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Evaluation of Instruments for Vehicle Emission Particle Sizing

Evaluation of Instrumentation for Vehicle Emission Particle Sizing

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DOE/DOESMMI Instrument Evaluation - Objectives

- Re-Design Sampling Arrangement
- Test QCM with Charge Equilibration
- Assess ELPI
- Assess Accuracy of SMPS Reported Concentrations
- Evaluate TEOM for Real-Time Measurements
- Evaluate Anderson MkIII



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DOT/DOE/SWIFT Instrument Evaluation - Project Structure

- * Stage I
 - Sample Column Design
 - ELPI/SMPS Calibration
- * Stage II
 - Steady-State Evaluation
- * Stage III
 - Transient Evaluation



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DOT/DOE/SWIFT Instrument Evaluation - Test Instruments

- * SMPS
- * QCM
- * ELPI
- * TEOM
- * Anderson MkIII



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Petri dish/SMIVR Instrument Evaluation - Sample Column

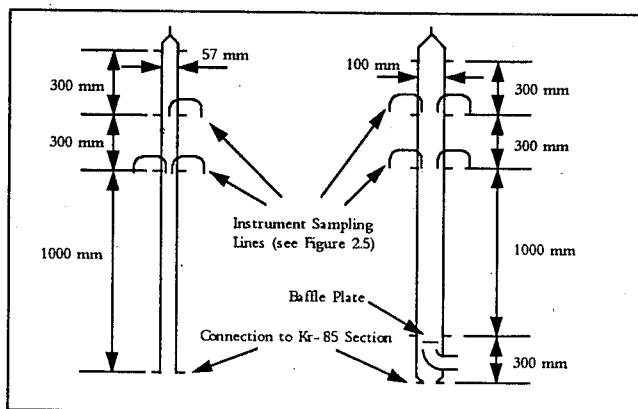
- Minimise Sampling Loss
- Allow Charge Equilibration
- Use Regulated Sample Probe (Without Chinese Hat)
- Instrument Sample Probes to Match Instrument Inlets
- Allow Further Dilution



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Petri dish/SMIVR Instrument Evaluation - Sample Column

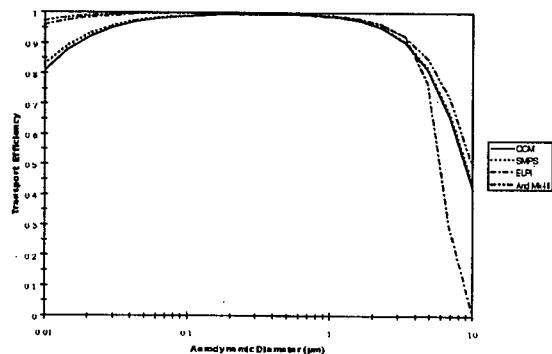


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DOE/DOE/SMMT Instrumentation Evaluation - Sample Column

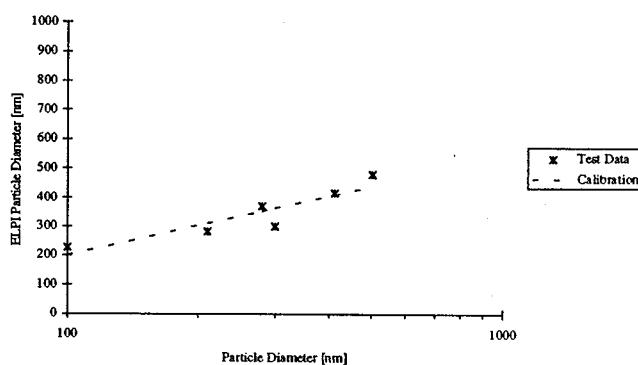
Total Transport Efficiency for each Instrument



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DOE/DOE/SMMT Instrumentation Evaluation - ELP Calibration



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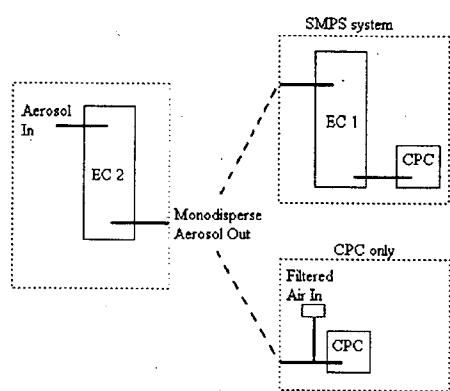
DO/DDESMVII Instrument Evaluation - ELPI Calibration

- Mass mode calibration close to manufacturers calibration
- Number mode calibration does not agree with mass mode calibration.
Small particles (~100nm) land on higher stages



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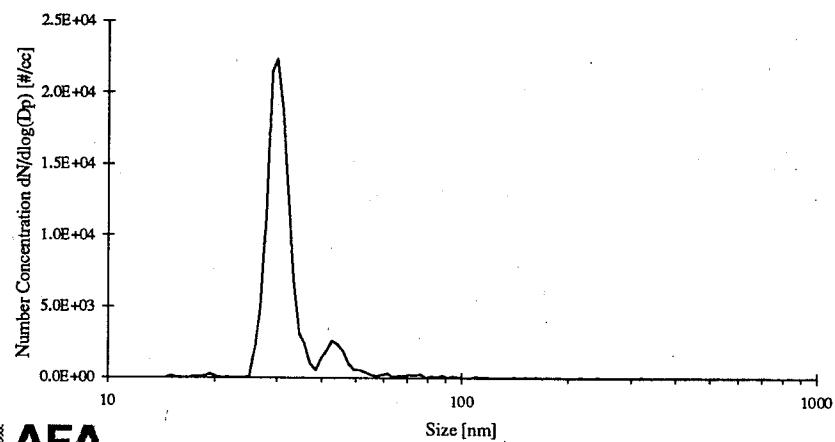
DO/DDESMVII Instrument Evaluation - SMPS Calibration



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PILOT/PROFSIMMIT Instrument Evaluation - SMPS Calibration

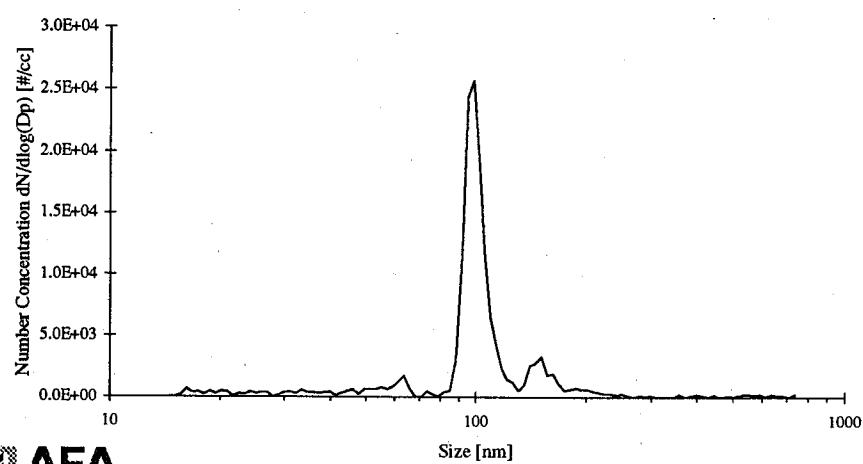
30nm Diesel Particles



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PILOT/PROFSIMMIT Instrument Evaluation - SMPS Calibration

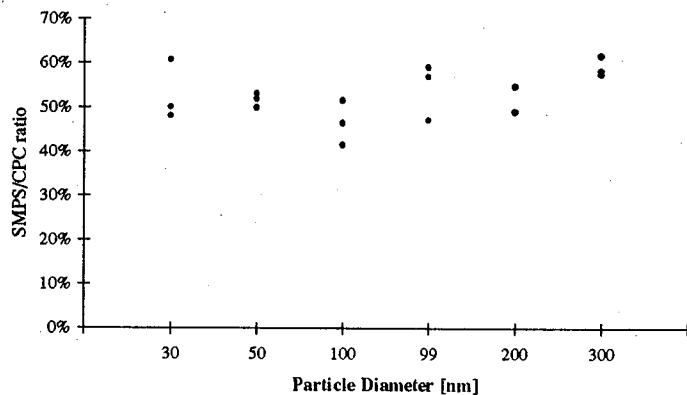
100nm Polystyrene Particles



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DOE/DOE/SMPS Instrument Evaluation - SMPS Calibration

SMPS Concentration Calibration



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DOE/DOE/SMPS Instrument Evaluation - SMPS Calibration

- SMPS Size Calibration Excellent
- Reported Concentration Systematically Lower than 'True' Concentration by a Factor of 2
- Size Selection for Transient Tests Very Good



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DOP/DPS/SMPS Instrument Evaluation - Steady State

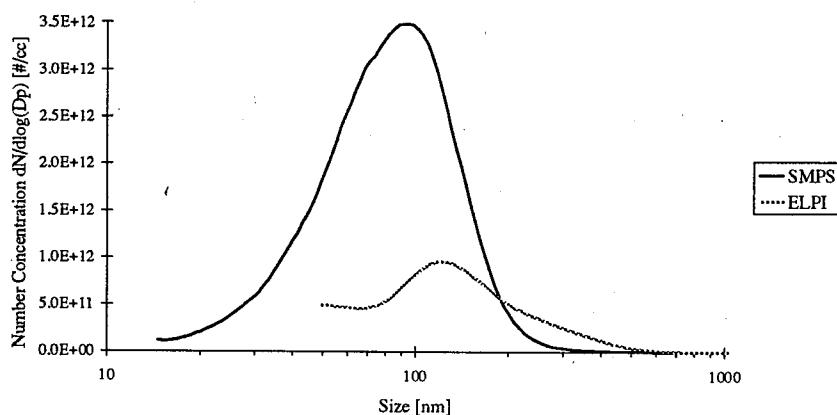
- Performed on Light-Duty CVS Tunnel
- 8.5 Kw Diesel Twin-Cylinder Engine
- Sampling Column
- Number Distributions
 - SMPS, ELPI
- Mass Distributions
 - ELPI, QCM, TEOM, Anderson MkIII
 - SMPS (Volume)



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DOP/DPS/SMPS Instrument Evaluation - Number Mode

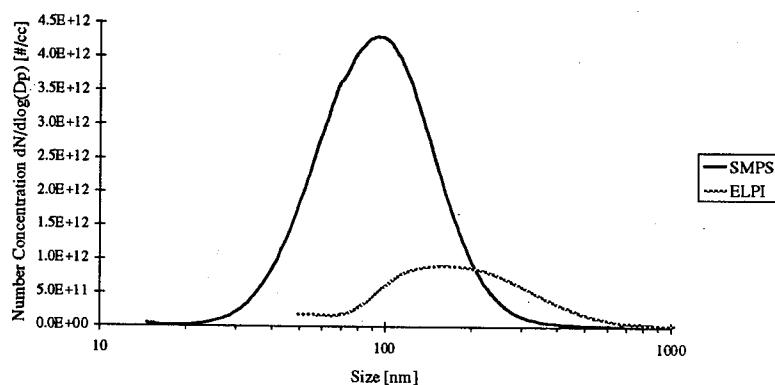
0load-2



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DOP/DOS/SMPS Instrument Evaluation - Number Mode

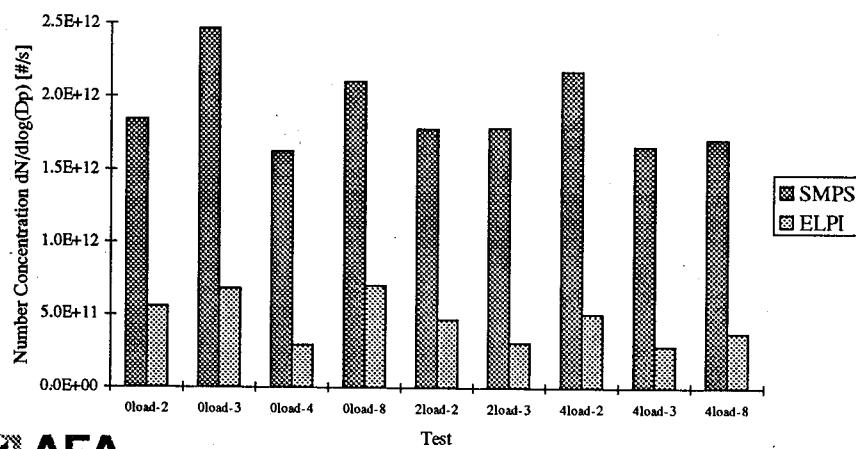
4load-2



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DOP/DOS/SMPS Instrument Evaluation - Number Mode

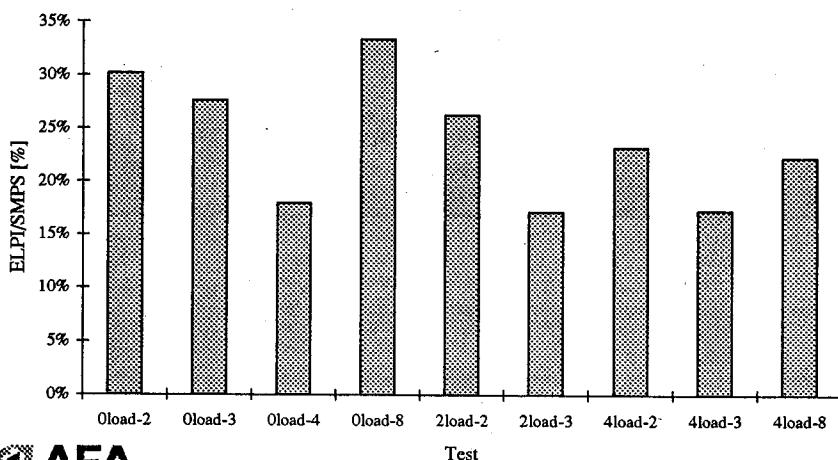
Total Particle Flux



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Dior/Bore/SMMI Instrument Evaluation - Number Mode

ELPI to SMPS Total Particle Flux Ratio

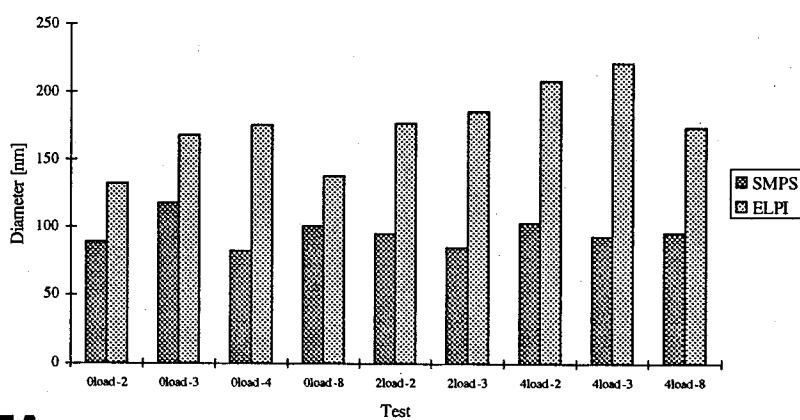


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Dior/Bore/SMMI Instrument Evaluation - Number Mode

Mean Particle Diameter



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DO/DOE/ESM/MTI Instrument Evaluation - Number Mode

- Correlation Between SMPS and ELPI
Number Distribution Shape
- ELPI Number Concentration
 $24\% \pm 6\%$ of SMPS Value
- ELPI reports higher particle size than
SMPS



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DO/DOE/ESM/MTI Instrument Evaluation - QCM

QCM Total Mass

Test	Charge Equilibration	QCM/Average of ELPI, TEOM, Anderson
Oload-6	No	11%
2load-6	No	2%
Oload-7	Yes	13%
4load-9	Yes	9%
4load-a	Yes	3%
Oload-a	Yes	13%
Oload-b	Yes	11%

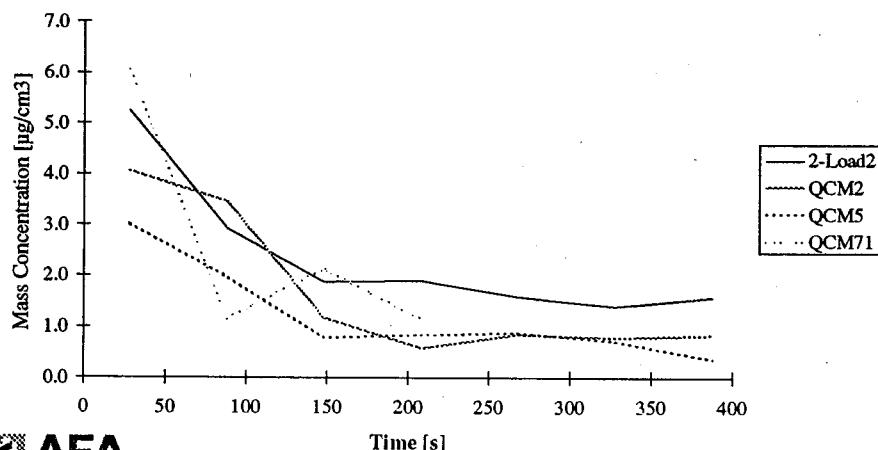


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Plot/POE/SMMI Instrument Evaluation - QCM

QCM Time Response to Steady State

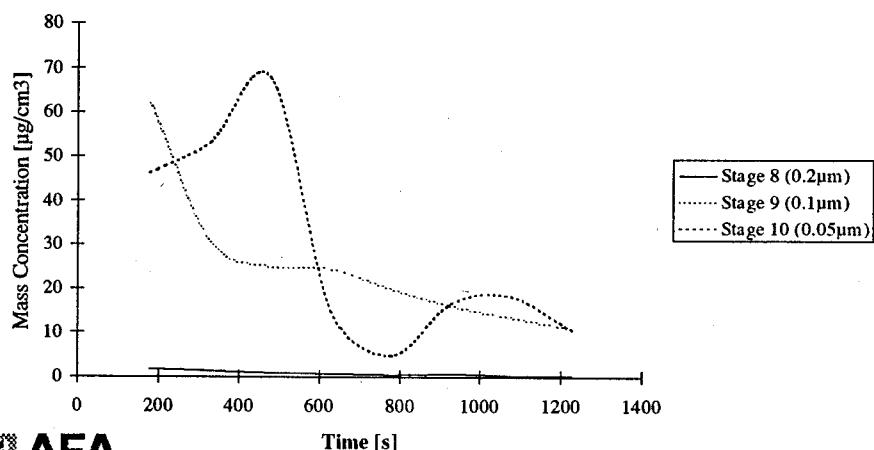


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Plot/POE/SMMI Instrument Evaluation - QCM

QCM Stage Mass Concentration



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POV/PoE/SMMT Instruments Evaluation - QCM

- ❖ QCM Unaffected by Charge Equilibration
- ❖ QCM Reported Mass Concentrations Low
- ❖ Loss of Stage Collection Efficiency Against Time (Loading)
- ❖ QCM Unsuitable for Vehicle Emissions

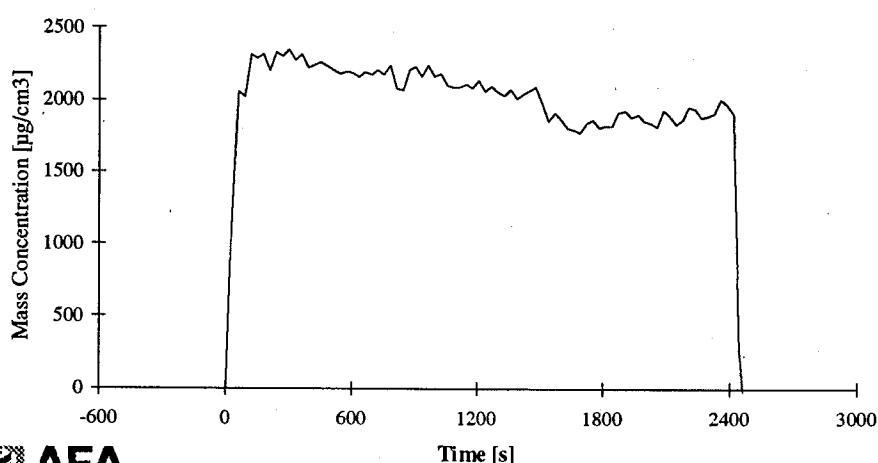


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POV/PoE/SMMT Instruments Evaluation - TEOM

TEOM Mass Concentration

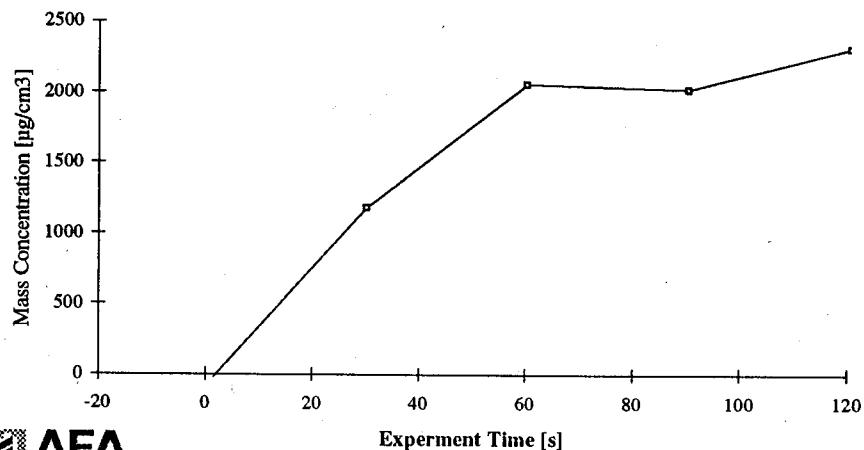


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DOP/DEPM INSTRUMENT Evaluation - TEOM

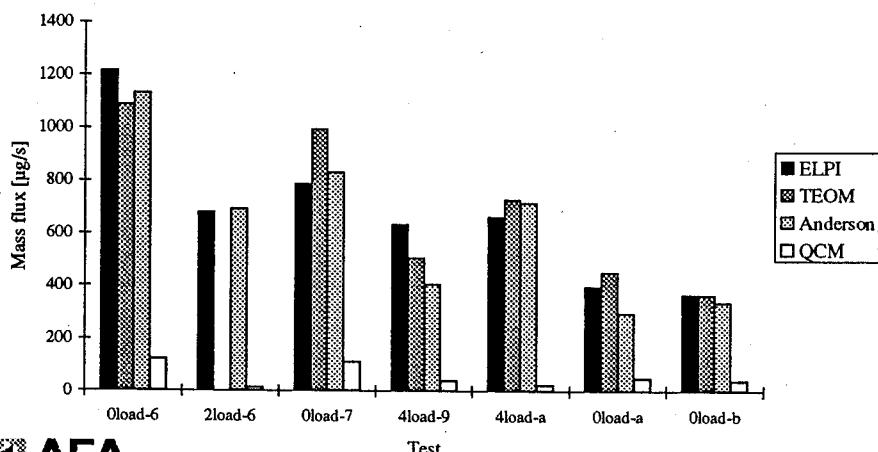
TEOM Mass Concentration



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DOP/DEPM INSTRUMENT Evaluation - Mass Flux

Mass Flux Measurements



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DOT/DOE/SMMI Instruments Evaluation - Mass Distribution

Mass Mean Particle Diameter

Test	Mass Mean Particle Diameter [nm]		
	SMPS (volume)	ELPI	QCM
0load-6	172	215	96
2load-6	202	278	114
0load-7	177	210	80
4load-9	255	311	288
4load-a	247	360	100
0load-a	151	189	85
0load-b	147	184	94

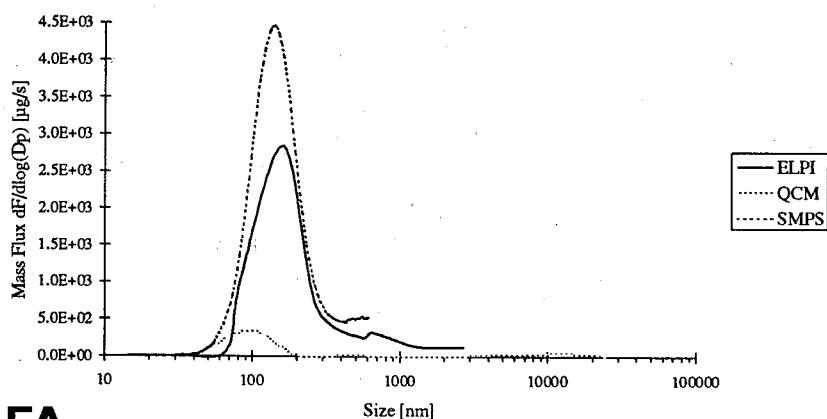


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DOT/DOE/SMMI Instruments Evaluation - Mass Distribution

0load-6

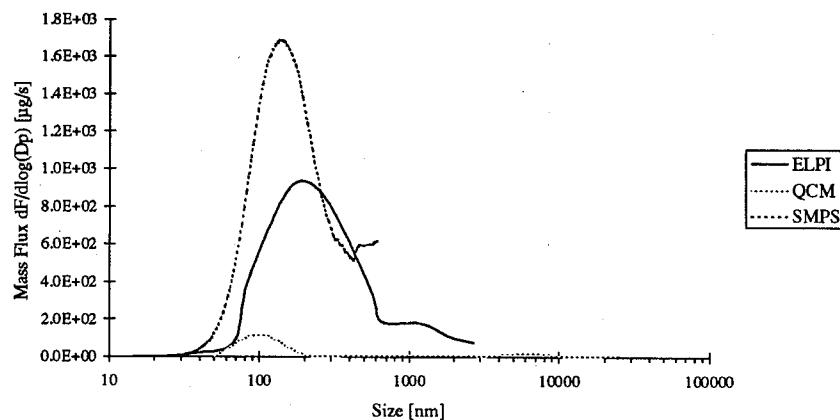


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DOP/DOESMIVI Instrument Evaluation - Mass Distribution

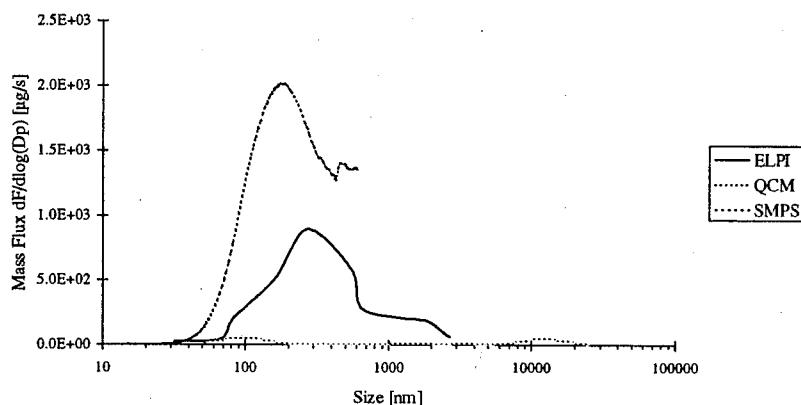
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DOP/DOESMIVI Instrument Evaluation - Mass Distribution

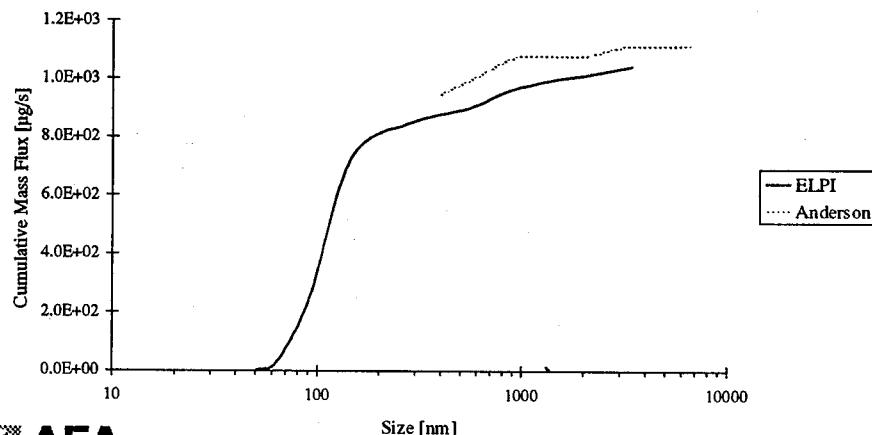
4load-a



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DOE/DOE/SMMT Instrument Evaluation - Mass Distribution

0load-6



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DOE/DOE/SMMT Instrument Evaluation - Drive Cycle

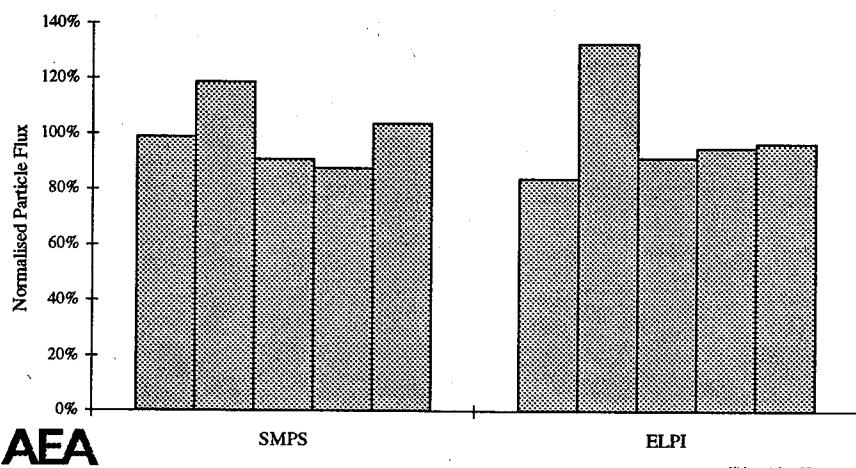
- Light & Medium Duty
 - ECE/EUDC
 - Transit Van, Montego, Vectra
- Heavy Duty
 - FIGE
 - Eagle II
 - RF73, City Diesel



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DOT/DOE/SMMT Instrument Evaluation - Number Mode

Normalised Particle Flux - V2 (ECE)

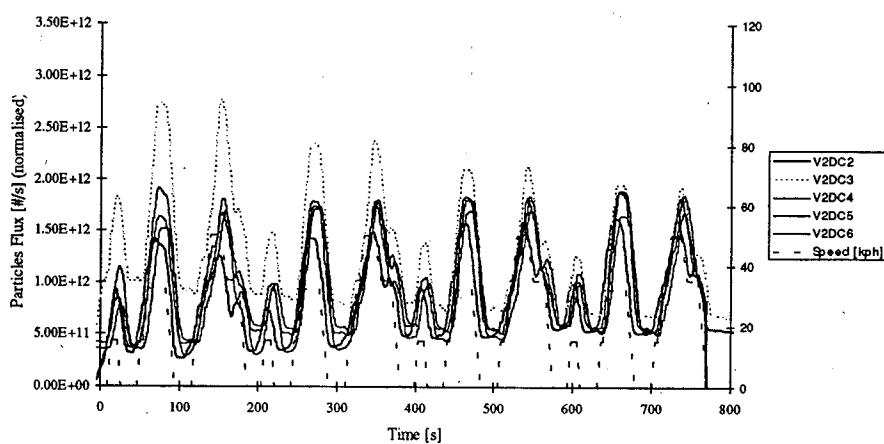


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DOT/DOE/SMMT Instrument Evaluation - Number Mode

Vehicle 2

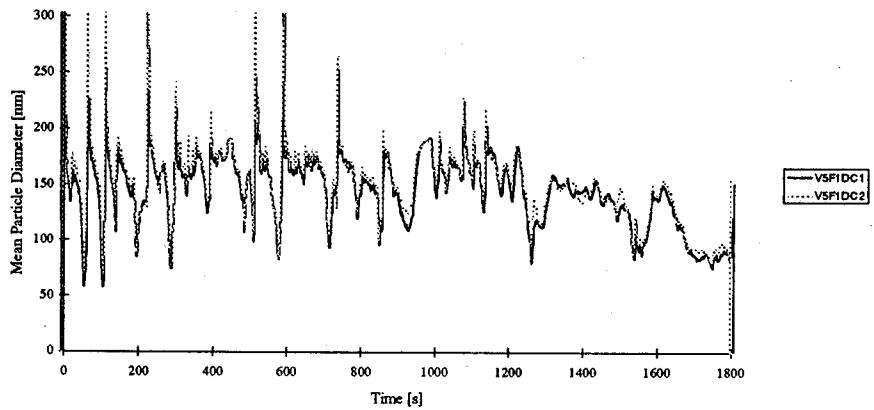


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DOT/DOE/SMMT Instrument Evaluation - Number Mode

Vehicle 5 Fuel 1



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DOT/DOE/SMMT Instrument Evaluation - Number Mode

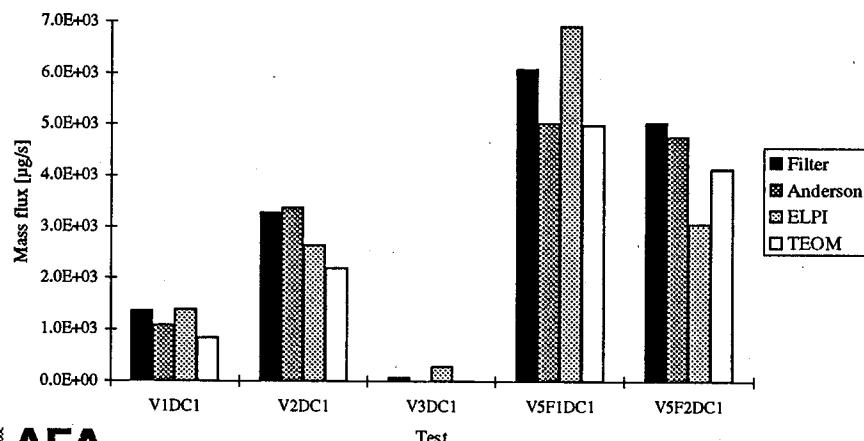
- ELPI repeatability as good as SMPS repeatability
- Time resolution good enough for drive cycle detail



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DOT/DOE/SMMT Instrument Evaluation - Mass Mode

Mass Flux Measurements Over Drive Cycles

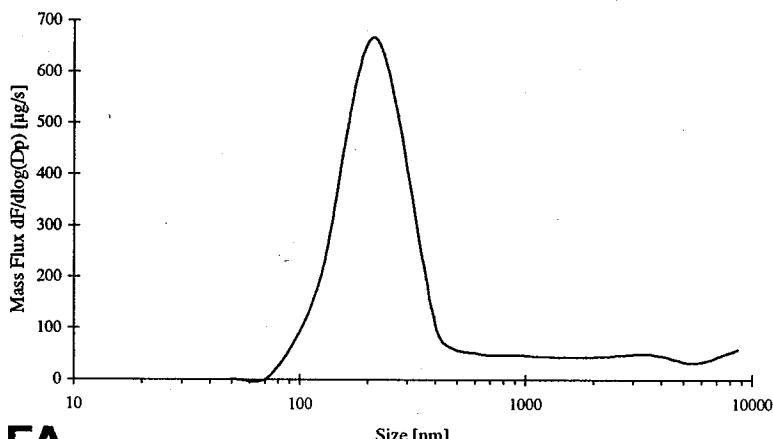


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DOT/DOE/SMMT Instrument Evaluation - Mass Mode

Vehicle 1

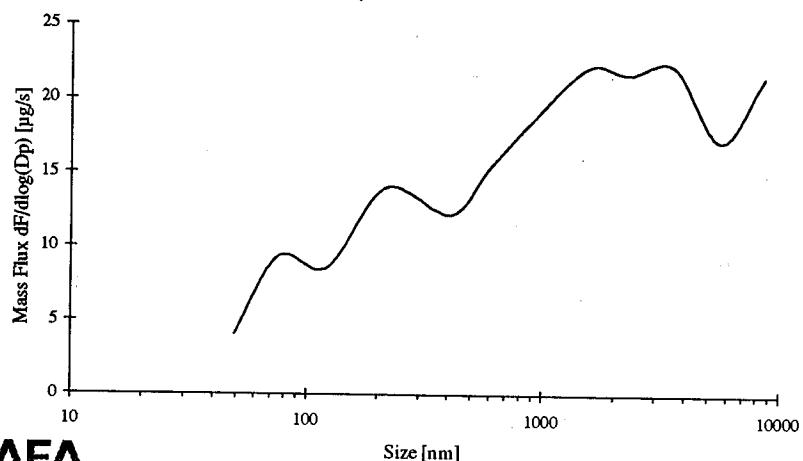


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DOE/DOE/SI/MI Instrumentation Evaluation - Mass Mode

Vehicle 3

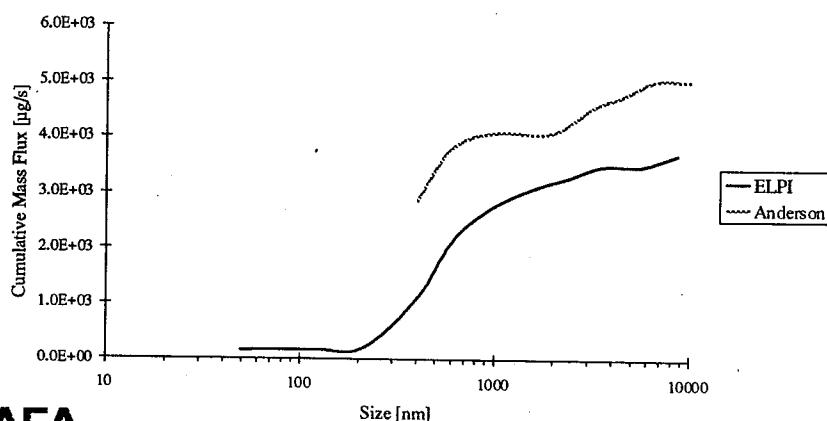


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DOE/DOE/SI/MI Instrumentation Evaluation - Mass Mode

Vehicle 5 - Fuel 1

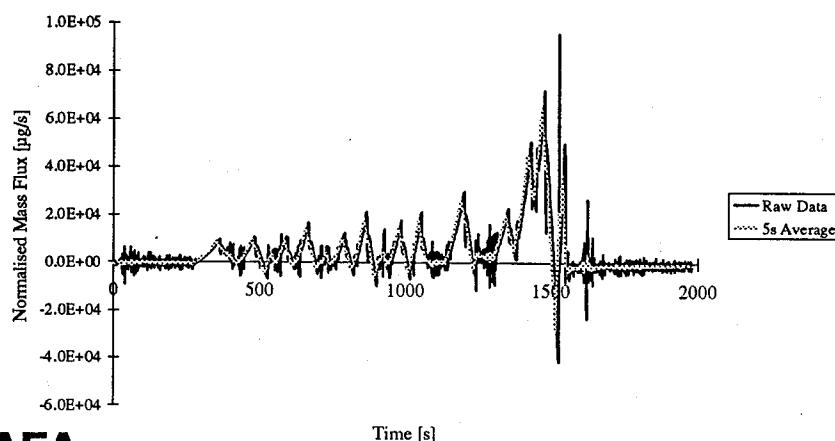


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DOT/DOE/SMMT Instrument Evaluation - Mass Mode

Teom Smoothing Over Drive Cycle

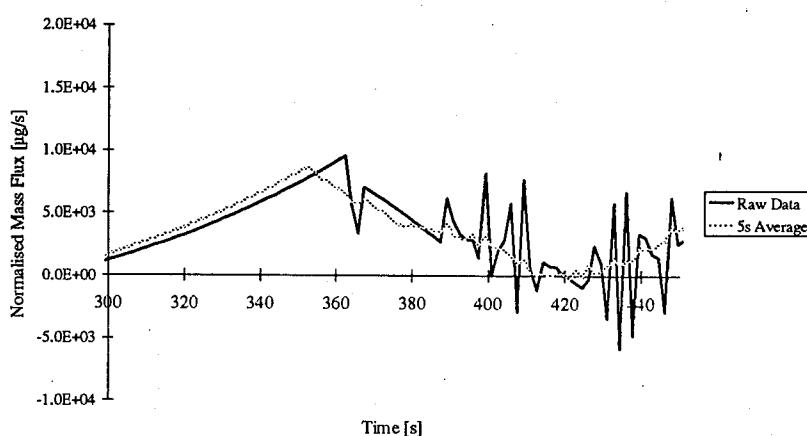


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DOT/DOE/SMMT Instrument Evaluation - Mass Mode

Teom Smoothing Over Drive Cycle



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DO/DOP/SMPS Instrument Evaluation - QCM

- Under Performs by 90% in Terms of Total Mass
- Problem not Charge Related
- Distribution Biased to Smaller Particles (Compared to ELPI/SMPS)
- Bad Coupling of Particles to Stages



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DO/DOP/SMPS Instrument Evaluation - ELPI (mass mode)

- Manufacturer's Calibration Needs Adjustment
- Reasonable Mass Flux Measurement
- Measures Cumulative Mass Distribution over Drive Cycle with Good Size Resolution.
- Not Real Time



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DOT/DOD/SMI/Instrument Evaluation - ELPI (number)

- ♦ Real-time Particle Size Distributions
- ♦ Good Repeatability over Drive Cycles and Steady States
- ♦ Stage Sizes in Number Mode Differ from Mass Mode Calibration
- ♦ Possible Max Concentration Problem
- ♦ Needs Further Calibration



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DOT/DOD/SMI/Instrument Evaluation - SMPS

- ♦ Excellent Size Resolution and Range for Steady State Tests.
- ♦ Concentration Out by Factor of 2
- ♦ Proven for Particle Emissions
- ♦ Restricted to Single Size over Drive Cycles



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DO/DOE/SMVII Instrument Evaluation - TEOM

- Measures Total Mass Concentration in Real-time
- Unstable Signal, Needs Smoothing



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DO/DOE/SMVII Instrument Evaluation - Anderson

- Cumulative Mass Size Distribution
- Resolution Only Good above 400nm
- Cheap Method for Checking for Large Particles



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DOP/DPS/SMPS Instrument Evaluation - Sampling

- Sampling Column Needed for Multiple Instrument Sampling
- Large Particle Seen, so Good Sampling for Mass Mode Measurements Required



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DOP/DPS/SMPS Instrument Evaluation Recommendations

- Number - Steady State
 - SMPS, ELPI?
- Number - Drive Cycle
 - ELPI? or SMPS
- Mass
 - ELPI (or Equivalent), Anderson MkIII?



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