FAST SCANNING USING TSI'S SCANNING MOBILITY PARTICLE SIZER™ (SMPS™) SPECTROMETER MODEL 3938

APPLICATION NOTE SMPS-006

TSI® Incorporated's Scanning Mobility Particle Sizer™ (SMPS™) spectrometer is widely used as the standard for measuring airborne particle size distributions and is also used to measure the size of nanoparticles suspended in liquids. SMPS spectrometer sizing is a discreet technique in which number concentrations are measured directly, with a high degree of absolute sizing accuracy and measurement repeatability. TSI's Model 3938 is the third generation of SMPS spectrometer, trusted by researchers for over 30 years.

The Model 3938 features ease-of-use improvements and advanced performance capabilities. Among these, a key feature of the Model 3938 is its fast scanning capability. The Model 3938 enables SMPS measurements with less than 10 seconds scanning time, allowing higher temporal resolution for tracking changes in aerosol size and concentration.

Fast Scanning Measurements

The fast scanning capability of the Model 3938 SMPS spectrometer is demonstrated by measurements of soot particles generated by a toaster. The toaster was operated in a 70 m^2 room; measurements were made during toaster operation for 3 minutes, with the SMPS spectrometer approximately 6 m from the toaster. Two Model 3938 SMPS systems were used: one was set for 5-s scans, and the other was set for 60-s scans (Fig. 1).

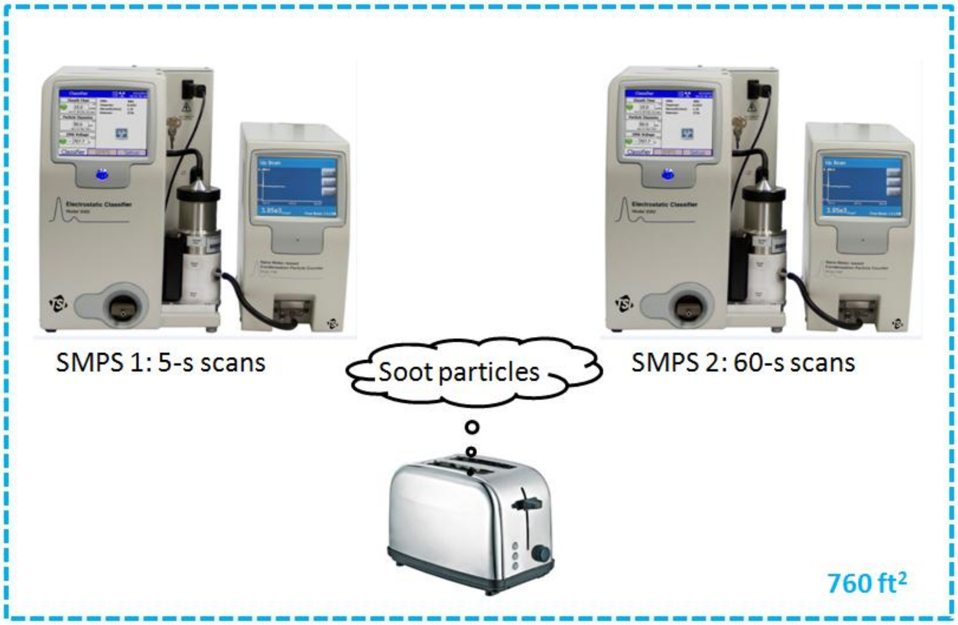

Figure 1: SMPS spectrometer set-up for fast scanning measurements of soot aerosol.

Results

The results in Figure 2 show particle size distribution measurements during toaster operation with 5-s scans and 60-s scans, respectively.

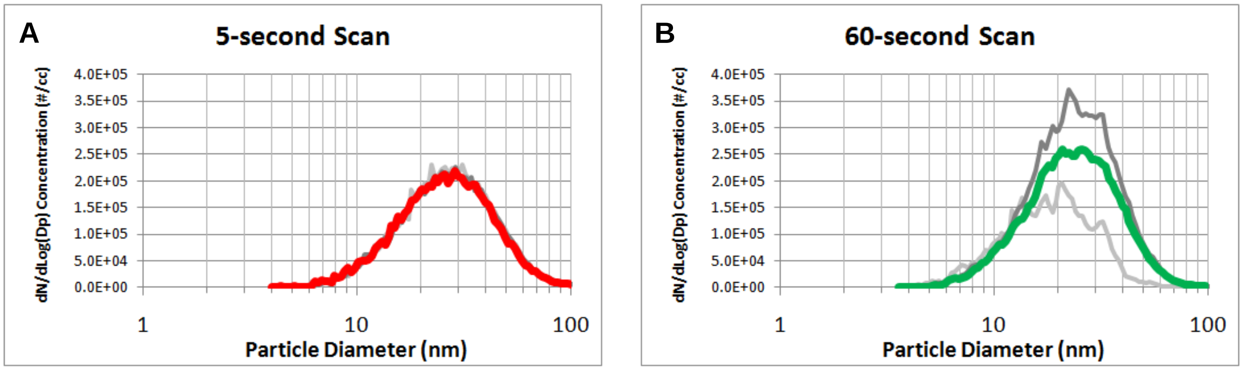

Figure 2: Particle size distributions during toaster operation, measured with (A) 5-s scans and (B) with 60-s scans.

The data in Fig. 2 demonstrate that faster scanning can capture changes in aerosol size or concentration that occur on a time scale of seconds rather than minutes. Figures 2A and 2B show three consecutive scans collected in 5 s and 60 s, respectively. The three distributions in Fig. 2B differ significantly because the 60-s scan time is too long to capture the dynamic nature of the soot aerosol. In contrast, the three distributions in Fig. 2A are nearly identical because the 5-s scan time is fast enough to monitor the aerosol on a relevant time scale.

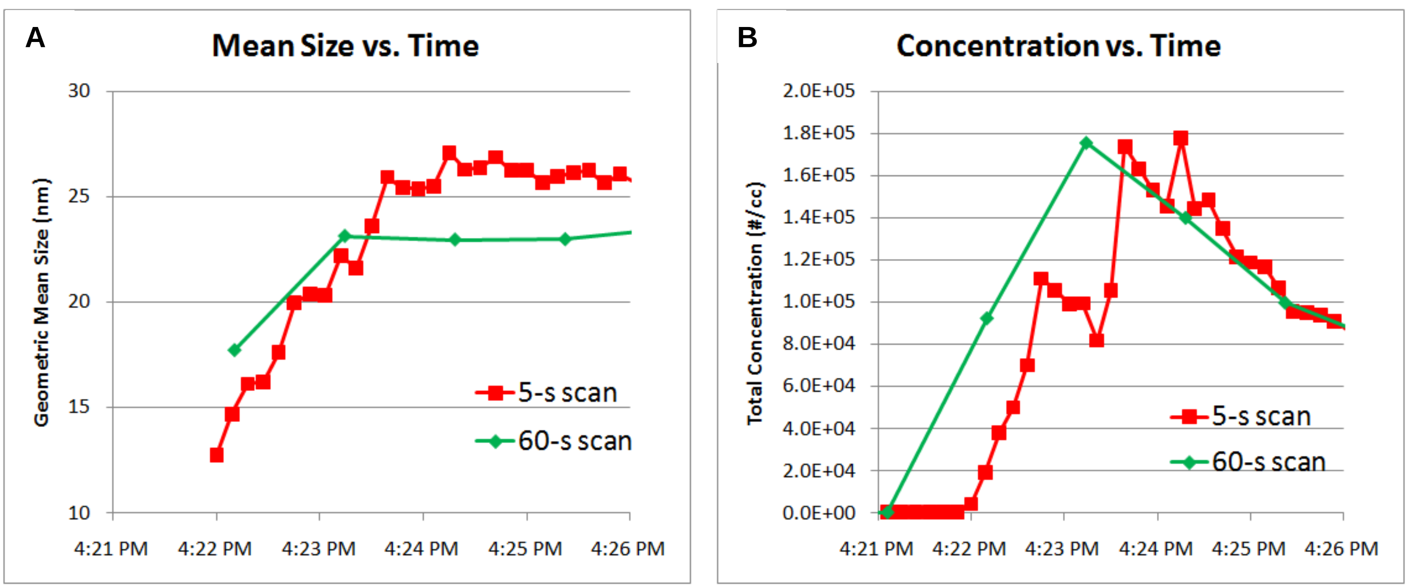

Figure 3: (A) Mean size and (B) total concentration vs. time during toaster operation, measured with 5-s scans and 60-s scans.

Figure 3 demonstrates the greater temporal resolution of the faster scans. In Fig. 3A, the mean particle size is plotted over time. The 60-s data show one notable change in mean size, from 4:22 to 4:23 PM; after the initial increase, the size remains stable. However, the 5-s data reveal a more dynamic nature; although the particle size follows an increasing trend, it does not increase continuously during the first 1–2 minutes of toaster operation. Instead, there are increases, plateaus, and decreases in the mean size. Also, the size continues to increase until after 4:24 PM, while the 60-s scans show a plateau after 4:23 PM. Because of the longer scan time, the 60-s data show a smaller maximum particle size compared with the 5-s data (23 nm vs. 27 nm).

In Fig. 3B, total concentration is plotted over time. The 60-s data show one peak in concentration, where the particle concentration increased during the first 2 minutes and then decreased. The 5-s data show a similar maximum concentration, but the maximum occurs about 1 minute later compared with the 60-s data. Also, there are three distinct concentration peaks and a more rapid decrease in concentration for the 5-s data. The temporal resolution of the faster scanning is able to capture fluctuations in concentration that are too fast to be detected by the longer scan time.

Fast Scanning – Considerations and Trade-offs

Fast scanning is well suited for polydisperse distributions at high concentrations. Faster scans are less ideal for monodisperse aerosols and low concentrations. There is a trade-off between resolution and scan time due to basic physical principles (Fig. 4). Faster scans result in fewer particles counted; thus, counting statistics become poorer as scan time decreases. The geometric standard deviation (σ_g) of the measured particle size increases as scan time decreases [1]. Results are shown for SMPS measurements at different scan times using the Model 3788 Condensation Particle Counter. At scan times greater than 20 seconds, the effect is negligible, increasing to 3% σ_g at 5 seconds. For certain applications, 3% standard deviation is acceptable, whereas other applications may require < 1% and would therefore benefit from longer scan times.

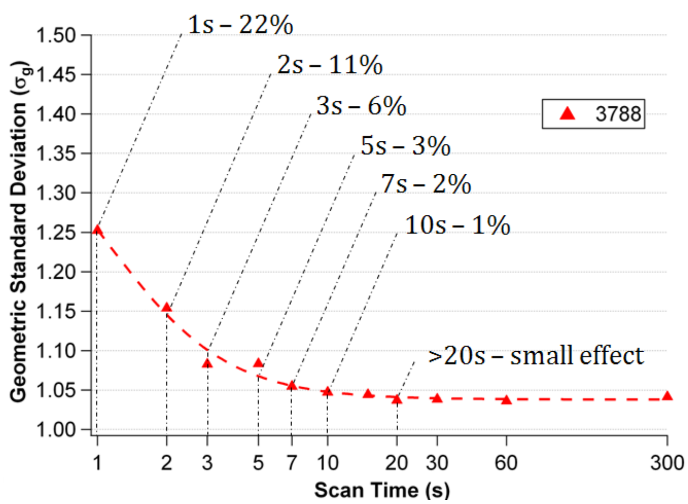

Figure 4: Geometric standard deviation (σ_g) of the measured particle size as a function of scan time for SMPS measurements using the Model 3788 Condensation Particle Counter [1].

For best results, (1) use CPCs with the fastest response times (3776, 3788) for high resolution, (2) use a short tube length (<25 cm) between the DMA and the CPC to reduce peak broadening, and (3) note that the time delay in the software can be adjusted for customized setups to improve accuracy.

Summary

The newest generation of SMPS Spectrometer, Model 3938, has the ability to collect a particle size distribution in a faster scan time of <10 seconds. The size resolution can be affected by scan time and can depend on several factors, including the aerosol concentration and CPC response time. Thus, the desired level of precision should be considered when setting the scan time. The data shown herein represent 5-s scans for a fast-changing aerosol at high concentrations. This application demonstrates the unique advantages of fast scanning for capturing changes in particle size and concentration with high temporal resolution.

Reference

Erickson et al. (2012), "Investigation of Fast Scanning SMPS Measurements: 16s and Below." *Presented at EAC 2012*, WG08S3O5

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