HORIBA
Automotive Test Systems

Performance of (Sub-23 nm) Particle Counting System Utilizing a Commercially Available PMP System

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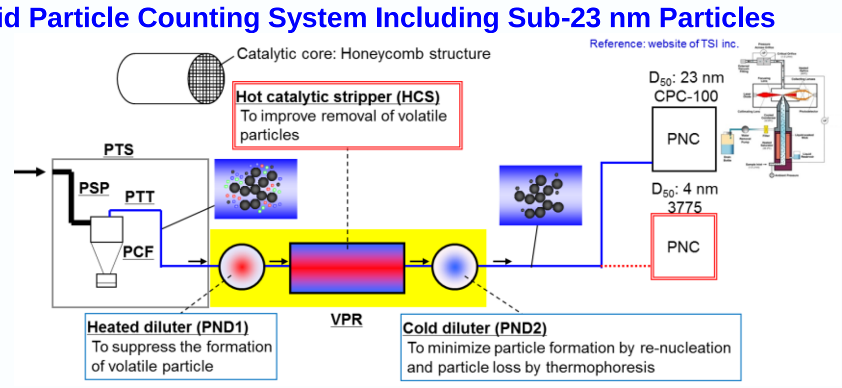
Configuration of Sub-23 nm PN Measurement System

Solid Particle Counting System Including Sub-23 nm Particles

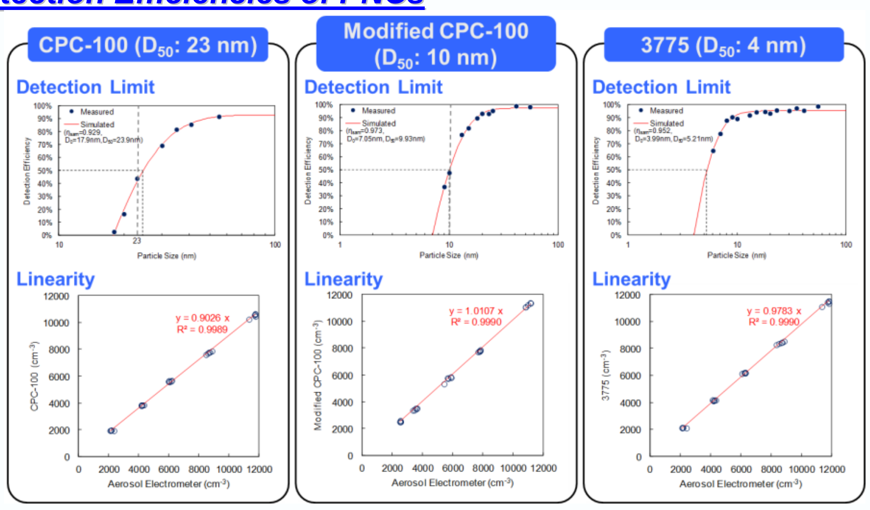


- ET was replaced by HCS in order to improve volatile removal performance
  - Oxidation catalyst can eliminate HCs by the oxidation ability
  - Absorption of sulfates
- PNC with D_{50} at 4 nm in parallel of PMP PNC (D_{50} = 23 nm)

Difficulties of Sub-23 nm Measurement

- Calibration of particle number counters
- Re-nucleation of volatile particles
  - High concentration volatile particles may cause re-nucleation at the VPR outlet
- Reduced solid particle penetration due to higher diffusion losses
  - VPR should be evaluated by sub-23 nm solid particles
  - The losses at PTT are still negligible?

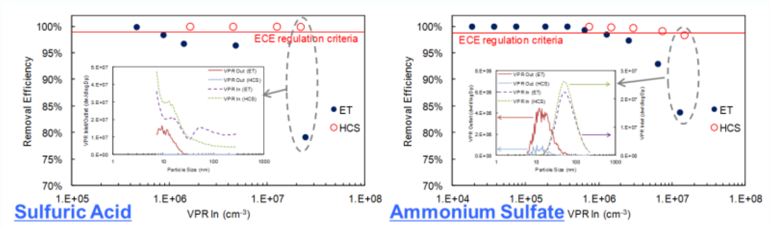
Detection Efficiencies of PNCs



- D_{50} of each PNC was at the specified particle diameters
- It is quite challenging to generate sub-10 nm poly-alpha-olefin particles
- D_{50} of PMP PNC was successfully adjusted down to 10 nm
  - ➡ Linearity should be verified when D_{50} is changed

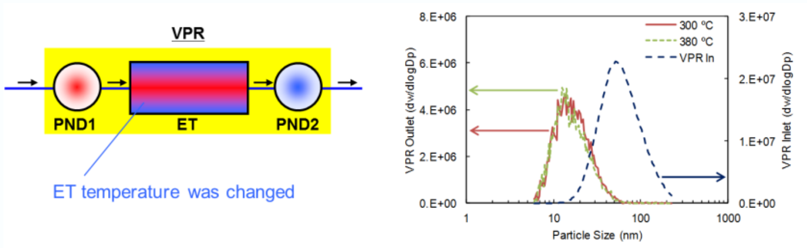
Volatile Particle Removal Performance of VPR

Comparison of Performance between ET and HCS



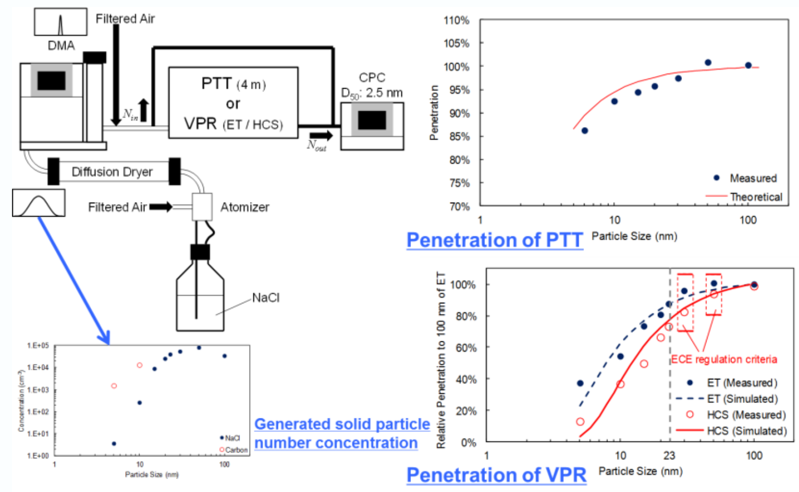
- The HCS has higher performance than ET
- Sizes of residual particles are mainly below 23 nm
  - ➡ Cause of high biases to sub-23 nm solid particle measurement

Cause of Residual Particles



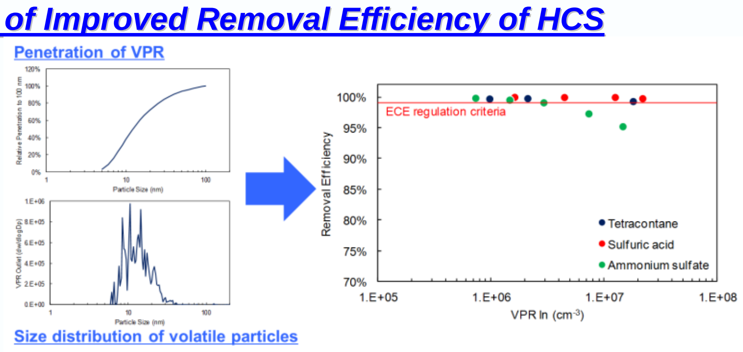
- Almost same removal efficiencies and size distributions were observed
  - ➡ Residual particles were generated mainly by the re-nucleation of high volatile fractions

Detection Efficiencies of PNCs



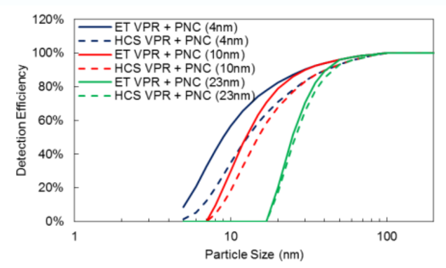
- It is challenging to generate sub-10 nm solid particles
- Lower penetrations were observed by smaller particles because of diffusion losses
- PTT penetration was still higher than 85% at 5 nm
- Penetration of VPR with the HCS was lower and more size dependent than the ET
  - ➡ Cause of measurement error of sub-23 nm particles

Cause of Improved Removal Efficiency of HCS



- Volatile particle removal performance can be improved by the reduced VPR penetration
  - … Removal efficiencies were corrected by VPR penetration and size distribution of residual volatile particles in order to clarify the cause of the improvement
  - Slightly decreased efficiency due to large amount of sub-23 nm volatile particles at VPR outlet
  - Removal efficiency of HCS is still higher than ET
  - ➡ Improved performance was not caused mainly by diffusion losses of VPR

Overall Detection Efficiency of the System



- Overall detection efficiencies of the system were estimated by verified PNC detection efficiencies and penetrations of VPR and PTT
- Difference between HCS and ET VPRs was significant with PNC which has smaller D_{50}
  - ➡ VPR penetration is dominant to the overall detection efficiency of the particle number measurement system

Conclusions

- The PTT length should be as short as possible in order to prevent particle losses of tiny nanoparticles for sub-23 nm particle measurement
- The higher reduction efficiencies of the HCS against high volatile particle concentration were observed compared with the conventional ET
- Penetration of the HCS tends to be lower than the ET because of the diffusion losses
- Establishment of particle generation procedures for PNC and VPR calibration are necessary because it is quite challenging to generate enough high concentration calibration particles

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