

猪场空气过滤器滤材的选择、测试及失效分析

Selection, testing, and failure analysis of filter materials for air filters in pig farms

Creating a Cleaner World™

The H&V Story

Science-driven solutions®

HV Hollingsworth
& Vose®

October 2025 / Confidential

H&V成立于1728年 H&V was founded in 1728

H&V公司总部位于美国波士顿。2004年，H&V在中国苏州成立亚太区总部-贺氏（苏州）特殊材料有限公司，并于2011年设立Mark Hollingsworth全球研发中心（简称MHGTC）。

H&V's headquarters is located in Boston, USA. In 2004, H&V established its Asia-Pacific headquarters, Heshi (Suzhou) Special Materials Co., Ltd., in Suzhou, China, and in 2011, it set up the Mark Hollingsworth Global Research and Development Center (MHGTC).



H&V先进的研发测试能力:

- TOPAS测试台, 中国最早具备ISO 16890-2016国际过滤器测试标准测试能力的实验室



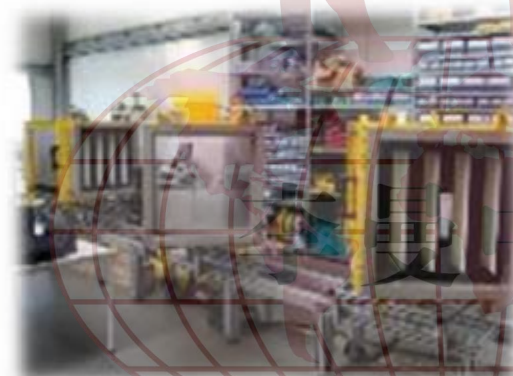
- 过滤性能的数值模型分析
- 为研发新型过滤材料提供微观研究及预测
- 为客户开发新型过滤器提供优化设计方案

HV Hollingsworth & Vose®

H&V广泛参与国内外空气过滤相关标准制定:

国内

- GBT14295-2019 空气过滤器
- GBT13554-2020 高效空气过滤器
- GBT18801-2015 空气净化器
- JG/T404-2013 空气过滤器用滤料
- GB/T 36370-2018 洁净室及相关受控环境空气过滤器应用指南
- CRAA 434~438 中国制冷空调工业协会标准-空气过滤器



国际

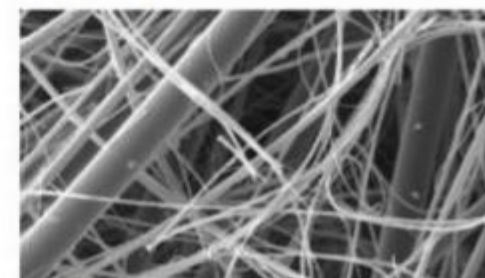
- ISO 16890-2016
- EN 779-2012
- ISO 14644

Confidential ISO 29463

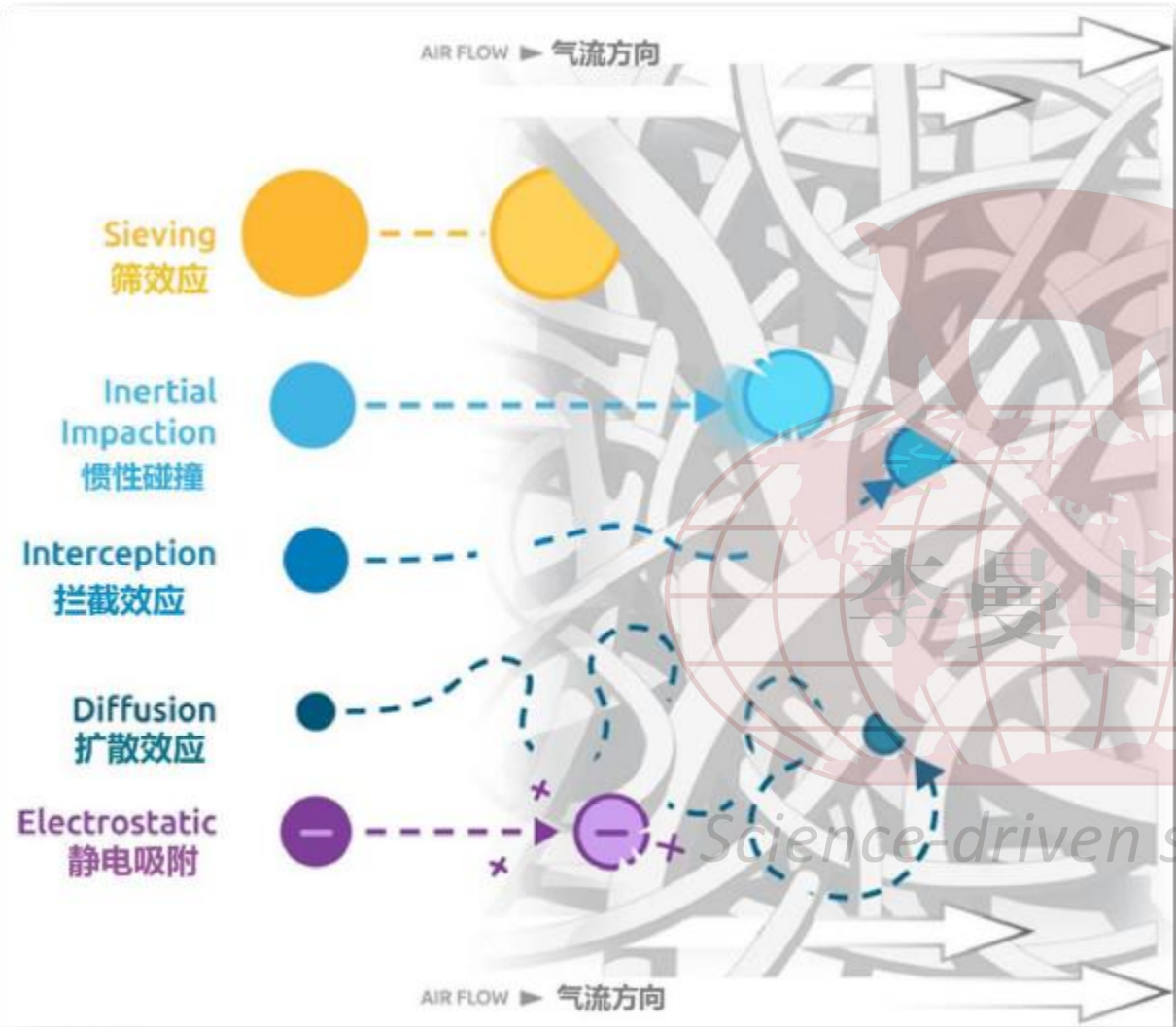
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ISO 16890 - The Global Air Filtration Standard
Feature article



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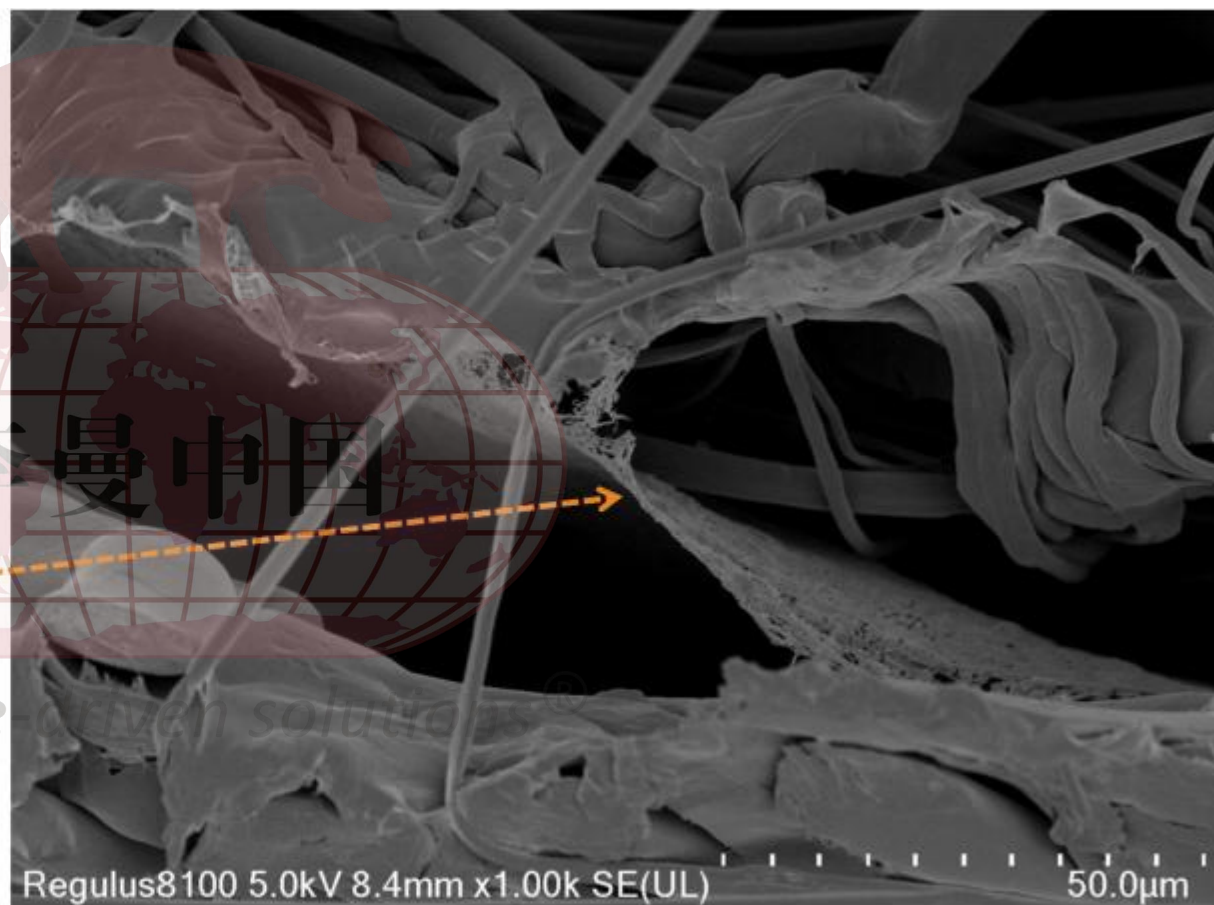
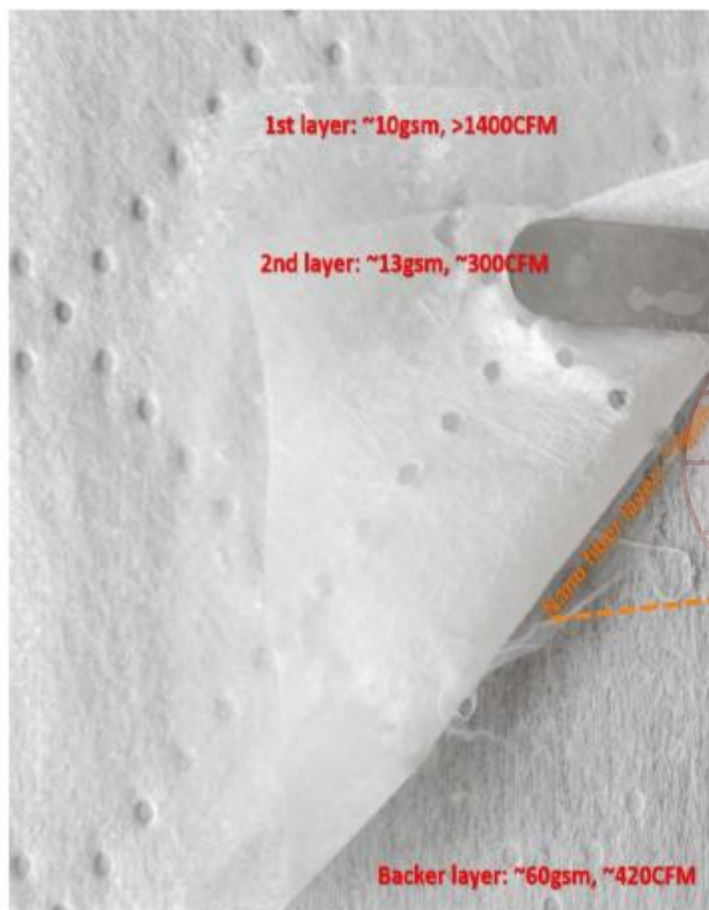


机械过滤 静电吸附



滤纸堵塞：过滤效率增加，风量减少

Filter paper clogging: increased filtration efficiency and reduced air volume



■ 静电吸附：熔喷布/干法合成纤维

Electrostatic adsorption: melt-blown/dry-synthetic fibers

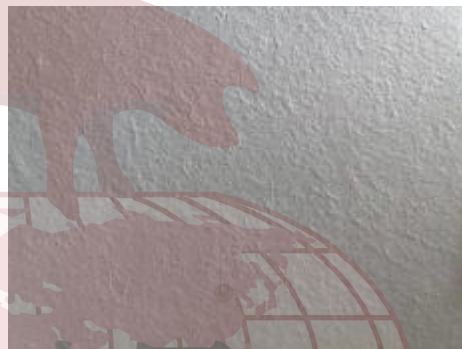


熔喷：熔喷聚丙烯+驻极母粒

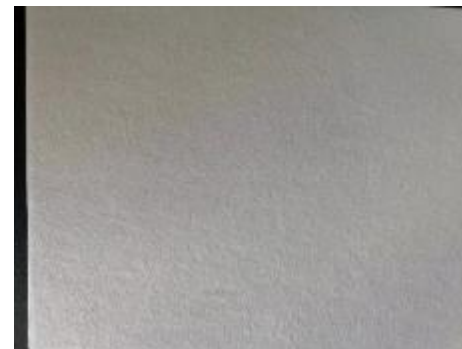


■ 机械效率：玻纤；湿法合成纤维； ePTFE； 静电纺丝

Mechanical efficiency: glass fiber; wet-spun synthetic fiber; ePTFE; electrospinning



玻璃纤维



湿法合成纤维



ePTFE



静电纺丝

HVAC

- EN779:2012
- Ashrae 52.2
- ISO 16890
- GB/T 14295-2008

High efficiency / Cleanroom

- EN1822
- ISO 29463
- GB/T 13554-2008
- GB/T 6165-2008

ASHRAE Standard 52.2-2012				ISO16890: 2016				EN	EN779: 2012			EN1822: 2009
Min. Efficiency Reporting Value	Composite Average Particle Size Efficiency (E_{ps}) % in Size Range, μm			Average of initial and discharged $E_m = (E_i + E_d)/2$		Initial efficiency (E_i)	Initial Arrestance (A_m)	Filter Class	Average Arrestance (A_m) of Synthetic Dust	Average Efficiency (E_{ps}) at 0.4 μm	Minimum Efficiency (E_{min}) at 0.4 μm	Initial Efficiency (E_i) at MPPS (typically 0.08 - 0.15 μm)
	Range 1	Range 2	Range 3	ePM1 (%)	ePM2.5 (%)	ePM10 (%)	Coarse (%)		Test Final dP 250Pa	Test Final dP 450Pa		
MERV	0.3-1.0	1.0-3.0	3.0-10.0	0.3-1.0	0.3-2.5	0.3-10.0	ISO Fine Dust		%	%	%	%
1			$E_{ps} < 20$				$A_m < 50$ Final dP 200 Pa	G1	$50 \leq A_m \leq 65$			
2			$E_{ps} < 20$					G2	$65 \leq A_m \leq 80$			
3			$E_{ps} < 20$					G3	$80 \leq A_m \leq 90$			
4			$E_{ps} < 20$					G4	$A_m \geq 90$			
5			$E_{ps} \geq 20$				$A_m \geq 50$ Final dP 300 Pa					
6			$E_{ps} \geq 35$									
7			$E_{ps} \geq 50$									
8		$E_{ps} \geq 20$	$E_{ps} \geq 70$									
9		$E_{ps} \geq 35$	$E_{ps} \geq 75$			$E_i > 50$		M5		$40 \leq E_{ps} \leq 60$		
10		$E_{ps} \geq 50$	$E_{ps} \geq 80$			$E_i > 70$		M6		$60 \leq E_{ps} \leq 80$		
T1	$E_{ps} \geq 20$	$E_{ps} \geq 65$	$E_{ps} \geq 85$		$E_m \geq 50$	$E_i > 70$						
12	$E_{ps} \geq 35$	$E_{ps} \geq 80$	$E_{ps} \geq 90$		$E_m \geq 50$	$E_i > 70$						
13	$E_{ps} \geq 50$	$E_{ps} \geq 85$	$E_{ps} \geq 90$	$E_m \geq 50$	$E_m \geq 85$	$E_i > 80$		F7		$80 \leq E_{ps} \leq 90$	$E_{min} \geq 95$	
14	$E_{ps} \geq 75$	$E_{ps} \geq 90$	$E_{ps} \geq 95$	$E_m \geq 70$	$E_m \geq 80$	$E_i > 90$		F8		$90 \leq E_{ps} \leq 95$	$E_{min} > 95$	
15	$E_{ps} \geq 85$	$E_{ps} \geq 90$	$E_{ps} \geq 95$	$E_m \geq 80$				F9		$95 \leq E_{ps}$	$E_{min} \geq 95$	
16	$E_{ps} \geq 95$	$E_{ps} \geq 95$	$E_{ps} \geq 95$									
								E10				$E_i \geq 85$
								E11				$E_i \geq 95$
								E12				$E_i \geq 99.5$
								H13				$E_i \geq 99.95$
								H14				$E_i \geq 99.995$
								U15				$E_i \geq 99.9995$
								U16				$E_i \geq 99.99995$
								U17				$E_i \geq 99.999995$
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A					

ASHRAE 52.2		粒径段（微米）			EN 779-2012		颗粒物粒径（微米）	
测试条件		不消静电			测试条件		去除静电, 终阻力450 Pa	
	MERV	0.3- 1.0	1.0-3.0	3.0- 10.0			0.4	
平均效率	15	≥85%	≥90%	≥95%	效率	F9	最低效率	平均效率
	16	≥95%	≥95%	≥95%			≥70%	≥95%

 Hollingsworth & Vose  Mark Hollingsworth Global Technology Center Suzhou, China				
ASHRAE 52.2 - AIR FILTER TEST RESULTS				
GENERAL				
Test no.	19120_3	Date	4/24/2022	Technician
Serial-No.	N/A	Time	3:36:24 PM	David
DEVICE TESTED				
Model	Flatsheet	Manufacturer:	N/A	
Type of media:	N/A	Free filter area:	0.13m²	
TEST DATA				
Test air flow rate	13.10 m³/h	Test air temperature	20.9°C	Test aerosol
		Test air relative humidity	63.6%RH	KCL
				Loading dust
				ISO A2 FINE
RESULTS				
Initial pressure drop:	48.1Pa	Initial arrestance:	100.0%	Dust holding capacity:
				6.2g
Final pressure drop:	150Pa / 250Pa / 350Pa	Final arrestance:	100.0%	Minimum efficiencies:
				E1=90.7% / E2=98.7% / E3=100.0%
				Filter class:
				MERV 15
Remarks				

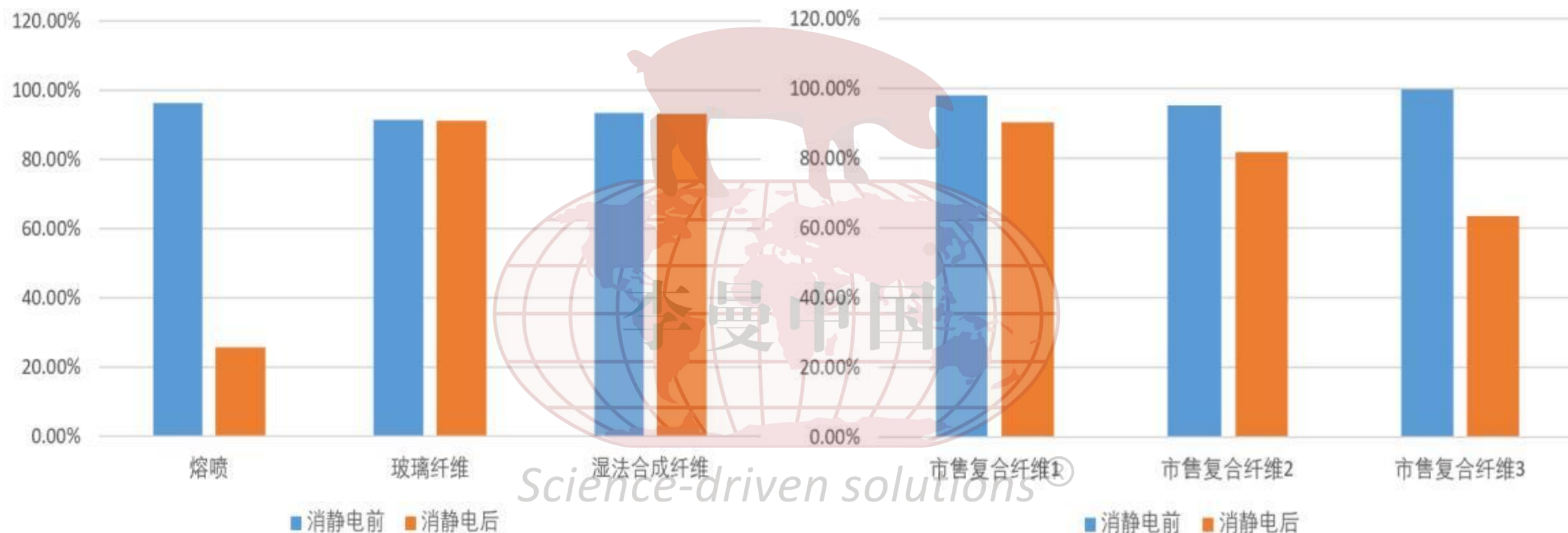
 Hollingsworth & Vose  Mark Hollingsworth Global Technology Center Suzhou, China				
EN 779:2012 - AIR FILTER TEST RESULTS				
Testing organisation:	HV	Report No.:	19761_8	
GENERAL				
Test no.:	19761_8	Date of test:	7/28/2022	Technician:
				Bruce
Test requested by:	Gavin			Device receiving date:
Device delivered by:	Gavin			N/A
DEVICE TESTED				
Model:	Flatsheet	Manufacturer:	N/A	Construction:
				N/A
Type of media:	N/A	Net effective filtering area:	0.13m²	Filter dimensions
				(width x height x depth):
				N/A
TEST DATA				
Test air flow rate:	25.25 m³/h	Test air temperature:	23.9°C to 25.3°C	Test aerosol:
		Test air relative humidity:	60.9% to 61.9%	DEHS
				Loading dust:
				ISO A2 FINE
RESULTS				
Initial pressure drop:	75Pa	Initial arrestance:	> 99 %	Initial efficiency (0.4µm):
				87.3 ± 0.3%
Final test pressure drop:	250Pa / 350Pa / 450Pa	Average arrestance:	> 99 %	Average efficiency (0.4µm):
				97.0 ± 0.1% / 97.9 ± 0.1% / 98.4 ± 0.1%
				Test dust capacity:
				3g / 5g / 6.5g
				Filter class:
				F9
				Energy class:
				N.A./N.A.
				Untreated / discharged efficiency of media (0.4µm):
				89 % / 89 %

H&V 猪场空气过滤材料解决方案- 玻纤& 净韧®

Classifications (Filter element @1000m ³ /h)	Grade names	Basis Weight	Caliper @2Kpa	AR @5.33cm/s	DOP efficiency 0.3μm @5.33cm/s	LOI	MD Tensile	MD Stiffness	Water Repellency
		gsm	mm	Pa	%	%	KN/m	mg	kPa
MERV15 ⁺	HE15731L	72	0.5	74	85	7	1.2	1000	6.2
MERV16 ⁺	HD2193			83	94				8.0
MERV15	PS0915A	85	0.6	66	75	78	2.0	1000	5.0
MERV15	PS0915L	60	0.4	54	75	75	1.6	450	5.5
MERV15 ⁺	PS0915H			69	85	72	1.8		6.2
MERV16	PS1016L			83	90	70	1.8		6.2
MERV16 ⁺	PS1016H			103	94	68	1.6		7.0

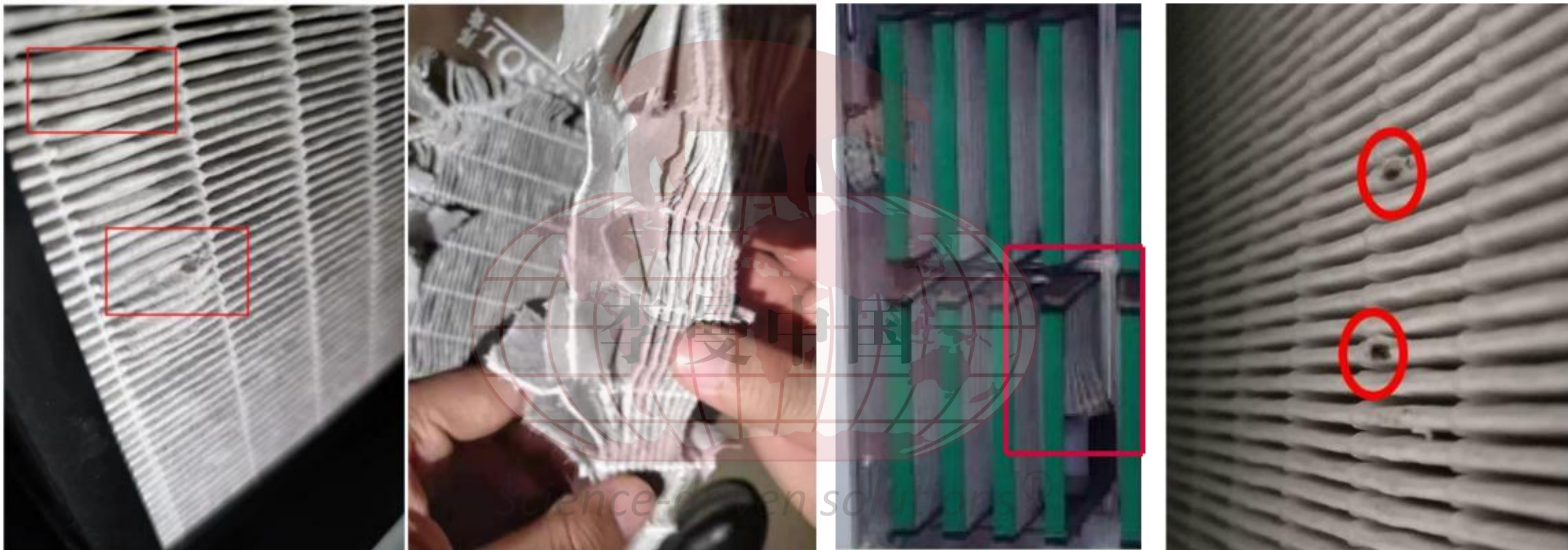
静电衰减：测试条件1000m³/h, 0.3-0.4μm DEHS

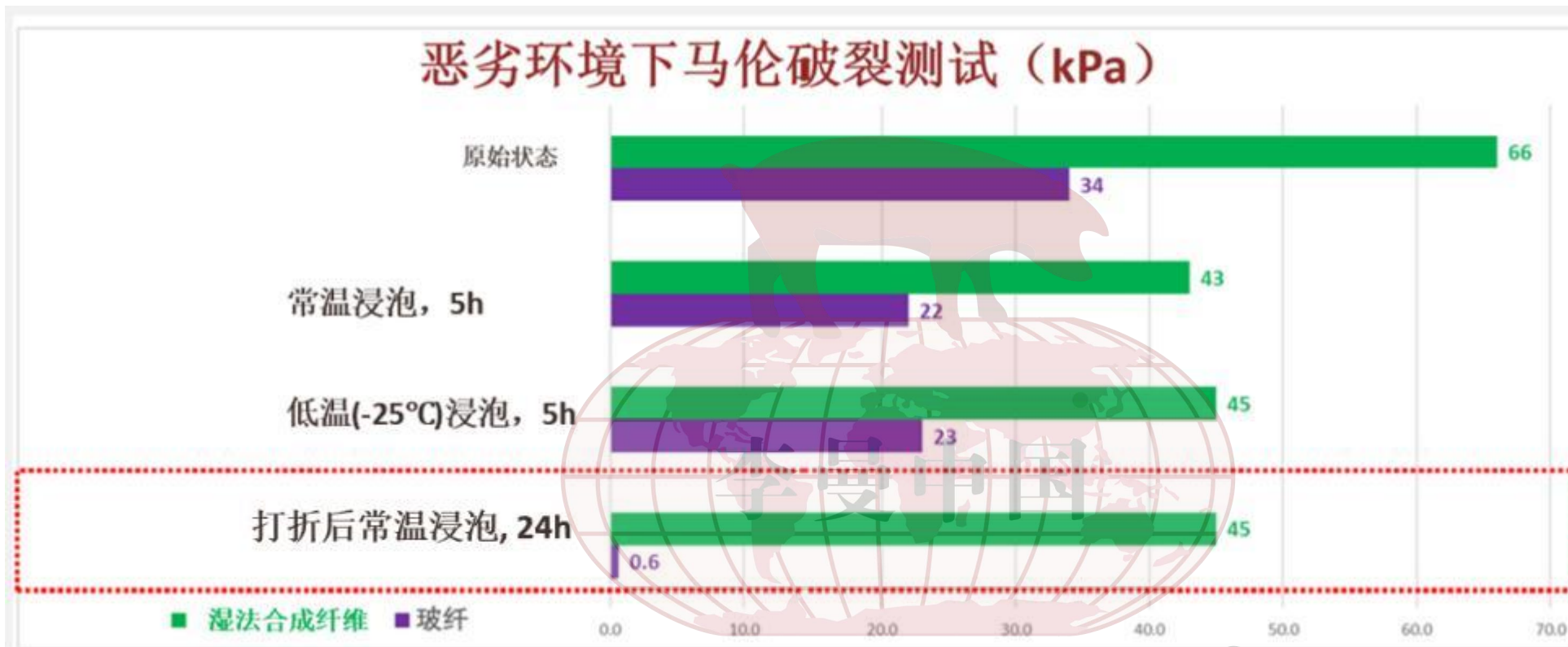
Electrostatic attenuation: Test conditions: 1000m³/h, 0.3-0.4μm DEHS



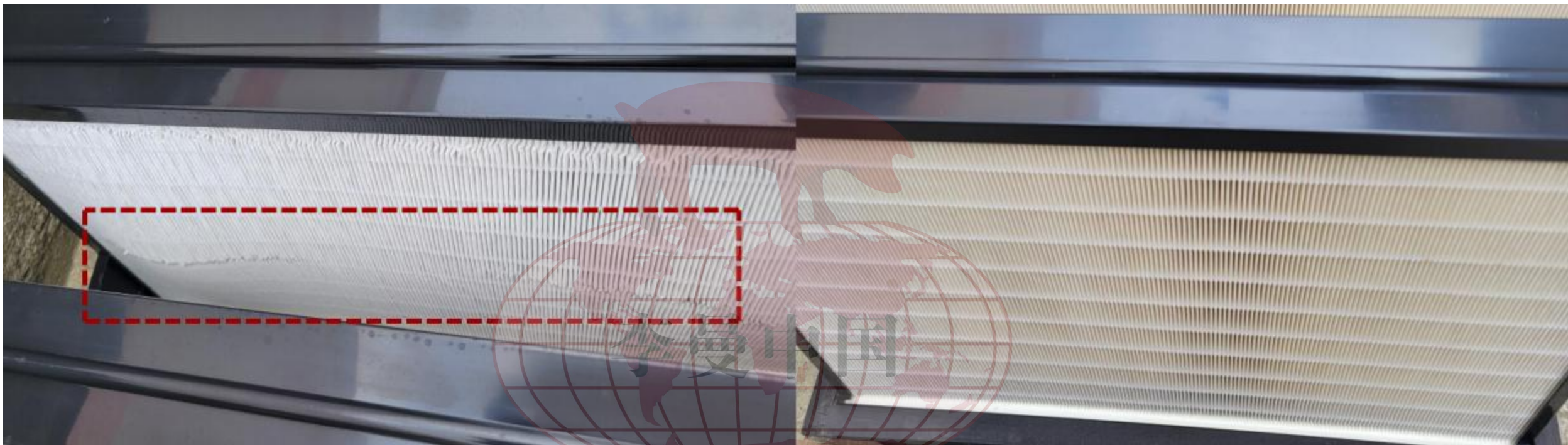
滤纸破损：潮湿环境导致滤纸强度下降

Filter paper damage: Moist environment leads to a decrease in filter paper strength





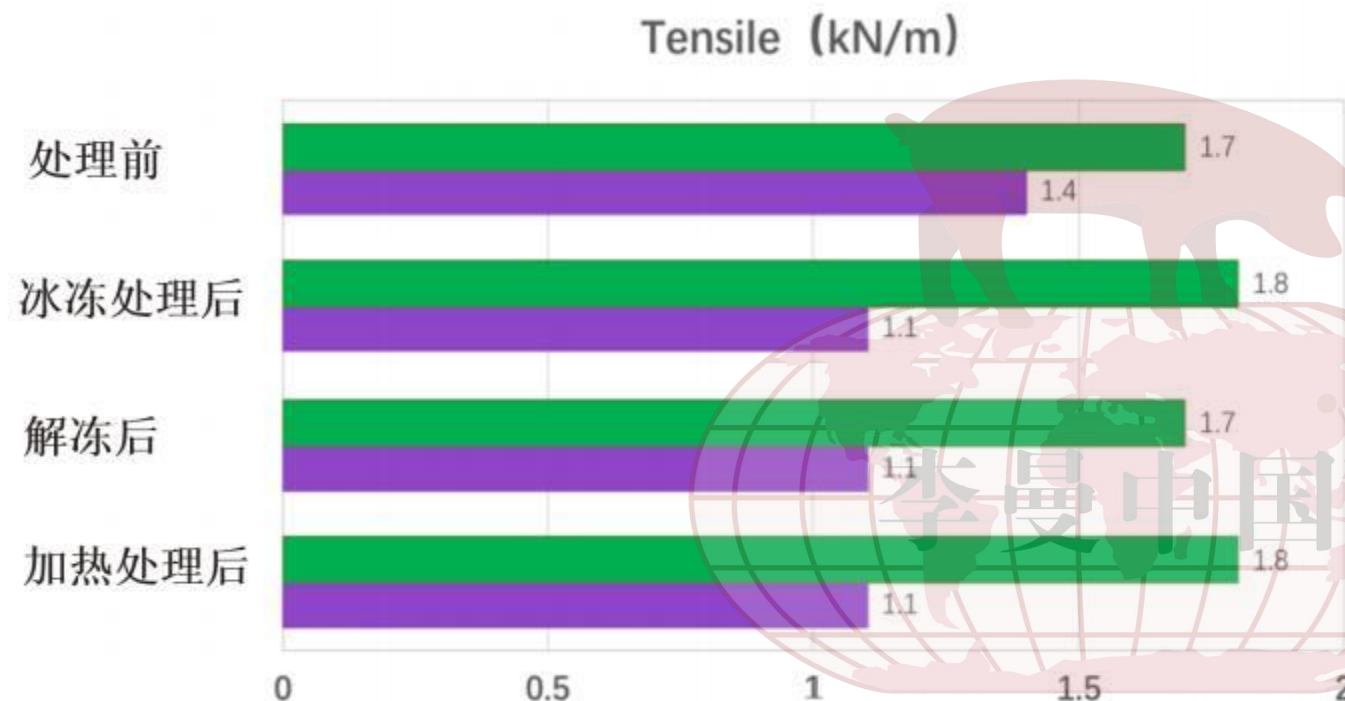
- ❖ 高湿环境对于打折后的玻纤滤纸的伤害比较大, 强度下降非常明显。
High humidity environment has a significant impact on discounted fiberglass filter paper, causing a notable decrease in its strength.
- ❖ 湿法合成纤维更适应高湿度的环境, 有效降低高湿环境的破损风险。
Wet-spun synthetic fibers are more adaptable to high-humidity environments, effectively reducing the risk of damage in such environments.



Science-driven solutions®

■ 玻璃纤维过滤器
Glass fiber filter

■ 合成纤维过滤器
Synthetic fiber filter



■ 玻璃纤维过滤器
Glass fiber filter

■ 合成纤维过滤器
Synthetic fiber filter

分别测试V-BANK在极寒条件下的拉伸强度。

Test the tensile strength of V-BANK under extremely cold conditions separately.

极寒条件储存解冻后，相较于玻璃纤维滤纸的拉伸强度高出接近50%。

After being stored and thawed under extremely cold conditions, the tensile strength of the material is compared to that of glass fiber filter paper. It is nearly 50% higher.

消毒剂的破坏

Destruction of disinfectant

消毒剂	浓度	浸泡时间
二氯异氰尿酸钠	1: 10	24h
戊二醛-癸甲溴铵	1: 50	24h
过硫酸氢钾	1: 50	24h
过氧乙酸	3%	24h
过氧化氢	1: 100	24h

测试滤纸初始效率: 5.33cm/s, 0.3µm DOP.

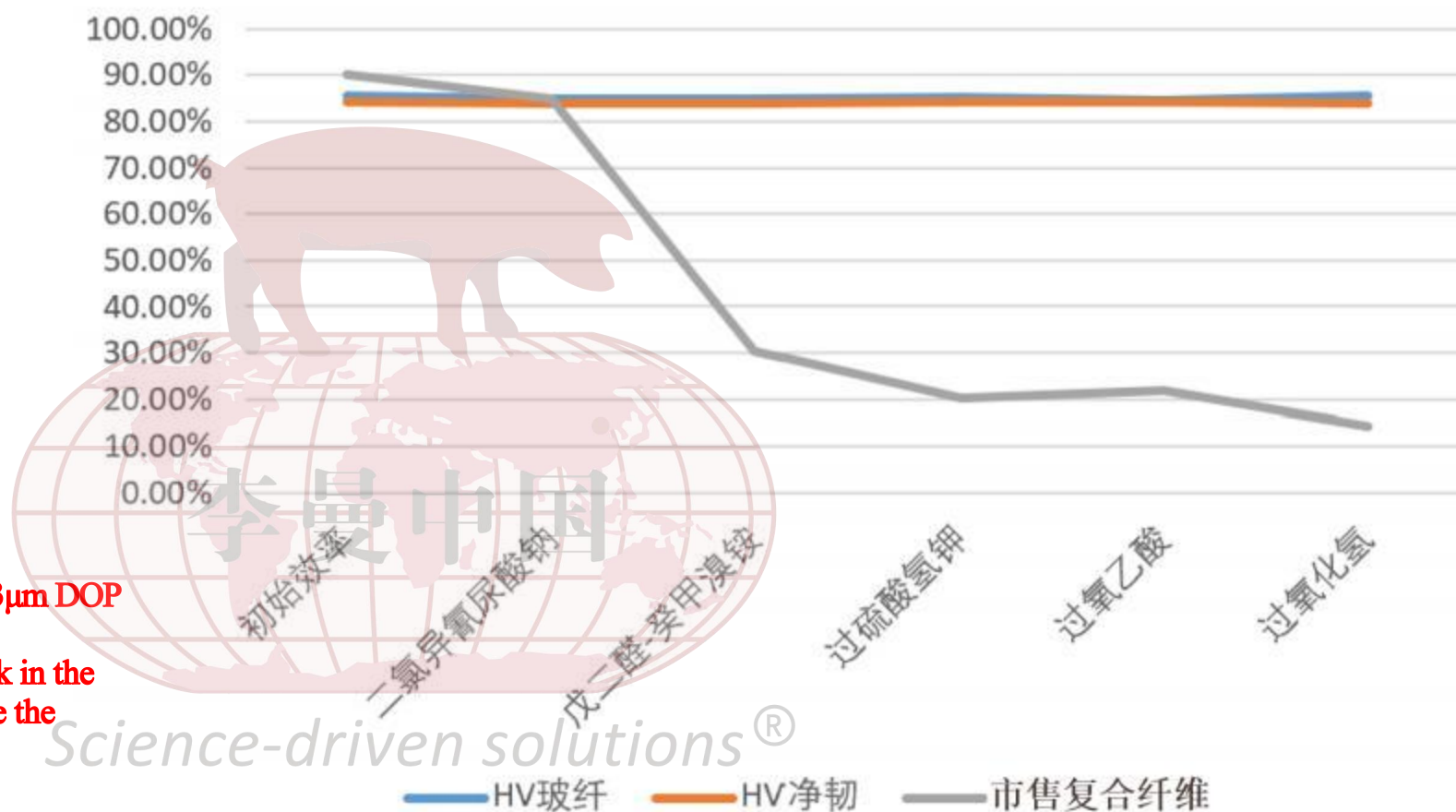
Initial efficiency of test filter paper: 5.33cm/s, 0.3µm DOP

浸泡在第一种消毒剂中24h后烘干测效率。Soak in the first disinfectant for 24 hours, then dry and measure the efficiency.

浸泡在第二种消毒剂中24h后烘干测效率。

Soak in the second disinfectant for 24 hours, then dry and measure the efficiency.

... ..



Classifications	Grade name	Basis Weight	Caliper @2Kpa	AR @5.33 cm/s	0.3µm DOP Penetration%	LOI%	MD Tensile	CD Tensile	MD Stiffness	Water Repellency	DIN 53 438-3	ASHRAE 52.2 Flat sheet test @2.8cm/s						
												E1(0.3-1.0µm)	E2(1.0-3.0µm)	E3(3.0-10.0µm)	DHC@ 150Pa	DHC@ 250Pa	DHC@ 350Pa	Indicative Classification
MERV16	HD2193	70	0.51	8.5	6	6.5	1.2	0.6	800	32	F1	98.4	99.9	99.9	3.3	5.5	7.7	MERV 16
MERV15 ⁺	HE15731L	70	0.51	7.5	15	6.5	1.2	0.8	900	25	F1	93.3	99.6	100.0	3.6	6.0	8.1	MERV 15
MERV15	PS0915A	85	0.56	6.7	25	75	2.2	1.4	1000	20	F3	90.7	98.7	100.0	2.1	4.2	6.2	MERV 15
MERV15 ⁺	TR877209	60	0.38	7.0	15	70	1.8	1.2	420	25	F3	92.8	98.9	100.0	3.5	6.3	8.7	MERV 15

📄 玻璃纤维滤纸中有机物含量是6.5%，每平方米重量70g，含无机物65.45g。

📄 The organic matter content in the glass fiber filter paper is 6.5%, with a weight of 70g per square meter, and it contains 65.45g of inorganic matter.

合成纤维滤纸中有机物含量是70%，每平方米重量60g，含无机物18g。

The organic content in synthetic fiber filter paper is 70%, with a weight of 60g per square meter and 18g of inorganic matter.

玻纤属于危废品，合成纤维滤纸焚烧以后的玻纤残余仅玻璃纤维滤纸的 **27.5%**

Glass fiber is classified as hazardous waste. The residual glass fiber after incineration of synthetic fiber filter paper is only 27.5% of that of glass fiber filter paper

滤材：净韧 PS0915H
Filter material: Jingren
PS0915H
过滤器： 5 V-Bank
Filter: 5 V-Bank
使用时间： 1年
Usage time: 1 year
效率： 93.71%@0.35um
Efficiency: 93.71% @ 0.35um
阻力： 25Pa
Resistance: 25Pa



Mark Hollingsworth

Global Technology Center

Suzhou, China



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Suzhou, China

Fractional Efficiency Test

Filter:	V-Bank	Sample-ID:	26210_1
Manufacturer:	N/A	Test-ID:	26210_1
Part-No.:	N/A	Serial-No.:	N/A
Face Area:	0.36m²	Filter Area:	N/A
Flowrate:	1000m³/h	Status:	26210_1
Weight:	N/A	Comment:	FEG

Test Conditions	
File:	26210_1.tfg
Flowrate:	1000m³/h
Barometric Pressure:	1009.6 hPa
Temperature:	23.8°C
Relative Humidity:	54.2%
Operator	Bruce
Face velocity:	N/A
Test aerosol:	KCl
Concentration:	1mg/m³
Tare Pressure:	N/A

Test Results	
Test start	2025/8/14 20:21
Test duration	0:05:21
Diff. Pressure	25Pa
Diff. Pressure	25Pa

Efficiency		Upstream	Downstream	
Measuring time [s]		120.0	120.0	
Measuring volume [cm³]		5660.0	5660.0	
Particle size	Upstream	Downstream		Efficiency
[µm]	[#]	[#]		[%]
0.35	154004	9687		93.71%
0.47	174184	10541		93.95%
0.62	60537	2359		96.10%
0.84	91995	3087		96.64%
1.14	48235	1205		97.50%
1.44	30077	549		98.17%
1.88	41297	715		98.27%
2.57	25490	307		98.80%
3.46	9080	90		99.01%
4.69	3045	20		99.34%
6.20	809	1		99.88%
8.37	410	0		100.00%



Creating a Cleaner World™

李曼中国

**EVOLVE TO
PROSPER**

science-driven solutions®

扫一扫上面的二维码图案，加我为朋友。