AMERICAN BUS ASSOCIATION
Representing the motorcoach, tour and travel industry

6/14/2006

Dear Colleague:

It is my pleasure to share with you "Commercial Bus Emissions Characterization & Idle Reduction: Idle & Urban Cycle Test Results." Prepared by the American Bus Association, with financial support from the U.S. Federal Highway Administration and in consultation with the Department of Energy and the Environmental Protection Agency, this report summarizes the results of emissions and fuel use testing conducted on commercial buses while idling and also while driving in simulated low-speed urban traffic ("urban cycle").

Motorcoach operators currently face a patchwork of varying idling ordinances across the nation and limited parking opportunities. When faced with no real alternative, operators sometimes choose to circulate in traffic, for operational and comfort reasons affecting both the passengers and the driver. The impact of that decision is measured in this report. Motorcoaches reduce congestion by taking cars off the road and are an energy efficient means of travel. Measured as a whole, the net annual emissions of motorcoaches and transit buses combined produce significantly less pollutants (nitrogen oxides and particulate matter) when compared with gasoline cars and light trucks. And upcoming EPA mandated diesel engine emission standards, which the industry is working with engine manufacturers to implement insure that emissions standards for new engines will reduce bus emissions even further.

It is often necessary for motorcoaches to idle in order to maintain cabin temperature and to operate the vehicle systems that will provide "safe and adequate service, equipment and facilities" (such as wheelchair lifts, air brakes, etc.) as is required under Section 14101 (a) of 49 USC. However, in recent years idling by buses has come under scrutiny because of its potential negative effect on urban air quality creating a conflict between safe operations and pollutant reduction initiatives. Further, it's important to understand that motorcoach operators do not benefit from idling their vehicles considering not only the associated environmental impact but also the cost of fuel and wear on the engine. This report provides helpful information for planners and policymakers that recognize the environmental and congestion-mitigating benefits of motorcoach transportation but, at the same time, must find ways to reduce vehicle emissions and improve air quality. This report demonstrates the need for planners to be thinking in terms of facilitating motorcoach travel by providing places for these vehicles to park rather than imposing policies that discourage motorcoach travel.

Our industry understands the environmental implications of motorcoach idling and we want to work towards solutions. It’s the industry’s intention to continue the dialog with state and local decision makers to find those solutions.
The sponsors of this report have produced this document as a first step which will be followed by a deeper look into the issue through meetings with federal, state and local officials and industry in the months ahead. Any input or questions are welcome and can be directed to the American Bus Association at 1-800-283-2877.

Sincerely,

Peter J. Pantuso
President and CEO

Commercial Bus
Emissions Characterization & Idle Reduction

Idle & Urban Cycle Test Results

June 14, 2006

Prepared for the:

American Bus Association

U.S. Department of Energy

U.S. Environmental Protection Agency

U.S. Federal Highway Administration

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Acknowledgements

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The authors would like to acknowledge the Federal Highway Administration, the Environmental Protection Agency, the Department of Energy and the American Bus Association for their contributions to this report as well as FHWA and ABA for their financial support, which made this testing possible.

Executive Summary

This report summarizes the results of emissions testing conducted on six motor coaches with engines between model years 1997 and 2004. Each bus was tested while idling and also while driving in simulated low-speed urban traffic. For both idle and urban driving each bus was also tested with and without the air conditioning system on[1].

The intent of this test program was to evaluate the potential effects of idle restriction polices on coach buses, particularly when coaches are forced to circulate in urban traffic to maintain appropriate cabin temperatures if restricted from idling and unable to park. While it would be preferred for motorcoaches to park when waiting for passengers to return from an excursion, a lack of dedicated motorcoach parking and driver facilities often forces motorcoach drivers to keep the vehicle running in order to maintain cabin temperature comfort.

The major findings of this testing include:

Emissions

- All of the tested buses emitted significantly more NO_x when driving in simulated urban traffic than when idling with the bus stationary. For older coaches NO_x doubled – increasing by 200 grams/hour (g/hr) on average when driving compared to idling. For newer coaches the increase in NO_x emissions from urban driving compared to stationary idling was 40%.
- If a coach bus is forced to circulate in traffic to maintain appropriate cabin temperatures, rather than idling while stationary, it will emit up to 22 pounds of excess NO_x emissions annually for only one hour per day of circulating. For older coaches, NO_x emissions from one hour of circulating are equivalent to NO_x emissions from two hours of stationary idling.
- NO_x emissions generally increased when the air conditioning was on compared to when it was not on. In this test program the increase was less during urban driving than while idling, but the relatively low ambient temperatures during the testing mean that the results are probably not fully reflective of actual summer results in many parts of the country.
- For both idling and urban driving, as well as with and without air conditioning, the two newest buses (2004 engines) produced significantly less NO_x than the four older buses. This is consistent with more stringent EPA emissions standards for the engines in these buses compared to the engines in the older buses.

Fuel Use

- All of the tested buses used significantly more fuel when driving in simulated urban

[1] Testing was conducted on an out-door track during times of relatively cool ambient temperature. For that reason the results with air conditioning on are not fully reflective of true summer conditions in most parts of the country. Increases in fuel use and emissions with air conditioning as compared to without air conditioning should be considered minimum values, and are illustrative only.

traffic than when idling with the bus stationary. For all buses fuel use at least doubled when driving compared to idling – increasing by 1 gallon per hour or more.

- If a coach bus is forced to circulate in traffic to maintain appropriate cabin temperatures, rather than idling while stationary, it will use up to 375 gallons more fuel in a year for only one hour per day of circulating.
- For all buses fuel use increased when the air conditioning was on compared to when it was not on, both when idling and when driving. In this test program the increase was less during urban driving than while idling, but the relatively low ambient temperatures during the testing mean that the results are probably not fully reflective of actual summer results in many parts of the country.
- For both idling and urban driving, as well as with and without air conditioning, the two newest buses (2004 engines) generally used less fuel than the four older buses. These buses were equipped with engines from a different manufacturer. It is not clear whether the difference in fuel use between older and newer coaches seen in this test program applies generally, or is a function of the specific engines tested.

		Older Coaches		New Coaches	
		NO_X	Fuel Use	NO_X	Fuel Use
		g/hr	gal/hr	g/hr	gal/hr
Idling	No AC	238	0.95	116	0.64
	AC on[1]	360	1.32	160	1.00
Urban Cycle	No AC	444	2.47	156	1.59
	AC on[1]	415	2.57	194	1.79

Table 1 Average Results – NO_X Emissions and Fuel Use

Background – Coach Bus Operations

The motor coach industry is relatively small – it is estimated that in 2005 there were approximately 38,000 motor coaches operating in the US and Canada[2]. By comparison the total number of Class 8 trucks operating on US highways in 2002 was over 2 million[3]. The US Department of Energy (USDOE) estimates that in 2002 intercity buses accounted for approximately 0.2% of highway vehicle-miles traveled and 0.1% of transportation energy use, compared to 4.9% of highway miles traveled for combination trucks, and 17% of transportation energy use for all medium/heavy trucks[4].

Coach buses are a very energy efficient means of travel. USDOE estimates that in 2000

[2] American Bus Association

[3] U.S. Census Bureau, *2002 Economic Census, Vehicle Inventory and Use Survey*, December 2004.

[4] U.S. Department of Energy, *Transportation Energy Data Book, Edition 24*, December 2004, Tables 2.4 and 3.5

the average energy use for intercity buses was 932 btu per passenger mile – compared to 3,611 btu per passenger mile for private automobiles and 4,515 btu per passenger mile for transit buses[5].

Coach buses are universally powered by diesel engines. All diesels, in buses as well as in highway trucks and nonroad equipment, contribute to the inventory of criteria pollutants all over the country, particularly nitrogen oxides (NO_X) and particulate matter (PM). EPA's 2002 National Emissions Inventory indicates that gasoline cars and light trucks produced over 44,000 tons of PM and almost 3.8 million tons of NO_X in that year, while heavy-duty diesel trucks produced over 87,000 tons of PM and 3.7 million tons of NO_X. By contrast heavy-duty diesel buses (including coaches and transit buses) produced only 7,400 tons of PM and 130,000 tons of NO_X.[6]

Current and future emissions standards for new diesel engines will dramatically reduce these emissions from the diesel fleet, including buses, in the near future. Allowable NO_x and PM levels from new buses sold in 1998 were 63% and 83% less, respectively, than the levels from buses sold ten years earlier[7]. New rules that will go into full effect in the 2010 model year will reduce allowable NO_x and PM by a further 90% or more[8]. The US Environmental Protection Agency estimates that based on normal fleet turnover total NO_x and PM emissions from onroad trucks and buses will fall by 77% and 84%, respectively, through 2020 -despite a 40% increase in vehicle miles traveled between now and then[9].

In recent years idling by buses and other urban vehicles has come under scrutiny because of its potential negative effect on urban air quality. Many cities have imposed blanket restrictions on idling of buses and trucks. There is no comprehensive data on idling behavior of coach buses. More is known, however, about idling by sleeper cab-equipped combination trucks. Operators of these trucks often rest in the sleeper cab for 8-10 hours per day, either at a truck stop or at a rest area along the highway. Often they keep the truck's main engine idling to provide heat/air conditioning and electrical power to the sleeper cab. Section 14101 (a) of title 49 of the United States code of law requires that motor carriers of passengers licensed to operate in interstate commerce must provide "safe and adequate service, equipment, and facilities." To meet this service standard, it is often necessary for a motorcoach to idle in order to pump up the motorcoach air pressure systems to ensure brake performance as required by 49 CFR 393.52; utilize Americans with Disabilities Act mandated wheelchair lifts; and operate the heating or air conditioning system to warm up or cool down the interior of the motorcoach.

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[5] Ibid, Table 2.12

[6] U.S. Environmental Protection Agency, *Final 2002 National Emissions Inventory*; from EPA Technology Transfer Network website, February 23, 2006. < http://www.epa.gov/ttn/chief/net/2002inventory.html>

[7] U.S. Environmental Protection Agency, *Emission Standards Reference Guide for Heavy Duty and Nonroad Engines*, EPA420-F-97-014, September, 1997

[8] U.S. Environmental Protection Agency, *Control of Air Pollution for New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements; Final Rule*, Federal Register, 66(12):5002. January 18, 2001

[9] U.S. Environmental Protection Agency, *Regulatory Impact Analysis Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*, EPA420-R-00-026, December, 2000

The combination of large numbers of trucks with daily long duration idling means that idling of trucks results in significantly more emissions and fuel use than idling of coach buses. The US Department of Energy estimates that idling heavy-duty trucks consume up to 840 million gallons of diesel fuel annually[10] in the US. This is 60% more fuel than was used by the entire motor coach industry in 2004[11].

Test Program

Test Buses

This study focused on the exhaust emissions from commercial buses used primarily for scheduled intercity, charter, tour/sightseeing, and private/contract commuter services. Vehicles in this 'motor coach' fleet are designed for long-distance travel, and are characterized by "integral construction with an elevated passenger deck located over a baggage compartment"[12].

GROUP	Engine Year	USEPA Emission Standards (g/bhp-hr)		% of Fleet
		PM	NO_X	
1	Pre 1990	0.6	6.0	0 - 5%
2	1991 – 1993	0.25	5.0	10 – 15%
3a	1994 – 1997	0.1	5.0	50 – 65%
3b	1998 – 2002	0.1	4.0	
4	2003 +	0.1	2.5	20 – 30%

Table 2 Current Motor coach Fleet

Vehicles in the US motor coach fleet are fairly uniform in terms of vehicle size and configuration, as well as engine type and size. The latest census of motor coach operators indicates that 60% of motor coaches are 40-feet long, 10% are 45-feet long, and 30% are between 35-feet and 40-feet.[13]

In terms of this study, the most important difference between different motor coaches is the engines' year of manufacture, since EPA emissions standards for diesel engines have changed dramatically in the last 20 years. Table 2 organizes the current motor coach fleet into five groups based on EPA emissions standards for NO_X and PM. Also shown is an estimate of the percentage of the current motor coach fleet that falls into each group[14].

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[10] U.S. Department of Energy, Energy Efficiency & Renewable Energy, *Idle Reduction Technologies for Heavy Duty Trucks, Technology Introduction Plan,* May 13, 2004

[11] American Bus Association

[12] American Bus Association

[13] American Bus Association, United Motor Coach Association, METRO Magazine

[14] Good data on the fleet composition is not available. These estimates are based on a fleet turn-over model created with input from the American Bus Association. Major assumptions include average age at replacement of 6-10 years for large fleets (25+ buses) and 10-15 years for small fleets (<25 buses). Large

Six buses were tested in this program, including two each from groups 3a, 3b, and 4 as noted in Table 1. Buses from groups 1 and 2 were not tested because they make up such a small percentage of the current fleet and many are likely to be retired within the next five years.

Details of the tested buses are shown in Table 3.

Number	Group	Motor coach		Engine		
		Make	Model	Year	Make	Model
1	3b	MCI	102-EL3	1999	DDC	S60
2	3a	MCI	102-DL3	1997	DDC	S60
3	3b	MCI	G4500	2001	DDC	S60
4	4	VanHool	Lier 1200	2004	CAT	C13
5	4	VanHool	C2045	2004	CAT	C13
6	3a	MCI	102-DL3	1997	DDC	S60

Table 3 Tested Buses

Test Plan

This project evaluated exhaust emissions of carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x) and hydrocarbons (HC) from coach buses while idling, as well as while operating over a slow speed stop-and-go test cycle designed to mimic a bus circulating in urban traffic. Coach fuel use was also measured. For both idling and the urban drive cycle, emissions and fuel use were also evaluated in simulated cold weather (no air conditioning) and warm weather (air conditioning on) conditions. On a coach bus air conditioning for the passenger cabin can add significant load to the engine, and is expected to affect both fuel use and emissions.

Since the testing took place in January in relatively cool weather it was not possible to test with the air conditioning system fully loaded as it would be when ambient temperatures are high. For idling tests, air conditioning was simulated by turning on the coach's "high idle" feature (boosting idle engine speed from 600- 700 rpm to 900-1000 rpm). This is consistent with the operating policies of most coach operators, and provides a reasonable minimum approximation of conditions in which the air conditioning compressor is periodically cycled on and off, as it would be when idling during the

fleets tend to replace old buses with new, while small fleets tend to purchase used buses from the larger fleets. Small fleets operate approximately 37% of motor coaches.

summer. During the urban driving tests the coach's cabin air conditioing system was turned on. Given the relatively low ambient temperatures it is likely that this simulation significantly under-estimated the true effect of air conditioning while circulating in traffic during summer conditions in many parts of the country.

For each test condition (idle no air conditioning; idle with air conditioning; urban cycle no air conditioning; urban cycle with air conditioning) data was collected from three 1,200-second (20 minute) repeat runs for each bus. Both the idle testing and urban cycle testing were conducted with the bus engine at normal operating temperature; no cold-start testing was conducted.

An example of the urban drive cycle used for this test program is shown in Figure 1. For this test, stops were laid out along a straight track every 0.1-mile. The bus operator accelerated away from a stop until he reached 20 miles per hour and maintained that speed until braking into the next stop, where he dwelled for 20 seconds before repeating for the remainder of the course. This test cycle proved to be very repeatable in practice. The average speed over the urban drive cycle varied between 5.9 and 7.1 mph for all runs for all buses. Percentage of idle during the urban cycle varied between 38.4% and 47.0% for all runs. For all buses the coefficient of variance[15] of average speed between the three repeat runs was less than 5.5%.

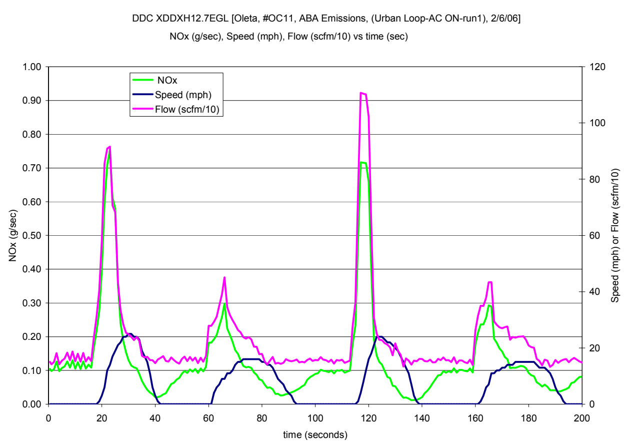

Figure 1 Urban drive cycle (typical)

For all buses and all test conditions CO_2 and NO_x emissions, and fuel use, were generally consistent from run to run, with a coefficient of variance of less than 10%. Both 1997 buses had a slightly higher variance in CO_2 emissions and fuel use from run to run during idle testing. Five of the buses had higher variance in NO_x emissions from run to run during one of four test conditions but not the others.

CO emissions were slightly more variable from run to run, and HC emissions were significantly more variable from all buses. The coefficient of variance of HC emissions from run to run was higher than 10% for virtually all buses in all test conditions and as high as 160% in some cases. Despite this variability, CO and HC emissions were generally low from all buses in all test conditions, as expected from diesel vehicles.

Data tables for all buses and all runs are included at Appendix A. For more details on the test program see DTC Test record No: SL-52-05, U.S. Army Aberdeen Test Center.

[15] Coefficient of variance = standard deviation / average

Emissions Test Results

The results of this test program for NO_X emissions are discussed below. All values shown for each bus are averages of the three repeat runs collected.

All of the tested buses had much higher NO_x emissions (g/hr) when driving on the urban drive cycle than when idling.

The use of the air conditioning system increased NO_x emissions for all of the tested buses when idling, and for half of the tested buses driving on the urban drive cycle, as compared to NO_x emissions without the air conditioning system on.

For each of the conditions tested (idle no AC, idle AC on, urban cycle no AC, urban cycle AC on) NO_x emissions were much lower for the two newest buses (2004 engines) than for the four older buses. This is consistent with more stringent EPA emissions standards for these engines than for the engines in the older buses.

Idle Emissions

NO_X emission rates for each tested bus while idling are shown in Figure 2, in the form of grams of emissions per hour of idling (g/hr).

As shown, NO_X emissions while idling on low idle without the air conditioning system on varied between 111 g/hr and 329 g/hr from the tested buses. The bus with the 1999 engine had the highest NO_X emissions, while the other three older buses emitted similar levels of NO_X. The two newest buses (2004 engines) emitted approximately 50% less NO_X than the older buses.

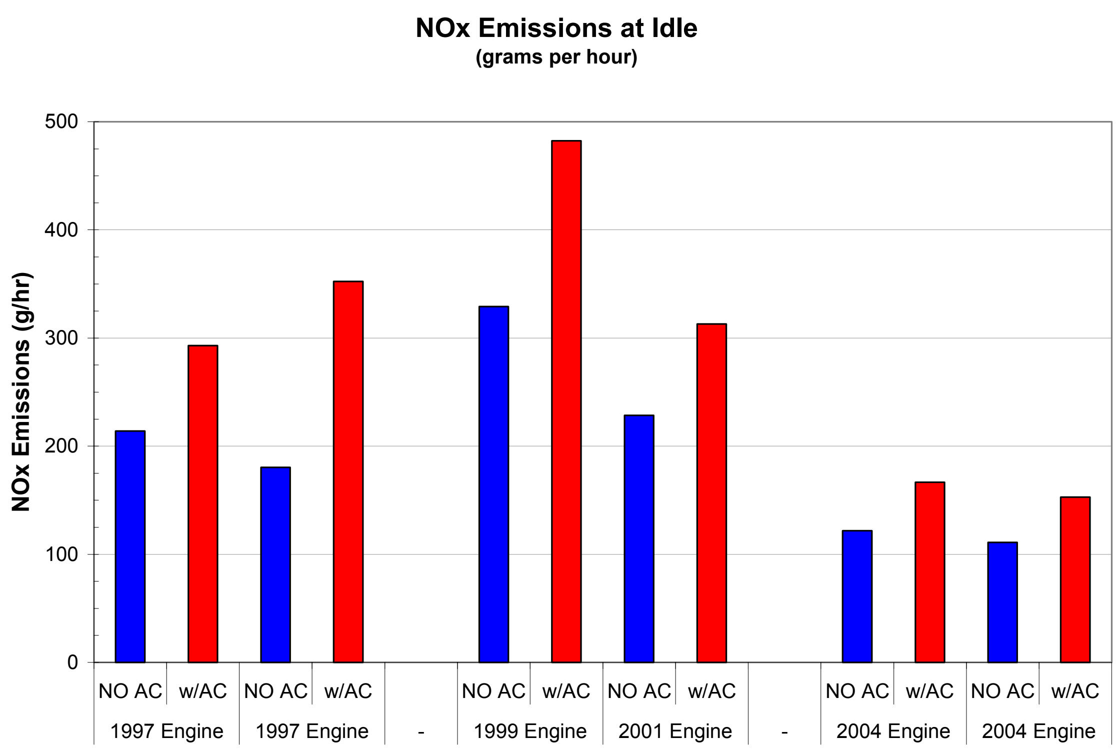

Figure 2

NO_x emissions while idling on high idle to simulate the air conditioning system being on varied between 152 g/hr and 482 g/hr from the tested buses. The bus with the 1999 engine had the highest NO_x emissions on high idle while the other three older buses emitted similar levels of NO_x on high idle. The two newest buses produced approximately 50% less NO_x on high idle than the older buses.

In all cases NO_x emissions increased with the engine on high idle compared to low idle. For most buses NO_x emissions increased by 36-46% on high idle; for one of the oldest buses NO_x emissions increased by 95%.

Urban Drive Cycle Emissions

NO_x emission rates for each tested bus while driving on the urban drive cycle are shown in Figure 3, in the form of grams of emissions per hour of driving (g/hr).

As shown, NO_x emissions while driving on the urban cycle without the air conditioning system on varied between 143 g/hr and 525 g/hr from the tested buses. The bus with the 1999 engine had the highest NO_x emissions; one bus with a 1997 engine had NO_x emissions similar to the bus with the 2001 engine, while NO_x emissions from the other 1997 engine bus were a bit lower.

The two newest buses emitted approximately 60% less NO_x on the urban cycle without air conditioning than the older buses did.

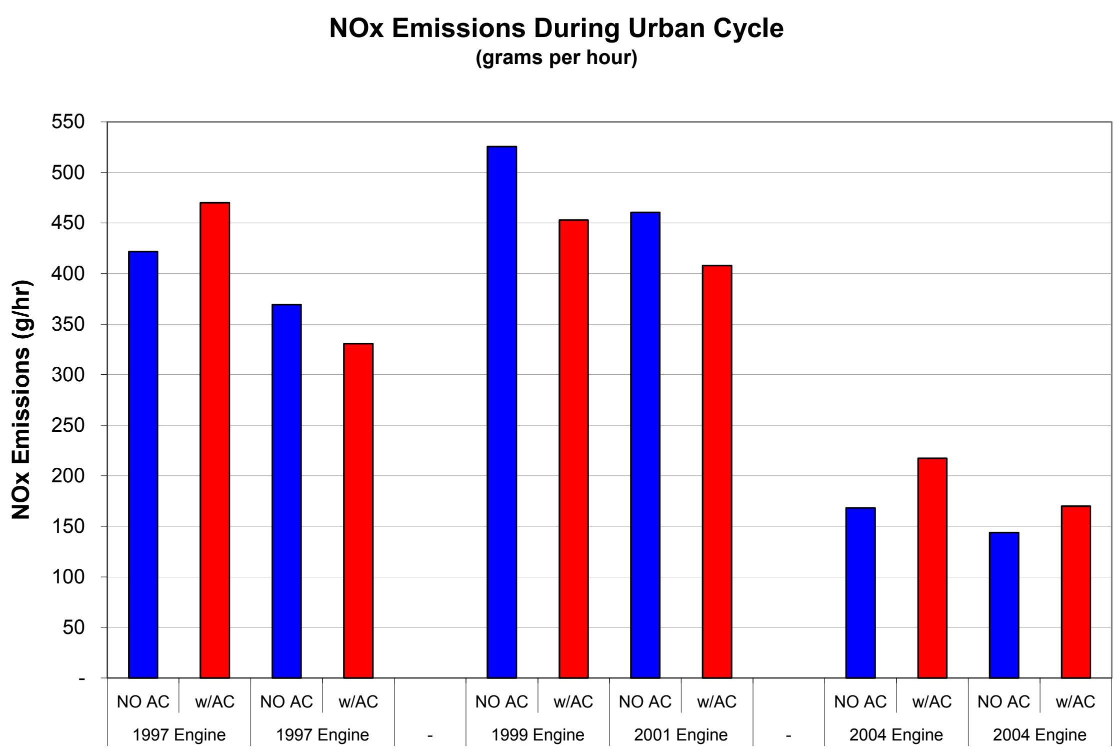

Figure 3

NO_X emissions while driving on the urban cycle with the air conditioning system on varied between 169 g/hr and 470 g/hr from the tested buses. Three of the four older buses emitted similar levels of NO_x on the urban cycle with the AC on, while the fourth (1997 engine) emitted less.

The two newest buses produced approximately 50% less NO_X on the urban cycle with the air conditioning system on than the older buses did.

For three of the six buses NO_x emissions were higher while driving on the urban drive cycle with the air conditioning system on than they were when driving on the urban drive cycle with the air conditioning system off. For the other three buses NO_x emissions were slightly lower with the AC system on. Given the low ambient temperatures during data collection, the actual level of NO_x emissions that would be experienced during the summer in many parts of the country while driving in urban traffic with the air conditioning system on are likely to be higher than those recorded in this test program.

Fuel Use Test Results

The results of this test program for coach fuel use are discussed below. All values shown for each bus are averages of the three repeat runs collected.

All of the tested buses had much higher fuel use (gal/hr) when driving on the urban drive cycle than when idling.

The use of the air conditioning system increased fuel use for all of the tested buses both when idling and when driving on the urban drive cycle, as compared to fuel use without the air conditioning system on. For all buses the increase in fuel use with AC on was much higher when idling than when driving on the urban drive cycle.

For each of the conditions tested (idle no AC, idle AC on, urban cycle no AC, urban cycle AC on) fuel use was lower for the two newest buses (2004 engines) than for three of the four older buses. These buses were equipped with engines from a different manufacturer. It is not clear whether the difference in fuel use between older and newer coaches seen in this test program applies generally, or is a function of the specific engines tested.

Idle Fuel Use

Fuel use rates for each tested bus while idling are shown in Figure 4, in the form of gallons of fuel used per hour of idling (gal/hr).

As shown, fuel use while idling on low idle without the air conditioning system on varied between 0.62 gal/hr and 1.28 gal/hr from the tested buses. The bus with the 1999 engine used the most fuel; one of the buses with a 1997 engine and the two buses with 2004 engines used only about half as much fuel, while fuel use by the other two buses (1997 engine and 2001 engine) fell between these extremes.

For all buses fuel use increased when operated on high idle with the air conditioning system on as compared to low idle without the AC system on. For the four older buses fuel use increased by 30-40%, while the increase was 50-60% for the two newest buses. Despite the larger percentage increase, fuel use on high idle was still lower for the two newest buses than for three out of four of the older buses.

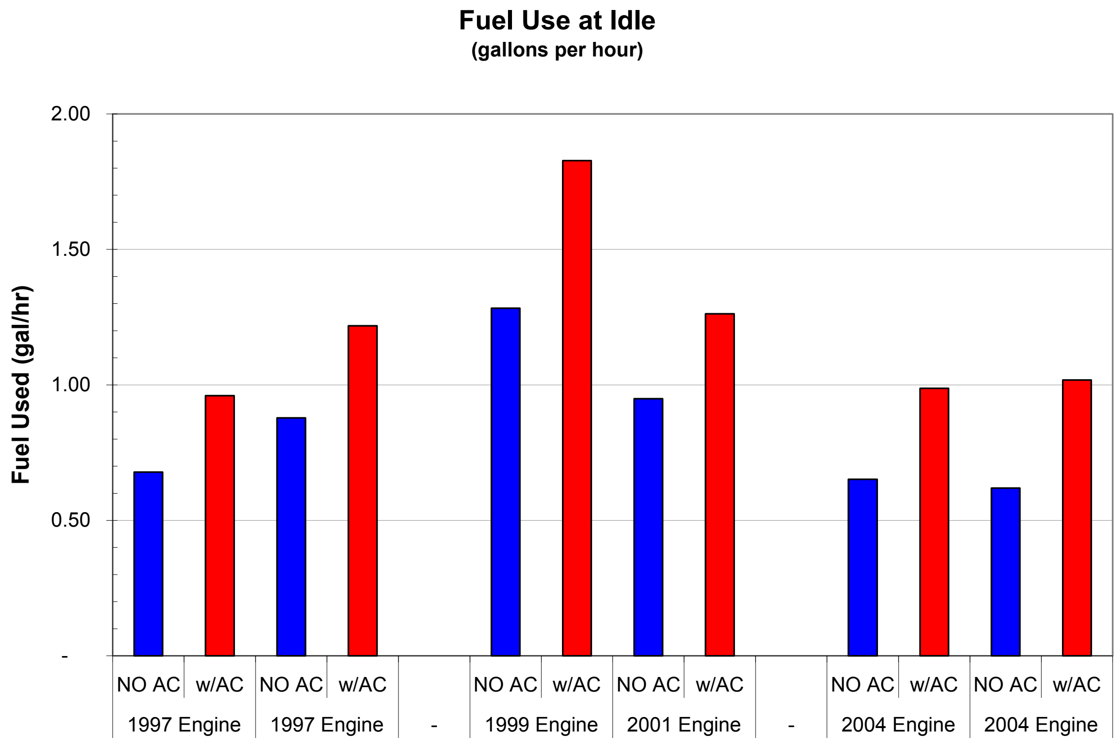

Figure 4

Urban Drive Cycle Fuel Use

Fuel use rates for each tested bus while driving on the urban drive cycle are shown in Figure 5, in the form of gallons of fuel used per hour of driving (gal/hr).

As shown, fuel use while driving on the urban drive cycle without the air conditioning system on varied between 1.57 gal/hr and 3.79 gal/hr from the tested buses. The bus with the 1999 engine used almost twice as much fuel as the other three older buses. The two newest buses (2004 engines) used about 20% less fuel than these three older buses.

For all buses fuel use increased slightly when driven on the urban drive cycle with the air conditioning system on compared to driving without the AC system on. This likely indicates that the air conditioning system did put additional load on the engine during these runs. However, the increase in fuel use was less than 10% for the older buses and less than 15% for the newer buses – less than a third of the increase in fuel use seen from simulated air conditioning use on idling buses.

Given the low ambient temperatures during data collection, the actual fuel use that would be experienced during the summer in many parts of the country while driving in urban traffic with the air conditioning system on are likely to be higher than those recorded in this test program.

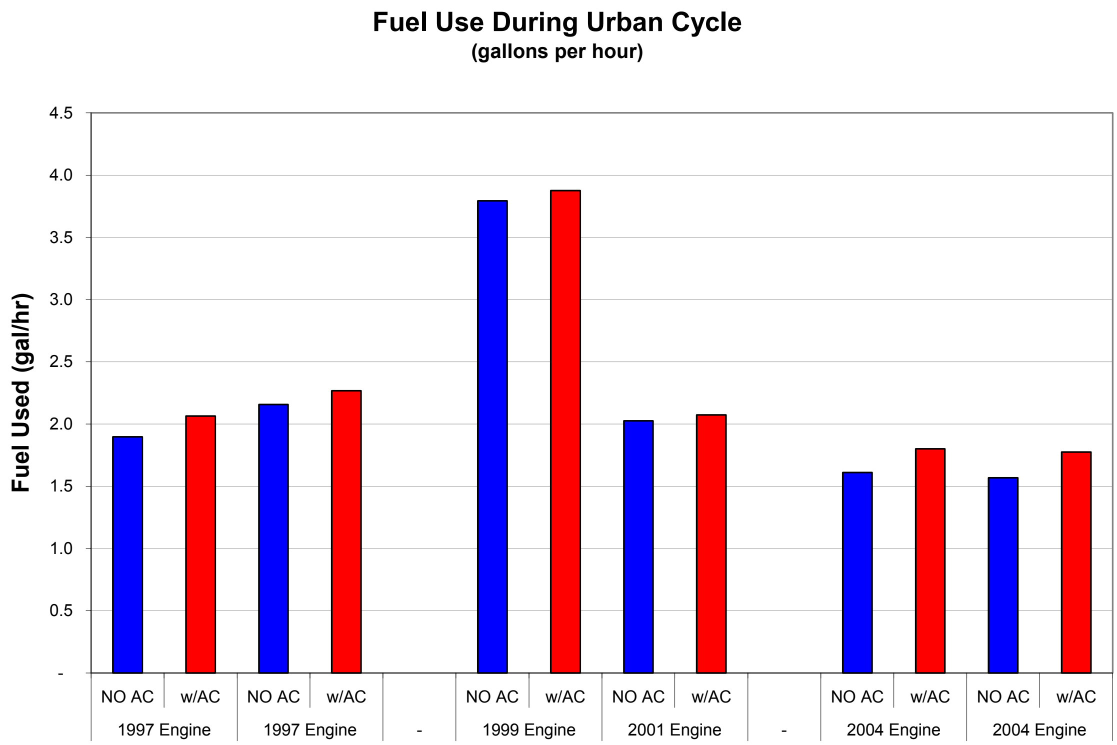

Figure 5

Idling vs Urban Driving

This section directly discusses the difference in NO_x emissions and fuel use from buses driven on the urban drive cycle compared to the same bus idling while stationary.

For all tested buses both fuel use and NO_x emissions increased significantly while driving on the urban drive cycle compared to stationary idling, though the increase was less for the two newest buses than for the four older buses.

Emissions

NO_X emissions from each bus while idling on low idle without the air conditioning system on and while operated on the urban drive cycle without the air conditioning system on is shown in Figures 6.

As shown, for all buses NO_X emissions increased significantly in urban driving compared to stationary idling, but less so for the newer buses than for the older buses. For three of the four older buses NO_X emissions doubled, while they increased by 60% for the fourth. For the two newest buses NO_X emissions increased by 30-40% in urban driving compared to idling.

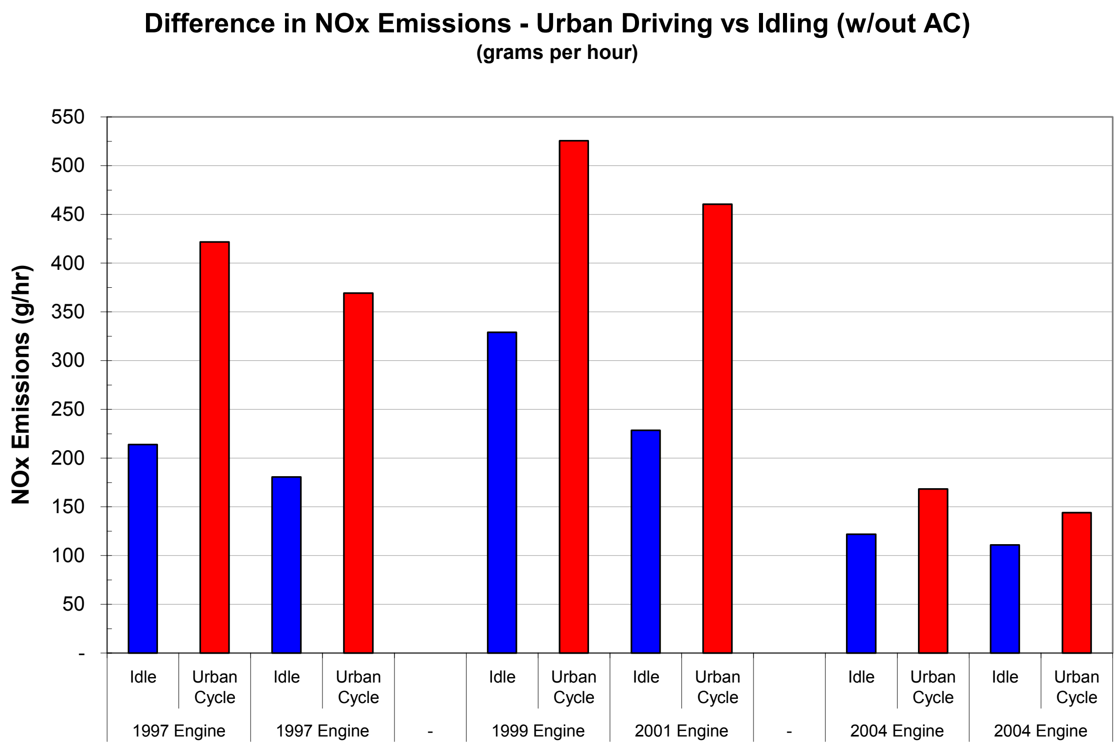

Figure 6

Fuel Use

Fuel use from each bus while idling on low idle without the air conditioning system on and while operated on the urban drive cycle without the air conditioning system on are shown in Figures 7.

As shown, for all buses fuel use at least doubled in urban driving compared to stationary idling – increasing by 1 gallon per hour or more for all buses. For the bus with the 1999 engine fuel use increased by 2.5 gal/hr in urban driving compared to stationary idling.

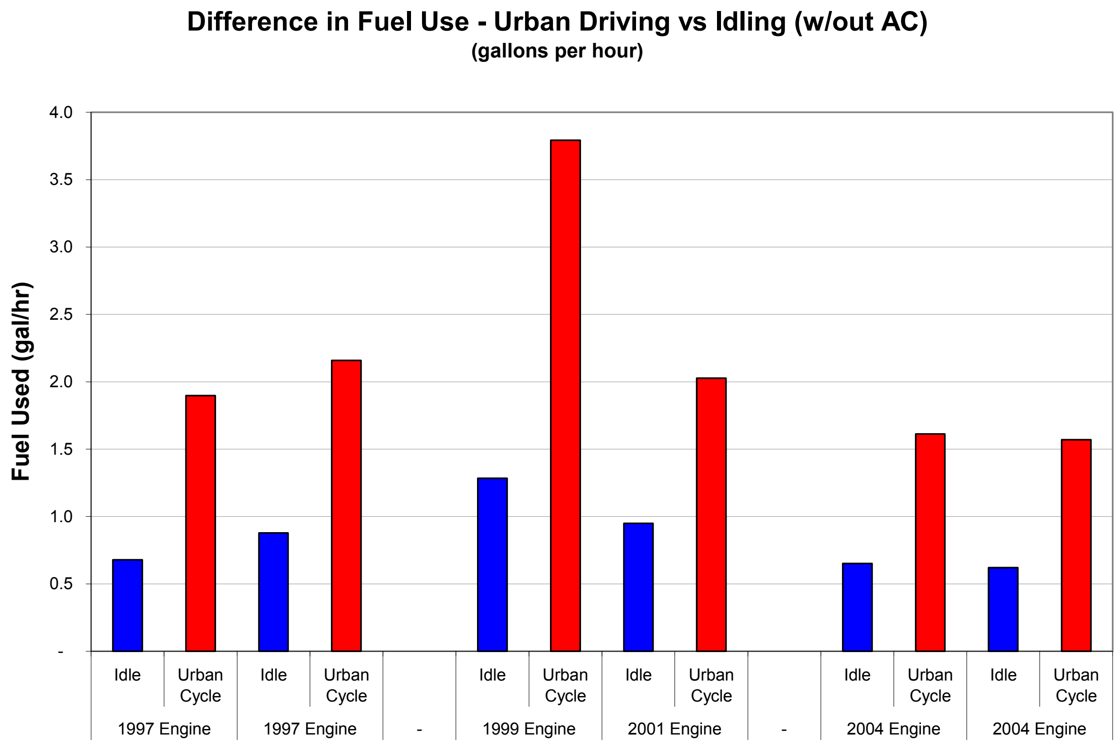

Figure 7

Policy Implications – Circulating vs Stationary Idling

In an attempt to reduce vehicle emissions and improve air quality, approximately 26 states and cities have enacted laws that restrict idling of diesel vehicles[16]. Typically, these laws set a maximum allowable idling period, anywhere from two to 15 minutes; operators of vehicles found parked and idling longer than the limit can be fined.

Generally these laws do not provide an exemption for coach buses to idle in order to maintain cabin air temperature for the operator and passengers as mandated by law. Yet many coach operators (particularly charter operators) must wait several hours or more with their bus for passengers to return from a visit to a tourist destination, etc. During that time most have no real alternative to sitting on their bus, since most cities do not provide secure parking areas and appropriate locations for bus operators to wait.

Since it can take as many as 30 minutes to bring the interior temperature of a motorcoach down to a comfortable temperature for the driver and passengers, some operators are faced with the choice of 1) disobeying the idling restriction and risking a fine, 2) sitting for extended periods on the coach in either very hot or very cold conditions, or 3) driving

[16] American Transportation Research Institute, *Compendium of Idling Regulations*, updated September 2004 < http//atri-online.org/research/results/idling_chart.pdf>

their coach around the city in traffic. For operators who choose to circulate in traffic these idle restriction laws are in fact producing the opposite effect of what they were intended to do.

As shown in this study circulating in traffic, as opposed to stationary idling, results in excess NO_X emissions of 200 g/hr on average for older coaches and 40 g/hr on average for new coaches without the air conditioning system on. Only one hour per day of circulating rather than idling to maintain an appropriate cabin temperature can result in over 22 lbs of excess NO_X emissions annually from an older coach and over 3 lbs of excess NO_X emissions annually from a newer coach. The impact is likely to be even higher in the summer[17]. For older coaches, every hour of circulating creates as much NO_x emissions as two hours of stationary idling.

Circulating in traffic rather than idling also wastes fuel. Older coaches use on average 1.5 gal/hr more fuel and newer coaches use on average 0.96 gal/hr more fuel when circulating than when idling without the air conditioning system on. Only one hour per day of circulating rather than idling to maintain an appropriate cabin temperature can increase annual fuel use by 375 gallons for an older coach and 250 gallons for a new coach. The impact is likely to be even higher in the summer [17].

[17] Assuming 50 weeks per year and 5 days per week. This calculation did not assume air conditioning use in the summer because the urban cycle air conditioning data was less certain than the idle data with air conditioning.

APPENDIX A – TEST RESULTS

IDLE TEST, no AC		Time	CO2	CO	NOx	HC	Fuel
		s	g/s	g/s	g/s	g/s	gal/s
Bus 1	Test 1	1200.2	3.68	0.0113	0.0921	0.0091	0.00036
	Test 2	1200.3	3.60	0.0112	0.0942	0.0096	0.00036
	Test 3	1200.6	3.52	0.0109	0.0879	0.0072	0.00035
	AVG	**1200.4**	**3.60**	**0.0111**	**0.0914**	**0.0086**	**0.00036**
	STDEV	0.2	0.08	0.0002	0.0032	0.0012	0.00001
	COV	***0.0%***	***2.2%***	***2.0%***	***3.5%***	***14.2%***	***2.3%***
Bus 2	Test 1	1192.4	1.74	0.0061	0.0550	0.0034	0.00017
	Test 2	1191.4	1.84	0.0063	0.0553	0.0043	0.00018
	Test 3	1194.6	2.13	0.0064	0.0680	0.0051	0.00021
	AVG	**1192.8**	**1.90**	**0.0063**	**0.0594**	**0.0043**	**0.00019**
	STDEV	1.658	0.203	0.0001	0.0074	0.0008	0.00002
	COV	***0.1%***	***10.7%***	***1.9%***	***12.5%***	***19.7%***	***10.8%***
Bus 3	Test 1	1200.6	2.84	0.0144	0.0603	0.0022	0.00028
	Test 2	1200.9	2.57	0.0074	0.0640	0.0025	0.00025
	Test 3	1201.0	2.57	0.0073	0.0661	0.0027	0.00025
	AVG	**1200.8**	**2.66**	**0.0097**	**0.0635**	**0.0025**	**0.00026**
	STDEV	0.2	0.15	0.0041	0.0029	0.0003	0.00002
	COV	***0.0%***	***5.8%***	***41.8%***	***4.6%***	***11.6%***	***6.4%***
Bus 4	Test 1	1201.0	1.87	0.0075	0.0366	0.0001	0.00018
	Test 2	1200.0	1.71	0.0074	0.0324	0.0017	0.00017
	Test 3	1196.9	1.74	0.0075	0.0326	0.0015	0.00019
	AVG	**1199.3**	**1.77**	**0.0075**	**0.0338**	**0.0011**	**0.00018**
	STDEV	2.1	0.08	0.0000	0.0024	0.0008	0.00001
	COV	***0.2%***	***4.8%***	***0.6%***	***7.0%***	***78.6%***	***6.0%***
Bus 5	Test 1	1200.2	1.80	0.0076	0.0320	0.0006	0.00018
	Test 2	1200.4	1.76	0.0075	0.0312	0.0013	0.00017
	Test 3	1187.4	1.67	0.0072	0.0293	0.0015	0.00017
	AVG	**1196.0**	**1.74**	**0.0075**	**0.0308**	**0.0011**	**0.00017**
	STDEV	7.4	0.07	0.0002	0.0014	0.0005	0.00001
	COV	***0.6%***	***3.8%***	***2.9%***	***4.4%***	***40.5%***	***3.6%***
Bus 6	Test 1	1200.2	2.34	0.0074	0.0472	0.0028	0.00023
	Test 2	1197.5	2.23	0.0074	0.0452	0.0033	0.00022
	Test 3	1199.0	2.85	0.0077	0.0580	0.0043	0.00028
	AVG	**1198.9**	**2.47**	**0.0075**	**0.0501**	**0.0035**	**0.00024**
	STDEV	1.3	0.33	0.0002	0.0069	0.0008	0.00003
	COV	***0.1%***	***13.5%***	***2.1%***	***13.7%***	***22.8%***	***13.3%***

APPENDIX A – TEST RESULTS

IDLE TEST, w/ AC		Time	CO2	CO	NOx	HC	Fuel
		s	g/s	g/s	g/s	g/s	gal/s
Bus 1	Test 1	1200.8	5.18	0.0207	0.1324	0.0095	0.00051
	Test 2	1194.0	5.23	0.0174	0.1342	0.0087	0.00052
	Test 3	1194.1	4.99	0.0210	0.1354	0.0091	0.00049
	AVG	**1196.3**	**5.13**	**0.0197**	**0.1340**	**0.0091**	**0.00051**
	STDEV	3.9	0.12	0.0020	0.0015	0.0004	0.00001
	COV	***0.3%***	***2.4%***	***10.2%***	***1.1%***	***4.9%***	***2.4%***
Bus 2	Test 1	1192.8	2.63	0.0082	0.0773	0.0060	0.00026
	Test 2	1200.1	2.71	0.0081	0.0835	0.0034	0.00027
	Test 3	1192.9	2.76	0.0081	0.0835	0.0043	0.00027
	AVG	**1195.2**	**2.70**	**0.0081**	**0.0814**	**0.0046**	**0.00027**
	STDEV	4.2	0.06	0.0000	0.0036	0.0013	0.00001
	COV	***0.4%***	***2.3%***	***0.1%***	***4.4%***	***28.8%***	***2.0%***
Bus 3	Test 1	1192.2	3.54	0.0305	0.0873	0.0041	0.00035
	Test 2	1200.1	3.52	0.0220	0.0868	0.0034	0.00035
	Test 3	1196.5	3.55	0.0220	0.0869	0.0037	0.00035
	AVG	**1196.3**	**3.54**	**0.0248**	**0.0870**	**0.0037**	**0.00035**
	STDEV	4.0	0.02	0.0049	0.0003	0.0004	0.00000
	COV	***0.3%***	***0.6%***	***19.8%***	***0.3%***	***10.6%***	***0.7%***
Bus 4	Test 1	1196.5	3.08	0.0099	0.0532	0.0002	0.00030
	Test 2	1197.3	2.66	0.0098	0.0428	0.0027	0.00026
	Test 3	1195.5	2.61	0.0098	0.0430	0.0022	0.00026
	AVG	**1196.5**	**2.79**	**0.0098**	**0.0463**	**0.0017**	**0.00027**
	STDEV	0.9	0.26	0.0000	0.0060	0.0013	0.00002
	COV	***0.1%***	***9.3%***	***0.4%***	***12.9%***	***78.9%***	***9.1%***
Bus 5	Test 1	1200.7	3.04	0.0099	0.0462	0.0011	0.00030
	Test 2	1200.9	2.78	0.0096	0.0400	0.0016	0.00027
	Test 3	1200.8	2.84	0.0096	0.0412	0.0019	0.00028
	AVG	**1200.8**	**2.89**	**0.0097**	**0.0425**	**0.0015**	**0.00028**
	STDEV	0.1	0.14	0.0002	0.0033	0.0004	0.00001
	COV	***0.0%***	***4.7%***	***1.9%***	***7.7%***	***25.6%***	***5.0%***
Bus 6	Test 1	1196.1	3.43	0.0165	0.1015	0.0032	0.00034
	Test 2	1200.2	3.49	0.0095	0.1013	0.0034	0.00034
	Test 3	1200.1	3.35	0.0183	0.0909	0.0029	0.00033
	AVG	**1198.8**	**3.42**	**0.0148**	**0.0979**	**0.0032**	**0.00034**
	STDEV	2.4	0.07	0.0046	0.0060	0.0003	0.00001
	COV	***0.2%***	***2.0%***	***31.3%***	***6.1%***	***8.9%***	***1.8%***

APPENDIX A – TEST RESULTS

		Test Cycle				Emissions				Fuel Use	
URBAN CYCLE, no AC		Time s	Distance mi	Avg Speed mph	% Idle Time	CO_2 g/s	CO g/s	NOx g/s	HC g/s	Fuel gal/s	Fuel mpg
Bus 1	Test 1	1200.5	2.44	7.0	45.5	10.92	0.0173	0.1207	0.0114	0.00108	1.89
	Test 2	1200.5	2.40	6.9	46.1	10.65	0.0162	0.1185	0.0092	0.00105	1.91
	Test 3	1200.5	2.54	7.3	44.5	10.64	0.0157	0.1987	0.0133	0.00103	2.02
	AVG	**1200.5**	**2.46**	**7.1**	**45.4**	**10.74**	**0.0164**	**0.1460**	**0.0113**	**0.00105**	**1.94**
	STDEV	0.0	0.07	0.2	0.8	0.16	0.0008	0.0457	0.0020	0.00002	0.07
	COV	***0.0%***	***2.9%***	***2.9%***	***1.8%***	***1.5%***	***5.0%***	***31.3%***	***18.1%***	***2.3%***	***3.6%***
Bus 2	Test 1	1200.5	2.33	6.3	40.9	5.67	0.0133	0.1247	0.0096	0.00056	3.47
	Test 2	1200.9	2.31	6.3	39.5	5.31	0.0123	0.1155	0.0081	0.00052	3.67
	Test 3	1200.1	2.38	6.5	39.2	5.16	0.0115	0.1113	0.0044	0.00051	3.90
	AVG	**1200.5**	**2.34**	**6.4**	**39.9**	**5.38**	**0.0124**	**0.1172**	**0.0074**	**0.00053**	**3.68**
	STDEV	0.4	0.04	0.1	0.9	0.26	0.0009	0.0069	0.0027	0.00003	0.22
	COV	***0.0%***	***1.5%***	***2.0%***	***2.3%***	***4.9%***	***7.5%***	***5.8%***	***36.5%***	***5.0%***	***5.8%***
Bus 3	Test 1	1200.3	2.22	6.5	40.2	6.25	0.0126	0.1351	0.0040	0.00061	3.01
	Test 2	1200.2	2.23	6.5	39.9	5.92	0.0121	0.1260	0.0035	0.00057	3.34
	Test 3	1200.3	2.28	6.6	39.0	5.78	0.0114	0.1226	0.0031	0.00051	3.90
	AVG	**1200.3**	**2.24**	**6.5**	**39.7**	**5.98**	**0.0120**	**0.1279**	**0.0035**	**0.00056**	**3.42**
	STDEV	0.1	0.03	0.1	0.6	0.24	0.0006	0.0065	0.0005	0.00005	0.45
	COV	***0.0%***	***1.4%***	***0.9%***	***1.6%***	***4.0%***	***5.0%***	***5.1%***	***12.9%***	***8.8%***	***13.2%***
Bus 4	Test 1	1200.5	2.22	6.3	42.6	4.59	0.0193	0.0479	0.0015	0.00045	4.10
	Test 2	1200.6	2.27	6.4	42.5	4.50	0.0194	0.0465	0.0026	0.00044	4.26
	Test 3	1200.5	2.18	6.5	42.7	4.57	0.0169	0.0458	0.0000	0.00045	4.04
	AVG	**1200.5**	**2.22**	**6.4**	**42.6**	**4.55**	**0.0185**	**0.0467**	**0.0014**	**0.00045**	**4.13**
	STDEV	0.1	0.05	0.1	0.1	0.05	0.0014	0.0011	0.0013	0.00001	0.11
	COV	***0.0%***	***2.0%***	***1.6%***	***0.2%***	***1.0%***	***7.5%***	***2.3%***	***95.5%***	***1.6%***	***2.8%***
Bus 5	Test 1	1200.4	2.26	6.4	41.8	4.60	0.0172	0.0441	0.0035	0.00045	4.15
	Test 2	1200.1	2.30	6.1	43.4	4.33	0.0118	0.0394	0.0014	0.00042	4.22
	Test 3	1200.9	2.30	6.5	41.0	4.37	0.0110	0.0364	0.0005	0.00043	4.45
	AVG	**1200.5**	**2.29**	**6.3**	**42.1**	**4.43**	**0.0133**	**0.0400**	**0.0018**	**0.00044**	**4.27**
	STDEV	0.4	0.02	0.2	1.2	0.15	0.0034	0.0039	0.0015	0.00002	0.16
	COV	***0.0%***	***1.0%***	***3.3%***	***2.9%***	***3.3%***	***25.3%***	***9.7%***	***85.6%***	***3.6%***	***3.7%***
Bus 6	Test 1	1200.7	2.10	6.0	45.8	6.29	0.0090	0.1486	0.0045	0.00062	2.83
	Test 2	1200.9	2.09	5.9	46.4	5.65	0.0102	0.0737	0.0054	0.00056	3.13
	Test 3	1200.4	2.19	6.2	46.7	6.34	0.0107	0.0854	0.0053	0.00062	2.92
	AVG	**1200.7**	**2.13**	**6.0**	**46.3**	**6.09**	**0.0100**	**0.1026**	**0.0051**	**0.00060**	**2.96**
	STDEV	0.3	0.06	0.2	0.4	0.38	0.0009	0.0403	0.0005	0.00004	0.15
	COV	***0.0%***	***2.6%***	***2.6%***	***1.0%***	***6.3%***	***8.9%***	***39.3%***	***9.7%***	***6.0%***	***5.2%***

APPENDIX A – TEST RESULTS

		Test Cycle				Emissions				Fuel Use	
URBAN CYCLE, w/ AC		Time	Distance	Avg Speed	% Idle	CO2	CO	NOx	HC	Fuel	Fuel
		s	mi	mph	Time	g/s	g/s	g/s	g/s	gal/s	mpg
Bus 1	Test 1	1200.0	2.42	6.9	46.2	11.04	0.0160	0.1209	0.0055	0.00108	1.86
	Test 2	1200.8	2.51	7.2	44.5	11.30	0.0166	0.1208	0.0078	0.00111	1.88
	Test 3	1200.7	2.45	7.1	44.5	10.59	0.0157	0.1357	0.0078	0.00104	1.94
	AVG	**1200.5**	**2.46**	**7.1**	**45.1**	**10.98**	**0.0161**	**0.1258**	**0.0070**	**0.00108**	**1.89**
	STDEV	0.4	0.05	0.1	1.0	0.36	0.0005	0.0086	0.0013	0.00004	0.04
	COV	***0.0%***	***1.9%***	***1.8%***	***2.1%***	***3.3%***	***2.8%***	***6.8%***	***18.9%***	***3.3%***	***2.2%***
Bus 2	Test 1	1200.9	2.41	6.5	40.7	6.10	0.0118	0.1402	0.0048	0.00060	3.34
	Test 2	1200.0	2.39	6.5	38.8	5.68	0.0107	0.1265	0.0032	0.00056	3.56
	Test 3	1200.9	2.41	6.6	37.4	5.72	0.0120	0.1251	0.0048	0.00056	3.56
	AVG	**1200.6**	**2.40**	**6.5**	**39.0**	**5.83**	**0.0115**	**0.1306**	**0.0043**	**0.00057**	**3.49**
	STDEV	0.5	0.01	0.0	1.7	0.23	0.0007	0.0083	0.0009	0.00002	0.13
	COV	***0.0%***	***0.5%***	***0.5%***	***4.3%***	***4.0%***	***6.1%***	***6.4%***	***21.6%***	***4.0%***	***3.6%***
Bus 3	Test 1	1201.0	2.20	6.4	40.1	6.09	0.0106	0.1167	0.0030	0.00060	3.07
	Test 2	1200.5	2.23	6.5	39.5	5.78	0.0104	0.1118	0.0027	0.00057	3.27
	Test 3	1200.3	2.31	6.8	38.4	5.71	0.0108	0.1115	0.0083	0.00056	3.42
	AVG	**1200.6**	**2.25**	**6.6**	**39.3**	**5.86**	**0.0106**	**0.1133**	**0.0046**	**0.00058**	**3.25**
	STDEV	0.4	0.06	0.2	0.9	0.20	0.0002	0.0029	0.0032	0.00002	0.18
	COV	***0.0%***	***2.5%***	***2.8%***	***2.3%***	***3.5%***	***1.9%***	***2.6%***	***68.4%***	***3.7%***	***5.4%***
Bus 4	Test 1	1200.6	2.21	6.3	42.5	5.41	0.0235	0.0616	0.0002	0.00053	3.54
	Test 2	1200.9	2.46	6.5	42.4	5.31	0.0139	0.0602	0.0002	0.00052	3.93
	Test 3	1200.3	2.32	7.0	40.2	5.48	0.0178	0.0593	0.0087	0.00045	3.57
	AVG	**1200.6**	**2.33**	**6.6**	**41.7**	**5.40**	**0.0184**	**0.0604**	**0.0030**	**0.00050**	**3.68**
	STDEV	0.3	0.13	0.4	1.3	0.09	0.0048	0.0012	0.0049	0.00004	0.22
	COV	***0.0%***	***5.4%***	***5.4%***	***3.1%***	***1.6%***	***26.2%***	***1.9%***	***162.3%***	***8.8%***	***5.9%***
Bus 5	Test 1	1200.6	2.21	6.3	42.5	5.13	0.0086	0.0484	0.0007	0.00050	3.66
	Test 2	1200.0	2.31	6.6	38.8	5.10	0.0092	0.0479	0.0002	0.00050	3.84
	Test 3	1200.4	2.31	6.6	40.1	4.92	0.0096	0.0453	0.0032	0.00048	3.98
	AVG	**1200.3**	**2.28**	**6.5**	**40.5**	**5.05**	**0.0091**	**0.0472**	**0.0014**	**0.00049**	**3.83**
	STDEV	0.3	0.06	0.2	1.9	0.11	0.0005	0.0017	0.0016	0.00001	0.16
	COV	***0.0%***	***2.5%***	***2.6%***	***4.6%***	***2.2%***	***5.5%***	***3.5%***	***118.8%***	***2.3%***	***4.2%***
Bus 6	Test 1	1200.5	2.11	6.0	46.4	6.44	0.0112	0.0894	0.0035	0.00063	2.81
	Test 2	1200.8	2.13	6.0	46.1	6.42	0.0110	0.0954	0.0045	0.00063	2.81
	Test 3	1200.8	2.21	6.3	45.0	6.38	0.0109	0.0908	0.0044	0.00063	2.93
	AVG	**1200.7**	**2.15**	**6.1**	**45.8**	**6.41**	**0.0110**	**0.0919**	**0.0041**	**0.00063**	**2.85**
	STDEV	0.2	0.05	0.2	0.7	0.03	0.0002	0.0031	0.0006	0.00000	0.07
	COV	***0.0%***	***2.5%***	***2.9%***	***1.6%***	***0.5%***	***1.4%***	***3.4%***	***13.9%***	***0.2%***	***2.4%***