SUMMARY: INVERSION MATRICES FOR ENGINE EXHAUST PARTICLE SIZER™ (EEPS™) SPECTROMETER MODEL 3090

APPLICATION NOTE EEPS-006 (US)

Contents

Introduction

To improve the agreement between EEPS™ spectrometer and SMPS™ spectrometer measurements, especially at larger particle sizes, TSI has developed two new matrices; one for compact aerosols (IM-compact) and one for soot-like agglomerate aerosols (IM-soot).

Observed EEPS Spectrometer and SMPS Spectrometer Discrepancy

Discrepancies between EEPS spectrometer and SMPS spectrometer PSDs have been reported by several sources. It has been reported that for small particles (<~75 nm) the size and concentration of particles as measured by EEPS spectrometer is consistent with SMPS spectrometer measurements; however, above 75 nm, the EEPS spectrometer begins to undersize particles, resulting in narrower particle distributions. It has also been reported that the discrepancy in sizing is more severe when sampling agglomerate particles such as engine soot.

Cause of EEPS Spectrometer and SMPS Spectrometer Discrepancy

Charging in a bipolar charger is dominated by diffusion, and the steady state charge distribution was determined by Fuchs and approximated by Wiedensohler. In this size range, bipolar charging is roughly independent of particle morphology, and the majority of particles exiting a bipolar charger have zero or one charge. As particle size increases the fraction of particles carrying multiple charges also increases. For non-spherical particles (like soot agglomerates) the surface area of the particles is significantly larger than the equivalent sphere (measured by SMPS). When a unipolar charger (as in the EEPS) is used this can result in a higher charge level for non-spherical particles and the result can be an undersizing of the particles.

Results Using New Matrices

The IM-compact and IM-soot matrices were evaluated by comparing SMPS spectrometer measurements to EEPS spectrometer measurements processed with the compact and soot matrices for compact aerosols and engine exhaust, respectively. Multiple EEPS units were tested on a variety of aerosol types to determine the bulk effect of the alternative matrices.

Compact Inversion Matrix Results

The EEPS spectrometer compact matrix results in much better agreement with the SMPS spectrometer size distributions. As the mode particle diameter increases the undersizing of the default matrix becomes apparent as does a narrowing of the size distribution. However, if the compact matrix is used, the resulting EEPS spectrometer distributions much more closely match the SMPS spectrometer distribution in both sizing (mean and width) and concentration. When the data are plotted on a volume weighted scale, the default matrix greatly underestimates particle volume. When using the compact matrix, the discrepancy in volume is significantly reduced.

Soot Inversion Matrix Results

Data were collected by EEPS spectrometer and SMPS spectrometer on multiple engine types running at several different conditions and compared to evaluate the performance of the EEPS spectrometer soot matrix. For both the low load and high load engine conditions, the EEPS spectrometer data processed with the soot matrix more closely match SMPS spectrometer data than EEPS spectrometer data processed using the default matrix. Additionally because the sizing of particles larger than 75 nm is drastically improved, when weighted for volume, the EEPS spectrometer soot matrix again agrees with SMPS spectrometer much more closely.

As a result of improved sizing performance, the agreement between SMPS spectrometer measured volume distributions and EEPS spectrometer measured volume distributions is significantly improved. Together with an assumption of soot density, the use of the soot inversion matrix significantly improves the ability of EEPS spectrometer to measure soot mass.

Overall Sizing Comparison

To examine the bulk sizing performance of the soot and compact EEPS spectrometer matrices, the mean diameter of several compact aerosols as measured by EEPS spectrometer. Using the default matrix, the mean diameter as measured by EEPS spectrometer is roughly 60% of that as measured by SMPS spectrometer. When the compact matrix is applied, the data follow a 1:1 trend across the entire size range. Likewise, for several different engine models and operating conditions, the geometric mean diameters as measured by EEPS spectrometer using the soot matrix follow a 1:1 trend with the geometric mean diameters as measured by SMPS spectrometer.

Software and Firmware Updates

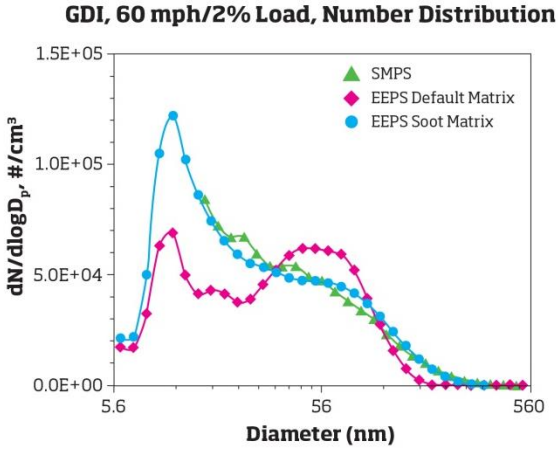
TSI has released MCU firmware version 3.13 and software version 3.2.5. Firmware version 3.13 allows an inversion matrix other than the default to be uploaded onto the EEPS instruments itself, displaying data on the front panel processed with the uploaded matrix. Software version 3.2.5 and firmware version 3.13 are available as free upgrades. Contact TSI support at particle@tsi.com, with the serial number and firmware version of the instrument to be upgraded. To upgrade to firmware version 3.13, the existing EEPS spectrometer firmware version must be version 3.0 or greater. Firmware version older than 3.0 cannot be upgraded to version 3.13 without being sent back to TSI for service due to hardware changes.

Using an Alternative Matrix in EEPS Spectrometer Software Version 3.2.5

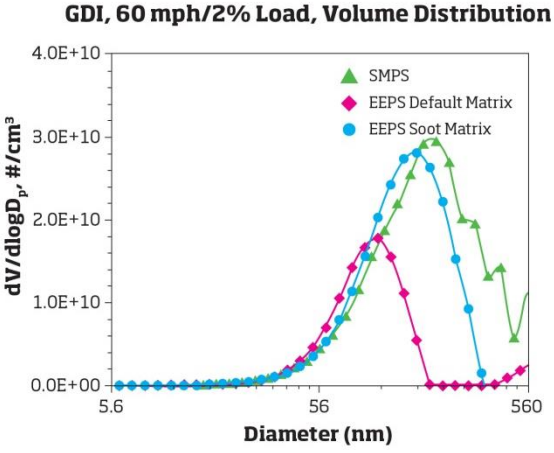
Information on using an alternative EEPS spectrometer matrix can be found in the EEPS spectrometer instruction manual located in the EEPS spectrometer software installation directory. Briefly, to reprocess data from an existing file, open the data file and navigate to the properties window by clicking **File>Properties**. In the "Instrument Matrix" section choose from "**DEFAULT**", "**COMPACT**", "**SOOT**", or a custom matrix from the drop down menu to select one of the alternate matrices. Click **Apply** to reprocess the data file. The file can then be saved under a different file name or can be saved over the existing file.

Which Inversion Matrix Should I use?

EEPS spectrometer Software version 3.2.5 allows the user to collect, and process data using any of the three included matrices (default, compact, soot) in addition to any custom matrices that may be created. In general, the soot matrix should be used for engine exhaust and the compact matrix reserved for studies in which it is known that the aerosol being sampled is near-spherical in nature.



The number distribution of engine emissions as measured by an SMPS spectrometer, and by the EEPS spectrometer using two data inversion matrices.



The volume distribution of engine emissions as measured by an SMPS spectrometer, and by the EEPS spectrometer using two data inversion matrices.

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