ITALIAN FILTER TESTING WORKSHOP 2022

RESPIRATORY PROTECTION TESTING ACCORDING TO EUROPEAN AND INTERNATIONAL STANDARDS

Martin Schmidt (Division Manager I&S)

PALAS®

Agenda

01 Introduction

02 Product Line

03 Technical Overview

04 In Comparison EN 149 and 42 CFR 84

05 Applications & Benefits

06 Conclusion

1

Introduction

Introduction

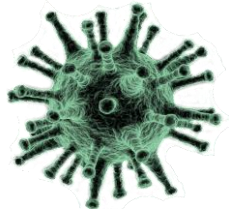
The Main Topic of Today for Everyone: Our Health and Covid-19

What can we do?

- Protect ourselves and the people around us from viruses which are spread out

- The most discussed item for this protection is right now the face mask or protective mask

- To ensure the effect of protection of a face mask, the defined and comparable test of efficiency is necessary!



Size: 120 nm up to 180 nm

2

Product Line

PMFT 1000 and PMFT 1000 M

Extension to Particle Filter Testing for Personal Protection Equipment Is Completing the Range

PMFT System

Face masks

Filter media

Filters for respiratory protective devices (half-mask or full facepieces)

PMFT 1000 F

PMFT System: Benefits in Mask Testing

- World's only system to test penetration by mass and efficiency by particle size based on EN 13274-7, EN 149, 42 CFR 84, ASTM 3502, GB 2626, EN 143, ISO 16900-3 **and** ASTM 2299-3, CWA 17553, SNR 30000 and others in one test system
- Salt and oil aerosol penetration measurement available in one test system
- The **PMFT System** maybe used for face masks (different mask holders available), filter cartridges for full face masks and flat sheet material
- Simulation of inhalation and exhalation breath resistance test procedure as well as valve test procedure included
- Excellent comparability in test results to reference institutes as TÜV Nord and green line media by NIOSH

PMFT System

3

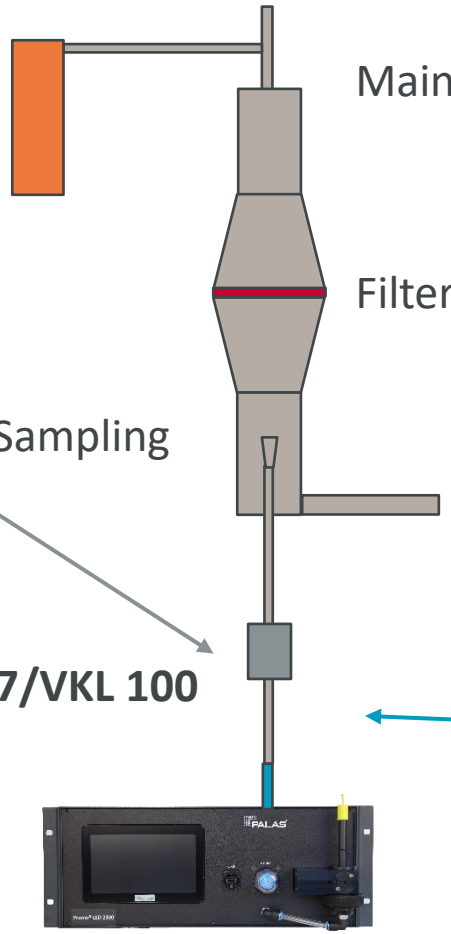
Technical Overview

PMFT System: Overview

- Two aerosol generators **PLG 1000** for salt and oil aerosol penetration incl. automatic control of air flow
- Computer control incl. **PMFT** firmware for different measurement procedures as penetration test, exposition test and breath resistance based on the various standards
- Predefined standard test procedures as well as individual test parameters are possible
- Filter holder **PMFT** with air flow control and safety door. Safe pneumatically controlled opening and closing of the duct for quick sample exchange
- Dilution system **VKL 100** (**PMFT 1000**) and **VKL 27** (1 x in **PMFT 1000 M**, 2 x in **PMFT 1000 F**) for best statistical data evaluation
- **PMFT 1000**: Detection of penetration with highly precise aerosol photometer **Promo® 1000**
- **PMFT 1000 M and F**: Detection of penetration with highly precise aerosol photometer **Promo® LED 2300**

PMFT 1000 and PMFT 1000 M Specifics

Integration of 2 x VKL 27 Allows Penetration Measurement up to 99.95 % Efficiency



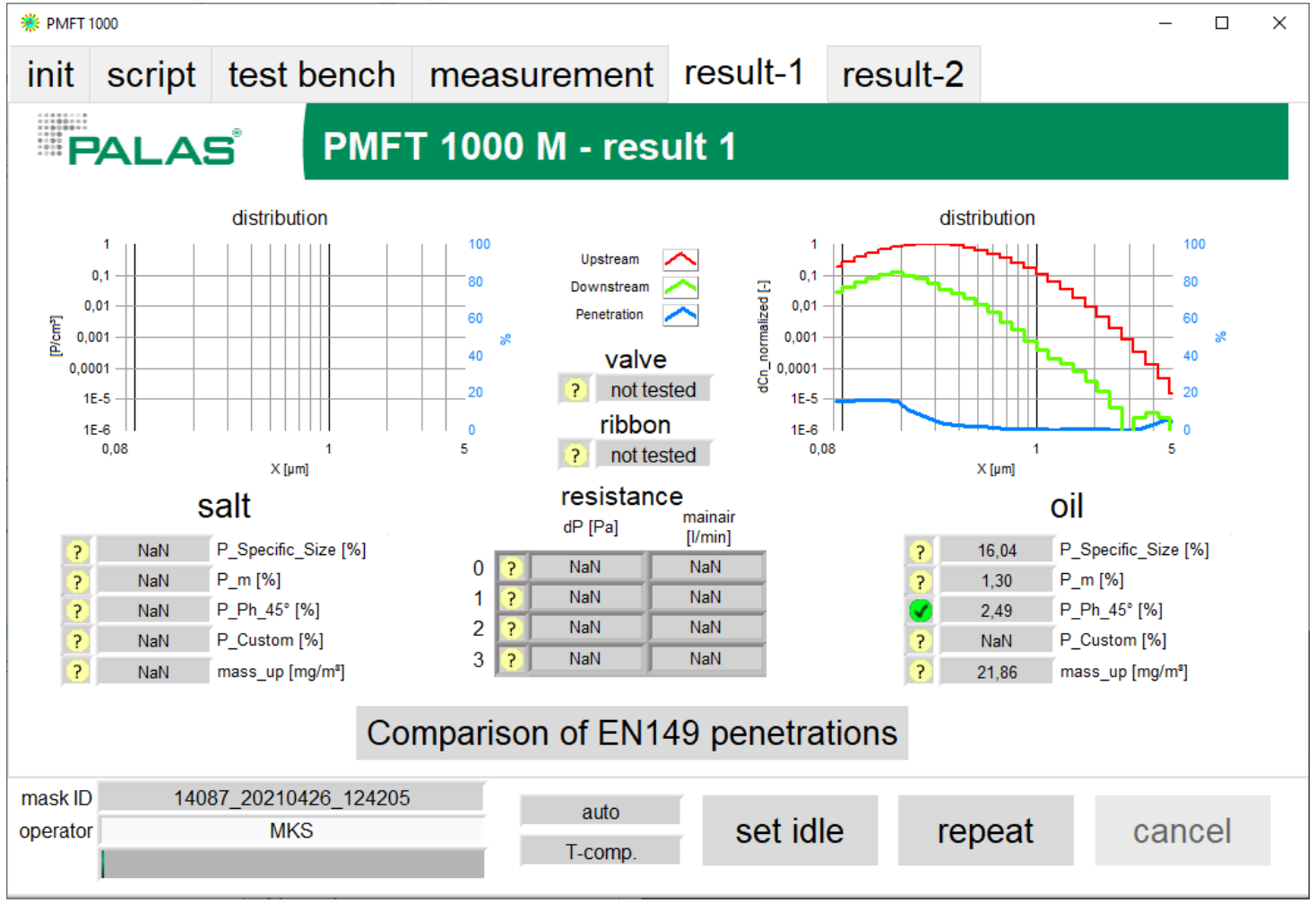
1. Upstream measurement with high concentration: two **VKL 27** for dilution factor > 700

2. Downstream measurement with low concentration: no dilution

Promo® LED 2000 /
Promo® 1000

Usual Penetration Result

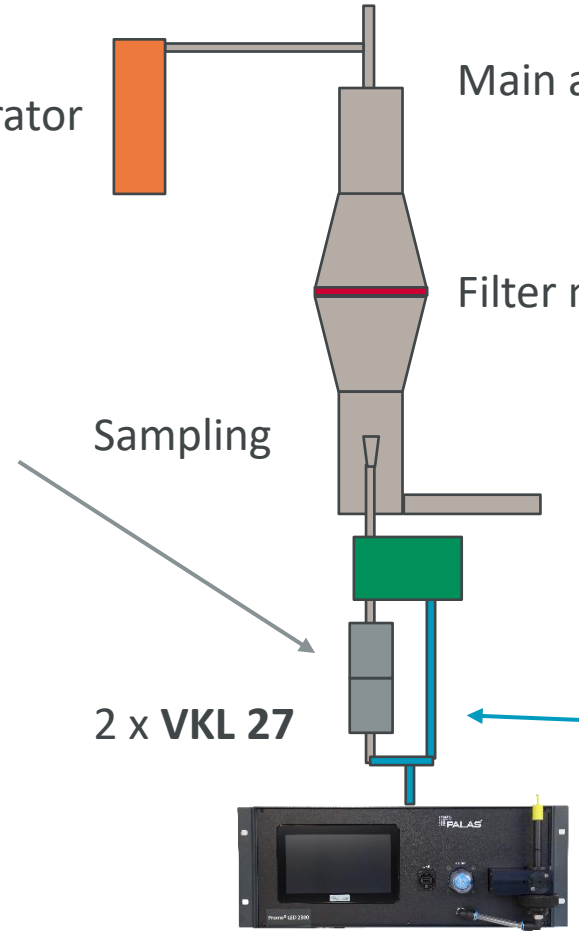
PMFT Result Screen



- Usual penetration result is just one overall penetration
- Additionally on display:
  - Upstream distribution
  - Downstream distribution
  - Penetration curve by particle size

PMFT 1000 F Specifics

Integration of 2 x VKL 27 and Switch-Over Box Allows Penetration Measurement up to 99.9995 % Efficiency



1. Upstream measurement with high concentration: two **VKL 27** for dilution factor > 700

2. Downstream measurement with low concentration: no dilution

Applicable Standards for Face Mask Penetration Testing

	EN 13274-7 (EN 149)		GB 2626		42 CFR 84	
Aerosol	NaCl	PaO	NaCl	PaO/DOP	NaCl	DOP
Mean diameter	0.06 – 0.1 µm	0.29 – 0.45 µm	0.055 – 0.095 µm	0.165 – 0.205 µm	0.055 – 0.095 µm	0.165 – 0.205 µm
Standard deviation	2 – 3	1.6 – 2.2	< 1.86*	< 1.6*	< 1.86*	< 1.6*
Concentration	4 – 12 mg/m³	15 – 25 mg/m³	< 200 mg/m³	50 – 200 mg/m³	< 200 mg/m³	< 200 mg/m³
Discharge	–	–	Required	Required	Required	Required
Air flow	95 l/min	95 l/min	85 l/min ±4 l/min	85 l/min ±4 l/min	85 l/min ±4 l/min	85 l/min ±4,25 l/min
Measurement device	Sodium flame photometer	Light scattering photometer	Particle detector	Particle detector	Light scattering photometer	Light scattering photometer
Measuring time	30 s	30 s	Lowest eff. during loading	Lowest eff. during loading	Lowest eff. during loading	Lowest eff. during loading
Pause time	180 s	180 s	Lowest eff. during loading	Lowest eff. during loading	Lowest eff. during loading	Lowest eff. during loading
Exposition	120 mg	120 mg	200 mg ±5 mg	200 mg ±5 mg	200 mg ±5 mg	200 mg ±5 mg
PMFT Remarks	✓	✓	✓ with upgrade kit	✓ with upgrade kit	✓ with upgrade kit	✓ with upgrade kit

*by additional software module

Applicable Standards for Full Mask Filter Penetration Testing

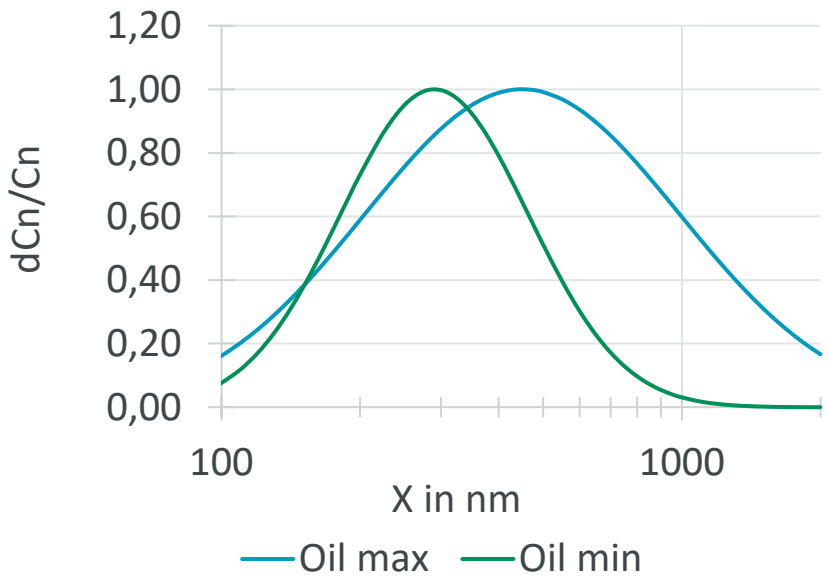
	ISO 16900-3		EN 143		NIOSH 42 CFR 84	
Aerosol	NaCl	PaO	NaCl	PaO	NaCl	DOP
Mean diameter	0.06 – 0,1 µm	0.16 – 0.21 µm	Approx. 0.06 µm	Approx. 0.16 µm	0.075 ± 0.020 µm	0.185 ± 0.020 µm
Standard deviation	1.4 – 1.8	1.4 – 1.8	Approx. 1.9	Approx. 2	< 1.86	< 1.60
Concentration	8 - 35 mg/m³	15 - 35 mg/m³	4 - 12 mg/m³	15 - 35 mg/m³		
Discharge	**Required**	–	**Required**	–	**Required**	–
Min. efficiency			P1: 80 %, P2: 94 %, P3: 99.5 %		P100/R100/N100: 99.97%, P99/R99/N99: 99%, P95/R95/N95: 95%	
Air flow	To be defined	To be defined	95 l/min	95 l/min	85 ± 4 l/min	85 ± 4 l/min
Temperature	22°C ± 3°C	24°C ± 8°C	22°C ± 3°C	24°C ± 8°C	25 ± 5°C	25°C ± 5°C
Rel. humidity	< 40 %	20 – 80 %	< 40 %	20 – 80 %	30 ± 10 %	30 ± 10 %
Measurement device	Sodium flame photometer*	Forward light scattering photometer 45°	Sodium flame photometer*	Forward light scattering photometer 45°	Forward light scattering photometer	Forward light scattering photometer
Measuring time	30 s	30 s	30 s	30 s	lowest eff. during loading	lowest eff. during loading
Pause time	180 s	180 s	180 s	180 s		
Exposition	150 mg	150 mg	120 mg	120 mg	< 200 mg	< 200 mg
PMFT remarks	✓	✓	✓	✓	✓	✓

*by additional software module

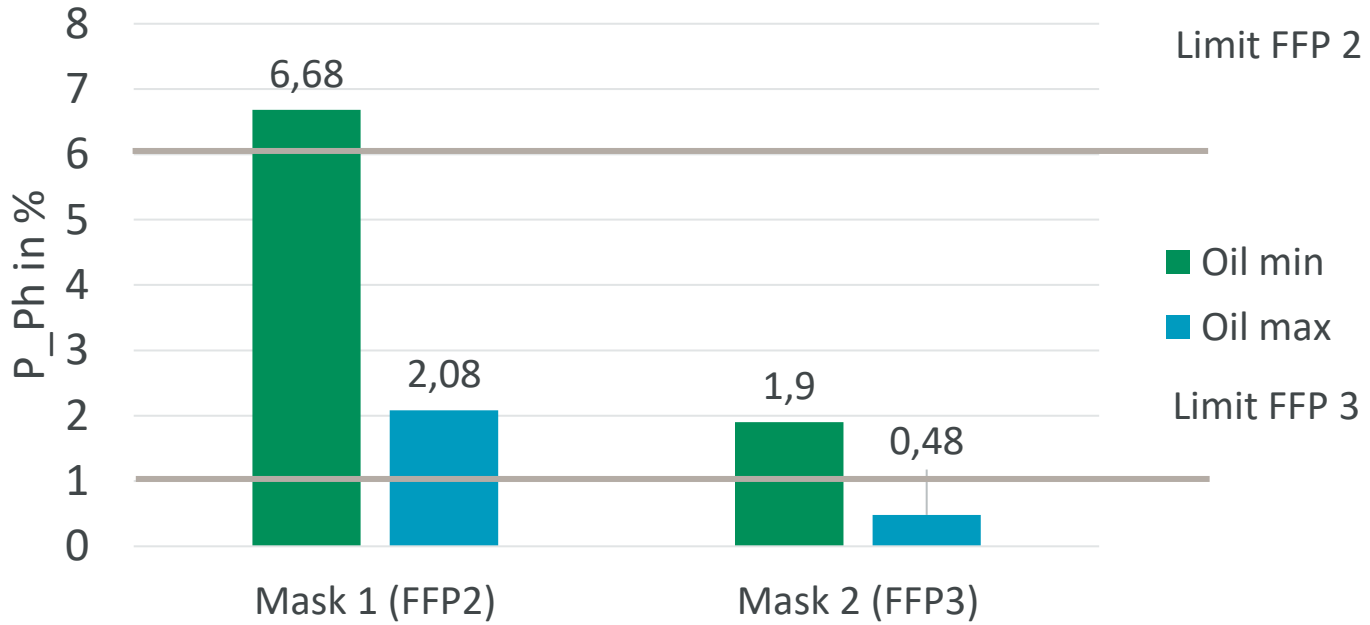
Problem: Influence of Aerosol Size Distribution on Penetration

Comparability within EN 149

- Strong variation for penetration results depending on aerosol size distribution
- Passing/failing of classification limits depends on particular test conditions



EN 149: max. and min. size distribution



Photometer or Aerosol Photometer with Size Detection?

- A photometer measures concentration by mass, **not** the particle size
- A photometer is calibrated on particle size. If particle size changes the mass concentration displayed changes as well!
- **Promo® 1000/ Promo® LED 2300** are scattered light photometers with single particle detection
- This technique measures particle size **and** concentration in the range of 0.1 up to 40 µm
- Based on the scattered light signals, the mass penetration up- and downstream of the mask is evaluated regarding the individual specification of the different standards as e. g., the used aerosol detector or the size distribution

• **For sodium flame photometer:** P_m :	Measurement of penetration with NaCl
• **For scattered light photometer:** P_ph_45°:	Measurement of penetration with oil and NaCl special calibration for GB 2626/ 42CFR84
• **For individual analysis:** P_Sars-Cov-2 (0.15 µm):	Measurement of penetration at predefined size (Standard 0.15 µm)

Light Scattering: At Single Particle vs. Particle Collective

Light scattering at single particle

Light beam

Scattered light impulse

Sensor

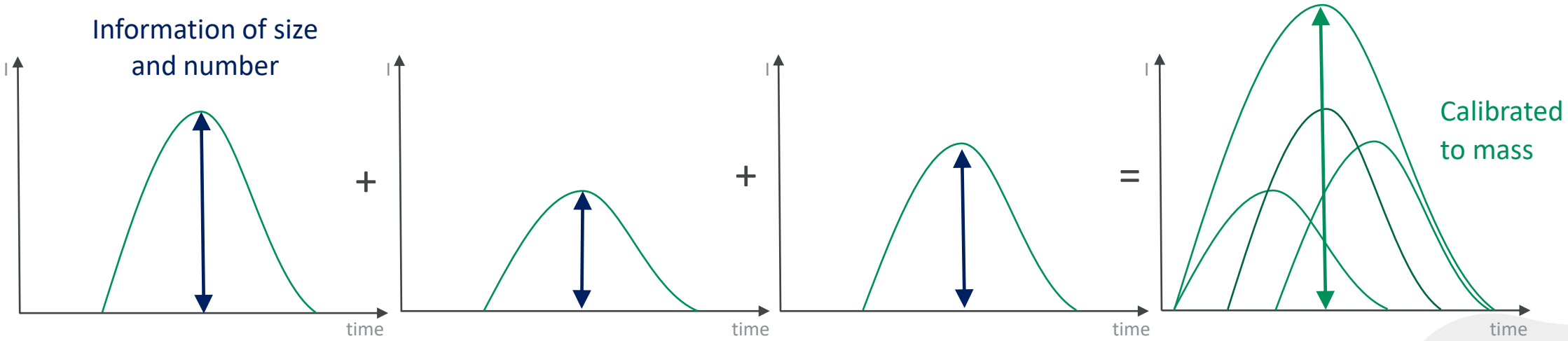
Photometer-light scattering at particle collective

Light beam

Scattered light impulse

Sensor

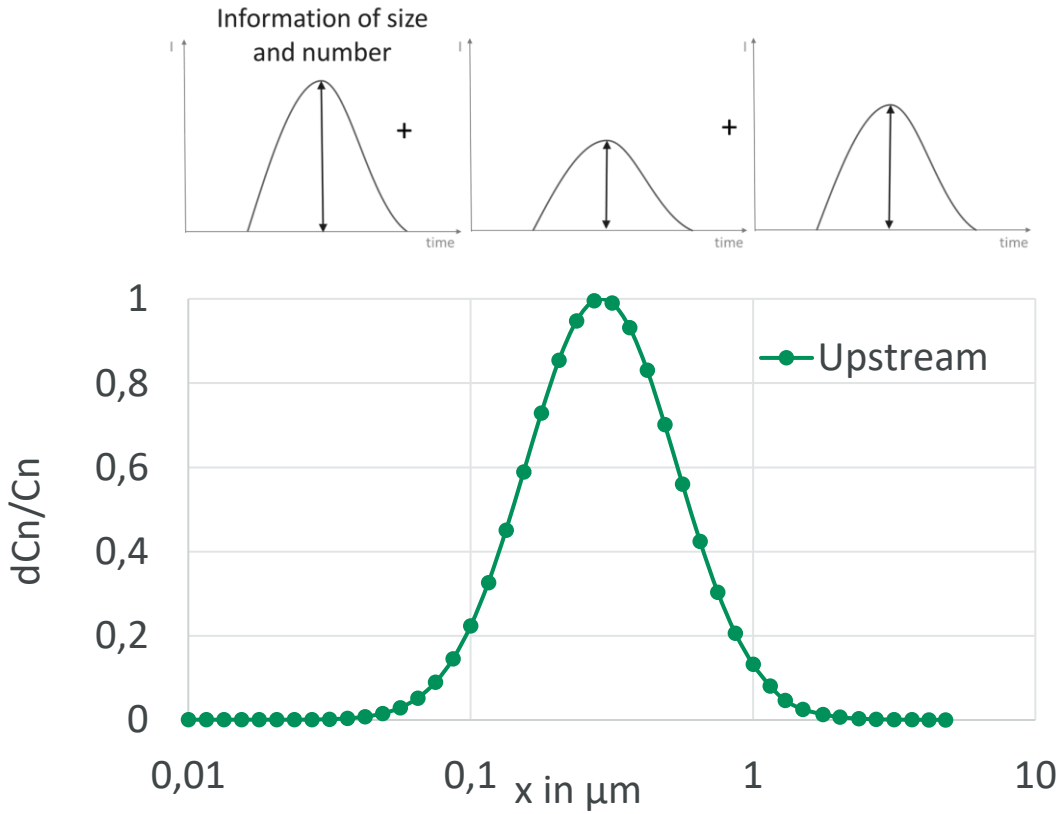
Information of size and number



Calibrated to mass

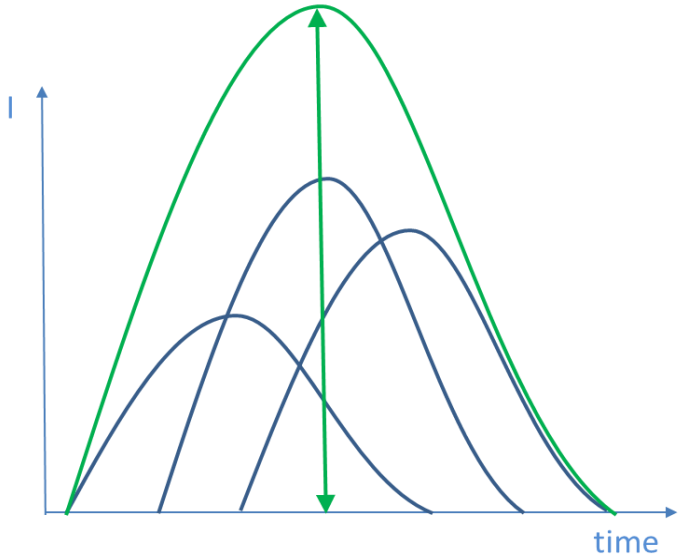
Light Scattering

At Single Particle



Information on number concentration by size

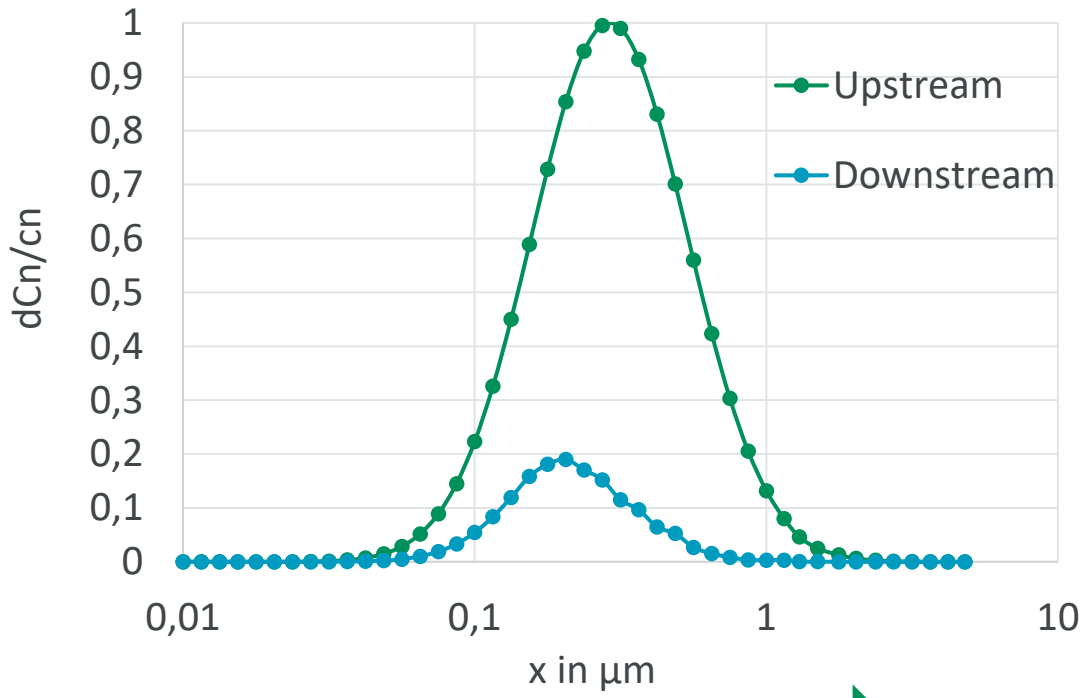
At Particle Collective

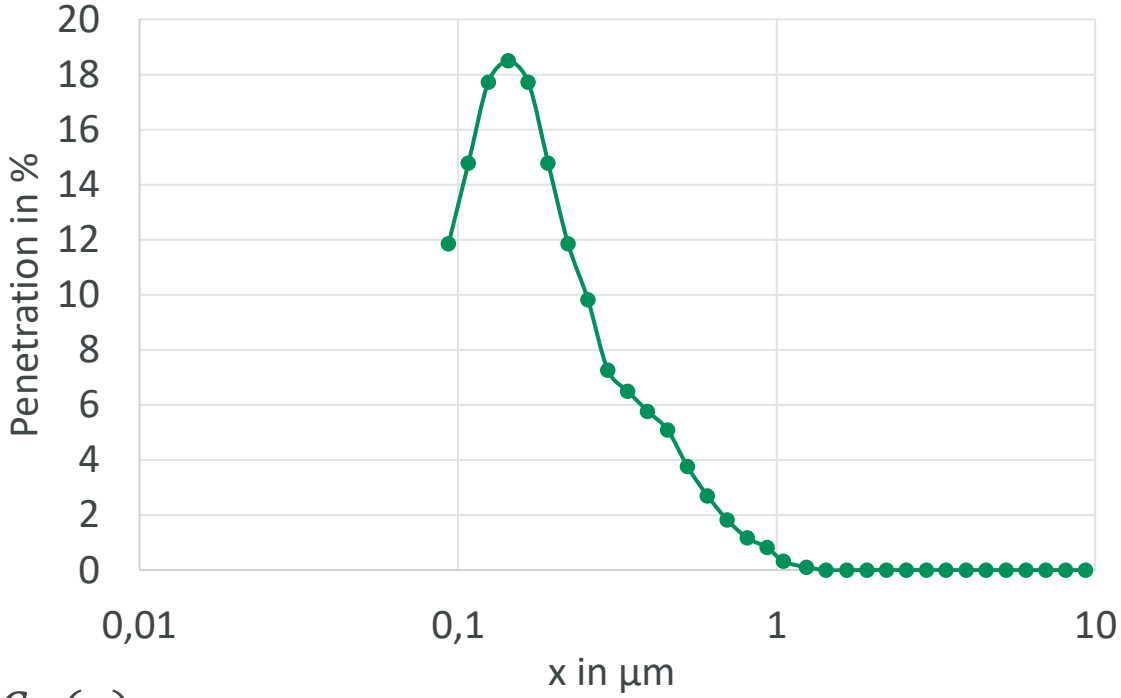


Information on mass concentration in mg/m³, only if size distribution does not change

Penetration Curve from Mask Testing

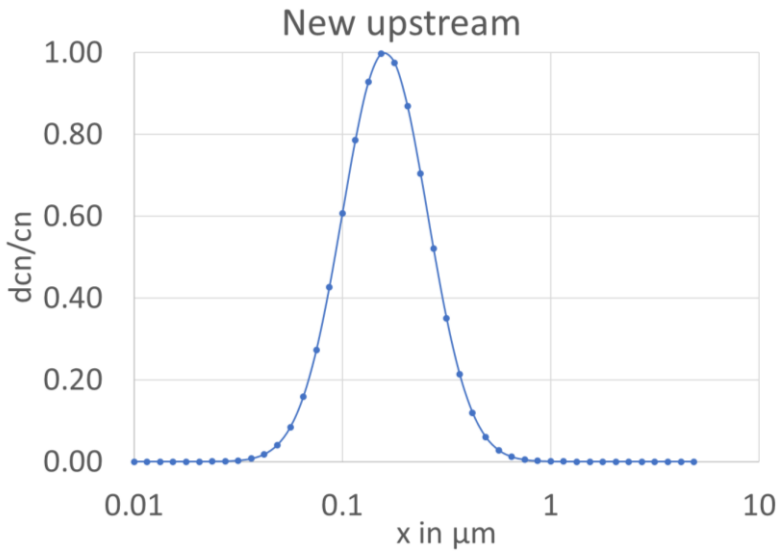
The size resolved measurement of particle size distribution allows the calculation of the penetration curve by particle size

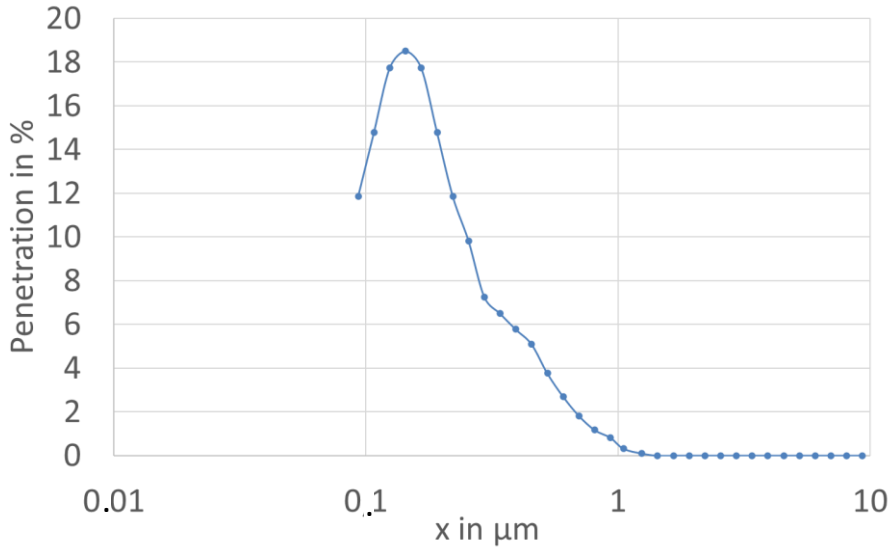


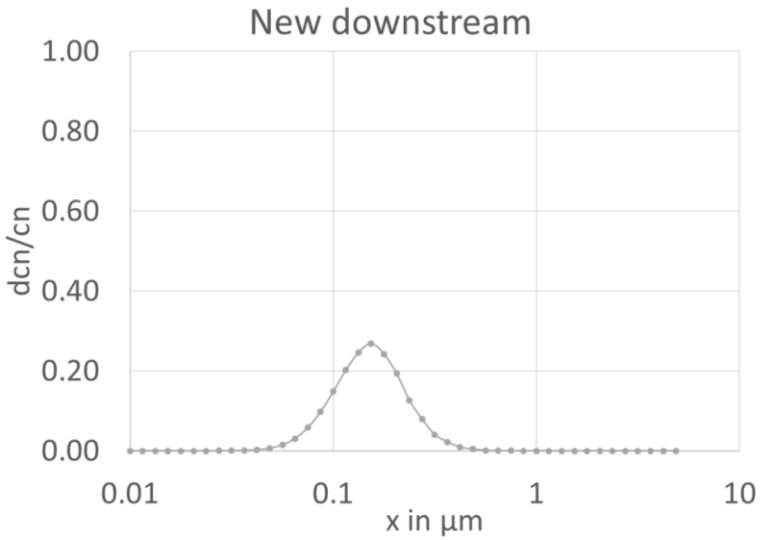


$$P_n(x) = \frac{Cn(x)_{downstream}}{Cn(x)_{upstream}}$$

Computing of the Penetration for Different Size Distributions





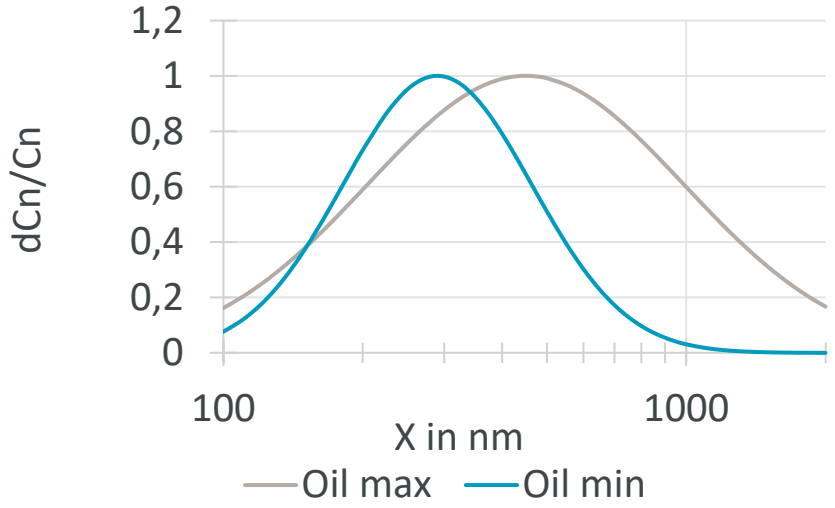


$$P_n(x) = \frac{Cn(x)_{downstream}}{Cn(x)_{upstream,\,new} * P(x)}$$

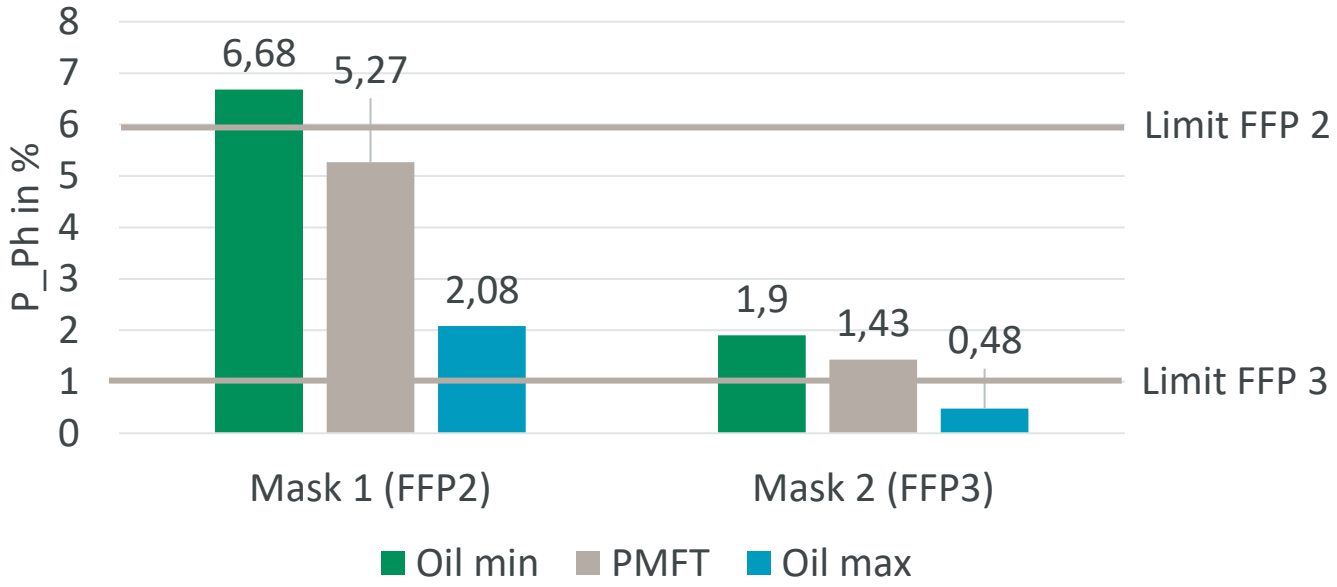
e.g., distribution according to 42 CFR 84

Result: Adjustable Aerosol Size Distribution for Mass Penetration

- Strong variation for penetration results depending on aerosol size distribution
- Passing/failing of classification limits depend on particular test conditions



EN 149: max. and min. size distribution

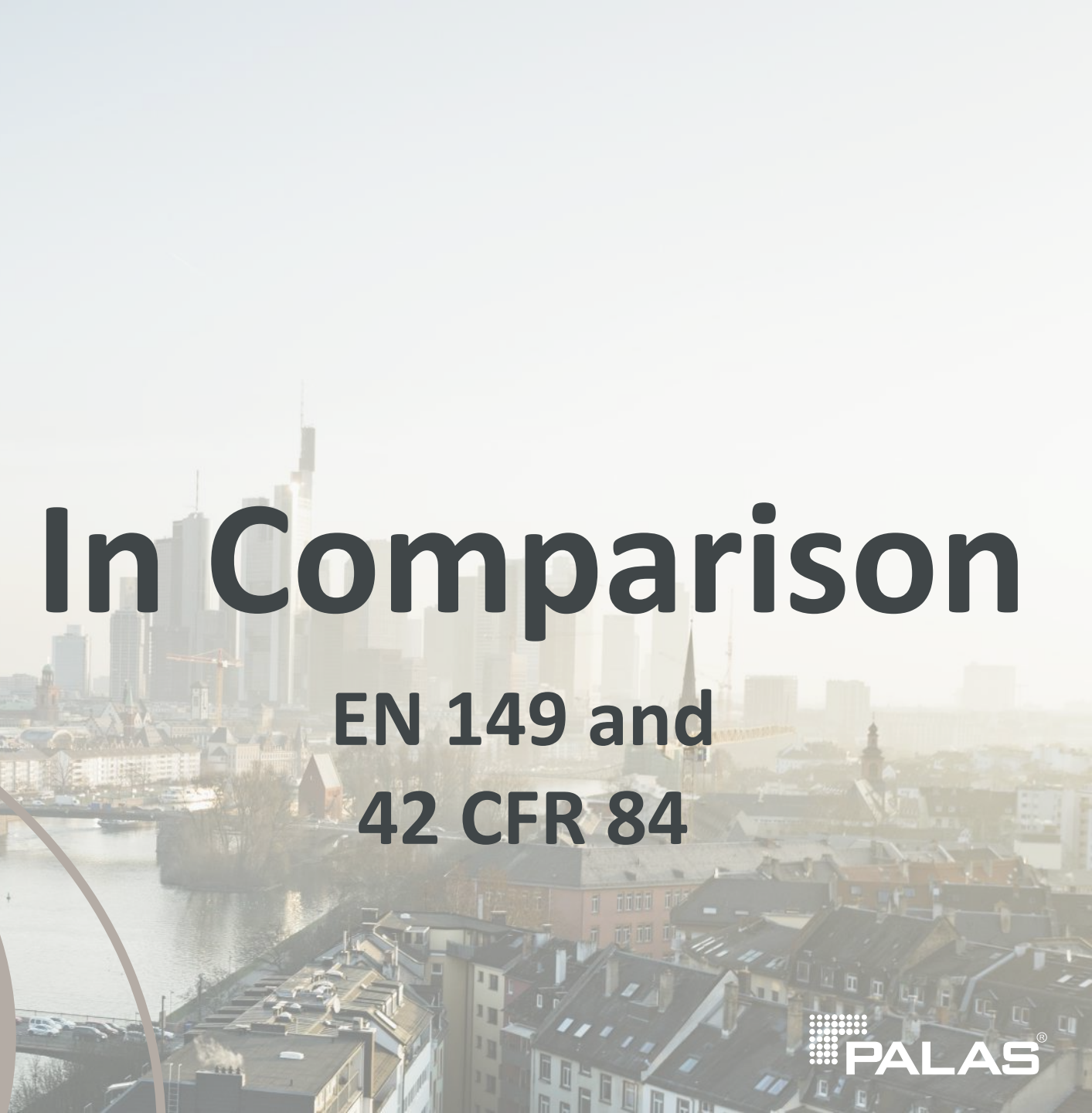


- Mass penetration results in the **PMFT System** are adjustable with regard to different size distributions and aerosol detection systems

4

In Comparison

EN 149 and
42 CFR 84



PMFT 1000 (M/F): Comparison of Measurement Results

Comparative Measurements of the Filter Media Test Rig PMFT 1000 M with Test Devices of DMT

“**TÜV NORD CERT**
is a notified body for the certification of particle filtering half masks (CE 0044).

In its laboratory for mask testing of DMT (TÜV NORD subsidiary), they have carried out comparative measurements, with regard to the penetration test according to EN 149 (respectively EN 13274-7), in cooperation with Palas®, a manufacturer in test stand and measuring equipment.

The aim is, to ensure that the measurement results of the PMFT 1000 M test stand (Palas GmbH), are comparable to those of a notified body (EN 149 compliant test). The PMFT 1000 is used by mask producers for quality assurance.”

PMFT 1000 (M/F): Comparison to DMT

Compared Test Equipment

Picture 1: Penetration test bench DMT (measuring chamber with Palas photometer welas®)

Picture 2: Test stand PMFT 1000 M from Palas®

PMFT 1000 (M/F): Comparison to DMT

„What was tested:

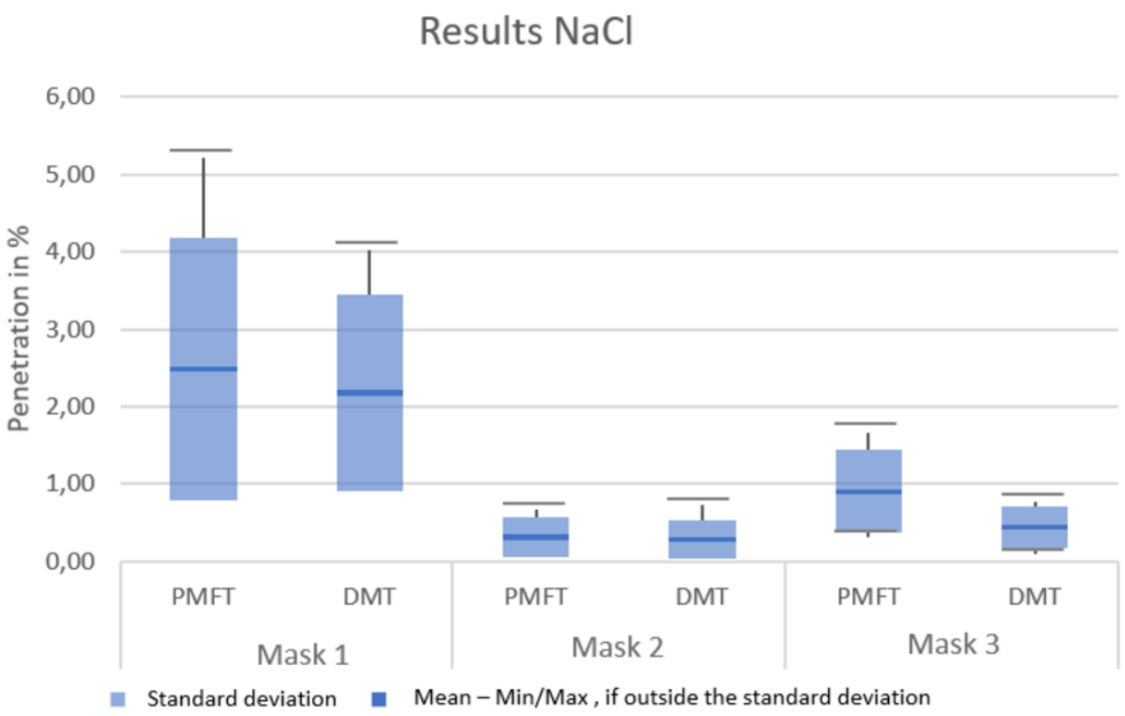
Three different, randomly selected masks from various manufacturers were tested, on the two test systems in the TÜV Nord laboratory. According to the manufacturer, all masks had an FFP2 or KN95 classification.

Testing was performed for each mask, using both – salt and paraffin oil as the test aerosol.

Several specimens of each batch were measured, to determine the mask's spread. Each mask was used only once in order to exclude the influence of loading effects on the penetration value.”

PMFT 1000 (M/F): Comparison to DMT

Results with NaCl:



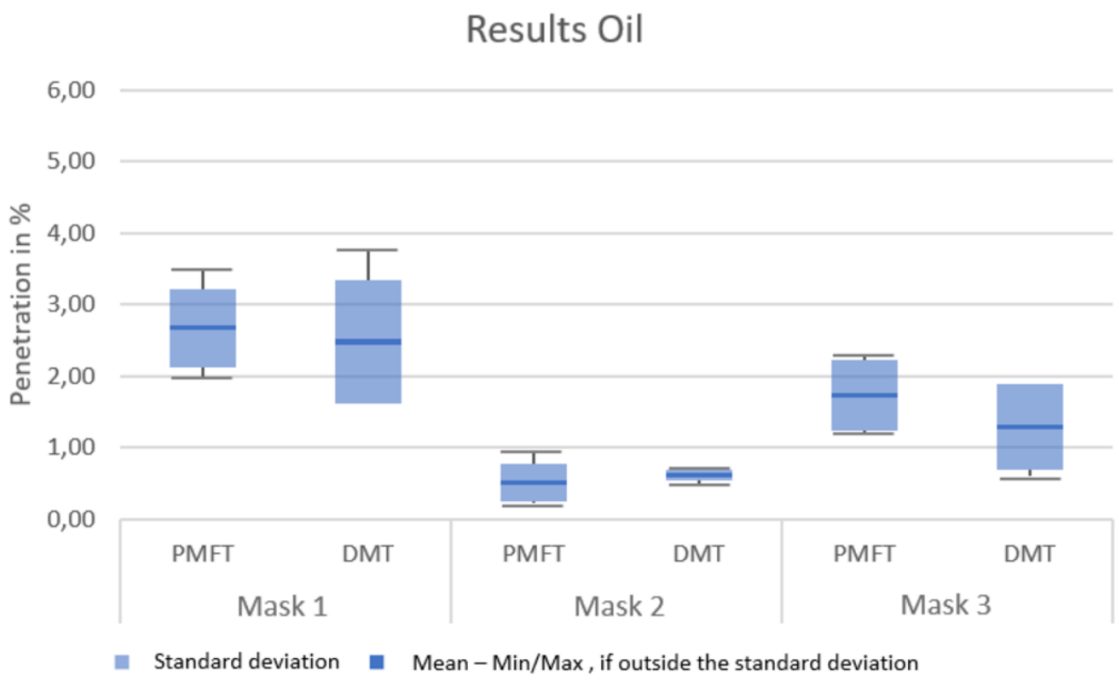
"Figure 2 shows the results of the measurements with **NaCl as test aerosol**.

The medium penetration of all tested specimens and the respective standard deviation are shown.

Measurements that fall outside the standard deviation, are shown as error bars and indicate the minimum or maximum penetration measured."

PMFT 1000 (M): Comparison to DMT

Results with Oil:



"Figure 3 shows the results of the measurements with **oil as test aerosol**.

An evaluation adapted to TÜV NORD's laboratory measurement procedure (DMT) was used to calculate the penetration from the PMFT measurement data."

PMFT 1000 (M/F): Comparison to DMT

“The figures show that differences between the test stands in the medium penetration, are significantly smaller than the spread of the respective mask type.

In summary, the comparative measurements have shown that the measured penetrations on the PMFT 1000 M agree very well with the results of the TÜV NORD respirator, testing laboratory (DMT).”

For certification requests you may contact: plq@dmt-group.com

New Software Module (Optional)

Comparison of EN149 penetrations

Comparison of EN149 penetrations

Test information

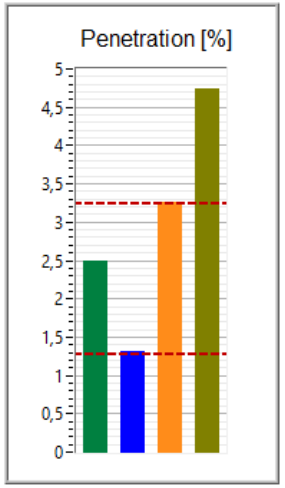
Operator	Date	Time	Version
MKS	12:42:05	26.04.2021	1.10.3.0

Basic information

Script	Efficiency Test (oil)
Aerosol	Oil
Main air	95.05 l/min
Generator air	2.19 l/min

Mask information

Mask ID	14087_20210426_124205
Mask los	
Mask type	FFP2 / x / x



Result

	EN149 min	EN149 max	PMFT	DMT	MF1	MF2
Penetration [%]	1.27	3.24	2.49	1.30	3.26	4.75
Based on X_g [µm]	0.45	0.29	0.29	0.29	0.185	0.13
Based on Sigma	2.2	1.6	1.85	1.85	2	1.9
Rating	P_Ph_45	P_Ph_45	P_Ph_45	P_m	P_Ph_45	P_Ph_45

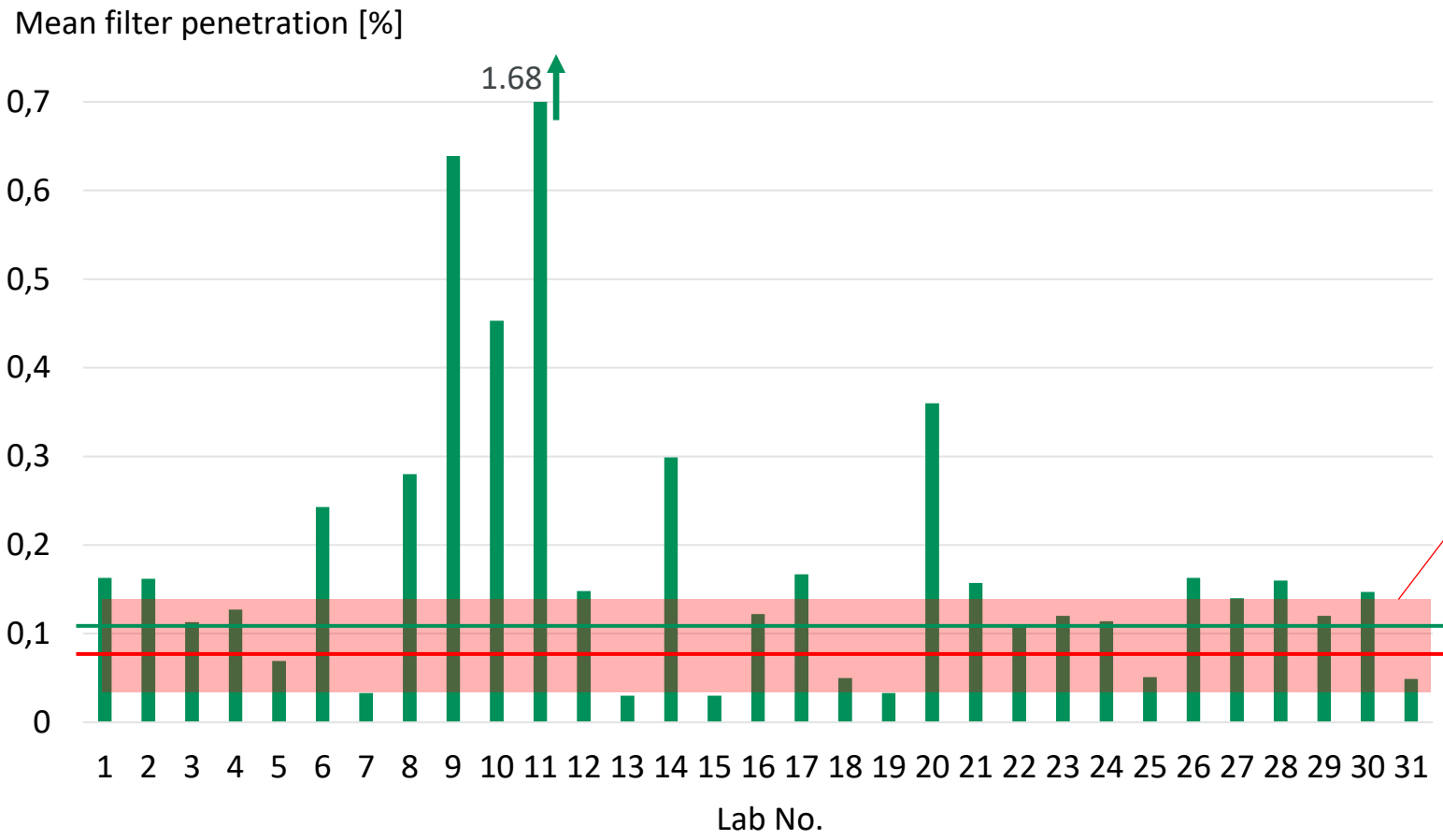
exit

Showing with regard to particle size distribution:

- Max. & min. possible penetration of EN 149
- PMFT standard result
- Comparable data of recommended body in Germany
- Comparable penetration results of external manufacturer

Round Robin Test with Paraffin Oil Aerosol acc. to EN 13274-7

Test Results from 4 Laboratories with PMFT 1000 and PMFT 1000 M Show Only Small Deviations



Mean results in comparison

	Mean Penetration [%]	σ
All	0.105	0.049
PMFT	0.086	0.045

Verification of Penetration Results with PMFT by SGS

Basis for NIOSH Testing – Green Line Media Test – Extract of Test Report

SGS IBR LABORATORIES

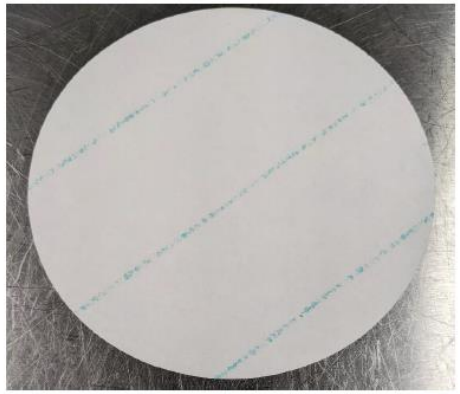
SGS IBR JN:24714

Report to: Sven Schütz
Palas GmbH
Greschbachstrasse 1
76229 Karlsruhe, Germany

PO Number: Wire Transfer

Sample Description: TSI AFT (Green Line) Test Media, PN 813010, Lot: 511483
Sample Source: TSI Inc. - Shoreview, MN
Date Received: 8/23/2021

Test Method: NIOSH TEB-APR-STP-0059 Determination of Particulate Filter Efficiency Level for N95 Series Filters against Solid Particulates for Non-Powered, Air-Purifying Respirators Standard Testing Procedure (STP)

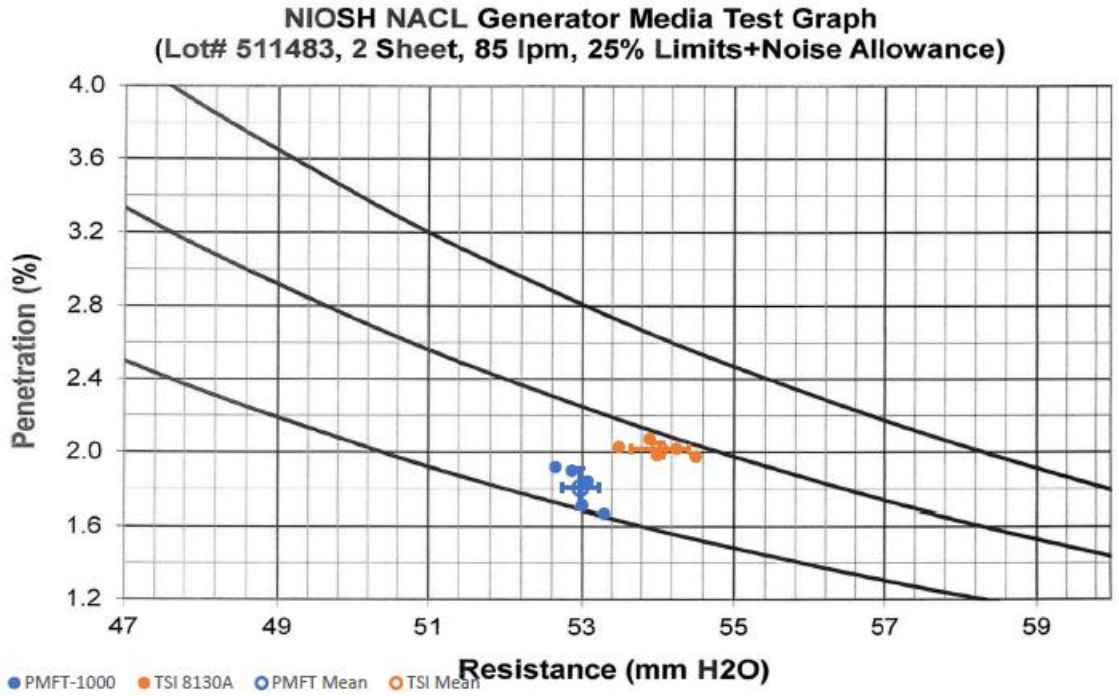


Signed: _____
Joseph Pryor
Technician, Laboratory C&P

Authorized by: _____
Daniel R. Miller
SGS IBR Laboratory Manager

Verification of Penetration Results with PMFT by SGS

Basis for NIOSH Testing – Green Line Media Test – 2 Sheets



Notice: These data relate only to the samples tested. This report may be copied only in its entirety.

Performed by: JWP

Data Location: JWP220203

SGS IBR Laboratories Inc., 11599 Morrissey Rd., Grass Lake, MI 49240 USA
Voice: +1 517 522 8453

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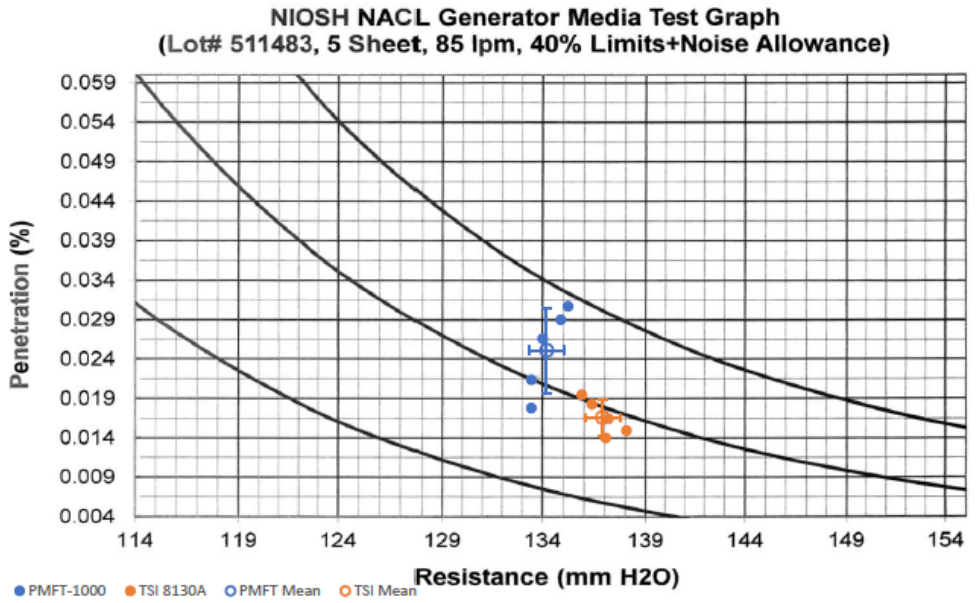
Verification of Penetration Results with PMFT by SGS

Basis for NIOSH Testing – Green Line Media Test – 5 Sheets



Notice: These data relate only to the samples tested. This report may be copied only in its entirety.

Performed by: JWP Data Location: JWP220203

IBR ID	Mfg	Model No.	Serial No.	Range	Cal Due Date
ATS-24	TSI	8130A	8175204808	1.0 µg/m3 to 200mg/m3	Cal w/use
ATS-24	TSI	8130A	8175204808	1.0 µg/m3 to 200mg/m3	Cal w/use
ATS-24	TSI	8130A	8175204808	1.0 µg/m3 to 200mg/m3	Cal w/use
AF-124	TSI	4045	40452047015	0-300 lpm	1/11/2023
RH-211	Omega	OM-DVTH	421-0417-0051	10-90%, 10-50C	5/16/2022
N/A	Palas	PMFT-1000	13960	N/A	12/17/2022

SGS IBR Laboratories Inc., 11599 Morrissey Rd., Grass Lake, MI 49240 USA
Voice: +1 517 522 8453

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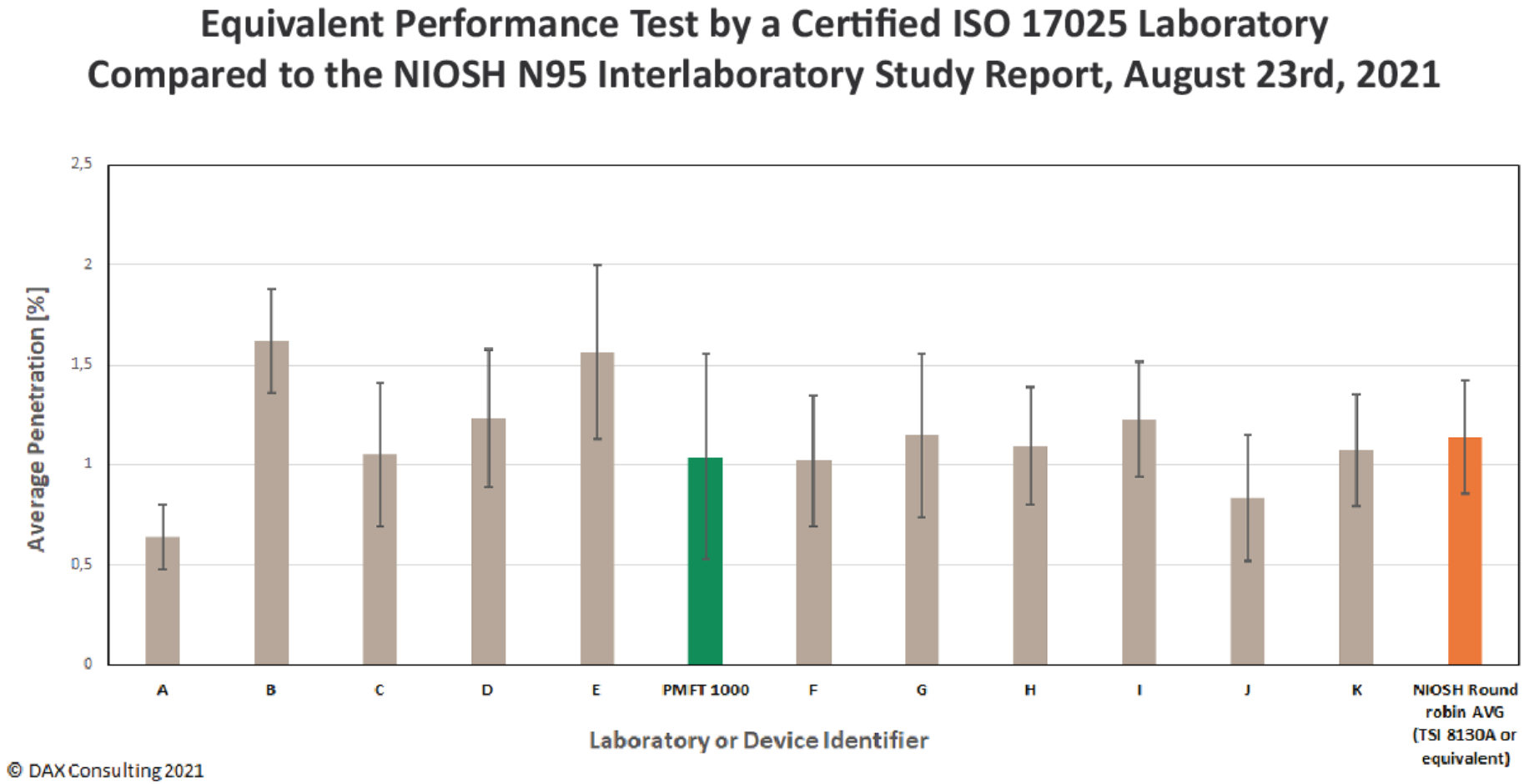
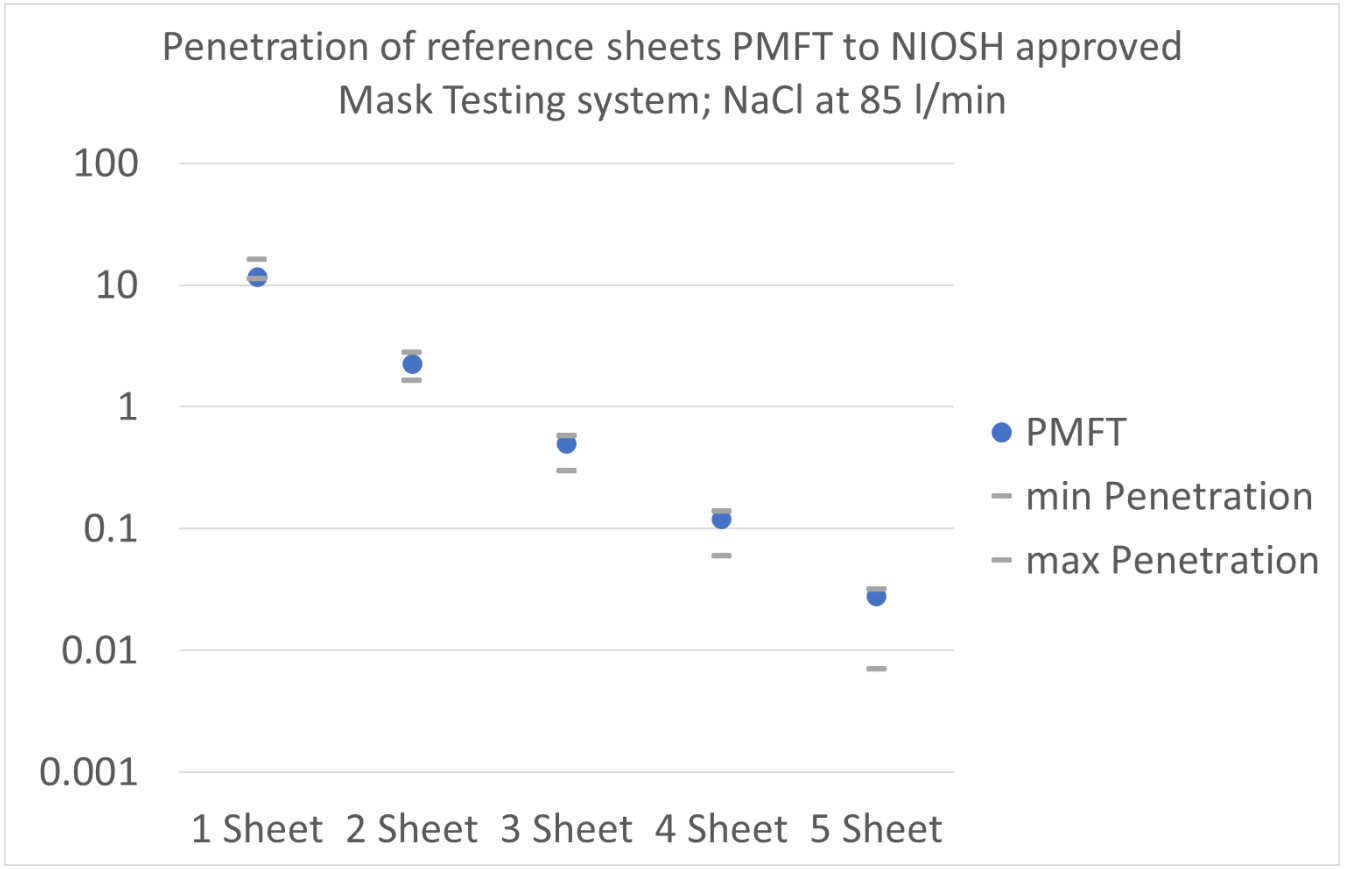
Penetration Results with PMFT by SGS, IBR Laboratories

Comparison of N95 Mask Testing with Round Robin Test Results in United States



PMFT 1000 (M): Comparison to Green Line Media

Excellent comparison to NIOSH Green Line Media (TSI 8130 A) at Different PMFT in Different Countries

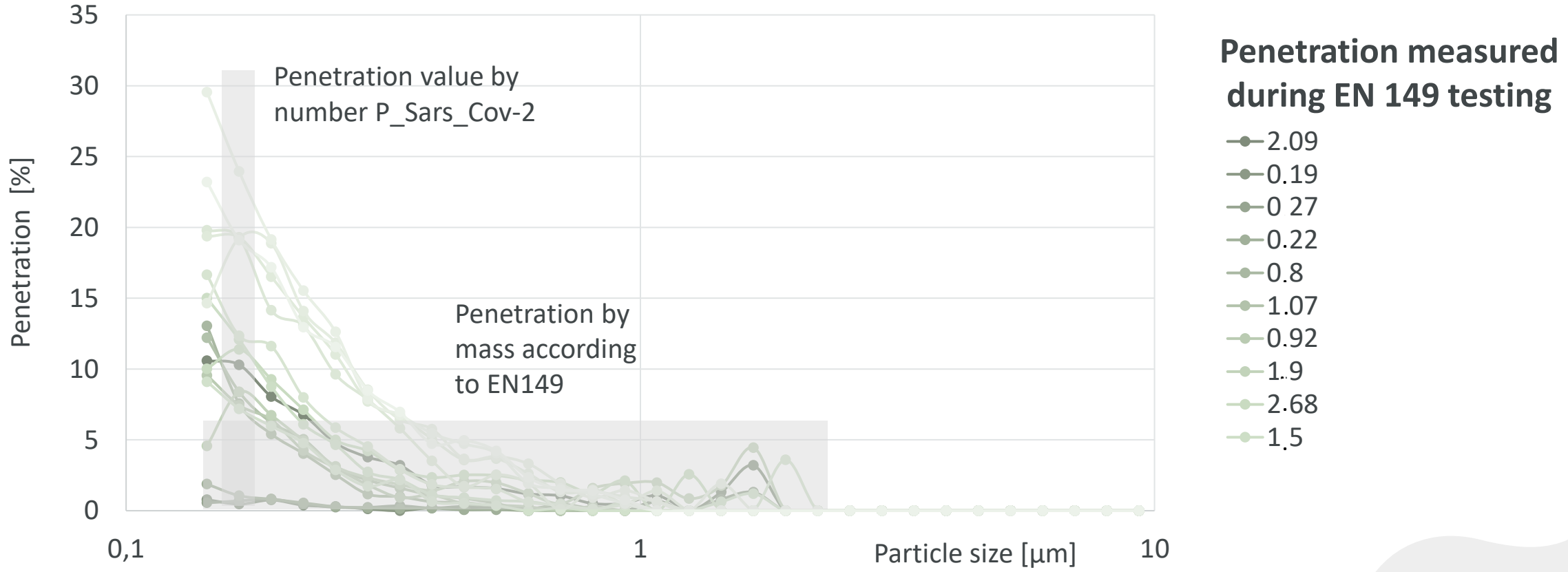


5

Applications & Benefits

Detection of Penetration by Particle Size of Various FFP-2 Masks

- Penetration by mass is insensitive against small particle – virus sizes!
- Penetration by particle size show real efficiency of small particle



Advantages of Detection of Penetration by Particle Size

- Information about efficiency or penetration of small particle as e. g., in the virus size range is more realistic for the degree of protection than the mass-based values
- Penetration by particle size is more sensitive against differences in product quality than mass penetration
- Possibility to obtain data for other applications:
  - ASTM 2299-3 penetration with PSL particle at different sizes (120 nm – 3 µm)
  - CWA 17553 penetration at 3 µm or SNR 30000 at 1 µm
- Adjustment of size distribution (mean diameter and standard deviation) by selection of mean diameter and standard deviation is only possible with measurement of the penetration by particle size

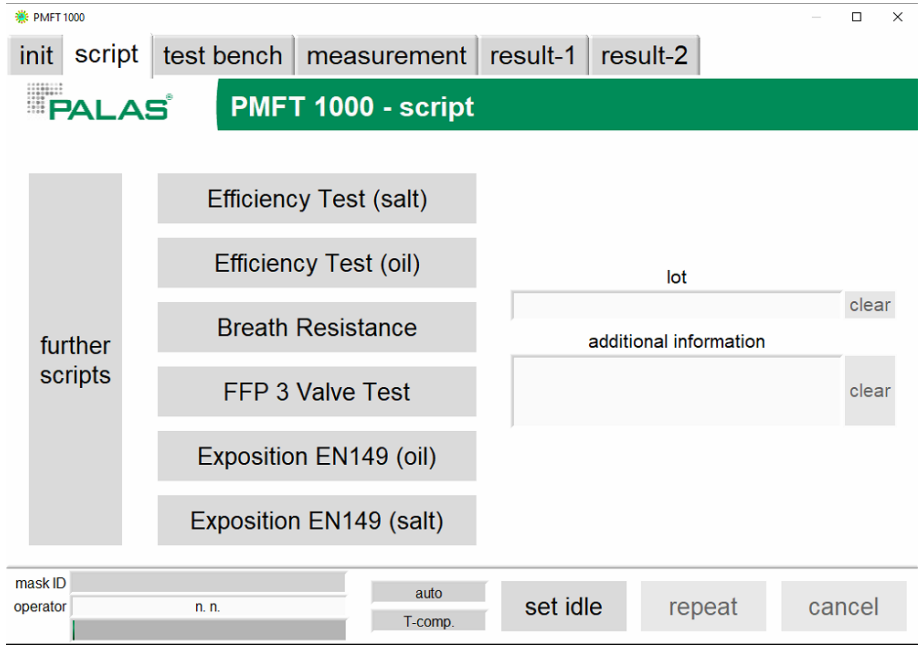
PMFT System

Advantages of Detection of Penetration by Particle Size

	ISO 16890-2:2020		ISO 29463-3: 2018 7.2. Test with Polydisperse Test Aerosol	ISO 11155-1: 2001		PMFT 1000	PMFT 1000 M
Test sample	Complete filter element		Flat sheet	Complete filter element		Flat sheet	Flat sheet
Aerosol	DEHS	KCl	DEHS/PaO	KCl	ISO 12103 A2 Fine	DEHS/PaO/KCl	DEHS/PaO/KCl
Efficiency by particle size	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Size range	0.3 µm up to 1 µm	0.3 µm up to 10 µm	6 points in MPPS*	0.3 µm up to 5 µm	5 µm up to 10 µm	0.12 µm up to 3 µm*	0.145 µm up to 10 µm*
Filter class EPM 1	0.3 µm up to 1 µm	–	–	–	–	Yes (EPM values to be calculated from efficiency by particle size)	Yes (EPM values to be calculated from efficiency by particle size)
Filter class EPM 2.5	–	0.3 µm up to 3 µm	–	–	–	Yes (EPM values to be calculated from efficiency by particle size)	Yes (EPM values to be calculated from efficiency by particle size)
Filter class EPM 10	–	0.3 µm up to 10 µm	–	–	–	No	No
Max. Efficiency	99%	99%	Up to 99.99999%	Not defined	Not defined	99.95 (extendable on request)	99.95 (extendable on request)
Measurement instrument	Optical particle counter	Optical particle counter	Optical particle counter	Optical particle counter	Optical particle counter	Aerosol photometer with particle sizing	Aerosol photometer with particle sizing
Minimum size resolution	8 channels 0.3 µm – 3 µm; 12 channels 0.3 µm – 10 µm	8 channels 0.3 µm – 3 µm; 12 channels 0.3 µm – 10 µm	Not defined	5 channels	5 channels	32 classes per decade	32 classes per decade
Dust Holding Capacity DHC	ISO 16890-3	ISO 16890-3	No	No	Yes	No	No
Aerosol discharge	–	Yes	Yes	Yes	Optional	Yes, with upgrade kit 42CFR84	Yes, with upgrade kit 42CFR84
Air flow	Defined by face velocity and filter area	Defined by face velocity and filter area	Defined by face velocity and filter area	Defined by face velocity and filter area	Defined by face velocity and filter area	1 – 27 m^3/h	1 – 27 m^3/h
Face velocity	Defined by manufacturer	Defined by manufacturer	defined by manufacturer	defined by manufacturer	defined by manufacturer	3.5 cm/s up to 70 cm/s	3.5 cm/s up to 70 cm/s
Pressure drop	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data evaluation	Defined test report	Defined test report	Defined test report	Defined test report	Defined test report	CSV-File including efficiency by particle size and pressure drop	CSV-File including efficiency by particle size and pressure drop

Adjustment of Test Specifications

- Basis for the comparable test of face masks and filter material are
  - Air flow
  - Testing time or exposure time
  - Aerosol concentration by mass (to be calibrated by operator)
- The test conditions are predefined in the procedure script at the **PMFT System**
- This ensures easy operation



Adjustment of Test Specifications

And as an addition:

- Individually programmed procedure scripts can be added by the supervisor
- Settings as alignment to the different types of scattered light photometer or sodium flame photometer by selection of the P_m and P_ph 45° value are included in the procedure script
- Settings as particle size distribution (mean diameter and standard deviation) by selection of mean diameter and standard deviation
- This feature is just available with measurement of the penetration by particle size

Available Procedure Scripts

EN 149:

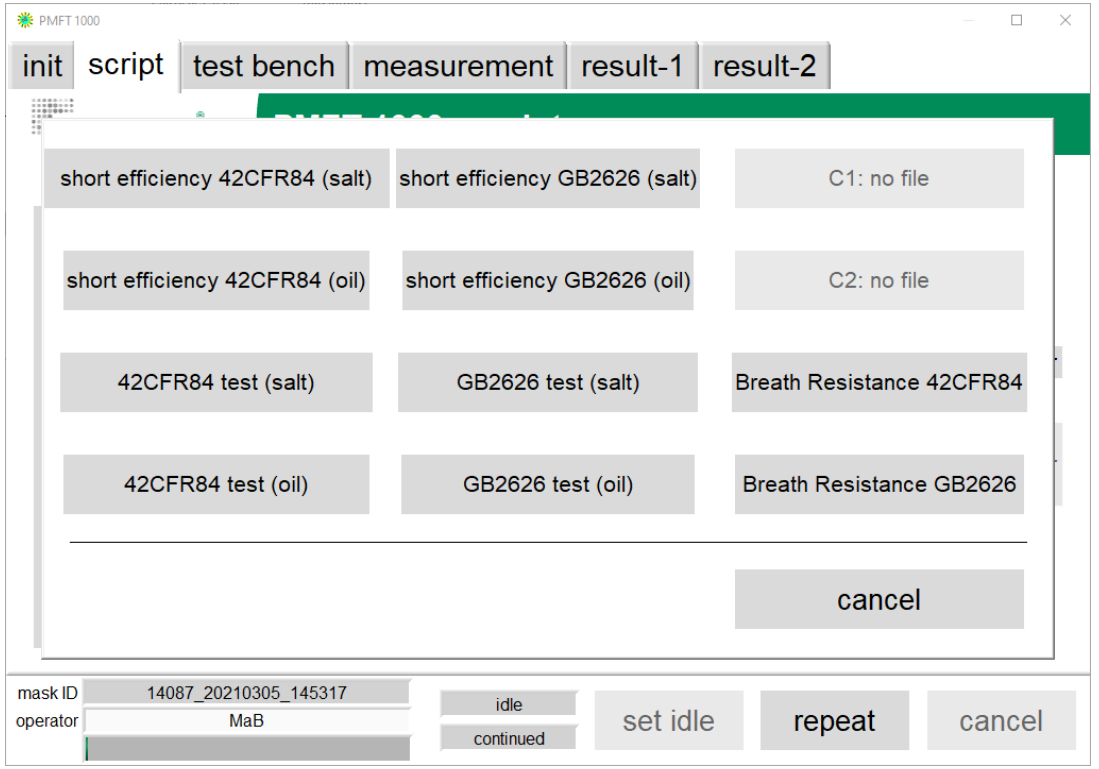
- Efficiency test salt
- Efficiency test oil
- Breath resistance
- FFP 3 valve test
- Exposition EN149 (salt)
- Exposition En149 (oil)

GB 2626:

- Short efficiency GB2626 (salt)
- Short efficiency GB2626 (oil)
- Breath resistance GB2626
- GB2626 test (salt)
- GB2626 test (oil)

42 CFR 84:

- Short efficiency 42CFR84 (salt)
- Short efficiency 42CFR84 (oil)
- Breath resistance 42CFR84
- 42 CFR84test (salt)
- 42 CFR84test (oil)



Press the button and follow instructions

Automatic Creation of PDF Report as well as .csv Report

Test report - PMFT 1000 - Salt penetration

Operator	Date	Time
Operator	**07/07/2020**	**14:19:18**

Customer information

Firm-name Address Contact Customer number

Basic information

Operation parameter	
Script	**Efficiency Test (salt)**
Aerosol	**Salt**
Main air	**95.00 l/min**
Generator air	**9.70 l/min**

Test conditions	
rel. humidity	**8.52 %**
Temperature	**24.17 °C**

Mask information

Mask ID	**0145_20200707_141918**
Mask los	**Lot name**
Mask type	**FFP 2**

Result

Penetration	Measurement	Upper limit	Result
P_m	**0.18 %**	6.00 %	pass
P_Ph_45°	**0.67 %**	6.00 %	pass
P_SARS_CoV-2 (0.15 µm)	**2.05 %**		

Test report - PMFT 1000 - Breath resistance / Valve test

Operator	Date	Time
svs	**06/16/2020**	**10:49:30**

Basic information

Operation parameter	
Script	**Breath Resistance**
Aerosol	**Pressurized air**

Test conditions	
rel. humidity	**5.03 %**
temperature	**23.10 °C**

Mask information

Mask ID	**0145_20200616_104930**
Mask type	**FFP 2**
Mask los	**test**

Result

Description	Main air	Differential pressure	Upper limit	Result
Inhalation	**28.49 l/min**	**48.25 Pa**	70.00 Pa	pass
Inhalation	**94.18 l/min**	**152.57 Pa**	240.00 Pa	pass
Exhalation	**153.80 l/min**	**261.86 Pa**	300.00 Pa	pass
Valve test	**NaN l/min**	**NaN Pa**		

Description	Result
Valve optical inspection	

6

Conclusion

Conclusion

- World's only system to test penetration by mass and efficiency by particle size based on **EN 13274-7, EN 149, 42 CFR 84, GB 2626, EN 143, ISO 16900-3 and ASTM 2299-3 in one test system**
- Salt and oil aerosol penetration measurement available in one test system
- The **PMFT System** may be used for masks for textiles (different mask holders available) and flat sheet material
- Measurement of penetration by particle size!
- Excellent comparability in test results to reference institutes as TÜV Nord and green line media by NIOSH
- Easy to operate for different standards by selection of the appropriate procedure script with menu driven software
- Automatic print out of reports as *.pdf and detailed results as *.csv file

PMFT System

Thank you for your attention!

Dipl.-Ing. Martin Schmidt

Division Manager Industry & Science

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