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16. Abstract

Air pollutant emissions and fuel consumption are the most important problems associated with vehicle idling. Truck idling in particular is more problematic than other vehicles mainly because of the duration of idling and the high amount of emissions produced. This report is intended to identify the characteristics of truck idling emissions by collecting data using an advanced portable emission measurement system (PEMS), in which the attempt is made to measure actual idling emissions from truck tailpipes and to relate measured emissions to altered pre-testing driving conditions. Employed for the testing is.the On-Board Emission Monitoring system OEM-2100^{TM}, an advanced PEMS. , This equipment can determine the second-by-second emissions of HC, CO, CO$_2$, O$_2$, and NOx in the exhaust gas by a functional equivalent of a repair-grade dual five-gas analyzer subsystem. Altered driving circumstances considered during truck idling tests include cold starts and hot starts, different distances and durations of driving before the tests, different roadway facility types used while driving, different durations of idling tests, etc. Measured emissions under all the different pre-testing driving conditions are then analyzed and compared. In addition, the measured idling emissions are compared with emissions estimated by the emission factor model MOBILE6 for the particular tested truck.

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Testing and Modeling of Truck Emissions While Idling

by

Lei Yu, Fengxiang Qiao, and Fatemeh Soltani

Report SWUTC/06/167650-1

Sponsored by the
Southwest Region University Transportation Center

Center for Transportation Training and Research
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September 2006

ABSTRACT

Air pollutant emissions and fuel consumption are the most important problems associated with vehicle idling. Truck idling in particular is more problematic than other vehicles mainly because of the duration of idling and the high amount of emissions produced. This report is intended to identify the characteristics of truck idling emissions by collecting data using an advanced portable emission measurement system (PEMS), in which the attempt is made to measure actual idling emissions from truck tailpipes and to relate measured emissions to altered pre-testing driving conditions. Employed for the testing is.the On-Board Emission Monitoring system OEM-2100^{TM}, an advanced PEMS. , This equipment can determine the second-by-second emissions of HC, CO, CO_2, O_2, and NOx in the exhaust gas by a functional equivalent of a repair-grade dual five-gas analyzer subsystem. Altered driving circumstances considered during truck idling tests include cold starts and hot starts, different distances and durations of driving before the tests, different roadway facility types used while driving, different durations of idling tests, etc. Measured emissions under all the different pre-testing driving conditions are then analyzed and compared. In addition, the measured idling emissions are compared with emissions estimated by the emission factor model MOBILE6 for the particular tested truck.

EXECUTIVE SUMMARY

Air pollutant emissions and fuel consumption are the most important problems associated with vehicle idling. Truck idling in particular is more problematic, mainly because of the duration of idling and the high amount of emissions produced. Vehicle idling can be done for a short or long period of time. Truck drivers usually practice both or either types of idling; stopping in the rest area for a short period of time and stopping to take a rest after a long drive. Idling associated with light duty vehicles is usually in the short period.

Research conducted in this report analyzed some of the characteristics of truck idling emissions. Major data used for this report were obtained by employing the On-board Emission Monitoring system OEM-2100, an advanced portable emission measurement systems (PEMS) used for testing. In this research, different scenarios for truck idling were considered and discussed. First, data for cold start idling was obtained and analyzed. Second, idling emissions on different days were compared. Third, idling emissions before and after driving and under different driving conditions were compared and contrasted. Fourth, the relationship between emission variables and driving distance was identified. Finally, the relationship between emission variables and driving duration prior to idling tests was discussed. After all the analysis were completed using the data collected by OEM-2100, idling emissions were modeled by the EPA standard model, MOBILE6.2. Then, estimated emissions via MOBILE6.2 were compared with the average emission idling data obtained through OEM-2100. Several conclusions can be drawn based on this research:

In cold start idling, there was a decay of FC, NOx, and CO_2, which lasted for more than 600 seconds before the engine reached its hot stabilized state (for the particular tested truck). Decay time for HC and CO could not be recorded in this research due to the limited data range.

Through the Confidence Interval Analysis done for each test, the amount of errors involved in the data collected by OEM-2100 was very small. Comparison between idling tests before and after driving showed that NOx pollutant values before driving were always lower, while HC and CO values were always higher than those after driving the truck. When the truck was driven on

freeways, the values of FC and CO_2 variables were lower in idling after driving than those before driving. However, when the truck was driven on non-freeway facilities, the results were reversed. Through this case study, therefore, it is illustrated that the facility types used for driving before idling tests affect pollutant production and fuel consumption during idling tests.

By analyzing the relationship between each variable (emissions and fuel consumption) and the driving distance/duration before the idling test, the general effect of these conditions on the emission produced during the post-driving idling test was assessed. It was found that by increasing the driving distance/duration, NOx and CO_2 emission production and fuel consumption decreases, while CO and HC emission production increases during the post-driving idling test.

Emissions tested by OEM-2100 have higher values in comparison with the emissions estimated by MOBILE6.2. OEM is recommended as an important system for collecting real-world emission data to improve the accuracy and applicability of emission estimation methods. In addition, the EPA has confirmed OEM's accuracy. MOBILE6.2 estimates are based on the average laboratory tests' results; therefore, in this research (testing one type of vehicle), emissions tested by OEM-2100 should reflect more real situations of emissions in idling. Further tests and comparisons should be conducted before more general conclusions can be reached.

To further identify general conclusions, the authors provide the following recommendations:

1. Test more trucks with cold start engine in order to determine, more accurately, the amount of time that it takes for the engine to reach its hot stabilized condition.
2. Test more trucks of different ages to address the findings of this case study.
3. Test trucks under different weather conditions to reflect effects on emissions production.
4. Use the findings from this research and tested vehicles at signalized intersections for the purpose of signal timing, which results in reduced vehicle emissions and improved air quality.

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DISCLAIMER

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CHAPTER 1: INTRODUCTION

1.1 Background

Air pollutant emissions and fuel consumption are the most important problems associated with vehicle idling. Truck idling in particular is more problematic, mainly because of the duration of idling and the high amount of emissions produced. Vehicle idling can be done for a short or long period of time. Truck drivers usually practice both or either types of idling; stopping in the rest area for a short period of time and stopping to take a rest after a long drive. Idling associated with light duty vehicles is usually in the short period.

Idling can be discretionary or non-discretionary. Discretionary idling happens only when the driver chooses to stop and idle, for example, when waiting in front of a convenience store to pickup another person. Alternatively, non-discretionary idling occurs throughout normal driving, for example, when waiting at a traffic signal, being stuck in traffic, or waiting for a train to cross (Zietsman and Perkinson, 2003).

Various problems associated with engine idling include pollutant emissions, noise pollution, driver discomfort, and unnecessary fuel and maintenance costs. Pollutant emissions recognized as diesel idling include carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM), oxides of nitrogen (NOx), and hydrocarbon (HC) (Perrot, et al., 2004).

Idling of long-haul trucks is a common practice in the Unites States. Freight haul drivers usually idle their engines for climate control while resting from long distance runs, and to maintain vehicle battery charge while using electrical appliances such as televisions and microwaves. In cold weather, idling keeps fuel and engine oil warm in order to prevent engine starting and operating problems. According to a study conducted by Argonne National Laboratory (ANL) (2000), an average sleeper cab tractor idles for 1,830 hours annually and consumes approximately one gallon of diesel fuel per hour. This type of idling can be reduced by utilizing several techniques such as direct-fired heaters, auxiliary power units (APUs), automatic engine idle systems, truck stop electrification (TSE), and advanced TSE (FHWA, 2003).

The focus of this research is on short-period idling. Short-period idling can be divided into two different scenarios, cold idling and hot idling. Cold idling refers to the idling time before driving the vehicle and includes the cold start mode of vehicle operation in which the vehicle typically emits higher pollutants and consumes more fuel compared with the hot start mode (Rakha et al., 2003). Hot idling refers to idling time after driving the vehicle. Results of this study could be used to improve mobile source emission inventories and motor vehicle emission budgets, to enforce the anti-idling regulations in many states even for idling in a short period of time, and as a result of that, to improve air quality.

Vehicle idling at a signalized intersection is defined as idling in a short period of time. Although this kind of idling cannot be prevented, the duration of idling at the signalized intersection can be reduced with signal timing improvements. Results of this study might be used for the purpose of signal timing improvement.

1.2 Research Objectives

The goal of this research is to identify the characteristics of emissions produced by trucks while idling at parking stations under different conditions. For this purpose, data from four different scenarios of idling are analyzed as follows:

1. Identifying the characteristics of emissions in the cold start mode,
2. Identifying emissions and fuel consumption in idling before and after driving the vehicle,
3. Studying such important factors as used roadway facility, driving time, and driving distance which affect the emissions produced during the idling time, and
4. Comparing the data collected by OEM-2100 with the EPA standard model-MOBILE6.2.

1.3 Outline of Report

- Chapter 2 - literature review of the state-of-the-art/practice.
- Chapter - design of study for the research.
- Chapter 4 - analysis of the data
  - -results of emission analysis
  - -modeling of the emissions by EPA emission estimation model MOBILE6.2
  - -comparison between collected emissions and estimated emissions
- Chapter 5 -conclusions of the research

CHAPTER 2: LITERATURE REVIEW

This chapter explores the state-of-the-art/practice of the research in this report. . Available literature related to the research includes vehicle idling emission, vehicle idling emission at signalized intersections, On-Board Emission Measurement system, and emission estimation models.

2.1 Vehicle Idling Emission

Throughout the United States, it is customary for freight haulers to idle the engines of their heavy-duty trucks for climate control (heating and cooling) and other reasons, while they are sleeping or resting on long distance runs. Although 15 states now have anti-idling regulations, it is estimated that diesel truck and bus idling consume 600 million gallons of fuel and produces significant levels of emissions every year (Department of Energy, 2001). Another survey estimates that the average idling duration for trucks is about six hours per day and about 1,700 hours per truck per year. On average, these trucks consume about 1,600 gallons per year for idling (Lutsey, et al., 2004). Continuous idling of heavy-duty diesel truck engines for cab space cooling and heating is costly to truck owners and operators, both in terms of fuel use and engine wear. Unnecessary idling is also wasteful of our nation's energy supply and damaging to our environment. Reduction of idling can help meet multiple goals including energy conservation and environmental protection (FHWA, 2003).

Emissions and fuel consumption during truck idling vary based on engine year, accessory loading, and engine speed. Limited evidence suggests that idling emissions may be affected by idling duration and vehicle operation prior to idling (Brodrick, et al., 2001). Extended idling causes the engine and exhaust temperature to drop and the amount of incompletely combusted fuel to increase, leading to the dilution of engine oil with fuel and to the excess of engine wear (Vojtisek-Lom, 2002). Recent emissions studies also show that extended diesel engine idling elevates PM, HC and CO emissions during operation following a period of idling (Vojtisek-Lom and Wilson, 2003; Yu, et. al., 2006). Another study conducted by Clean Air Technologies Inc.

suggests that making a heavy-duty diesel (HDD) vehicle stop and re-accelerate is likely to create excess PM emissions (Vojtisek-Lom, 2004). This study also suggests that extended HDD idling produces more PM per unit of time than short idling and reduces the efficiency of exhaust after-treatment devices.

Variations of the different pollutants in idling do not follow the same pattern. NOx and CO_2 show some dynamics variation during the first few hours of idling until they reach their steady states. It is observed that it takes about three hours of idling for the emissions to reach their steady state conditions (Lim, 2002).

During cold start operation, incomplete combustion occurs in the engine because the efficiency is lower due to low temperature. As a result, hydrocarbons (HC) and carbon monoxide (CO) emissions are significantly higher during cold start engine operation due to low air-to-fuel ratios and poor performance of cold catalytic converters. On the other hand, the cold start results in lesser increases in oxides of nitrogen (NOx) emissions compared to the HC and CO emissions (Wayson, et al., 1998). Some studies suggest that importance of cold start emissions may be overstated, because the cold-start period was estimated to last for about 200 seconds (Rakha, et al., 2003; Singer, et al., 1999).

However, a recent study on short-period idling and restarts in light duty gasoline vehicles by Zietsman, et al. (2005) shows that emissions accumulated due to cold starts are significantly greater (as much as 15 times greater for NOx, 3 times greater for VOC, and 2 times greater for CO) than what is achieved in restarts after hot soaks. These authors have also found that there is no clearly defined preferred option between short-period idling and restarts in light duty vehicles. In the case of NOx emissions, the idling option is preferable because it results in almost zero emissions, whereas, restarts consistently produce higher emissions. In the case of VOC and CO emissions, restarts produce fewer emissions than idling.

2.2 Vehicle Idling Emission at Signalized Intersections

Understanding the relation between vehicle emissions and traffic control measures is an important step toward reducing the potential for global warming, smog, ozone depletion, and respiratory illness (Rouphail et al., 2003). Highway vehicles contribute substantially to national and local emissions of CO, HC, NOx, and PM (EPA, 2001; National Research Council, 2000). As explained earlier, stopping at signalized intersections is defined as idling in a short period of time. Traffic signal timing improvement is the most widespread congestion management practice in the United States (Guensler, 2000; Hallmark, et al., 2000). Signal timing improvements can include simple changes in timing plans or complex computer-controlled signal coordination along an entire corridor (Unal, et al., 2003). As a result of effective signal timing improvement, congestion is reduced, safety is increased, and the amount of emissions released to the air is also reduced.

In a study conducted in Atlanta, significant reduction in CO emissions was observed when the traffic signals were coordinated (Hallmark, et al., 2000). Another study suggests that acceleration produces the highest emission rate, whereas idling produces a lower rate (Unal, et al., 2003). Therefore, efforts aimed only at reducing stop time may not always be successful in achieving overall reductions in air pollution emissions. This study also suggests that coordinated signal timing improves traffic flow, which leads to reduction in vehicle emissions and moderate improvements in Level of Service (LOS).

2.3 Emission Testing and Data Collection Methods

Existing emission collection techniques include: in-laboratory emission testing, remote emission sensing technique, and on-board emission monitoring system. Different emission collection techniques have different pros and cons.

In laboratory, data is collected by using dynamometer and a sophisticated bank of scientific equipment under controlled testing conditions. Laboratories are expensive to run and the data collected typically do not provide accurate real world information. Moreover, vehicles testing in a traditional laboratory setting do not factor in the effects of aggressive driving, high-speed operation, highly transient operation (full-throttle or leapfrog acceleration), air conditioning use, local road, traffic, and climatic conditions (Qiao and Yu, 2005).

The advanced infrared Remote Emission Sensor (RES) collects on-road vehicle exhaust emissions economically and conveniently. Although RES was proven to be useful in screening for the High Emitter Vehicles (HEV) on the road (Bishop et al, 1994; Sorbe, 1995; and Jack, et al., 1995), there are many advantages using RES in emission model evaluation and emission model development (Yu, 1998). This is because the emission data collected by RES will naturally reflect the on-road vehicle fleet combinations and current vehicular technologies. It is also inexpensive and easy to use compared with the in-laboratory emission testing.

On-Board Emission Monitoring system (OEM-2100), manufactured by Clean Air Technologies Inc., is one kind of the Portable Emission Monitoring System (PEMS) that has been used in this report. The OEM-2100 System is designed to measure vehicle mass exhaust emissions under actual on-road driving conditions using vehicle and engine operating data and concentrations of pollutants in exhaust gas sampled from the tailpipe. The OEM-2100 system is typically placed in the passenger seat or on the vehicle floor and records second-by-second emissions, fuel consumption, vehicle speed, engine rpm and temperature, throttle position, and other parameters (OEM-2100 Manual, 2003). Figure 1 shows two examples of system installations (OEM-2100).

Figure 1. Examples of OEM-2100 Installation Locations.

The system is comprised of a five-gas analyzer, an engine diagnostic scanner, and an on-board computer. Second-by-second mass exhaust emission concentrations of HC, CO, CO_2, NOx, and PM for diesel engine vehicles, and NOx, HC, CO, CO_2, and O_2 for gasoline-powered vehicles are measured by the five gas analyzer. The second-by-second exhaust mass flow is calculated based on the intake air mass flow, known composition of intake air, measured composition of exhaust, and user-supplied composition of fuel. Multiplying the exhaust mass flow by the concentrations of different pollutants yields grams-per-second emission data. This calculation is proprietary, but generally involves a mass balance equation, whereby the matter coming into the engine must equal the matter coming out of the engine (OEM-2100 Manual, 2003; and Vojtisek-Lom & Allsop, 2001). The engine scanner also downloads second-by-second engine and vehicle data from the On-Board Diagnostics (OBD) link of the vehicle. This data includes the engine's RPM and speed. Acceleration is also estimated by the instrument based on the vehicle's speed (Stodolsky, et al., 2000).

It is important to mention the function of "Bag Control." In many cases, it is desired to delineate tests into a set of time periods. The OEM-2100 allows the instrument operator to tag the data output file for particular tests, and to create summary reports for each test. The system has adopted the term "bag" for these tests-a name borrowed from the traditional laboratory setting, where the exhaust sample from each test segment is collected in a separate physical bag, and later analyzed to obtain the amount of emissions per test segment. While there is no real exhaust sample stored in the OEM-2100 system, the software integrates the distance, fuel use and emissions over the duration of each "bag," and reports this summary at the end of the test and in the output file (Qiao and Yu, 2005).

The precision and accuracy of the OEM-2100 was tested by the New York Department of Environmental Conservation (NYDEC) and at the U.S. EPA's National Fuels and Vehicle Emissions Laboratory in Ann Arbor, Michigan. Three light-duty gasoline vehicles, 1997 Oldsmobile Sedan, 1998 Plymouth Breeze and 1997 Chevy Blazer, were tested by NYDEC using the I/M 240 and NYCC driving cycles. Two light-duty vehicles, a Mercury Grand Marquis and a Dodge full size pickup truck were tested by EPA using the FTP, US06, NYCC, and FWY-HI driving cycles at Ann Arbor. The emissions were measured simultaneously by the dynamometer equipment and by the OEM-2100. OEM-2100 has good precision, as reflected in R^2 values compared to the dynamometer of 0.90 to 0.99. The standard error was less than ten percent of the mean emissions for all of the pollutants except for the comparison of OEM-2100 hydrocarbon measurements with Flame Ionization Detector (FID) measurements, which had a standard error of 24 percent of mean emissions. Test results have shown that OEM-2100 has good precision particularly for NOx and CO_2 pollutants (Clean Air Technology Inc. and Frey, 2003).

2.4 Emission Estimation Models

Over the past few decades, numerous emission models have been developed for estimating mobile source emissions, which include the U.S. Environmental Protection Agency (EPA) emission factor model MOBILE which is used in all states except California; EMFAC for the state of California; Comprehensive Modal Emission Models, CMEM; traffic-Simulation-Based Emission Models such as INTEGRATION and CORSIM; and numerous other microscopic emission models (Yu, et al., 2004).

MOBILE is a computer model, developed by the United States Environmental Protection Agency (EPA) to predict emissions for regional mobile source emissions in all the states of the U.S. except California where the state uses EMFAC model mandated by the California Air Resources Board (CARB). MOBILE is designed to estimate aggregated regional emissions. Estimated emission factors from MOBILE include volatile organic compound (VOC), carbon monoxide (CO), and oxide of nitrogen (NOx) that are estimated on different speed values. First developed in 1978, the MOBILE model has been updated several times to cover and reflect new emission regulations and modeling needs. Some updates were made in 1996 with the release of MOBILE5b. But, MOBILE6 is the first version with major revision released in January 2002. The ability to estimate a number of exhaust particulates and related pollutants, hazardous air pollutants (HAPs) and carbon dioxide (CO_2) has been added to the expanded versions of MOBILE6, called MOBILE6.1/6.2 (EPA- MOBILE6.2 Manual, 2003).

In the newest version, MOBILE6.2, emission rates for a particular pollutant are given in grams per mile for a given average speed. Unit grams per mile can be converted into different units, such as grams per second, based on a given speed for comparison purposes. MOBILE6.2 cannot estimate idling emissions directly; however, laboratory tests have shown that emissions produced in idling are similar to emissions produced when the vehicle is driven at the speed of 2.5 mph. Thus, to estimate emissions in the idling mode, MOBILE6.2 can be employed as a vehicle running at the speed of 2.5 mph (EPA-MOBILE6.2 Manual, 2003).

2.5 Summary

Truck idling contributes significantly to both energy consumption and air emissions. Truck idling emission is a complicated phenomenon that must be considered independently of the other mobile emissions. Recently, EPA and other organizations and institutions have examined idling for brief periods of time, and also for long-duration idling emissions on diverse groups of heavy-duty trucks under various engine speeds, ambient temperatures, and accessory loads. Even so, the operation of engine idling before driving and after different driving conditions has not been fully examined. This research attempts to measure actual idling emissions from truck tailpipes and relate the measured emissions with the altered pre-testing driving conditions. The OEM-2100 is employed for testing of emissions. This instrument has a good accuracy that is tested by EPA, Ann Arbor, and Clean Air Technologies Inc. At last, the MOBILE6.2 emission estimation model, which is the EPA modal standard, is chosen for the purpose of data comparison with the measured emissions.

CHAPTER 3: DESIGN OF THE STUDY

This chapter describes the design of the study. The design of study includes data collection, emission data analysis, emission estimation by MOBILE6.2 and comparison of the emissions measured by OEM-2100 with the estimated emissions by MOBILE6.2.

3.1 Data Collection

On-Board Emission Monitoring system (OEM-2100) was used in this study to collect the data for truck idling. While collecting data, three different scenarios have been considered, (i) cold start engine, (ii) idling before driving the truck, and (iii) idling after driving the truck. The general process in collecting the emission data follows this order:

1. Equipping the test vehicle with the OEM-2100 system,
2. Starting and idling the truck for about 30 minutes,
3. Driving the truck to different roadway facilities, “freeway and non-freeway,” for at least 45 minutes,
4. Idling the vehicle for about 15 to 30 minutes after driving, and
5. Repeating the last two steps.

Collecting data for the first scenario, the cold start engine, should be done after a 12-hour soak period. Soak Period is defined as the duration of time in which the vehicle's engine is not operating before preceding a successful vehicle start. An engine start with a soak time exceeding 12 hours is referred to as a cold start, while a start with a shorter soak time is called a hot start (EPA- MOBILE6.2 Manual, 2003).

Data collected for the truck includes fuel consumption, HC, CO, CO_2, NOx, and PM in terms of grams per second. In addition, engine RPM and vehicle activity data such as speed and acceleration are recorded. It should be noted that in this study the emission data collected during the driving period is not considered.

3.2 Emission Data Analysis

Idling emission analysis includes analysis of cold start engine emissions, comparison of idling emissions for different days, comparison of idling emissions before and after driving, and the relationship between emission variables and driving distance, duration of driving, and roadway facilities used prior to the idling test. In order to observe the characteristics of different emission factors during the cold start idling, the temporal variation distribution of each emission factor versus time is drawn on the chart. In order to show the results on the chart, Microsoft Excel is used in this analysis.

Emissions produced while idling before driving and after driving are also compared to identify the effects of driving on emissions. Another analysis is to find out the effects of driving distance, duration of driving and roadway facilities used prior to the idling test on the emissions produced during the idling time after driving.

3.3 Emission Estimation by MOBILE6.2

The emissions tested by OEM-2100 are compared with the EPA approved emission estimation model MOBILE6.2. Unlike OEM-2100 that measures the second-by-second real time emissions, MOBILE6.2 is a macroscopic emission estimation model, which estimates the average emissions produced by a particular vehicle type.

As explained earlier, MOBILE6.2 cannot estimate the emissions caused by idling directly. Therefore, for this case study, the vehicle has been modeled as being driven with the speed of 2.5 mph. MOBILE6.2 input files have been modeled based on the condition of the tests. Default input files such as Speed VMT, Hourly VMT, and mix VMT have also been changed in special test conditions.

Compared emission factors from MOBILE6.2 are HC (VOC), CO, and NOx, while PM and CO_2 are not included since they are not shown in the MOBILE6.2 general output. At last, the final emission results from two different methods will be compared and contrasted.

CHAPTER 4: RESULTS AND ANALYSIS

This chapter presents the results and analysis of the research. They include the process of emission data collection by OEM-2100, emission data analysis, emission estimation by MOBILE6.2, and, finally, the comparison between the data collected by OEM-2100 and the data estimated by MOBILE6.2.

4.1 Data Collection

This section is dedicated to explaining the data collection process. While collecting data, three different modes were considered, (i) cold start engine, (ii) idling before driving the truck, and (iii) idling after driving the truck. The test vehicle was a 2004 International truck with a 7200-cc engine displacement and with almost 1000 miles mileage. Tests were carried on during six days in March 2004 in Houston, Texas. Each day, the test process was as follows: (i) equipping the test vehicle with the OEM-2100 system, (ii) starting and idling the truck for about 30 minutes, (iii) driving the truck to different roadway facilities for at least 45 minutes, (iv) idling the vehicle for about 20 to 30 minutes after driving the truck, and (v) repeating the last two steps.

Data collected by OEM was summarized in a tab-delimited format in the "emissions" file and then converted to a spreadsheet format, Microsoft Excel. As clarified in the previous chapters, the collected data includes fuel consumption, HC, CO, CO_2, NOx, and PM in terms of grams per second. In this study, it should be noted that the emission data collected during the driving period was not considered, neither was the PM emission due to the problem associated with the PM sensor.

4.2 Analysis of Data Collected Through Real-Time Emission Test

This section includes analysis of cold start engine emissions, comparison of idling emissions for different days, comparison of idling emissions before and after driving, the relationship between emission variables and driving distance, and the relationship between emission variables and driving duration prior to idling test.

4.2.1 Cold Start Engine Emission

Cold start emission data was collected on March 31, 2004. Due to the difficulties during the installation of the OEM system with the cold start engine, this was the only date that the cold start engine was tested. As clarified earlier, the cold start engine refers to the engine start after a 12-hour soak period. Figures 2 to 6 show the characteristics of cold start engine for fuel consumption (FC) and emissions produced versus time.

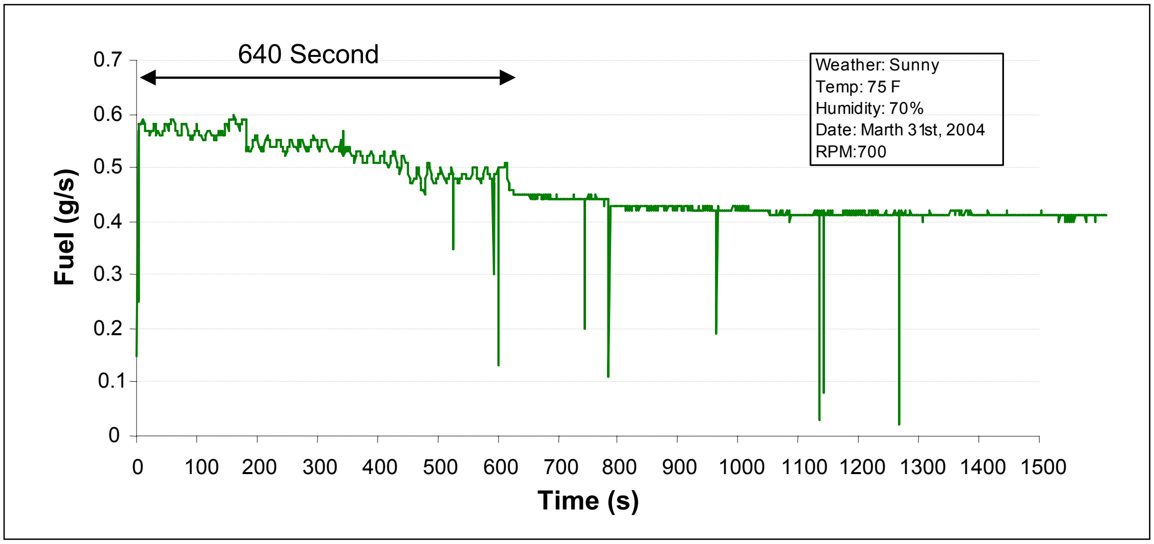


Figure 2. Temporal Variation of FC versus Time in Cold Start Engine.

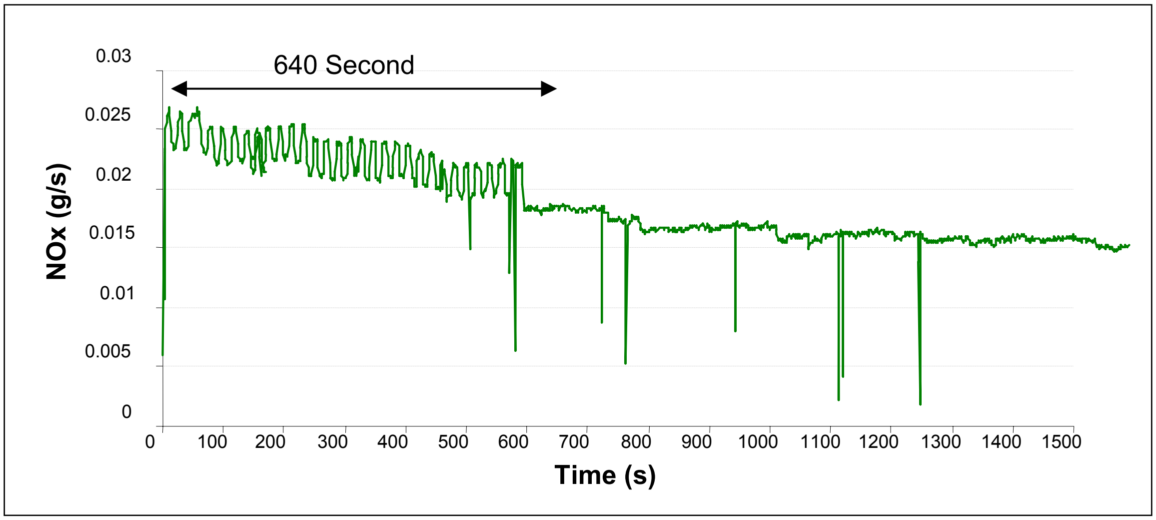


Figure 3. Temporal Variation of NO_X Emission versus Time in Cold Start Engine.

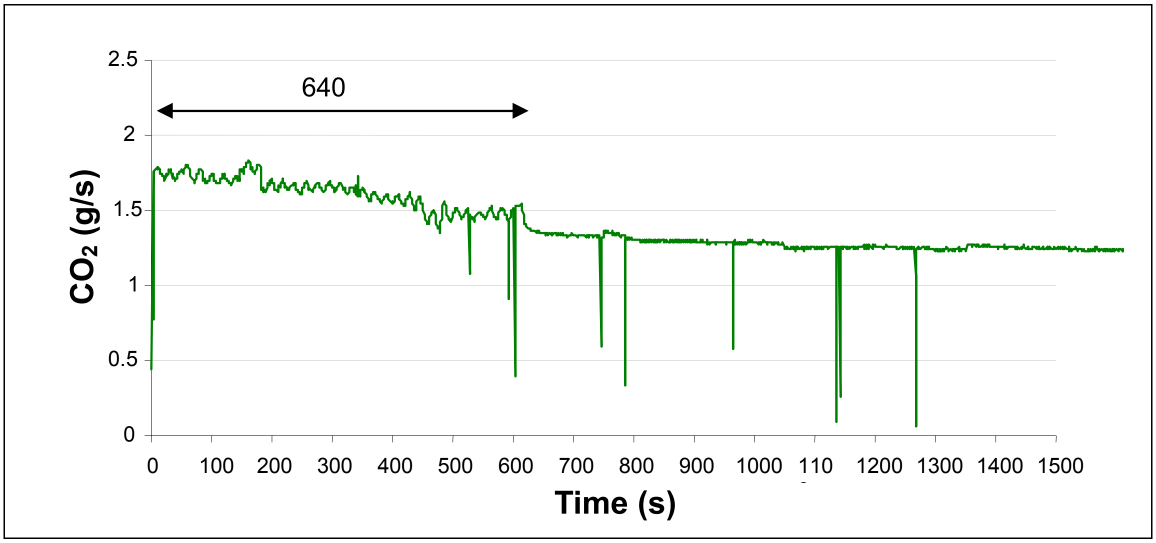


Figure 4. Temporal Variation of CO_2 Emission versus Time in Cold Start Engine.

As shown in Figures 2 to 6, the temporal variation for FC and emissions caused by cold start engine diminishes by the time the engine attains hot stabilized condition. Figures 2 to 4 show that the general patterns of FC, NOx, and CO_2 graphs are similar, while the temporal variation of these three variables diminishes. These figures demonstrate that the time needed for the engine to reach the hot stabilized condition is about 640 seconds. Obviously, the truck produces higher emissions during the temporal cold start engine.

Based on Figure 5, the temporal variation of HC emission in cold start tends to be stabilized through time. However,due to the limitation of data, the time interval needed for the temporal variation to be stabilized cannot be identified through Figure 5. Also, as for the CO emission showed in Figure 6, it is not clear when its temporal variation in cold start is stabilized. No attenuation trends can be identified.

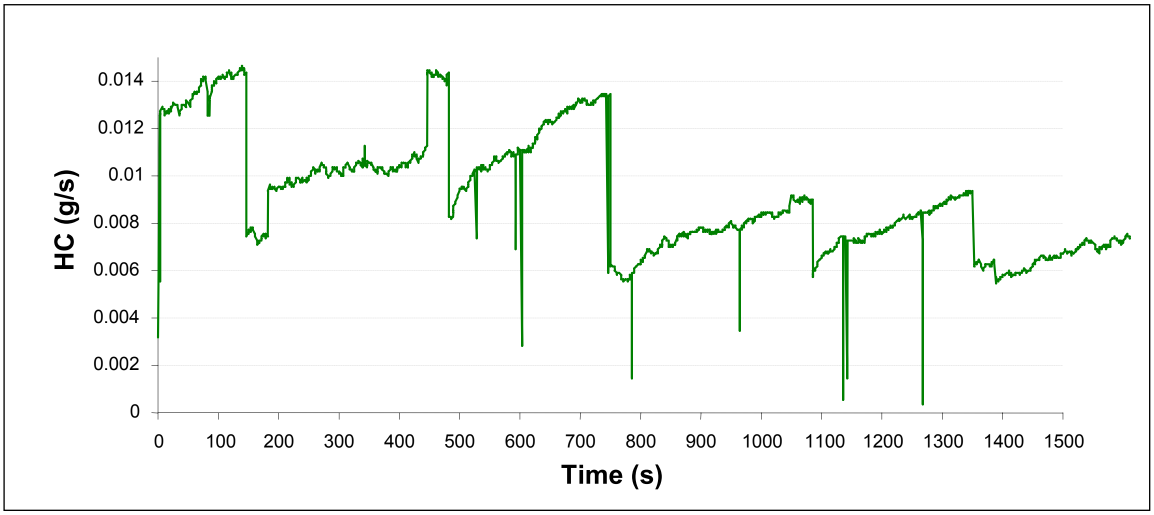


Figure 5. Temporal Variation of HC Emission versus Time in Cold Start Engine.

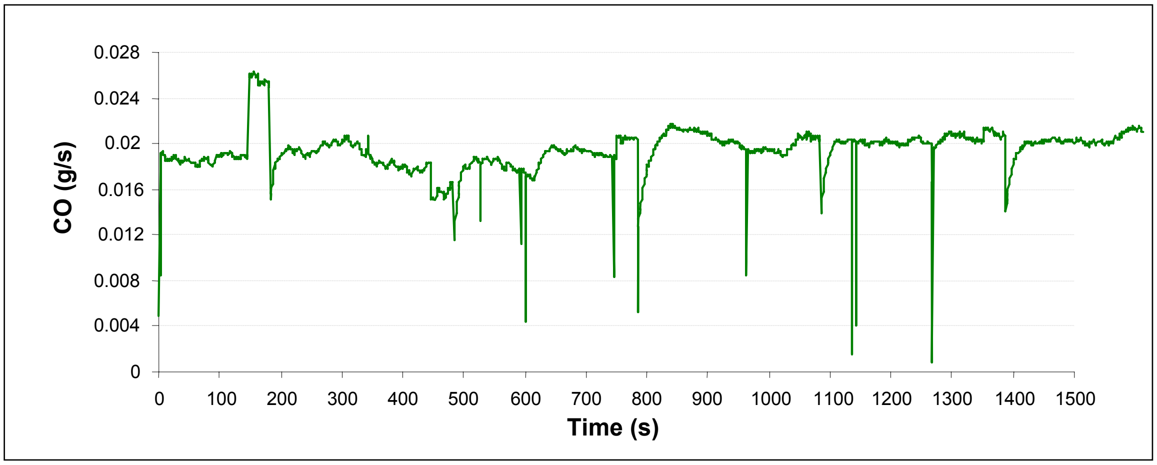


Figure 6. Temporal Variation of CO Emission versus Time in Cold Start Engine.

4.2.2 Comparison of Idling Emission for Different Days

For the purpose of comparing the emission factors in different idling tests and identifying the amount of errors associated with each test, the Confidence Interval Analysis was utilized. Average emission factors and confidence interval for each idling test has been calculated and compared in Table 1 and Table 2.

Confidence Interval gives a statistical estimate of the amount of errors involved in data. The Confidence level chosen is 95 %. The confidence interval is calculated by:

$$\bar{x} \pm k_{\alpha}(\frac{\sigma}{\sqrt{n}}) \tag{1}$$

Where: $\bar{x}$ is the average value of variable, K_{α} is the percentile of the Normal distribution variation at the cumulative probability level $\alpha/2$ and $(1-\alpha/2)$. K_{α} is 1.96 if the confidence level α is chosen as 0.05, σ is the standard deviation, and n is the size of samples.

Due to the large amount of data, confidence intervals in Table 1 and Table 2 were calculated by using Microsoft Excel functions. Based on these tables, the difference between the upper limit and the lower limit in each confidence interval is very small; consequently, the amount of errors is considered very small. FC and emissions for different days are quite different, meaning that other factors might be in effect, one of which is whether the truck has been driving before idling tests and, if so, for how long. Therefore, it would be interesting to compare the idling emissions before and after driving, and also to examine the relationships between the driving distance/duration and the emissions afterwards.

Table 1. Confidence Intervals for Emissions and FC in Idling Tests Before Driving

	Idling Emissions before Driving (g/s)				
Test Date	Fuel	NO_x	HC	CO	CO_2
March 25	**0.38949 ± 0.00064**	**0.01158 ± 0.00003**	**0.00416 ± 0.00004**	**0.01419 ± 0.00015**	**1.19865 ± 0.00168**
March 26	**0.41069 ± 0.00242**	**0.01068 ± 0.00008**	**0.00516 ± 0.00003**	**0.01801 ± 0.00008**	**1.25759 ± 0.00731**
March 28	**0.40447 ± 0.00209**	**0.01046 ± 0.00005**	**0.00829 ± 0.00013**	**0.01847 ± 0.00013**	**1.22766 ± 0.00580**
March 29	**0.37465 ± 0.00037**	**0.00908 ± 0.00002**	**0.00616 ± 0.00005**	**0.02099 ± 0.00011**	**1.13411 ± 0.00143**
March 30	**0.40657 ± 0.00587**	**0.01401 ± 0.00020**	**0.00705 ± 0.00031**	**0.01940 ± 0.00038**	**1.23611 ± 0.01767**
March 31	**0.41370 ± 0.00216**	**0.01483 ± 0.00009**	**0.00728 ± 0.00011**	**0.01955 ± 0.00010**	**1.25759 ± 0.00665**

Table 2. Confidence Intervals for Emissions and FC in Idling Tests After Driving

	Idling Emissions after Driving (g/s)				
Test Date	Fuel	NO_x	HC	CO	CO_2
March 25	**0.44077 ± 0.00109**	**0.01349 ± 0.00003**	**0.00306 ± 0.00002**	**0.01160 ± 0.00006**	**1.36703 ± 0.00335**
March 26	**0.44478 ± 0.00106**	**0.01363 ± 0.00106**	**0.00300 ± 0.00002**	**0.01138 ± 0.00004**	**1.38266 ± 0.00321**
March 28	**0.38012 ± 0.00423**	**0.01184 ± 0.00012**	**0.00412 ± 0.00005**	**0.01314 ± 0.00019**	**1.17054 ± 0.01291**
March 29	**0.36545 ± 0.00144**	**0.01058 ± 0.00004**	**0.00358 ± 0.00004**	**0.01856 ± 0.00019**	**1.11838 ± 0.00383**
March 30	**0.40043 ± 0.00247**	**0.01443 ± 0.00009**	**0.00552 ± 0.00006**	**0.01601 ± 0.00014**	**1.22627 ± 0.00751**
March 31	**0.43502 ± 0.00468**	**0.01793 ± 0.00022**	**0.00367 ± 0.00004**	**0.01184 ± 0.00018**	**1.34659 ± 0.01496**

4.2.3 Comparison of Idling Emissions Before and After Driving

In this section, idling emissions, before and after driving the truck, are compared and analyzed. Through the trial and error analysis before presenting this section, it has been found that the roadway facility type used for driving prior to each test affects the emission production and fuel consumption during the idling thereafter. As a result, the 6-day testing period was divided into two categories. The first category includes the days 25th, 26th and 31st of March, and the second category includes the days 28th 29th, and 30th of March. The difference between these two categories is the testing manner. On March 25, 26, and 31, after the first idling (before driving), the truck was driven on non-freeways, and after the second idling it was driven on freeways. On March 26, 29, and 30, after the first idling (before driving), the truck was driven on freeways, and after the second idling,it was driven on non-freeways.

4.2.4 Comparison of Emissions for the Days 25th, 26th, and 31st

Figures 7 to 11 illustrate the comparison of idling emission factors and FC before and after driving the truck for the days 25th, 26th, and 31st, using the same testing method. The height of each bar represents the average values of the variables in the test. As shown in these figures, different days have different numbers of idling tests. The first bar in each day represents the idling test before driving the truck; the second bar represents the idling test after driving the truck on non-freeways (NF); and the third bar represents the idling tests after driving the truck on freeways (F).

Based on the idling conditions explained for Figures 7 to 11, several conclusions can be derived for each variable during the idling tests:

1. FC, and CO_2 values before driving the truck are lower than those after driving on non-freeways.
2. FC and CO_2 values after driving on freeways are lower than those after driving on non-freeways.
3. NOx values before driving the truck are always lower than those after driving.

4. NOx values after driving on non-freeways are higher than those after driving on freeways.
5. HC values before driving the truck are higher than those after driving.
6. CO values before driving the truck are higher than those after driving.
7. CO values after driving on freeway are higher than those after driving on non-freeways.

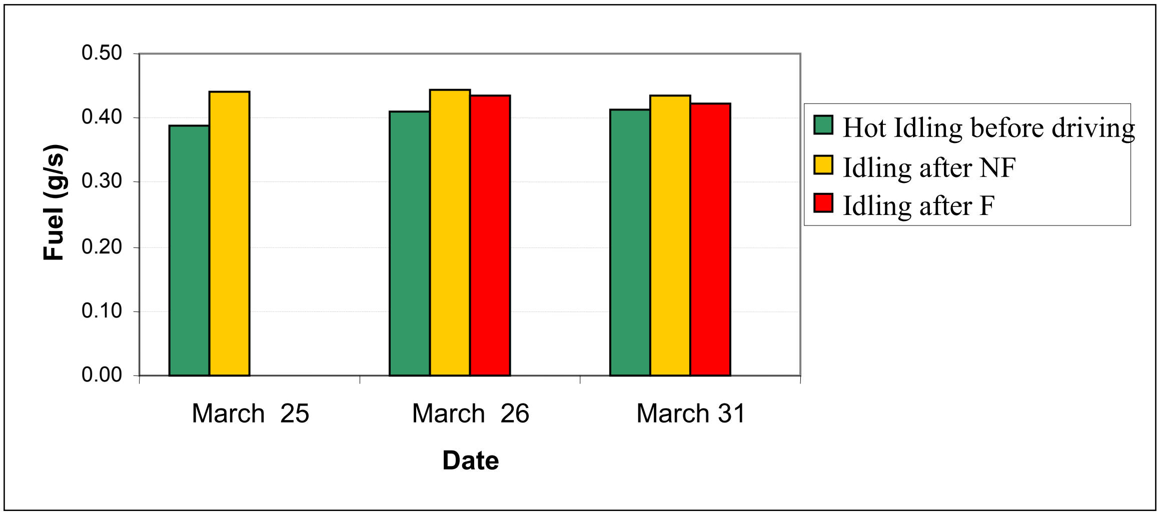


Figure 7. Comparison of Fuel Consumption in Idling Before and After Driving.

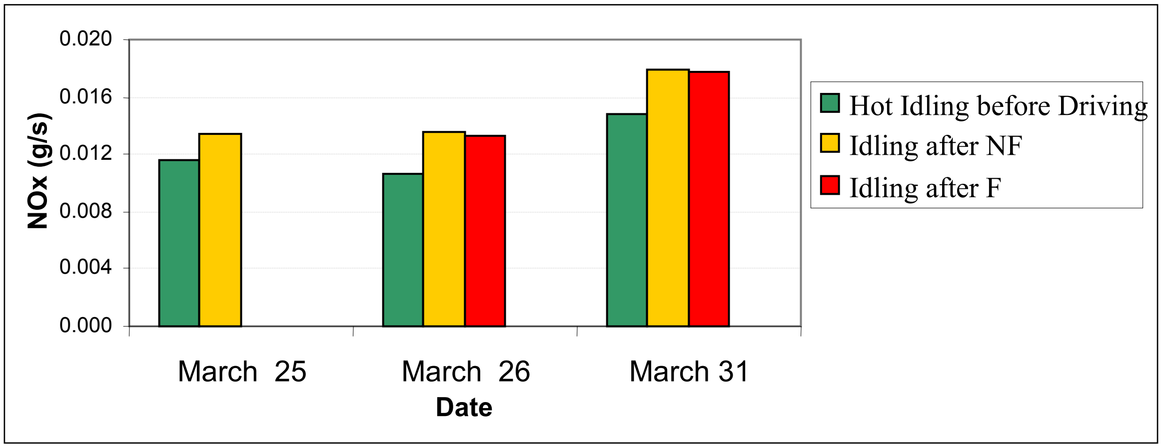


Figure 8. Comparison of NOX Emission in Idling Before and After Driving.

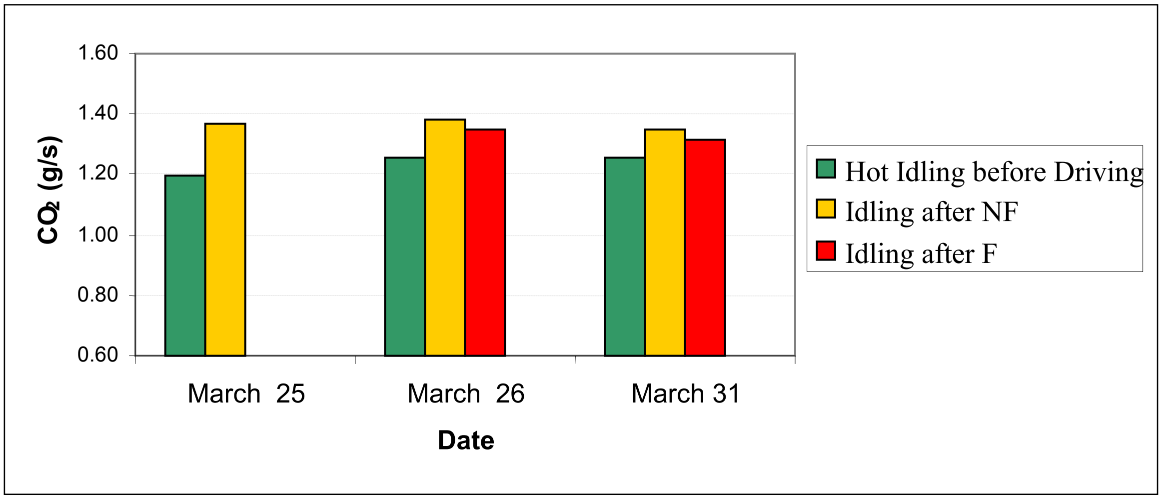


Figure 9. Comparison of CO_2 Emission in Idling Before and After Driving.

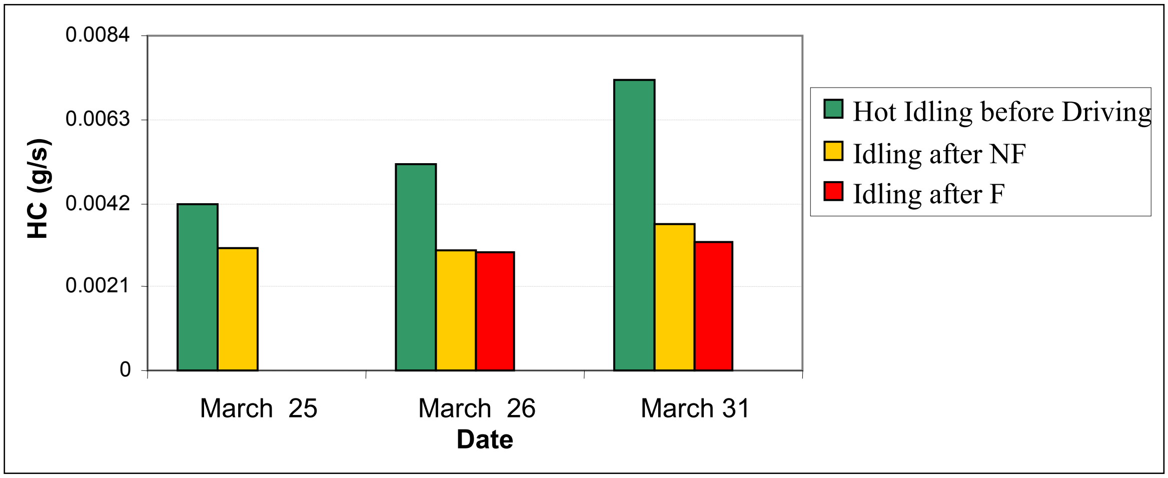


Figure 10. Comparison of HC Emission in Idling Before and After Driving.

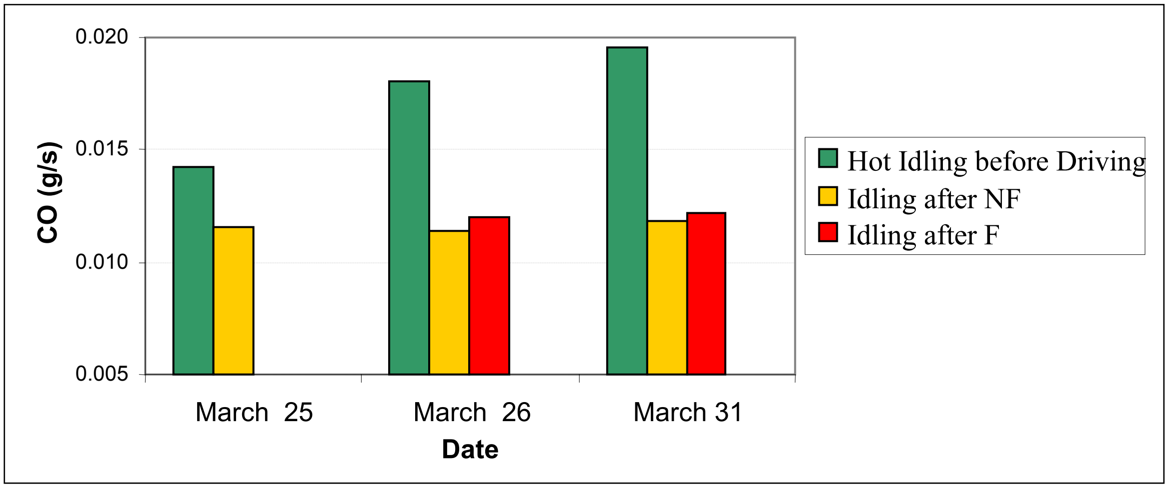


Figure 11. Comparison of CO Emission in Idling Before and After Driving.

4.2.5 Comparison of Emissions for Days 28th, 29th, and 30th

Figures 12 to 16 illustrate the comparison of idling emission factors and FC before and after driving the truck for the days 28th, 29th, and 30th, using the same testing method. The height of each bar represents the average values of the variables in the test. As shown in these figures, different days have different numbers of idling tests. The first bar in each day represents the idling test before driving the truck, the second bar represents the idling test after driving the truck on freeways (F), and the third bar represents the idling test after driving the truck on non-freeways (NF). The fourth bar on March 29th represents the truck idling after driving on both freeways and non-freeways.

Based on the idling conditions explained for Figures 12 to 16, the following conclusions can be made for each variable during the idling tests:

1. FC and CO_2 values before driving the truck are higher than those after driving on freeways.
2. FC and CO_2 values after driving on freeways are lower than those after driving on non-freeways.
3. NOx values before driving the truck are lower than those after driving.
4. NOx values after driving on non-freeways are higher than those after driving on freeways.
5. HC values before driving the truck are higher than those after driving.
6. CO values before driving the truck are higher than those after driving.
7. CO values after driving on freeways are higher than those after driving on non-freeways.

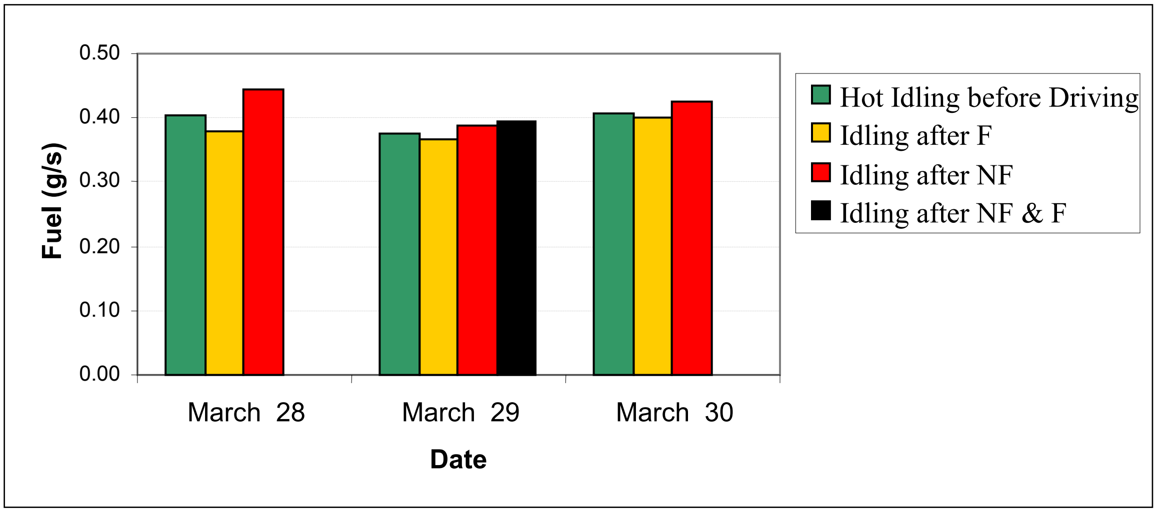


Figure 12. Comparison of Fuel Consumption in Idling Before and After Driving.

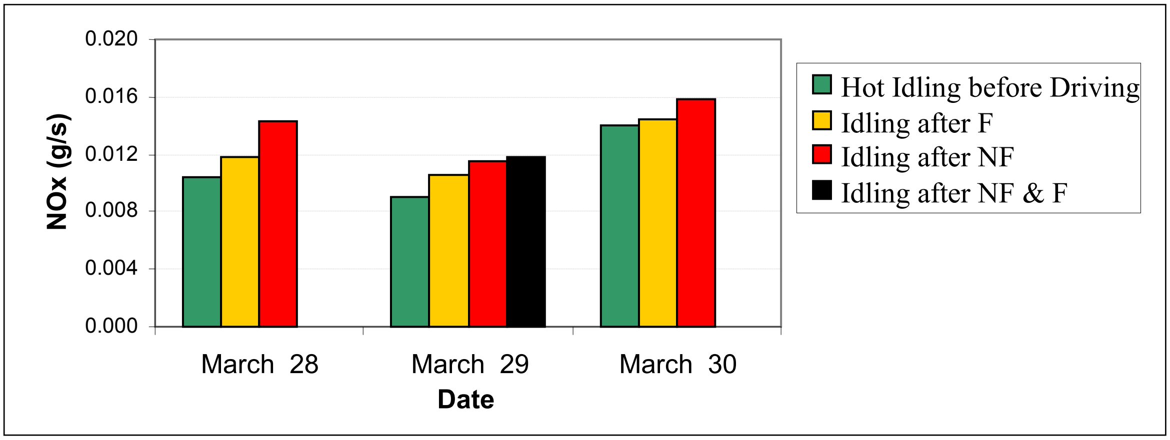


Figure 13. Comparison of NO_X Emission in Idling Before and After Driving.

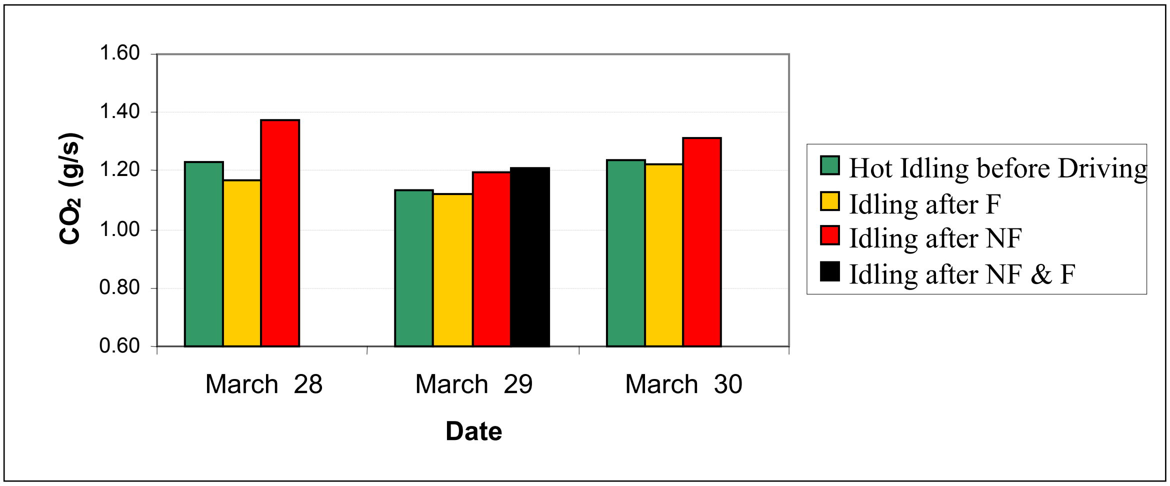


Figure 14. Comparison of CO_2 Emission in Idling Before and After Driving.

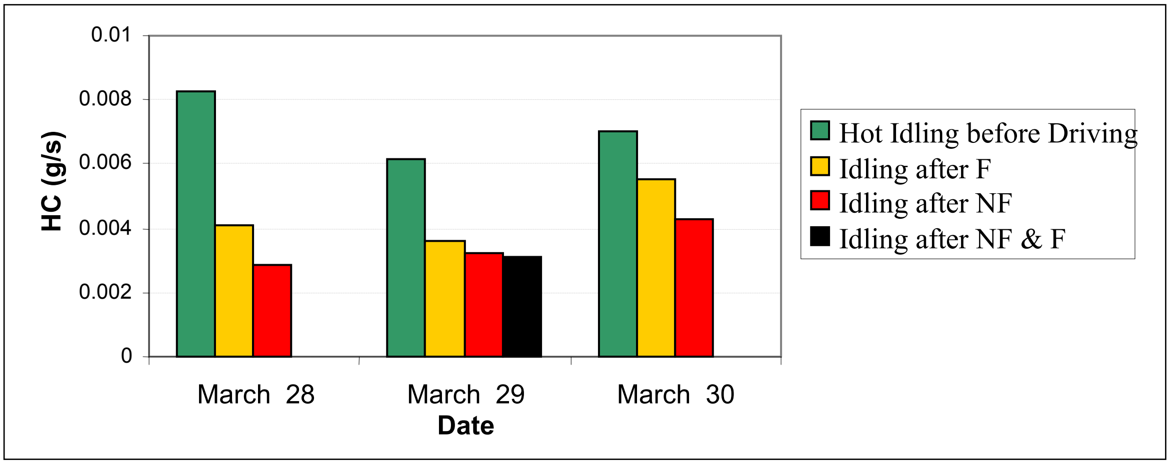


Figure 15. Comparison of HC Emission in Idling Before and After Driving.

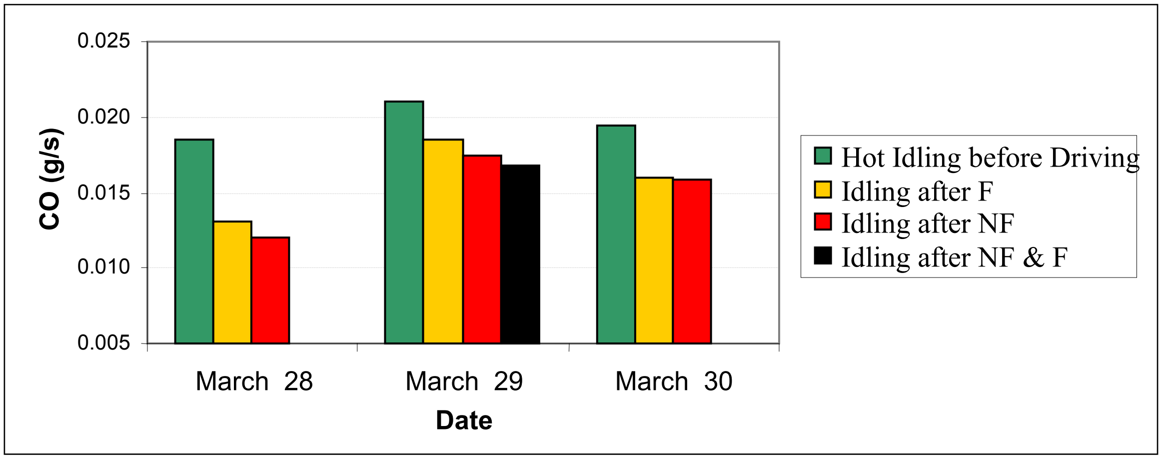


Figure 16. Comparison of CO Emission in Idling Before and After Driving.

4.2.6 Comparison between Emissions of the 6-Day Testing Period

To further identify the influence of the roadways, driving before idling tests on the collected emissions and FC data, summarized FC and emissions were organized in Tables 3 and Table 4. These tables show the average of various emission factors and fuel consumption in the idling time periods before and after driving the truck. Table 3 presents the average values over the three days (March 25, 26, and 31) when the truck was driven twice, first on non-freeways and then on freeways. Table 4 presents the same average data over the other three days (March 28, 29, 30) when the truck was driven three times, first on freeways, then on non-freeways, and finally on both freeways and non-freeways.

Table 3. Average of Emission Factors and Fuel Consumption on March 25, 26 and 31

Idling	FC (g/s)		NO_x (g/s)		HC (g/s)		CO (g/s)		CO_2 (g/s)	
(March 25, 26, 31)	F	NF	F	NF	F	NF	F	NF	F	NF
Before Driving	**0.4046**		**0.0124**		**0.0055**		**0.0173**		**1.2379**	
After 1st Driving		**0.4413**		**0.0145**		**0.0032**		**0.0115**		**1.3699**
After 2nd Driving	**0.4340**		**0.0138**		**0.0030**		**0.0120**		**1.3465**	

F= Freeway
NF= non-freeway

Table 4. Average of Emission Factors and Fuel Consumption on March 28, 29 and 30

Idling	FC (g/s)		NO_x (g/s)		HC (g/s)		CO (g/s)		CO_2 (g/s)	
(March 28, 29, 30)	F	NF	F	NF	F	NF	F	NF	F	NF
Before Driving	**0.3952**		**0.0112**		**0.0072**		**0.0196**		**1.1993**	
After 1st Driving	**0.3801**		**0.0121**		**0.0043**		**0.0160**		**1.1661**	
After 2nd Driving		**0.4284**		**0.0154**		**0.0040**		**0.0151**		**1.3210**
After 3rd Driving	**0.3934**		**0.0118**		**0.0031**		**0.0168**		**1.2120**	

F= Freeway
NF= non-freeway

Tables 3 and 4 corroborate the findings derived from Figures 7 to 16. In addition, they present better conclusions with regards to effects of the facilities used by the truck before the idling test. Based on Tables 3 and 4, as well as on the comparison of the idling conditions presented in Figures 7 to 16, the following conclusions can be derived for each variable during the idling tests:

1. FC and CO_2 values before driving the truck are lower than those after driving on non-freeways (March 25, 26, and 31).
2. FC and CO_2 values before driving the truck are higher than those after driving on freeways (March 28, 29, and 30).
3. FC and CO_2 values after driving on freeways are lower than those after driving on non-freeways no matter what type of roadway facilities were used previously.
4. NOx values before driving the truck are always lower than those after driving.
5. NOx values after driving on non-freeways are higher than those after driving on freeways no matter what type of roadway facilities were used previously.
6. HC values before driving the truck are always higher than those after driving. HC values decrease by time no matter what type of roadway facilities were used before the idling test.
7. CO values before driving the truck are always higher than those after driving.
8. CO values after driving on freeways are higher than those after driving on non-freeways no matter what type of facilities were used first.

4.2.7 Relationships between Emission Variables and Driving Distance before Idling

Figures 17 to 21 show the relationship between each variable and the driving distance before the idling test. These figures were prepared based on the first idling tests after driving the truck for the indicated distance. Note that each point represents the average amount of emission factor in each test. The data points in each plot are divided into two clusters where the data is obtained under two different testing conditions. The first cluster contains data collected after the truck was driven on non-freeways (condition I), while the second cluster contains data obtained after the truck was driven on freeways (condition II). By employing the Microsoft Excel, a trend can be drawn to visualize the relationship between conditions I and II.

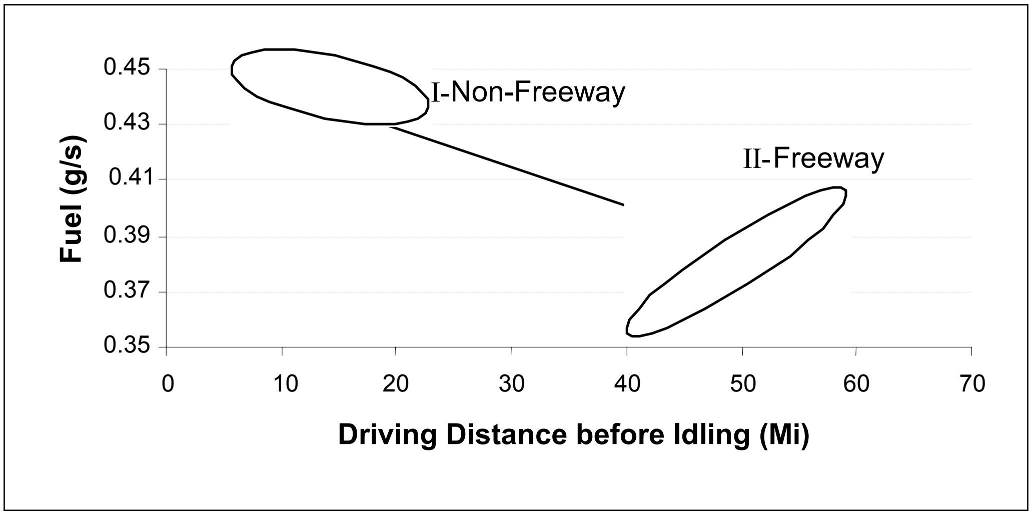


Figure 17. Relationship between FC and Distance Driven before Idling.

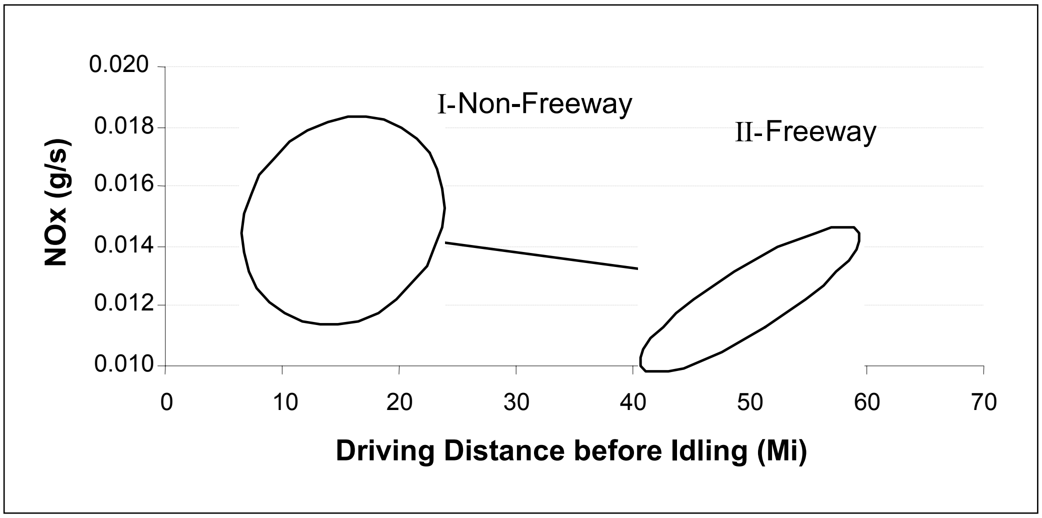


Figure 18. Relationship between NO_X and Distance Driven before Idling.

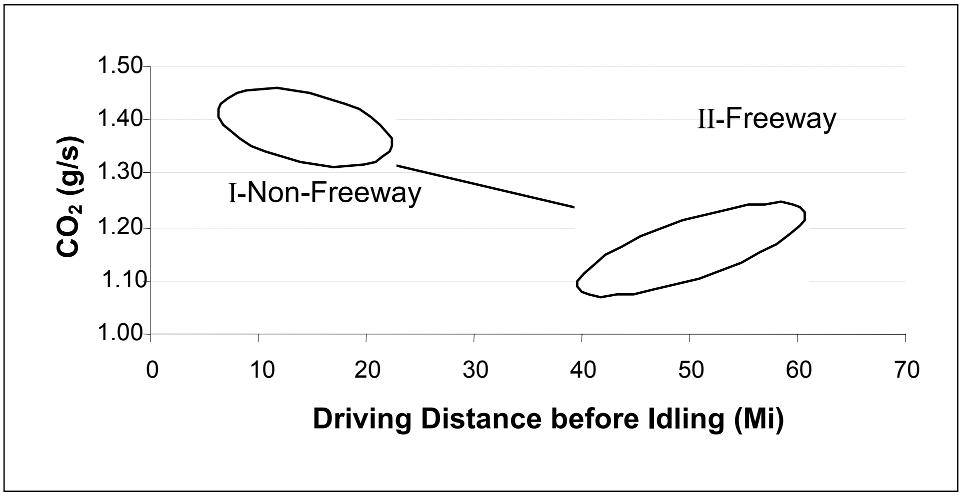


Figure 19. Relationship between CO_2 and Distance Driven before Idling.

Figure 20. Relationship between CO and Distance Driven before Idling.

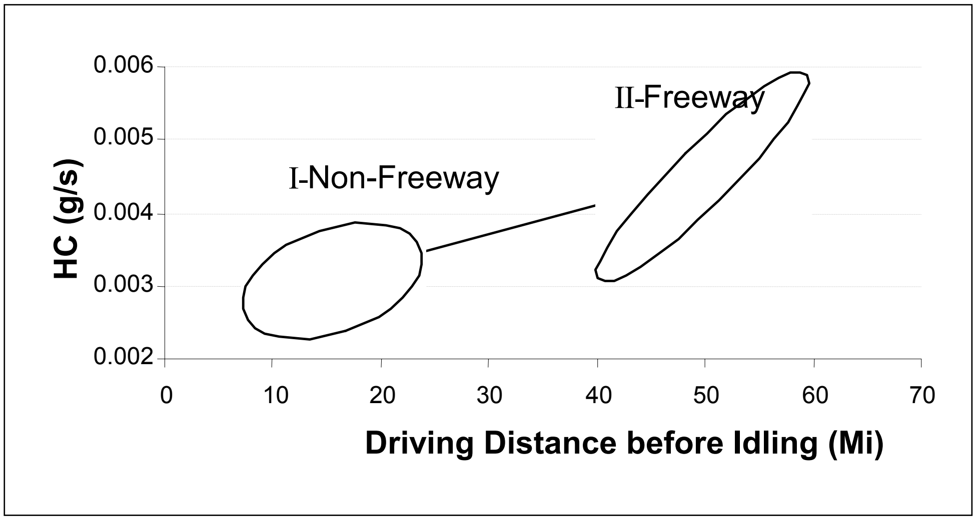


Figure 21. Relationship between HC and Distance Driven before Idling.

Since testing conditions I and II are different, the test results differ. However, some general conclusions can still be made for the whole set of data under both conditions. The above figures show that the general trends for FC, NOx and CO_2 emissions decrease, while HC and CO emissions increase as the distance driven increases before idling test. On the other hand, if only the cluster of data under condition II is considered, the above conclusion may be different. All the figures except Figure 20 show that NOx, HC and CO_2 emission factors and fuel consumption increase with the increase of the driving distance before idling if the truck is driven on freeways.

4.2.8 Relationships between Emission Variables and Driving Time Interval before Idling

In Figures 22 to 26, the testing results versus the driving duration before idling are presented. In these figures, the general trends also show a decrease in NOx and CO_2 emissions and fuel consumption, and an increase in HC and CO emissions as the driving durations before idling increase. This evaluation is the most reliable finding from these figures (Figures 22 to 26). By evaluating the data from conditions I and II separately, no clear results can be obtained; therefore, more tests are needed to verify the relationship between driving duration before the idling test and emission factors under certain facility conditions.

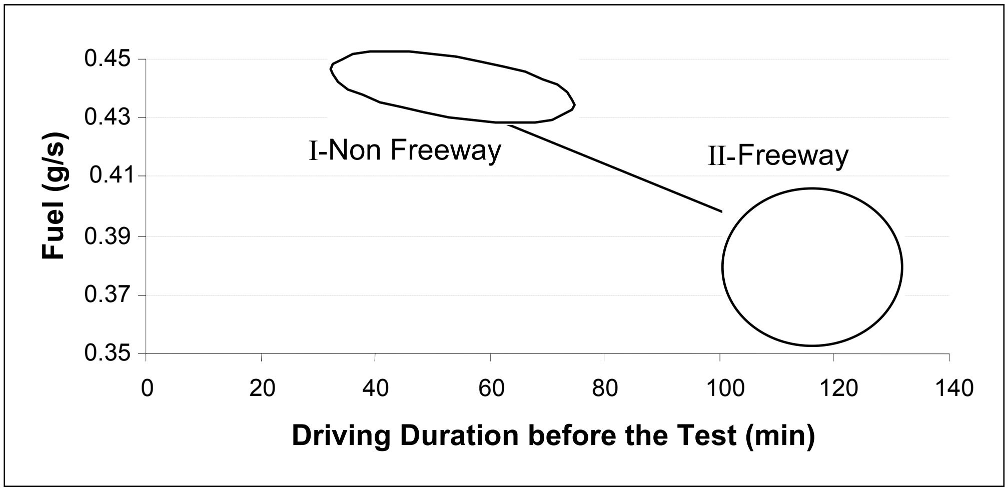


Figure 22. Relationship between FC and Driving Duration before Idling.

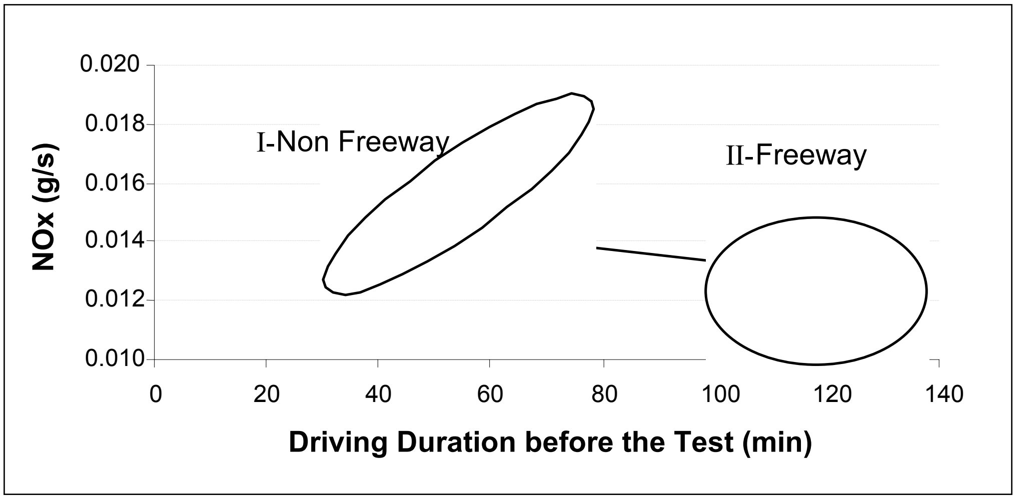


Figure 23. Relationship between NO_X and Driving Duration before Idling.

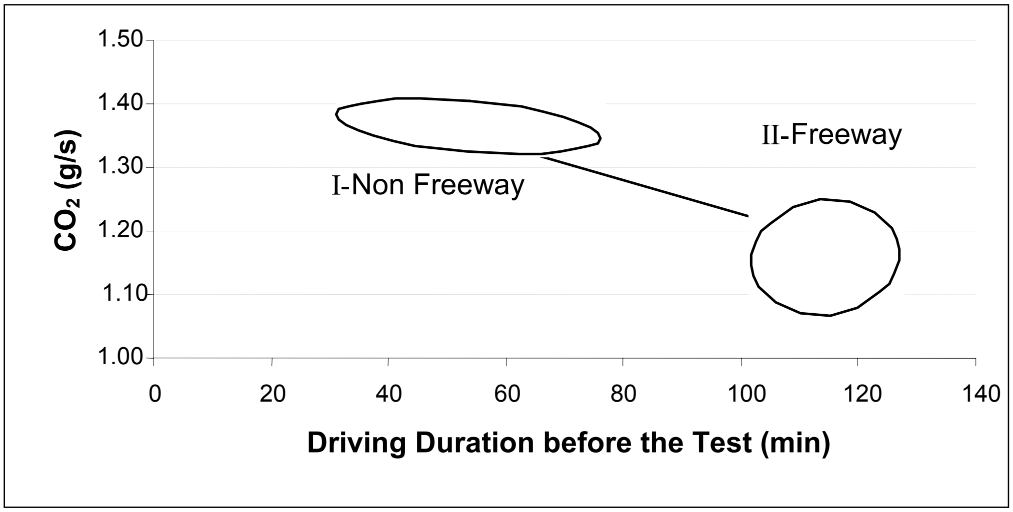


Figure 24. Relationship between CO_2 and Driving Duration before Idling.

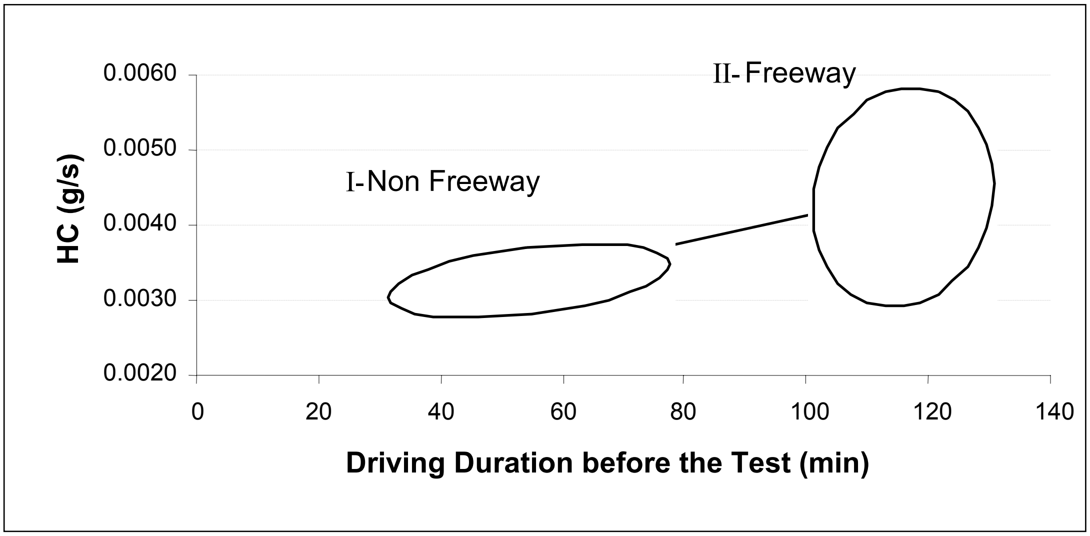


Figure 25. Relationship between HC and Driving Duration before Idling.

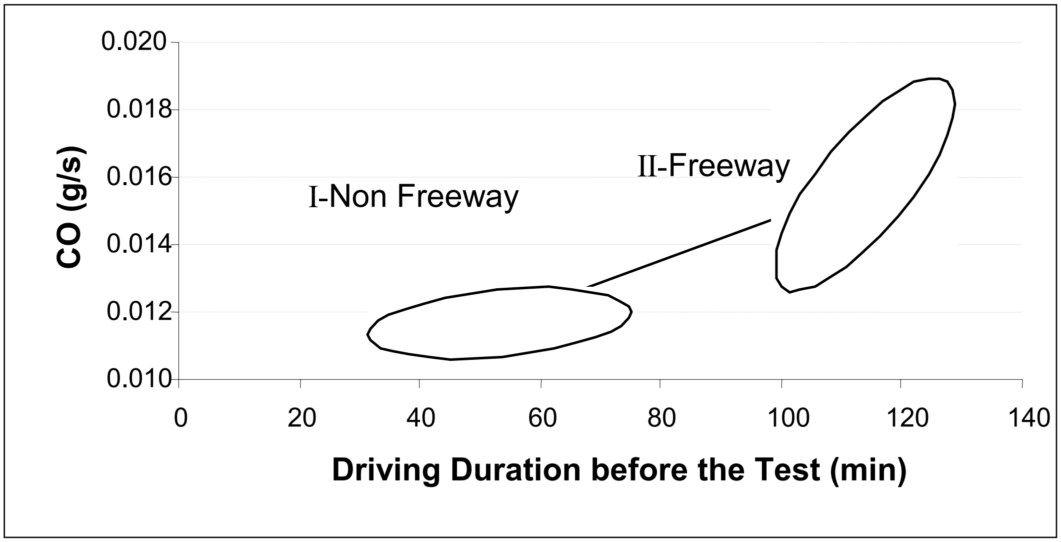


Figure 26. Relationship between FC and Driving Duration before Idling.

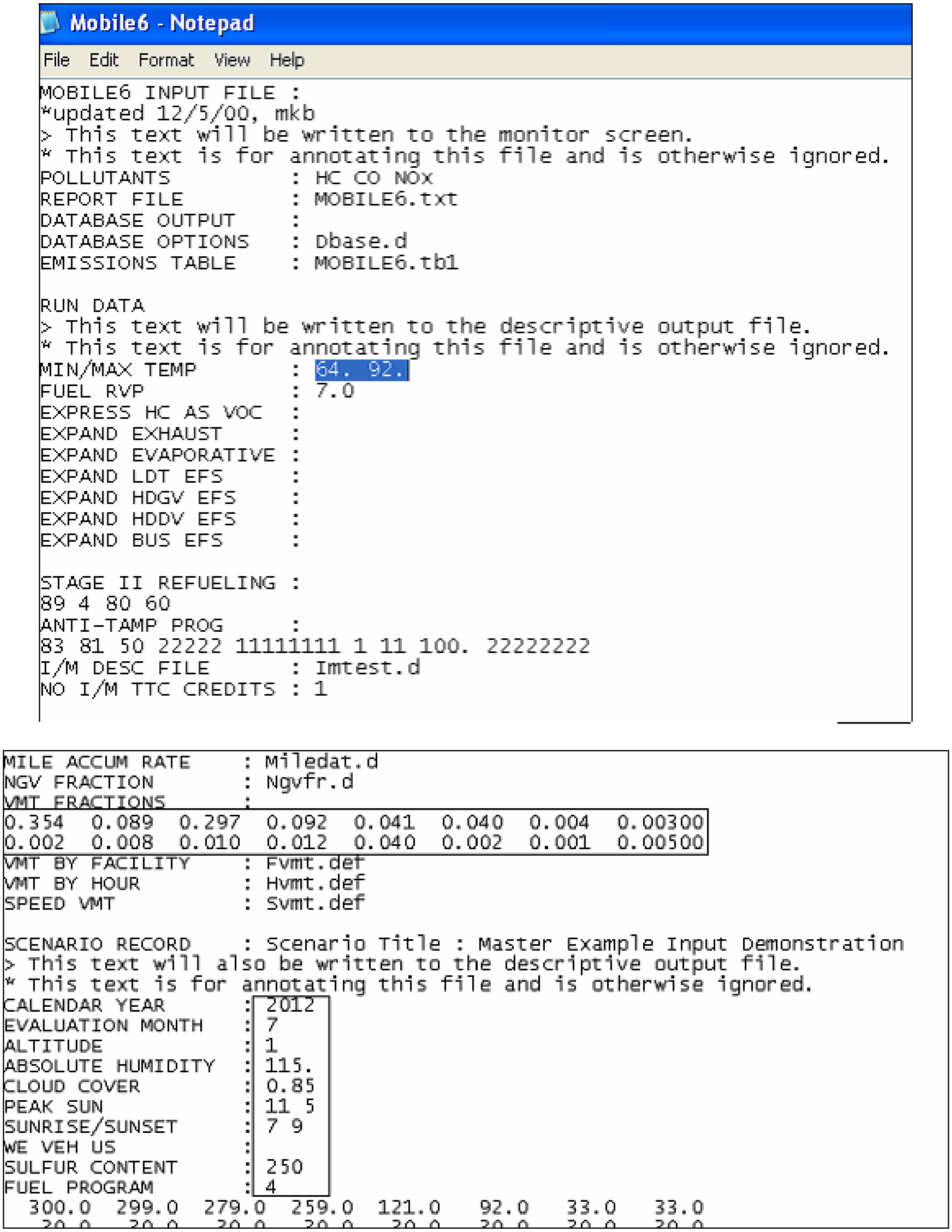
4.3 Emission Estimation by MOBILE6.2

This section presents the emissions estimated by using the macroscopic emission estimation model, MOBILE6.2. As explained earlier, MOBILE6.2 cannot estimate emissions caused by idling directly; therefore, the vehicle has been modeled as being driven at the speed of 2.5mi/hr. MOBILE6.2 includes default values for a large range of conditions that affect emission rates. Basic emission rates of MOBILE6.2 are derived from emission tests conducted under standard conditions of temperature, fuel, and driving cycle (EPA, 2003). Running the software without changing the default values gives the average emissions based on a wide variety of vehicles. Therefore, in order to estimate the emissions for a particular testing condition and vehicle, MOBILE6.2 input files should be modeled based on those conditions.

MOBILE6.2 has a 28-vehicle classification. Based on the classification, the vehicle type used in this research is HDDV6 (class 6 heavy-duty diesel vehicle). In order to run the software based on the testing conditions, some necessary input files such as Mobile6.in, Hvmt, Regdata, Svmt, vmtmix, and fvmt have been modified.

4.3.1 Changing the MOBILE6.in Input File

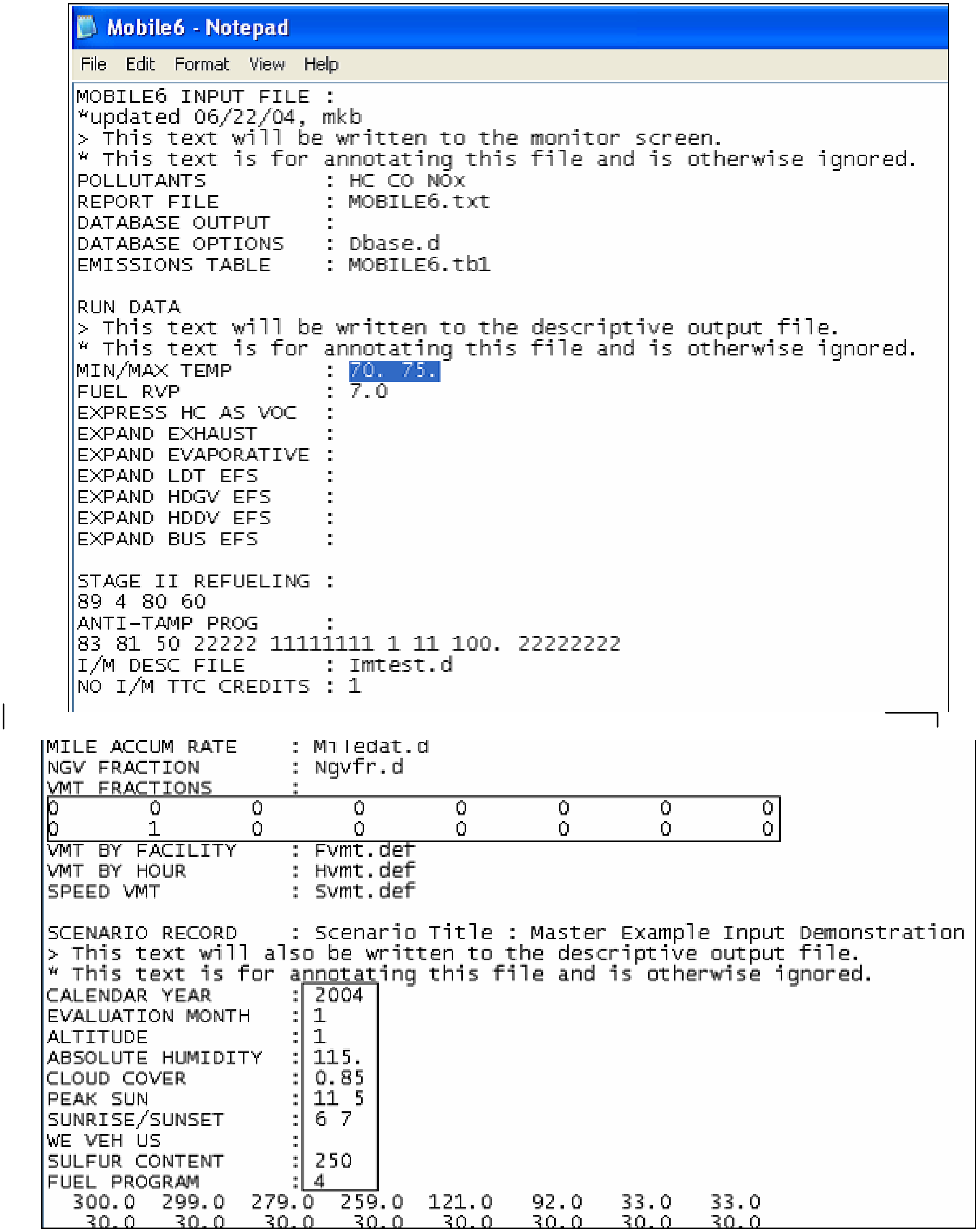
Figure 27 shows the default values in the original file of Mobile6.-in before any changes, while Figure 28 shows the file Mobile6.-in after the changing process. In these figures, each box represents the data that has to be changed (in Figure 27) or the data that has been changed (in Figure 28). As shown in Figure 28, the date, Max/Min temperature, VMT fractions, calendar year, evaluation month, absolute humidity, cloud cover, peak sun, and sunrise/sunset have been changed. Because the weather condition affects the production of vehicle's emissions, it is very important that it be modified. VMT fractions represent the distribution of the entire vehicle miles traveled (VMT) by each of the 16 vehicle classes. This classification for VMT slightly differs from the 28-vehicle classification. In the 16-vehicle classification, some classes were combined: for example, "class 6 heavy-duty diesel vehicle" and "class 6 heavy-duty Gasoline vehicle" in the 28-vehicle classification were combined and represented as "class 6 heavy-duty vehicle" in the 16-vehicle classification. Therefore, in order to run the software for the class 6 heavy duty, all the fractions for other vehicle classes should be set to number 0 and the fraction for HDV6 should be set to number 1.



```
MOBILE6 INPUT FILE :
*updated 12/5/00, mkb
> This text will be written to the monitor screen.
* This text is for annotating this file and is otherwise ignored.
POLLUTANTS            : HC CO NOx
REPORT FILE           : MOBILE6.txt
DATABASE OUTPUT       :
DATABASE OPTIONS      : Dbase.d
EMISSIONS TABLE       : MOBILE6.tb1

RUN DATA
> This text will be written to the descriptive output file.
* This text is for annotating this file and is otherwise ignored.
MIN/MAX TEMP          : 64.  92.
FUEL RVP              : 7.0
EXPRESS HC AS VOC     :
EXPAND EXHAUST        :
EXPAND EVAPORATIVE    :
EXPAND LDT EFS        :
EXPAND HDGV EFS       :
EXPAND HDDV EFS       :
EXPAND BUS EFS        :

STAGE II REFUELING :
89 4 80 60
ANTI-TAMP PROG        :
83 81 50 22222 11111111 1 11 100. 22222222
I/M DESC FILE         : Imtest.d
NO I/M TTC CREDITS : 1
```

```
MILE ACCUM RATE      : Miledat.d
NGV FRACTION         : Ngvfr.d
VMT FRACTIONS        :
0.354   0.089   0.297   0.092   0.041   0.040   0.004   0.00300
0.002   0.008   0.010   0.012   0.040   0.002   0.001   0.00500
VMT BY FACILITY      : Fvmt.def
VMT BY HOUR          : Hvmt.def
SPEED VMT            : Svmt.def

SCENARIO RECORD      : Scenario Title : Master Example Input Demonstration
> This text will also be written to the descriptive output file.
* This text is for annotating this file and is otherwise ignored.
CALENDAR YEAR        : 2012
EVALUATION MONTH     : 7
ALTITUDE             : 1
ABSOLUTE HUMIDITY    : 115.
CLOUD COVER          : 0.85
PEAK SUN             : 11 5
SUNRISE/SUNSET       : 7 9
WE VEH US            :
SULFUR CONTENT       : 250
FUEL PROGRAM         : 4
  300.0   299.0   279.0   259.0   121.0    92.0    33.0    33.0
```

Figure 27. Original Input File of Mobile6.in.



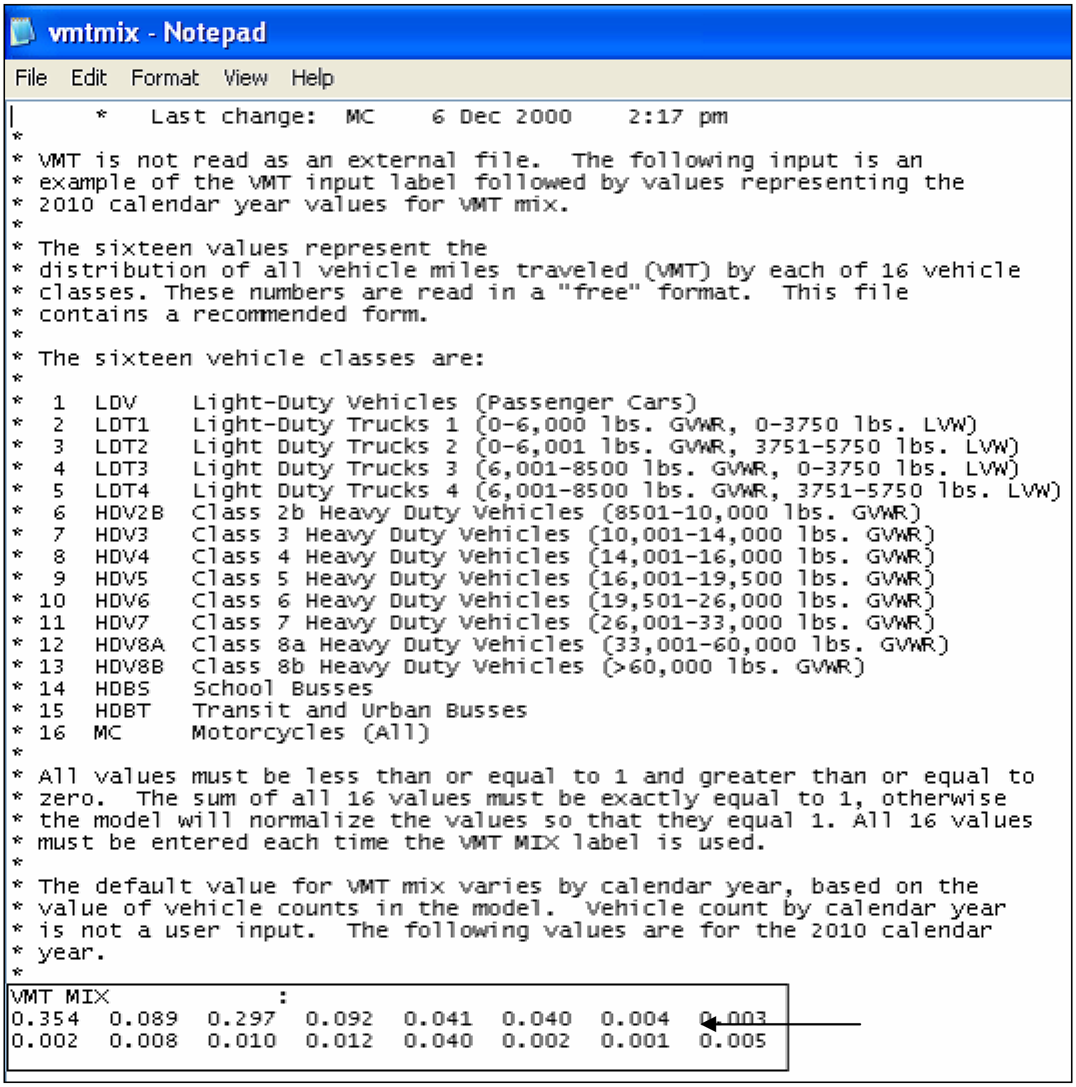
```
MOBILE6 INPUT FILE :
*updated 06/22/04, mkb
> This text will be written to the monitor screen.
* This text is for annotating this file and is otherwise ignored.
POLLUTANTS           : HC CO NOx
REPORT FILE          : MOBILE6.txt
DATABASE OUTPUT      :
DATABASE OPTIONS     : Dbase.d
EMISSIONS TABLE      : MOBILE6.tb1

RUN DATA
> This text will be written to the descriptive output file.
* This text is for annotating this file and is otherwise ignored.
MIN/MAX TEMP         : 70. 75.
FUEL RVP             : 7.0
EXPRESS HC AS VOC    :
EXPAND EXHAUST       :
EXPAND EVAPORATIVE   :
EXPAND LDT EFS       :
EXPAND HDGV EFS      :
EXPAND HDDV EFS      :
EXPAND BUS EFS       :

STAGE II REFUELING :
89 4 80 60
ANTI-TAMP PROG       :
83 81 50 22222 11111111 1 11 100. 22222222
I/M DESC FILE        : Imtest.d
NO I/M TTC CREDITS : 1
```

```
MILE ACCUM RATE      : Miledat.d
NGV FRACTION         : Ngvfr.d
VMT FRACTIONS        :
0       0       0       0       0       0       0       0
0       1       0       0       0       0       0       0
VMT BY FACILITY      : Fvmt.def
VMT BY HOUR          : Hvmt.def
SPEED VMT            : Svmt.def

SCENARIO RECORD      : Scenario Title : Master Example Input Demonstration
> This text will also be written to the descriptive output file.
* This text is for annotating this file and is otherwise ignored.
CALENDAR YEAR        : 2004
EVALUATION MONTH     : 1
ALTITUDE             : 1
ABSOLUTE HUMIDITY    : 115.
CLOUD COVER          : 0.85
PEAK SUN             : 11 5
SUNRISE/SUNSET       : 6 7
WE VEH US            :
SULFUR CONTENT       : 250
FUEL PROGRAM         : 4
  300.0  299.0  279.0  259.0  121.0   92.0   33.0   33.0
   30.0   30.0   30.0   30.0   30.0   30.0   30.0   30.0
```

Figure 28. Changed Input File of Mobile6.in.

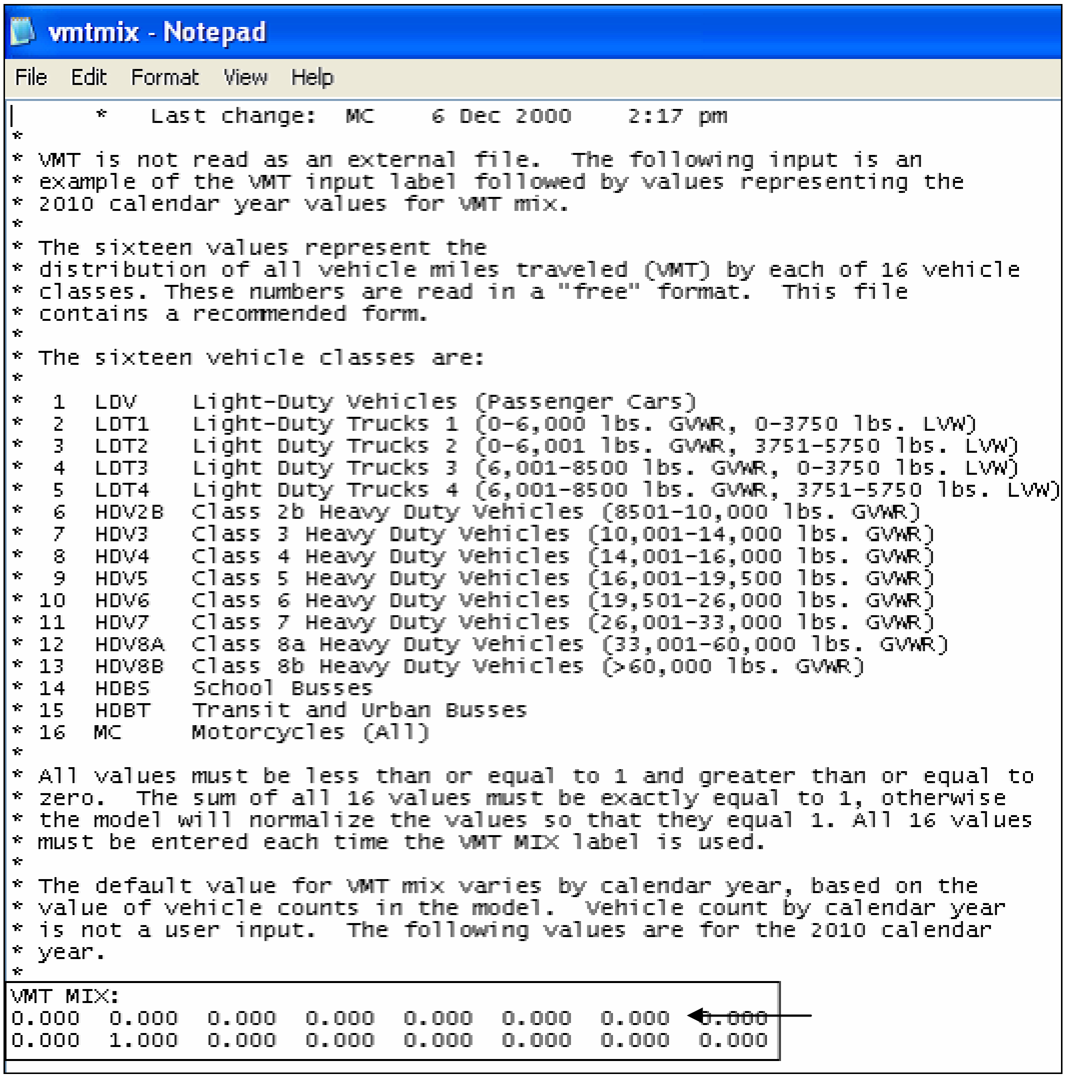
4.3.2 Changing the Vmtmix Input File

Figure 29 shows the default values in the original file of vmtmix, while Figure 30 shows the file vmtmix after the changing process. As shown in Figure 30, the VMT fraction factors have been changed. Again, these changes have been done based on what was explained in the last section.



```
      *   Last change:  MC    6 Dec 2000    2:17 pm
*
* VMT is not read as an external file.  The following input is an
* example of the VMT input label followed by values representing the
* 2010 calendar year values for VMT mix.
*
* The sixteen values represent the
* distribution of all vehicle miles traveled (VMT) by each of 16 vehicle
* classes. These numbers are read in a "free" format.  This file
* contains a recommended form.
*
* The sixteen vehicle classes are:
*
*  1  LDV    Light-Duty Vehicles (Passenger Cars)
*  2  LDT1   Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
*  3  LDT2   Light Duty Trucks 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
*  4  LDT3   Light Duty Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
*  5  LDT4   Light Duty Trucks 4 (6,001-8500 lbs. GVWR, 3751-5750 lbs. LVW)
*  6  HDV2B  Class 2b Heavy Duty Vehicles (8501-10,000 lbs. GVWR)
*  7  HDV3   Class 3 Heavy Duty Vehicles (10,001-14,000 lbs. GVWR)
*  8  HDV4   Class 4 Heavy Duty Vehicles (14,001-16,000 lbs. GVWR)
*  9  HDV5   Class 5 Heavy Duty Vehicles (16,001-19,500 lbs. GVWR)
* 10  HDV6   Class 6 Heavy Duty Vehicles (19,501-26,000 lbs. GVWR)
* 11  HDV7   Class 7 Heavy Duty Vehicles (26,001-33,000 lbs. GVWR)
* 12  HDV8A  Class 8a Heavy Duty Vehicles (33,001-60,000 lbs. GVWR)
* 13  HDV8B  Class 8b Heavy Duty Vehicles (>60,000 lbs. GVWR)
* 14  HDBS   School Busses
* 15  HDBT   Transit and Urban Busses
* 16  MC     Motorcycles (All)
*
* All values must be less than or equal to 1 and greater than or equal to
* zero.  The sum of all 16 values must be exactly equal to 1, otherwise
* the model will normalize the values so that they equal 1. All 16 values
* must be entered each time the VMT MIX label is used.
*
* The default value for VMT mix varies by calendar year, based on the
* value of vehicle counts in the model.  Vehicle count by calendar year
* is not a user input.  The following values are for the 2010 calendar
* year.
*
VMT MIX                 :
0.354  0.089  0.297  0.092  0.041  0.040  0.004  0.003
0.002  0.008  0.010  0.012  0.040  0.002  0.001  0.005
```

Figure 29. Original Input File of Vmtmix.

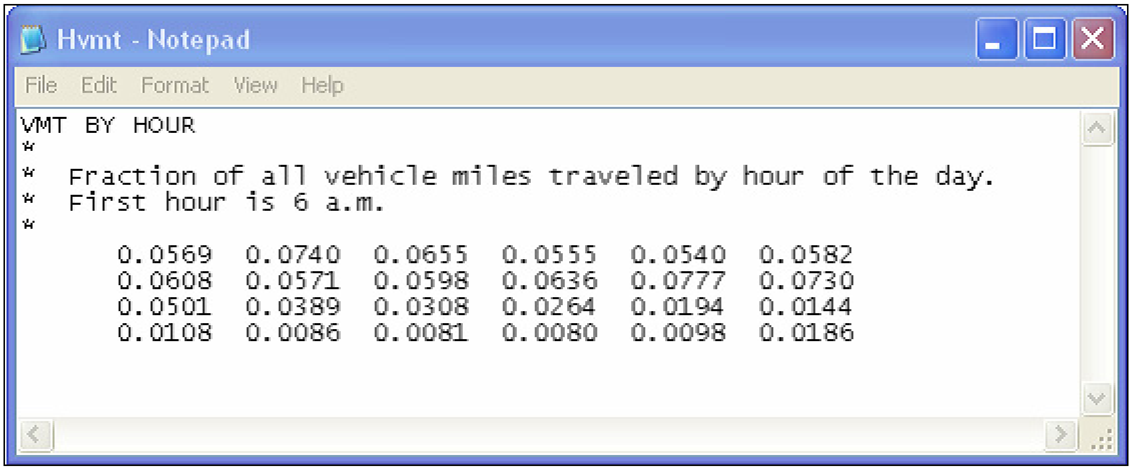


```
      *   Last change:  MC    6 Dec 2000    2:17 pm
*
* VMT is not read as an external file.  The following input is an
* example of the VMT input label followed by values representing the
* 2010 calendar year values for VMT mix.
*
* The sixteen values represent the
* distribution of all vehicle miles traveled (VMT) by each of 16 vehicle
* classes. These numbers are read in a "free" format.  This file
* contains a recommended form.
*
* The sixteen vehicle classes are:
*
*  1  LDV    Light-Duty Vehicles (Passenger Cars)
*  2  LDT1   Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
*  3  LDT2   Light Duty Trucks 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
*  4  LDT3   Light Duty Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
*  5  LDT4   Light Duty Trucks 4 (6,001-8500 lbs. GVWR, 3751-5750 lbs. LVW)
*  6  HDV2B  Class 2b Heavy Duty Vehicles (8501-10,000 lbs. GVWR)
*  7  HDV3   Class 3 Heavy Duty Vehicles (10,001-14,000 lbs. GVWR)
*  8  HDV4   Class 4 Heavy Duty Vehicles (14,001-16,000 lbs. GVWR)
*  9  HDV5   Class 5 Heavy Duty Vehicles (16,001-19,500 lbs. GVWR)
* 10  HDV6   Class 6 Heavy Duty Vehicles (19,501-26,000 lbs. GVWR)
* 11  HDV7   Class 7 Heavy Duty Vehicles (26,001-33,000 lbs. GVWR)
* 12  HDV8A  Class 8a Heavy Duty Vehicles (33,001-60,000 lbs. GVWR)
* 13  HDV8B  Class 8b Heavy Duty Vehicles (>60,000 lbs. GVWR)
* 14  HDBS   School Busses
* 15  HDBT   Transit and Urban Busses
* 16  MC     Motorcycles (All)
*
* All values must be less than or equal to 1 and greater than or equal to
* zero.  The sum of all 16 values must be exactly equal to 1, otherwise
* the model will normalize the values so that they equal 1. All 16 values
* must be entered each time the VMT MIX label is used.
*
* The default value for VMT mix varies by calendar year, based on the
* value of vehicle counts in the model.  Vehicle count by calendar year
* is not a user input.  The following values are for the 2010 calendar
* year.
*
VMT MIX:
0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
0.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000
```

Figure 30. Changed Input File of Vmtmix.

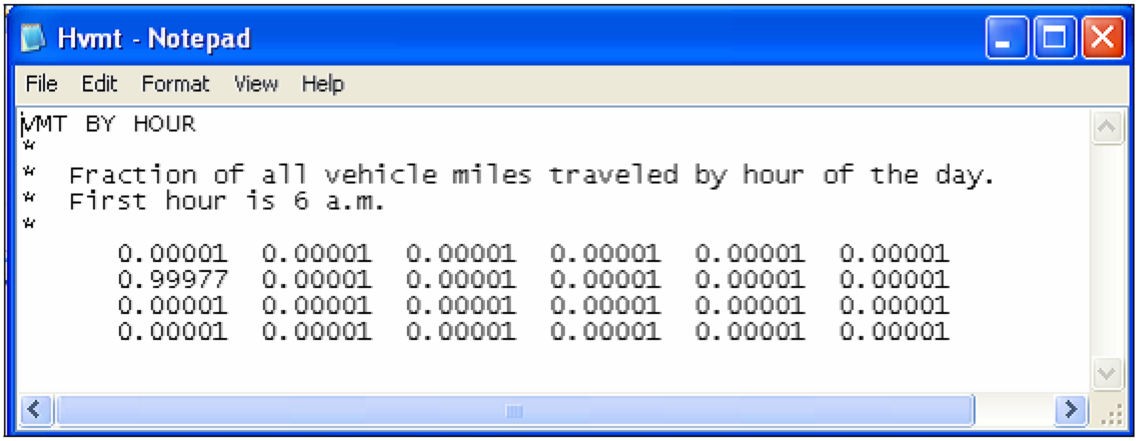
4.3.3 Changing the Hymt Input File

Figures 31 and 32 show the original and changed input file for Hvmt. Command “VMT by hour” permits the user to allocate the total VMT among the 24 hours of the day. The values of “VMT by hour” are independent of the facility type, meaning that the VMT fraction covers all the different facility types. MOBILE6.2 uses national data for the default of this file (EPA, 2003). The first fraction in the input data is the VMT at 6 a.m. In this research, based on the testing condition, the VMT at 12 p.m. has been changed. Because most of the idling tests have been done around noon, the Hvmt fraction at 12 p.m. has been set to (almost) number 1, while all the other fractions were set to number zero.



```
VMT  BY  HOUR
*
*   Fraction of all vehicle miles traveled by hour of the day.
*   First hour is 6 a.m.
*
        0.0569  0.0740  0.0655  0.0555  0.0540  0.0582
        0.0608  0.0571  0.0598  0.0636  0.0777  0.0730
        0.0501  0.0389  0.0308  0.0264  0.0194  0.0144
        0.0108  0.0086  0.0081  0.0080  0.0098  0.0186
```

Figure 31. Original Input File of Hvmt.



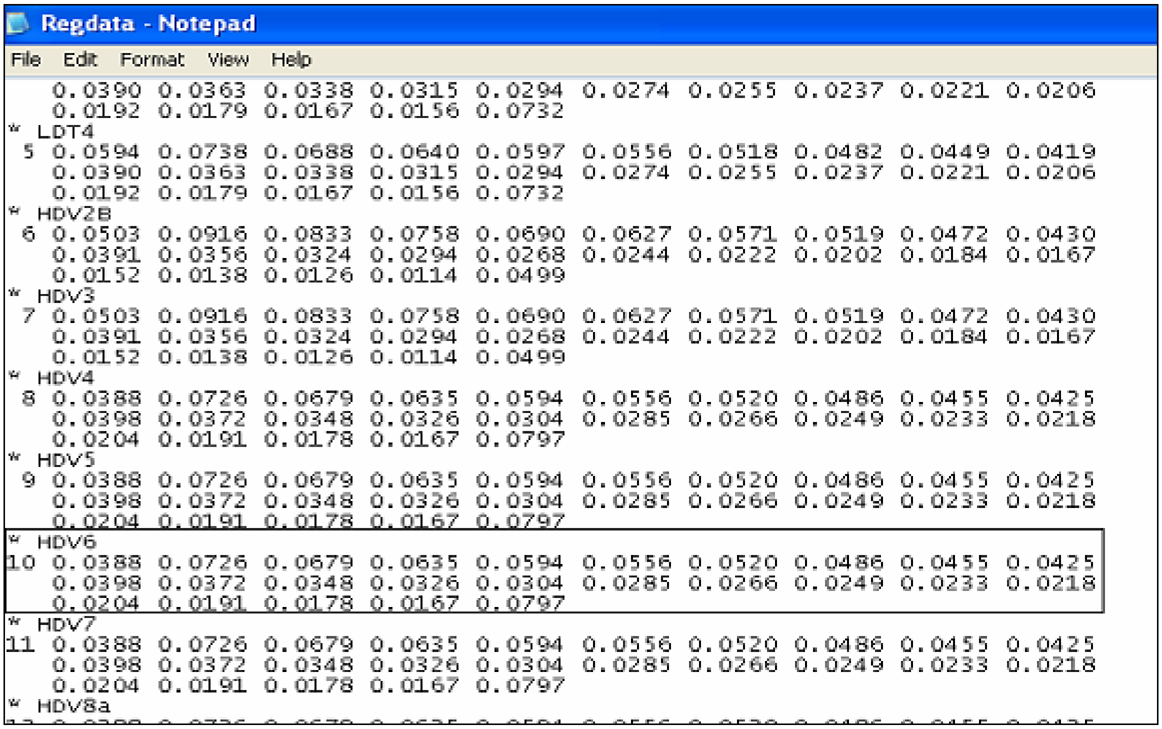
```
VMT  BY  HOUR
*
*   Fraction of all vehicle miles traveled by hour of the day.
*   First hour is 6 a.m.
*
        0.00001  0.00001  0.00001  0.00001  0.00001  0.00001
        0.99977  0.00001  0.00001  0.00001  0.00001  0.00001
        0.00001  0.00001  0.00001  0.00001  0.00001  0.00001
        0.00001  0.00001  0.00001  0.00001  0.00001  0.00001
```

Figure 32. Changed Input File of Hvmt.

4.3.4 Changing the Regdata Input File

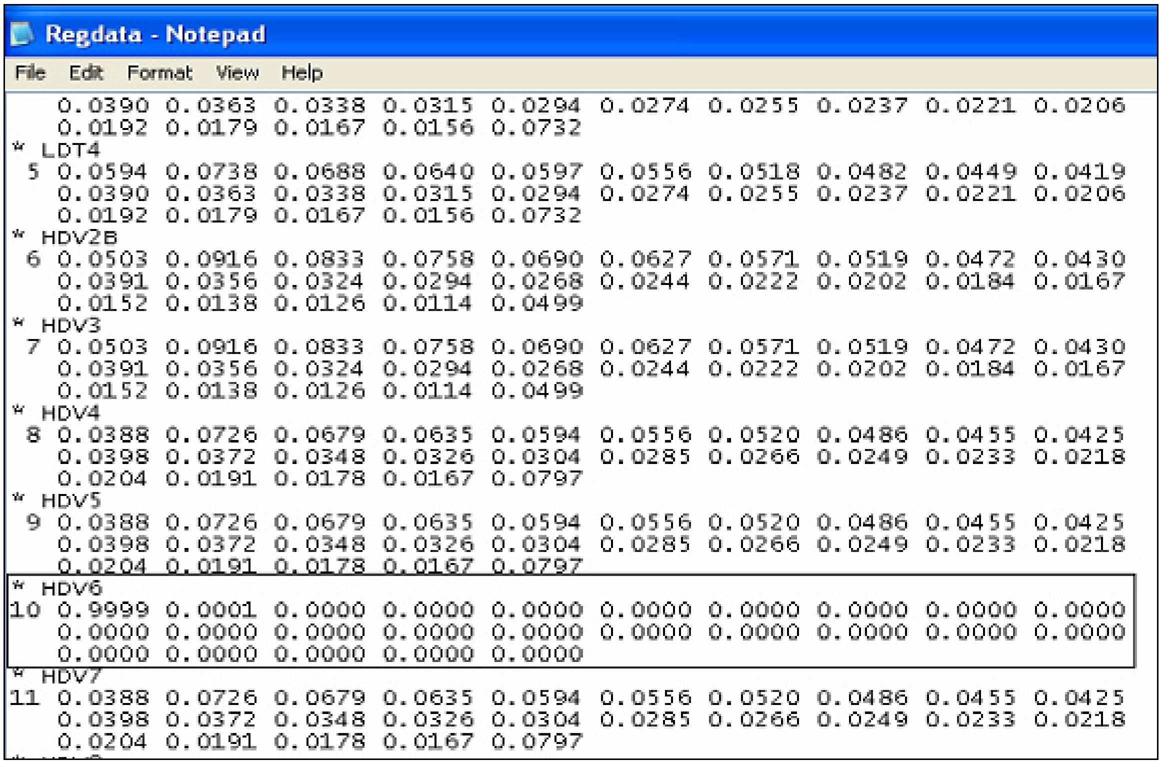
Figures 33 and 34 represent the original and changed Regdata files. The Regdata file contains the user-supplied age distributions of the vehicles. There are 16 sets of values in the file, representing 16 combined gasoline/diesel vehicle class distributions. Each distribution contains 25 values which represent the fraction of all vehicles in that class (gasoline and diesel) of that age in July.

The first number in each set represents age 1 and the last number is for age 25, which includes all vehicles 25 years old or older (EPA, 2003). Because the tested vehicle is a 2004 heavy-duty truck, the first number in the set HDV6 has been set to number 1, while all the other fractions were set to zero.



```
   0.0390 0.0363 0.0338 0.0315 0.0294 0.0274 0.0255 0.0237 0.0221 0.0206
   0.0192 0.0179 0.0167 0.0156 0.0732
* LDT4
 5 0.0594 0.0738 0.0688 0.0640 0.0597 0.0556 0.0518 0.0482 0.0449 0.0419
   0.0390 0.0363 0.0338 0.0315 0.0294 0.0274 0.0255 0.0237 0.0221 0.0206
   0.0192 0.0179 0.0167 0.0156 0.0732
* HDV2B
 6 0.0503 0.0916 0.0833 0.0758 0.0690 0.0627 0.0571 0.0519 0.0472 0.0430
   0.0391 0.0356 0.0324 0.0294 0.0268 0.0244 0.0222 0.0202 0.0184 0.0167
   0.0152 0.0138 0.0126 0.0114 0.0499
* HDV3
 7 0.0503 0.0916 0.0833 0.0758 0.0690 0.0627 0.0571 0.0519 0.0472 0.0430
   0.0391 0.0356 0.0324 0.0294 0.0268 0.0244 0.0222 0.0202 0.0184 0.0167
   0.0152 0.0138 0.0126 0.0114 0.0499
* HDV4
 8 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV5
 9 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV6
10 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV7
11 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV8a
```

Figure 33. Original Input File of Regdata.

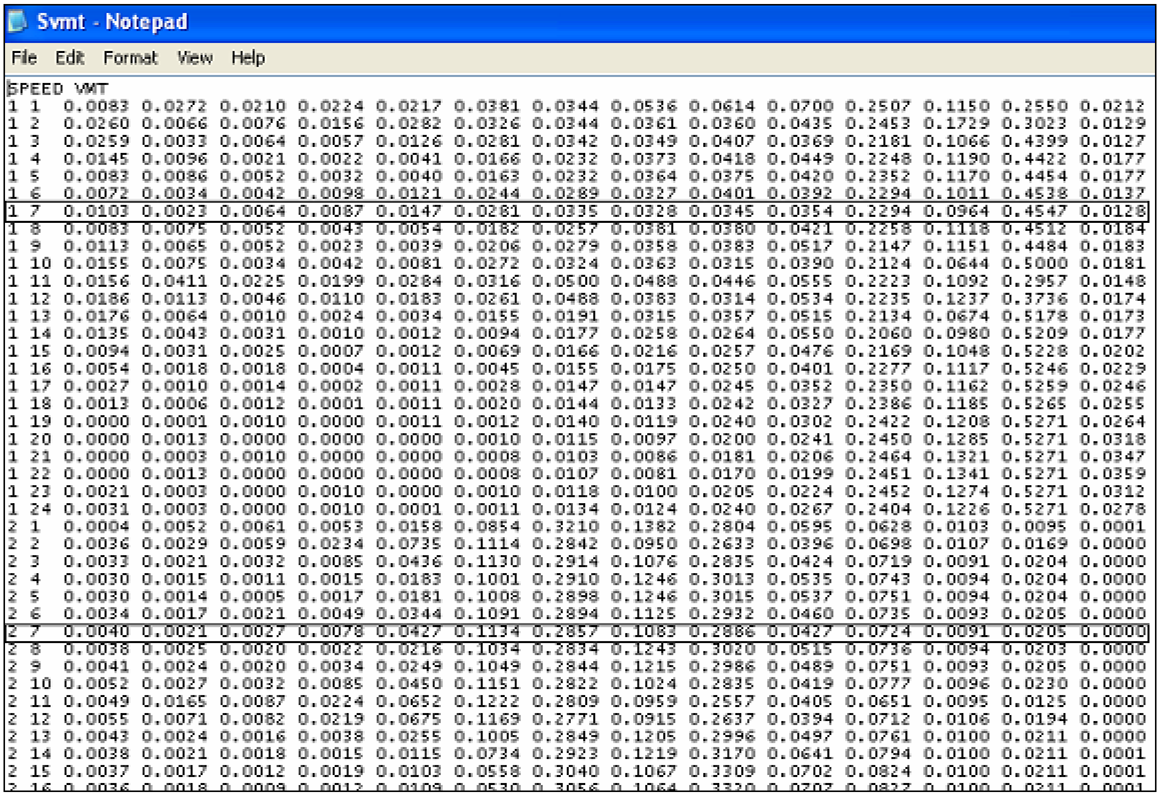


```
   0.0390 0.0363 0.0338 0.0315 0.0294 0.0274 0.0255 0.0237 0.0221 0.0206
   0.0192 0.0179 0.0167 0.0156 0.0732
* LDT4
 5 0.0594 0.0738 0.0688 0.0640 0.0597 0.0556 0.0518 0.0482 0.0449 0.0419
   0.0390 0.0363 0.0338 0.0315 0.0294 0.0274 0.0255 0.0237 0.0221 0.0206
   0.0192 0.0179 0.0167 0.0156 0.0732
* HDV2B
 6 0.0503 0.0916 0.0833 0.0758 0.0690 0.0627 0.0571 0.0519 0.0472 0.0430
   0.0391 0.0356 0.0324 0.0294 0.0268 0.0244 0.0222 0.0202 0.0184 0.0167
   0.0152 0.0138 0.0126 0.0114 0.0499
* HDV3
 7 0.0503 0.0916 0.0833 0.0758 0.0690 0.0627 0.0571 0.0519 0.0472 0.0430
   0.0391 0.0356 0.0324 0.0294 0.0268 0.0244 0.0222 0.0202 0.0184 0.0167
   0.0152 0.0138 0.0126 0.0114 0.0499
* HDV4
 8 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV5
 9 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
* HDV6
10 0.9999 0.0001 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
   0.0000 0.0000 0.0000 0.0000 0.0000
* HDV7
11 0.0388 0.0726 0.0679 0.0635 0.0594 0.0556 0.0520 0.0486 0.0455 0.0425
   0.0398 0.0372 0.0348 0.0326 0.0304 0.0285 0.0266 0.0249 0.0233 0.0218
   0.0204 0.0191 0.0178 0.0167 0.0797
```

Figure 34. Changed Input File of Regdata.

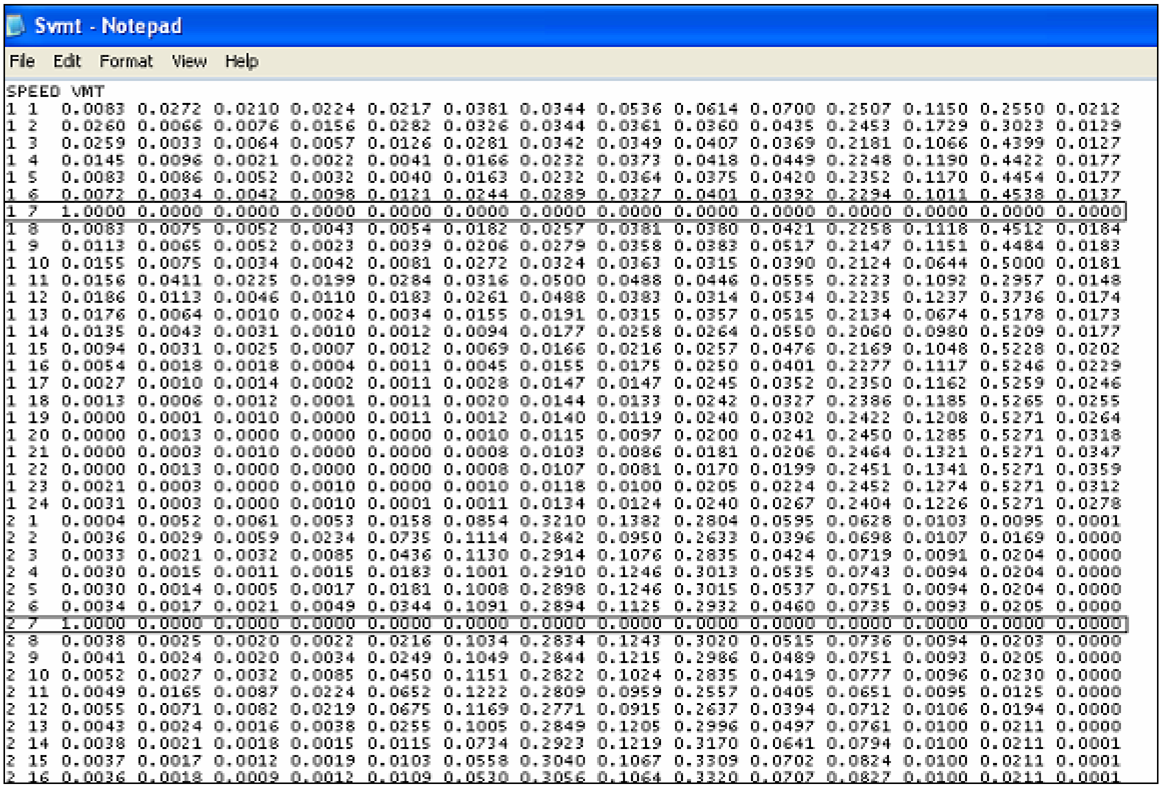
4.3.5 Changing the Symt Input File

Figures 35 and 36 show the original and changed Svmt input files. The speed VMT (Svmt) command permits the user to replace the default values with a VMT distribution over fourteen average speed bins. Average speed values are between 2.5 and 65 miles per hour. Each row represents an hour of the day, the first row representing 6 a.m. (EPA- MOBILE6.2 Manual, 2003). Because MOBILE6.2 in this research should be modeled for the idling test at 12 p.m., the first number in Row 7 (12 p.m.) that represents the VMT fraction for the speed of 2.5 mph has been set to number 1, while the rest of the fractions have been set to zero.



```
SPEED VMT
1 1   0.0083 0.0272 0.0210 0.0224 0.0217 0.0381 0.0344 0.0536 0.0614 0.0700 0.2507 0.1150 0.2550 0.0212
1 2   0.0260 0.0066 0.0076 0.0156 0.0282 0.0326 0.0344 0.0361 0.0360 0.0435 0.2453 0.1729 0.3023 0.0129
1 3   0.0259 0.0033 0.0064 0.0057 0.0126 0.0281 0.0342 0.0349 0.0407 0.0369 0.2181 0.1066 0.4399 0.0127
1 4   0.0145 0.0096 0.0021 0.0022 0.0041 0.0166 0.0232 0.0373 0.0418 0.0449 0.2248 0.1190 0.4422 0.0177
1 5   0.0083 0.0086 0.0052 0.0032 0.0040 0.0163 0.0232 0.0364 0.0375 0.0420 0.2352 0.1170 0.4454 0.0177
1 6   0.0072 0.0034 0.0042 0.0098 0.0121 0.0244 0.0289 0.0327 0.0401 0.0392 0.2294 0.1011 0.4538 0.0137
1 7   0.0103 0.0023 0.0064 0.0087 0.0147 0.0281 0.0335 0.0328 0.0345 0.0354 0.2294 0.0964 0.4547 0.0128
1 8   0.0083 0.0075 0.0052 0.0043 0.0054 0.0182 0.0257 0.0381 0.0380 0.0421 0.2258 0.1118 0.4512 0.0184
1 9   0.0113 0.0065 0.0052 0.0023 0.0039 0.0206 0.0279 0.0358 0.0383 0.0517 0.2147 0.1151 0.4484 0.0183
1 10  0.0155 0.0075 0.0034 0.0042 0.0081 0.0272 0.0324 0.0363 0.0315 0.0390 0.2124 0.0644 0.5000 0.0181
1 11  0.0156 0.0411 0.0225 0.0199 0.0284 0.0316 0.0500 0.0488 0.0446 0.0555 0.2223 0.1092 0.2957 0.0148
1 12  0.0186 0.0113 0.0046 0.0110 0.0183 0.0261 0.0488 0.0383 0.0314 0.0534 0.2235 0.1237 0.3736 0.0174
1 13  0.0176 0.0064 0.0010 0.0024 0.0034 0.0155 0.0191 0.0315 0.0357 0.0515 0.2134 0.0674 0.5178 0.0173
1 14  0.0135 0.0043 0.0031 0.0010 0.0012 0.0094 0.0177 0.0258 0.0264 0.0550 0.2060 0.0980 0.5209 0.0177
1 15  0.0094 0.0031 0.0025 0.0007 0.0012 0.0069 0.0166 0.0216 0.0257 0.0476 0.2169 0.1048 0.5228 0.0202
1 16  0.0054 0.0018 0.0018 0.0004 0.0011 0.0045 0.0155 0.0175 0.0250 0.0401 0.2277 0.1117 0.5246 0.0229
1 17  0.0027 0.0010 0.0014 0.0002 0.0011 0.0028 0.0147 0.0147 0.0245 0.0352 0.2350 0.1162 0.5259 0.0246
1 18  0.0013 0.0006 0.0012 0.0001 0.0011 0.0020 0.0144 0.0133 0.0242 0.0327 0.2386 0.1185 0.5265 0.0255
1 19  0.0000 0.0001 0.0010 0.0000 0.0011 0.0012 0.0140 0.0119 0.0240 0.0302 0.2422 0.1208 0.5271 0.0264
1 20  0.0000 0.0013 0.0000 0.0000 0.0000 0.0010 0.0115 0.0097 0.0200 0.0241 0.2450 0.1285 0.5271 0.0318
1 21  0.0000 0.0003 0.0010 0.0000 0.0000 0.0008 0.0103 0.0086 0.0181 0.0206 0.2464 0.1321 0.5271 0.0347
1 22  0.0000 0.0013 0.0000 0.0000 0.0000 0.0008 0.0107 0.0081 0.0170 0.0199 0.2451 0.1341 0.5271 0.0359
1 23  0.0021 0.0003 0.0000 0.0010 0.0000 0.0010 0.0118 0.0100 0.0205 0.0224 0.2452 0.1274 0.5271 0.0312
1 24  0.0031 0.0003 0.0000 0.0010 0.0001 0.0011 0.0134 0.0124 0.0240 0.0267 0.2404 0.1226 0.5271 0.0278
2 1   0.0004 0.0052 0.0061 0.0053 0.0158 0.0854 0.3210 0.1382 0.2804 0.0595 0.0628 0.0103 0.0095 0.0001
2 2   0.0036 0.0029 0.0059 0.0234 0.0735 0.1114 0.2842 0.0950 0.2633 0.0396 0.0698 0.0107 0.0169 0.0000
2 3   0.0033 0.0021 0.0032 0.0085 0.0436 0.1130 0.2914 0.1076 0.2835 0.0424 0.0719 0.0091 0.0204 0.0000
2 4   0.0030 0.0015 0.0011 0.0015 0.0183 0.1001 0.2910 0.1246 0.3013 0.0535 0.0743 0.0094 0.0204 0.0000
2 5   0.0030 0.0014 0.0005 0.0017 0.0181 0.1008 0.2898 0.1246 0.3015 0.0537 0.0751 0.0094 0.0204 0.0000
2 6   0.0034 0.0017 0.0021 0.0049 0.0344 0.1091 0.2894 0.1125 0.2932 0.0460 0.0735 0.0093 0.0205 0.0000
2 7   0.0040 0.0021 0.0027 0.0078 0.0427 0.1134 0.2857 0.1083 0.2886 0.0427 0.0724 0.0091 0.0205 0.0000
2 8   0.0038 0.0025 0.0020 0.0022 0.0216 0.1034 0.2834 0.1243 0.3020 0.0515 0.0736 0.0094 0.0203 0.0000
2 9   0.0041 0.0024 0.0020 0.0034 0.0249 0.1049 0.2844 0.1215 0.2986 0.0489 0.0751 0.0093 0.0205 0.0000
2 10  0.0052 0.0027 0.0032 0.0085 0.0450 0.1151 0.2822 0.1024 0.2835 0.0419 0.0777 0.0096 0.0230 0.0000
2 11  0.0049 0.0165 0.0087 0.0224 0.0652 0.1222 0.2809 0.0959 0.2557 0.0405 0.0651 0.0095 0.0125 0.0000
2 12  0.0055 0.0071 0.0082 0.0219 0.0675 0.1169 0.2771 0.0915 0.2637 0.0394 0.0712 0.0106 0.0194 0.0000
2 13  0.0043 0.0024 0.0016 0.0038 0.0255 0.1005 0.2849 0.1205 0.2996 0.0497 0.0761 0.0100 0.0211 0.0000
2 14  0.0038 0.0021 0.0018 0.0015 0.0115 0.0734 0.2923 0.1219 0.3170 0.0641 0.0794 0.0100 0.0211 0.0001
2 15  0.0037 0.0017 0.0012 0.0019 0.0103 0.0558 0.3040 0.1067 0.3309 0.0702 0.0824 0.0100 0.0211 0.0001
2 16  0.0036 0.0018 0.0009 0.0012 0.0109 0.0530 0.3056 0.1064 0.3320 0.0707 0.0827 0.0100 0.0211 0.0001
```

Figure 35. Original Input File of Svmt.

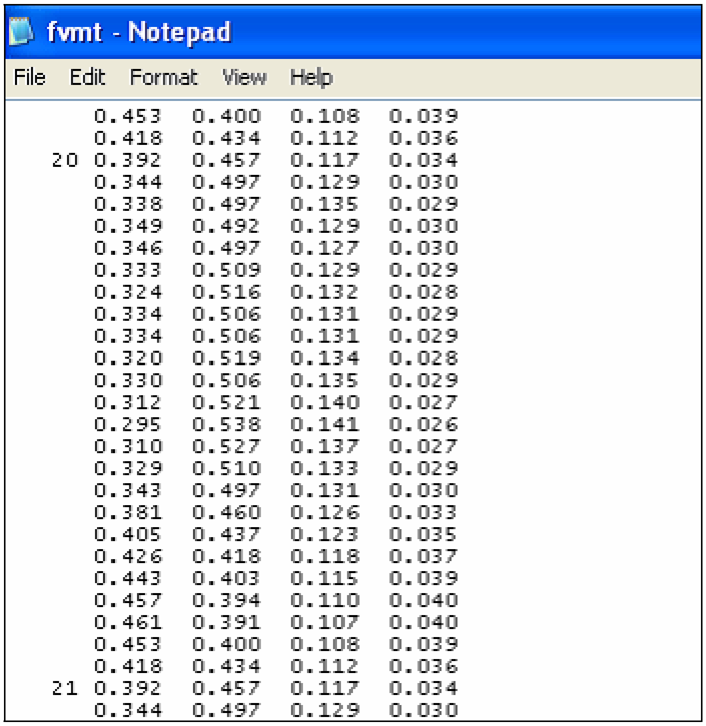


```
SPEED VMT
1 1   0.0083 0.0272 0.0210 0.0224 0.0217 0.0381 0.0344 0.0536 0.0614 0.0700 0.2507 0.1150 0.2550 0.0212
1 2   0.0260 0.0066 0.0076 0.0156 0.0282 0.0326 0.0344 0.0361 0.0360 0.0435 0.2453 0.1729 0.3023 0.0129
1 3   0.0259 0.0033 0.0064 0.0057 0.0126 0.0281 0.0342 0.0349 0.0407 0.0369 0.2181 0.1066 0.4399 0.0127
1 4   0.0145 0.0096 0.0021 0.0022 0.0041 0.0166 0.0232 0.0373 0.0418 0.0449 0.2248 0.1190 0.4422 0.0177
1 5   0.0083 0.0086 0.0052 0.0032 0.0040 0.0163 0.0232 0.0364 0.0375 0.0420 0.2352 0.1170 0.4454 0.0177
1 6   0.0072 0.0034 0.0042 0.0098 0.0121 0.0244 0.0289 0.0327 0.0401 0.0392 0.2294 0.1011 0.4538 0.0137
1 7   1.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1 8   0.0083 0.0075 0.0052 0.0043 0.0054 0.0182 0.0257 0.0381 0.0380 0.0421 0.2258 0.1118 0.4512 0.0184
1 9   0.0113 0.0065 0.0052 0.0023 0.0039 0.0206 0.0279 0.0358 0.0383 0.0517 0.2147 0.1151 0.4484 0.0183
1 10  0.0155 0.0075 0.0034 0.0042 0.0081 0.0272 0.0324 0.0363 0.0315 0.0390 0.2124 0.0644 0.5000 0.0181
1 11  0.0156 0.0411 0.0225 0.0199 0.0284 0.0316 0.0500 0.0488 0.0446 0.0555 0.2223 0.1092 0.2957 0.0148
1 12  0.0186 0.0113 0.0046 0.0110 0.0183 0.0261 0.0488 0.0383 0.0314 0.0534 0.2235 0.1237 0.3736 0.0174
1 13  0.0176 0.0064 0.0010 0.0024 0.0034 0.0155 0.0191 0.0315 0.0357 0.0515 0.2134 0.0674 0.5178 0.0173
1 14  0.0135 0.0043 0.0031 0.0010 0.0012 0.0094 0.0177 0.0258 0.0264 0.0550 0.2060 0.0980 0.5209 0.0177
1 15  0.0094 0.0031 0.0025 0.0007 0.0012 0.0069 0.0166 0.0216 0.0257 0.0476 0.2169 0.1048 0.5228 0.0202
1 16  0.0054 0.0018 0.0018 0.0004 0.0011 0.0045 0.0155 0.0175 0.0250 0.0401 0.2277 0.1117 0.5246 0.0229
1 17  0.0027 0.0010 0.0014 0.0002 0.0011 0.0028 0.0147 0.0147 0.0245 0.0352 0.2350 0.1162 0.5259 0.0246
1 18  0.0013 0.0006 0.0012 0.0001 0.0011 0.0020 0.0144 0.0133 0.0242 0.0327 0.2386 0.1185 0.5265 0.0255
1 19  0.0000 0.0001 0.0010 0.0000 0.0011 0.0012 0.0140 0.0119 0.0240 0.0302 0.2422 0.1208 0.5271 0.0264
1 20  0.0000 0.0013 0.0000 0.0000 0.0000 0.0010 0.0115 0.0097 0.0200 0.0241 0.2450 0.1285 0.5271 0.0318
1 21  0.0000 0.0003 0.0010 0.0000 0.0000 0.0008 0.0103 0.0086 0.0181 0.0206 0.2464 0.1321 0.5271 0.0347
1 22  0.0000 0.0013 0.0000 0.0000 0.0000 0.0008 0.0107 0.0081 0.0170 0.0199 0.2451 0.1341 0.5271 0.0359
1 23  0.0021 0.0003 0.0000 0.0010 0.0000 0.0010 0.0118 0.0100 0.0205 0.0224 0.2452 0.1274 0.5271 0.0312
1 24  0.0031 0.0003 0.0000 0.0010 0.0001 0.0011 0.0134 0.0124 0.0240 0.0267 0.2404 0.1226 0.5271 0.0278
2 1   0.0004 0.0052 0.0061 0.0053 0.0158 0.0854 0.3210 0.1382 0.2804 0.0595 0.0628 0.0103 0.0095 0.0001
2 2   0.0036 0.0029 0.0059 0.0234 0.0735 0.1114 0.2842 0.0950 0.2633 0.0396 0.0698 0.0107 0.0169 0.0000
2 3   0.0033 0.0021 0.0032 0.0085 0.0436 0.1130 0.2914 0.1076 0.2835 0.0424 0.0719 0.0091 0.0204 0.0000
2 4   0.0030 0.0015 0.0011 0.0015 0.0183 0.1001 0.2910 0.1246 0.3013 0.0535 0.0743 0.0094 0.0204 0.0000
2 5   0.0030 0.0014 0.0005 0.0017 0.0181 0.1008 0.2898 0.1246 0.3015 0.0537 0.0751 0.0094 0.0204 0.0000
2 6   0.0034 0.0017 0.0021 0.0049 0.0344 0.1091 0.2894 0.1125 0.2932 0.0460 0.0735 0.0093 0.0205 0.0000
2 7   1.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2 8   0.0038 0.0025 0.0020 0.0022 0.0216 0.1034 0.2834 0.1243 0.3020 0.0515 0.0736 0.0094 0.0203 0.0000
2 9   0.0041 0.0024 0.0020 0.0034 0.0249 0.1049 0.2844 0.1215 0.2986 0.0489 0.0751 0.0093 0.0205 0.0000
2 10  0.0052 0.0027 0.0032 0.0085 0.0450 0.1151 0.2822 0.1024 0.2835 0.0419 0.0777 0.0096 0.0230 0.0000
2 11  0.0049 0.0165 0.0087 0.0224 0.0652 0.1222 0.2809 0.0959 0.2557 0.0405 0.0651 0.0095 0.0125 0.0000
2 12  0.0055 0.0071 0.0082 0.0219 0.0675 0.1169 0.2771 0.0915 0.2637 0.0394 0.0712 0.0106 0.0194 0.0000
2 13  0.0043 0.0024 0.0016 0.0038 0.0255 0.1005 0.2849 0.1205 0.2996 0.0497 0.0761 0.0100 0.0211 0.0000
2 14  0.0038 0.0021 0.0018 0.0015 0.0115 0.0734 0.2923 0.1219 0.3170 0.0641 0.0794 0.0100 0.0211 0.0001
2 15  0.0037 0.0017 0.0012 0.0019 0.0103 0.0558 0.3040 0.1067 0.3309 0.0702 0.0824 0.0100 0.0211 0.0001
2 16  0.0036 0.0018 0.0009 0.0012 0.0109 0.0530 0.3056 0.1064 0.3320 0.0707 0.0827 0.0100 0.0211 0.0001
```

Figure 36. Changed Input File of Svmt.

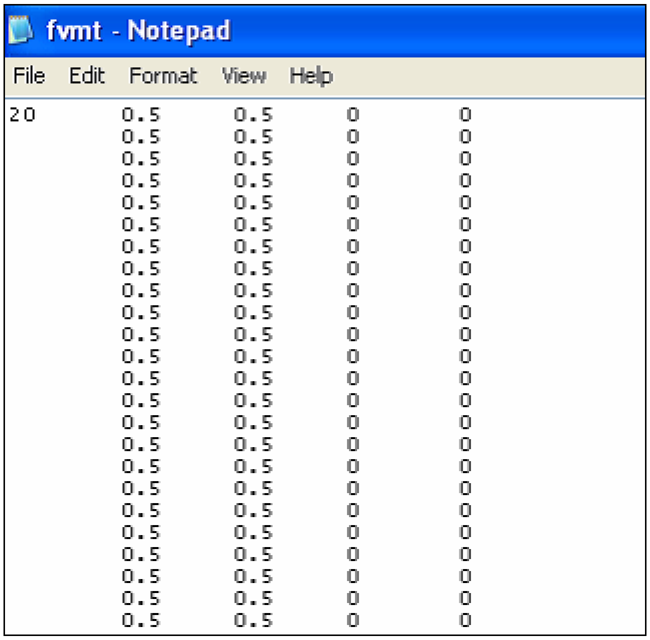
4.3.6 Changing the Fymt Input File

Figures 37 and 38 show the original and changed fvmt input files. The fvmt command allows users to allocate the total VMT to various roadway or facility types by vehicle class. The "VMT by facility" (fvmt) command also permits users to enter VMT distributions for each of the 28 vehicle classes across four roadway types for each of the 24 hours of the day (EPA, 2003). The Four roadway types include freeway, arterial, local, and ramps. The model for this research is based on freeway and arterial facilities; therefore, the fvmt fractions for these two have been set to 0.5 and for the rest of the facility types to zero, as shown in Figure 38. The vehicle class is HDDV6.



```
    0.453  0.400  0.108  0.039
    0.418  0.434  0.112  0.036
 20 0.392  0.457  0.117  0.034
    0.344  0.497  0.129  0.030
    0.338  0.497  0.135  0.029
    0.349  0.492  0.129  0.030
    0.346  0.497  0.127  0.030
    0.333  0.509  0.129  0.029
    0.324  0.516  0.132  0.028
    0.334  0.506  0.131  0.029
    0.334  0.506  0.131  0.029
    0.320  0.519  0.134  0.028
    0.330  0.506  0.135  0.029
    0.312  0.521  0.140  0.027
    0.295  0.538  0.141  0.026
    0.310  0.527  0.137  0.027
    0.329  0.510  0.133  0.029
    0.343  0.497  0.131  0.030
    0.381  0.460  0.126  0.033
    0.405  0.437  0.123  0.035
    0.426  0.418  0.118  0.037
    0.443  0.403  0.115  0.039
    0.457  0.394  0.110  0.040
    0.461  0.391  0.107  0.040
    0.453  0.400  0.108  0.039
    0.418  0.434  0.112  0.036
 21 0.392  0.457  0.117  0.034
    0.344  0.497  0.129  0.030
```

Figure 37. Original Input File of Fvmt.



```
20      0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
        0.5     0.5     0       0
```

Figure 38. Changed Input File of Fvmt.

4.4 Data Comparison between OEM-2100 and MOBILE6.2

This section presents the comparison between the data collected by OEM-2100 and the estimated values by MOBILE6.2. Data obtained in the output file of MOBILE6.2 is in grams per mile. In order to make the data estimated by MOBILE6.2 comparable with the data collected by OEM-2100, MOBILE6.2 estimated values were converted to the unit of grams per second by multiplying MOBILE6.2 estimates (gram/mi) by the equivalent speed of 2.5mi/hr and dividing the result by 3600 sec/hr. The equation is shown below:

$$Emission(g/s) = Emission(g/mi) \times 2.5(mi/hr)/3600(s/hr) \quad (2)$$

Figure 39 shows the comparison between data obtained from MOBILE6.2 and data collected from OEM-2100. The compared emission factors are HC (VOC), CO, and NOx, while PM and CO_2 are not included since they are not shown in MOBILE6.2 general outputs.

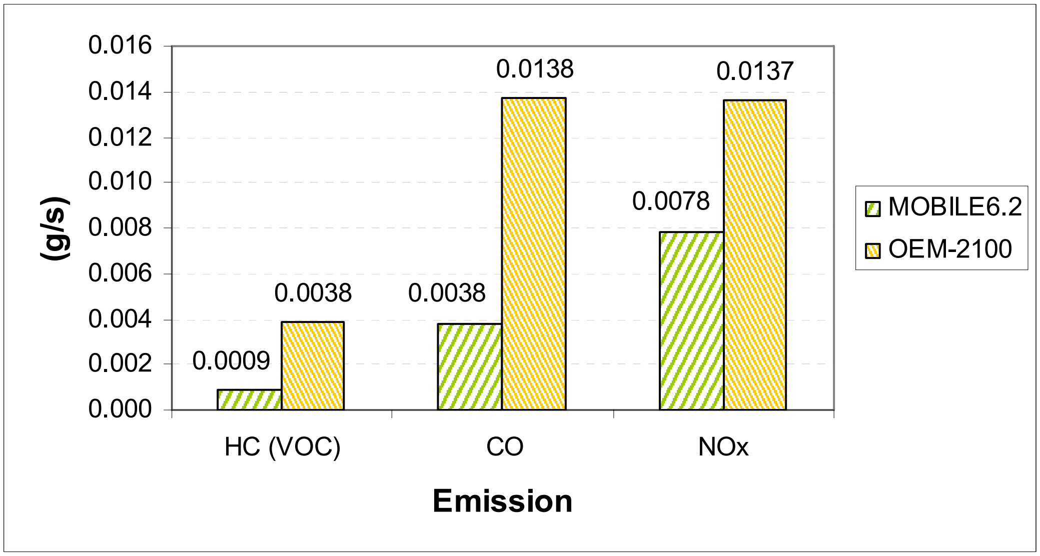


Figure 39. Comparison of Emissions Tested by OEM-2100 and MOBILE6.2.

Figure 39 shows that there is a big difference between the tested emissions and MOBILE6.2 estimates. Generally, emissions tested by OEM-2100 are higher than emissions estimated by MOBILE6.2. Recall that MOBILE6.2 estimates were based on the average laboratory test results for a range of tested vehicles, and emissions tested by OEM-2100 should reflect more real situations of emissions in idling for a single vehicle. Therefore, attention should be paid when

MOBILE6.2 is employed in estimating the vehicle idling emissions in the Houston area, especially for HDDV6. It should also be noted that since only one kind of vehicle in the category of HDDV6 was tested in this research, and only limited idling tests were conducted, these tests might not fully represent the vehicle emission characteristics during the idling. As more tests are conducted, the accuracy and reliability of the testing results by OEM-2100 may be determined.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Research conducted in this report analyzed some of the characteristics of truck idling emissions. The major data used for this report were obtained by employing the On-board Emission Monitoring system (OEM-2100) for testing. In this research, different scenarios for truck idling were considered and discussed. First, data for cold start idling was obtained and analyzed. Second, idling emissions on different days were compared. Third, idling emissions before and after driving and under different driving conditions were compared and contrasted. Fourth, the relationship between emission variables and driving distance was identified. Finally, the relationship between emission variables and driving duration prior to idling tests was discussed. After all the analysis were completed using the data collected by OEM-2100, idling emissions were modeled by the EPA standard model, MOBILE6.2. Then, estimated emissions via MOBILE6.2 were compared with the average emission idling data obtained through OEM-2100. Several conclusions can be drawn based on this research:

In cold start idling, there was a decay of FC, NOx, and CO_2, which lasted for more than 600 seconds before the engine reached its hot stabilized state (for the particular tested truck). Decay time for HC and CO could not be recorded in this research due to the limited data range.

Through the Confidence Interval Analysis done for each test, it was found that the amount of errors involved in the data collected by OEM-2100 was very small.

Comparison between idling tests before and after driving showed that NOx pollutant values before driving were always lower, while HC and CO values were always higher than those after driving the truck. As for FC and CO_2, it was found when the truck was driven on freeways; the values of these variables were lower in idling after driving than those before driving the truck. However, when the truck was driven on non-freeway facilities, the results were reversed. Through this case study, therefore, it is illustrated that the facility types used for driving before idling tests affect pollutant production and fuel consumption during the idling tests.

By analyzing the relationship between each variable (emissions and fuel consumption) and the driving distance/duration before the idling test, the general effect of these conditions on the emission produced during the post-driving idling test was assessed. It was found that by increasing the driving distance/duration, NOx and CO_2 emission production and fuel consumption decreases, while CO and HC emission production increases during the post-driving idling test.

Emissions tested by OEM-2100 have higher values in comparison with the emissions estimated by MOBILE6.2. OEM is recommended as an important system for collecting real-world emission data to improve the accuracy and applicability of emission estimation methods. In addition, the EPA has confirmed OEM's accuracy. MOBILE6.2 estimates are based on the average laboratory tests' results; therefore, in this research (testing one type of vehicle), emissions tested by OEM-2100 should reflect more real situations of emissions in idling. Further tests and comparisons should be conducted before more general conclusions can be reached.

To further identify general conclusions, the authors provide the following recommendations:

5. Test more trucks with cold start engine in order to determine, more accurately, the amount of time that it takes for the engine to reach its hot stabilized condition.
6. Test more trucks of different ages to address the findings of this case study.
7. Test trucks under different weather conditions to reflect the weather's effect on emissions production.
8. Use the findings from this research and test some vehicles at signalized intersections for the purpose of signal timing, which result in reduced vehicle emissions and improved air quality

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