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Estimating Truck Emissions at the El Paso - Ciudad Juarez Border

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ABSTRACT

The overall goal of the project was to develop and apply a methodology to estimate emissions produced by trucks from Mexico crossing the El Paso-Ciudad Juarez border locations. The specific objectives of the study were to develop a:

- *border crossing fleet profile* - profile of the make, model, and year of trucks crossing the two main border bridges;
- *border crossing travel profile* –profiles of the drive cycles (acceleration, deceleration, cruising, idling, and creep idling) of trucks crossing the two main border bridges; and
- *border crossing emissions profile* –estimates of idling emissions and driving emissions of trucks crossing the two main border bridges

Portable emissions measurement system (PEMS) equipment along with Tapered Element Oscillating Micro-balance (TEOM) was used to measure the truck emissions. The project provided insight into the fleet, travel, and emissions characteristics of trucks crossing the El Paso-Ciudad Juarez border locations.

INTRODUCTION

More than four million trucks cross the border annually from Mexico into the United States (Bureau of Transportation Statistics, 2005). With an economic recovery underway, that number is expected to rise. The higher demand at commercial border crossings and changes in freight border crossing processes resulting from the recent evolution of security measures and programs affect commercial vehicles crossing into the United States The unfortunate side effects of increased trade and new security measures for commercial traffic between Mexico and the U.S. is higher truck traffic that increases congestion levels and vehicle emissions, which have a significant impact on air quality in the border metropolitan area. This project is one of the first steps to quantify the emissions of trucks idling at the Mexican border locations. The overall goal of the project was to develop a methodology for estimating idling emissions from trucks crossing northbound at the two major El Paso – Juarez commercial crossings (Bridge of the Americas and the Zaragoza/Ysletta bridge). The specific objectives were to develop border crossing fleet profiles, border crossing travel profiles, and border crossing emissions profiles.

Border crossing fleet profiles were developed by surveying crossing trucks over several days at the two major international bridges. Border crossing travel profiles (crossing time, acceleration, deceleration, cruising, and idling) of trucks crossing from Ciudad Juarez into El Paso were determined by instrumenting trucks with global positioning system (GPS) units and collecting second-by-second data as the trucks crossed the border locations. Border crossing emissions profiles were determined by using Portable Emission Measurement System (PEMS) units as well as Tapered Element Oscillating Micro-balance (TEOM) equipment. The trucks were subjected to different modes of idling and emissions (including particulate matter) were collected on a second-by-second basis. For the crossing emissions the trucks were equipped with PEMS units and emissions were collected as the trucks crossed the major bridges.

The study produced results on truck volumes by time of day, vehicle classification, and age profiles. The study also produced specific drive cycles for the two bridges, representing travel characteristics across the borders. Finally, the study produced emissions results of trucks subjected to a range of idling modes and during crossing of the borders. Comparisons were made between emissions levels produced in this study and those found in previous studies performed in the United States.

The paper is comprised of seven sections. The first section contains the introduction to the paper. The second section describes the study area. The third section describes the approach. The fourth section discusses the results and the fifth section describes the conclusions. The sixth and seventh sections describe the acknowledgements and references, respectively.

DESCRIPTION OF THE STUDY AREA

The majority of freight shipped through the El Paso-Ciudad Juárez port-of-entry system is maquiladora trade. This arrangement has evolved into a system of transfer stations, distribution centers and warehouses on the U.S. side of the border and manufacturing plants in Mexico. Most maquiladora assembly plants are located in the southeast portion of the El Paso-Ciudad Juárez metropolitan area. The merchandise is shipped through two major international border crossings – Bridge of the Americas and Zaragoza/Ysleta.

Bridge of the Americas (BOTA)

The BOTA facility is located in the center of the El Paso-Ciudad Juárez metropolitan area. The bridge is used for truck and passenger vehicle movements and includes two separate structures, one for northbound traffic and one for southbound traffic. Truck traffic is accommodated by two dedicated outside lanes on each bridge structure and no tolls are collected at this commercial crossing.

The BOTA operates from 6 a.m. to 6 p.m. Monday through Friday and from 6 a.m. to 2 p.m. on Saturdays. Empty truck traffic prefers using this free bridge to avoid paying the toll at the Zaragoza Bridge. On October 27, 2003 one of BOTA's two northbound lanes was converted to a designated FAST lane. Approximately 15% of the total northbound truck volume at this crossing is now expedited across the border through this lane. Figure 1 shows a schematic diagram of the BOTA.

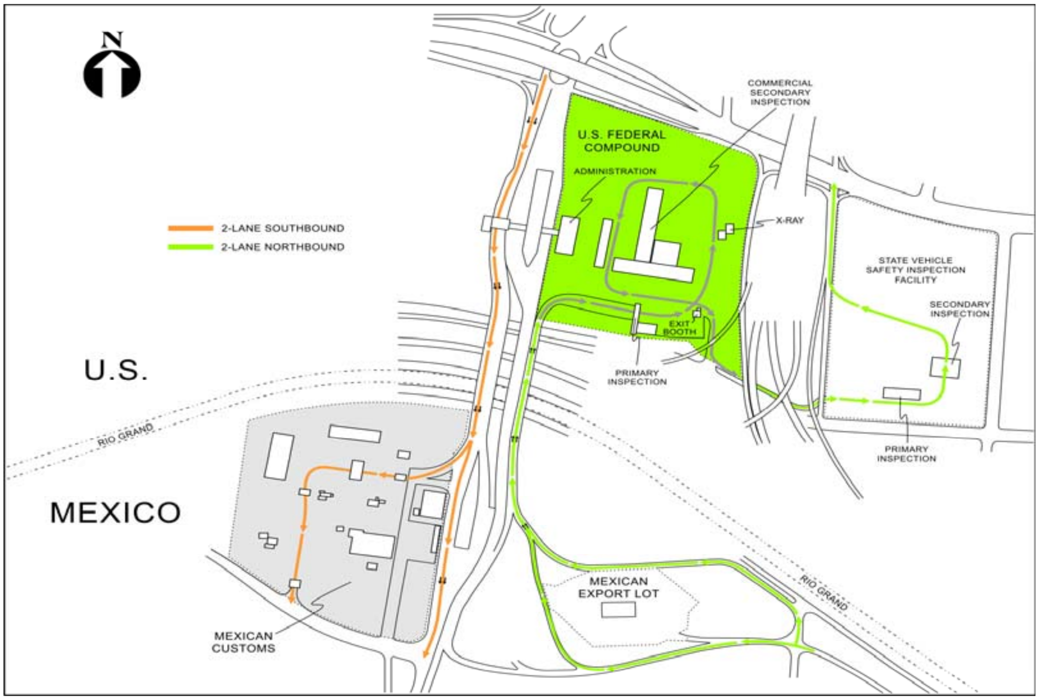

Figure 1. Border Crossing Schematic at the Bridge of the Americas.

Zaragoza/Ysleta

The Zaragoza border crossing is located on the southeast side of El Paso. The crossing's bridge is comprised of two separate structures, one for commercial traffic and the other for passenger vehicles. The truck bridge is a four-lane facility with two lanes per direction. It is open from 8 a.m. to midnight, Monday to Friday, and 9 a.m. to 5 p.m. on Saturdays. The northbound toll is collected on the Mexican side of the border and is approximately $10 for a commercial truck. Figure 2 shows a schematic diagram of the border crossing at the Zaragoza Bridge.

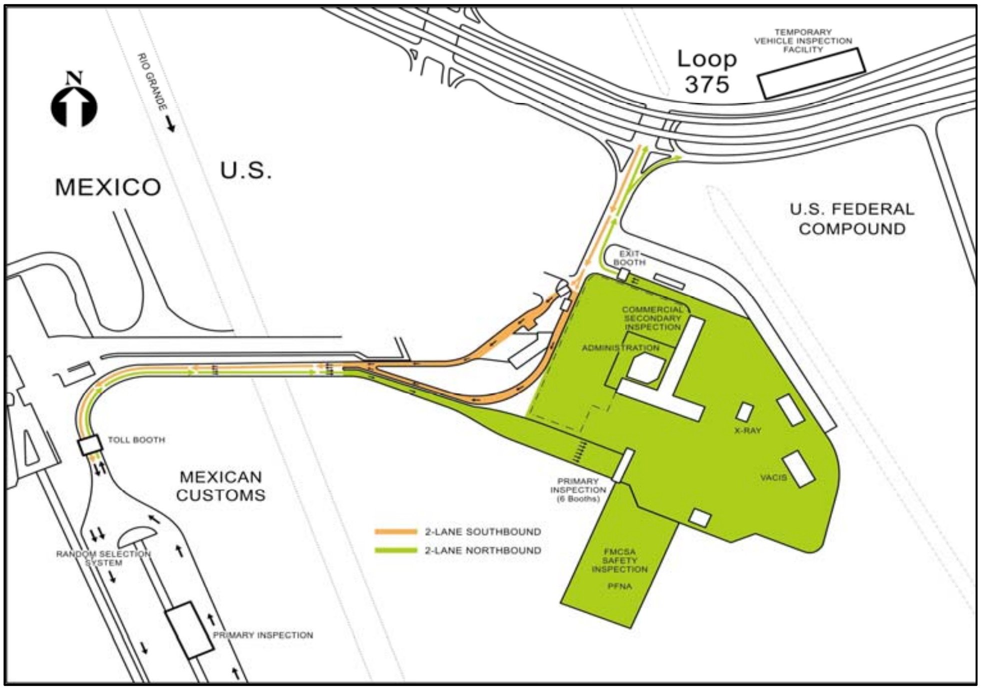

Figure 2. Border Crossing Schematic at Zaragoza Bridge.

APPROACH

Border Crossing Fleet Profile

As mentioned earlier, the focus of this study was on heavy-duty diesel tractor-trailer trucks. The following information was obtained for the border crossing fleet profile:

- total number of heavy-duty diesel tractor-trailer trucks typically crossing the two border locations by time-of-day (northbound and southbound);
- model year distribution of trucks from Mexico crossing the border at the two border locations studied;
- engine sizes and manufacturers of trucks from Mexico crossing the border; and
- fleet owners of trucks from Mexico crossing the border.

The study team performed counts and interviews at the two international bridges during May 2005 and obtained additional information through the following sources:

- Mexican Trucking Association (CANACAR);
- Mexican Department of Transportation (SCT);
- Federal Motor Carrier Safety Administration (FMCSA);
- Texas Department of Public Safety (DPS); and
- Mexican trucking companies.

Border Crossing Travel Profile

The travel profile for trucks crossing the border will help determine the drive cycle patterns from which aspects such as queuing and idling can be inferred. Specifically, the border crossing travel profile refers to time and space information of the trucks as they travel through the border locations.

Global positioning system (GPS) equipment installed on board the commercial vehicles was used to take sample profiles in September 2004 and June 2005. The GPS equipment was installed in Mexico at the carrier yard and was uninstalled in El Paso once the truck finished all inspections. The GPS equipment that was used provides coordinate information on a second-by-second basis. Northbound truck drive cycles were recorded at the BOTA and Zaragoza crossings.

Border Crossing Emissions Profile

The PEMS unit used in this study was the OEM-2100 "Montana" system manufactured by Clean Air Technologies International, Inc. The OEM-2100 system is comprised of a gas analyzer, a particulate matter (PM) measurement system, an engine diagnostic scanner, a global positioning system (GPS), and an on-board computer (CATI, 2003). Oak Ridge National Laboratory (ORNL) provided a partial flow dilution tunnel, a Rupprecht and Patashnick Model 1105 TEOM gravimetric filter equipment and assorted sampling pumps.

A PEMS unit was placed at a stationary location to collect truck idling information in conjunction with the equipment provided by the Oak Ridge National Laboratory. A manageable sample of trucks were tested based on make, model year, and engine size as determined through the fleet profile step. Emissions data were collected under various modes of idling—high RPM, low RPM, air conditioning on, air conditioning off, and snaps (instances of full throttle engine thrusts). In addition, PEMS units were deployed to obtain the emissions for trucks from Mexico traveling across the border at the study locations. PEMS units were installed on trucks on the Mexican side of the border and then removed on the U.S. side of the border.

RESULTS

Fleet Profile

The average weekday volume of northbound traffic at BOTA was 1,311 trucks, with Thursdays being slightly busier than other days (*4*). From 6 a.m. to 8 a.m., northbound commercial crossings are restricted to empty vehicles. After 8 a.m., both laden and empty northbound trucks are permitted to cross the border at this location. Northbound commercial crossings peak between 11 a.m. and noon, and begin to decline rapidly after 4 p.m. The average weekday volume of northbound traffic at Zaragoza was 1,157 trucks, with Mondays being slightly lighter than the other weekdays. Laden trucks comprise the majority of traffic at this port of entry, except for the 8 a.m. to 9 a.m. period when a large number of empty vehicles cross into the U.S. Peak northbound demand at Zaragoza occurs around 10 a.m., with additional afternoon peaks occurring at 5 p.m. and 7 p.m.

It was found that very few long-haul tractors are used at the two border crossings, except for those that travel to and from Chihuahua City, which is close enough to allow the truck to make a day trip. This peculiar traffic characteristic shows that the same tractors are the ones that are used on a daily basis. Figure 3 shows a distribution of the model years of trucks crossing into El Paso. The analysis of the model year information shows that 25 different model years represent the total fleet composition. From these 25, three (1993, 1995 and 1996) represent one third of the total fleet, and 10 model years spanning from 1991 to 2002 represent almost three quarters of the total fleet spectrum. It may also be noticed that 20% of the fleet is 1990 or older (more than 15 years old).

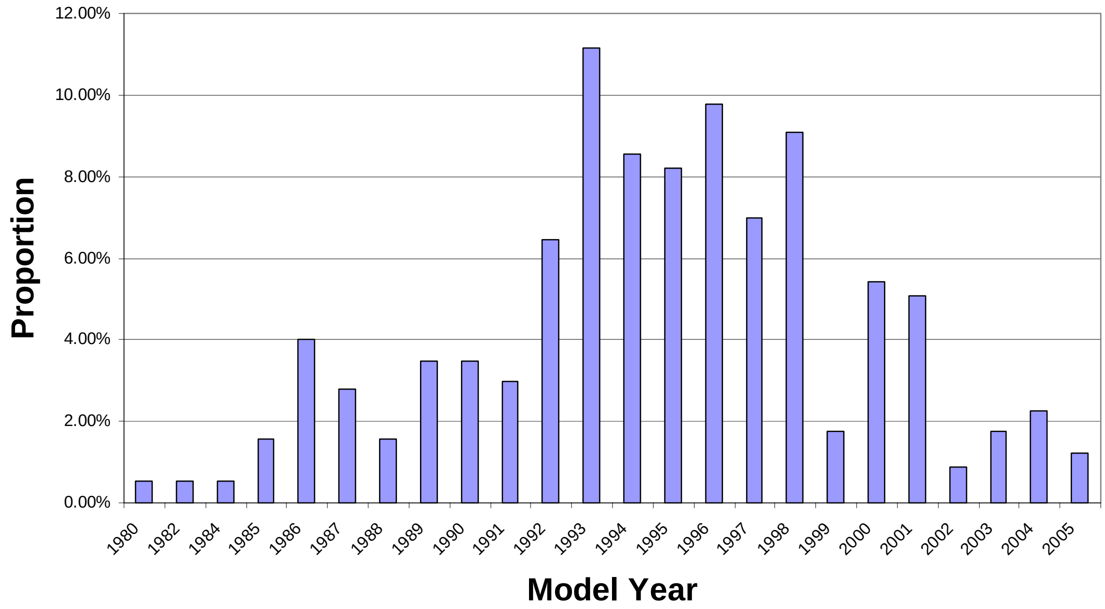

Figure 3. Class 8 Surveyed Fleet Proportion by Model Year.

Travel Profiles

In order to effectively analyze the drive-cycles, each drive-cycle was divided into distinct sections. For both BOTA and Zaragoza bridges, the first part of the drive-cycle includes the section from the entrance to the Mexican Customs compound to the U.S. primary inspection booth. The second part of the drive-cycle includes the truck movements within the U.S. federal compound, from the primary inspection booth to the exit booth. The third section of the drive-cycle stretches from the exit booth of the U.S. federal compound to the exit of the state Safety Inspection Facility (SIF). Information for this third section of the drive-cycle was only collected for the BOTA crossing, in which the SIF is adjacent to the U.S. federal compound. Figure 4 shows the drive cycle sections for BOTA.

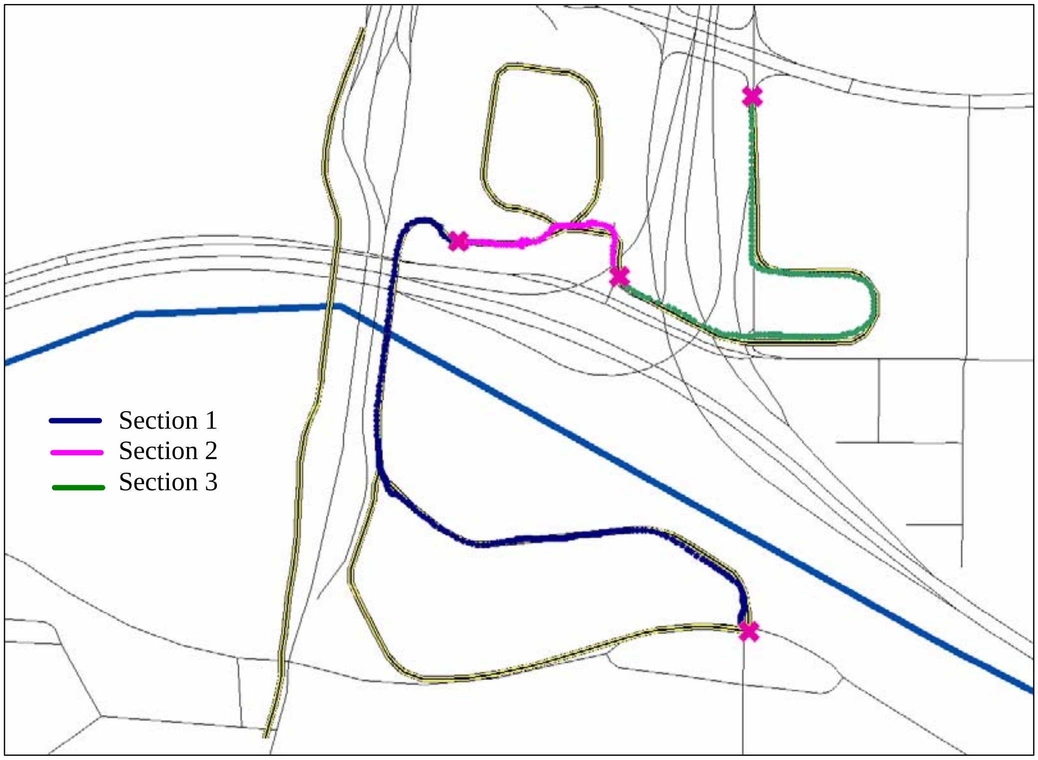

Figure 4. BOTA Drive-cycle Sections.

Idling was a key aspect of this research. General idling occurs when the vehicle is at a total standstill whereas creep idling occurs when the vehicle is moving at a speed less than 5 mph and has an acceleration or deceleration less than 0.5 mph/sec. This threshold for creep idling seemed to be an appropriate divider between trucks involved in creep idling and actually driving based on previous research performed on truck acceleration rates (May, 1990).

Table 1 shows a summary of the travel times, idling, and creep idling percentages for the two bridges for the various sections. The travel times are estimated by allocating probabilities to the extremely long travel times observed during the surveys. It may be seen that the average percentage idling and creep idling for both bridges are above 60%. In addition, the travel time for

Zaragoza is more than that for BOTA. This can be ascribed to the fact that Zaragoza has higher percentage idling and creep idling than the BOTA bridge.

Table 1. Summary of Travel Time, Idling and, Creep Idling.

Section	BOTA			Zaragoza		
	Travel Time (min)	% Normal Idle	% Creep Idle	Travel Time (min)	% Normal Idle	% Creep Idle
1	8.5	41%	18%	11.1	36%	13%
2	8.2	62%	13%	23.0	75%	8%
3	4.2	13%	29%	-	-	-
Total	21.0	45%	18%	34.2	63%	9%

Border Crossing Emissions Profile

Idling

The main focus of the emissions data collection was on idling because it is anticipated that this is the mode that can most effectively be addressed with possible emissions reduction strategies. The idling data was collected for nine trucks using the following five test modes.

- Air Conditioning Off – Low Idle (600-700 rpm)
- Air Conditioning Off – High Idle (~1000 rpm)
- Air Conditioning On – Low Idle (600-700 rpm)
- Air Conditioning On – High Idle (~1000 rpm)
- Snap idle test

The first four tests were performed for at least a 15-minute period. The snap idle tests consisted of five consecutive ramps to full throttle from the idle position for a period of five seconds each.

Table 2 shows engine data for each of the nine trucks tested for idling. The table shows that the ages of the trucks range from 1985 to 1998, covering the bulk of the ages identified during the survey shown in Figure 3. Also, note that the miles accumulated are not necessarily in relation to the age of the trucks, indicating that rebuilding of engines might have occurred. This sample of trucks is not intended to be a statistically significant sample, instead it provides a good indication of the emissions impact of trucks crossing the border.

Table 2. Trucks Tested for Idling Emissions.

Truck No.	Year	Vehicle Make	Engine Model	Engine Displacement (L)	Miles Accumulated
1	1998	International	Cummins M11-370E	10.82	712,590
2	1989	International	Cummins 350	14.00	1,720,000
3	1996	International	Cummins 350 BICAM3	14.00	151,848
4	1987	International	Cummins 350	14.00	1,283,536
5	1985	International	Cummins 350	14.00	Unknown
6	1996	Volvo	Cummins M11	10.82	1,118,896
7	1994	International	Detroit Diesel Series 60	12.70	694,878
8	1992	Unknown	Cummins L10	10.02	501,178
9	1998	Dina	Cummins M11 Plus	10.82	1,088,931

In Texas NOx and PM are key pollutants emitted by heavy duty diesel trucks. The results for these two pollutants are discussed in the following sections.

NOx Emissions

Figure 5 shows the accumulated NOx emissions for the various trucks under the various idling modes. Note that EPA's current guidance on extended idling emissions for Class 8 trucks is 135 g/hr (Environmental Protection Agency, 2004). Figure 5 shows that the EPA recommended 135 g/hr is only exceeded by Trucks 7 and 8 and mostly in the high-idle mode. In addition, the range of NOx emissions shown in Figure 5 are also in line (even slightly lower) than results of previous studies that showed a range of 50 to 350 g/hr for more than 40 trucks that were tested under various idling modes (Lambert, 2002a), (Lambert, 2002b).

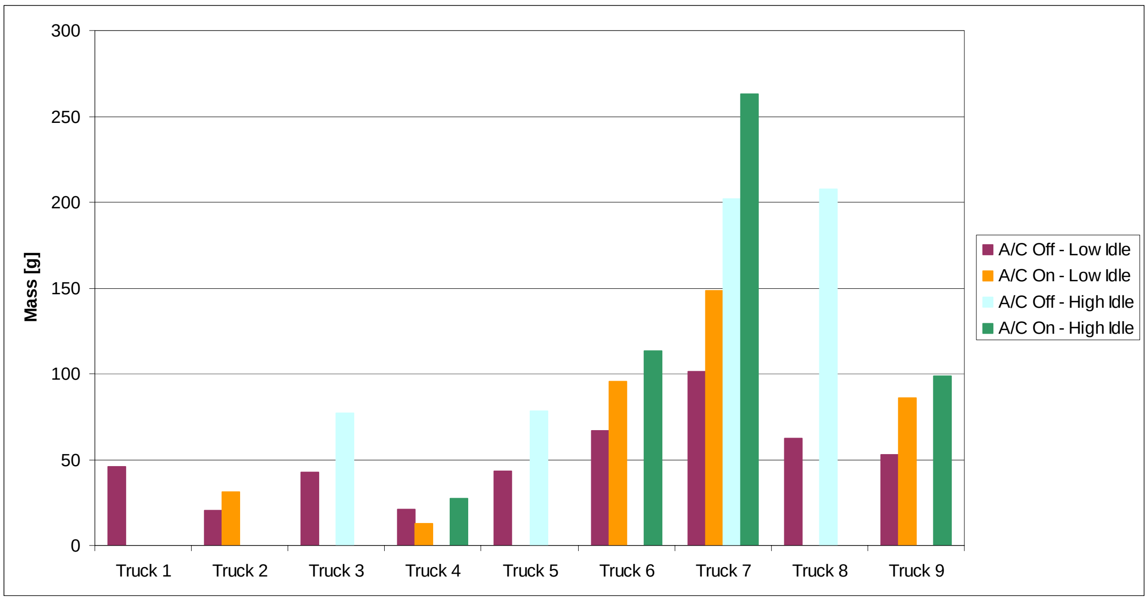

Figure 5. NOx Simulated 1-hour Mass Accumulation (g).

PM Emissions

Figure 6 shows the accumulated PM emissions for the various trucks under the various idling modes. This figure shows that the PM rate ranges from 0.7 to 3.3 g/hr. This rate, based on the TEOM, is typically 30% to 40% lower than what could be measured with a pure filter-based method. The range is also similar to previous studies such as the DOE-EPA idling study performed in Aberdeen, MD that produced a very similar range of values. It can, therefore, be concluded that the trucks from Mexico sampled in El Paso do not have higher PM rates than U.S. trucks tested in Aberdeen (Storey, 2003).

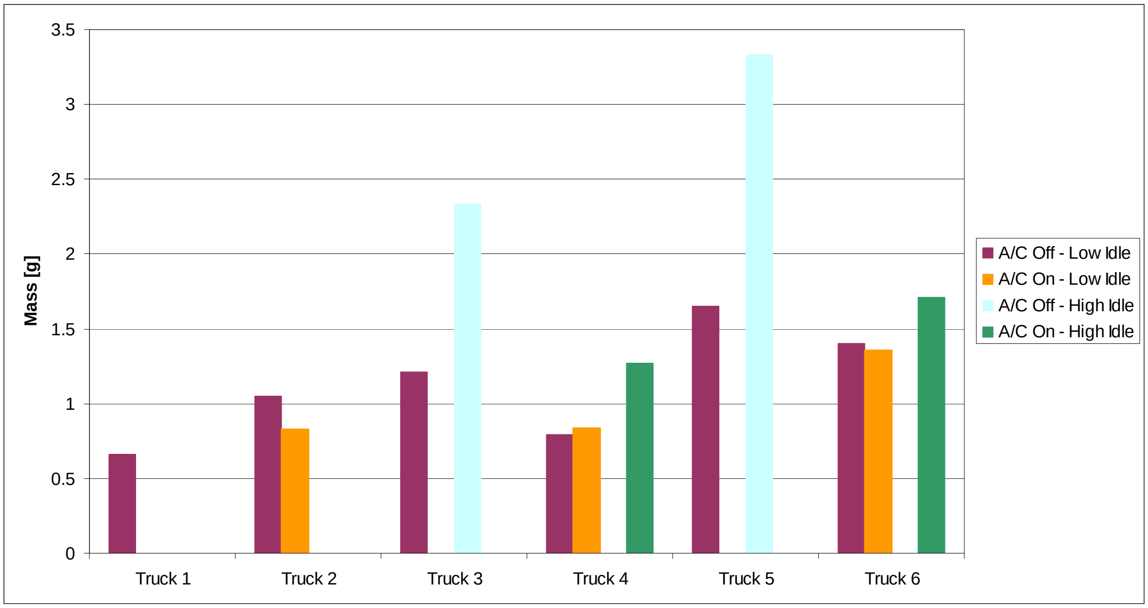

Figure 6. PM Simulated 1-hour Mass Accumulation (g).

Table 3 shows the daily, weekly, monthly, and yearly emissions due to idling and creep idling for the two bridges. It may be seen in Table 3 that the total emissions for Zaragoza is slightly higher than that for BOTA. The reason is because the travel time for Zaragoza is slightly longer. In addition, it may be noticed that the annual emissions are not particularly high as compared with the total on-road mobile source emissions for the El Paso region (less than 1%). However, it should be noted that the approximately 24 tons of NOx and 0.3 tons of PM emissions at the two bridges can be significant for an area such as El Paso wanting to stay in attainment for ozone and

PM. In addition, it should be noted that these emissions are generated in a very small geographic area (two border bridges), resulting in high concentrations of pollutant emissions in these areas.

Table 3. Total Emissions Due to Idling and Creep Idling.

Period	BOTA				Zaragoza			
	NOx	**HC**	**CO**	**PM**	**NOx**	**HC**	**CO**	**PM**
Daily (kg/day)	27.2	3.4	10.6	0.4	38.0	5.0	13.6	0.5
Weekly (kg/week)	190.6	24.1	74.1	2.7	265.7	34.9	95.2	3.8
Monthly (kg/month)	817.0	103.2	317.7	11.6	1138.9	149.4	407.9	16.3
Yearly (ton/year)	9.9	1.3	3.9	0.1	13.9	1.8	5.0	0.2

Crossing Data

In addition to developing idling emissions rates, the research team also investigated the feasibility of collecting truck emissions during actual crossings from Mexico into the U.S. As described earlier, several teams were deployed to handle the logistics of this complicated task.

The study team found that this process was workable, but due to the extremely sensitive nature of the fairly new technology, numerous challenges were encountered. PEMS technology in general is an emerging science and will experience some growing pains before it can be considered fully robust. The fact that no technician was allowed to accompany the equipment resulted in several cases where data was lost due to loss of power or other causes. For example, the extremely hot temperature in El Paso during the end of June, 2005 (sometimes in excess of 105 degrees Fahrenheit) caused the equipment to regularly overheat resulting in data losses. In addition, power losses were caused due to the equipment bouncing around.

Regardless, the study team was still able to collect data for five crossings. For illustration purposes, Figure 7 shows the NOx emissions and speeds for three crossings at BOTA. These plots show that there is some correlation between speed and NOx emissions and that NOx emissions rise considerably with an increase in speed. In addition, the plots show that there is a clear pattern between the different speed profiles, illustrating the importance of developing generic drive cycles that can be used to develop emissions estimation.

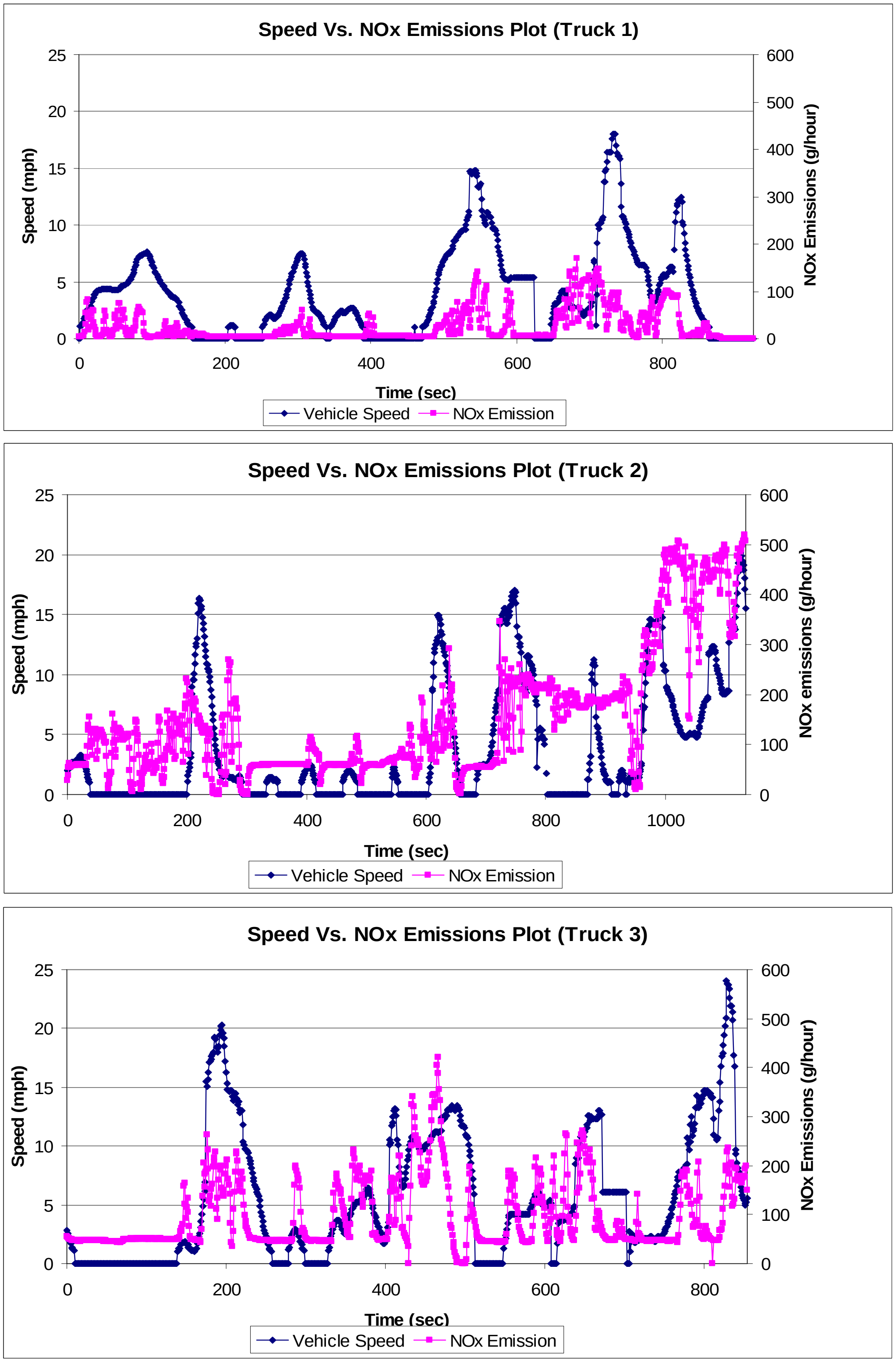

Figure 7. Speed and NOx Emissions for Three Crossings.

CONCLUSIONS

Fleet Profiles

- From the approximately 1,800 trucks that were surveyed on a typical day crossing from Mexico into El Paso at both the BOTA and Zaragoza bridges, 89% were found to Class 8 (tractor-trailer) trucks with 11% being the smaller Class 5 trucks.
- There were 25 different model years (stretching from 1980 to 2005) found during the survey. It was found that more than 20% of the vehicles are more than 15 years old.
- Over 200 different carriers were detected during the survey, although only 16 make up 50% of the total trips.

Travel Profile

- The average crossing time at the Zaragoza Bridge was longer than that for BOTA. During the first section of the trip, that includes the crossing from Mexico into the U.S., the crossing time is a function of the traffic congestion at the bridge. Crossing through the second section of the trip is a function of number of inspections and congestion at inspection stations.
- From the drive cycle samples it was found that vehicles idle or creep idle for more than 60% of the time during the typical border crossing process (50% in Section 1 and 75% while inside the federal compound).

Emissions Profiles

- Nine trucks were tested ranging from 1985 to 1998 with between 150,000 and more than 1.7 miles accumulated. The displacement of the engines ranged from 10 liters to 14 liters. These trucks were subjected to four different idling modes.
- It was found that there is no clear correlation between the age of the trucks and the NOx emissions rates. There is also no clear correlation between the miles accumulated and the NOx emissions rates. Only two of the nine trucks had NOx emission rates higher than the 135 g/hr guidance by the EPA.
- It was found that there is no clear correlation between the age of the trucks and the PM emissions rates. The PM rate tends to increase with the higher engine loads. The PM rate ranges from 0.7 to 3.3 g/hr, which is inline with the results of other studies performed in the U.S. As in the case with NOx, only two trucks exceeded the EPA guidance for PM emissions during long duration idling.
- It was found that approximately 24 tons on NOx and 0.3 tons of PM are produced on an annual basis by trucks idling at BOTA and Zaragoza bridges. These emissions are not particularly high as compared with the total on-road mobile source emissions for the El Paso region (less than 1%). However, it should be noted that these emissions can be significant for an area such as El Paso wanting to stay in attainment for ozone and PM. In addition, it should be noted that these emissions are generated in a very small geographic area (two border bridges), resulting in high concentrations of pollutant emissions in these areas.
- The study team found that it was possible to collect emissions of a truck during actual crossings through the U.S.-Mexico border. However, due to the extensive coordination

effort and the extremely sensitive nature of the fairly new technology, numerous challenges were encountered. Regardless, the study team was still able to collect emissions data for five crossings.

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