HORIBA Ltd,

Automotive Measurement R&D Dept.

Shun Fukami

Development Tools for Advanced On-Board Emissions Measurements of NMHC and Particulates, Plus a Coaching Tool for Increasing RDE Test Yield

March 22nd 2018

8th PEMS Conference

Contents

- Background
- On-board NMHC measurement
- On-board Sub-23nm PN measurement
- Coaching tools for RDE
- Conclusion

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- **Background**
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Demands of new analyzer for PEMS

- **NMHC**
  - **Necessity for measuring CH_4 gas emitted from HDV.**
  - **Demand for CNG (Compressed Natural Gas) engine.**

- **Sub-23nm PN**
  - **Higher health effect from smaller particle**
  - **Study for GDI engine on-road**

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NMHC analyzer unit for PEMS

Heated tube

Principle

- Vacuum type hot **Dual-FID** is adopted.
- NMC(Non-methane Cutter) method is used.

Measurement components

- THC, CH_4, NMHC (calculated)

Features

- **Calibration gas**

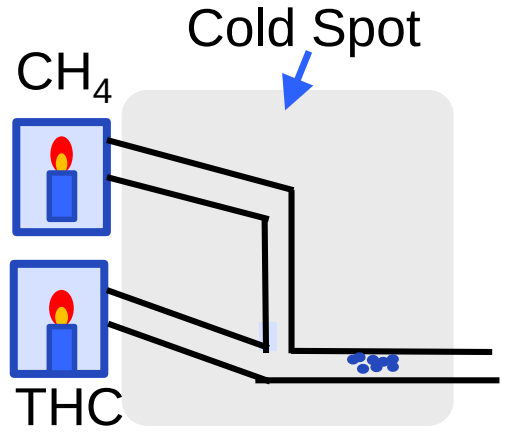
  CH_4 : Possible to be calibrated by using both C_3H_8 and CH_4.

- **In-line filter**

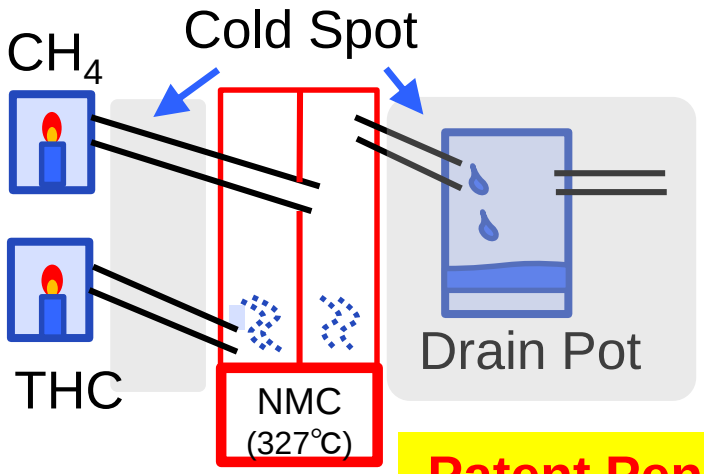
  Heated filter and tube are united.

Dual FID in PEMS

- **Difficulty of Dual FID**
  - **Not ignited : Pressure interference at ignition**
  - **Misfire : The clogging caused by condensed water**



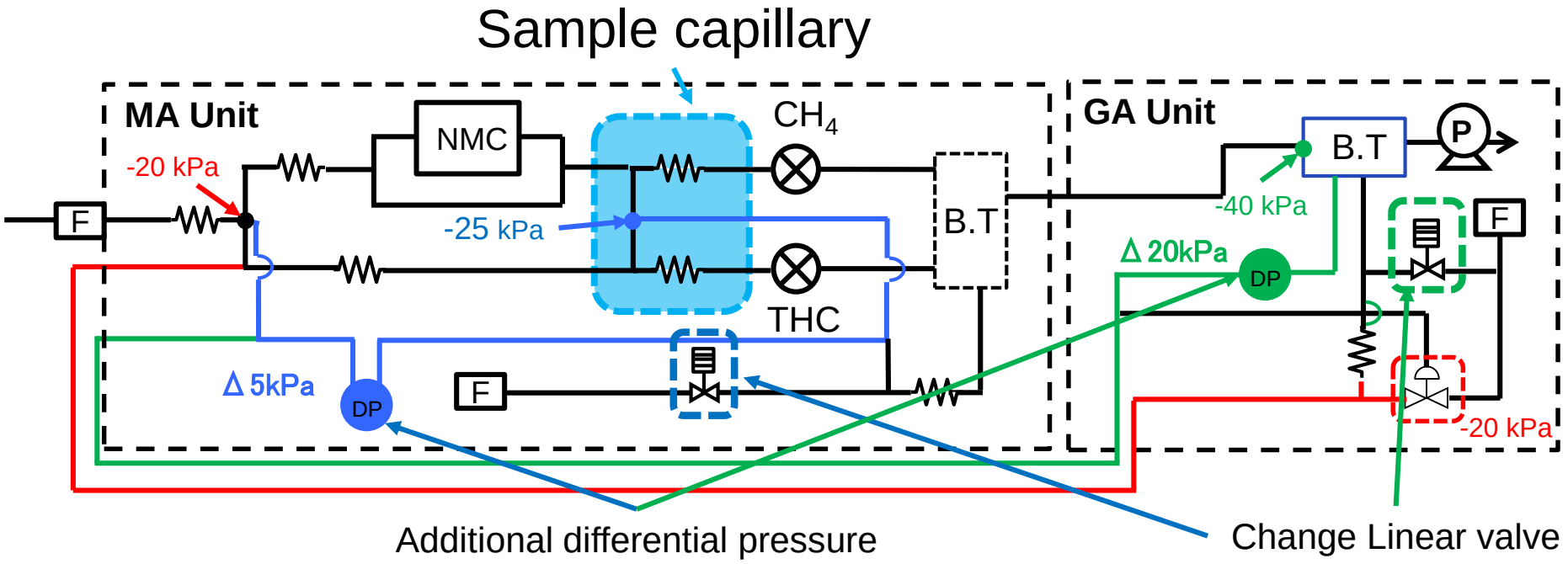
- **Break through**
  - **Added buffer tank to reduce the pressure interference.**
    - **Condensed water is vaporized utilizing residual heat of NMC.**
  - **Added the drain pot outside the system and prevent from clogging the water.**



Patent Pending

Stability for environmental change

- **Using linear valve for the flow control, not regulator**
  - **It is important to control the differential pressure(DP) of sample capillary continuously.**
  - **F/B control by linear valve with additional DP sensors.**

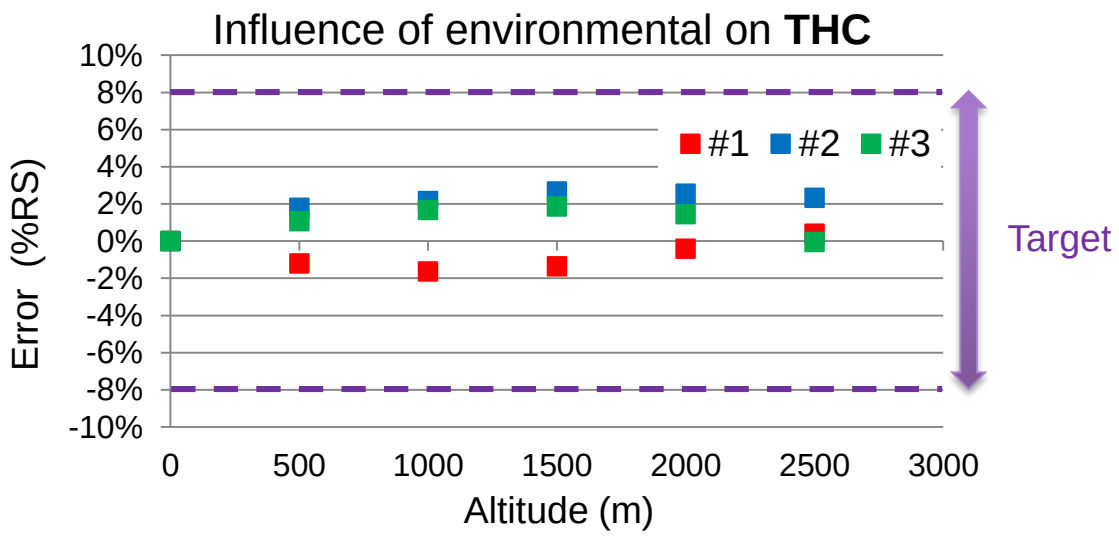


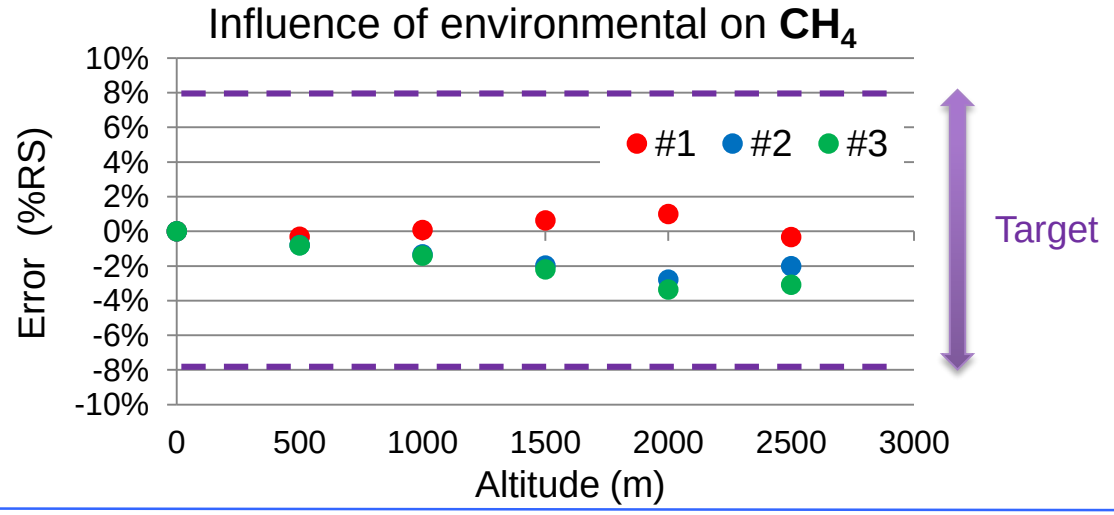
Patent Pending

Environmental performance on Mt. Fuji

- **Environmental testing @ Mt. Fuji**

Span Gas : 96 ppmC





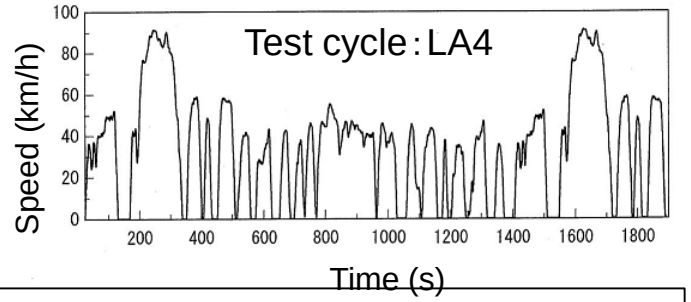
Correlation tests on chassis dyno

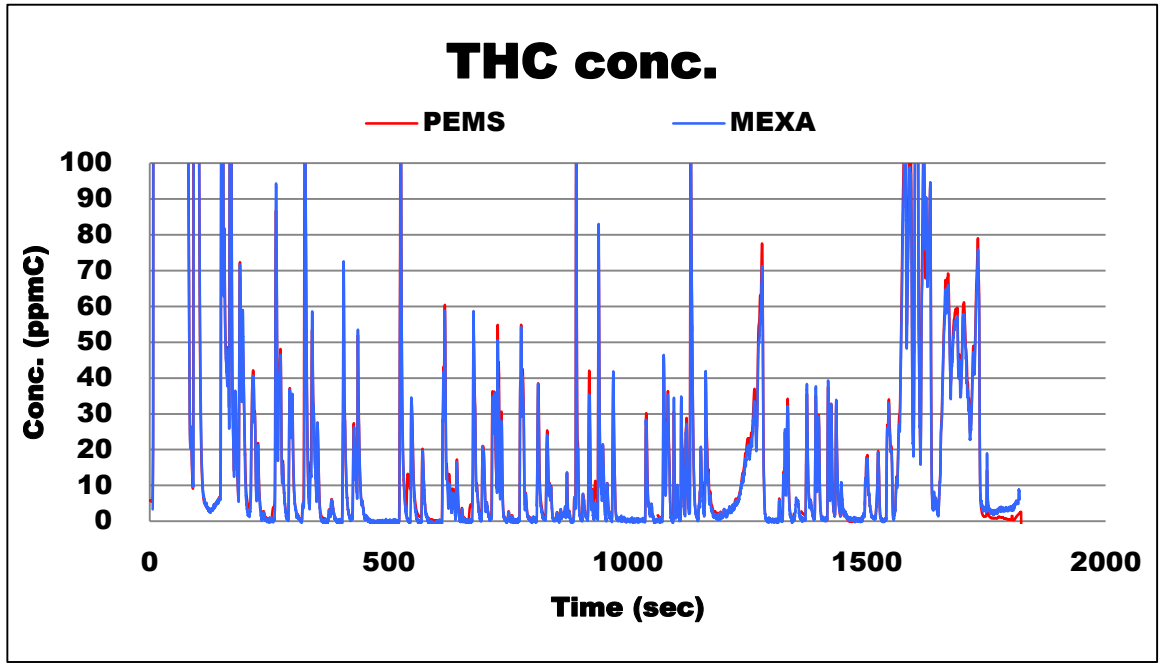
- **Lab system vs PEMS**

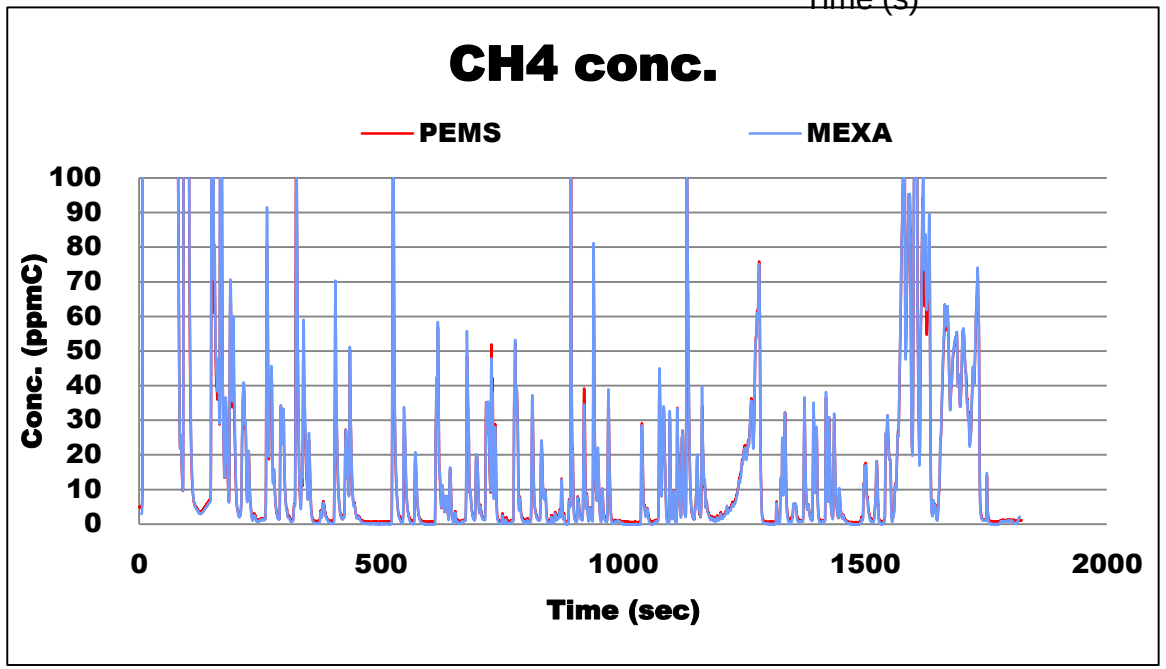
  (On the chassis dyno @ HORIBA E-LAB Cell3)

  - **Test vehicle : CNG engine**

HORIBA BIWAKO E-HARBOR







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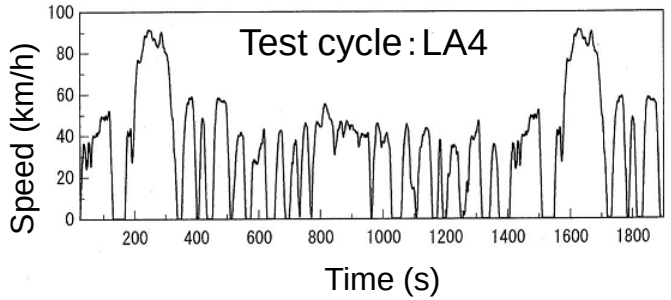
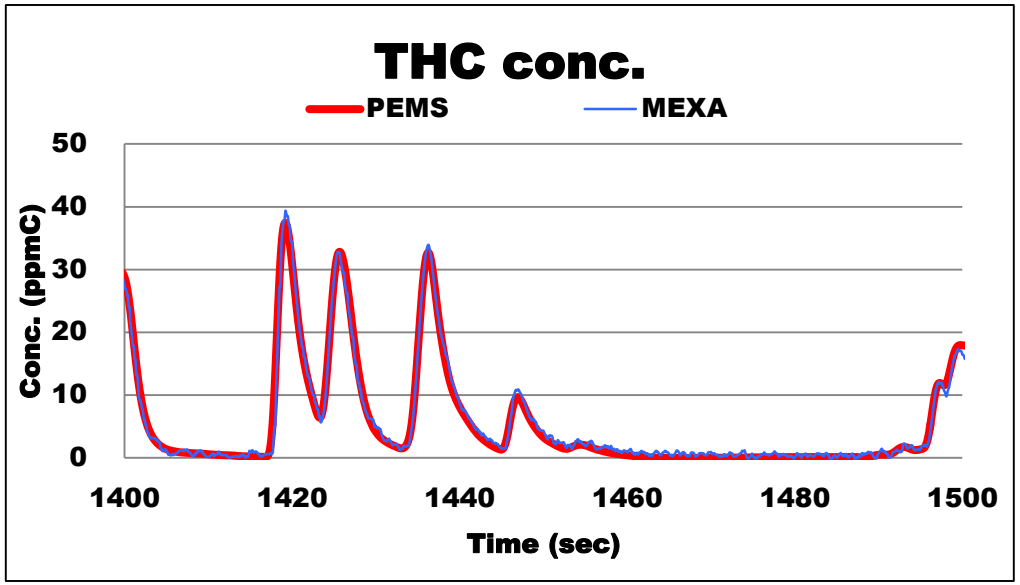
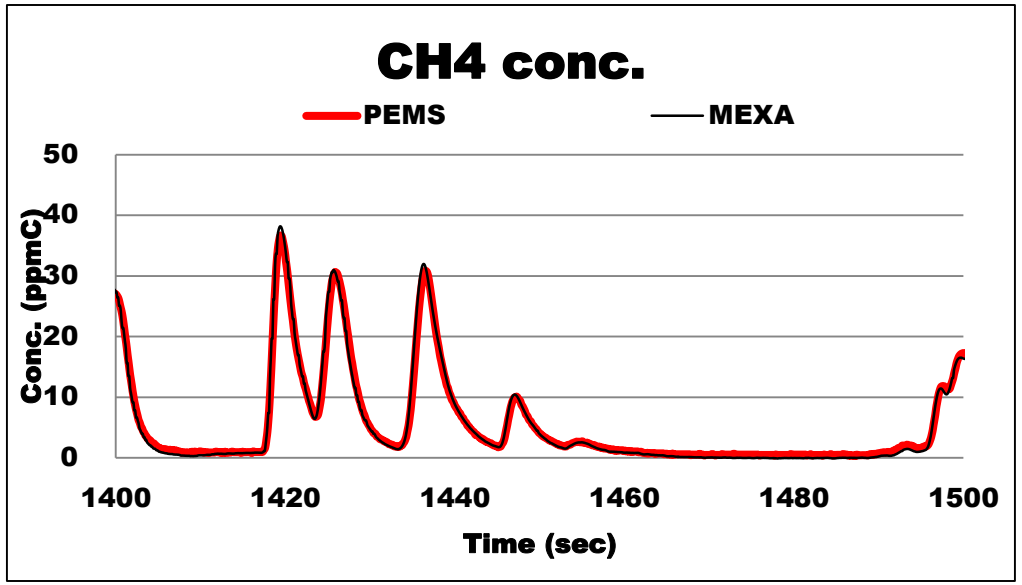






Good correlation with conventional device at Laboratory correlation test.

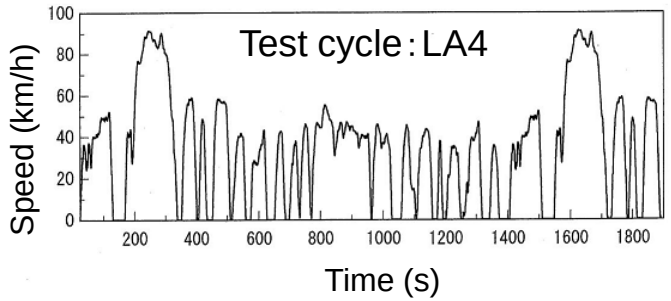
Correlation tests on chassis dyno

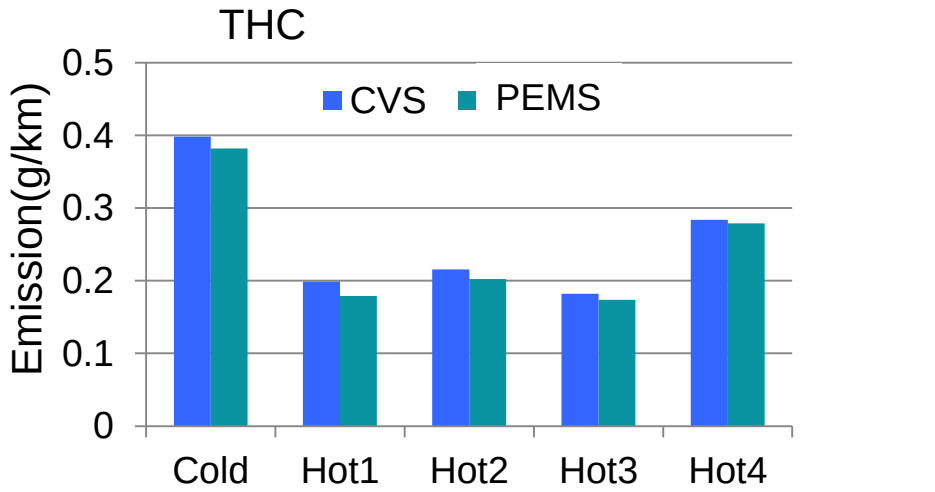
- **CVS vs PEMS**

  (On the chassis dyno @ HORIBA E-LAB Cell3)

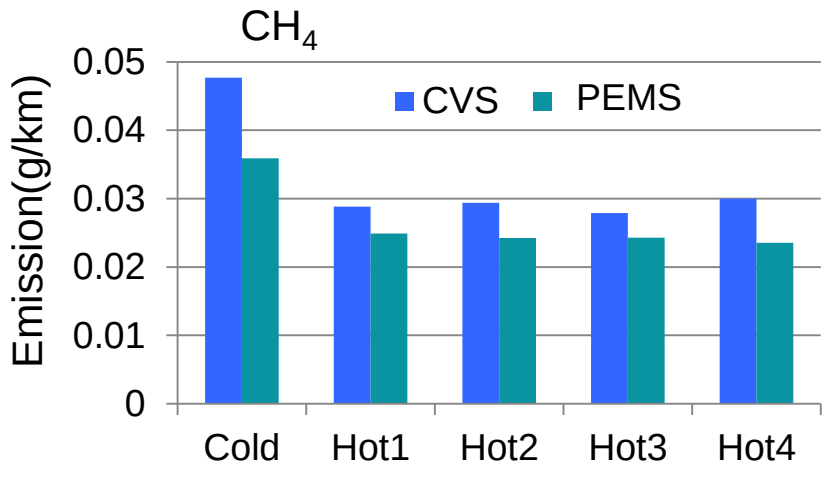
  - **Test vehicle : CNG engine**

HORIBA BIWAKO E-HARBOR





Error (%) (CVS vs PEMS)					STD
4.1	9.9	6.1	4.7	1.8	≦15.0



Difference (g/km) (CVS vs PEMS)					STD
0.012	0.004	0.005	0.004	0.006	≦0.015

Good correlation with CVS at Laboratory correlation test.

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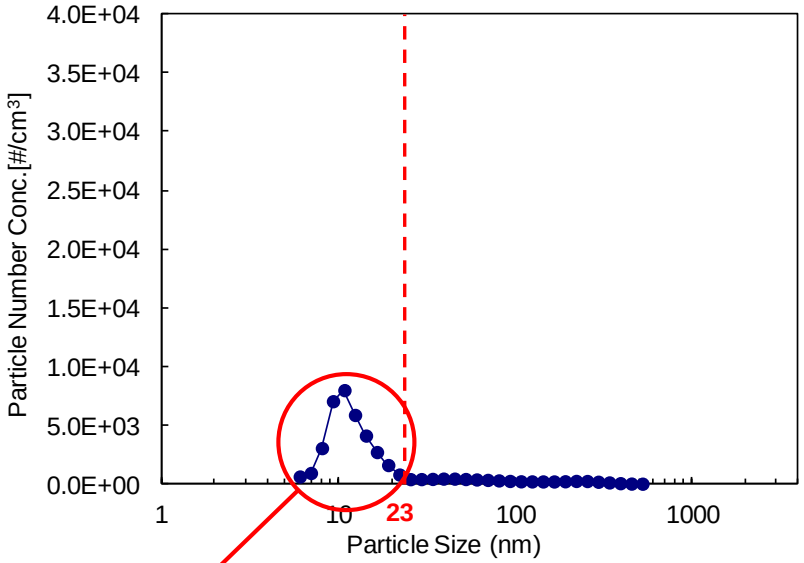
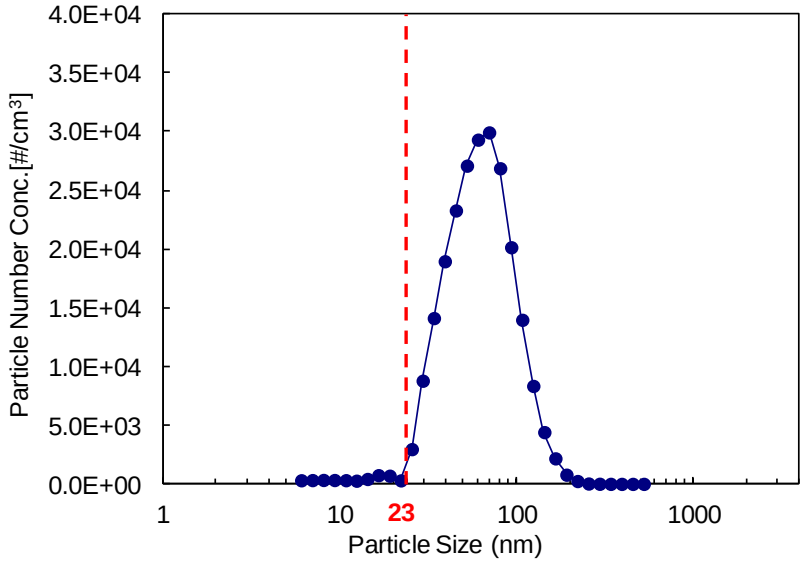
Size of Particles on vehicle exhaust

Idle



2500 min^{-1} 100 N·m

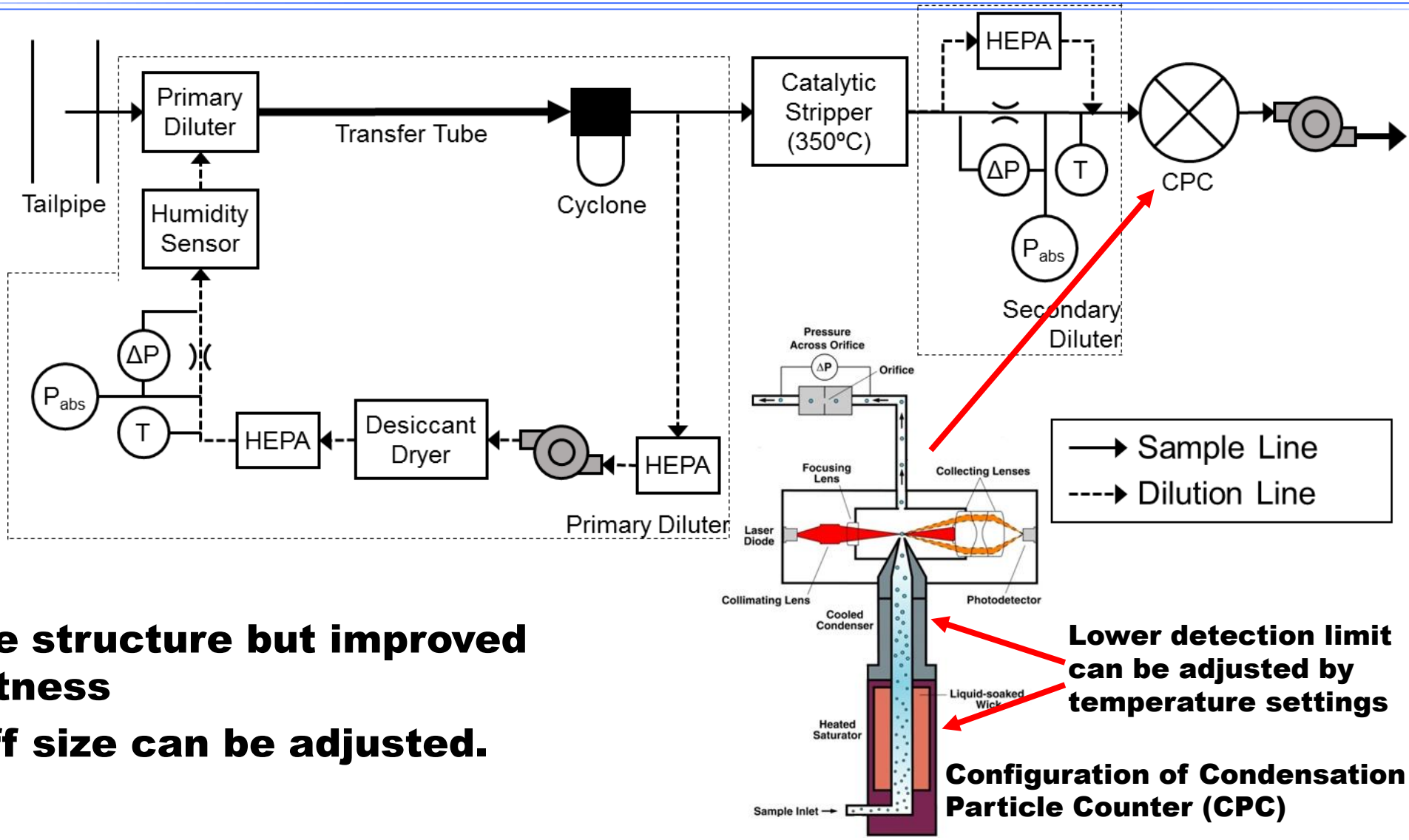


Only solid particles?

*Size distributions of a 2.0 L turbo charged common rail diesel engine at VPR outlet (DF:750, raw exhaust measurement, HORIBA internal data)

- **Some researches showed evidences about the existence of sub-23 nm solid particles at VPR(Volatile Particle Remover) outlet**
- **Sub-23 nm solid particles are considered as ash contents generated from the metal additives in lubricant oil**
- **PMP compliant systems cannot detect such fine particles**

Configuration of PN-PEMS

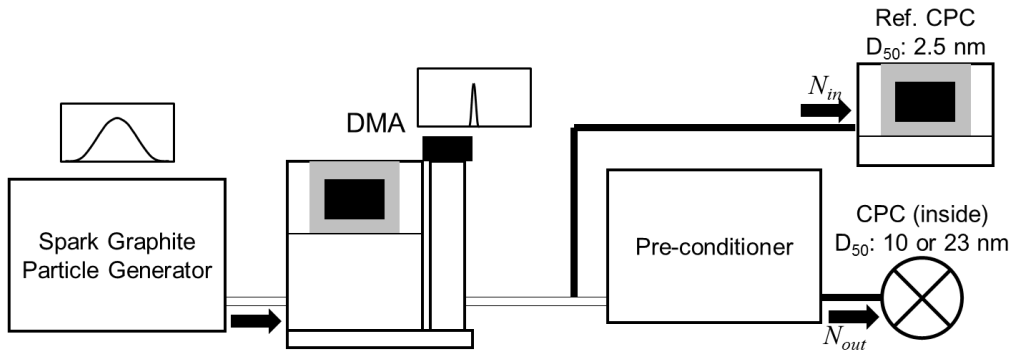


- ✓ **Simple structure but improved robustness**
- ✓ **Cut-off size can be adjusted.**

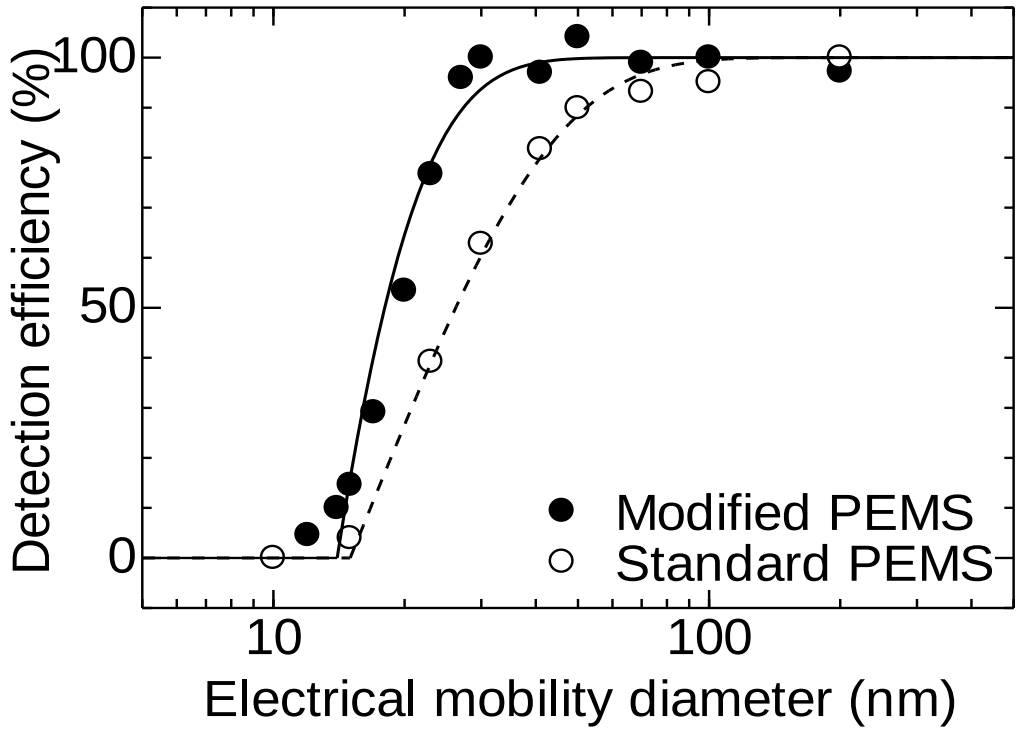
Lower detection limit can be adjusted by temperature settings

Configuration of Condensation Particle Counter (CPC)

System Detection Efficiency

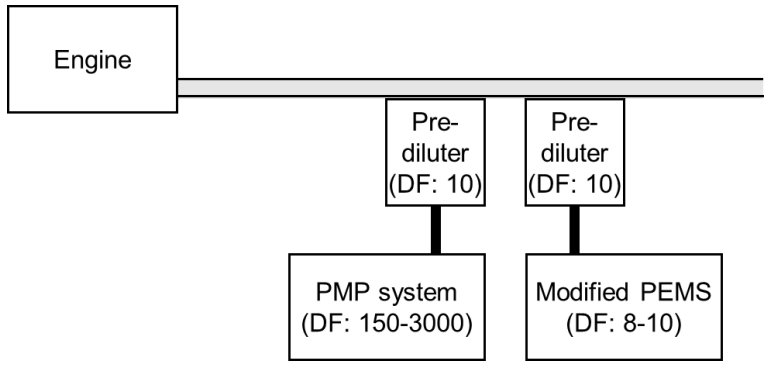


Parameters	Modified PEMS	Standard PEMS
D_0	14.0 nm	15.0 nm
D_{50}	18.0 nm	26.2 nm

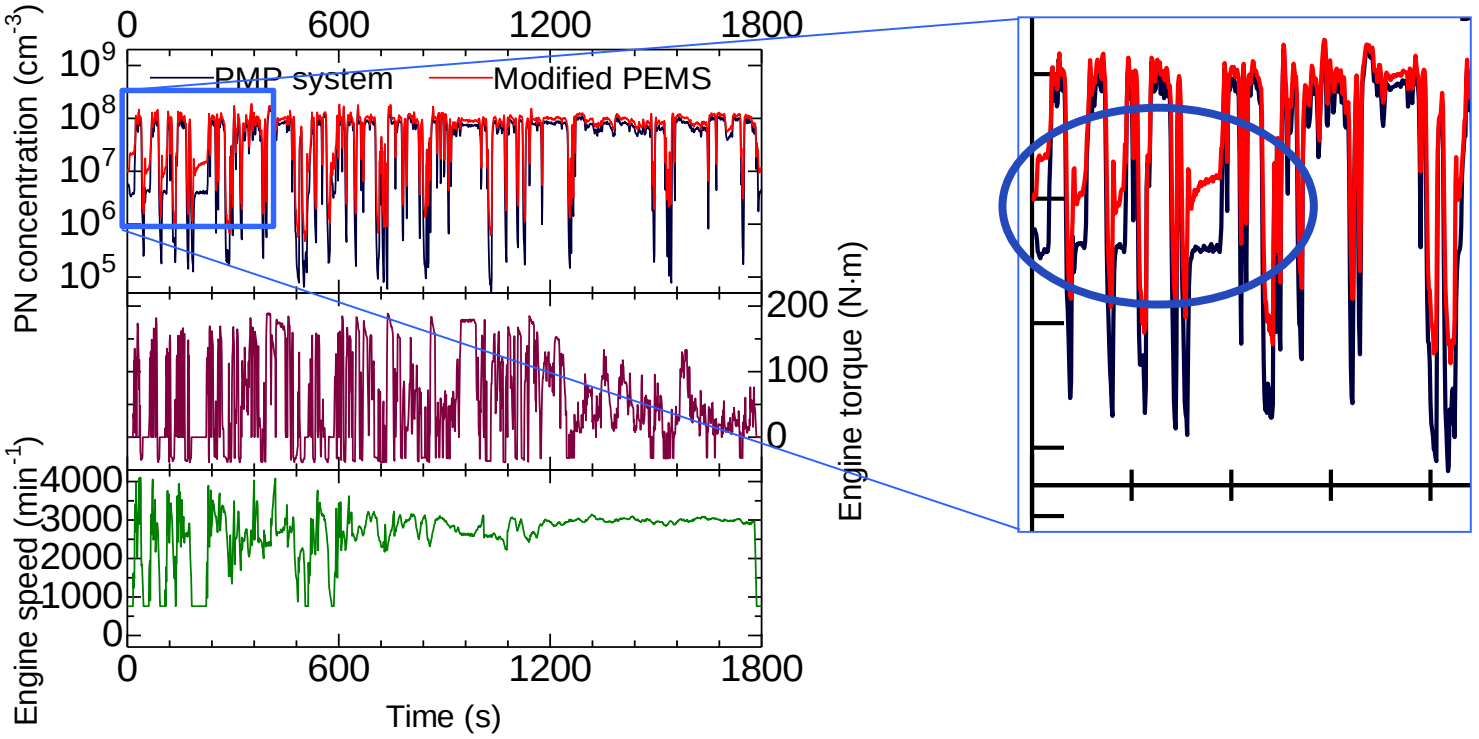


- **Modified lower detection limit of the CPC inside of the PN-PEMS extended particle size range**
- **Modified PN-PEMS has steeper cut-off performance due to higher particle losses in the pre-conditioner**

Comparison on Engine Dynamometer without DPF

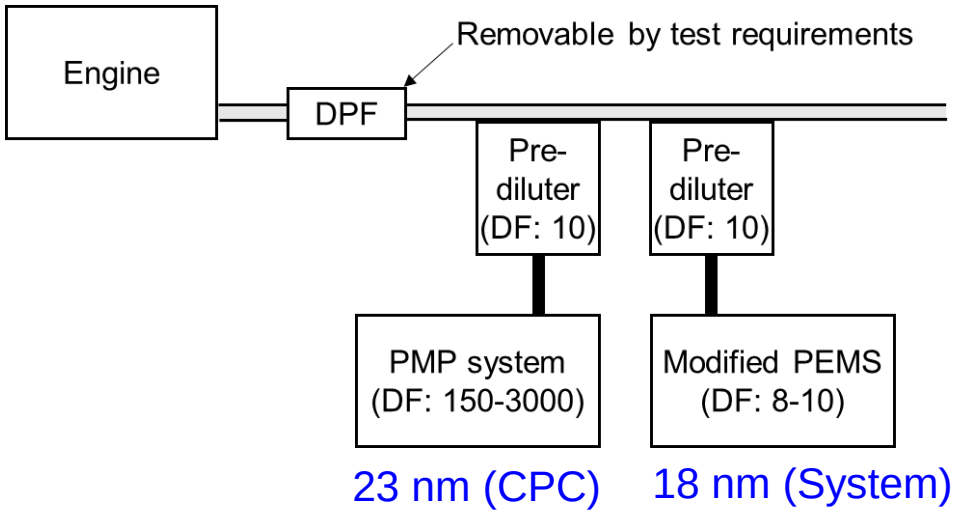


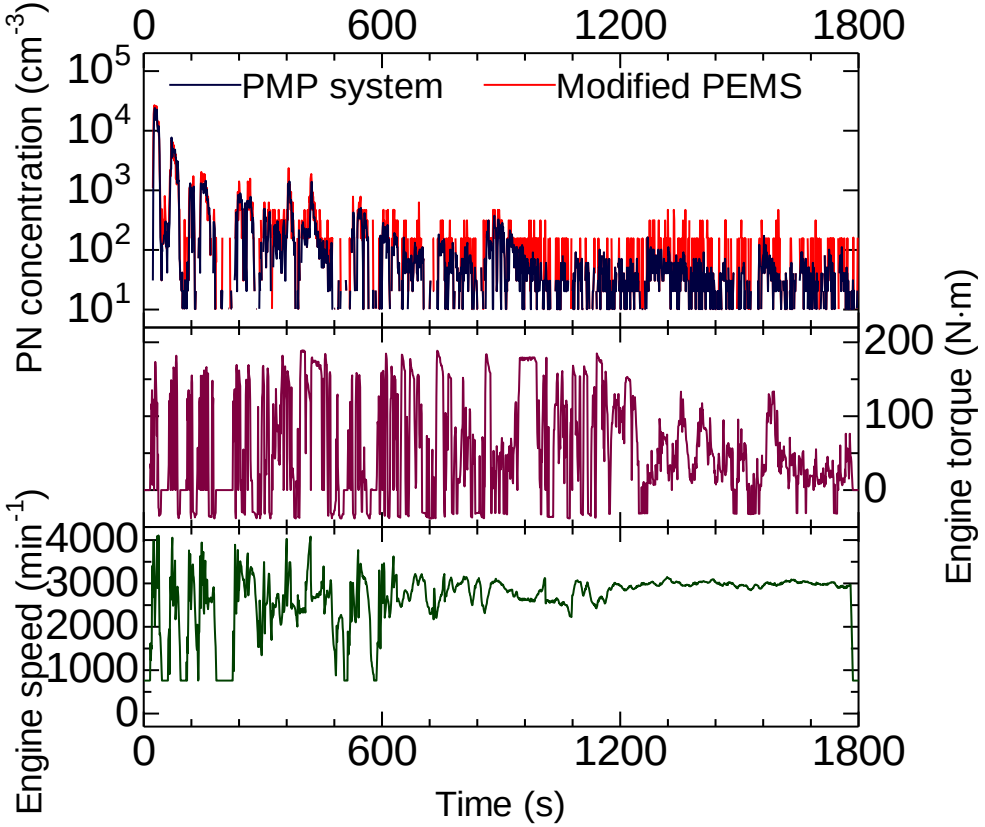
23 nm (CPC) 18 nm (System)



- **ETC test cycle was performed by a diesel engine without DPF**
- **Difference was observed only at idle mode during the warmup phase due to higher amount of small particle emission**

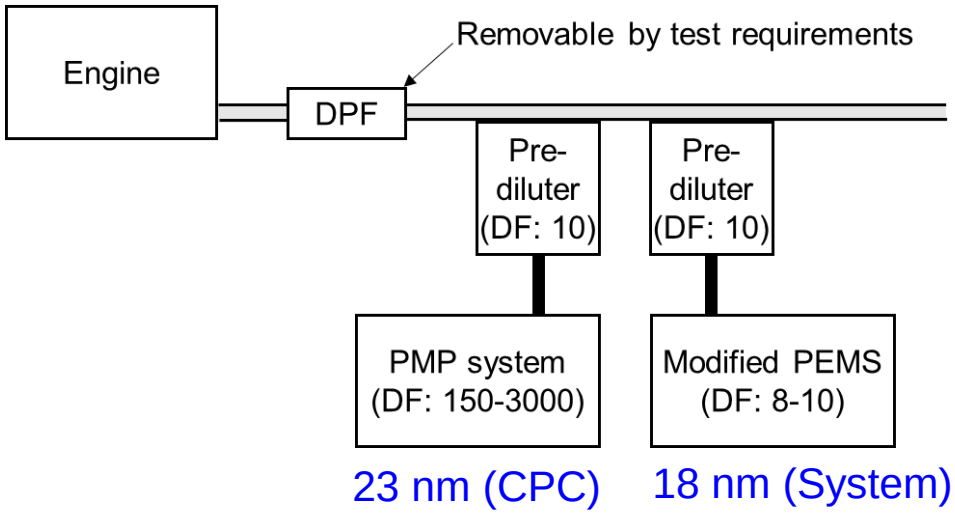
Comparison on Engine Dynamometer with DPF

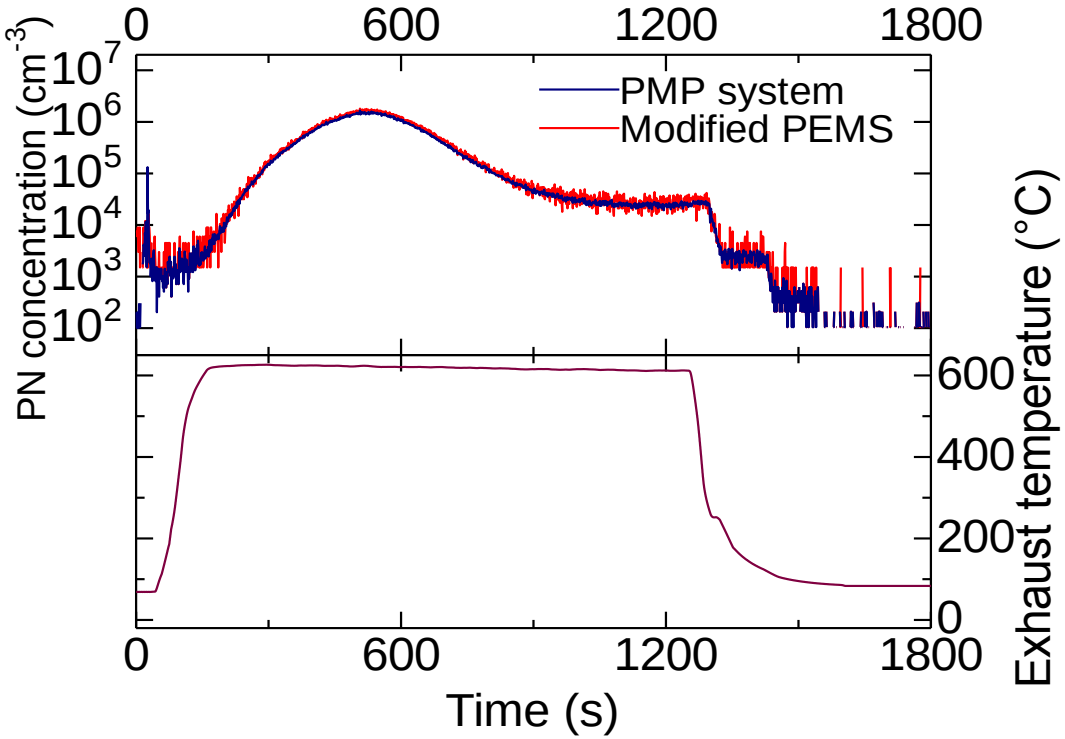




- **ETC test cycle was performed by a diesel engine equipped with a DPF**
- **Almost the same real-time PN concentrations were observed**
- **The result suggests high filtration efficiency of the DPF with sub-23 nm particles**

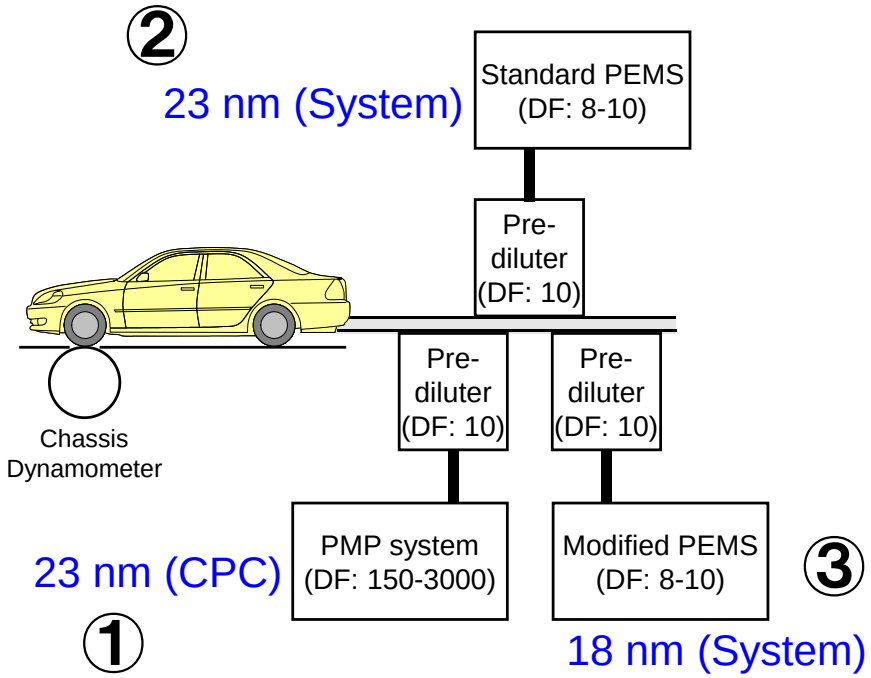
Comparison during DPF Regeneration

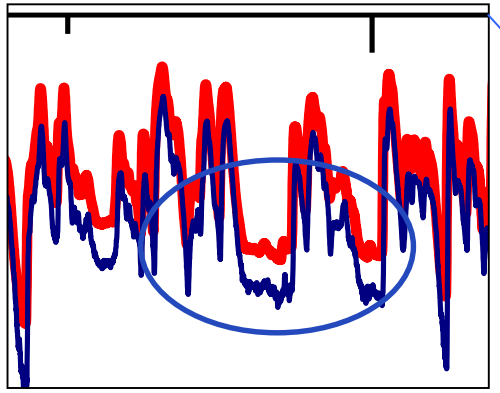


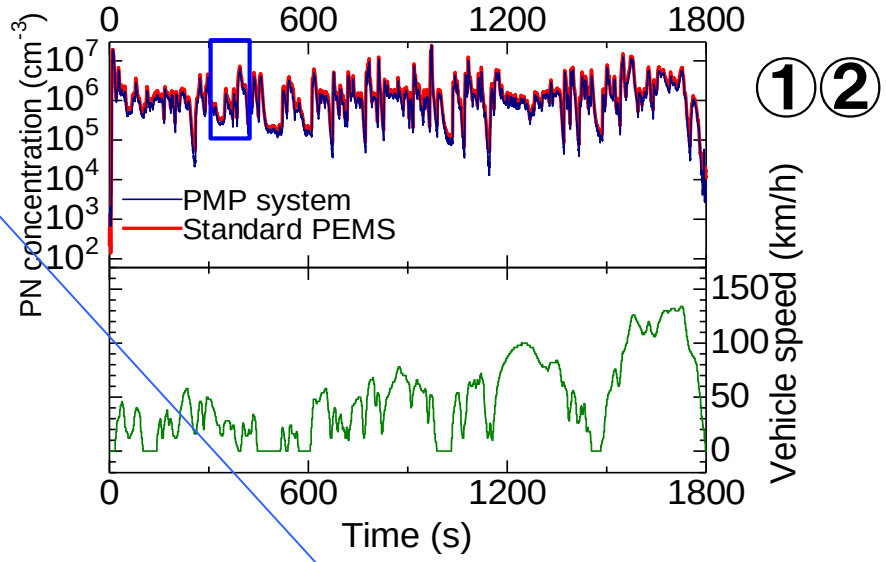


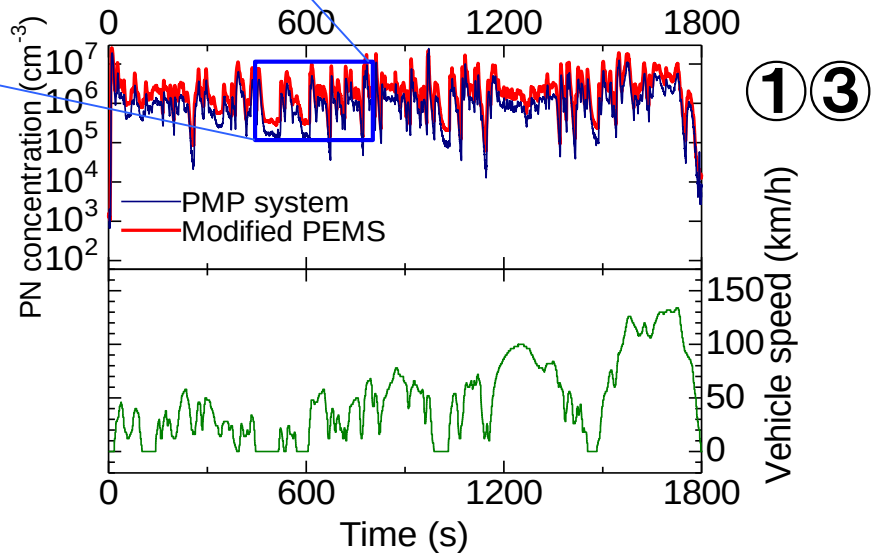
- **The DPF was regenerated by a high speed and high load steady state operation condition**
- **No difference was observed even with high amount of volatile components**
- **Sufficient volatile particle removal performance was ensured**

Comparison on Chassis Dynamometer with GDI vehicle





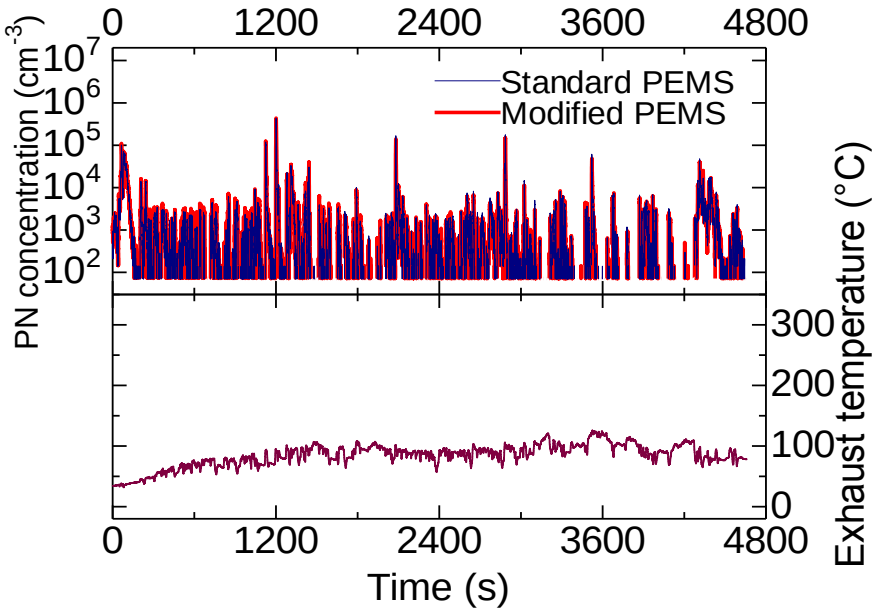




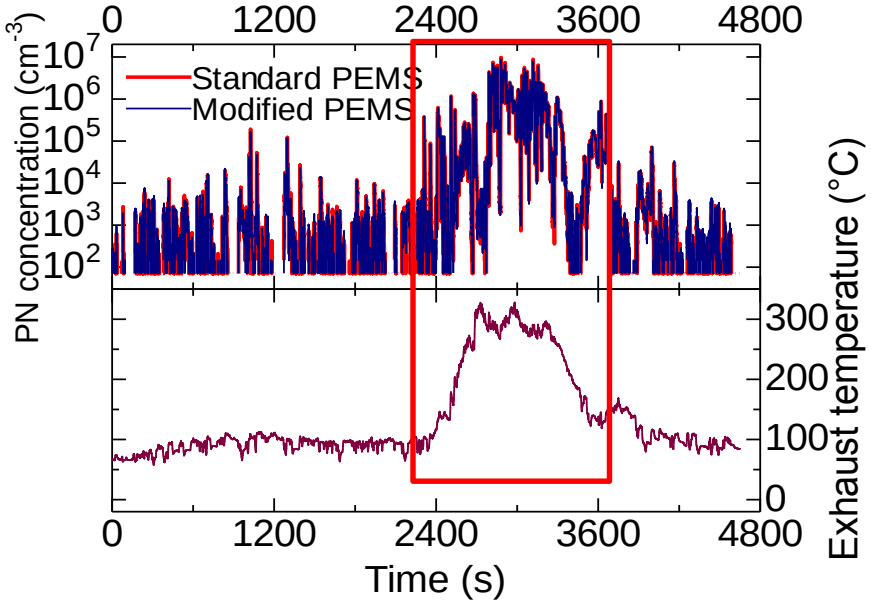
- **WLTC was performed by a vehicle equipped with a direct injection gasoline engine**
- **Small difference was observed during engine warmup due to the difference of lower detection efficiency of CPC**

On-Road Testing

Without DPF Regeneration



With DPF Regeneration



- **On-road tests were performed by a diesel vehicle equipped with a DPF**
- **Almost the same real-time PN concentrations were observed regardless of DPF regeneration**
- **The result suggests high filtration efficiency of the DPF with sub-23 nm particles again**

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RDE Test Validity

- **A valid RDE test needs to meet a comprehensive list of criteria**

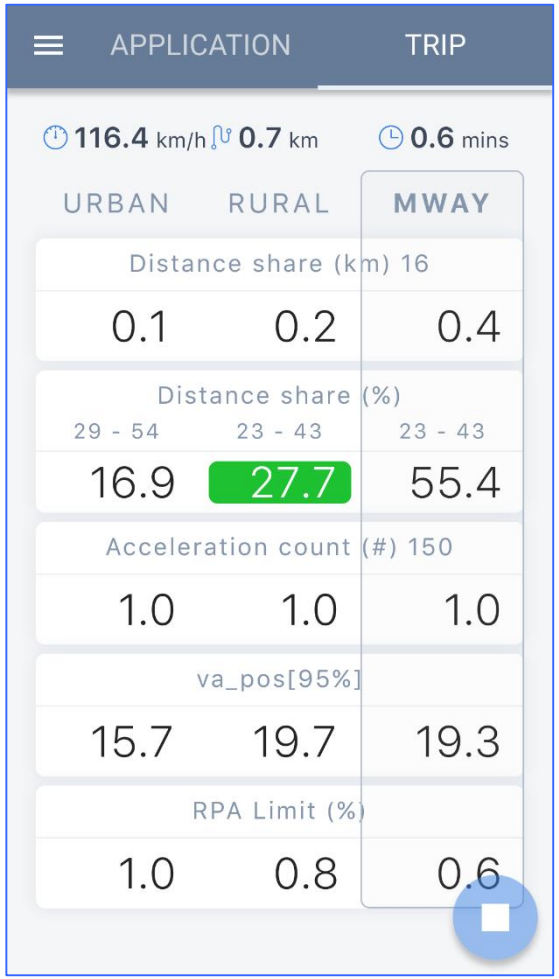
Parameter		Provision set in the legal text	
Payload		≤90% of maximum vehicle weight	Location and Weather
Altitude	Moderate	0 to 700 m	
	Extended	Between 700 and 1300 m	
Altitude difference		No more than a 100-m-altitude difference between start and finish	
Cumulative altitude gain		1200 m/100 km	
Ambient temperature[14]	Moderate	0°C to 30°C	
	Extended	From –7°C to 0°C and 30°C to 35°C	
Stop percentage		Between 6% and 30% of urban time	Driving Style
Maximum speed[15]		145 km/h (160 km/h for 3% of motorway driving time)	
Dynamic boundary conditions	Maximum metric	95th percentile of *v*a* (speed * positive acceleration)	
	Minimum metric	RPA (relative positive acceleration)	
	Curves shapes shown in Figure 2.		
Use of auxiliary systems		Free to use as in real life (operation not recorded)	

Source: The ICCT January, 2017 policy update on RDE test procedure

Any data point falling outside of the boundary conditions makes the whole test invalid

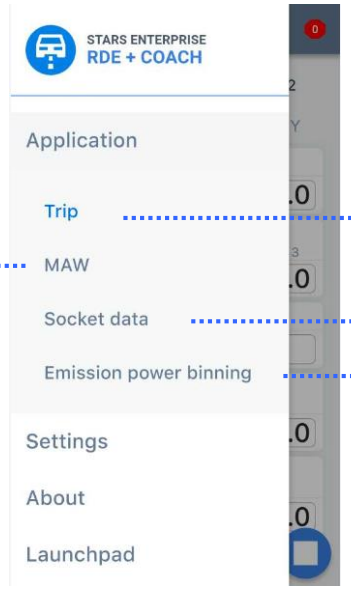
RDE CoDriver

- **The ideal tool to manage the complicated RDE test requirements**
  - **RDE CoDriver is a mobile app providing real-time guidance for the driver ensuring that the test will meet the required criteria**
  - **Can be utilized in conjunction with a PEMS for actual testing or stand-alone to train inexperienced drivers**
  - **The system immediately informs the driver in case a data point falls out of boundary, minimizing wasted test time**
  - **Supports moving-average window (EMROAD) and power-binning (CLEAR) method**
  - **Maximizes the output of valid RDE tests**



RDE CoDriver

During test

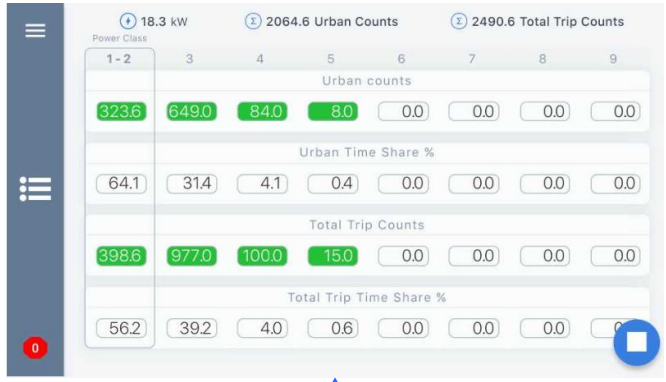


Menu

Trip

PEMS Data

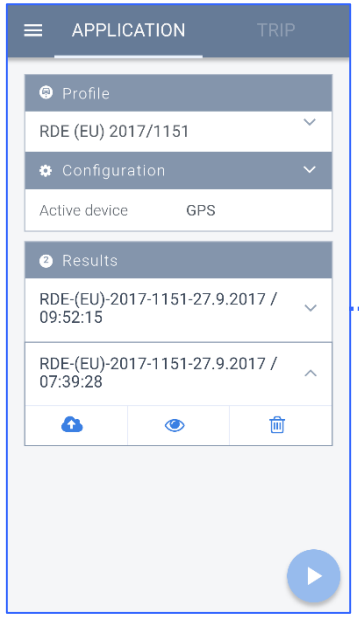
MAW – Moving Average Window

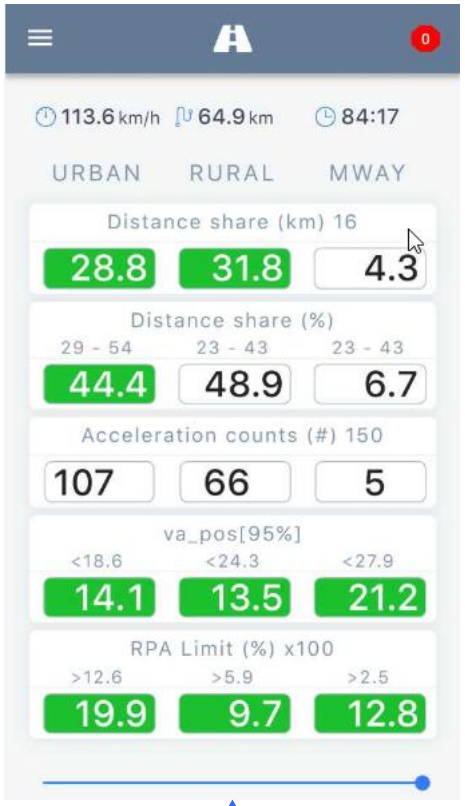


Emission power binning

RDE CoDriver

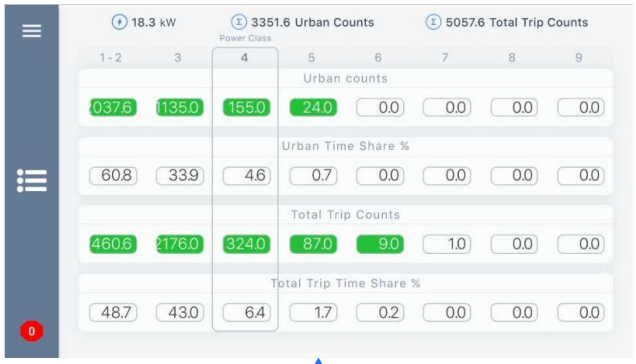
Test result





Trip

MAW – Moving Average Window



Emission power binning

Result Views

RDE+ Data Manager

Bringing the road data into the lab

- The RDE+ Data Manager provides a direct link from the RDE CoDriver to the test laboratory
- Drivers can upload the test results to the central data storage, so engineers and can immediately review them or replicate the test on a chassis dyno
- Engineers can observe the RDE CoDriver display from their office
- Engineers can transfer new configuration data to the
RDE CoDriver

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Conclusion

On-board NMHC measurement

- The Vacuum type Dual-FID detector was newly developed. It has countermeasure against “not ignited” and “misfire”.
- The stable data was obtained for environmental change in real driving by reexamining the control of differential pressure.
- Good correlation result with CVS at laboratory was obtained.

On-board Sub-23nm PN measurement

- It was possible to observe differences in PN concentrations between the PMP compliant laboratory system and the modified sub-23 nm system. This result suggests the smaller size particles are contained in vehicle exhaust.
- Since filtration efficiency of the DPF to sub-23 nm particles was high, small measurement difference between different lower detection limit settings was observed.

Coaching tools for RDE

- It gives real-time guidance for the driver ensuring that the test will meet the required criteria. This maximizes the output of valid RDE tests
- The RDE+ Data Manager provides a direct link from the RDE CoDriver to the test laboratory. Engineers can observe the RDE CoDriver display from their office

HORIBA
Automotive Test Systems

Thank you

Thank you

감사합니다

Cảm ơn

ありがとうございました

Dzięk uj ę

धन्यवाद

Grazie

Merci

谢谢

நன்ற

ขอบคุณครับ

Obrigado

Σας ευχαριστούμε

شُكْرا

Tack ska ni ha

Большое спасибо

Danke

Gracias