FOCUS Event – 20\textsuperscript{st} ETH-NPC, June 16\textsuperscript{th}, 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 efficiency
- 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

**EFFECTIVENESS TEST OF EMISSION CONTROL SYSTEM**

- emission measurements: short test or OBD read out
  - failed
  - passed
  - checks adjustments repairs

**PERIODIC EMISSION CONTROL SYSTEM MAINTENANCE**

- checks adjustments repairs +
- verification test (short test)

- Test-only-stations
- Test+repair-stations/shops

On-road (on-site) supervision test
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 intervals

• 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
2. 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

- **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 downstream is needed to get information about engine raw emission and filter efficiency.

Filtration efficiency:

$$\eta = \frac{(PN1 - PN2)}{PN1} \cdot 100 \%$$

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

Back pressure – weekly 95%-percentiles

Source: Paul Nöthiger Electronic
Typical I&M Procedure - Checks

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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

- Identification of the vehicle
- Measurement of PN at low idle (end pipe)
- If the limit of \((CH \text{ regulation})\) 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
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)

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

but
Inspecting vehicles does not reduce pollution, **MAINTAINING / REPAIRING** them does.