HEPA空氣過濾測試及能耗評估

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簡報內容

- EPA/HEPA/ULPA 空氣濾網測試
- 濾網能耗測試

EPA、HEPA和ULPA過濾器標準

EN 1822 (ISO 29463:2011) High efficiency air filters (EPA, HEPA and ULPA)

- Part 1 : 2019 (2017)
  - Classification, performance testing, marking
- Part 2 : 2009 (2011)
  - Aerosol production, measuring equipment, particle counting statistics
- Part 3 : 2009 (2018)
  - Testing flat sheet filter media
- Part 4 : 2009 (2011)
  - Determining leakage of filter element (Scan method)
- Part 5 : 2009 (2022)
  - Determining the efficiency of filter element

IEST-RP-CC001 HEPA and ULPA Filters
IEST-RP-CC007 Testing ULPA Filters
IEST-RP-CC021 Testing HEPA and ULPA Filter Media
IEST-RP-CC034 HEPA and ULPA Filter Leak Tests

EPA, HEPA 和ULPA 過濾器分級

歐洲與國際標準之分級

Filter Class (Group)	Overall value		Local value		Filter Class (Group)
ISO 29463	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)	EN 1822
	≧ 85	≦ 15			E10
ISO 15 E	≧ 95	≦ 5	--	--	E11
ISO 20 E	≧ 99.0	≦ 1	--	--	
ISO 25 E	≧ 99.5	≦ 0.5	--	--	E12
ISO 30 E	≧ 99.90	≦ 0.1	--	--	
ISO 35 H	≧ 99.95	≦ 0.05	≧ 99.75	≦ 0.25	H13
ISO 40 H	≧ 99.990	≦ 0.01	≧ 99.95	≦ 0.05	
ISO 45 H	≧ 99.995	≦ 0.005	≧ 99.975	≦ 0.025	H14
ISO 50 U	≧ 99.9990	≦ 0.001	≧ 99.995	≦ 0.005	
ISO 55 U	≧ 99.9995	≦ 0.0005	≧ 99.9975	≦ 0.0025	U15
ISO 60 U	≧ 99.99990	≦ 0.0001	≧ 99.9995	≦ 0.0005	
ISO 65 U	≧ 99.99995	≦ 0.00005	≧ 99.99975	≦ 0.00025	U16
ISO 70 U	≧ 99.999990	≦ 0.00001	≧ 99.99995	≦ 0.00005	
ISO 75 U	≧ 99.999995	≦ 0.000005	≧ 99.999975	≦ 0.000025	U17

HEPA 和ULPA 過濾器分級

美國標準之分級

MMD: Mass Median Diameter

ASHRAE 52.2:1999	IEST-RP-CC001.3		
Grade	Grade	Efficiency	Particle Size
MERV 17	HEAP (Type A)	≧99.97%	0.3 μm (MMD)
MERV 18	HEAP (Type C)	≧99.99%	0.3 μm (MMD)
MERV 19	HEPA (Type D)	≧99.999%	0.3 μm (MMD)
MERV 20	ULPA (Type F)	≧99.999%	0.1-0.2 μm

澳洲標準之分級

MPPS: Most Penetration Particular Size

AS 4260:1997			EN 1822-1:2009 (ISO 29463-1)		
Grade	Efficiency	Particle Size	Grade	Efficiency	Particle size
Grade 1	≧99.97%	0.3 μm (MMD)	H13 (ISO 35H)	≧99.95%	MPPS
Grade 2	≧99.99%	0.3 μm (MMD)			
Grade 3	≧99.999%	0.3 μm (MMD)	H14 (ISO 45H)	≧99.995%	MPPS
Grade 4	≧99.999%	0.12 μm			

濾材種類

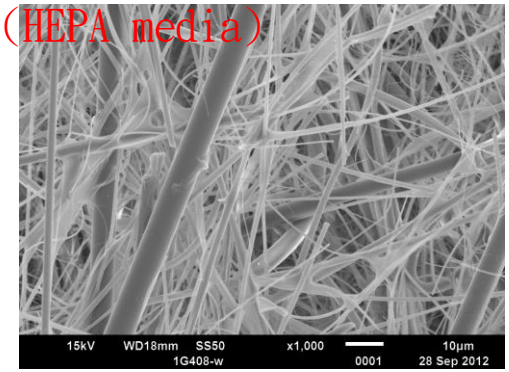
奈米纖維定義：<1μm

Electro-spinning　ePTFE

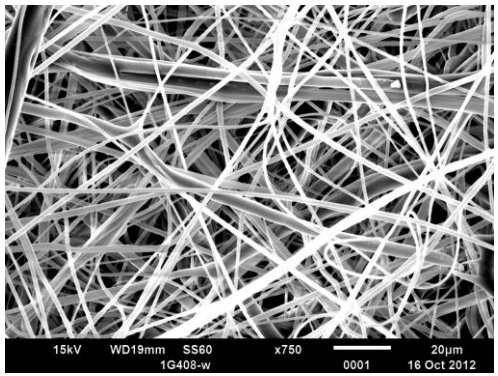
Fiber →Filter media ← Flat sheet

厚度：：
~500μm
纖維直徑:
0.1~10μm
基重 ~80gsm

Micro glass fiber(微玻纖)
(HEPA media)



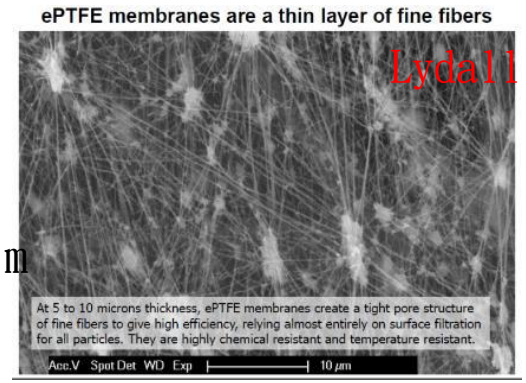
Melt blown (熔噴)

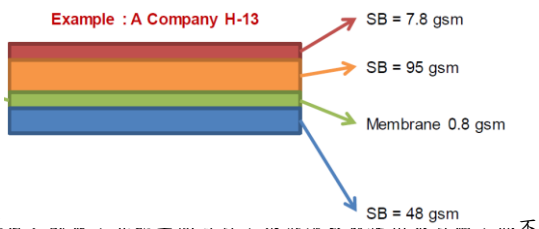


梭織物

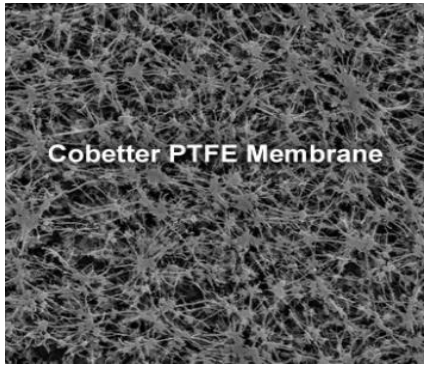
厚度:
5~10μm
纖維直徑:
0.02~0.2μm
基重 ~0.8gsm

ePTFE

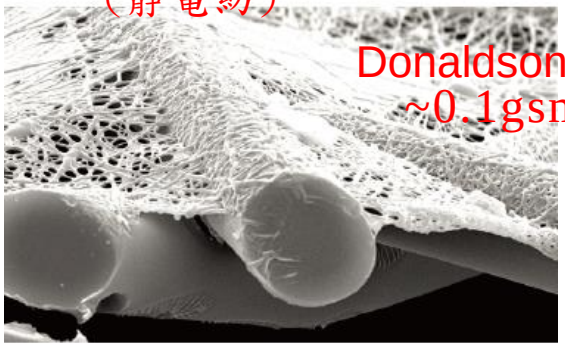




ePTFE 厚度: 20~500μm



Electrospinning
(靜電紡)



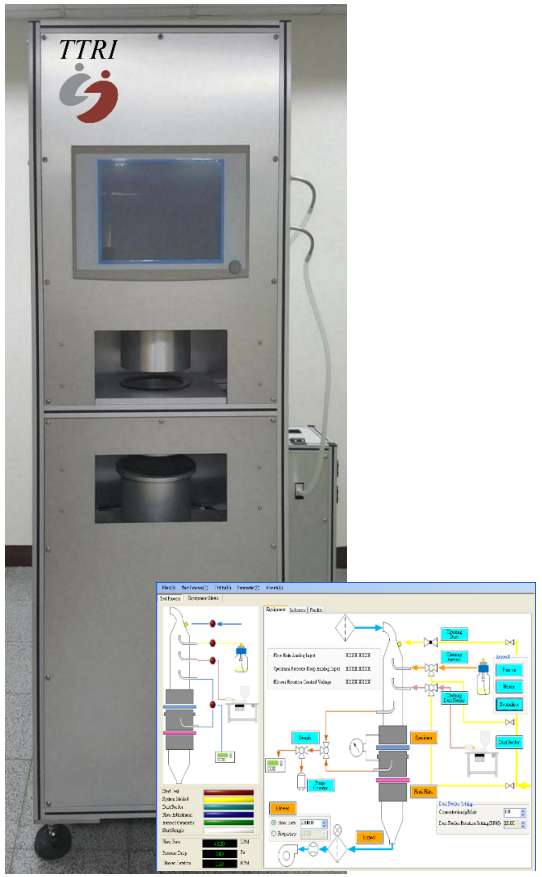
影響過濾效率的因子

1. 纖維帶電量　2. 表面風速　3. 填充密度
4. 濾材厚度　5.纖維直徑

濾料效率測試

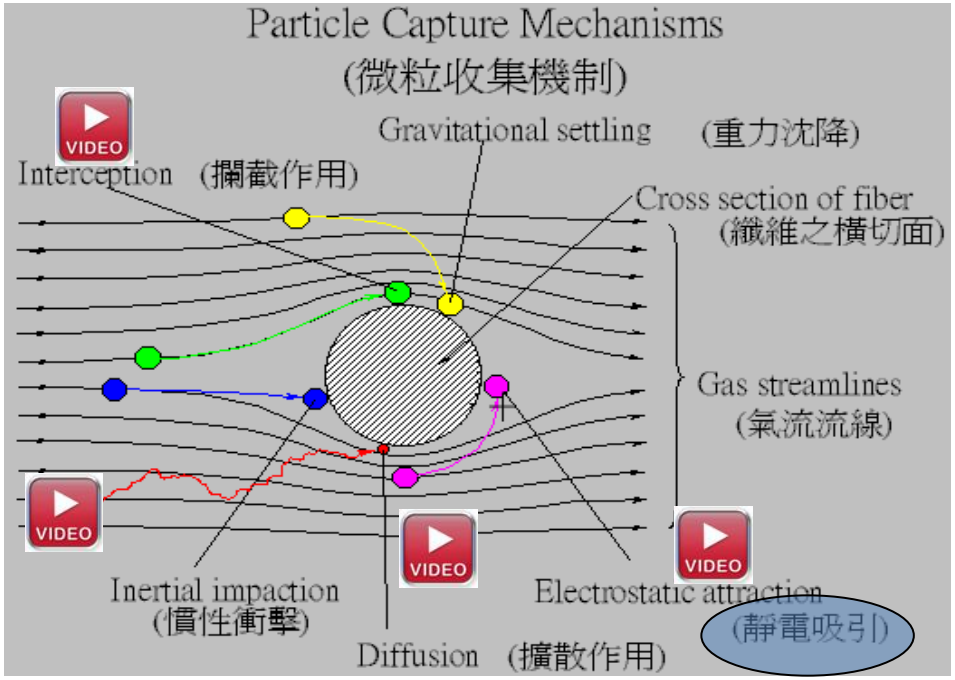
TSI 8130

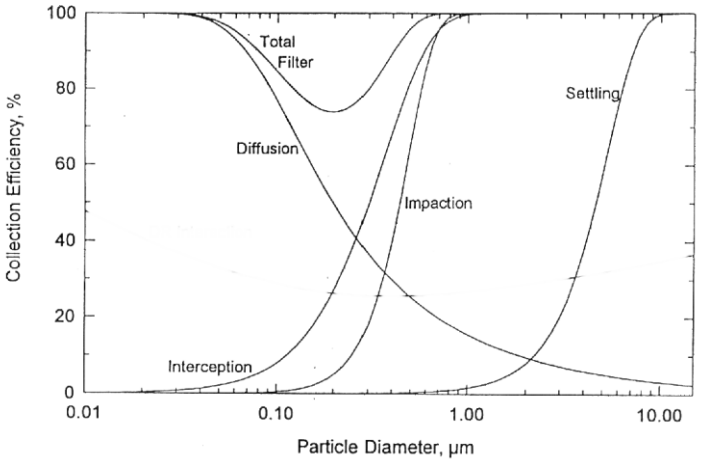
TSI 3160

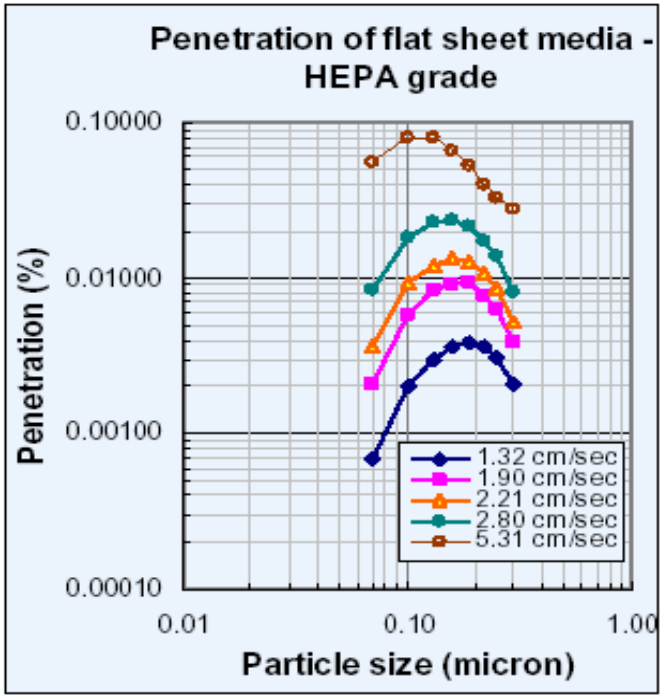


濾料效率測试
(ASHRAE 52.2; EN 779)

微粒捕集機制



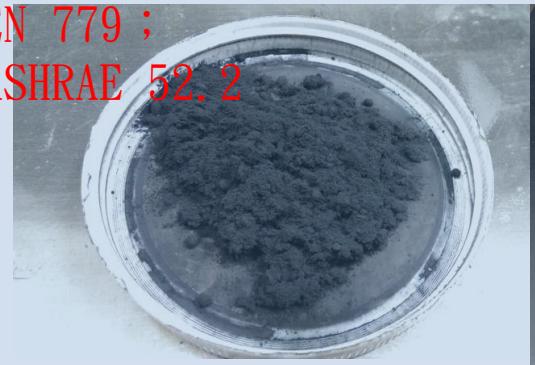




測試用 氣膠種類

粉塵負載測試，重量捕集率

EN 779；
ASHRAE 52.2



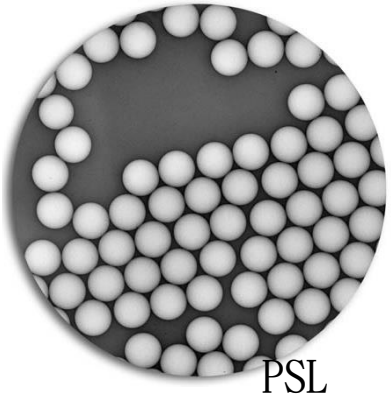
ASHRAE Dust

ISO 16890；
ISO 11155

ISO A2 Fine Dust

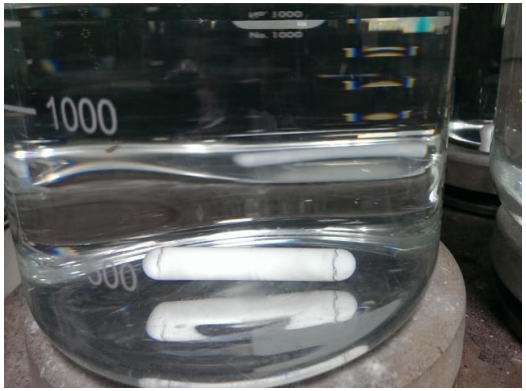
微粒子過濾效率測試

KCl（鹽霧）



PSL

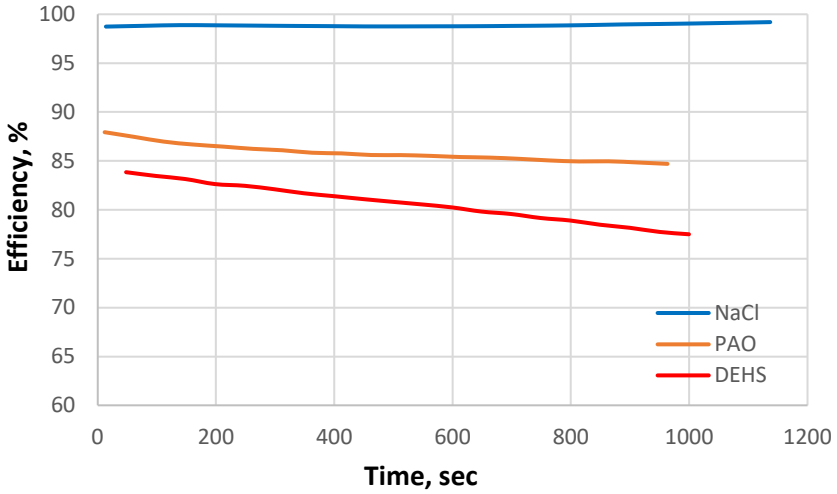
DEHS
（油霧）

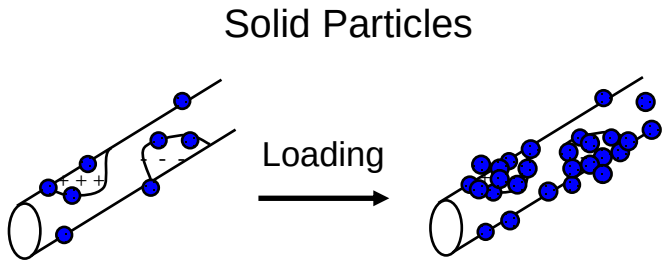


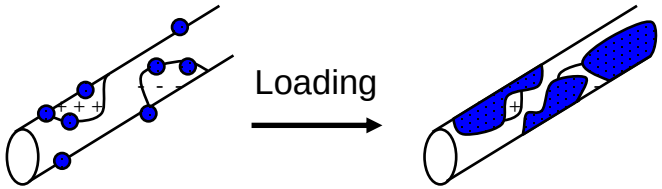
KCl 水溶液（30%）
NaCl 水溶液（2%）

不同氣溶膠的濾效差異

熔喷濾材
MB



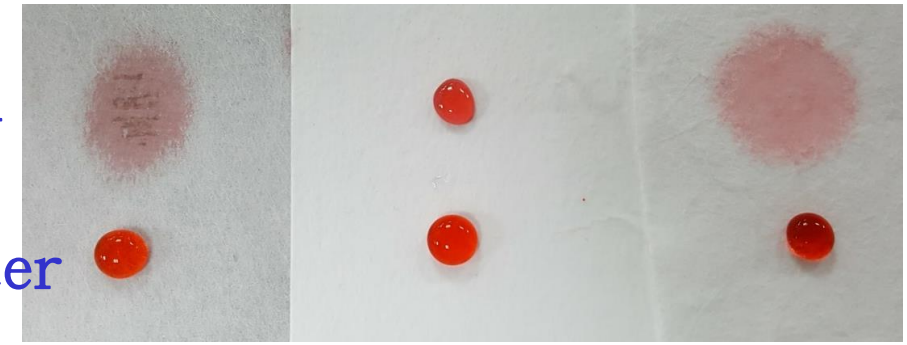




ePTFE Glass fiber PP MB

Oil

Water



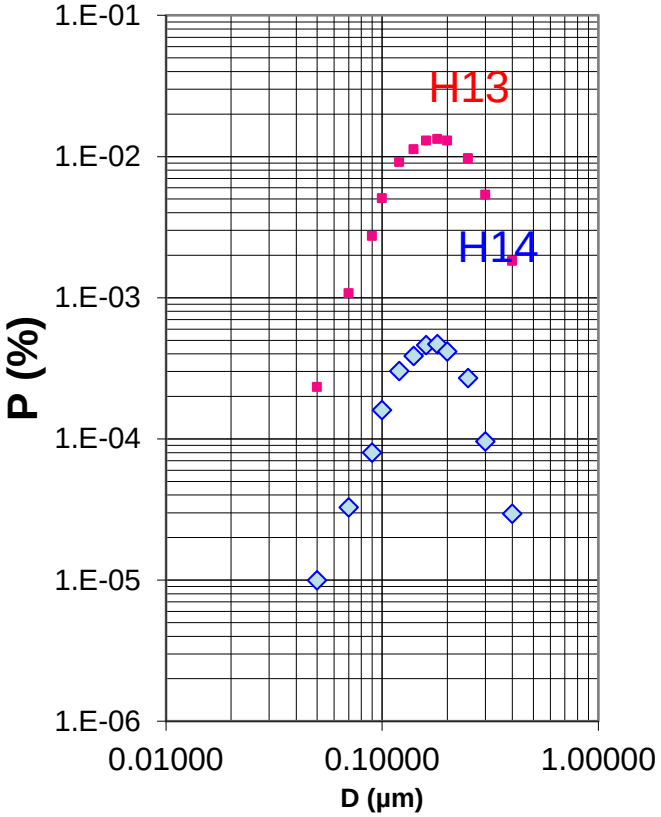
玻纖與ePTFE濾材的MPPS

測試流速：1.8 cm/sec

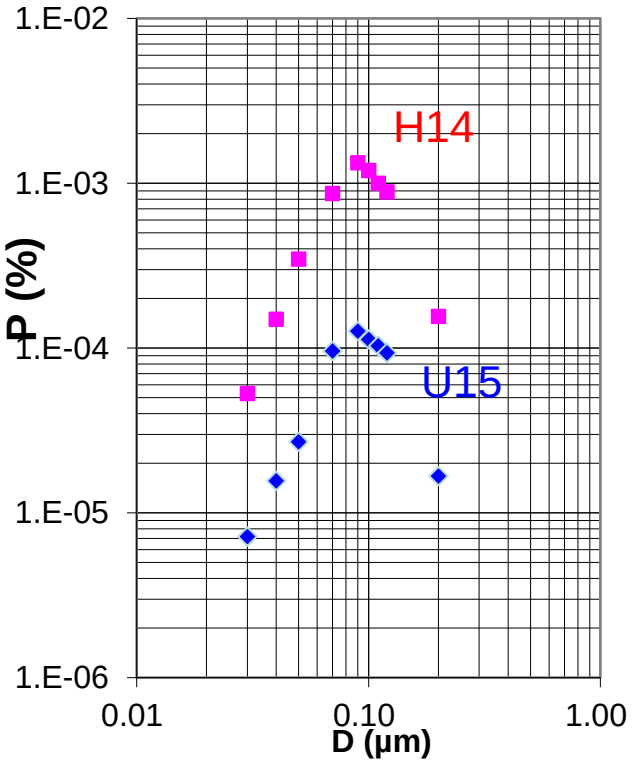
量測濾網基材於不同粒徑下的過濾效能,找尋MPPS可量測的最大過濾效率為99.999999%

MPPS

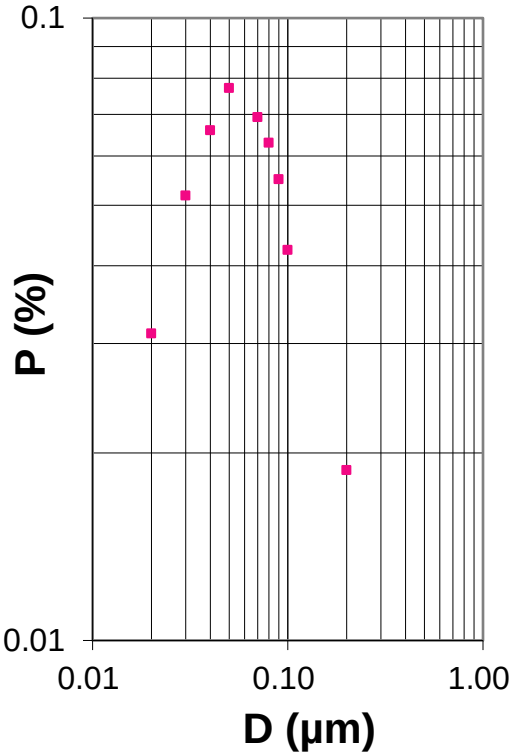
玻纖: 0.1~0.2um



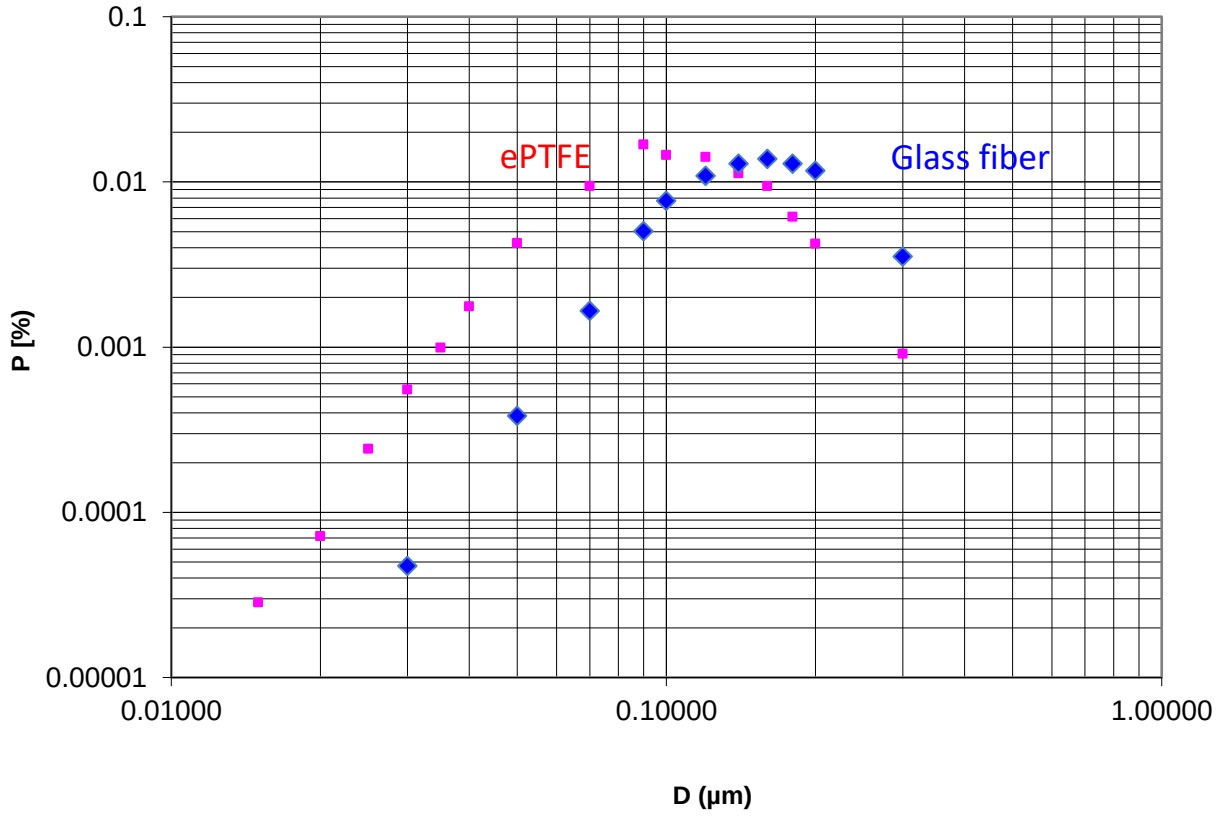
ePTFE: < 0.1um



熔噴不織布（帶靜電）



玻纖與ePTFE濾材的MPPS



氣膠濃度檢測裝置

- 光學粒子計數器（>100 *nm*）
  （Optical Particle Counter）
- 凝結核微粒計數器（2.5~*1000 nm*）
  （Condensation Particle Counter）
- 光度計（0.1~10 *um*）
  （Photometer）

空調系統的成本分析及濾網能耗計算

空調系統的成本分析

能耗

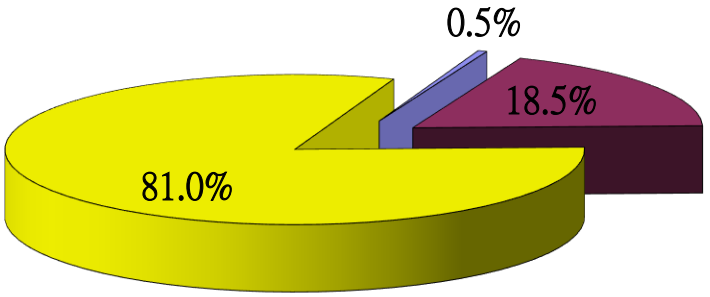
(kWh)= Q ΔP t /(η 1000)

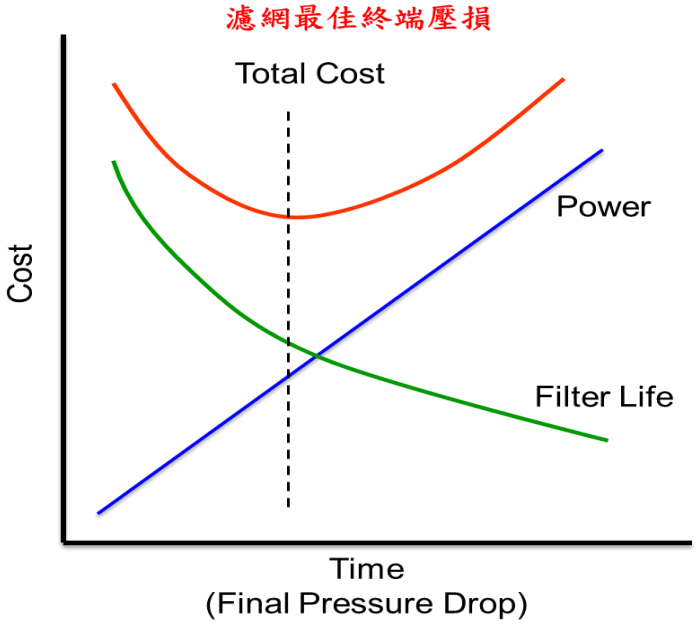
Q = Air Flow (m^3/sec)（流量）

ΔP = Avg. Pressure Loss（平均壓損）

t = Time in Operation (hrs)（運轉時間）

η = Fan Efficiency（風扇效率）





資料來源：NAFA

空調系統的成本分析

	Initial Cost	Energy Cost	Initial Cost % of Total	Energy Cost % of Total
MERV 6-11 Pleated Filter	$4	$46	8%	92%
MERV 11-15 Final Filter	$70	$304	19%	81%

資料來源：Kimberly-Clark

不同壓損濾網的使用成本分析

	Filter A		Filter B
Efficiency	MERV 14		MERV 14
Filter Style	12" Deep Rigid		12" Deep Rigid
Media Area	120 sq. ft.		120 sq. ft
Initial Cost	$70	5 /year	$65
Initial ▲P	0.45" Water Gauge (WG)		0.65" WG
Final ▲P	1.50" WG		1.50" WG
DHC	300g		300g
Filter Life	12 months		12 months
Energy Cost	$276/year	29 /year	$305/year

Calculation: Energy Consumption = Q*dP*t/n/1000
Assumes 24/7/365 operation, energy cost of $.08/kWh, fan, motor, drive efficiency (n) of 58 percent

總費用：
29-5=24

Source: Kimberly-Clark

ISO 16890-1過濾器分級

類 別	組 別	需 求			等級標示值
		$ePM_{1,min}$	$ePM_{2.5,min}$	ePM_{10}	
粗效過濾器 (Coarse Filter)	ISO Coarse	-	-	<50%	初始重量捕集率
中效過濾器 (Fine Filter)	ISO ePM10	-	-	≧50%	ISO ePM10
	ISO ePM2.5	-	≧50%	-	ISO ePM2.5
	ISO ePM1	≧50%	-	-	ISO ePM1

Efficiency	Size range, µm
ePM_{10}	$0,3 \leq x \leq 10$
$ePM_{2,5}$	$0,3 \leq x \leq 2,5$
ePM_1	$0,3 \leq x \leq 1$

例：

ISO Coarse 60 %

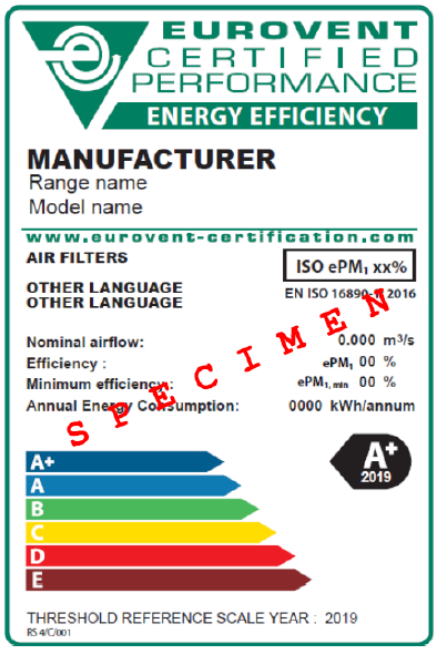
ISO ePM10 60 %

ISO ePM2.5 80 %

ISO ePM1 85 %

ISO ePM1 >95 %

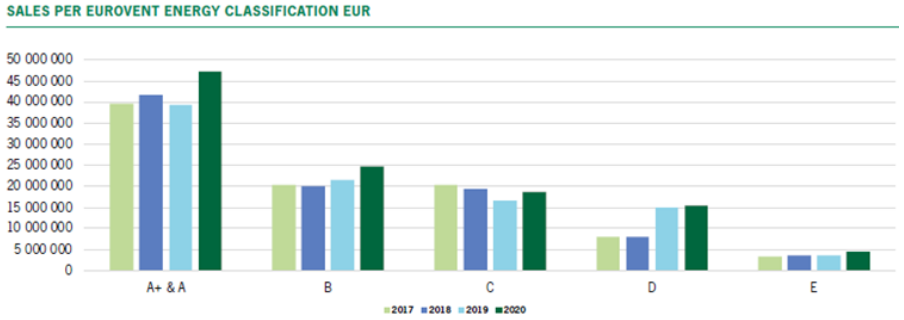
Eurovent 4/21:2018 能耗分級



M_X = 200 g (AC Fine)	AEC in kWh/y FOR ePM_1					
	ePM_1 and $ePM_{1,min} \geq 50\%$					
	A+	A	B	C	D	E
50&55%	800	900	1050	1400	2000	>2000
60&65%	850	950	1100	1450	2050	>2050
70&75%	950	1100	1250	1550	2150	>2150
80&85%	1050	1250	1450	1800	2400	>2400
>90%	1200	1400	1550	1900	2500	>2500

M_X = 250 g (AC Fine)	AEC in kWh/y FOR $ePM_{2.5}$					
	$ePM_{2.5}$ and $ePM_{2.5,min} \geq 50\%$					
	A+	A	B	C	D	E
50&55%	700	800	950	1300	1900	>1900
60&65%	750	850	1000	1350	1950	>1950
70&75%	800	900	1050	1400	2000	>2000
80&85%	900	1000	1200	1500	2100	>2100
>90%	1000	1100	1300	1600	2200	>2200

M_X = 400 g (AC Fine)	AEC in kWh/y FOR ePM_{10}					
	$ePM_{10} \geq 50\%$					
	A+	A	B	C	D	E
50&55%	450	550	650	750	1100	>1100
60&65%	500	600	700	850	1200	>1200
70&75%	600	700	800	900	1300	>1300
80&85%	700	800	900	1000	1400	>1400
>90%	800	900	1050	1400	1500	>1500



Eurovent 濾網認證

紡織產業綜合研究所
Taiwan Textile Research Institute

http://www.eurovent-certification.com/

Brand	Range	Model	Filter class	Energy Efficiency Class ...	Annual Energy Consum... kWh/annum	Init. press. drop at 100% Pa	Init. press. drop at 50% Pa	Init. press. drop at 75% Pa	Init. press. drop at 125% Pa
AAF	DriPak GX	DriPak GX ePM1 65% 59...	ISO ePM1 65%	C	1280	110	48	78	144
AAF	DriPak GX	DriPak GX ePM1 65% 59...	ISO ePM1 65%	B	1070	90	36	62	123
AAF	DriPak GX	DriPak GX ePM1 65% 59...	ISO ePM1 65%	E	>2050	140	62	100	183
AAF	DriPak GX	DriPak GX ePM1 85% 59...	ISO ePM1 85%	E	>2400	220	100	159	284

Model	drop at 75%	Init. press. drop at 125% Pa	ePM1 Av. Eff. %	ePM1 Min. Eff. %	ePM2.5 Av. Eff. %	ePM2.5 Min. Eff. %	ePM10 Av. Eff. %	Airflow Rate m³/s	Basic design	Depth/Length mm	Filter Media	No of bags or Vs	Face dimensions mm
DriPak GX ePM1 65% 59...		144	67	67	75	75	92	0.944	Bag	525	Glass	8	592x592
DriPak GX ePM1 65% 59...		123	67	67	75	75	92	0.944	Bag	635	Glass	10	592x592
DriPak GX ePM1 65% 59...		183	67	67	75	75	92	0.944	Bag	635	Glass	6	592x592
DriPak GX ePM1 85% 59...		284	85	85	90	90	97	0.944	Bag	360	Glass	10	592x592

Eurovent 4/21 能源效率計算

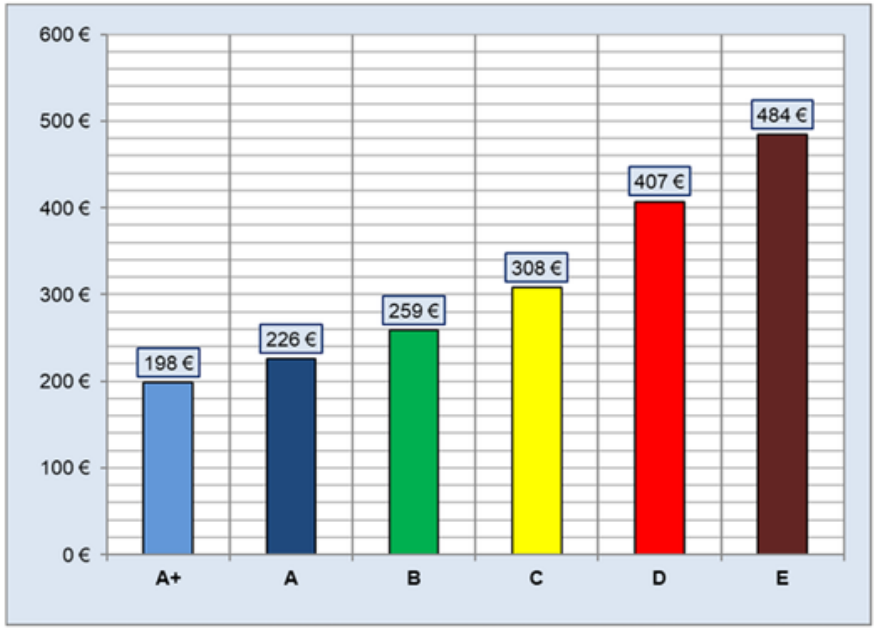
$$W = \frac{q_v \times \overline{\Delta P} \times t}{\eta \times 1000}(kWh)$$

$q_v = 0.944\ m^3/s$ 2000 CFM; 3400 CMH

$t = 6000h$ 一年使用時數

$\eta = 0.5$ 風機效率

$\overline{\Delta P} : P_a$ 平均壓損：初始壓損與預設階段下(如 M_X=200g AC Fine)之壓損平均值



Within a period of one year, one pocket filter of filter class ePM1 75% according to ISO16890, using a volume flow rate of 3.400 m3/h consumes EUR 407 in engery efficiency class D and EUR 198 in engery efficiency class A+. Changing the filters from energy efficiency class D to A+ resukts in an energy costs saving of 51% (EUR 209).

假設： EUR 0.22 per kWh

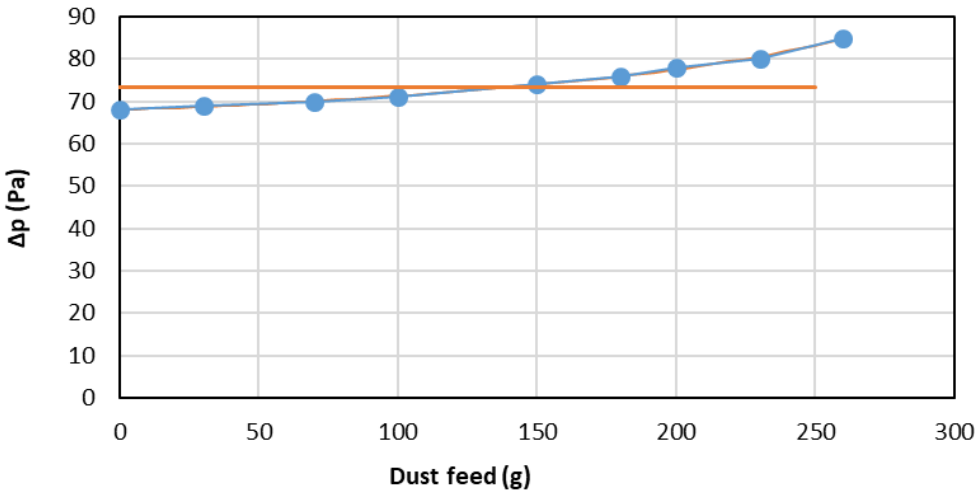
平均壓損計算

$$\overline{\Delta p_i} = 0{,}5 \cdot (\Delta p_i + \Delta p_{i-1}) \text{ where } i = 1 \ldots n-1$$

$$\overline{\Delta p_n} = \Delta p_{n-1} + 0{,}5 \cdot \frac{\Delta p_n - \Delta p_{n-1}}{m_n - m_{n-1}} \cdot (M_x - m_{n-1}) \text{ where } m_{n-1} < M_x \text{ and } m_n \geq M_x$$

$$\Delta m_i = m_i - m_{i-1} \text{ and } \Delta m_n = M_x - m_{n-1}$$

階段	積塵量 m_i (g)	壓降 Δp_i, (Pa)	粉塵增加量 Δm_i (g)	平均壓降 $\overline{\Delta p_i}$ (Pa)
0	0	68		
1	30	69	30	68.5
2	70	70	40	69.5
3	100	71	30	70.5
4	150	74	50	72.5
5	180	76	30	75.0
6	200	78	20	77.0
7	230	80	30	79.0
8	250	85	20	82.5



$$\overline{\Delta p} = \frac{1}{M_x} \cdot \sum_{i=1}^{n} \overline{\Delta p_i} \cdot \Delta m_i \qquad \overline{\Delta p} = 73.4 \text{ Pa}$$

ISO group	ISO ePM_1	ISO $ePM_{2,5}$	ISO ePM_{10}
Amount of dust fed M_x	200 g	250 g	400 g

Table 1: Total amount of dust fed

謝謝指教

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