# Comparison of Experimental and First Principles Modeling Results for the PMTrac® Electrostatic Soot Sensor

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This presentation summarizes results to date by EmiSense and our strategic partners to design, fabricate, test, and characterize our latest generation (B2) of PMTrac sensors and develop a first-principles-based model that characterizes sensor performance. Our model predicts the PMTrac sensor's signal (nA) as a function of soot mass concentration (mg/m3), exhaust gas temperature (EGT), exhaust gas velocity (EGV), and soot particle size (nm). The PMTrac sensor is an in situ electrostatic soot sensor with a concentric electrode design similar to a differential mobility analyzer (DMA). The electrostatic and particle physics equations developed for the DMA[2, 3] are valid, but the isothermal and constant sample flow assumptions aren't. Thus, we must determine the actual temperature and sensor sample flow rate (since the sensor operates directly in the exhaust over a wide range of EGVs and EGTs without a sample pump). Our sensor model also contains heat transfer and computational fluid dynamics (CFD) flow modules in addition to an electrostatic and particle physics module.

The PMTrac sensor model agrees well with experimental test results over a wide range of test conditions ($150 < \mathrm{EGT}\ (^{o}\mathrm{C}) < 500$, $10 < \mathrm{EGV}\ (\mathrm{m/s}) < 90$, $1 < \mathrm{PM}\ (\mathrm{mg/m}^3) < 18$) for different soot sources. The following test platforms were used: 1) a small (675 cc) diesel generator (1992 Onan 4.0kW Genset) with heated dilution air, 2) an engine dynamometer using a 1998 DDC Series 60 heavy-duty highway 12.7 L engine as part of EmiSense testing as well as SwRI's PSPD consortium, [4] and 3) a Jing mini-CAST soot generator.

The sensor was characterized using a Jing mini-CAST soot generator to generate monodisperse and/or bimodal soot particles ranging in geometric mean diameter (GMD) from approximately 15 to 110 nm. A TSI Scanning Mobility Particle Sizer (SMPS) was used to characterize particle size and charge distribution of soot entering and leaving the sensor. The influence of PSD, charge distribution, applied voltage, and sample flow rate on sensor output was characterized. The PMTrac sensor signal is amplified several orders of magnitude higher than expected if the observed current were solely caused by combustion-generated charged particles depositing their charge. These tests have enabled us to gain a better understanding of the sensor's operating principle, validate our unified sensor model, and confirm our signal amplification mechanism. Additional detailed results and discussion of the electroagglomeration mechanism will be presented.

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[1] Presenter
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[3] DB Kittelson et al., "Electrostatic Collection of Diesel Particles," SAE 860009, (1986).
[4] I Khalek, "Particle Sensor Performance and Durability (PSPD) for OBD Applications and Beyond," UCR PM PEMS Conference (2013).