Presented to PMP TF-II
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Present Situation with JARI system

- Focuses on PN Measurement, and sometimes PM -

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Today's Contents

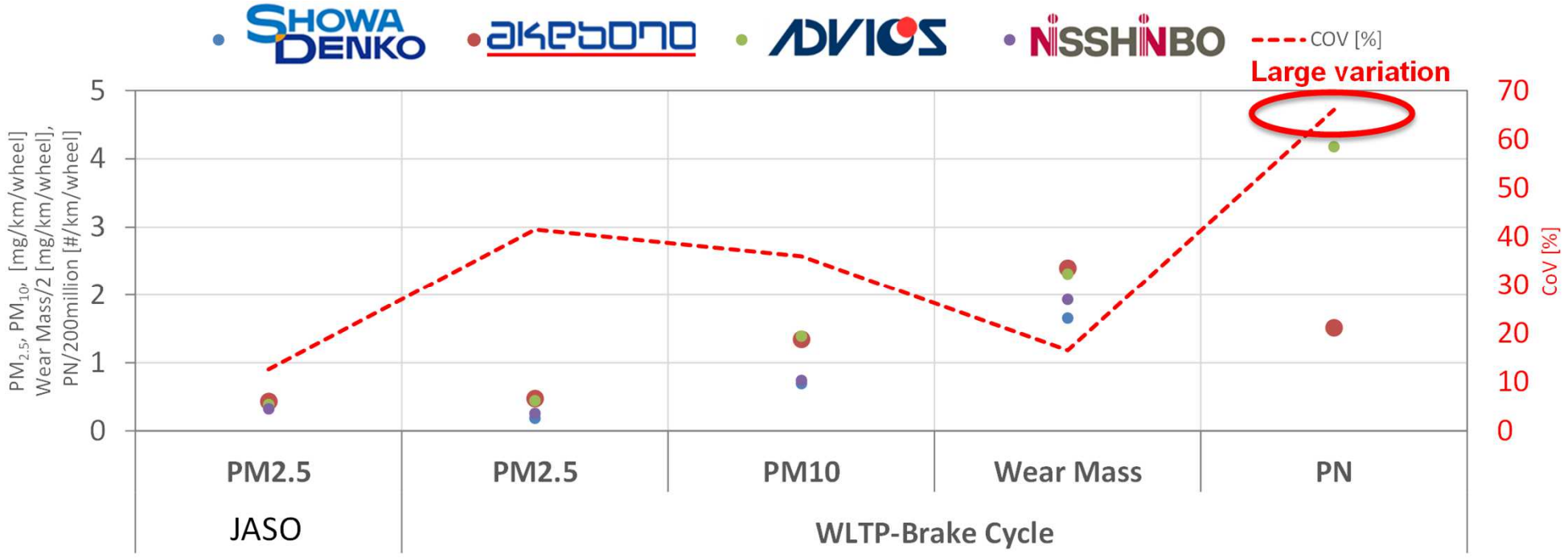
- Background
- JARI's Current Status
- Total Number Counts
- Nanoparticle Size Distributions
- Concluding Remarks

Background (1)

FYI, No discussion

- ◆JASO C470 has been established, but PN measurement variability is a problem under WLTP-Brake cycle conditions.
- ◆JARI is considering the measurement of both PN and PM, while accepting the individual requirements of the manufacturer and the government.

Interlaboratory Comparison for PM and PN measurement

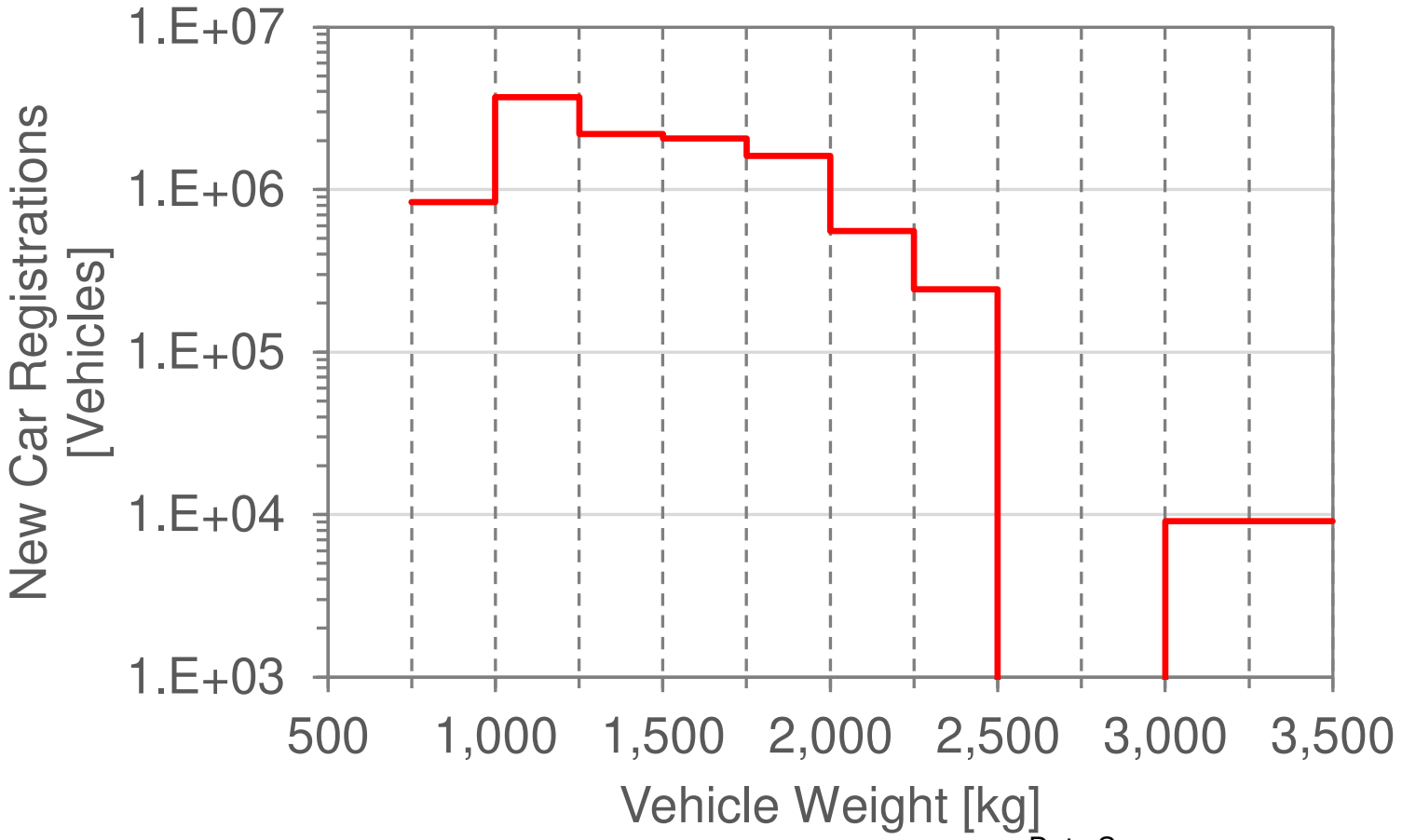


Follow-up for EuroBrake 2021

Background (2)

FYI, No discussion

- ◆New vehicle registrations in Japan from 2017 to 2019 show the popularity of vehicles with low vehicle weight.
- ◆As shown in the later slide, Japan is concerned about the accuracy of emission measurements because vehicles with less vehicle weight have less brake emissions.



Data Sources:
http://www.jada.or.jp/data/month/m-brand-ranking/
https://www.zenkeijikyo.or.jp/statistics/tushokaku

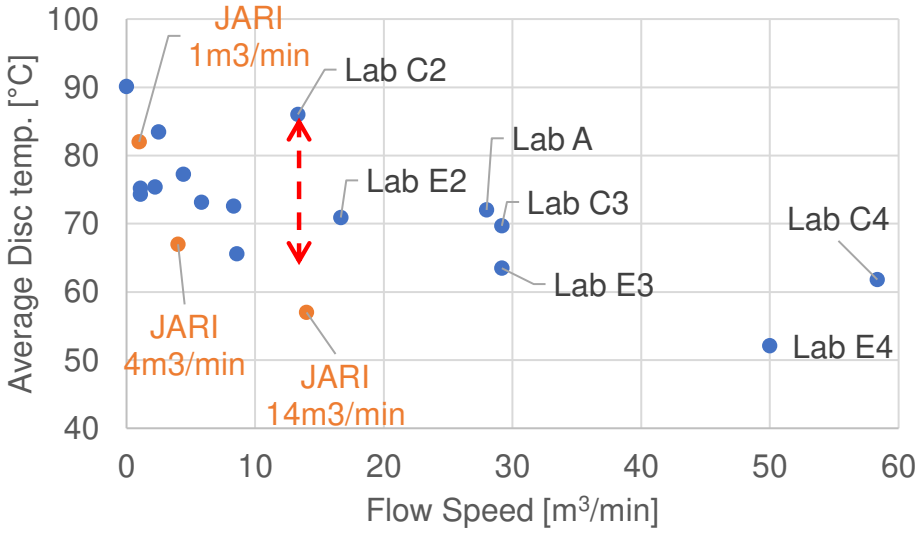
Background (3)

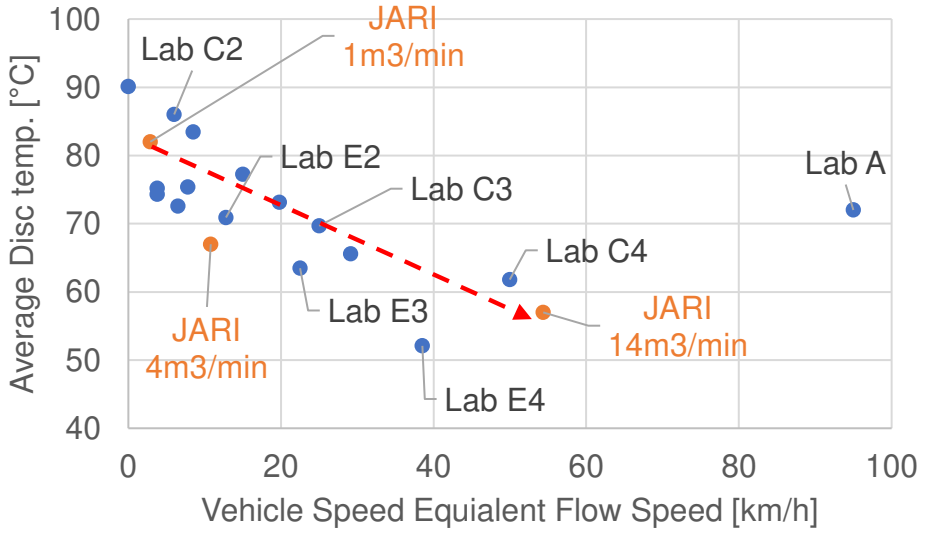
FYI, No discussion

- **Since basic design concept differs significantly from vehicle to vehicle, there is a concern that brake temperature of all vehicles may not converge to temperature defined in test procedure.**
- **A test procedure that does not result in a uniform brake temperature in a real vehicle is not desired, and a test procedure that is closer to that of a real vehicle (e.g., wind speed assuming average vehicular speed in test cycle) would be able to obtain a consensus from the administrative side.**

If brake temperature is controlled by wind speed, brake temperature is controlled in different ways.
(Due to different shape of enclosure)

If brake temperature is controlled by wind speed assuming vehicular speed, the control of brake temperature tends to be reasonable.





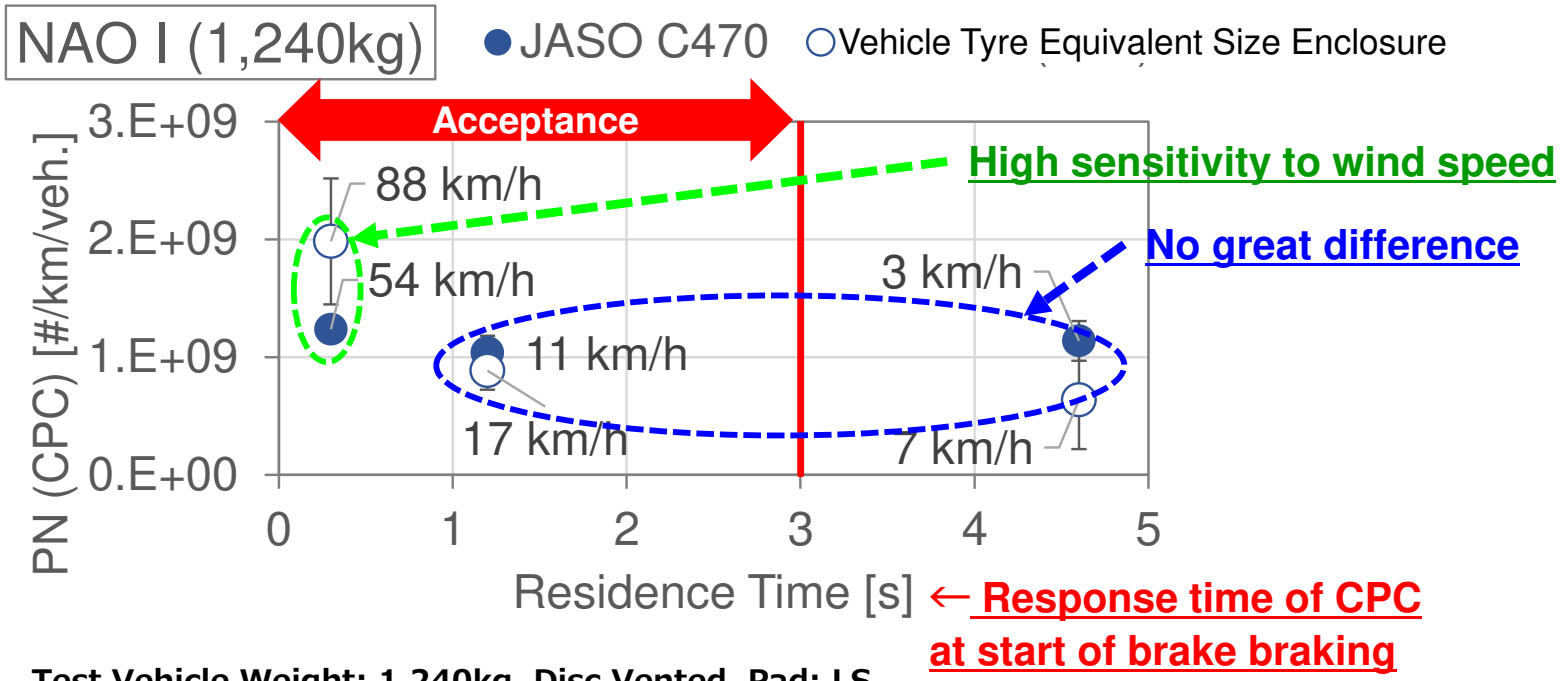
PMP Brake Temperature Interlaboratory Test : Vehicle Test Mass : 1,600kg, Brake Force Distribution 71.625%
JARI Results : Vehicle Test Mass : 1,683kg, Brake Force Distribution 80%

Background (4)

FYI, No discussion

- Unable to find clear evidence data to define Residence Time for total PN measurement.
- No significant difference in total PN measurements due to enclosure design.
- Since wind speed assuming vehicle speed affects total PN emissions, it is recommended to clarify definition of the wind speed around brake.

【PN (CPC3750)】

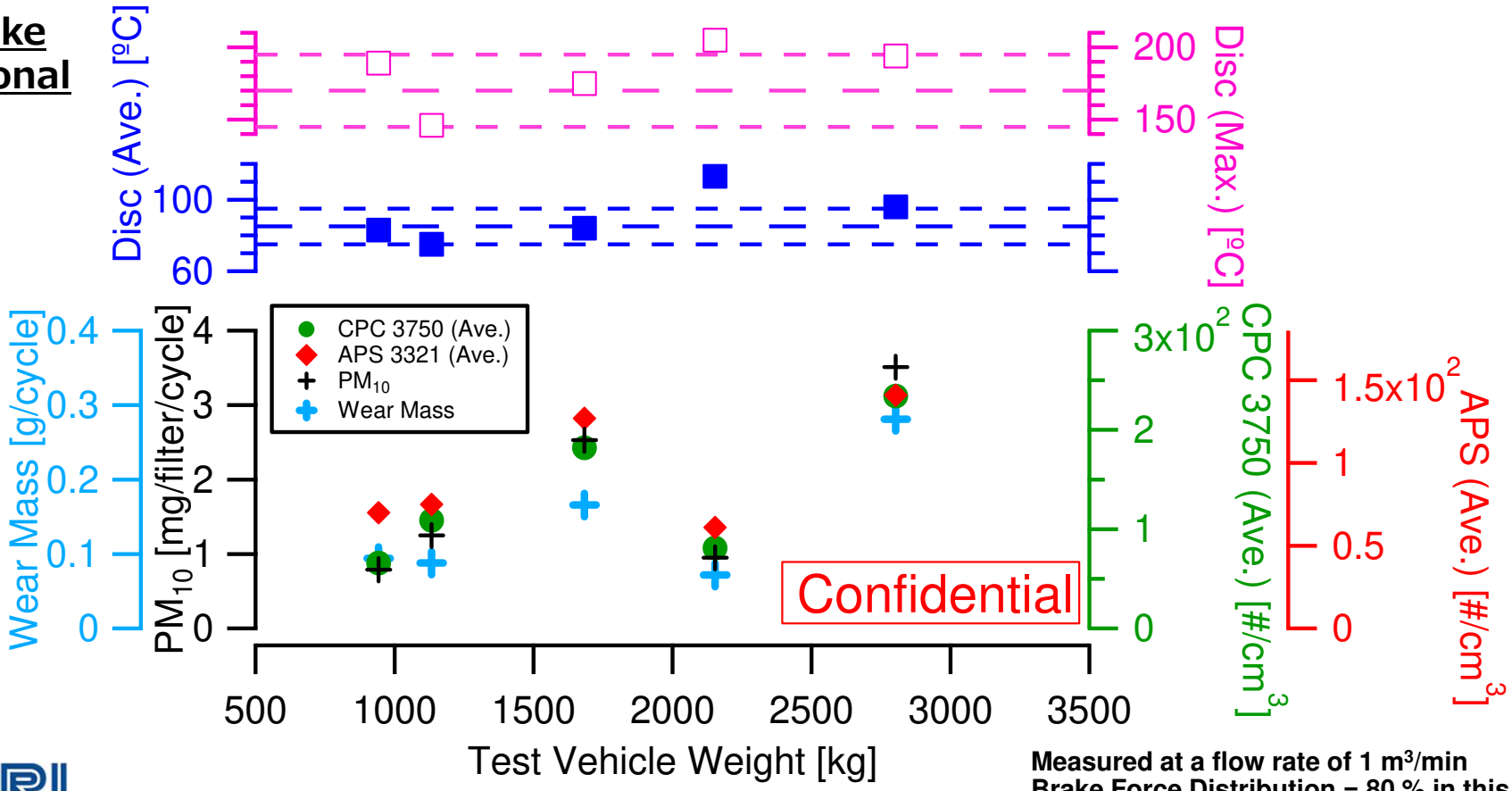


Test Vehicle Weight: 1,240kg, Disc Vented, Pad: LS
Vehicle Speed on Plots [km/h]
= assuming Moving Wind (Vehicular Speed)
= Anemometer beside on the Disc [m/s] x 3600 [s/h] / 1000 [km/m] x Attenuation Factor α [-]
Here, α = 1 (Actual Vehicular α < 1)

Background (5)

- ◆Brake couplings with similar characteristics tend to be increase PN and PM emissions in response to vehicle weight.
- ◆Different brake couplings with different characteristics tend to increase PN and PM emissions in response to vehicle weight and different.
- ◆At the same time, the brake temperature criterion is not robust as a test method because exceeding the brake temperature criterion does not indicate an increase in PN and PM emissions.

Front Brake
Conventional
n=3

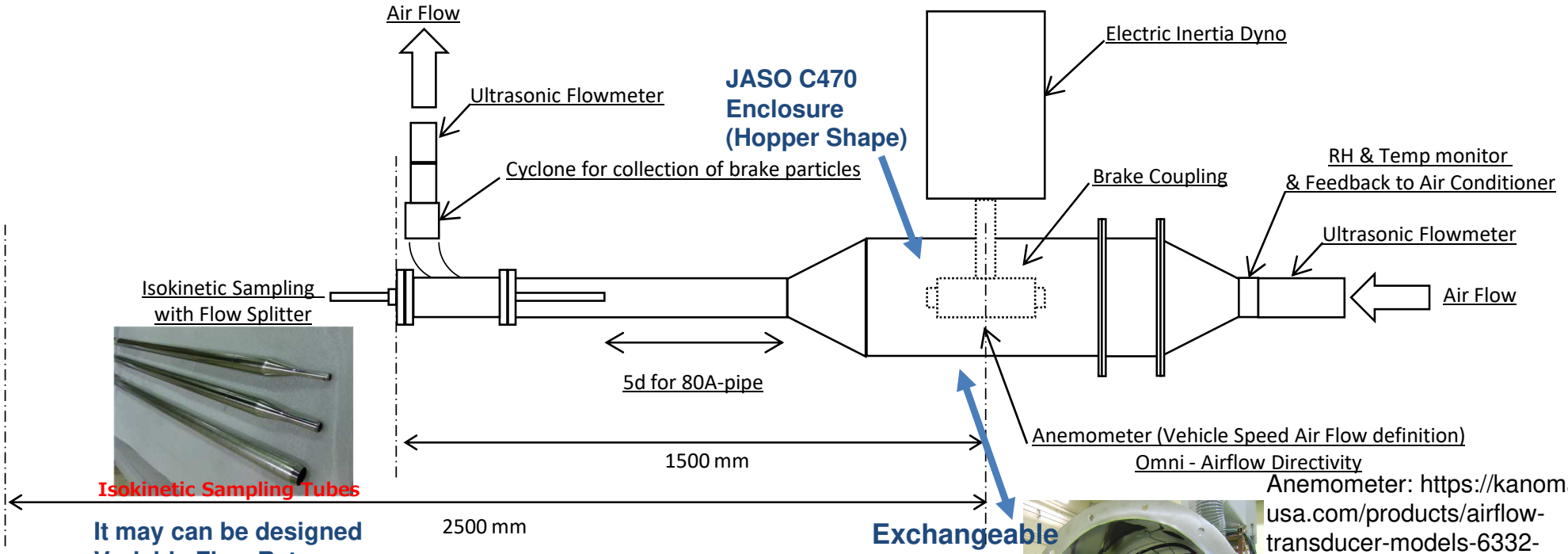


Measured at a flow rate of 1 m³/min
Brake Force Distribution = 80 % in this study.
Ref: Hagino, In Preparation

JARI's Current Status (1)

- ◆For now, dust-tolerant ultrasonic volumetric flowmeters installed at the entrance and exit of the enclosure.
- ◆For next, an anemometer is installed to measure the wind speed corresponding to the vehicle speed wind.

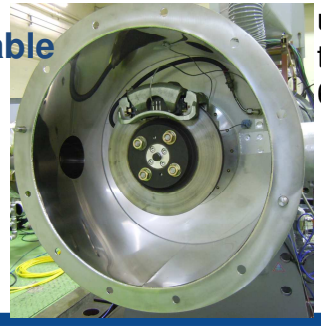
View of the device from above



It may can be designed Variable Flow Rate Isokinetic Sampling System

https://www.tandfonline.com/doi/full/10.1080/02786826.2012.709336
https://amt.copernicus.org/articles/12/5741/2019/

Anemometer: https://kanomax-usa.com/products/airflow-transducer-models-6332-6332d/

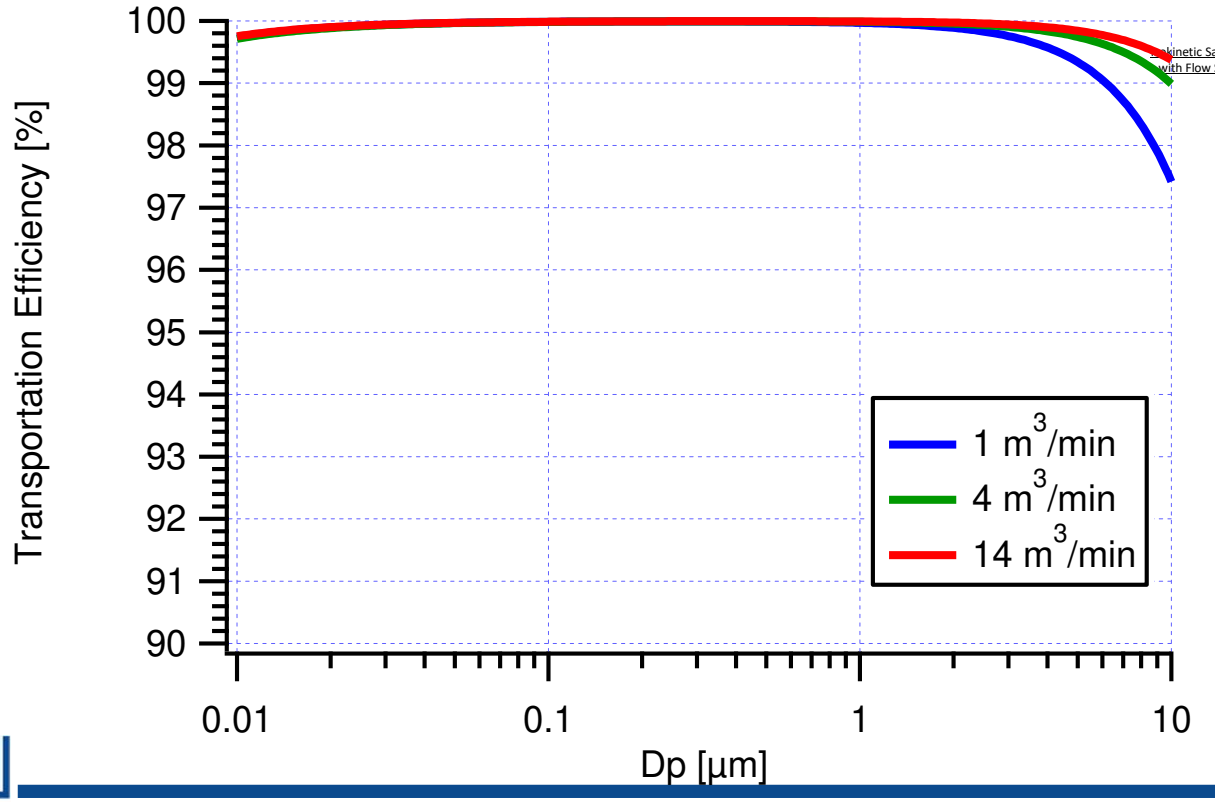


Vehicle Tyre Equivalent Size (Exchangeable to Minimum Volume Enclosure)

JARI's Current Status (2): Transport

- ◆Transport efficiency can be calculated.
- ◆Since the turbulent deposition loss varies greatly depending on the wind speed around disk, it is recommended to define it by wind speed assuming vehicle speed rather than by volume flow rate.

Transport efficiency from center of brake couplinng

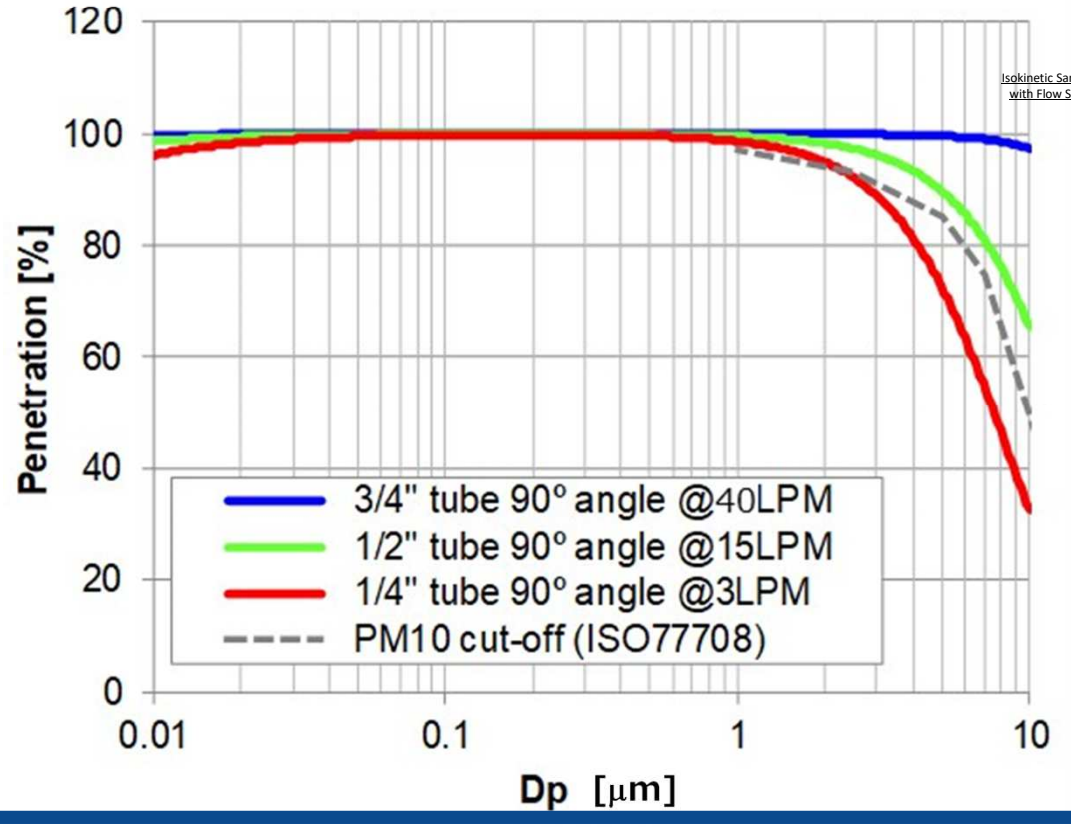


Note:
The turbulent deposition loss of particles due to the swirling wind generated by the disk is not taken into account here.
It is necessary to discuss whether the measurement should be closer to that of a real vehicle, taking into account the deposit on the wheel (for example, measurement with the wheel and tire mounted).

JARI's Current Status (3): Extraction with Bending

- ◆Under the same isokinetic sampling conditions, even a pipe bent at 90° can be drawn efficiently, depending on the combination of pipe diameter and suction flow rate.
- ◆Since the extraction efficiency can be easily evaluated by calculation (e.g. PLC with open source code by Max Planck).
- ◆If the collection efficiency defined by the protocol (e.g., 80±20 % at 10um) can be confirmed by calculation, it is possible to ensure

Extraction efficiency from tunnel with isokinetic sampling

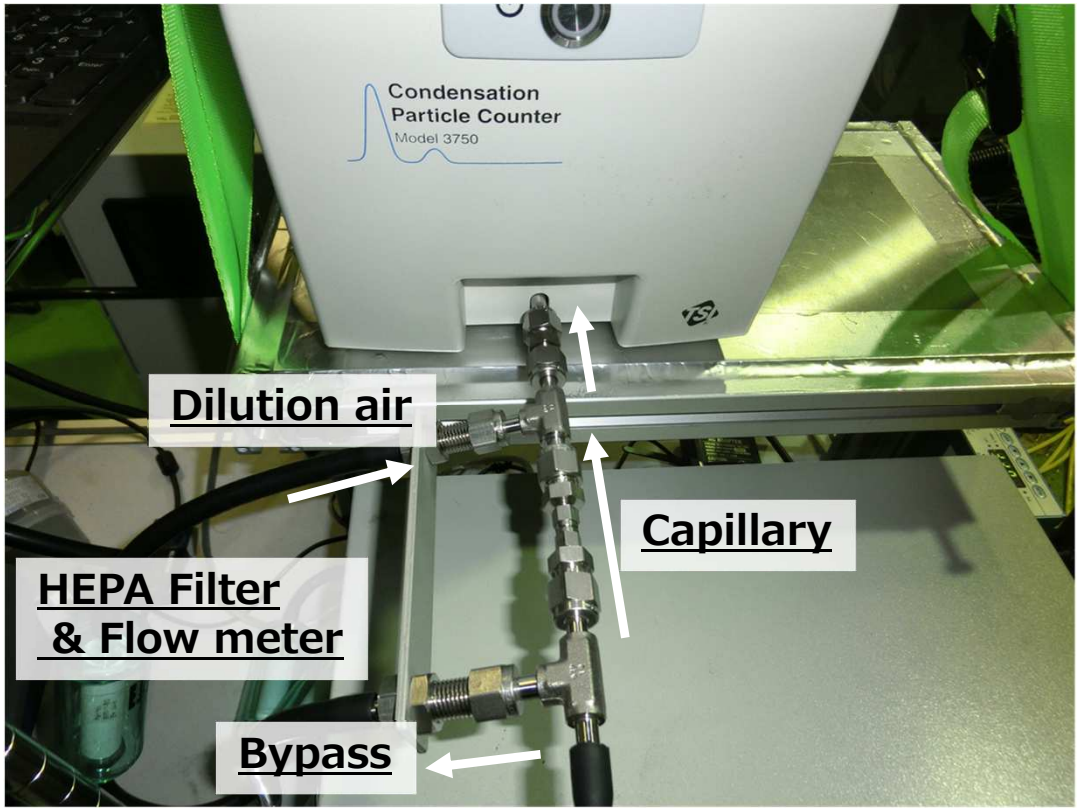


Isokinetic Sampling Tubes

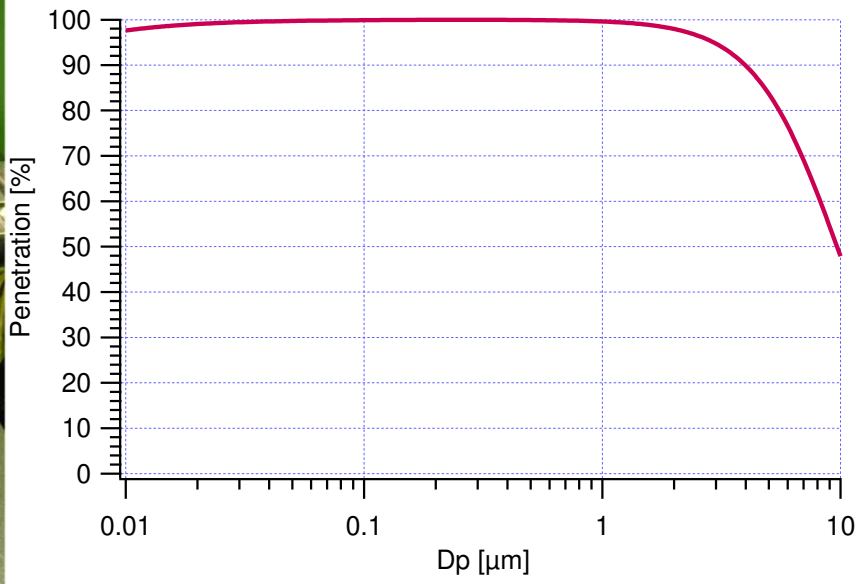
Note: Keeping response time approximately constant

Total Number Counts (1)

- Capillary diluter is installed downstream of $PM_{2.5}$ cyclone to reduce clogging of CPC.
- Volatile particle removers for coarse particles are not available, so measurement of volatile particles is premature.

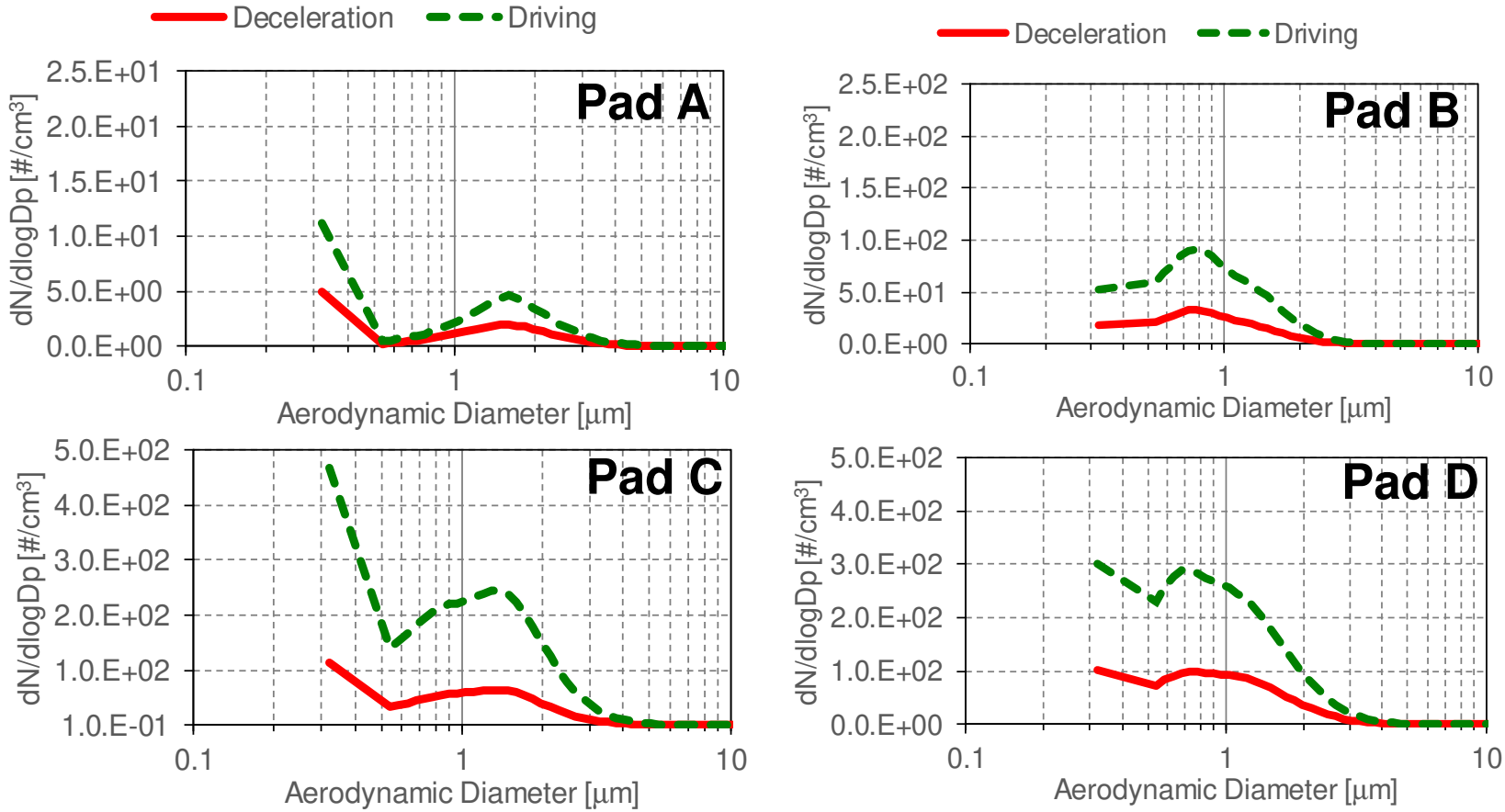


Extraction efficiency of Capillary at 1:10 dilution ratio



Total Number Counts (2): Coarse Particles

- Either APS 3321 or OPS3380 is used.
- It is recommended to equip an orifice diluter with a dilution factor of 10.
- It is important to evaluate the total emission because the PN emission tends to be higher during acceleration than deceleration.

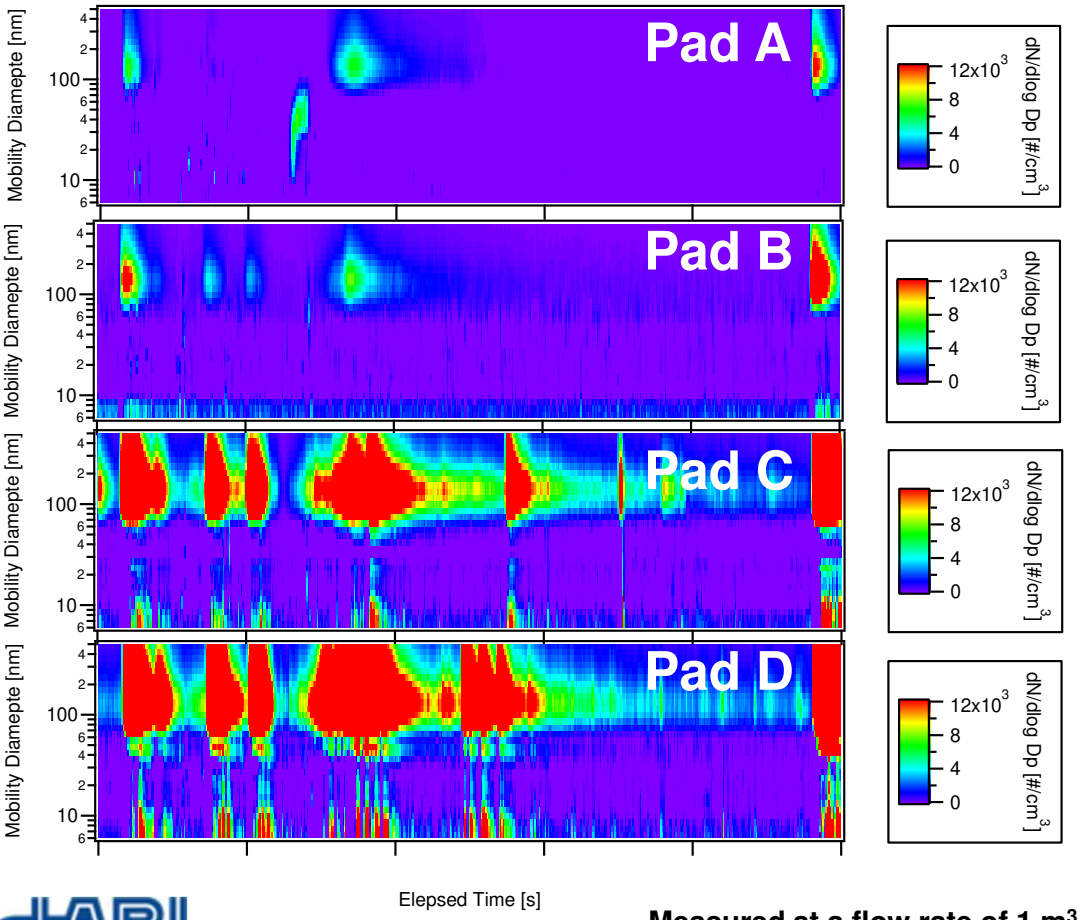


Measured at a flow rate of 1 m³/min

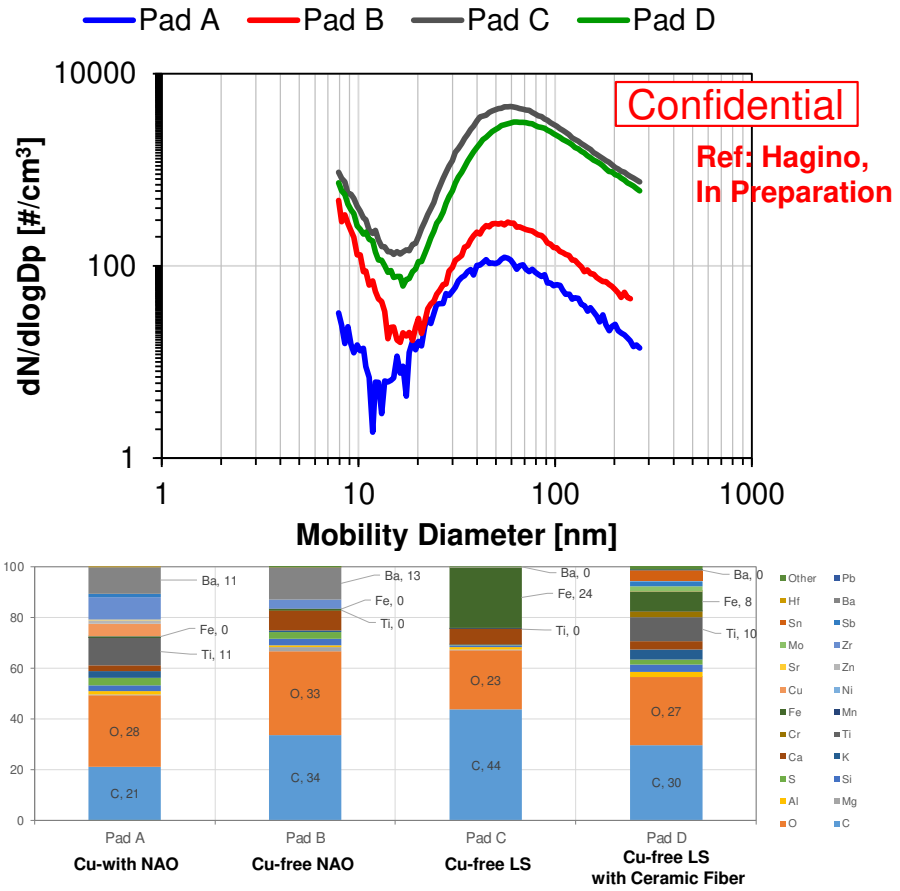
Nanoparticle Size Distributions

- FMPS detected that particles of Sub10 nm were emitted, and emission pattern was different depending on brake material.
- Sub-10 nm particles can be founded by SMPS with residence time 60s, but proportion of such the particles is small based on the particle size distribution, so it is sufficient to measure Sub-23 nm particles in emission gas measurement.

【PN (FMPS 3091 with Response time approx. 4.6 s)】



【PN (SMPS with Response time approx. 60 s)】



Measured at a flow rate of 1 m³/min

Follow-up for EuroBrake 2021, Hagino EB2020-FBR-019

Concluding Remarks

- Residence time is less sensitive to PN emissions than wind speed, which is assuming vehicle speed.
- Since total ratio of PN detected at 10 nm or less is small based on particle size distributions, CPC for sub-23 nm used in vehicle exhaust measurement is sufficient.

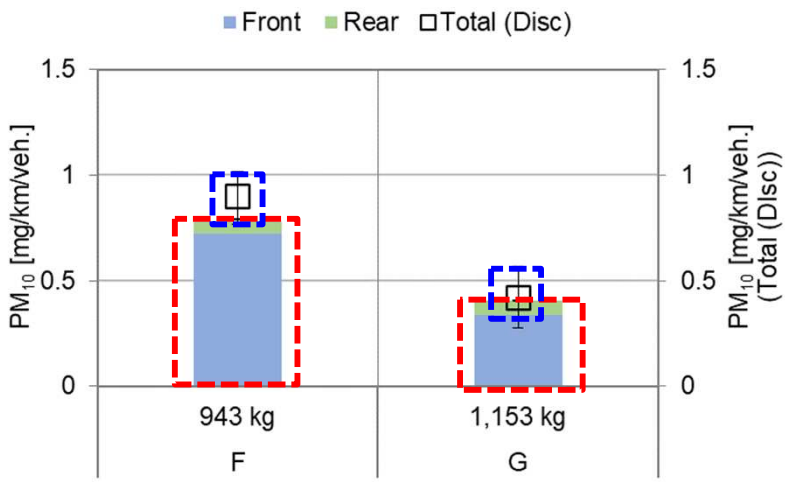
Spare Slides

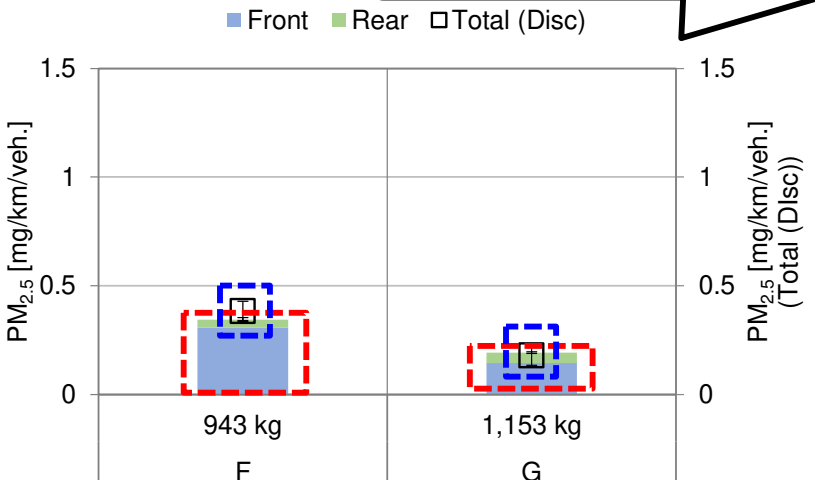
Difference in emissions for one vehicle

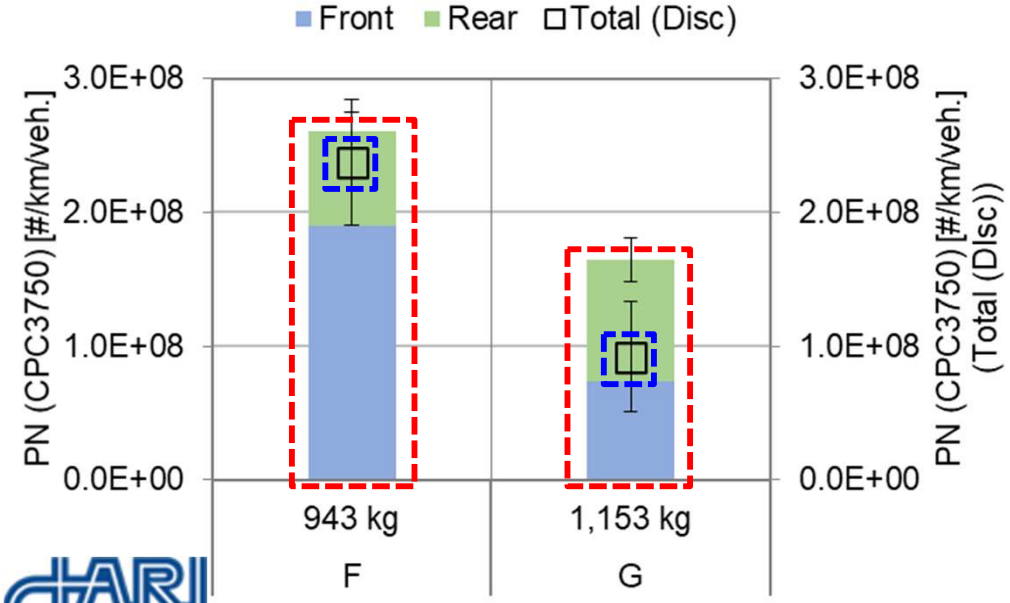
PN [#/km/veh.] = PN $_{\text{front axel}}$ x 2 + PN $_{\text{front axel}}$ x (1- Brake Force Distribution)/1 x 2
Brake Force Distribution = 0.8 in this study.

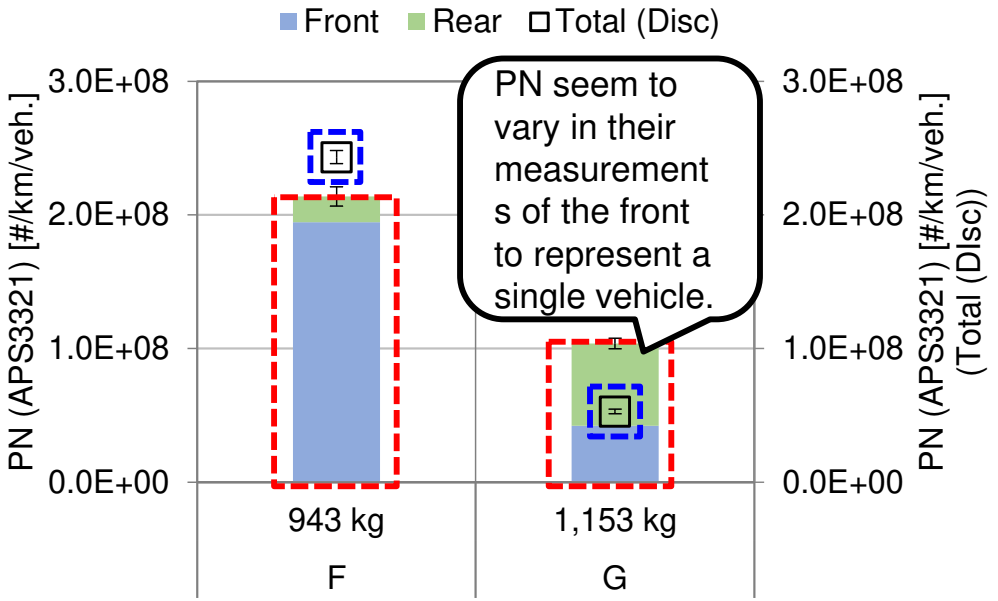
PN [#/km/veh.] = PN $_{\text{front axel}}$ x 2 + PN $_{\text{rear axel}}$ x 2
Brake Force Distribution = 0.8 in this study.

PM can represent one vehicle just by measuring front axle.







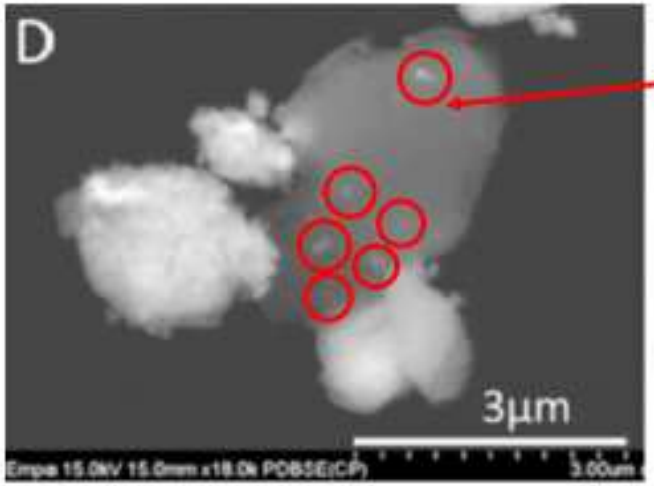


PN seem to vary in their measurement s of the front to represent a single vehicle.

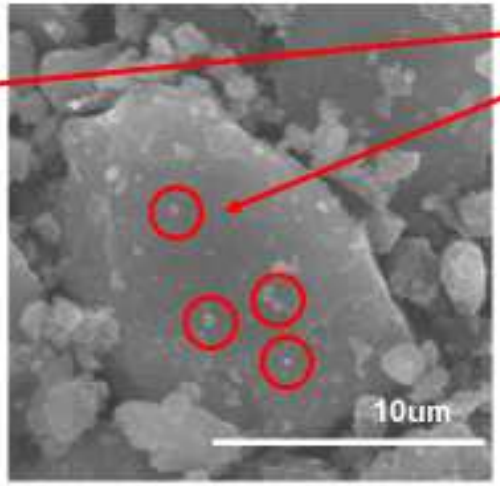
Spare Slides

Crucial PN Measurements Issue

- There was no discussion on particle coagulation linked with PN stable measurements in the sampling methodologies.
- Typical mechanisms are considered as follows:
  - Turbulent deposition on aerosol particles
  - Thermophoretic deposition on aerosol particles



Ref: Liati et al., Atmos. Environ. (2019)
tunnel flow ~50 m^3/min



Ref: Hagino, (2020)
tunnel flow 1 m^3/min

Small size particles deposited on large particles

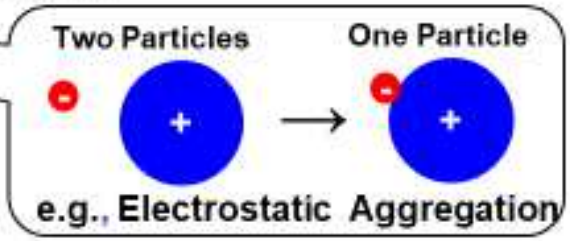
Unstable "PN" Measurement

Spare Slides

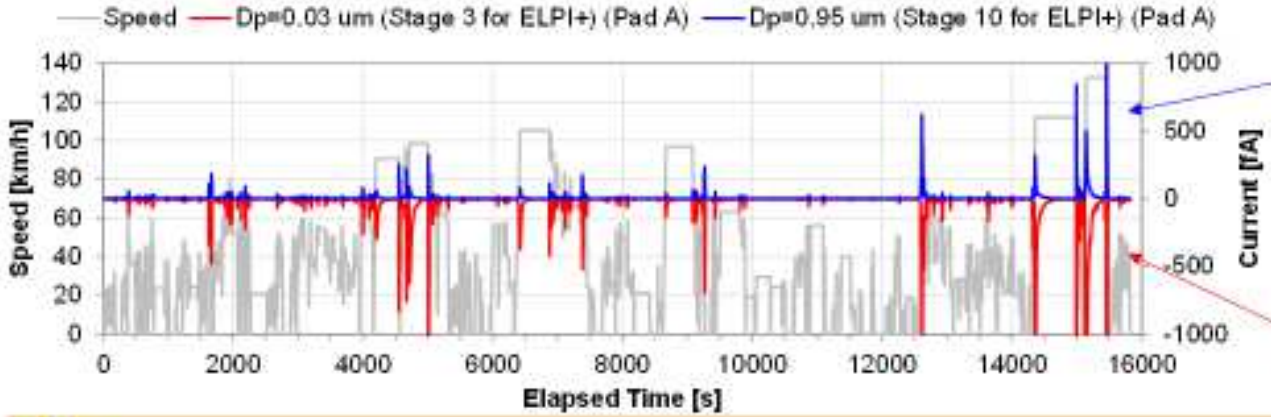
PN Size Measurements Issue

- + and - electrically charged particles (e.g., using ELPI+) were found.
- A discussion on the electrostatic aggregation caused by the tribo-charged particles may be necessary.
- Deposition of charged particles on lung airways is 5 or more times higher than that of neutral particles (Cohen et al., Health Phys. 1998).

Cohen et al., Deposition of charged particles on lung airways, Health Phys., 74 (1998), pp. 554–560



[e.g., Time tendency of net particle charging state measured by ELPI+, as shown in femto-ampere during WLTP-Brake Cycle]



Positively charged particles dominant for $Dp_{50\%}$ = 0.95 um.

Negatively charged particles dominant for $Dp_{50\%}$ = 0.03 um.

EuroBrake

EB2020-FBR-019