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Effect of Thermal Conditioning on Nano-Particle Measurement

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Fluctuation in the measurement result of nano-particles is a common problem with recent available instruments. Therefore thermal conditioning of the sampling gas before measurement using the so-called Thermo-Conditioner was proposed in order to restrain the fluctuation in nano-particle measurement at the GRPE/PMP research council of the United Nation.

A major portion of nano-particle forms in the full dilution tunnel where dilution of the exhaust gas occurs at the room temperature. The prime objective of this thermo-conditioner is to vaporize the volatile fraction by re-heating the diluted gas to a certain temperature and cooling down again to room temperature. As the result measurement fluctuation due to volatile fractions can be avoided. However, it is a newly developed device and the performance of this device is not sufficiently understood yet for many measuring parameters. Therefore practical application of this device needs the consideration of widely different measuring parameters.

In this study we have attempted to clarify the effect of thermo-conditioner on the nano-particle measurement for different measuring parameters. Among the parameters the quality of the raw exhaust gas, the dilution ratio and temperature of the diluted gas before thermal conditioning, and the thermal conditioning temperature were considered as the main. Exhaust gas from a medium duty DI diesel engine was used for analysis. Scanning Mobility Particle Sizer (SMPS) was used for measuring the size distribution of nano-particles.

Slide 8 shows the particle distribution at different sampling points for low load condition. At this condition the exhaust gas is significantly influenced by the dilution conditions. It is found that the accumulation mode particles do not experience any

influence by sampling point and thermal treatment of exhaust gas. The fluctuation in concentration of nuclei mode particles within the range of 10~30 nm is suppressed by the hot dilution and thermal conditioning of exhaust gas.
The most interesting thing is that without the hot dilution and thermal conditioning of exhaust gas the 10~30 nm nuclei mode particles shows higher concentration due to cold dilution in the full dilution tunnel.

The effect of hot dilution temperature on nano-particle distribution is shown in slide 9. The engine was running at idling condition and sampling was done at the point before silencer. Tests were done both with and without thermal conditioning of exhaust gas. It shows that hot dilution and thermal conditioning of exhaust gas has very slight influence on the accumulation mode particles. Without thermo-conditioning the concentration of nuclei mode particles decreases significantly with increases in the hot dilution temperature. When thermo-conditioning is done at 300°C it was found that the nuclei mode particles become smaller and the influence of hot dilution temperature decreases. However the nuclei mode particles of 10 nm in diameter or less show no significant variations even with hot dilution and or thermo-conditioning.

The slide 11 shows the effect of thermo-conditioning temperature on nano-particle distribution at the point after dilution tunnel. The engine was operated at idling condition. Therefore it can be said that the nuclei mode particles in this graph include both the combustion-generated particles and the particles formed in the dilution tunnel due to cold dilution. The results show that without thermo-conditioning and thermo-conditioning at 100°C the concentration of nuclei mode particles is very high, the size ranges 10~40 nm with peak at 18 nm. As the thermo-conditioning temperature increases the peak shifts to the left and the concentration decreases. However the accumulation mode particles experience no significant influences.

Slide 12 shows that without thermo-conditioning there is significant number concentration of nuclei mode particles at low load condition. However it is suppressed significantly when thermo-conditioning is done even at a temperature of 100°C. Therefore it is thought that most of the nuclei mode particles represented by the black circles are formed in the dilution tunnel due to condensation of water by cold dilution. Further increases in the thermo-conditioning temperature from 100-300 °C show decreases in the concentration of nuclei mode particles due to increases in the evaporation of the volatile fractions (HC). The nuclei mode particles almost disappear and concentration becomes saturated at the thermo-conditioning temperature of 300°C. Therefore it can be thought that thermo-conditioning possibly can suppress almost all the nuclei mode particles formed in the dilution tunnel due to cold dilution.

Based on the discussions, we would like to classify the nano-particles into three groups. These are schematically represented in slide 13. Particles having the size of less than 15 nm are considered in the first group. These particles are not affected by the thermo-conditioning temperature even up to 400°C. Therefore it is thought that these particles are core of nuclei particles which may be ash or carbon or heavy HC having the boiling point over 400°C.

Particles within the size range of about 15-30 nm are considered in the second group. These are significantly affected by the thermo-conditioning and therefore assumed to be particles those may or may not consist a solid core depending on the condition but always consist some volatile fractions. There are two types of volatile fractions. First one is may be water condensed due to cold dilution and the second one is molecular HC having the boiling point of less than 300°C.

Particles larger than these size ranges are considered in the third group. Most of these are solid particles such as soot or agglomerate of some solid soot. These cannot be affected by thermo-conditioning.

It was found that the Nuclei-mode particles having the diameter of about 15-30 nm is significantly influenced by the thermal conditioning temperature while the accumulation mode particles having the diameter of about 100 nm remain almost the same.

Thermal conditioning at a temperature of 300°C was found to be sufficient for stabilizing nano-particles.

Thermo-conditioner can vaporize almost all the volatile fraction forms due to cold dilution in the full dilution tunnel. But it cannot vaporize all the combustion-generated nuclei-mode particles (core).

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Measurement Problems of Nano-PM

Nano-particles are very unstable and sensitive to circumferential condition such as temperature, humidity and exposure time to ambient.

Quantitative measurement is very difficult because value is significantly affected by the measurement principle, and technique, therefore it is difficult to use the present measuring instruments for regulatory measurement.

It is necessary to make the nano-particles characteristically stable so that accurate measurement will be possible which will lead to the possibility of regulation.

Motivation

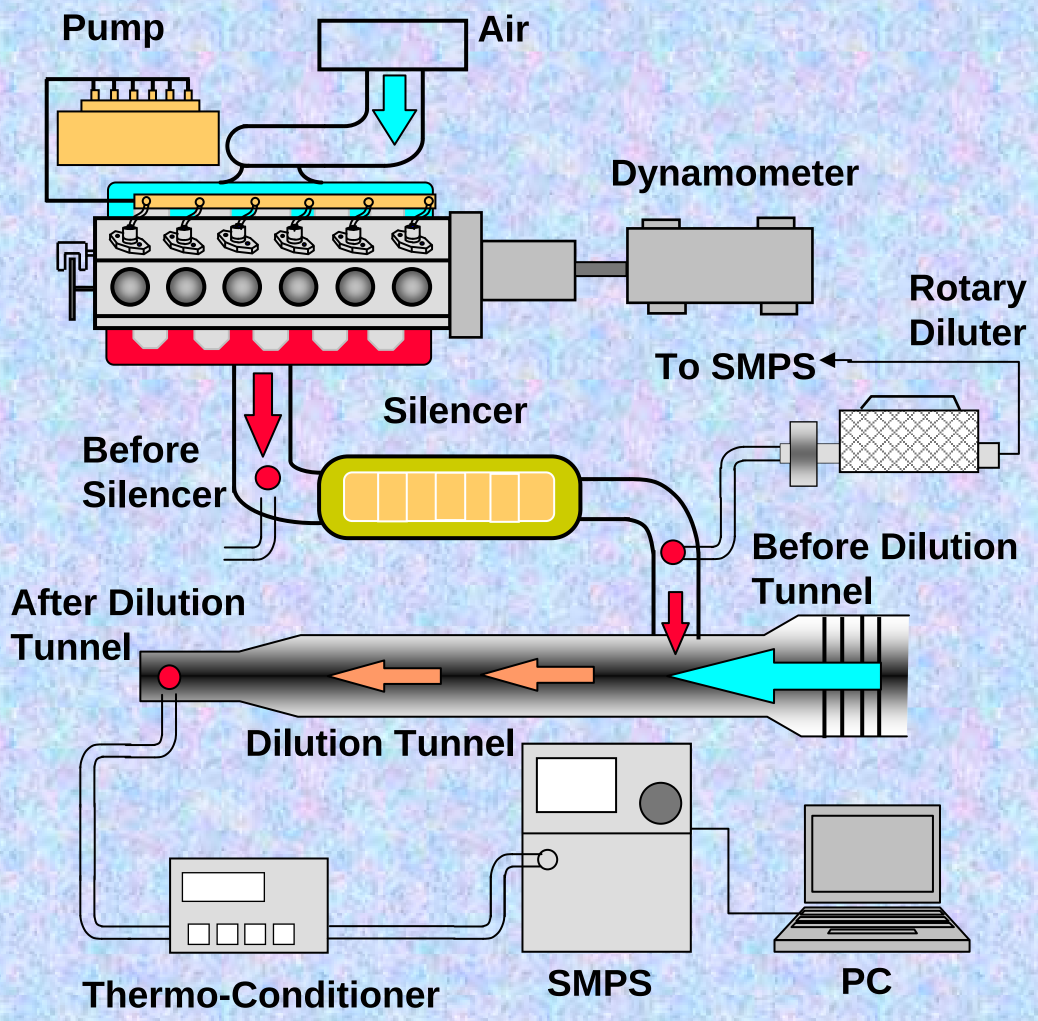
Thermo-Conditioner was proposed in order to restrain the fluctuation in nano-particle measurement at the GRPE/PMP research council of the United Nation.

It is a newly developed device and the characteristics of the thermo-conditioned nano-particles are completely unknown under different conditions.

Objective of this study is to investigate the effect of thermo-conditioner on the nano-particle

Therefore it is possible to clarify the characteristics on nano-particles

Experimental System



Test Conditions

Idling	550 rpm 0 N-m
Low load	1200 rpm 98 N-m
Medium load	1620 rpm 460 N-m
High load	2160 rpm 600 N-m

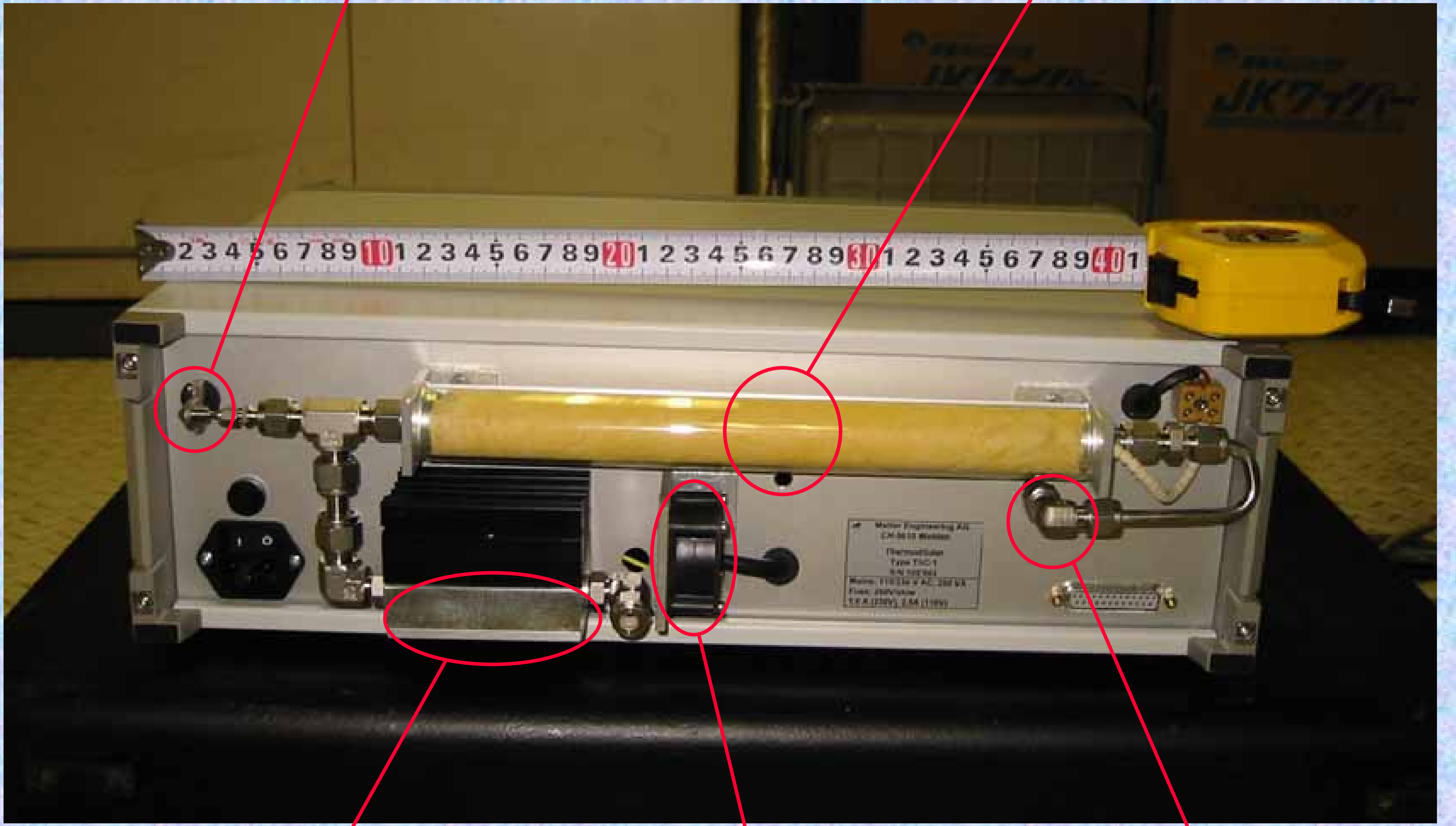
Engine specification

Engine type	DI Diesel
Injection system	Common rail
Bore X Stroke	114 X 130 mm
Swept volume	7.96 Liter
Emission standard	Japan 1998

Thermo-Conditioner

Thermo-Couple

Heating tube



Radiator

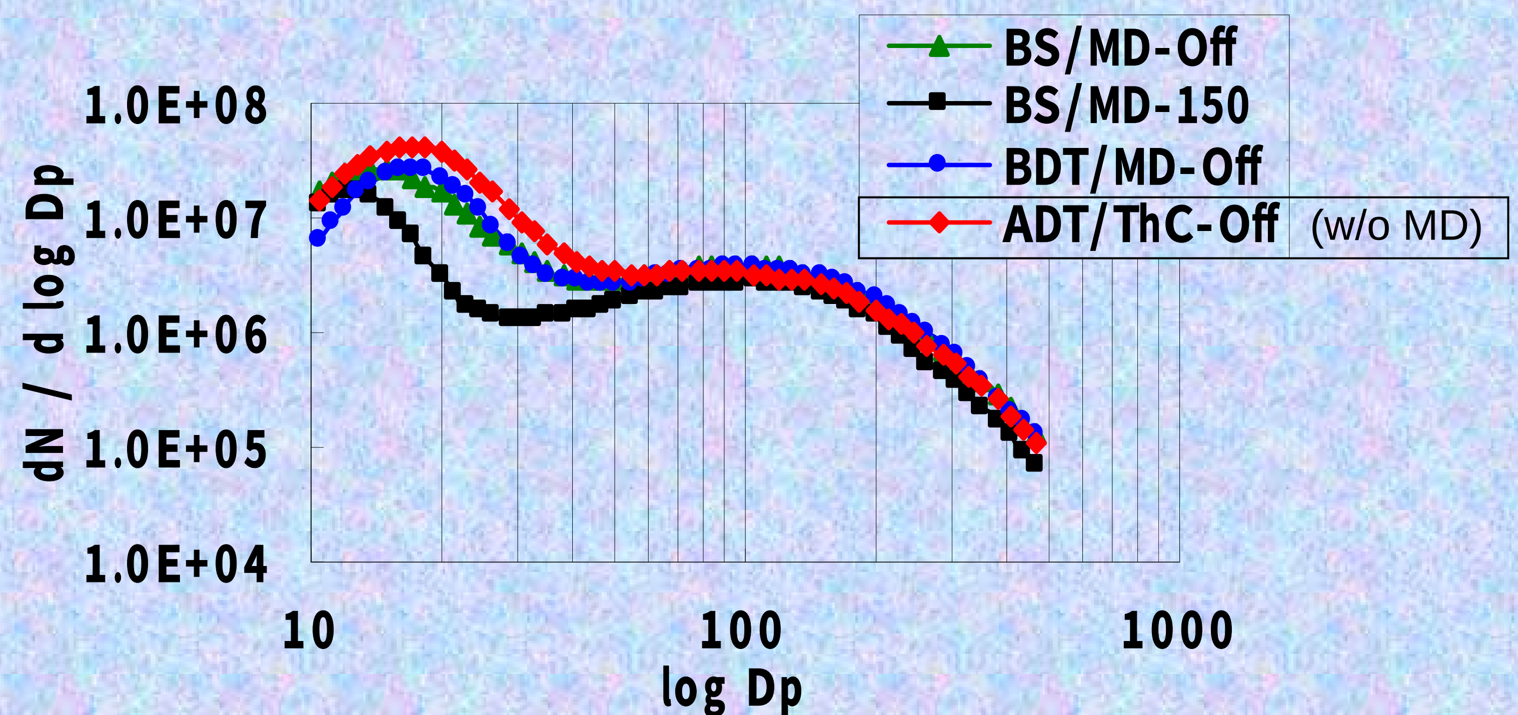
Cooling fan

Sample In

Results and Discussion

1. Effect of Sampling Point
2. Effect of Dilution Temperature
3. Effect of Thermo-Conditioner

1. Effect of Sampling Point

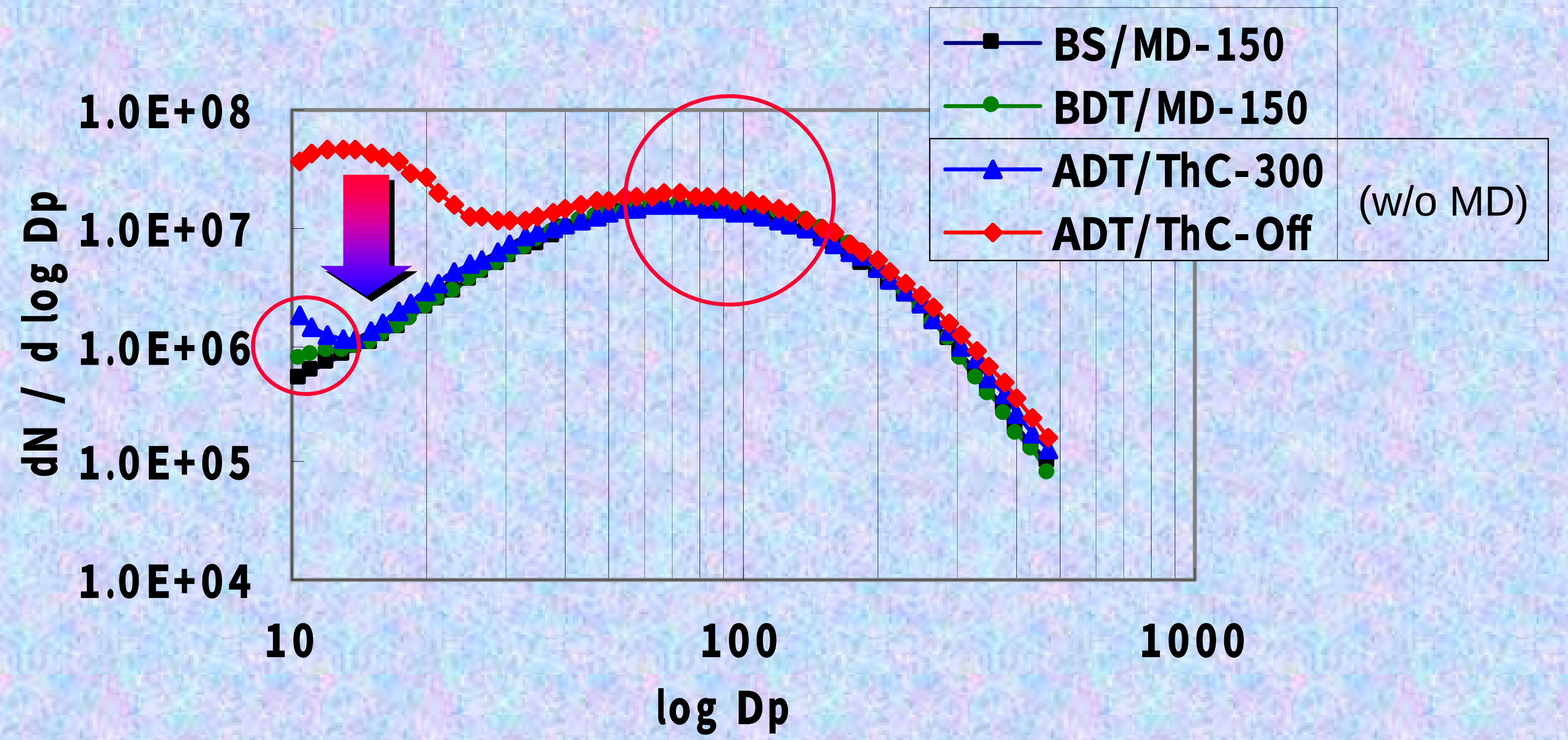


Idling Condition:
Speed: 550 rpm
Torque: 0 N-m

BS: Before Silencer
BDT: Before Dilution Tunnel
ADT: After Dilution Tunnel

MD: Rotary Disk Diluter   ThC: Thermo-Conditioner

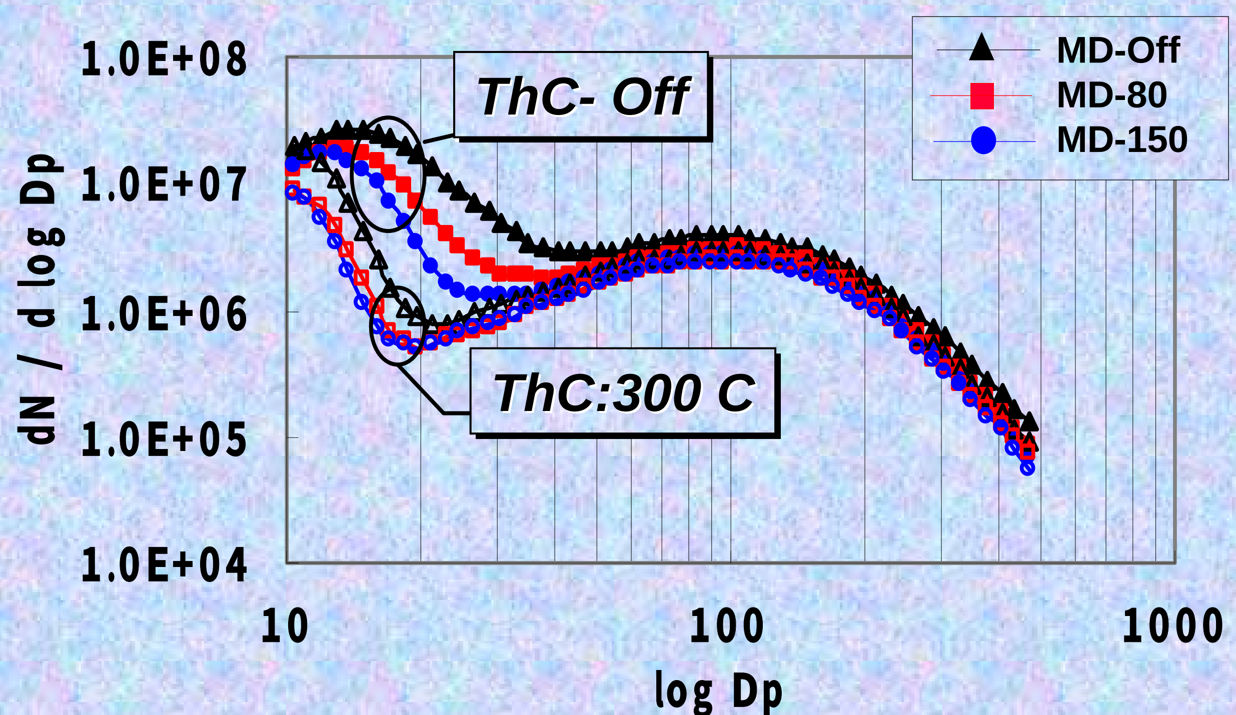
1. Effect of Sampling Point



Low load Condition:
Speed: 1200 rpm
Torque: 98 N-m

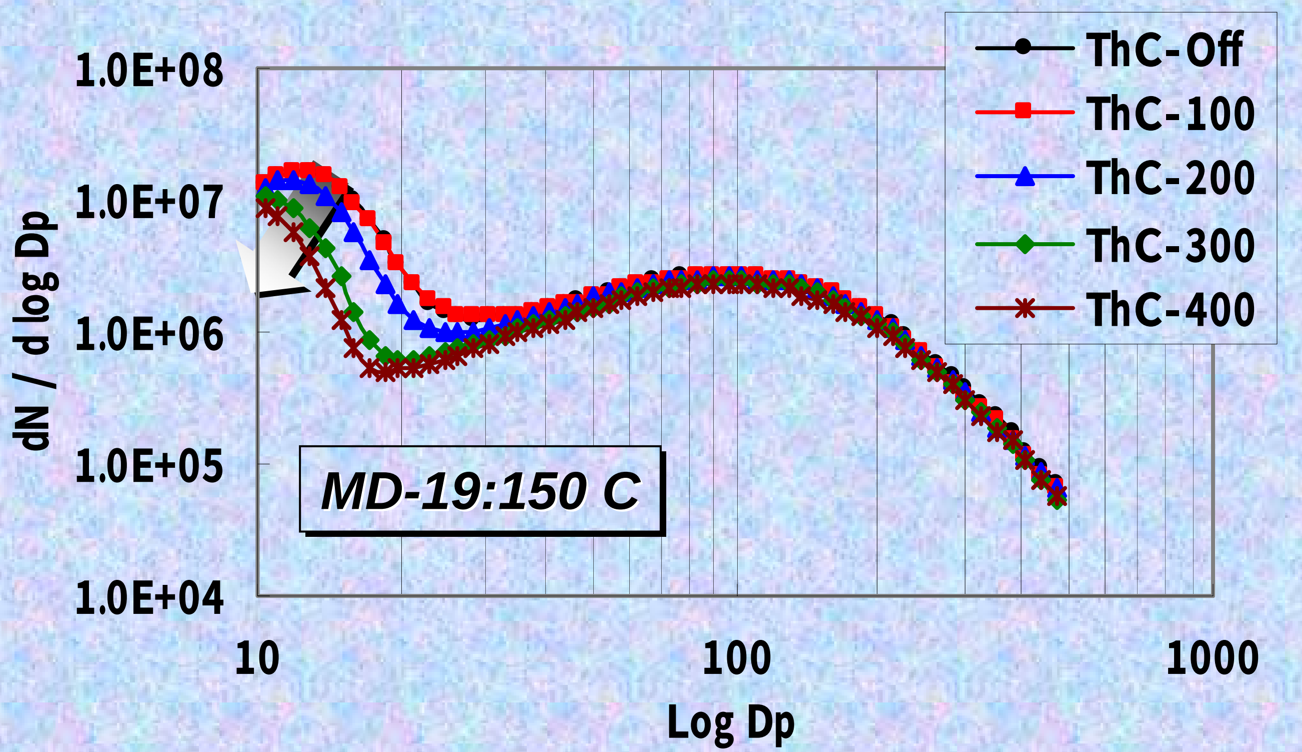
BS: Before Silencer
BDT: Before Dilution Tunnel
ADT: After Dilution Tunnel

2. Effect of Dilution Temperature



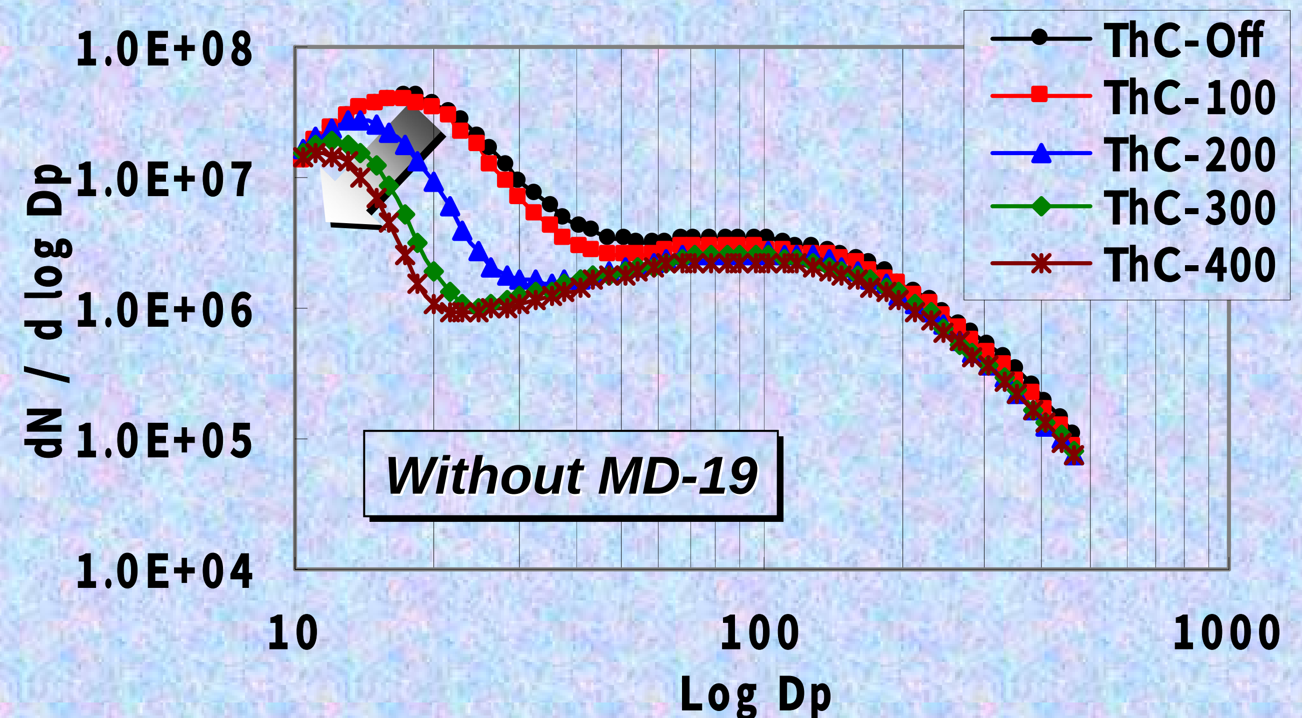
Sampling point: Before silencer
Idling condition:
Speed: 550 rpm
Torque: 0 N-m

3. Effect of Thermo-Conditioner



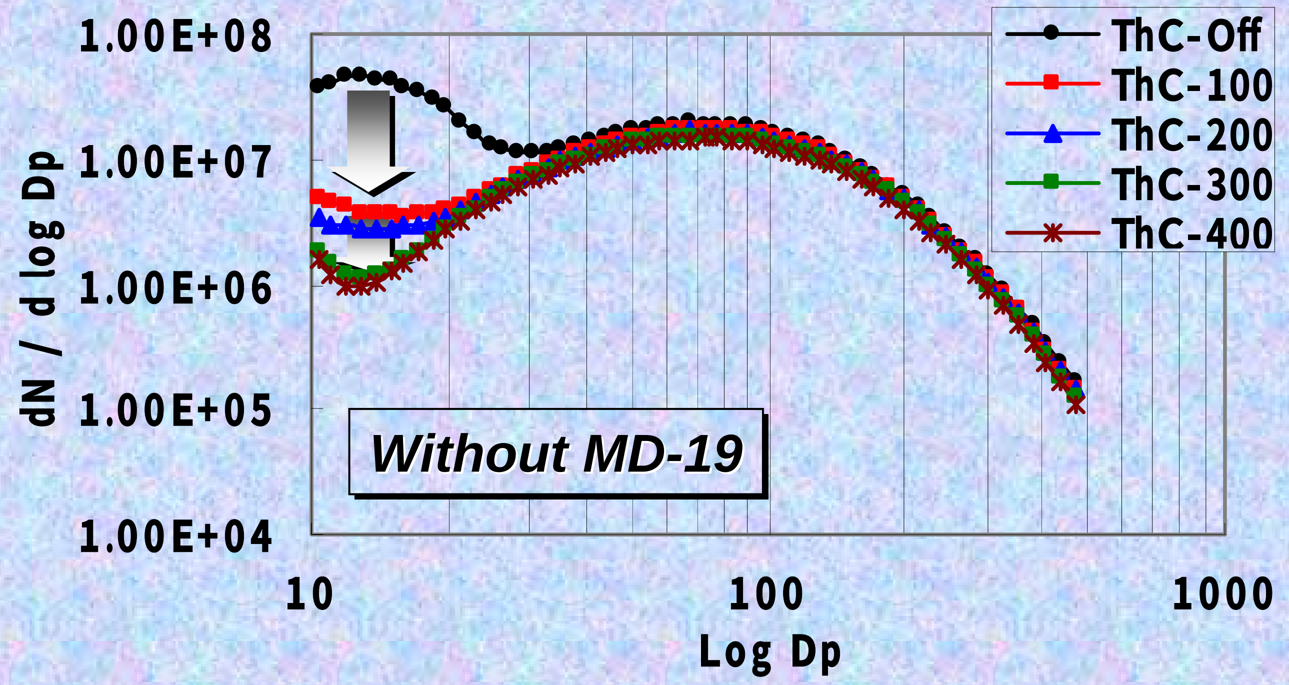
Sampling point: Before silencer
Dilution: Hot at 150 °C
Idling condition:
Speed: 550 rpm
Torque: 0 N-m

3. Effect of Thermo-Conditioner



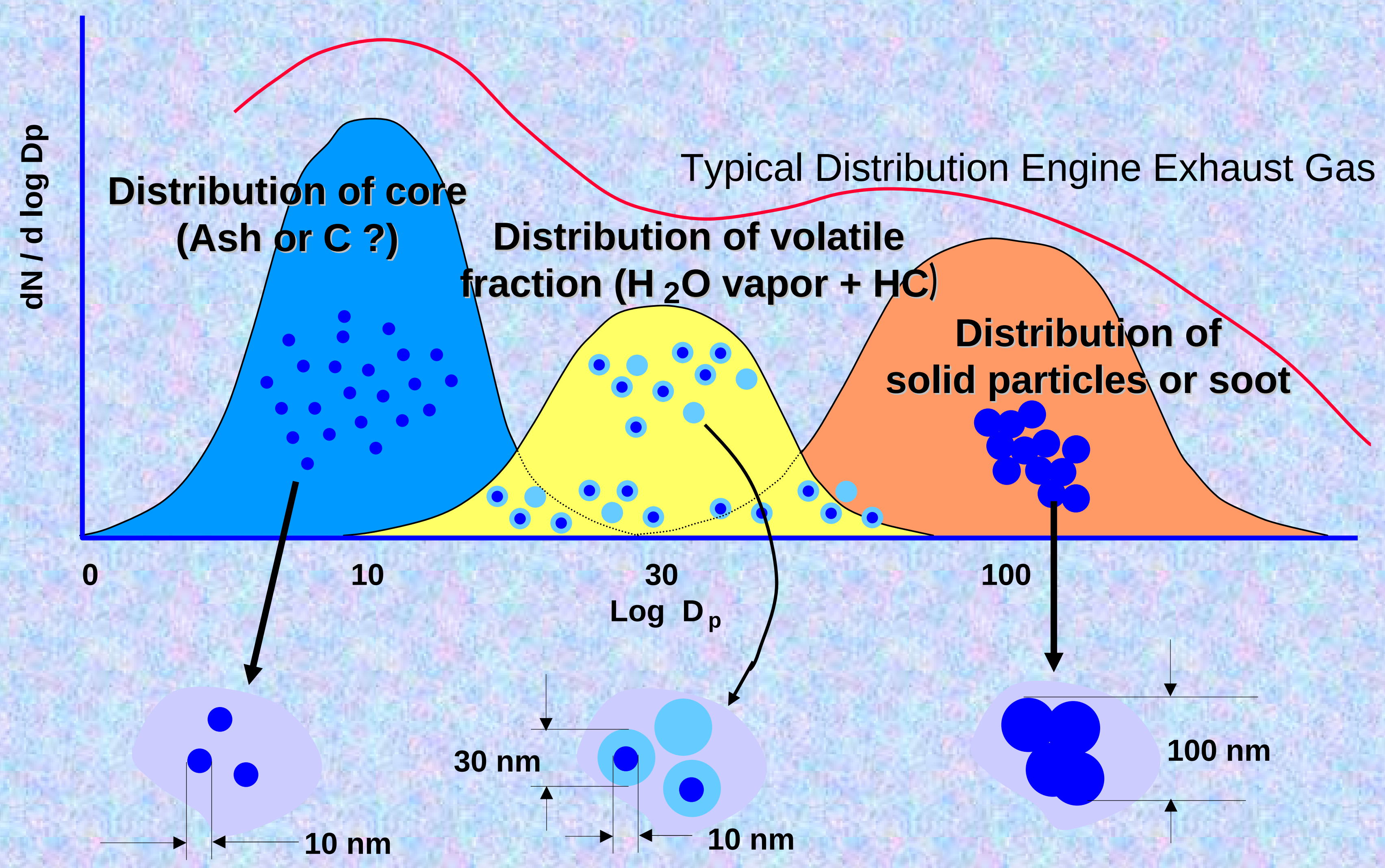
Sampling point:
After dilution tunnel
Idling condition:
Speed: 550 rpm
Torque: 0 N-m

3. Effect of Thermo-Conditioner



Sampling point:
After dilution tunnel
Low load condition:
Speed: 1200 rpm
Torque: 98 N-m

Nano-Particle Model



Conclusions

Nuclei-mode particles having the diameter of about 15-30 nm is significantly influenced by the thermal conditioning temperature while the accumulation mode particles having the diameter of about 100 nm remain almost the same.

Thermal conditioning at a temperature of 300 °C was found to be sufficient for stabilizing nano-particles.

Thermo-conditioner can vaporize almost all the volatile fraction forms due to cold dilution in the full dilution tunnel. But it cannot vaporize all the combustion-generated nuclei-mode particles (core).

Thank you

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