15th ETH-Conference on Combustion Generated Nanoparticles
June 26th – 29th 2011

Paper/Poster-Abstract Form

Name of Author	Hiromu Sakurai
Co-Authors	Keizo Saito, Tsuyoshi Taishi, Tetsuji Koyama
Affiliation	National Institute of Advanced Industrial Science and Technology (AIST)
Mailing address	1-1-1 Umezono, Tsukuba, Ibaraki 305-8563 Japan
Phone / Fax	+81-29-861-2294 / +81-29-861-4070
E-mail	hiromu.sakurai@aist.go.jp

Title: Errors in determination of VPR's Particle Concentration Reduction Factor

Abstract: (min. 300 – max. 500 words)

The abstracts for papers and posters must contain unpublished information on the research subject: background, investigation methods, results and conclusions. Graphs and references are very welcome. Acronyms should be avoided. Abstracts with < 300 words can not be considered. General information on products which are already commercially available can not be accepted as presentations for the conference but are very welcome at the exhibition of particle filter systems and nanoparticle measurement instruments.

We investigated sources of errors in determination of the particle concentration reduction factor (f_r) of the volatile particle remover (VPR) used in legislated vehicle emission measurement. Sodium chloride and soot are two of the most frequently used materials of particles used in the f_r evaluation. We identified two sources of errors that are associated with the use of these materials: One is the variation of the detection efficiency of condensation particle counters (CPCs) against sodium chloride particles, which was found to depend on the preheated temperature of the particles. The other is the size shrinkage of soot particles generated with a propane flame burner that are not thermally pre-treated, when the particles were heated at temperatures typically set at the evaporation tube of VPRs. These two sources of errors have presumably caused disagreement of f_r values obtained with particles of the two materials. We found that, by selecting appropriate CPCs and also by sufficiently pre-heating the particles, disagreement due to these errors could be eliminated. As a result, consistent f_r values were obtained between measurements with the two different particle materials, i.e., sodium chloride and soot.

Short CV:

B.Eng. (1992) and M.Eng. (1994) in Chemical Engineering at University of Tokyo; Ph.D. (1999) in Chemistry at Pennsylvania State University; Postdoctoral Research Associate (1999 - 2003) at University of Minnesota; Permanent researcher at AIST (2004 - present) as a metrologist in aerosol particle measurement.

Return by e-mail latest 18th of April 2011 to
ttm.a.mayer@bluewin.ch

Errors in determination of VPR's Particle Concentration Reduction Factor

Hiromu Sakurai, Keizo Saito
National Institute of Advanced Industrial Science and Technology (AIST)
Contact: hiromu.sakurai@aist.go.jp

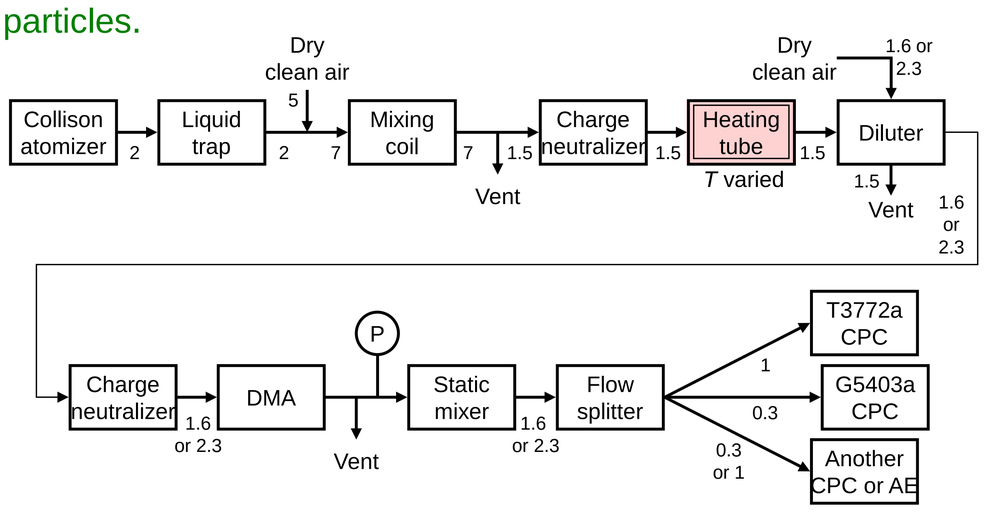
Tsuyoshi Taishi, Tetsuji Koyama
Tsukasa Sokken Co., Ltd.

Purpose of the study

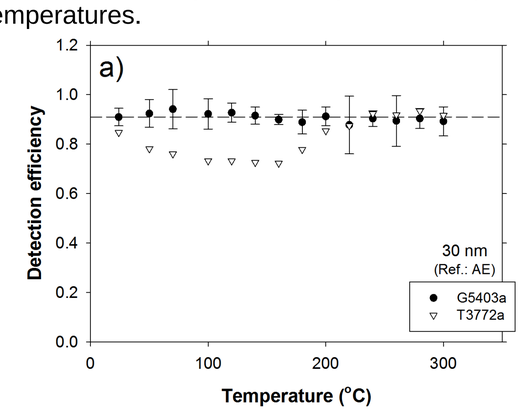
- Particle concentration reduction factor(PCRF: *fr*) will be used in legislated vehicle emission measurement, we must be able to evaluate the performance of the volatile particle remover(VPR) accurately.
- Investigated the sources of errors in determination of the PCRF with the use of NaCl and CAST.

Investigation of NaCl

The detection efficiency of CPCs depend on the preheated temperature of the particles.

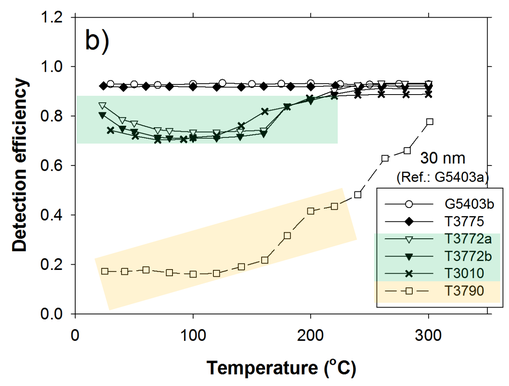


Detection efficiency of CPCs against NaCl particles that were pre-heated at various temperatures.



(a) Detection efficiencies of G5403a and T3772a with particles of 30 nm diameter that were obtained in the measurement with the aerosol electrometer (AE) used as the reference

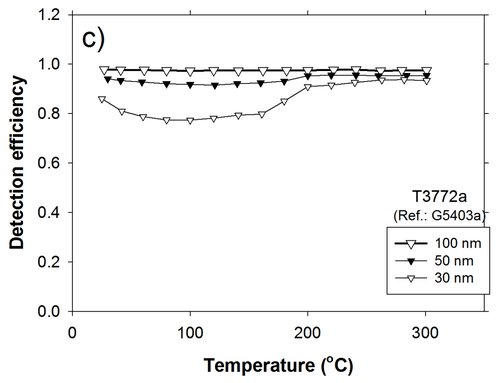
- It is obvious in the plot that the detection efficiency of the two CPCs behaved differently against the heating temperature.
- The G5403a CPC showed essentially no change in detection efficiency with the heating temperature.



(b) Detection efficiencies of six CPCs at 30 nm that were obtained
with G5403a as the reference.

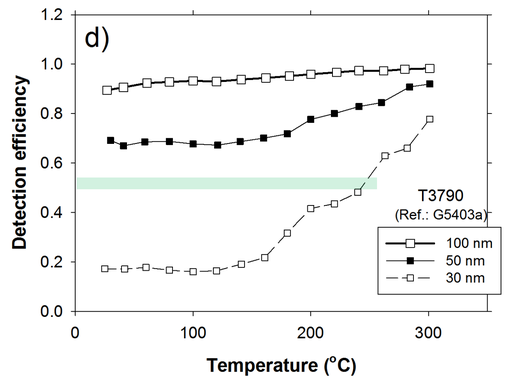
- In this figure, there are three groups that showed different magnitudes of temperature-dependent variation of the detection efficiency.
- For T3790 that showed the most significant temperature dependence, the detection efficiency did not reach to a plateau within the temperature range studied.

Detection efficiency of CPCs against the heating temperature at particle sizes of 30 nm, 50 nm, and 100 nm.



(c) Detection efficiencies of T3772a with G5403a as the reference at 30, 50, and 100 nm.

- This figure shows that the magnitude of the temperature-dependent variation of the detection efficiency had size dependence, and that the variation against the heating temperature was less significant for larger particles.
- At 100 nm, the detection efficiency was essentially constant and independent of the heating temperature in the range studied.



(d) Detection efficiencies of T3790 with G5403a as the reference at 30, 50, and 100 nm.

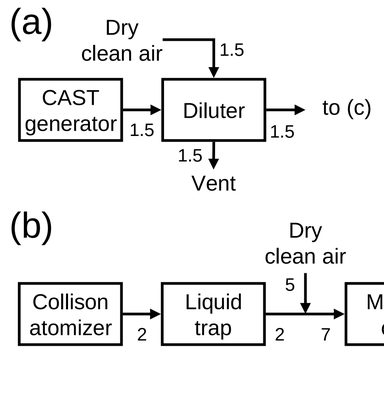
- The detection efficiency of T3790 was less than 50 % for 30 nm particles at most of the temperatures. That was due to the material dependence of the detection efficiency of this CPC.
- For T3790, the detection efficiency against NaCl particles was less than that against poly-alpha olefin (PAO) particles when compared at the same particle size.

- Nobody knows, physical property of NaCl particles changed at the pre-heating and caused the variation of the detection efficiency.
- NaCl particles did not change size when heated.
- There is a possibility that the humidity in the CPC may have played a role together with the pre-heating.

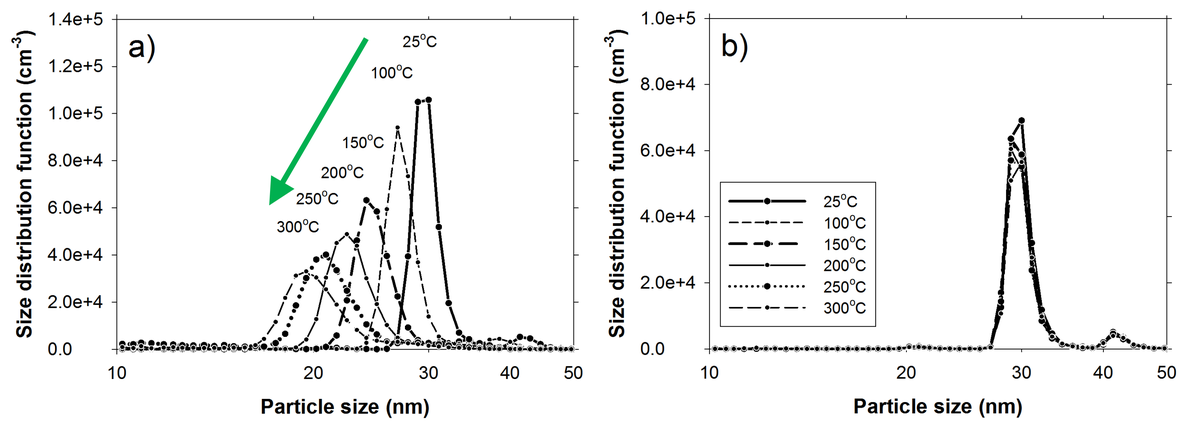
- The difference of the CPC detection efficiency between heated and unheated NaCl particles implies that the *fr* evaluation may result in underestimation, if unheated NaCl particles are used and also if a CPC of a large d50 is used.
- To avoid underestimation of *fr* at 30 nm when using NaCl particles, it is required to use CPCs of d50 equal to or less than 5 nm, or to heat particles at ~ 300 deg C before introducing to the VPR if the CPCs are of d50 = 10 nm.
- CPCs of d50 = 23 nm should not be used in 30 nm *fr* evaluation at all if NaCl is used.

Size change resulting from heating

CAST particles should be pre-heated at temperatures above 200 deg C.
NaCl particles did not change size when heated.



Size distributions of DMA-classified (a) CAST and (b) NaCl particles after heated at varied temperatures.
The size distribution curve had the mode diameter at ~ 30 nm at room temperature.



- The curve of distribution shifted to smaller sizes with the temperature increased.
- This suggests that soot particles generated by the CAST generator would shrink too when they were passed through a VPR, if they were not pre-heated.

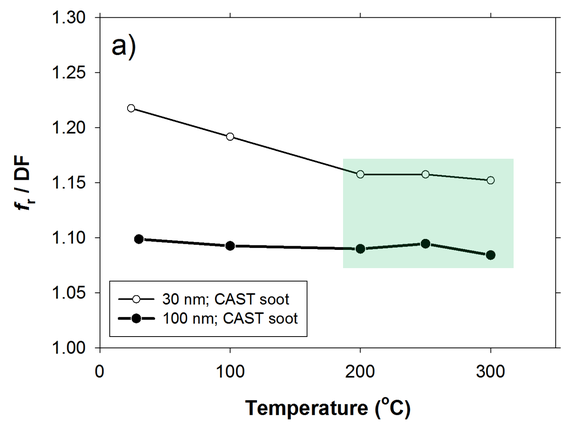
- The size distribution did not change at all while the heating temperature was changed.
- This provides evidence that the temperature-dependent variation of the CPC detection efficiency against NaCl particles was not caused by change of particle size.

- The shrinkage of CAST particles upon heating implies that *fr* would be overestimated, because particles which becomes small in the VPR would be more easily lost in the VPR.
- The appropriate pre-heating temperature may be different. Nevertheless, the temperatures suggested by this study provide a guide in finding the appropriate pre-heating temperature for each condition.

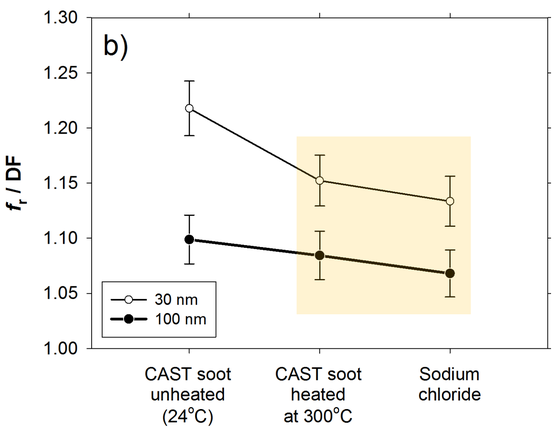
Comparison of PCRF

Consistent results would be obtained in the *fr* evaluation either with NaCl or soot particles.

Results of *fr* measurements for a VPR with particles of 30 and 100 nm in diameter, expressed as the ratio of *fr* /DF.



(a) The observed *fr*/DF ratios when the VPR was set at DF = 100, with soot particles generated with the CAST generator which were pre-heated at various temperatures before being introduced into the VPR.



(b) Comparison of the observed *fr*/DF ratios obtained with soot particles by CAST without pre-heating, soot particles by CAST with pre-heating at 300ºC, and NaCl particles.

Conclusions

- The experimental observations in this study suggest that consistent results would be obtained in *fr* measurement for VPRs, while the particles used in the measurement were either NaCl or soot, if the particles were pre-heated properly and if CPCs of sufficiently small d50 were used.
- We hope these results help developing better *fr* evaluation techniques and improving reproducibility of the *fr* measurement.

Acknowledgements

The authors acknowledge Dr. Masaaki Tsuji, Ms. Emiko Ohnuma, and other technical staff of AIST for their assistance during the course of this study.
This work was financially supported by the Ministry of Economy, Trade and Industry (METI) of Japan.