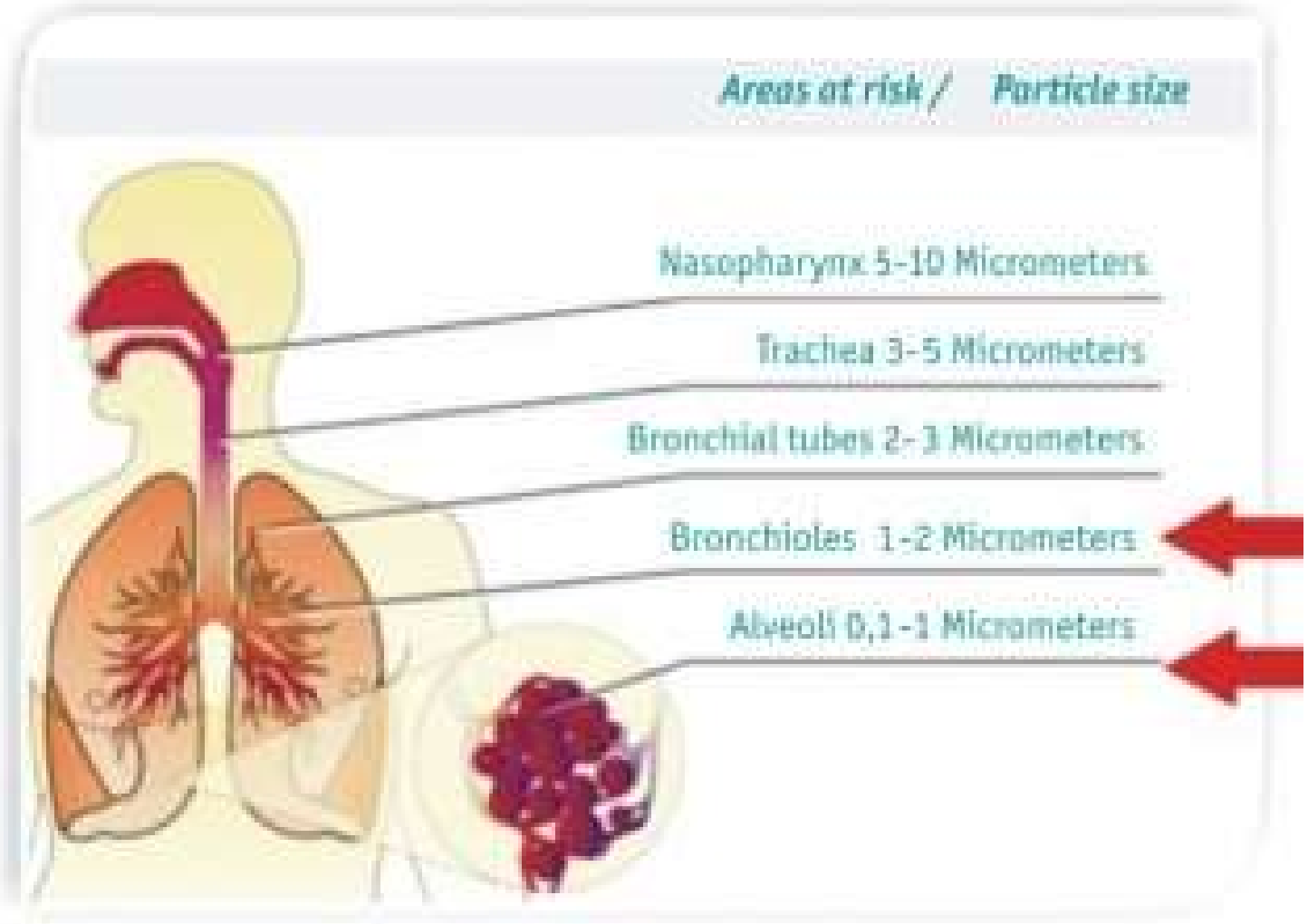
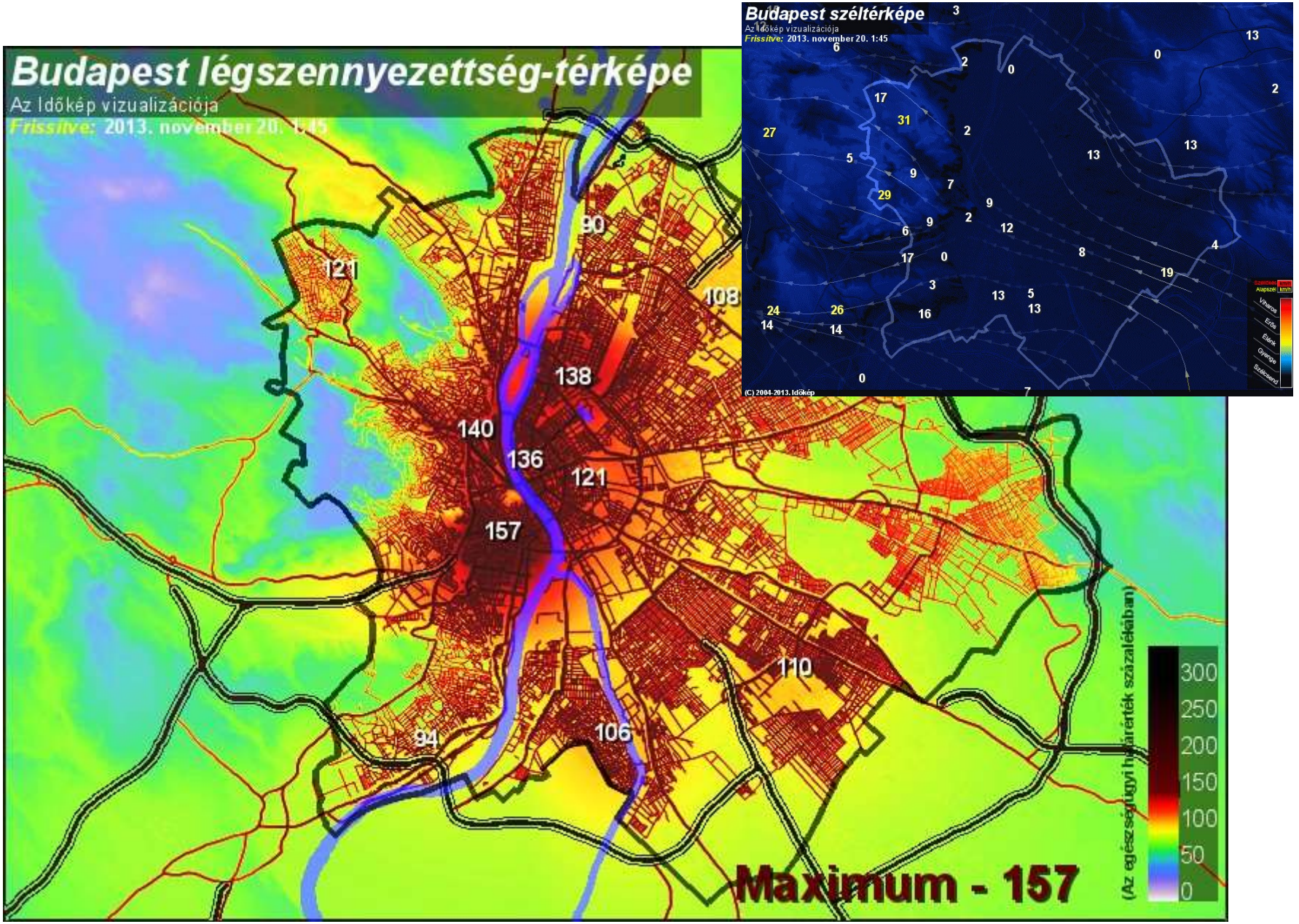
# Solid Emission Measurement Devices

Dr. Ákos Bereczky

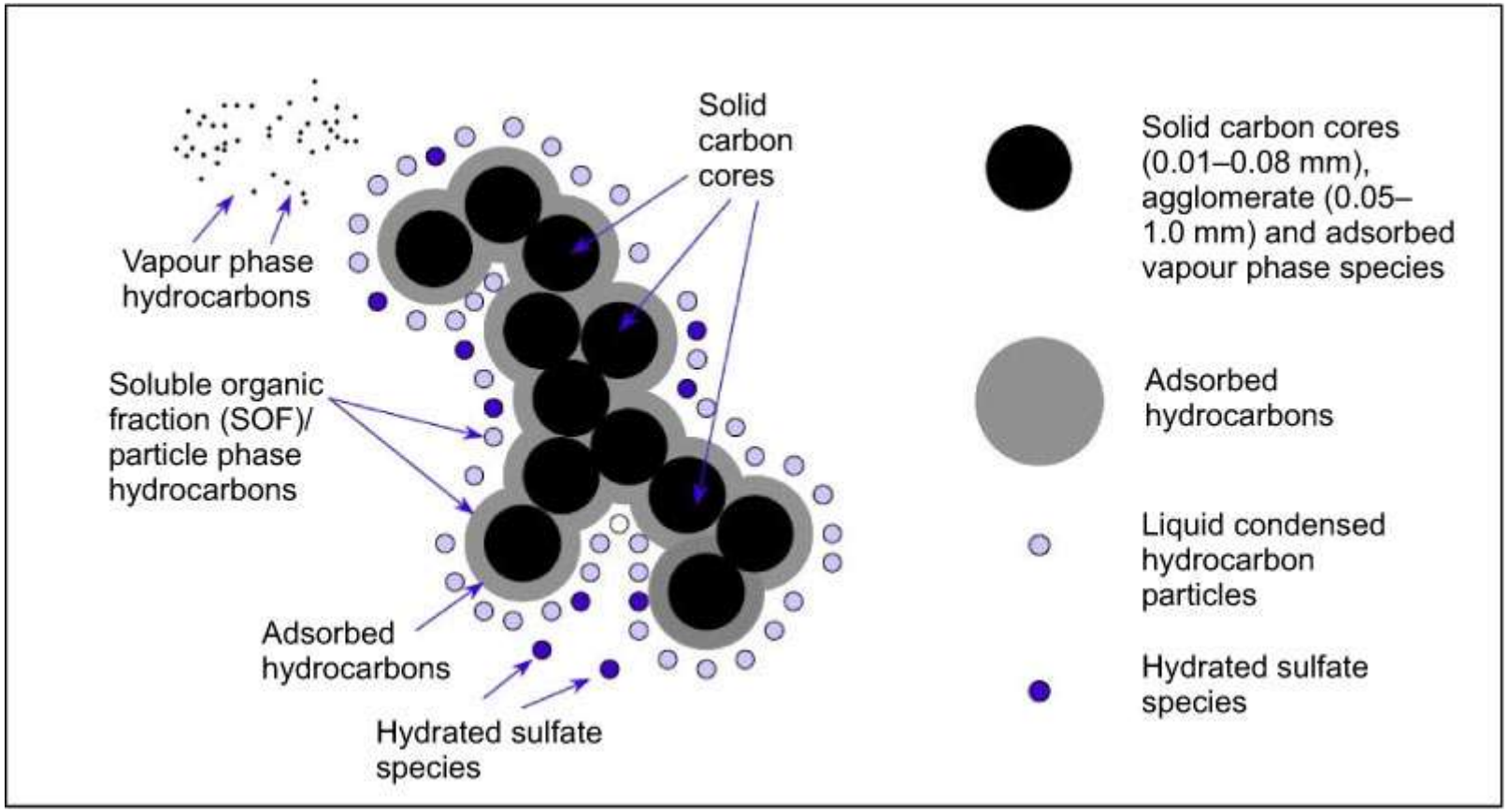
# Why it is important?




Budapest légszennyezettség-térképe
Az Időkép vizualizációja
Frissítve: 2013. november 20. 1:45
90
121
108
138
140
136
121
157
110
106
94
Maximum - 157
(Az egészségügyi határérték százalékában)
300
250
200
150
100
50
0


Budapest széltérképe
Az Időkép vizualizációja
Frissítve: 2013. november 20. 1:45
(C) 2004-2013. Időkép

*Schematic representation of diesel particulate matter (PM) formed during combustion of atomised fuel droplets.*




Martyn V. Twigg & Johnson Matthey PLC: Cleaning the Air We Breathe – Controlling Diesel Particulate Emissions from Passenger Cars, Platinum Metals Rev., 2009, 53, (1), 27

# Particulate Matter (PM)

•Diesel-Engines [g/kWh or g/km], *(ECE R49)*
•Ambient Aerosol Monitoring [µg/m3]

- PM10 - size less than or equal to 10 micrometers
- PM2.5 - size less than or equal to 2.5 micrometers
- Nanoparticles [particles/$cm^3$]

# Solid Emission Types:

- Dust [mg/$Nm^3$]
  - Power generation industry,
  - Waste incineration equipments,
  - Residue burning equipments,

  (*DIRECTIVE **2001/80/EC** OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*)
- Particulate Matter (PM) or Soot
  - Diesel-Engines [g/kWh or g/km], *(ECE R49)*
  - Ambient Aerosol Monitoring [µg/$m^3$]
- Smoke [$m^{-1}$]
  - Diesel-Engines

  *(ECE R24, ECE R49)*

# Dust Concentration Monitors

- Transmissiometry
  - Dry gases
  - Accuracy: +/- 2%
- Scatter-light
  - Dry and wet gases
  - Accuracy: <+/- 2%
- Gravimetric
  - Dry gases
  - Accuracy: <+/- 1%

# Gravimetric

## ISO 9096 and ISO/CD 12141.2,

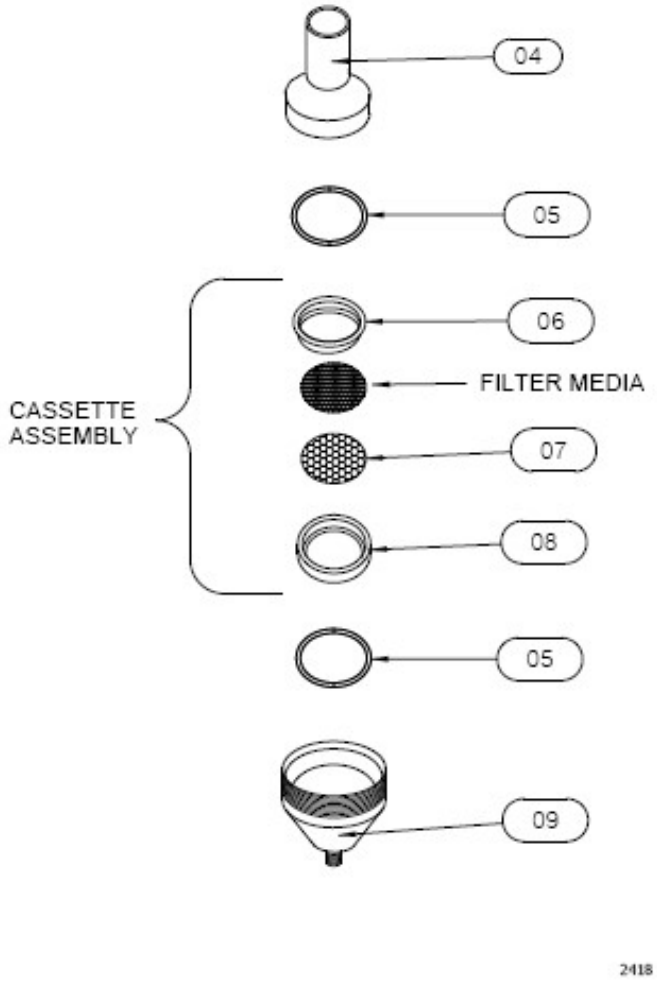



Figure 4. Exploded View of Filter Cassette and Filter Holder

www.bgiusa.com/

# Gravimetric measurement

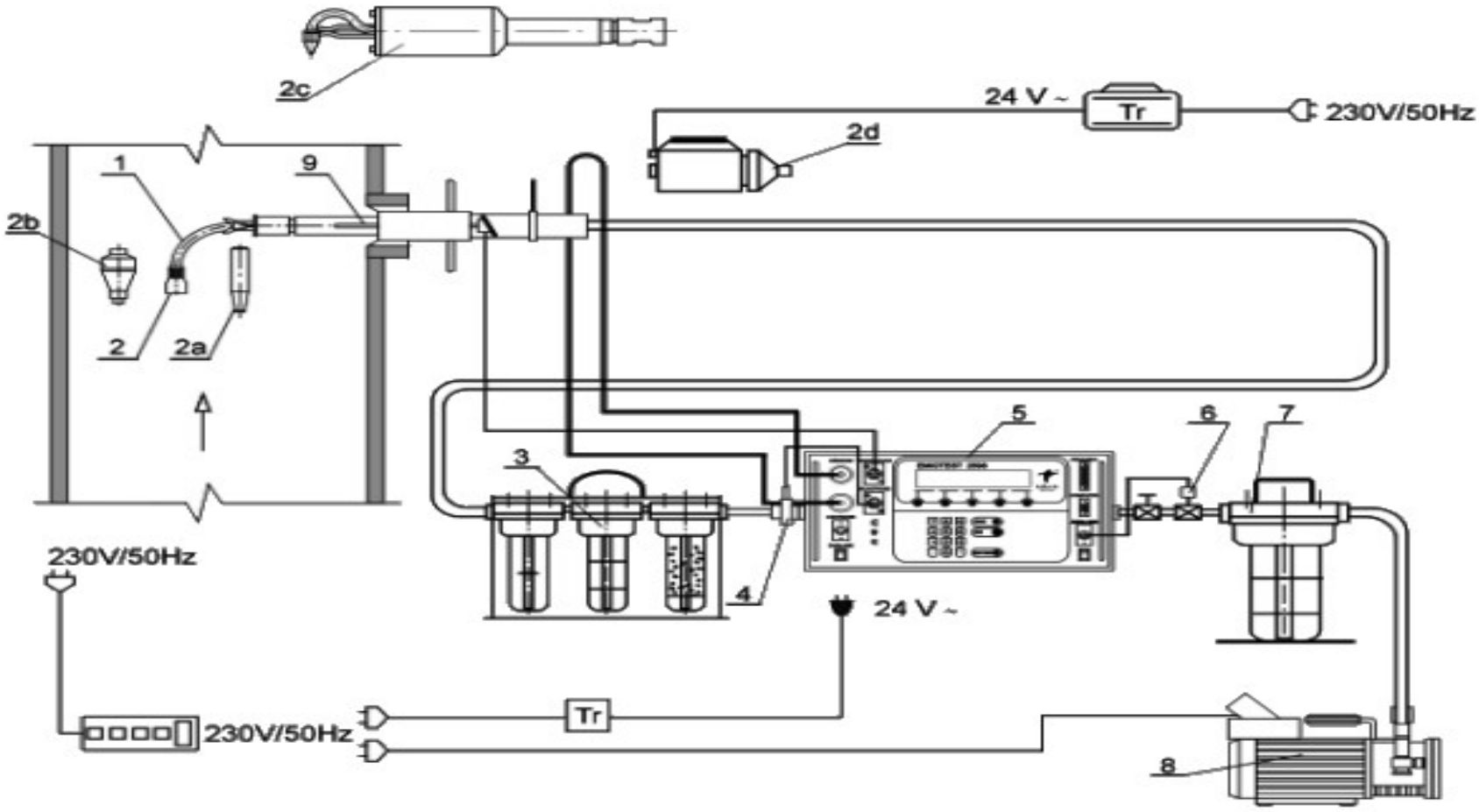
- Conditioning of the filter (24h)
- Weighting of the filter (M0)

- Sampling

- Conditioning of the filter (48h)
- Weighting of the filter (M1)

- Mass of the sample: M1-M0

filters are conditioned and weighed at 295 K (22 °C) ± 3 K, relative humidity of 45 ± 8 % (DIRECTIVE 97/68/EC )



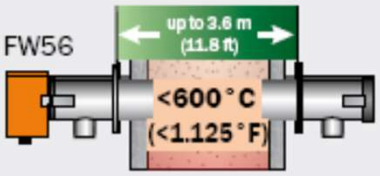

•Segmented or one-parted velocity (integrated with gas velocity measurement system) **probe aspiration** (1) with exchangeable heads depending on the structure of measuring stub pipes and applied way of dust filtration and exchangeable aspiration tips (2)
•Dust separators used during the internal (2a,2b,2c) and external (2d) filtration (directly in the duct or on external part of aspiration line)
•Three-chamber moisture separator (3)
•Hygrometer module (4)
•Control unit of the set (5)
•Control valve module with the servomotor of the automatic control (6)
•High-efficiency vacuum pump (8) with the surge vessel (7)
•Temperature probe (9)

## APPLICATION RANGE FOR THE TRANSMISSIOMETER

200 mg/m³ ... 20 g/m³

- Limit value monitoring at small boiler plants
- Filter monitoring
- Dry gases

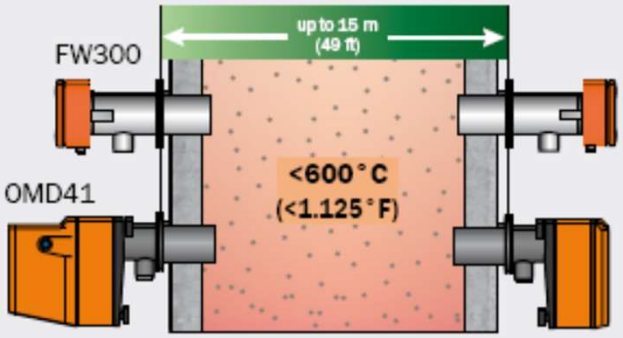
FW56




- Dust measurement
- Electrostatic precipitator monitoring
- U.S. EPA compliant
- Dry gases

FW300

OMD41




## APPLICATION RANGE FOR THE SCATTER-LIGHT MEASURING DEVICES

0 ... 200 mg/m³

FW100

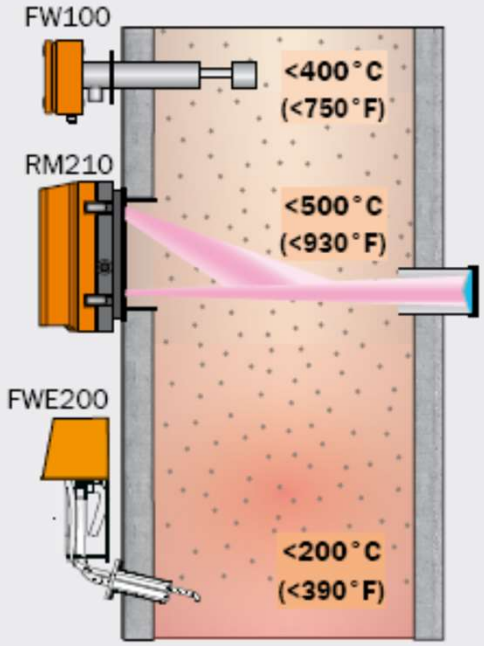
- Bag filter monitoring
- Dust measurement
- Dry gases

RM210

- Dust measurement
- Dry gases

FWE200

- Dust measurement
- Wet gases



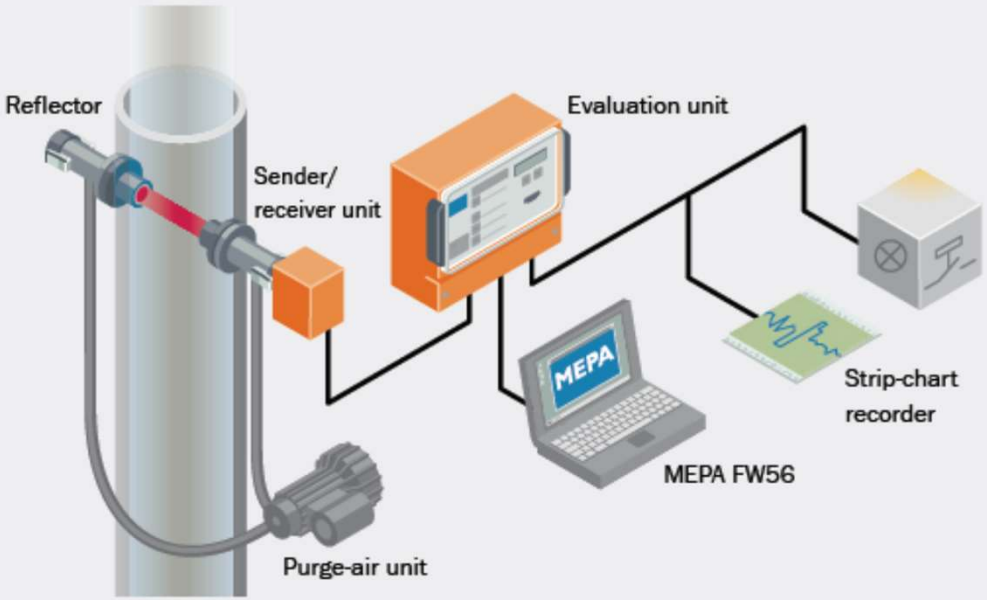

Gravimetric

Sick-Maihak

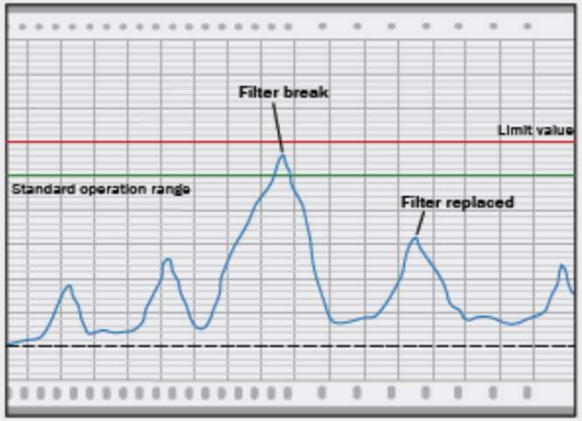
# Transmissiometry

- When a light beam shines through a mixture of gas and particles, the particles weaken the beam by absorption and scattering. The more particles in the light beam, the stronger the weakening of the beam.
- The comparison of the intensities of initial light and received light supports a precise statement of the transmission.
- After conversion of the transmission in extinction and a gravimetric comparison measurement, the result is displayed in mg/m3.

# Transmissiometry




Monitoring of several measuring points with FW56 MEPA software



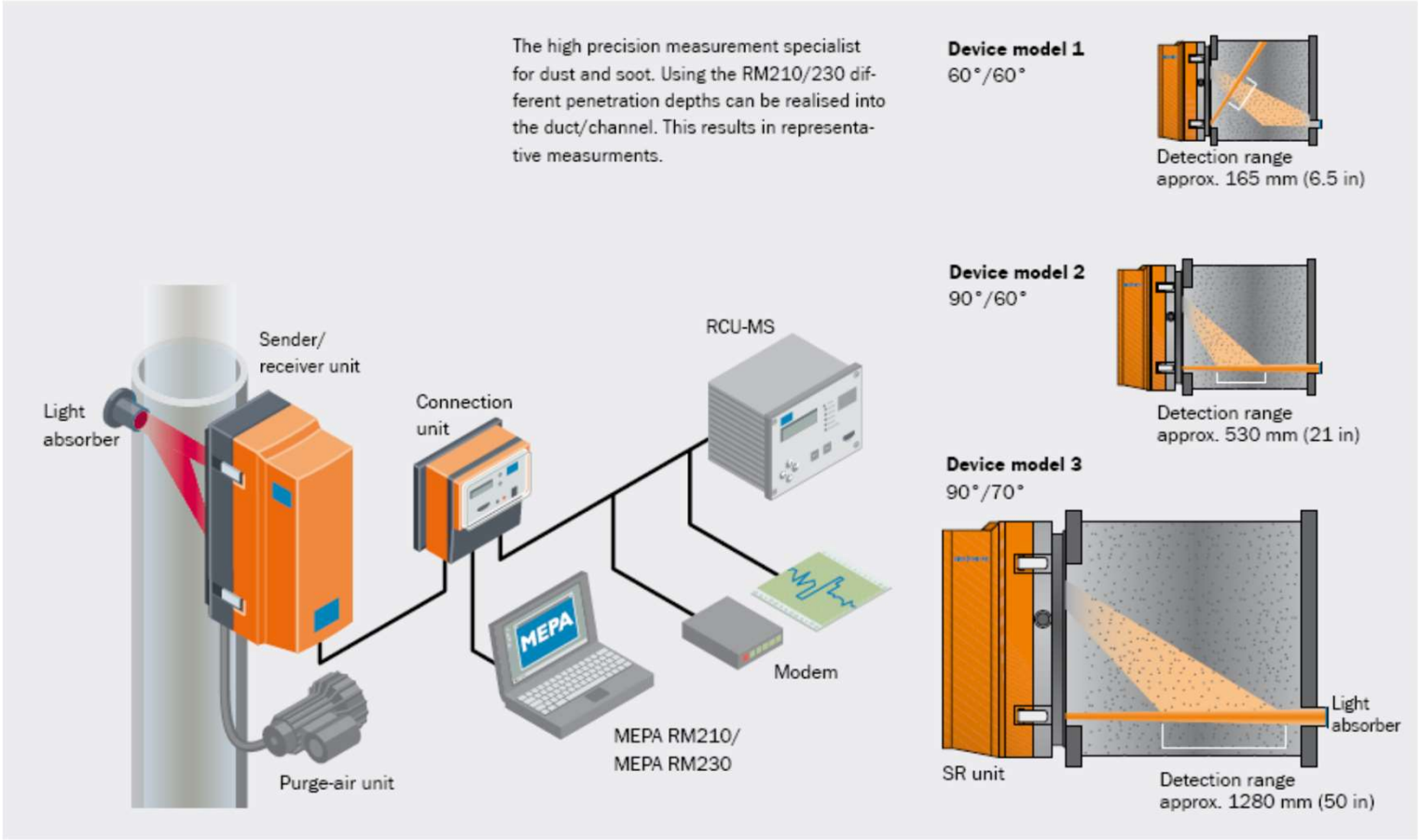

Measuring value recording of a filter break detection

Sick-Maihak

# Scatter-light

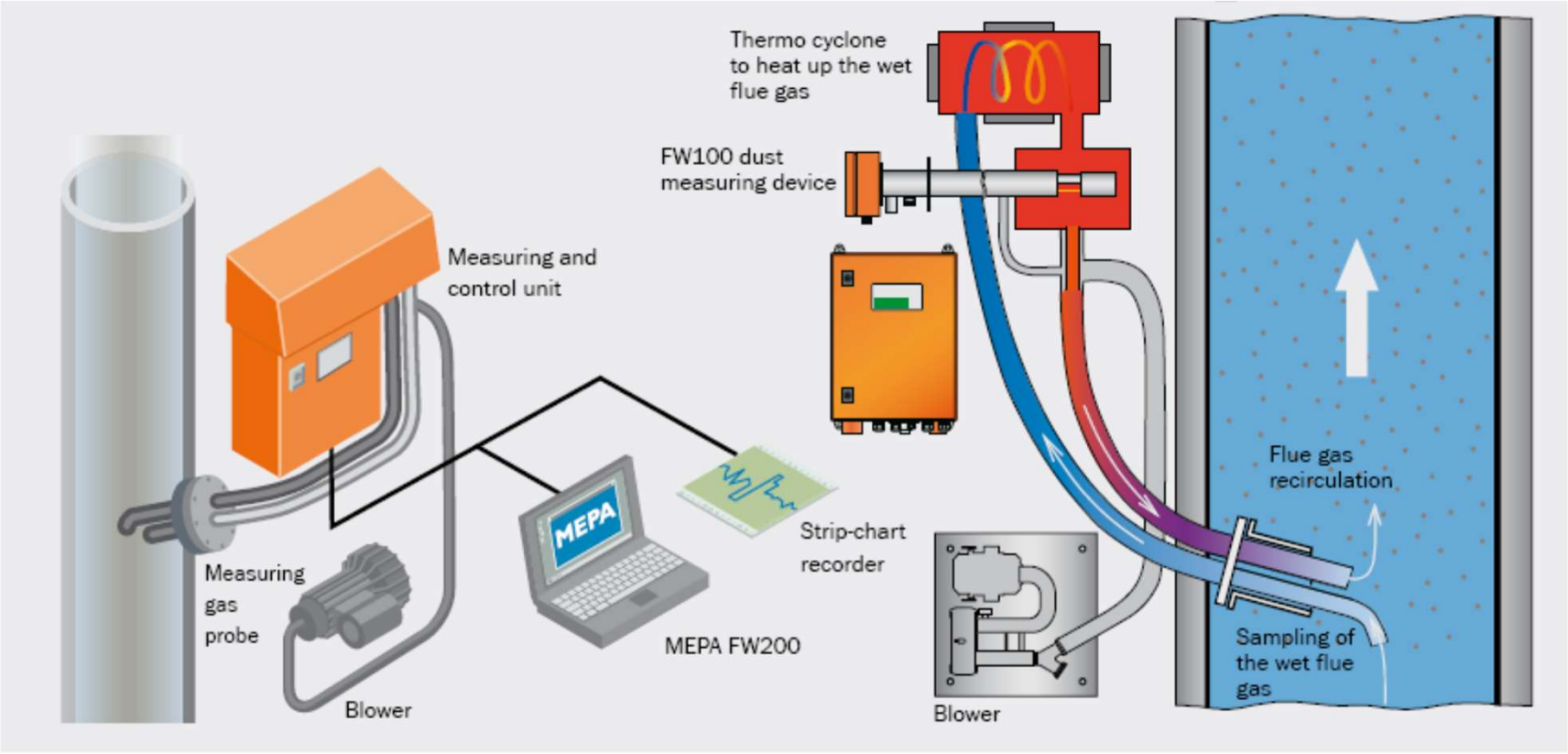
- A light sender radiates light that is scattered by the particles in the gas which is then detected by a sensitive detector. The dispersed light principle is suited for small dust loads – also under 1 mg/m3.
- The correlation between measured value indication and dust load is determined by means of gravimetric comparison measurements.
- Both backwards and forwards scattering are used for scattered light measurement applications.

# Scatter-light (dry-gases)




Sick-Maihak

# Scatter-light (wet-gases)




Sick-Maihak

# Particulate Matter (PM)

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- Ambient Aerosol Monitoring [µg/m3]

- PM10 - size less than or equal to 10 micrometers
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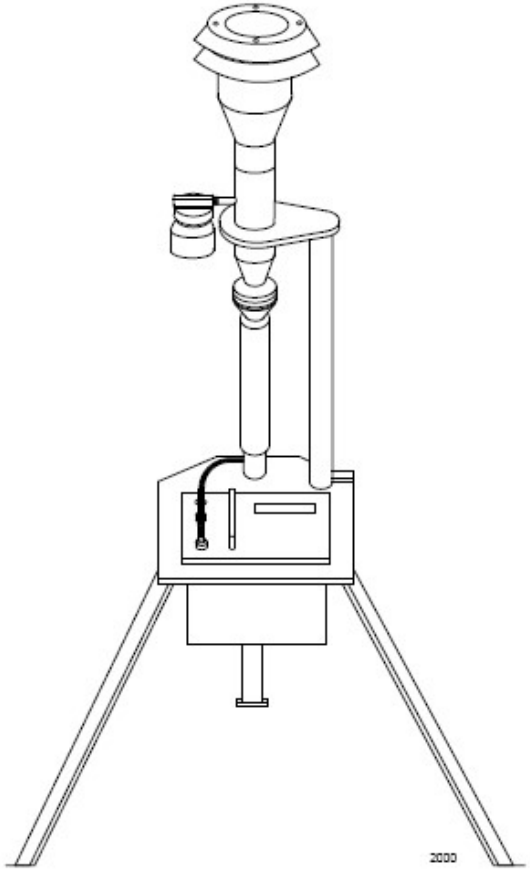
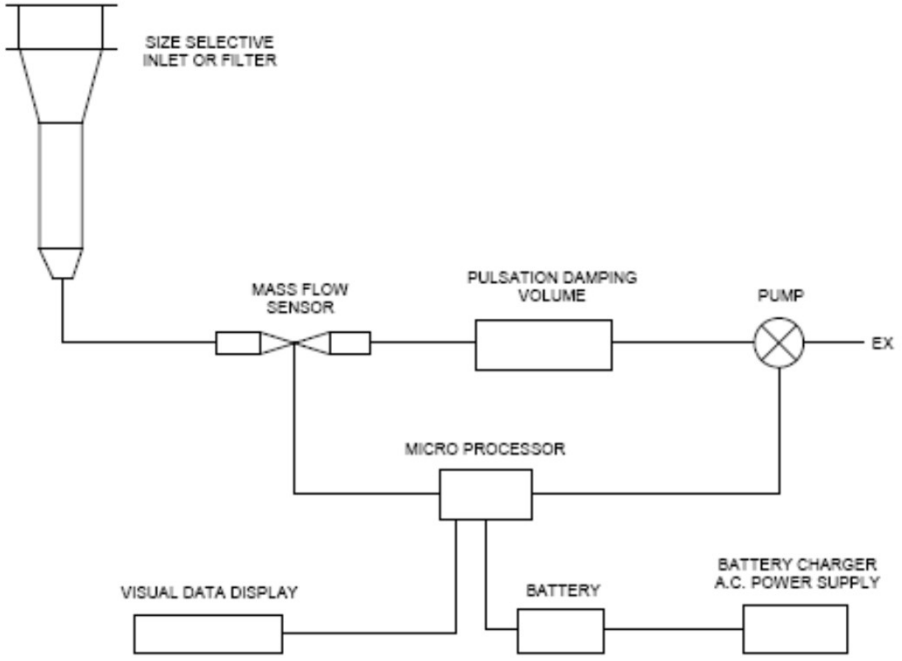
# Ambient Aerosol Monitoring



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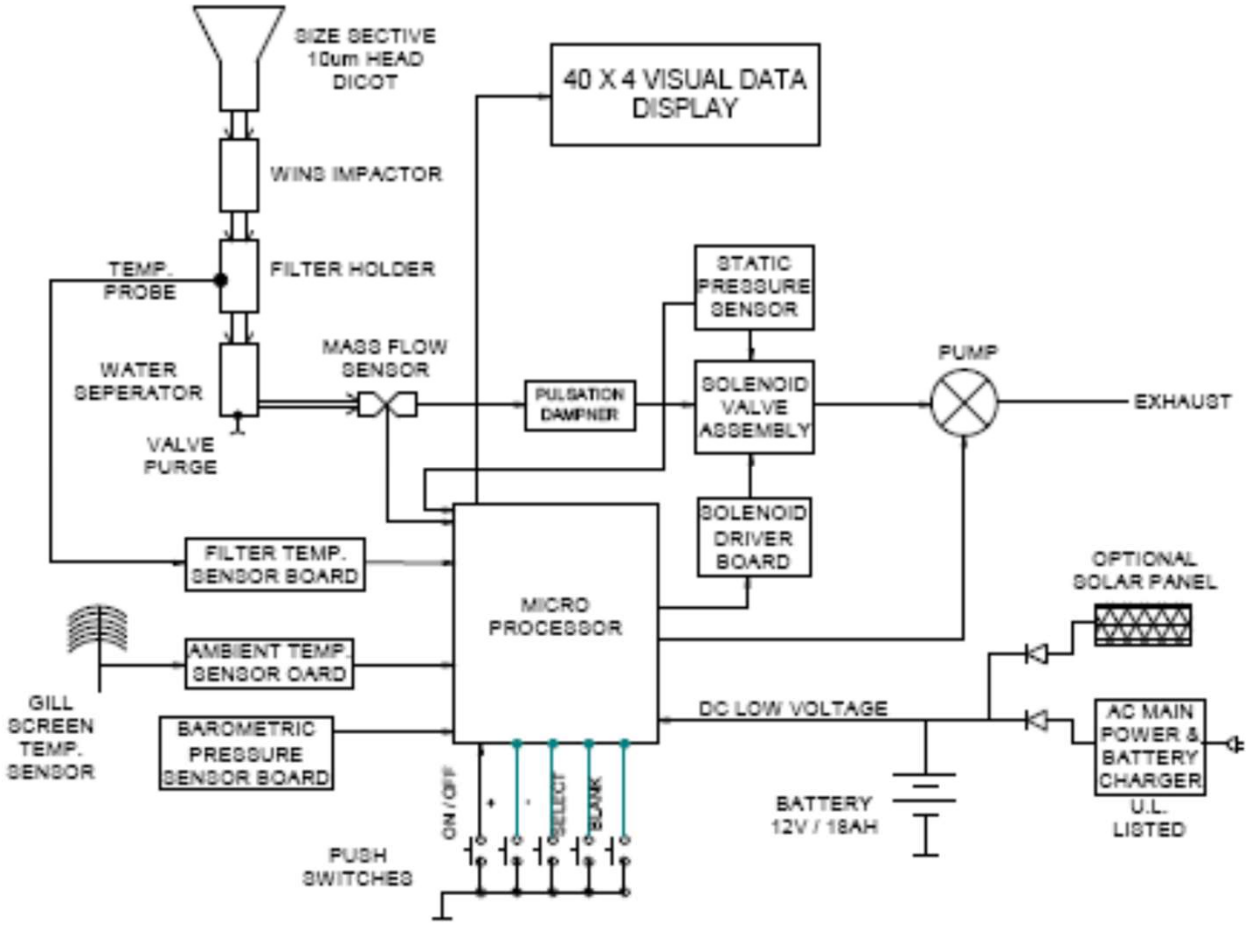
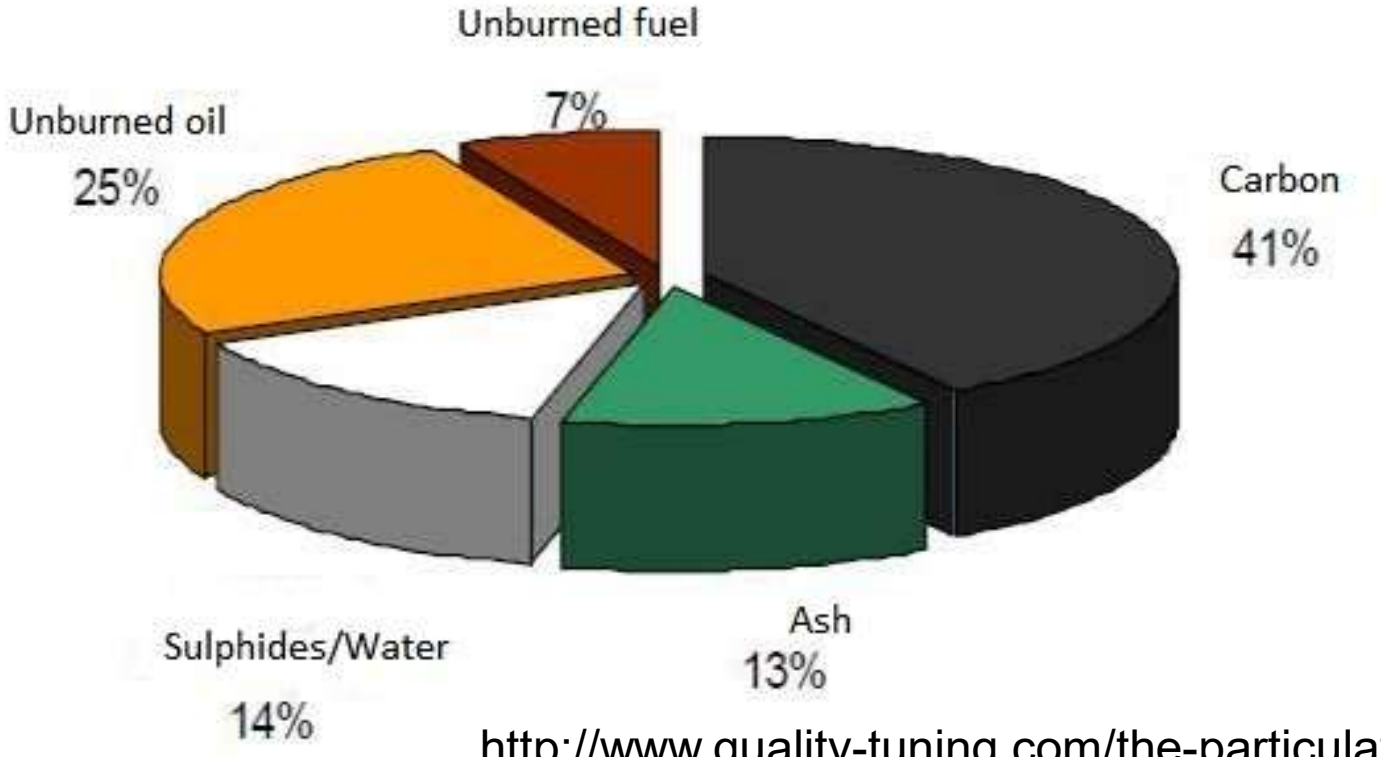
# Ambient Aerosol Monitoring




www.bgiusa.com/

# Heat Engines [g/kWh or g/km]

- ICE,
- Gasturbines,




http://www.quality-tuning.com/the-particulate-emissions-in-diesel-engines

# Particulate Sampling System (PM measuring)

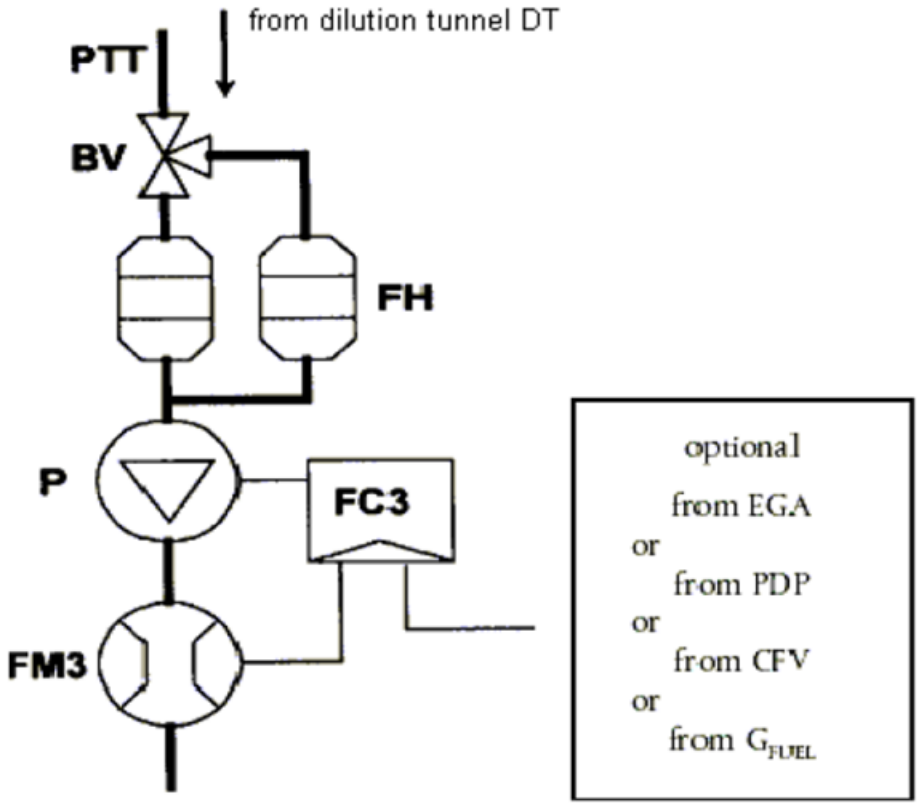



**Figure 2.** Particulate Sampling System according to the Directive 1999/96/EC. FH = Filter Holder, P = Pump, EGA = Exhaust gas Analyser, $G_{FUEL}$ = Fuel mass Flow rate, FM = Flow Measurement (Device), BV = Ball Valve

DIRECTIVE 97/68/EC

# Gravimetric

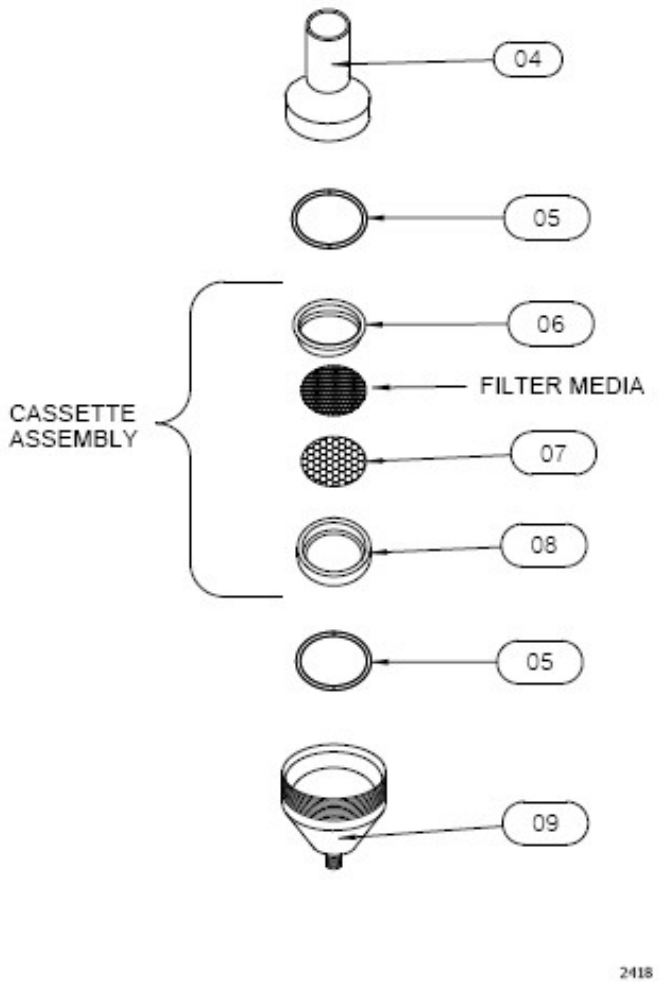



Figure 4. Exploded View of Filter Cassette and Filter Holder

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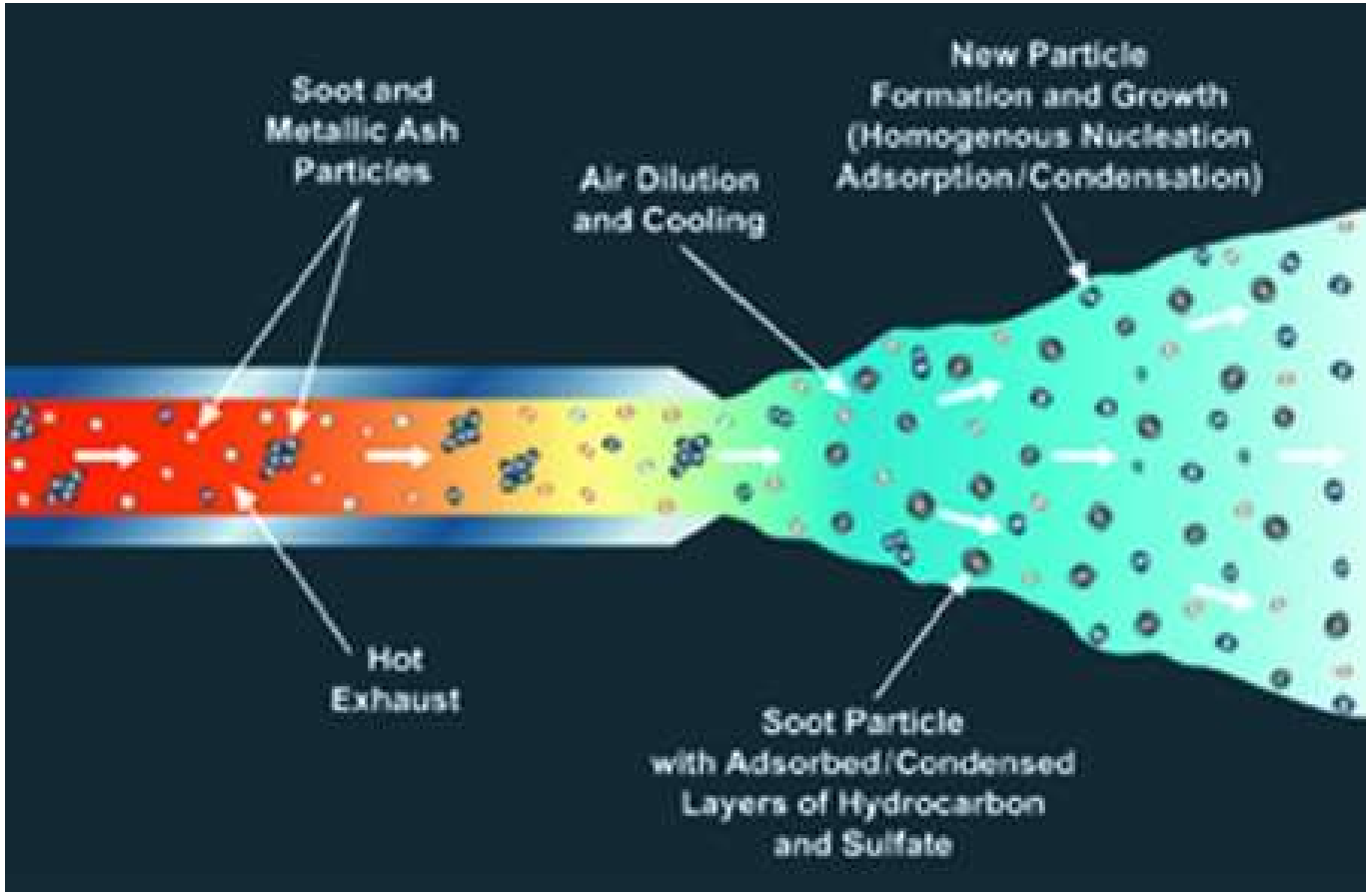
- Mass of the sample: M1-M0

filters are conditioned and weighed at 295 K (22 °C) ± 3 K, relative humidity of 45 ± 8 % (DIRECTIVE 97/68/EC )

Atmospheric dilution and cooling of hot diesel exhaust may trigger the nucleation of new particles such as semi-volatile hydrocarbons and sulfuric acid.




*Imad A. Khalek*:The Particulars of Diesel Particle Emissions

# Partial Flow Dilution System

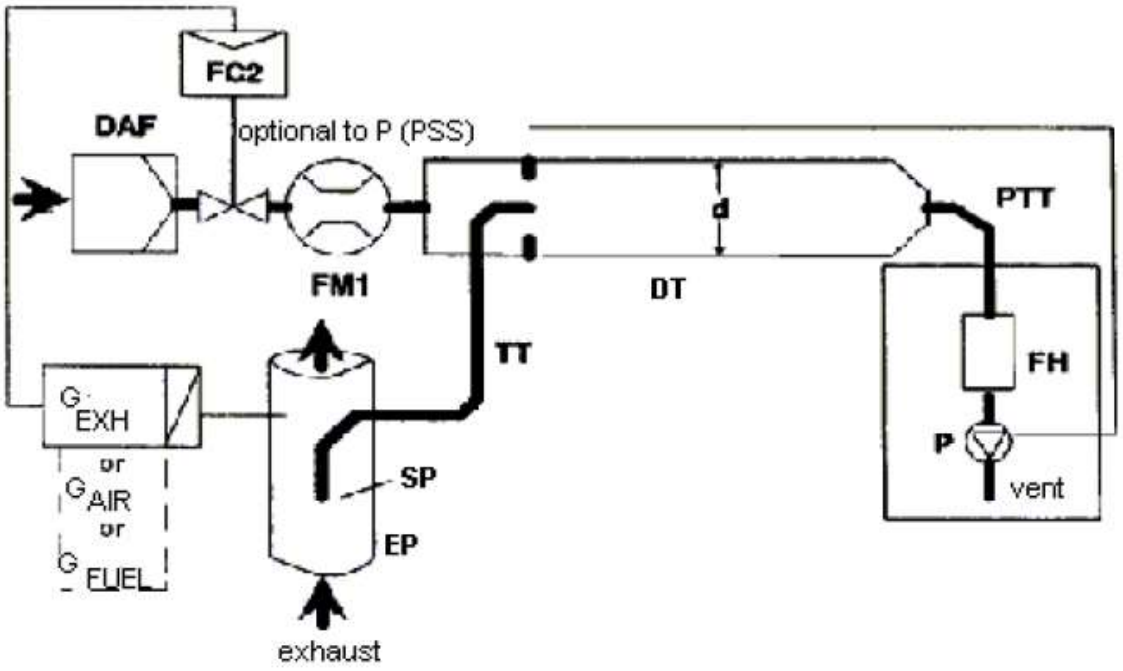



**Figure 4**. Partial flow dilution system with total sampling according to the Directive 1999/96/EC. $G_i$ = Mass flow rate, SP = Sampling Probe, TT = Transfer Tube, DT = Dilution Tunnel

DIRECTIVE 97/68/EC

Partial Flow Dilution System

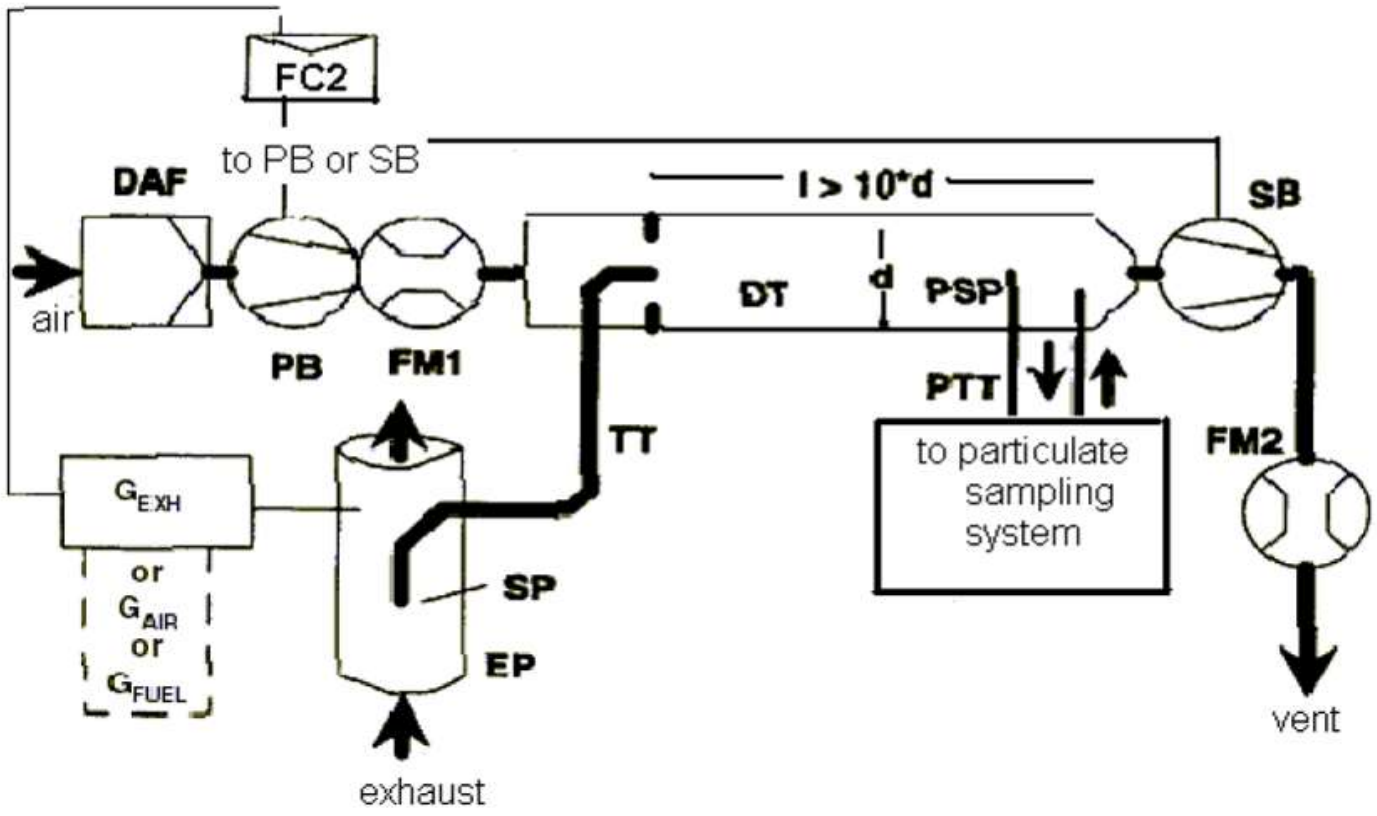



**Figure 5.** Partial flow dilution system with flow control and fractional sampling (SB: Suction Blower) control according to the Directive 1999/96/EC. PB = Pressure Blower, ISP = Isokinetic Sampling Probe, PDT = Pressure Transducer, TT = Transfer Tube, PSP = Particulate Sampling Probe, PTT = Particulate Transfer Tube

DIRECTIVE 97/68/EC

Full Flow Dilution System

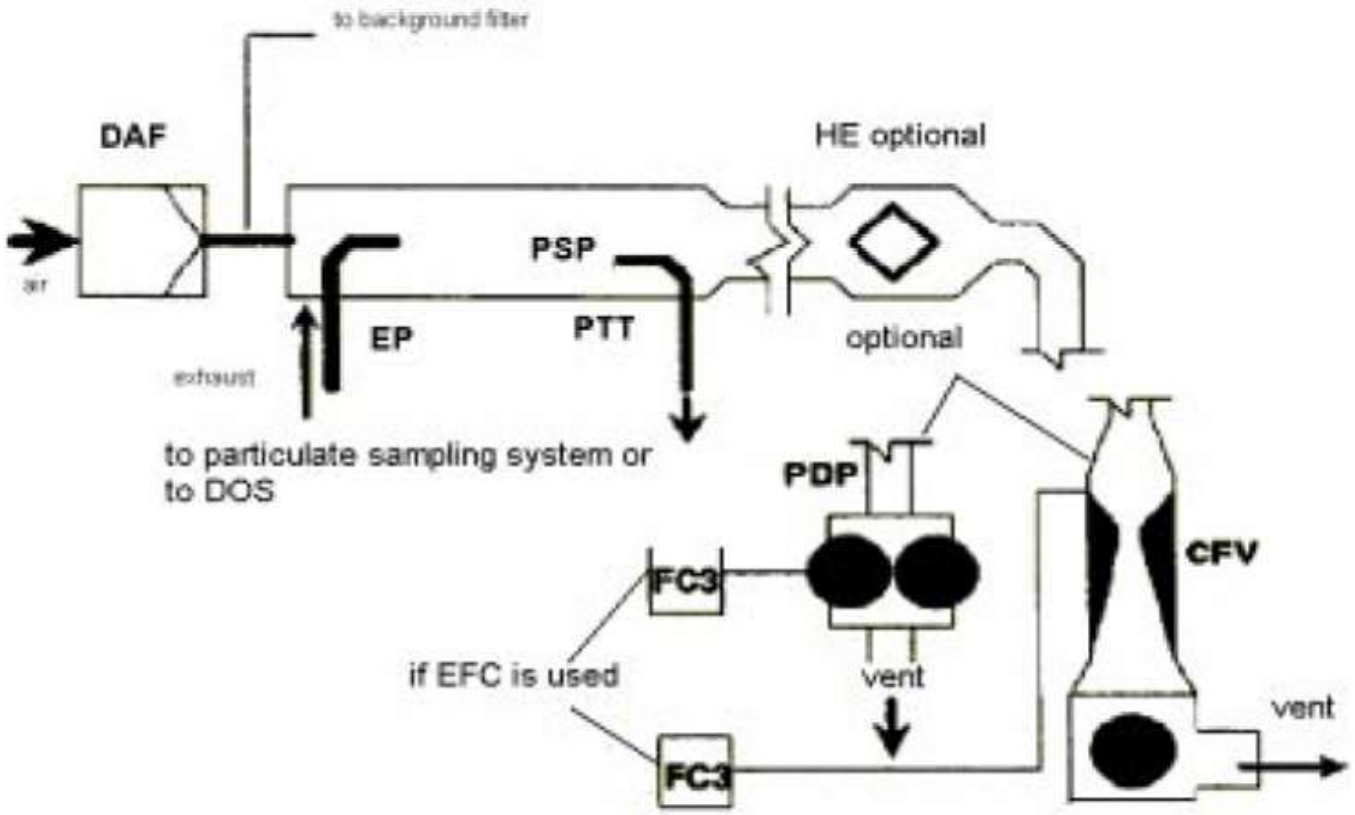
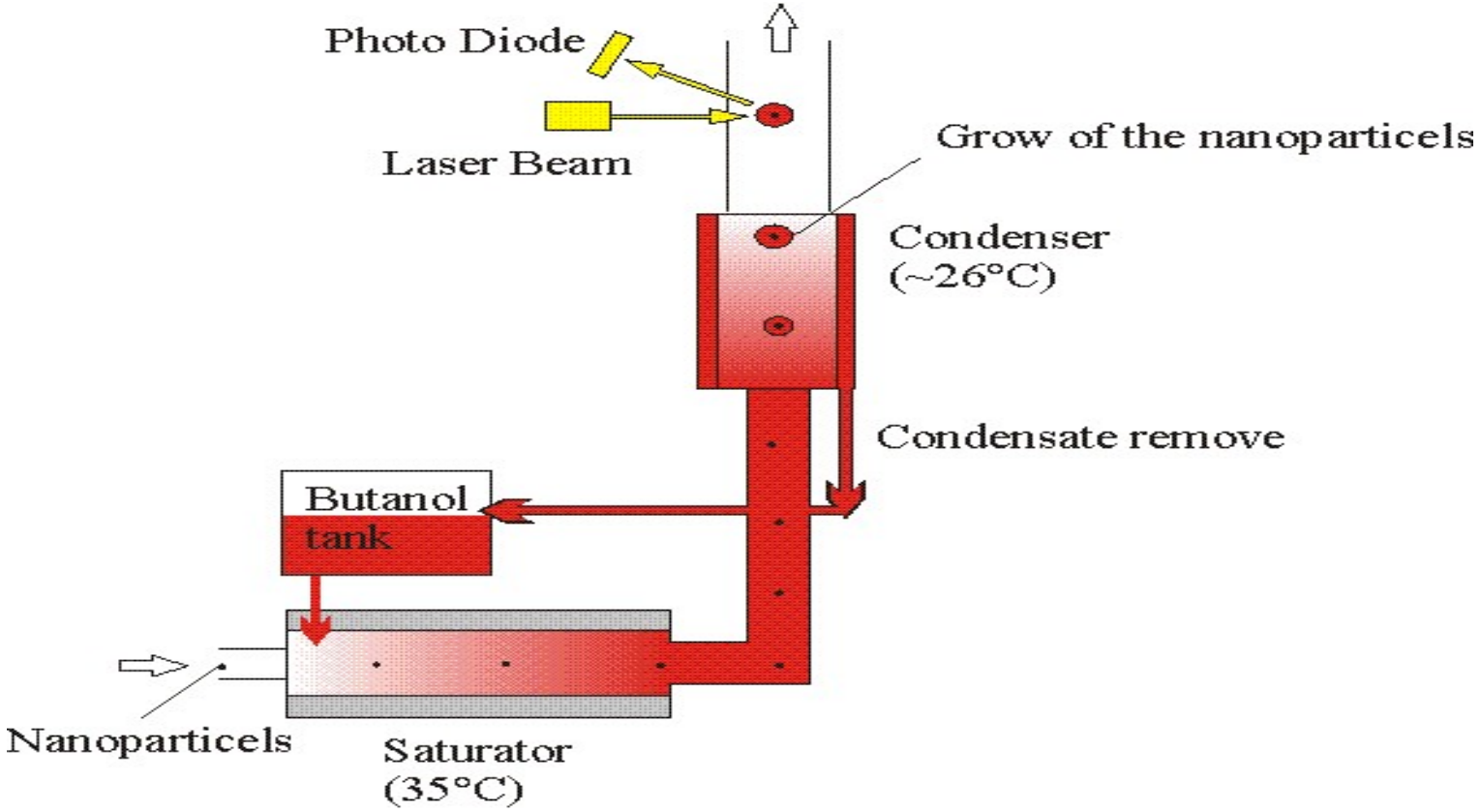



**Figure 1.** The full flow dilution system according to the Directive 1999/96/EC. DAF = Dilution Air Filter, EP = Exhaust Pipe, PSP = Particulate Sampling Probe, PTT = Particulate Transfer Tube, HE = Heat Exchanger, EFC = Electronic Flow Compensation, PDP = Positive Displacement Pump, CVF = Critical Flow Venturi, FC = Flow Controller

DIRECTIVE 97/68/EC

# Nanoparticles [particles/cm$^3$]

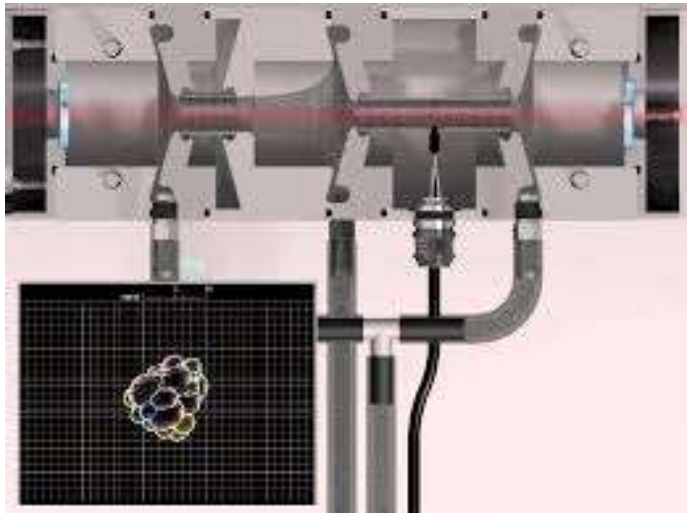



Condensation Particle Counter (CPC)

GRIMM Aerosol Technic

# Photo Acoustic Soot Sensor (PASS)

**continuous measurement**



highly-absorbent soot particles is irradiated with modulated light

↓

periodic warming and cooling

↓

expansion and contraction

↓

sound wave

↓

detection with microphones

https://www.youtube.com/watch?v=x5kvB4Jm-yI

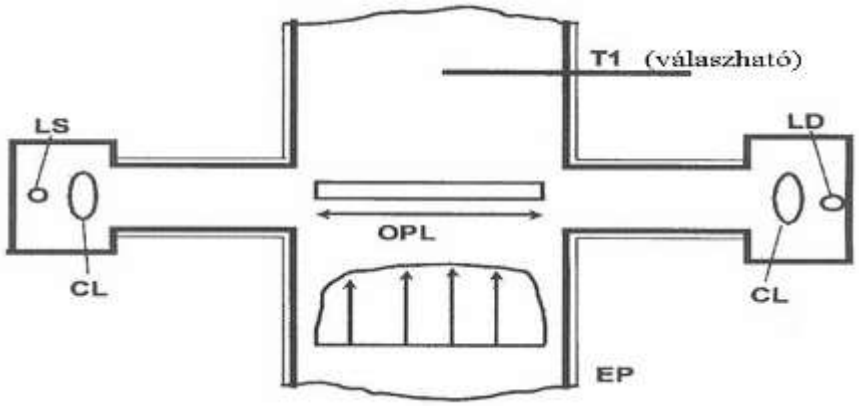
# Smoke - Opacimeter

| | |
|---|---|
| Measurement value output | Opacity N [%] or absorption coefficient k [$m^{-1}$] |
| Measurement range | N = 0 ... 100 % or k = 0 ... 10 $m^{-1}$ |

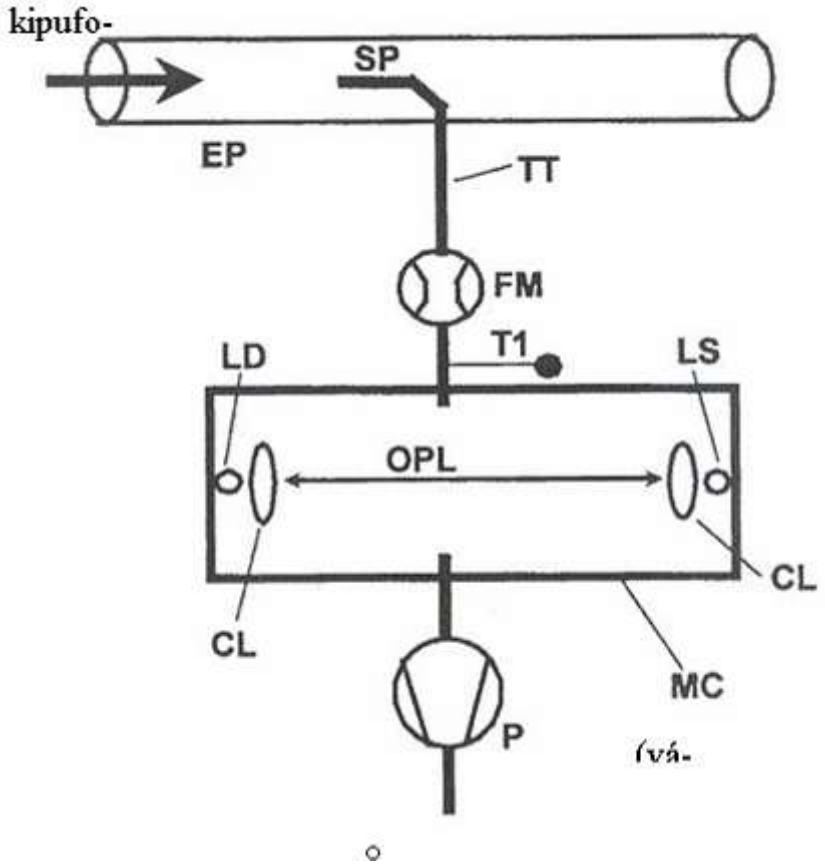
As the Opacimeter measurement value results from the attenuation of visible light in the measuring chamber, the smoke density value is in effect the result of black smoke ("C"), blue smoke (hydrocarbon vapour) and white smoke (water vapour). In addition to the well known ECE R24 test procedure, the European authorities are now preparing the introduction of a new Opacity Homologation Test as part of the ECE R49 Heavy Duty Emission legislation for the EURO III amendment.

# Smoke - Opacimeter

Green LED, wave lenght: 550 - 550 nm

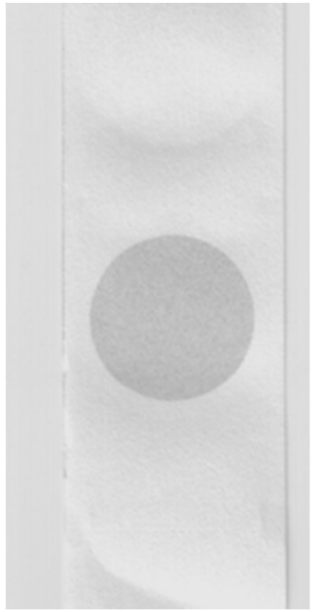



Full-flow system

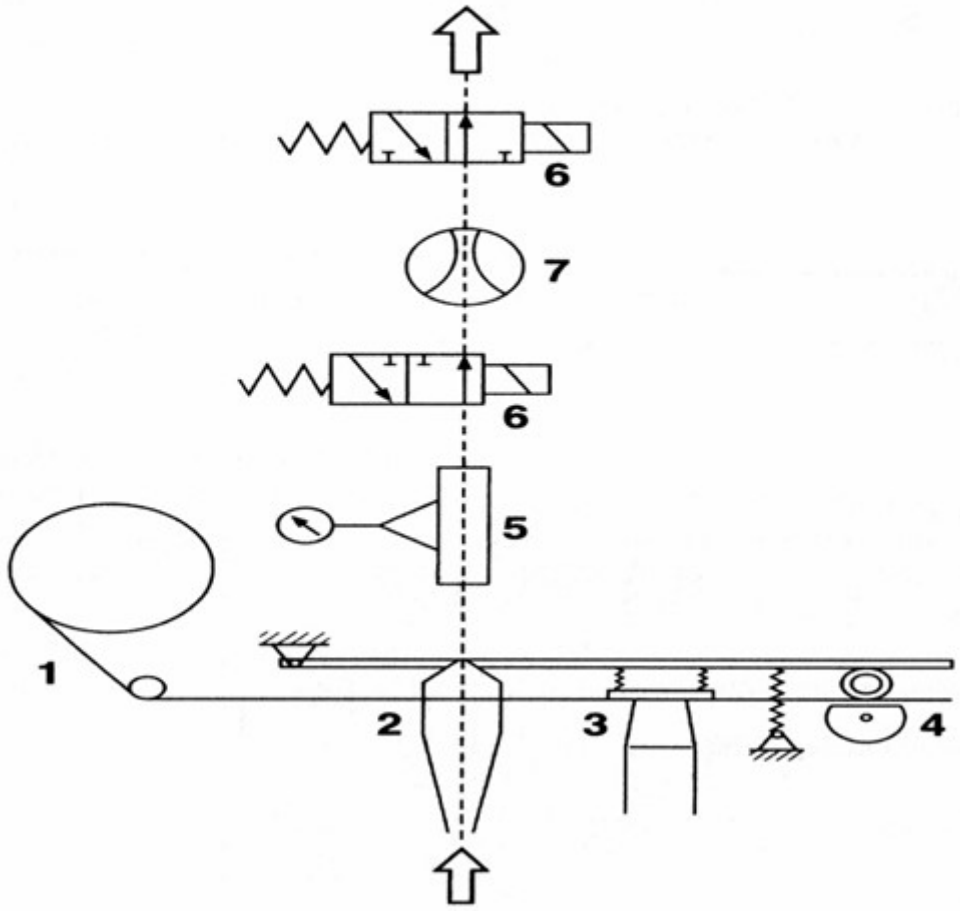



Partial-flow system

# Filter Smoke Number (FSN)



***Smoke tester*** *(filter method)*
*1 Filter paper, 2 Gas passage, 3 Reflective photometer, 4 Paper transport, 5 Volume measurement, 6 Changeover valve for purge air, 7 Pump.*



# Components of the reflectometer head and measurement principle of the Filter Smoke Meter

Definition of the paper blackening ($P_B$) measurement value:

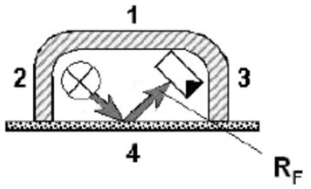
$$P_B = \frac{100 - R_R}{10}$$

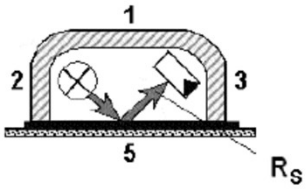
$$R_R = \frac{R_S}{R_F} \cdot 100\,\%$$

$R_S$.....reflectometer value of the sample

$R_F$.....reflectometer value of the unblackened filter paper

$R_R$ .....relative brightness of the sample (relative radiance factor)




1 ..... Reflectometer

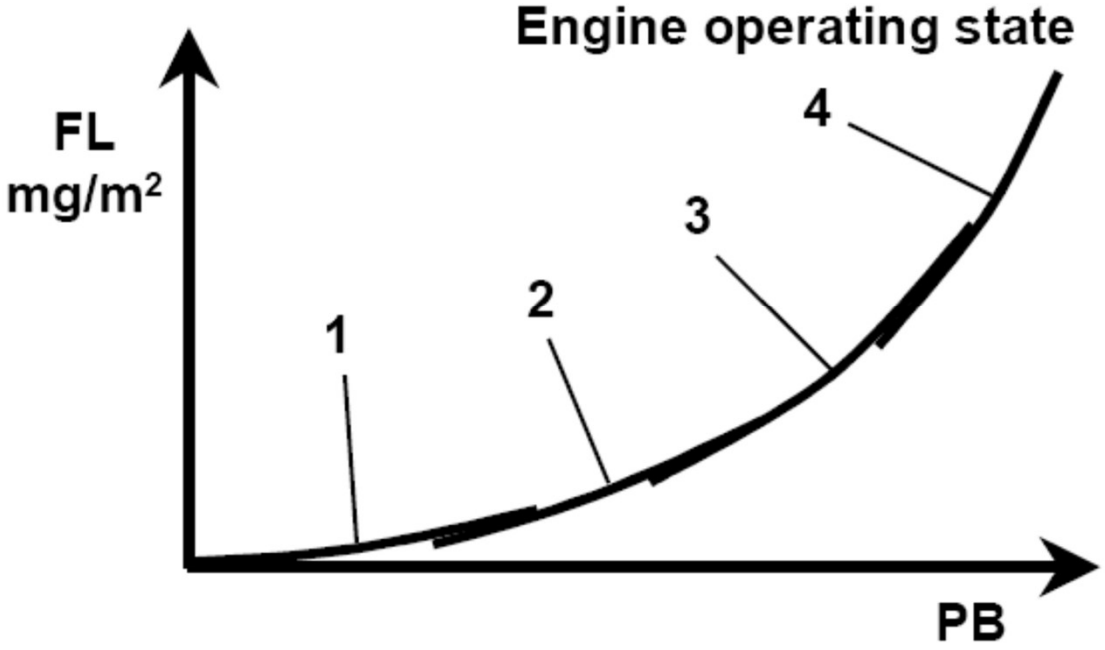
2 ..... Light source

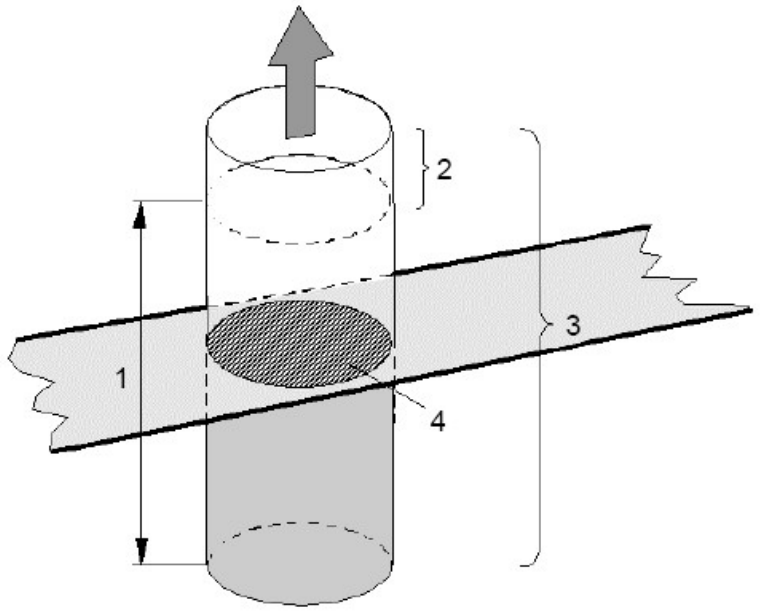
3 ..... Detector

4 ..... Clean filter

5 ..... Blackened filter

# Relationship between filter loading (FL) and paper blackening (PB).





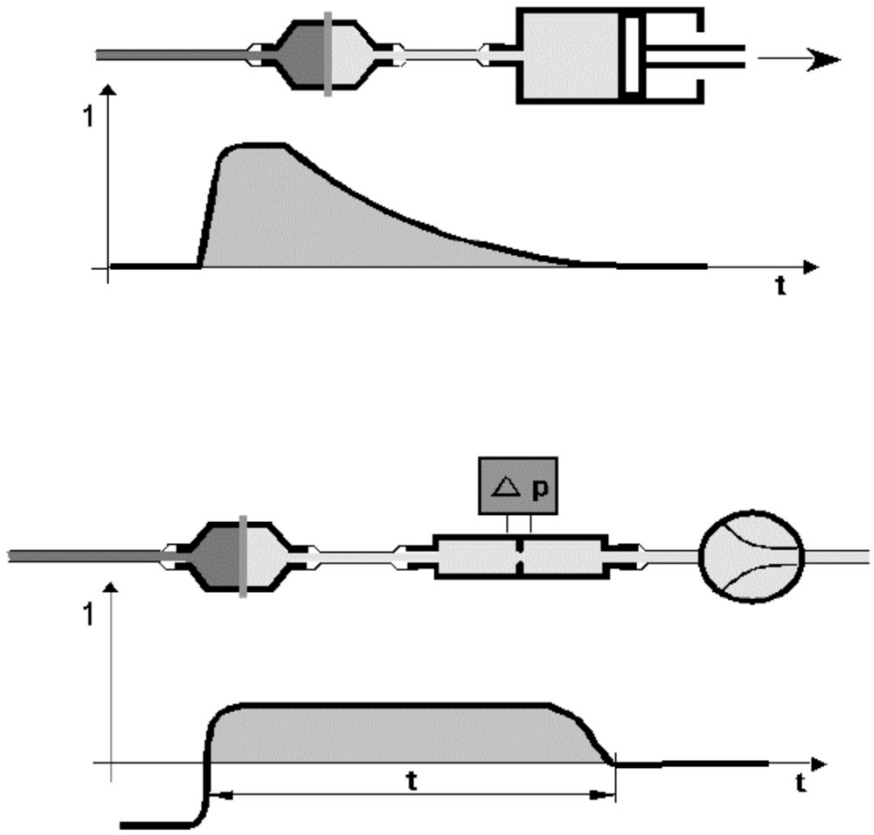

1 ..... Effective sampling length

2 ..... Dead volume

3 ..... Sampled volume

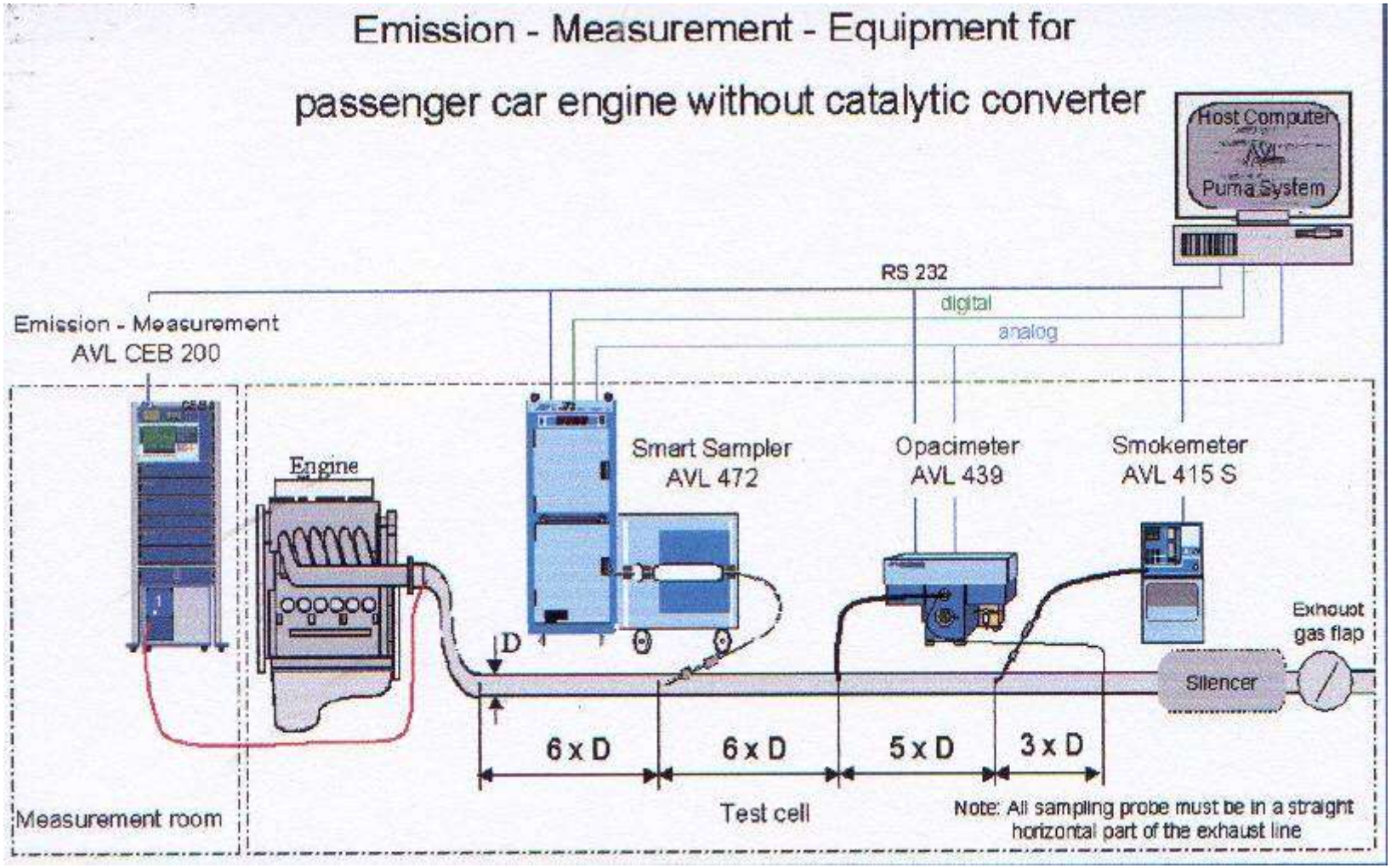
4 ..... Filter area

Fig. 1: Principle of exhaust gas sampling with FSN measurement devices (AVL 415, AVL 415S). Relationship between sampled volume, effective length and filter area

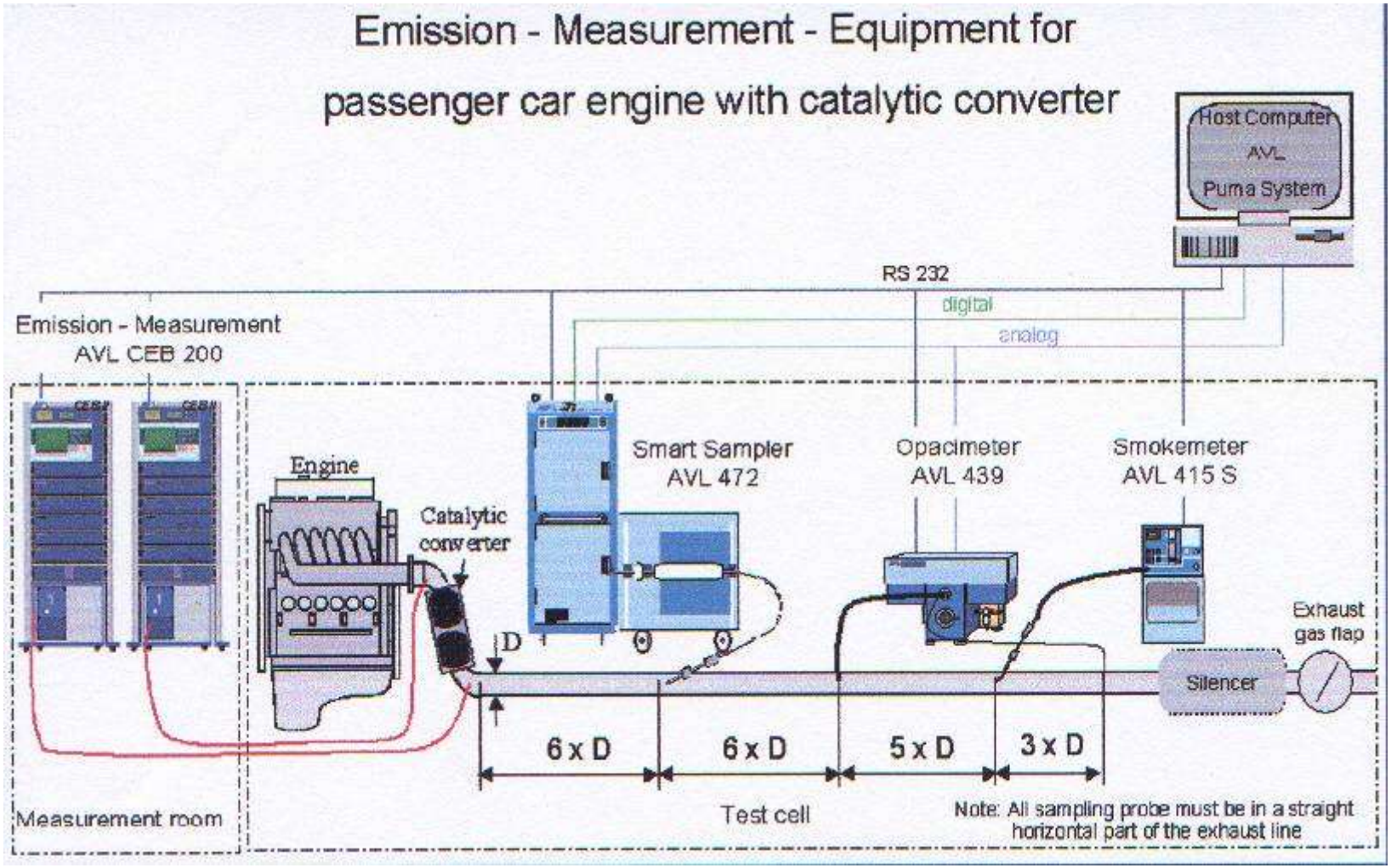



1 ..... Flow of exhaust gas

Fig. 2: Piston pump versus diaphragm pump


Emission - Measurement - Equipment for
passenger car engine without catalytic converter
Host Computer
Puma System
RS 232
digital
analog
Emission - Measurement
AVL CEB 200
Engine
Smart Sampler
AVL 472
Opacimeter
AVL 439
Smokemeter
AVL 415 S
D
Exhaust
gas flap
Silencer
6 x D
6 x D
5 x D
3 x D
Measurement room
Test cell
Note: All sampling probe must be in a straight
horizontal part of the exhaust line

AVL


Emission - Measurement - Equipment for
passenger car engine with catalytic converter
Host Computer
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Engine
Catalytic
converter
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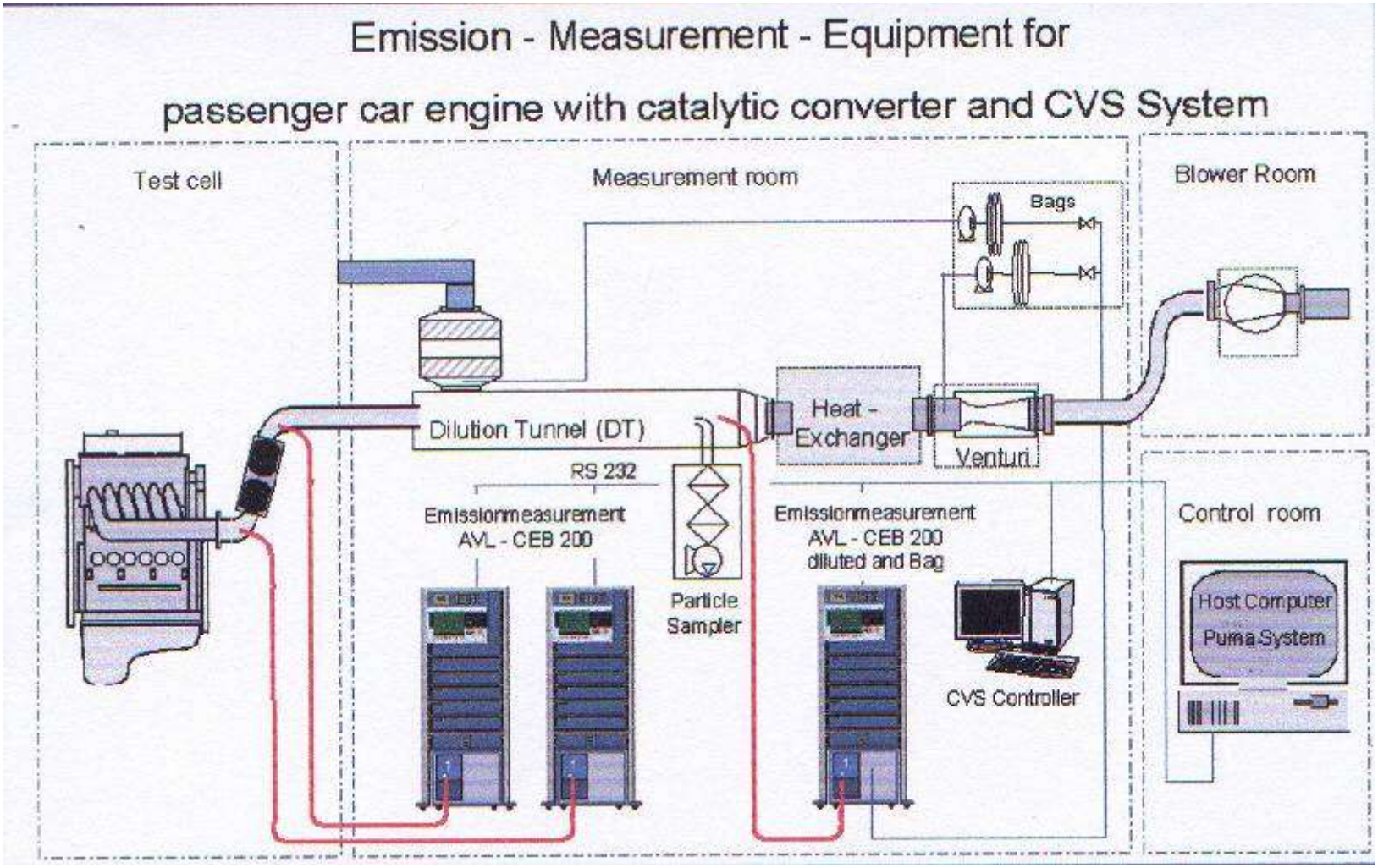
Emission - Measurement - Equipment for
passenger car engine with catalytic converter and CVS System
Test cell
Measurement room
Blower Room
Bags
Dilution Tunnel (DT)
Heat - Exchanger
Venturi
RS 232
Emissionmeasurement AVL - CEB 200
Particle Sampler
Emissionmeasurement AVL - CEB 200 diluted and Bag
CVS Controller
Control room
Host Computer Puma System

AVL

# Literature:

- *http://www.empa.ch/plugin/template/empa/*/20987/---/l=2*
- *http://ec.europa.eu/enterprise/automotive/*
- http://www.emio.com.pl/dev/epyl.html