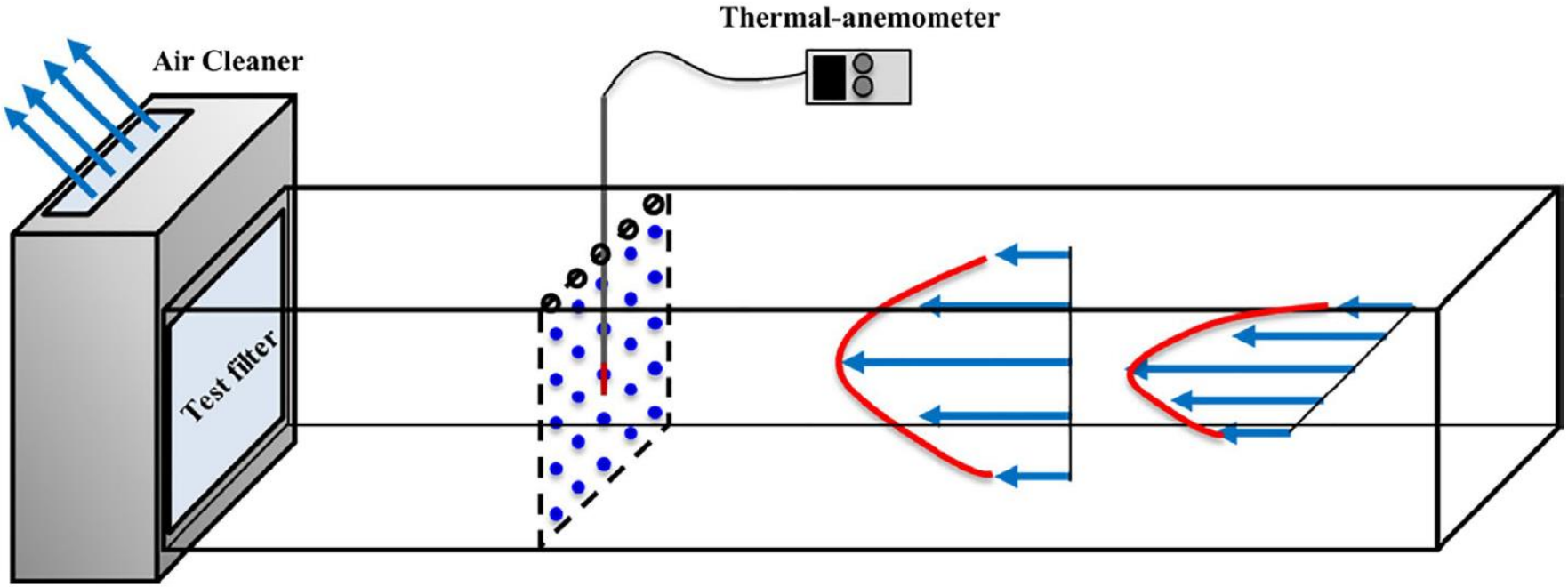


FIGURE 2 Experimental apparatus used for the actual air flow rate test

Results

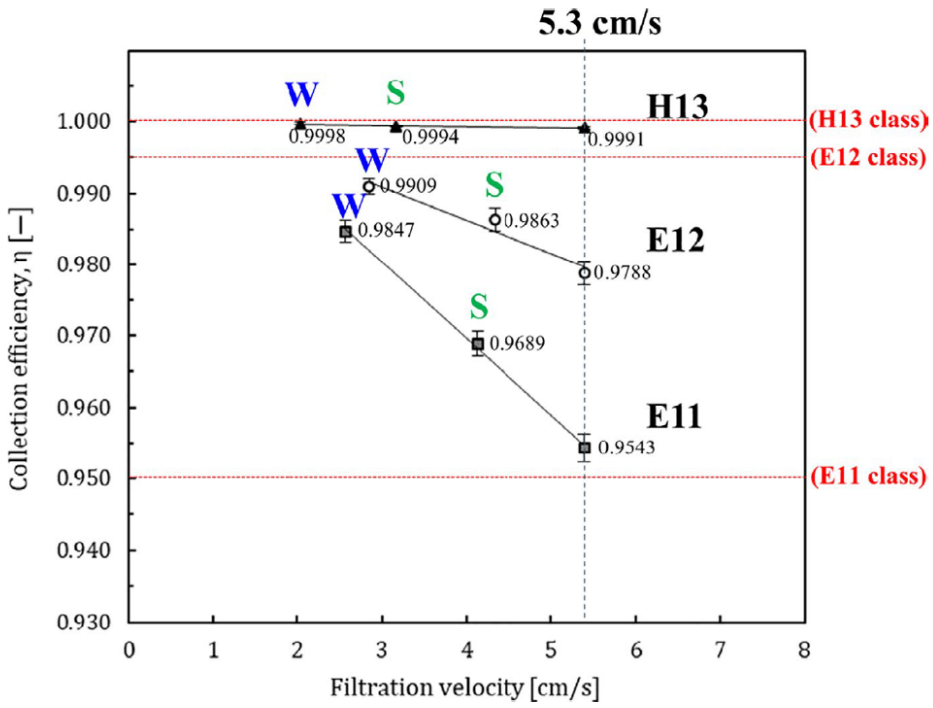


FIGURE 6 Collection efficiency outcomes of the test filter media as a function of the filtration Velocity

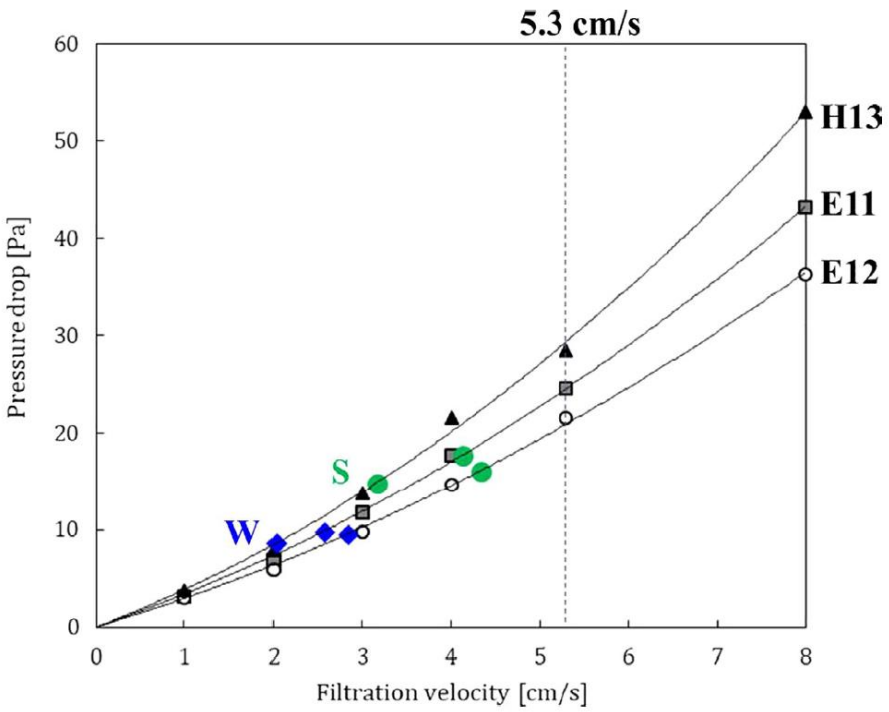


FIGURE 7 Pressure drops of the test filter media as a function of the filtration velocity

Indoor Air 2020, 1–10

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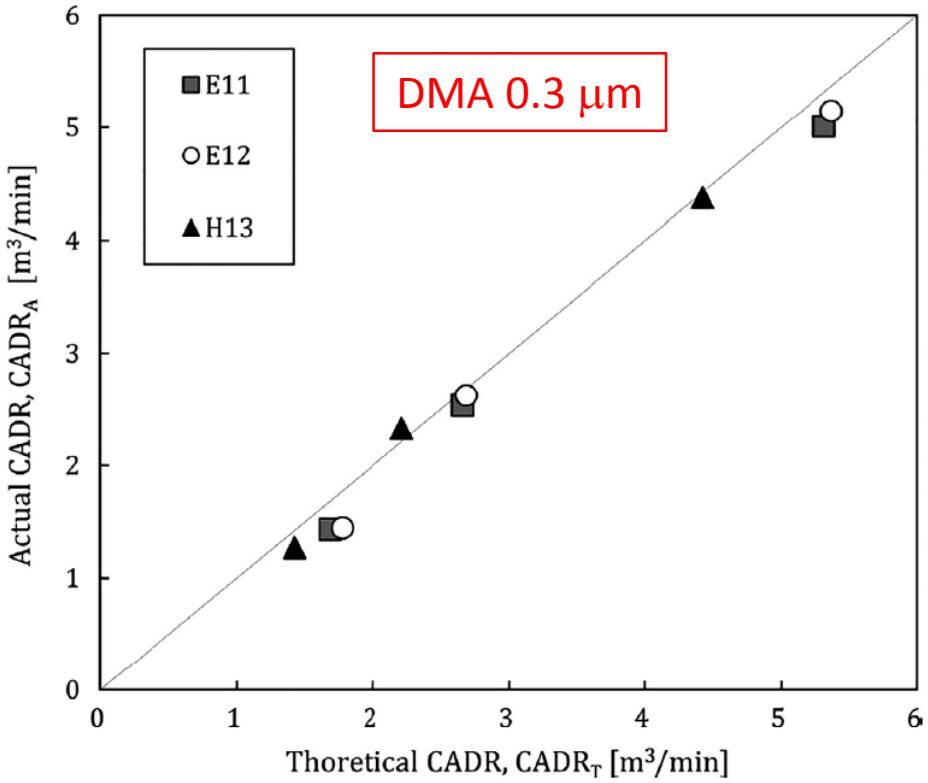
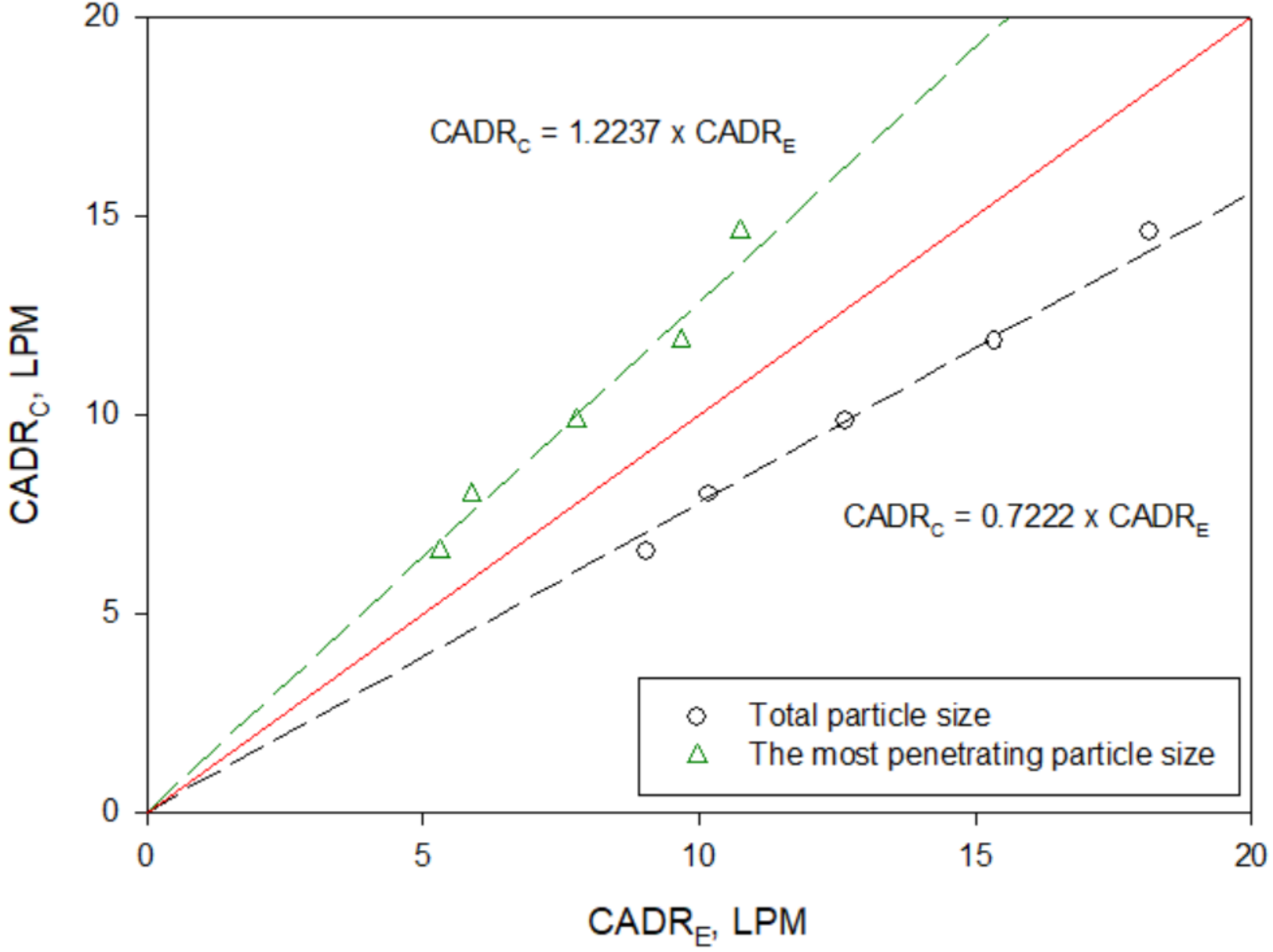


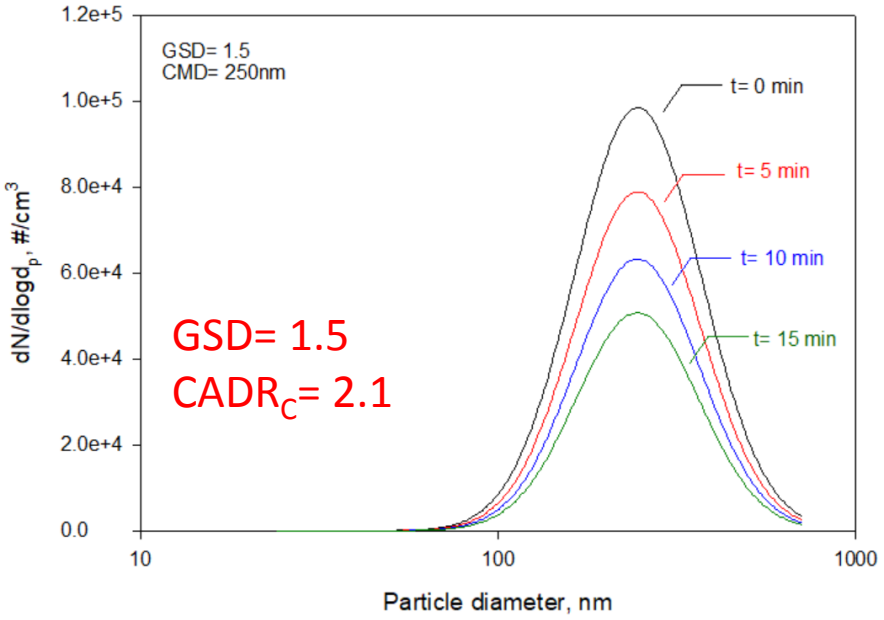
FIGURE 9 Comparison of theoretically calculated and experimentally determined CADR values

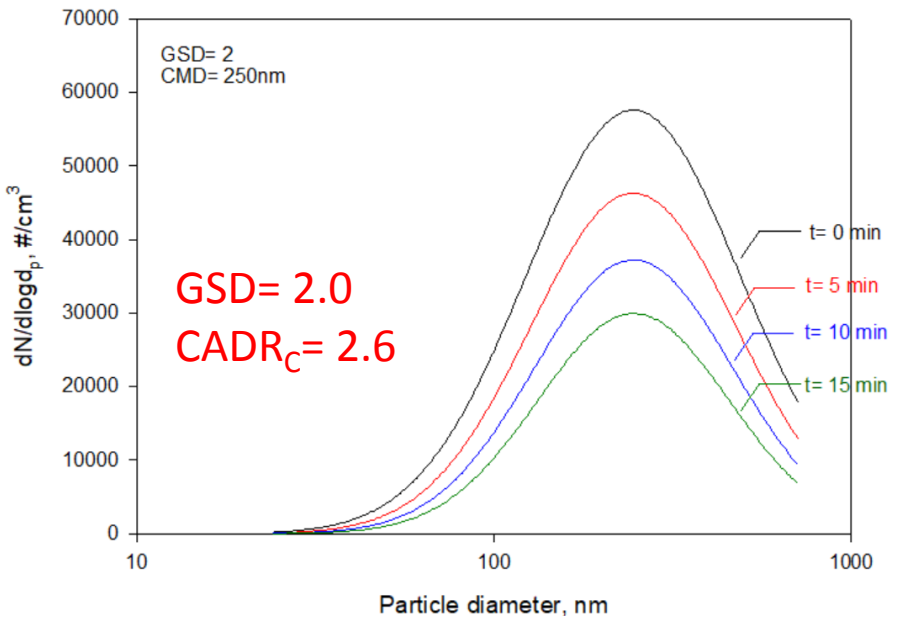
TABLE 4 Comparison of theoretically calculated and experimentally determined Clean Air Delivery Rate (CADR) values

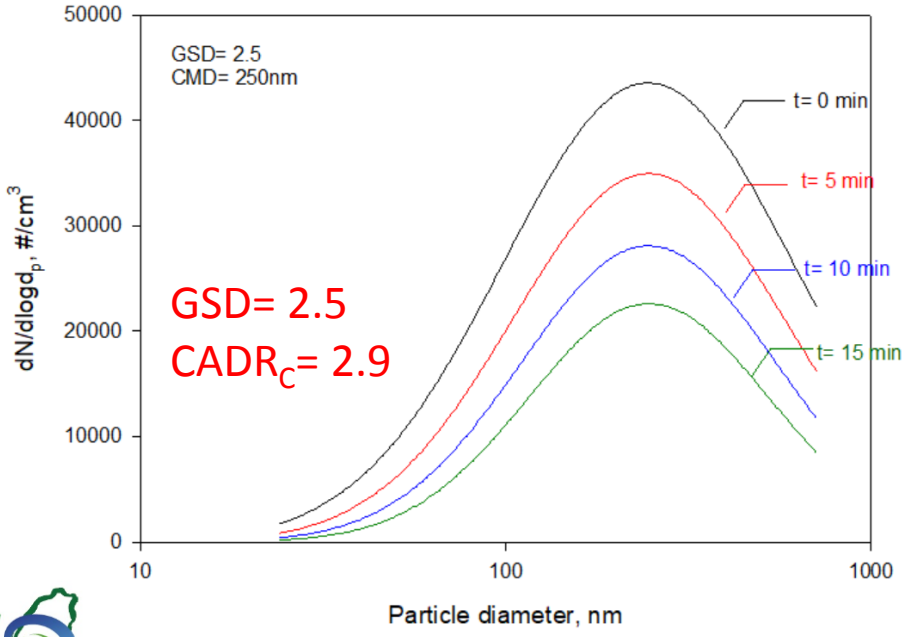
Filter	Operating Mode	CADR$_T$ (mean ± SD) [m^3/min]	CADR$_A$ (mean ± SD) [m^3/min]
E11	W	1.68 ± 0.36	1.43 ± 0.01
E12	W	1.77 ± 0.30	1.44 ± 0.04
H13	W	1.42 ± 0.30	1.27 ± 0.02
E11	S	2.66 ± 0.42	2.53 ± 0.02
E12	S	2.69 ± 0.45	2.63 ± 0.07
H13	S	2.21 ± 0.44	2.33 ± 0.04
E11	SS	5.32 ± 0.84	5.01 ± 0.01
E12	SS	5.38 ± 0.90	5.15 ± 0.05
H13	SS	4.42 ± 0.87	4.37 ± 0.03

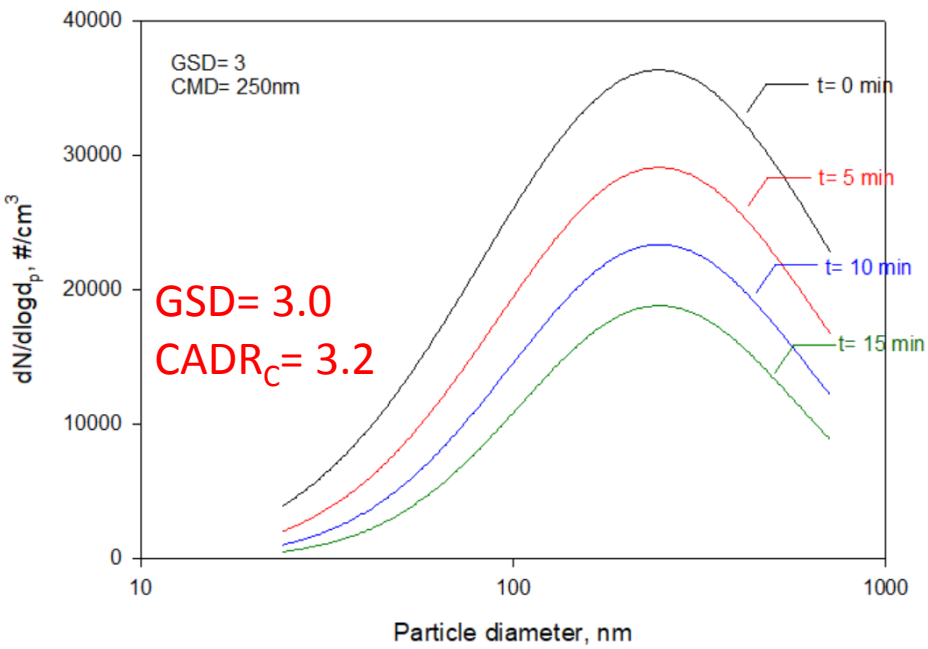


圖六、CADR$_C$與CADR$_E$相關性









圖七、不同GSD下對CADR的影響

新風機效能測試方法與量測系統建置

(Performance Evaluation of Outdoor Air Cleaners)

Introduction

- **Outside Air Cleaner (OAC)**, an air purifying unit, can directly purify outdoor air before transporting into building environment.

- Conventional **CADR** evaluation requires a large space and well-regulated conditions, while **"flow rate (Q) & efficiency (η)"** method mostly relies on filter penetration test and flow rate measurement.

- A facility for the rapid evaluation of OAC performance were built in this study.

Experimental setup

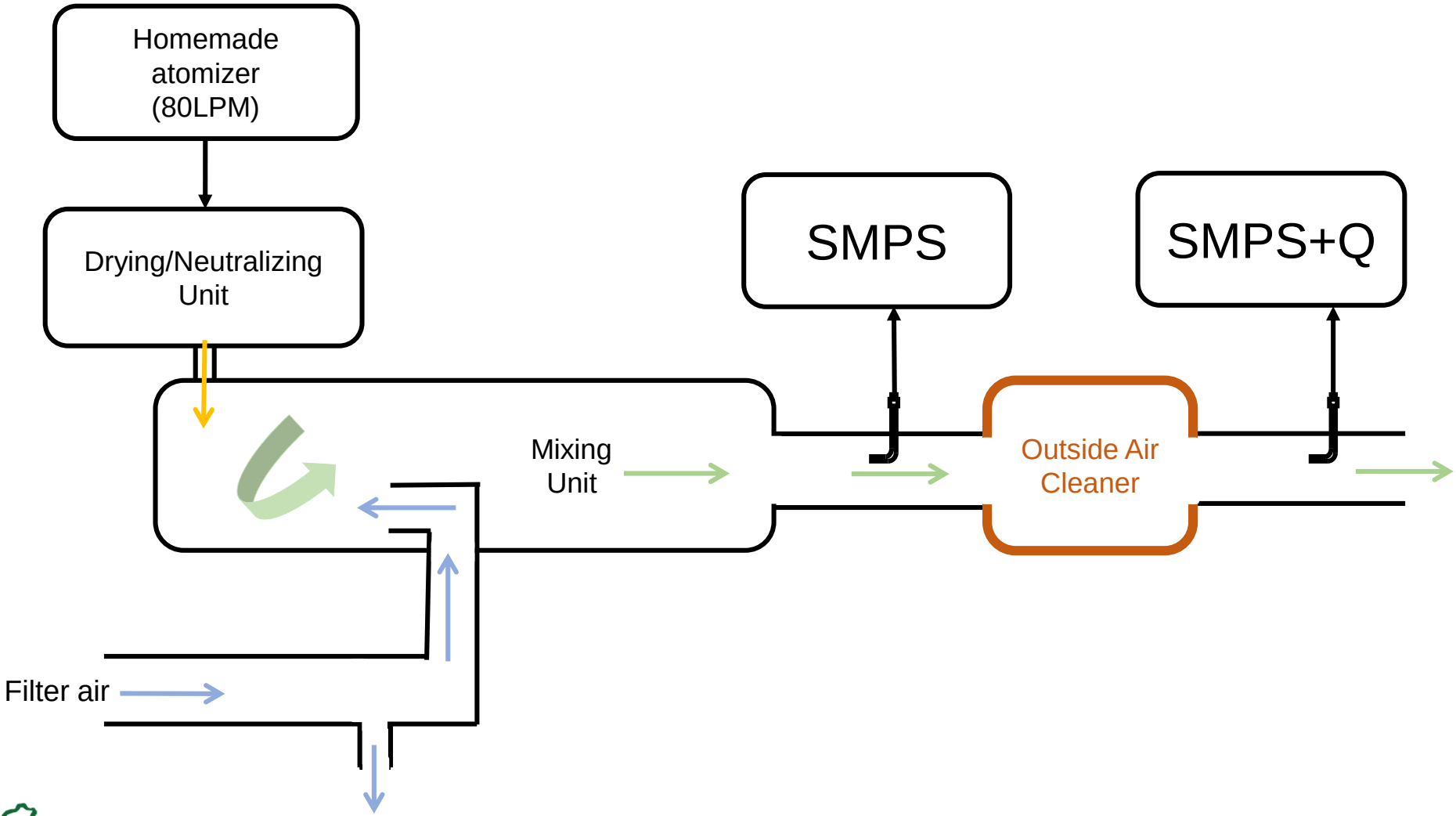


Figure. Experimental system setup of penetration test.

Table. Summary of selected OAC.

Brand		B	A-1	A-2	A-3
Filter	Filter size	35 x 21 cm =735 cm^2	20.5 x 25 cm =512.5 cm^2	20.5 x 25 cm =512.5 cm^2	20.5 x 25 cm =512.5 cm^2
	Pleat count	75	53	57	57
Fan type		axial fan	centrifugal fan		
Voltage		220V	110V	110V	220V

Results and discussion

Pitot tube test

動壓, mm H_2O
風速, m/s
風量, LPM

OAC / Mode	B (220V)	A -1 (110V)	A -2 (110V)	A -3 (220V)
Low	1.27 mm H_2O 4.59 m/s 4863 LPM	0.20 1.83 1945	0.25 2.05 2175	**皮托管無法判讀** 熱線式風速計讀值： 0.78 m/s 1277 LPM
Median		1.0 4.10 4349	0.89 3.84 4069	0.38 2.51 2663
High	1.905 5.62 5956	1.27 4.59 4863	2.29 6.15 6524	1.651 5.23 5544

Brand	B(220V)		A-1(110V)			A-2(110V)			A-3(220V)		
Mode	Low	High	Low	Median	High	Low	Median	High	Low	Median	High
Superficial velocity, m/s	4.8	5.5	1.8	4.1	4.4	1.9	3.8	6.2	1.2	2.4	5.0
Flow rate, LPM	5122	5798	1923	4385	4712	2062	4071	6579	1277	2548	5315
Filter Efficiency	0.86	0.85	0.85	0.83	0.8	0.97	0.95	0.94	0.95	0.95	0.93
CADR, LPM	4405	4928	1635	3640	3770	2000	3867	6184	1213	2421	4943
Operating power, W	20.6	28.4	27.1	71	115	23	45.7	126.6	12.4	23.5	75.7
Standby power, W	0			1.3			1.3			2.12	
Energy consumption, W	20.6	28.4	25.8	69.7	113.7	21.7	44.4	125.3	10.3	21.4	73.6
CADR/W	214	174	63	52	33	92	87	49	118	113	67

Performance Measurement

Methods of Air Cleaner

◆乾淨空氣供給率(Clean Air Delivery Rate, CADR)

$$CADR = \eta_{filter} \cdot Q_{AC}$$

$CADR$ = Clean Air Delivery Rate, L/ min

η_{filter} = Filter efficiency, %

Q_{AC} = Outdoor Air Cleaner flow rate, L/min

◆能量消耗(Energy consumption, W)

Operating power(watt) − *Standby power*(watt) = Energy comsumption(watt)

◆新風機效能(Performance of Air Cleaner, P)

$$P = \frac{CADR}{W}$$

P = Performance of Air Cleaner, L/min/watt

$CADR$ = Clean Air Delivery Rate, L/ min

W = Energy comsumption, watt

Flow rate measurement

- 量測儀器：熱線式風速計 (Tsi 8386)
- 量測系統：新風機下游設置約為管徑5倍長之風管，並於管徑3倍長處設置測定點
- 測量步驟：

  將管道截面積以同心圓平分成三等份，於同一垂直線上測定6個點，將測得的速度值平均後，可以得到平均速度(V)。

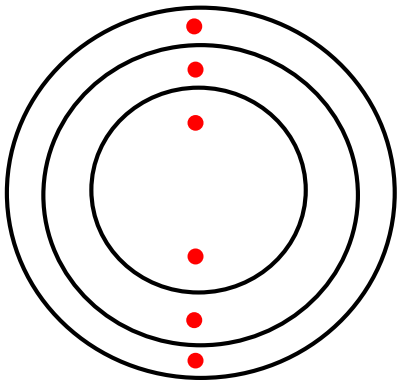
- **風量計算**：

$$Q_{FAS} = V \times \pi r^2 \times 1000 \times 60$$

Q_{OAC} = Outdoor Air Cleaner flow rate, L/min

$V = Average\ wind\ velocity$, m/s

$\pi r^2 = Pipe\ section\ area$, m^2



Efficiency measurement

- 量測儀器：電移動度分析儀 (Scanning Mobility Particle Sizer, SMPS)
- 量測系統：於實驗系統上下游風管量測
- 測量步驟：
  1. 開啟微粒產生系統及Filter Air(微粒產生系統濃度約10^4 -10^5#/cm^3，CMD約60-70nm)
  2. 將風機調至欲量測的操作模式(低、中或高風量)，並於系統上游端多於風量出口處量測風速(V<0.1 m/s)
  3. 使用SMPS量測三組上游及下游微粒濃度(上下游各自微粒濃度差異於5%內)
- **過濾效率計算**：

$$\boldsymbol{Penetration = \frac{N_{out}}{N_{in}} \times 100\%}$$

$$\boldsymbol{\eta_{filter} = 1 - Penetration}$$

$Penetration$ = Particle penetration, %

N_{in} = Upstream particle concentration, #/cm^3

N_{out} = Downstream particle concentration, #/cm^3

η_{filter} = Filter efficiency, %