PN measurements according to Reg. 49 Annex 4c

PNC Stability Experience at Scania Engine Development

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Test Cell Development

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Scania Technical Centre

All in one place in Södertälje

- Laboratory
- Proving grounds
- Design, styling
- 2,800 engineers
- Production nearby

- Engines
- Gearboxes, axles
- Electronics
- Truck cabs, chassis
- Buses, chassis modules

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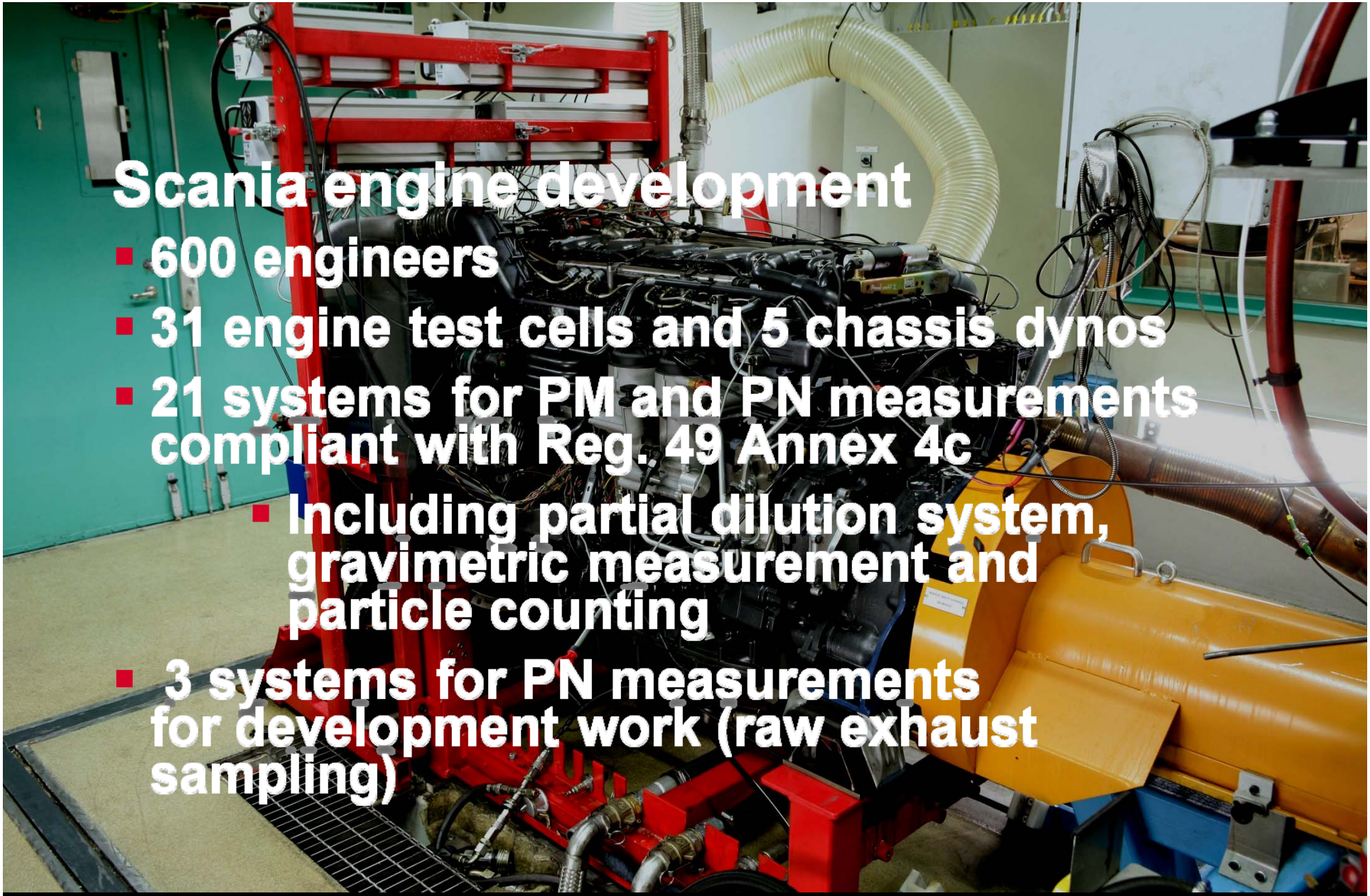

Scania engine development

- 600 engineers
- 31 engine test cells and 5 chassis dynos
- 21 systems for PM and PN measurements compliant with Reg. 49 Annex 4c
  - Including partial dilution system, gravimetric measurement and particle counting
- 3 systems for PN measurements for development work (raw exhaust sampling)

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Background

- **4 particle counters sent to instrument supplier for annual service and calibration**
- **All four instruments failed validation deviation >10% from calibration**
  - **VPR validation passed for PCRF = 10 x 10**
  - **CPC validation failed. Deviation 14 to 70%**
- **The particle counters**
  - **complied with Regulation No. 49, Annex 4c**
  - **have *exclusively been used in diluted exhaust* (CVS mode)**
  - **were *less than 12 months old* when validated (delivered August 2010)**
  - ***did not indicate any errors***

Validation results

Limit 10%

		VPR validation		
No	VPR	10 x 10	200 x 20	1000 x 10
215	GH0672	7%	14%	8%
216	GH0672	6%	19%	34%
217	GH0672	3%	15%	9%
218	GH0672	11%	14%	17%

CE_{41} > 0.9

CE_{23} = 0.38 -0.62

slope = 0.9-1.1

		CPC validation			
No	CPC old	23 nm	41 nm	slope	
215	71011091	14%	36%	24%	counting 0
216	71011224	32%	59%	70%	
217	71011225	40%	75%	86%	
218	71011226	31%	82%	25%	

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CPC Validation - Results

- **CPC validation failed for all 4 units s/n 215, 216, 217 and 218**
- **Scania standard procedure to exchange CPC annually**
- **Reliability of collected data between calibration and validation?**
  - **Reply from instrument supplier (October 12, 2011):**

"You can **either correct them or disregard the measurement**"

"Based on these results: [...] the **only data that can be trusted**

s/n 216 LOW with 30% correction for the PNC

s/n 217 LOW and HIGH (PND2-10) with 14% correction for the PNC"

- **Validation failed due to drift of the CPC**

"For PNCs it's the **degradation of the wick** due to exhaust aerosol (see our publication in JAS, 42, 195-203, 2011"

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CPC Validation – Actions to be taken

- Ensure good measurement accuracy during engine development work
  - Understand the dignity of the failed validation
    - Parallel particle counters for WHTC testing
    - On-site check with soot particles
  - Service of all particle counters
    - Exchange of wick + better butanol quality
  - Traceability of the particle counters in the test cells
- Lessons learned - Ensure that deviation is not repeated
  - New routine for on-site check
  - New service procedure

Scania Results - On-site CPC check against reference CPC

Serial number	Months used	Ambient air + ET		mini-CAST + VPR	Ambient air + ET
		PND1 [h]	Old wick	Several conc. levels	New wick
296	0	43	-5.6%	8.5%	-
217	2.5	433	-3.0%	12.6%	-
114	6	2449	-35.4%	-28.5%	2.6%
283	6		-16.6%	-5.7%	-
284	6	81	-18.4%	-3.2%	-
274	7	95	6.9%	3.9%	-
158	9	946	21.0%	11.5%	-

- Degradation might occur after 6 months use
  - Exchange of wick re-establishes the counting efficiency
- Discrepancy between the available variable to monitor usage and the actual time used
  => need for a PNC service alert
- Check with ambient air less accurate than mini-CAST check
- Overestimation >10% might occur after 9 months use

⇒ On-site checks demands skilled engineers to draw correct conclusions

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New routine for CPC on-site check and new service need

Recommendations from instrument supplier:

- **On-site check with ambient air ideally monthly.**

  1 test cell daily to manage 21 units within one month.
  Approx. 1 h / unit incl. warming up

- **When difference with ambient air is outside ±10% tests with mini-CAST are conducted to specify the difference.**

  Approx. 3 h / unit

- **If the difference is outside ±10%, the wick of the PNC is exchanged.**

  Approx. 2 h / unit

- **Repeat of the ambient air and mini-CAST tests.**

  Approx. 4 h / unit

TOTAL: **Minimum: 1 h / unit monthly in the test cell**
Expected: 4 h / unit monthly times 21 units

=> 50 % of a full time to check stability of Scania's particle counters

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Summing up

- Although following Annex 4c of Reg. 49, instruments may underestimate PN by up to 70%
- On-site check of PNC with reference PNC
  - Ambient air check less accurate than soot generator check
  - Time consuming: 4h + installation and warm up time
  - Need for skilled engineer for analysis of results
- Maturity of the PN measurement method?
- Long term stability of the complete particle counter instrument?
- Repeatability of the calibration and validation methods?

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Thank you for your attention

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