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SECTION 1. Fine particle size measurement instruments

- Scanning Mobility particle Size (SMPS)

- Electrical Low Pressure Impactor (ELPI)

SECTION 2. Fine particle size distribution in diesel exhaust and ambient air

- Number Concentration

- Volume (Mass) Concentration

SECTION 3. Effect of dilution ration and humidity upon diesel fine particle size distribution

- Dilution Ratio

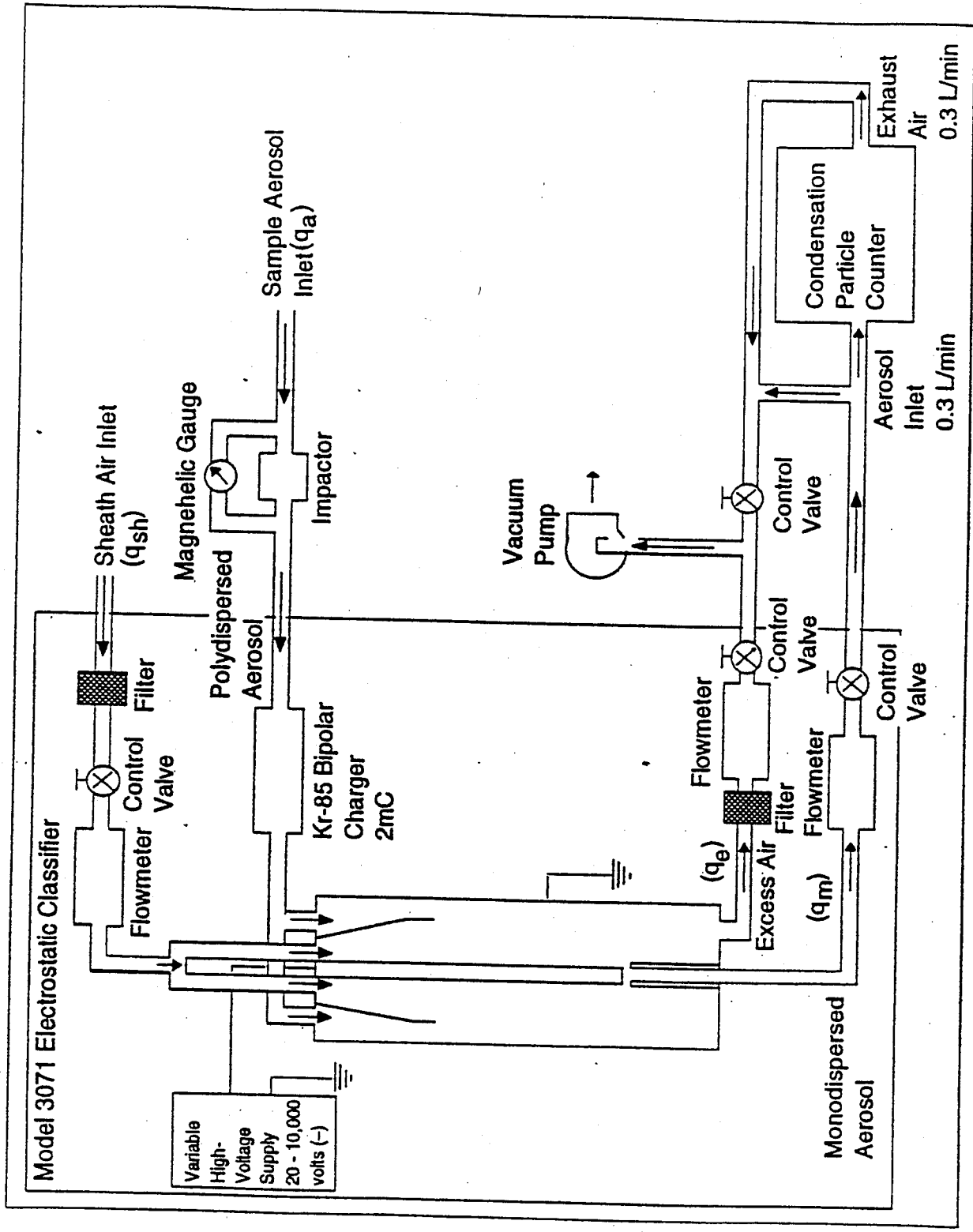- Humidity of Dilution Air

SECTION 4. Conclusion
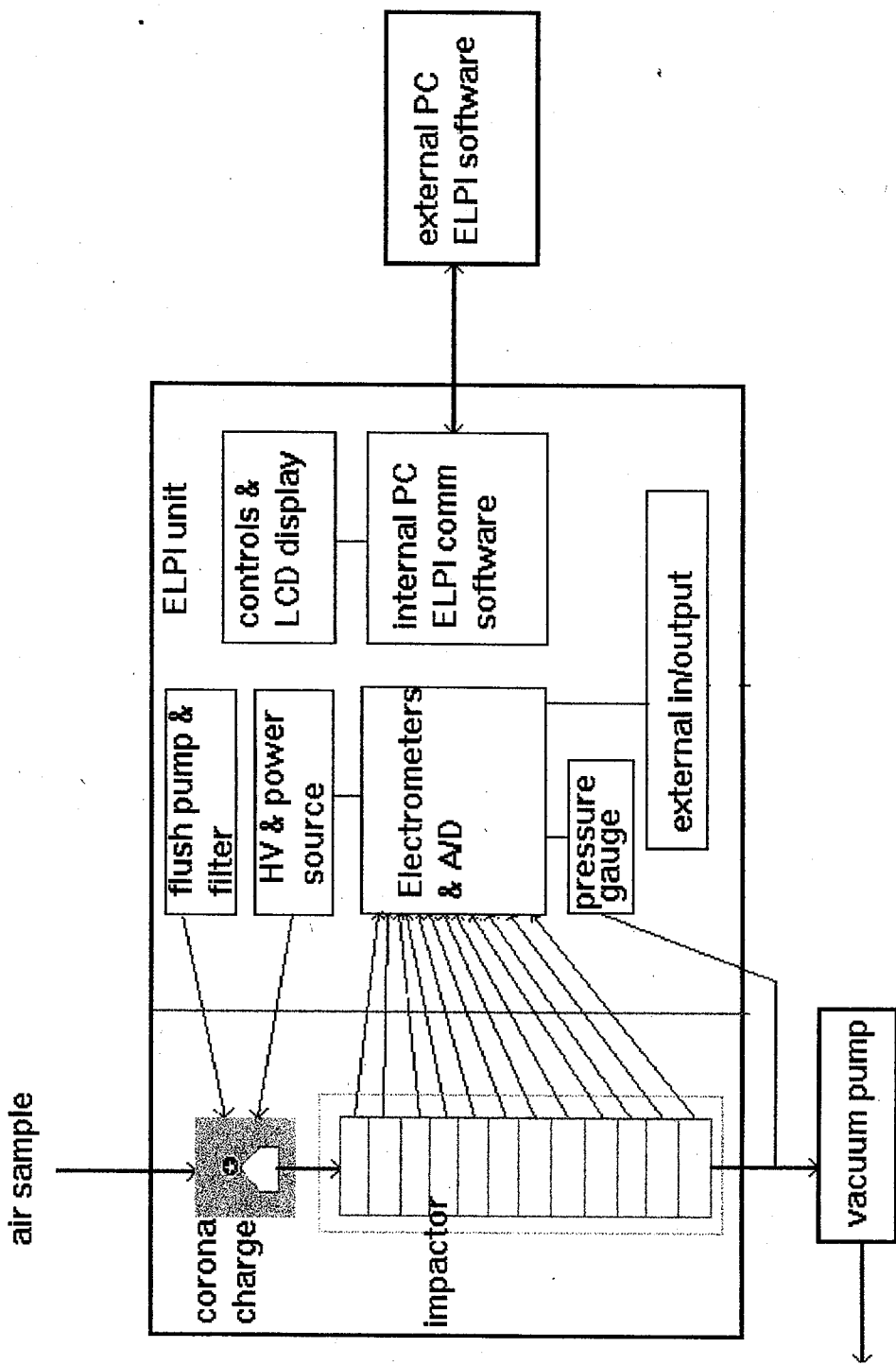
Figure B-1
Schematic of the SMPS System
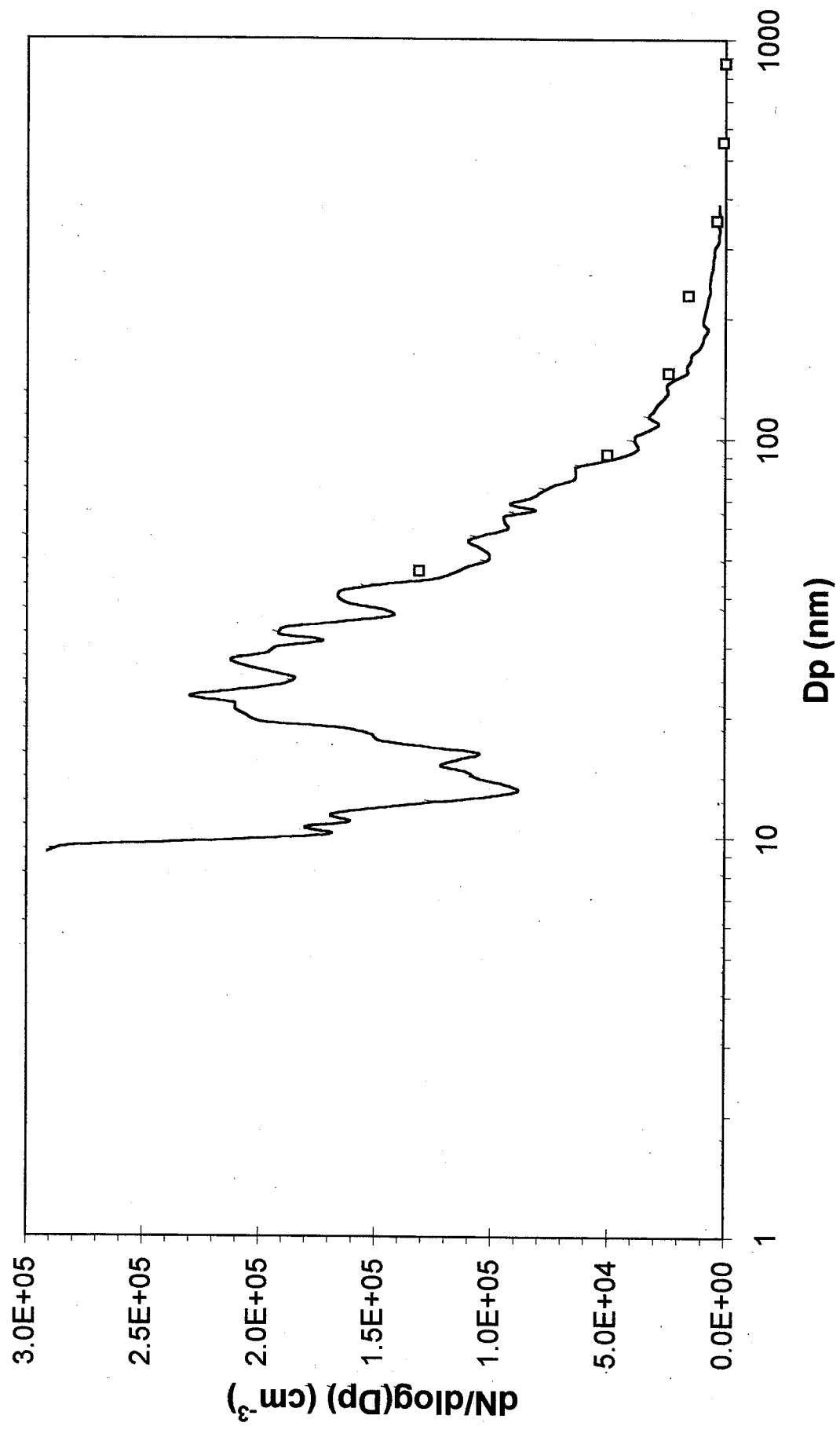
Figure 4. The scheme of ELPI operation principle.

100 seconds up scan for the SMPS (Roadside)

dN/dlog(Dp) (cm⁻³) axis values: 3.0E+05, 2.5E+05, 2.0E+05, 1.5E+05, 1.0E+05, 5.0E+04, 0.0E+00

Dp (nm) axis values: 1, 10, 100, 1000

engine emission

mode 1 (2600 rpm, 100% load, dr=264)

dN/dlog(Dp) (cm⁻³)

Dp (μm)

SMPS
ELPI
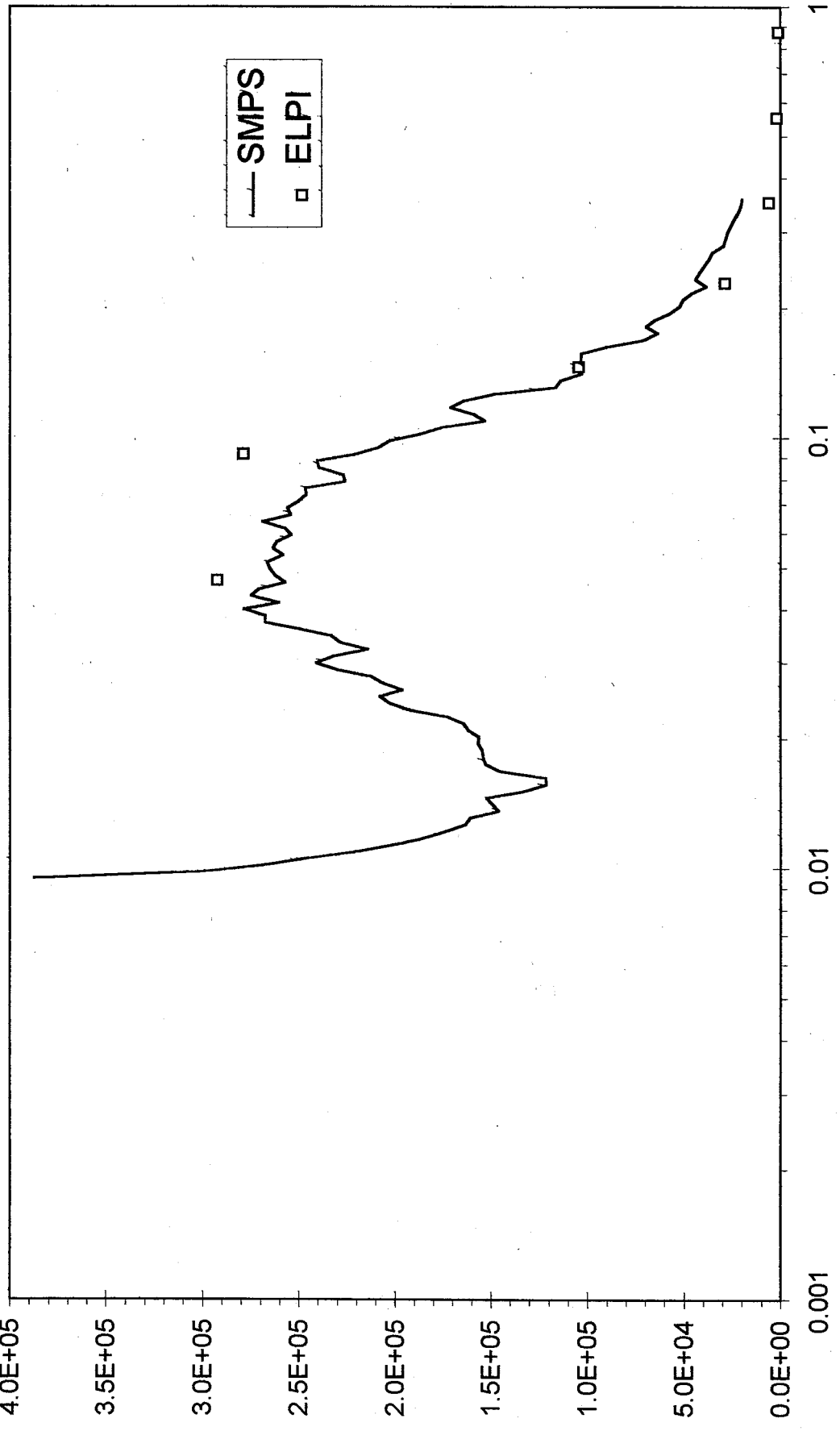
Comparison of NaCl Aerosol Size Distribution

Legend:
- —— SMPS
- ■ Aerodyn (d=1.0)
- ● Stokes (d=2.17)

X-axis: Dp (nm), ranging 10 to 10000

Y-axis: dN/dlog(Dp) (cm^{-3}), ranging 1.00E+03 to 1.00E+07

(6)
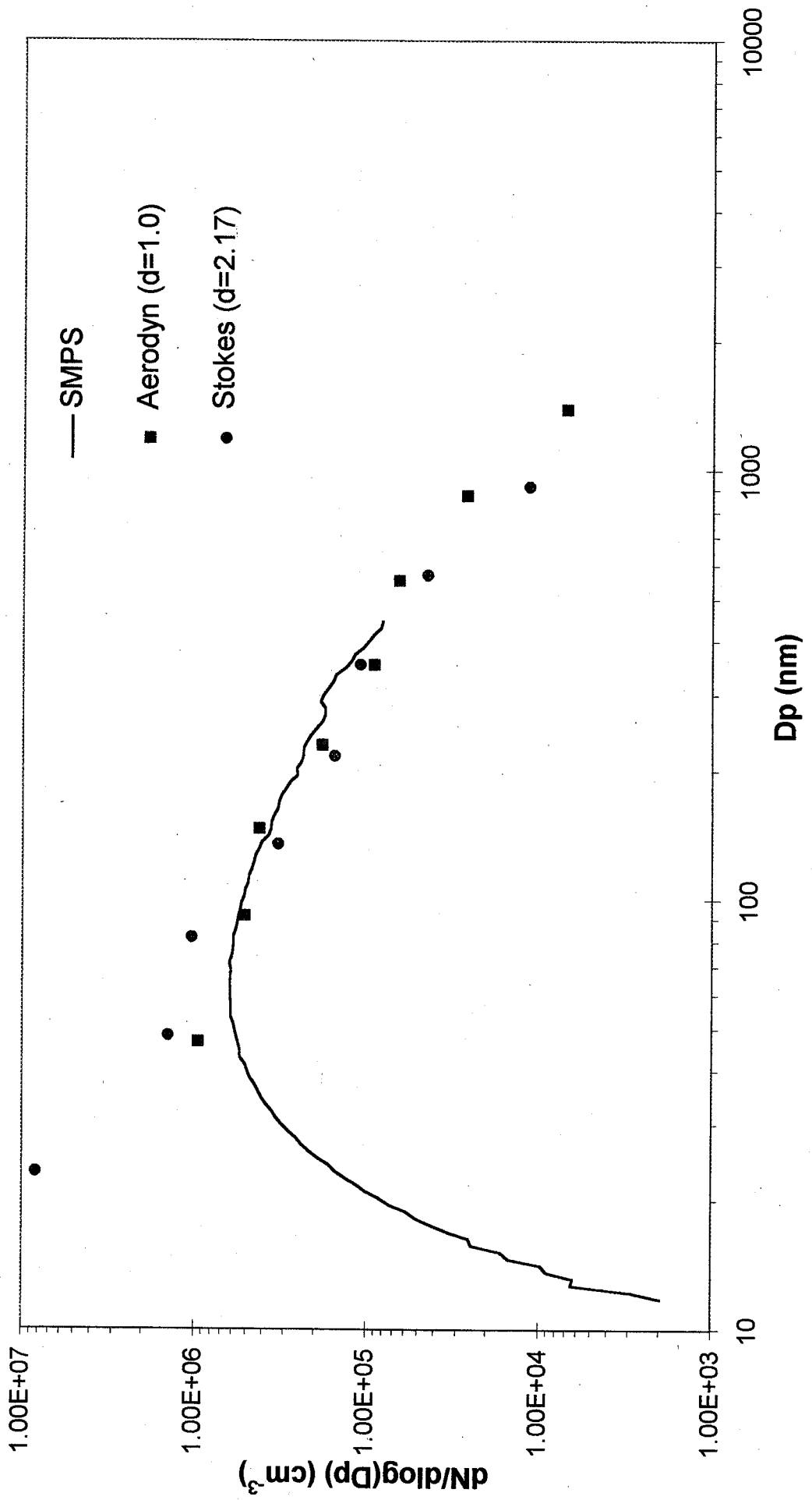
Total mass (eight hours) (Roadside)

ELPI measurement
Gravimetric method

mass (mg): 0.1, 0.09, 0.08, 0.07, 0.06, 0.05, 0.04, 0.03, 0.02, 0.01, 0

ELPI stage

1 (47nm) 2 3 4 5 6 7 8 9 (2.18μm)
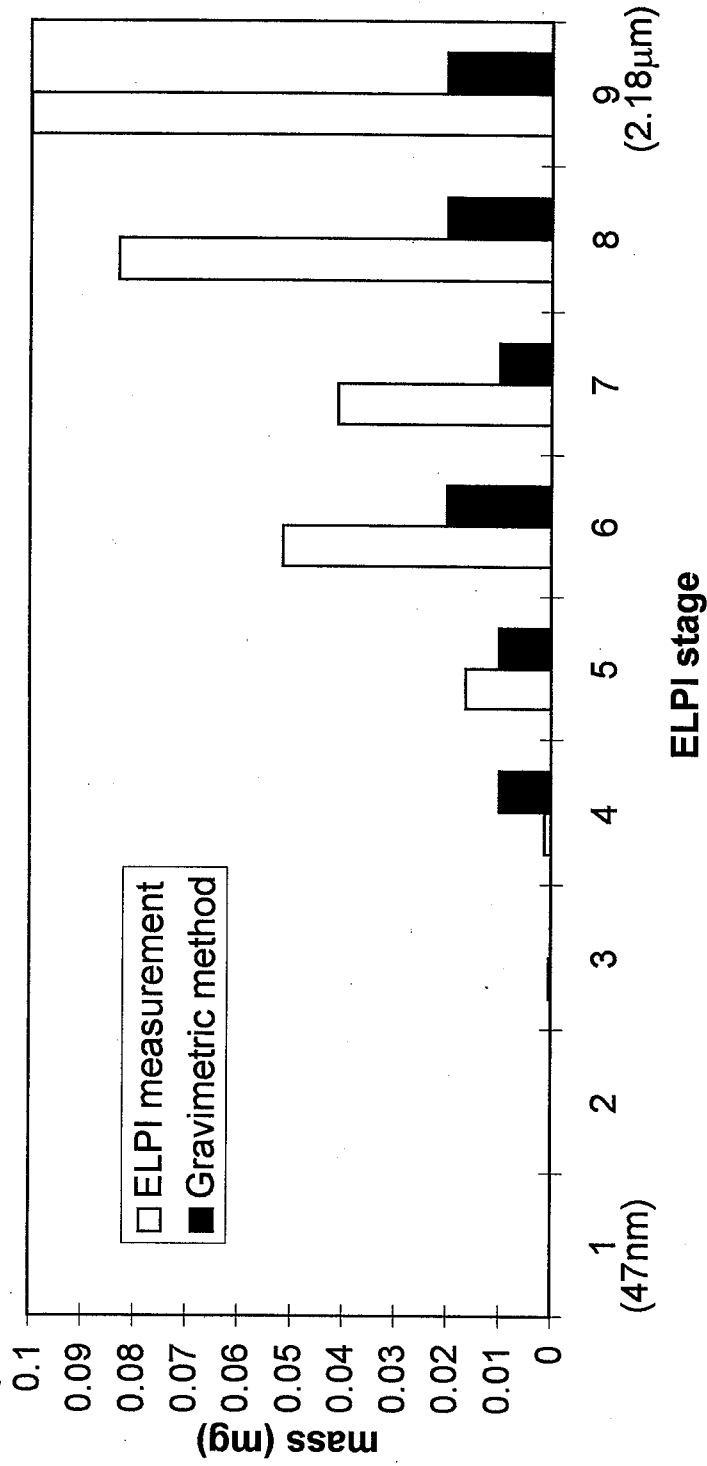
Eight Hour Average Particle Concentration

Method	mg $/m^3$
ELPI measurement	0.29
ELPI impactor	0.09
TEOM (EUN)	0.08

(7)

engine emission

1600 rpm 25% load (34 minutes sampling)

☐ ELPI measurement
■ Gravimetric method

Mass (mg) (y-axis): 0.35, 0.3, 0.25, 0.2, 0.15, 0.1, 0.05, 0

ELPI stage (x-axis): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
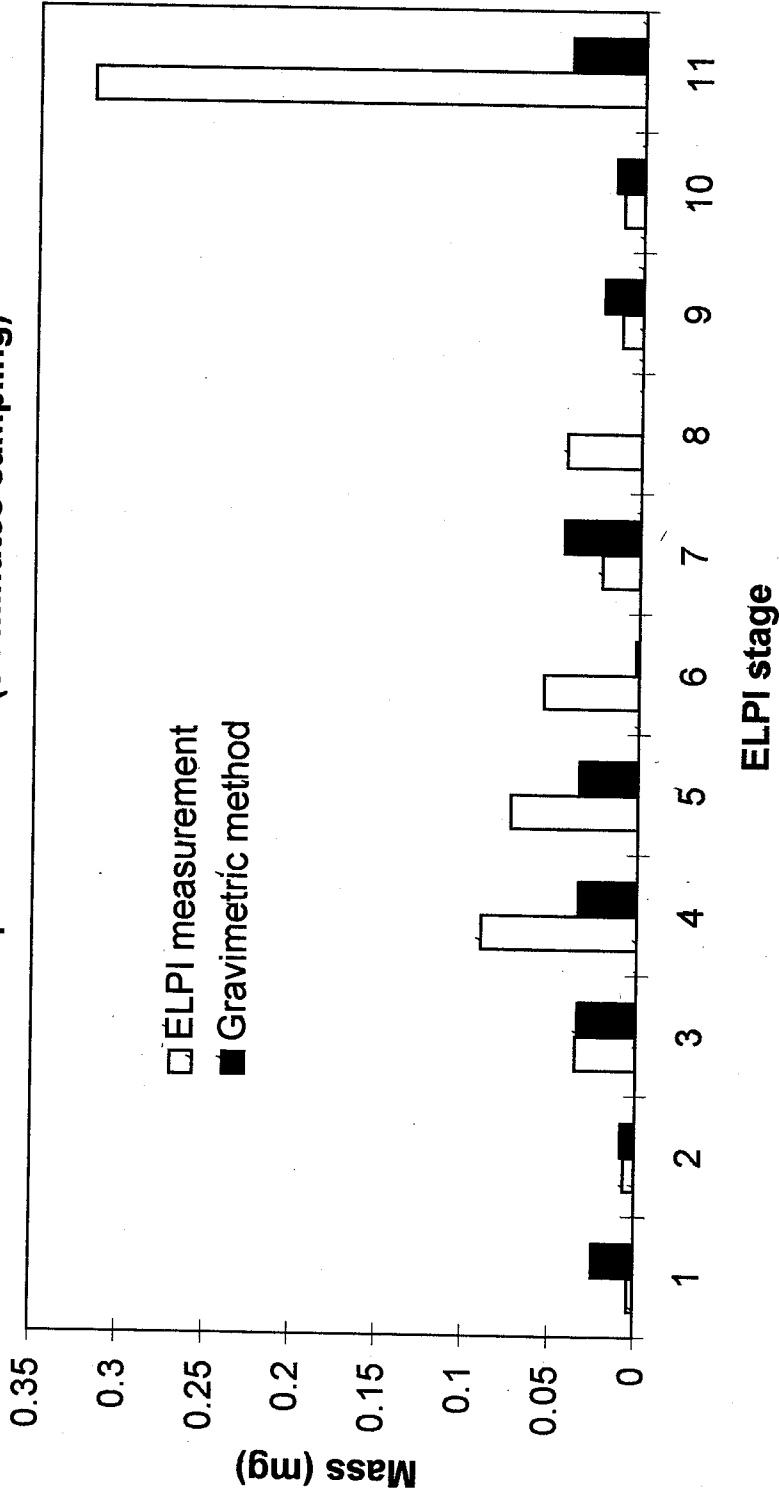
Method	mg /m³	
ELPI measurement	57.57	(up to stage 8, 2.69 µm)
ELPI impactor	59.64	
Filter	30.78	

Ratio of Gravimetric to ELPI Mass

High efficiency filter

Positive Displacement pump

26.5 C, 39% rh

SMPS

NOx analyzer

thermal precipitator

dry air

diluter

additional dilution air

ELPI

Filter sampling

Pump

dry air

NOx, CO, HC analyser

Engine

instruments

1600 rpm 50% load

dN/dlog(Dp) (cm^{-3})

Values on y-axis: 1.60E+09, 1.40E+09, 1.20E+09, 1.00E+09, 8.00E+08, 6.00E+08, 4.00E+08, 2.00E+08, 0.00E+00

Dp (µm) — x-axis: 0.001, 0.01, 0.1, 1

Legend:
- DR=1090
- dr=54
- dr=28

Run	Dilution ratio	Number concentration (# /cm^3)	Volume concentration ($\mu m^3/cm^3$)
1	1090	7.3E+08	2.0E+04
2	54	3.0E+08	1.9E+04
3	28	2.9E+08	2.3E+04

1600 rpm 25% load
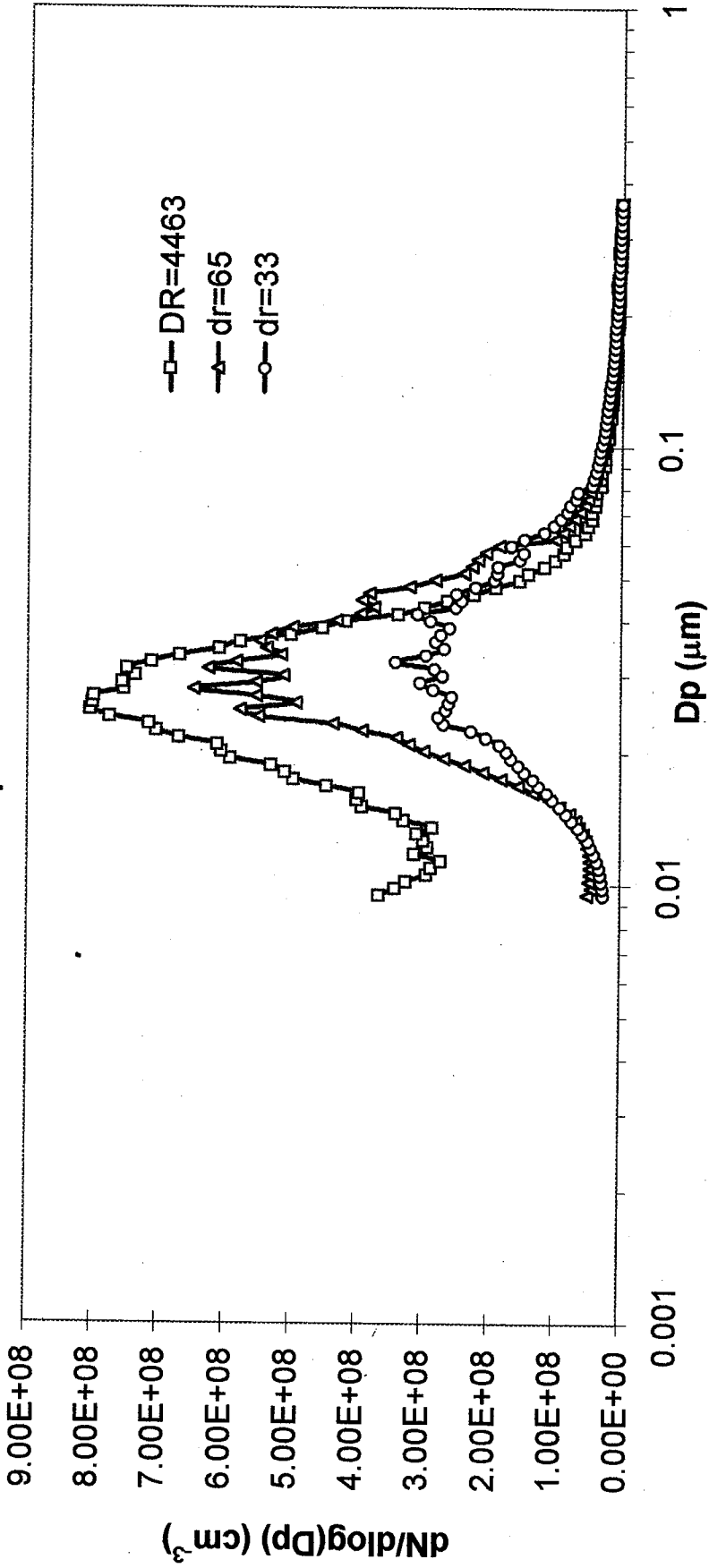
Run	Dilution ratio	Number concentration (#/cm³)	Volume concentration (µm³/cm³)
1	4463	3.3E+08	2.7E+04
2	65	2.6E+08	2.9E+04
3	33	1.7E+08	2.9E+04

1600 rpm 100% load
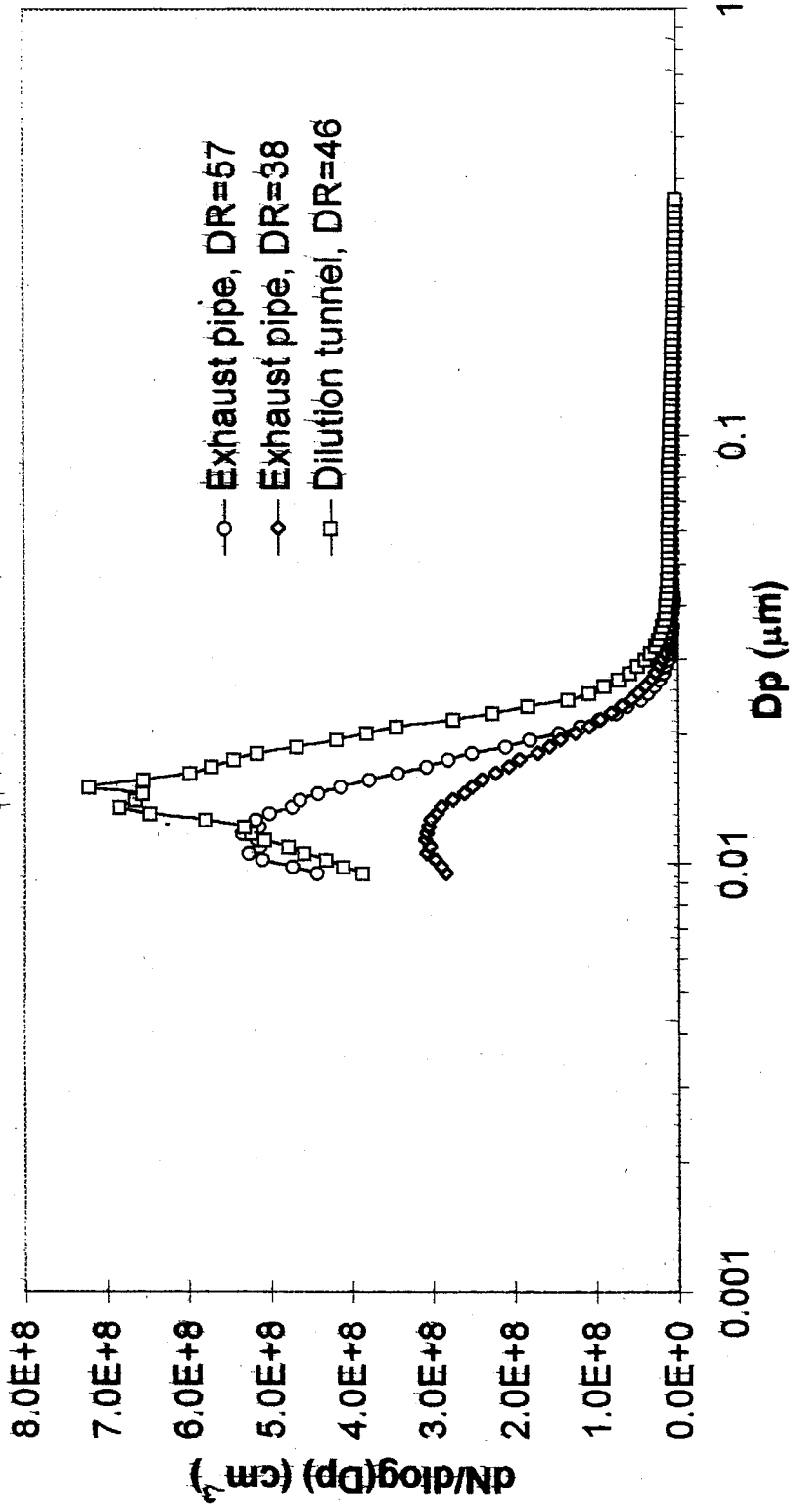
dN/dlog(Dp) (cm⁻³)

8.0E+8
7.0E+8
6.0E+8
5.0E+8
4.0E+8
3.0E+8
2.0E+8
1.0E+8
0.0E+0

0.001   0.01   0.1   1

Dp (μm)

—○— Exhaust pipe, DR=57
—◇— Exhaust pipe, DR=38
—□— Dilution tunnel, DR=46

Sampling from	Dilution ratio	Number Concentration (# /cm3)	Ratio of Vol. Con. SMPS/Filter
Exhaust pipe	57	1.41E+08	0.44
Exhaust pipe	38	1.11E+08	0.59
Dilution Tunnel	46	2.17E+08	0.70

1600 rpm 10% load
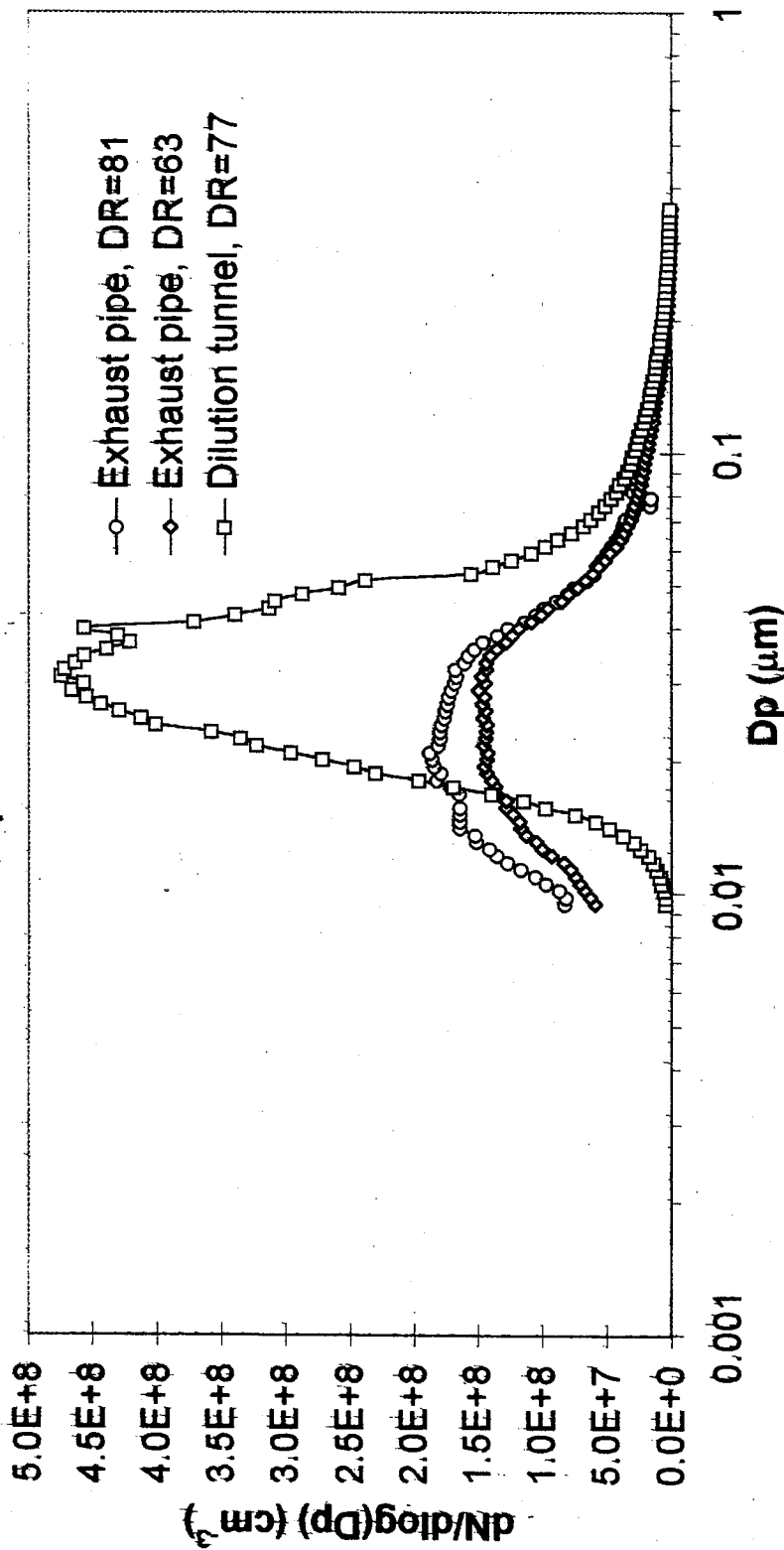
— Exhaust pipe, DR=81
— Exhaust pipe, DR=63
— Dilution tunnel, DR=77

dN/dlog(Dp) (cm⁻³) vs Dp (μm)

Y-axis: 5.0E+8, 4.5E+8, 4.0E+8, 3.5E+8, 3.0E+8, 2.5E+8, 2.0E+8, 1.5E+8, 1.0E+8, 5.0E+7, 0.0E+0

X-axis: 0.001, 0.01, 0.1, 1

Sampling from	Dilution ratio	Number Concentration (# /cm3)	Ratio of Vol. Con. SMPS/Filter
Exhaust pipe	81	1.00E+08	0.52
Exhaust pipe	63	1.00E+08	0.67
Dilution Tunnel	77	2.30E+08	1.05

Conclusion

- In the measurement of fine particles (up to 0.43 μm), good agreement is found between the SMPS and the ELPI.

- Particle size distribution in a modern diesel engine exhausts varies with the engine speed and load. Particle size distribution at a busy roadside has been measured: the number concentration of particles larger than 72 nm is almost stable, around 3.5×10^4 cm^{-3}; particle number concentration averaged on 11 SMPS runs is 1.8×10^5 cm^{-3}, and more than half of them are smaller than 30 nm, which reflects the fresh traffic emission; average number concentration distribution shows two peaks, 10 nm and 22 nm, however, the former peak is limited by the SMPS measuring range.

- One should be cautious when using the ELPI for determining mass concentrations; the ELPI value can be a factor of two in error; also one should be careful when using the Stokes diameter setting.

- Increasing dilution ratio, the peak diameter of particle number concentration decreases, total particle number concentration increases and volume concentration slightly decreases.

- Increasing humidity in dilution air, the peak diameter of particle number concentration increases, total particle number and volume concentrations increase. This is also confirmed by comparing the SMPS volume data to Perkins filter data converted from mass concentrations assuming unit density.

- Analogous to 52 °C for the filter mass collection, dilution ratio and humidity in dilution air should be considered in a standard method for measuring fine particles.