Cairo Air Improvement Project

Compressed Natural Gas Component

Emission Performance Testing of a Transit Bus Chassis with a Cummins C8.3G Engine Using CNG Fuel

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Emissions Performance Testing of a Transit Bus Chassis with a Cummins C8.3G Engine using CNG Fuel

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ABSTRACT

Alternative energy sources to replace diesel fuel have been sought in heavy vehicle applications to reduce dependence on imported oil and to reduce environmental impact of tailpipe emissions. Spark ignited lean burn natural gas fueled engines have found applications in transit buses, school buses and trucks. West Virginia University, through use of one of its Transportable Heavy-Duty Vehicle Emissions Testing Laboratories, characterized the emissions of a transit bus chassis intended for use in Cairo, Egypt. Funding for the research was provided by Chemonics International, Inc. who was managing the Cairo bus program. The bus chassis was powered by a Cummins C8.3G engine that was fueled by compressed natural gas (CNG). The laboratory employed a chassis dynamometer utilizing flywheels to mimic vehicle inertia and air-cooled eddy current power absorbers to account for road load. Engine exhaust was routed to a full-scale dilution tunnel, and regulated gas emissions and particulate matter in the exhaust were measured. The vehicle was exercised through portions of the SAE J1376 standard procedures, namely the Central Business District (CBD) cycle, and Arterial (ART) cycle during emissions characterization. The emissions results of this bus chassis show lower level emissions of carbon monoxide (CO), non-methane hydrocarbon (NMHC) and particulate matter (PM) when compared to similar Cummins C8.3 CNG powered school buses without catalytic converters, and similar emissions level of NO_x. Test results on the Cairo bus chassis without a catalytic converter show higher CO, NO_x, and NMHC emissions compared to those school buses. The bus chassis with a catalyst had low emissions levels and is suited to use in transit operations to improve ambient air quality measures.

INTRODUCTION

Many regions have found themselves under pressure to comply with the Clean Air Act. Clark, et al. [1], have presented a discussion of the increasing demands to reduce PM from heavy-duty vehicles. In particular, a Health Effects Institute report has associated diesel PM with respiratory disease [2]. One response to such pressures has been the introduction of alternatively fueled vehicles into public transit and school bus fleets.

Working with the United States Department of Energy (DOE) Office of Transportation Technologies (OTT), West Virginia University (WVU) has designed, constructed, and operates two transportable heavy-duty vehicle emissions testing laboratories (Figure 1). The laboratories customarily travel to transit agencies and trucking facilities to measure vehicle emissions. Detailed information pertaining to the transportable laboratories can be found in technical papers [3, 4, 5], which present the design of the two laboratories, and present previous emissions data collected from both conventional and alternatively fueled vehicles.

Detailed information pertaining to the transportable laboratories can be found through the Internet at the following web sites:

- http://www.cemr.wvu.edu/~wwwatf/TransportableLaboratory.html (WVU Transportable Laboratory)
- http://www.afdc.nrel.gov/web_view/emishdv.html (NREL database)
- http://www.ott.doe.gov/ (DOE OTT)

LABORATORY DESCRIPTION

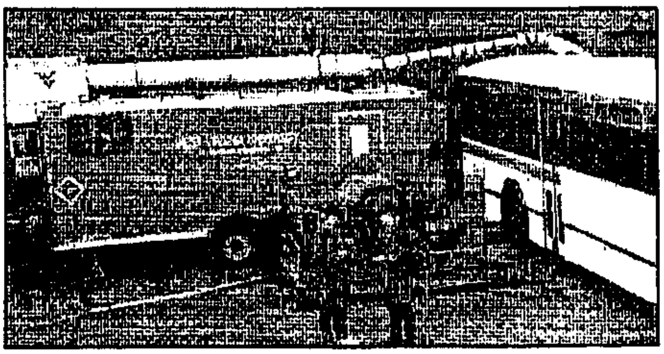

Figure 1 -- Laboratory #1 showing the dilution tunnel on top of the instrumentation trailer, and one of the sets of flywheels and power absorbers used to mimic vehicle inertia and road load losses.

Each laboratory consists of a dynamometer test bed and an instrumentation trailer. The test bed is designed such that a tractor truck can transport it to the test site. Once the test bed is lowered to the ground, subject vehicles can then be driven on and secured to the test bed. Before a vehicle is mounted on the test bed, the outer drive wheels of the vehicle are removed and replaced by special hub adapters (Figure 2). This provides a connection to transmit power directly from the drive axle of the vehicle to the dynamometer. Each dynamometer unit consists of speed-increasing gearboxes with a power absorber and a flywheel set. Each flywheel set consists of a series of selectable discs used to simulate vehicle inertia. Each power absorber applies a retarding force to simulate additional load to reflect air drag and rolling resistance that the vehicle would encounter during operation.

"Road load" is the power required driving a vehicle on level road at steady speed. It was calculated using the following equation [6]:

$$P_r = (C_r Mg + \tfrac{1}{2}\rho_a C_D A_V V^2)V \qquad (1)$$

Where
P_r = road-load power
C_r = coefficient of rolling resistance
ρ_a = ambient air density
C_D = drag coefficient
A_v = frontal area of vehicle
V = vehicle speed

For the present research, road load was predicted using a drag coefficient of 0.79 and a coefficient of tire rolling resistance of 0.00938. During the test cycle, inline torque cells and speed transducers monitor axle torque and speed.

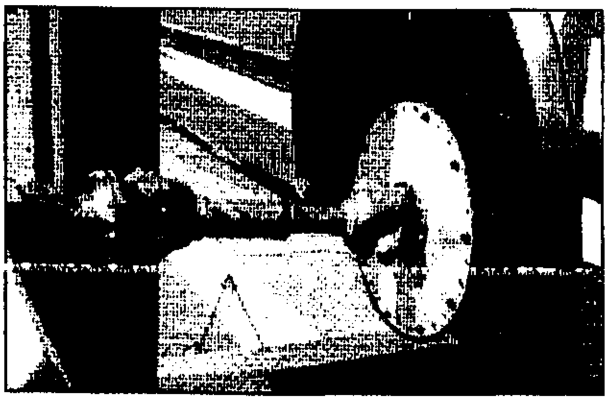

Figure 2 – Hub adapter close-up

The instrumentation trailer houses the emissions measurement equipment, data acquisition system and the control hardware necessary for the operation of the test bed. Exhaust emissions from the subject vehicle are piped to a 45cm diameter dilution tunnel integrated into the instrumentation trailer. The tunnel mixes the exhaust with ambient air, which both cools and dilutes the exhaust. Dilution tunnel flow is controlled using a critical flow venturi system (CVS). A two-stage blower system maintains critical flow through various sized venturi throat restrictions to maintain a constant volume flow of dilute exhaust during testing. The flow rate used in the present research was approximately 1350 standard ft^3/min (0.64 m^3/sec) for all transient tests.

TEST METHODS

After the laboratory was set up at the home base in Morgantown, WV, a comprehensive calibration schedule was followed to insure that the gas sampling system, associated analyzers, and test bed instrumentation were working properly. In particular, each analyzer was calibrated and checked using ten evenly spaced concentrations of the gas under consideration with air as the diluent. The integrity of the dilution tunnel and associated plumbing was verified weekly using a propane injection. This procedure involved introducing a known amount of propane into the dilution tunnel using a critical flow orifice injection kit. The hydrocarbon concentration measured using the hydrocarbon analyzer was then compared to that calculated from the injection kit. Recovery differences of -0.960%, and -0.558% on September 30,1999 indicated that there were no leaks and that the analysis system was operating satisfactorily. Propane injections with recovery differences less than ±2% were also conducted on October 8, October 12, and October 13 to monitor system performance after changing the venturi that controls tunnel flow to different sizes when doing steady state tests.

Two different simulated vehicle test weights (TW) were calculated, representing the typical in-use seated vehicle weight (SVW) and rated gross vehicle weight (GVW). The SVW was calculated to be 30,110 lbs (13,670kg) by summing the chassis weight, vehicle body weight, driver's weight, and the weight of half the maximum passenger load. The GVW is calculated to be 35,210 lbs by summing the chassis weight and the payload. Average human weight was taken as 150 lbs (68kg).

The vehicle was operated on the dynamometer to warm the vehicle's engine and transmission as well warming dynamometer equipment. The vehicle was operated until the differentials of the dynamometer system reached 100°F (37.8°C). This provided a uniform starting point for all testing.

At least one practice test cycle was then performed to allow the driver to become familiar with vehicle characteristics, and to allow the instrument operator to determine proper analyzer settings. Prior to taking the first data set, the vehicle's transmission was set to neutral and the engine was allowed to idle for a period of 17 minutes. The vehicle was then driven though a set of practice ramps to expel constituents that may have collected in the exhaust system. Twenty seconds after completion of the final practice ramp, data collection was initiated as the vehicle was operated through the transient test schedule.

The driver was provided with a visual speed trace on a monitor displaying both the actual and the desired vehicle speed. The driver was instructed to follow the desired speed trace as closely as possible. While the driver operated the vehicle through the speed cycle, emissions concentrations and vehicle performance were monitored and recorded in the instrumentation trailer at a 10Hz rate.

Dilute exhaust samples were drawn from heated sample probes located 4.5m from the mouth of the dilution tunnel. The samples were routed to the respective analyzers using heated sampling lines. Levels of carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbon (HC), and carbon dioxide (CO_2) were measured continuously, then integrated over the complete test cycle. A sample of the ambient "background" air was collected in a Tedlar® bag and analyzed at the end of each test. The background measurements were then subtracted from the continuous measurements.

For each test on a CNG fueled vehicle, a sample of the dilute exhaust was collected in Tedlar® bags. These samples were shipped to the Mechanical and Aerospace Department gas chromatograph laboratory for hydrocarbon speciation analysis. A Varian 3600 gas chromatograph was used to determine the ratio of methane to non-methane hydrocarbons (NMHC).

A gravimetric measurement of particulate matter was obtained using 70mm filters, weighed before and after testing. The filters were conditioned for temperature and humidity in an environmental chamber before each weighing to reduce error due to variation in water content. In addition, a Rupprecht & Patashnick tapered element oscillating microbalance (TEOM) was used to monitor the real-time instantaneous PM.

Figure 3 – Fuel tank hanging on a load cell for continuous mass fuel flow measurement

To measure the mass fuel consumption on a continuous basis, an apparatus was fabricated to hold a light-weight aluminum/fiber-wound cylinder which acted as the fuel storage for the bus chassis. A load cell was used to measure the instantaneous weight of the cylinder, from which the instantaneous fueling rate can be determined. (Figure 3)

In order to ensure that the data gathered represented the vehicle's performance, testing was considered to be complete only when a minimum of four complete tests was performed and the tests were shown to be statistically repeatable. In the case that data from one test were known to be incorrect due to driver error or analyzer malfunction, only data from satisfactory tests were used to determine emissions averages.

TEST CYCLES

The bus chassis tested in this program was exercised through the Central Business District (CBD) speed-versus-time cycle and Arterial (ART) cycle, as described by the Society of Automotive Engineers' Recommended Practice J1367. The CBD driving cycle was developed as a general representation of the transit bus operation in a downtown business district. This cycle consists of fourteen identical segments, each segment including 10 seconds of acceleration, 18.5 seconds of 20mph (32.2km/hr) cruise, 4.5 seconds of deceleration and 7 seconds of idle. The total distance covered by the cycle was 2 miles (3.2km) over a period of 568 seconds. The CBD cycle target speed schedule is shown in Figure 4. A sample actual driving speed vs. time plot from the CBD Cycle is shown in Figure 24.

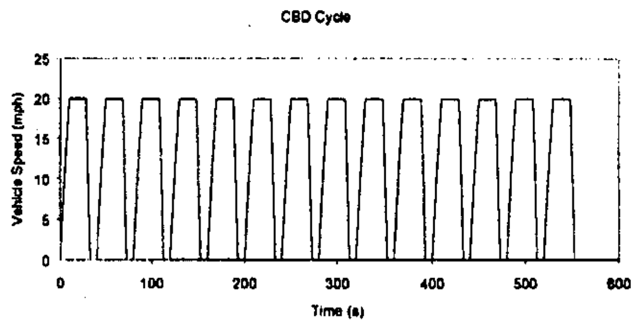

Figure 4 – CBD Test Schedule

The ART cycle consists of four identical segments, each segment including 29 seconds of acceleration, 22.5 seconds of 40mph (64.4km/hr) cruise, 9 seconds of deceleration and 7 seconds of idle. The ART cycle target speed schedule is shown in Figure 5. A sample actual driving speed vs. time plot from the ART Cycle is shown in Figure 25.

The bus chassis was tested both with and without the catalytic converter inline to monitor the emissions changes for both CBD cycle and ART cycle.

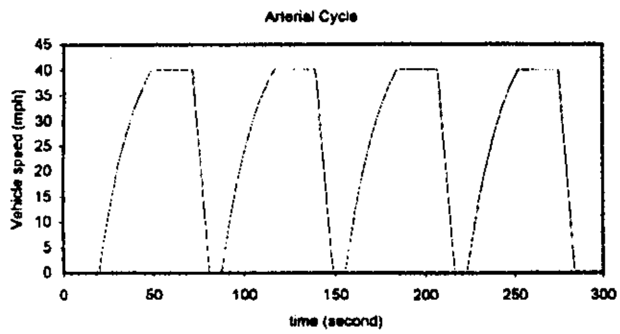

Figure 5 – ART Test Schedule

Four sets of steady state tests were also performed to serve as a method to identify "defeat" strategies that could result in increased emissions levels. One set of tests was run at the rated horsepower engine speed of 2400 RPM with five different loadings. The second set was run at the rated torque engine speed of 1400 RPM with five different loadings. The third set was run at the engine speed of 1900 RPM which was between the rated maximum power and rated maximum engine torque. The fourth set was run with the engine idling in neutral gear. The bus transmission was locked to the third gear for the 2400 RPM and 1900 RPM steady state tests, and it was locked to the fourth gear for the 1400 RPM steady state tests. For all three different engine speeds, to establish the maximum loading for that engine speed, the bus was first brought up the target engine speed, then gradually loaded with the power absorbers to a level when the engine speed started dropping. Five different loadings for each non-idle engine speed were then 0%, 25%, 50%, 75% and 100% of the maximum loading for that speed. Each non-idle steady state operating point was tested for five minutes, except that for the maximum loading, when the power absorbers could not hold for the load that long and started losing torque, less time was employed. Half an hour was employed for the idle tests to give an over all average. All steady states tests were conducted both with and without the catalytic converter inline. All steady state points were tested until sufficient steady state data were collected. Data were taken only after bus reached a steady state.

TEST VEHICLE

The tested transit bus chassis is one of the CNG bus chassis for a USAID-funded project in Cairo, Egypt, managed by Chemonics International, Inc. The chassis serial number of 28277. More detailed engine information is listed in Table 1.

The CNG fuel used for testing was provided by a CNG compressor station adjacent to the WVU test facility, with the natural gas provided by Hope Gas Inc. GC analysis showed a 95.1% level of methane in the CNG fuel.

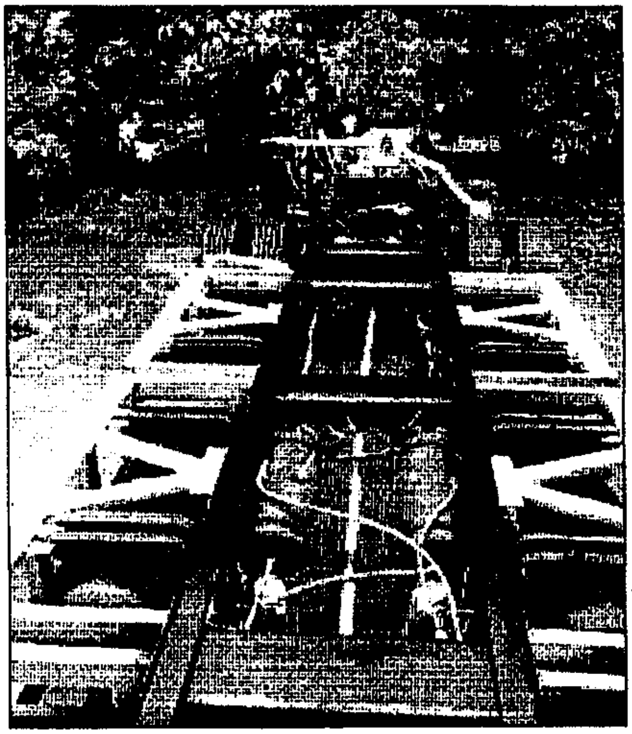

Figure 6 – Transit bus chassis tested. The engine is at the rear of the chassis.

Table 1 – Engine Information

Engine Model	Cummins C8.3-250G
Engine Type	4-Cycle; In-Line; 6-Cyclinder
Aspiration	Turbocharged/Charge Air Cooled
Certification	EPA & CARB
Compression Ratio	10.5:1
Engine ID Number	45884141
CPL Code	2463
Engine Rated Power	BHP 250 @ 2400 RPM
Peak Torque	660 ft-lb @ 1400 RPM
Engine Displacement	8.3

between this bus chassis with similar buses previously characterized by the WVU research team (Table 7). Results from steady state tests were presented in gram per second (Table 8) and grams per axle hp-hr (Table 9). Table 10 shows the TEOM and 70mm filter data comparison; Table 11 and Table 12 show the speciated carbonyl analysis results, and Table 13 shows fuel consumption calculation using different methods. In addition, each test is described in a "short report" appended to this document.

TRANSIENT TESTS

Table 2 through Table 5 present the eight transient test results of the bus chassis using the CBD cycle and the ART cycle, both with and without a catalytic converter inline, and with the test weight of seated GVW and rated GVW. Table 6 presents the summary of these eight tests. Figure 7 through Figure 11 show the sample continuous emissions of CO, CO_2, NO_x, and HC, and continuous exhaust temperature through an ART cycle test. Figure 12 through Figure 16 shows the average emissions in grams/mile for CBD and ART cycles.

As shown in the summary table (Table 6), HC, CO and NO_x were substantially lower for the catalyst than the non-catalyst tests. For the CBD cycle, emissions with catalyst had the effect of reducing NO_x by 42% for seated vehicle weight (SVW) tests and about 18% for rated gross vehicle weight (GVW) tests. CO was reduced more than 10-fold for both SVW and GVW. NMHC was reduced more than 30-fold for both SVW and GVW. There was minor or no effect of PM for SVW and about 30% of PM reduction for GVW was observed. For the ART cycle, emissions with catalyst had the effect of reducing NO_x by 51% for SVW and about 37% for GVW tests. CO was reduced more than 10-fold for both SVW and GVW tests. NMHC was reduced more than 7 times for SVW and about 17 times for GVW tests. PM was reduced by about 30% for both SVW and GVW tests. The catalyst is an oxidizing catalyst and the bus chassis has lean burn operation. It is expected that the catalyst would diminish HC and CO content of the exhaust substantially. Although oxidizing catalyst may reduce the soluble organic fraction of PM, the levels of PM from this bus chassis were so low that they were at the limits of detection of the laboratory. Levels of NO_x reduction ascribed to the catalyst were higher than the authors would have anticipated.

COMPARISON WITH SIMILAR BUSES

Emissions from this bus chassis were compared with emissions from similar Cummins C8.3-250 engine school buses tested in California in 1998 [7] (Table 7). Eleven CNG engines tested in reference [7] were 1997 model Cummins spark ignited lean burn C8.3-250G engines (CPL 2167) with oxygen sensor feedback control, and did not utilize an after-treatment device. Three diesel engines tested in reference [7] were 1998 model Cummins compression ignited, turbo-charged C8.3-250 engines (CPL 1566), and utilized a catalytic converter (# 26265).

Test data comparison (Table 7) shows that the Chemonics (Cairo) bus chassis with a catalyst had lower CO, NMHC and PM emissions than the D2 and CNG school buses tested in California, while the NO_x emissions were equivalent. The PM emissions from the Chemonics bus chassis were 82% lower than the PM emissions from the school buses in California. Also, the NO_x was 4% lower than the NO_x emissions from the comparative diesel buses. The Chemonics bus chassis tested without a catalyst had higher CO, NO_x and NMHC than those from the school buses tested, while PM emissions were still lower. The test weight for the Chemonics bus chassis was about 5.5% higher than the CNG school buses, and the fuel economy was about 12% lower than that from the CNG school buses.

STEADY STATE TEST RESULTS

The steady state results from Table 8, Table 9 and Figures 17 to 20 show no defeat or off-cycle emissions. This is asserted because the emissions from transient tests yielded NO_x values, in g/axle hp-hr, that were generally not exceeded by the steady state operation. For example, the CBD value of 41.11 grams over 4.36 axle hp-hr (9.43 g/axle hp-hr NO_x) is exceeded by only few of the steady state point emissions values. There was a substantial reduction of CO, NMHC, and NO_x emissions with a catalyst inline to those without a catalyst. This trend in these results matches the results from transient tests. PM emissions were very low for these steady state tests, and were below our measuring capacity. The PM weights on 70mm filters were barely detectable and close to their respective background filters weights. PM data listed in Table 8 and Table 9 are not considered to be above the laboratory detection limit.

TEOM TESTS AND RESULTS

The real-time instantaneous PM was monitored by using a Rupprecht & Patashnick tapered element oscillating microbalance (TEOM) model 1105 for all transient and steady state tests. The TEOM pumps a constant flow sample (2LPM) of diluted exhaust gas through a small filter, the mass of which is continuously inferred. The key component of the TEOM is a hollow, tapered, oscillating element on which the filter is mounted. During operation, the element oscillates at its natural frequency. Simply, it can be represented by a spring-mass system in which a change in mass correlates to a change in resonant frequency. As the filter weight changes due to particulate build up, the frequency of the element oscillation changes. By measuring the resonant frequency, the change in mass on the filter can be inferred. The TEOM was primarily designed for diesel vehicle instantaneous PM monitoring, and it was not accurate for natural gas fueled vehicle PM integrated mass calculation. The PM emissions were extremely low for the Chemonics NG vehicle, and there was high water content in the exhaust, which will be attached to the filter and add and remove transient mass. The evaporation of the water on the filter after a period of time will decrease the mass on the filter. The total mass from TEOM from a transient test (Figure 21) shows this water evaporation process.

Table 10 lists all TEOM data and the comparison with the 70mm filter data. All PM weight on the TEOM filter was calculated by subtracting the initial weight from the final weight. Total cycle PM data from TEOM was not corrected with background because the background measurement of TEOM was below a reasonable measurement limit. For comparison, the total PM data from 70mm filters were not corrected for background. The ratio of TEOM PM mass over 70mm filter PM mass is only for reference. It was concluded that the emissions of this bus chassis were below the limit for which TEOM detection was practical. The 70mm filter PM should be employed to characterize this bus chassis, and even in that case the accepted methods have margined accuracy.

CARTRIDGE CARBONYL ANALYSIS RESULTS

Cartridge carbonyl analysis was conducted by Automotive Testing Laboratory, Inc. in Ohio. Cartridge samples were collected by using aldehyde (2,4-DNPH cartridge) sampling system. One standard liter per minute (SLPM) dilute exhaust was run through the cartridge during the test, controlled by a mass flow controller. Only selected tests were chosen for 2,4-DNPH cartridge sampling. Original detailed analysis results are listed in Table 12. Formaldehyde and acetaldehyde were also calculated in grams per cycle for all samples (Table 11). Because of the lack of the background sample, all final calculations of grams per cycle were not background corrected. However, the background correction for aldehydes would be minor. 100% of cartridge recovery was all assumed for all calculation. From the analysis, Formaldehyde takes the majority of the NMHC in the emissions, ranging from 70% up to about 96%. This is expected for the combustion of methane. Also, data showed that the catalyst reduced formaldehyde by an average ratio of 30.

FUEL CONSUMPTION MEASUREMENT

A fuel tank was hung by a load cell to monitor the continuous fuel mass flow for all transient tests. This apparatus was not applied to steady state tests because the fuel tank was not big enough for a complete heavy loading steady state test. A comparison between the carbon weight from emissions and from the fuel tank weight loss was made for transit tests, as shown in Table 13. Less than 5% of difference was found between these two measurements. The short reports appended to this report show fuel consumption based on CO_2 measurements. These have, therefore, been verified by the weighing method.

GENERAL DISCUSSION

1. The bus engine hesitated after idling for period of time. The bus could only run up to about 3 MPH even though the driver maintained a full throttle. This happened at the beginning of each test or after the engine was idling for about more than 20 seconds. This problem sometimes caused the whole test run to be void, and the reason for this problem was unclear. A very high HC emission was noticed accompanying this hesitation, and caused the non-repeatability of HC from run to run. A sample CBD run that includes this behavior is shown in Figure 22. After days of frustration, it was observed that, if the driver pushed the gas pedal and applied the brake simultaneously with the bus not moving, it eliminated the problem. After the bus was running, there was no lack of power to keep up with the cycle. This was the only functional concern identified.

2. NO_x emissions were not repeatable from run to run for some of the transient tests. The reason for that is for some of the ramps in the transient test, NO_x was high during the cruise time. (Figure 23) This NO_x mode would not repeat itself from ramp to ramp, causing a lower non-repeatability of the NO_x emissions. However, these variations may have been driver induced and are not believed to be a cause for concern or an indication of an intended off cycle strategy.

CONCLUSIONS

Emissions from a CNG fueled transit bus chassis powered by Cummins C8.3-250G engine were characterized using a chassis dynamometer based test procedure with the Central Business District test cycle and Arterial test cycle, and 15 non-idle steady state tests, both with and without catalytic after-treatment devices. This CNG powered bus chassis (with catalyst) showed a lower CO, NMHC, and PM emissions rate to those of similar Cummins C8.3 powered CNG (without catalyst) and Diesel (with catalyst) school buses tested in California in 1998. It should be noted that the CO, NO_x, and NMHC measured from the engine without catalyst were higher than those with a catalyst. It is concluded that this bus chassis did not show steady state "off-cycle" emissions behavior and that this bus chassis emitted emissions consistent with the demand for ambient air quality improvement.

ACKNOWLEDGMENTS

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REFERENCES

1 Clark, N.N., Gautam, M., Lyons, D.W., Bata, R.M., Wang, W., Norton, P., and Chandler, K. "Natural Gas and Diesel

Bus Emissions: Review and Recent Data." SAE Paper 973203, 1997
2 Bagley, S.T., Baumgard, K.J., Gratz, L.D., Johnson, J.H., and Leddy, D.G., "Characterization of Fuel and Aftertreatment Device Effects on Diesel Emissions", Health Effect Institute Research Report, Number 76, September 1996.
3 Chandler, K., Malcosky, N., Motta, R., Norton, P., Kelly, K., Schumacher, L. and Lyons, D. W., "Alternative Fuel Transit Bus Evaluation Program Results", SAE, Paper 961082, 1996.
4 Clark, N.N., Messer, T. J., McKain, D.L., Wang, W., Bata, R., Gautam, M. and Lyons, D.W., "Use of the West Virginia University Truck Cycle to Evaluate Emissions from Class 8 Trucks", SAE, Paper 951016, 1995.
5 Clark, N. N., Gadapati, C. J., Kelly, K., White, C. L., Lyons, D. W., Wang, W., Gautam, M. and Bata, R., "Comparative Emissions from Natural Gas and Diesel Buses", SAE, Paper 952746, 1995.
6 Wang, W., Bata, R., Lyons, D. W., Clark, N.N., Palmer, M.G., Gautam, M., Howell, A. D., Rapp, B.L., "Transient Response in a Dynamometer Power Absorption System," SAE Paper 920252, 1992.
7 Clark, N., Gautam M., Boyce, J., Wang, W., Lyons, D., "Emissions Performance of Natural Gas and Diesel Fueled School Buses with Cummins 8.3 Liter Engines", Proceeding of the Spring Technical Conference of the ASME Internal Combustion Engine Division, ICE-Vol. 32-2, Paper No. 99-ICE-176.

APPENDIX

- Emissions components and fuel economy measured or calculated:

  CO: Carbon monoxide measured by Rosemount 880A NDIR analyzer from Tedlar® bag sample.
  NO_x: Oxides of nitrogen measured by Rosemount 955 NO/NO_x analyzer from continuous channel integrated over test time.
  FIDHC: Total hydrocarbon measured by the Rosemount 402 hydrocarbon analyzer using flame ionization detection (FID), without any response factor correction.
  CH_4, NMHC: Methane and Non-methane Hydrocarbon measured by West Virginia University Gas Chromatograph (GC) laboratory. A sample of the dilute exhaust was collected in individual Tedlar® bags and the ratio of CH_4 to NMHC is determined through hydrocarbon speciation analysis
  PM: Particulate matter measured using 70mm filters (grams/mile)
  CO_2: Carbon dioxide measured by Rosemount 868 NDIR analyzer from continuous channel integrated over test time.
  mile/gal: Fuel economy calculated using carbon count method. For CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.
  BTU/mile: Calculated fuel energy used by the vehicle, in BTU/mile.
  Miles: Total actual driving distance

- Short reports are attached below.

Table 2 -- Emissions (in grams/cycle) and Fuel Economy for CBD Cycle Tests

Test ID	Run ID	Test Date	Test Start Time	Miles	Axle hp-hr	CO	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU/mile
CBD Cycle, with Catalytic Convertor, SVW														
1336	1	10/4/99	11:19:35 AM	2.04	4.37	2.97	4587	N/A	15.56	14.20	0.05	0.15	3.31	38868
1336	2	10/4/99	12:16:31 PM	2.06	4.28	N/A	4674	45.52	14.77	13.43	0.08	0.04	3.27	39241
1336	3	10/4/99	12:45:59 PM	2.05	4.37	2.90	4730	37.95	16.73	15.18	0.13	0.05	3.22	39884
1336	4	10/4/99	1:15:27 PM	2.04	4.35	2.81	4504	35.68	18.40	16.71	0.13	0.26	3.36	38271
1336	5	10/4/99	1:44:55 PM	2.04	4.40	3.19	4624	44.59	17.33	15.83	0.03	0.04	3.28	39156
1336	6	10/4/99	2:14:24 PM	2.04	4.38	3.05	4834	41.82	N/A	N/A	N/A	0.03	3.14	40954
			Average:	**2.04**	**4.36**	**2.98**	**4659**	**41.11**	**16.56**	**15.07**	**0.08**	**0.096**	**3.26**	**39396**
CBD Cycle, without Catalytic Convertor, SVW														
1355	1	10/14/99	12:07:50 PM	2.01	4.58	40.64	4580	67.26	53.07	46.67	1.89	0.09	3.15	40823
1355	4	10/14/99	1:36:15 PM	2.02	4.48	38.36	4553	70.50	49.21	43.21	1.82	0.10	3.20	40196
1355	5	10/14/99	2:05:43 PM	2.04	4.43	39.69	4500	72.00	45.41	38.26	3.28	0.10	3.26	39372
1355	6	10/14/99	2:35:11 PM	2.03	4.50	41.45	4522	72.43	49.22	41.53	3.50	0.10	3.24	39675
			Average:	**2.02**	**4.50**	**40.04**	**4539**	**70.55**	**49.23**	**42.42**	**2.62**	**0.096**	**3.21**	**40016**
CBD Cycle, with Catalytic Convertor, GVW														
1340	1	10/7/99	9:27:45 AM	2.03	5.12	2.04	5178	42.26	17.88	16.25	0.11	N/A	2.91	44100
1340	2	10/7/99	9:57:13 AM	2.02	5.07	3.50	5102	54.64	16.76	15.21	0.13	0.01	2.95	43521
1340	3	10/7/99	10:26:41 AM	2.04	5.00	3.33	5117	44.82	17.68	16.09	0.10	0.01	2.97	43324
1340	4	10/7/99	10:56:09 AM	2.05	4.98	4.35	5125	48.55	19.10	17.35	0.13	0.05	2.97	43313
1340	5	10/7/99	11:29:05 AM	2.04	5.03	3.96	5199	49.90	23.92	21.76	0.14	0.08	2.90	44263
1340	6	10/7/99	11:58:33 AM	2.05	4.95	1.89	5070	31.19	19.87	18.09	0.09	0.04	3.01	42727
			Average:	**2.04**	**5.02**	**3.18**	**5132**	**45.23**	**19.20**	**17.46**	**0.12**	**0.037**	**2.95**	**43541**
CBD Cycle, without Catalytic Convertor, GVW														
1352	1	10/13/99	7:21:23 PM	2.05	5.14	40.32	4850	63.39	63.79	53.72	4.63	0.10	3.02	42521
1352	4	10/13/99	8:49:55 PM	2.06	4.87	37.78	4853	55.17	51.21	42.98	3.87	0.04	3.07	41904
1352	5	10/13/99	9:19:23 PM	2.03	4.86	37.67	4741	47.66	66.43	58.37	2.42	0.03	3.06	42064
			Average:	**2.04**	**4.96**	**38.59**	**4815**	**55.40**	**60.48**	**51.69**	**3.64**	**0.055**	**3.05**	**42163**

* MPG: Mile per gallon, for CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 3 -- Emissions (in grams/cycle) and Fuel Economy for ART Cycle Tests

Test ID	Run ID	Test Date	Test Start Time	Miles	Axle hp-hr	CO	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU
ART Cycle, with Catalytic Convertor, SVW														
1337	1	10/5/99	10:25:11 AM	2.03	5.07	1.42	3882	43.61	N/A	N/A	N/A	0.08	3.88	33134
1337	2	10/5/99	10:50:20 AM	2.00	5.04	1.29	3885	34.01	25.63	23.30	0.16	0.09	3.81	33746
1337	3	10/5/99	1:42:40 PM	2.00	5.02	1.99	3832	25.64	21.98	20.08	0.04	0.09	3.87	33233
1337	4	10/5/99	2:07:39 PM	2.02	5.05	1.12	3785	45.95	18.54	16.72	0.25	0.05	3.95	32536
1337	5	10/5/99	2:32:31 PM	2.02	4.98	1.40	3806	30.47	16.20	14.69	0.13	0.07	3.94	32648
1337	6	10/5/99	2:57:23 PM	2.01	5.02	2.07	3912	32.23	20.53	18.68	0.11	0.05	3.80	33797
			Average:	**2.01**	**5.03**	**1.55**	**3850**	**35.32**	**20.58**	**18.69**	**0.14**	**0.071**	**3.87**	**33182**
ART Cycle, without Catalytic Convertor, SVW														
1354	1	10/14/99	10:28:18 AM	2.02	4.90	18.87	3682	68.27	27.83	24.00	1.46	0.12	4.00	32114
1354	2	10/14/99	10:53:16 AM	2.02	4.92	19.65	3572	70.10	29.51	25.85	1.15	0.09	4.12	31228
1354	3	10/14/99	11:18:07 AM	2.02	4.97	17.76	3572	73.98	26.40	23.09	1.06	0.08	4.13	31121
1354	4	10/14/99	11:42:59 AM	2.03	4.91	18.40	3661	77.12	26.77	23.09	1.40	0.11	4.05	31717
			Average:	**2.02**	**4.93**	**18.67**	**3622**	**72.37**	**27.63**	**24.01**	**1.27**	**0.101**	**4.07**	**31545**
ART Cycle, with Catalytic Convertor, GVW														
1339	2	10/6/99	1:56:10 PM	2.04	5.75	2.02	4211	39.30	23.08	21.04	0.08	0.09	3.59	35769
1339	3	10/6/99	2:22:10 PM	2.05	5.74	1.29	4187	37.05	21.22	19.31	0.11	0.08	3.63	35383
1339	4	10/6/99	2:47:01 PM	2.02	5.62	0.34	4095	38.55	19.60	17.86	0.09	0.08	3.65	35191
1339	5	10/6/99	3:11:53 PM	2.03	5.76	2.26	4272	37.33	21.71	19.75	0.12	0.09	3.52	36467
1339	6	10/6/99	3:36:45 PM	2.07	5.73	0.92	4243	37.06	17.96	16.28	0.15	0.07	3.62	35502
			Average:	**2.04**	**5.72**	**1.37**	**4202**	**37.86**	**20.72**	**18.85**	**0.11**	**0.080**	**3.60**	**35662**
ART Cycle, without Catalytic Convertor, GVW														
1353	1	10/13/99	9:48:51 PM	2.04	5.54	21.61	4033	46.47	32.20	27.04	2.42	0.13	3.70	34769
1353	2	10/13/99	10:13:43 PM	2.04	5.56	23.47	3916	74.83	28.15	24.52	1.24	0.11	3.81	33703
1353	3	10/13/99	10:38:34 PM	2.02	5.48	21.29	3889	67.65	29.25	25.05	1.72	0.12	3.79	33892
1353	4	10/13/99	11:03:26 PM	2.01	5.47	23.20	3844	50.64	N/A	N/A	N/A	0.13	3.78	34030
			Average:	**2.03**	**5.51**	**22.39**	**3920**	**59.90**	**29.87**	**25.53**	**1.79**	**0.122**	**3.77**	**34098**

* MPG: Mile per gallon, for CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 4 -- Emissions (in grams/mile) and Fuel Economy for CBD Cycle Tests

Test ID	Run ID	Test Date	Test Start Time	Miles	Axle hp-hr	CO	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU/mile
CBD Cycle, with Catalytic Convertor, SVW														
1336	1	10/4/99	11:19:35 AM	2.04	4.37	1.46	2250	N/A	7.63	6.96	0.02	0.07	3.31	38868
1336	2	10/4/99	12:16:31 PM	2.06	4.28	N/A	2272	22.13	7.18	6.53	0.04	0.02	3.27	39241
1336	3	10/4/99	12:45:59 PM	2.05	4.37	1.41	2308	18.52	8.16	7.41	0.06	0.02	3.22	39884
1336	4	10/4/99	1:15:27 PM	2.04	4.35	1.38	2212	17.52	9.04	8.21	0.06	0.13	3.36	38271
1336	5	10/4/99	1:44:55 PM	2.04	4.40	1.56	2265	21.83	8.49	7.75	0.02	0.02	3.28	39156
1336	6	10/4/99	2:14:24 PM	2.04	4.38	1.49	2366	20.47	N/A	N/A	N/A	0.02	3.14	40954
			Average:	**2.04**	**4.36**	**1.46**	**2279**	**20.09**	**8.10**	**7.37**	**0.04**	**0.047**	**3.26**	**39396**
CBD Cycle, without Catalytic Convertor, SVW														
1355	1	10/14/99	12:07:50 PM	2.01	4.58	20.26	2283	33.53	26.46	23.27	0.94	0.05	3.15	40823
1355	4	10/14/99	1:36:15 PM	2.02	4.48	18.99	2254	34.91	24.37	21.39	0.90	0.05	3.20	40196
1355	5	10/14/99	2:05:43 PM	2.04	4.43	19.50	2211	35.38	22.31	18.80	1.61	0.05	3.26	39372
1355	6	10/14/99	2:35:11 PM	2.03	4.50	20.37	2222	35.59	24.19	20.41	1.72	0.05	3.24	39675
			Average:	**2.02**	**4.50**	**19.78**	**2243**	**34.85**	**24.33**	**20.97**	**1.29**	**0.048**	**3.21**	**40016**
CBD Cycle, with Catalytic Convertor, GVW														
1340	1	10/7/99	9:27:45 AM	2.03	5.12	1.01	2554	20.84	8.82	8.02	0.05	N/A	2.91	44100
1340	2	10/7/99	9:57:13 AM	2.02	5.07	1.73	2520	26.99	8.28	7.51	0.06	0.00	2.95	43521
1340	3	10/7/99	10:26:41 AM	2.04	5.00	1.63	2508	21.96	8.66	7.88	0.05	0.01	2.97	43324
1340	4	10/7/99	10:56:09 AM	2.05	4.98	2.13	2504	23.72	9.34	8.48	0.06	0.02	2.97	43313
1340	5	10/7/99	11:29:05 AM	2.04	5.03	1.94	2554	24.51	11.75	10.69	0.07	0.04	2.90	44263
1340	6	10/7/99	11:58:33 AM	2.05	4.95	0.92	2471	15.20	9.68	8.82	0.05	0.02	3.01	42727
			Average:	**2.04**	**5.02**	**1.56**	**2518**	**22.20**	**9.42**	**8.57**	**0.06**	**0.018**	**2.95**	**43541**
CBD Cycle, without Catalytic Convertor, GVW														
1352	1	10/13/99	7:21:23 PM	2.05	5.14	19.71	2371	30.98	31.18	26.26	2.26	0.05	3.02	42521
1352	4	10/13/99	8:49:55 PM	2.06	4.87	18.33	2354	26.76	24.84	20.85	1.88	0.02	3.07	41904
1352	5	10/13/99	9:19:23 PM	2.03	4.86	18.60	2341	23.53	32.80	28.82	1.19	0.01	3.06	42064
			Average:	**2.04**	**4.96**	**18.88**	**2355**	**27.09**	**29.61**	**25.31**	**1.78**	**0.027**	**3.05**	**42163**

* MPG: Mile per gallon, for CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 5 -- Emissions (in grams/mile) and Fuel Economy for ART Cycle Tests

Test ID	Run ID	Test Date	Test Start Time	Miles	Axle hp-hr	CO	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU
ART Cycle, with Catalytic Convertor, SVW														
1337	1	10/5/99	10:25:11 AM	2.03	5.07	0.70	1913	21.49	N/A	N/A	N/A	0.04	3.88	33134
1337	2	10/5/99	10:50:20 AM	2.00	5.04	0.65	1938	16.96	12.79	11.62	0.08	0.05	3.81	33746
1337	3	10/5/99	1:42:40 PM	2.00	5.02	0.99	1912	12.80	10.97	10.02	0.02	0.04	3.87	33233
1337	4	10/5/99	2:07:39 PM	2.02	5.05	0.56	1877	22.79	9.19	8.29	0.12	0.03	3.95	32536
1337	5	10/5/99	2:32:31 PM	2.02	4.98	0.69	1886	15.10	8.03	7.28	0.07	0.03	3.94	32648
1337	6	10/5/99	2:57:23 PM	2.01	5.02	1.03	1947	16.04	10.22	9.30	0.05	0.02	3.80	33797
			Average:	**2.01**	**5.03**	**0.77**	**1912**	**17.53**	**10.24**	**9.30**	**0.07**	**0.035**	**3.87**	**33182**
ART Cycle, without Catalytic Convertor, SVW														
1354	1	10/14/99	10:28:18 AM	2.02	4.90	9.36	1826	33.86	13.80	11.90	0.73	0.06	4.00	32114
1354	2	10/14/99	10:53:16 AM	2.02	4.92	9.74	1771	34.76	14.63	12.82	0.57	0.05	4.12	31228
1354	3	10/14/99	11:18:07 AM	2.02	4.97	8.80	1771	36.67	13.08	11.44	0.53	0.04	4.13	31121
1354	4	10/14/99	11:42:59 AM	2.03	4.91	9.07	1805	38.02	13.19	11.38	0.69	0.05	4.05	31717
			Average:	**2.02**	**4.93**	**9.24**	**1793**	**35.83**	**13.68**	**11.89**	**0.63**	**0.050**	**4.07**	**31545**
ART Cycle, with Catalytic Convertor, GVW														
1339	2	10/6/99	1:56:10 PM	2.04	5.75	0.99	2060	19.22	11.29	10.29	0.04	0.04	3.59	35769
1339	3	10/6/99	2:22:10 PM	2.05	5.74	0.63	2040	18.06	10.34	9.41	0.06	0.04	3.63	35383
1339	4	10/6/99	2:47:01 PM	2.02	5.62	0.17	2031	19.12	9.72	8.86	0.04	0.04	3.65	35191
1339	5	10/6/99	3:11:53 PM	2.03	5.76	1.11	2102	18.37	10.68	9.72	0.06	0.04	3.52	36467
1339	6	10/6/99	3:36:45 PM	2.07	5.73	0.45	2052	17.92	8.69	7.88	0.07	0.03	3.62	35502
			Average:	**2.04**	**5.72**	**0.67**	**2057**	**18.54**	**10.14**	**9.23**	**0.05**	**0.039**	**3.60**	**35662**
ART Cycle, without Catalytic Convertor, GVW														
1353	1	10/13/99	9:48:51 PM	2.04	5.54	10.58	1974	22.74	15.76	13.23	1.18	0.06	3.70	34769
1353	2	10/13/99	10:13:43 PM	2.04	5.56	11.48	1915	36.60	13.77	11.99	0.61	0.05	3.81	33703
1353	3	10/13/99	10:38:34 PM	2.02	5.48	10.55	1926	33.51	14.49	12.40	0.85	0.06	3.79	33892
1353	4	10/13/99	11:03:26 PM	2.01	5.47	11.56	1916	25.24	N/A	N/A	N/A	0.06	3.78	34030
			Average:	**2.03**	**5.51**	**11.04**	**1933**	**29.52**	**14.67**	**12.54**	**0.88**	**0.060**	**3.77**	**34098**

* MPG: Mile per gallon, for CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 6 -- Emisisons and Fuel Economy Summary for CBD and ART Cycle Tests

Emissions in grams/cycle

CBD Cycle	Miles	Axle hp-hr	CO*	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU/mile
with Catalytic Convertor, SVW	2.04	4.36	2.98	4659	41.11	16.56	15.07	0.08	0.096	3.26	39396
without Catalytic Convertor, SVW	2.02	4.50	40.04	4539	70.55	49.23	42.42	2.62	0.096	3.21	40016
with Catalytic Convertor, GVW	2.04	5.02	3.18	5132	45.23	19.20	17.46	0.12	0.037	2.95	43541
without Catalytic Convertor, GVW	2.04	4.96	38.59	4815	55.40	60.48	51.69	3.64	0.055	3.05	42163
ART Cycle	**Miles**	**Axle hp-hr**	**CO**	**CO2**	**NOx**	**FIDHC**	**CH4**	**NMHC**	**PM**	**MPG***	**BTU/mile**
with Catalytic Convertor, SVW	2.01	5.03	1.55	3850	35.32	20.58	18.69	0.14	0.071	3.87	33182
without Catalytic Convertor, SVW	2.02	4.93	18.67	3622	72.37	27.63	24.01	1.27	0.101	4.07	31545
with Catalytic Convertor, GVW	2.04	5.72	1.37	4202	37.86	20.72	18.85	0.11	0.080	3.60	35662
without Catalytic Convertor, GVW	2.03	5.51	22.39	3920	59.90	29.87	25.53	1.79	0.122	3.77	34098

Emissions in grams/mile

CBD Cycle	Miles	Axle hp-hr	CO*	CO2	NOx	FIDHC	CH4	NMHC	PM	MPG*	BTU/mile
with Catalytic Convertor, SVW	2.04	4.36	1.46	2279	20.09	8.10	7.37	0.04	0.047	3.26	39396
without Catalytic Convertor, SVW	2.02	4.50	19.78	2243	34.85	24.33	20.97	1.29	0.048	3.21	40016
with Catalytic Convertor, GVW	2.04	5.02	1.56	2518	22.20	9.42	8.57	0.06	0.018	2.95	43541
without Catalytic Convertor, GVW	2.04	4.96	18.88	2355	27.09	29.61	25.31	1.78	0.027	3.05	42163
ART Cycle	**Miles**	**Axle hp-hr**	**CO**	**CO2**	**NOx**	**FIDHC**	**CH4**	**NMHC**	**PM**	**MPG***	**BTU/mile**
with Catalytic Convertor, SVW	2.01	5.03	0.77	1912	17.53	10.24	9.30	0.07	0.035	3.87	33182
without Catalytic Convertor, SVW	2.02	4.93	9.24	1793	35.83	13.68	11.89	0.63	0.050	4.07	31545
with Catalytic Convertor, GVW	2.04	5.72	0.67	2057	18.54	10.14	9.23	0.05	0.039	3.60	35662
without Catalytic Convertor, GVW	2.03	5.51	11.04	1933	29.52	14.67	12.54	0.88	0.060	3.77	34098

* MPH: Miles per gallon, For CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 7 -- Emissons and Fuel Economy Comparison with Those from Similar School Bus Tests

Buses	Test Weight (lbs)	CO*	NOx	NMHC	PM	CO2	MPG**	BTU/mile
(A): Chemonics Bus with Catalytic Convertor	30110	1.46	20.09	0.04	0.047	2279	3.26	39396
(B): Chemonics Bus without Catalytic Convertor	30110	19.78	34.85	1.29	0.048	2243	3.21	40016
(C): 3 School Bus Average with D2 Fuel with Catalyst [Ref 7]	28531	1.52	20.99	0.49	0.261	2001	5.08	25615
(D): 11 School Bus Average with CNG Fuel w/o Catalyst [Ref 7]	28531	10.72	19.03	0.99	0.140	1949	3.71	34672
% benefit of (A) over (D):		86%	-6%	96%	66%	-17%		
% benefit of (A) over (C):		4%	4%	92%	82%	-14%		

* All emissions in total grams per mile

** MPH: Miles per gallon, For CNG fuel, 137 ft^3 CNG as STP is equivalent to one gallon of diesel fuel.

Table 8 -- Emissions (in grams/second) for Steady State Tests

Test Set Up***	Time (sec)	Avg Axle HP	Avg Bus Speed (MPH)	Avg Axle Torque* (ft-lb)	grams/second						
					CO	CO_2	NO_x	FIDHC	CH_4	NMHC	PM**
With Catalytic Converter											
2400RPM, 0% Load	300	29	29.3	625	0.0007	11.0	0.01	0.018	0.017	0.000	5.4E-05
2400RPM, 25% Load	300	63	33.9	1185	0.0007	17.3	0.03	0.020	0.018	0.000	1.1E-04
2400RPM, 50% Load	300	116	35.2	2108	0.0017	23.8	0.25	0.010	0.009	0.000	3.1E-04
2400RPM, 75% Load	275	156	35.1	3035	0.0029	29.8	0.57	0.011	0.010	0.000	1.1E-03
2400RPM, 100% Load	150	208	34.1	3899	0.0033	34.7	0.61	0.021	0.019	0.000	3.3E-03
1900RPM, 0% Load	300	13	28.1	305	0.0005	9.3	0.00	0.004	0.003	0.000	-1.1E-04
1900RPM, 25% Load	300	53	27.9	1221	0.0005	13.0	0.04	0.011	0.010	0.000	-6.1E-05
1900RPM, 50% Load	300	95	27.9	2178	0.0006	17.3	0.09	0.019	0.017	0.000	-3.2E-05
1900RPM, 75% Load	300	137	27.9	3145	0.0010	22.1	0.15	0.023	0.021	0.000	2.8E-05
1900RPM, 100% Load	120	180	28.2	4101	0.0031	27.3	0.38	0.023	0.021	0.000	1.5E-04
1400RPM, 0% Load	300	12	29.2	264	0.0005	6.9	0.00	0.017	0.015	0.000	-4.3E-05
1400RPM, 25% Load	300	43	29.2	940	0.0002	9.7	0.02	0.027	0.024	0.001	-6.5E-05
1400RPM, 50% Load	300	73	29.0	1617	0.0011	12.7	0.09	0.022	0.020	0.000	5.1E-06
1400RPM, 75% Load	300	104	28.9	2305	0.0007	16.2	0.18	0.030	0.028	0.000	-4.7E-05
1400RPM, 100% Load	300	136	29.0	3003	0.0009	19.5	0.40	0.026	0.024	0.000	-3.1E-05
Idle	1800.8				0.0004	2.0	0.00	0.006	0.006	0.000	3.2E-05
Without Catalytic Converter											
2400RPM, 0% Load	300	31	29.2	683	0.0478	10.6	0.01	0.151	0.128	0.010	-1.9E-04
2400RPM, 25% Load	300	63	33.6	1210	0.0699	16.4	0.05	0.163	0.138	0.011	-8.5E-05
2400RPM, 50% Load	300	115	35.4	2081	0.1221	23.2	0.32	0.113	0.095	0.008	-2.9E-05
2400RPM, 75% Load	300	166	35.3	3004	0.1327	29.1	0.77	0.090	0.076	0.006	2.9E-04
2400RPM, 100% Load	185	195	35.1	3559	0.1249	32.3	0.98	0.090	0.076	0.006	1.2E-04
1900RPM, 0% Load	300	14	28.2	328	0.0426	8.9	0.01	0.139	0.119	0.008	-1.6E-05
1900RPM, 25% Load	300	54	27.9	1238	0.0523	12.6	0.05	0.143	0.125	0.005	-3.8E-05
1900RPM, 50% Load	300	94	27.8	2158	0.0719	17.0	0.14	0.120	0.105	0.005	8.6E-04
1900RPM, 75% Load	300	136	27.8	3139	0.0918	21.8	0.19	0.143	0.125	0.006	2.4E-05
1900RPM, 100% Load	160	181	27.9	4156	0.1060	27.6	0.48	0.132	0.115	0.005	7.2E-05
1400RPM, 0% Load	300	12	29.3	255	0.0314	6.8	0.00	0.095	0.083	0.004	-2.9E-05
1400RPM, 25% Load	300	41	29.0	911	0.0334	9.5	0.02	0.101	0.089	0.004	3.5E-05
1400RPM, 50% Load	300	72	29.1	1593	0.0471	12.8	0.10	0.099	0.087	0.004	3.8E-05
1400RPM, 75% Load	300	134	28.9	2294	0.0544	15.4	0.19	0.112	0.097	0.006	2.7E-05
1400RPM, 100% Load	210	139	29.1	3058	0.0474	18.8	0.54	0.101	0.089	0.003	-5.6E-05
Idle	1800.3				0.0016	1.7	-0.01	0.013	0.010	0.002	4.1E-04

* The average axle torque is the average total axle torque for both rear drive wheels.

** PM emissions were very low and below the detectable limit.

*** The percentage load of each is only approximate. Actual loads are expressed as axle HP in column 3.

Table 9 -- Emissions (in grams/Axle hp-hr) for Steady State Tests

Test Set Up***	Time (sec)	Avg Axle HP	Avg Bus Speed (MPH)	Avg Axle Torque* (ft-lb)	grams/hp-hr						
					CO	CO_2	NO_x	FIDHC	CH_4	NMHC	PM**
With Catalytic Converter											
2400RPM, 0% Load	300	29	29.3	625	0.092	1391	1.1	2.29	2.08	0.01	0.0068
2400RPM, 25% Load	300	63	33.9	1185	0.042	993	2.0	1.13	1.02	0.01	0.0066
2400RPM, 50% Load	300	116	35.2	2108	0.052	738	7.9	0.31	0.28	0.01	0.0096
2400RPM, 75% Load	275	166	35.1	3035	0.062	646	12.3	0.24	0.22	0.01	0.0243
2400RPM, 100% Load	150	208	34.1	3899	0.056	602	10.5	0.38	0.34	0.01	0.0548
1900RPM, 0% Load	300	13	28.1	305	0.129	2502	0.8	1.03	0.92	0.02	-0.0296
1900RPM, 25% Load	300	53	27.9	1221	0.031	879	2.7	0.76	0.69	0.00	-0.0041
1900RPM, 50% Load	300	95	27.9	2178	0.025	657	3.6	0.72	0.66	0.01	-0.0012
1900RPM, 75% Load	300	137	27.9	3145	0.026	581	3.9	0.61	0.55	0.01	0.0007
1900RPM, 100% Load	120	180	28.2	4101	0.062	545	7.7	0.47	0.42	0.01	0.0030
1400RPM, 0% Load	300	12	29.2	264	0.150	2080	0.7	5.02	4.58	0.01	-0.0128
1400RPM, 25% Load	300	43	29.2	940	0.021	818	1.8	2.30	2.03	0.07	-0.0055
1400RPM, 50% Load	300	73	29.0	1617	0.055	622	4.3	1.09	0.99	0.01	0.0002
1400RPM, 75% Load	300	104	28.9	2305	0.024	560	6.1	1.06	0.95	0.01	-0.0016
1400RPM, 100% Load	300	136	29.0	3003	0.023	518	10.5	0.70	0.64	0.01	-0.0008
Idle	1800.8										
Without Catalytic Converter											
2400RPM, 0% Load	300	31	29.2	683	5.525	1229	1.1	17.36	14.78	1.11	-0.0219
2400RPM, 25% Load	300	63	33.6	1210	3.966	932	2.8	9.22	7.79	0.64	-0.0048
2400RPM, 50% Load	300	115	35.4	2081	3.824	727	9.9	3.52	2.99	0.24	-0.0009
2400RPM, 75% Load	300	166	35.3	3004	2.883	632	16.7	1.94	1.65	0.12	0.0063
2400RPM, 100% Load	185	195	35.1	3559	2.301	596	18.1	1.65	1.40	0.11	0.0023
1900RPM, 0% Load	300	14	28.2	328	10.721	2219	1.7	35.02	29.93	2.11	-0.0050
1900RPM, 25% Load	300	54	27.9	1238	3.480	840	3.4	9.47	8.31	0.36	-0.0025
1900RPM, 50% Load	300	94	27.8	2158	2.763	653	5.4	4.61	4.02	0.20	0.0328
1900RPM, 75% Load	300	136	27.8	3139	2.426	577	5.0	3.77	3.30	0.15	0.0006
1900RPM, 100% Load	160	181	27.9	4156	2.106	549	9.5	2.62	2.29	0.11	0.0014
1400RPM, 0% Load	300	12	29.3	255	9.675	2089	0.8	29.33	25.67	1.17	-0.0090
1400RPM, 25% Load	300	41	29.0	911	2.912	832	1.8	8.85	7.75	0.34	0.0031
1400RPM, 50% Load	300	72	29.1	1593	2.345	635	5.0	4.94	4.32	0.20	0.0019
1400RPM, 75% Load	300	104	28.9	2294	1.890	536	6.7	3.89	3.36	0.20	0.0009
1400RPM, 100% Load	210	139	29.1	3058	1.232	487	14.0	2.62	2.32	0.09	-0.0014
Idle	1800.3										

* The average axle torque is the average total axle torque for both rear drive wheels.

** PM emissions were very low and below the detectable limit.

*** The percentage load of each is only approximate. Actual loads are expressed as axle HP in column 3.

Table 10 -- TEOM and 70mm Filter data comparion (Page 1 of 3)

Test	Run	Vmix (SCF)	TEOM Time (second)	TEOM Filter Weight (grams)**	TEOM Flow Rate (SLPM)	TEOM Sample Vol (SCF)	TEOM Cycle PM* (grams)	70mm Filter Filter Weight (micrograms)	70mm Filter Sample Vol (SCF)	70mm Filter Cycle PM* (grams)	Ratio TEOM/70mm
1336	3	13215	567.9	1.97E-06	2.00	0.67	0.039	0.317	43.9	0.095	0.41
	4	13238	601.9	1.56E-06	2.00	0.71	0.029	1.025	44.0	0.308	0.09
	5	13234	578.8	1.72E-06	2.00	0.68	0.034	0.303	43.9	0.091	0.37
1337	1	6688	314.6	3.29E-06	2.00	0.37	0.060	0.339	22.3	0.102	0.59
	2	6681	307.9	2.56E-06	2.00	0.36	0.047	0.386	22.3	0.116	0.41
	3	6627	317.5	2.50E-06	2.00	0.37	0.044	0.361	22.1	0.108	0.41
	4	6650	305.8	2.37E-06	2.00	0.36	0.044	0.241	22.2	0.072	0.61
	5	6631	312.1	2.25E-06	2.00	0.37	0.041	0.290	22.1	0.087	0.47
	6	6614	308.9	3.10E-06	2.00	0.36	0.056	0.237	22.0	0.071	0.79
1338	1	43383	1783.2	3.65E-06	2.00	2.09	0.076	0.718	143.1	0.218	0.35
1339	2	6559	310.4	4.64E-06	1.97	0.36	0.085	0.391	21.8	0.117	0.72
	3	6577	311.8	4.25E-06	2.00	0.37	0.076	0.370	21.9	0.111	0.69
	4	6565	304.9	4.42E-06	2.00	0.36	0.081	0.369	21.9	0.111	0.73
	5	6554	312.1	4.53E-06	2.00	0.37	0.081	0.395	21.8	0.119	0.68
	6	6558	309.5	4.62E-06	2.00	0.36	0.083	0.344	21.8	0.103	0.81
1340	1	13206	593.9	2.74E-06	2.00	0.70	0.052	0.169	43.8	0.051	1.02
	2	13289	578.2	3.27E-06	2.00	0.68	0.064	0.255	44.1	0.077	0.83
	3	13281	600.8	3.09E-06	2.00	0.71	0.058	0.268	44.1	0.081	0.72
	4	13313	591.0	3.04E-06	2.00	0.69	0.058	0.388	44.2	0.117	0.50
	5	13287	584.3	2.00E-06	2.00	0.69	0.039	0.488	44.1	0.147	0.26
1344	1	4854	130.0	6.58E-05	2.00	0.15	2.092	2.637	9.4	1.366	1.53
	3	8324	315.0	1.39E-05	2.00	0.37	0.312	1.040	17.9	0.483	0.65
	4	8902	316.5	8.95E-07	2.00	0.37	0.021	0.168	20.0	0.075	0.29
	5	8628	306.8	4.25E-06	2.00	0.36	0.102	0.312	19.7	0.136	0.75
	6	9222	314.6	1.31E-06	2.00	0.37	0.033	0.165	21.9	0.070	0.47
	7	3332	122.1	6.62E-06	2.00	0.14	0.154	0.312	5.5	0.191	0.81
	8	8917	310.2	2.02E-06	2.00	0.36	0.049	0.202	19.8	0.091	0.54
	10	6924	262.1	1.24E-05	2.00	0.31	0.279	0.738	15.7	0.326	0.86
	11	8550	307.7	5.36E-06	2.00	0.36	0.127	0.333	18.9	0.151	0.84

* All total cycle PM data were not corrected with background.

** PM weight on TEOM filter was calculated by substracting the inital weight from the final weight.

Table 10 – TEOM and 70mm Filter data comparion (Page 2 of 3)

Test	Run	Vmix (SCF)	TEOM Time (second)	TEOM Filter Weight (grams)**	TEOM Flow Rate (SLPM)	TEOM Sample Vol (SCF)	TEOM Cycle PM* (grams)	70mm Filter Filter Weight (micrograms)	70mm Filter Sample Vol (SCF)	70mm Filter Cycle PM* (grams)	Ratio TEOM/70mm
1345	1	3357	125.8	1.04E-05	2.00	0.15	0.236	0.062	5.8	0.036	6.64
	2	9210	299.9	1.33E-06	2.00	0.35	0.035	0.073	22.0	0.031	1.14
	3	8641	311.8	7.22E-06	2.00	0.37	0.170	0.126	18.8	0.058	2.94
	4	9111	320.0	3.37E-06	2.00	0.38	0.082	0.070	21.5	0.030	2.75
	5	8923	306.4	5.56E-06	2.00	0.36	0.138	0.079	20.3	0.035	3.98
	6	9168	306.6	2.00E-06	2.00	0.36	0.051	0.048	21.5	0.020	2.49
	7	3373	129.4	9.11E-06	2.00	0.15	0.202	0.122	5.6	0.073	2.76
	8	9141	305.8	3.64E-06	2.00	0.36	0.093	0.114	21.6	0.048	1.92
	9	8607	306.0	6.40E-06	2.00	0.36	0.153	0.159	18.5	0.074	2.08
	10	8838	309.3	3.83E-06	2.00	0.36	0.093	0.132	19.8	0.059	1.58
1346	1	8725	297.2	1.49E-06	2.00	0.35	0.037	0.132	19.3	0.060	0.62
	2	9263	305.6	3.96E-07	2.00	0.36	0.010	0.130	21.8	0.055	0.18
	3	8958	307.2	3.28E-06	2.00	0.36	0.082	0.084	20.4	0.037	2.22
	4	9187	310.0	7.50E-07	2.00	0.36	0.019	0.126	22.0	0.053	0.36
	5	9073	304.7	2.48E-06	2.00	0.36	0.063	0.151	21.6	0.063	0.99
	6	9313	308.7	7.92E-07	2.00	0.36	0.020	0.099	21.8	0.042	0.48
	7	8790	307.2	5.09E-06	2.00	0.36	0.124	0.074	19.5	0.033	3.72
	8	9193	306.8	2.00E-06	2.00	0.36	0.051	0.061	22.0	0.026	2.00
	9	8927	306.0	3.47E-06	2.00	0.36	0.086	0.109	20.5	0.047	1.82
	10	9031	309.3	1.61E-06	2.00	0.36	0.040	0.132	21.5	0.056	0.72
1348	1	6270	186.4	1.81E-05	2.00	0.22	0.519	0.133	10.4	0.081	6.45
	2	11557	310.8	8.10E-07	2.00	0.36	0.026	0.061	22.1	0.032	0.81
	3	10441	304.3	1.53E-05	2.00	0.36	0.447	0.320	18.8	0.178	2.51
	4	11112	309.3	4.20E-06	2.00	0.36	0.128	0.132	20.7	0.071	1.81
	5	10725	308.1	1.02E-05	2.00	0.36	0.301	0.161	18.2	0.095	3.17
	7	6572	195.9	1.71E-05	2.00	0.23	0.490	0.167	11.0	0.100	4.91
	8	11135	306.6	4.84E-06	2.00	0.36	0.150	0.144	20.0	0.080	1.87
	9	10353	306.8	1.36E-05	2.00	0.36	0.390	0.358	17.7	0.210	1.86
	10	10725	300.7	9.72E-06	2.00	0.35	0.295	0.156	17.6	0.095	3.10

* All total cycle PM data were not corrected with background.

** PM weight on TEOM filter was calculated by substracting the inital weight from the final weight.

Table 10 -- TEOM and 70mm Filter data comparion (Page 3 of 3)

			TEOM					70mm Filter			
Test	Run	Vmix (SCF)	Time (second)	Filter Weight (grams)**	Flow Rate (SLPM)	Sample Vol (SCF)	Cycle PM* (grams)	Filter Weight (micrograms)	Sample Vol (SCF)	Cycle PM* (grams)	Ratio TEOM/70mm
1349	1	6400	186.4	3.27E-06	2.00	0.22	0.096	0.076	9.6	0.051	1.89
	2	11621	306.2	6.84E-07	2.00	0.36	0.022	0.135	21.8	0.072	0.31
	3	10889	303.2	9.57E-06	2.00	0.36	0.293	0.091	19.3	0.051	5.69
	4	11604	305.6	2.01E-06	2.00	0.36	0.065	0.070	21.3	0.038	1.70
	5	4965	145.5	1.21E-05	2.00	0.17	0.351	0.075	9.5	0.039	8.98
	6	11372	305.3	3.67E-06	2.00	0.36	0.116	0.072	21.9	0.037	3.11
	8	10845	305.3	1.13E-05	2.00	0.36	0.342	0.131	19.1	0.074	4.61
	9	11061	306.2	7.43E-06	2.00	0.36	0.229	1.136	20.0	0.628	0.36
	10	11315	305.3	4.00E-06	2.00	0.36	0.126	0.097	20.8	0.053	2.39
	11	11062	306.2	6.92E-06	2.00	0.36	0.213	0.100	20.3	0.055	3.90
1350	2	11266	303.9	5.06E-06	2.00	0.36	0.160	0.127	21.4	0.067	2.39
	3	11404	309.3	1.66E-06	2.00	0.36	0.052	0.098	21.6	0.052	1.01
	4	11393	306.0	1.42E-06	2.00	0.36	0.045	0.103	21.9	0.054	0.84
	5	10337	307.0	6.97E-06	2.00	0.36	0.200	0.166	18.9	0.091	2.20
	6	11353	304.5	1.13E-07	2.00	0.36	0.004	0.163	21.6	0.086	0.04
	7	11279	312.9	4.13E-06	2.00	0.37	0.127	0.133	21.0	0.071	1.78
	9	11027	307.4	5.70E-06	2.00	0.36	0.174	0.064	20.1	0.035	4.97
	10	7850	245.6	7.18E-06	2.00	0.29	0.196	0.061	13.6	0.035	5.55
	11	6166	185.2	4.09E-06	2.00	0.22	0.116	0.024	10.5	0.014	8.21
1352	1	12769	614.9	1.08E-05	2.00	0.72	0.191	0.660	42.5	0.198	0.96
	4	12823	546.1	2.63E-06	2.00	0.64	0.053	0.458	42.7	0.138	0.38
	5	12890	600.4	3.49E-06	2.00	0.70	0.064	0.423	42.8	0.127	0.50
1353	1	6415	320.4	1.12E-05	2.00	0.38	0.190	0.584	21.4	0.175	1.09
	2	6439	300.9	1.05E-05	2.00	0.35	0.191	0.526	21.5	0.157	1.21
	3	6448	342.0	1.27E-05	2.00	0.40	0.204	0.556	21.5	0.167	1.22
	4	6444	302.6	1.38E-05	1.90	0.34	0.264	0.589	21.5	0.176	1.50
1354	1	6532	297.6	5.76E-06	2.00	0.35	0.108	0.557	21.8	0.167	0.65
	2	6536	293.6	6.50E-06	2.00	0.34	0.123	0.480	21.9	0.143	0.86
	3	6547	281.5	5.69E-06	2.00	0.33	0.113	0.446	21.9	0.133	0.84
	4	6544	299.5	4.95E-06	2.00	0.35	0.092	0.514	21.8	0.154	0.60
1355	1	13065	561.4	5.24E-06	2.00	0.66	0.104	0.641	43.4	0.193	0.54
	4	13031	594.8	7.26E-06	2.00	0.70	0.135	0.674	43.3	0.203	0.67
	5	13030	566.4	5.48E-06	2.00	0.66	0.107	0.656	43.3	0.197	0.54
	6	13004	579.7	5.69E-06	2.00	0.68	0.109	0.664	43.2	0.200	0.54
1356	1	42984	1523.8	2.32E-05	2.00	1.79	0.557	3.593	142.3	1.086	0.51

* All total cycle PM data were not corrected with background.

** PM weight on TEOM filter was calculated by substracting the inital weight from the final weight.

Table 11 -- Cartridge Carbonyl Analysis Results
(Formaldehyde was the most prominent.)

Test Set Up	Test ID	Formaldehyde (ug/cartridge)	Acetaldehyde (ug/cartridge)	Time (sec)	Sample Vol (SCF)	Vmix (SCF)	Formaldehyde (g/cyc)	Acetaldehyde (g/cyc)
With Catalytic Converter								
ART, Seated GVW	1337-6	1.959	0.066	291.5	0.171	6614	**0.076**	**0.003**
CBD, Rated GVW	1340-3	1.872	0.069	568	0.334	13281	**0.075**	**0.003**
CBD, Rated GVW	1340-4	1.727	0.088	568	0.334	13313	**0.069**	**0.004**
ART, Rated GVW	1341-1	2.092	0.067	291.5	0.171	6619	**0.081**	**0.003**
@2400, 100%	1344-1	1.360	0.080	180	0.106	4854	**0.062**	**0.004**
@1900, 100%	1345-7	0.034	0.019	120	0.070	3373	**0.002**	**0.001**
@1400, 100%	1346-7	0.267	0.029	300	0.176	8790	**0.013**	**0.001**
Idle	1338-1	0.884	0.054	1800.8	1.058	43383	**0.036**	**0.002**
Without Catalytic Converter								
CBD, Seated GVW	1355-2	74.339	1.137	568	0.334	13012	**2.899**	**0.044**
CBD, Seated GVW	1355-3	73.458	1.215	568	0.334	13036	**2.870**	**0.047**
ART, Seated GVW	1354-2	40.474	0.885	291.5	0.171	6536	**1.545**	**0.034**
ART, Seated GVW	1354-3	42.923	0.823	291.5	0.171	6547	**1.641**	**0.031**
CBD, Rated GVW	1352-3	66.611	1.341	568	0.334	12893	**2.574**	**0.052**
ART, Rated GVW	1353-2	53.462	0.879	291.5	0.171	6439	**2.010**	**0.033**
@2400, 100%	1347-7	18.468	0.536	115	0.068	3673	**1.004**	**0.029**
@1900, 100%	1349-5	27.927	0.481	140	0.082	4965	**1.686**	**0.029**
Idle	1356-1	52.730	3.025	1800.3	1.058	42984	**2.143**	**0.123**

Note

1. No background corrected for each sample
2. Assume 100% recovery of the cartridge

Table 12 -- Original Cartridge Carbonyl Analysis from Automotive Testing Laboratory, Inc.

	1337-6	1338-1	1340-3	1340-4	1341-1	1342-1	1344-1	1345-7	1346-7	1347-7	1349-5	1352-3	1353-2	1354-2	1354-3	1355-2	1355-3	1356-1	Blank
Formaldehyde	1.959	0.884	1.872	1.727	2.092	0.932	1.360	0.034	0.267	18.468	27.927	66.611	53.462	40.474	42.923	74.339	73.458	52.730	0.038
Acetaldehyde	0.066	0.054	0.069	0.088	0.067	0.055	0.080	0.019	0.029	0.536	0.481	1.341	0.879	0.885	0.823	1.137	1.215	3.025	0.097
Acetone	0.011	0.047	0.077	0.092	0.025	0.008		0.036	0.024		0.078	0.143	0.009	0.121	0.092	0.082	0.122	0.635	0.161
Acrolein	0.279	0.033	0.096	0.080	0.178	0.056	0.016			0.029	0.181	0.436	0.204	0.338	0.303	0.300	0.324	1.030	
Propionaldehyde	0.027	0.020	0.022	0.027	0.015	0.013	0.034	0.013	0.007	0.083	0.032	0.096	0.080	0.064	0.062	0.081	0.093	0.322	
MEK	0.018	0.039			0.022						0.013	0.022		0.011		0.115	0.016	0.137	
Methacrolein											0.103	0.046		0.024	0.024	0.020	0.022	0.256	
n-Butyraldehyde		0.020								0.041		0.019	0.018	0.003	0.016		0.022	0.142	
Benzaldehyde		0.034	0.021	0.025		0.018				0.068		0.077	0.068	0.049	0.054		0.058	0.482	
n-Valeraldehyde												0.022						0.086	
o/m/p-Tolunaldehyde	0.015	0.023		0.021		0.018										0.024		0.173	
n-Hexaldehyde	0.009	0.023	0.012	0.016		0.014				0.009						0.026	0.026	0.084	
p-Xylylaldehyde															0.028	0.088	0.184	1.710	
Others/Unknows	0.196	0.068	0.025	0.027	0.292	0.118	0.454	0.008	0.017	0.528	0.245	0.616	0.597	0.428	0.351	0.658	0.603	2.497	
Total W/'others'	**2.580**	**1.245**	**2.194**	**2.103**	**2.691**	**1.232**	**1.944**	**0.110**	**0.344**	**19.762**	**29.060**	**69.429**	**55.317**	**42.397**	**44.676**	**76.870**	**76.143**	**63.309**	
Total Wout/'others'	**2.384**	**1.177**	**2.169**	**2.076**	**2.399**	**1.114**	**1.490**	**0.102**	**0.327**	**19.234**	**28.815**	**68.813**	**54.720**	**41.969**	**44.325**	**76.212**	**75.540**	**60.812**	

Note:

1. All data were corrected for blank level

Table 13 -- Fuel consumption comparison between through fuel tank weight and emissions analysis

	Fuel Tank					
Test #	Initial Weight (lbs.)	Final Weight (lbs.)	Difference (grams)	Carbon Weight (grams)	Emissions Carbon Weight (grams)	% Difference
1336-01	79.2	75.5	1706	1277	1267	-0.8%
1336-02	84.3	80.5	1735	1299	1289	-0.7%
1336-03	78.0	74.2	1711	1281	1308	2.1%
1336-04	82.5	78.8	1697	1270	1247	-1.8%
1336-05	76.1	72.3	1725	1292	1279	-0.9%
1336-06	83.6	79.8	1725	1292	1339	3.7%
1337-02	89.0	85.9	1417	1061	1084	2.2%
1337-03	76.7	73.5	1460	1093	1067	-2.4%
1337-04	86.7	83.7	1384	1036	1050	1.4%
1337-05	81.2	78.1	1403	1050	1054	0.4%
1337-06	75.9	72.7	1446	1082	1087	0.5%
1339-02	76.1	72.7	1536	1150	1171	1.9%
1339-03	90.1	86.7	1574	1178	1163	-1.3%
1339-04	84.3	80.9	1578	1182	1136	-3.9%
1339-05	78.5	75.0	1597	1196	1187	-0.8%
1339-06	86.4	83.1	1526	1143	1175	2.8%
1340-01	73.9	69.7	1910	1430	1430	0.0%
1340-02	88.0	83.9	1858	1391	1409	1.3%
1340-03	81.3	77.3	1844	1380	1414	2.5%
1340-04	87.7	83.6	1839	1377	1418	3.0%
1340-05	80.4	76.2	1886	1412	1443	2.1%
1340-06	73.8	69.7	1901	1423	1403	-1.4%
1352-01	83.1	79.0	1844	1380	1400	1.4%
1352-04	80.8	76.6	1920	1437	1388	-3.4%
1352-05	86.3	82.3	1806	1352	1371	1.4%
1353-01	79.8	76.4	1531	1146	1140	-0.6%
1353-02	88.8	85.6	1465	1096	1105	0.7%
1353-03	83.1	79.9	1465	1096	1097	0.1%
1353-04	87.1	83.9	1455	1089	1097	0.7%
1354-01	85.2	82.3	1341	1004	1039	3.4%
1354-02	85.9	83.0	1318	986	1010	2.4%
1354-03	80.8	77.7	1384	1036	1007	-2.8%
1354-04	90.4	87.4	1375	1029	1032	0.2%
1355-01	85.0	81.1	1782	1334	1316	-1.3%
1355-04	89.9	86.2	1721	1288	1304	1.3%
1355-05	84.0	80.4	1649	1235	1287	4.2%
1355-06	87.2	83.3	1782	1334	1297	-2.8%

Figure 7 -- Sample Continuous CO Emissions from an ART Cycle Test

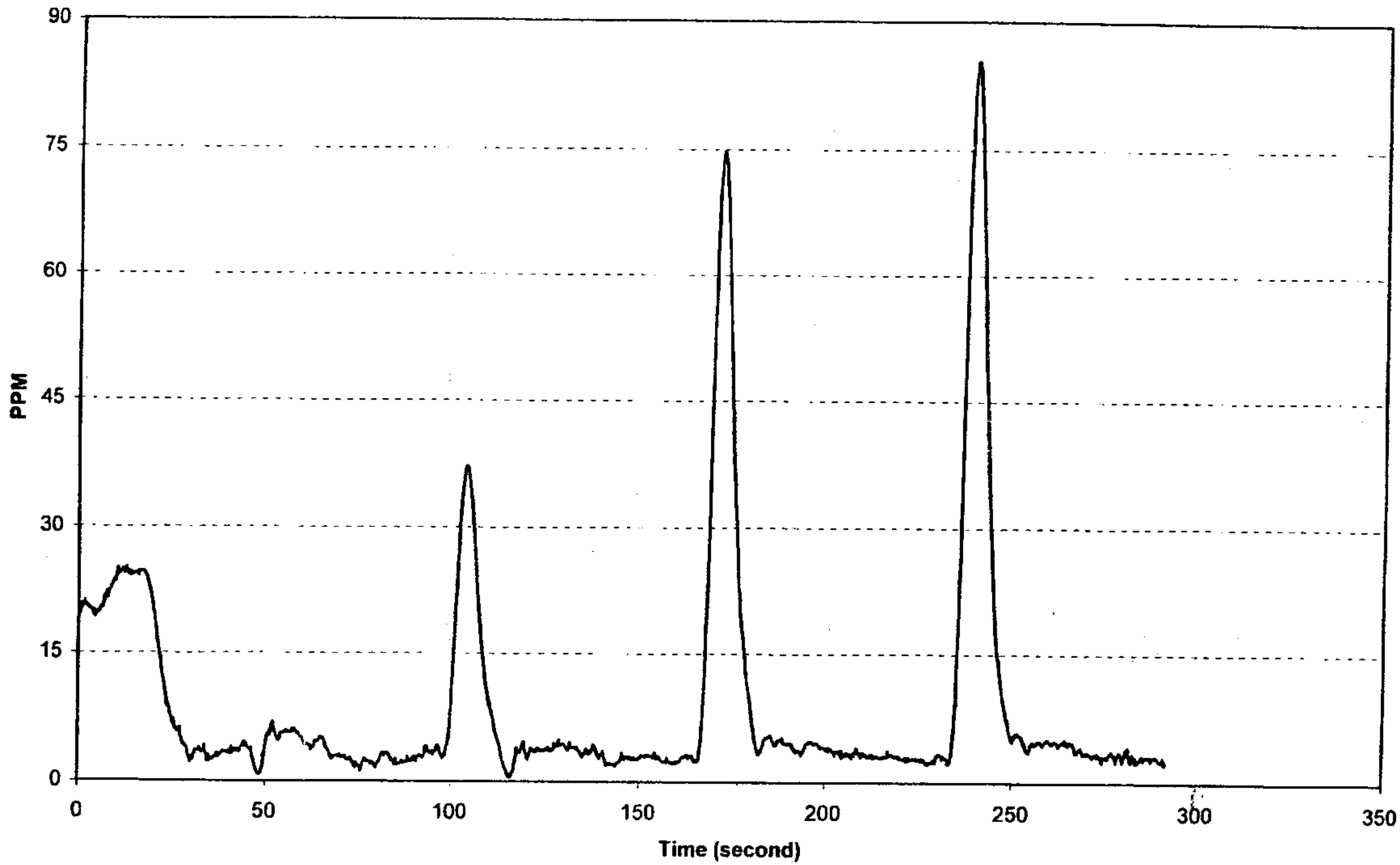


Figure 8 -- Sample Continuous CO_2 Emissions from an ART Cycle Test

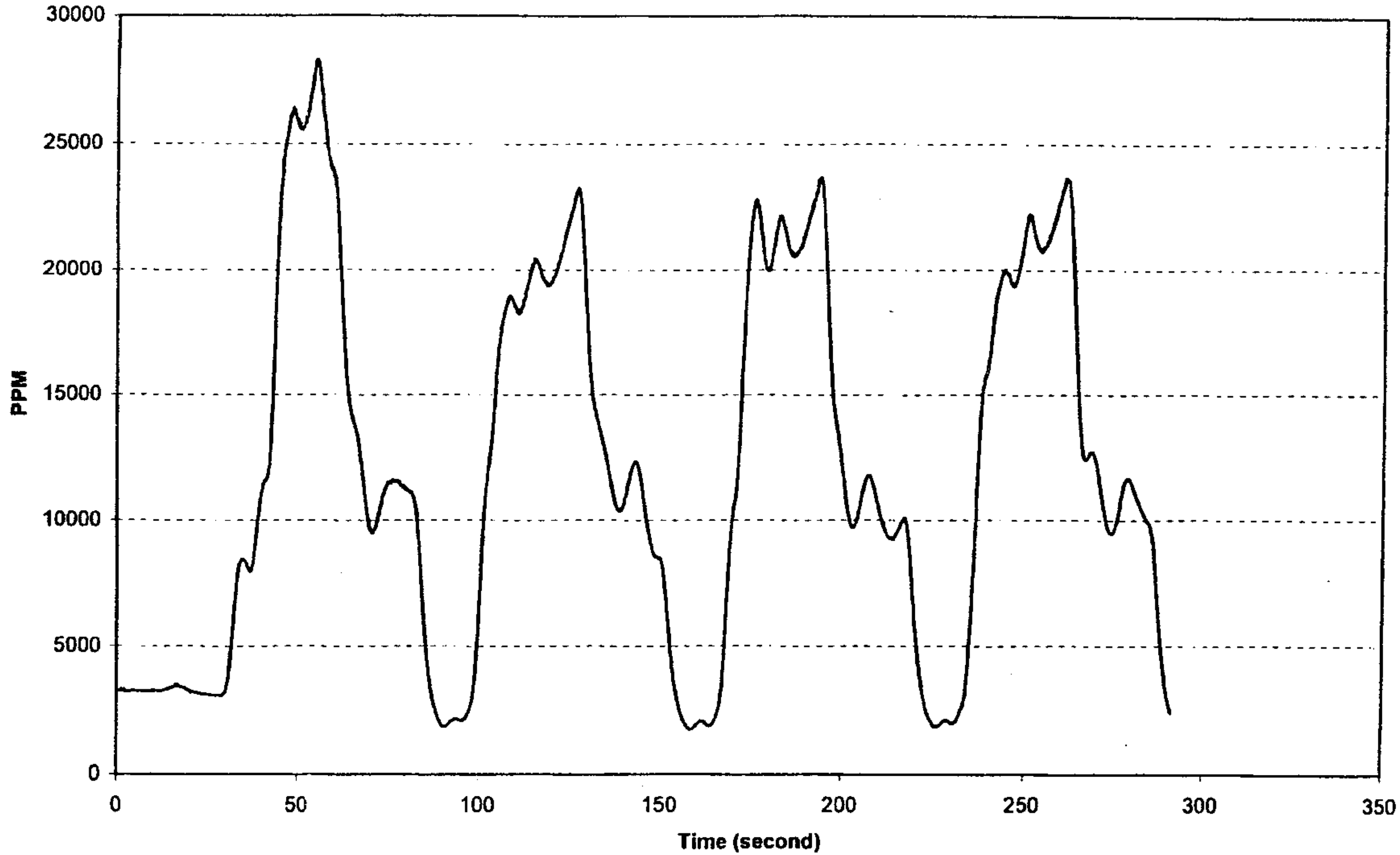


Figure 9 -- Sample Continuous NOx Emissions from an ART Cycle Test

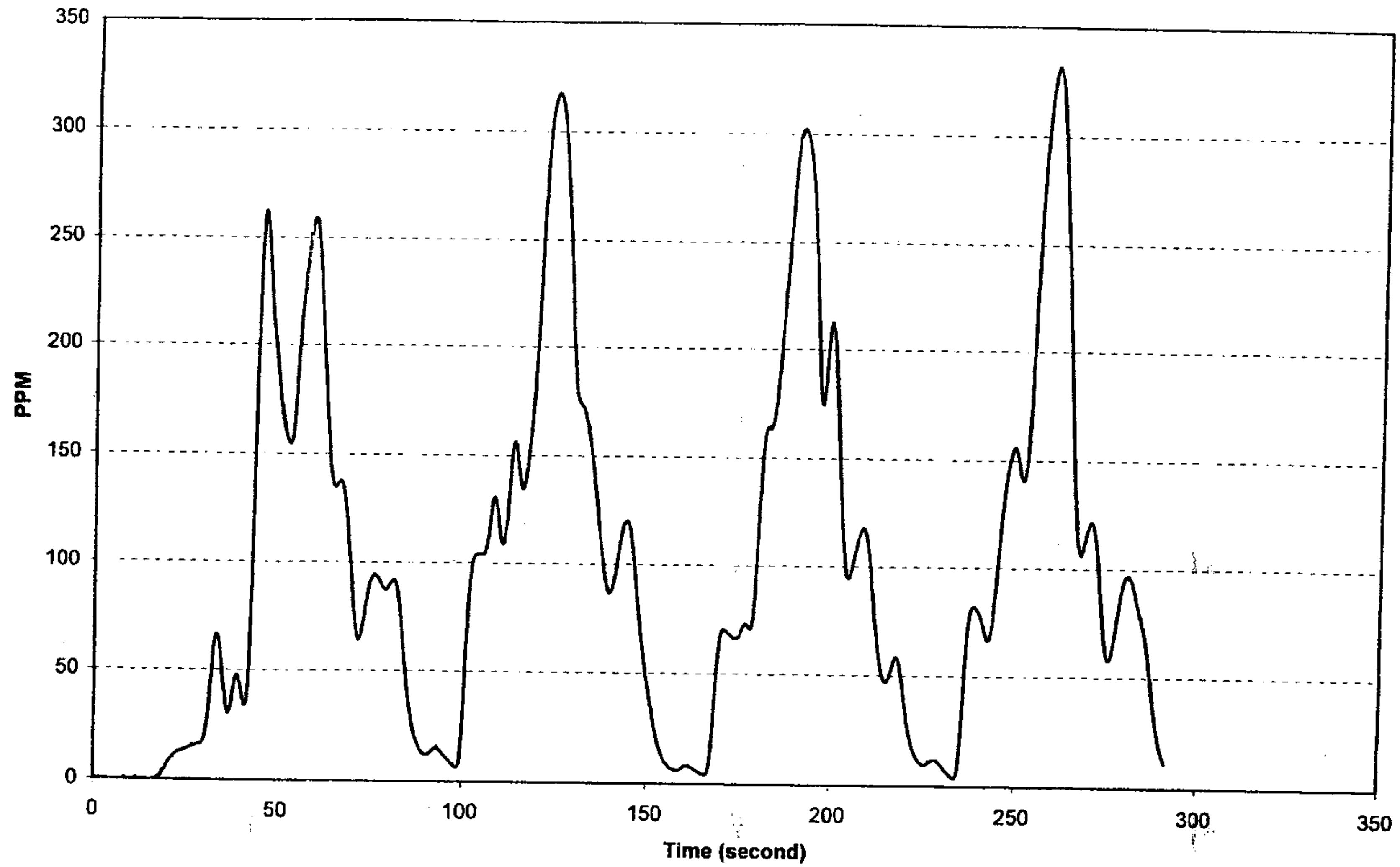


Figure 10 -- Sample Continuous HC Emissions from an ART Cycle Test

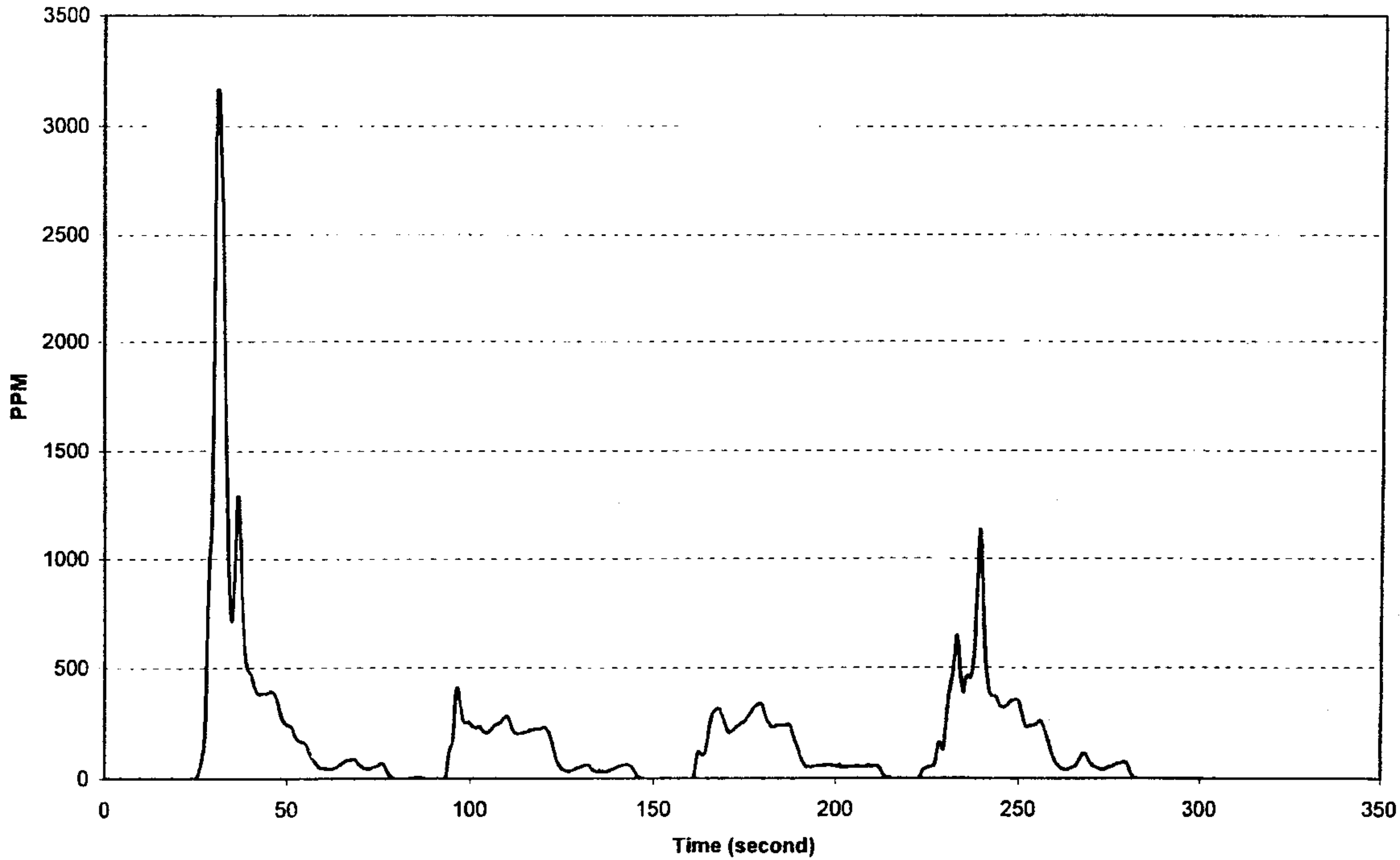


Figure 11 – Sample Continuous Exhaust Temperature from an ART Cycle Test

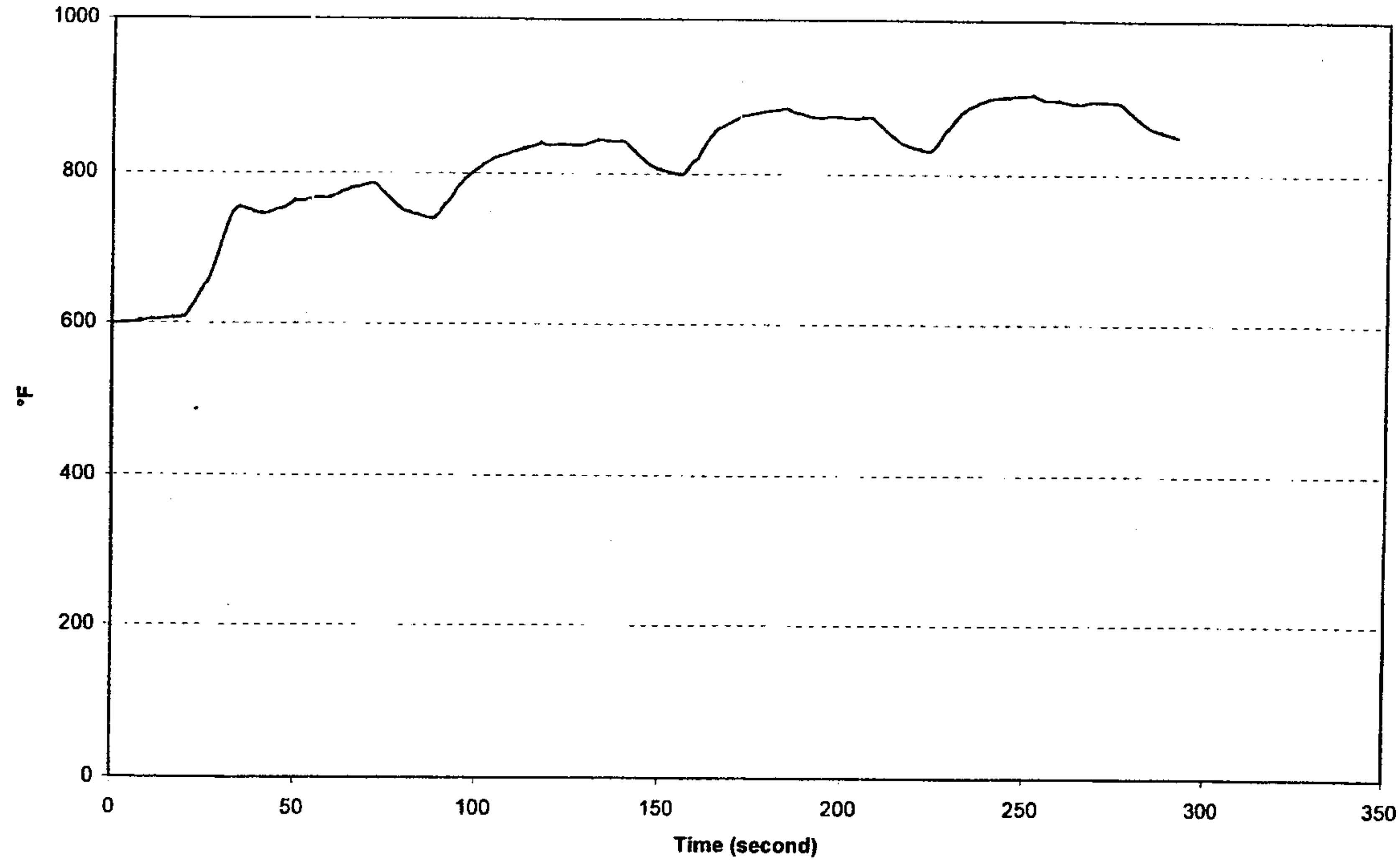


Figure 12 -- Average CO Emissions for CBD Cycle and ART Cycle

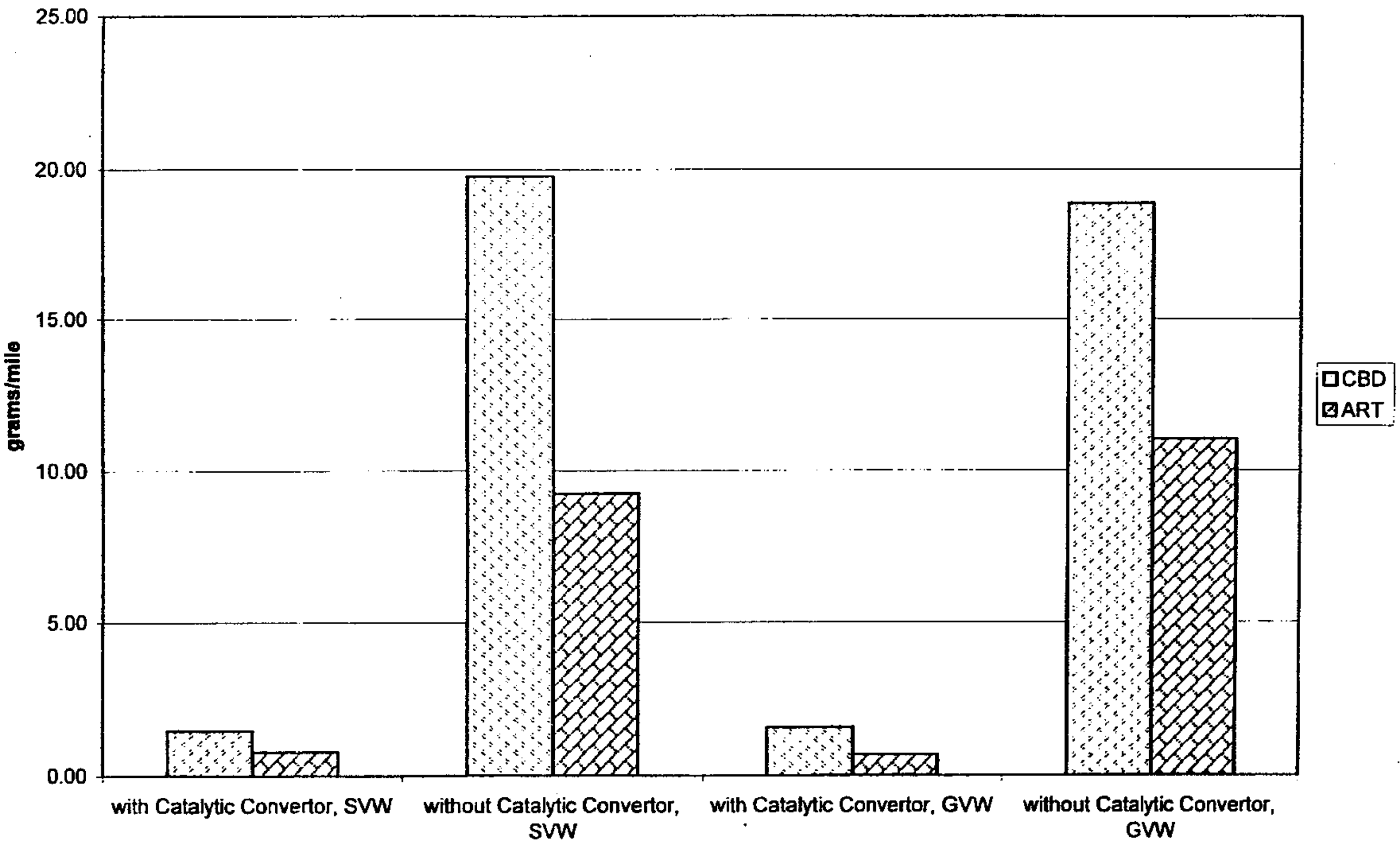


Figure 13 -- Average CO_2 Emissions for CBD Cycle and ART Cycle

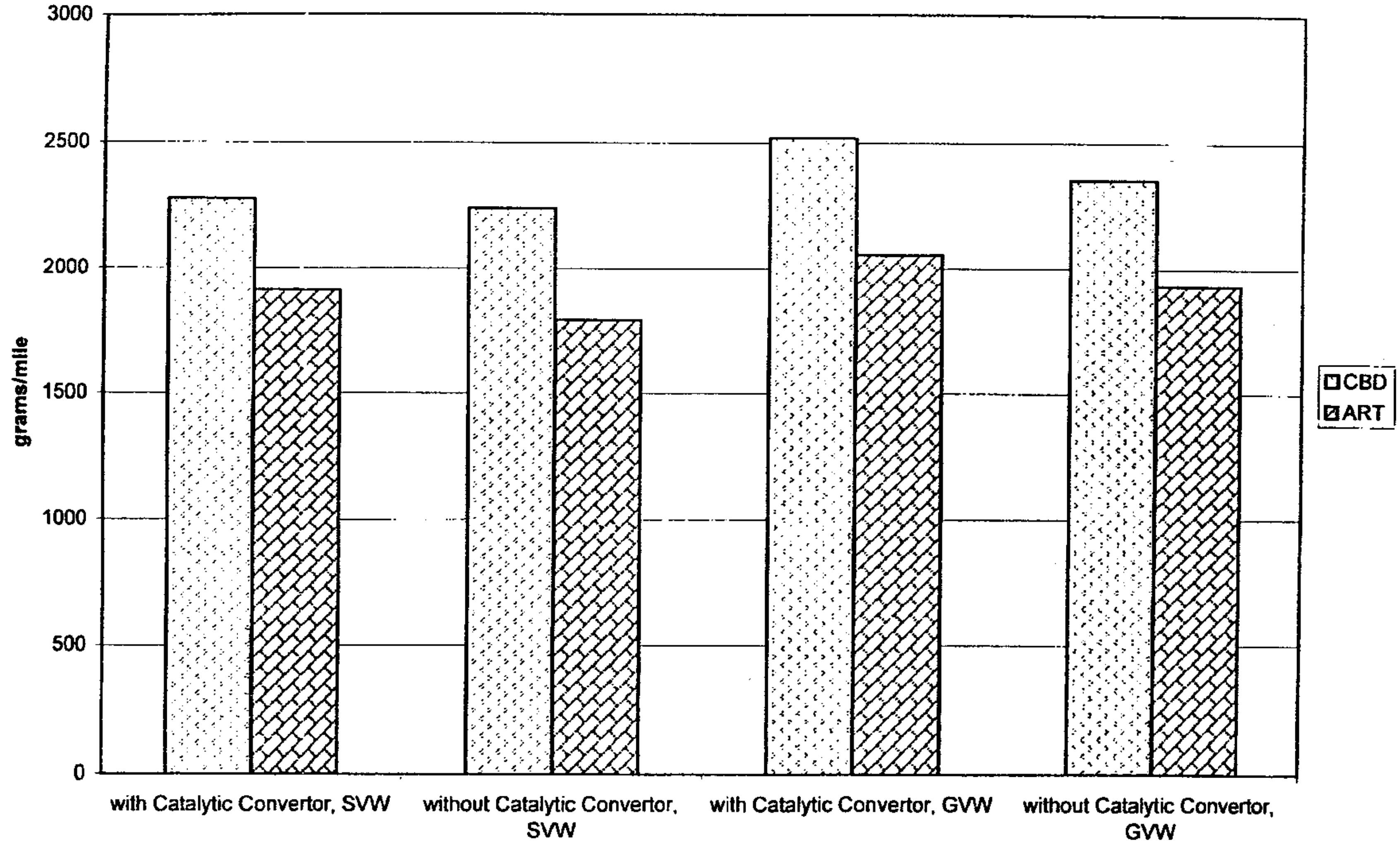


Figure 14 – Average NOx Emissions for CBD Cycle and ART Cycle

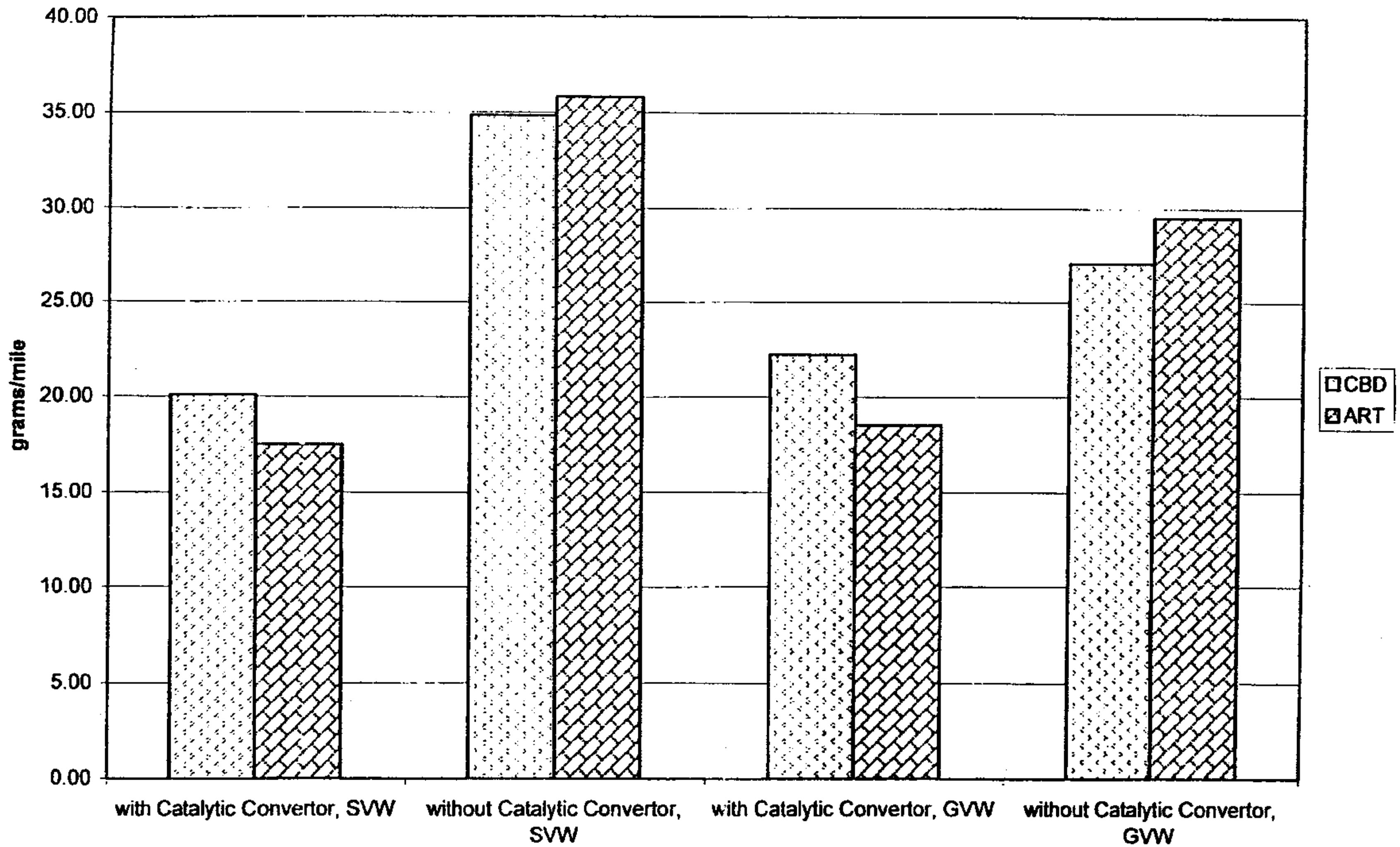


Figure 15 -- Average NMHC Emissions for CBD Cycle and ART Cycle

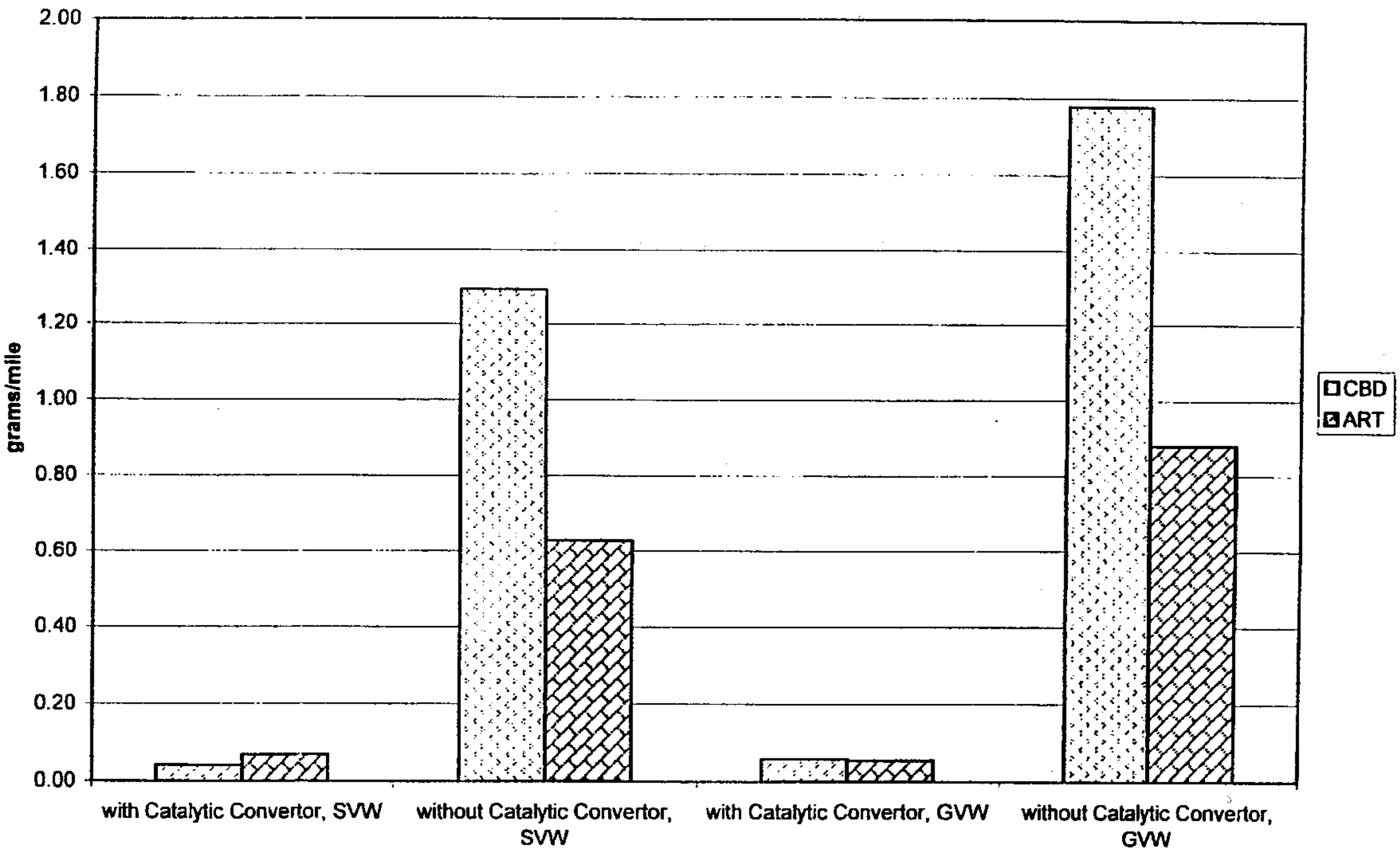


Figure 16 -- Average PM Emissions for CBD Cycle and ART Cycle

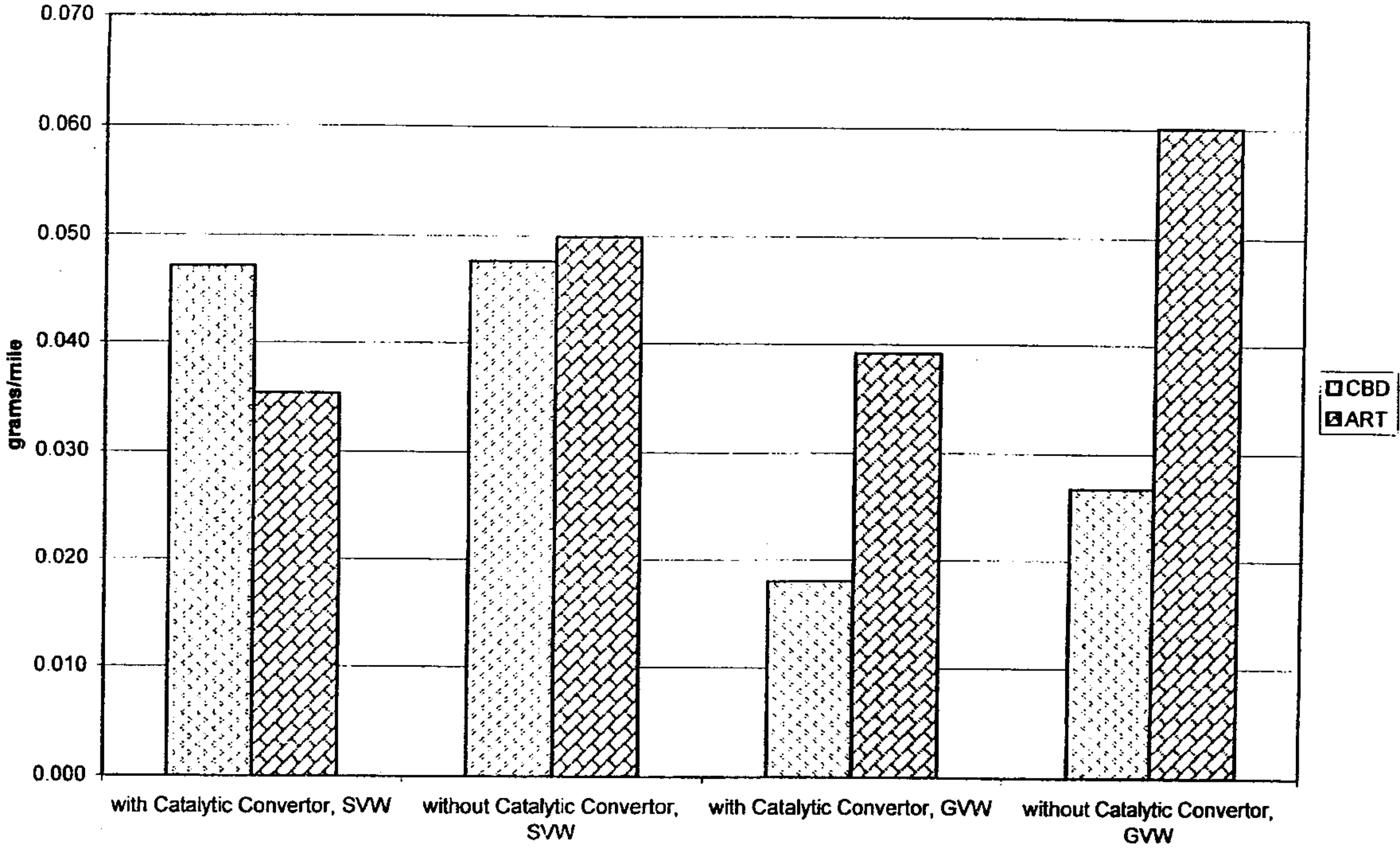


Figure 17 -- CO Emissions for Steady State Tests

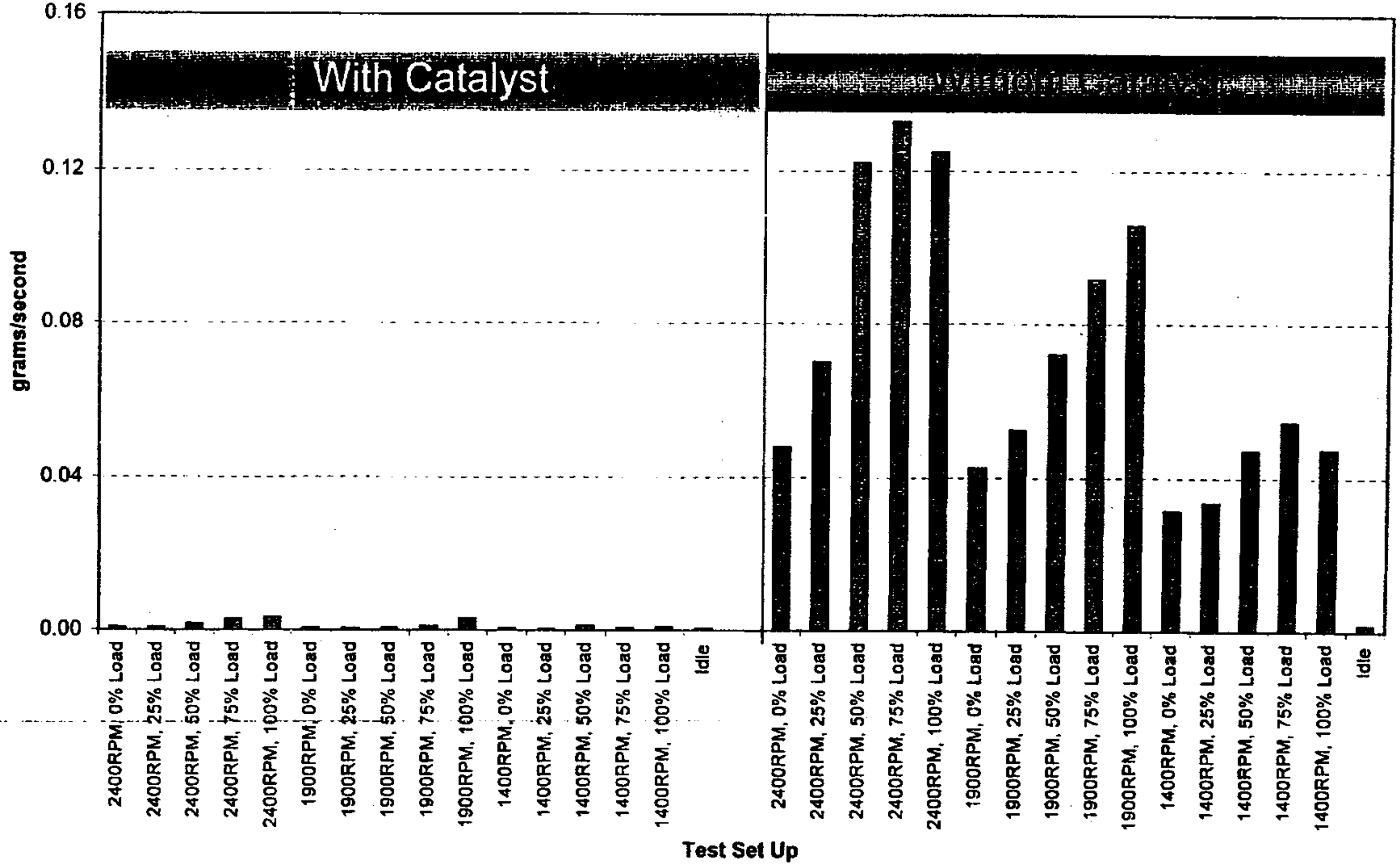


Figure 18 -- CO2 Emissions for Steady State Tests

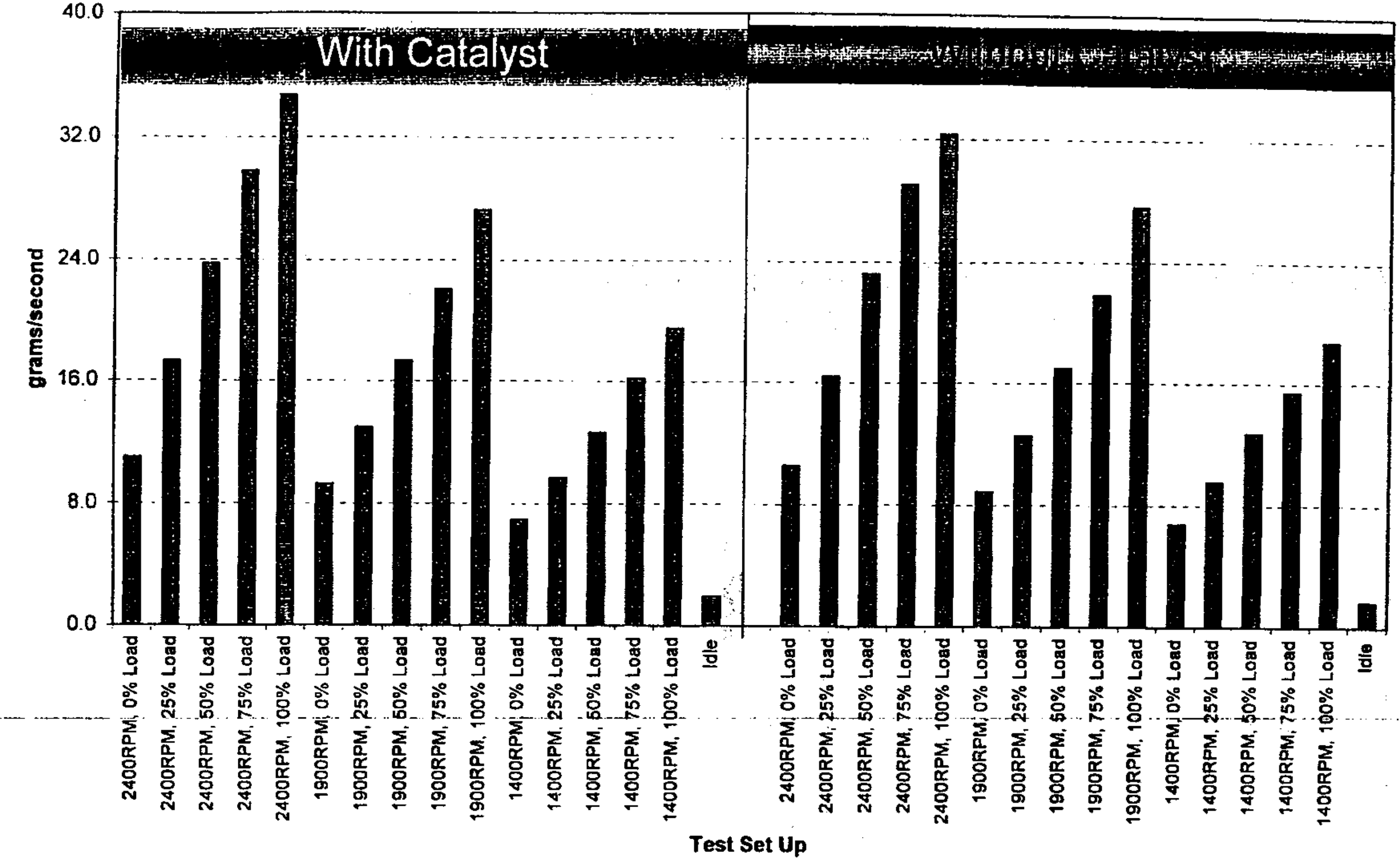
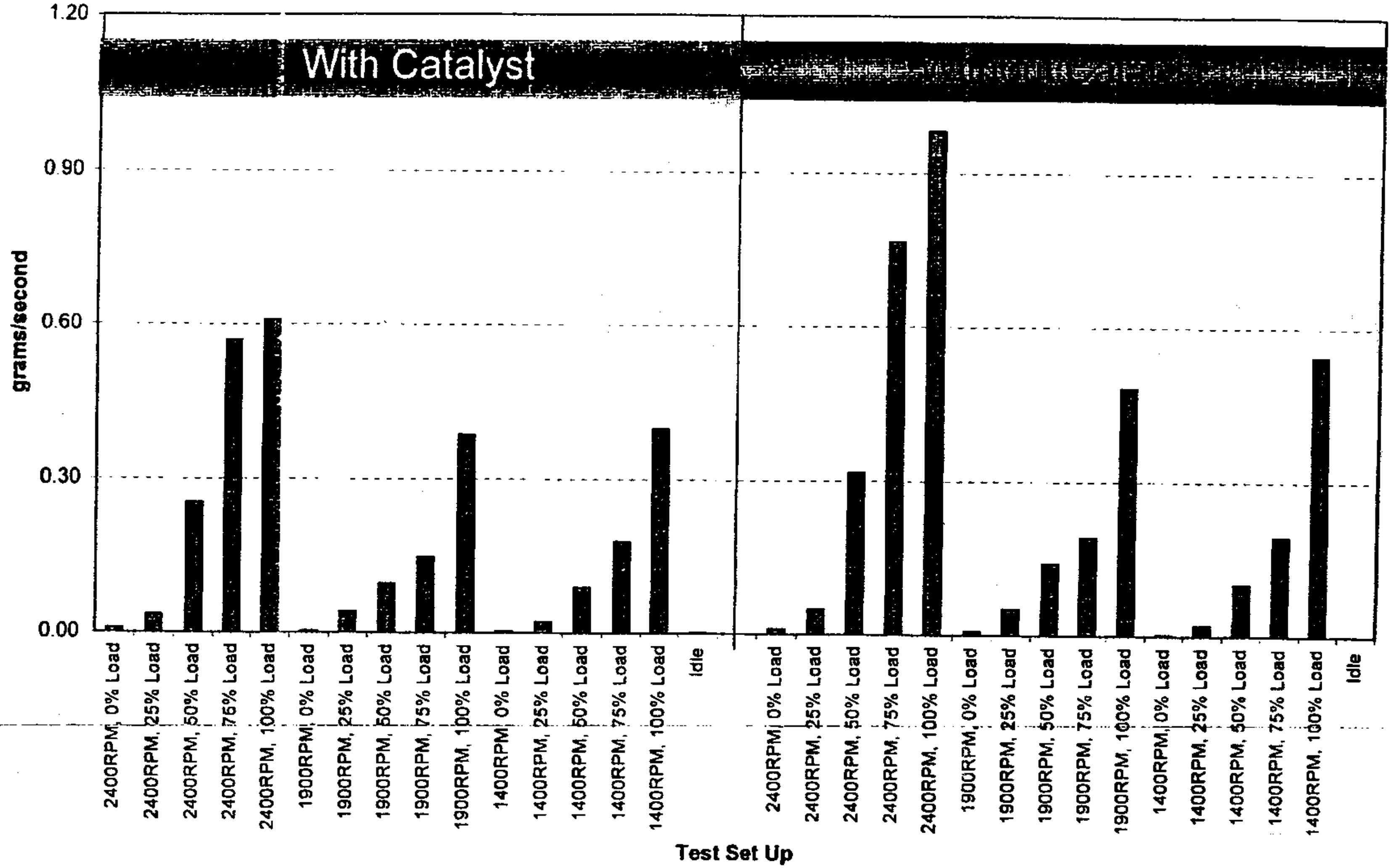


Figure 19 -- NOx Emissions for Steady State Tests



ady State Tests

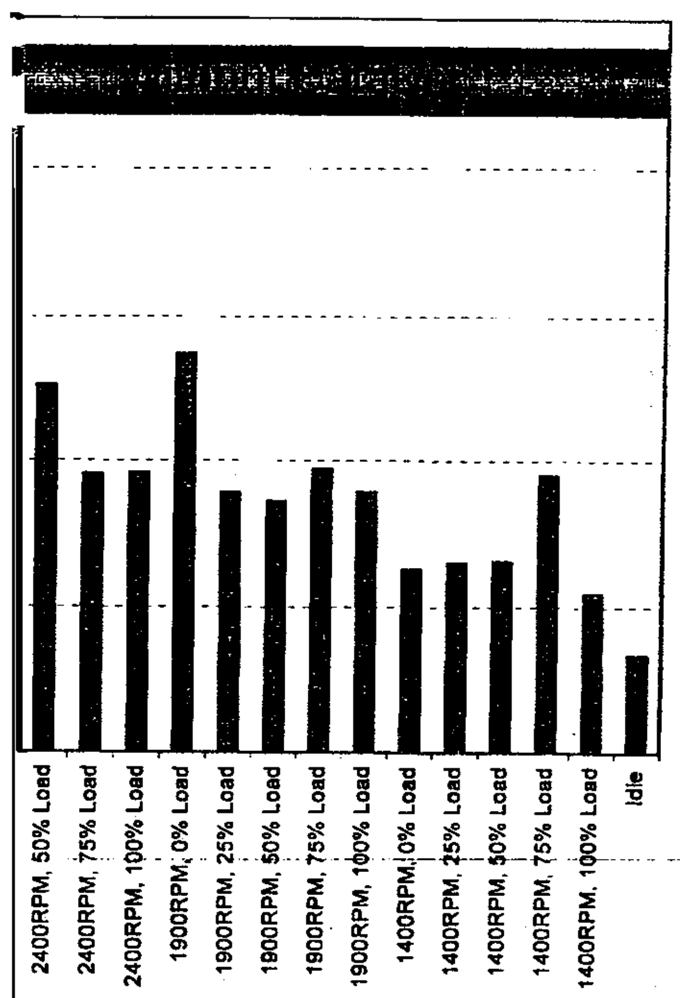


Figure 21 -- Continuous TEOM Samples

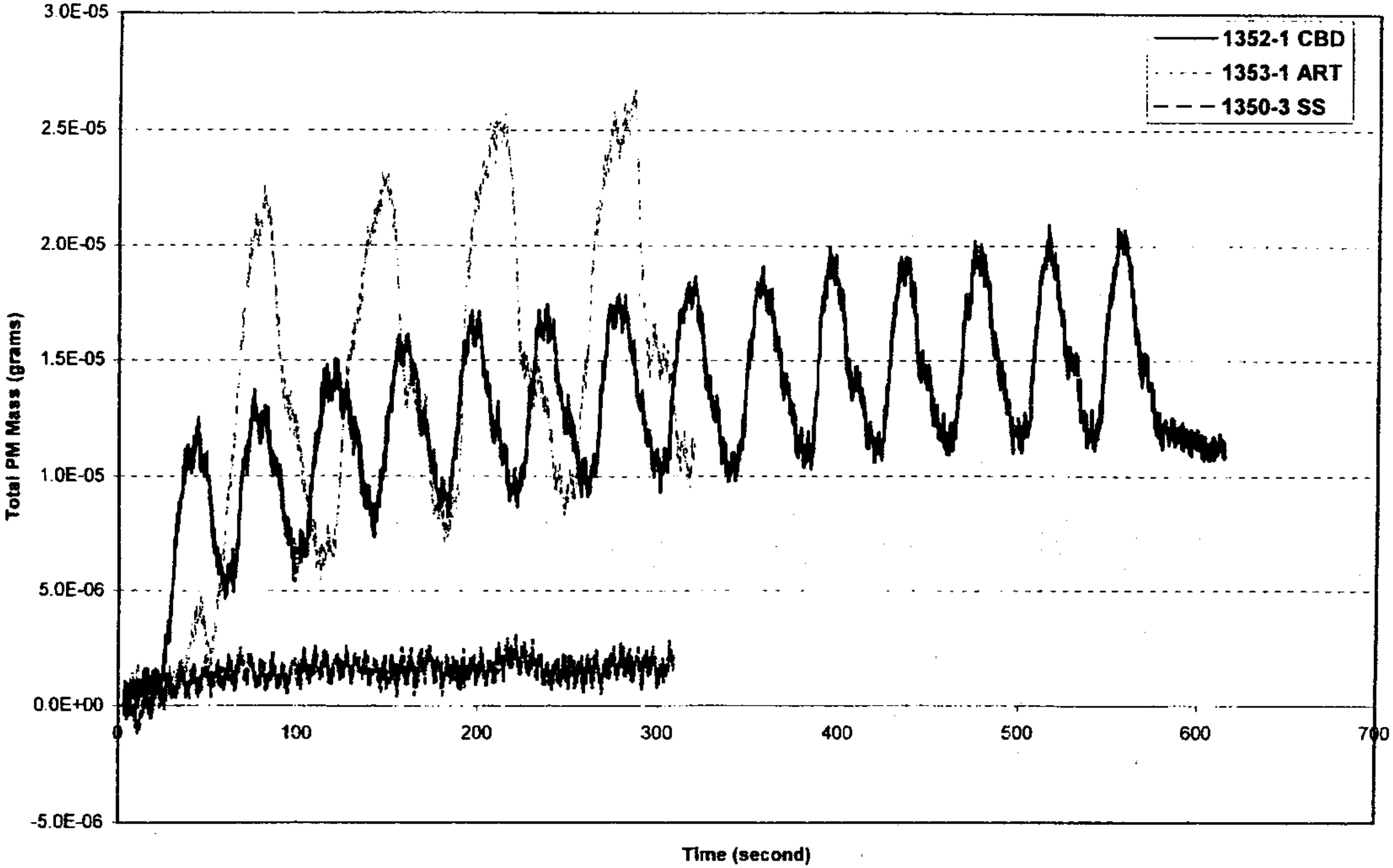


Figure 22 -- Bus Hesitated at the Beginning of the Cycle
(Test Number 1352-2, void)

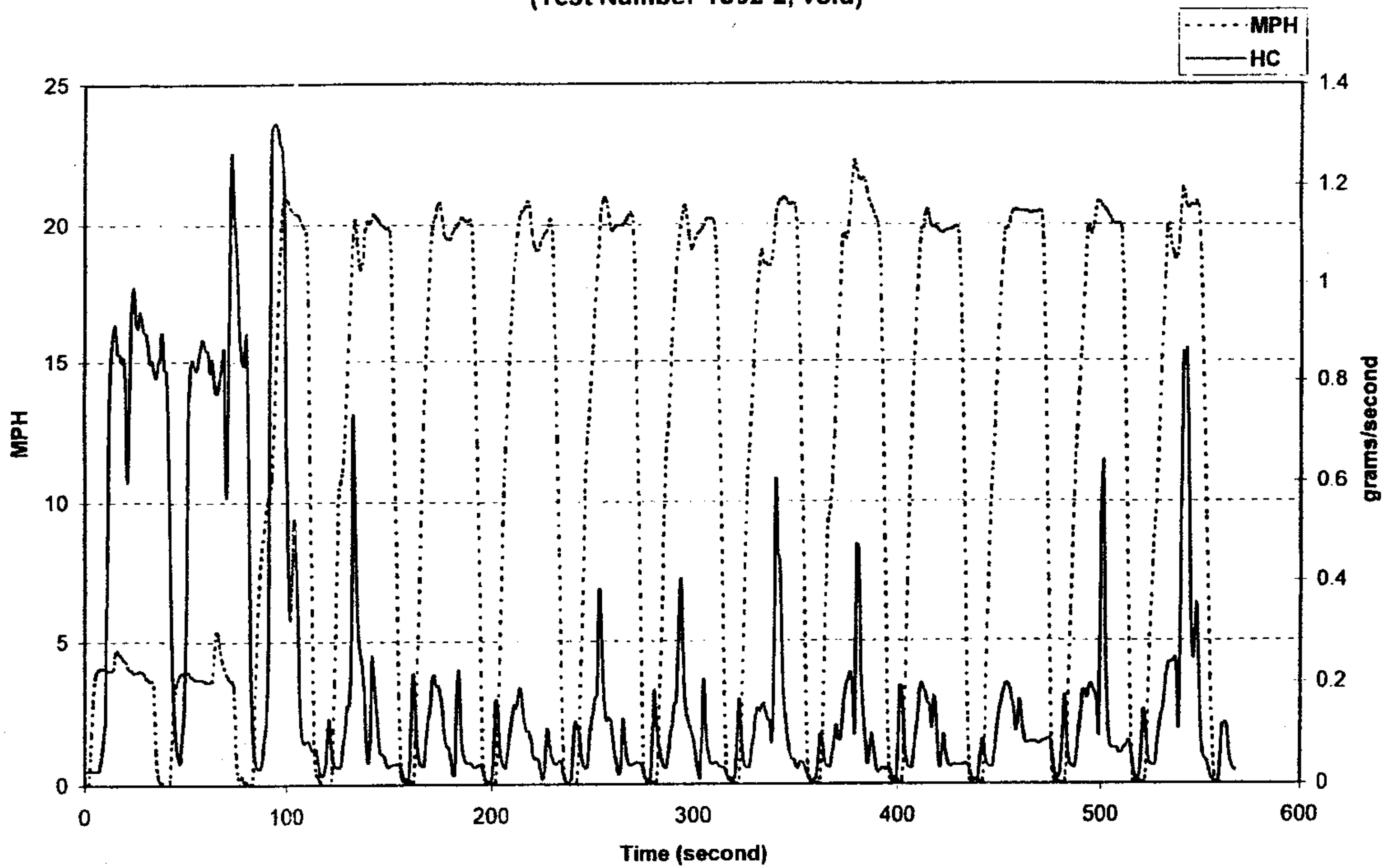


Figure 23 -- High NOx Mode Ramps in a CBD Cycle (Test Number 1340-1)

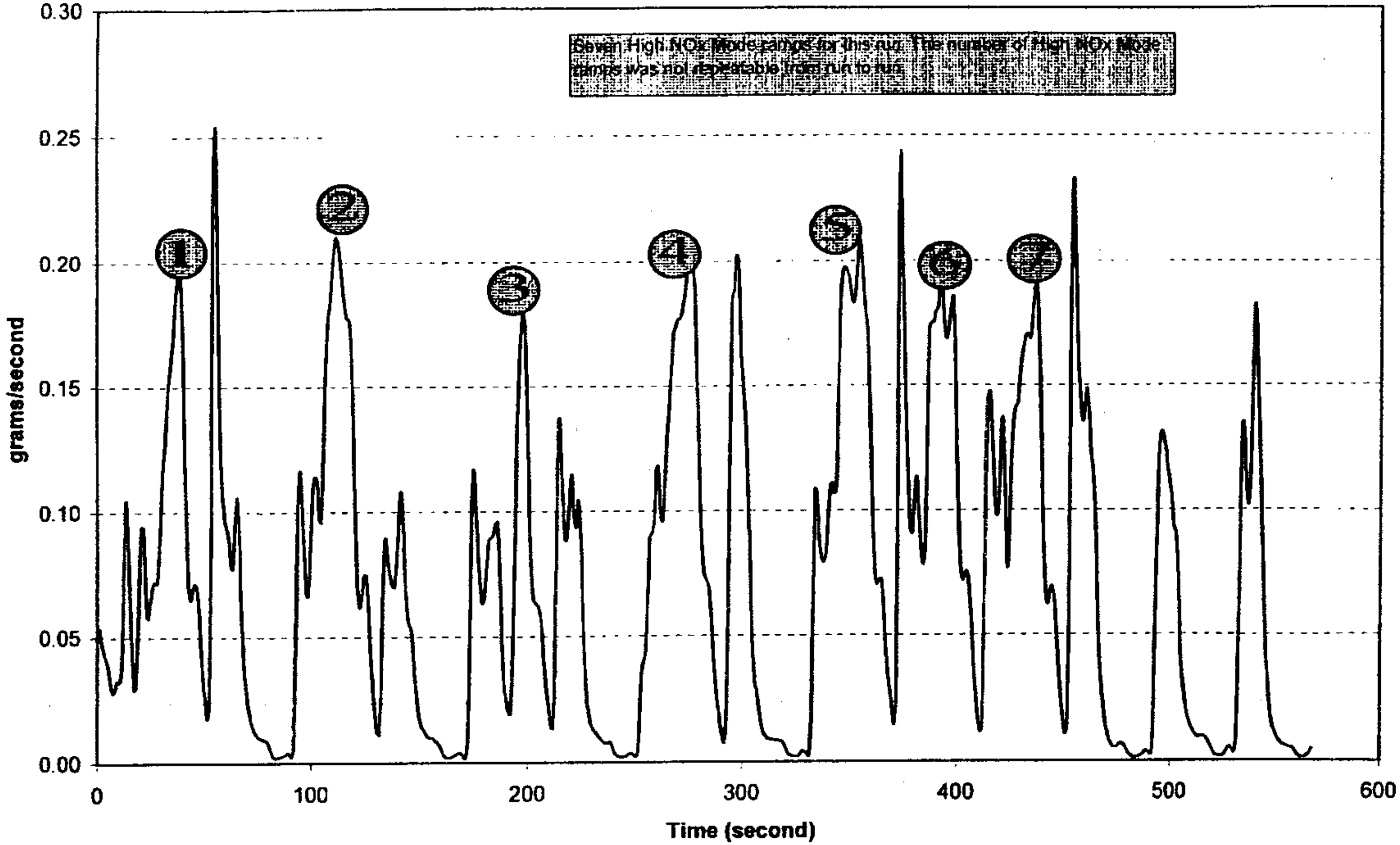


Figure 24 -- Actual Driving Speed vs. Time Sample Plot from the CBD Cycle

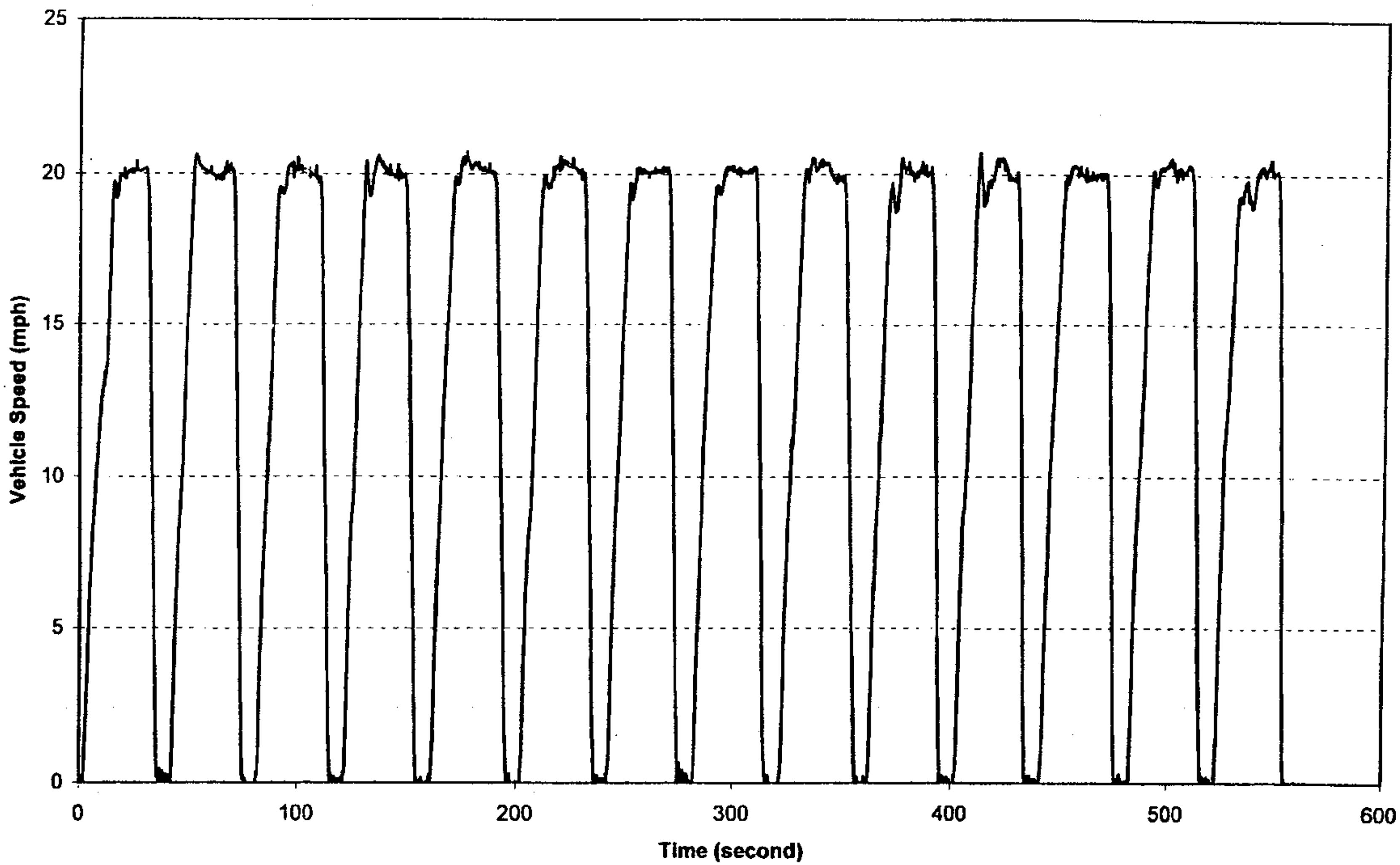
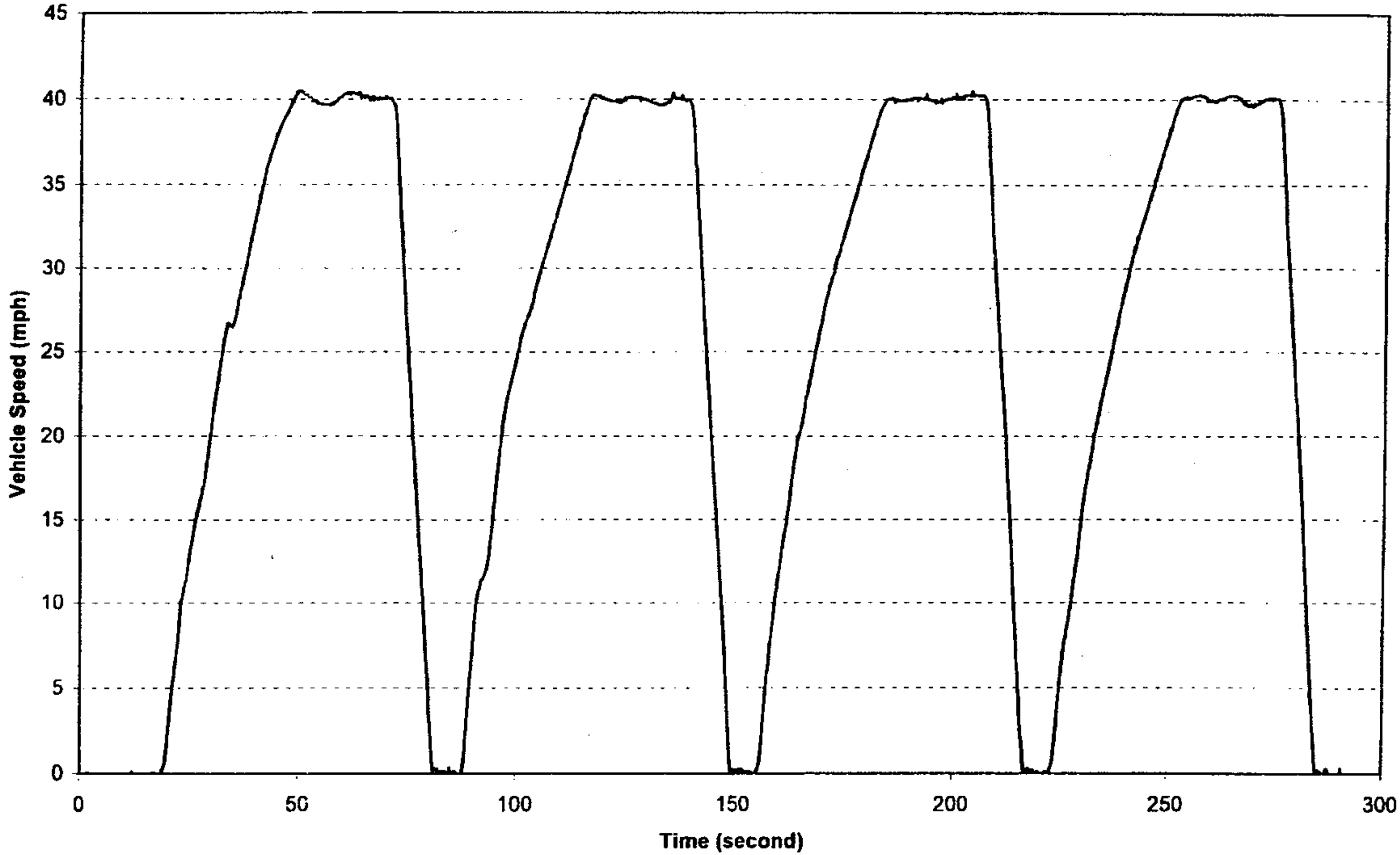


Figure 25 – Actual Driving Speed vs. Time Sample Plot from the ART Cycle



Test Sequence Number: 1336
WVU Test Reference Number: CI-EXP-CNG

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	30110
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Catalytic Converter Manufacturer	Donaldson
Test Cycle	CBD
Test Date	10/4/99
Engineer	W. Xie
Driver	G. England

Emissions Results (g/mile) — **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1336-1	1.46	*	7.63	7.0	0.02	0.071	2250	3.31	38868	2.04
1336-2	*	22.1	7.18	6.5	0.04	0.022	2272	3.27	39241	2.06
1336-3	1.41	18.5	8.16	7.4	0.06	0.024	2308	3.22	39884	2.05
1336-4	1.38	17.5	9.04	8.2	0.06	0.129	2212	3.36	38271	2.04
1336-5	1.56	21.8	8.49	7.8	0.02	0.022	2265	3.28	39156	2.04
1336-6	1.49	20.5	**	**	**	0.016	2366	3.14	40954	2.04
1336 Average	1.46	20.1	8.10	7.4	0.04	0.047	2279	3.26	39396	2.04
Std. Dev.	0.07	2.0	0.72	0.7	0.02	0.045	53	0.08	926	0.01
CV%	4.9	10.1	8.9	8.9	51.4	95.0	2.3	2.3	2.4	0.4

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the seated gross vehicle weight (GVW). Bus had a catalytic converter installed.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

* A value was measured and identified as an apparent outlier, and therefore is not reported and not used to compute other parameters or the average values.
** A value cannot be calculated because the parameters required for calculation are not available.

Test Sequence Number: 1337
WVU Test Reference Number: CI-EXP-CNG-ART

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	30110
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Catalytic Converter Manufacturer	Donaldson
Test Cycle	ART
Test Date	10/5/99
Engineer	W. Xie
Driver	G. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1337-1	0.70	21.5	**	**	**	0.039	1913	3.88	33134	2.03
1337-2	0.65	17.0	12.8	11.6	0.08	0.047	1938	3.81	33746	2.00
1337-3	0.99	12.8	11.0	10.0	0.02	0.043	1912	3.87	33233	2.00
1337-4	0.56	22.8	9.2	8.3	0.12	0.025	1877	3.95	32536	2.02
1337-5	0.69	15.1	8.0	7.3	0.07	0.032	1886	3.94	32648	2.02
1337-6	1.03	16.0	10.2	9.3	0.05	0.025	1947	3.80	33797	2.01
1337 Average	0.77	17.5	10.2	9.3	0.07	0.035	1912	3.87	33182	2.01
Std. Dev.	0.19	3.9	1.8	1.7	0.04	0.009	27	0.06	530	0.01
CV%	25.2	22.0	17.6	17.8	55.6	26.7	1.4	1.6	1.6	0.5

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the seated gross vehicle weight (GVW). Bus had a catalytic converter installed.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

** A value cannot be calculated because the parameters required for calculation are not available.

Test Sequence Number: 1339
WVU Test Reference Number: CI-EXP-CNG-ART-GVW

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	35210
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Catalytic Converter Manufacturer	Donaldson
Test Cycle	ART
Test Date	10/6/99
Engineer	W. Xie
Driver	G. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1339-2	0.99	19.2	11.3	10.3	0.04	0.042	2060	3.59	35769	2.04
1339-3	0.63	18.1	10.3	9.4	0.06	0.038	2040	3.63	35383	2.05
1339-4	0.17	19.1	9.7	8.9	0.04	0.039	2031	3.65	35191	2.02
1339-5	1.11	18.4	10.7	9.7	0.06	0.043	2102	3.52	36467	2.03
1339-6	0.45	17.9	8.7	7.9	0.07	0.034	2052	3.62	35502	2.07
1339 Average	0.67	18.5	10.1	9.2	0.05	0.039	2057	3.60	35662	2.04
Std. Dev.	0.39	0.6	1.0	0.9	0.01	0.003	27	0.05	496	0.02
CV%	57.8	3.2	9.8	9.9	26.0	8.2	1.3	1.4	1.4	1.0

Test Purpose:
Collect emission data on a Chemonics transit bus chasssis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the rated gross vehicle weight (GVW). Bus had a catalytic converter installed.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

Test Sequence Number: 1340
WVU Test Reference Number: CI-EXP-CNG-GVW

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	35210
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Catalytic Converter Manufacturer	Donaldson
Test Cycle	CBD
Test Date	10/7/99
Engineer	W. Xie
Driver	G. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1340-1	1.01	20.8	8.82	8.0	0.05	**	2554	2.91	44100	2.03
1340-2	1.73	27.0	8.28	7.5	0.06	0.003	2520	2.95	43521	2.02
1340-3	1.63	22.0	8.66	7.9	0.05	0.005	2508	2.97	43324	2.04
1340-4	2.13	23.7	9.34	8.5	0.06	0.023	2504	2.97	43313	2.05
1340-5	1.94	24.5	11.75	10.7	0.07	0.038	2554	2.90	44263	2.04
1340-6	0.92	15.2	9.68	8.8	0.05	0.021	2471	3.01	42727	2.05
1340 Average	1.56	22.2	9.42	8.6	0.06	0.018	2518	2.95	43541	2.04
Std. Dev.	0.49	4.0	1.24	1.1	0.01	0.014	32	0.04	565	0.01
CV%	31.6	18.2	13.2	13.3	16.1	79.0	1.3	1.3	1.3	0.5

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the rated gross vehicle weight (GVW). Bus had a catalytic converter installed.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

** A value cannot be calculated because the parameters required for calculation are not available.

Test Sequence Number: 1352
WVU Test Reference Number: CI-EXP-CNG-GVW-NOCAT

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	35210
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Test Cycle	CBD
Test Date	10/13/99
Engineer	J. Boyce
Driver	G. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1352-1	19.7	31.0	31.2	26.3	2.26	0.049	2371	3.02	42521	2.05
1352-4	18.3	26.8	24.8	20.8	1.88	0.018	2354	3.07	41904	2.06
1352-5	18.6	23.5	32.8	28.8	1.19	0.013	2341	3.06	42064	2.03
1352 Average	18.9	27.1	29.6	25.3	1.78	0.027	2355	3.05	42163	2.04
Std. Dev.	0.7	3.7	4.2	4.1	0.54	0.019	15	0.02	320	0.02
CV%	3.9	13.8	14.2	16.1	30.4	71.4	0.6	0.8	0.8	0.9

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the rated gross vehicle weight (GVW). The catalytic converter installed was bypassed before the test.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

Test Sequence Number: 1353
WVU Test Reference Number: CI-EXP-CNG-ART-GVW-NOCAT

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	35210
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds.
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Test Cycle	ART
Test Date	10/13/99
Engineer	J. Boyce
Driver	G. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1353-1	10.6	22.7	15.8	13.2	1.18	0.063	1974	3.70	34769	2.04
1353-2	11.5	36.6	13.8	12.0	0.61	0.054	1915	3.81	33703	2.04
1353-3	10.5	33.5	14.5	12.4	0.85	0.059	1926	3.79	33892	2.02
1353-4	11.6	25.2	**	**	**	0.064	1916	3.78	34030	2.01
1353 Average	11.0	29.5	14.7	12.5	0.88	0.060	1933	3.77	34098	2.03
Std. Dev.	0.6	6.6	1.0	0.6	0.29	0.005	28	0.05	467	0.02
CV%	5.0	22.3	6.9	5.0	33.0	7.8	1.4	1.4	1.4	0.9

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the rated gross vehicle weight (GVW). The catalytic converter installed was bypassed before the test.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

** A value cannot be calculated because the parameters required for calculation are not available.

Test Sequence Number: 1354
WVU Test Reference Number: CI-EXP-CNG-ART-NOCAT

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	30110
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Test Cycle	ART
Test Date	10/14/99
Engineer	W. Xie
Driver	C. Leasor

Emissions Results (g/mile) / **Fuel Economy**

Run Seq. No.	CO	NO_x	RDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1354-1	9.36	33.9	13.8	11.9	0.73	0.059	1826	4.00	32114	2.02
1354-2	9.74	34.8	14.6	12.8	0.57	0.047	1771	4.12	31228	2.02
1354-3	8.80	36.7	13.1	11.4	0.53	0.042	1771	4.13	31121	2.02
1354-4	9.07	38.0	13.2	11.4	0.69	0.052	1805	4.05	31717	2.03
1354 Average	9.24	35.8	13.7	11.9	0.63	0.050	1793	4.07	31545	2.02
Std. Dev.	0.40	1.9	0.7	0.7	0.09	0.007	27	0.06	459	0.01
CV%	4.4	5.2	5.2	5.6	15.0	14.3	1.5	1.5	1.5	0.3

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the seated gross vehicle weight (GVW). The catalytic converter installed was bypassed before the test.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.

Test Sequence Number: 1355
WVU Test Reference Number: CI-EXP-CNG-NOCAT

Fleet Owner Full Name	Chemonics International Inc.
Fleet Address	1133 20th St. NW, Suite 600
Fleet Address (City, State, Zip)	Washington, DC 20036
Vehicle Type	Chassis Bus
Vehicle ID Number (VIN)	Not Available
Vehicle Manufacturer	Thomas Built
Vehicle Model Year	1999
Gross Vehicle Weight (GVW) (lb.)	35210
Vehicle Total Curb Weight (lb.)	16455
Vehicle Tested Weight (lb.)	30110
Odometer Reading (mile)	11
Transmission Type	Automatic
Transmission Configuration	5-Speeds
Number of Axles	2
Engine Type	Cummins C8.3-250G
Engine ID Number	45884141
Engine Displacement (Liter)	8.3
Number of Cylinders	6
Engine Rated Power (hp)	250
Primary Fuel	CNG
Test Cycle	CBD
Test Date	10/14/99
Engineer	W. Xie
Driver	C. Leasor

Emissions Results (g/mile) **Fuel Economy**

Run Seq No	CO	NO_x	FIDHC	CH_4	NMHC	PM	CO_2	mile/gal	BTU/mile	Miles
1355-1	20.3	33.5	26.5	23.3	0.94	0.045	2283	3.15	40823	2.01
1355-4	19.0	34.9	24.4	21.4	0.90	0.050	2254	3.20	40196	2.02
1355-5	19.5	35.4	22.3	18.8	1.61	0.047	2211	3.26	39372	2.04
1355-6	20.4	35.6	24.2	20.4	1.72	0.048	2222	3.24	39675	2.03
1355 Average	19.8	34.9	24.3	21.0	1.29	0.048	2243	3.21	40016	2.02
Std. Dev.	0.7	0.9	1.7	1.9	0.43	0.002	33	0.05	636	0.01
CV%	3.3	2.7	7.0	8.9	33.4	4.2	1.5	1.6	1.6	0.7

Test Purpose:
Collect emission data on a Chemonics transit bus chassis operating on CNG fuel.

Special Procedures:
Flywheel was set up to simulate the seated gross vehicle weight (GVW). The catalytic converter installed was bypassed before the test.

Observations:
The bus engine hesitated for the first ramp, causing high hydrocarbon emissions.