Extended Abstract

Measuring Particles less than 23 nm using PMP Methodology

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We evaluate the validity of enhancing the measurement size range with PMP methodology to 2.5 nm by replacing PNC from various aspects. Results of D50 evaluation of PNC using electrospray particle generator were shown in Fig. 1. Increasing uncertainty in lower particle diameters was observed. The reason was shown in Fig. 2. The number of particles produced by electrospray aerosol generator decreased with smaller particles. CoVs are more than 15 % for the particles below 5 nm.

We also performed evaluation of PCRF with the particles of 15, 30, 50 and 100 nm. The results is shown in Fig. 3. The losses at VPR increased with the smaller particles and it was almost 30 % at 15nm.

In the measurements of exhaust gas from gasoline DI vehicles, the ratio of particles below 23 nm in total emission in cold mode was 13.7 %. In hot mode, the ratio increased to 42.7 %. In this condition, these small particles were emitted mainly during high speed operations. Experimental fluctuations of the measurements with PNC_2.5 in cold and hot modes were similar to those by PNC_23 suggesting the enhancement of the size range to 2.5 nm with PMP methodology did not increase experimental uncertainty.

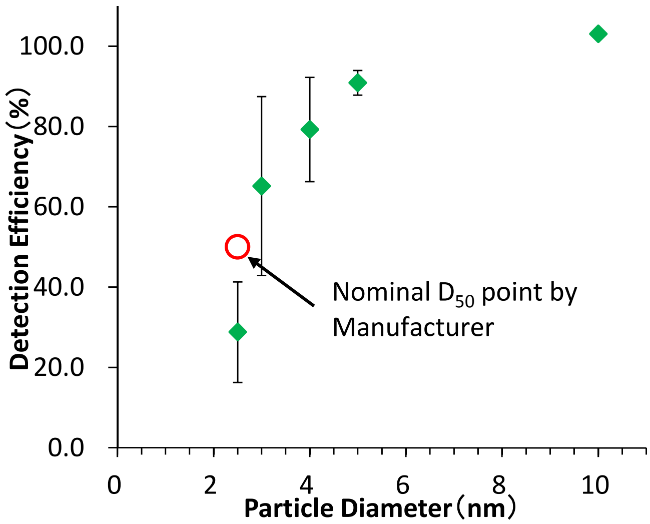

Fig. 1 Results of Detection efficiency measurement of PNC which D50 is 2.5 nm.

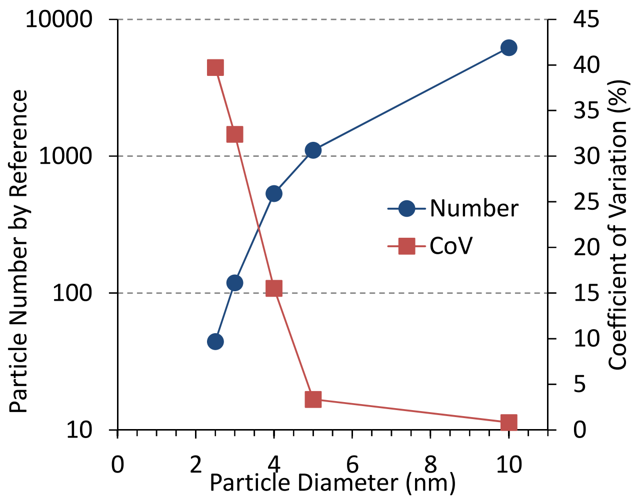

Fig.2 The number of particle at the inlet of PNC and observed CoV in the experiment shown in Fig.2.

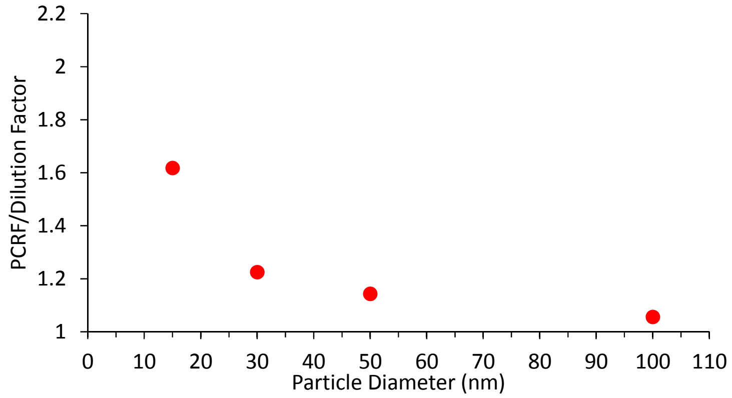

Fig. 3 Results of PCRF measurement at 15, 30, 50 and 100 nm.

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Perspective of starting PN regulation in Japan

•Ministry of Environment (MOE) seems to think PM2.5 have been more urgent matter than PN.

•MOE has understand merits of measuring PN against traditional PM measurement.

- High sensitivity
- Real-time measurement

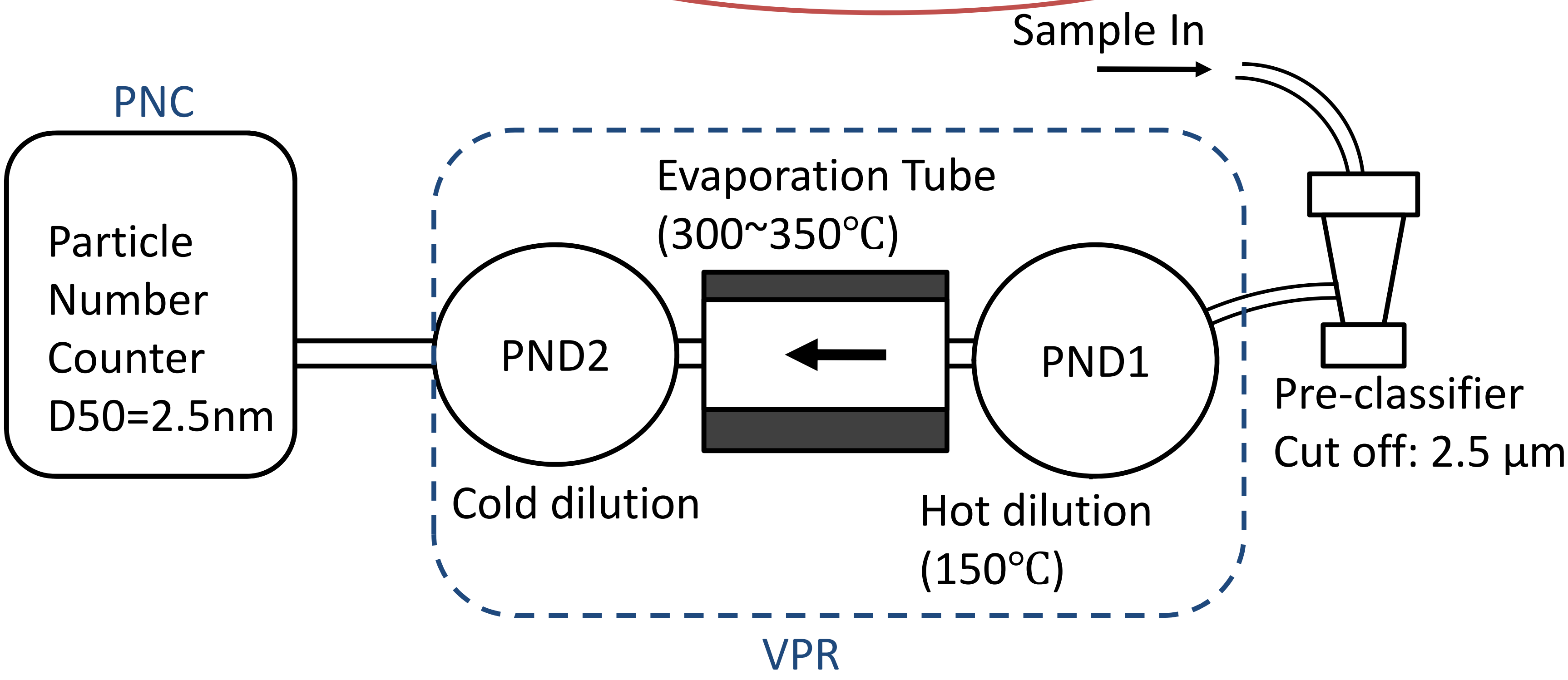
•MOE has regarded that some issues are existing.

- Consistency with PM2.5 and SPM standards
- Calibration procedures

These are not official comment of Japanese government.

European situation

- The hottest topics seems to be lowering a detection limit of PN and PN-PEMS.



The easiest way to lowering detection limit is replacing PNC.

Can accurate results be obtained with this method?
Are there any necessities to change the calibration procedure?

Calibration requirement for PN measurement

•Periodic calibrations and confirmations have been required for PN measuring system.

- PNC D50 check (50 % ± 12 % @ 23nm, >90 % @41nm)
- PNC k factor estimation
- VPR removal efficiency check (tetracontane > 30nm)
- VPR PCRF estimation (@30nm, @50nm and @100nm)

Objective

- Checking whether PMP calibration procedures can be performed with PNC which D50 is 2.5nm(PNC_2.5).
  - Detection efficiency of PNC_2.5 down to 2.5nm.
  - VPR PCRF estimation @ 15nm.

- Measuring Exhaust particles from G-DI and diesel without DPF.

Discussing the possibility of lowering detection limit of PN and the effect of changing PCRF correction procedure on the results.

Measurement systems

Source : AVL

AVL APC

PMP methodology (D50 =23nm)

Source : TSI

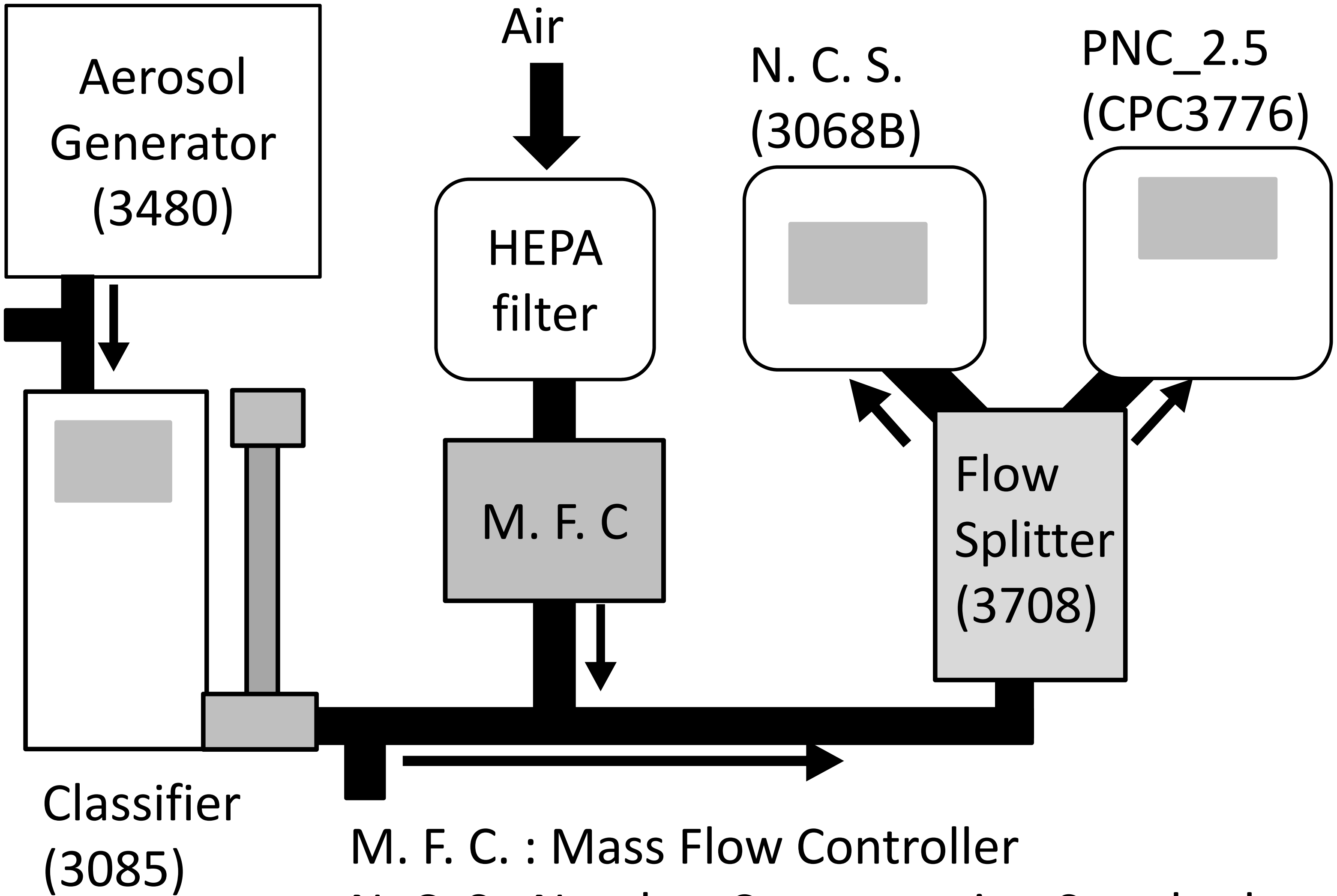
TSI CPC3776

Counter (PNC_2.5)

•TSI CPC3776 was added downstream of VPR.

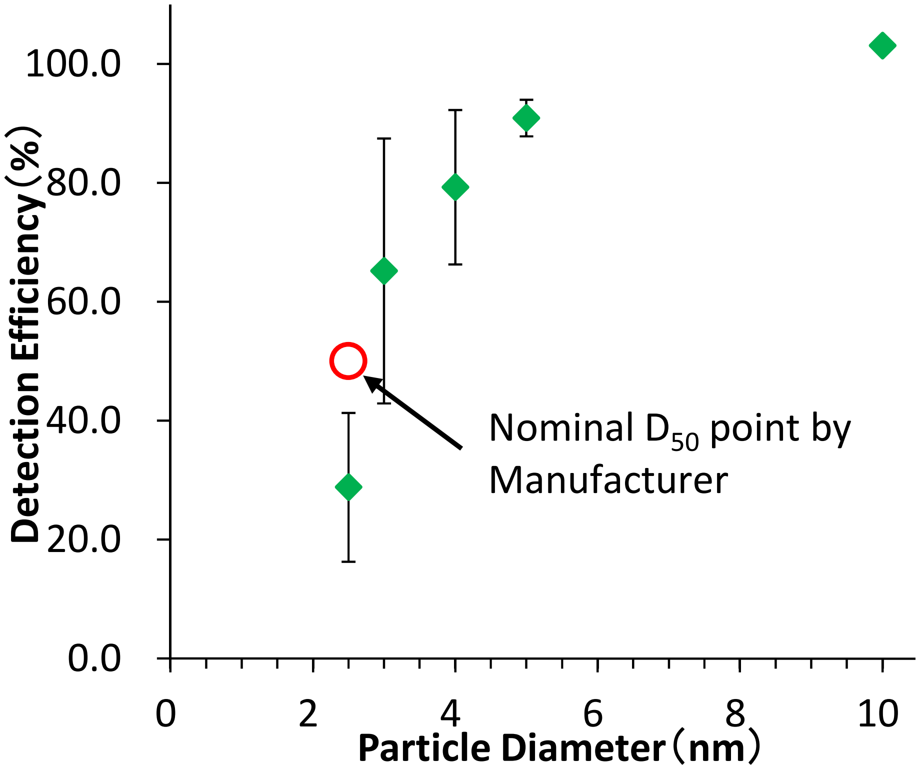
•Normal counter (CPC_23) was also used simultaneously

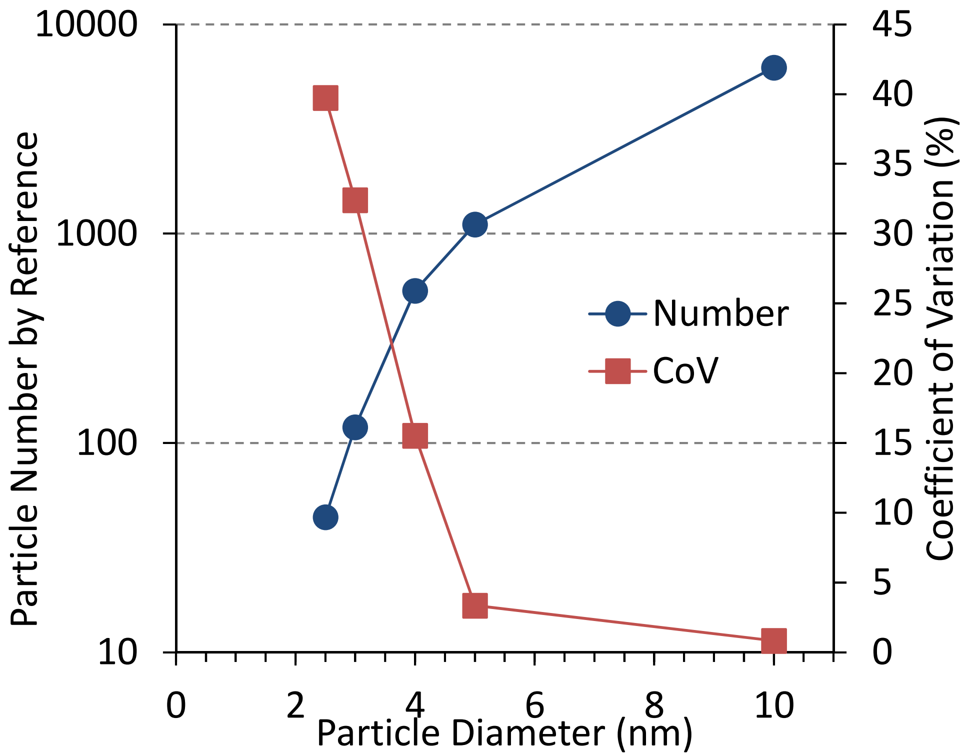
Set Up for PNC Detection Efficiency Check



M. F. C. : Mass Flow Controller
N. C. S.: Number Concentration Standard

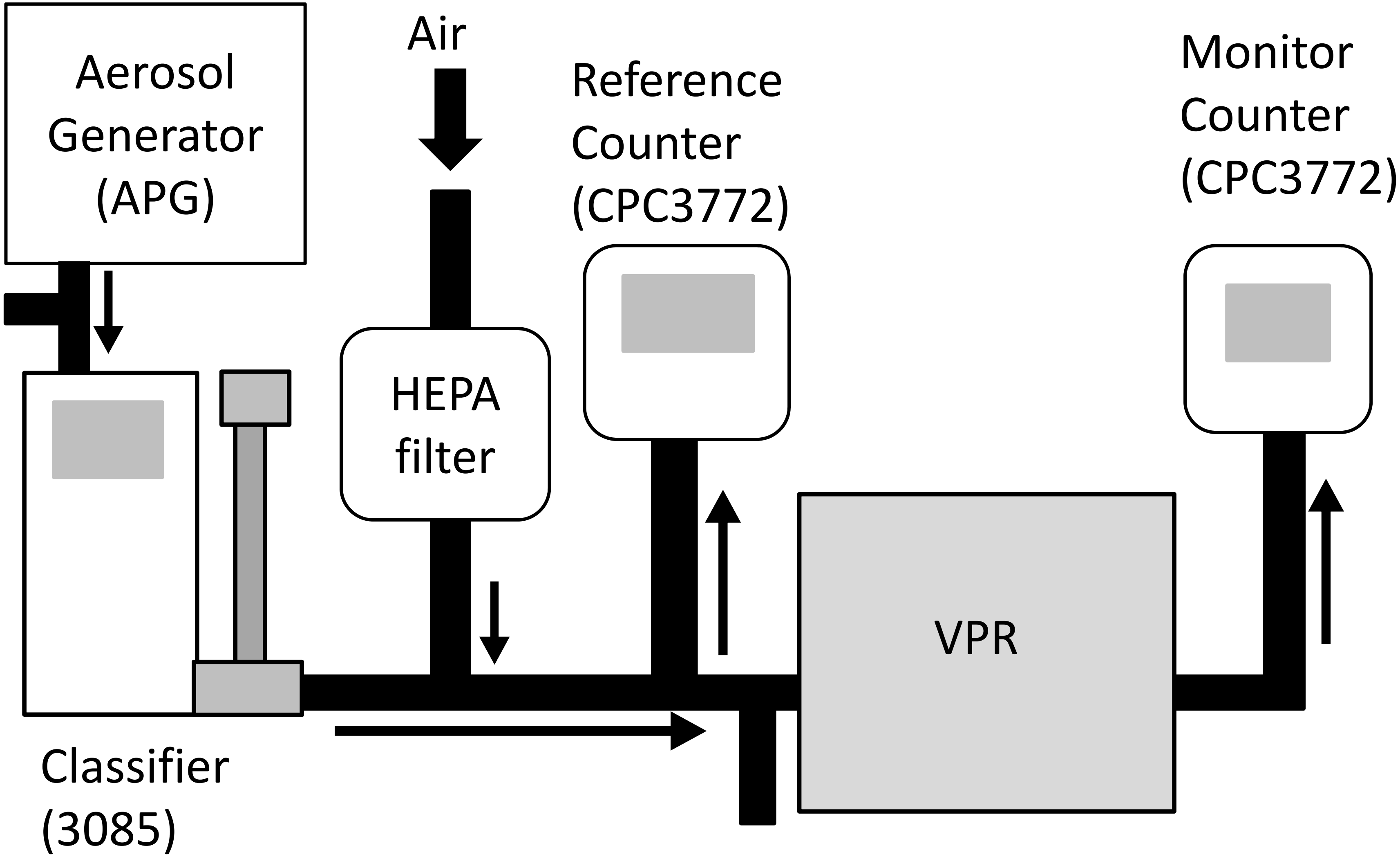
Results of PNC Detection Efficiency Check





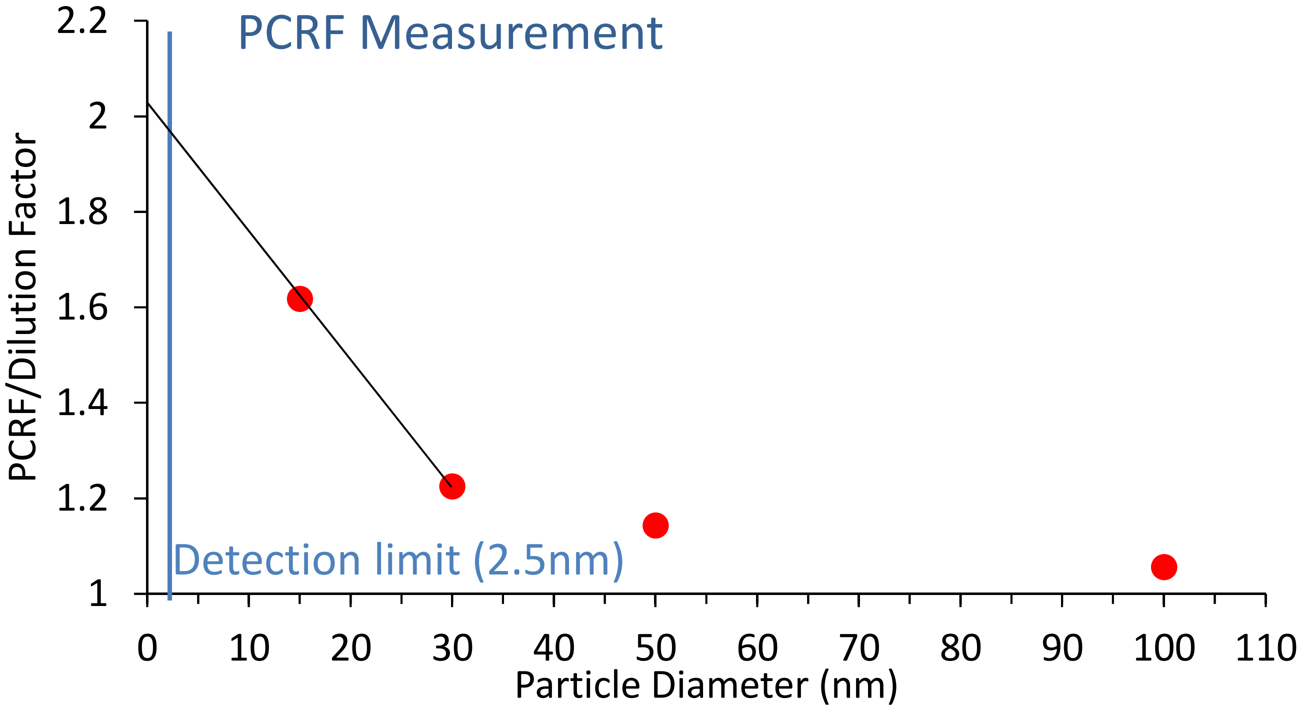
- **We could perform detection efficiency check to 2.5 nm.**
- **D50 of PNC_2.5 was slightly higher than nominal value.**
- **Particles for calibration decreased considerably below 10 nm, and this increased σ.**

Set Up for PCRF Check



D50 of CPC 3772 = 10 nm

Results of VPR check

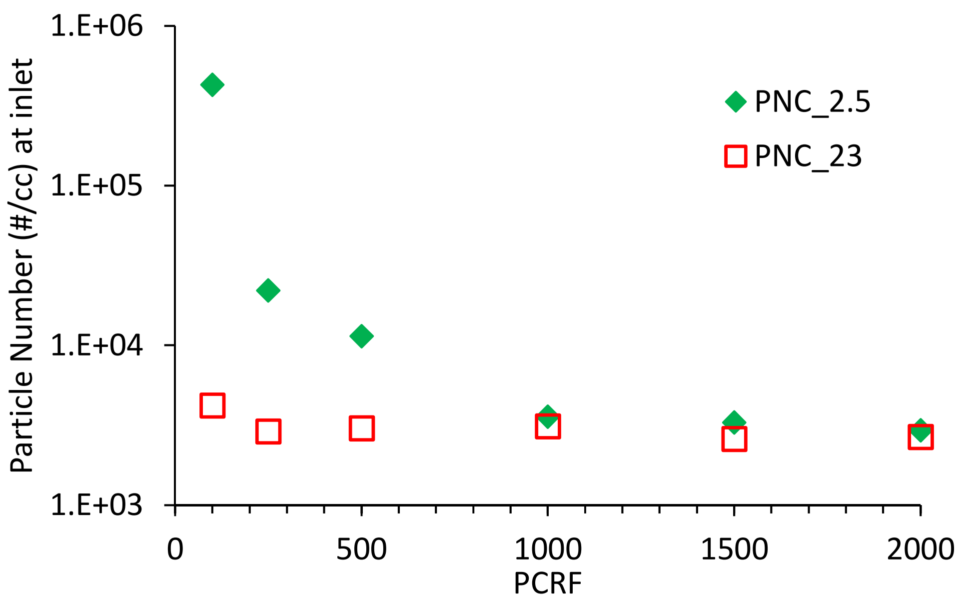


- PCRFs were measured at 15, 30, 50 and 100nm.
- PCRF/Dilution factor at 15 nm was over 1.5 (loss = 33.3%).
- **PCRF/Dilution factor at 5 nm will be over 1.9 (loss = 48%).**
  - **These values will be used to correct the exhaust emission in latter section.**

Exhaust measurement

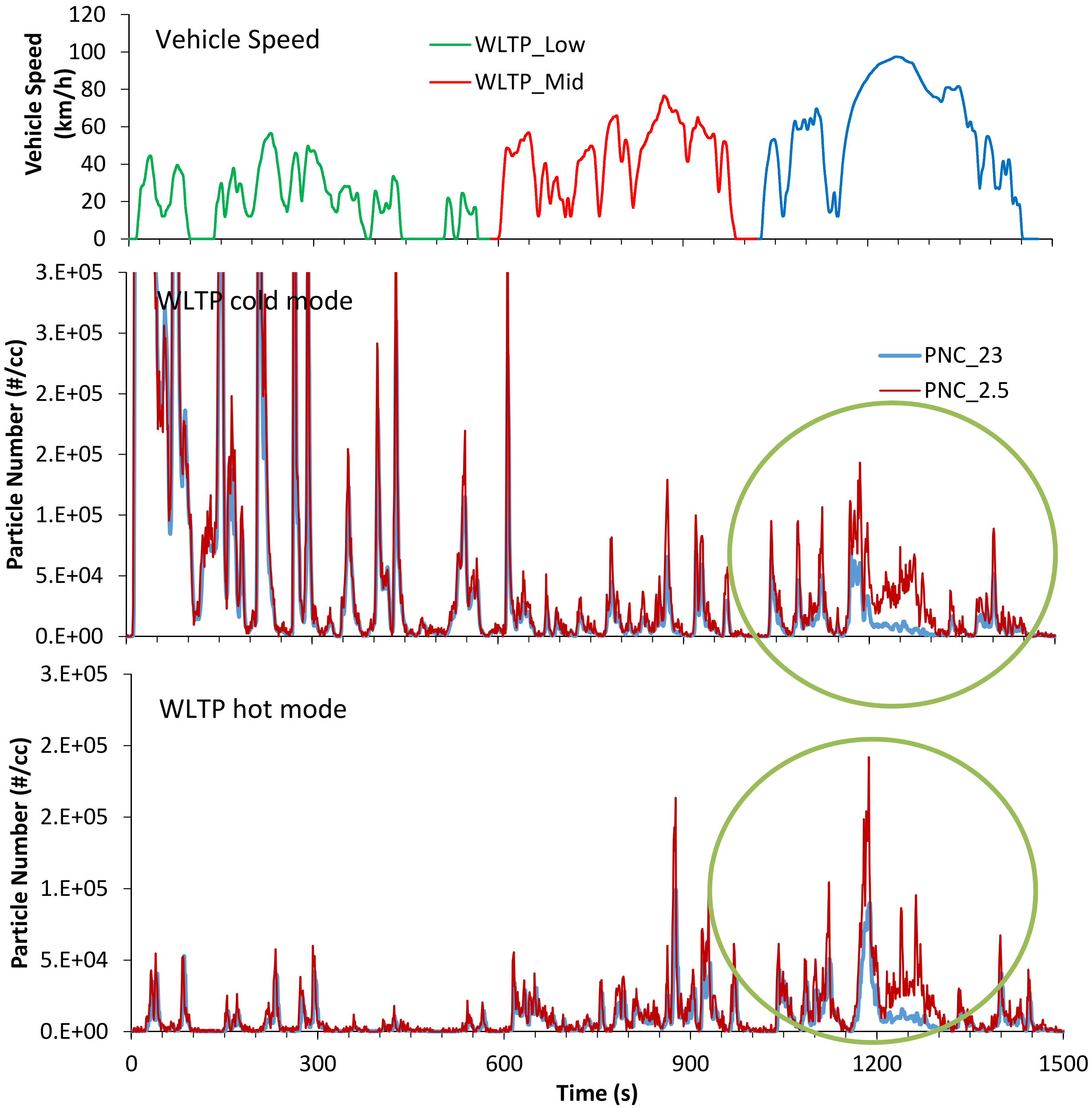
- •Exhausts from G-DI passenger car (Mazda CX-5) were measured by PMP methodology with PNC_2.5 and PNC_23.
- •PCRF was set to over 1000 to avoid re-nucleation of semi-volatile particles.

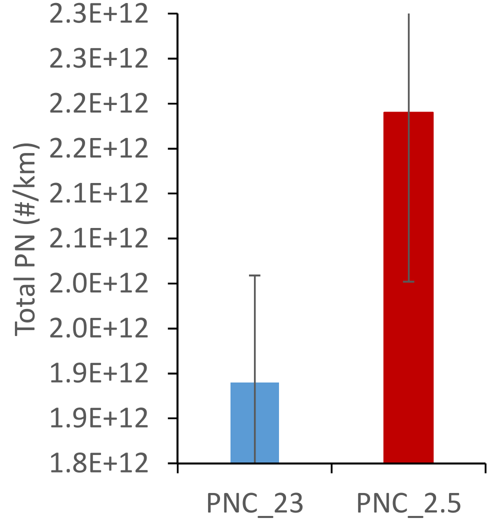
PCRF Selection for exhaust measurement

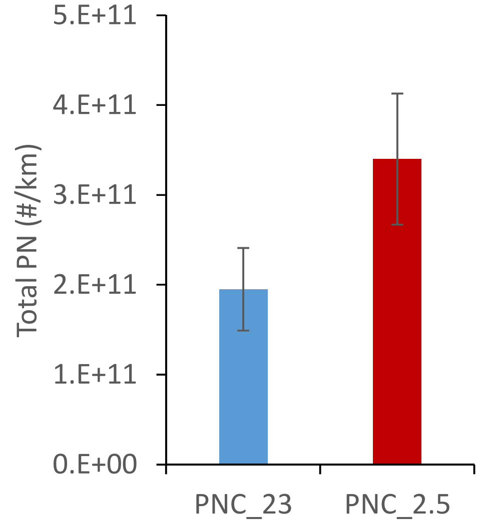


G-DI 60km constant speed operation

PN measurement from G-DI



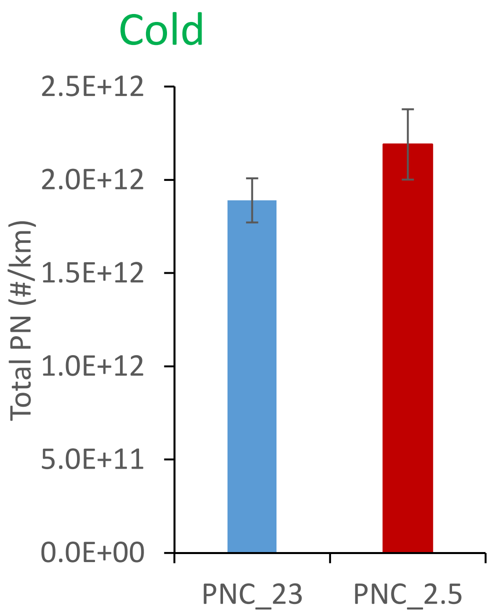


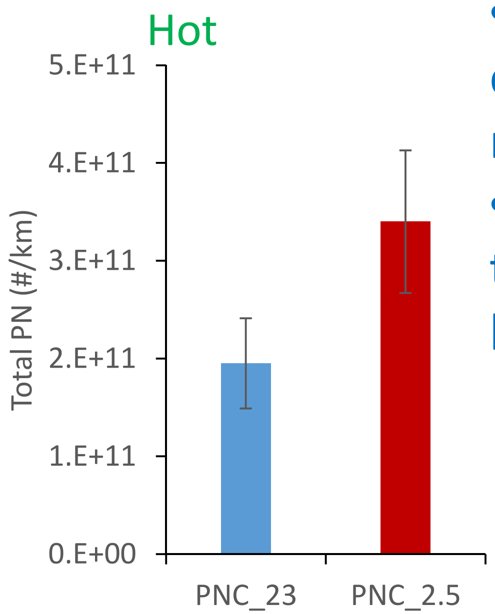


Discussion for PCRF estimation

Case	Base	No change	2 PCRF	Average	2 PCRF Ex	Extreme
PNC	PNC_23	PNC_2.5	PNC_2.5	PNC_2.5	PNC_2.5	PNC_2.5
PCRF	Traditional	Traditional	Traditional for >23nm, PCRF(15) for < 23 nm	Averaged PCRF(15,30,50 and 100)	Traditional for >23nm, PCRF(5) for < 23 nm	Averaged PCRF(**5**,30,50 and 100)
cold	1.89E+12	2.19E+12	2.32E+12	2.42E+12	2.39E+12	2.55E+12
(%)	100.0	115.9	122.5	128.0	126.4	135.1
hot	1.95E+11	3.40E+11	4.01E+11	3.75E+11	4.36E+11	3.96E+11
(%)	100.0	174.4	205.4	192.6	223.7	203.3

Unit #/km





- Results increased to 15~35 % in the cold mode, 74~123 % in the hot mode.
- Average of 4 diameter is higher than 2 PCRF in the cold mode, but lower in the hot mode.

Measurement from Diesel vehicle (w/o DPF)

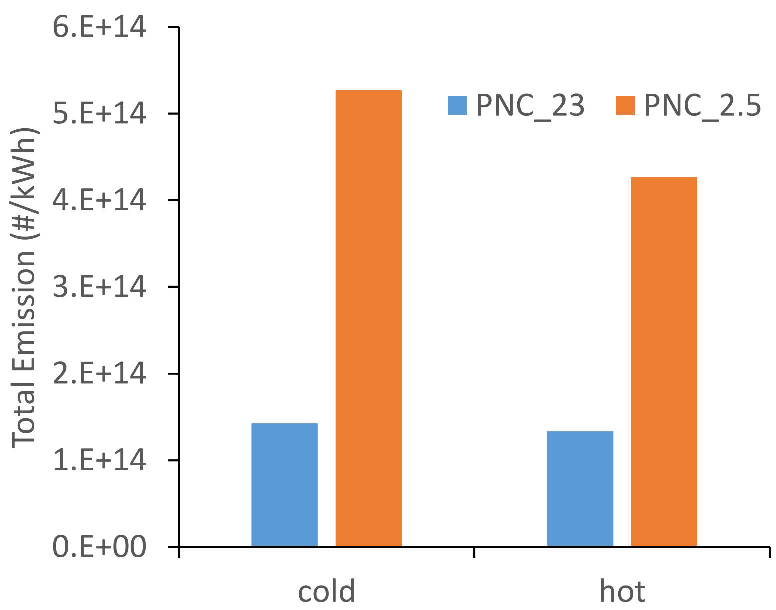
Isuzu Elf (w/o DPF)

- **Tested vehicle is no DPF, small sized heavy duty truck.**
- **Tested mode was JE05 (cold and hot).**

Results from diesel truck w/o DPF

Case	Base	No change	2PCRF	Average	2 PCRF Ex	Extreme
PNC	PNC_23	PNC_2.5	PNC_2.5	PNC_2.5	PNC_2.5	PNC_2.5
PCRF	Traditional	Traditional	Traditional for >23nm, PCRF(15) for < 23 nm	Averaged PCRF(15,30,50 and 100)	Traditional for >23nm, PCRF(**5**) for < 23 nm	Averaged PCRF(**5**,30,50 and 100)
cold	1.43E+14	5.27E+14	6.88E+14	5.82E+14	7.83E+14	6.15E+14
(%)	100.0	369.7	482.3	408.3	548.8	431.1
hot	1.34E+14	4.27E+14	5.49E+14	4.71E+14	6.22E+14	4.98E+14
(%)	100.0	319.6	411.3	353.0	465.5	372.7

Unit : #/kWh



- The emission blow 23 nm was 3 or 4 times higher than over 23 nm.
- Differences between Average of 4 diameter and using 2 PCRF were significant.
- Difference between the results with PCRF(15) and PCRF(5) is not serious.

Conclusion

- A part of calibration procedures which are required by PMP were performed with PMP methodology with PNC which D50 is 2.5nm.
- Fluctuation of PNC detection efficiency increased with smaller size particles below 10 nm, because of decrease of particle concentration at the exit of DMA.
- PCRF (15) was 1.6 and we estimated PCRF(5) to be 1.9 by linear assumption.
- G-DI measurement showed increased emissions of particles below 23 nm at high speed conditions.
- Total particle emissions in cold mode increased, but mostly over 23nm.
- The effects of correction procedures on the results were evaluated. Traditional, using 2 PCRF, and average of 4 diameter corrections were performed. Results varied by the procedure of correction of PCRF.
- The difference of using PCRF(15) and PRRF(5) was not serious.
- Results increased 15~125% in G-DI, 220~450% in non-DPF diesel from PMP methodology.

Acknowledge

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