Preliminary Assessment of a Matter Engineering Rotating Disk Diluter (Type MD19-2E)

E L Sandbach, J R Osbourn and I A Marshall

Aerosol Science Centre, Netcen, AEA Technology plc, Culham, Abingdon, Oxon, OX14 3ED

The Matter Engineering Rotating Disk Diluter MD19-2E is an aerosol dilution unit using the principle of hot dilution. This method keeps the aerosol below its dew point during and after the dilution thus avoiding the generation of volatile particles by nucleation. This diluter is of particular importance as it may be suitable for the number measurements outlined in the UN-ECE Particulate Measurement Programme (PMP).

Solid caesium iodide particles produced by a condensation aerosol generator were used to assess the performance of the diluter. The generator produced a uni-modal polydisperse particle distribution (20 nm modal diameter) with a concentration of the order of 10^6 particles cm^{-3}. Particle concentrations and size distributions were measured upstream and downstream of the diluter operated at a number of temperature settings using a condensation particle counter (CPC) and scanning mobility particle sizer (SMPS). A calibration function was calculated to relate actual dilution performance to diluter setting. An assessment was also made on whether the observed dilution was consistent across all the particle diameters measured.

It is favourable to remove volatile particles from vehicle emissions measurements as they are particles which are highly sensitive to temperature and humidity changes. Volatile particles can introduce significant uncertainty in vehicle emission measurement and their removal generates test data that is much more repeatable. Tetracontane ($C_{40}H_{82}$) particles produced by the same condensation generator were used to assess whether hot dilution was a suitable method to suppress volatile particles. The test aerosol was a uni-modal polydisperse particle distribution (60 nm modal diameter) with a concentration of the order of 10^6 particles cm^{-3}. Significant reductions in particle diameter and concentration were observed downstream of the diluter with the magnitude of the reduction being directly proportional to the diluter temperature setting. Three diluter temperature settings were selected, Room Temperature, 80 °C and 120 °C. It was found that at 80 °C expected number concentrations were close to those anticipated, indicating that no condensation due to cooling is occurring, and that while some evaporation of volatile particles does occur, it is insufficient to completely evaporate a significant number of individual particles.

At 120^{O}C significant numbers of individual volatile particle were completely evaporated during dilution indicating that hot dilution appeared to be a viable method for the suppression of volatile particles from a measured sample of aerosol. Further characterisation is required to establish the conditions under which complete volatile particle removal can be achieved.

Short CV:

Emma Sandbach is a Consultant within the Aerosol Science Centre of **netcen**. She has 3 years technical experience in Aerosol Science, specialising in instrument calibration and measurement of automotive particulate emissions. She recently undertook the role of Vehicle Emissions Measurement Specialist for the UK Department for Transport in the UNECE GRPE Particle Measurement Programme (PMP). Emma is responsible for delivering the vehicle particulate emissions measurements within the Aerosol Science Centre of **netcen**. She is a member of the UK Aerosol Society, Institute of Vehicle Engineers and the Institute of Physics where she is working towards achieving Chartered Physicist Status.

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Summary

Solid caesium iodide particles were used to assess the dilution performance of the diluter. Particle concentrations and size distributions were measured upstream and downstream of the diluter operated at a number of temperature settings using a Condensation Particle Counter (CPC) and Scanning Mobility Particle Sizer (SMPS). A calibration function was calculated to relate actual dilution performance to diluter setting. An assessment was also made on whether the observed dilution was consistent across all the particle diameters measured.

Tetracontane ($C_{40}H_{82}$) particles were used to assess whether hot dilution was a suitable method to suppress volatile particles. Significant reductions in particle diameter and concentration were observed downstream of the diluter with the magnitude of the reduction being directly proportional to the diluter temperature setting.

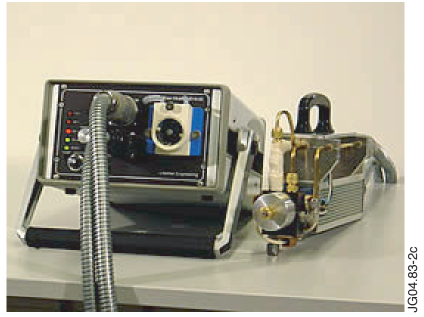

Figure 1: Matter Engineering Rotating Disk Diluter Type MD19-2E

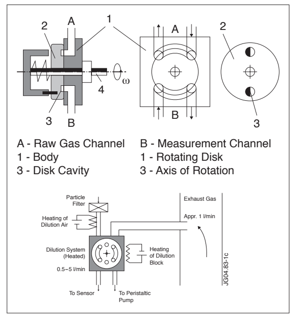

Figure 2: Schematic diagram of rotating disk diluter

Introduction

The Matter Engineering Rotating Disk Diluter MD19-2E is a dilution unit using the principle of hot dilution. This method keeps the aerosol below its dew point during and after the dilution thus avoiding the generation of volatile particles by nucleation. This diluter is of particular importance as it may be suitable for the number measurements outlined in the UN-ECE Particulate Measurement Programme (PMP).

Figure 1 illustrates the principle of the dilution method. There are two separate gas channels: the raw gas channel (A) and the diluted measurement channel (B). A rotating disk (2) is placed in front of the two gas channels and through its cavities (3) transports small volumes of the aerosol from the raw gas channel to the measurement channel. The ratio of the dilution of raw gas is a linear function of the cavity volume, the number of cavities on the disk, the frequency of rotation and the flow in the diluted gas channel.

Method

The experimental set-up is shown in Figure 3. The aerosol generator (shown in Figure 4) was used to generate both solid and volatile particles and consisted of a ceramic crucible heated via an electric Bunsen. The bulk material was placed in the ceramic crucible and was heated to near its boiling point. A small flow was introduced into the crucible to displace vapour from the surface of the bulk material to a cooler region of the generator where condensation occurred. Particle diameters were varied by controlling the rate of vapour transport from the crucible and/or the subsequent cooling rate of the vapour.

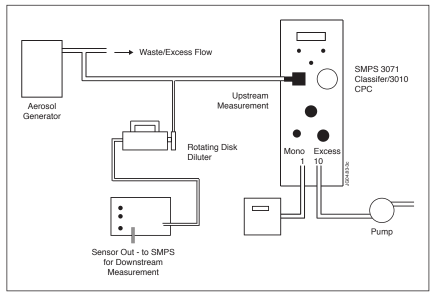

Figure 3 Experimental Set-up for Diluter Assessment

Figure 4: Aerosol Generator

Results

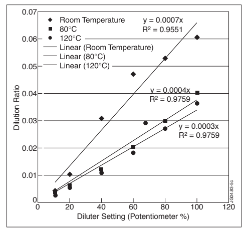

Figure 5 Diluter Calibration (10 Cavity Disk) with Solid Polydisperse Particles

Solid Caesium Iodide Particles

Dilution ratios over the range of diluter operating conditions were established by comparing upstream and downstream particle concentrations of solid polydisperse caesium iodide particles (Figure 5).

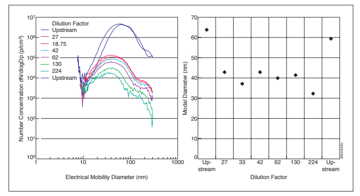

Figure 6: Polydisperse volatile aerosol at 80°C

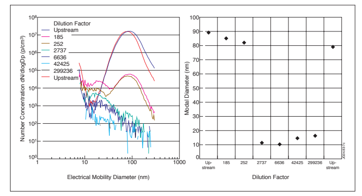

Figure 7: Polydisperse volatile aerosol at 120°C

Volatile Tetracontane Particles

The diluter was used to condition polydisperse distribution of volatile caesium iodide particles at room temperature, 80°C and 120°C. Examples of the resulting SMPS-measured size distributions are reported in Figures 6 and 7, along with indications of changes in modal diameter with temperature and diluter setting.

Dilution at elevated temperature reduces the number concentration of volatile particles. However, it was necessary to establish whether the reduced number concentrations observed were consistent with the dilution settings employed or whether an additional reduction in particle number concentration had occurred as a consequence of the elevated dilution gas temperatures. The modal diameter of volatile particles was smaller at higher dilution temperatures suggesting that some volatile particle evaporation had taken place. Any additional particle number reduction was assessed by calculating the expected downstream number concentration using the calibration ratios determined with solid non-volatile particles (Figure 5) and comparing this concentration with the actual concentration measured when testing with volatile particles. These concentrations were expressed as a ratio of expected concentration:measured concentration which was given the label of "suppression ratio". Suppression ratios larger than unity indicate that enhanced reduction in particle number concentration has occurred over and above that predicted from dilution factors alone. The calculated suppression ratios calculated for the diluter are shown in Figure 8.

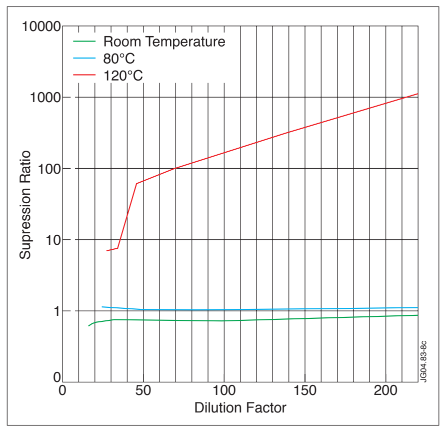

Figure 8 Suppression Ratios as a Function of Dilution Factors and Temperatures

At room temperature the suppression ratio is smaller than unity. This could indicate that there is either generation of particles by condensation occurring due to the cooling effect of the dilution, or there is a decrease in losses of particles due to diffusion if the modal diameter of the volatile aerosol is significantly larger than that of the solid particles used in the dilution factor calibration.

At 80°C the expected number concentrations were close to those anticipated, indicating that no condensation due to cooling is occurring, and that while some evaporation of volatile particles does occur (See Figure 8), it is insufficient to completely evaporate a significant number of individual particles. This observation suggests a further obvious dependence of suppression ratio on the initial diameter of the volatile particles under dilution.

Conclusion

Hot dilution appears to be a viable method for the suppression of volatile particles from a measured sample of aerosol. Further characterisation is required to establish the conditions under which complete volatile particle removal can be achieved.

References

Ch. Hueglin, L, Scherrer and H. Burtscher "An accurate, continuously adjustable dilution system (1:10 to $1:10^4$) for submicron aerosols" J. Aerosol Sci. 28 (6)

Matter Engineering AG Operation Handbook Rotating Disk Diluter type MD19-2E for Particulate Emissions

Acknowledgments

This work was funded through the UK DTI Valid Analytical Measurement (VAM) programme.