REPRODUCIBILITY OF ENGINE EXHAUST PARTICLE SIZER™ (EEPS™) SPECTROMETER MODEL 3090

APPLICATION NOTE EEPS-008 (A4)

Contents

Introduction

TSI's Engine Exhaust Particle Sizer™ (EEPS™) spectrometer measures the size distribution and number concentration of engine exhaust particulates with a time resolution of 0.1 seconds. EEPS spectrometer measures particle size in 32 channels from 5.6 to 560 nm, and can measure particle number concentrations as low as 3000 particles cm^{-3}. The EEPS spectrometer has found wide adoption in the engine emissions market sector; as the regulatory environment continues to challenge engine manufacturers, the capabilities of the EEPS spectrometer will become increasingly valuable to those in that sector. When data—such as number concentration—are critical, can the EEPS spectrometer be relied upon? Looking at EEPS spectrometer performance relative to the competition, as well as to the instrument-to-instrument consistency of EEPS spectrometer as they are manufactured, reveals the consistency and high performance of this fleet of instruments.

EEPS Spectrometer *vs.* the Competition

In 2006 the Japan Clean Air Program tested a total of 14 fast-sizing instruments (eight EEPS instruments from TSI, and six instruments from a competitor) against a Scanning Mobility Particle Sizer™ (SMPS™) spectrometer under a variety of conditions to explore the sizing and counting accuracy of the instruments (Ikeda & Iwakiri 2006). The aerosol source for these tests was a 2002 diesel light-duty truck, operated under a variety of conditions. Emissions from the truck were diluted and introduced into a sampling manifold, from which all fast sizers, as well as the SMPS spectrometer, drew their samples.

Results from this testing showed that compared to the competitor's instruments, the TSI EEPS spectrometer was both more precise and more accurate with respect to measuring both particle size and particle number concentrations. In fact, particle number concentrations as detected by the two types of fast sizers could vary by as much as a factor of two; the authors of the study concluded that comparing number concentrations measured by the two different instruments is not advisable.

While this study demonstrates the strength of EEPS spectrometer relative to the competition, it was performed with only eight EEPS instruments. Ten years later, would a similar study reach the same conclusion? Examining TSI's manufacturing data on every individual instrument ever produced demonstrates the consistency of EEPS spectrometer.

EEPS Instruments: Over a Decade of Consistency

Before each EEPS instrument is shipped to a customer, it is tested against both an SMPS and a Condensation Particle Counter (CPC) to ensure it sizes and counts aerosol particles accurately. It is challenged with a monodisperse 100 nm aerosol, as well as a polydisperse aerosol; results from both of these challenges are compared to measurements made by both of the other instruments.

Repeatability in Particle Sizing

A fast particle sizer is only as good as its sizing accuracy, and the gold standard for sizing accuracy is the SMPS. When challenged with a monodisperse 100 nm aerosol, EEPS instruments' measurement of these particles agrees with SMPS measurements within a few percent, as shown in Figure 1.

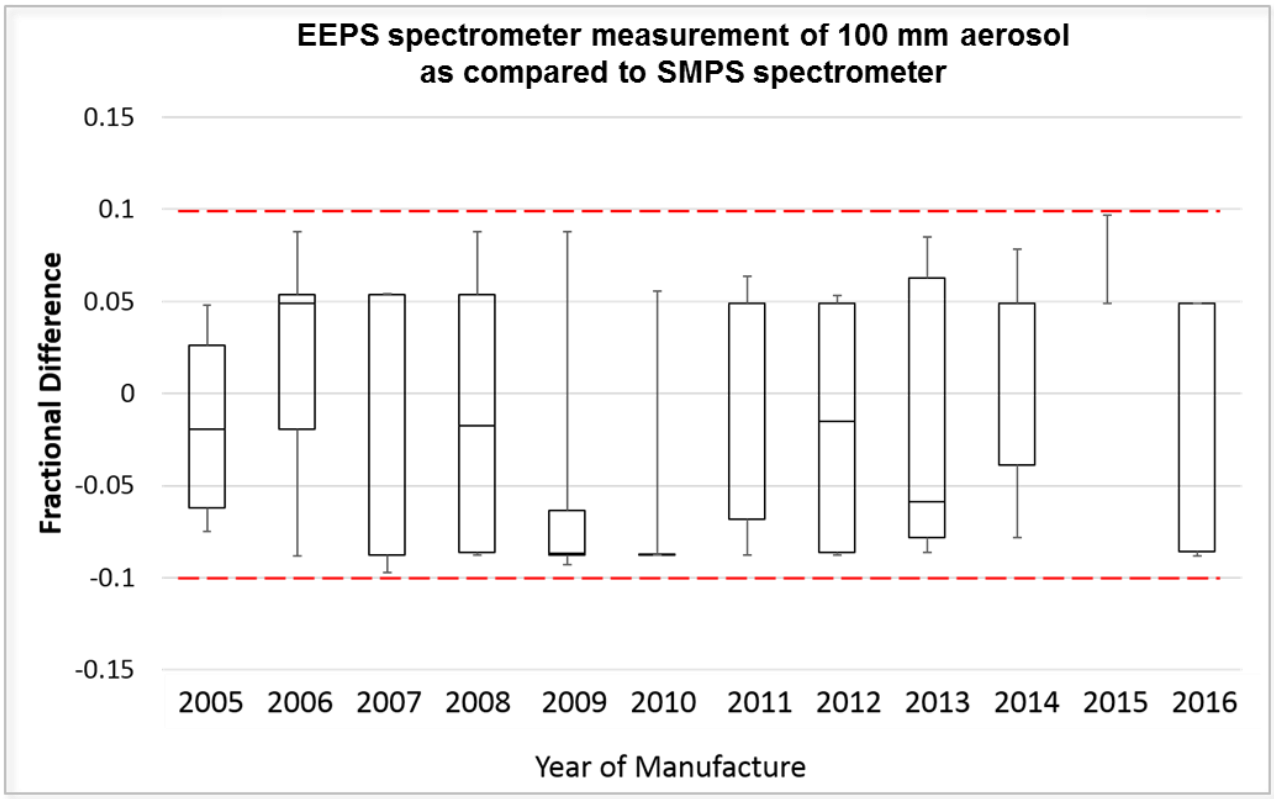

Figure 1: EEPS instruments' measurement of 100 nm classified aerosol, compared to SMPS spectrometer measurement of the same aerosol, grouped by year of manufacture. The oddly shaped plot for 2015 is due to the fact that 92% of EEPS instruments manufactured that year deviated from SMPS measurements by the same value, ~ 5%. The dashed lines represent ±10%, TSI's internal requirement for EEPS–SMPS agreement.

In addition to pre-classified aerosol, each EEPS instrument is challenged with a polydisperse aerosol. The mode (most common) particle size measured by the EEPS spectrometer is then compared to the mode as measured by SMPS. Figure 2 shows that since 2011, every single EEPS instrument sizes the polydisperse aerosol comparably to an SMPS spectrometer.

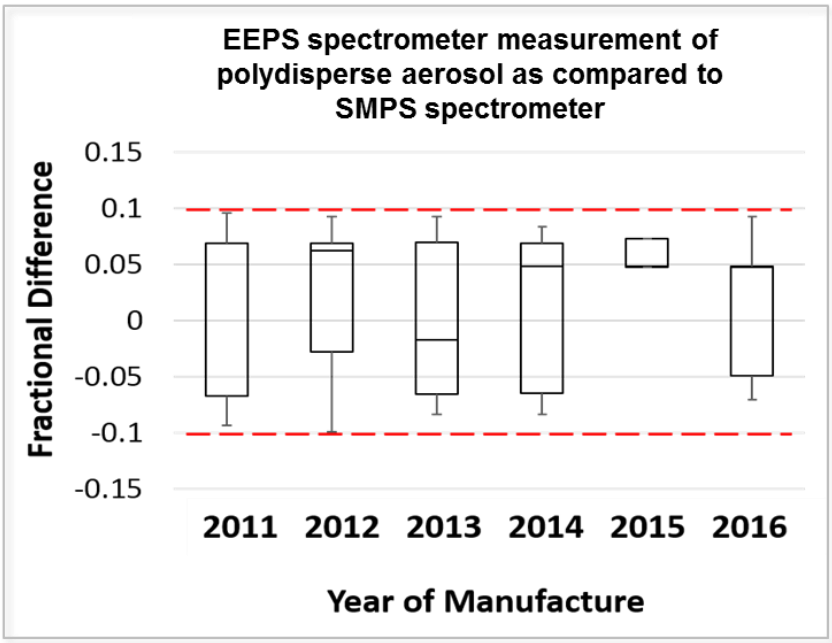

Figure 2: EEPS instruments' sizing of polydisperse aerosol, as compared to SMPS spectrometer, grouped by year of manufacture.

Repeatability in Particle Counting

Particle number concentrations are a valuable metric, and EEPS instruments are ever becoming more precise in this regard. Figure 3 shows how, on an annual basis, EEPS instruments' response compares to a CPC when both are challenged with a 100 nm classified aerosol. While every single EEPS instrument falls within TSI's internal specifications, repeatability is becoming sharper with time. EEPS spectrometer' particle number concentration measurement of a polydisperse aerosol is also growing more precise with time, as shown in Figure 4.

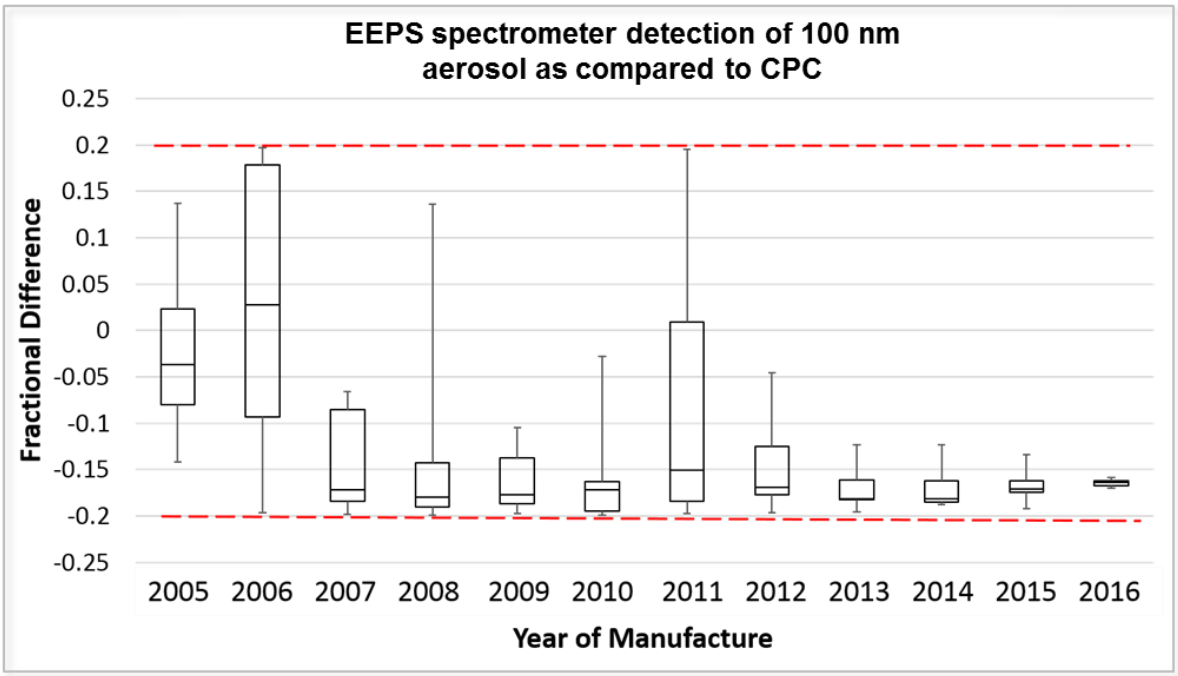

Figure 3: EEPS instruments' detection of monodisperse aerosol, as compared to CPC.

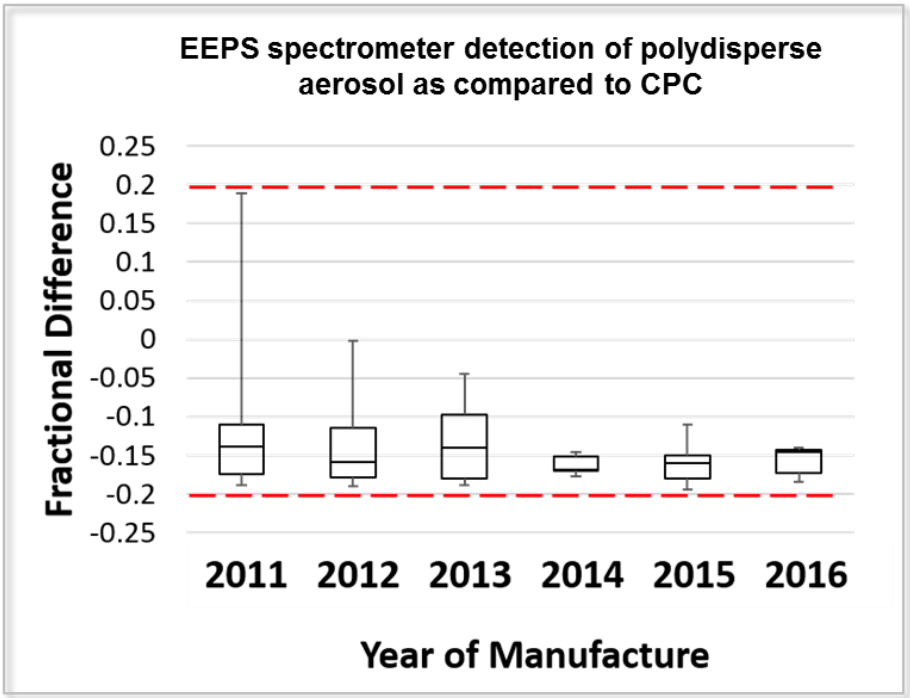

Figure 4: EEPS instruments' detection of polydisperse aerosol, as compared to CPC, grouped by year of manufacture.

Conclusions

TSI's Engine Exhaust Particle Sizer spectrometer has established itself as a valuable tool for measuring engine emissions, as well as other fast-changing aerosols. It has been shown to count and size particles more accurately than the competition, and TSI's manufacturing procedures have resulted in a fleet of instruments capable of producing repeatable and reliable measurements.

References

Ikeda, T. and Iwakiri, Y. JCAP II Cross Check Tests on High-Speed Particle Sizing Instruments. *10th ETH Conference on Combustion Generated Nanoparticles*, 2006

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