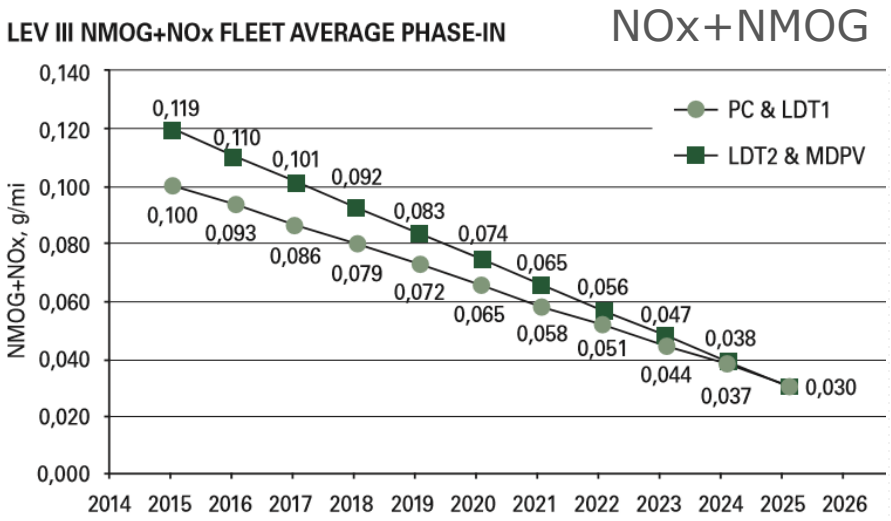
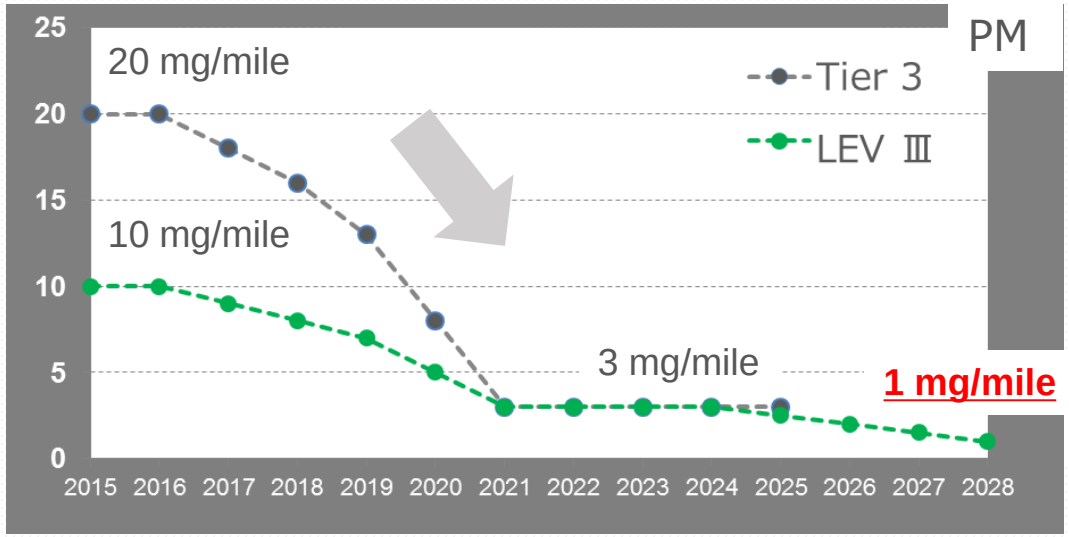
Development of Compact Multi Gas Measurement System (NCEM©)

NGK SPARK PLUG CO., LTD.

Introduction



source: world emissions standards ,Delph



source: Nikkei Automotive, 2016.March

- Real world emissions
- Development of low emissions engines

Challenges with existing PEMS

・Size ・Power consumption

・Weight ・Complexity

Simpler and more user-friendly tools have a role to play

■Target position

Cost

$100,000 over

$50,000 to 30,000

$10,000

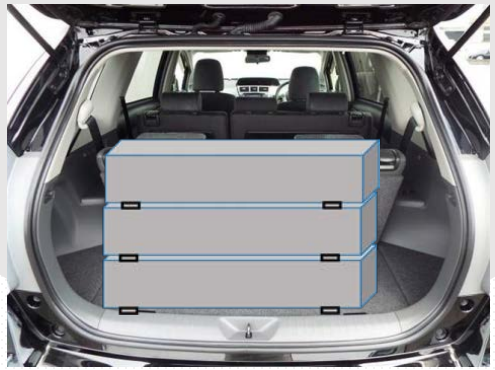
Single meters
Garage use tool

・No real time measurement

Our system
⇒ Vehicle R&D

・Pre-check
・Monitoring etc.

PEMS ⇒ Emission certification



Repeatability

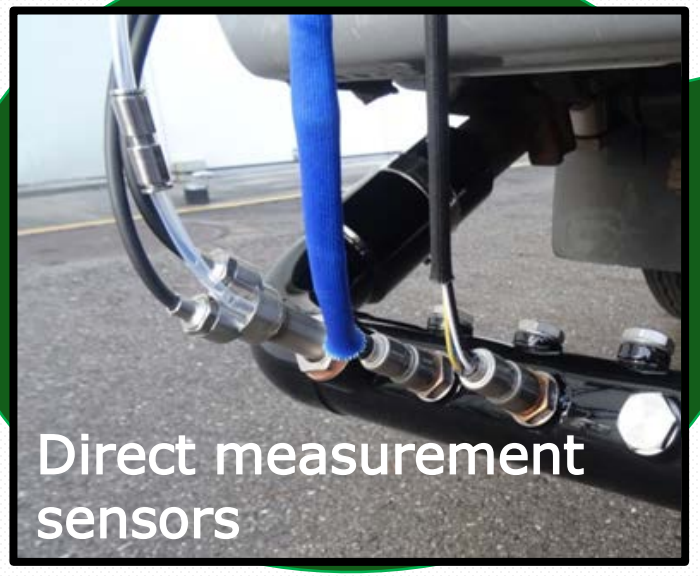
We think there is a place for systems with lower accuracy than existing PEMS, but that are highly portable and cost effective.

■Key features of NCEM

DC 12V/24V Battery
(less than 10Amp MAX.)
or AC 100-240V

- ✓ Simple and easy use
- ✓ Light weight (<15kg)
- ✓ Modulor

GPS Location information



PC monitoring

USB data logging

OBD Ⅱ
Vehicle information

Sensors
- **PM/PN (Newly developed)**
- **NOx (OEM)**
- A/F

Purpose of this presentation

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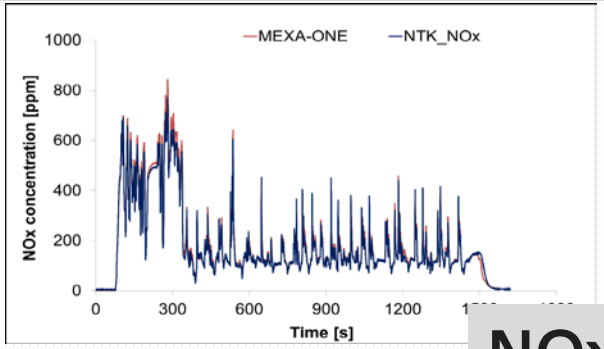
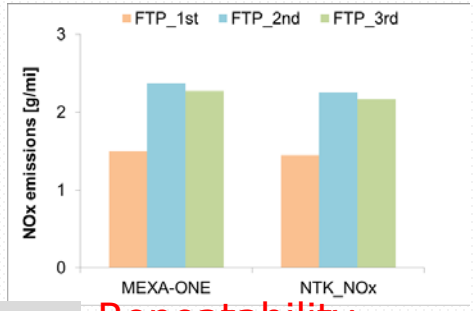
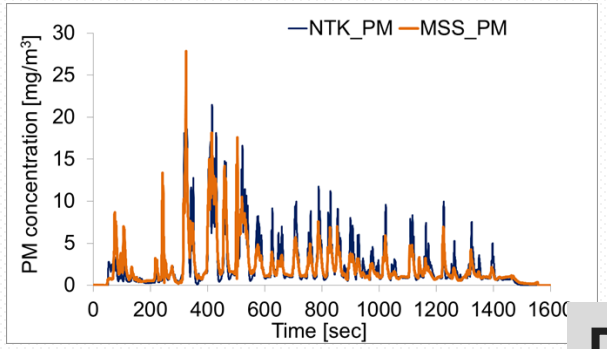
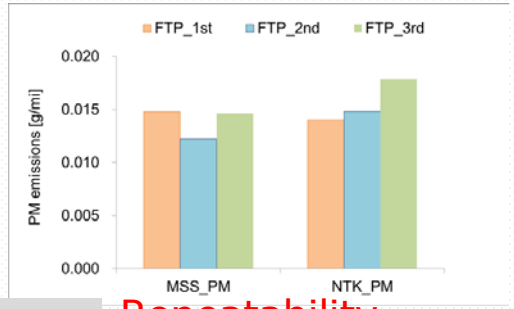
PEMS workshop 2016





NOx Repeatability 4.9% 4.5%





PM Repeatability 22.2% 18.5%

NCEM has good accuracy and repeatability in case of high emission concentrations on a chassis dynamometer.

PEMS workshop 2017

Evaluation of NCEM performance under expected actual use conditions.

- On-road driving emissions
- Pre-DPF environment on an engine dyno

On road vehicle evaluation

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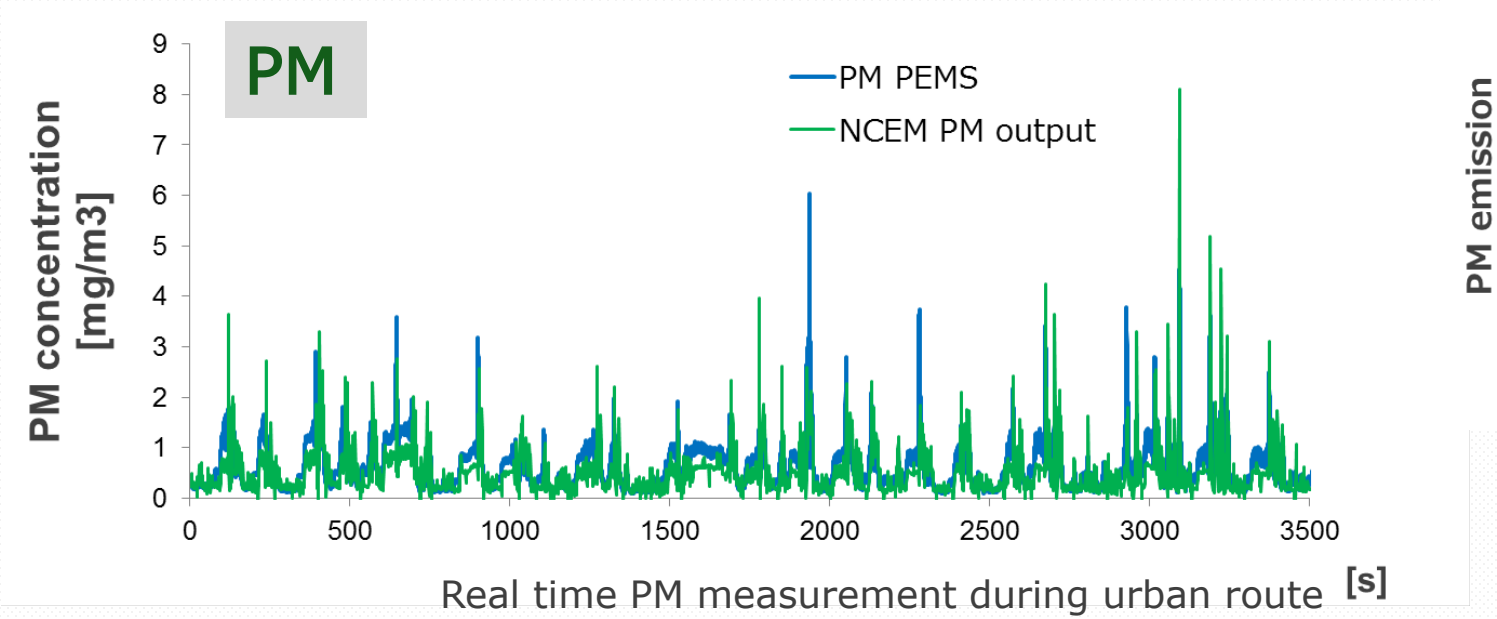
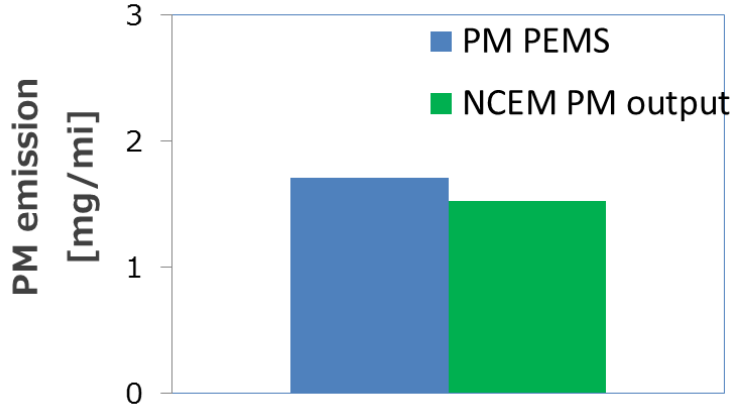
NTK test
(PM comparison : concentrations between 1-2mg/m3)





PM PEMS	NCEM
mg/mi	mg/mi
1.705	1.522

2005MY
Lite Duty
Diesel

Error -10.7%

We confirmed good correlation with a PEMS in the case of high emissions levels.

On road vehicle evaluation

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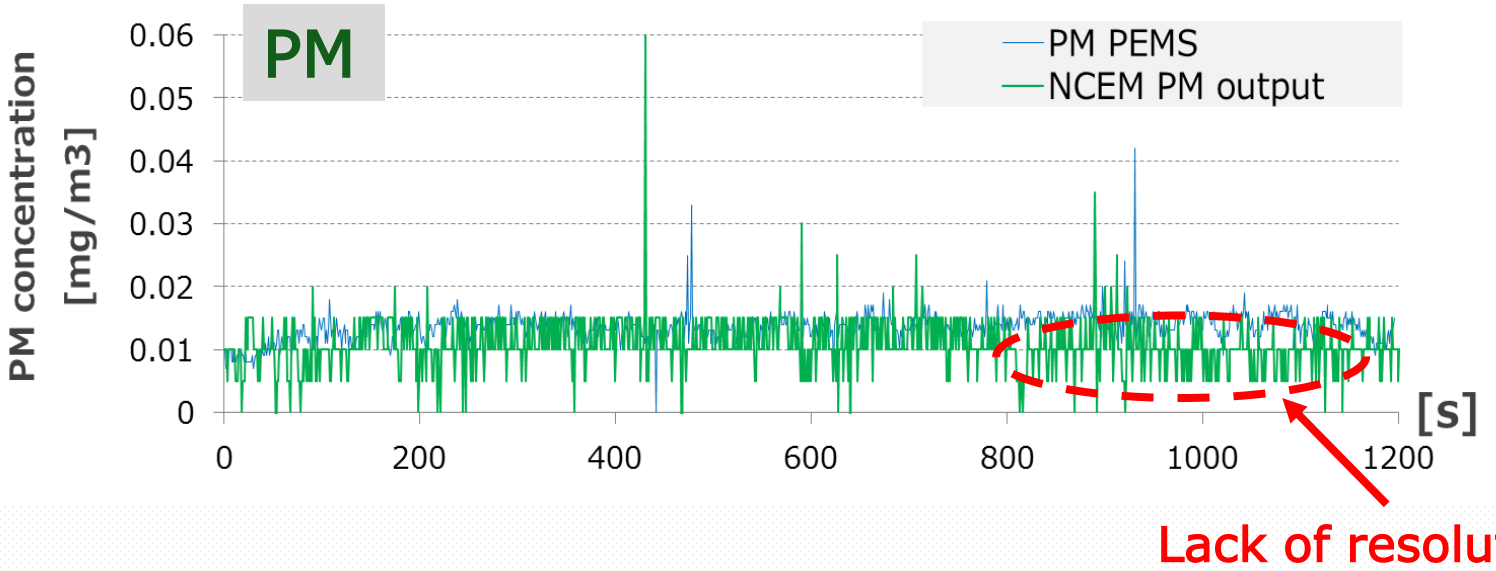
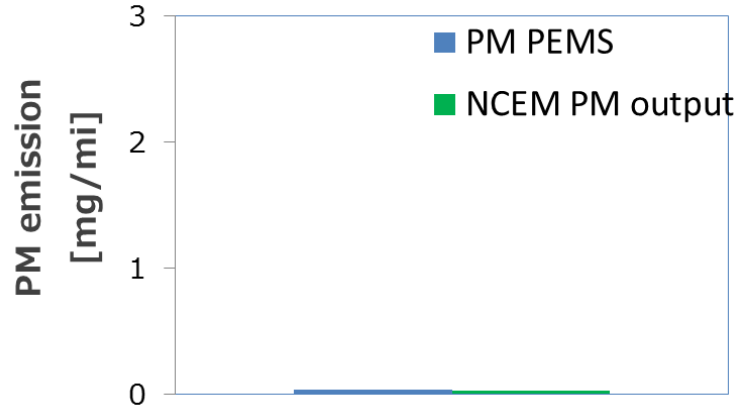
NTK test (PM comparison at low concentrations)



Lack of resolution



PM PEMS	NCEM
mg/mi	mg/mi
0.0319	0.0245

2013MY
Lite Duty
Diesel
(LEVⅡ)

There was not enough resolution for low concentration measurements. ・PM ~0.01mg/m3.

⇒ **Need to improve**

On road vehicle evaluation

Test results at UCR

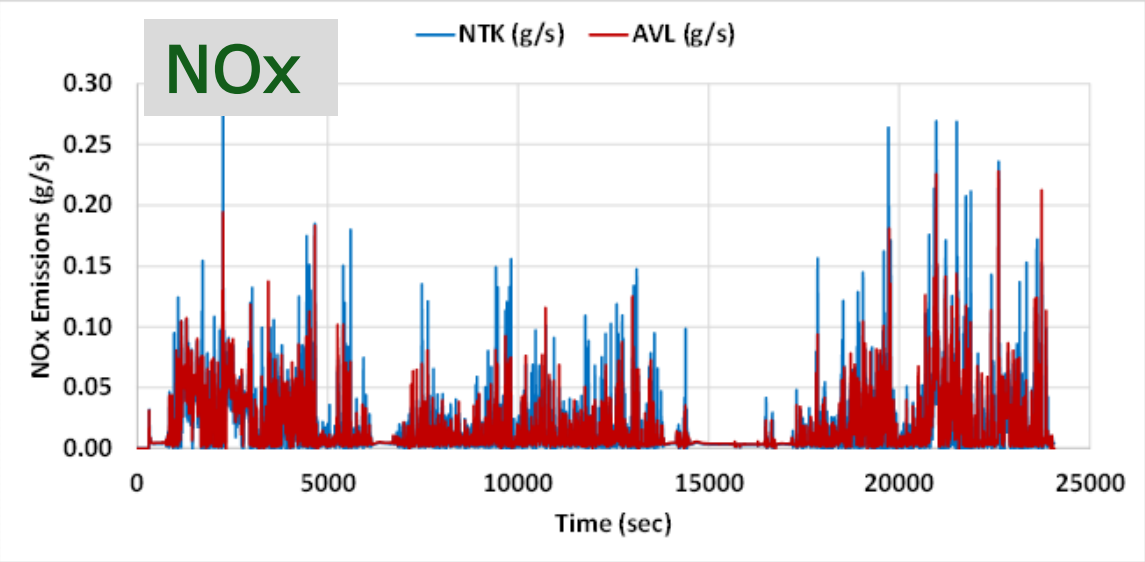


Table 2 Summary of route emission levels for freeway and local driving

Results	*NCEM (g/mi)*	*AVL (g/mi)*		*NCEM (mg/mi)*	*AVL (mg/mi)*		*NCEM (#/mi)*	*AVL (#/mi)*
	NO_x	NO_x	NO_2/NOx	PM	PM-soot	PM	PN	PN
Freeway Arterial_1	2.17	2.26	27%	0.086	0.108	0.110	4.15E+11	2.22E+10
LA Down Town_1	2.30	2.26	34%	0.401	0.148	0.205	1.94E+12	3.07E+10
LA Down Town_2	2.47	2.39	35%	0.470	0.166	0.212	2.27E+12	4.46E+10
Idle, Creep	5.76	6.36	17%	0.800	0.368	1.056	3.87E+12	7.62E+10
Freeway Arterial_2	2.29	2.33	28%	0.114	0.109	0.131	5.49E+11	3.32E+10

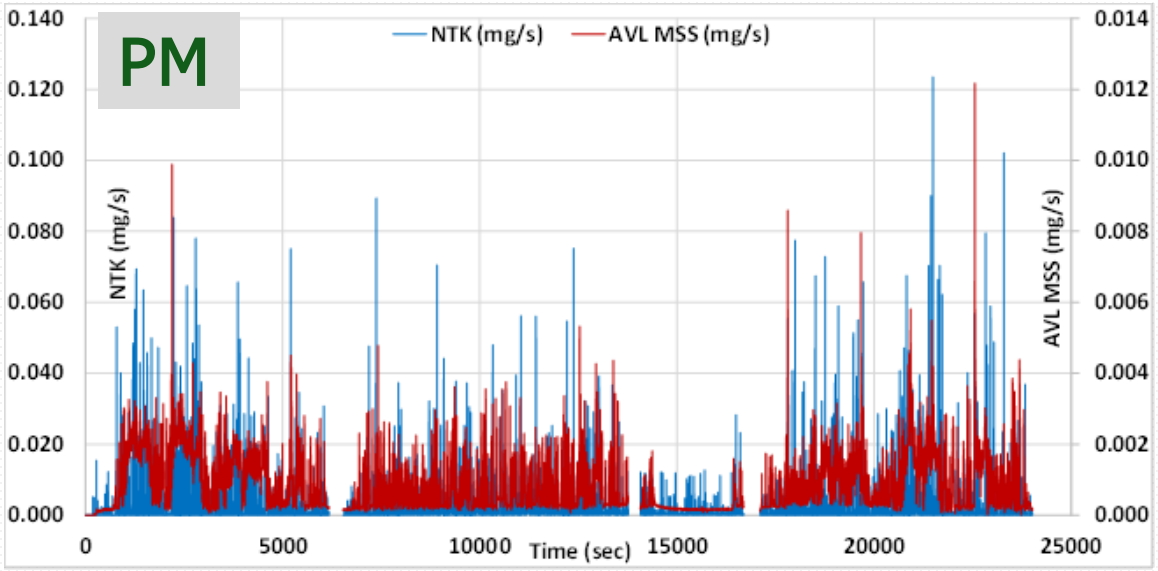
Error less than 10%

NOx comparisons:

Measurements were consistent with PEMS in each test. Error between NCEM and PEMS was less than 10% over a mixture of highway and city driving.

On road vehicle evaluation

Test results at UCR



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PM: Maximum error 68%

PN: One order of magnitude higher

PM/PN comparisons:

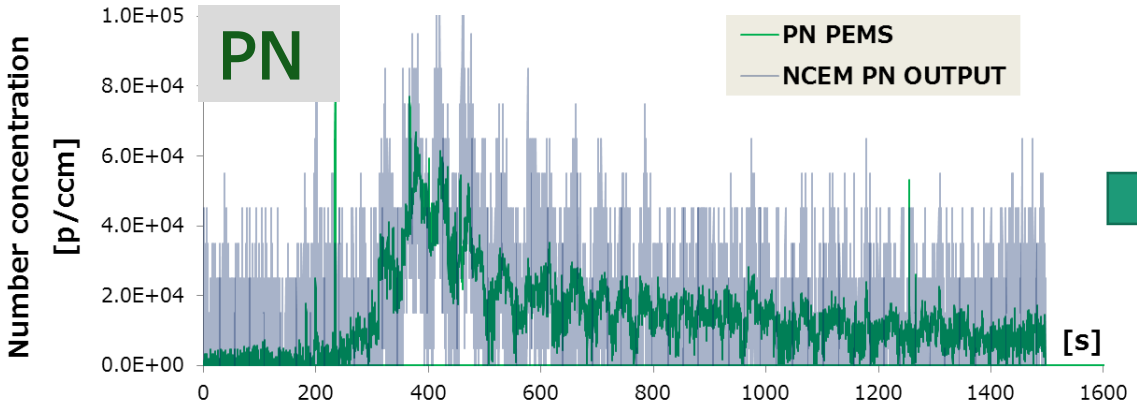
Significant deviation from the PEMS was observed at these very low tailpipe concentrations. ・PM <0.02 (mg/m3) ・PN <1E+04 (p/ccm)

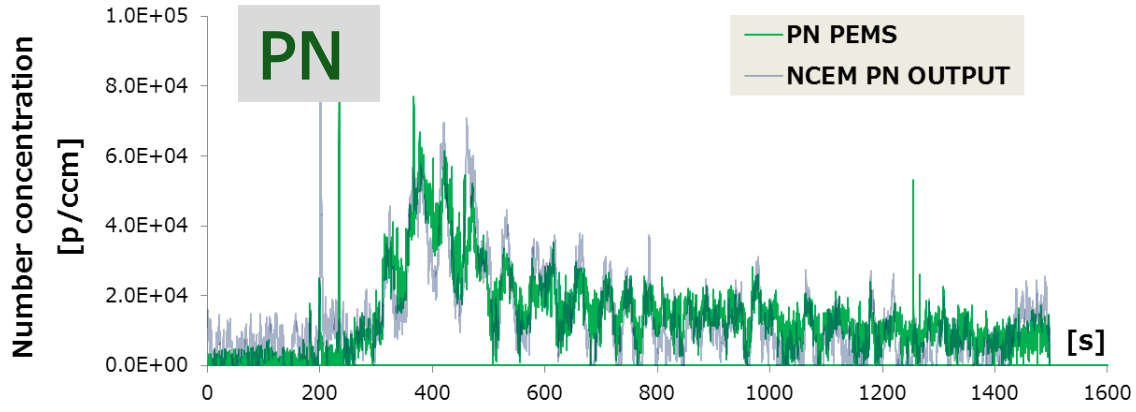
Cause: the output current offset introduces significant error.

⇒ **Need to improve**

Improvements

Resolution and noise reduction

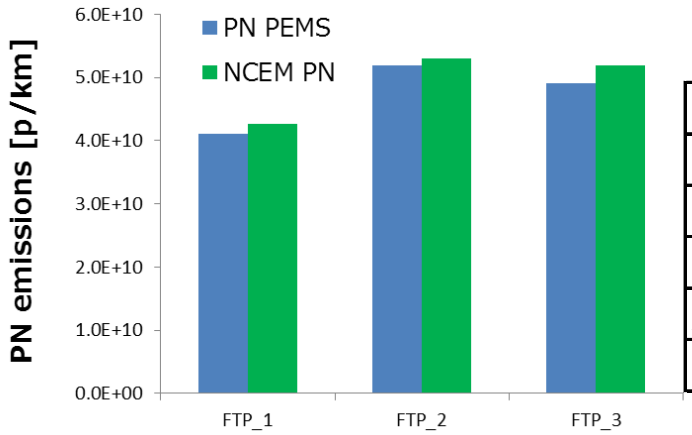




Problem : Noise and insufficient resolution

Solution : ⊖ Improved resolution
PN 10000 ⇒ **125 p/ccm**
PM 0.005 ⇒ **0.001 mg/m3**
⊖ Software filter optimization

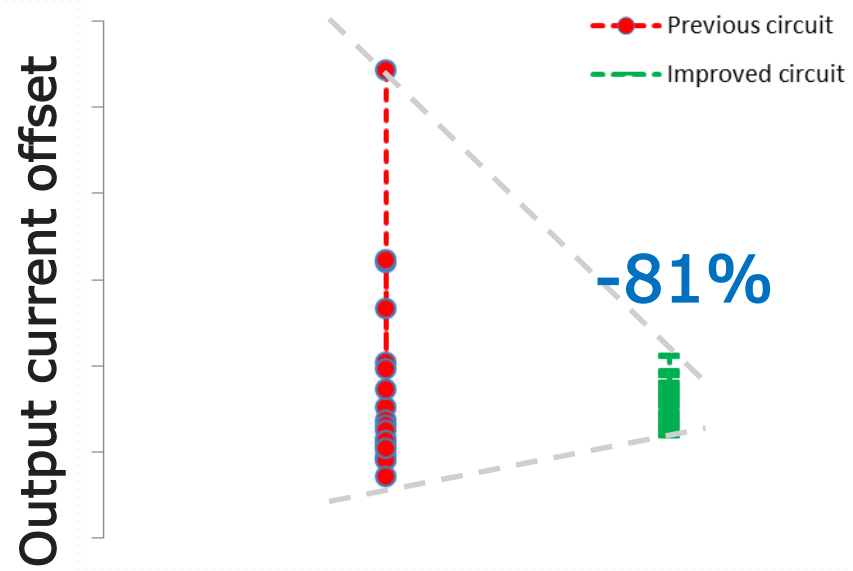
Effect :
Good repeatability (FTP run, 3 times)
with PN PEMS under threshold of 6E+11 (p/km)



	PN PEMS	NCEM PN
FTP 1	4.11E+10	4.26E+10
FTP 2	5.19E+10	5.29E+10
FTP 3	4.91E+10	5.19E+10
Ave.	4.74E+10	4.92E+10
COV [%]	11.9	11.6

Improvements

Offset variation reduction



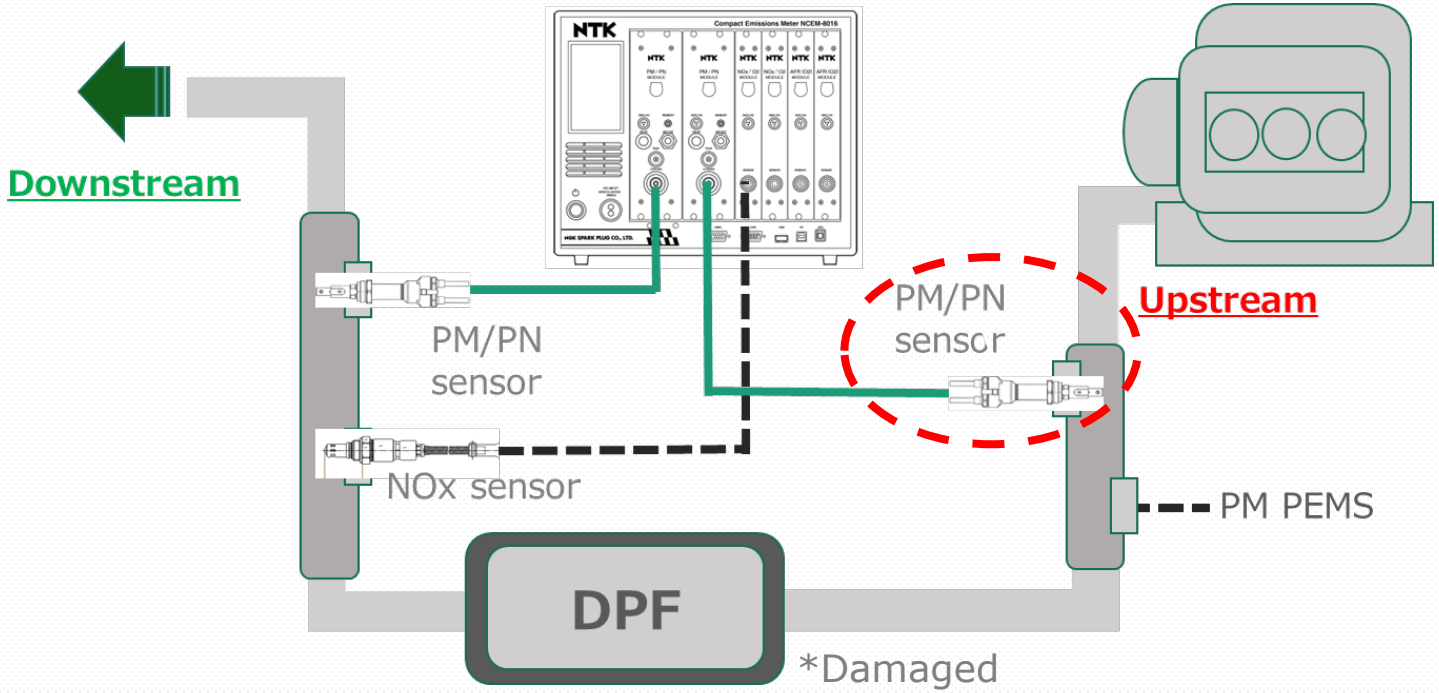
10 PM/PN sensors
Current offset
(2 measurements)

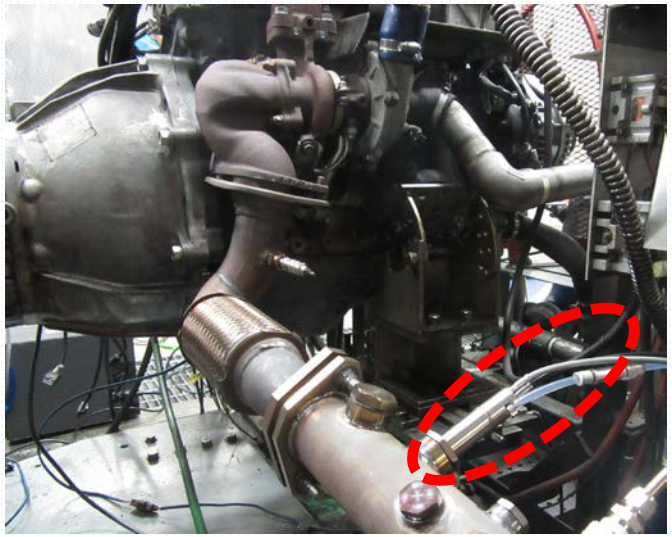
Problem : Large deviations from PEMS were observed at very low concentrations because of offset current variation.

Solution : Improved the PM/PN module circuit.

Effect : Offset variation could be reduced by 81%.
PM offset noise : < **0.01 mg/m3**
PN offset noise : < **5E+04 p/ccm**
(In case of particle size 60nm configuration)

Evaluation results (engine test)





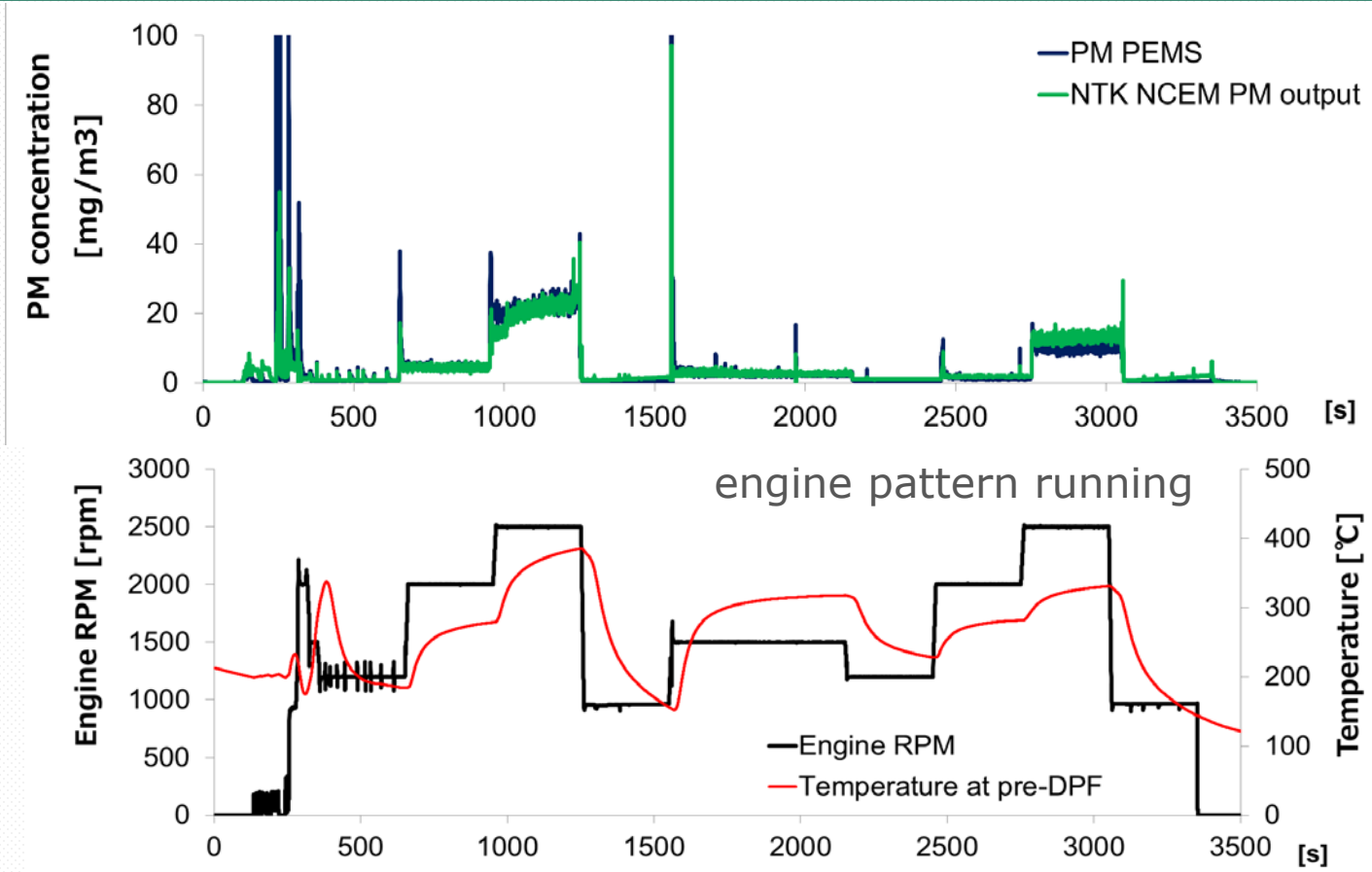
Engine
・TOYOTA
2KD-FTV
Diesel 2494cc

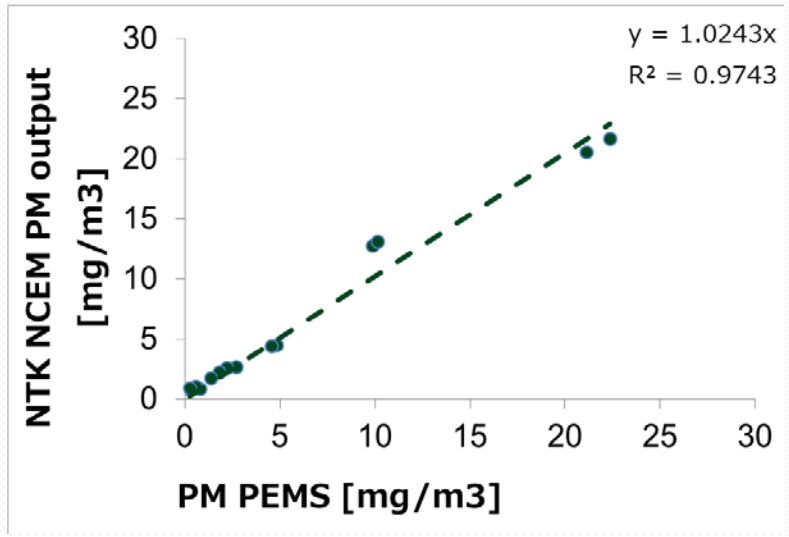
PM/PN sensor

Engine test (pre-DPF and post-DPF)

We performed engine tests to confirm the possibility of pre-DPF PM and PN measurements.

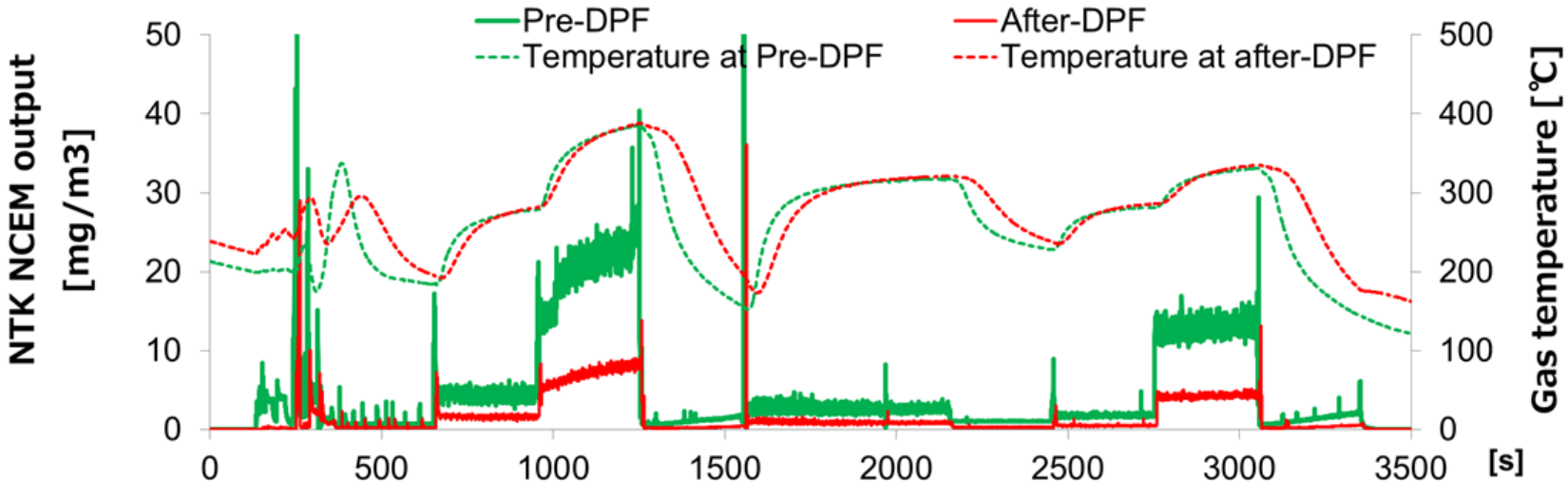
Evaluation results (engine test)





・NCEM PM output had good correlation with PM PEMS
at pre-DPF condition. (R^2=0.97)

■ Evaluation results (engine test)



RPM[rpm]	1200	2000	2500	1400	1500
Torque[Nm]	45	100	143.2	2.25	140.5
Pre-DPF [mg/m3]	0.80	4.38	20.52	0.77	2.23
After-DPF [mg/m3]	0.27	1.63	6.84	0.19	0.75
Rate [%]	-66.9	-62.9	-66.7	-75.7	-66.3

This damaged DPF reduced PM by **68%.**

・We confirmed NCEM has the potential for real-time measurement
of DPF efficiency.

■Future work

Next development products

Ⅰ. PM/PN module for pre-DPF measurements

Pomp capacity is not sufficient for high exhaust pressure conditions.

Ⅱ. Mass flow module

To calculate distance specific emissions with NCEM alone.

Ⅲ. Other sensors (CO2, etc.)

Conclusion

sensor	signal	Upper range	Resolution	Repeatability
PM/PN (particle size 60nm configuration)	PM	50 mg/m3	0.005 ⇒ 0.001 mg/m^3	±10%
	PN	1.0E+8 #/cm3	10000 ⇒ 125 p/ccm	
NOx	NOx	1500 ppm	0.5 ppm	
AFR	O2	27.7%	0.01%	

✓ NOx performance was good compared with current PEMS.
✓ PM/PN performance was sufficient to measure concentrations below the emissions threshold.⇒ **NCEM has the potential to be a valuable screening tool.**
✓ In addition, we confirmed NCEM has the potential to be used for measurement of DPF efficiency.

We expect that NCEM will be a good development tool.

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Thank you for your attention.