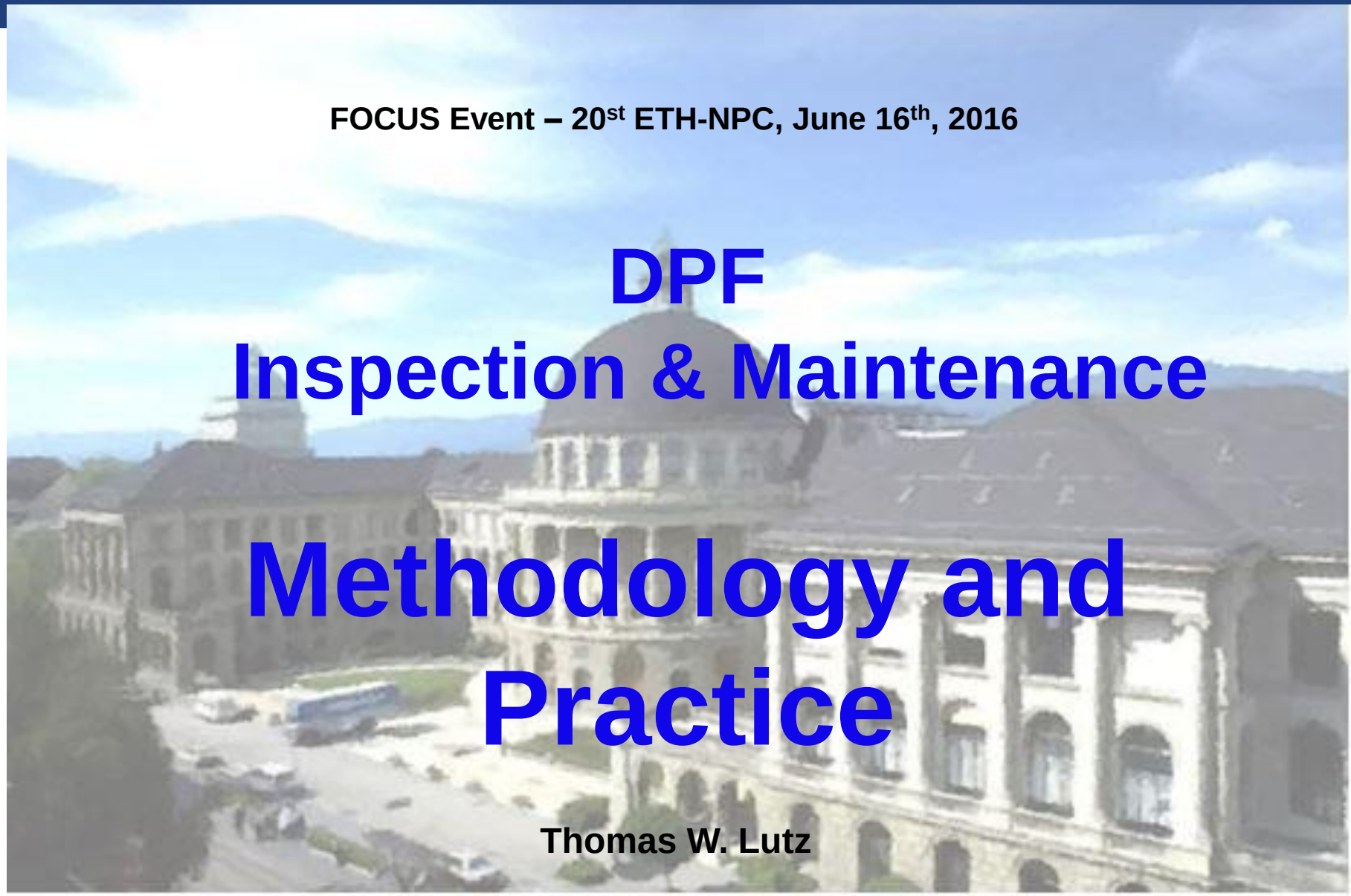


FOCUS Event – 20st ETH-NPC, June 16th, 2016

DPF Inspection & Maintenance

Methodology and Practice

Thomas W. Lutz

Maintenance must be a periodic routine

Emission control must become part of maintenance

→ **Guarantees emission stability**

→ **Reduces overall costs**

(by preventive repair, avoidance of operation interruptions…)

Engine life and emission stability depend mainly on maintenance

Technical Requirements

- The vehicles are equipped with certified filters ($\eta > 97\%$) and wireless dataloggers
- Certified PN (plus CO) measurement devices, portable, low cost and highly sensitive are available
- The obligation for periodical maintenance of emission relevant components, particle emission checks and documentation is defined by a mandatory regulation

Potential of PN-Measurement

- Fast, handheld, accurate PN-measurement for:
  - Fleet maintenance and control
  - Roadside measurement
  - Official periodic emission checks

- Verify filter efficency
- Detect small repairable DPF defects
- Indicate the need for filter exchange
- Detect engine malfunctions

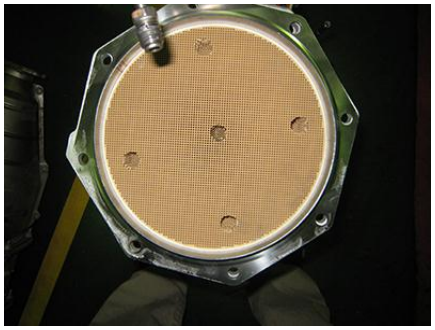
Portable Particle Emission Analyser

Condensation nucleus counter by TSI - NPET

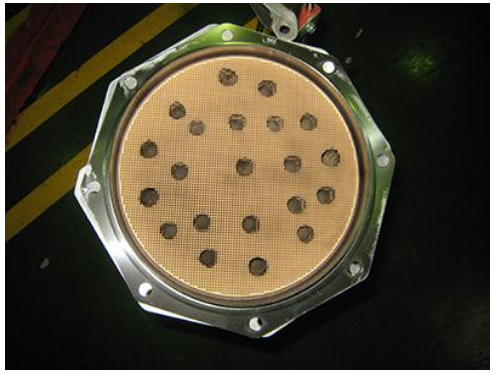
Diffusion charging by TESTO - PEPA

Can small failures be detected by PN at low idle ?

1 hole (0.5%)



5 holes (2.7%)



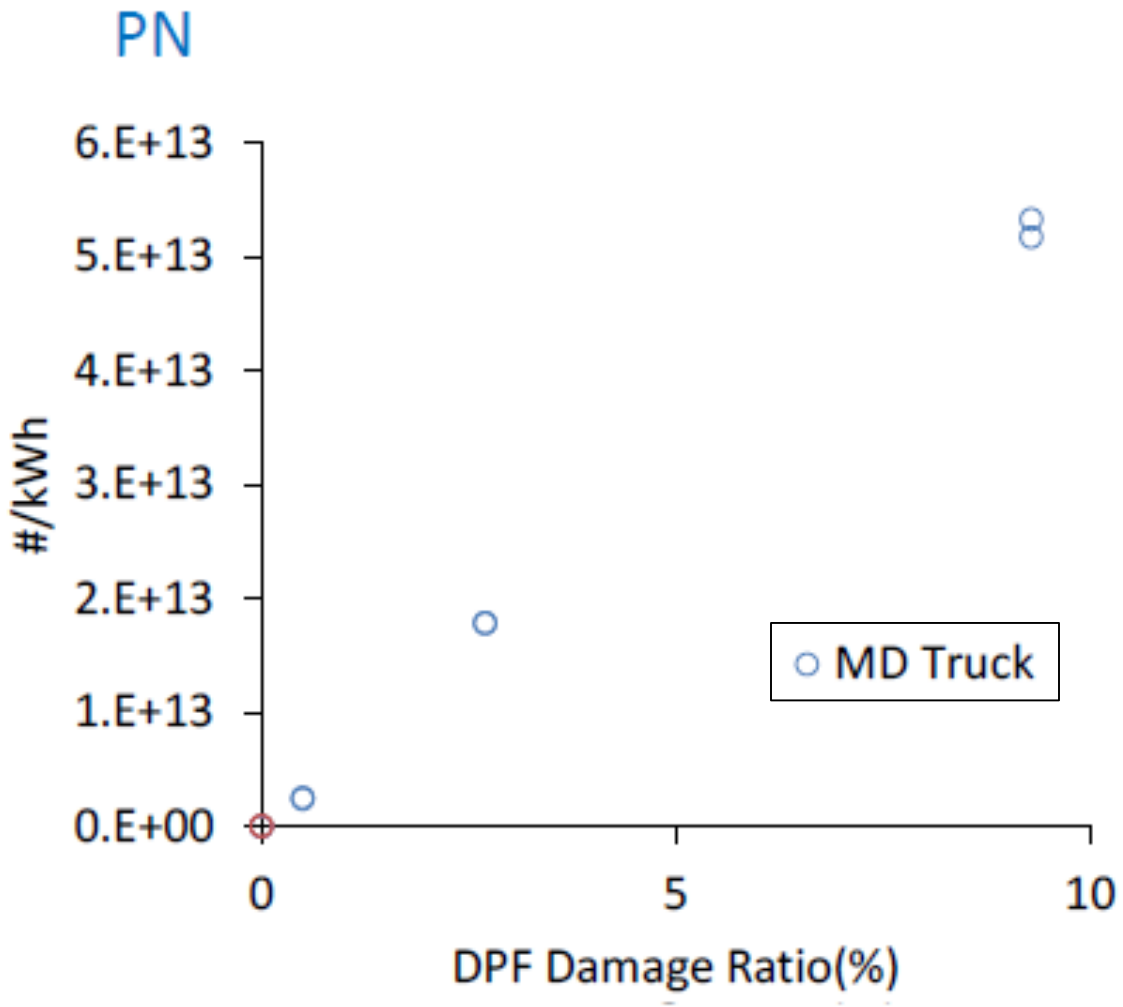
17 holes (9.3%)

41 holes(22.5%)

Completely (100%)

Source: Yamada, ETH-NPC 2015

PN Increase vs. DPF Damage



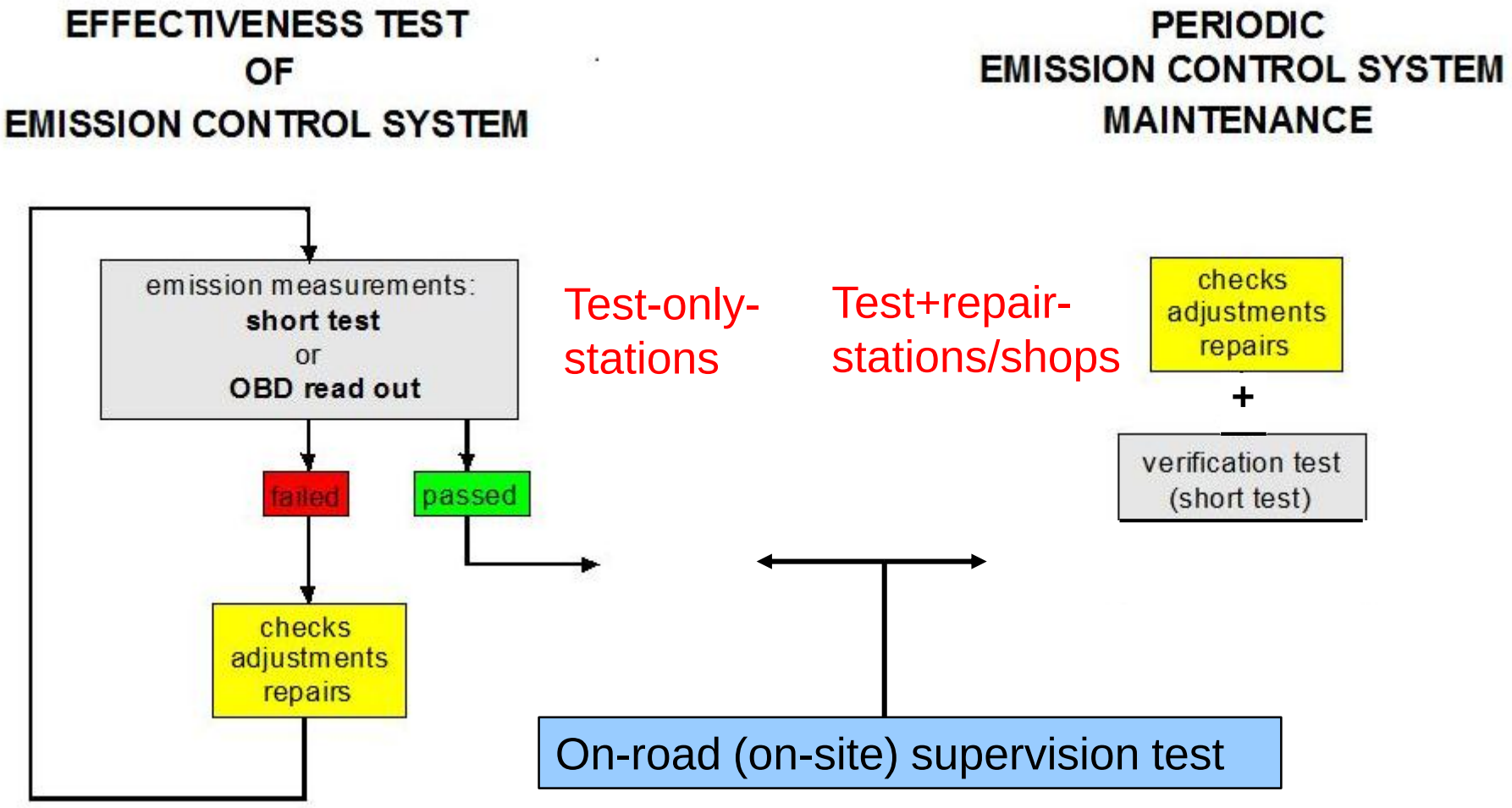
Measured at low idle

Source: Yamada, ETH-NPC 2015

I&M Organization

	Run by:
Test-only-stations	- Authorities - Authorized private organizations
Test+repair-stations/shops	- Private workshops - Users/fleet owners
Supervision on-road/on-sites	Authorities

General I&M Strategies



I&M Concept Elements (1)
(to be defined)

- **Vehicle categories liable to I&M**
- **I&M concept**
- **I&M procedures:** - tests
  - minimum maintenance
- **I&M intervalls**
- **Quality criteria for I&M performers:** - personnel
  - equipment
- **Certification of I&M performers**

I&M Concept Elements (2)

- **Costs**
- **Data collection / individual documentation**
- **Quality control of I&M performers:** e.g. test equipment (periodical calibration)
- **Enforcement by on-road tests:**
  - procedure
  - crew training
  - equipment
  - financing
  - fines

etc.

Typical I&M Procedure - Checks

① **Regular inspection (every x month, *authorized institution*) (e.g. busses)**

② **Periodical maintenance of emission relevant components (*user, workshop*) (e.g. NRMM CH)**

③ **Supervision on-road (on-site) (*authorities*)**

Regular Inspection – Inspection Scope

①

- **Identification of the vehicle**
- **Measurement of PN at low idle (end pipe)**
  - PN < 100’000/cc → filter system OK
  - PN > 1’000’000/cc → filter or engine failure

► The operator of the vehicle is obligated to a regular engine and filter system maintenance procedure and a retest by an authorized institution

Typical I&M Procedure - Checks

① Regular inspection (every x month, *authorized institution*) (e.g. busses)

② **Periodical maintenance of emission relevant components (*user, workshop*) (e.g. NRMM CH)**

③ Supervision on-road (on-site) (*authorities*)

Maintenance of Emission Relevant Components: Procedure

②

- ***Visual Checks:*** - tightness of all systems
  - oil and soot deposits in the exhaust pipe
  - signs of overheating of the filter housing
- ***Maintenance*** of engine, filter system and crank case ventilation (in case of a closed version), corresponding to the instructions of the manufacturer
- ***Data analysis*** (wireless datalogger), e.g.:
  - too high backpressures (when and where on the route)
  - temperatures (e.g. low idle phases)
- ***Cleaning of filter*** *if necessary,* → the cleaned filter has to be checked by a PN measurement at low idle (end pipe)

Maintenance of Emission Relevant Components: Procedure (cont.)

- ***Determination of filter efficiency***

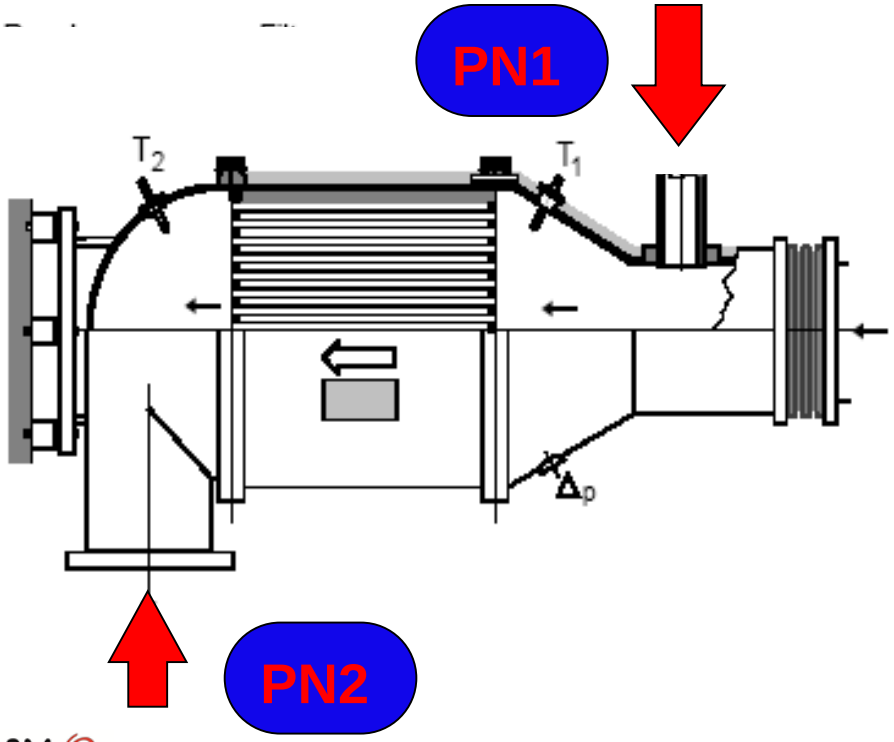
  ►If the efficiency is below 90% and the PN emission is above the allowed limit:

  ▼

- ***Visual check*** of the filter for damages (if less than 10%: → repair, otherwise replacement)
- If a ***bad engine condition*** is *assumed:* measurement of PN or opacity before filter at free acceleration and determination of the k-value, ev. oil analysis
- ***DOC*** (CRT systems)*:* CO conversion measurement: If necessary, cleaning of DOC or replacement
- ***Confirmation*** in the inspection document

Determination of Filter Efficiency

The filter masks the engine. Measurement upstream and down-stream is needed to get information about engine raw emission and filter efficiency



PN1 before the filter determines the emission status of the engine itself, eventual failures, leakages, deterioration, aging

Filtration efficiency:

$$\eta = (PN1-PN2)/PN1 \cdot 100\ [\%]$$

Repair Small Failures by Ceramic Cement

W.Haldenwanger

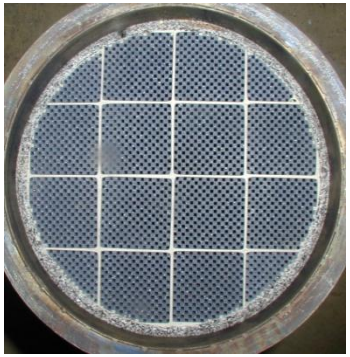
Technische Keramik GmbH

Teplitzer Strasse 27

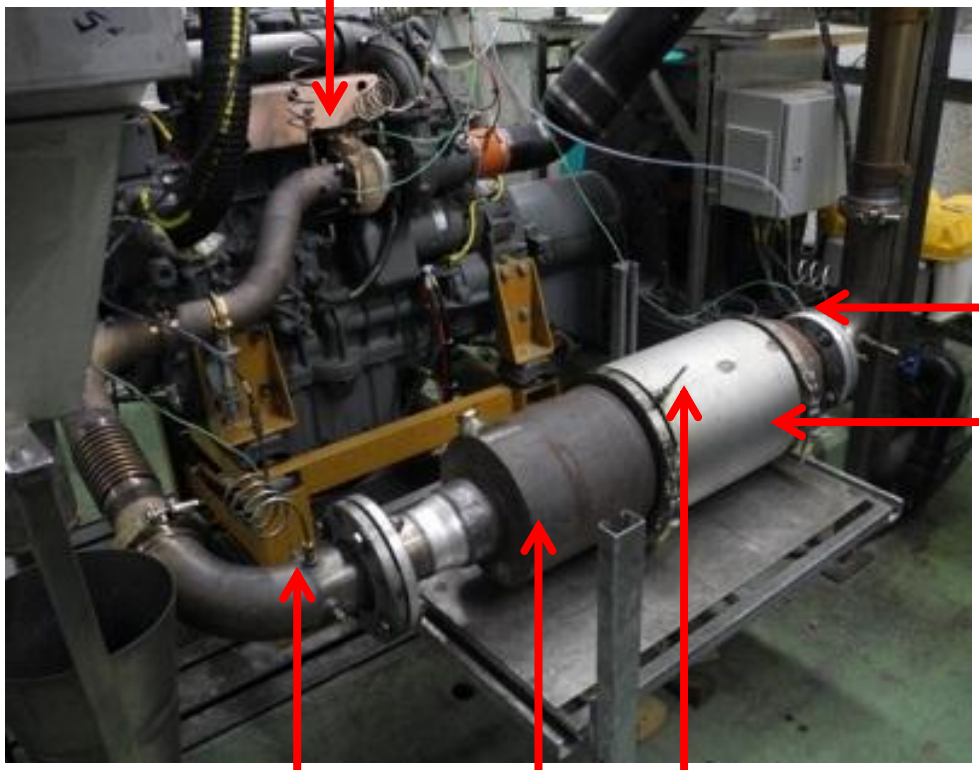
D-84478 Waldkraiburg

WH Feuerfestkitt Teil A und B

www.haldenwanger.de



DOC Light-off Testing



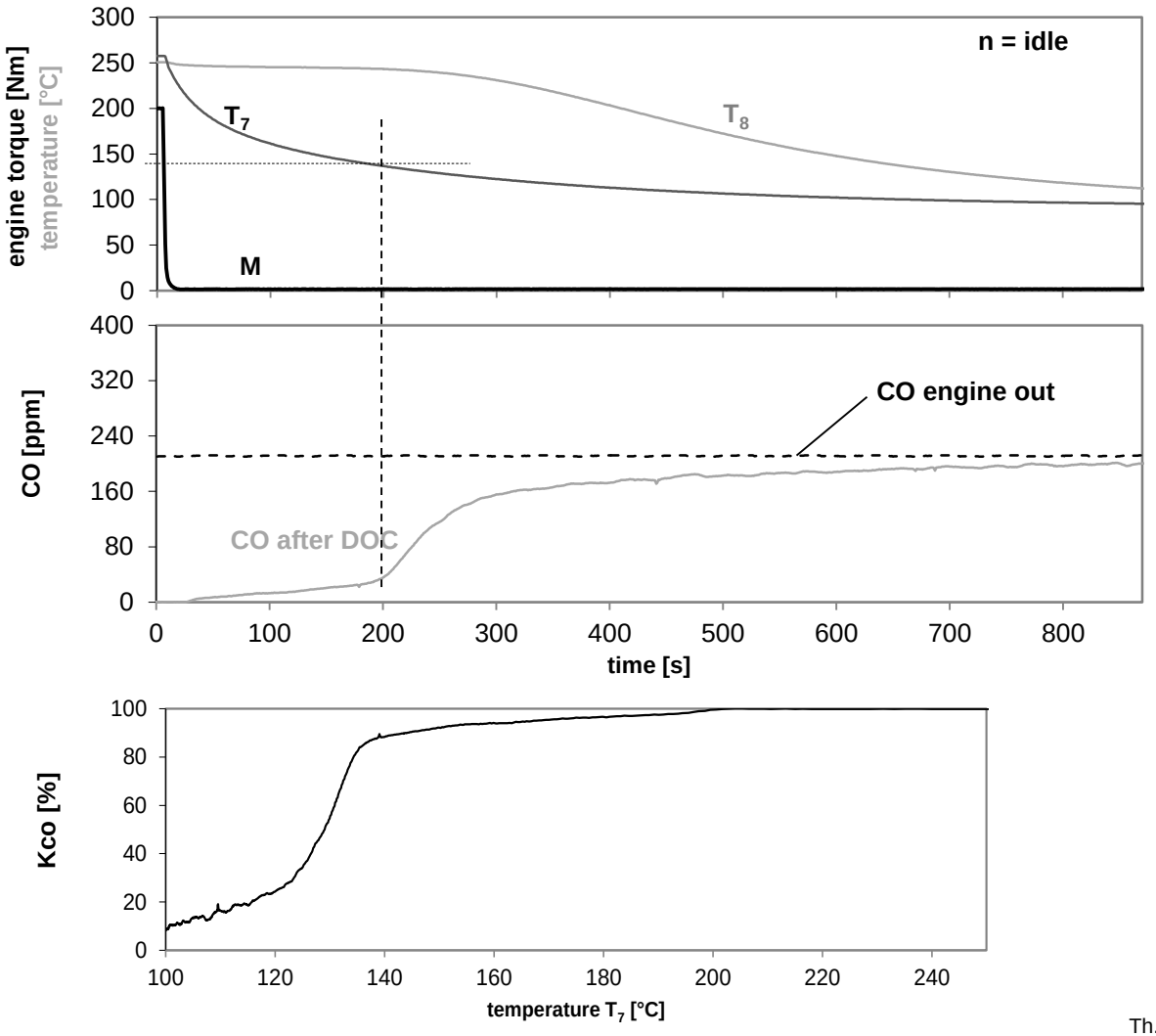
VERT-investigations on a Liebherr D934 Engine, Okt. 2015

Test facility:

Berne University of Applied Sciencies
Biel-Bienne, Switzerland
IC-Engines and Exhaust Gas Control

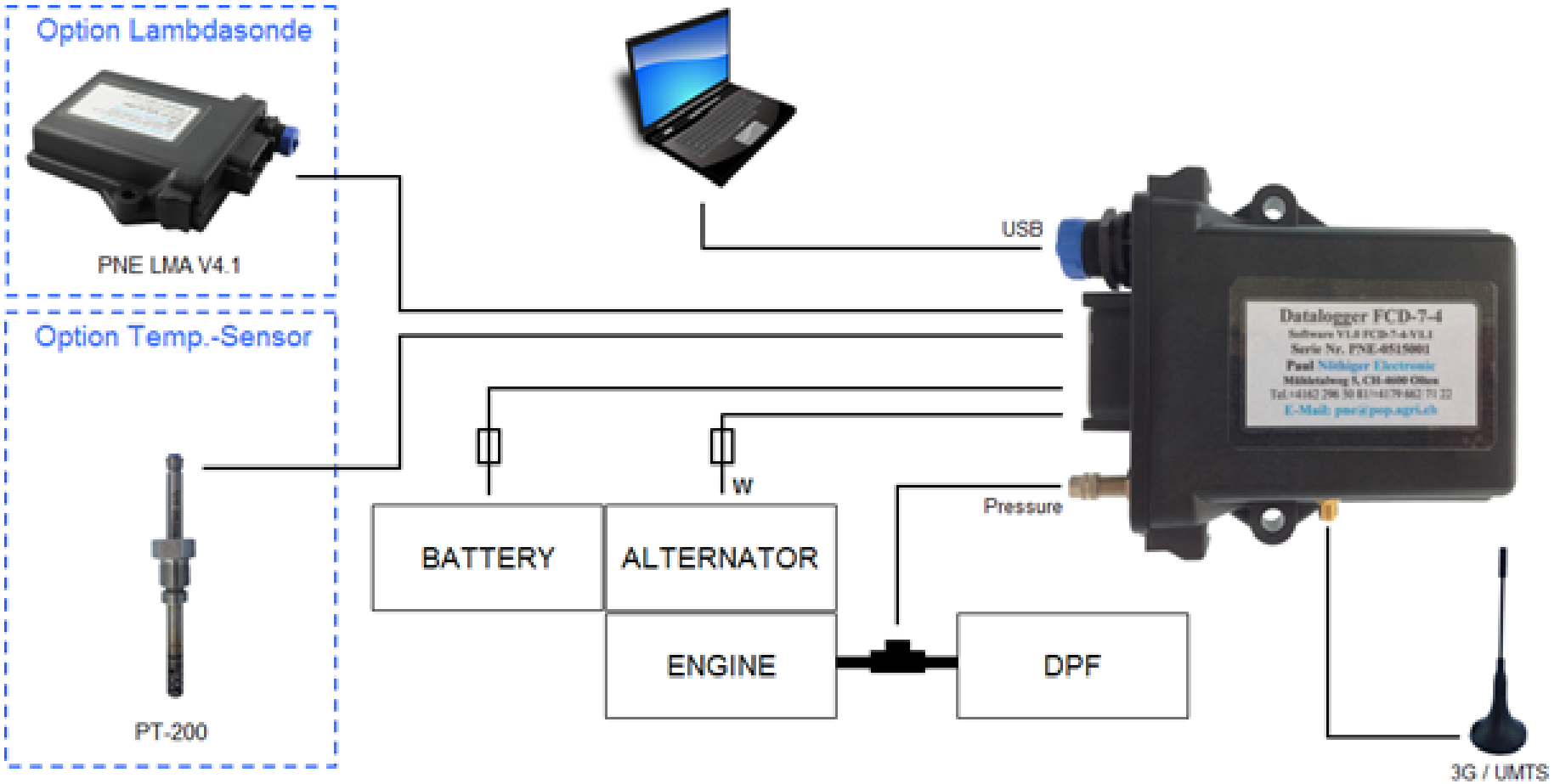
Source: BFH

DOC Light-off Test During Cooling down at Idle



Source: BFH

Filter Monitoring System (FMS): Elements



Source: Paul Nöthiger Electronic

Store Data

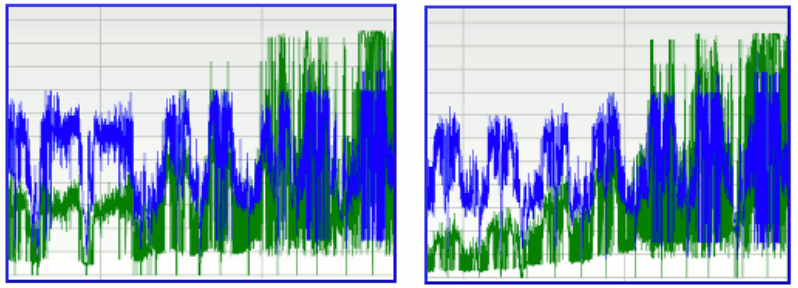
- **On-board memory**
- **Server database**
- **Download data from memory: (password protected)**
  - local: USB, WLAN, Bluetooth
  - remote: GSM *(GPRS)*

GSM = General System for Mobile Communication

Source: Paul Nöthiger Electronic

Evaluation

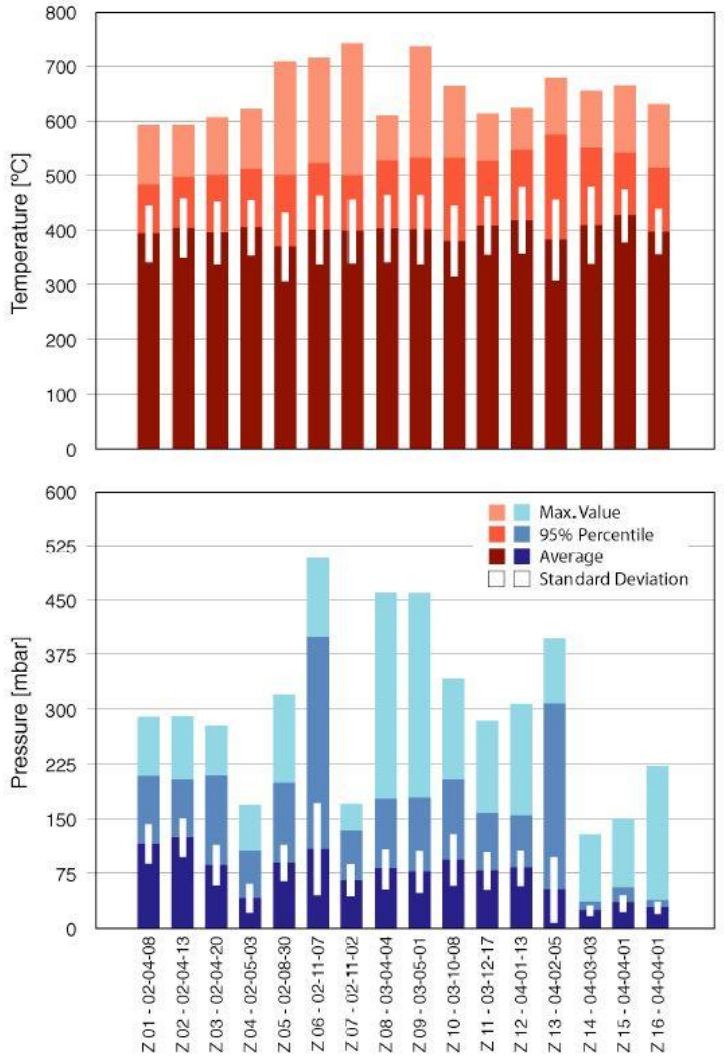
- Statistics of DPF and vehicle operation
- Separation of operating hours and idle time
- Real time display and stored data analysis
- Trends of temperature and back pressure (normal, unusual)
- Comparison of vehicles and filters
- Prediction for filter cleaning and other maintenance needs



Source: Paul Nöthiger Electronic

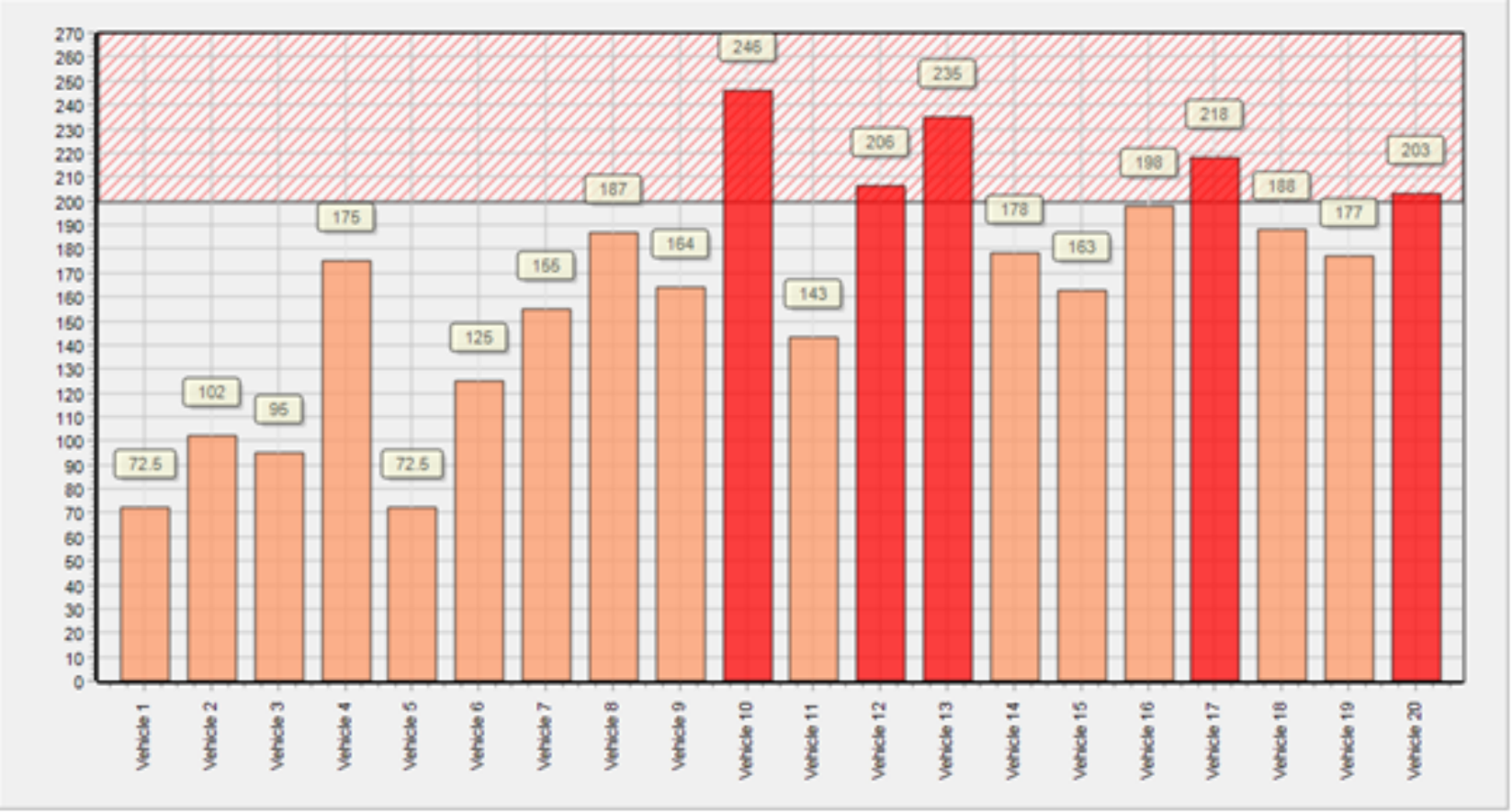
Trend Analysis

Background informations about longterm trends of filter loading
and exhaust gas temperatures,
- allows conclusion on normal or unusual operation of filter and engine



Source: Paul Nöthiger Electronic

Fleet Overview Report



Source: Paul Nöthiger Electronic

Back pressure – weekly 95%-percentiles

Typical I&M Procedure - Checks

① Regular inspection (every x month, *authorized institution*) (e.g. busses)

② Periodical maintenance of emission relevant components (*user, workshop*) (e.g. NRMM CH)

③ **Supervision on-road (on-site) (*authorities*)**

Supervision Test – On-road / On-site

③

- **Identification of the vehicle**
- **Measurement of PN at low idle** (end pipe)
- **If the limit of** (*CH regulation*) **250’000 #/cm^3 is exceeded:**

► then the operator of the vehicle is obliged to a regular engine and DPF system maintenance procedure and a retest by an authorized institution

On-road Check

Santiago de Chile,
July 2015

Equipment:
TSI-NPET

Individual Documentation

Content:

- Vehicle main data
- (retrofit date)
- low and high idle speed
- (start of fuel delivery)
- PN before and after filter at low idle
- rubrics for inspection confirmations

CH Inspection Document

ABGAS-WARTUNGSDOKUMENT

FICHE D'ENTRETIEN DU SYSTÈME ANTIPOLLUTION

DOCUMENTO SULLA MANUTENZIONE RELATIVA AI GAS DI SCARICO

Diesel

Muss stets im Fahrzeug mitgeführt werden
Doit toujours rester dans le véhicule
Il presente documento deve sempre accompagnare il veicolo

CH

Gesetzliche Vorschriften auf Seite 6 und 7
Voir prescriptions légales aux pages 6 et 7
Prescrizioni legali, vedere pagine 6 e 7

1

① Fahrzeugdaten / *Données du véhicule* / Dati del veicolo

- Marke
  Marque
  Marca
- Fahrzeugtyp
  Type du véhicule
  Tipo veicolo
- Fahrgestell-Nr.
  No du châssis
  Telaio no
- Motor-Kennzeichen
  Identification du moteur
  Identificazione motore

② Messbedingungen / *Conditions de mesure* / Condizioni di misurazione

- – Motor auf Betriebstemperatur bringen.
  – Alle elektrischen Verbraucher ausschalten.
  – Erfolgt die Messung in grösseren Höhen als 600 m ü. M., so sind bei Fahrzeugen ohne Druckkorrektur zur Berücksichtigung des Höheneinflusses vom gemessenen Wert, je 0,25 m^{-1} bzw. 0,5 Bacharach pro 400 m grössere Höhe abzuziehen. Es ist der korrigierte Wert einzutragen.
  – Weitere Angaben des Herstellers beachten.
- – *Chauffer le moteur à sa température de marche.*
  – *Déclencher tous les consommateurs électriques.*
  – *Pour tenir compte de l'influence de l'altitude sur les véhicules sans correction de pression, lorsque des mesures sont effectuées à des altitudes excédant 600 m, on déduira respectivement 0,25 m^{-1} ou 0,5 indice de noircissement Bacharach par tranche de 400 m au-dessus.*
  Il y a lieu d'inscrire la valeur corrigée sur la fiche d'entretien.
  – *Consulter attentivement les indications du constructeur.*
- – Portare il motore a temperatura di marcia.
  – Staccare tutti i consumatori di elettricità.
  – Per poter tener conto dell'influenza barometrica esercitata sui veicoli senza correttore di pressione, nel caso di misurazioni effettuate ad altitudini superiori a m. 600, si dedurrà rispettivamente 0,25 m^{-1} o 0,5 indice di opacizzazione Bacharach per fasce supplementari di 400 m.
  Solo il valore corretto viene registrato sul foglio di manutenzione.
  – Attenersi alle indicazioni del costruttore.

2

Sollwerte des Herstellers / *Valeurs du constructeur* / Dati del costruttore		
③ Kontrollwerte / *Indications de réglage* / Indicazioni di regolazione		
• Leerlaufdrehzahl *Régime de ralenti* Regime del minimo		min^{-1}
• Obere Leerlaufdrehzahl *Régime maximal à vide* Regime massimo, a vuoto		min^{-1}
• Förderbeginn *Commencement du débit* Inizio mandata	- statisch *statique* statica	mm^{3}
	- dynamisch *dynamique* dinamica	$^{-1}/min^{-1}$
• Plomben und/oder Versiegelungen *Plombs et/ou sceaux* Piombi e/o sigilli		
④ Rauchemissionswerte / *Valeurs des émissions de fumées* / Valori delle emissioni di fumo		
• Trübungskoeffizient *Coefficient d'opacité* coefficiente d'opacità	maximal *maximum* massimo	m^{-1}
• Schwärzungszahl *Degré de noircissement* grado di annerimento	maximal *maximum* massimo	Bacharach
⑤ Bestätigung / *Attestation* / Attestazione		
		Datum Sign.
• Der Unterzeichnende bestätigt, dass die Abgaswertung nach Herstellervorschrift und unter Verwendung der vorgeschriebenen Messgeräte ausgeführt wurde. • *Le soussigné atteste que le service d'entretien du système antipollution a été exécuté conformément aux indications du constructeur et en utilisant les appareils de mesure prescrits.* • Il firmatario attesta che il servizio di manutenzione del sistema anti-inquinamento conformemente alle indicazioni del costruttore e utilizzando gli apparecchi di misura prescritti.		Stempel / *Timbre* / Timbro

Conclusions

The needs
for the implementation of a consistent I&M strategy

- **The instruments are ready:**
  - PN-measurements at low idle for DPF and engine control
  - Filter monitoring with remote control (datalogging)
  - DOC-conversion activity control is in the test phase (CRT systems)

but

- **Regulations are needed**
- **Periodic independent checks are needed**
- **A documentation is needed** (emission document on-board)

Inspecting vehicles does not reduce pollution,
MAINTAINING / REPAIRING
them does

Cliff Grove, Automotive Diagnostics,
SPX Corporation, USA 1996