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**Issues in Measurement of
Particle Size Distributions
from In-Use Heavy-Duty Vehicles**

“Nanoparticle Measurements”

**Second ETH Workshop
Zurich, Switzerland**

Issues in Measurement of Particle Size Distributions from In-Use Heavy-Duty Vehicles

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**Department of Mechanical
and
Aerospace Engineering**

**College of Engineering
and Mineral Resources**

Summary of Vehicles Tested by Vehicle Type and Fuel Type

(January 1992 - March 1998)

Diesel	CNG	LNG	Methanol	Ethanol	Biodiesel	Dual	Other	Total
247	50	32	60	92	28	18	3	530
130	147	46			15	4	1	343
65	28					2	2	97
47	16		41		2	4	3	113
489	241	78	101	92	45	28	9	1083

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Objectives

- TO CHARACTERIZE THE SIZE-DISTRIBUTION OF PARTICULATE MATTER EMISSIONS FROM IN-USE HEAVY VEHICLES.
- TO ACQUIRE BOTH SIZE-SELECTIVE AND TOTAL PARTICULATE MATTER DATA, IN THE FIELD, FROM IN-USE VEHICLES OPERATING ON DIESEL AND ALTERNATIVE FUELS.
- ADDRESS THE RELATIONSHIPS BETWEEN TOTAL PARTICULATE MATTER, PM_{10} AND $PM_{2.5}$ FRACTIONS, AND SIZE-SELECTIVE PARTICULATE MATTER DISTRIBUTIONS.

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Global Objectives

- TO QUANTIFY THE EMISSIONS BENEFITS OFFERED BY ALTERNATIVE FUELS AND NEW GENERATION ENGINES IN HEAVY DUTY VEHICLE USE.
- TO SUPPLY THE RESULTING DATA TO THE NATIONAL ALTERNATIVE FUELS DATA CENTER FOR PERMANENT RECORDS, AND TO MAKE THE DATA AVAILABLE TO THE TRANSIT AUTHORITIES.

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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

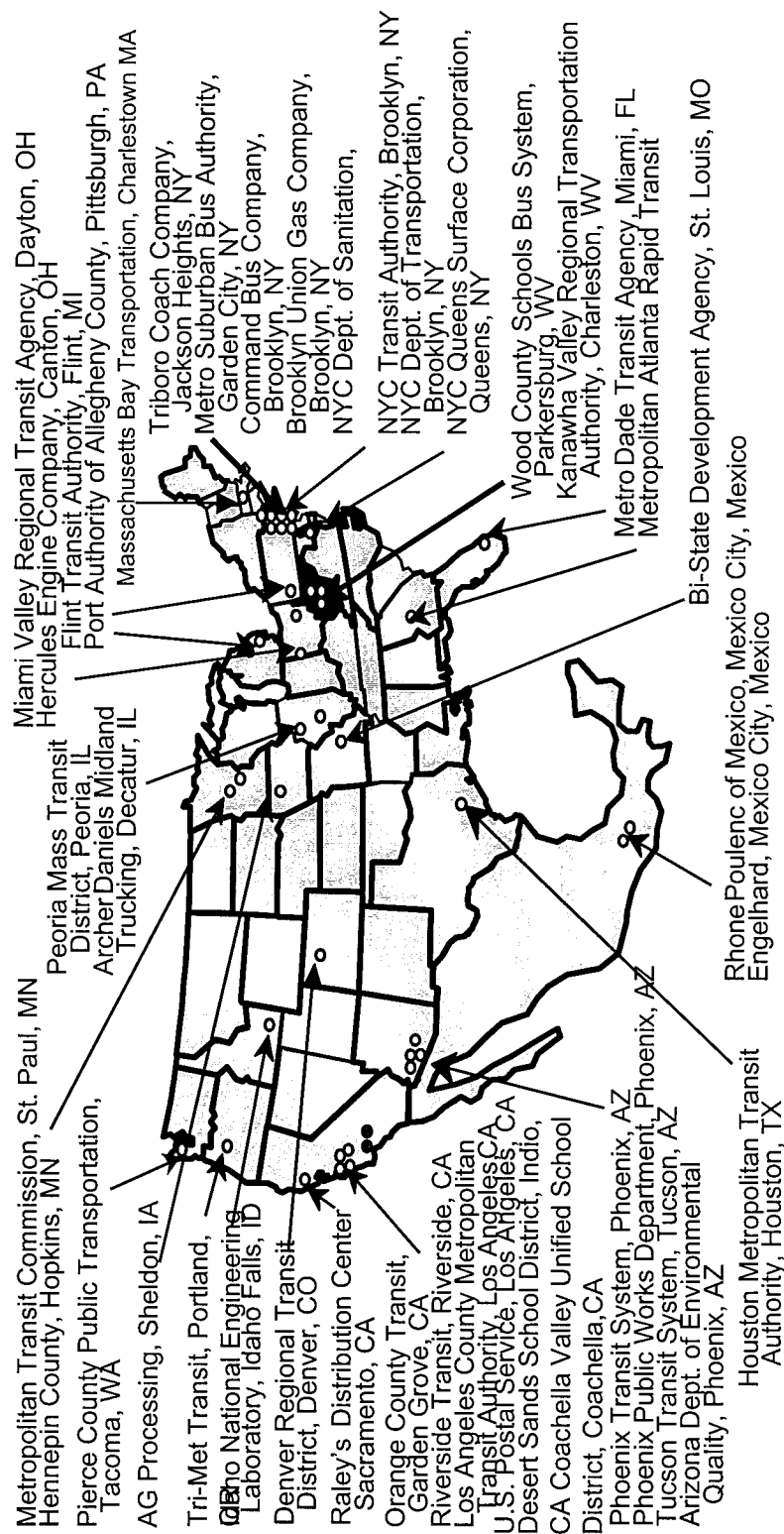
- IDENTIFY CHARACTERISTIC DRIVING CYCLES FOR PARTICULATE MATTER TESTING
 - TEST IN-USE HEAVY VEHICLES OVER REPRESENTATIVE DRIVING CYCLES USING THE WVU TRANSPORTABLE HEAVY-DUTY VEHICLE EMISSIONS TESTING LABORATORY
 - CENTRAL BUSINESS DISTRICT (CBD) CYCLE FOR BUSES
 - WVU 5-PEAK TRUCK CYCLE FOR TRUCKS
 - STEADY-STATE MODES FOR DEVELOPMENT WORK
- MEASURE IN-USE VEHICLE EMISSIONS OF PM_{10} , $PM_{2.5}$, SIZE-SELECTIVE PARTICULATE MATTER, AND TOTAL PARTICULATE MATTER
 - TOTAL EXHAUST DOUBLE DILUTION TUNNEL - TOTAL PARTICULATE MATTER
 - 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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Test Sites and Agencies where the WVU



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Transportable Heavy Duty Vehicle Emissions Testing Laboratories

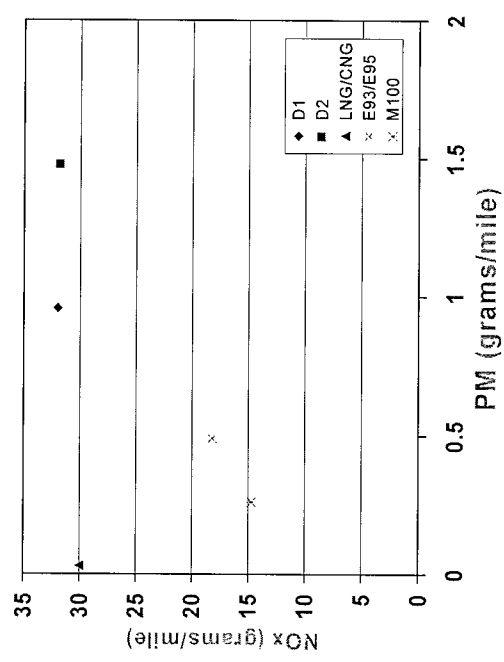
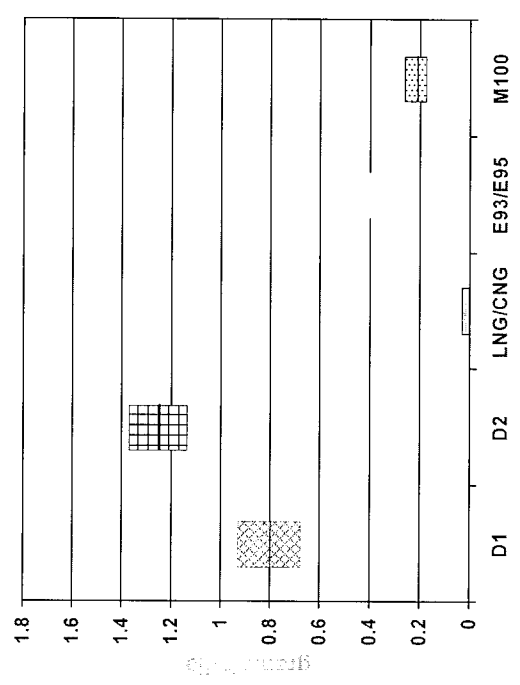
- **TWO HEAVY- DUTY LABORATORIES CONDUCT EMISSIONS TESTING OF ALTERNATIVE AND CONVENTIONAL FUEL VEHICLES:**
- **EACH LABORATORY INCLUDES:**
 - **TRANSPORTABLE DYNAMOMETER ON A SEMI-TRAILER THAT CAN BE LOWERED TO THE GROUND**
 - **FLYWHEELS TO SIMULATE INERTIA AND POWER ABSORBERS TO MIMIC ROAD LOAD**
 - **TOTAL EXHAUST TUNNEL FOR EXHAUST DILUTION(DOUBLE DILUTION)**
 - **LABORATORY TRAILER HOUSING CONTROLS AND EMISSIONS MEASURING EQUIPMENT**

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MEAN AND 95% CONFIDENCE INTERVAL OF PM EMISSIONS & STATISTICAL RESULTS OF PM AND NO_x EMISSIONS (BUSES TESTED ON WVU-TRUCK CYCLE)

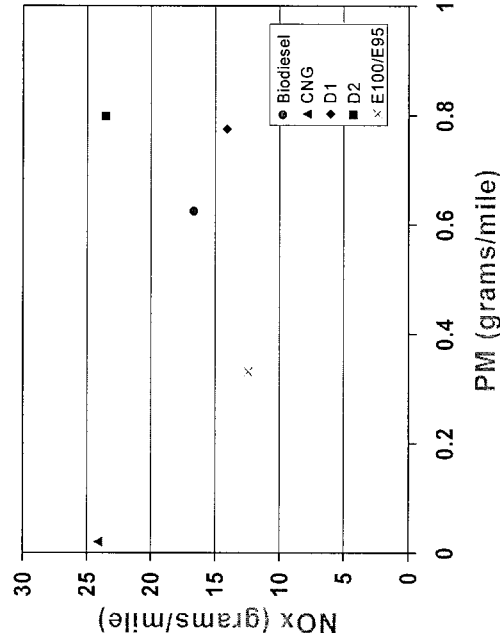
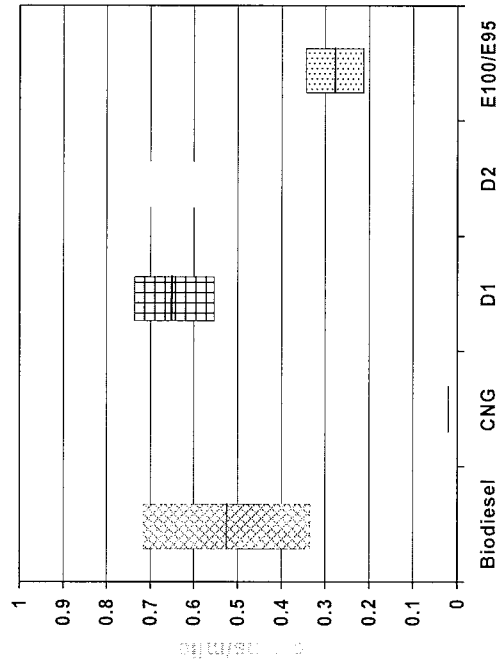


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MEAN AND 95% CONFIDENCE INTERVAL OF PM EMISSIONS & STATISTICAL RESULTS OF PM AND NO_x EMISSIONS (TRUCKS TESTED ON WVU-TRUCK CYCLE)

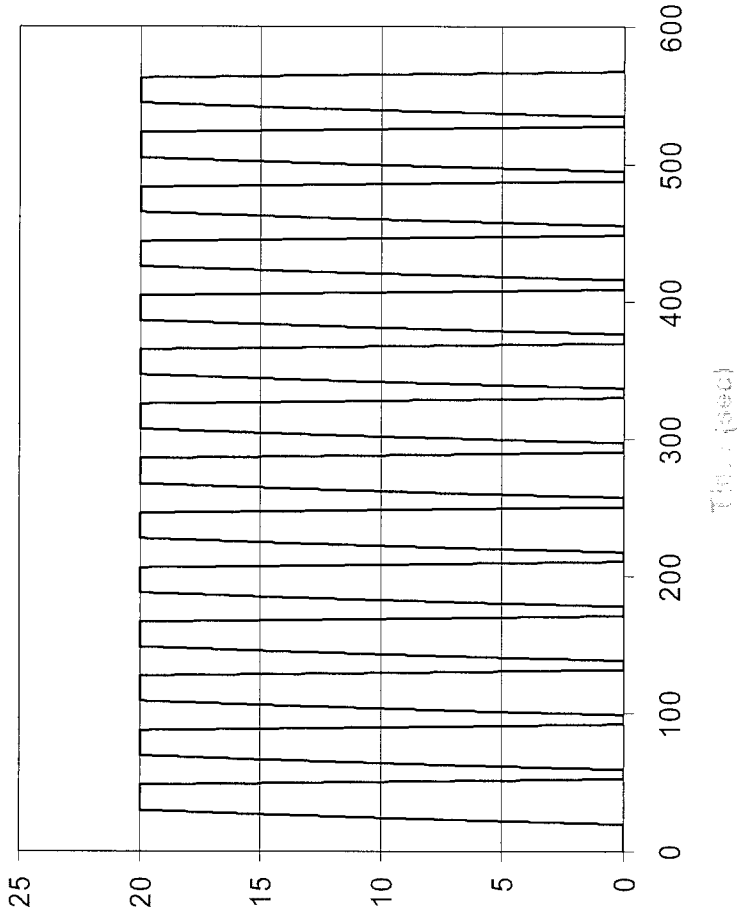


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Central Business District (CBD) Bus/Truck Cycle

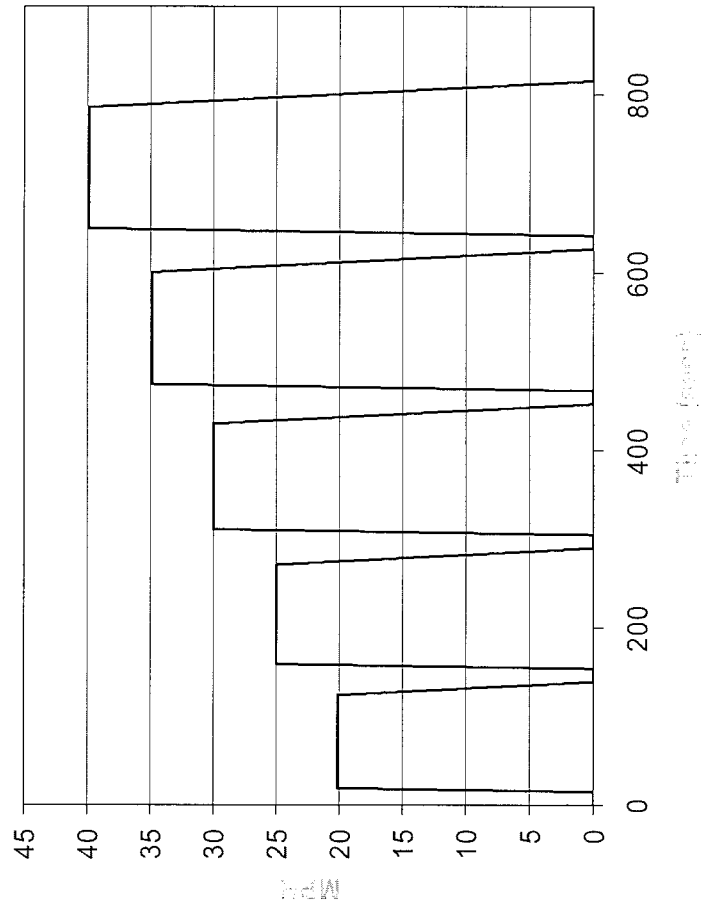


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5-mile Truck Cycle



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TEST VEHICLES AND ENGINES

• Diesel Vehicle No. 1

- Mack 1997 Diesel Refuse Truck
- Automatic Transmission, 4-speed
- Truck GVW 75220
- Test Weight 42000
- E-7-300, 6-cylinder, 12 liter, Rated at 300 hp

• Diesel Vehicle No. 2

- Mack 1997 Diesel Refuse Truck
- Automatic Transmission, 4-speed
- Truck GVW 75220
- Test Weight 42000
- E-7-300, 6-cylinder, 12 liter, Rated at 300 hp

• Diesel Transit Bus

- Collins Transit Bus
- Automatic Transmission, 5-speed
- Truck GVW 18780
- Test Weight 17914
- Cummins B5.9-175, 6-cylinder, 5.9 liter, Rated at 175 hp

• LNG Vehicle No. 1

- Mack E-7-300 1997 LNG Refuse Truck
- Automatic Transmission, 4-speed
- Truck GVW 75220
- Test Weight 42000
- E7G-325, 6-cylinder, 12 liter, Rated at 300 hp

• CNG Transit Bus

- Collins Transit Bus
- Automatic Transmission, 5-speed
- Bus GVW 18780
- Test Weight 17914
- Cummins B5.9-195, 6-cylinder, 5.9 liter, Rated at 195 hp

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Current Particle Sizing Projects at West Virginia University

- Size-Distribution of Diesel Particulate Matter from In-Use Heavy-Duty Vehicles
- Speciation of Size-Selective Particulate Matter from In-Use Heavy-Duty Vehicles
- Size-Distribution of Particulate Matter from Mining Engines with/without Exhaust After-treatment Devices
- Particulate Matter Sampling Methodology (with Univ. Of Minnesota)

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



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



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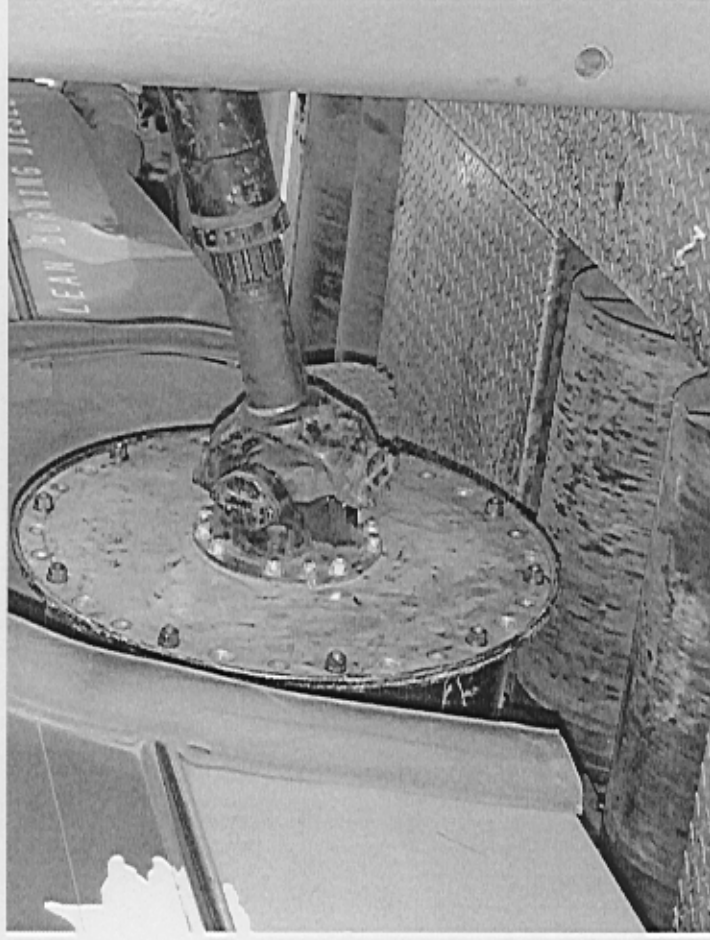


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Hub Adapters Used on the WVU Transportable Heavy-Duty Vehicle Emissions Laboratory




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Inside the Emissions Trailer of WVU Transportable Heavy-Duty Vehicle Emissions Laboratory



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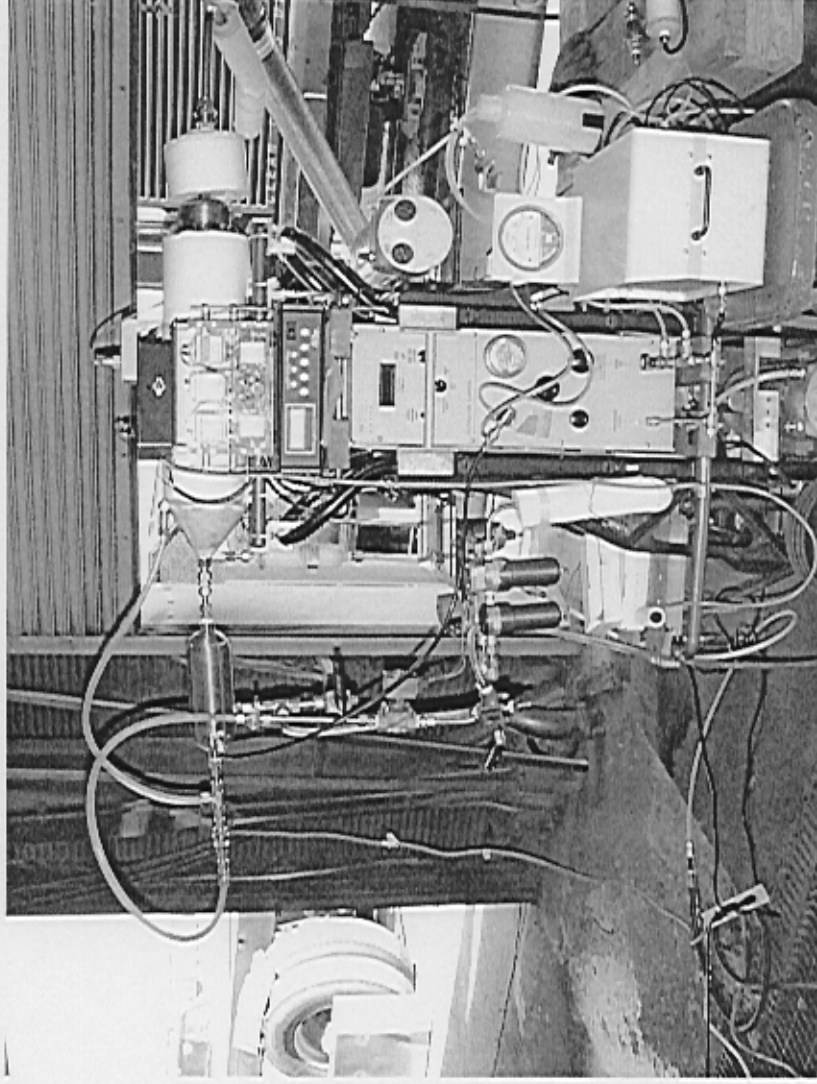


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Picture of Size-Selective Particulate Matter Sampling System (with a Variable Dilution Ratio Mini-Tunnel)



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Entire Particle Size Distribution of Particulate Matter Emitted from a Diesel Transit Bus operated at Steady State on a Chassis Dynamometer (Repeatability Tests)

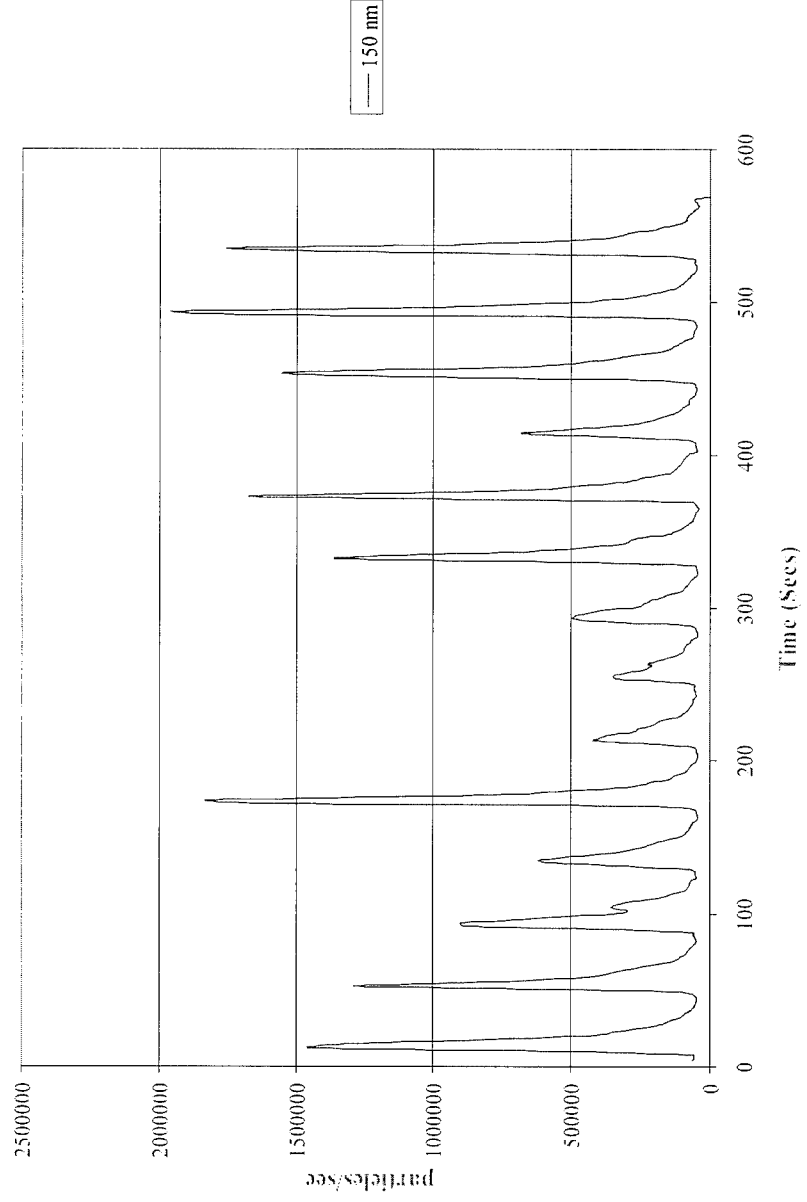


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Real-time Tracking of 150 nm Particle Size : Collins Transit Bus Operated on a CBD Cycle with Diesel Fuel # 2

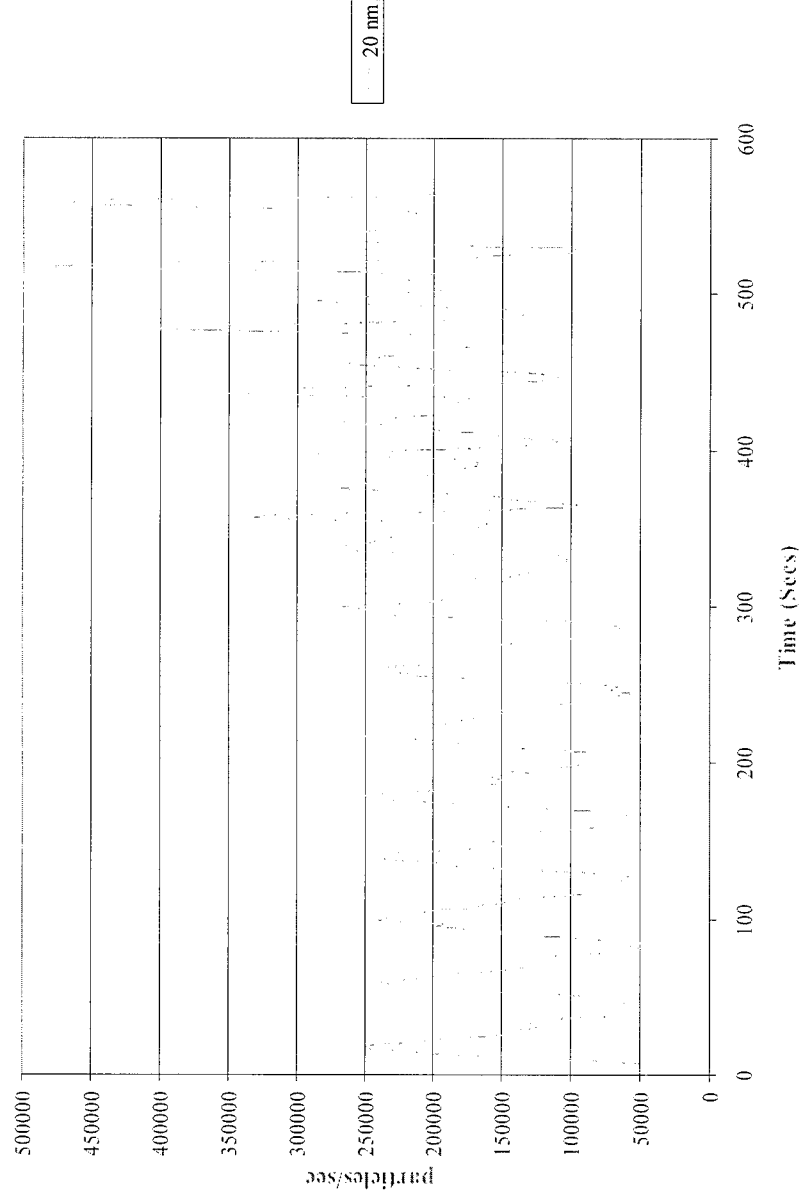


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Real-time Tracking of 20 nm Particle Size : Collins Transit Bus Operated on a CBD Cycle with Diesel Fuel # 2

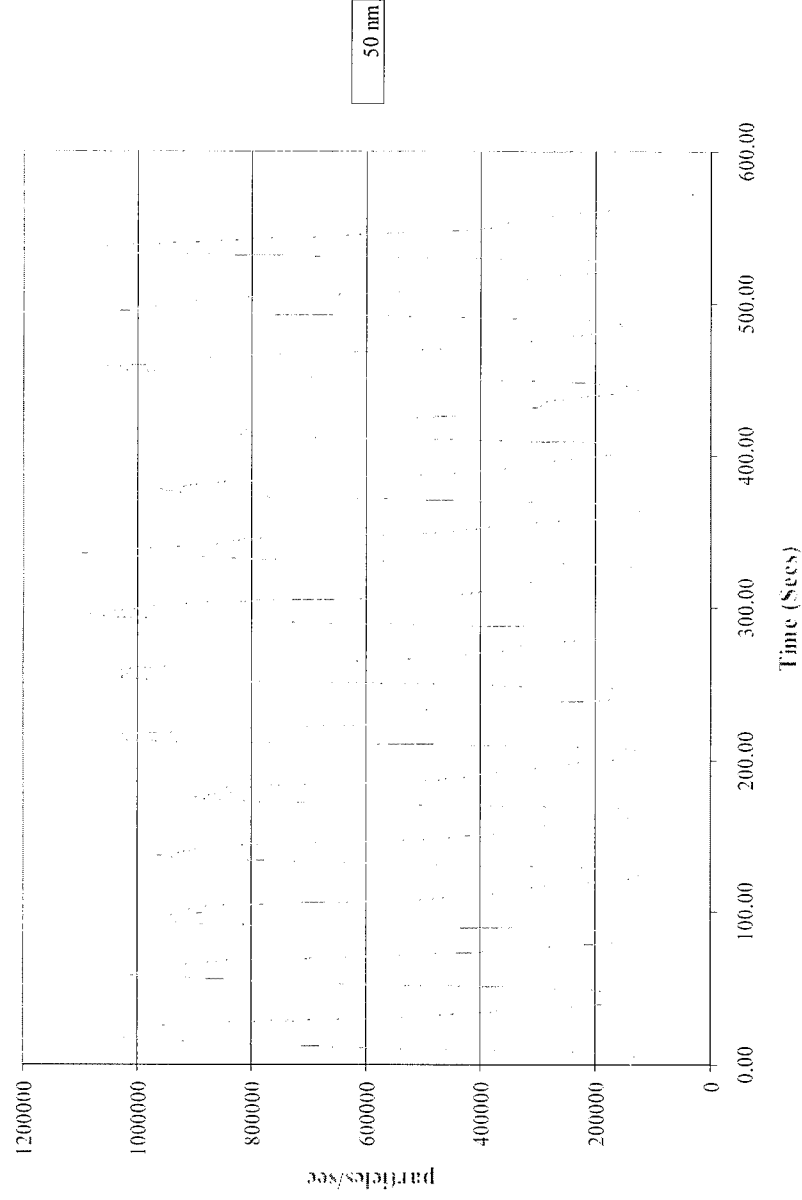


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Real-time Tracking of 50 nm Particle Size : Collins Transit Bus Operated on a CBD Cycle with Diesel Fuel # 2

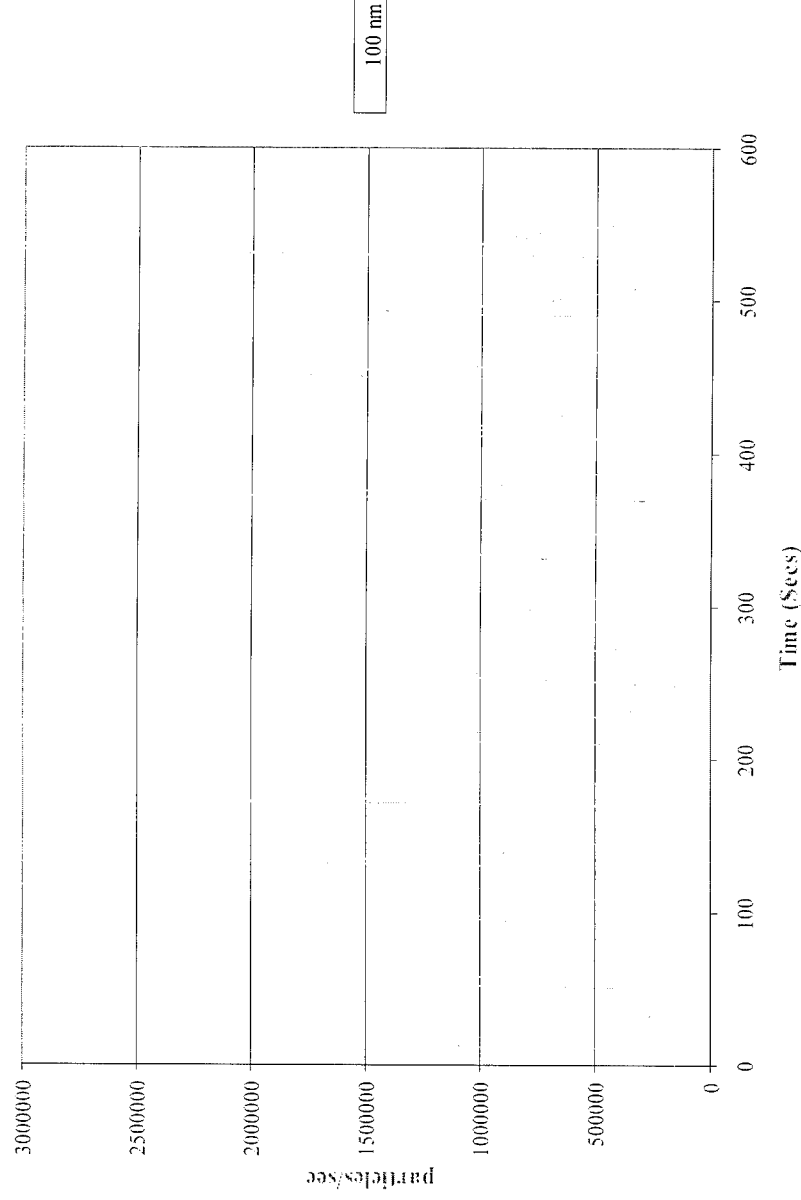


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Real-time Tracking of 100 nm Particle Size : Collins Transit Bus Operated on a CBD Cycle with Diesel Fuel # 2

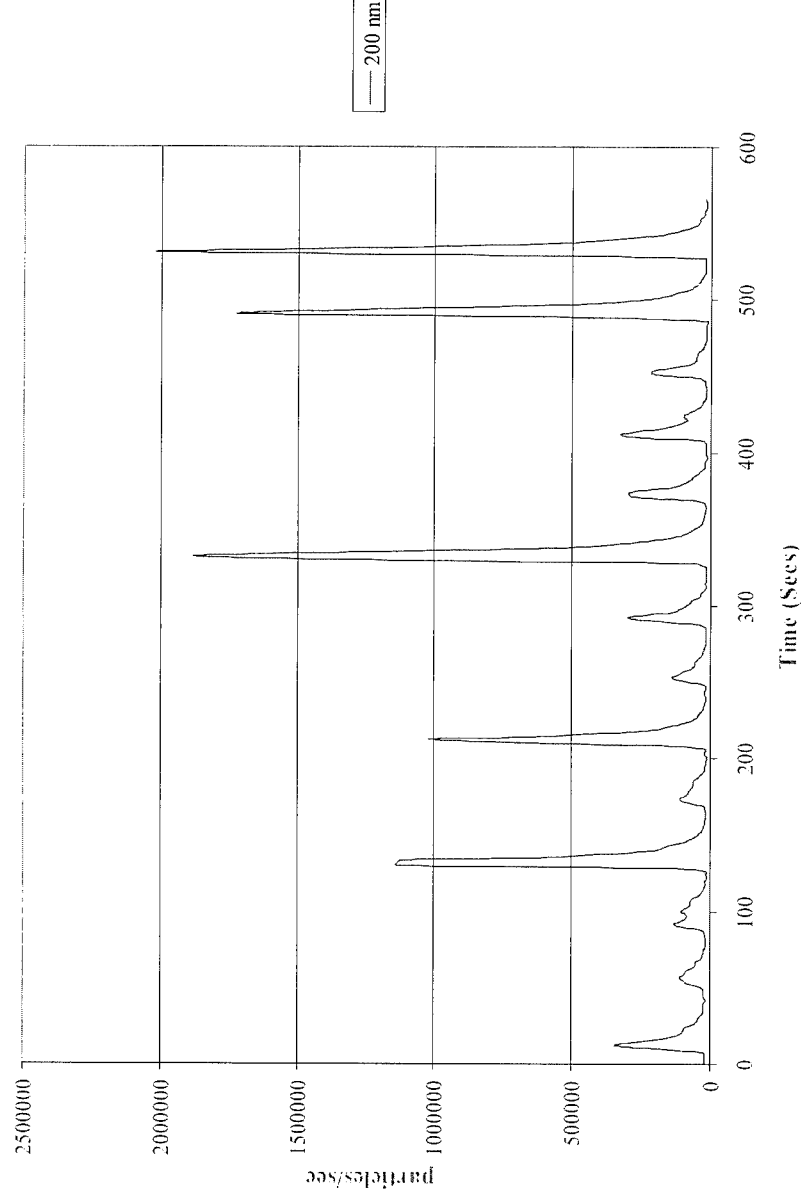


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Real-time tracking of 200 nm Particle Size : Collins Transit Bus Operated on a CBD Cycle with Diesel Fuel # 2

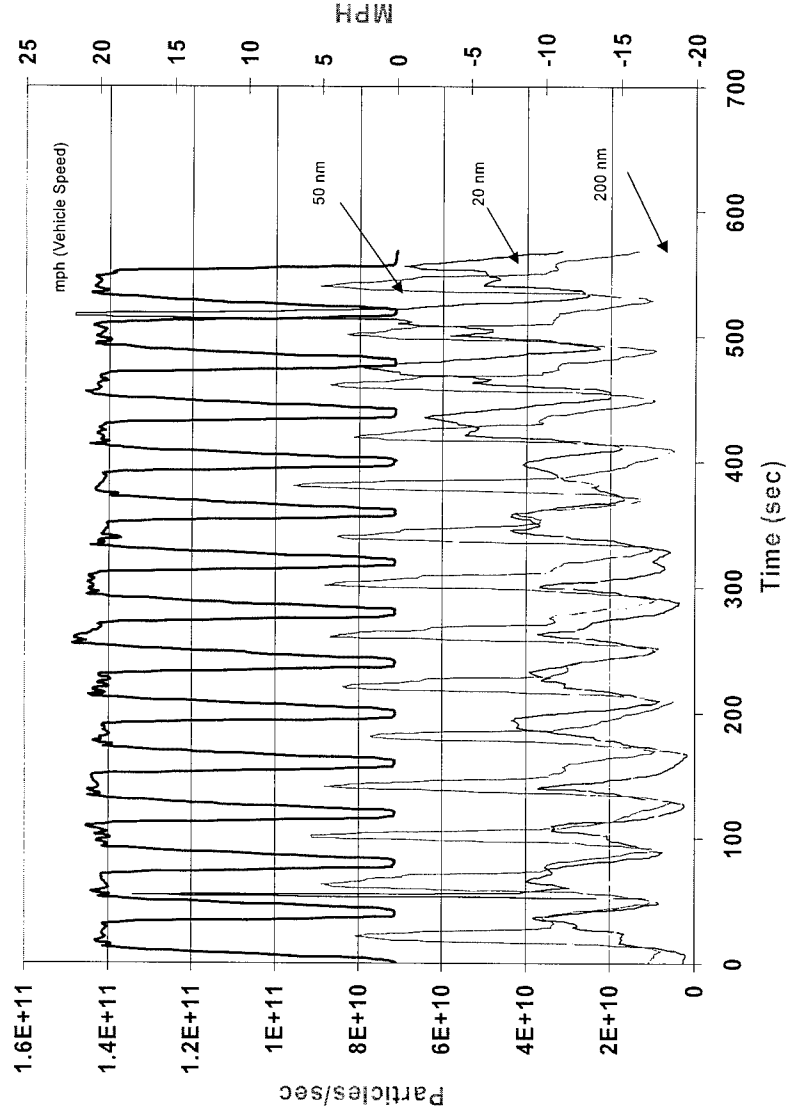


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In-Use Mack E-7 Refuse Truck # 2 Operated on a CBD Cycle with Diesel Fuel # 2 (Total Exhaust Tunnel)

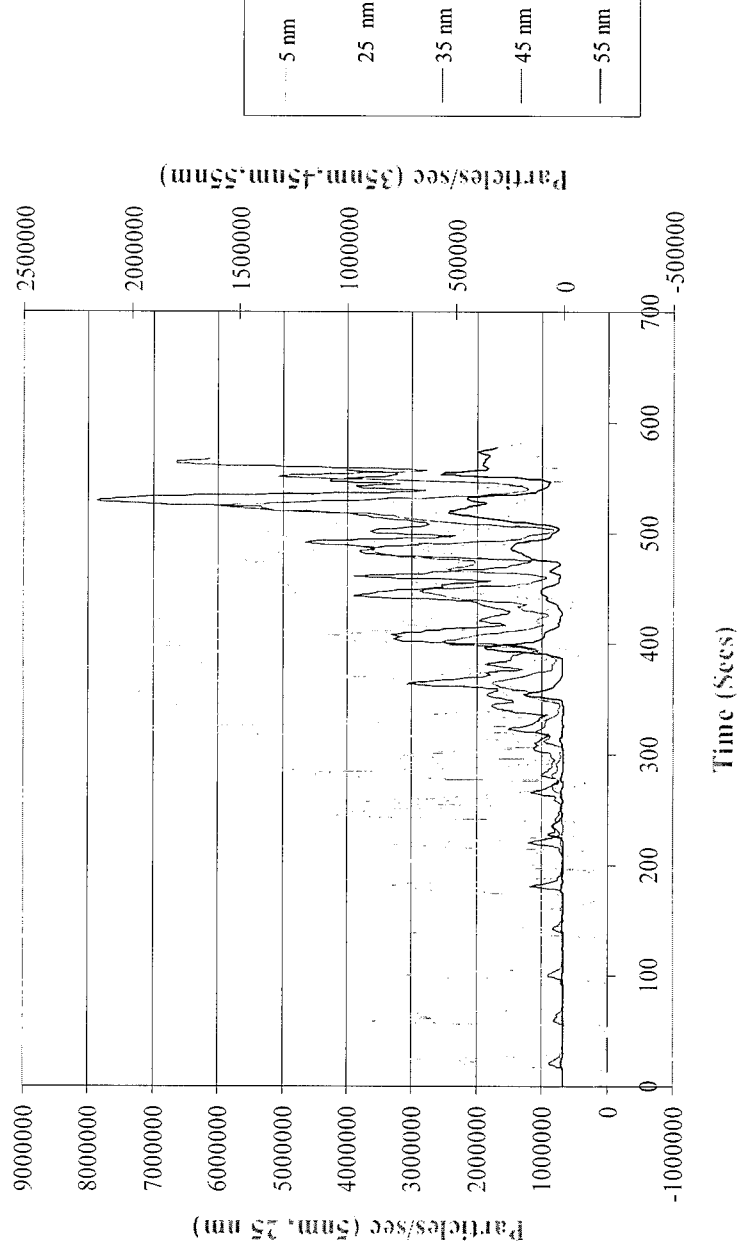


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Real-time Particle Size Distributions: Collins-Cummins B5.9-175 Transit Bus Operated on a CBD Cycle with LNG



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The Big Question

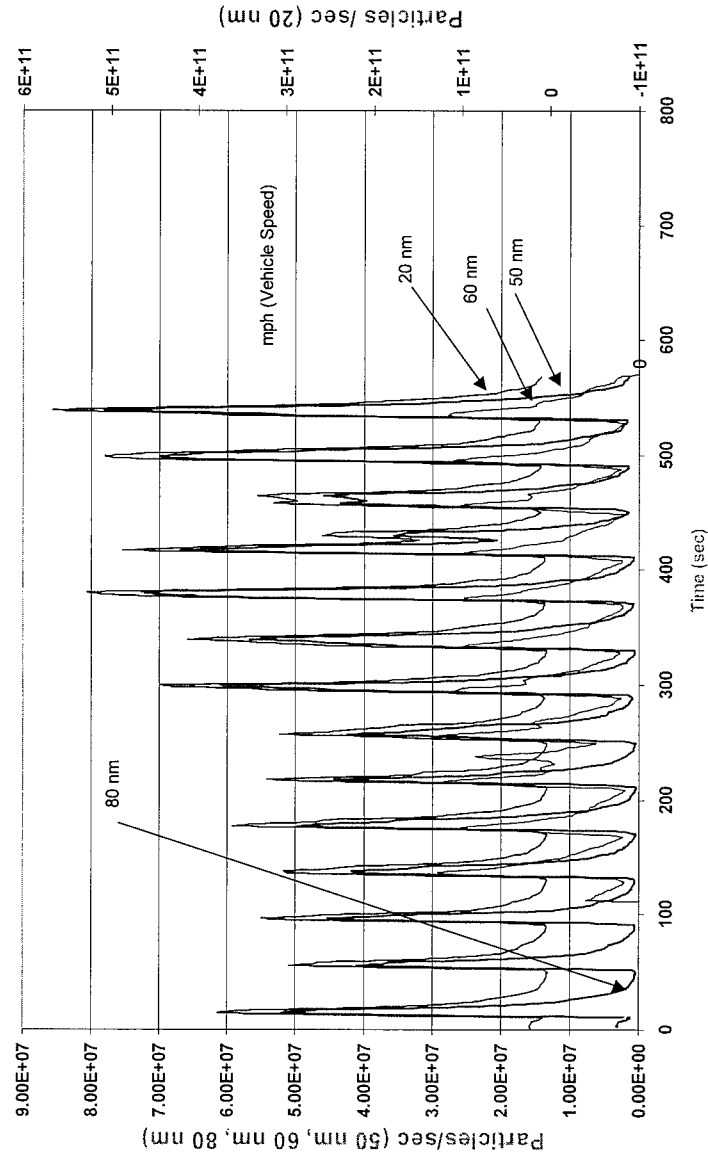
IS NATURAL GAS REALLY A “CLEAN” FUEL ?

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Real-time Particle Size Distributions: In-Use Mack E-7 Refuse Truck # 1 Operated on a CBD Cycle with LNG (Total Exhaust Tunnel)

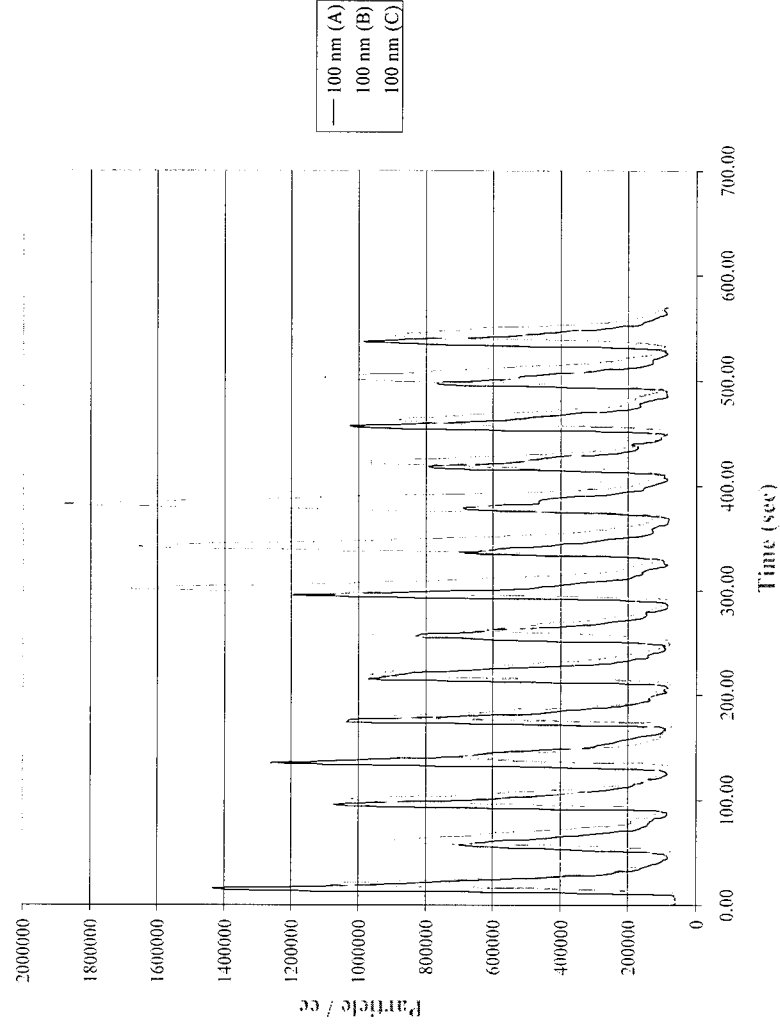


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Repeatability of Real-time Particle Size Distributions: Collins-Cummins Transit Bus Operated on CBD Bus Cycle with D2 Diesel



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