PTI-Test of Nonroad Mobile Machines by Particle Number at High Idle in Switzerland

J. Czerwinski, A. Mayer, V. Hensel / VERT

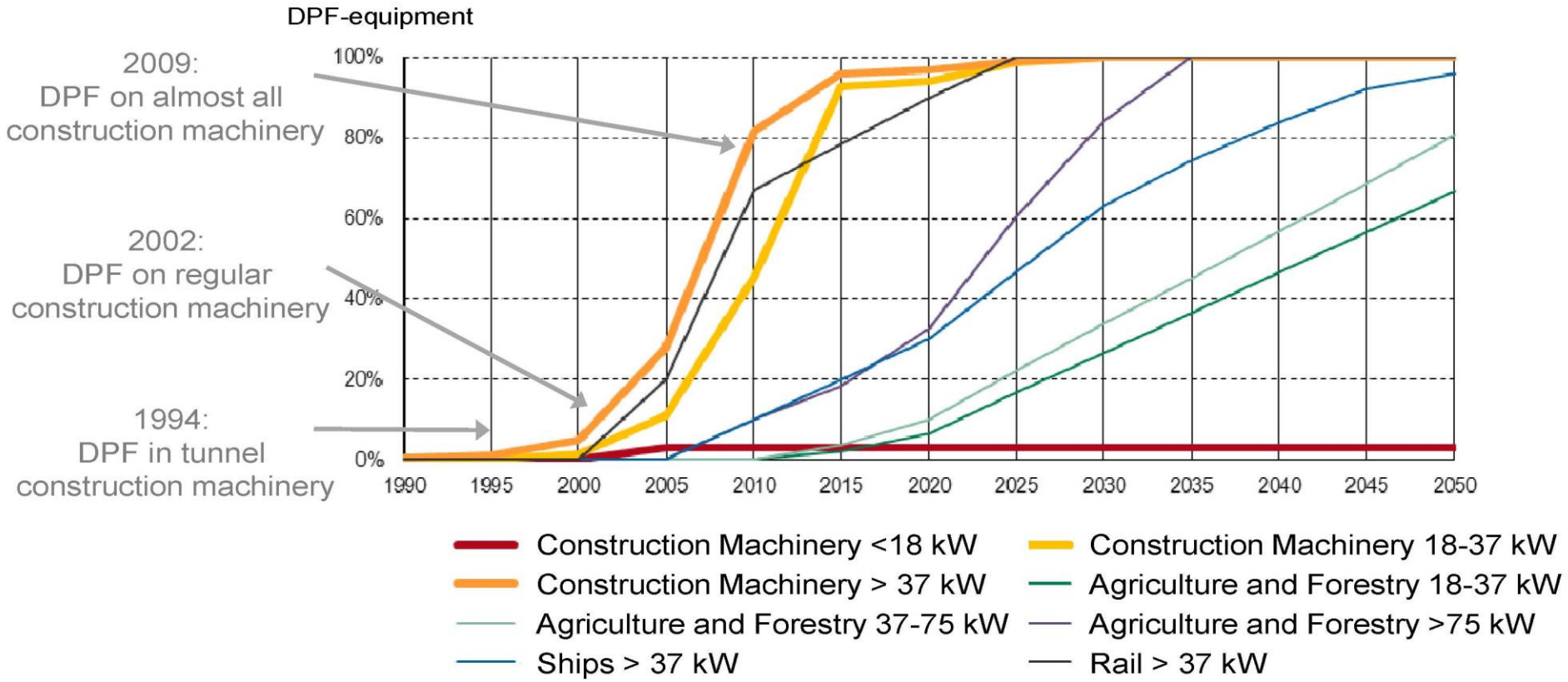
P. Comte, D. Engelmann, / AFHB

VERT Web Focus Event NPTI, July 07th 2021

Contents

- VERT Field Test - 1996
- Swiss contributions to the portable PN measuring technics - 1998
- Swiss Guideline “Air Pollution Control at Construction Sites” - 2002
- METAS Certification of a portable particle counter – 2010/12
- Application of NPET for the NRMM fleet control - 2015
- Conclusions

Mobile machinery with DPF in Switzerland



Source: FOEN, 2015

> 50‘000 NRMM retrofitted with VERT certified DPF

Swiss Guideline 2002

"Air Pollution Control at Construction Sites"

with:

2002 opacity emission check every 24 months,

2012 option fort PN

2016:

PN at high idle

limit value 250'000 P/cc

METAS certified instruments

Initial VERT Field Control since 1996

Opacity. Black Carbon, Gases

Lessons learned:
VERT Endurance Test VFT2: 2000 hrs
most important part of VERT DPF certification

- Information, education & motivation of personnel
- Datalogging (onboard electronic control)
- Periodic inspection & maintenance by workshops
- Responsibilities: user, retrofitter, manufacturer of engine
- Switch from Opacity (PM) to PN 10-500 nm for sensitivity. simplicity and reliability → first NanoMet-Instrument developed by ME with two sensors: DC and

Swiss metrological contributions to the development of portable PN measuring devices:

- Matter Engineering – **NanoMet** consisting of PAS-and DC-sensors + rotating disc minidiluter (Dr.U.Matter, Dr.M.Kasper) – roll out Hanover Messe **1998, also used in Mexico, Chile and Canadian Mines**
- Institute for Sensors and Signals FHNW further development of DC sensors, PN personal monitoring (Prof.Dr.H.Burtscher)
- NANEOS – Partector portable particle detector (Prof.Dr.M.Fierz)
- FHNW PN sensor for construction machines, certified by METAS 2020 (https://www.fhnw.ch/en/about-fhnw/schools/school-of-engineering/institutes/research-projects/periodic-technical-inspection-for-diesel-soot-emissions)

→ Worldwide Dissemination of Nanoparticle Metrology by the ETH Conference on Combustion Generated Nanoparticles, first ETH-NPC 1997

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Swiss Federal Office of Metrology METAS

Portable Combustion Particle Counter for On-site Control of Diesel Engines

Jürg Schlatter

IAC 2010, Helsinki FI
August 29th to September 3rd 2010

Considerations of most important conditions and characteristics :

- **Limitations of Opacimeters**

- **For PN analyzers:**

Selection of PN metrics [for quick tests #/cc]
Range for size & number
Efficiency
Error limits
Time constant

- **VAMV** … Swiss Ordinance about Exhaust Gas Measuring Instruments for IC_Engines

OAPC … Swiss Ordinance for Air Protection Control

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

New Swiss legislation on portable particle counters for construction machinery

Jürg Schlatter
Federal Office of Metrology METAS, Lindenweg 50, CH-3003 Bern-Wabern, Switzerland

16th ETH-Conference on Combustion Generated Nanoparticles, June 24nd to 27th 2012

Motivation and objectives

The Swiss Ordinance on Air Pollution Control (OAPC[1]) specifies the particle emissions from construction machines with diesel engines by defining a limit value of 10^{12} particles per kWh. This limit makes high requirements on the instruments for the machine homologation and the periodic emission control on site. The regulations for homologation are going to be internationally harmonized (particle number concentration measurements for road vehicles in ECE-R49 and R83[2]). The current regulation for the periodic control of road vehicles is unpersuasive for construction machines with particle filters, because the sensitivity of opacimeters is too weak. Therefore FOEN and METAS evaluated new measuring instrument types based on the particle counting principle.

Since the feasibility for portable particle counters for exhaust measurements could be proven the Department of Justice and Police intends to define the requirements for «nanoparticle measuring instruments» in the existing Ordinance on Exhaust Measurement Instruments (VAMV[3]).

Emission control for construction machines

According to the best available technique only construction machines equipped with efficient i.e. closed particle filters fulfil the requirements of the Swiss Legislation. The clean air act defines in Annex 4 paragraph 32 the requirements for the filters to retain 97 % of all particles in the size range from 20 nm to 300 nm.

The control of the emission is made by the measurement of the particle number concentration. An initial control has to be passed during the homologation procedure of either the machine or the particle filter system. A periodic control of the machines on duty is executed every two years by fabricants, retailers or owners. Additional spot tests may made by the authorities.

Up to now opacimeters were used for the periodic control. Since the sensitivity of optical instruments is not sufficient for nanoparticles the new type of particle counters shall replace the opacimeters after a transition period.

Metrologigal requirements

Number concentration measurement

- The measuring range shall be from 5×10^4 cm^{-3} to 5×10^6 cm^{-3}.
- Values outside the measuring range shall be indicated as below or above the indicated concentration range.
- The reference conditions for the result shall be actual ambient conditions.

Error limits for number concentration measurement

As a function of particle size and particle composition the counting efficiency E shall be within following limits:

Particle (mobility) diameter	Permitted range for E
23 nm solid particles	$E < 50$ %
41 nm solid particles	50 % $< E$
80 nm solid particles	70 % $< E < 130$ %
200 nm solid particles	$E < 200$ %
30 nm tetracontane droplets	$E < 5$ %

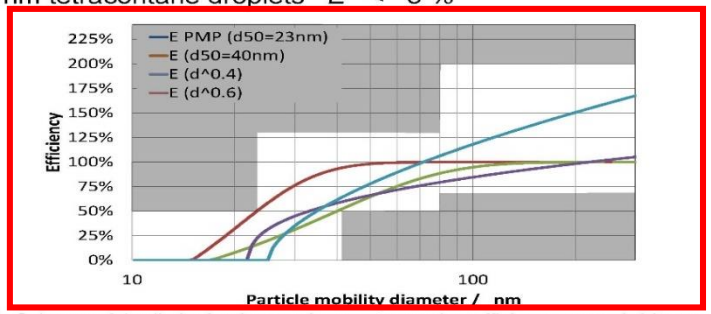


Figure 2: Schema of the limits for the number concentration efficiency curve (white area) and examples of efficiency curves conform to the requirements (curves)

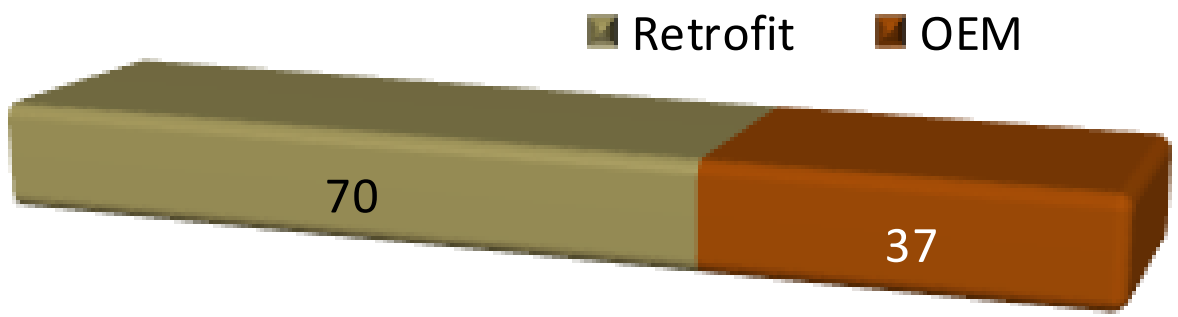
Disturbances

The following disturbances shall not falsify the indication of results :

- Particles below 20 nm (e.g. particles from additives)
- Corrosive exhaust gas components and condensates
- High temperatures of exhaust gas

Fleet Control by PN and Opacity

107 Construction Machines (B 485 2017)



Measuring instruments

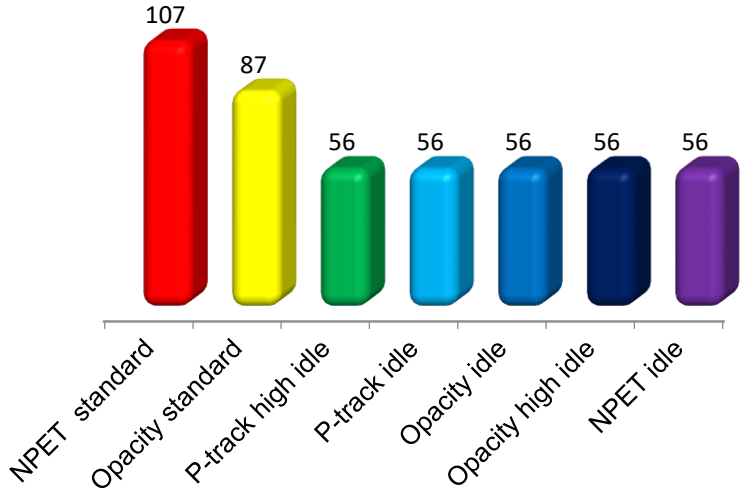
University of Applied Sciences
Biel-Bienne, Switzerland
IC-Engines and Exhaust Gas Control

Parameter	Measuring method	Type	Manufactor	SN
Atmospheric pressure	Pressure cell	HM30	Thommen AG	A 041118
Humidity and temperature	Capacitiv sensor	A1	Rotronic	18761 042
Particulate number	Condensation Particle Counter (CPC) + thermoconditioning + dilution + catalytic stripper	NPET 3795	TSI	3795-150507* 3795-152401**
Particulate number	Condensation Particle Counter (CPC)	P-Trak 8525***	TSI	8525-02090007
Opacity	Absorption	Dismoke 4000	AVL	BO 7071

P-Trak

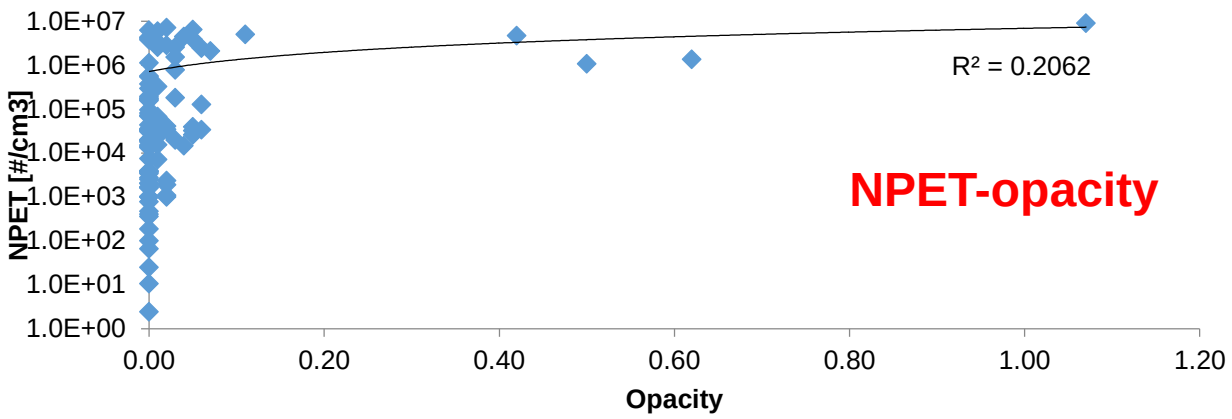
NPET 3795

Dismoke 4000

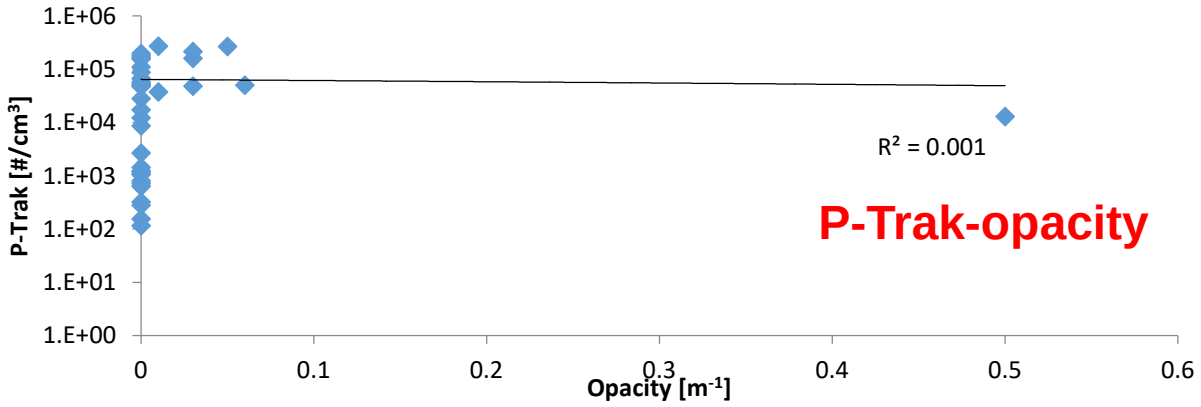


Samples of each measurement types

No Correlation Opacity / PN



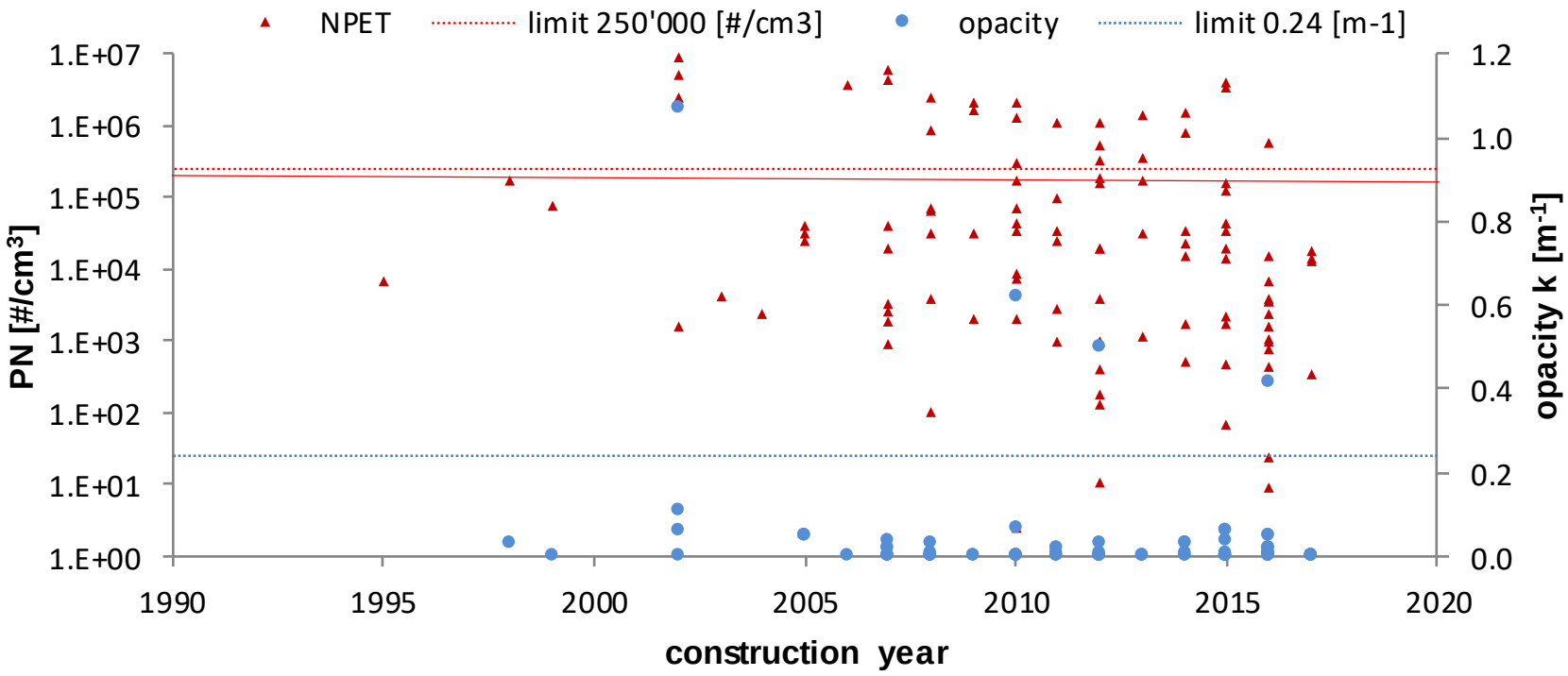
NPET-opacity



P-Trak-opacity

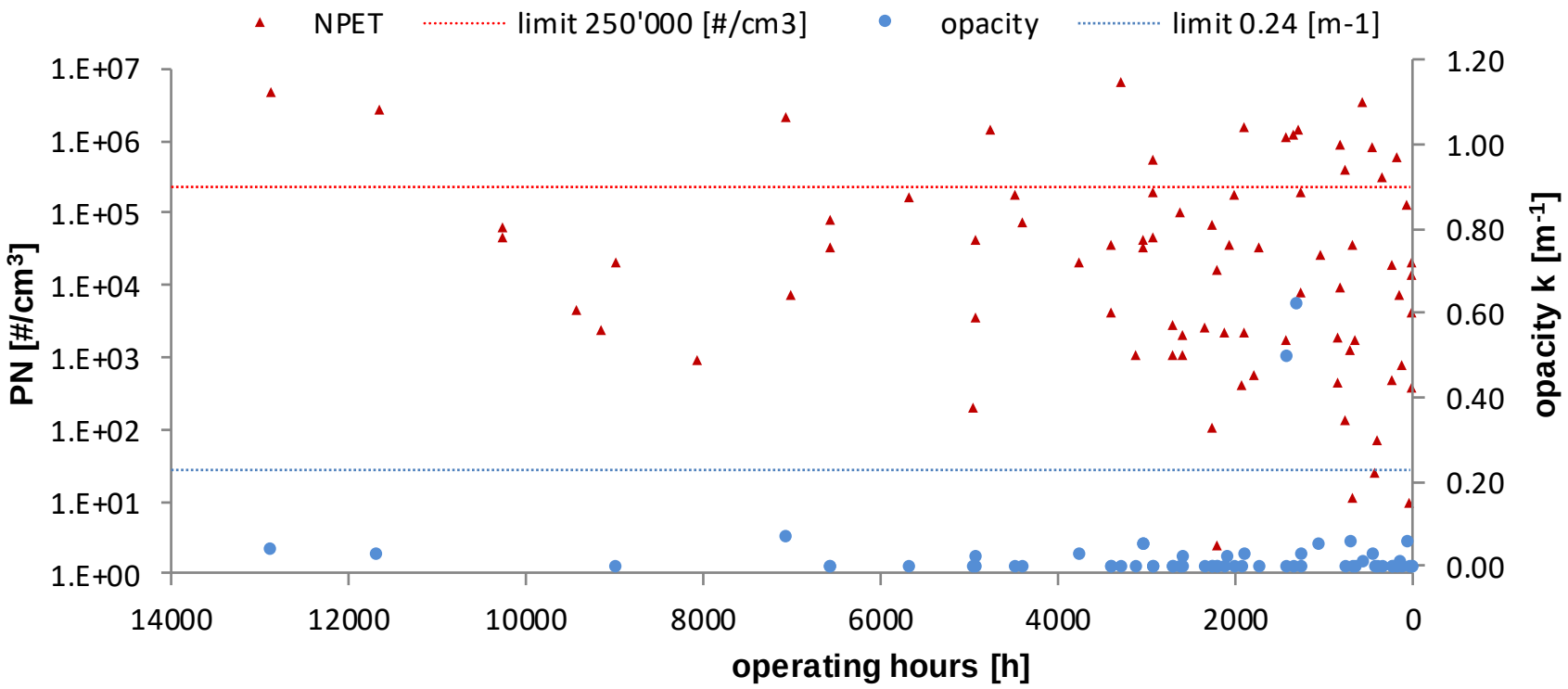
Comparison PN NPET@high idle versus Opacity@free acceleration

Depending on immatriculation year ?



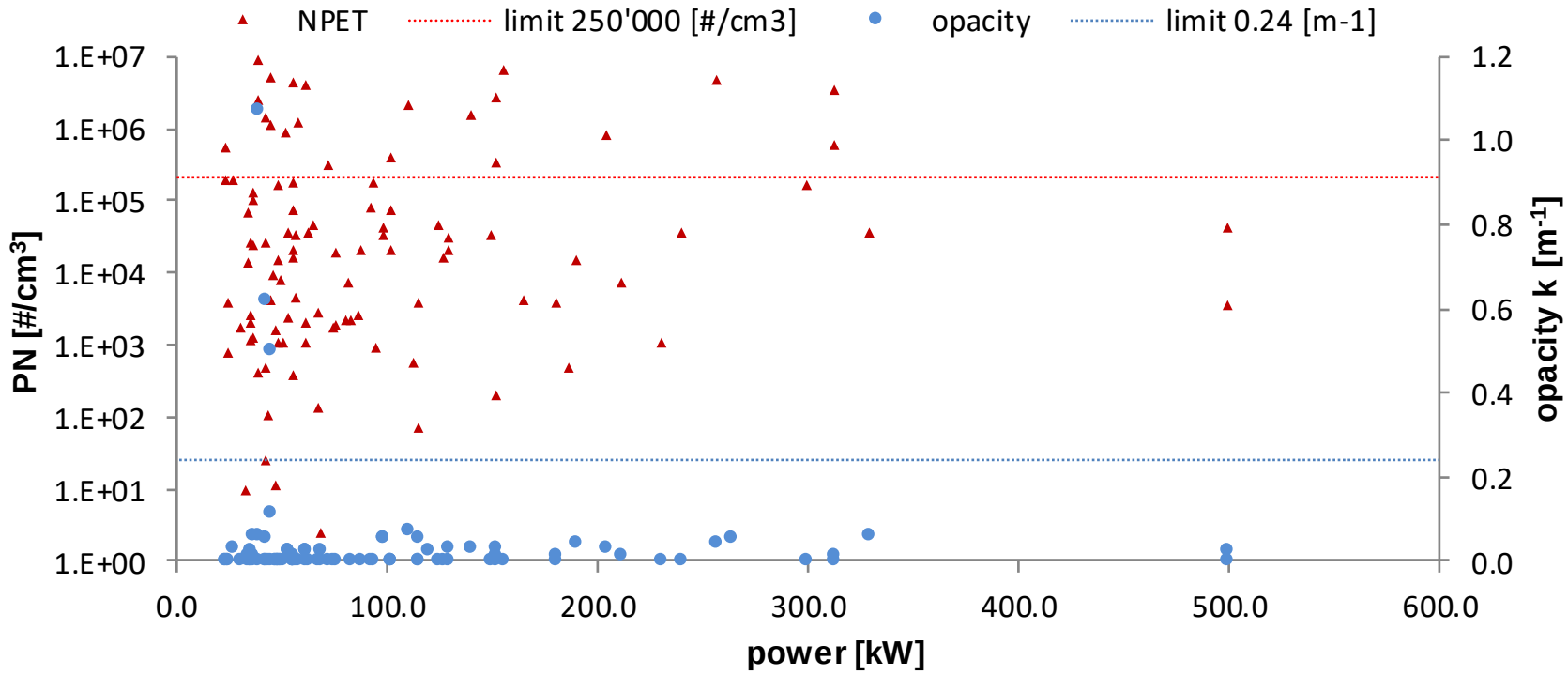
Comparison PN NPET@high idle versus Opacity@free acceleration

Depending on operation hours ?



Comparison NPET@high idle
Opacity@free acceleration

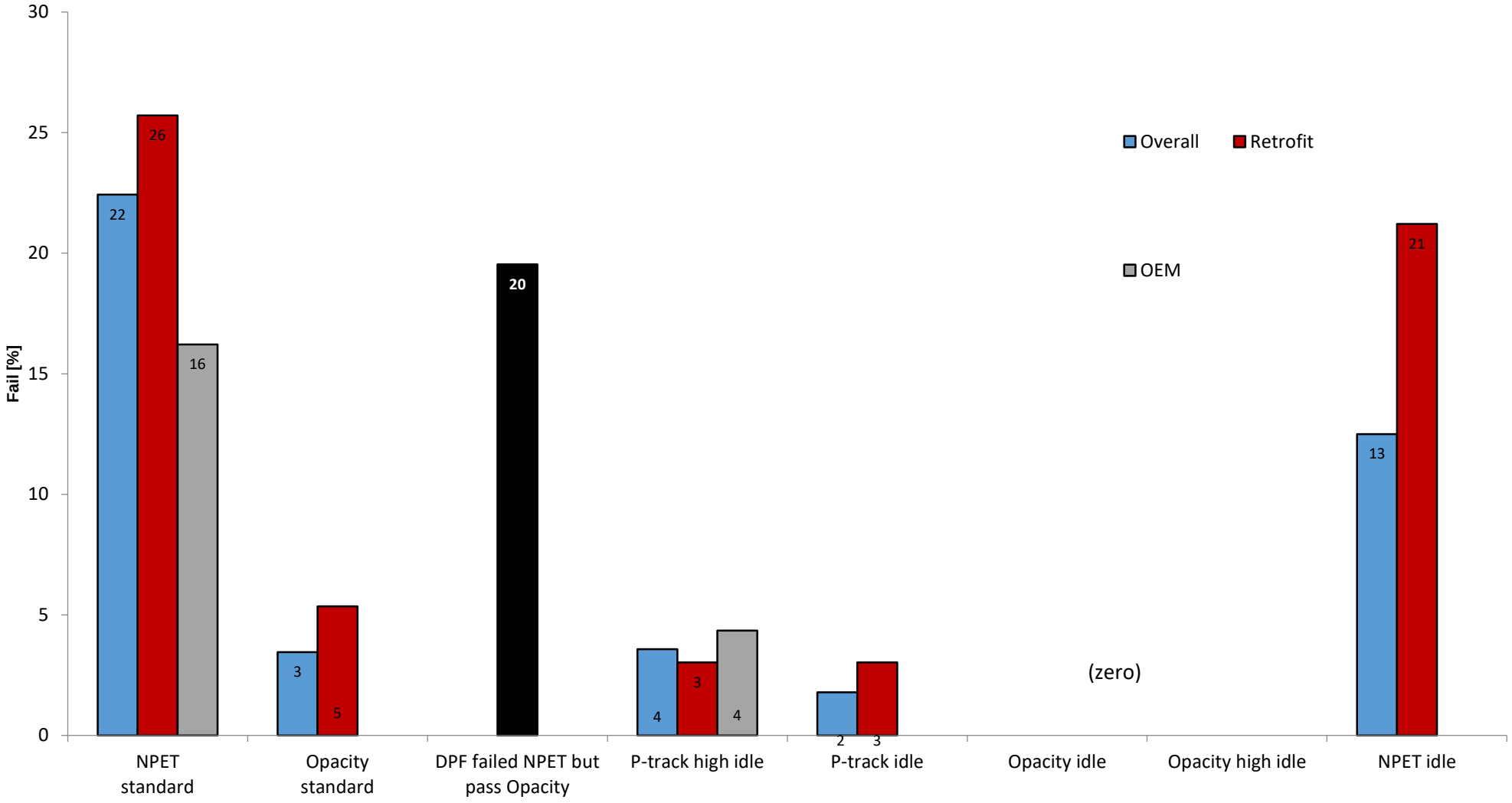
Depending on engine power ?



Failures do not depend on engine power, operation time, immatriculation year nor brand
These failures are random, missing maintenance or manipulation - only detectable by 100% PTI

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

Failure rate detection with different methods



Swiss Summary promoting PN PTI

- The 25 years experiences of DPF retrofit and VERT field testing 1996
- Development and promoting of portable PN measuring devices 1998
- Swiss Guideline “Air Pollution Control at Construction Sites” 2002
- 1st legal certification of a PN analyzer for field application 2014
- Demonstration of the feasibility of PN PTI 2015
- Average failure rate 20% in the NRMM fleet 2016

→How to eliminate these high polluters: annual PTI by PN idle is indispensable combined with preventive maintenance

By common efforts: legislation, R&D, testing, market control & PTI significant improvements of occupational health protection are possible.

Thank you for your attention!