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

呼吸防護精進

Advancing respiratory protection

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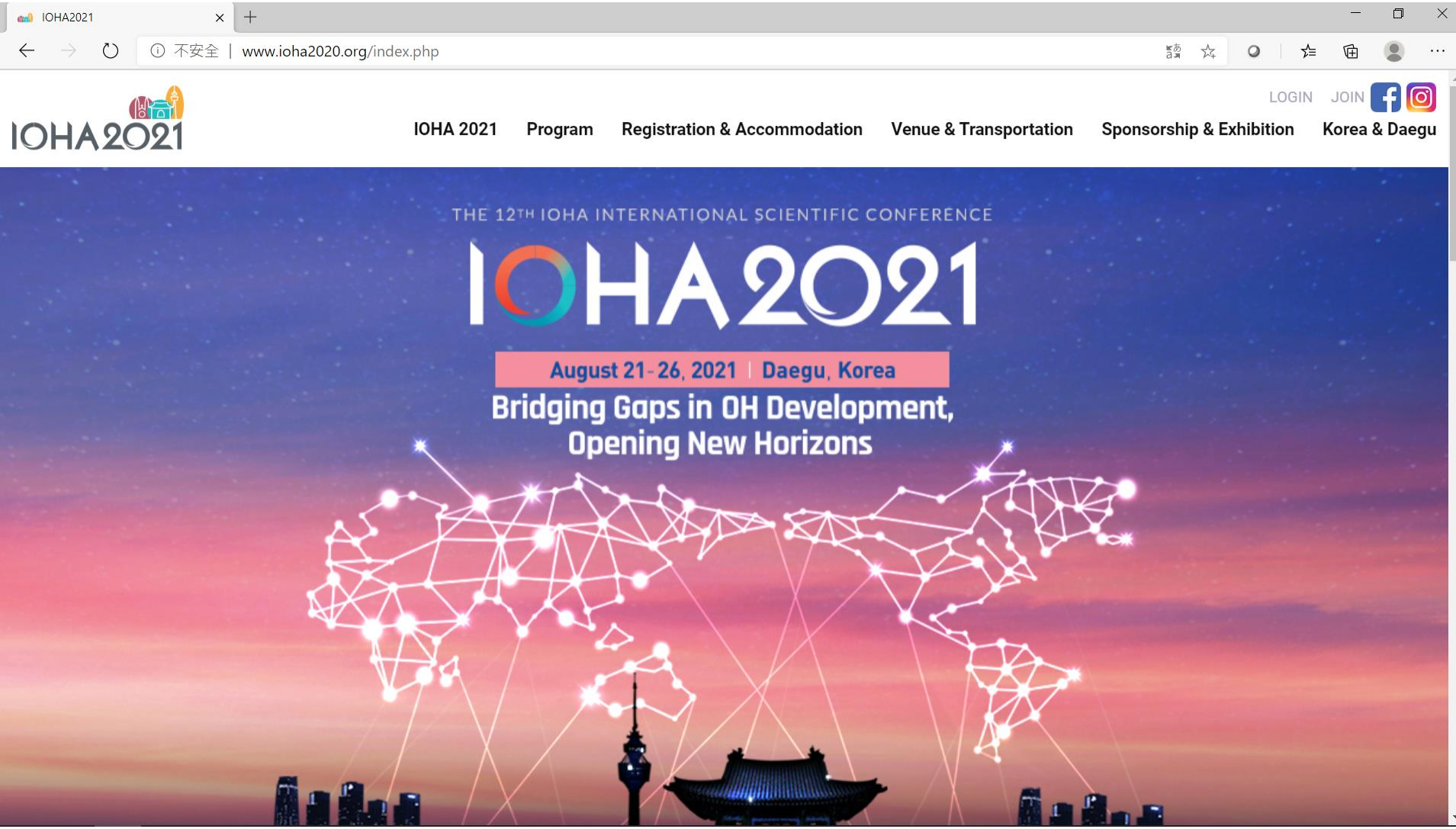
International Occupational Hygiene Association **(IOHA)**
International Society for Respiratory Protection **(ISRP)**
Asian Network of Occupational Hygiene **(ANOH)**

呼吸防護精進

Advances in Respiratory Protection

US OSHA estimates that **5 million workers** in 1.3 million workplaces are required to wear respirators. These devices protect workers from "*insufficient oxygen environments, harmful dusts, fogs, smokes, mists, gases, vapors and sprays*," the agency notes, adding that compliance with its Respiratory Protection Standard "could avert hundreds of deaths and thousands of illnesses annually."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August 21-26, 2021 | Daegu, Korea
Bridging Gaps in OH Development,
Opening New Horizons

The **International Occupational *Hygiene* Association** (**IOHA**) represents the global community of occupational hygienis
hygiene
are dedi
inherent principles of occupational hygiene.

國際職業衛生學會

代表職業衛生技師

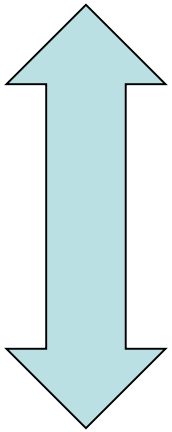
The **International Society for Respiratory Protection** – **ISRP**, is a non-profit organization whose charter is to provide an educ
involved RP is
to bring nals
in the fie
their opinions, disclose their research findings, and share ideas through the Society.

國際呼吸防護學會

產、官、學

International Occupational *Hygiene* Association

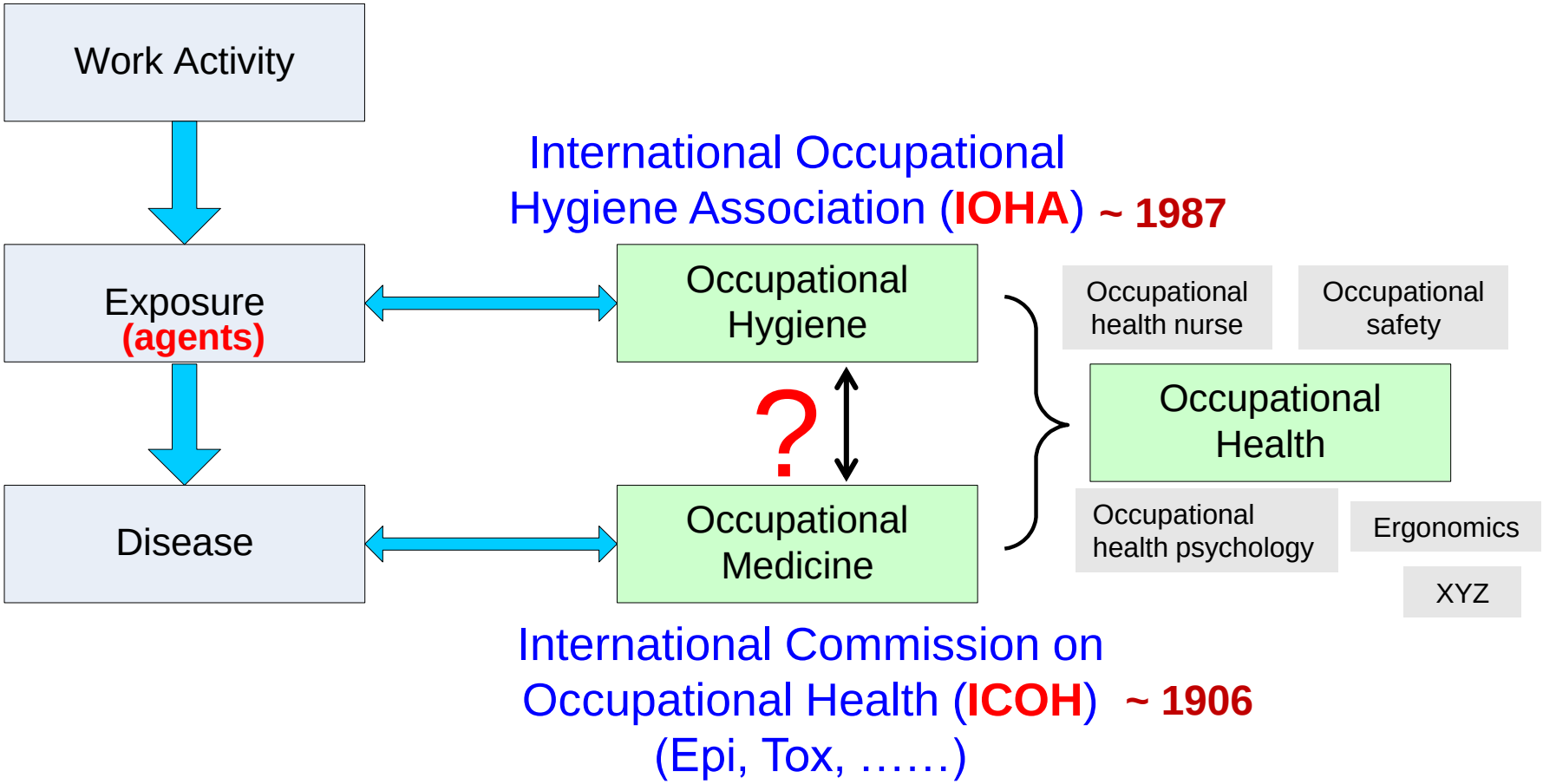
Health（健康）



Differences?

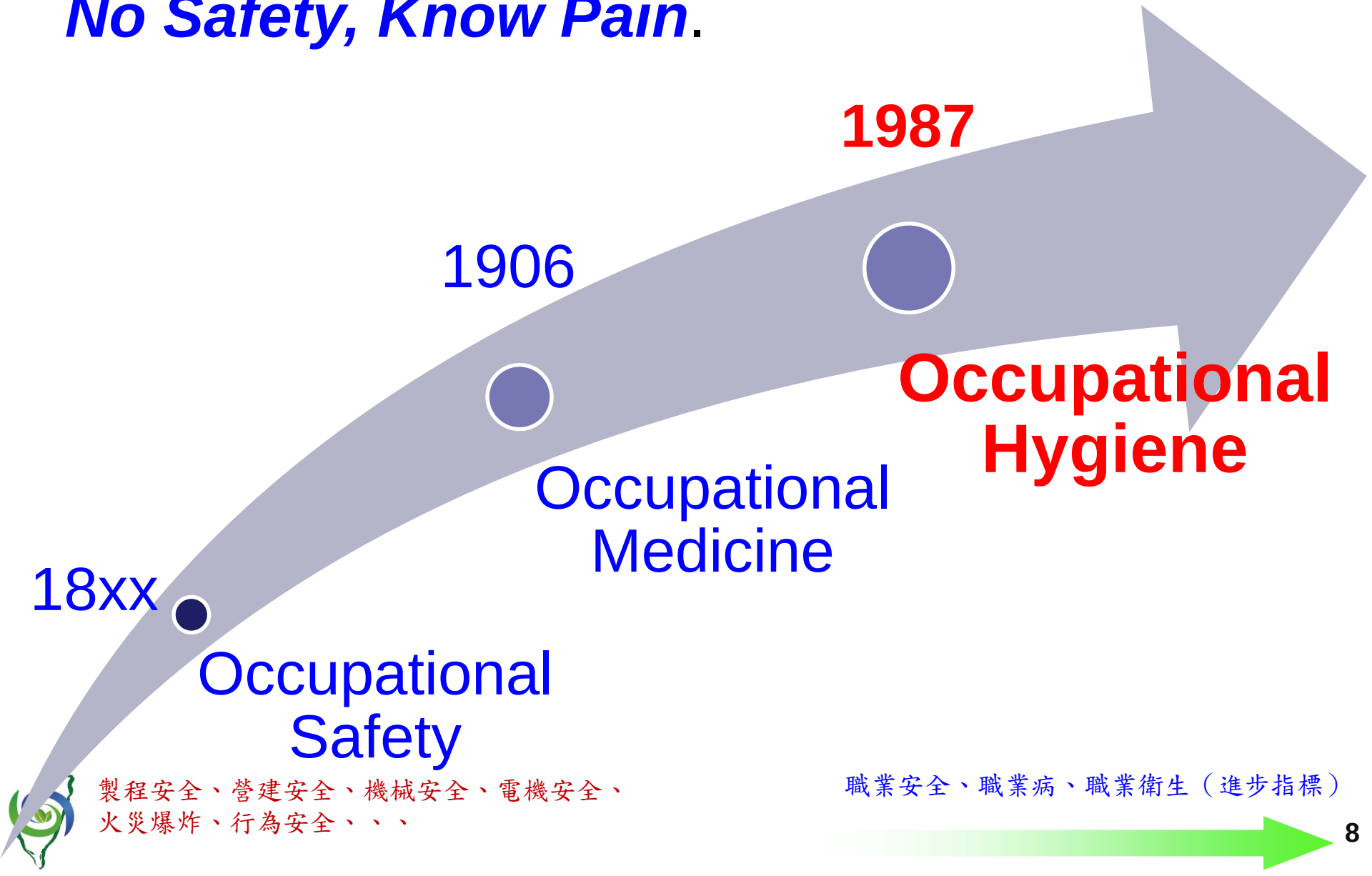
Hygiene（衛生）

What is Occupational Hygiene?



Know Safety, No Pain.

No Safety, Know Pain.



Why '*Hygiene*'?

The word hygiene is derived from the name of the Greek goddess of health known as **Hygeia**. She was the daughter of **Asklepios** (希臘神話中之醫神) and sister to **Panacea** (萬能藥). While her father and sister were connected with the treatment of existing disease Hygeia was regarded as being concerned with the ***preservation of good health*** and the ***prevention of disease***.

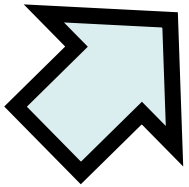
What is the difference between *Industrial* and *Occupational* Hygiene?

None really. The term Industrial Hygiene originated in the USA while in other parts of the world it is known as Occupational Hygiene. In some ways the term Occupational is a better description as health risks occur in all places that people work such as offices, shops, hospitals and farms, not just in places you would think of as industrial.

Occupational Hygiene: an interdisciplinary profession.

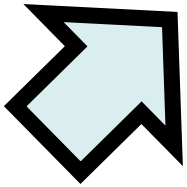
Control (Management)

控制管理



Evaluation (Measurement)

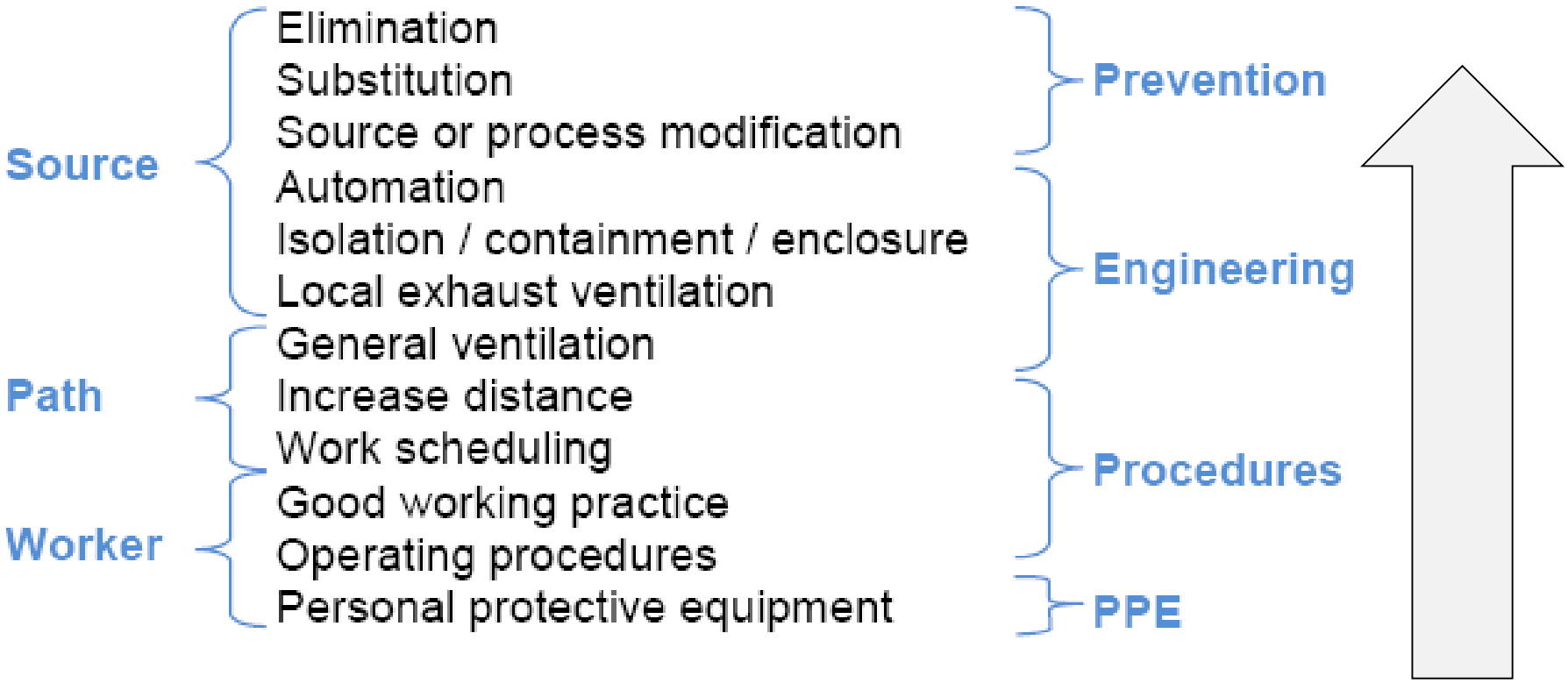
評估量測



Identification (Recognition)

認知辯識

Hierarchy of Control



Types of Control Measures

Elimination

Substitution

Isolation

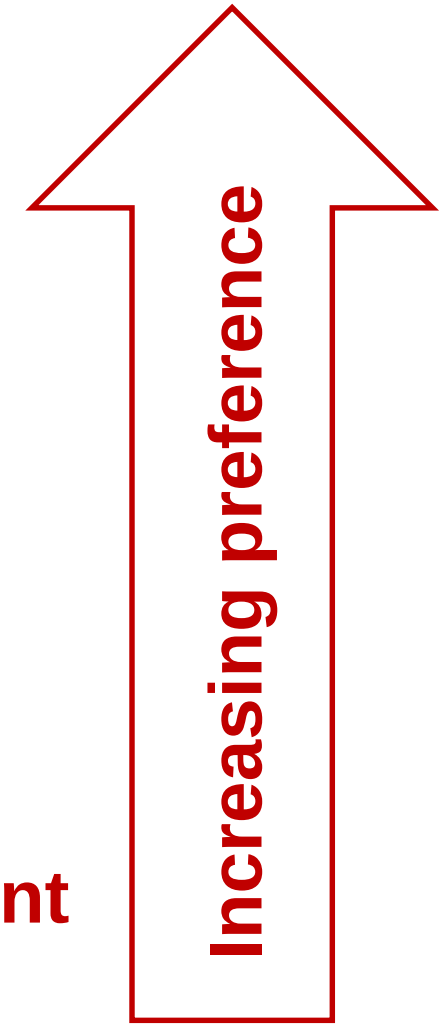
Segregation

Engineering Control

Administrative Control

Personal Protective Equipment

(PPE)



Types of **PPE**

(Safety and Hygiene)

- Head protection
- Eye & Face protection
- Hearing protection
- Respiratory protection
- Hands / Gloves protection
- Body / Clothing protection
- Foot protection
- Protection against falling

RPE

Routes of Entry into the Body

For a chemical to exert its harmful effect, it must first come into contact with or enter the body. The three main routes of exposure in the workplace are inhalation, absorption, and ingestion.

Inhalation is the most common route of entry of health hazards.

Respiratory Protection

Certification program

- NIOSH
  - Manufacturers
    - Filtration efficiency
    - Air resistance
    - Valve leakage
    - Product auditing
    - ???
    - ???

Management program

- OSHA
  - Users (Administrator)
    - Fit testing
    - Cartridge exchange
    - Training
    - Maintenance…..
    - ???
    - ??? *PDCA*

(Management)

Respiratory Protection Program elements

- Procedures for selecting respirators for use in the workplace;
- Medical evaluations of employees required to use respirators;
- **Fit testing** procedures for tight-fitting respirators;
- Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;
- Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;
- Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;
- Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;
- Training of employees in the proper use of respirators, including putting on and removing them, any limitations on their use, and their maintenance; and
- Procedures for regularly evaluating the effectiveness of the program.

美國呼吸防護計畫 （29 CFR 1910.134）

危害評估

- 是什麼？有多少？我能接受的是多少？有沒有其他的方法？…
- 資訊越清楚，防護具的選用就越「經」確。

（未知的有害環境視為「IDLH」）

- 自主使用
  - 過濾面體口罩
  - 過濾面體等級以上之呼吸防護具
- 規定使用
  - 呼吸防護具的選擇
  - 醫學評估
  - **密合度測試**
  - 呼吸防護具的使用
  - 供氣品質的確保
  - 清潔、保養、與存放
  - **教育訓練**
  - 計畫評估

呼吸防護計畫書的重要性：

- 防止佩戴後的負面效應；
- 讓呼吸防護具發揮應有的效能；
- 持續有效。

確保呼吸防護具性能之必要措施！

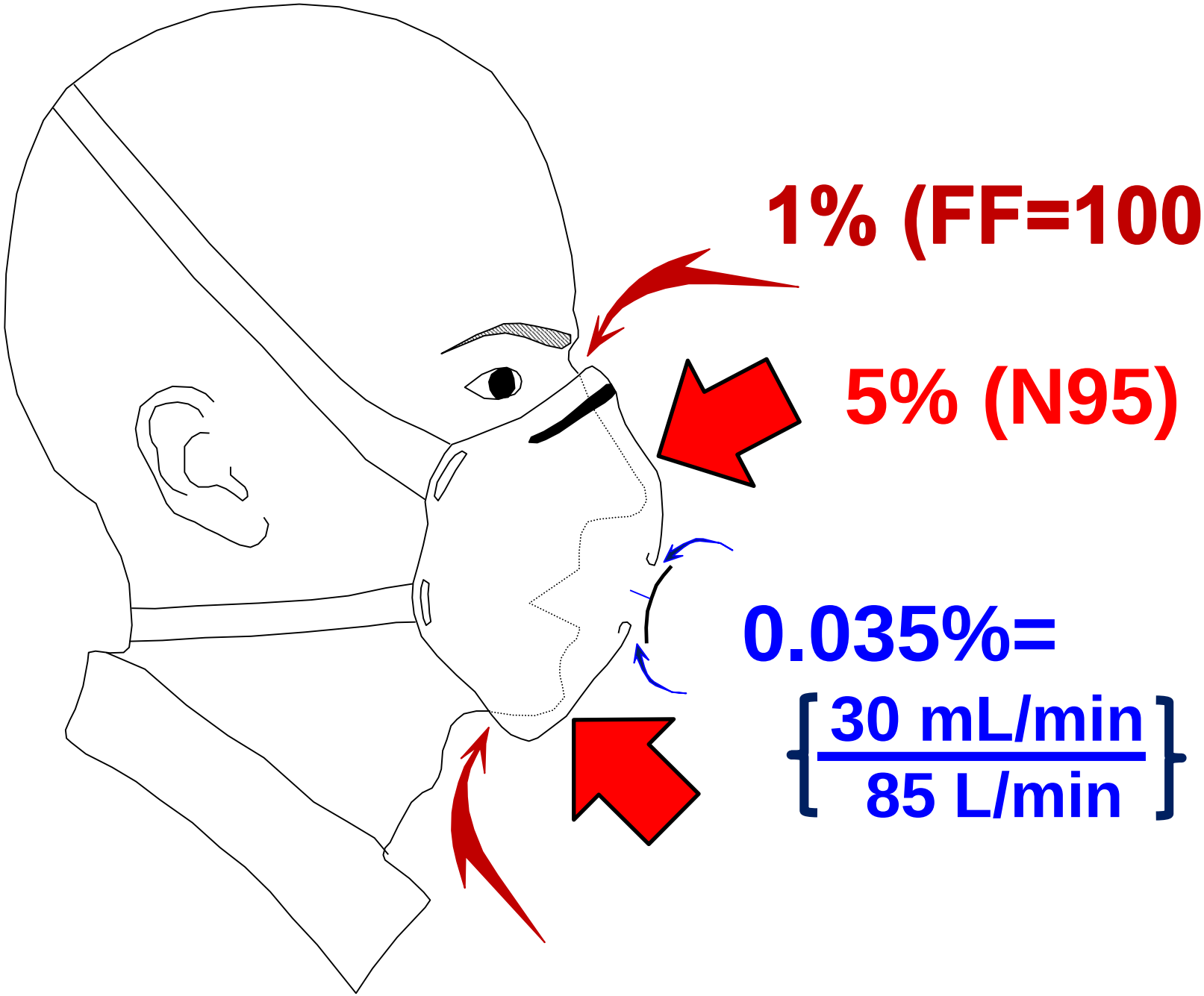
表面功夫？

➢ Fit testing (CFR 1910.134 App A)

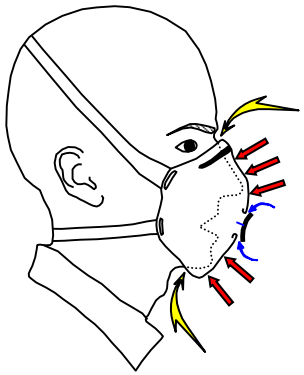
The test subject shall be allowed to pick the most acceptable respirator from **a sufficient number of respirator models and sizes** so that the respirator is acceptable to, and correctly fits, the user.

➢ Strap tension?

How much strap tension is needed?


1% (FF=100)
5% (N95)
0.035%=
{30 mL/min / 85 L/min}

Routes of entry



1. Filter penetration
2. Face seal leakage
3. Valve leakage and other parts

} Total inward leakage

	N95		N100			
	Fit factor = **100**				Fit factor = **1000**	
	Leakage (%)	Contribution (%)	Leakage (%)	Contribution (%)	Leakage (%)	Contribution (%)
Filter penetration	5	83	0.03	3	0.03	18
Face-seal leakage	1	16.5	1	94	0.1	61
Valve leakage★	0.035	0.5	0.035	3	0.035	21

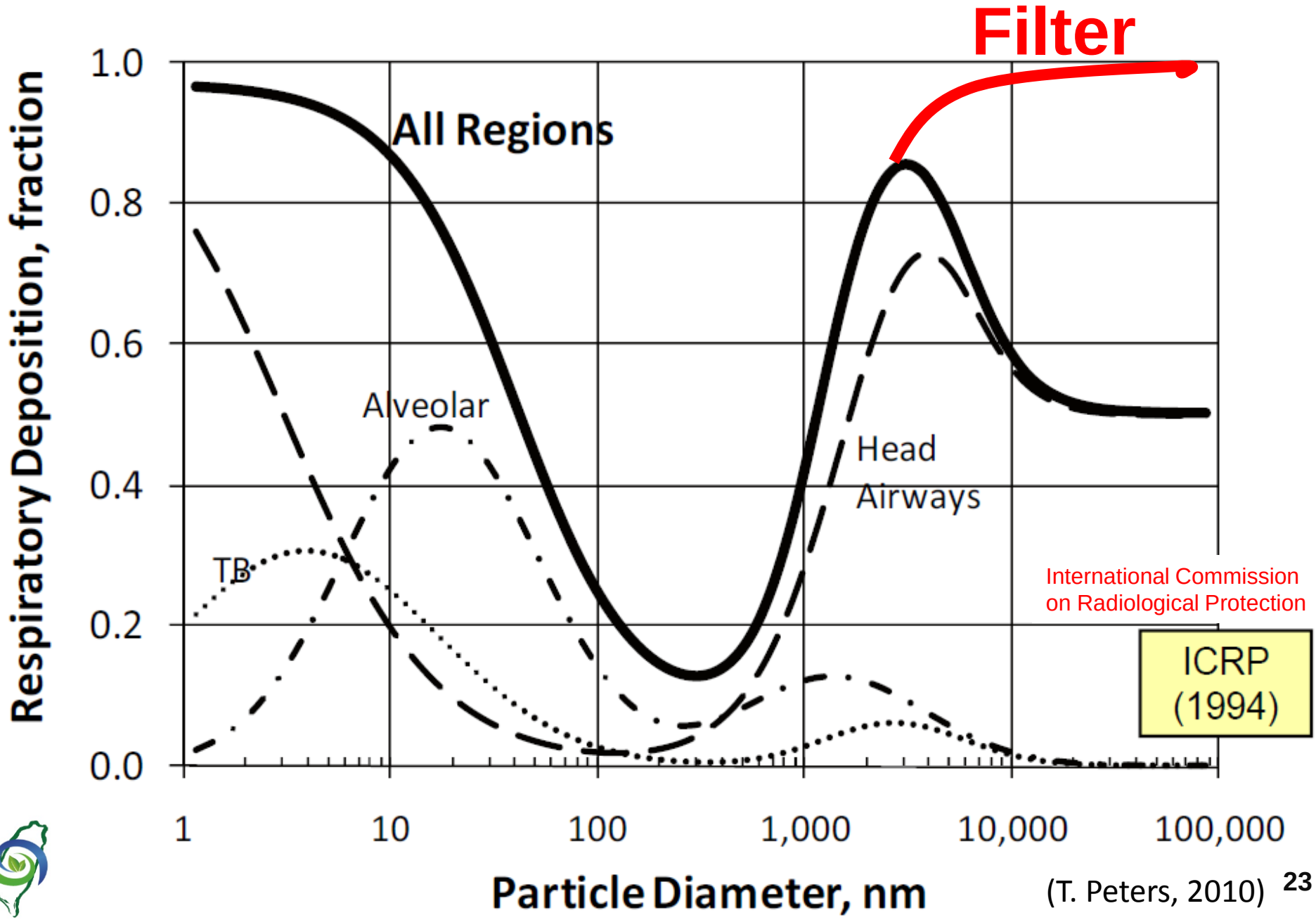
★ Assuming exhalation valve leakage is 30mL/min, under flow rate of 85 L/min.

Exhalation valve leakage becomes more significant as the protection level increases.

Introduction

- The process of filtration is complicated, and although the general principles are well known there is still a gap between theory and experiment.
- Therefore, filtration is still an active area for theoretical and experimental research.

Respiratory Deposition

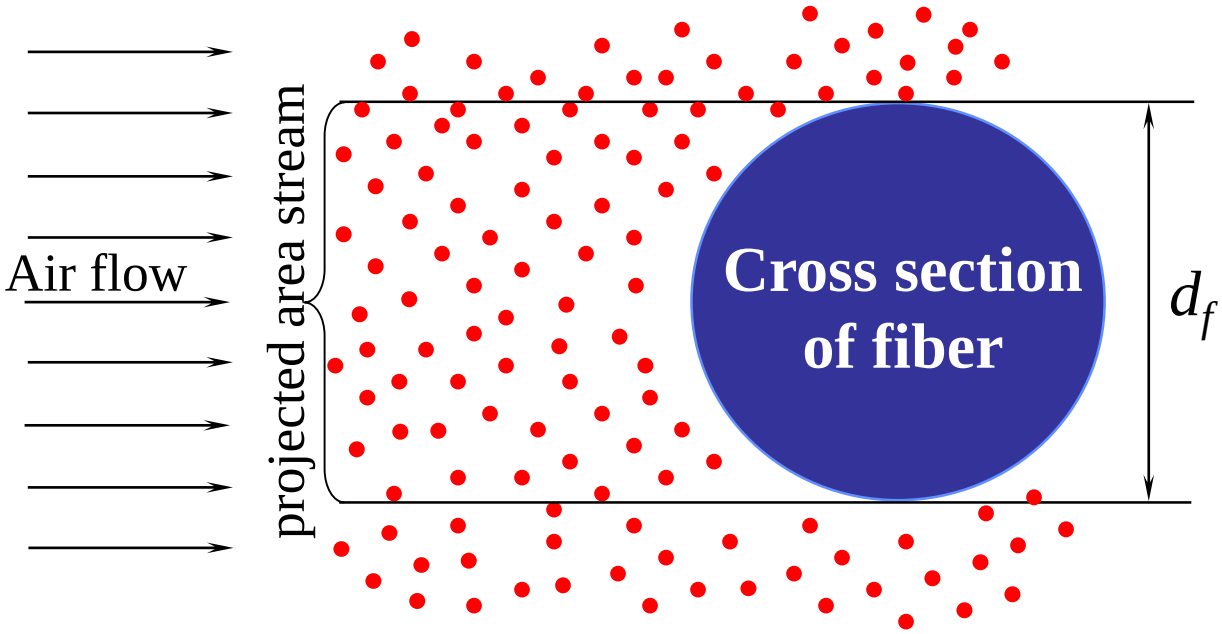


(T. Peters, 2010)

Aerosol Filtration

Single Fiber Efficiency, E_Σ

The fraction of particles approaching a fiber in the region defined by the projected area of the fiber that are ultimately collected on the fiber



$$E_\Sigma = \frac{\text{number collected on unit length}}{\text{number geometrically incident on unit length}}$$

Assumptions:

- A particle sticks if it contacts the fiber.
- The flow inside a filter will be laminar.

Deposition Mechanisms

1. **Interception**
2. **Inertial impaction**
3. **Diffusion**
4. **Gravitational settling**
5. **Electrostatic attraction**

mechanical collection mechanisms

- Coulombic attraction
- Dielectrophoretic force
- Image force

The five deposition mechanisms form the basis set of mechanisms for all types of aerosol particle deposition, including *deposition in a lung*, *in a sampling tube*, or *in an air cleaner*.

Electret filter

- Filter composed of charged fiber.
- With high particle collection efficiency and low pressure drop.
- Charges will lose when exposed to ionizing radiation, high temperature, high humidity, or aerosol particles.

- 駐極體？
- 充電方式？
- 強制老化？

Filter Quality Factor (Figure of Merit, FOM)

A useful criterion for comparing different types of filters and filters of different thickness.

$$q_F = \frac{\ln\left(\frac{1}{P}\right)}{\Delta p}$$

P : aerosol penetration

Δp : pressure drop

Comparisons of q_F must be made for the same face velocity and test aerosol particle size.

Q: what does the best filter should be?

Table 1. Effect of operational factors on aerosol penetration, filter quality, and MPS within the simulated range.

Parameters	Unit	Aerosol penetration	Filter quality	Most penetrating particle size
Face velocity	cm/s	↑	↓↓↓	↑, ↓*
Fiber diameter	μm	↑	↑↓	↑
Packing density	—	↓	↓	↓
Filter thickness	mm	↓	—	↓, —*
Charge density	C/m^2	↓	↑↑	↓

* : mechanical filter

Advantages of nanofibers: the ***slip-flow*** phenomena

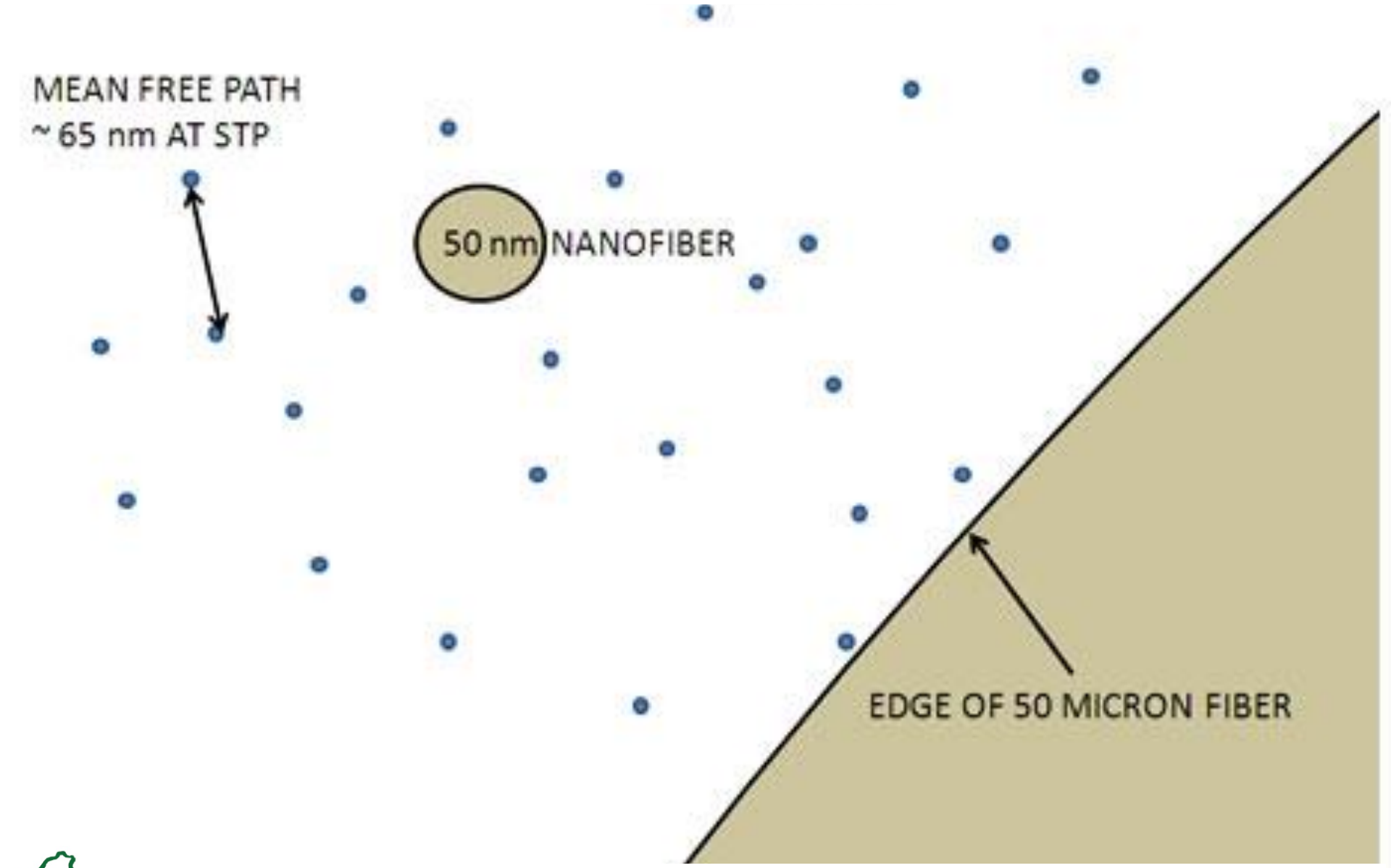


Figure: Hypothetical photograph snap-shot of air molecules near a 50 nm nanofiber and a 50 micron diameter fiber

Literature review

- Electrospinning is a process of electrostatic fiber formation by which uses electrical forces to produce polymer fibers from polymer solution, with nanometer scale diameters. (Ahn et al., 2006)

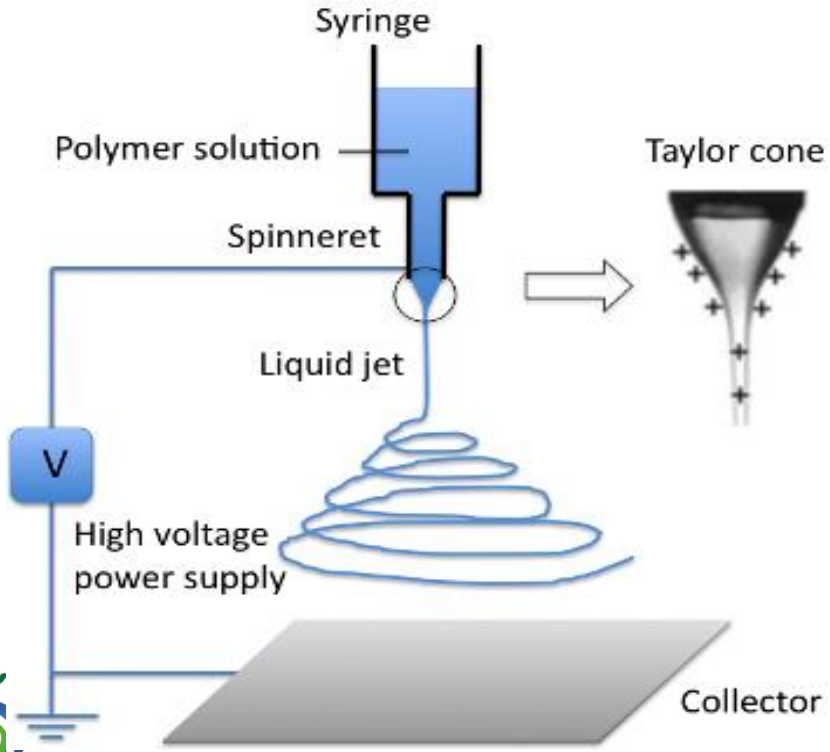
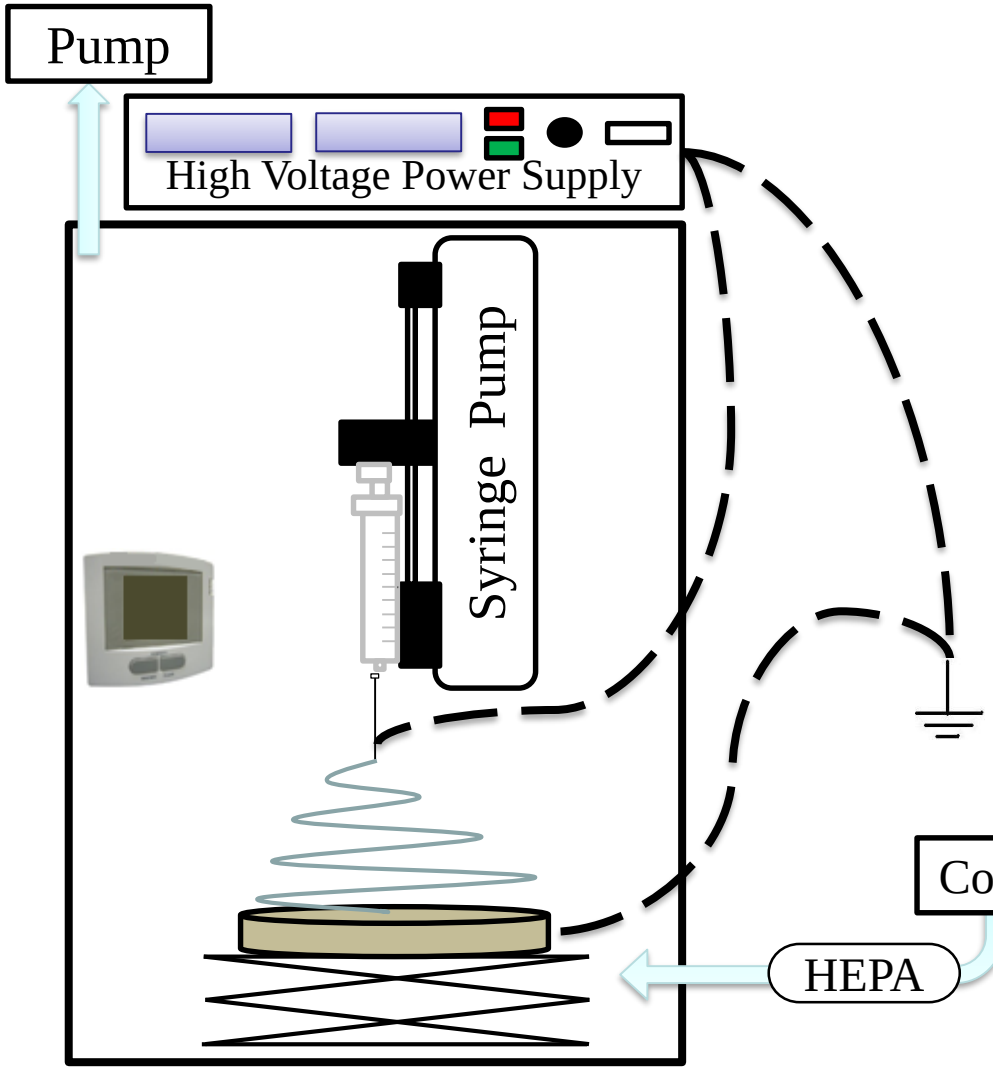


Fig. 1. The schematic diagram of electrospinning. (Athira et al., 2014)

Table 1. Processing parameters in electrospinning.

Effect factor	Parameter
Solution properties	Molecular weight of polymer
	Concentration
	Viscosity
	Electrical conductivity
	Surface tension
Processing condition	Applied voltage
	Distance from needle to collector
	Volume feed rate
	Needle diameter
Ambient condition	Temperature
	Humidity

Experimental method



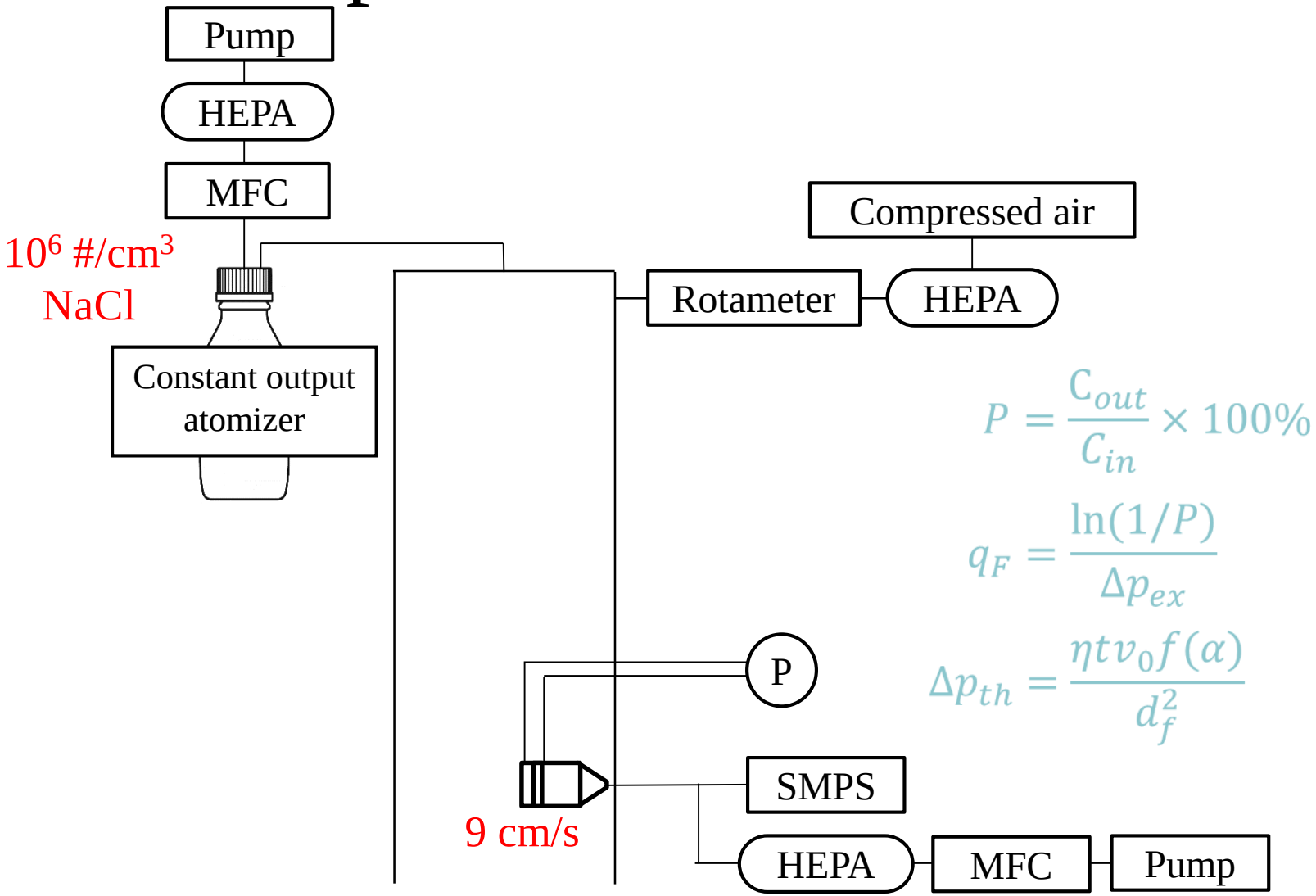
$$\alpha = \frac{V_m}{V}$$

$$V_m = \frac{m}{\rho_{PMMA}}$$

$$V = A \times t$$

Fig. 4. Schematic diagram for electrospinning.

Experimental method



$$P = \frac{C_{out}}{C_{in}} \times 100\%$$

$$q_F = \frac{\ln(1/P)}{\Delta p_{ex}}$$

$$\Delta p_{th} = \frac{\eta t v_0 f(\alpha)}{d_f^2}$$

Fig. 5. Schematic diagram and processing parameters for filtration.

Results and discussions (1/11)

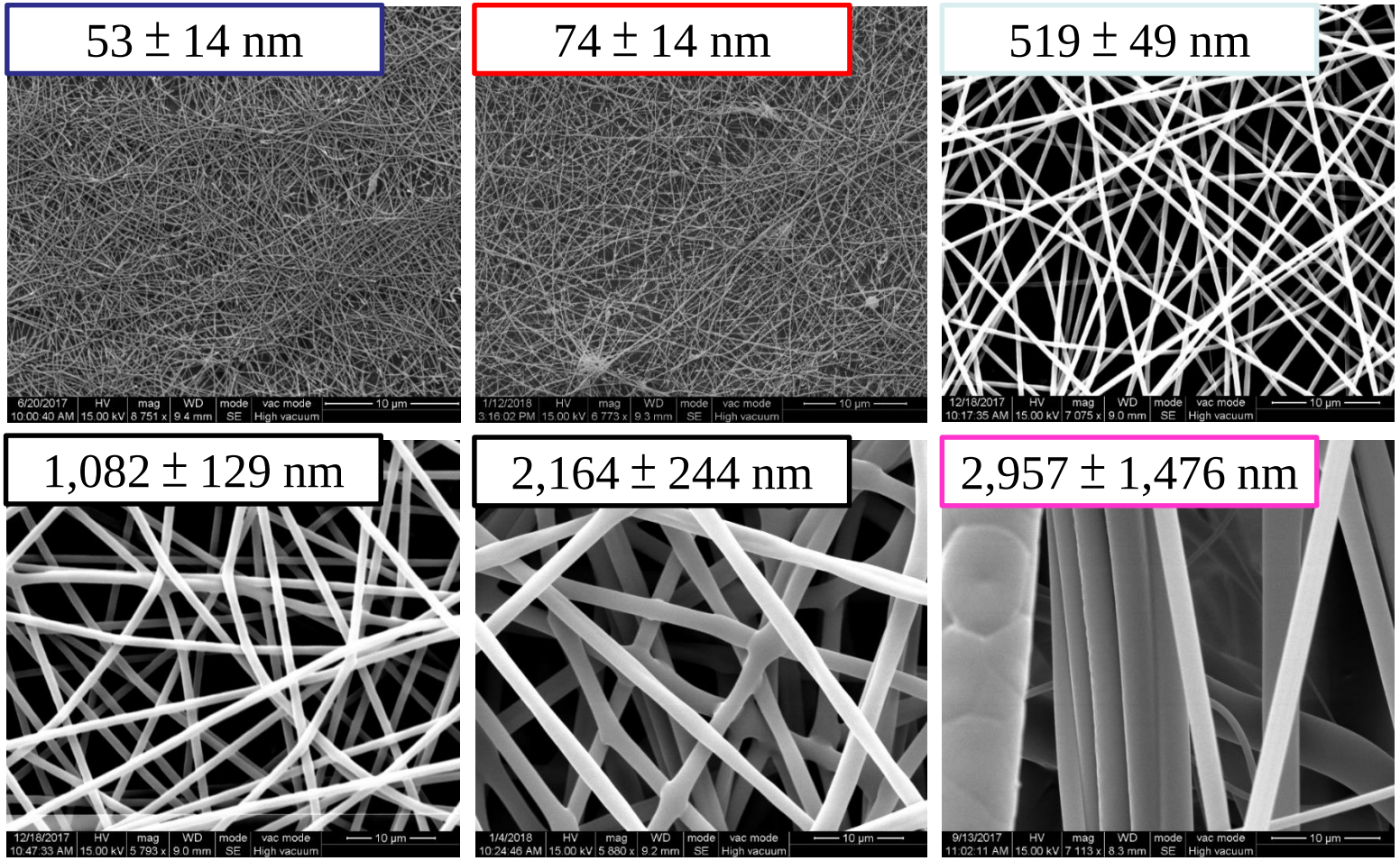
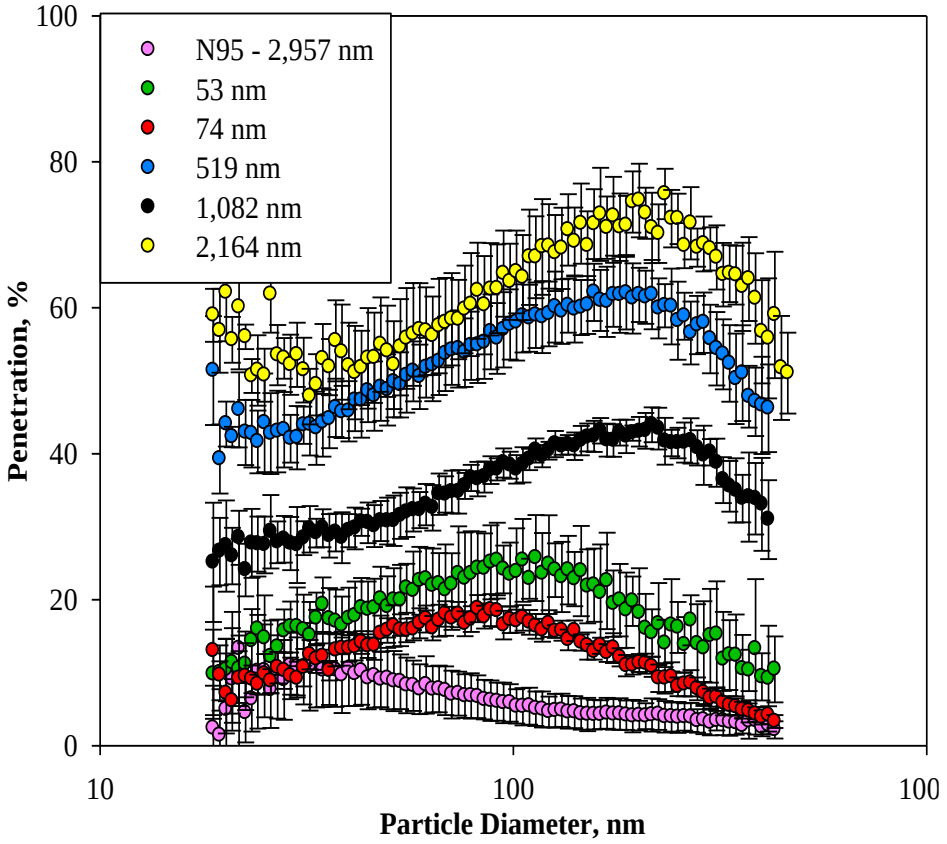


Fig. 6. SEM image of PMMA fiber and N95 fiber.

Results and discussions (6/11)



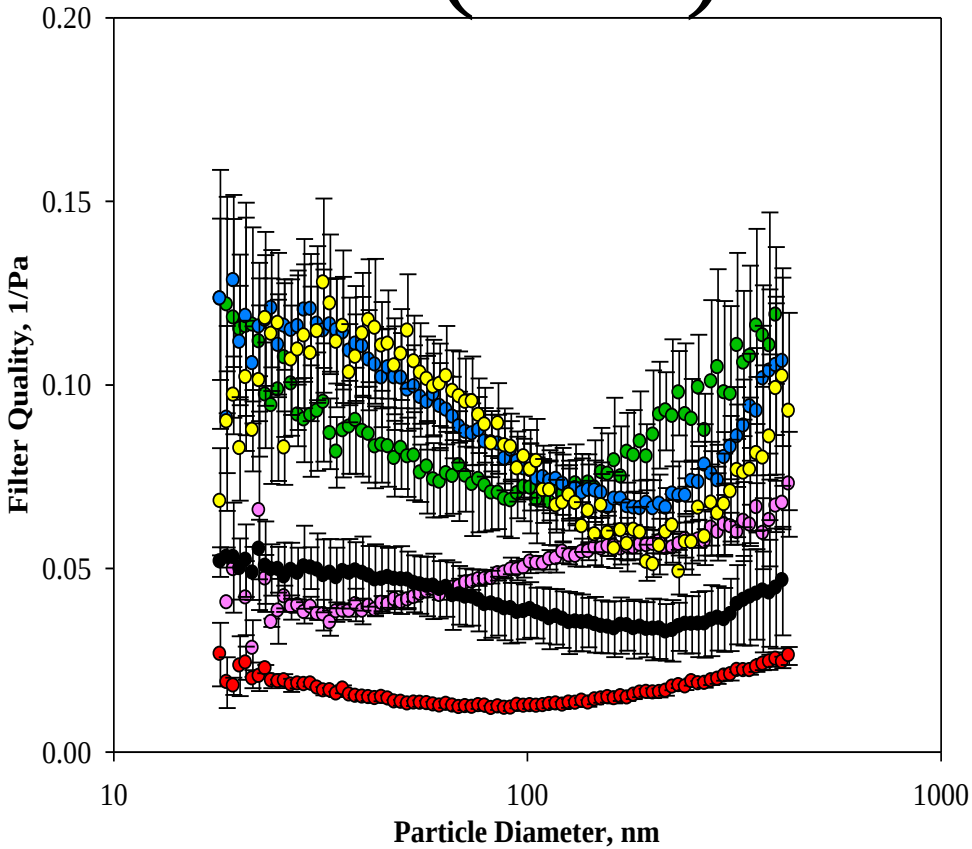


Fig. 11.The penetration and filter quality of PMMA fiber filter and N95 filter.

	N95-2,957	53	74	519	1,082	2,164
P, %	5.9	20.5	14.5	54	38	62
q_F, 1/Pa	0.05	0.08	0.01	0.08	0.04	0.08

Strap tension- system diagram

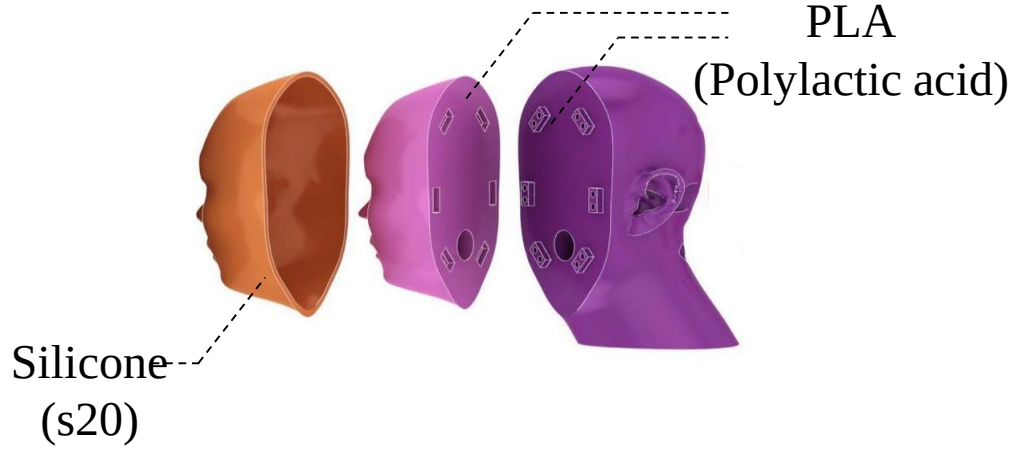


Figure 1. The standard Chinese head-forms

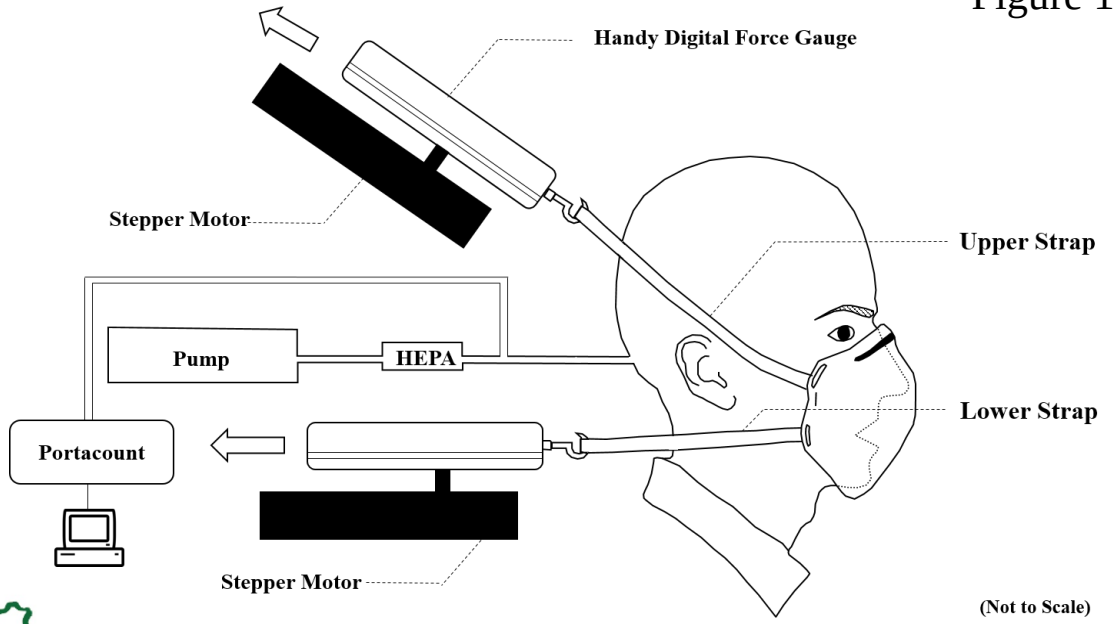


Figure. The standard Chinese head-form fit testing system

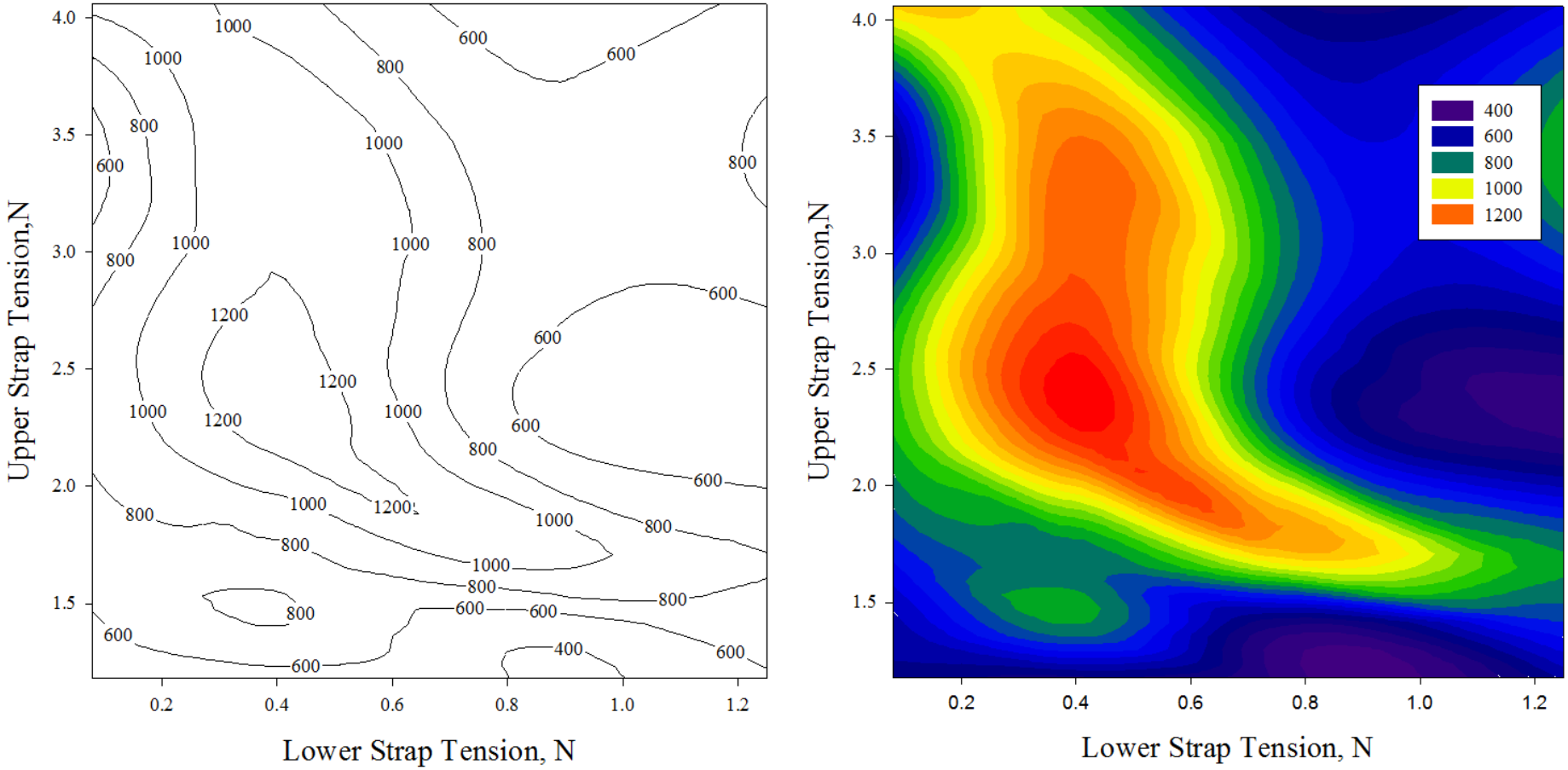
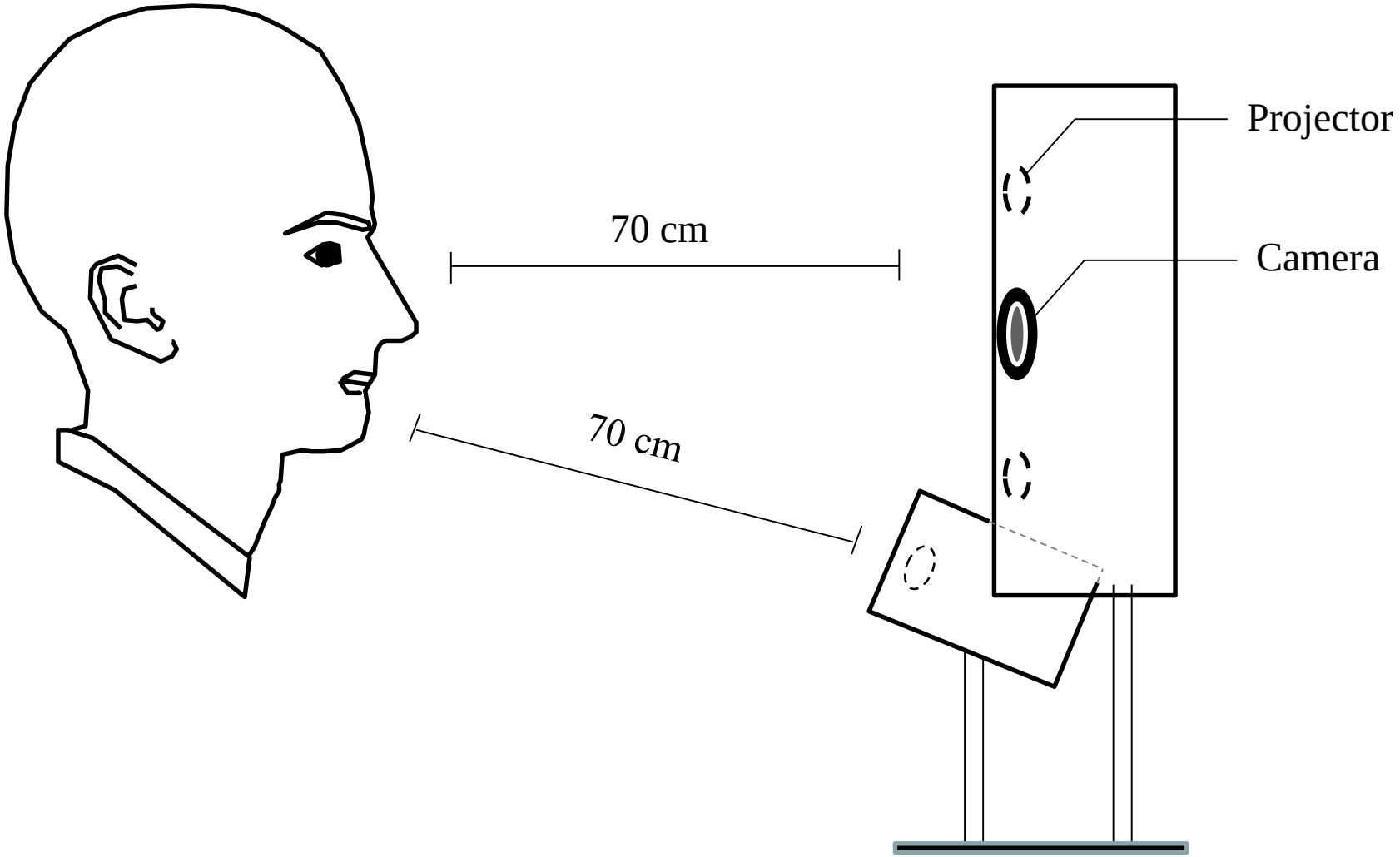
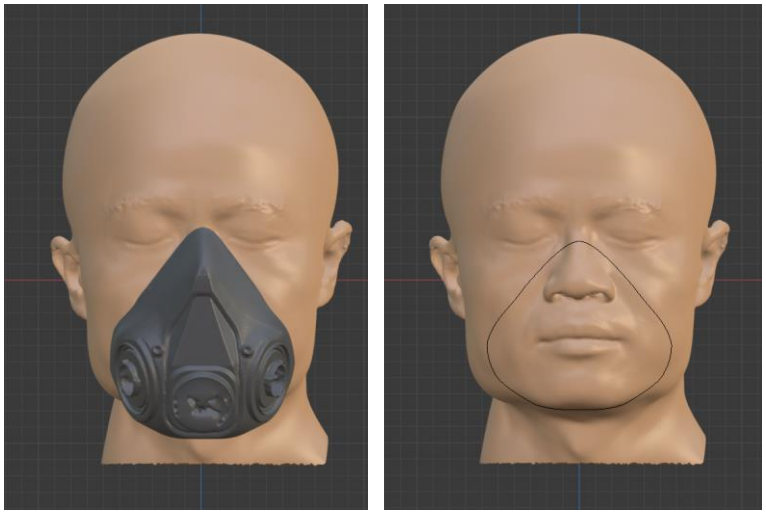


Figure. Fit factor of a Subject wearing a 3M 1860 (N95) at different upper and lower strap tensions

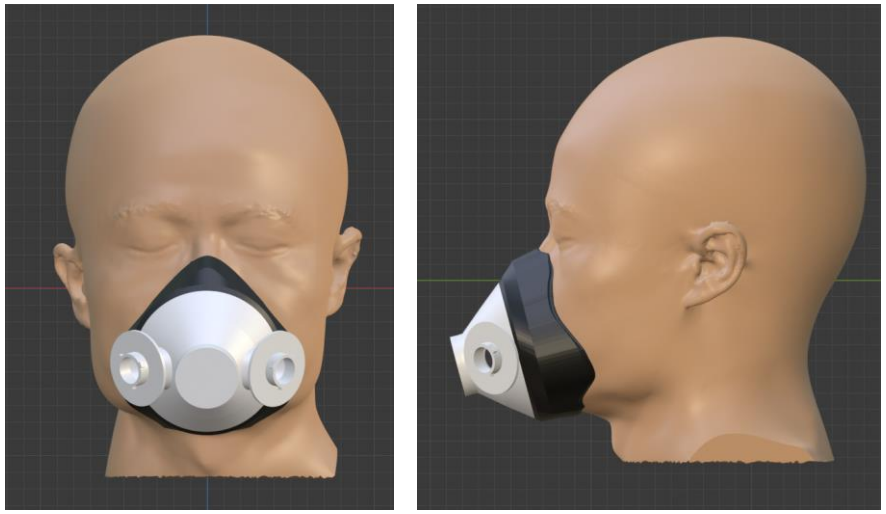
繫帶造成的勒痕

3D Scanning 3D Printing Customized Respirators





(a) Selection of the rim



(c) Make the holes for exhaust valve and cartridges.

(b) Extrude the contact area

Figure. Fabrication flow of the customized respirators in CAD software.

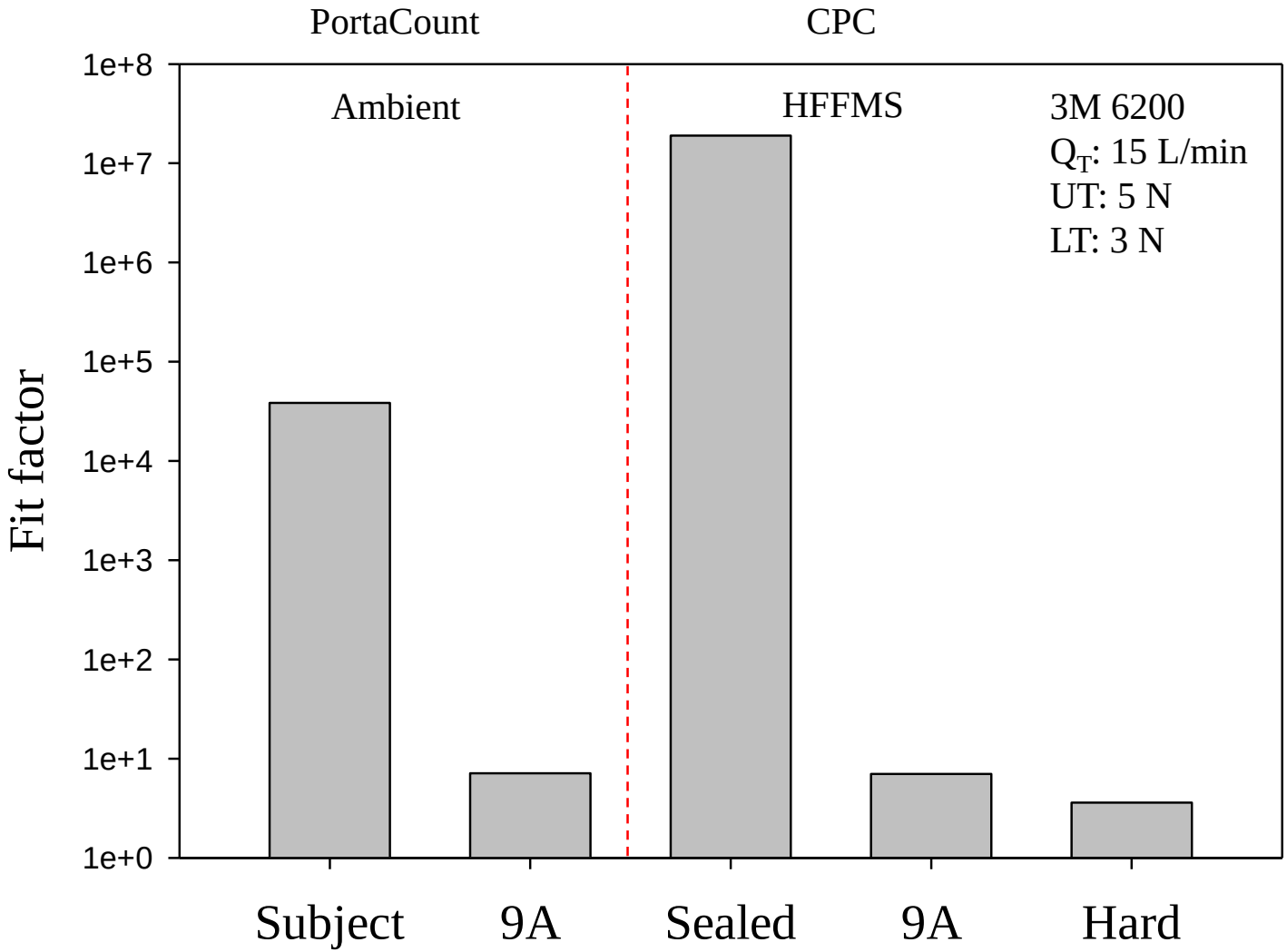


Figure 7. Fit factor of the 3M half-mask measured in the HFFMS.

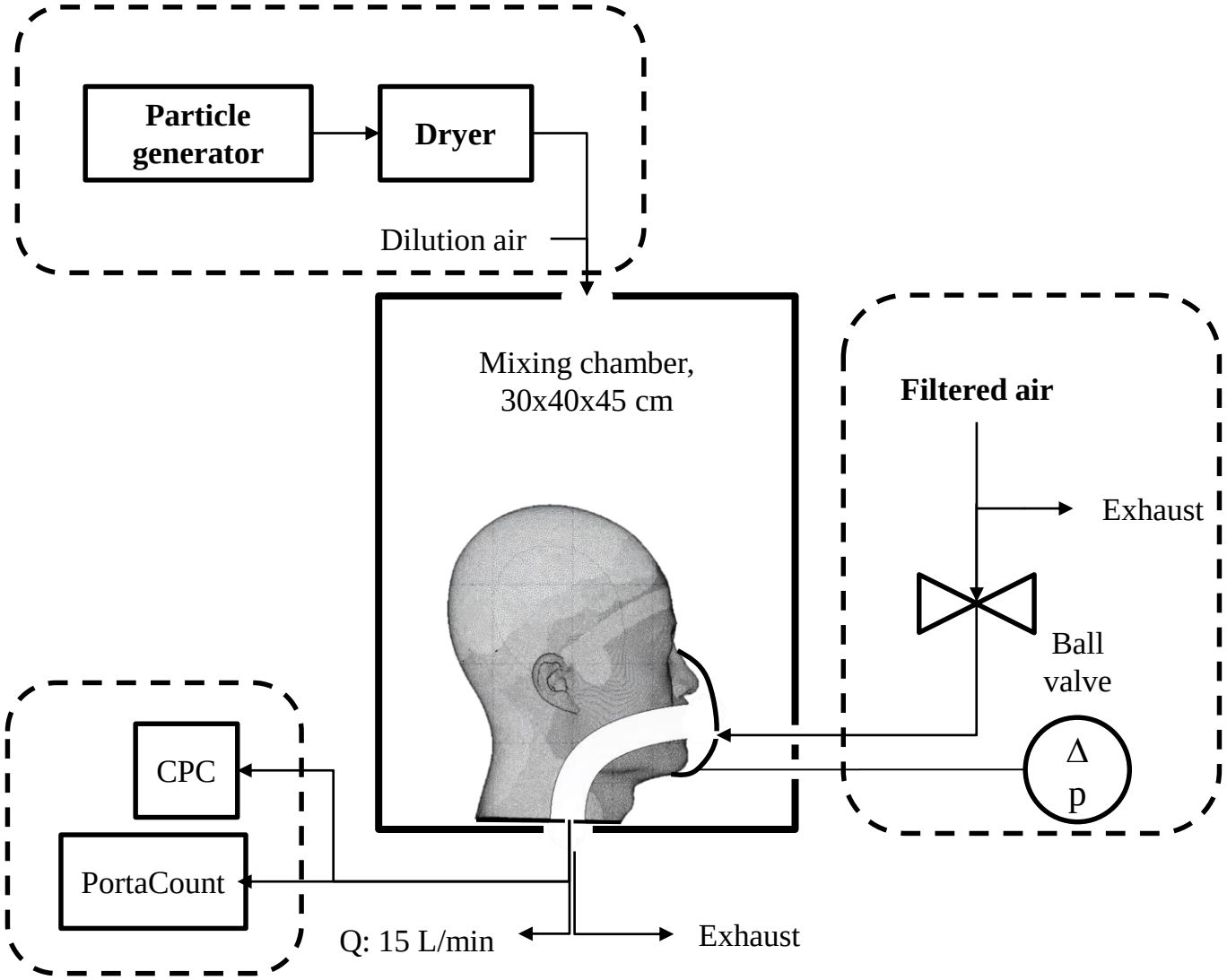


Figure 4. Schematic diagram of the **high-fit-factor** measurement system.

Limitations of current fit test methods

- Ambient aerosols (*overestimation?*)

  TSI - PortaCount

  Kanomax - AccuFit

- Leak flow rate (OHD)

Introduction – Constant flow PAPR

https://www.3m.com/
https://www.draeger.com/en-us_us/Homehttps://www.srsafety.com/?locale=int

Figure. Constant-flow PAPRs with loose-fitting and tight-fitting respirators

Breath-responsive PAPR

http://www.sts-japan.com/ https://www.srsafety.com/?locale=int

Figure. Breath-responsive PAPRs with tight-fitting respirators

Materials and Methods

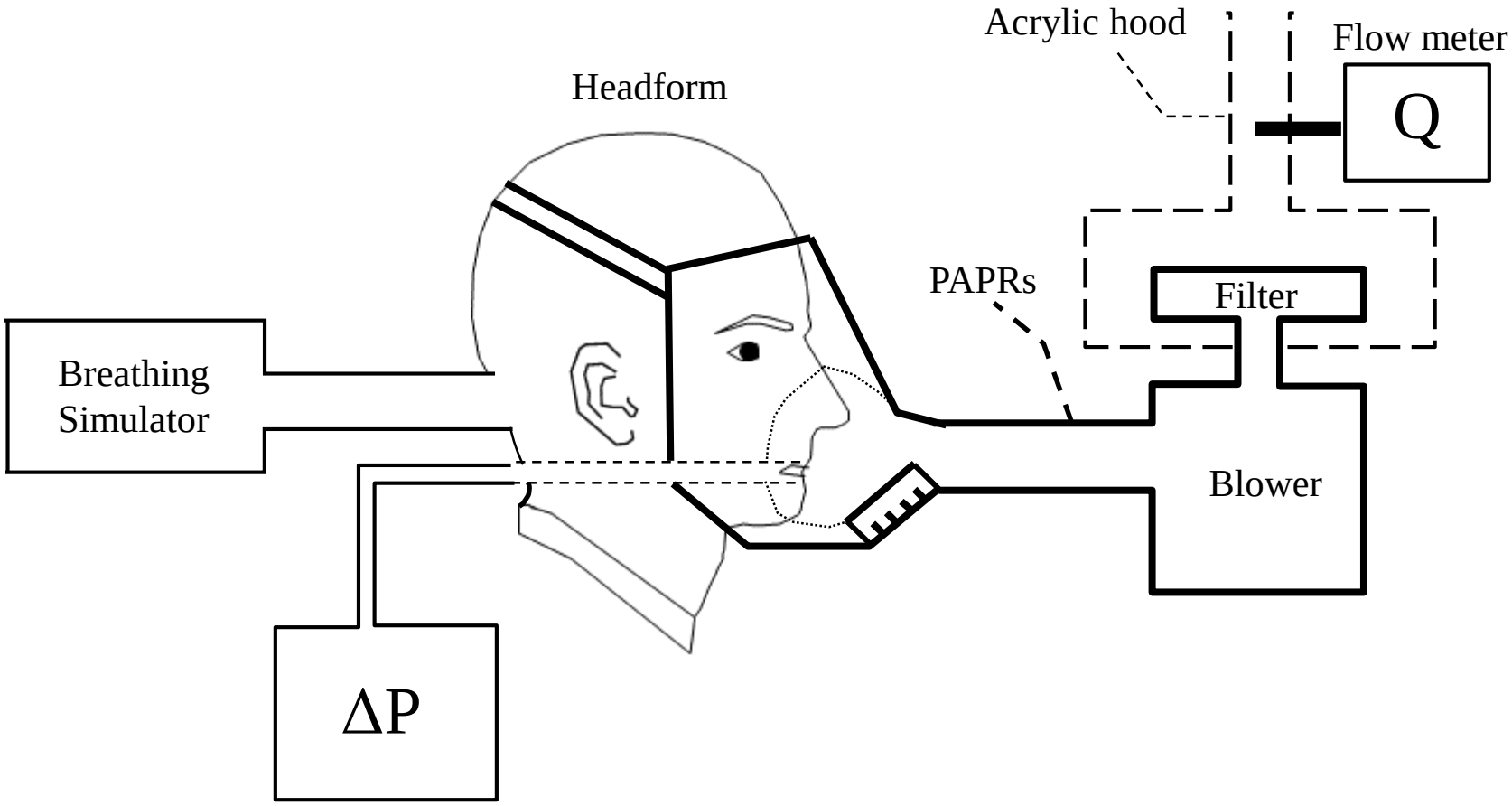
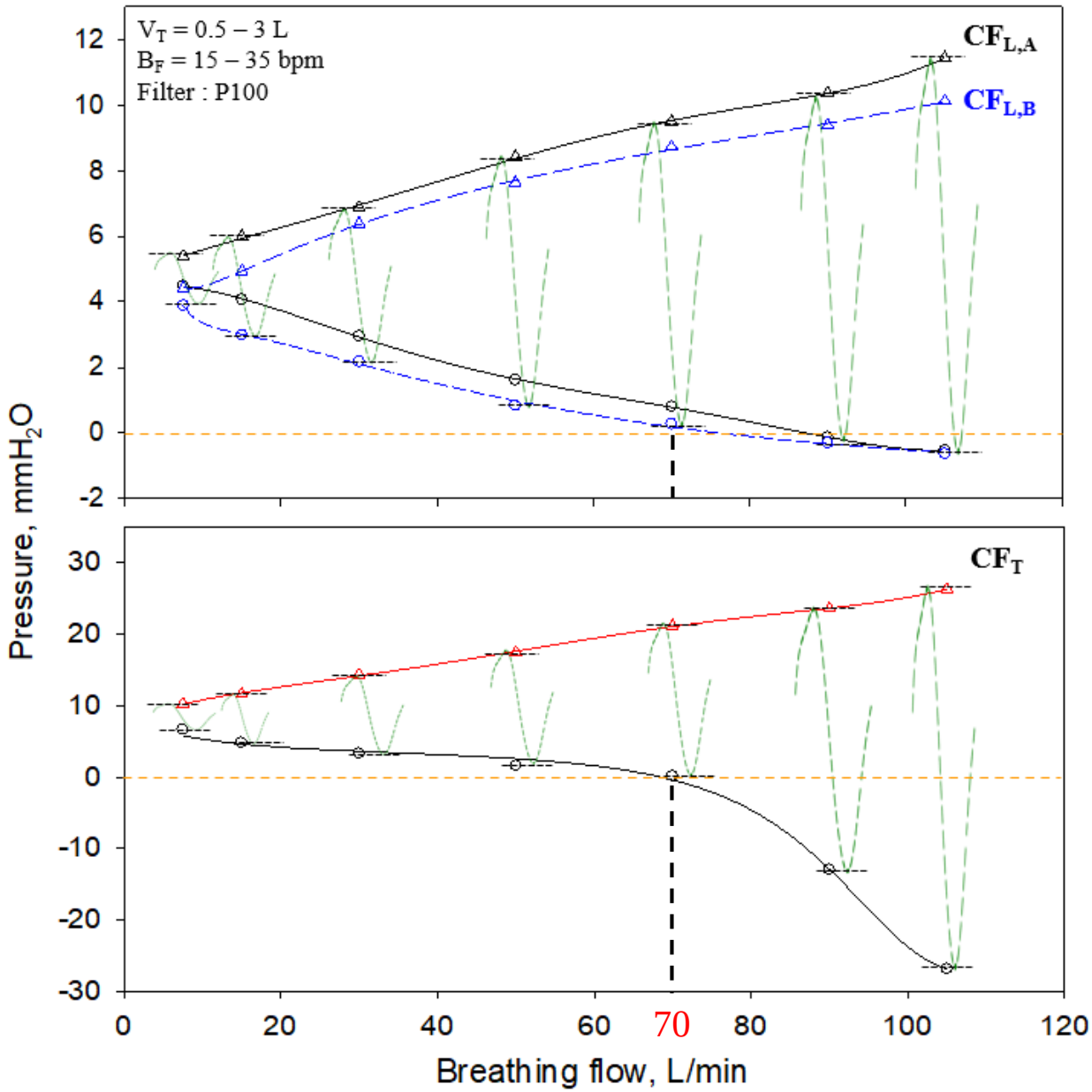


Fig . Schematic diagram of the experimental system set-up for evaluating of commercial PAPRs

Results and discussion



Loose-fitting

Tight-fitting

Fig . The effect of different breathing flow on pressure in type of ***constant flow PAPRs***

Results and discussion

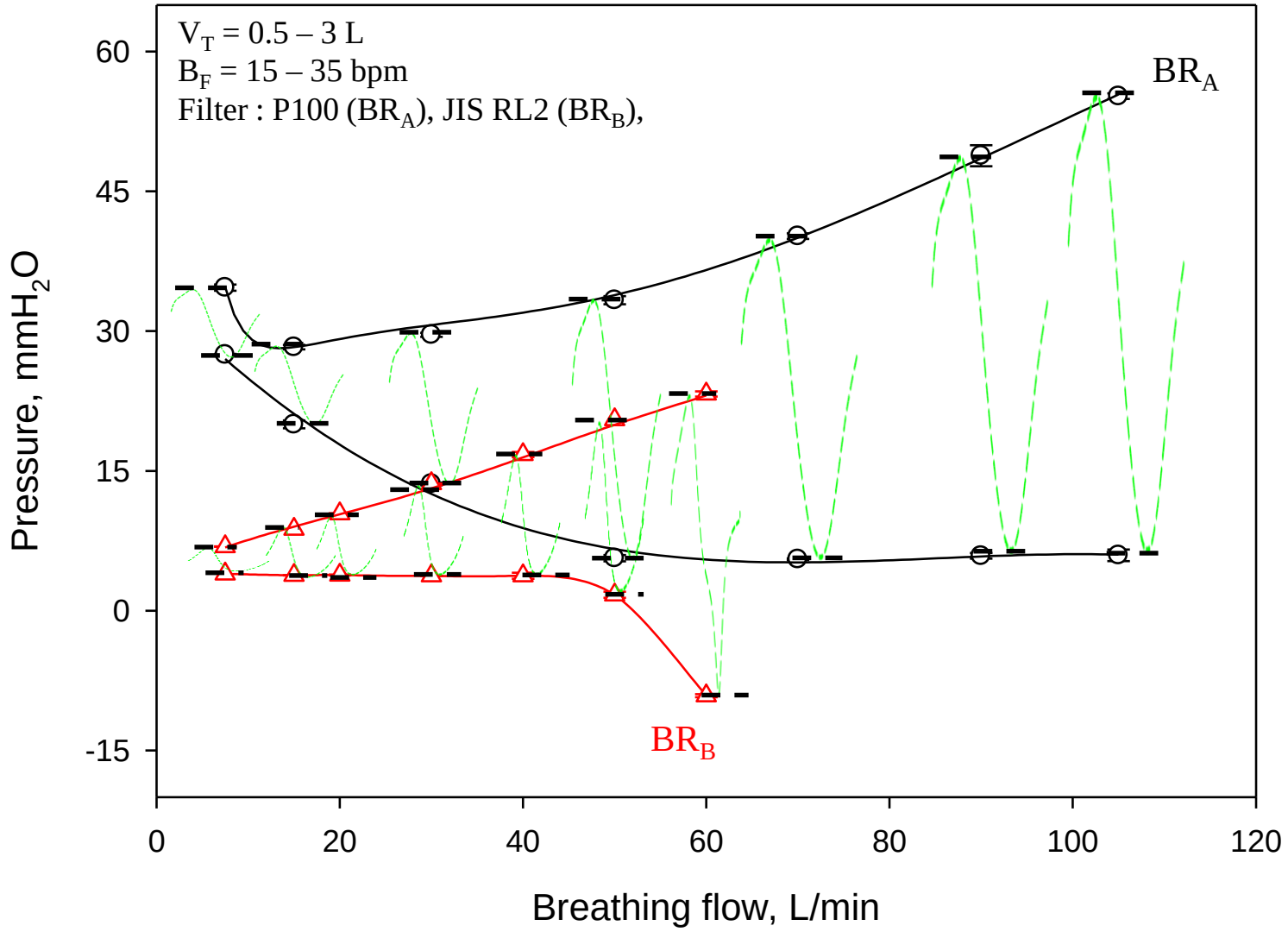


Fig . The effect of different breathing flow on pressure in type of ***breath-responsive PAPRs***

Results and discussion - BR_A

Figure. Breath-responsive PAPRs with big blower (BR_A)

Results and discussion - BR_B

Figure. Breath-responsive PAPRs with small blower (BR_B)

呼吸防護精進（Advancing Respiratory Protection）

完整呼吸防護推動（1）產品製造方的品質驗證與管理、（2）產品使用方正確有效的管理系統建置以及管理人員的培訓。

（1）產品製造方：

新世代奈米纖維濾材研發：高過濾效率與低空氣阻抗

呼吸回饋動力濾淨式呼吸防護具效能評估與改進

3D掃描3D列印呼吸防護具研發：過濾面體與橡（矽）膠面體

呼吸防護產品各元件的全面檢測（取代抽測？）。等等、、、、

（2）產品使用方：

密合度測試：更快更準更穩的定性與定量密合度測試方法

呼吸防護具繫帶的重要性：最適當繫帶張力才會有最佳密合

教育訓練：不只是懂得如何正確穿戴與使用，更需要知道為何需要配戴。等等、、、、

Thanks for your attention!