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New instruments for PN-based periodic control:

Results of a first measurement campaign

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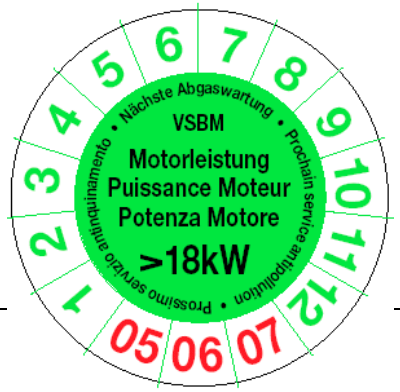
Overview

- Swiss Regulation
- PN-based periodic control of construction machines
  - Measuring procedure
  - Reference value
- Measurement campaign
  - Results
  - Conclusions
- Work in Progress

Swiss Regulation

- The Swiss Ordinance on Air Pollution Control (OAPC) requires a limit value for particle number emission (1×10^{12} particles/kWh) for non-road mobile machinery (NRMM) used on construction sites.
  → this limit can only be met with diesel particulate filters (DPF).

- Periodic control of the machine every second year, done by the owner (Construction Guideline Air) .



PN-based periodic control of construction machines

- Current regulation for the periodic control of construction machines: opacimeter
  → ineffective for machines with particle filters.
  Sensitivity of opacimeters is too low.

- FOEN and METAS defined requirements for «nanoparticle measuring instruments» in the existing Ordinance on Exhaust Measurement Instruments (VAMV).

- In 2012 instrument manufacturers were invited by METAS to develop instruments.
  → under constructio

• official measurement procedure
• reference value

Measuring procedure for the official measurement

Conditioning of the engine and DPF:

- 4 to 6 free accelerations, until engine + DPF are warm
- Stay at maximum speed / high idle speed, until the engine is constant.

Measuring:

- Start measuring by pressing the button of your instrument.
- Read the result and compare with the reference value

Measurement, done by the instrument

Duration of the measurement: 40 seconds

- 15 sec waiting period
- 5 sec measurement 1 → mean 1
- 5 sec break
- 5 sec measurement 2 → mean 2
- 5 sec break
- 5 sec measurement 3 → mean 3

overall mean

The reference value

Reference value of 2.5×10^5 particles/cm^3

(analog to 1×10^{12} particles/kWh written in the OAPC)

- overall mean < reference value: passed
  → DPF and engine are in good condition.
- overall mean > reference value: failed
  →The problem has to be solved. Any use of the machine on a construction site is prohibited.

Measurement campaign

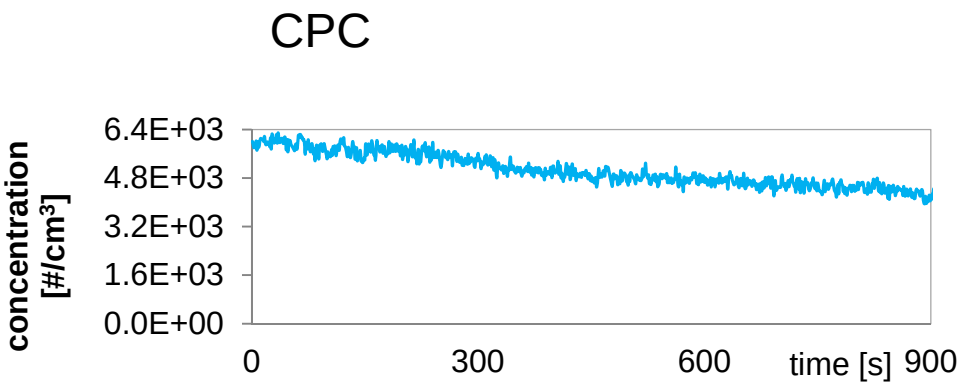
- Measurement campaign at AVESCO, Langenthal in April 2014
- Organization: FOEN, realisation and analysis: Laboratory for IC-Engines and Exhaust Gas Control, Biel
- 3 day-campaign, 15 measurements at construction machines, 4 measurements at stationary engines (compressors)
- 1 reference instrument (CPC 3790 TSI)
- 4 prototype instruments
- Aims: Testing the reference value and the measurement procedure.

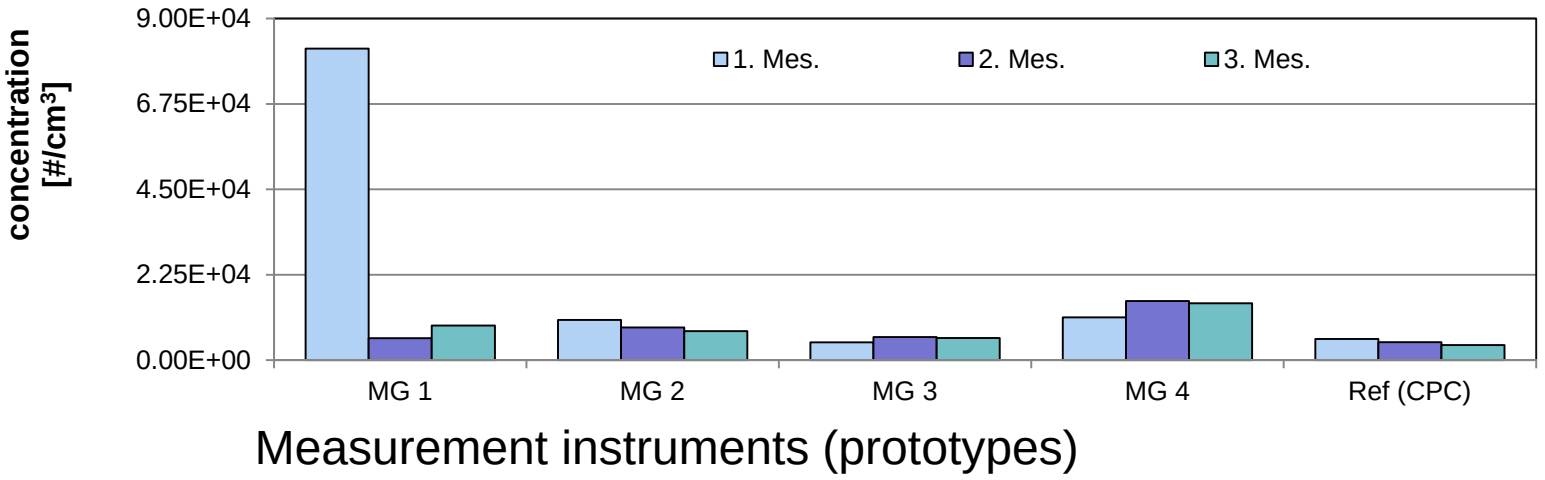
Measurement campaign

construction machine	chassis number.	type of engine	cylinder capacity	power	emission level	working hours	DPF	notes
[-]	[-]	[-]	[lt]	[kW]	[-]	[hours]	[-]	
Caterpillar 305E	CAT0305ECXFA03375	C2.4	2.4	31.2	IIIA	4.1	Dinex	
Caterpillar TH414C	YC5A1789CKEK00298	C3.4B	3.4	75	IIIA	15	OEM	
Caterpillar 308E2	CAT0308ELTMX00810	C3.3BT	3.3	49	IIIA	6.9	OEM	
Caterpillar M313D	CATM313DCK3D00240	C4.4	4.4	102	IIIB	59	OEM	
Caterpillar 908H	CAT0908HJLMD00476	C3.4T	3.3	59	IIIA	2291	HJS	
Caterpillar 259B	CAT0259BKYYZ00955	C3.4	3.4	55	IIIB	354	Mobiclean	
Caterpillar CC34	CAT0CC34C34600176	C2.2	2.2	34.1	IIIA	1462	HJS	
Caterpillar CS56	CAT0CS56CFCS00489	C6.6	6.6	108	IIIA	1311	HJS	3 x
Caterpillar 303C	CAT0303CJBXT04518	S3Q2-Y3SCM	1.9	23.2	IIIA	2501	HJS	DPF broken
Caterpillar 308C	CAT0308CEKCX01901	4M40-E1	2.835	40.5	II	5682	HJS	
Kaeser M200	WKA0F3500D4929321	CAT. C6.6	6.6	205	IIIA	3	Dinex	
Kaeser M43	WKA0F085162343073	Kubota V1505-T	1.5	33	II	1007	HJS	DPF broken
Kaeser M45-G	WKA0F1200E4985793	Kubota V2203-M	2.197	34	IIIA	1.4	HJS	2x
Thwaites Mach 474	SLCM474Z1309C5145	Yanmar 4TNV88-XWA2	2.19	33.3	IIIA	5.9	Dinex	
Thwaites Mach 474 w/o DPF	SLCM474Z1409C7418	Yanmar 4TNV88-XWA2	2.19	33.3	IIIA	1.1	-	
Thwaites Mach 580	SLCM580Z1306C5895	Yanmar 3TNV88-XWA2	1.642	24.8	IIIA	2.3	Dinex	

Results (1/3)

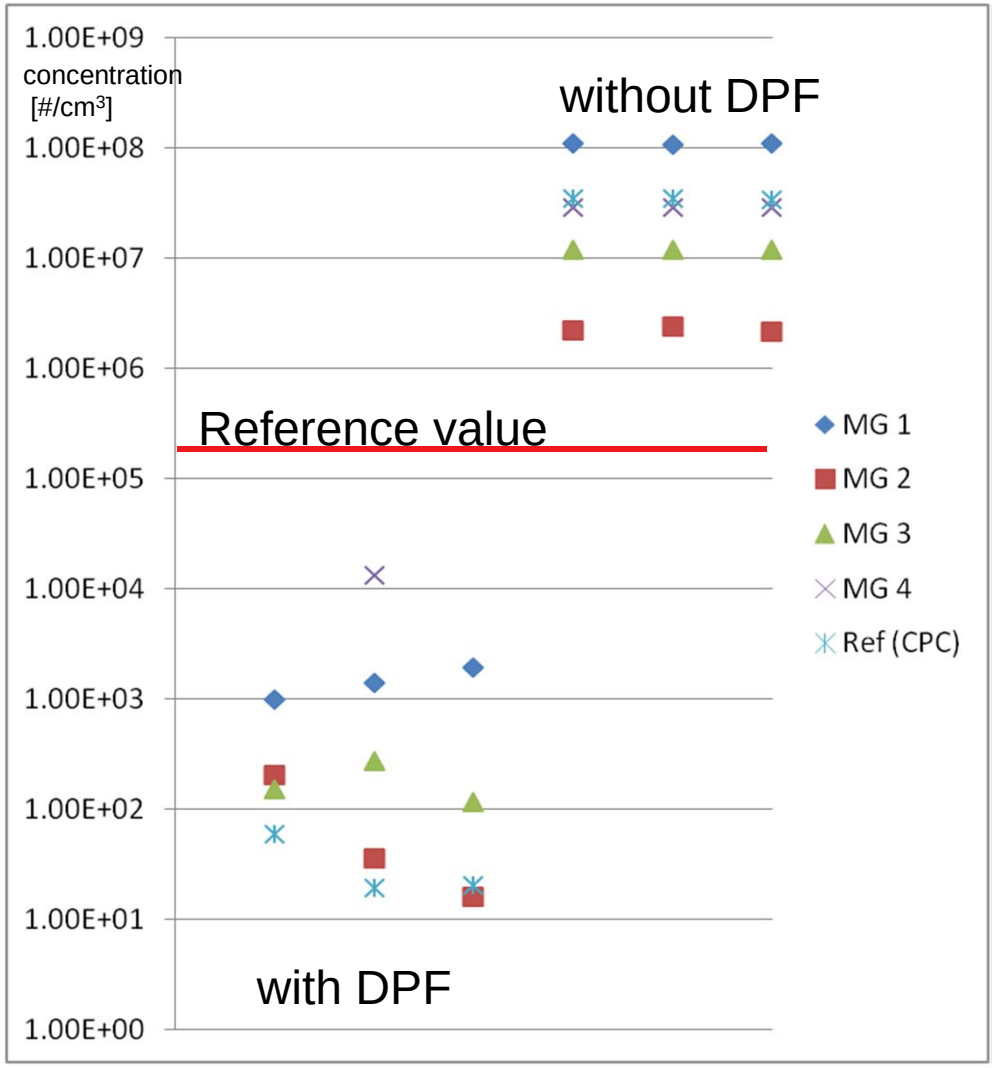
Caterpillar 305E CR



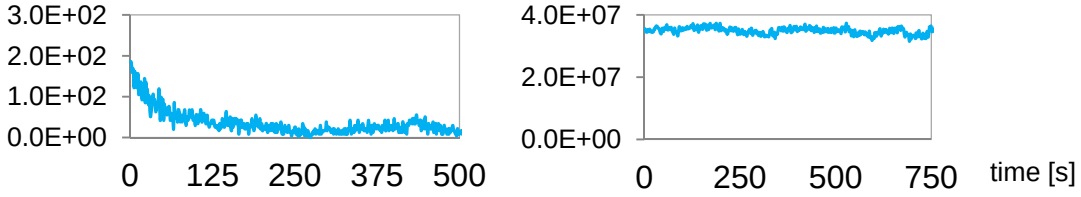


Results (2/3)

Thwaites Mach 474
- with DPF
- without DPF



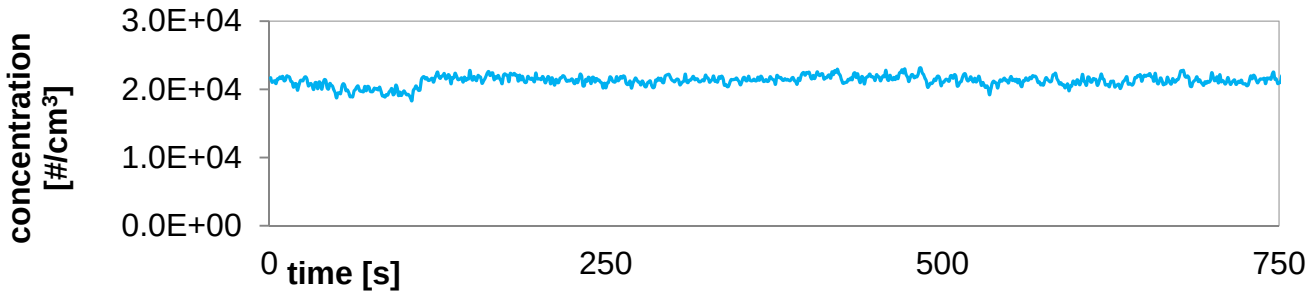
CPC
concentration
[#/cm3]



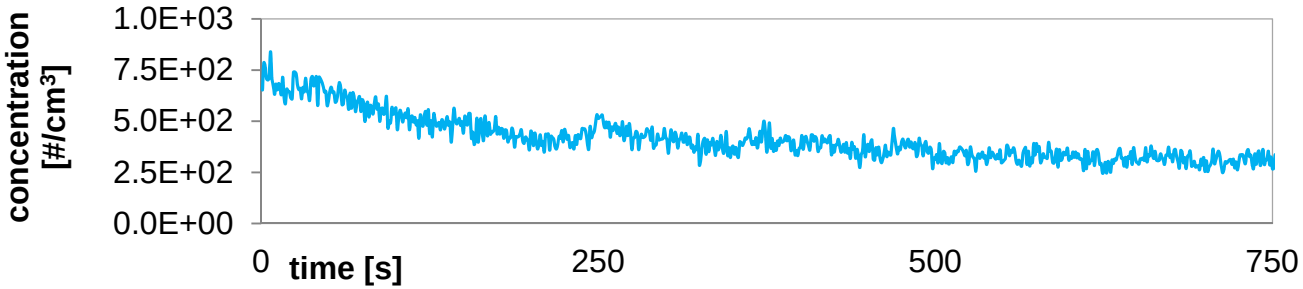
Results (3/3)

CPC

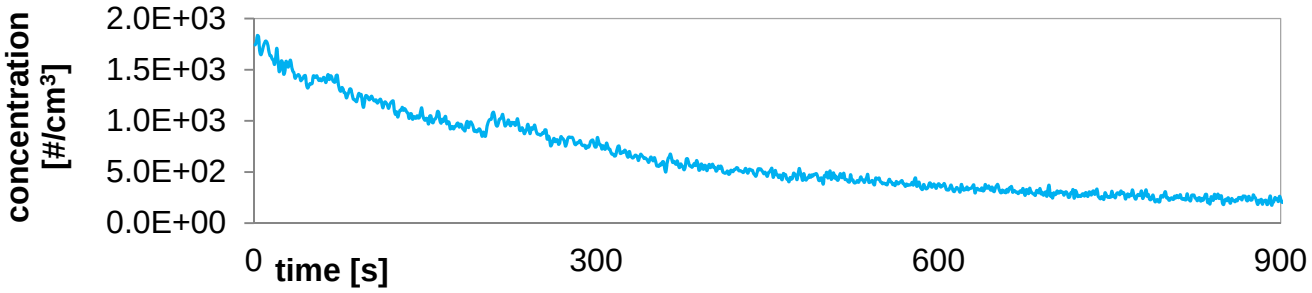
Caterpillar CS56



Caterpillar 308C



Caterpillar 308E2



Conclusion of the measurement campaign

- The reference value of 2.5×10^5 particles/cm^3 was well suited to make a distinction between good working and faulty DPF.
- The measuring procedure was appropriate, no problems appeared.

- The particle number emissions decreased over time → conditioning of the engine + DPF
- It was no problem for the engines to stay at maximum speed for about 15 minutes.

Work in Progress:

- An addition of the Construction Guideline Air with the measurement procedure and the reference value is planned.
  - For the periodic inspections of construction machines by the operator the new type of particle counters shall replace the opacimeters after a transition period.

- Switzerland's PN-based periodic control as a model for other applications with PN-limits.

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- to the contributors of the prototype instruments.

In case of questions:

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