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Particle Size Distribution from Heavy Duty Diesel and Natural Gas Vehicles

Particle Size Distribution from Heavy-duty Diesel and Natural Gas Vehicles

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**National Research Center for Alternative
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OBJECTIVES

- TO CHARACTERIZE THE SIZE-DISTRIBUTIONS AND CONCENTRATIONS OF PARTICULATE MATTER EMISSIONS FROM DIESEL AND NATURAL GAS IN-USE HEAVY-DUTY VEHICLES.



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FACTORS AFFECTING NANO-PARTICLE FORMATION

- COMPLEX POST-COMBUSTION AND POST TAIL-PIPE REACTIONS; PARTICLE TRANSFORMATIONS
- FACTORS AFFECTING GAS-TO-PARTICLE TRANSFORMATIONS (BREAR, 1998):
 - DILUTION RATIOS
 - EXHAUST COOLING RATES
 - RESIDENCE TIME
 - TEMPERATURE
 - HUMIDITY
 - AMBIENT AEROSOL



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NEED FOR IN-USE EXHAUST EMISSIONS MEASUREMENTS?

- EXHAUST EMISSIONS FROM VEHICLES ARE A FUNCTION OF:
 - VEHICLE CHARACTERISTICS
 - AGE; INERTIA; USAGE; TRANSMISSION; FRONTAL AREA; DRIVING PATTERNS CONTROL DEVICES; FUEL TYPE.
 - AMBIENT CONDITIONS
 - TEMPERATURE; HUMIDITY; BAROMETRIC PRESSURE



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APPROACH

- IDENTIFY CHARACTERISTIC DRIVING CYCLES
 - TEST IN-USE HEAVY VEHICLES OVER REPRESENTATIVE DRIVING CYCLES USING THE WVU TRANSPORTABLE HEAVY-DUTY VEHICLE EMISSIONS TESTING LABORATORY
 - CENTRAL BUSINESS DISTRICT (CBD) CYCLE FOR BUSES
 - WVU 5-PEAK TRUCK CYCLE FOR TRUCKS
 - ANY OTHER CYCLE INCLUDING STEADY-STATE MODES
- MEASURE IN-USE VEHICLE EMISSIONS OF GASES, TOTAL PARTICULATE MATTER, SIZE-SELECTIVE PARTICULATE MATTER, $PM_{2.5}$, AND PM_{10}
 - TOTAL EXHAUST DOUBLE DILUTION TUNNEL - TOTAL PARTICULATE MATTER AND GASES
 - PORTABLE MINI-DILUTION TUNNEL WITH VARIABLE DILUTION RATIO CONTROLS: SMPS (SCANNING MOBILITY PARTICLE SIZER) - SUBMICROMETER SIZE-SELECTIVE DISTRIBUTIONS
 - MICRO-ORIFICE UNIFORM DEPOSIT IMPACTOR - SUBMICROMETER SIZE-SELECTIVE DISTRIBUTIONS
 - CYCLONES - PM_{10} AND $PM_{2.5}$ FRACTIONS.



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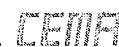


Transit Bus Being Tested on the WVU Transportable Heavy-Duty Vehicle Emissions Laboratory

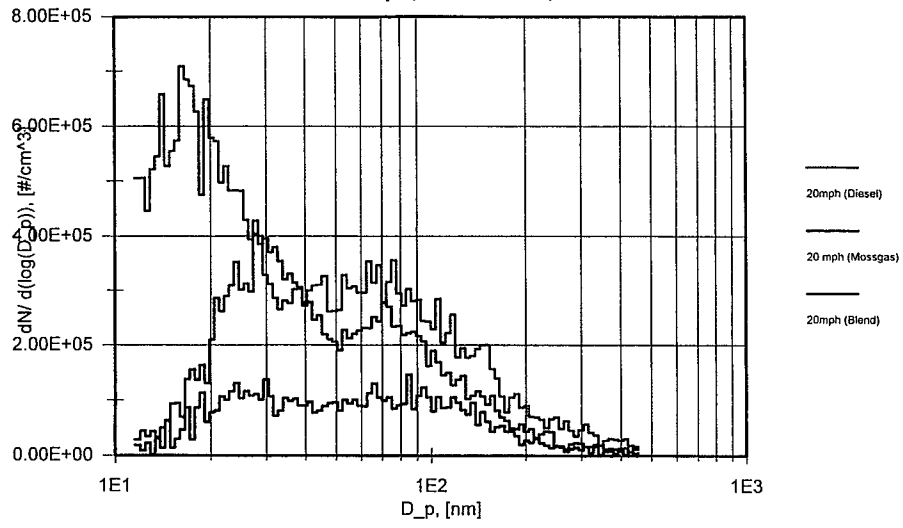


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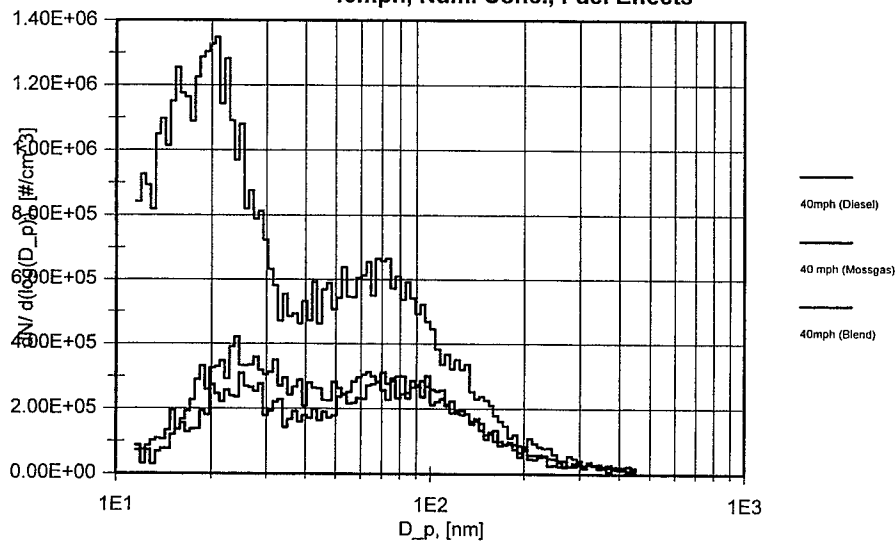
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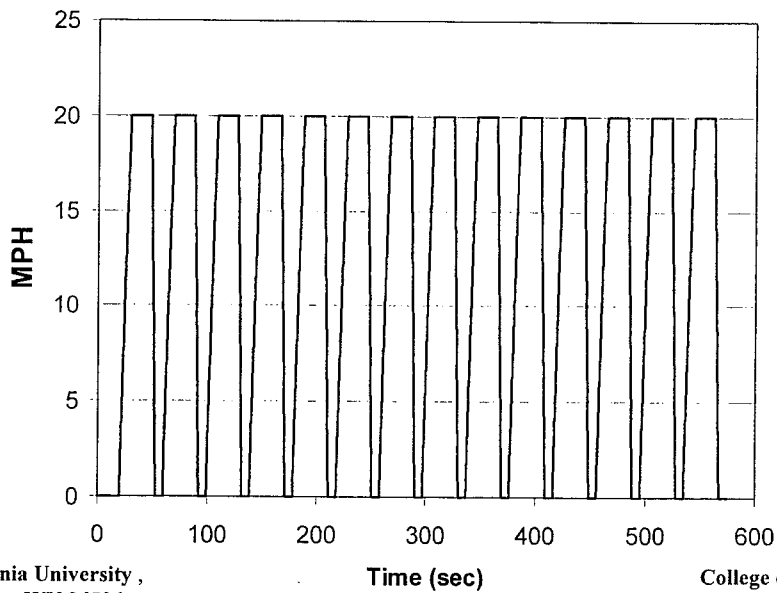
DDC 6V92 With Cat. Converter (6), SS,
20mph, Num. Conc., Fuel Effects



DDC 6V92 With Cat. Converter (6), SS,
40mph, Num. Conc., Fuel Effects



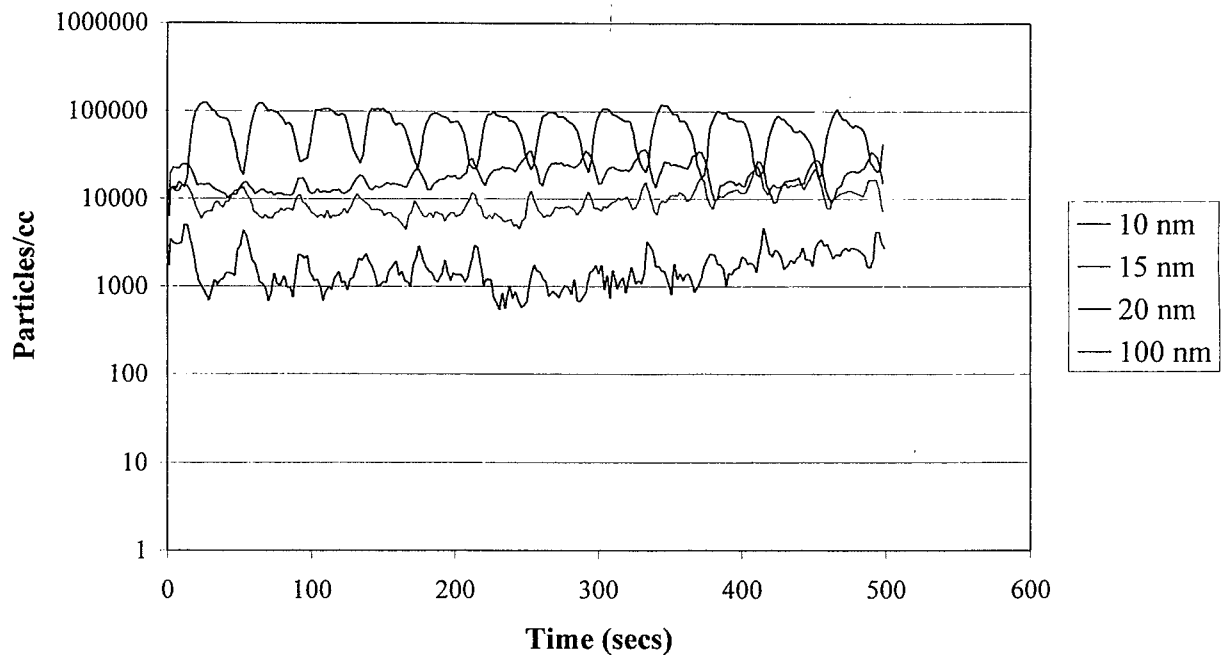
CENTRAL BUSINESS DISTRICT (CBD) BUS/TRUCK CYCLE



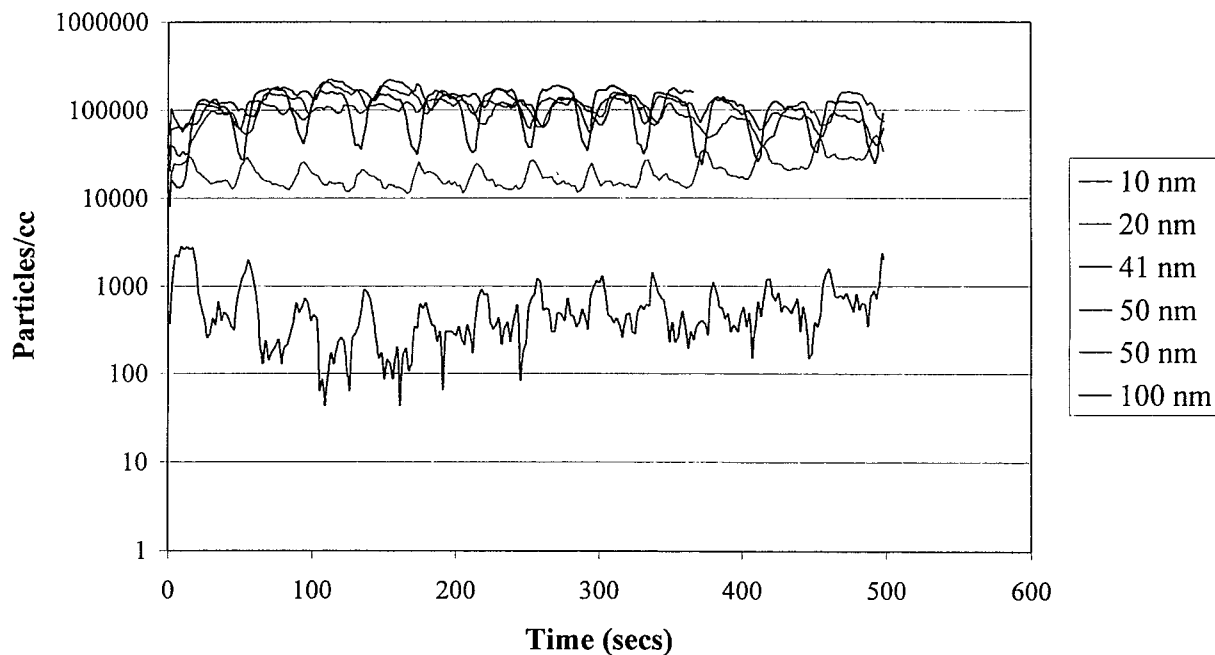
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Transit Bus 11, Cummins M11, D2, DR= 22:1, CBD Cycle

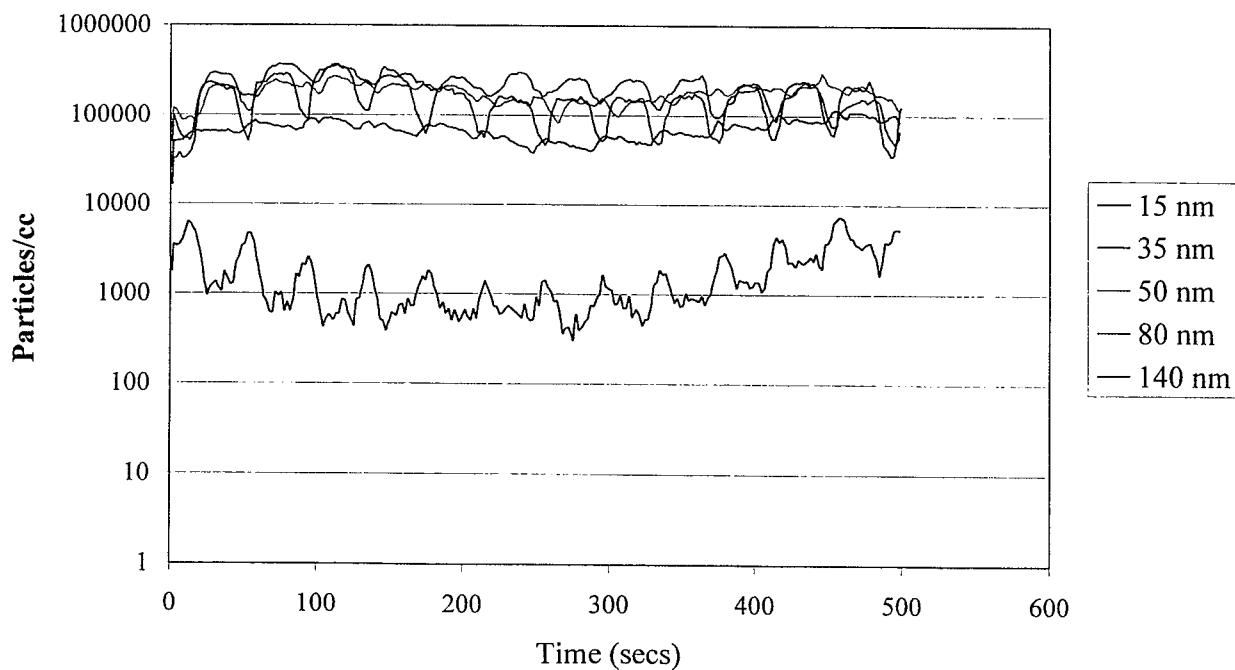


Transit Bus 13, Cummins M11, D2, DR= 22:1, CBD Cycle



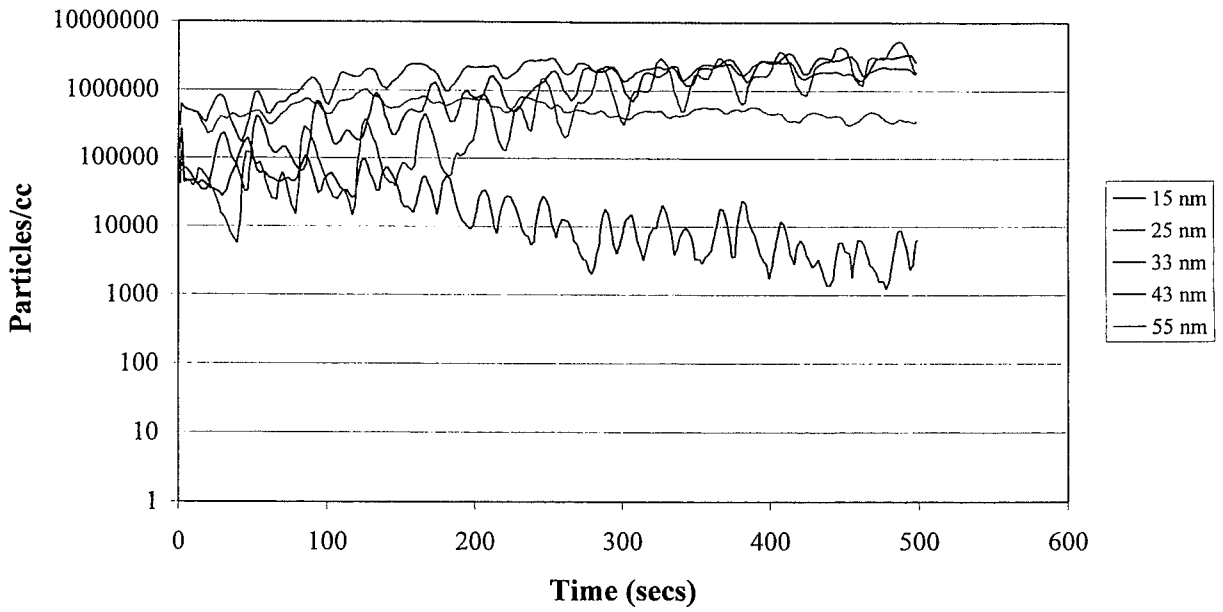
Bus 4222

Transit Bus 14, Cummins M11, D2, DR= 22:1, CBD Cycle



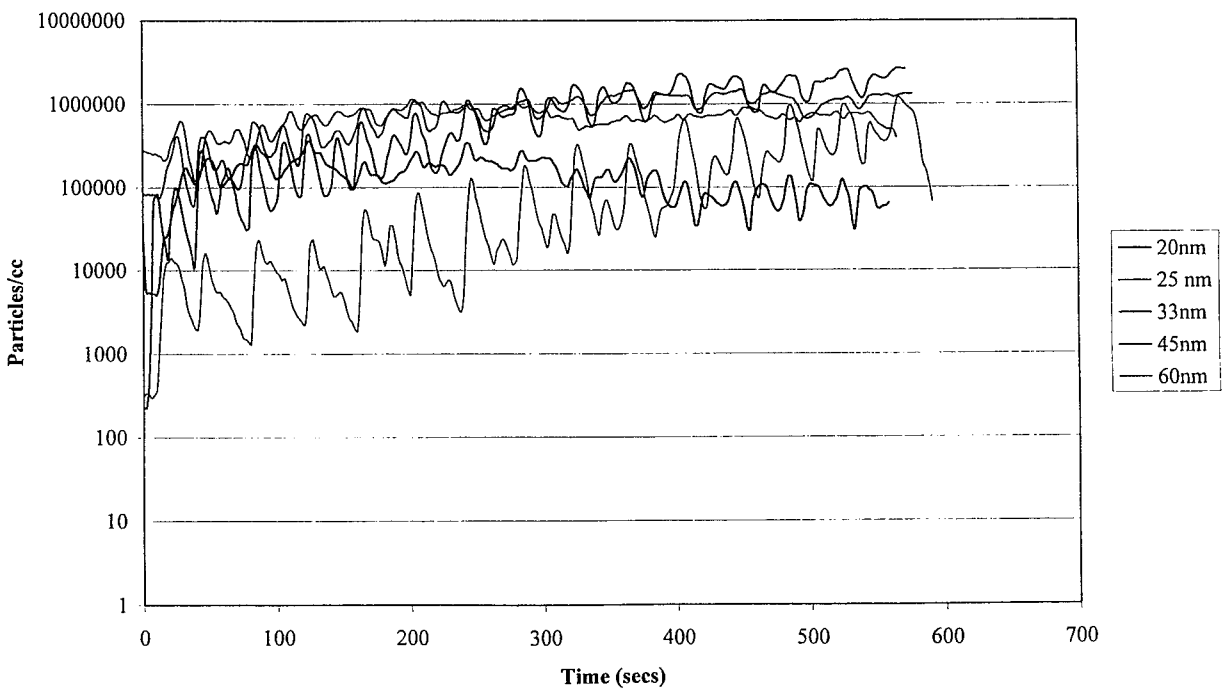
Bus 4221

**Transit Bus 3, Cummins L10-G, LNG, DR= 22:1,
CBD Cycle**



Bus 4329

**Transit Bus 4, Cummins L10-G, LNG, DR= 22:1, CBD Cycle
(CPC 3010)**



Bus 4328

WHAT IS THE NATURE OF THESE OBSERVED NANOPARTICLES?

- CARBONACEOUS PARTICLES?
- NUCLEATED ORGANICS?
- WATER DROPLETS?
- NUCLEATED SULFURIC ACID
- NUCLEATED METALLIC ASH (LUBE OIL BASED)?



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WHAT IS THE NATURE OF THESE OBSERVED NANOPARTICLES?

- IF THE ULTRAFINES ARE WATER DROPLETS - THERE MAY NOT BE ANY PROBLEMS.
- BUT, ARE THESE WATER DROPLETS?
- LET'S LOOK AT THE *MOUDI* DATA



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MICRO-ORIFICE UNIFORM DEPOSIT IMPACTOR (MOUDI)

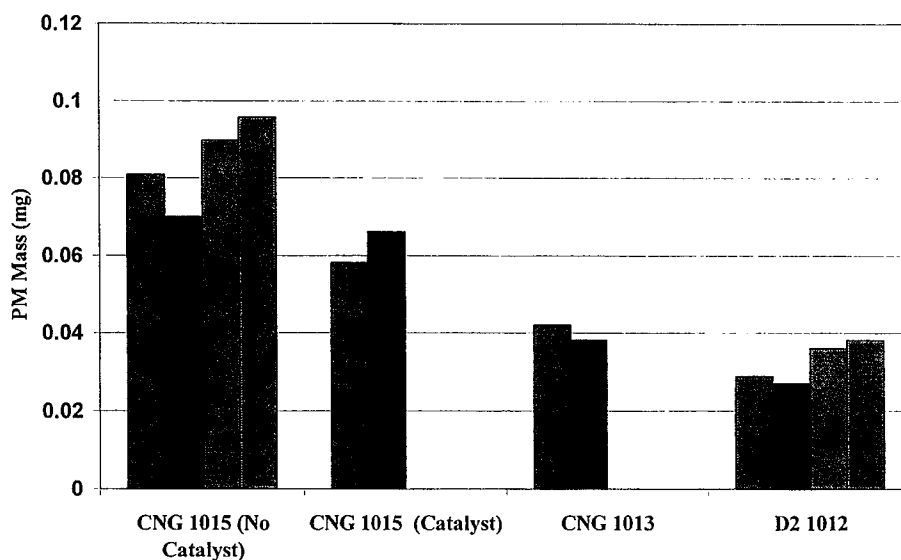
STAGES	CUT-POINT
1	10 μ m
2	5.6 μ m
3	3.2 μ m
4	1.8 μ m
5	1.0 μ m
6	0.56 μ m
7	0.32 μ m
8	0.18 μ m
9	0.10 μ m
10	0.056 μ m



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MOUDI AFTER-FILTER WEIGHTS 1991 CUMMINS ISB-175 DIESEL & B5.9-165G CNG, TRANSIT BUSES, CBD CYCLE, DENVER CO



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CONCLUSIONS

- CNG VEHICLES EXHIBIT VERY LOW PM MASS EMISSION RATES. BUT, NUMBER COUNT OF NANOPARTICLES MAY BE VERY HIGH.
- DIESEL AND NATURAL GAS *MOUDI* AFTER-FILTER WEIGHTS (LESS THAN 56 nm) WERE COMPARABLE.
- CNG AFTER-FILTER WEIGHTS WERE HIGHER!
- HOWEVER, FURTHER INVESTIGATION IS NEEDED INTO THE NATURE OF THE ULTRAFINES.



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