

Technical Background about BSL-3/4 labs and Isolation Wards
HEPA-filter housing design feature

Claus Schweinheim
Caverion Deutschland GmbH
Head of business unit Krantz

Revenue

2.5

EUR billion



Strong market position
in all key countries

13

Countries,
head offices in
Finland

250

locations close to
costumers

18,000

employees

5.500

Servicefahrzeuge

33,000

Shareholders.
Trading in Helsinki
stock exchange

55%

Service and
maintenance of
total revenue.

Markets


Automotive Industry


Banks


Office Buildings


Printing Companies


Shopping Centres / Stores


Airports


Aircraft Painting Hangars


Laboratories


Hotels


Isolation Wards


Nuclear Power Plants


Cinemas


Hospitals


Exhibition Halls


Museums


Pharmaceutical Industry
Chemical Industry


Production Facilities


Restaurants


Swimming Pools


Sports Halls / Performance Halls


Broadcasting Studios


Theatres


Assembly Halls / Convention Centres


Insurance companies

Filter Systems & Dampers

- HEPA Filter Systems



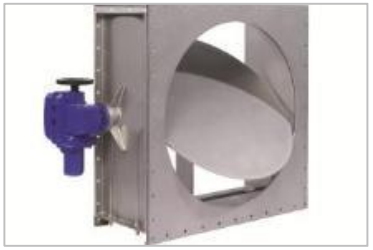



- Adsorption Filter Systems





- Dampers



- Dampers
- Air Flow Controller

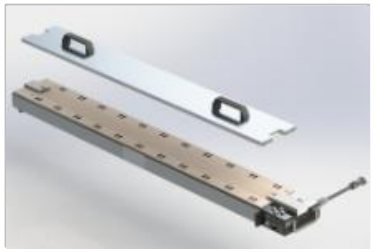





Accessory / Miscellaneous / Ventilation Units

- HEPA Filter Elements
- Leak Test Device
- Heat Seal Device

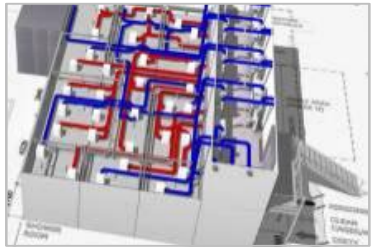


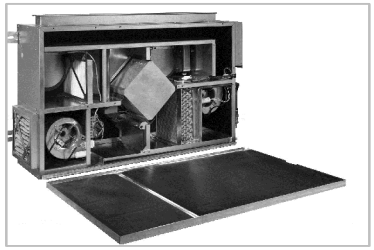
- Vortex Air Flow Measurement
- Gastight Doors

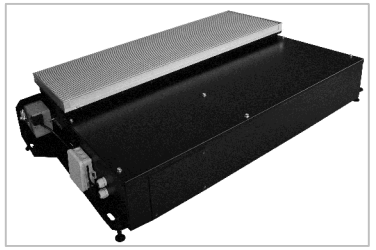
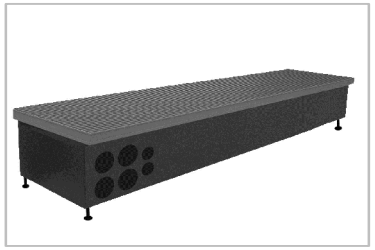



- Multifunctional Bio-Safety Laboratories



- Ventilation Units



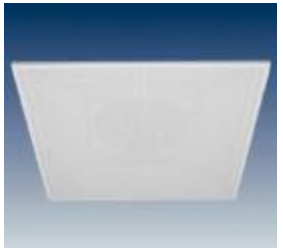



Some of our Air Distribution Systems

- Ceiling Air Outlets



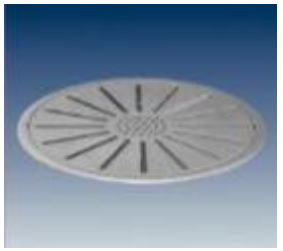




- Sidewall Air Outlets
- Floor Air Outlets







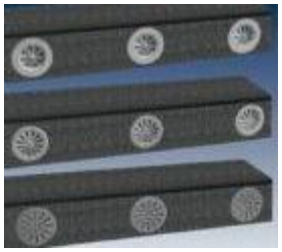
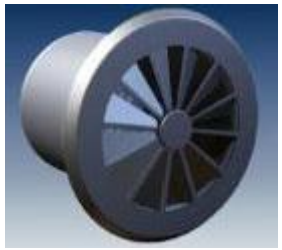
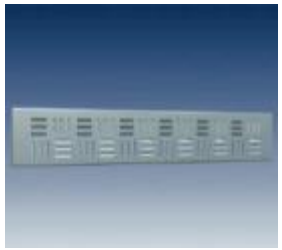
- Displacement Outlets for the Commercial Sector
- Displacement Outlets for the Industrial Sector







- Air Outlets for assembly rooms

– Turbulent mixing ventilation or low-turbulence displacement ventilation for commercial and industrial applications
– Air flow rates ranging from 20 m³/h to 10 000 m³/h

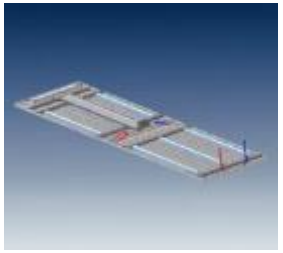
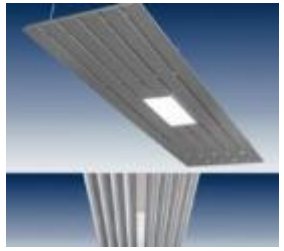
Cooling and Heating Systems

- High-capacity Ceiling Systems





- Chilled sails

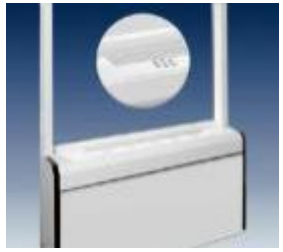
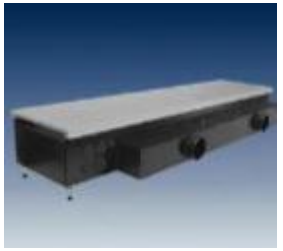
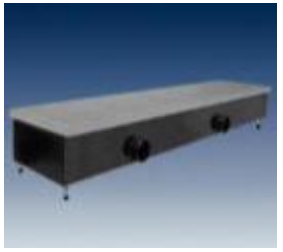
- Chilled beams






- Façade-/Floor-mounted Systems



Quality Management

- DIN EN ISO 9001
- KTA 1401, IAEA 50 C
- ASME NQA-1
- 10CFR50 Appendix B by Tractebel
- DIN EN ISO 3834-2:2006
- ASME Boiler and Pressure Vessel Code, Section iX

- **Background of BSL-3/4 laboratories**
- **Background Isolation Wards**
- **Qualification of HEPA filter qualification according to international rules**
- **References**

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Standards and guidelines – USA

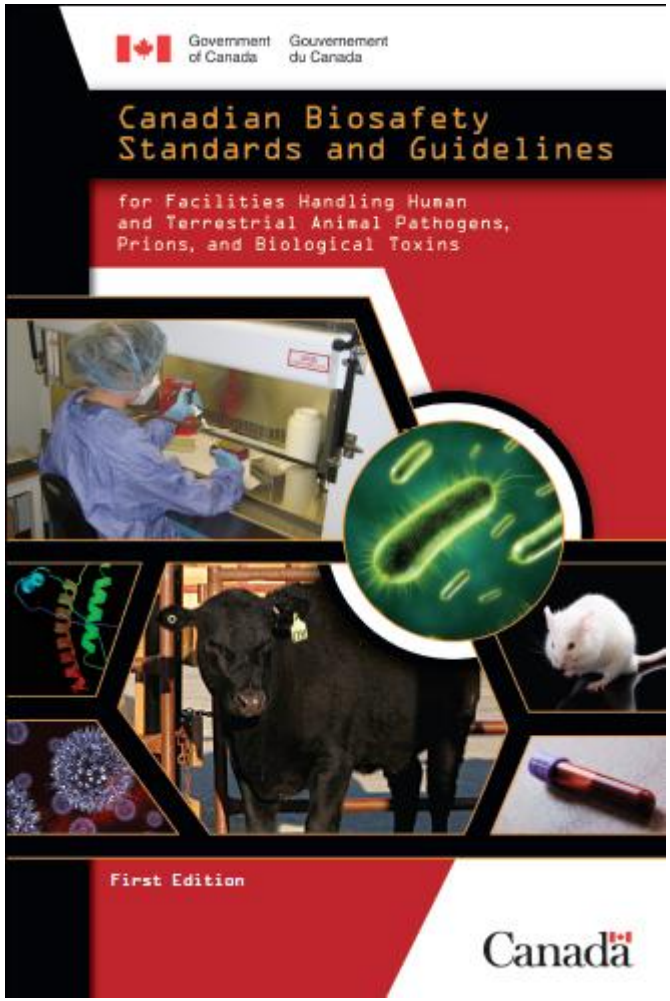


- BMBL Biosafety in Microbiological and Biomedical Laboratories, Centers of Disease Control and Prevention (CDC) & National Institutes of Health (NIH) 5th Edition 2007
- Army Regulations and Pamphlet 385-69



From the Foreword
„Biosafety in Microbiological and Biomedical Laboratories (BMBL) quickly became the cornerstone of biosafety practice and policy in the United States…We wish to emphasize that the 5th edition of **the BMBL remains an advisory document** recommending best practices for the safe conduct of work in biomedical and clinical laboratories from a biosafety perspective, and is not intended as a regulatory document though we recognize that it will be used that way by some.“

Standards and guidelines – Canada



From The Preface:
„The first edition of the Government of Canada‘s Canadian Biosafety Standards and Guidelines **(CBSG) is a harmonized national Standard** for the handling and storing of human and terrestrial animal pathogens and toxins in Canada. The CBSG is a result of a joint initiative undertaken by the Public Health Agency of Canada (PHAC) and the Canadian Food Inspection Agency (CFIA) to update and harmonize three existing Canadian biosafety standards and guidelines for the design, construction and operation of facilities in which pathogens or toxins are handled and stored“

Directive– European Community

DIRECTIVE 2000/54/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 18 September 2000
on the protection of workers from risks related to exposure to biological agents at work
(seventh individual directive within the meaning of Article 16(1) of Directive 89/391/EEC)

Article 1

Objective

1. This directive has as its aim the **protection of workers against risks to their health and safety**, including the prevention of such risks, arising or likely to arise from exposure to biological agents at work.
It lays down particular minimum provisions in this area

Standards and guidelines – European Community



- EN 12 128 Laboratories for Research, Development and Analysis
- EN 1620 Large scale manufacturing and production processes
- EN 1822 HEPA and ULPA filters
- (…)

Standards and guidelines – European Community



Key EU Biosafety legislation

- Common EU legislation on biosafety focuses on **the prevention of risks related to the handling** of dangerous biological materials by the workforce as well as during transport.

- In addition to common EU directives and regulations, EU member states have implemented **many national laws**, **ordinances and other regulations** to prevent exposure to dangerous biological material, to protect human, animal and plant health and to regulate the safe handling of dangerous biological materials

Standards and guidelines - Germany



- GenTG Gentechnik Gesetz [Genetic Engineering Code]
- GenTSV Gentechnische Schutzverordnung [Genetic Engineering Protection Rules]

Edition: October 2013
GMBl No. 51/52 of 17.10.2013
Amended June 2014, GMBl No. 38

Technical Rules for Biological Agents	**Protective measures for activities involving biological agents in laboratories**	**TRBA 100**

The Technical Rules for Biological Agents (TRBA) reflect the state of the art, the **state of occupational health and occupational hygiene** as well as other sound work-scientific knowledge relating to activities involving biological agents

Biosafety Levels for Infectious Agents and Containment According to BMBL

BSL	Agents	Practices	Safety Equipment (Primary Barriers)	Facilities (Secondary Barriers)
1	Not known to consistently cause disease in healthy adults	Standard Microbiological Practices	None required	Open bench top sink required
2	Associated with human disease, hazard = percutaneous injury, ingestion, mucous membrane exposure	BSL-1 practice plus: ● Limited access ● Biohazard warning signs ● "Sharps" precautions ● Biosafety manual defining any needed waste decontamination or medical surveillance policies	Primary barriers = Class I or II BSCs or other physical containment devices used for all manipulations of agents that cause splashes or aerosols of infectious materials; PPEs: laboratory coats; gloves; face protection as needed	BSL-1 plus: ● Autoclave available
3	Indigenous or exotic agents with potential for aerosol transmission; disease may have serious or lethal consequences	BSL-2 practice plus: ● Controlled access ● Decontamination of all waste ● Decontamination of lab clothing before laundering ● Baseline serum	Primary barriers = Class I or II BCSs or other physical containment devices used for all open manipulations of agents; PPEs: protective lab clothing; gloves; respiratory protection as needed	BSL-2 plus: ● Physical separation from access corridors ● Self-closing, double-door access ● Exhausted air not recirculated ● Negative airflow into laboratory
4	Dangerous/exotic agents which pose high risk of life-threatening disease, aerosol-transmitted lab infections; or related agents with unknown risk of transmission	BSL-3 practices plus: ● Clothing change before entering ● Shower on exit ● All material decontaminated on exit from facility	Primary barriers = All procedures conducted in Class III BSCs or Class I or II BSCs in combination with full-body, air-supplied, positive pressure personnel suit	BSL-3 plus: ● Separate building or isolated zone ● Dedicated supply and exhaust, vacuum, and decon systems ● Other requirements outlined in the text

Canadian Biosafety Standards and Guidelines (CBSG) – Laboratories for Research, Development and Analysis

Requirements	CL2	CL2-Ag	CL3	CL3-Ag	CL4
HVAC system to provide sufficient air changes per hour (AC/hr) under normal operation to maintain airflow, based on facility function	■	■	■	■	■
Inward directional airflow to be provided (Not required for CL2 SA zones and zones where prions are handled)	□	■	■	■	■
Monitoring device(s) that visually demonstrate inward directional airflow to be provided for the containment zone		■	■	■	■
Pressure differential monitoring lines penetrating the containment barrier to be provided with HEPA filtration or acceptable alternative			■	■	■
Audible or visual alarms to be provided inside and outside the containment zone to signal HVAC systems failure			■	■	■
Supply and exhaust air systems to be independent of other areas. CL3 air systems may be combined with areas of lower containment when provided with effective **backdraft protection**			■	■	■
Supply air duct to be provided with effective backdraft protection			■	■	

Canadian Biosafety Standards and Guidelines (CBSG) – Laboratories for Research, Development and Analysis

Requirements	CL2	CL2-Ag	CL3	CL3-Ag	CL4
Supply air to be HEPA filtered					■
Supply air systems to be automatically interlocked with exhaust air system to prevent sustained positive pressurization of the containment zone			■	■	■
Exhaust air to be passed through a HEPA filter			■	■	
Exhaust air to be passed through two stages of HEPA filtration					■
HEPA filters to conform to the Institute of Environmental Sciences and Technology (IEST)-RP-CC001.5			■	■	■
HEPA filter housings to be designed to withstand structural changes at applied pressure of 1 000 Pa (i.e., 4 inches water gauge [in. w.g.]) in accordance with testing requirements in American Society of Mechanical Engineers (ASME) N511 and AG-1			■	■	■

Canadian Biosafety Standards and Guidelines (CBSG) – Laboratories for Research, Development and Analysis

Requirements	CL2	CL2-Ag	CL3	CL3-Ag	CL4
HEPA filter housings to be designed to allow *in situ* filter isolation, decontamination and testing			■	■	■
Supply air ductwork located between the containment barrier and backdraft protection to be sealed airtight in accordance with Sheet Metal and Air Conditioning Contractors National Association (SWACNA) Seal Class A			■	■	■
Exhaust air ductwork located between the containment barrier and HEPA filter(s) or isolation damper(s) to be sealed airtight in accordance with SWACNA Seal Class A			■	■	■
Effective airflow control devices to be provided on supply and exhaust air systems			■	■	■
All sections of supply and exhaust air systems located outside the containment barrier to be accessible for maintenance and repair					■
Supply and exhaust air ductwork to be provided with isolation dampers for isolation and decontamination of contaminated ductwork			■	■	■

EN 12128 Biotechnology – Laboratories for Research, Development and Analysis

Requirements	Physical contamination level			
	1	2	3	4
Containment level labelled	Yes[2)]	Yes	Yes	Yes
Hazard zones labelled with biohazard sign	-	Yes	Yes	Yes
Adequate space for each worker	Yes	Yes	Yes	Yes
Laboratory rooms separated by doors	No[3)]	Yes	Yes (lockable)	Yes (physically separated)
Entry to laboratory via an airlock	No	No	Optional[4)]	Yes
Provision of an observation window, or alternative	No	Yes	Yes	Yes
Surfaces impervious to water, easy to clean and resistant to cleaning agents etc.	Yes (bench)	Yes (bench)	Yes (bench, floor)	Yes (bench, floor, walls and ceiling

EN 12128 Biotechnology – Laboratories for Research, Development and Analysis

Requirements	Physical contamination level			
	1	2	3	4
Hand washing facilities	Yes	Yes	Yes	Yes
Provision of taps that can be operated without being touched by hand	Optional	Yes	Yes	Yes
Personnel shower	Optional	Optional	Optional	Yes (in airlock system)
Hand disinfection	Optional	Yes	Yes	Yes
Provision of storage for protective clothing within the laboratory or unit	Optional	Yes	Yes	Yes
Ventilation - Means of maintaining a negative pressure - Extract air to be filtered using HEPA filtration	 No No	 No No	 Optional Yes	 Yes Yes (via 2 HEPA filters)
Input air to be filtered using HEPA filtration	No	No	No	Yes

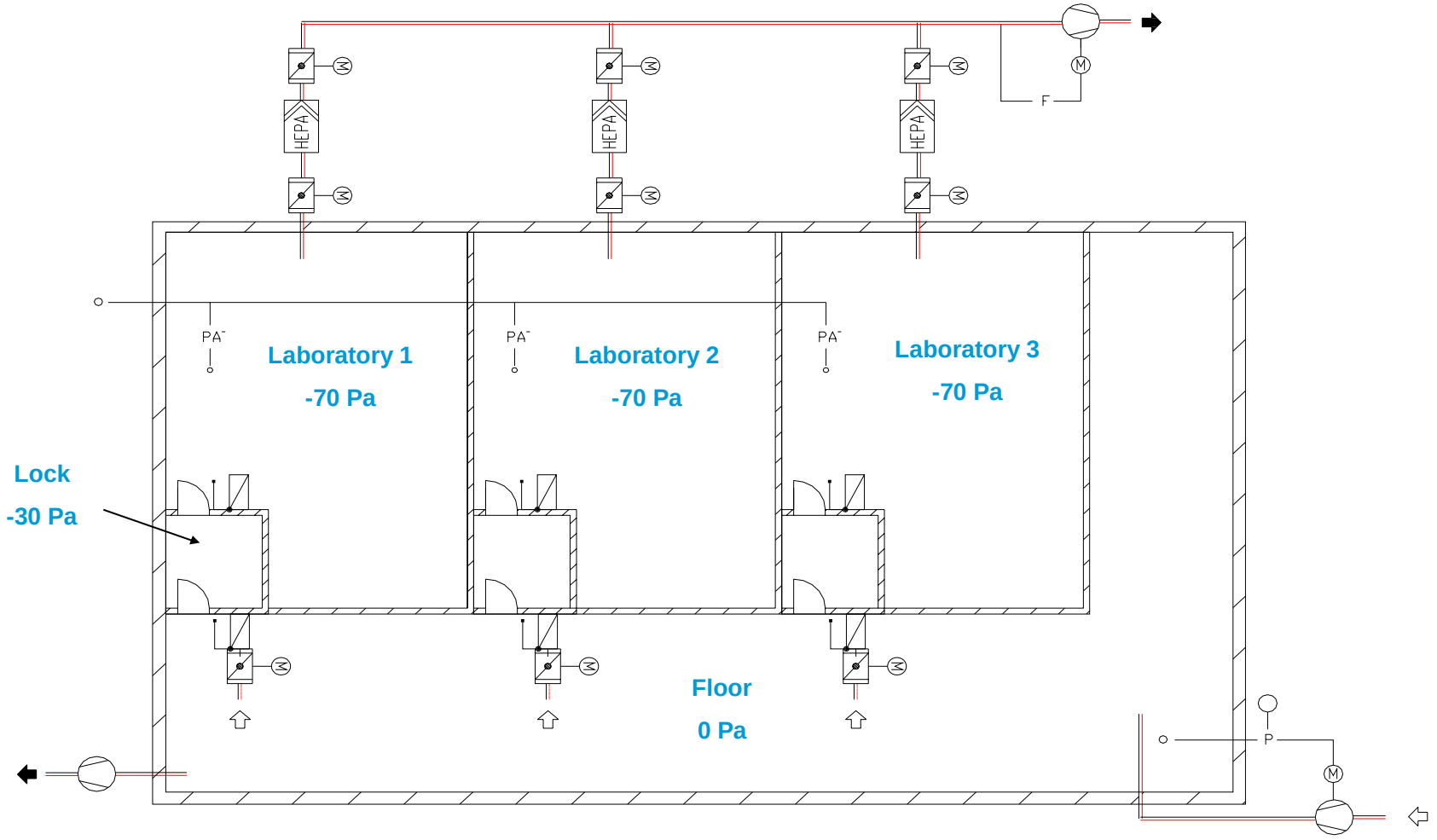
EN 12128 Biotechnology – Laboratories for Research, Development and Analysis

Requirements	Physical contamination level			
	1	2	3	4
Alarm system fitted to detect unacceptable air pressure changes	No	No	Yes	Yes
Laboratory sealable to permit fumigation	No	Optional	Yes	Yes
Laboratory design to permit vector, e.g. insect and rodent, control	No	Optional	Yes	Yes
Laboratory to contain its own, dedicated, equipment	No	No	Yes	Yes
Provision of microbiological safety cabinet	Optional	Optional	Yes	Yes (class III)
Provision of emergency electrical supply	No	No	Optional	Yes
Means of outside communication, e.g. hands-free telephone or equivalent	No	No	Optional	Yes

EN 12128 Biotechnology – Laboratories for Research, Development and Analysis

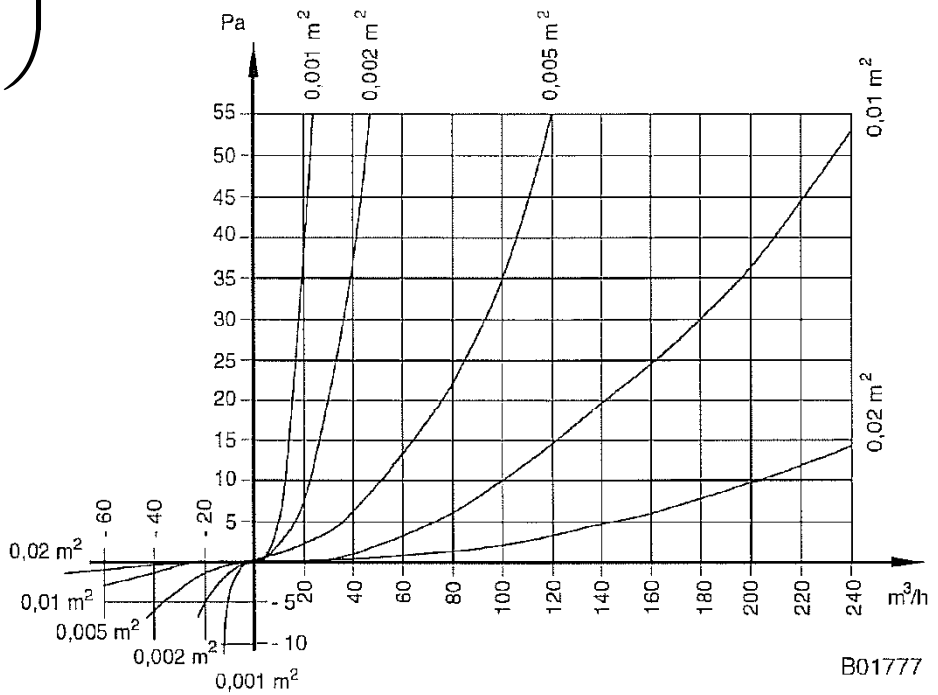
Requirements	Physical contamination level			
	1	2	3	4
Provision of an autoclave - accessible within laboratory suite - in laboratory, double-ended	 No -	 No -	 Yes Optional	 - Yes
Waste disposal system - documented - validated	 No -	 Yes -	 - Yes	 - Yes
Effluent treatment	No	Optional	Yes	Yes

Flow chart, class 3, example

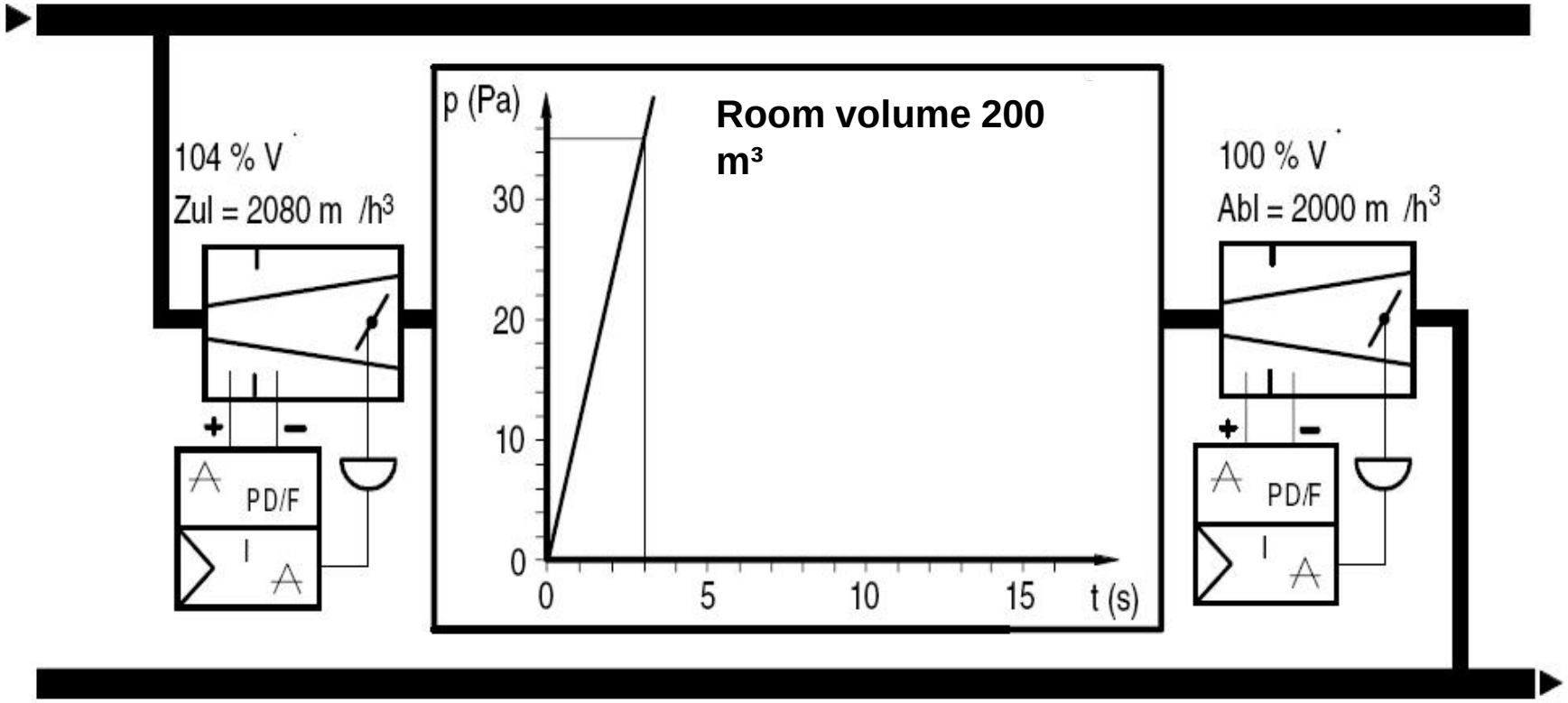


Flow chart, class 4, example

$$\Delta p = \frac{\rho}{2} \cdot \left(\frac{\dot{V}}{A \cdot \mu} \right)^2$$



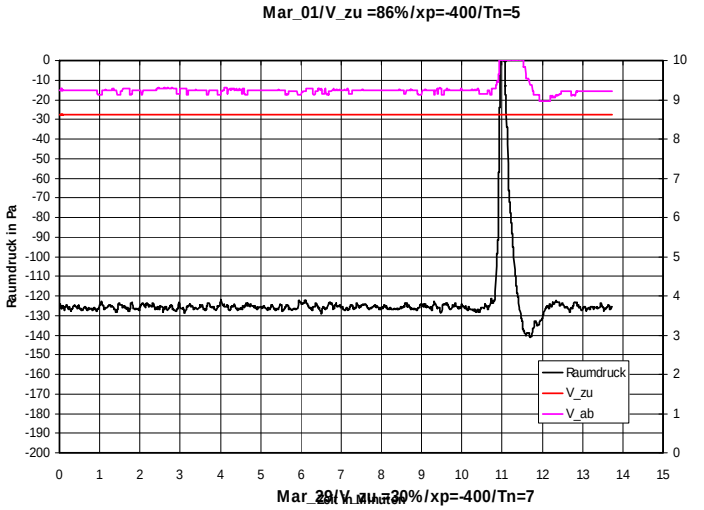
Flow chart, class 4, example

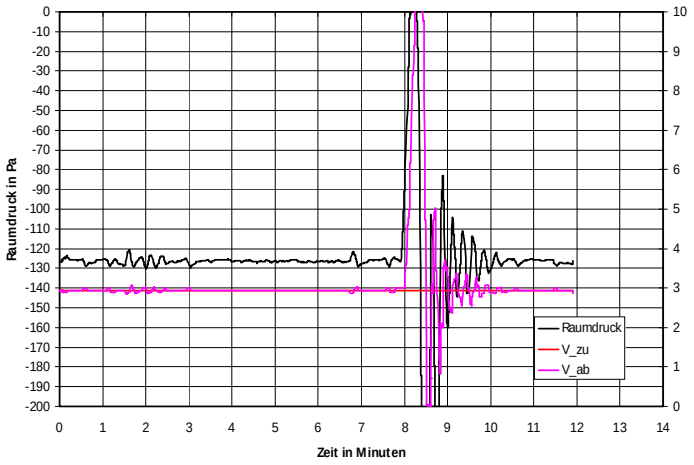


Pressure increase in an air tight room

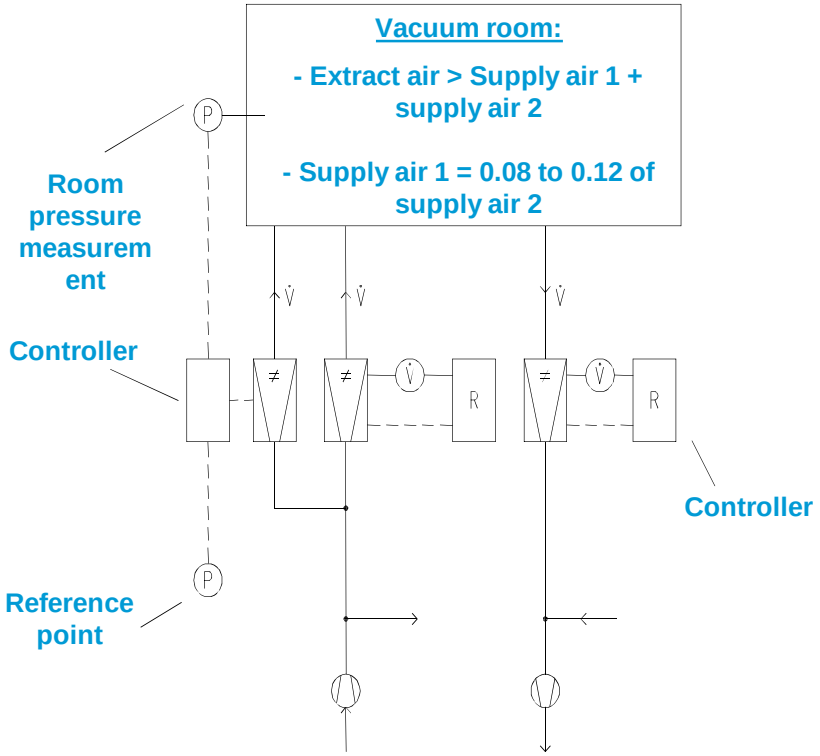
Flow chart, class 4, example



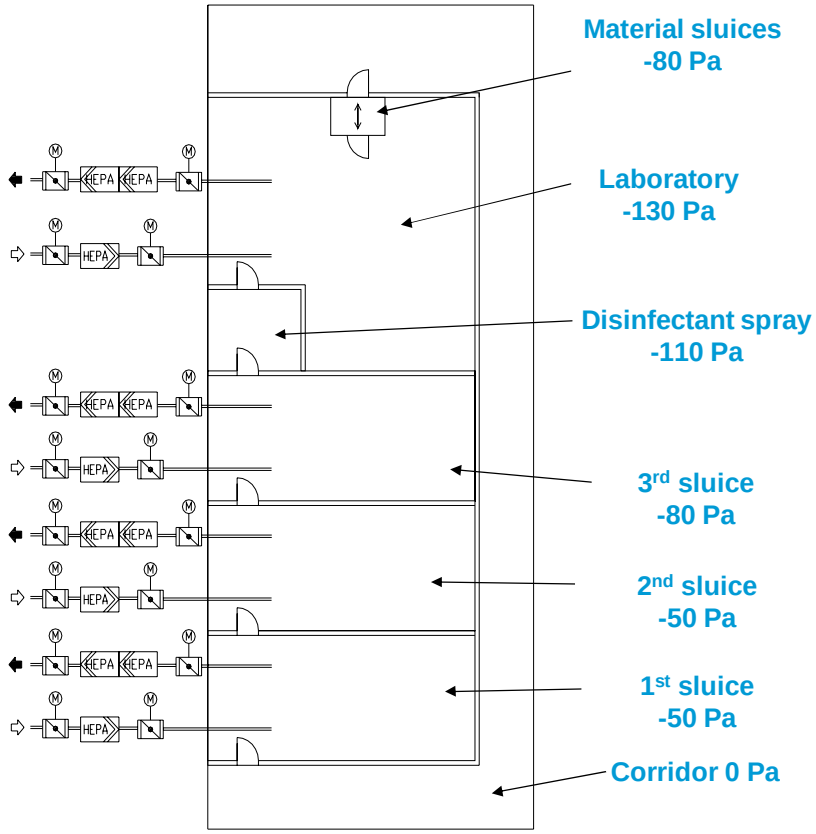




Flow chart, class 4, example



Room pressure control for containments

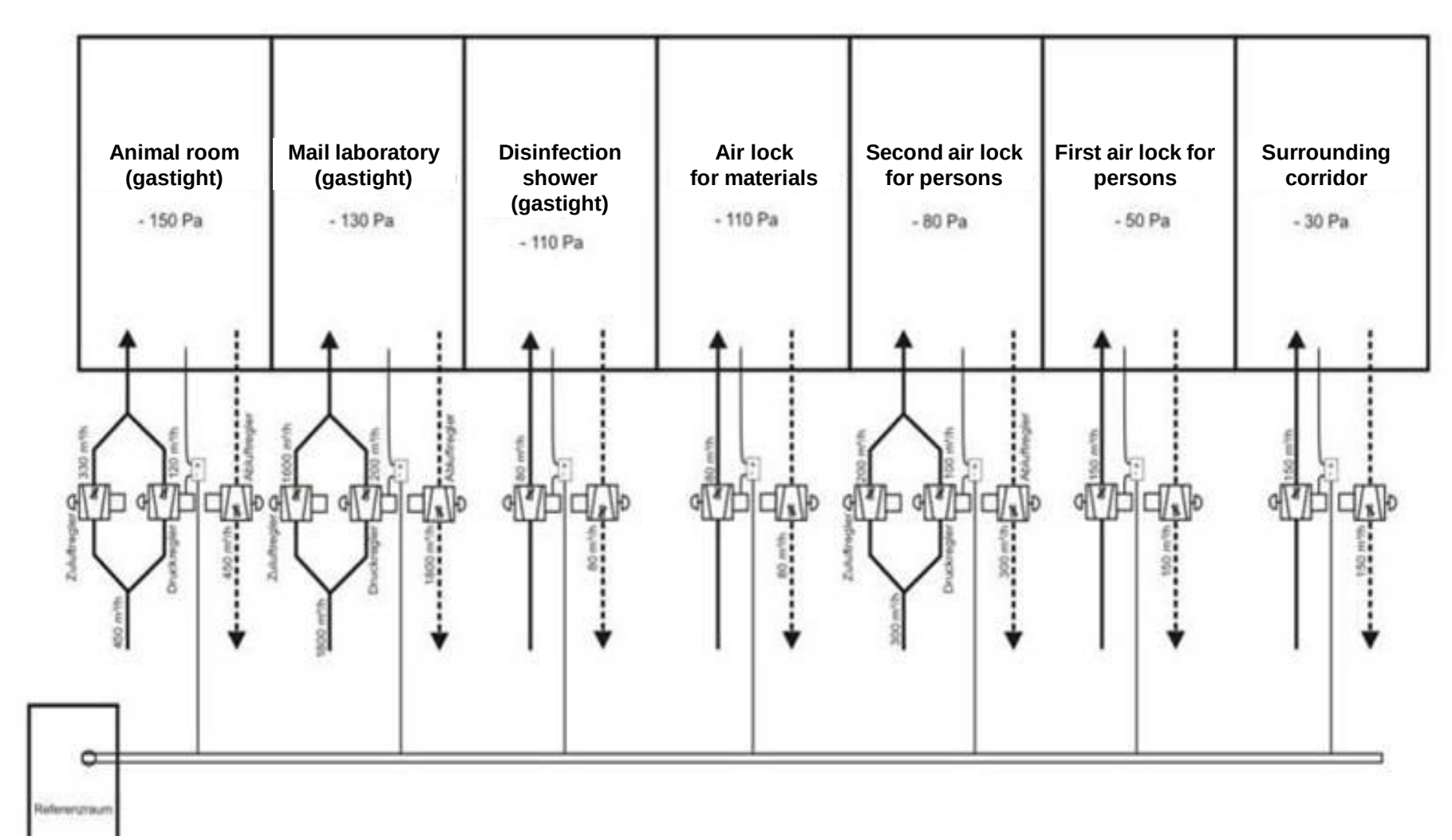


Flow chart, class 4, example





Flow chart, class 4, example



- Background of BSL-3/4 laboratories
- **Background Isolation Wards**
- Qualification of HEPA filter qualification according to international rules
- References

Isolation wards in Hong Kong

- Princess Margaret Hospital – Infectious Diseases Control Centre
- Prince of Wales Hospital
- Queen Elizabeth Hospital
- Queen Mary Hospital
- Tseung Kwan O Hospital
- Nethersole Hospital
- United Christian Hospital
- Tuen Mun Hospital
- Pamela Youde Nethersole Eastern Hospital
- Kwok Wah Hospital
- Pok Oi Hospital
- Prince of Wales Hospital – Extension
- North Lantau Hospital

Tseung Kwan O Hospital







Queen Elizabeth Hospital





Guidelines

- **United States of America -** including the Centers for Disease Control and Prevention (CDC), American Institute of Architects (AIA) and American Society for Heating and Refrigeration Engineers (ASHRAE).
- **United Kingdom - D**epartment of Health
- **Canada -** Canadian Health Care Facilities and Other Institutional Settings
- **Australia -** from Victoria and Queensland territory levels (Dept of Human Services, Victoria)
- **Japan -** Working Committee for Buildings/Engineering of Patient's Bedroom for Infectious Diseases, Health Publications
- **Norway -** Norwegian work environment regulation 1322; Norwegian isolation guideline
- **Denmark -** Recommendation regarding type and furnishing of isolation units that can be used for patients with infectious diseases and that satisfies the requirements for airborne infection isolation

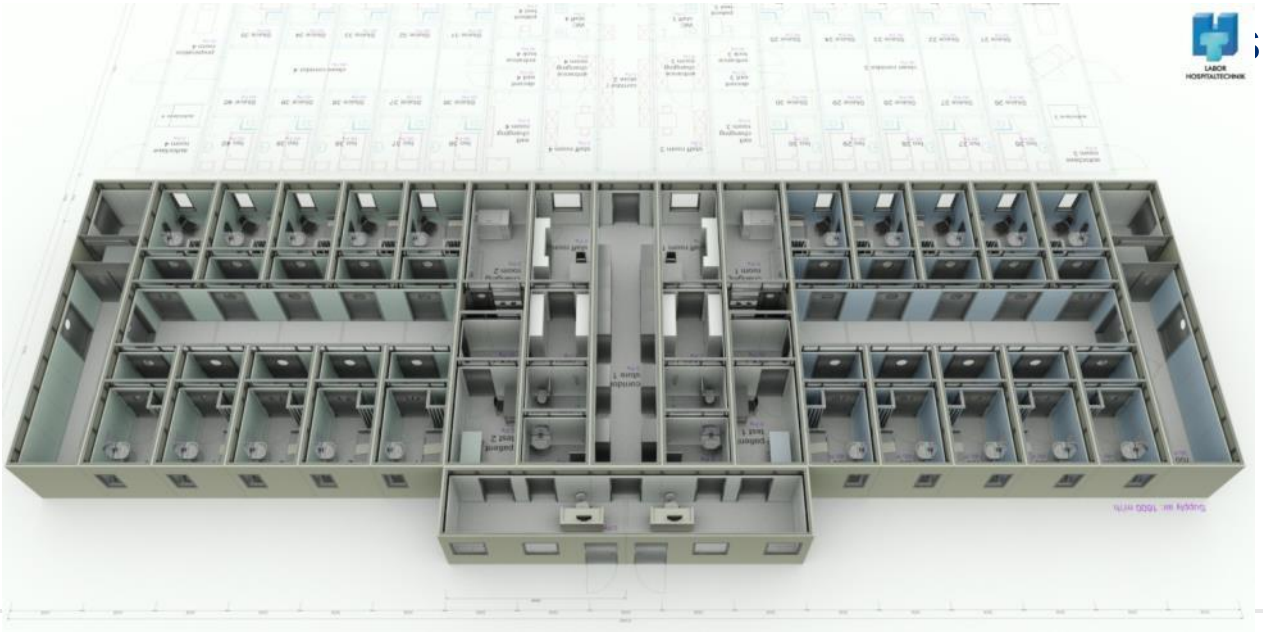
  Nordic Innovation Centre - Best Practice in Design and Testing of Isolation Rooms in Nordic Hospitals

Physical barriers

- **Primary barrier (Personal Protection Equipment – PPE)**
- **Secondary barrier (Containment design with filtered exhaust air system)**

CONCEPT

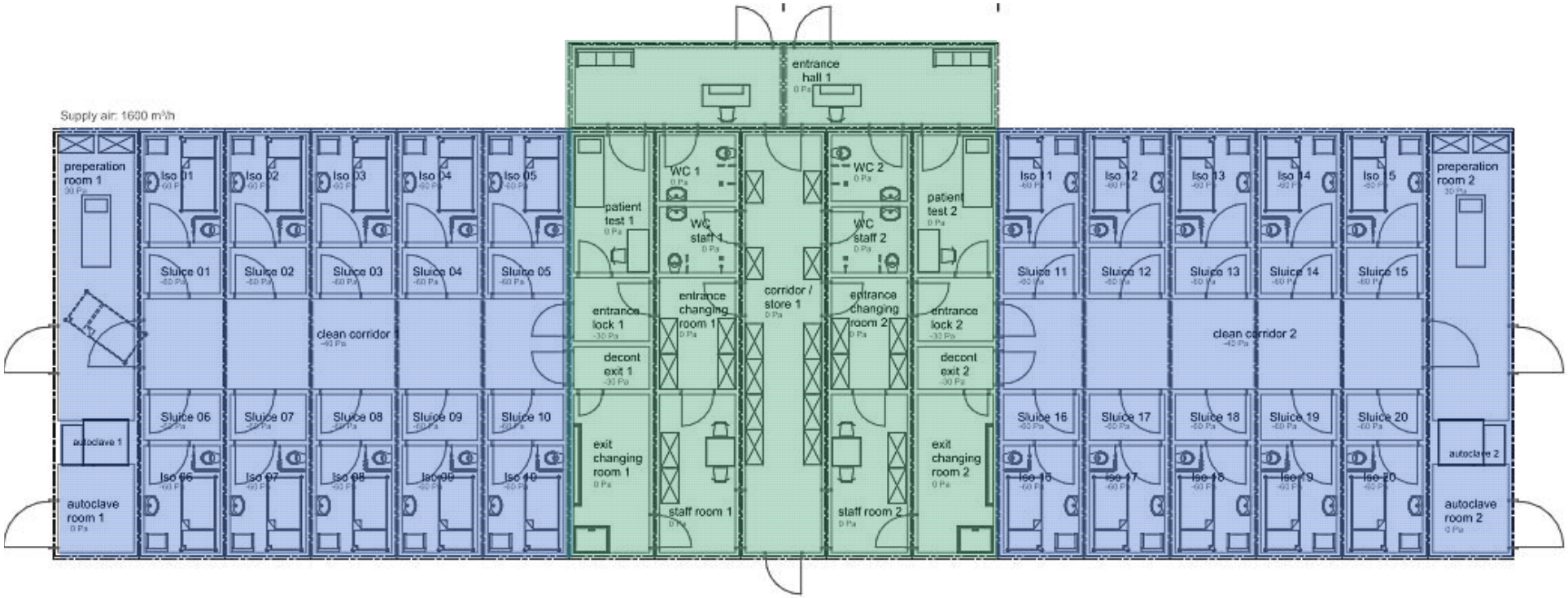
- This concept of an Ebola station shows a hermetically sealed self-sufficient HIGH SAFETY LABORATORY in the center with gas-tight doors and walls, equipped with chemical wet-showers for secure decontamination of the medical staff. Personnel access is provided with electronically secured access control system.





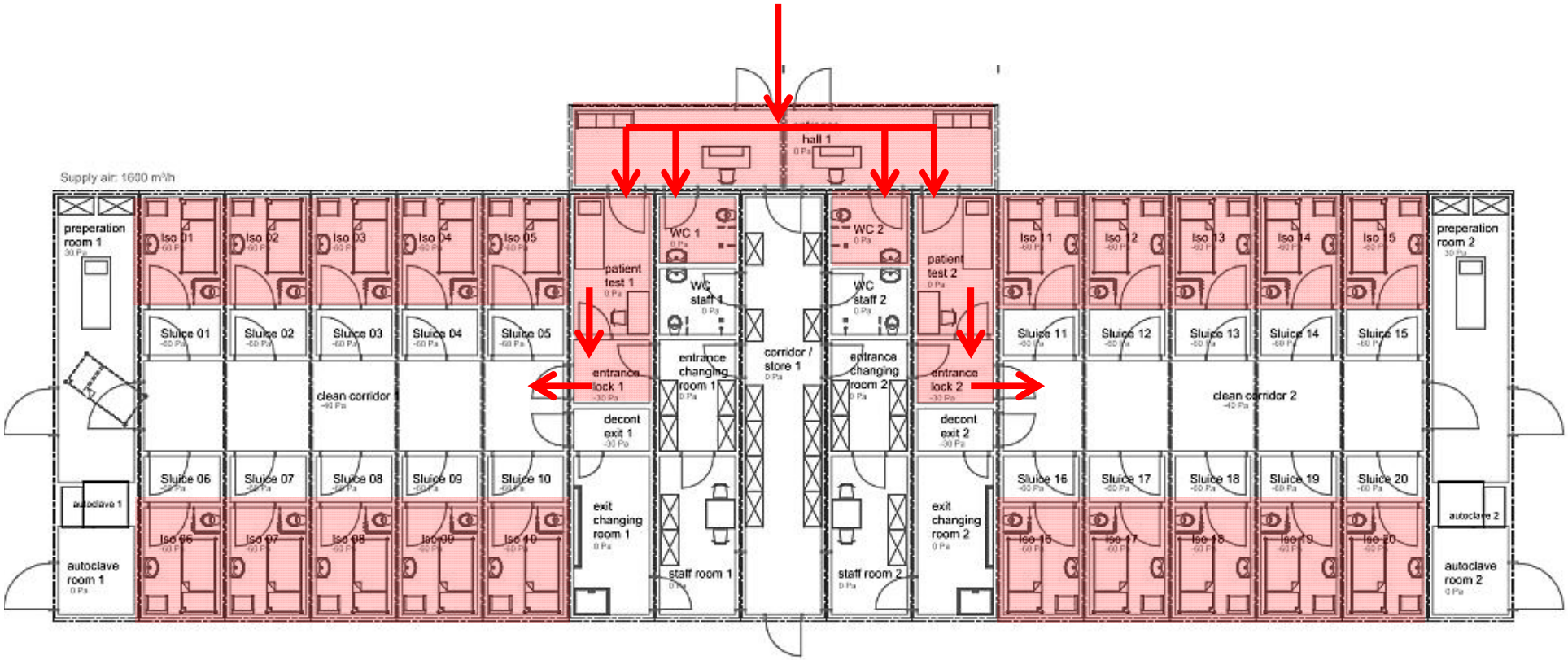
TREATMENT CENTER

ISOLATION AREA	LAB AREA	ISOLATION AREA



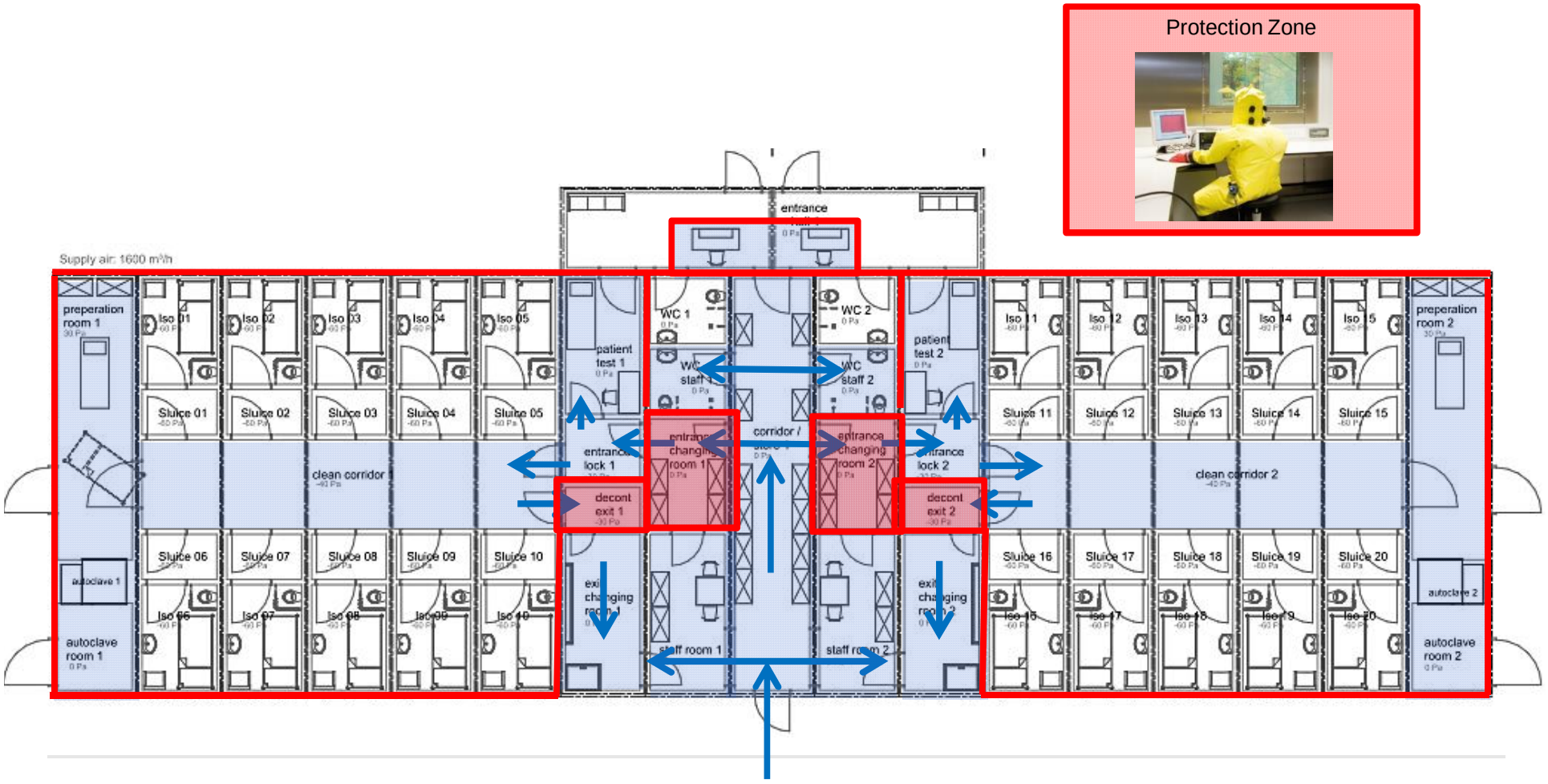
PATHS

Patient



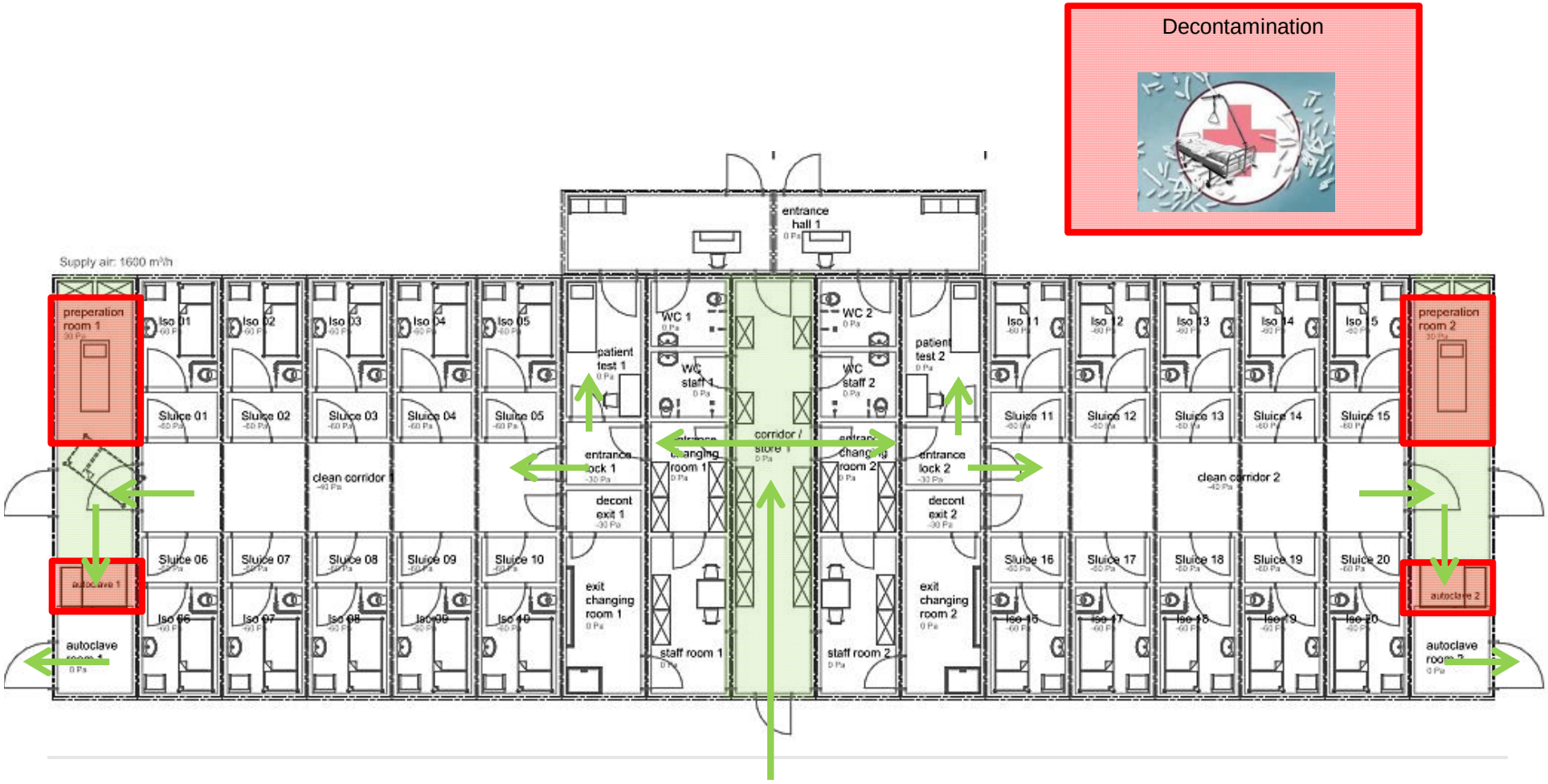
PATHS

Staff


Protection Zone
Supply air: 1600 m³/h
entrance
preperation room 1
Iso 01
Iso 02
Iso 03
Iso 04
Iso 05
patient test 1
WC 1
WC staff 1
WC 2
WC staff 2
patient test 2
Iso 11
Iso 12
Iso 13
Iso 14
Iso 15
preperation room 2
Sluice 01
Sluice 02
Sluice 03
Sluice 04
Sluice 05
Sluice 11
Sluice 12
Sluice 13
Sluice 14
Sluice 15
clean corridor 1
entrance lock 1
entrance changing room 1
corridor /
entrance changing room 2
entrance lock 2
clean corridor 2
decont exit 1
decont exit 2
Sluice 06
Sluice 07
Sluice 08
Sluice 09
Sluice 10
Sluice 16
Sluice 17
Sluice 18
Sluice 19
Sluice 20
autoclave 1
autoclave room 1
staff room 1
staff room 2
autoclave 2
autoclave room 2

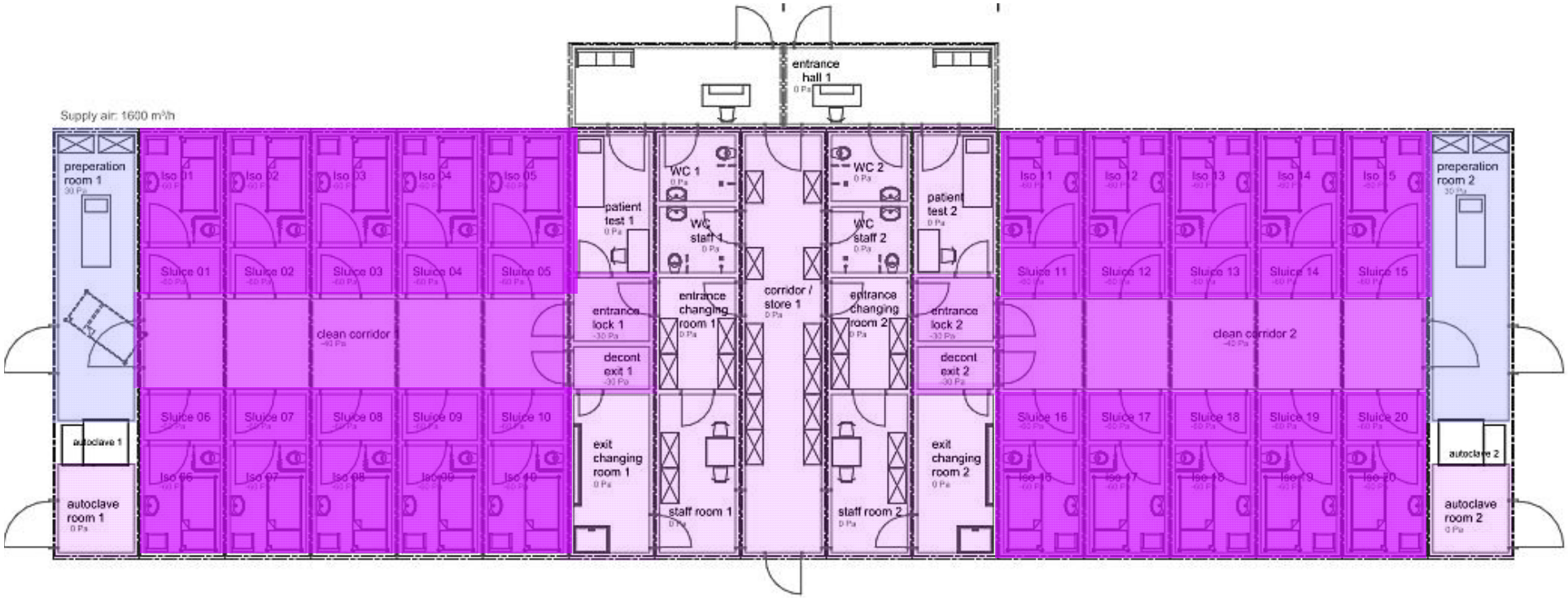
PATHS

Material



PRESSURE RATES

lab area + staff rooms 0 Pa	Entrance lock+decont exit - 30 Pa	clean corrioder - 40 Pa	sluice+isolation room - 60 Pa	preparation room + 30 Pa



Negative Pressure Isolation Rooms

Recommendations of Engineering Control feature for isolation ward with patients with airborne infectious disease

- Use of HEPA-Filter systems in central exhaust air plant
- Sealed rooms, with suitable windows, doors, ceilings etc.
- Ventilation with ≥ 12 ACH (Air change rate)
- Negative air flow situation:
  - Air flows from clean areas to dirty areas
  - Design of ventilation systems avoid secondary air flows
- Room air pressure differences >2.5Pa
- Exhaust ventilation system:
  - Fan unit redundancy design 2x50%
  - HEPA Filter unit redundancy design 6x20%
- Suitable Gastight doors

Best Practice of Ventilation Parameters

- **Ventilation strategy**

  Create and maintain a pressure cascade

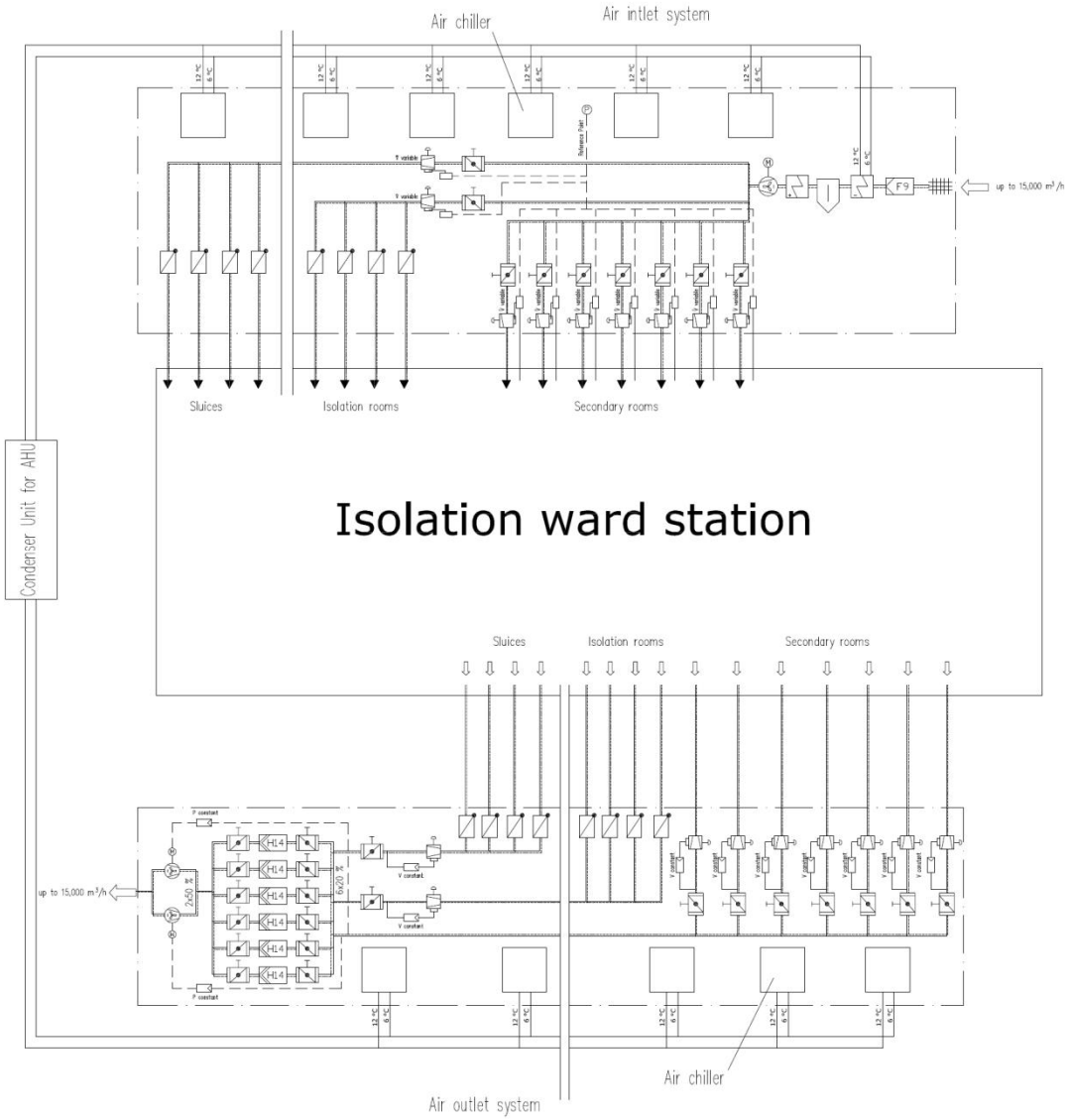
- **Pressure Different between rooms of pressure cascade**

  Pressure differential > 10Pa may not yield significant containment improvement in isolation room

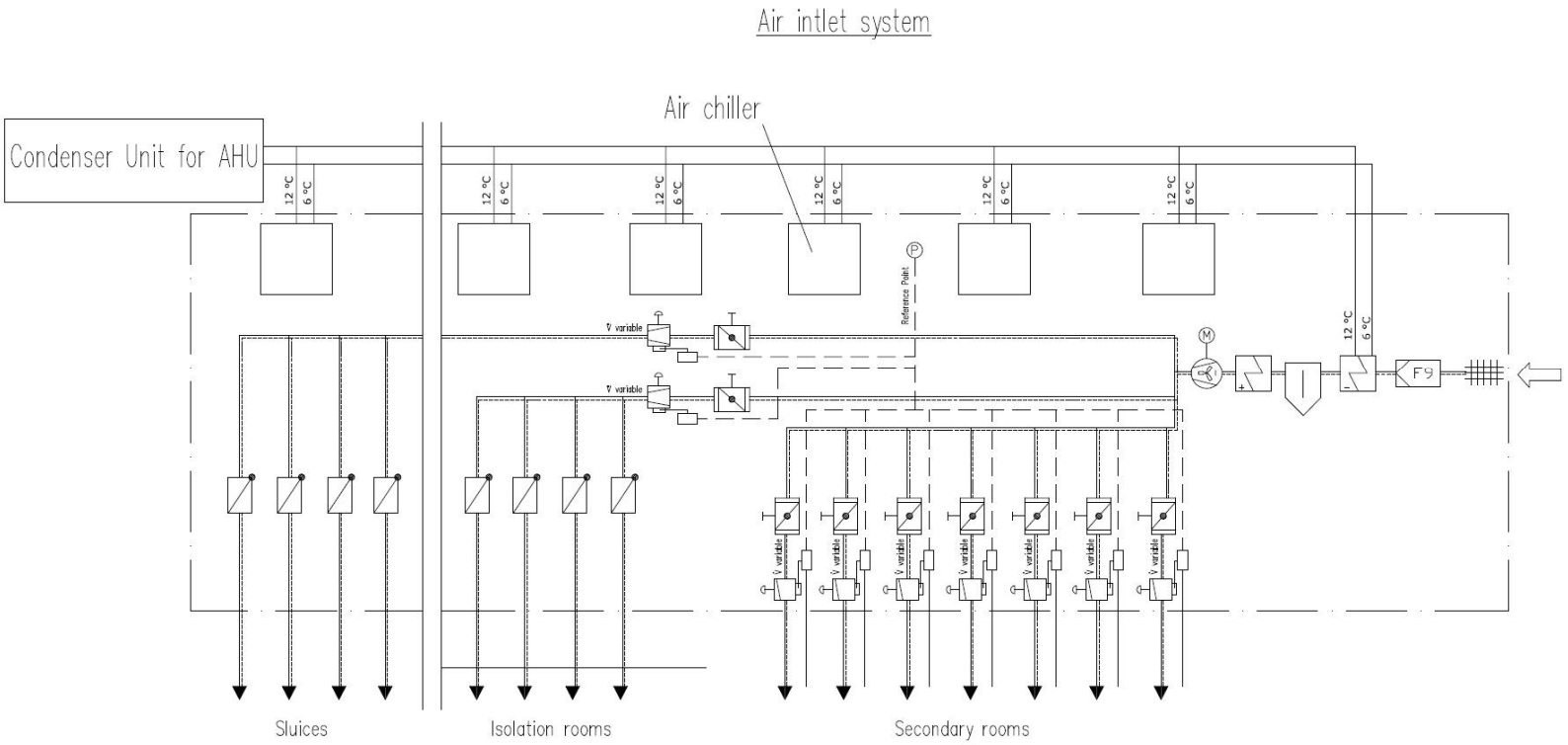
  Higher pressure differential increase turbulence from door opening and reduce level of containment

  The norm chosen 10 – 15 Pa for patient room-anteroom and anteroom corridor

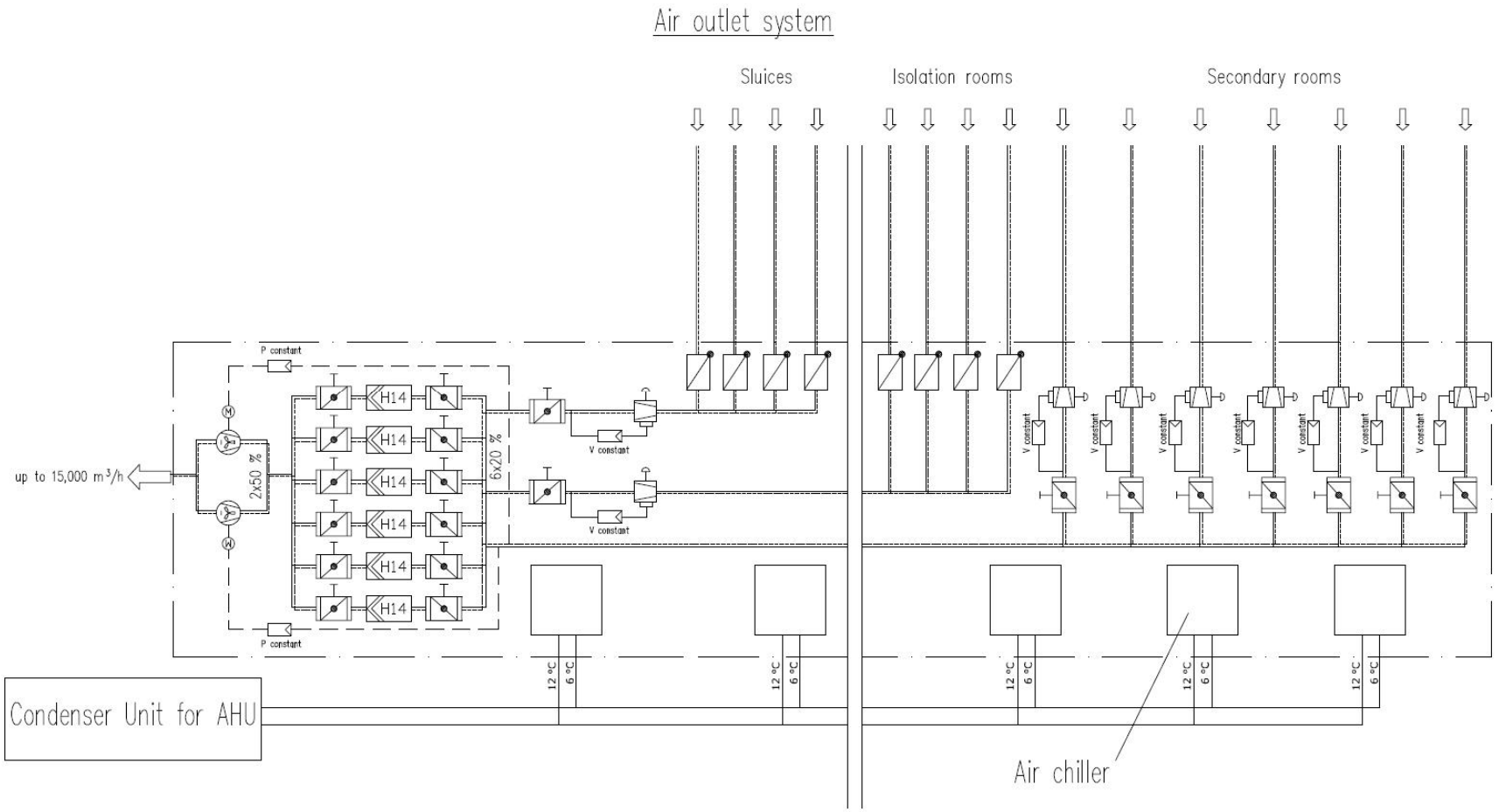
Schematic Air Flow



Schematic Air Flow – Supply Air



Schematic Air Flow – Exhaust Air

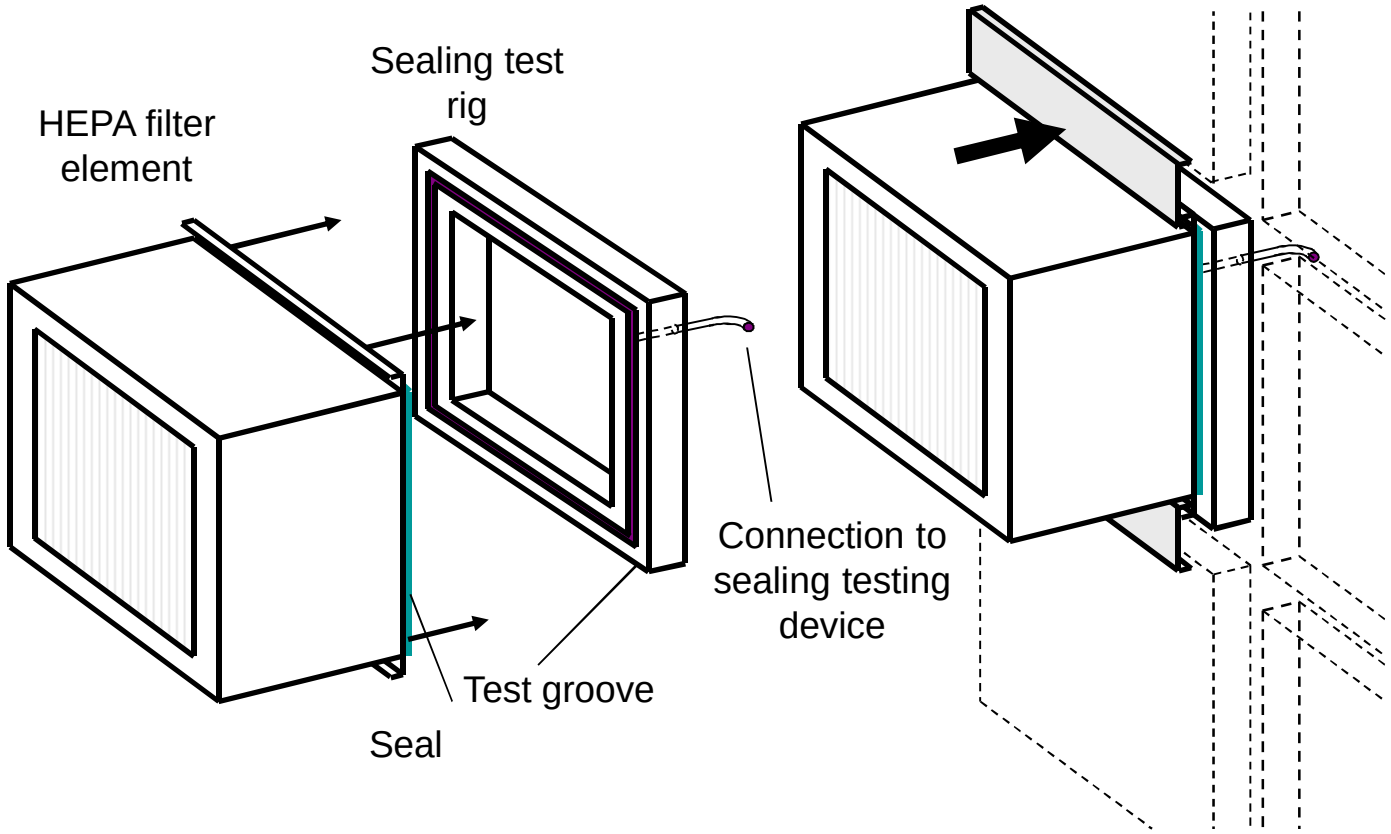


- Background of BSL-3/4 laboratories
- Background Isolation Wards
- **Qualification of HEPA filter qualification according to international rules**
- References

Summary of HEPA filter requirements

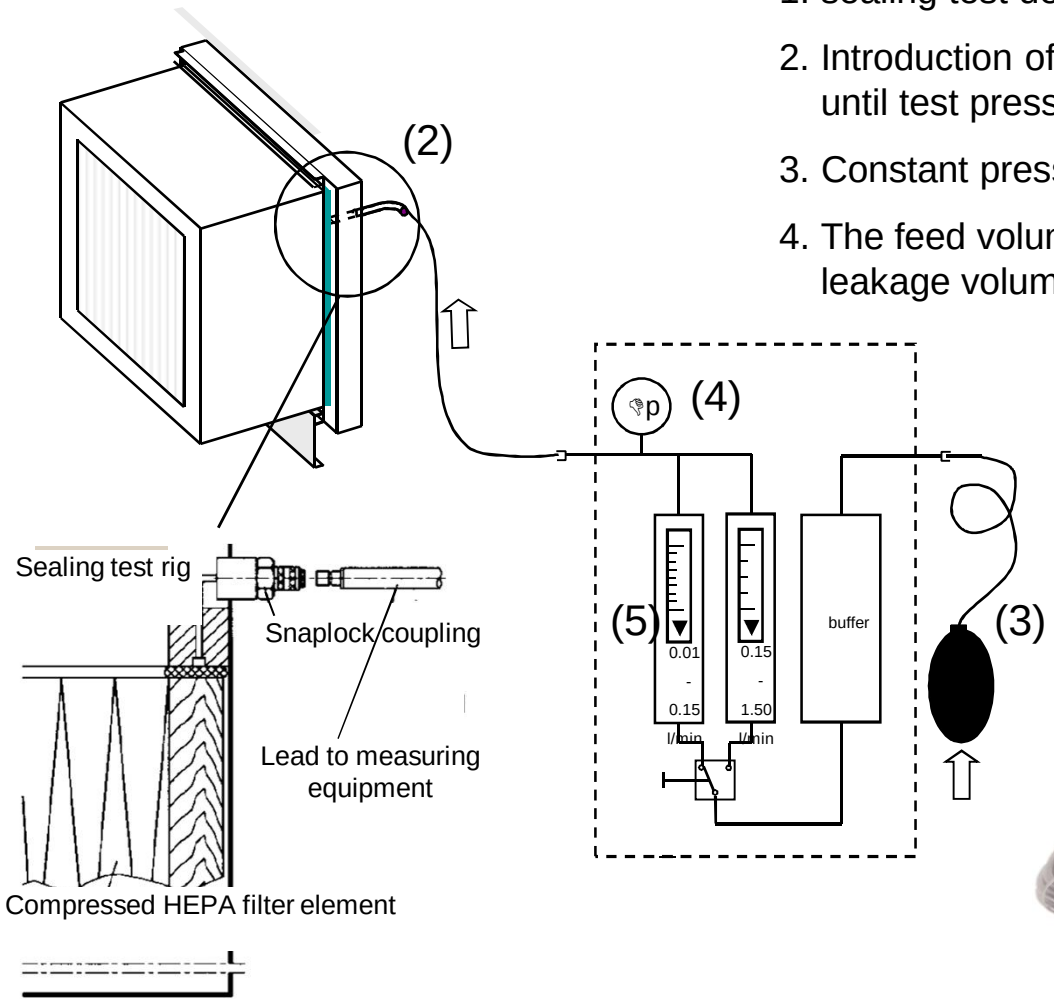
- HEPA filters undergo a **leakage and seating inspection** after installation.
- It must be possible to **inspect HEPA filters as installed** (also series-installed HEPA filters individually). (Scan-Test preferred)
- **Fumigation** with formalin or hydrogen peroxide must be possible.
- **There must be a possibility to exchange HEPA filters with contamination**

Sealing inspection



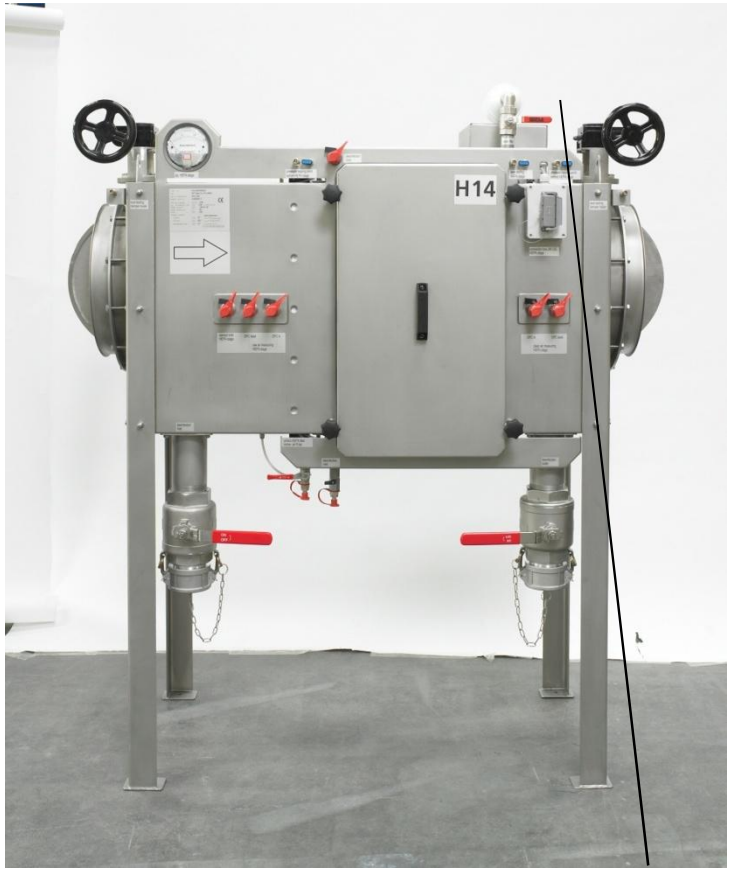
Leak test device type LTD

1. sealing test device (1) connection to a snaplock coupling (2)
2. Introduction of air into test groove via hand pump (3) until test pressure (2,000 Pa) is achieved
3. Constant pressure maintained by continued hand pumping
4. The feed volume flow to maintain constant pressure is the leakage volume flow





Sealing inspection

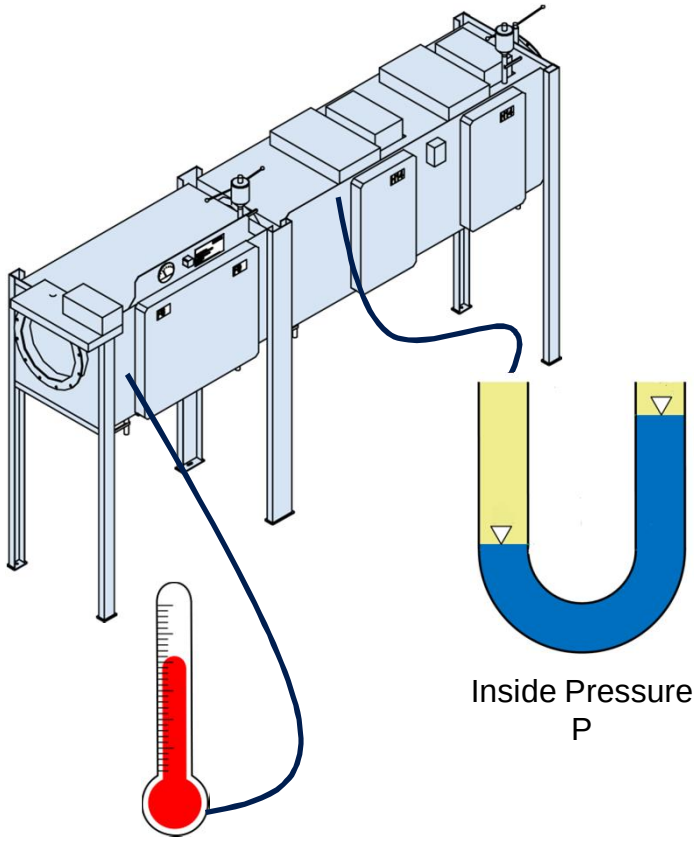


Snaplock coupling for fixing the filter seating sealing



Sealing test device, LTD type

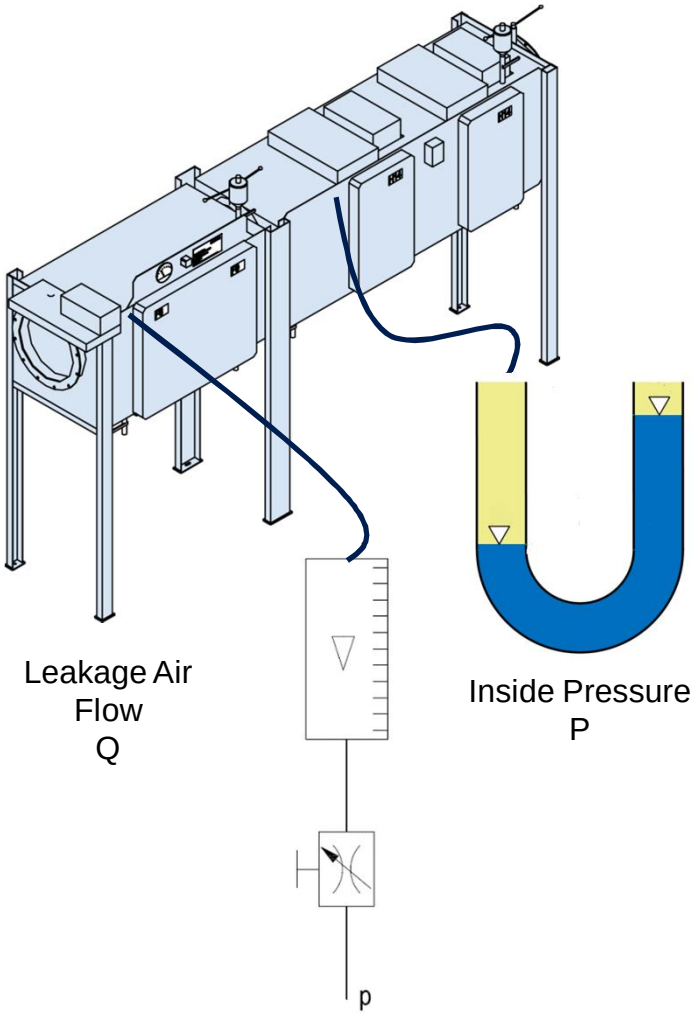
Leak Test by Pressure Decay Method



1. Close Test Object hermetically
2. Inner Volume of Test Object must be known V [m³]
3. Apply initial Pressure P_i [Pa (abs)]
4. Read initial Temperature T_i [K]
5. Wait measuring time Δt [min]
6. Read final Pressure P_f [Pa (abs)]
7. Read final Temperature T_f [K]
8. Calculate Leakage Air Flow Q [l/sec]

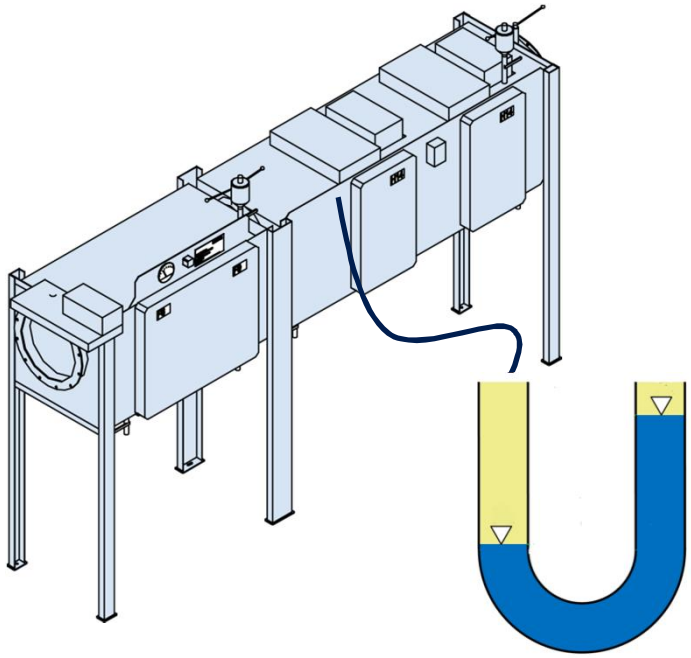
$$Q = \left(\frac{P_i}{T_i} - \frac{P_f}{T_f}\right) \cdot \left(\frac{V}{R \cdot \Delta t \cdot 60 \cdot 1.201}\right)$$

Leak Test by Constant Pressure Method



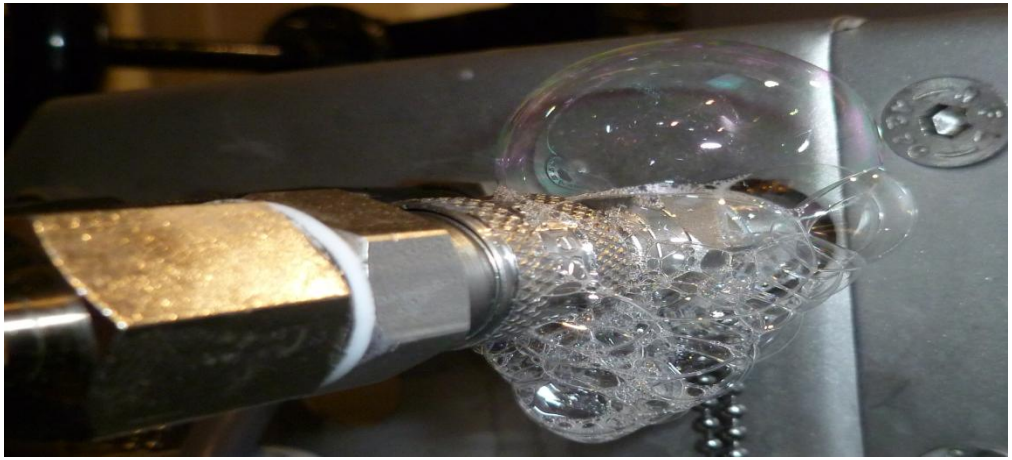
1. Close Test Object hermetically
2. Apply Test Pressure P_t [Pa]
3. Adjust Control Valve to keep Test Pressure constant
4. Wait for System to balance
5. Read Leakage Air Flow directly
6. No further calculation required

Leak Test by Bubble Leak Location Method



Inside Pressure
P

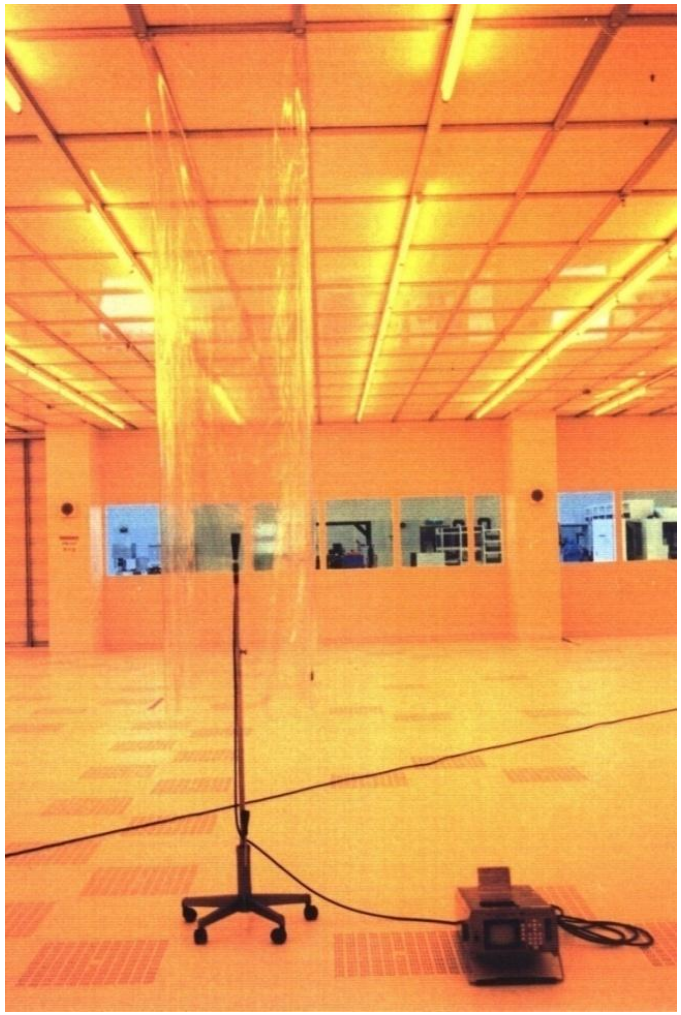
1. Close Test Object hermetically
2. Apply Test Pressure P_t [Pa]
3. Apply foaming Agent
4. Inspect visually for Bubbles
5. Bubbles can be seen
   Leakage Air Flow can **not** be determined



Summary of HEPA filter requirements

- HEPA filters undergo a **leakage and seating inspection** after installation.
- It must be possible to **inspect HEPA filters as installed** (also series-installed HEPA filters individually). (Scan-Test preferred)
- **Fumigation** with formalin or hydrogen peroxide must be possible.
- **There must be a possibility to exchange HEPA filters with contamination**

Filter system SCF | hightec
HEPA filter element testing - background





Filter System SCF | hightec
HEPA filter element testing

DIN EN 1822 (Part 1 to part 5)
Aerosol filter (HEPA and ULPA)

T1: Classification, performance testing, marking

T2: Aerosol production, measuring equipment, particle count statistics

T3: Plane filter medium testing

T4: Filter element leak testing (scan procedure)

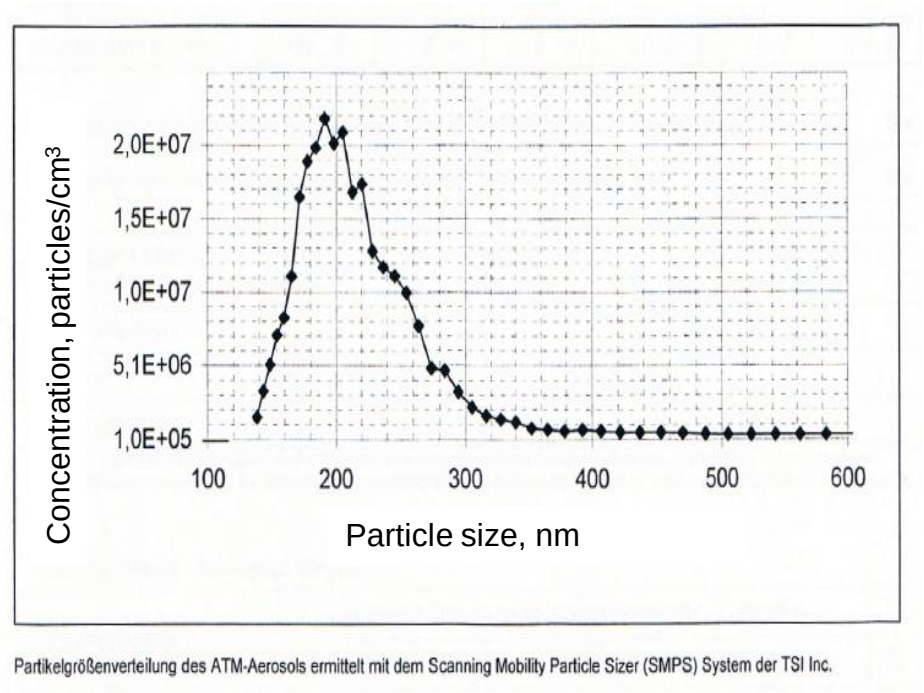
T5: Filter element efficiency testing

Filter System SCF | hightec
HEPA filter element testing

Filter class	Integral value		Local reading	
	Precipitation [%]	Permeability [%]	Precipitation [%]	Permeability [%]
E 10	85	15	-	-
E 11	95	5	-	-
E 12	99.5	0.5	-	-
H 13	99.95	0.05	99.75	0.25
H 14	99.995	0.005	99.975	0.025
U 15	99.9995	0.0005	99.9975	0.0025
U 16	99.99995	0.00005	99.99975	0.00025
U 17	99.999995	0.000005	99.9999	0.0001



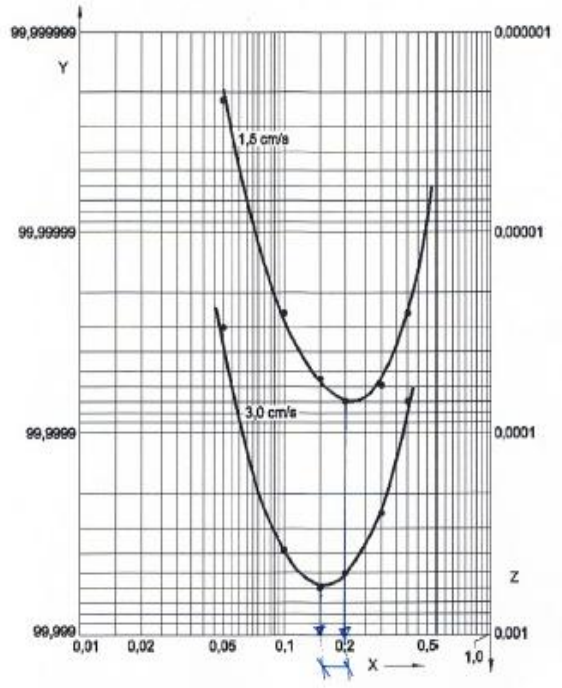
Test aerosol and MPPS



Partikelgrößenverteilung des ATM-Aerosols ermittelt mit dem Scanning Mobility Particle Sizer (SMPS) System der TSI Inc.

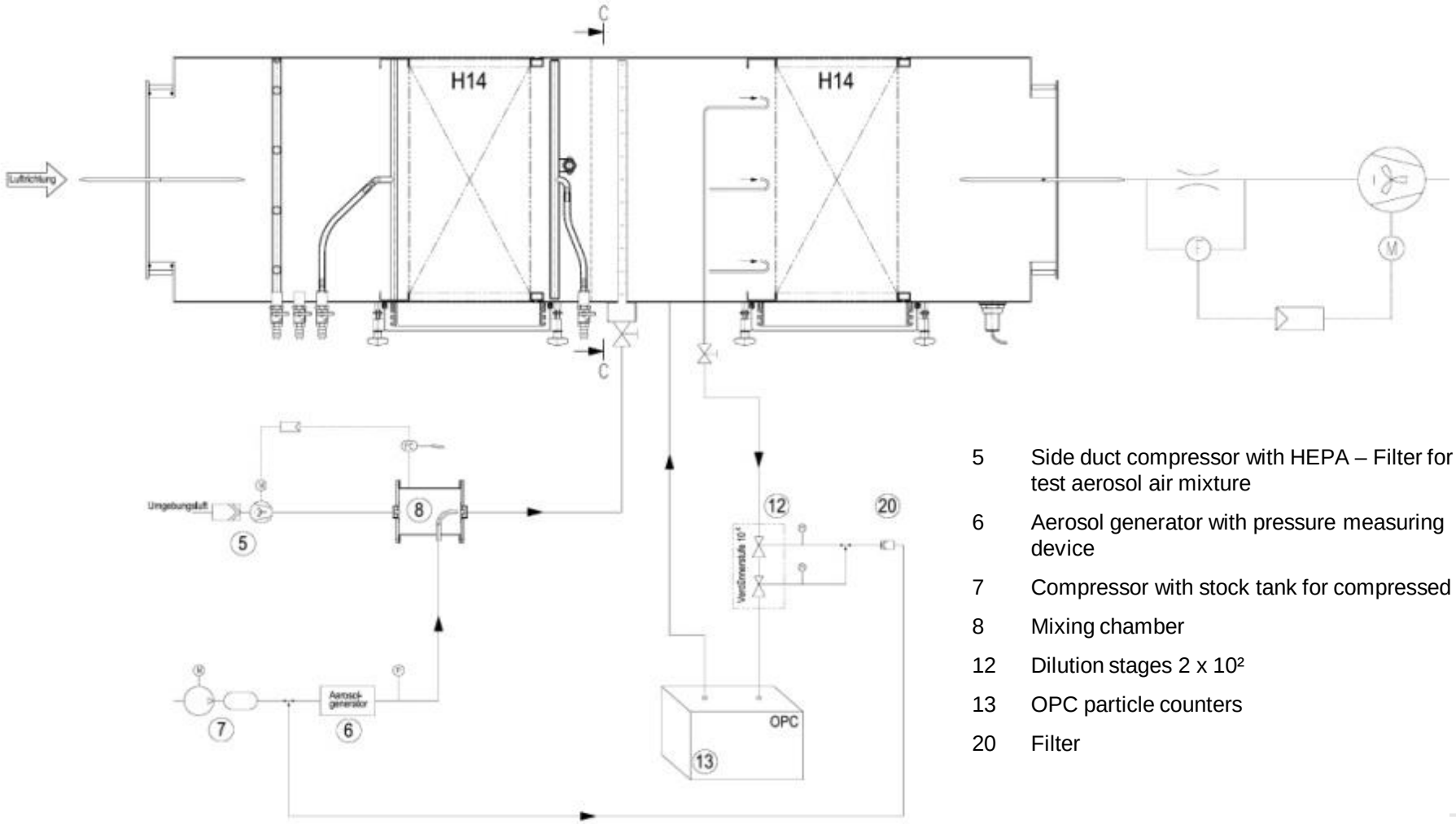
Total DEHS
particle concentration >10^8 particles/cm³

DIN EN 1822-1



Volume flow = 2,000 m³/h = 0.55 m³/s
Filter area = approx. 34 m²
Speed = 0.016 m/s = 1.6 cm/s
MPPS: 0.15 µm – 0.20 µm

Aerosol dispersion setup



5	Side duct compressor with HEPA – Filter for test aerosol air mixture
6	Aerosol generator with pressure measuring device
7	Compressor with stock tank for compressed air
8	Mixing chamber
12	Dilution stages 2 x 10^2
13	OPC particle counters
20	Filter

Setup



Efficiency and leak test measurement: Third party certificate



ZERTIFIKAT ◆ CERTIFICATE ◆ 認證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD Industrie Service

CERTIFICATE

TÜV SÜD Industrie Service GmbH
Business Area Energy und Technology

certificates that the company

Caverion Deutschland GmbH
Krantz Filter Systems and Dampers

has provided the evidence, that the requirements of

EN1822-4, Edition 2009

for the

Scanning equipment Typ SCF Highsc

are fulfilled.

Certificate Nr. Z 8-ET 2214 01 valid until: 2017 07 31

The detailed inspection result are demonstrated in the associated Test-Report Nr. ETAZ_20140701.

Munich, 2014-08-01

Rainer Hero
Head of Business Area
Energy and Technology

Dr. Reinhard Kohl
Head of department
Plant Operations and Safety Analysis

TÜV SÜD Industrie Service GmbH, Energy and Technology, Westendstr. 199, D-80686 München

TÜV

Third party approval certifiate of TÜV Süd (International renounced approval body)

Summary of HEPA filter requirements

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- **There must be a possibility to exchange HEPA filters with contamination**

Advantages and disadvantages of fumigation

Formaldehyde, gaseous	Hydrogen peroxide, gaseous
Recognised, standardised procedures for vegetative bacteria, fungi and viruses (A and B area).	(Still) no universal standard procedure.
For sporicidal activity (C and D area) high temperatures (65°C) and humidity (100%) are required.	Broad spectrum of activity (ABCD area) feasible at room temperature and without high humidity.
Long ventilation periods (days!), complex subsequent cleaning after neutralisation.	Residue-free process without subsequent cleaning.
Toxic, carcinogenic and sensitising potential of the aldehyde (LG 30 ppm, recommended TLV 0.3 ppm).	Harmful to health and/or irritant potential (LG, 75 ppm, recommended TLV 0.5 ppm).
Validation not required at present	High validation effort.
Permission must be sought from competent authority in each case (TRGS 522).	Not required
Potentially damaging effect on electronic components and devices.	For highly porous surfaces, catalytic and adsorbent materials are suitable only in certain conditions. Good compatibility with electrical and electronics systems.
Relatively simple equipment with low level of automation.	Higher costs of the systems due to a high level of automation

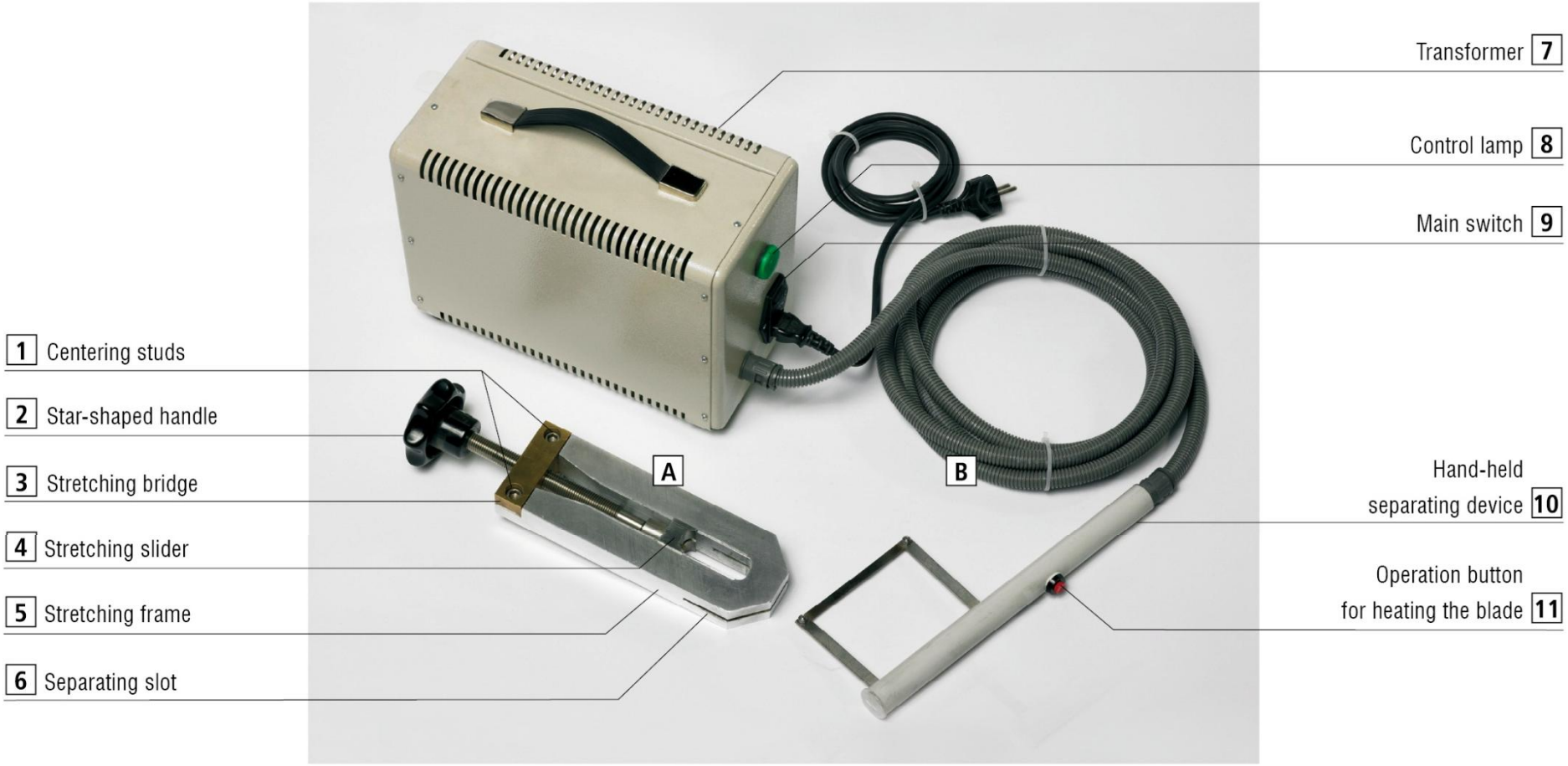
Setup



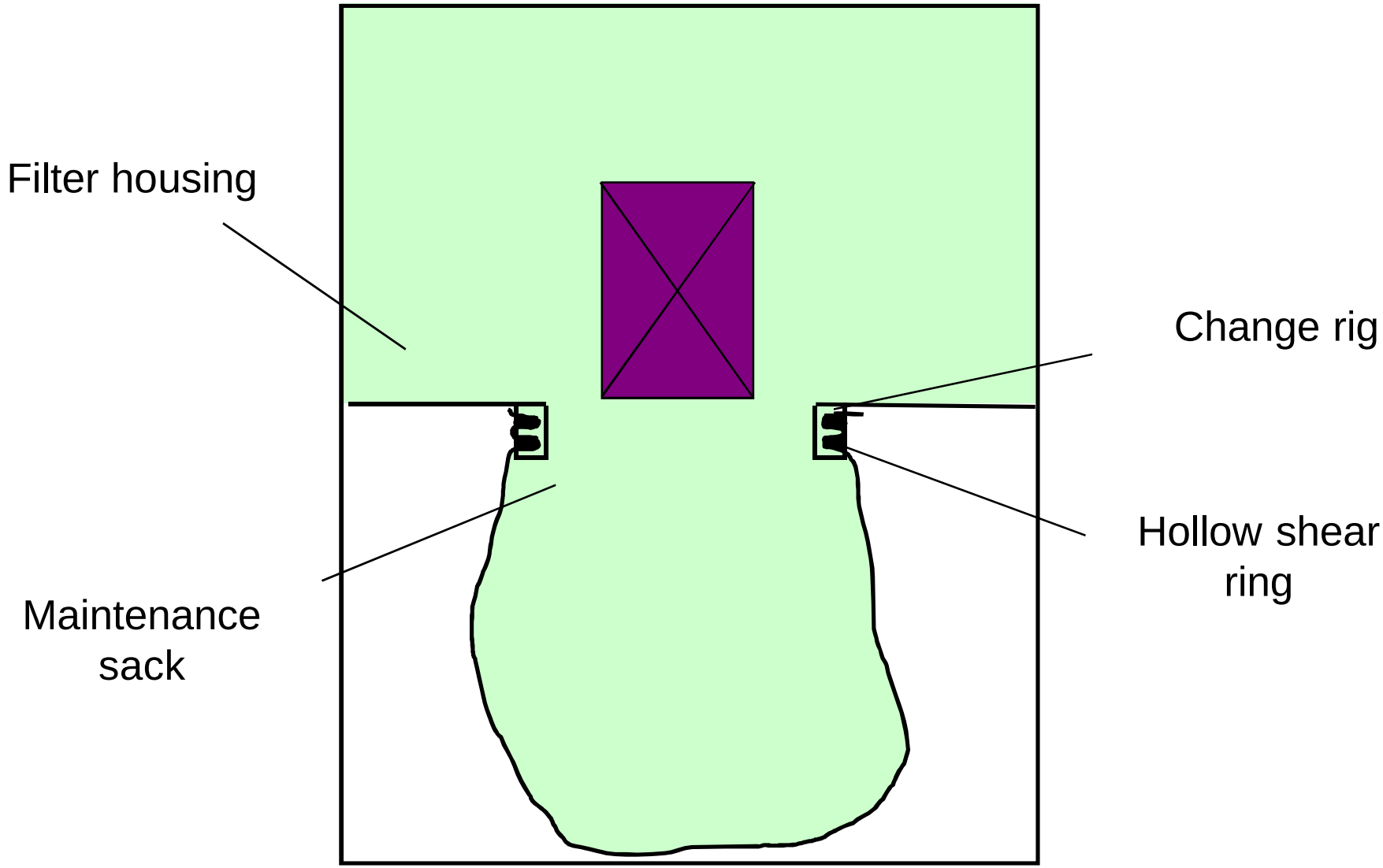
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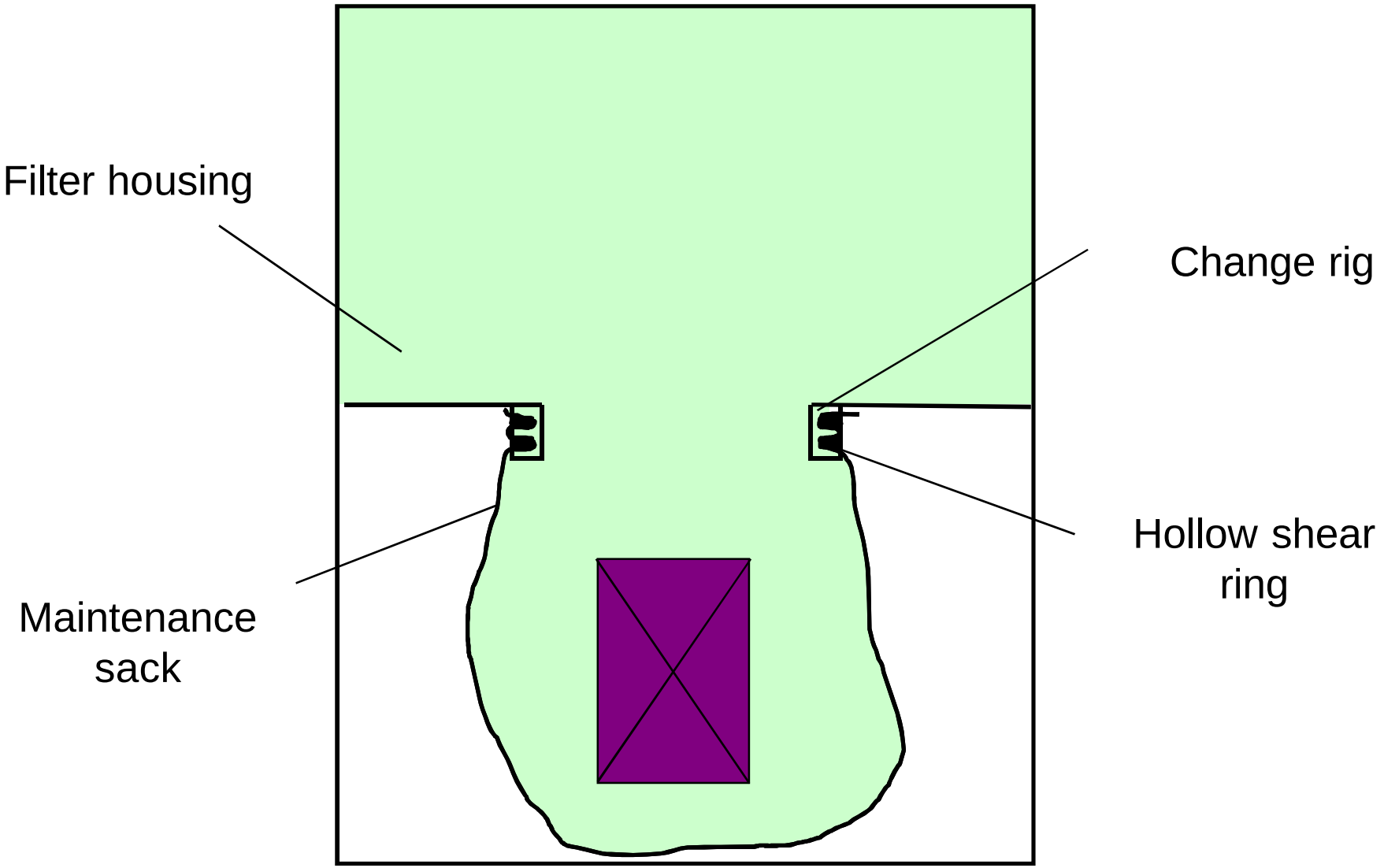
Filter system SCF | hightec: contamination-free filter change



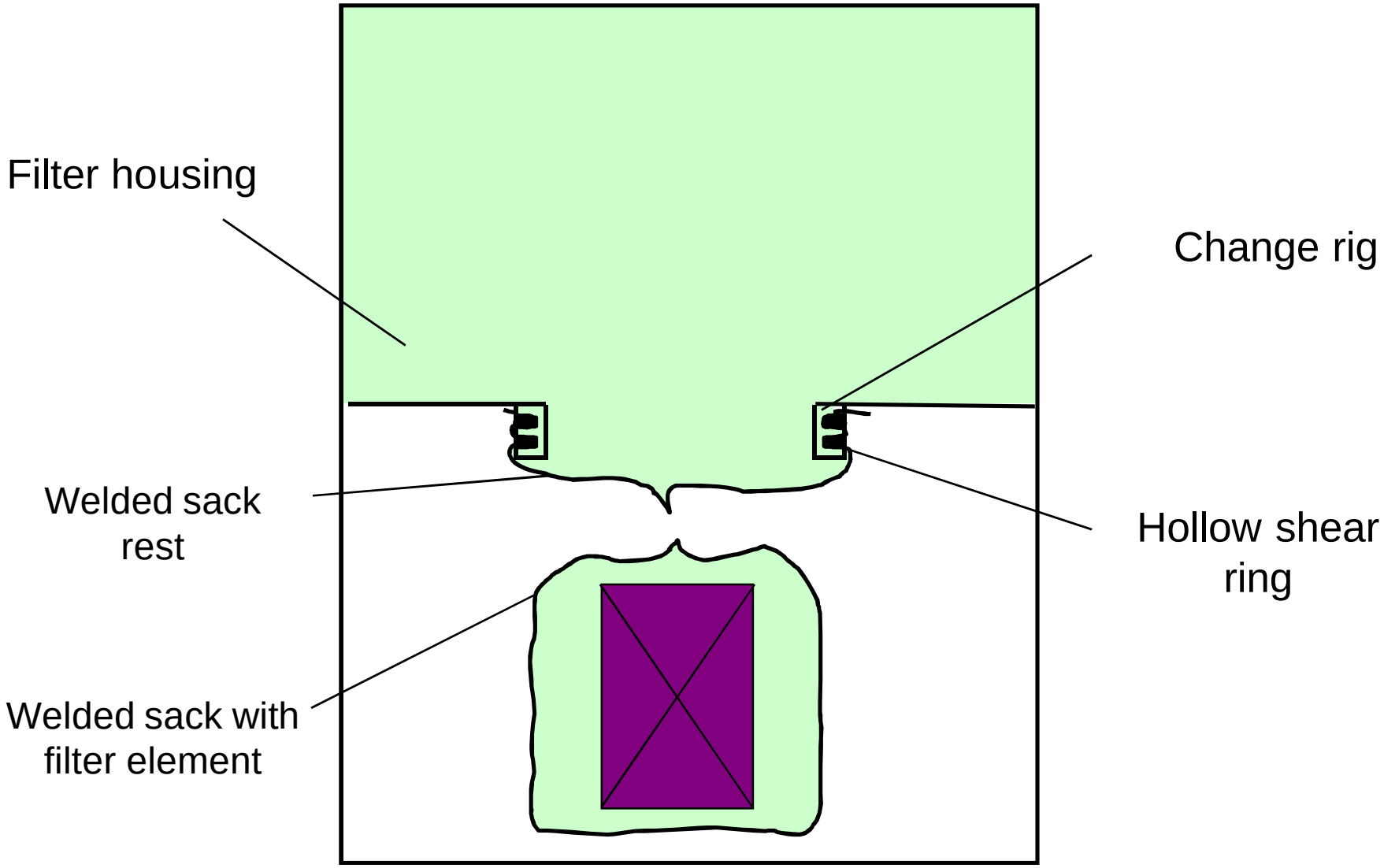
Filter system SCF | hightec: contamination-free filter change



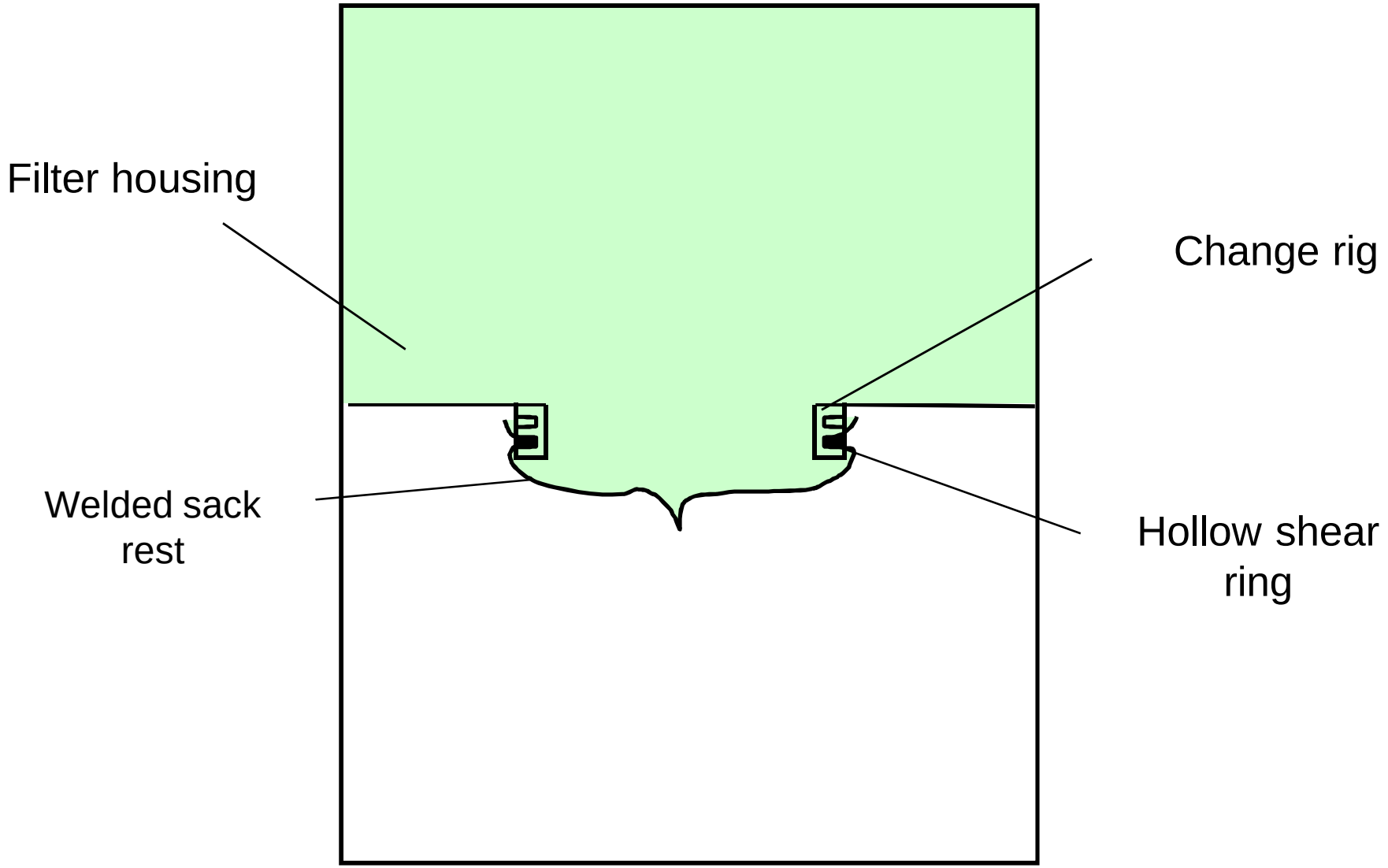
Filter system SCF | hightec: contamination-free filter change



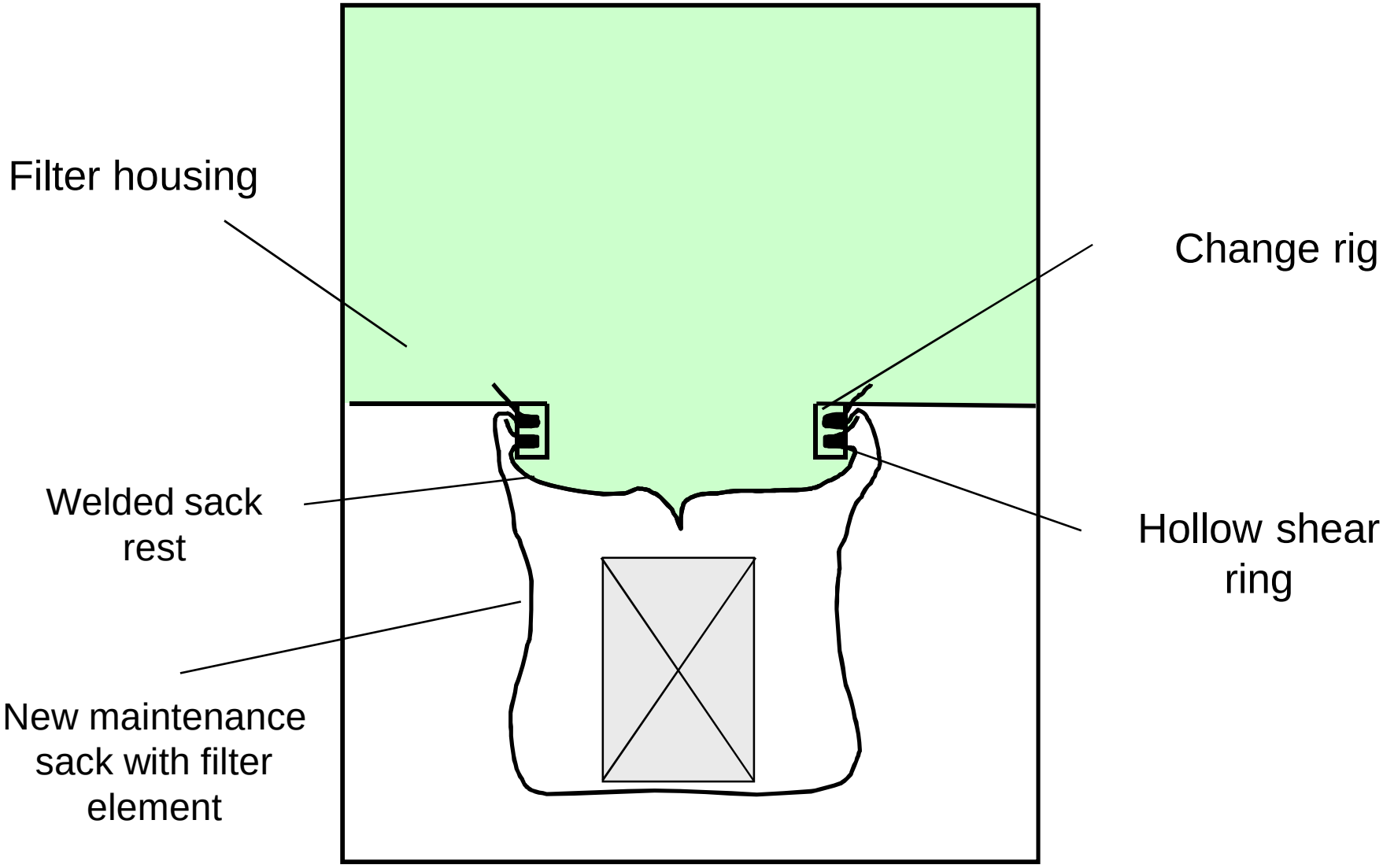
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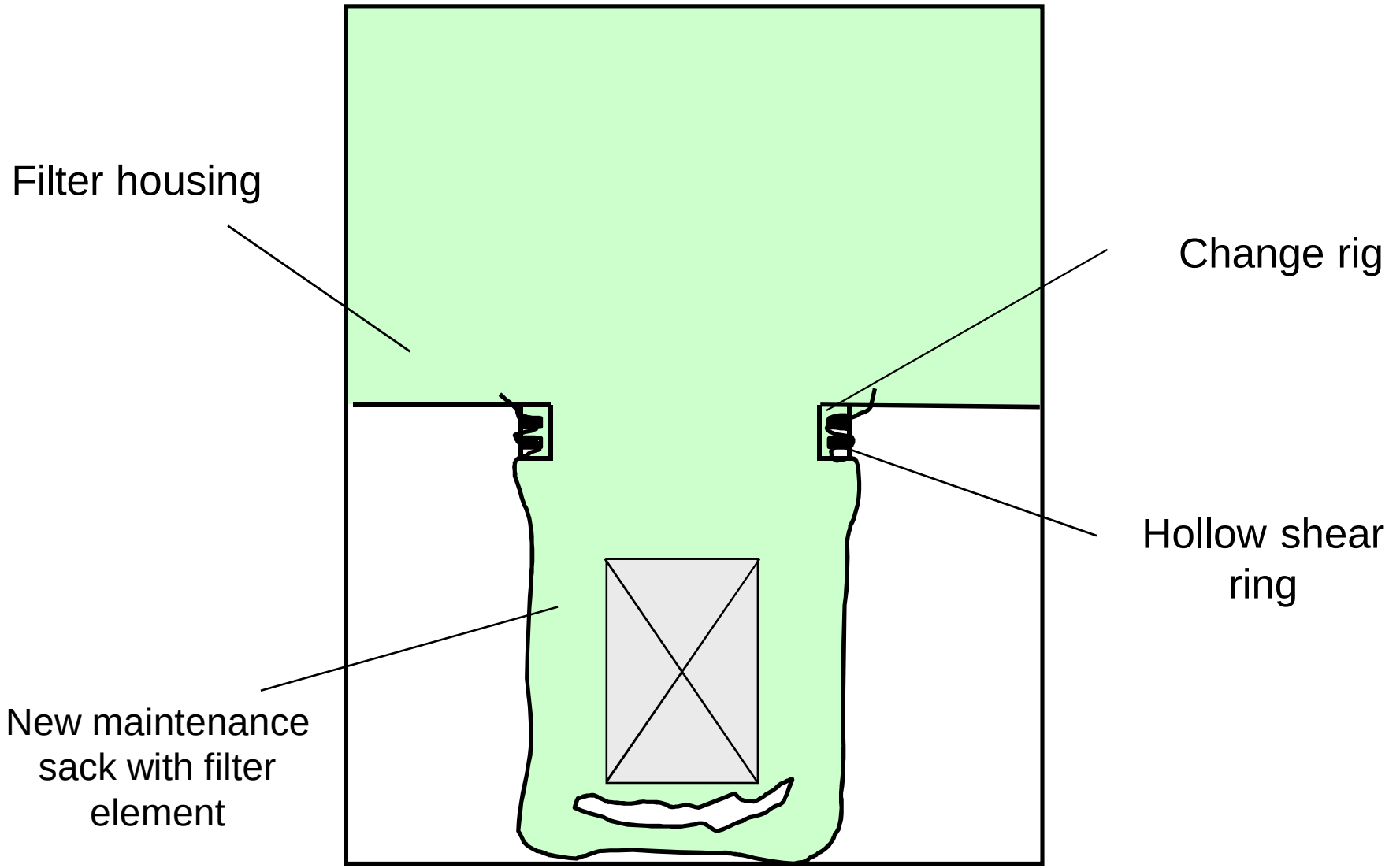
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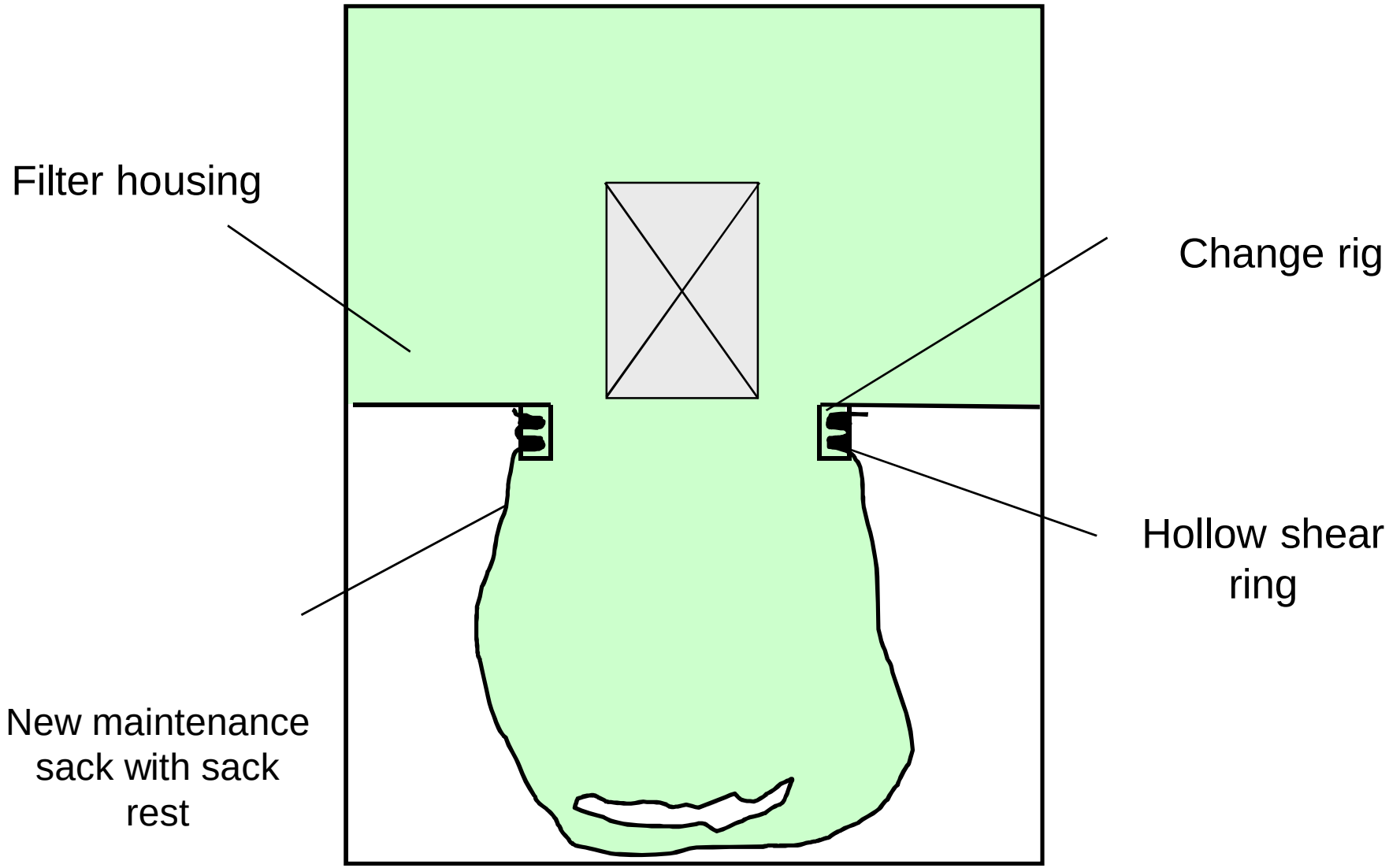
Filter system SCF | hightec: contamination-free filter change



Filter system SCF | hightec: contamination-free filter change



Filter system SCF | hightec: contamination-free filter change



Filter system SCF | hightec: contamination-free filter change





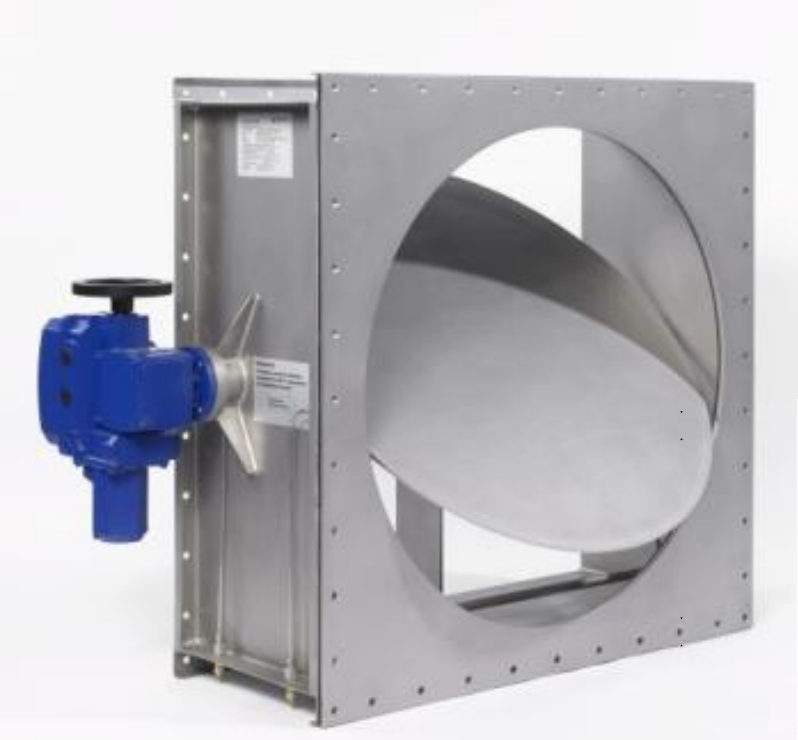


Filter system SCF | hightec: contamination-free filter change



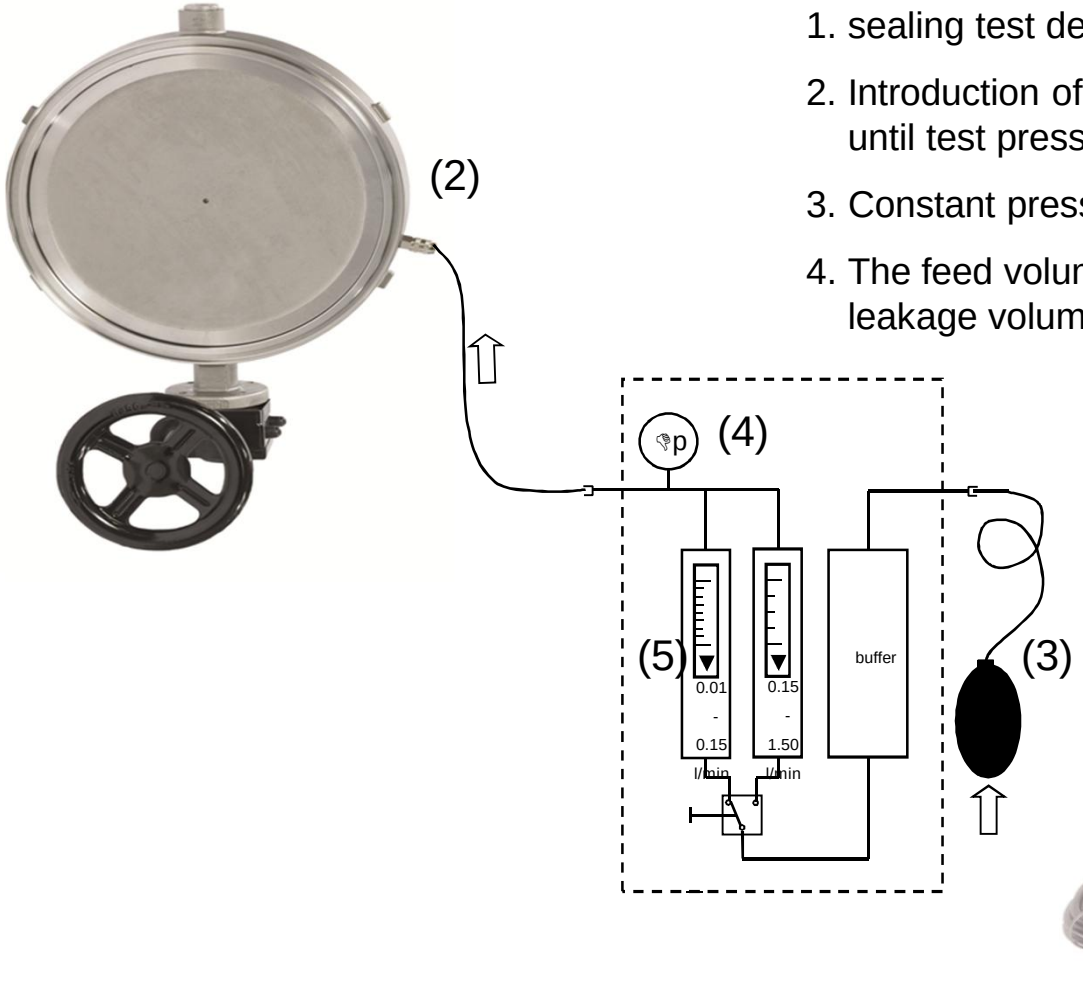


Gastight damper type GD-R and GD-C





Leak test device type LTD



1. sealing test device (1) connection to a snaplock coupling (2)
2. Introduction of air into test groove via hand pump (3) until test pressure (2,000 Pa) is achieved
3. Constant pressure maintained by continued hand pumping
4. The feed volume flow to maintain constant pressure is the leakage volume flow



Gastight rectangular shut-off damper type GD-R

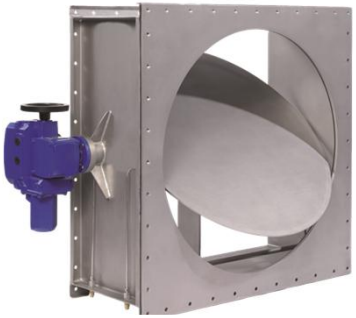
Shaft turn 0° : damper blade closed and clamped by toggle lever mechansim (without auxiliary energy)



Shaft turn 60° : first damper blade is pulled back linearly ➔no transverse loading of sealing



Shaft turn 120°: damper blade goes over to a tilt movement



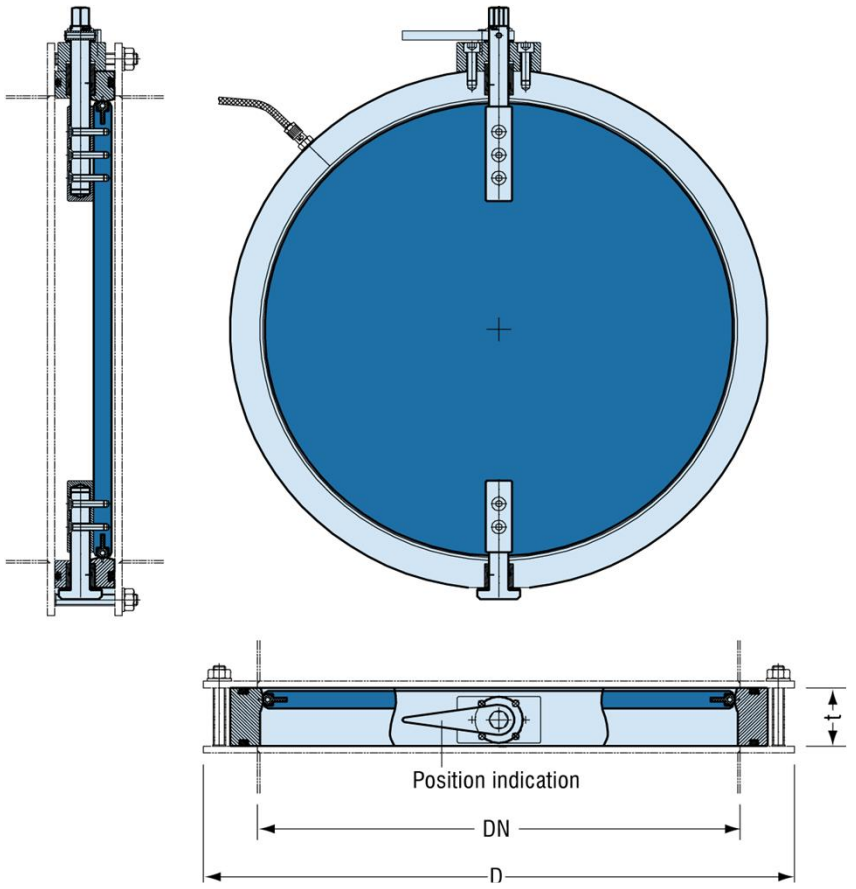
Shaft turn 180° : Damper blade opened completely and clamped by toggle lever mechanism



- „gastight“ acc. DIN 25 496: leakage max. 10 l / (h x m²) at 1 bar, 20 °C and Δp = 2,000 Pa
- with surrounding proofnut for tightness test

Gastight circular shut-off damper, type GD-C





- „gastight“ acc. DIN 25 496: leakage max. 10 l / (h x m²) at 1 bar, 20 °C and Δp = 2,000 Pa
- with surrounding proofnut for tightness test

- Background of BSL-3/4 laboratories
- Background Isolation Wards
- Qualification of HEPA filter qualification according to international rules
- References

References





Public Health Laboratory, Hong Kong
BSL-3 Laboratory

References

National Public Healthcare Laboratory
Vilnius, Litauen
BSL3 Labor





References

Bernhard - Nocht - Institute, Hamburg, Germany

class 2, 3 and 4 labs.	2,800 m²
class 4 containment	130 m²
Animal and system rooms, etc.	2.400 m²





Bernhard-Nocht-Institute (BNI), Hamburg



HEPA filter system - replacement laboratory



HEPA filter system - main laboratory

References

Marburg University, Germany
class 4 Lab: 170 m²
Operational since December 2007





Class 4 laboratory – University of Marburg





References

Friedrich – Loeffler – Institute, Isle of Riems, Germany
BSL3 / BSL4 laboratory





References

Institute for Animal Health, Pirbright, UK
BSL3 / BSL4 laboratory





References



Rijksinstituut voor Volksgezondheid
en Milieu
Ministerie van Volksgezondheid,
Welzijn en Sport

rivm
onderzoek in dienst
van mens en milieu

RIVM, Bilthoven, The Netherlands
BSL3 / BSL4 laboratory



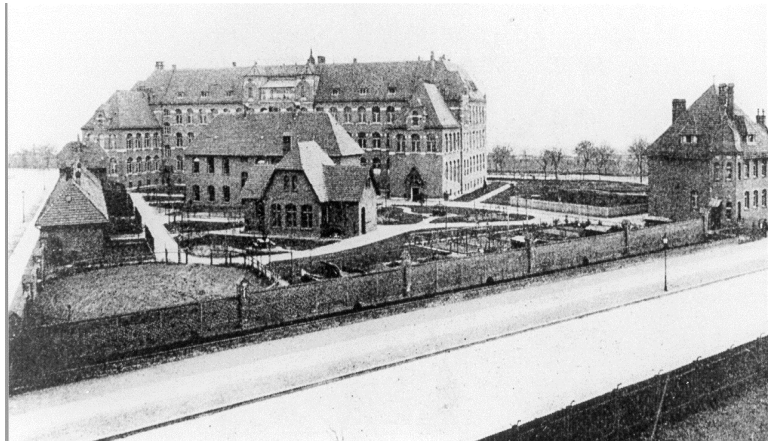
rivm
Rijksinstituut voor
Volksgezondheid en Milieu

Quelle Photos:
RIVM
RT Architekten

References

ROBERT KOCH INSTITUT

Robert-Koch-Institute, Berlin, Germany
BSL3 / BSL4 laboratory





Quelle Photos:
Robert-Koch-Institut
Henn Architekten

References

Kansas State University,
Manhattan KS, USA





References

Kunming Institute of Zoology, PR China,
Gastight doors





References

Lanzhou Veterinary Research Institute (LVRI, CAAS),
P.R. China,





A trademark of Caverion