PMP Phase 3 Heavy-duty Validation Exercise – Golden Engineer's Observations

PMP WG Meeting, Dec 14th 2009, JRC Ispra

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Content

- Role of Golden Engineer
- Participating Laboratories
- Observations
- Conclusions
- DR49

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Role of Golden Engineer in HD-VE

- To produce, and update where necessary, a guide for testing
  - Inter-laboratory guide for heavy-duty testing (ILG_HD)
- To provide technical support to the Programme Manager from JRC, and test laboratories during the validation exercise
  - Preliminary visit to discuss the programme, R49 and ILG_HD and identify potential issues with testing at the laboratory visited
  - Commissioning visit to witness first tests and troubleshoot if necessary
- To report, at the end of the inter-laboratory correlation exercise:
  - Experiences of the application of the measurement systems
  - Experiences of the implementation of the particle number and revised particulate mass procedures within the Inter-lab guide (and draft R49 documentation)

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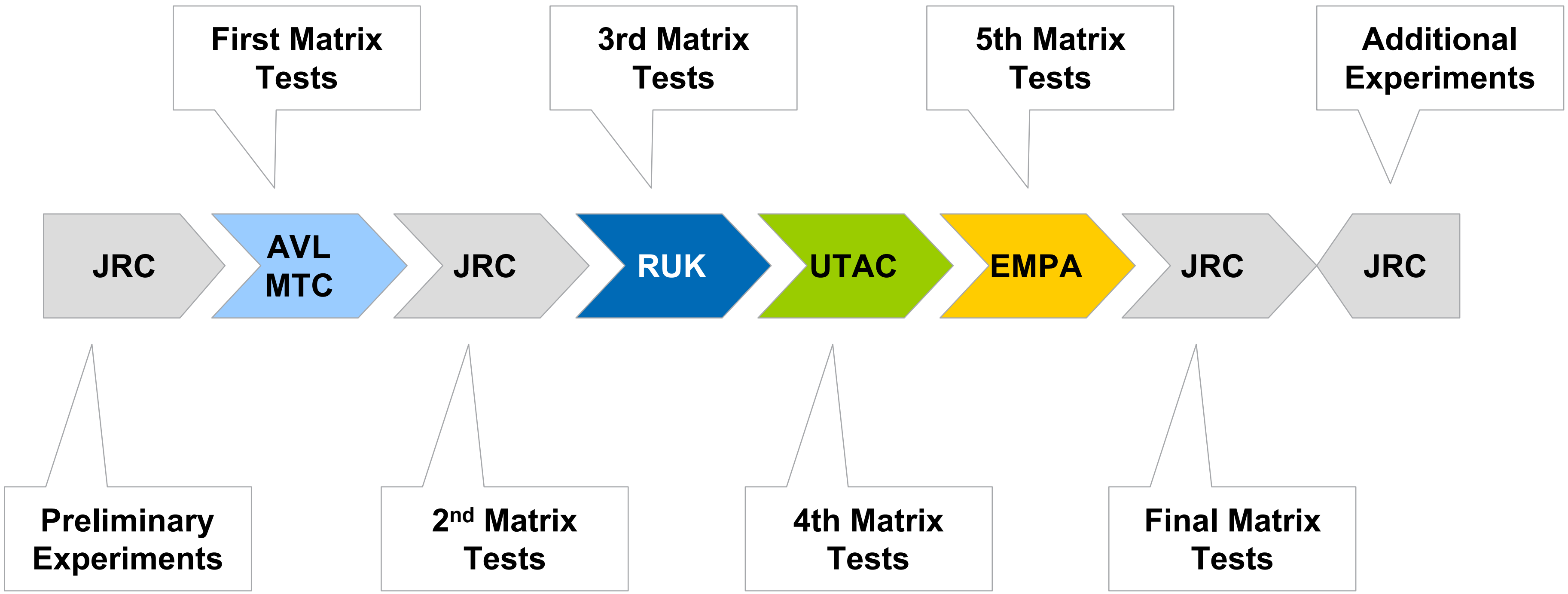
Test Order and Participating Labs



- JRC measurements twice in the test sequence and two sets of experiments to investigate issues
  - Internal standard
  - Preliminary experiments to help establish the test protocol
  - Additional experiments to investigate issues arising and of interest

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Observations
Familiarity with PN measurements

- All labs participating in the HD validation exercise had previously participated in the light-duty work
  - DR49 is substantially similar to the R83 PN Annex, ILG_HD is more prescriptive
  - No major issues with the concepts for sampling and measurements from the CVS
    - Some concerns about using the SPCS systems
      - Power requirements [Details added to ILG_HD]
      - Installation and commissioning [JRC helped out]
      - Sampling manifold [JRC provided]
      - Sample return to CVS [Required but may be not necessary]
  - Participating labs were unfamiliar with making particle number measurements from partial dilution tunnel (PDT) systems, so the many discussions were around this

Observations
PN from PDTs was new and concerning

- Issues raised
  - Hardware modifications needed to make simultaneous PM and PN measurements possible
  - Hardware and/or software corrections required for valid PM data
  - Sample probe – raw exhaust
  - Sample probe – from the PDT
  - Use of a cyclone
  - Generic operating conditions   [Defined in preliminary experiments]

Observations
Facility Modifications

- All labs were relatively well prepared for the programme
- Hardware actions were limited to
  - LEPA, Carbon, HEPA filters for CVS dilution air
  - Improved quality of dilution air for secondary tunnels (PM)
  - Control of filter face temperature to 47°C ± 5°C
    - Heating of secondary dilution air
    - Implementation of heating chambers to contain cyclone and filter holder

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Observations
PM Sampling

- Filter holders (CVS and PDT)
  - Some labs used current PM holders without a back-up
  - Other labs used US07 style holders
  - All labs used TX40 filters
- Weighing Processes
  - No labs reported any reference filter failures
    - (within ±5μg versus ≤ 30 day rolling average)
    - One lab had 1 of 3 filters borderline
      - 10μg variance required?
  - Some labs needed to install real-time RH and Temp monitoring in their weighing environments
- Background PM
  - In most cases equal to or higher than sample masses
  - Same effect in CVS and PDT
  - Some CVS systems had very high PM backgrounds

Observations
PN 'Golden Systems'

- Functionality
  - One SPCS suffered from overheating problems, but this was resolved by applying external cooling at all labs
- Validation
  - No labs reported any failures of the validation exercises

EMPA

Test	Pass Requirement	SPCS-19	SPCS-20
PNC Zero	<0.2#/cm^3	0.01	0.01
PNC Flow	1.00l/min +/- 0.05	0.95	0.96
System zero	<0.5#/cm^3	0.1	0.02
PNC temperature SPCS temperatures	Green LED Software Pass	Green LED Software Pass	Green LED Software Pass

- Background Particle Number Levels
  - Similar between PDT
  - Much more variable between CVS
  - Generally much higher from CVS

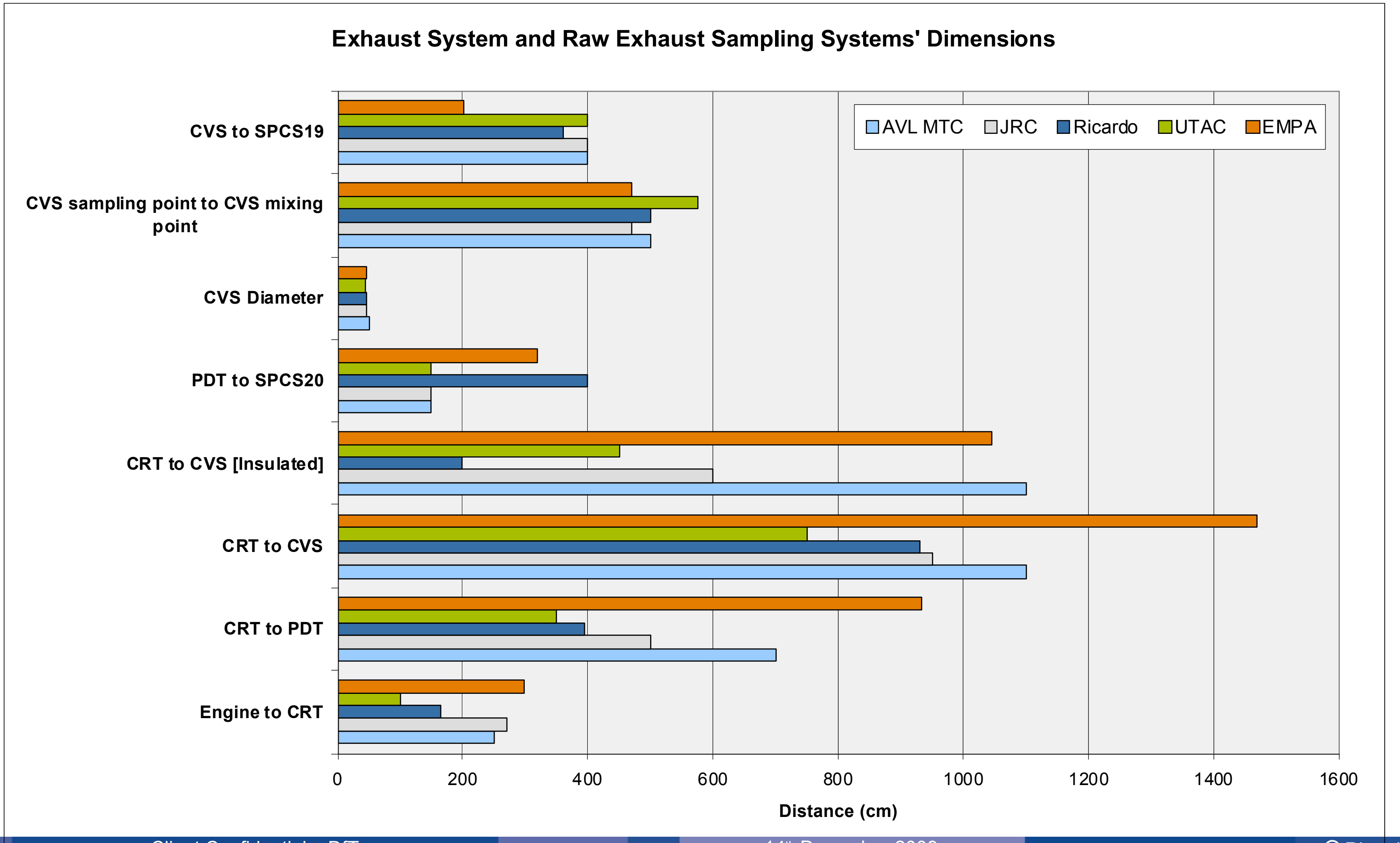
PN Background (#/cm^3)

	CVS	PDT
AVL-MTC	n/a	n/a
JRC	6	4.5
Ricardo	2082	3.2
UTAC	120	375* / 30
EMPA	49	2

UTAC PDT Background reduced tenfold by air filter swap to HEPA

Observations
Exhaust and Sampling System Installations

- Exhaust system installations were as similar as was practically possible
  - Engine – CRT distance could be critical for emissions [impact to be studied]
  - Temperature gradients could be critical for PM [No obvious effect seen]



Observations
Dilution Tunnels

- CVS facilities were broadly similar
- Tunnel residence times controlled to 1.6s to 2.3s range
- Much larger range in secondary tunnel dimensions and residence time
  - (0.4s to 7.8s)
  - No discernible impact on PM

	AVL MTC	JRC	Ricardo	UTAC	EMPA
CVS flowrate [Nm3/min]	72	80	60	80	80
CVS length [cm]	500	470	500	575	470
CVS diameter [cm]	50	47	46	45	47
CVS Heat exchanger	No	Yes	Yes	Yes	Yes
Preclassifier cutpoint [um]	2.5	2.5	2.5	2.5	2.5
Secondary tunnel flowrate [lpm]	50	50	60	50	40
Secondary tunnel DF	2	2	2	2	2
Secondary tunnel length [cm]	30	64	100	30	200
Secondary tunnel diameter [cm]	8	8.6	10	8	1.4
Secondary Tunnel volume (dm3)	1.5	3.7	7.9	1.5	0.3
CVS Residence time (s)	1.90	1.61	2.28	1.97	1.61
2° tunnel residence time (s)	1.81	4.46	7.85	1.81	0.46

- PDT systems were operated at similar conditions at all labs
  - Range of tunnel sizes with different PDT manufacturers (different t_{res})
  - Little evidence of systematic differences in PN
  - No evidence of PM impact

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Conclusions

- Labs were confident with the measurements of PM and PN from CVS systems but required more support with the PDT approach
- After specific discussions on sampling, flow corrections and measurement protocols, no labs experienced difficulties with simultaneous measurements of PM and PN from PDT during the exercise
- Several facilities required upgrades to dilution air filtration
  - Mostly CVS, but some PDT systems' filtration is substantially poorer quality than others
- Weighing facilities do not always have the required RH and temp monitoring capabilities
- Reference filter checks were always passed, but it might be wise to have a 10µg tolerance
- The GPMS systems performed extremely well and daily validation exercises were passed without issue throughout the exercise
  - For the SPCS system at least, daily validation is unnecessary
- Background particle number levels were higher and more variable in CVS systems than in PDT systems
- Background PM was frequently higher than sample masses even from PDT systems that showed very low background PN

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DR49 – possible recommendations

- PN measurements from partial flow to be integrated along with specific PDT performance for sampling
  - Sample probe dimensions / lengths may not need to be as prescriptive as the full flow procedures, and some are not relevant / unachievable
- Dilution air requirements for PDT systems to be rigorously defined
- Preconditioning requirements or cleaning requirements might be valuable as recommendations
- Implement thresholds for background subtraction with particle numbers and particulate mass from high background facilities
  - Similar to 1mg/km maximum subtraction in light-duty R83
  - Possibly
    - 2.2mg/kWh PM = 22% of Euro VI PM limit
    - $1.8x10^{11}$/kWh = 22% of proposal for Euro VI PN limit on WHSC
    - [1mg is 22% of Euro 6 PM limit]