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Automotive Test Systems

Solid Particle Counting System SPCS

Cambridge Particle Conference

22nd May 2006

PMP : Solid Particle Number Counting

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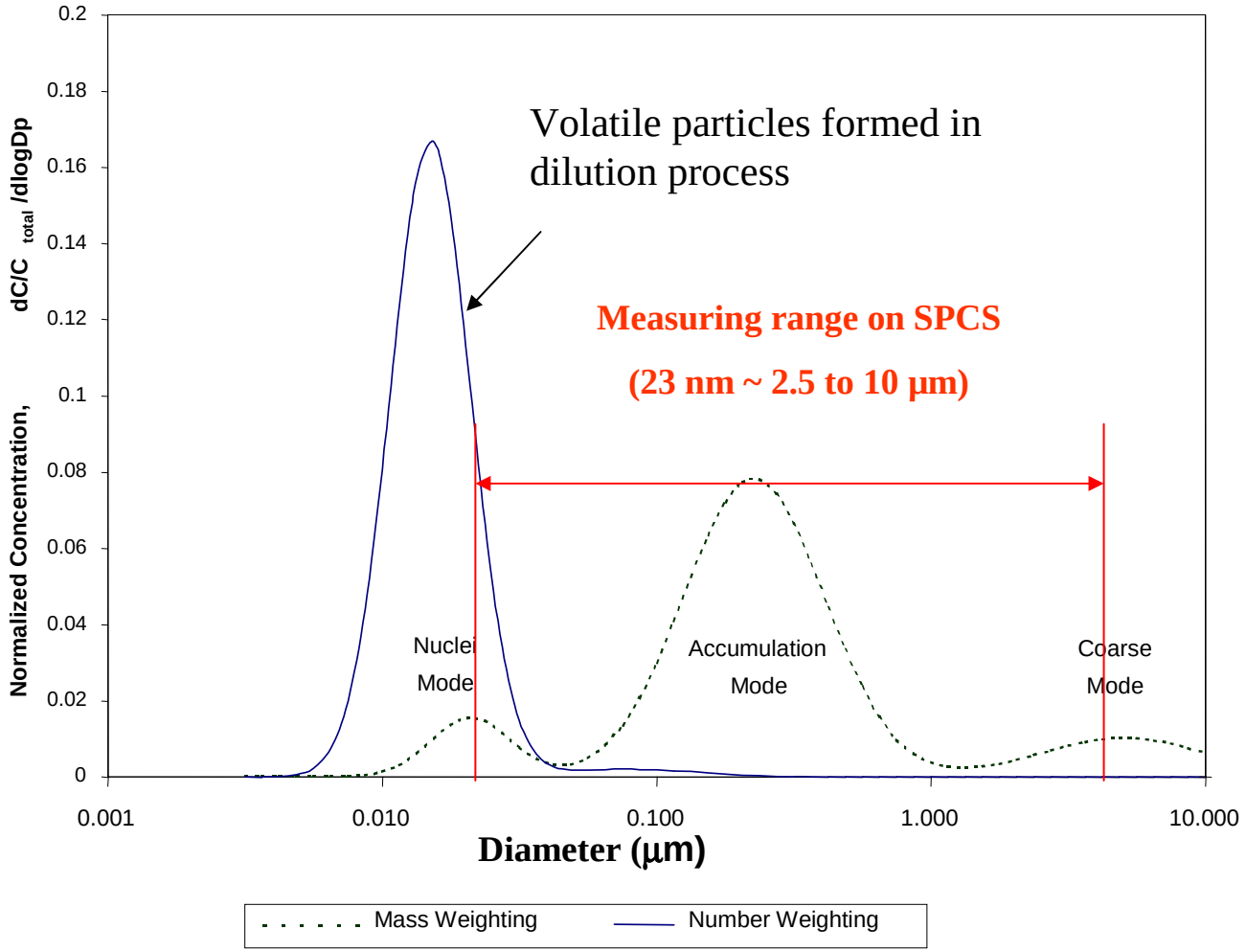
- With the increasing interest in the health effects of particulate emissions and continuing reduction of levels of emission, the PMP (Particulate Measurement Program) was initiated to make a complete review the principles and methods of particulate measurement

- Following the phases of literature study, review of candidate systems and a program of testing/validation, two methods were selected to be used in a global correlation exercise
  - Filter based gravimetric measurement from diluted exhaust as current legislation, with improvements along the lines specified by EPA for 2007 HDD (heated sampling, particle size classification etc)
  - Counting the number of solid particles emitted from the vehicle

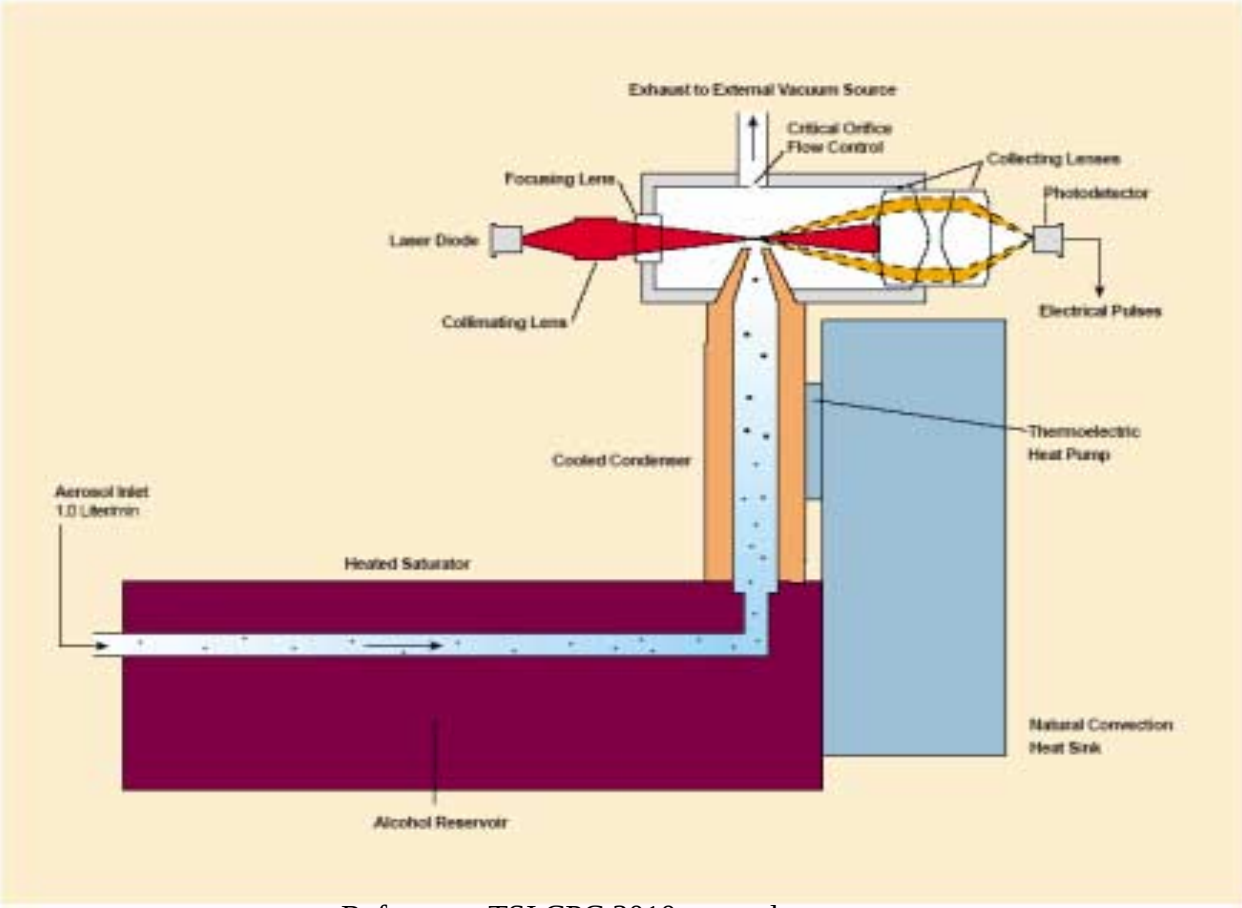
- Draft requirements and regulations were issued for instrument developers and testing authorities / laboratories

Solid Particle Number Counting



Reference: Kittelson D. B., J. Aerosol Sci., 28: 575-580, 1998

Condensation Particle Counter (CPC)

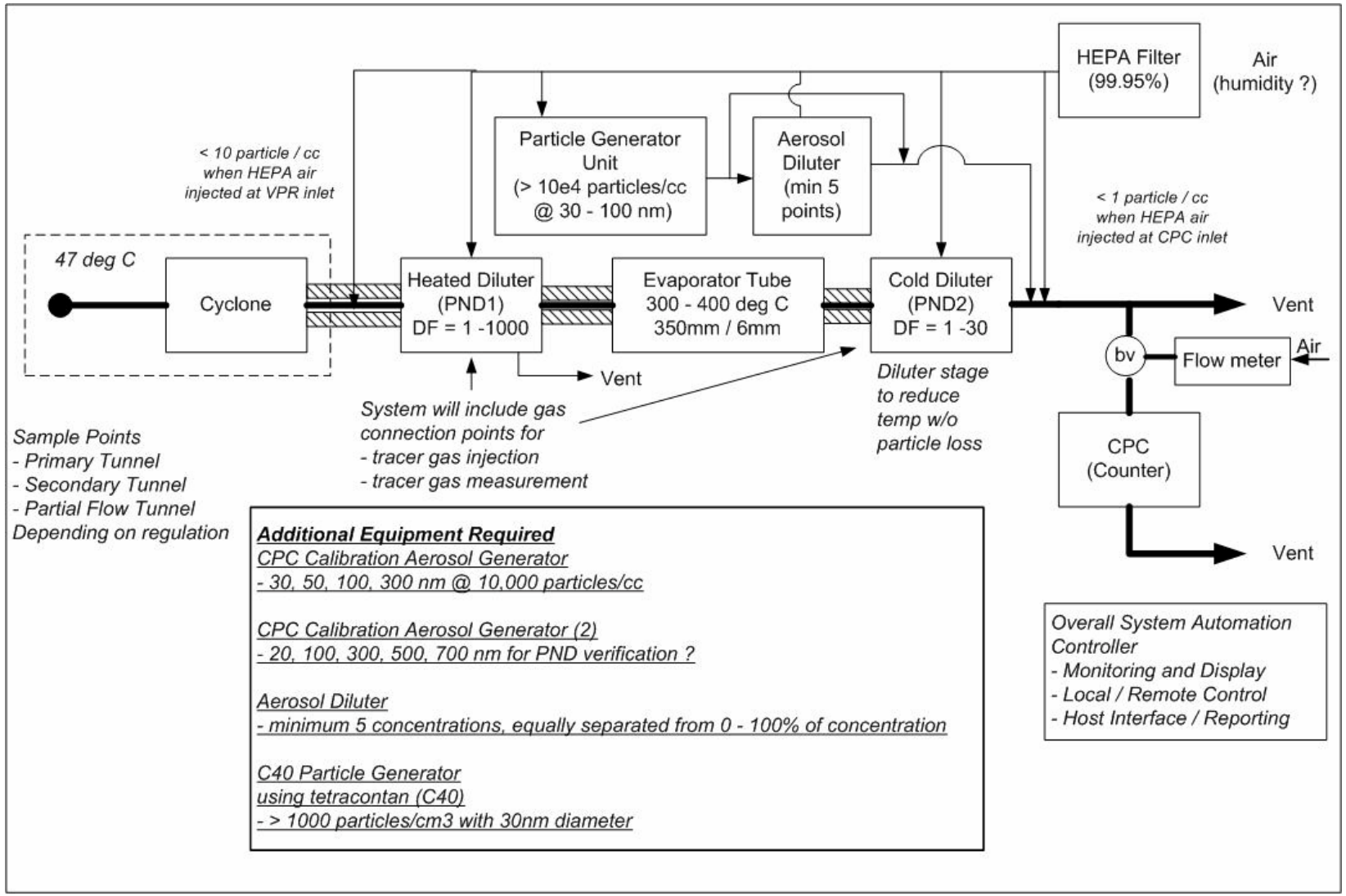


Reference: TSI CPC 3010 manual

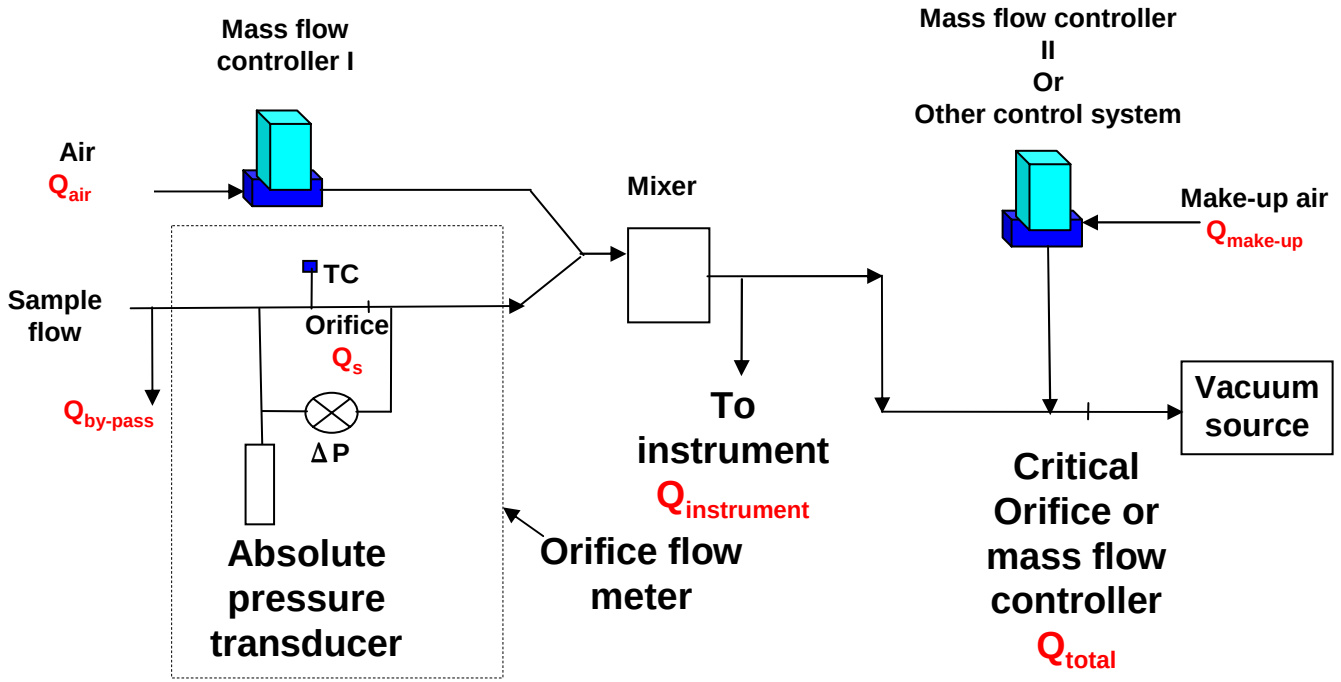
TSI Model 3010D is used in the SPCS prototypes

Design is modified to give the particle size classification specified in the GRPE-PMP draft regulation

Schematic To Meet GRPE-PMP



SPCS Wide Range Diluter



- *No moving parts*
- *Low dead volume*
- *Accurate dilution ratio*
- *Minimum contamination*
- *Used as PND1 and PND2*

- *Ideal for remote control*
- *Wide dilution ratio range*
- *High penetration for particles*
- *Not sensitive to sample pressure (with PID control)*

Prototype System Appearance

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Front

Back

Fully Automated Control on Prototype

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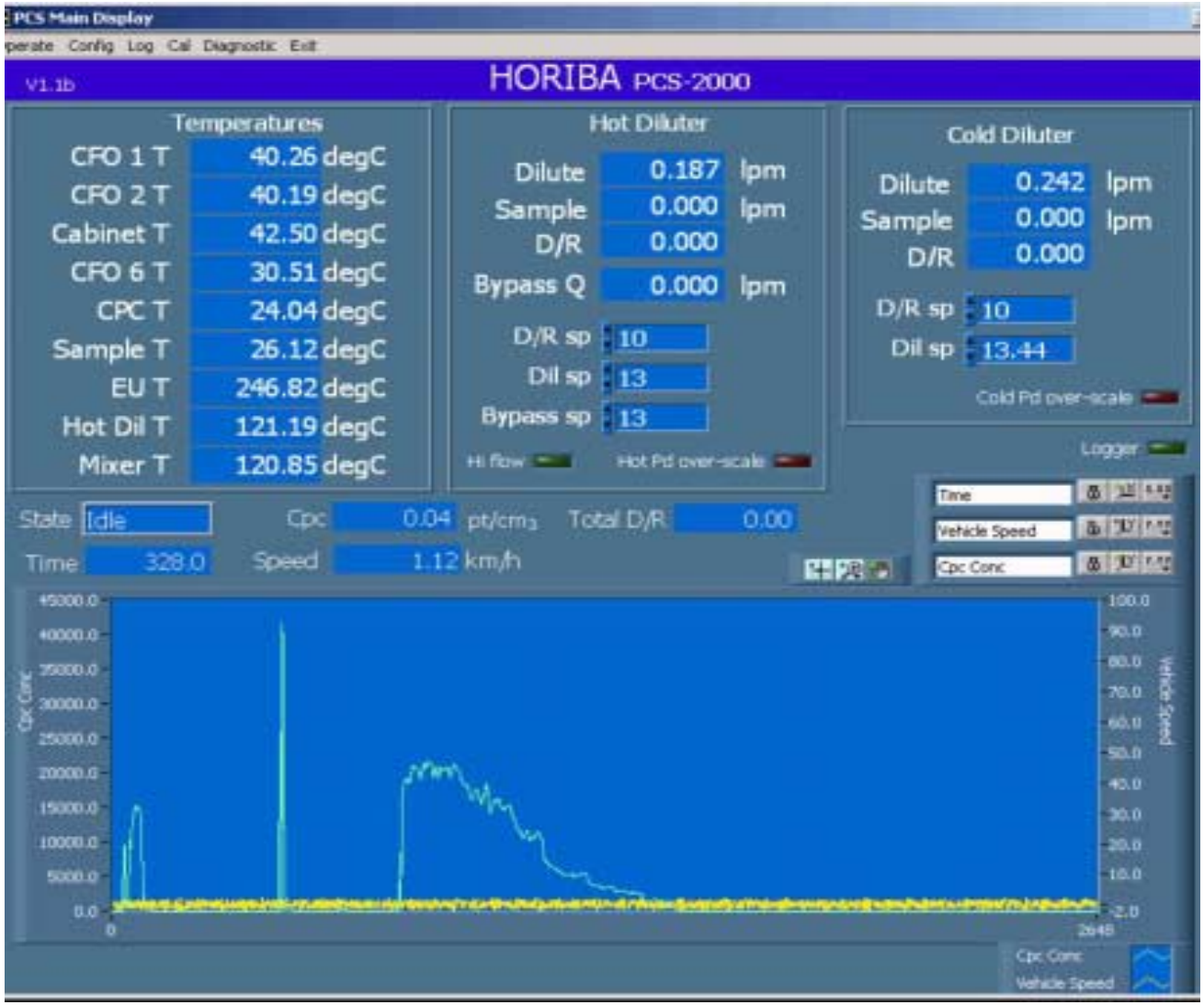

- Control and data acquisition with NI Fieldpoint process I/O and Labview software
- Automated operations including check functions
- Configurable data log
- Data log rate up to 5 Hz
- Real-time dilution ratios
- Easy to operate

Key Requirements For SPCS (PMP specifications)

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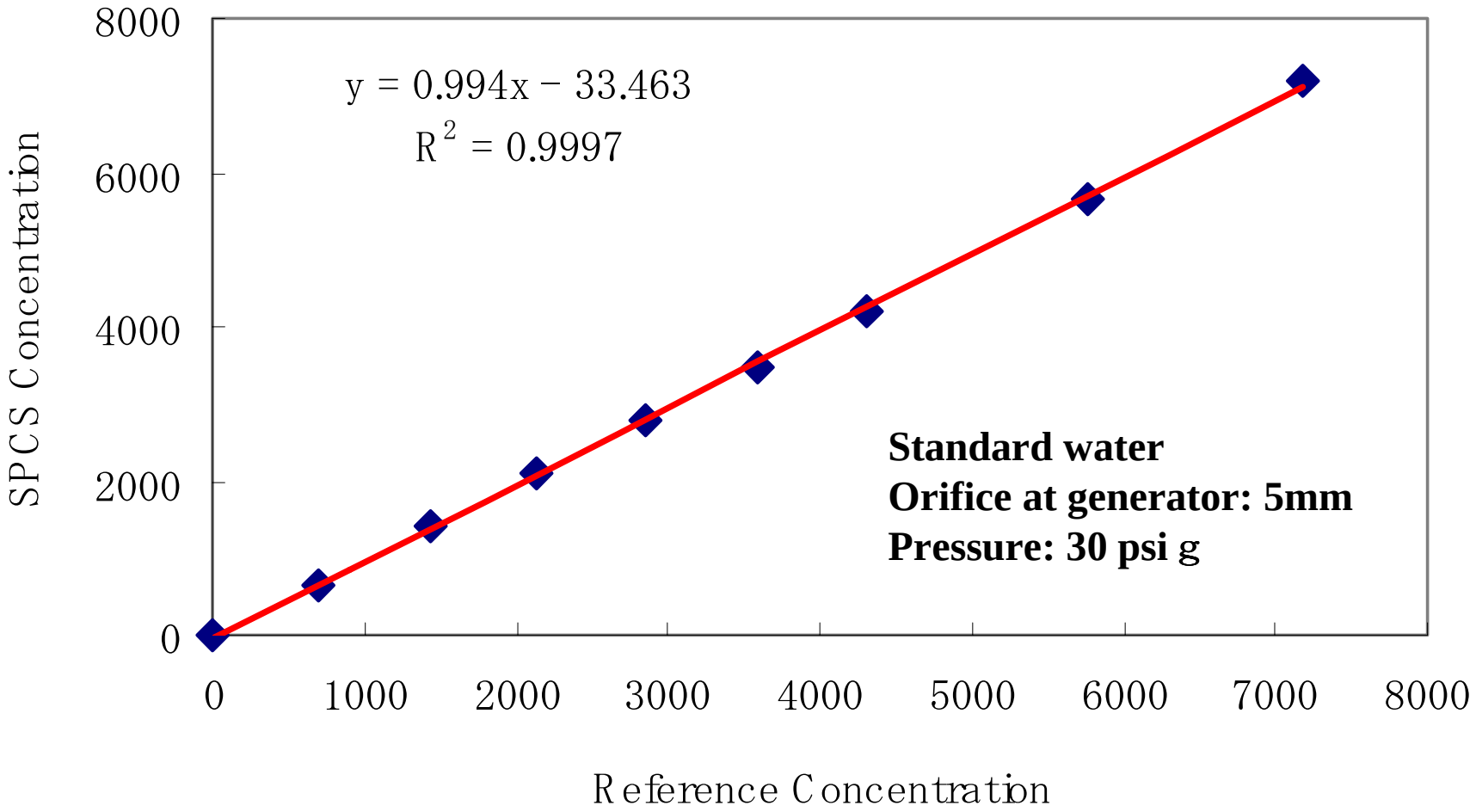
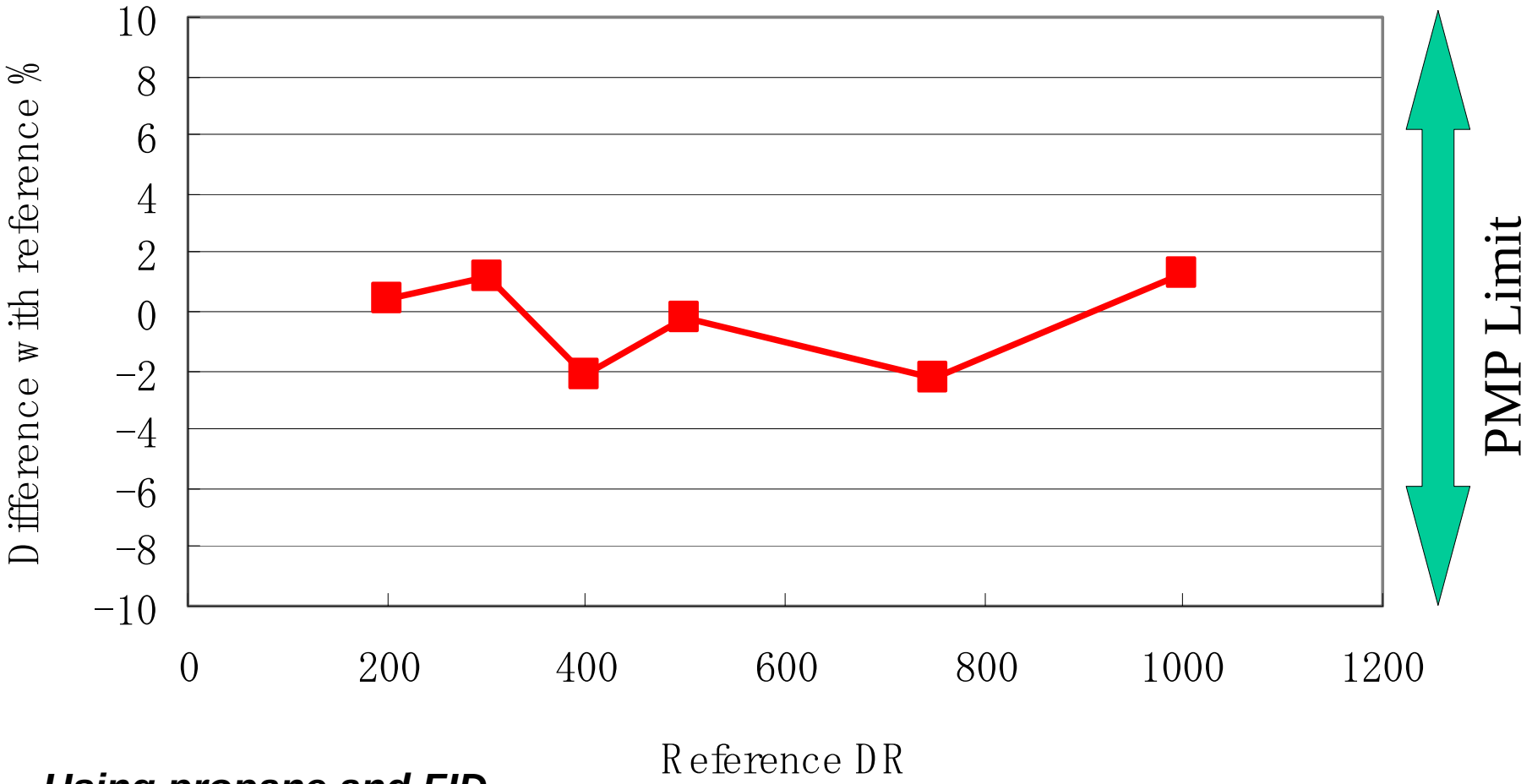
- Daily linearity check, using particle generator and particle gas divider ($R^2 > 0.95$)
- Confirmation of the dilution ratios (+/- 10%)
  - Using gas tracer method and actual single size particles
- Removal of particles from volatile HCs (> 90 %)
  - Using tetracontan (C40) vaporiser into Evaporation Tube
- Low losses of solid particles (< 10 %)
  - Using particle generator and single particle size selection to confirm the solid particle penetration through the system at various sizes

Daily Linearisation Check (Automatic)



Dilution Ratio Check

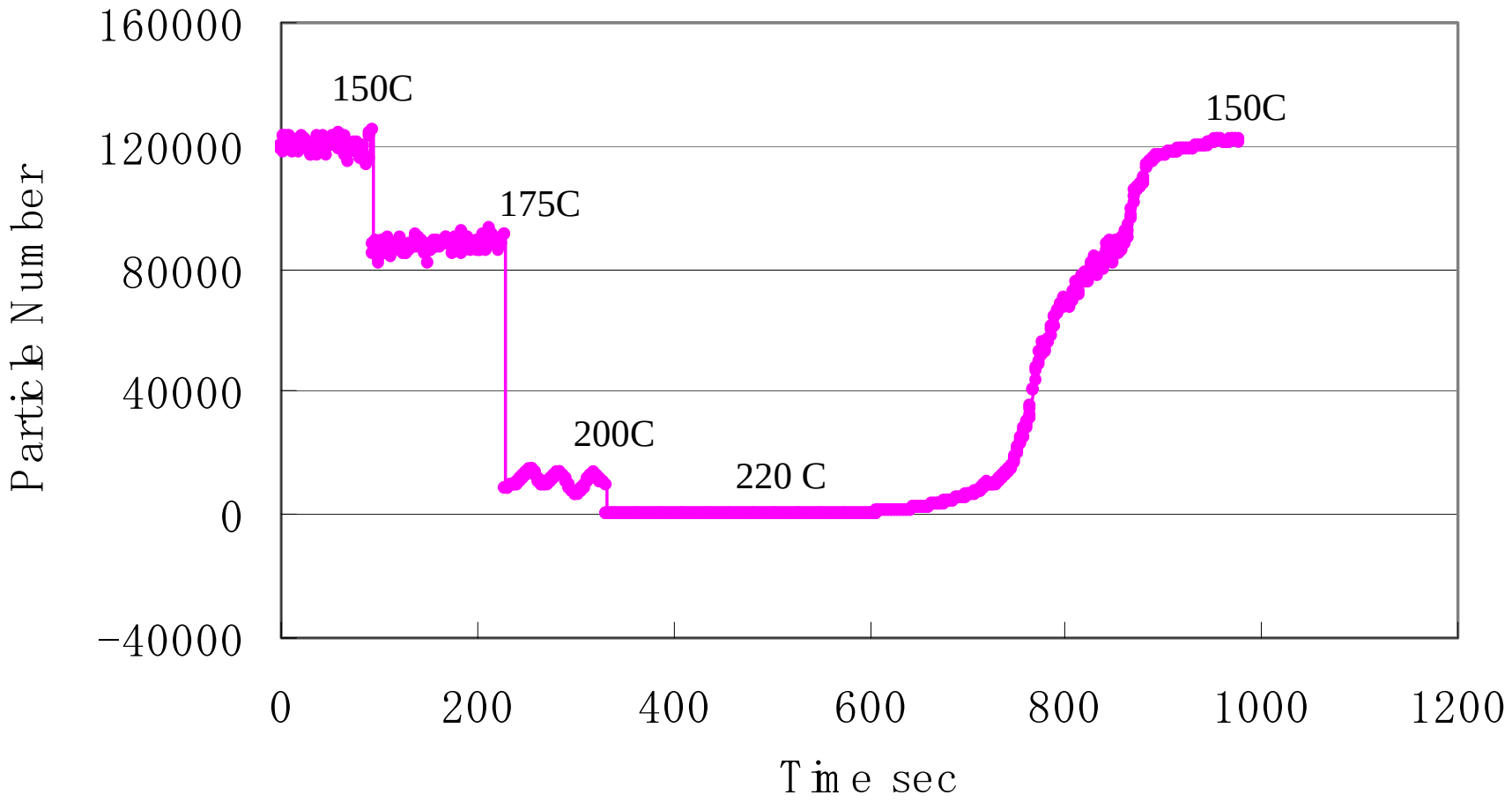


Using propane and FID as tracer gas

Removal Of Volatile HC Particles

Evaporation Tube Temperature Dependency

C40 concentration (100 nm particles) downstream of EU as the function of temperature set point



Volatile Particle Removal Efficiency

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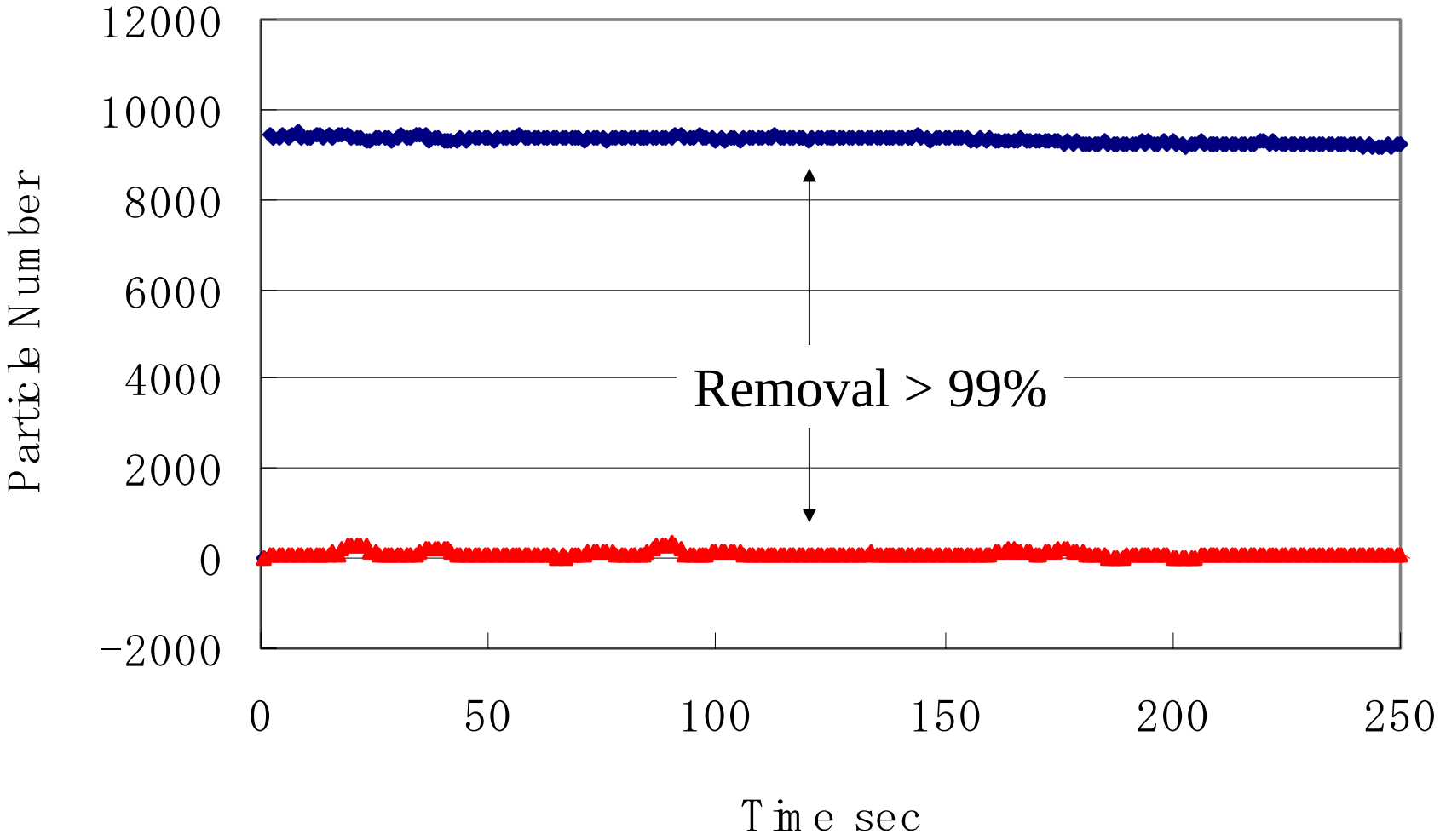
C40 concentration (100 nm size) downstream of EU as the function of set point



Particle Losses In SPCS

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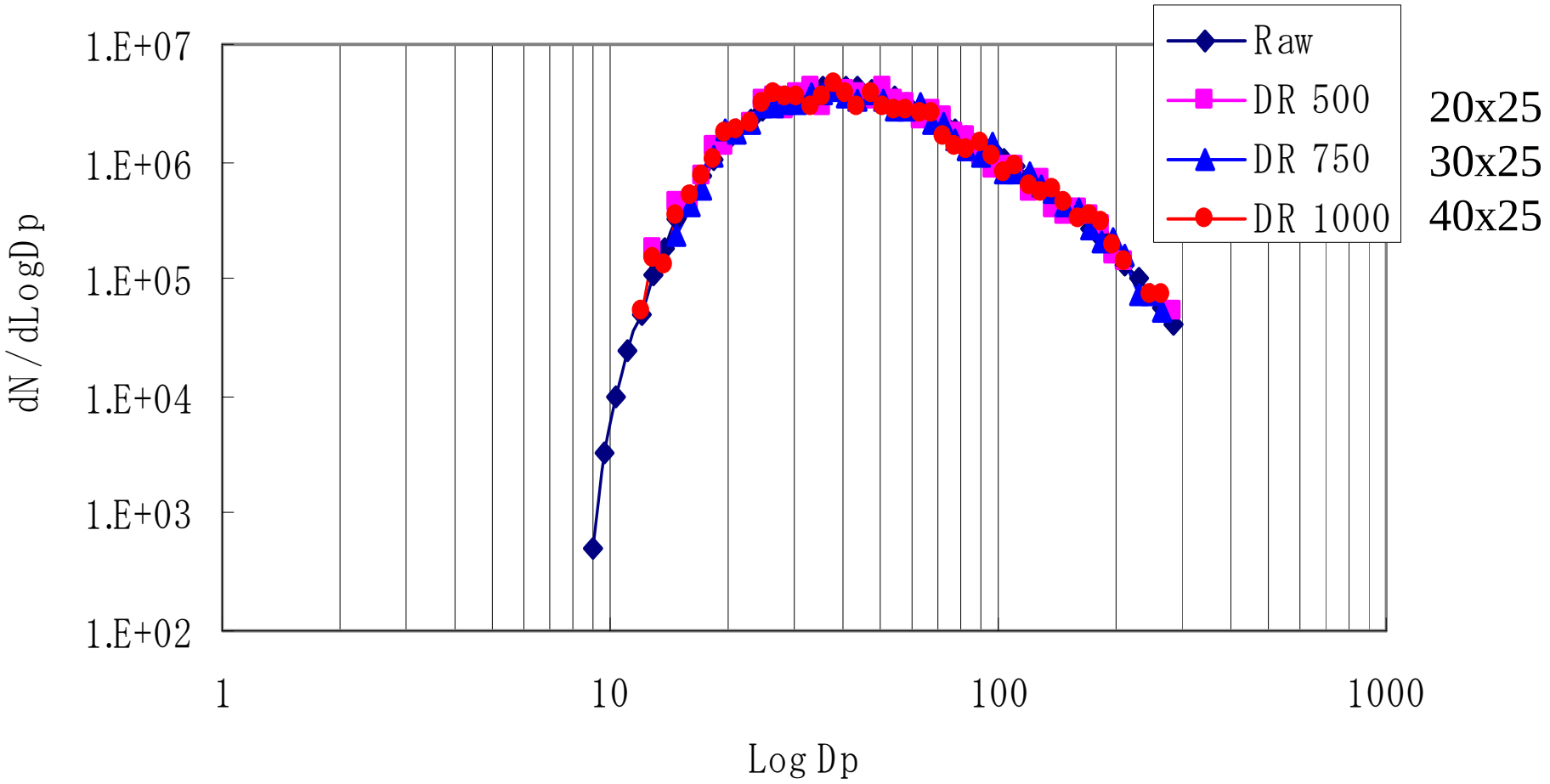
Penetration > 98%



Initial Testing, Diesel On Chassis Dyno

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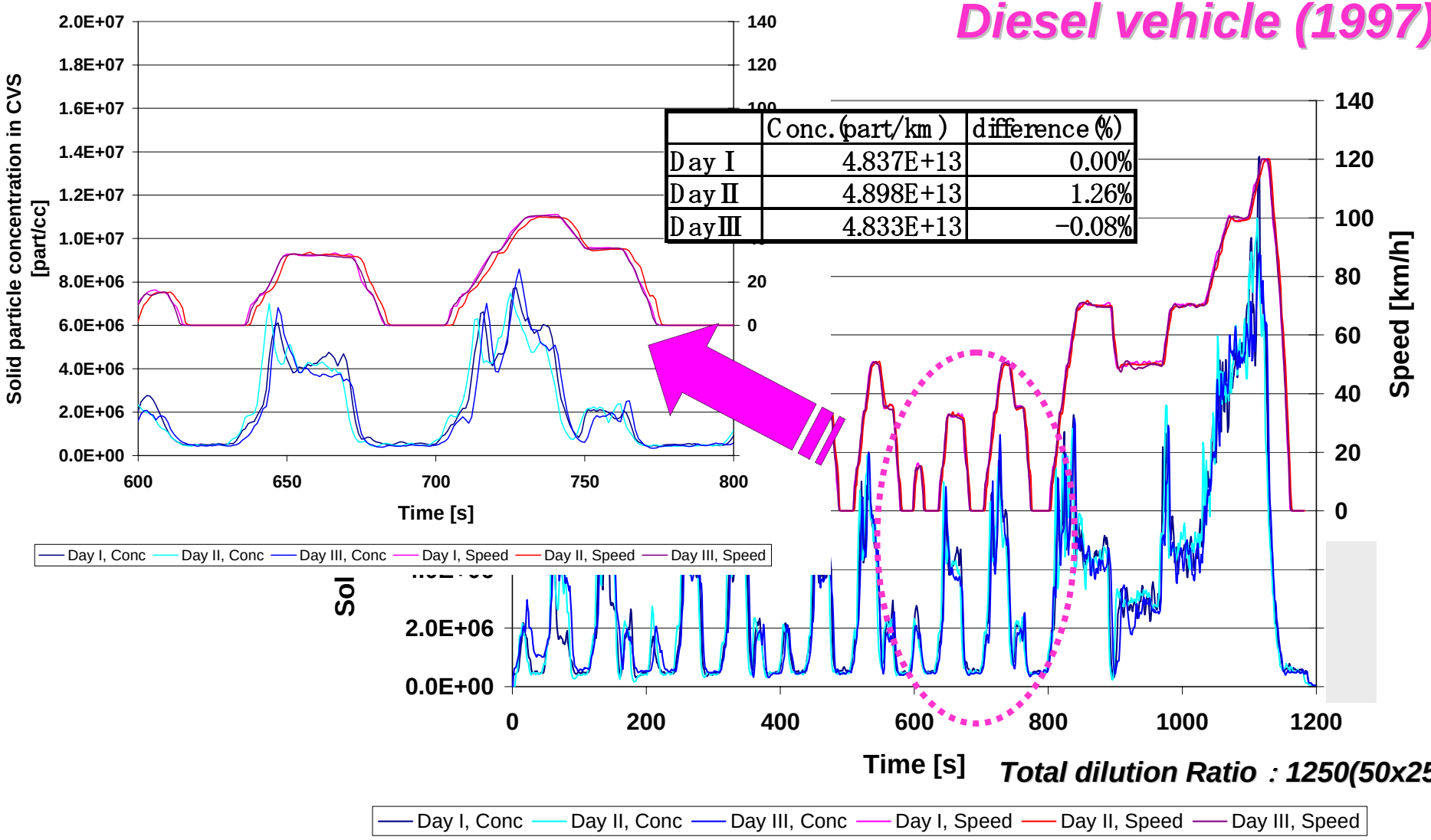
Diesel vehicle (1997)



	Conc.(part/km)	difference(%)
Day I	4.837E+13	0.00%
Day II	4.898E+13	1.26%
Day III	4.833E+13	-0.08%

Total dilution Ratio : 1250(50x25)

Day I, Conc Day II, Conc Day III, Conc Day I, Speed Day II, Speed Day III, Speed

SPCS In PMP Inter - Lab Correlation

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Part	No	Lab:	PMP testing period:
A	1	VELA, JRC, Italy	9 to 17 November
A	2	AVL MTC Sweden	29 November-3 Dec 04
A	3	Ricardo Consulting Engineers UK	Mid January 05
A	4	Lab of Applied Thermodynamics (LAT) Greece	Early February 05
A	5	RWTÜV Germany	Late February 05
A/B	6	VELA, JRC, Italy	March 05
			April- Transfer to Japan
B	7	NTSEL Japan	Early May 05
B	8	National Motor Vehicle Emission Research Lab, Korea	Early June 05
		Interim Report	*June 05 –Transfer to Europe*
B	9	Shell UK	July 05
B	10	UTAC France	Late July 05
B	11	VELA, JRC, Italy	August-September 05
		Final Report	*October-November 05*

Actually September

SPCS In PMP Inter - Lab Correlation

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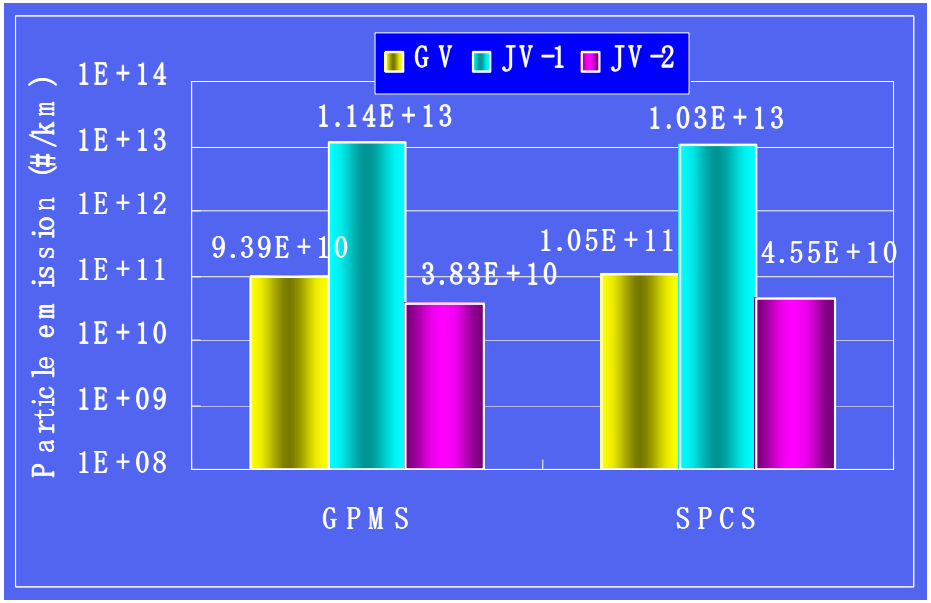
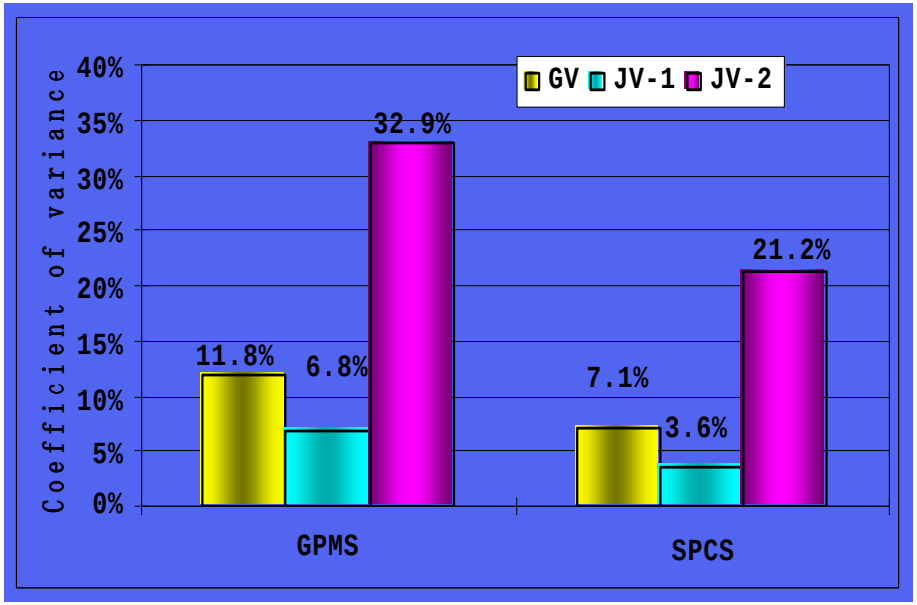
Golden Car

Golden System

SPCS In PMP Correlation Exercise



Particle emission from different vehicles



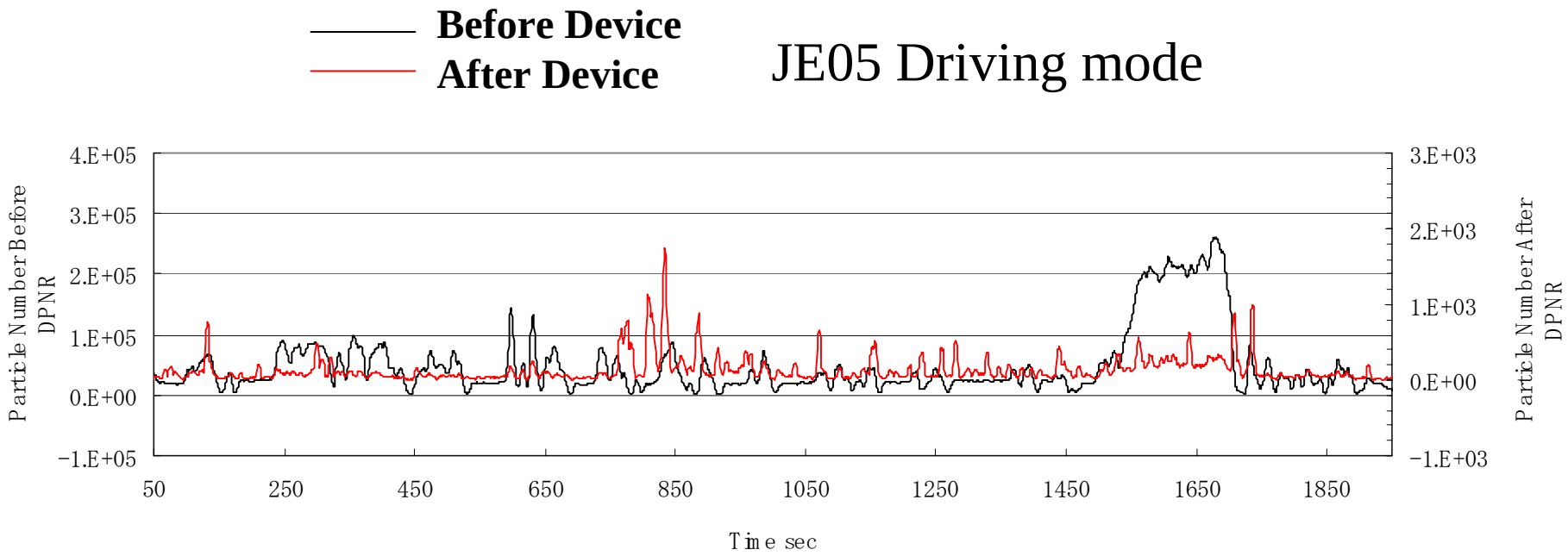
Repeatability of measurement by GPMS and SPCS

Outline of tested vehicles

	Fuel	Disp.cm³	Engine type	After treatment
GV	Diesel	1997	TC, Common rail D.I	SiC DPF
JV-1	Gasoline	2990	NA, Direct Injection	TWC + de NOx Cat.
JV-2	Diesel	1998	TC, Common rail D.I	DPF + Oxi. Cat.

Inter-Lab Correlation Exercise @NTSEL

Particle Trap Efficiency Measurements



SPCS Actions after ILCE

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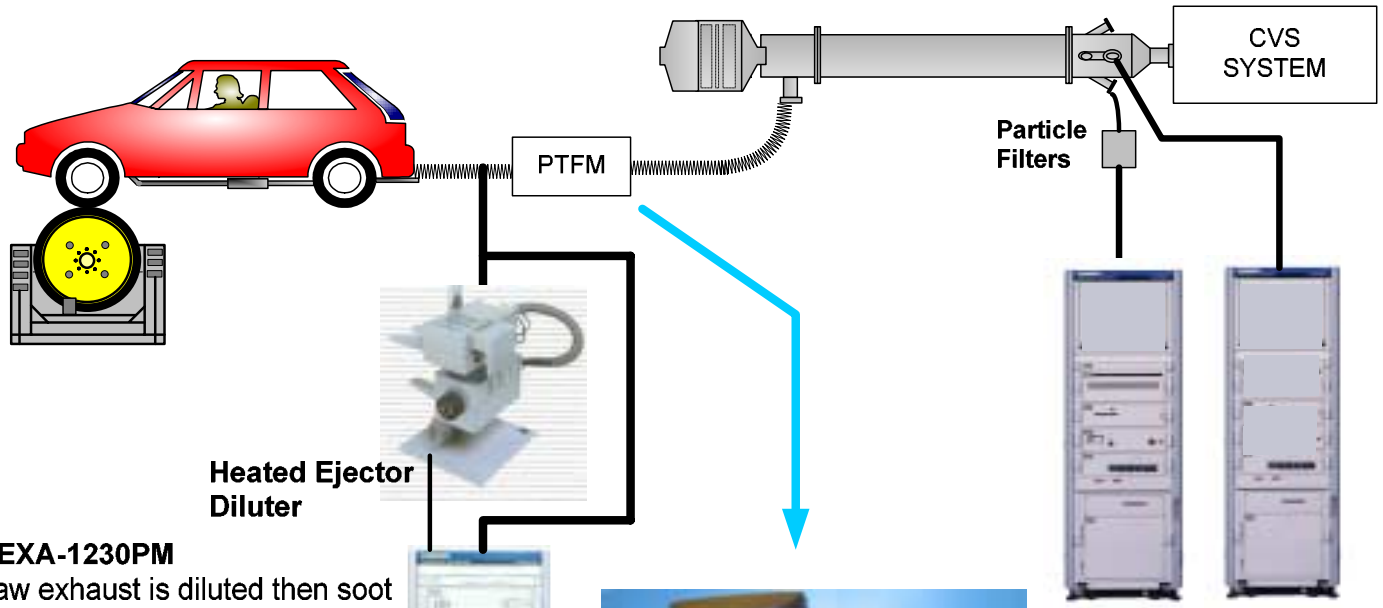
- Prototype SPCS updated after ILCE in Japan
  - minor modifications incl software

- Prototype SPCS in the HE Chassis Cell
  - Testing on EU spec vehicles and cycles
  - Comparison with other PM measurements
    - Full flow dilution CVS with gravimetric PM
    - TEOM (on CVS/DLT)
    - MEXA-1230PM on direct raw exhaust with a standalone PTFM (Pitot Tube Flow Meter)

SPCS Data in HE Test Cell

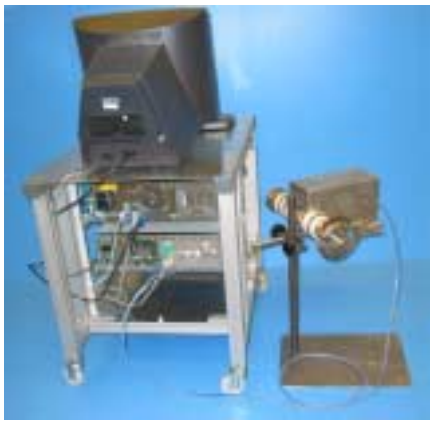


MEXA-1230PM
Raw exhaust is diluted then soot content is measured using DC Sensor

SOF is measured from raw exhaust using HFID differential method (190 / 47 deg C)

Soot / SOF concentrations are converted to mass base using real time exhaust flow rate from PTFM

MEXA-1230PM

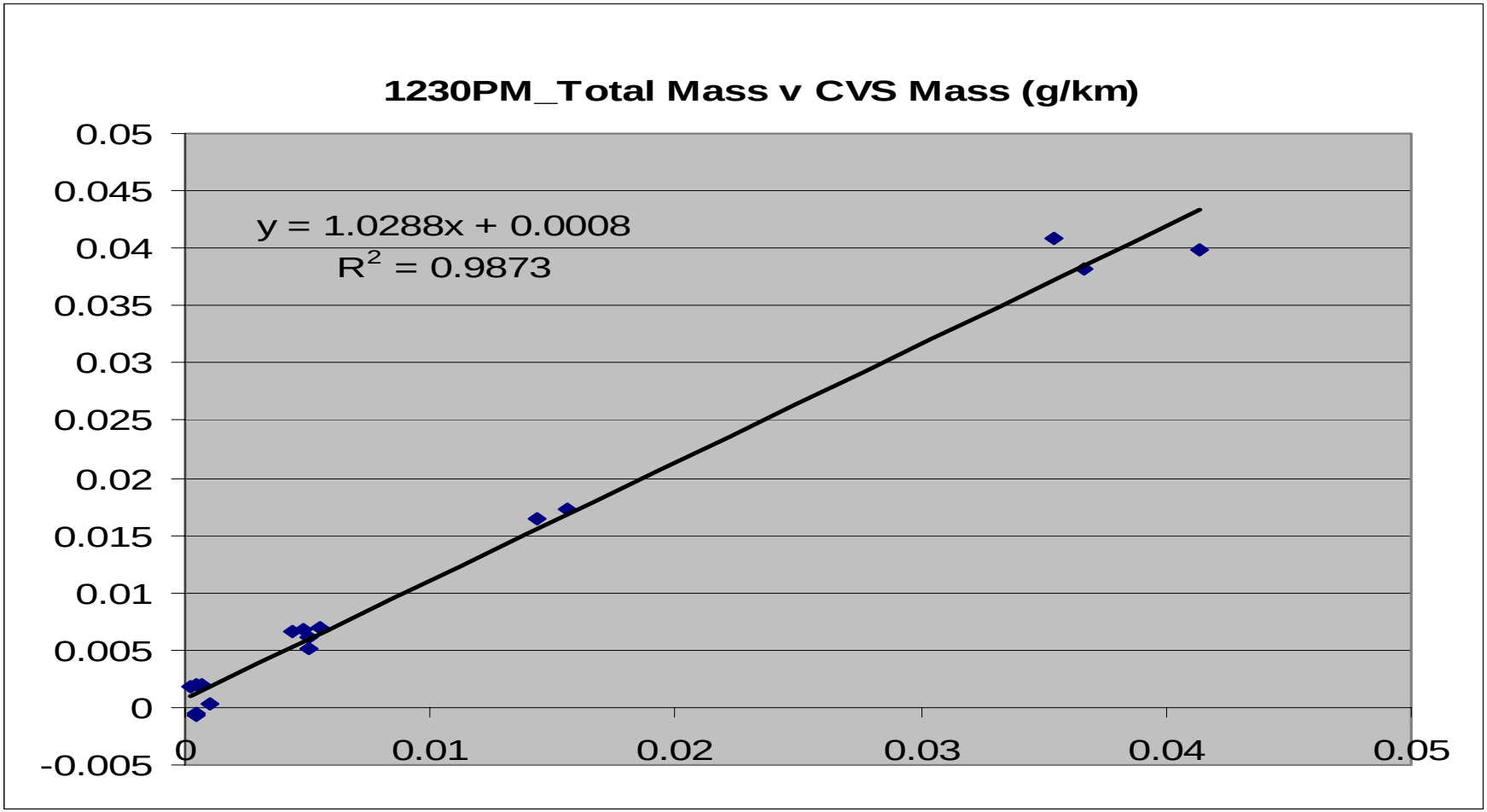


PITOT TUBE FLOW METER

Gravimetric PM Mass is measured using a conventional dilution tunnel, CVS and particulate sampler

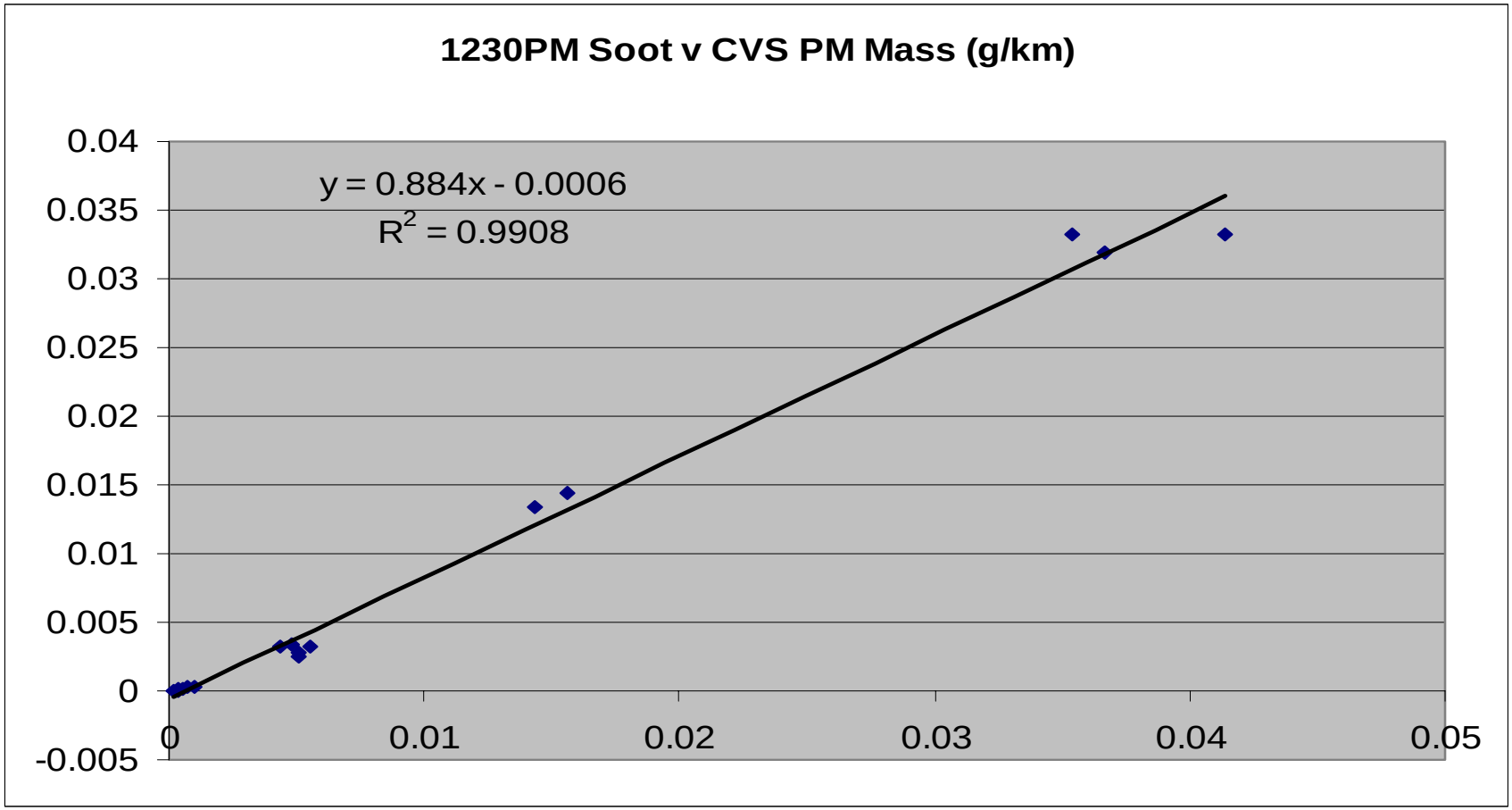
SPCS unit samples from the dilution tunnel directly with fast bypass into integrated cyclonic separator and then particle dilution and counting

SPCS Data in HE Test Cell



Vehicle comparative data shown above includes diesel w/o DPF, diesel with new and used DPF, gasoline MPI with TWC with cold and hot starts

SPCS Data in HE Test Cell



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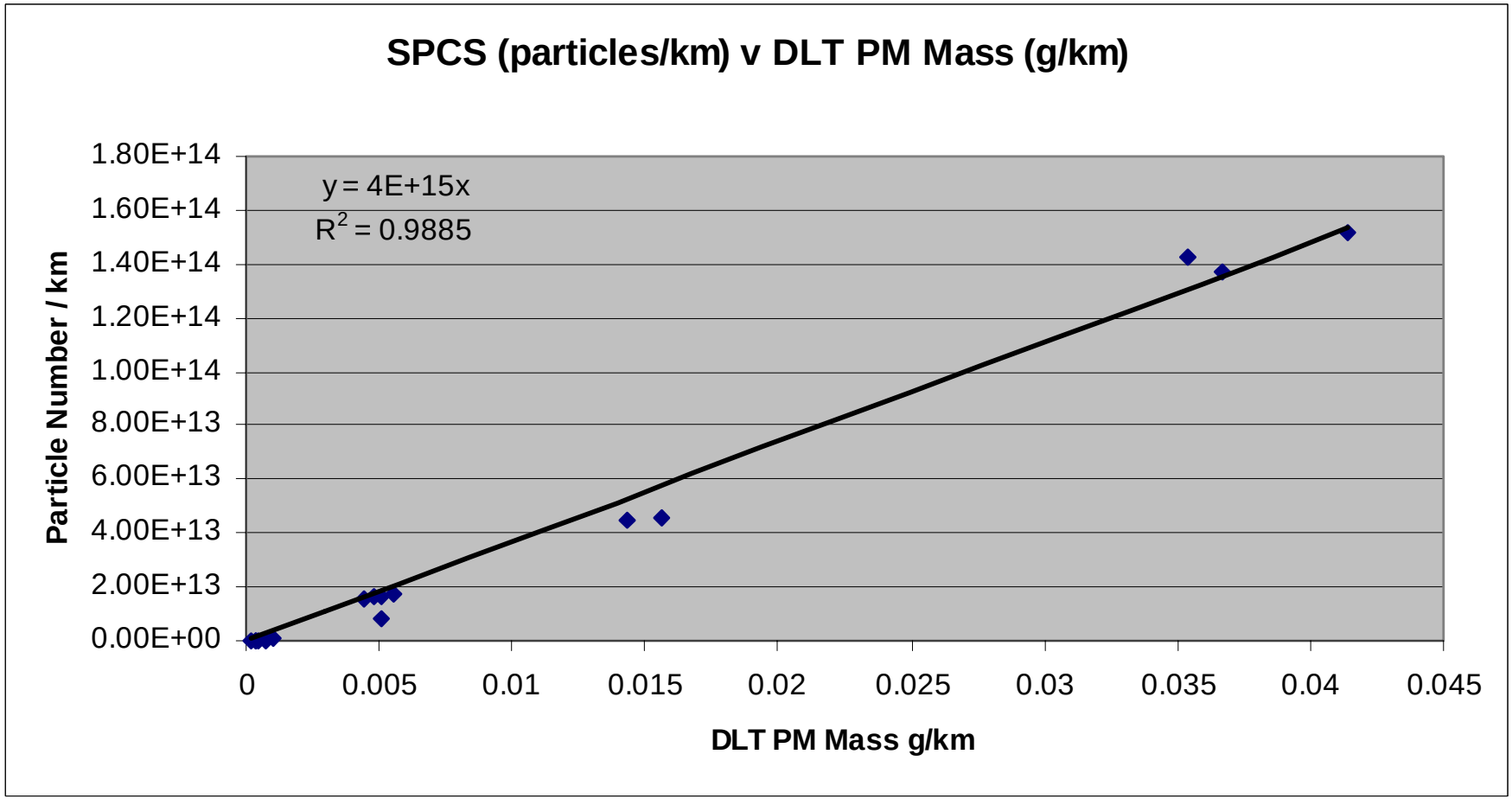

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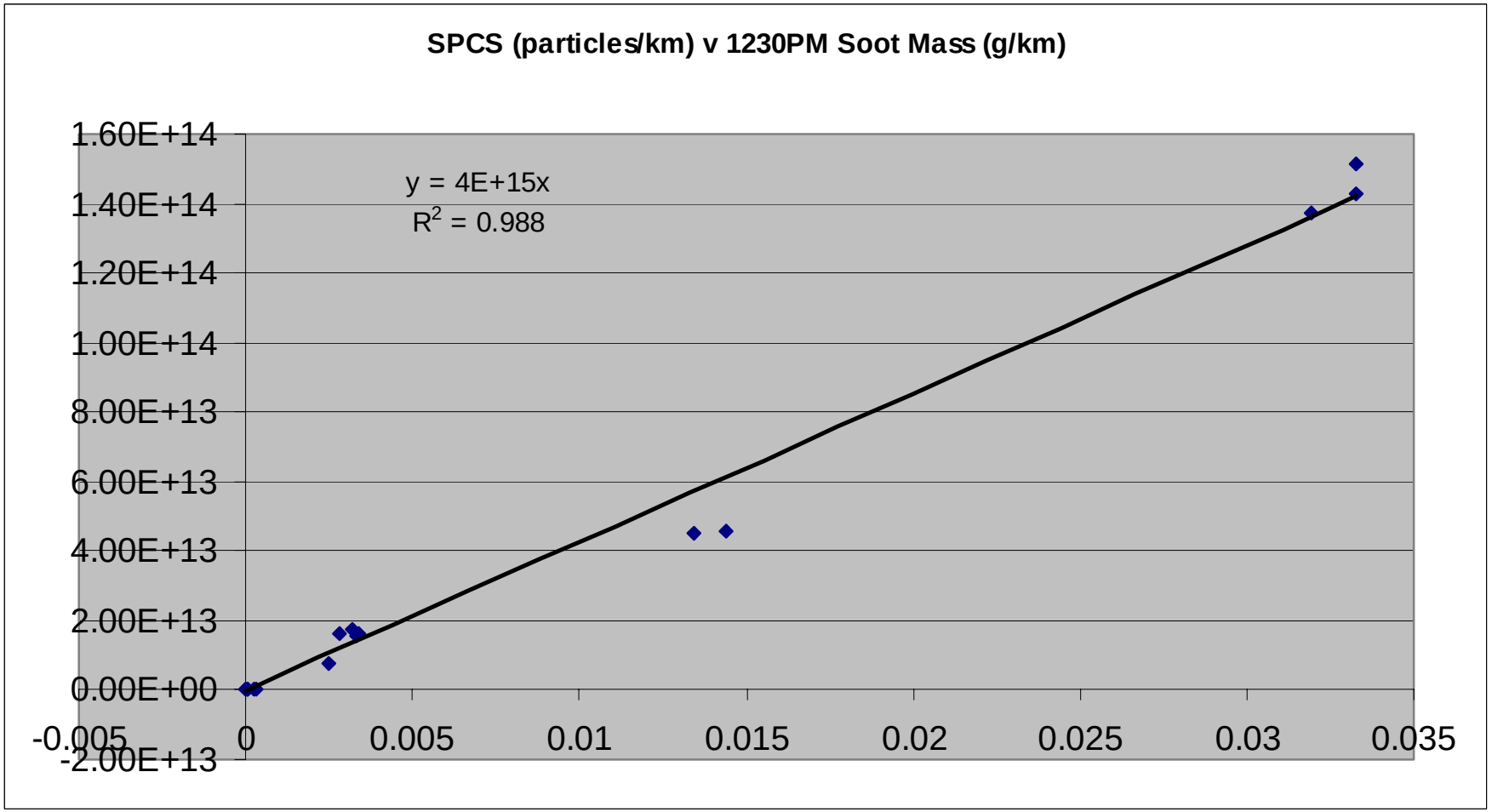

Vehicle comparative data shown above includes diesel w/o DPF, diesel with new and used DPF, gasoline MPI with TWC for cold and hot starts

SPCS Future Actions

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- SPCS prototypes (2 sets) will be taken to JRC ISPRA for final session of PMP Inter Lab Correlation Exercise
- SPCS has been offered for use in the HDD Particle Number Program
- Timing for if and when a particle number regulation will be applied remains open
- EU Auto Industry representatives and individual manufacturers have objected to the inclusion of particle number counting in the draft LD Stage 5 regulations
  - Current absence of practical, traceable calibration/verification system
- Prototype SPCS results shows good potential for a highly sensitive soot measurement system
- Production SPCS scheduled for deliveries in April 2007 .