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Determination of Alternative Fuels Combustion Products: Phase 3 Report

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Foreword

This report covers the third phase of a continuing program conducted by the Department of Emissions Research of Southwest Research Institute (SwRI) for the National Renewable Energy Laboratory (NREL). This program was authorized by NREL Subcontract No. YAW-3-13253-01. Midwest Research Institute operates and manages NREL for the U.S. Department of Energy. This program began on October 1, 1993 and concluded on November 20, 1997. Phase III testing was conducted from November 1996 through July 1997. The initial project was based on SwRI proposal 08-14326 to NREL. Tasks covered in this report are based on SwRI proposal 08-19417-B. The overall program was identified within SwRI as project 08-6068. Ms. Michelle Bergin of NREL's Center for Transportation Technologies and Systems in Golden, Colorado was the technical monitor for this phase. Other NREL technical monitors during this program were Mr. Brent Bailey and Mr. Chris Colucci. The SwRI project manager was Dr. Lawrence R. Smith, and the project leader was Mr. Kevin A. Whitney. Mr. Danny Terrazas, laboratory supervisor, was responsible for emissions testing.

Abstract

This report describes the laboratory efforts to characterize particulate and gaseous exhaust emissions from a passenger vehicle operating on alternative fuels. Tests were conducted at room temperature (nominally 72°F) and 20°F utilizing the chassis dynamometer portion of the FTP for light-duty vehicles. Fuels evaluated include Federal RFG, LPG meeting HD-5 specifications, a national average blend of CNG, E85, and M85. Exhaust particulate generated at room temperature was further characterized to determine polynuclear aromatic content, trace element content, and trace organic constituents.

For all fuels except M85, the room temperature particulate emission rate from this vehicle was about 2 to 3 mg/mile. On M85, the particulate emission rate was more than 6 mg/mile. In addition, elemental analysis of particulate revealed an order of magnitude more sulfur and calcium from M85 than any other fuel. The sulfur and calcium indicate that these higher emissions might be due to engine lubricating oil in the exhaust. For RFG, particulate emissions at 20°F were more than six times higher than at room temperature. For alcohol fuels, particulate emissions at 20°F were two to three times higher than at room temperature. For CNG and LPG, particulate emissions were virtually the same at 72°F and 20°F. However, PAH emissions from CNG and LPG were higher than expected. Both gaseous fuels had larger amounts of pyrene, 1-nitropyrene, and benzo(g,h,i)perylene in their emissions than the other fuels.

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Acronyms and Abbreviations

ADP	Adaptive Digital Processor
CARB	California Air Resources Board
cfm	cubic foot per minute
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CVS	constant volume sampler
DFI	direct filter injection
DNPH	2,4-dinitrophenylhydrazine
E85	85% denatured ethanol and 15% gasoline
ECM	engine control module
ECU	engine control unit
EGO	exhaust gas oxygen
EGR	exhaust gas recirculation
EPA	Environmental Protection Agency
FID	flame ionization detector
ft	foot
FTP	Federal Test Procedure
GC	gas chromatograph
GC/FID	gas chromatograph/flame ionization detector
GC/MS	gas chromatograph/mass spectrometry
g/mi	grams per mile
hp	horsepower
HC	hydrocarbons
HPLC	high performance liquid chromatograph
lb	pound
L/min	liters per minute
LPG	liquefied petroleum gas
M85	85% methanol and 15% gasoline
mg	milligram
mg/mile	milligrams per mile
mi	mile
MIR	maximum incremental reactivity
mL	milliliter
mm	millimeter
MOUDI	micro-orifice uniform deposit impactor
mph	miles per hour
MS	mass spectrometer
MTBE	methyl tertiary-butyl ether
NDIR	non-dispersive infrared
ng	nanogram
NMHC	non-methane hydrocarbons

Acronyms and Abbreviations (Cont'd)

NMOG	non-methane organic gas
NREL	National Renewable Energy Laboratory
NO_x	oxides of nitrogen
OD	overdrive
OEM	original equipment manufacturer
OMHCE	organic material hydrocarbon equivalent
OMNMHCE	organic material non-methane hydrocarbon equivalent
PAH	polynuclear aromatic hydrocarbons
PCV	positive crankcase ventilation
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
RF-A	Reference Fuel A
RFG	reformulated gasoline
RVP	Reid Vapor Pressure
SAE	Society of Automotive Engineers
scfm	standard cubic feet per minute
SIR	selected ion monitoring
SwRI	Southwest Research Institute
TEOM	Tapered Element Oscillating Microbalance
THC	total hydrocarbons
TLEV	transitional low emission vehicle
UDDS	urban dynamometer driving schedule
UEGO	universal exhaust gas oxygen
ug	micrograms
uL	microliter
URDI	University of Dayton Research Institute
um	micrometer
uv	ultraviolet
VIN	vehicle identification number
VOC	volatile organic compound
VOF	volatile organic fraction

I. Introduction

In October 1993, SwRI began researching alternative fuel combustion products for NREL. The work was conducted to help NREL increase understanding about the effects of alternative fuels on air quality. Initially, the objective of this project was to identify 99% of volatile organic exhaust species generated from alternative-fueled light-duty vehicles over the Federal Test Procedure (FTP). SwRI tested vehicles operating on CNG, LPG, methanol, ethanol, and reformulated gasoline. Exhaust species from these vehicles were identified and quantified for fuel/air equivalence ratios of 0.8, 1.0, and 1.2. Tests were conducted with and without a catalyst in place to determine the effects of a catalytic converter on species formation. These data were submitted to NREL as the Phase I Final Report.

In March 1995, the scope of this study was expanded to include four additional tasks: 1) identifying species of hydrocarbon exhaust emissions from a light-duty vehicle modified to operate on butane and butane blends; 2) evaluating NREL's Variable Conductance Vacuum Insulated Catalytic Converter Test Article 4 (TA-CC4) for reduction of cold-start FTP exhaust emissions from a Ford FFV Taurus operating on E85 after extended soak periods; 3) supporting the University of Dayton Research Institute (UDRI) in defining correlations between engine-out combustion products identified by SwRI during chassis dynamometer testing, and those found by UDRI during flow tube reactor experiments; and 4) characterizing small-diameter particulate matter from a Ford Taurus FFV operating in a simulated fuel-rich failure mode on CNG, LPG, M85, E85, and reformulated gasoline. This information can be found in the Phase II Final Report.

On August 21, 1996, SwRI received a fully executed contract modification to conduct additional testing under this program. This Phase III report summarizes project activity for the additional testing.

A. Objective

The objective for this phase of the project was to characterize particulate mass emissions and particulate size distribution from a passenger vehicle operating on Federal RFG, LPG, CNG, E85, and M85. This project complemented SwRI's previous work for NREL. Here the test vehicle operated over the FTP during normal conditions (stoichiometric operation) instead of a simulated fuel-rich failure mode. Additionally, testing simulating winter conditions (20°F) helped compare the effects of cold-start fuel enrichment and exhaust system temperature on primary exhaust particulate formation. To better understand the composition of primary exhaust particulate, analysts collected samples during stoichiometric operation at room temperature. The samples were characterized to determine polynuclear aromatic content, trace element content, and trace organic constituents.

B. Approach

A 1994 Ford Taurus FFV was used for this program. It was also used in the previous Phase II study to characterize exhaust particulate emissions from alternative fuels operating in a simulated fuel-rich failure mode. Prior to testing, the vehicle was driven more than 500 miles to stabilize exhaust emissions. No modifications to the vehicle were necessary while conducting tests on RFG and M85. Testing on E85 required the engine controller be provided with an SwRI-generated fuel composition signal calibrated for an ethanol/gasoline fuel blend. The gaseous fuels were evaluated by installing appropriate conversion kits made by IMPCO Technologies and a fuel controller made by Autotronic Controls. To properly weight the particulate emissions over the FTP for cold- and hot-start operation, emissions were sampled over a four-bag FTP. To generate a sufficient mass of particulate for subsequent analysis, particulate samples were collected over replicate FTPs. For the 20°F evaluations, samples were collected over duplicate FTPs with the same set of filters. Duplicate tests were chosen based on experience gained in Phase II of this program. In Phase II, the feasibility of measuring primary exhaust particulate from alternative fuels was investigated with the same test vehicle used in this study. Researchers were able to measure particulate over duplicate FTPs when the vehicle was running fuel-rich to simulate a failure mode. This rich operation is similar to command fuel enrichment control strategies used with liquid fuels at low temperatures. Researchers expected that less particulate would be generated at 72°F than at 20°F, so additional replicate tests were necessary during room temperature FTPs to collect enough particulate on the filters. Based on the project budget, triplicate FTPs were conducted. Gaseous emissions were collected during all tests on a bag-by-bag basis. In all, 25 FTPs were conducted during these evaluations.

C. Test Vehicle

The test vehicle was a 1994 Ford Taurus FFV with a 3.0L V-6 engine, a three-way catalyst, exhaust gas recirculation, and about 20,000 odometer miles. Table 1 provides a more detailed description of this vehicle, which conformed to EPA and CARB regulations applicable to 1994 model year vehicles introduced into commerce solely for sale in California, and has been certified to meet the CARB TLEV standards. Figure 1 shows the vehicle undergoing testing.

Table 1. Vehicle Description

Item	Configuration of Ford Taurus FFV
Model year	1994
Body style	4-door GL sedan
Transmission	4-speed automatic OD
VIN	1FALP5217RG228907
Vehicle Odometer	~20,000 miles at start of testing
Tires	P205/65 R15
Accessories	power locks, windows, steering, brakes, air conditioning
Engine family	RFM3.0V8F2EA
Engine type	3.0L V-6
Fuel system	multi-point fuel injection
Ignition system	electronic
Emission control system	underbody three-way catalyst, heated oxygen sensor, EGR
Chassis Dynamometer: Inertia Setting Road Load @ 50 mph	 3500 lb 6.8 hp

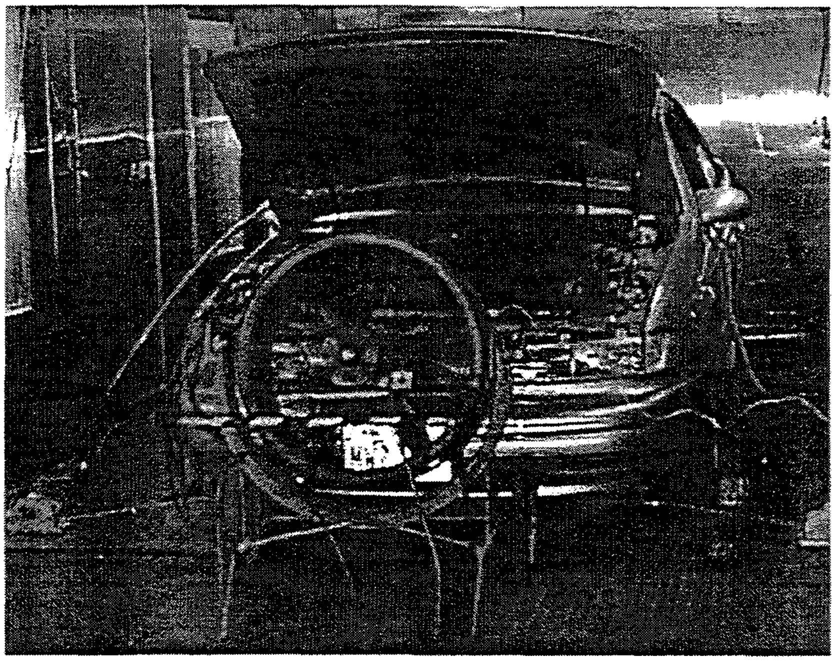

Figure 1. Ford Taurus FFV on Chassis Dynamometer During FTP Evaluation

The vehicle was operated in stock configuration with RFG and M85. For operation on E85, the vehicle's fuel composition sensor was replaced with an SwRI-generated signal calibrated for an ethanol/gasoline fuel blend. The stock sensor was calibrated for methanol, which caused excessive fuel enrichment during open-loop operation on E85. SwRI's circuit was calibrated to provide an appropriate amount of open-loop fuel enrichment when operating on E85. This circuit was originally developed and verified by SwRI under NREL Subcontract No. YAW-3-12243-01, "Development of a Dedicated Ethanol Ultra-Low Emission Vehicle." For operation on LPG and CNG, the Taurus FFV was equipped with an appropriate conversion kit for each of the gaseous fuels. Both kits used IMPCO fuel regulators and mixers and Autotronic closed-loop fuel controllers. SwRI installed and tuned the kits according to the manufacturers' instructions.

D. Test Fuels

This program used five different test fuels for emissions evaluations. The RFG represents a typical summer-grade gasoline available in an ozone non-attainment area. It was purchased in September 1996, from a commercial service station in metropolitan Dallas, Texas. The LPG was purchased from a San Antonio, Texas distributor and was represented as meeting HD-5 specifications. The E85 was a blend of 85 percent ethanol (denatured with 5 percent gasoline) and 15 percent RF-A gasoline. The M85 consisted of 85 percent methanol and 15 percent RF-A gasoline. SwRI custom blended the CNG to represent average gas composition available in the United States, as given in SAE Paper 912364. Table 2 shows compositions of the gaseous fuels. Selected properties for reformulated gasoline and the alcohol fuels are given in Table 3.

Table 2. Gaseous Fuels Composition

Constituent	Mole %	
	CNG	LPG
Methane	95.90	ND [a]
Ethane	1.80	4.40
Propylene	ND	ND
Propane	0.20	93.5
Butane	0.04	0.30
Iso-Butane	0.02	1.20
Pentane	0.01	ND
Iso-Pentane	0.01	0.60
Hexane	0.01	ND
Heptane	0.01	ND
Octane	ND	ND
CO_2	0.97	ND
Nitrogen	1.03	ND

[a] ND - not detected

Table 3. Properties of the Liquid Fuels

Fuel Specifications	RFG	E85	M85
Distillation, ASTM D-86			
IBP, °F	106	135	124
50%, °F	187	174	146
90%, °F	355	175	147
FBP, °F	416	263	285
RON, ASTM D-2699	92.5	108.7	109.5
MON, ASTM D-2700	83.7	99.7	100.6
(R+M)/2	87.9	104.2	105.1
RVP, ASTM D-4814	7.0	5.5	8.0
Specific Gravity, ASTM D-4052	0.744	0.790	0.793
Carbon, wt %	87.4	60.0	43.1
Hydrogen, wt %	13.0	13.2	12.7
Oxygen, wt %	2.2	26.8	44.2
Oxygenates, ASTM D-4815			
MTBE, vol %	9.07	0	0
DIPE, vol %	0.29	0	0
TAME, vol %	1.94	0	0
ETBE, vol %	0.13	0	0
NPA, vol %	0.09	0	0
Ethanol, vol %	0	82.4	0
Methanol, vol %	0	0	85.6

E. Test Procedures

Gaseous and particulate exhaust emissions were evaluated with each test fuel at room temperature (72°F nominal) and at 20°F. Testing included the chassis dynamometer portion of the Federal Test Procedure for light-duty vehicles. For testing at 20°F, the vehicle was soaked for at least 12 hours at test temperature prior to emission evaluations. Test cell temperature was controlled to 20±5°F throughout the cycle. To properly weight the particulate emissions over the FTP for cold- and hot-start operation, emissions were sampled over a four-bag FTP. This consisted of a cold-start phase (Bag 1) followed by a stabilized phase (Bag 2), a ten-minute soak, and a hot-start phase (Bag 3) followed by another stabilized phase (Bag 4). One set of particulate filters was collected during Bags 1 and 2 of the FTP (cold UDDS), and a second set was collected during Bags 3 and 4 of the FTP (hot UDDS). This technique allowed a comparison of exhaust emission rates for cold-start and hot-start operation. To generate a sufficient mass of particulate for subsequent analysis, samples were collected over three replicate FTPs (conducted on consecutive days) using the same particulate filter sets for the room temperature evaluations. For the 20°F evaluations, samples were collected over duplicate FTPs with a second group of filter sets. Gaseous emissions for all tests were collected on a bag-by-bag basis.

Fuel changeovers for RFG, M85, and E85 included the steps given below:

1. Disconnect the fuel supply line to the engine and purge all fuel from the fuel tank using the vehicle fuel pump.
2. Reconnect the fuel supply line. Add two to three gallons of the new fuel to the fuel tank. Idle vehicle for ten minutes.
3. Disconnect the fuel supply line to the engine and purge all fuel from the fuel tank using the vehicle fuel pump.
4. Reconnect the fuel supply line. Fill the tank with the new fuel.

Following the fuel changeover (gaseous *and* liquid fuels), the following sequence was performed to ensure that the engine management system had adapted to the new fuel properties.

1. Perform highway fuel economy test (HFET) driving cycle
2. Turn ignition key off for 5 minutes
3. Start car and idle for 1 minute, turn ignition key off and wait 1 minute
4. Start car and idle for 1 minute, turn ignition off and wait 1 minute
5. Perform the urban dynamometer driving schedule (UDDS) cycle
6. Soak for one hour before performing another UDDS cycle and overnight soak as preparation for FTP testing.

1. Driving Cycle

All exhaust emissions were evaluated using the chassis dynamometer portion of the FTP for light-duty vehicles specified in the *Code of Federal Regulations, Title 40, Part 86, Subpart B*. The FTP uses the UDDS, which totals 1372 seconds. The UDDS is divided into a 505-second segment and an 867-second segment. An FTP is composed of a 505-second cold-start transient portion (Bag 1) and an 867 cold stabilized portion (Bag 2), followed by a 10-minute soak, then a 505-second hot-start transient portion (Bag 3). For this study an additional 867-second test segment (Bag 4) followed the 505-second hot-start transient phase. Table 4 summarizes the cycle duration, driving distance, and average speed of the UDDS. Figure 2 shows a typical three-bag FTP driving schedule with the cold and hot test segments identified.

Table 4. Summary of FTP Driving Schedule

Segment	Duration, seconds	Distance, miles	Average Speed, miles/hr
Transient phase	505	3.60	25.7
Stabilized phase	867	3.90	16.2
UDDS	**1372**	**7.50**	**19.7**

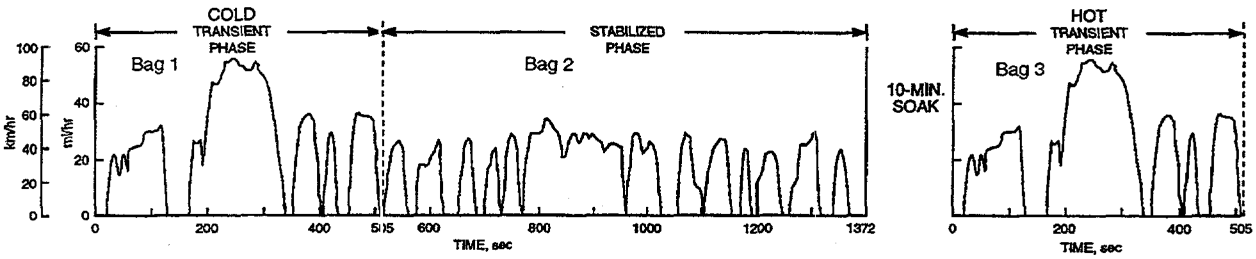

Figure 2. FTP Driving Cycle

2. Chassis Dynamometer and CVS

A Clayton Model ECE-50 passenger car dynamometer with a direct-drive variable inertia flywheel system was used for all testing. The inertia system simulates vehicle weights from 1,000 pounds (lbs) to 4,875 lbs in 125-lb increments. The vehicle hood was opened during all cycles and closed during soak periods. A 5,000 cfm cooling fan in front of the test vehicle provided air flow during all tests. During soak periods, the fan was turned off.

SwRI constant volume sampler (CVS) No. 2 was used for all evaluations. The CVS system includes a 10-inch diameter by 16-foot dilution tunnel for the collection of particulate samples. A schematic of CVS No. 2 is given in Figure 3. This CVS has a nominal flow rate of 325 scfm. All dilution air was filtered prior to entering the tunnel. An MSA Ultra™ filter was used to remove particles from the air. A charcoal filter absorbed background hydrocarbons. An MSA Dustfoe™ Space Filter was used as a backup filter to collect additional particles. Testing during Phase II of this program showed that these filters remove about 84% of the laboratory ambient air particle mass. The background particulate contributed less than 0.05% of the total mass collected on any filter during testing. The average temperature in the dilution tunnel at the particulate sampling zone was 110°F, and did not exceed 125°F during testing.

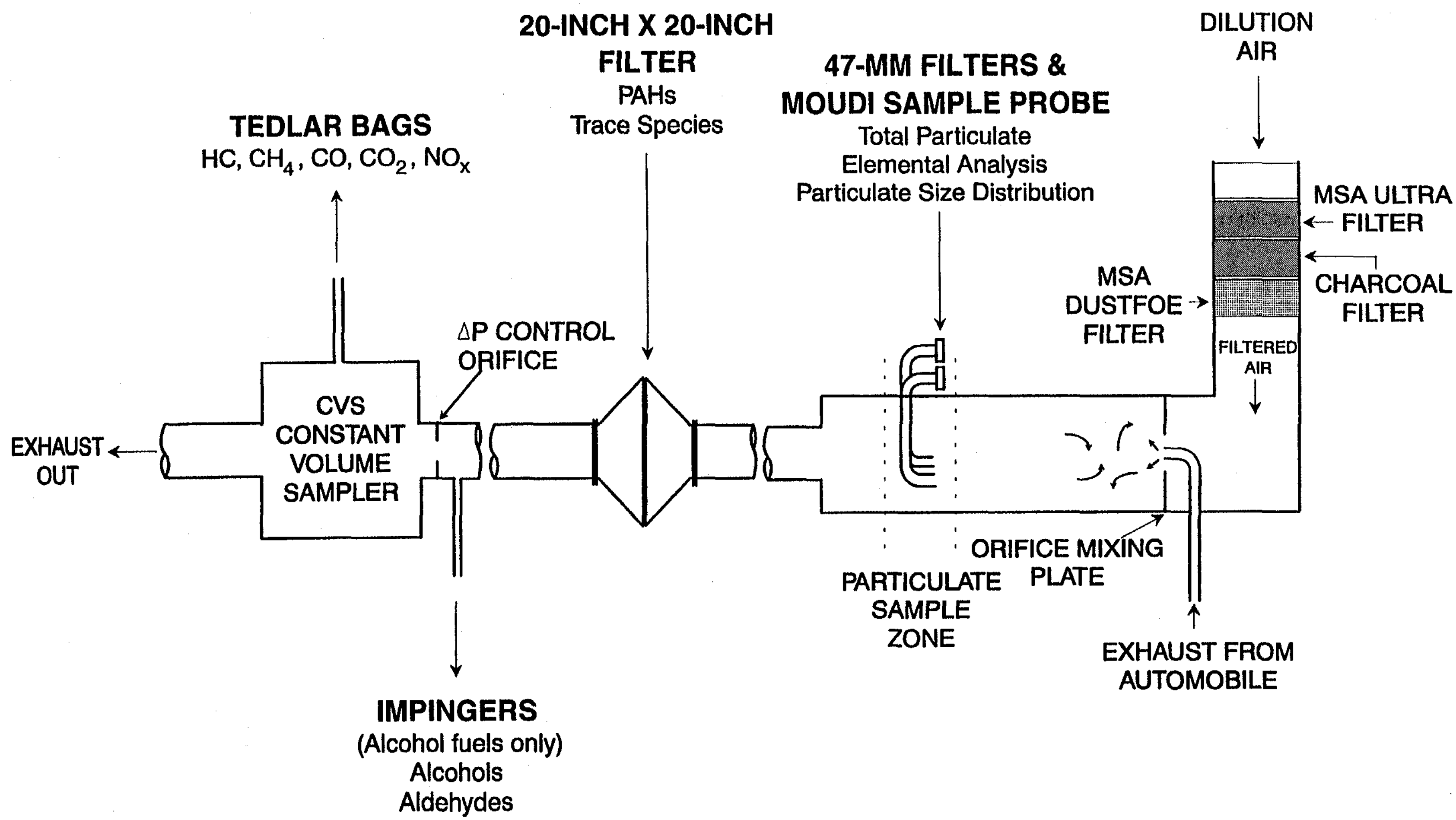

Figure 3. Schematic Representation of SwRI CVS No. 2

F. Emissions Sampling and Analysis Procedures

Table 5 summarizes exhaust emissions sampling and analytical techniques used in this program. A more detailed description of these techniques is listed below.

Table 5. Exhaust Species Collection and Analysis Methods

Compounds	Method of Collection	Method of Analysis
Total Hydrocarbons	Bag	FID
Carbon Monoxide	Bag	NDIR
Oxides of Nitrogen	Bag	Chemiluminescent analysis
Carbon Dioxide	Bag	NDIR
Methane	Bag	GC-FID
Aldehydes and Ketones[a]	Impingers containing DNPH	HPLC-UV
Methanol and Ethanol[a]	Impingers containing water	GC-FID
Particulate Mass	Fluorocarbon coated glass fiber filter	Gravimetric
Particle Size Distribution	MOUDI	Gravimetric

[a] for determination of OMHCE

1. Regulated Gaseous Emissions

THC or OMHCE, CH_4, CO, NO_x, and CO_2 emissions were measured using the EPA protocols for light-duty emissions testing given in the *Code of Federal Regulations, Title 40, Part 86, Subpart B*. Proportional exhaust gas samples of THC, CH_4, CO, NO_x, and CO_2 were collected in Tedlar bags for subsequent analyses. THC concentrations were determined using an FID, CO and CO_2 using NDIR instruments, and NO_x using a chemiluminescent instrument. Wet absorption techniques were used to collect methanol, ethanol, and aldehydes for the determination of OMHCE. These techniques are discussed in more detail in Sections I.F.5 and I.F.6.

Methane levels were measured using a gas chromatograph (GC) equipped with an FID, according to the Society of Automotive Engineer (SAE) J1151 procedure. The GC system was equipped with a packed column to resolve methane from other hydrocarbons in the sample. Samples were introduced into a 5-mL sample loop via a diaphragm pump. For analysis, the valve was switched to the inject position. The helium carrier gas swept the sample from the loop toward the detector through a 61-cm × 0.3-cm Porapak N column in series with a 122-cm × 0.3-cm molecular sieve 13X column. Once the methane peak passed into the molecular sieve column, the helium flow was reversed through the Porapak N column to vent. Peak areas were compared to an external calibration standard.

2. Particulate Emissions

All particulate samples were collected simultaneously from the same sampling zone in the dilution tunnel. The sample probe system is shown in Figure 4. Proportional total particulate mass samples were collected from the dilution tunnel using 47-mm Pallflex T60A20 fluorocarbon-coated glass fiber filters. Filters were conditioned and weighed in accordance with the *Code of Federal Regulations* for light-duty vehicles. Particle size distribution was measured with a Model 110 Micro-Orifice Uniform Deposit Impactor (MOUDI) using an isokinetic sampling probe. The flow rate through the MOUDI was 30 L/min. Stages 3 through 10 were used to collect particulate mass at equivalent aerodynamic diameter cut-off ranges of 6.2 µm, 3.1 µm, 1.8 µm, 1.0 µm, 0.54 µm, 0.31 µm, 0.17 µm, 0.09 µm, and 0.056 µm. The particles were collected on 47-mm foil substrates. The MOUDI is pictured in Figure 5.

The MOUDI operates the same as any inertial cascade impactor with multiple nozzles. At each stage, jets of particle-laden air impinge upon an impaction plate. Particles larger than the cut-size of that stage cross the air streamlines and remain on the impaction plate. Smaller particles have less inertia. Because they cannot cross the streamlines, they proceed to the next stage. Smaller nozzles with higher air velocity collect finer particles. The process continues through the cascade impactor until the smallest particles are collected on the final glass fiber backup filter. By rotating every other stage of the impactor and holding the others stationary, every nozzle plate/impaction plate combination has relative rotation. This rotation allows the MOUDI to achieve near uniform particle deposition.

3. Polynuclear Aromatic Hydrocarbons

All dilute exhaust was passed through 20-inch×20-inch in-line Pallflex T60A20 fluorocarbon-coated glass fiber filters to sample polynuclear aromatic hydrocarbons (PAH). The in-line filter was located immediately downstream of the dilution tunnel, prior to the CVS blower. The 20-inch×20-inch filter holder is shown in Figure 6. Exposed filter media were stored at 4°C following sampling and prior to extraction. Filter media were processed with toluene by Soxhlet extraction. Solvents were ultra high purity Fisher Optima®. To monitor extraction efficiency, one hundred µL of a surrogate solution containing 4,4'-dibromobiphenyl, anthracene-d10, and p-terphenyl-d14 at a level of 20 ng/µL was spiked onto the media just prior to extraction. The concentration of surrogate compounds was 2.0 ng/µL at final volume.

To concentrate extracts, they were transferred to Kuderna-Danish apparatus, heated over a steam bath, and reduced to a volume of several mL. Quantitative transfer of the extracts to vials followed. They were further concentrated with a stream of nitrogen to reach a final volume of 1 mL. Sample extracts were stored at 4°C. Matrix analyses were made by spiking a blank sample (solvent only) with a standard solution of all target analytes, and treating it in the same manner as the sampling media.

GC/MS analysis was performed on a quadrupole instrument operated in selected ion monitoring (SIR) mode. Separation of PAHs involved injecting a 1 µL aliquot of the sample extract onto a 60 meter DB-5 capillary column. An internal standard solution made up of several deuterated PAHs was spiked into the extract at the time of analysis. The solution was used for calculating response factors. This method resulted in a detection limit of 0.001 µg/mile for all target compounds.

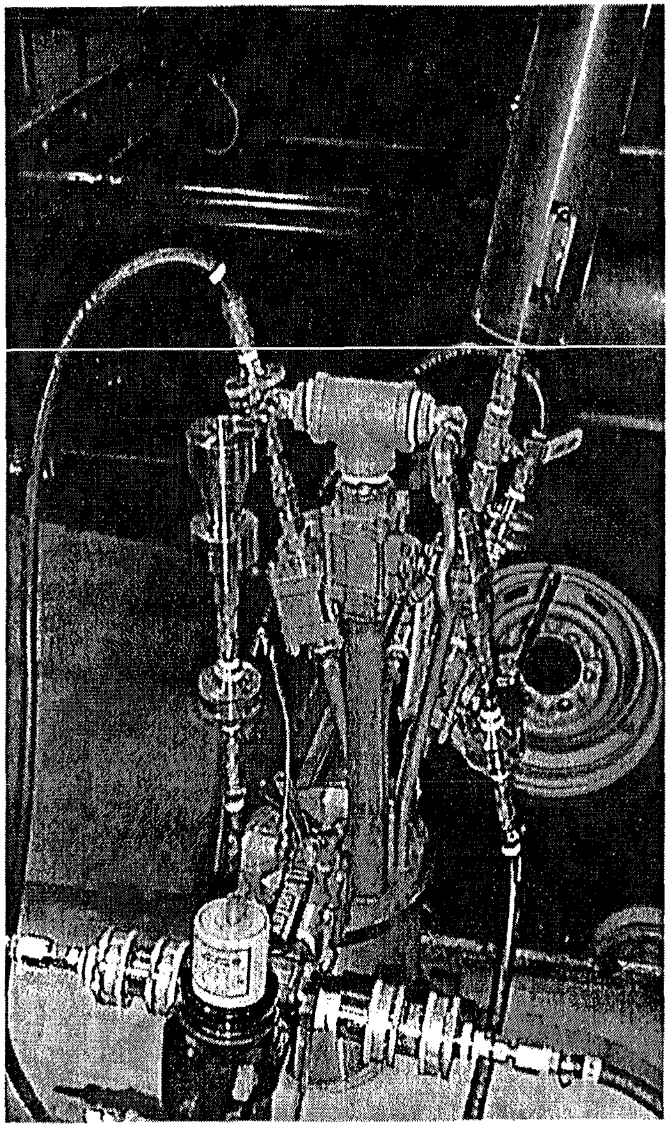

Figure 4. Multi-Probe, Simultaneous Particulate Sampling System

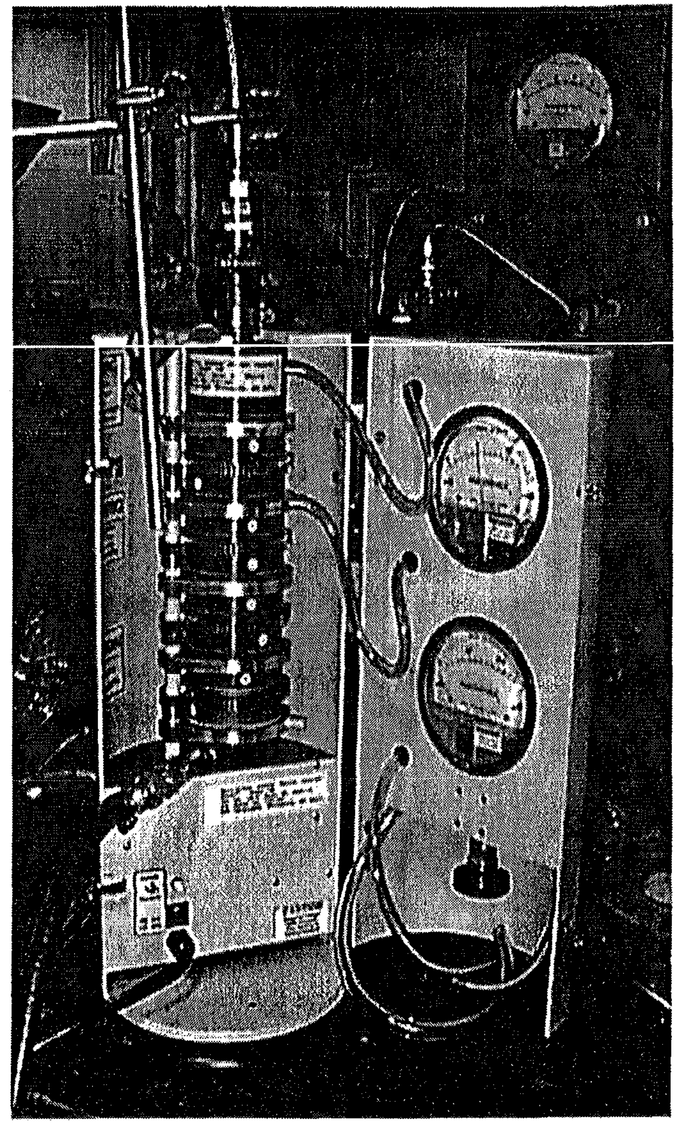

Figure 5. Micro-Orifice Uniform Deposit Impactor (MOUDI)

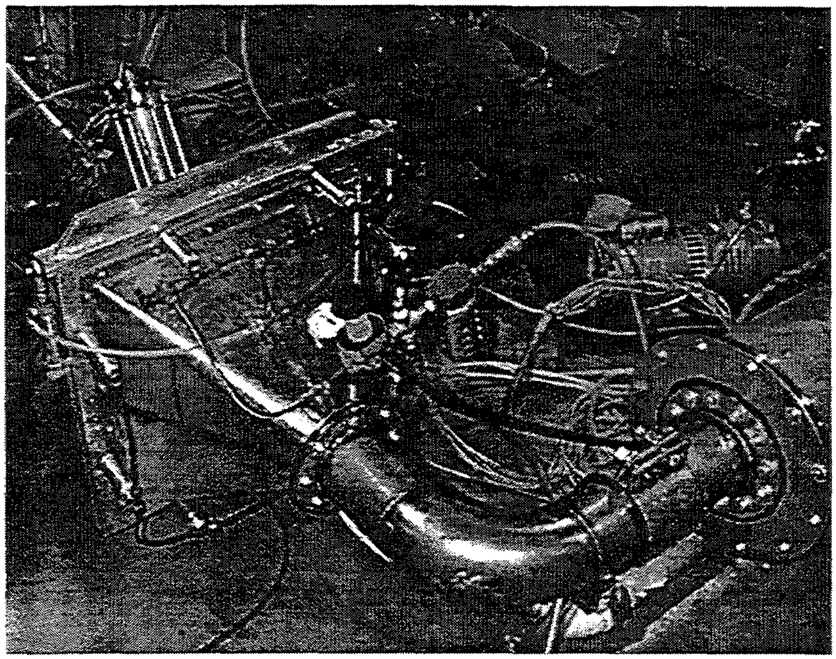

Figure 6. 20-inch × 20-inch Filter Holder for PAH Sampling

4. Elemental Analysis

Proportional particulate samples were collected from the dilution tunnel using 47-mm Nuclepore polycarbonate membrane filters (0.4 µm pore size) for subsequent elemental analysis. Filter media were sent to PIXE Analytical Laboratories in Tallahassee, Florida for elemental analysis by Proton Induced X-ray Emission. This method identifies all elements from Sodium through Uranium. The detection limits for individual elements are given in Appendix A.

5. Trace Species Identification

In addition to PAH analysis, qualitative analysis of particulate filter extracts using GC/MS identified additional classes of compounds. These were present in trace quantities, and were not included in the PAH analyses. Filter extracts were split into two aliquots, one-half being subjected to a clean-up procedure and quantitative PAH analysis described in I.F.3. The other half of the extracts were not cleaned so as not to alter the samples. Although these extracts were very dark to black in color and contained some precipitate, analysts felt any cleanup might alter or remove some of the trace compounds. Rather than filter the extracts, the precipitate was allowed to settle to the bottom of each vial. The liquid portion of each extract was then analyzed to characterize as many components as possible.

Qualitative analysis was performed with a gas chromatograph (GC) equipped with a DB-5MS analytical column and a quadrupole mass spectrometer detector. The instrument parameters were similar to those used for PAH quantitation described in Section I.F.3. Identification of unknown peaks was made by comparing the sample mass spectrum with those in the Wiley library, which contains thousands of spectra. A computer algorithm selects the best candidates, then the analyst chooses the compound by matching significant ions and ion ratios of the sample spectrum to the candidate library spectra. An exhaustive effort to identify all species in the extracts was not made, as it was beyond the scope of the project.

6. Alcohols

Methanol and ethanol were collected by bubbling exhaust through glass impingers. Each impinger contained 25 mL of deionized water maintained at ice-bath temperature. Exhaust samples were collected continuously during test cycles at a nominal flow rate of 4 L/min through a Teflon sample line at 102°C (215°F). For analysis, a 1-µL portion of the sample was injected into the GC equipped with an FID and an analytical column. The analytical column was a 0.53-mm × 30-m capillary type with a 1-µm film of DB-WAX as the stationary phase. GC carrier gas was helium at a column head pressure of approximately 4 psi. The column oven temperature was maintained at 70°C for 1 minute, then ramped to 110°C at 10°/minute, and held at 110°C for 5 minutes. External standards in deionized water were used to quantify the results. Detection limits for this procedure were on the order of 0.06 ppm in dilute exhaust. This method is consistent with EPA and CARB protocols.

7. Aldehydes and Ketones

An HPLC procedure was used to analyze of aldehydes and ketones. Samples were collected by bubbling dilute exhaust at a nominal flowrate of 4 L/min through chilled glass impingers containing an acetonitrile solution of 2,4-DNPH and perchloric acid. For analysis, a portion of the acetonitrile solution was injected into a liquid chromatograph equipped with a UV detector. External standards of the aldehyde and ketone DNPH derivatives were used to quantify the results. The aldehydes and ketones included formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, crotonaldehyde, isobutyraldehyde/methylethylketone (not resolved from each other during normal operating conditions, reported together), benzaldehyde, and hexanaldehyde. Detection limits for this procedure were about 0.005 ppm aldehyde or ketone in dilute exhaust. This method is consistent with EPA and CARB protocols.

II. Vehicle Testing

The vehicle for this project had been used in Phase II testing. However, it had not been operated for more than 10 months. In preparation for testing, the vehicle received maintenance and a tune-up. A quick check of emissions with the vehicle on a chassis dynamometer indicated it was operating properly. The vehicle was driven approximately 500 miles on Howell EEE emission certification test fuel to ensure emissions were stabilized before testing began. Driving included in-use urban and highway miles on local roadways. During mileage accumulation, the CHECK ENGINE light lit up sporadically. A diagnostic check revealed no ECU codes being set. Further investigation revealed at least one of the oxygen sensors was fouled. A visual inspection of the oxygen sensors showed they were both heavily coated with soot. This coating was a result of Phase II testing in a fuel-rich engine failure mode. New oxygen sensors were installed and the vehicle was driven an additional 250 miles. The CHECK ENGINE light did not illuminate during this additional mileage accumulation.

Following mileage accumulation, an FTP exhaust emission test was conducted on the vehicle to ensure it was operating properly. For this test, the vehicle was operated on Howell EEE emission certification test fuel. A comparison of results from this test and a previous Phase II baseline test are shown in Table 6. Detailed computer printouts of these emission tests are included in Appendix B. During the baseline test conducted on October 12, 1995, the vehicle was operated on RFG purchased at a service station in metropolitan Houston, Texas. Prior to the December 13, 1996, check-out test, the vehicle had not been operated for nearly 11 months. These tests showed the vehicle was running satisfactorily. Confirmation of the vehicle's proper operation also occurred during initial FTP testing at ambient temperature on RFG. These results are presented in the final column of Table 6.

Table 6. Comparison of Phase III FTP Tests with Previous Baseline Test

Test No.	FT-1213-CK	FT-RFG-BASE	Average of 3 FTPs
Test Date	12/13/96	10/12/95	12/96
Fuel	Howell EEE	RFG	RFG
THC, g/mi	0.14	0.14	0.18
CO, g/mi	1.91	1.44	1.96
NO_x, g/mi	0.09	0.16	0.14

Testing on RFG proceeded without incident, as did the 72° tests on both M85 and E85. However, the vehicle was very difficult to start with both the alcohol blends following the overnight soak at 20°F. To ensure the vehicle started consistently during testing and would not stall after the initial crank, the driver opened the throttle slightly during cranking and left it open during the first 10 seconds of idle. Using this technique, cranking times were approximately 8 seconds with M85, and 12 seconds with E85. In order to minimize the number of variables in this study, no adjustments were made to the volatility of the alcohol fuels between 72°F and 20°F. However, current recommendations given in ASTM D5798 and SAE Paper 940764 do call for reduced alcohol content and increased volatility of methanol and ethanol blends in winter. Additional studies will be needed to characterize the effects of RVP on particulate emissions.

Problems occurred during installation of the IMPCO LPG fumigation system on the Ford Taurus FFV. Although the system appeared to be operating properly, exhaust emissions were much higher than expected. SwRI consulted with Mr. Jerry Hutton and Mr. Mark Jones of IMPCO Technologies, Inc. to resolve this matter. After an investigation, IMPCO reported the ADP fuel control system they provided was incompatible with the Ford engine management system. They recommended replacing the IMPCO ADP processor with a controller manufactured by Autotronic Controls Corp. This controller was designed to work specifically with the Ford EEC-IV engine management system. The Autotronic controller was installed on the vehicle; however, emissions from the vehicle were still higher than expected.

While resolving this problem, a series of hot-start tests and FTPs were conducted. Table 7 presents a limited selection of Bag 2 results obtained while troubleshooting the LPG conversion. It also shows the baseline data obtained on Howell EEE prior to the installation of the LPG conversion kit. Based on SwRI's previous experience, it was expected that emissions from LPG would be as low as or lower than emissions from gasoline.

Table 7. Comparison of Select Bag 2 Emission Results

Vehicle Configuration	Fuel	Test Number	THC, g/mi	CO, g/mi	NO_x, g/mi
Pre-conversion	EEE	FT-1213-CK	0.138	4.355	0.114
IMPCO-ADP	LPG	LPG-CK-14	0.485	5.916	0.537
IMPCO-Autotronic	LPG	LPG-CK-15	0.558	10.154	1.373
	EEE	EEE-CK-01	0.116	4.064	0.519
Conversion removed	EEE	EEE-CK-02	0.157	4.113	0.102

Emission data from test LPG-CK-14 represent the best results obtained with the IMPCO ADP processor. With the ADP system installed, THC emission were more than three times higher and NO_X emissions were over four times higher than the gasoline baseline. After installing the Autotronic controller, emissions results from test LPG-CK-15 indicated further tuning of the system would not achieve the desired goal. Staff at IMPCO and Autotronic questioned whether the catalysts and oxygen sensors on the vehicle were operating properly. To check this, two additional tests with Howell EEE gasoline were conducted.

Test EEE-CK-01 was conducted with the Autotronic controller still installed and operating in gasoline mode. Bag 2 emission results presented in Table 7 show NO_X was high compared to the baseline. Prior to the EEE-CK-02 test, the Autotronic engine controller was removed from the vehicle (the LPG pressure regulator and carburetor were not removed). Bag 2 results presented in Table 7 and FTP results presented in Table 8 show that the vehicle operated like it did at the start of the test program. Therefore, the catalysts and oxygen sensors were still working properly, and there was still a problem with the conversion kit.

Table 8. Comparison of Check-Out FTP with Previous Baseline FTP

Test No.	EEE-CK-02	FT-1213-CK
Test Date	04/28/97	12/13/96
Fuel	Howell EEE	Howell EEE
THC (g/mi)	0.182	0.142
CO (g/mi)	2.24	1.91
NO_x (g/mi)	0.081	0.092
Fuel Economy (mpg)	20.12	19.70

SwRI discussed this problem in detail with Mr. Jerry Hutton and Mr. Brad Gardner of IMPCO, and Mr. Roger Pringle of Autotronic. On May 16 and 17, 1997, Mr. Troy Hicks from Autotronic visited SwRI. Mr. Hicks found the low-pressure regulator was fitted with an incorrect spring and fuel-control valve. After installing a new pressure regulator spring, a series of hot-start 505-second (Bag 3) tests were conducted to determine the effects of two different fuel control valves on exhaust emissions. The results of these tests, given in Table 9, show that the large fuel control valve provided by Autotronic produced lower exhaust emissions. This valve was used for all subsequent testing.

Table 9. Effect of Fuel Control Valve on Bag 3 Emissions

		Bag 3		
Vehicle Configuration	Test Number	THC, grams	CO, grams	NO_x, grams
Gasoline Baseline	EEE-CK-02	0.27	2.88	0.29
LPG Large FCV	LPG-CK-18	0.31	0.82	1.36
LPG Small FCV	LPG-CK-19	0.54	2.08	1.43
LPG Large FCV	LPG-CK-20	0.44	1.09	1.16

During additional tuning, feedback control was switched between the engine's front and rear bank exhaust gas oxygen (EGO) sensors. This helped identify problems with distribution and mixing of the LPG in the intake manifold. The results of these tests are shown in Table 10. When the rear EGO sensor was used for closed-loop feedback control, the vehicle produced high CO and low NO_X. The EGO sensor feedback controlled a stoichiometric mixture for the rear bank of the engine in this configuration. Thus, results indicated the front bank was rich compared to the rear bank. Additionally, when the front EGO sensor was used for stoichiometric closed-loop feedback control, the vehicle produced high NO_X, indicating lean operation of the rear bank compared to the front bank. The front EGO sensor was used in the feedback loop for all subsequent testing to investigate the fuel distribution problem.

Table 10. Effect of Oxygen Sensor Feedback on Bag 3 Emissions

Vehicle Configuration	Test Number	Bag 3		
		THC, grams	CO, grams	NO_X, grams
Gasoline Baseline	EEE-CK-02	0.27	2.88	0.29
LPG Rear EGO Sensor	LPG-CK-16	1.43	11.18	0.02
LPG Front EGO Sensor	LPG-CK-17	0.81	1.57	1.67
LPG Rear EGO Sensor	LPG-CK-21	1.21	10.66	0.23
LPG Front EGO Sensor	LPG-CK-23	0.55	1.28	0.97

The LPG conversion kit was modified further to improve fuel distribution. However, none of the changes positively affected exhaust emissions. Due to the design of the intake manifold on this vehicle, it may not be suited for the carbureted LPG conversion kit provided by IMPCO for this project. On this vehicle, exhaust gas recirculation (EGR) and positive crankcase ventilation (PCV) ports are close to separate intake runners for the rear bank of the engine. This placement could cause lean operation of the rear bank while using the conversion kit. The location of EGR could not be changed. However, a port for the evaporative canister purge line would provide better distribution of PCV in the intake manifold. Since the canister was not used during operation on LPG, the PCV was relocated to this position. In addition, the fuel mixer was adjusted slightly rich to compensate for the rear bank's lean operation. The results of these modifications lowered NO_X further, as shown in Table 11. Researchers felt the intake manifold would need major modifications to further enhance fuel distribution. Such modifications were outside the scope of this project, therefore the test sequence with LPG was initiated with this final configuration.

Table 11. Effect of PCV Location on Bag 3 Emissions Results

Vehicle Configuration	Test Number	Bag 3		
		THC, grams	CO, grams	NO_X, grams
Gasoline Baseline	FT-1213-CK	0.20	3.14	0.48
LPG Front EGO Sensor Control	LPG-CK-23	0.55	1.28	0.97
LPG Re-route PCV, Rich Adjustment	LPG-CK-27	0.36	2.47	0.78

During the third of the three tests on LPG at 72°F, the vehicle operated poorly. It produced higher emissions throughout the cycle compared to the two previous runs. Further diagnosis of the conversion kit installation and operation was inconclusive. In addition, during the 20°F tests on LPG, the vehicle seemed to operate very lean, and experienced slight misfire. A thorough review of the vehicle and conversion kit revealed no obvious problems. Better operation of the LPG system might have been achieved, but further calibration of the kit at 20°F was beyond the scope of this study.

Following LPG tests, the CNG conversion kit was installed. An initial emission test indicated the kit was operating properly. Although the poor fuel distribution observed during LPG operation was also seen with CNG, vehicle emissions were near ULEV levels. Therefore, no additional tuning was necessary. Tests on CNG were without incident, and the vehicle operated satisfactorily under all conditions.

III. Test Results and Discussion

This section includes the results of tests on all fuels. Gaseous exhaust emissions, particulate mass emissions, particulate composition, and particulate size distribution results are provided.

A. Gaseous Exhaust Emissions

Gaseous exhaust emissions were analyzed for THC and NMHC, OMHCE and OMNMHCE where appropriate, CO, and NO_x. Table 12 presents the results of these analyses. Figures 7 and 8 show results by fuel and test temperature. Detailed computer printouts of these tests are included in Appendix C. Although investigation of gaseous emissions was not the primary focus of this study, some general observations can be made.

Table 12. Average FTP Results

Fuel	Exhaust Constituent	Average of 3 FTPs at 72°F	Average of 2 FTPs at 20°F	% Change 72°F to 20°F
RFG	THC	0.18	0.68	282
	NMHC	0.15	0.60	304
	CO	1.96	6.59	236
	NO_x	0.14	0.10	-28
M85	OMHCE	0.22	1.98	808
	OMNMHCE	0.15	0.87	480
	CO	2.24	5.76	157
	NO_x	0.09	0.12	33
E85	OMHCE	0.22	1.29	486
	OMNMHCE	0.10	0.35	250
	CO	3.41	5.72	67
	NO_x	0.13	0.16	23
LPG	THC	0.26	0.36	38
	NMHC	0.16	0.25	56
	CO	2.26	1.34	-41
	NO_x	0.26	1.48	469
CNG	THC	0.79	0.71	-10
	NMHC	<0.01	<0.01	7
	CO	1.32	1.39	5
	NO_x	0.16	0.29	81
TLEV 50,000 Mile Standard, g/mi	NMOG	0.125		
	CO	3.4		
	NO_x	0.2		

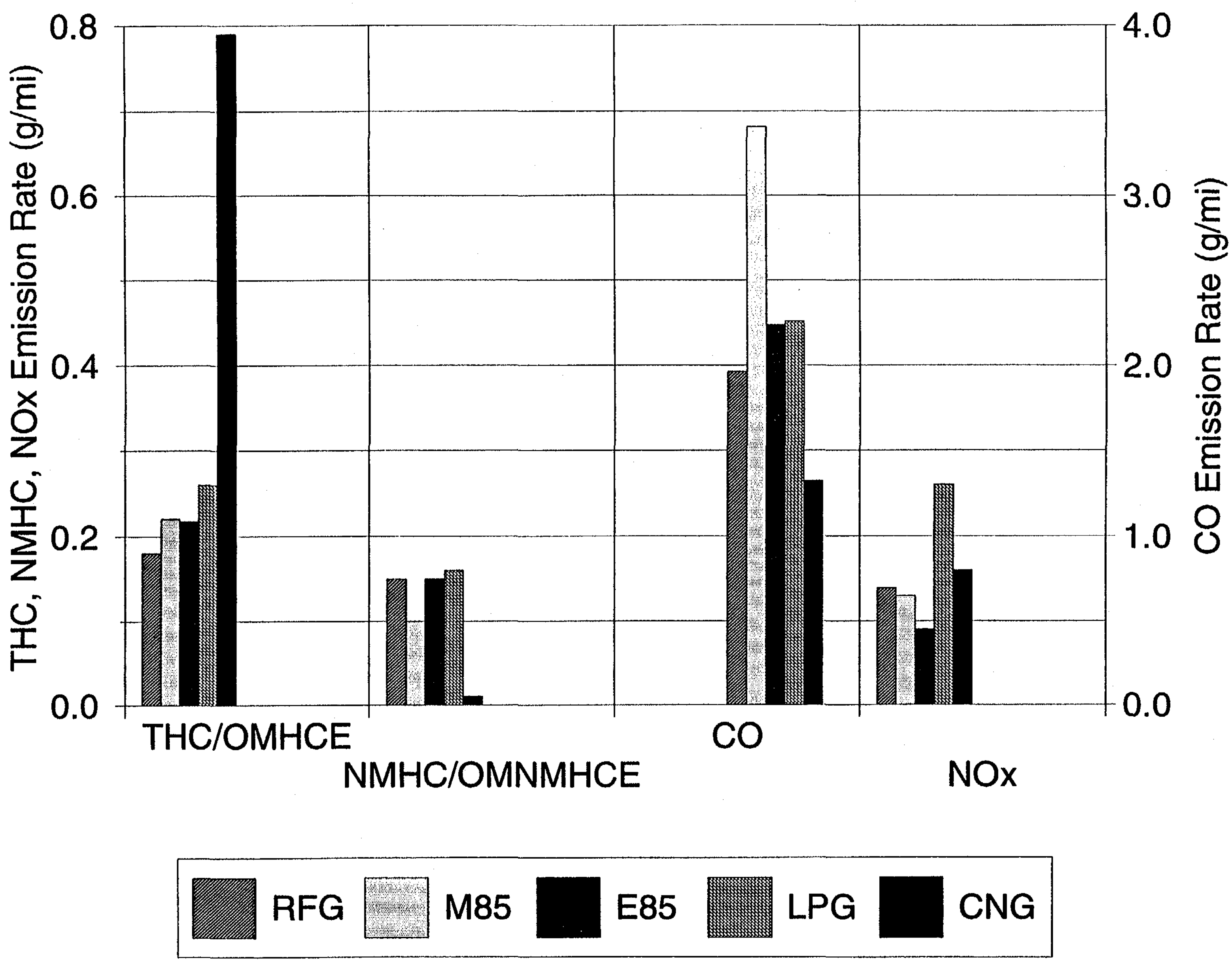

Figure 7. Average FTP Gaseous Exhaust Emissions at 72°F

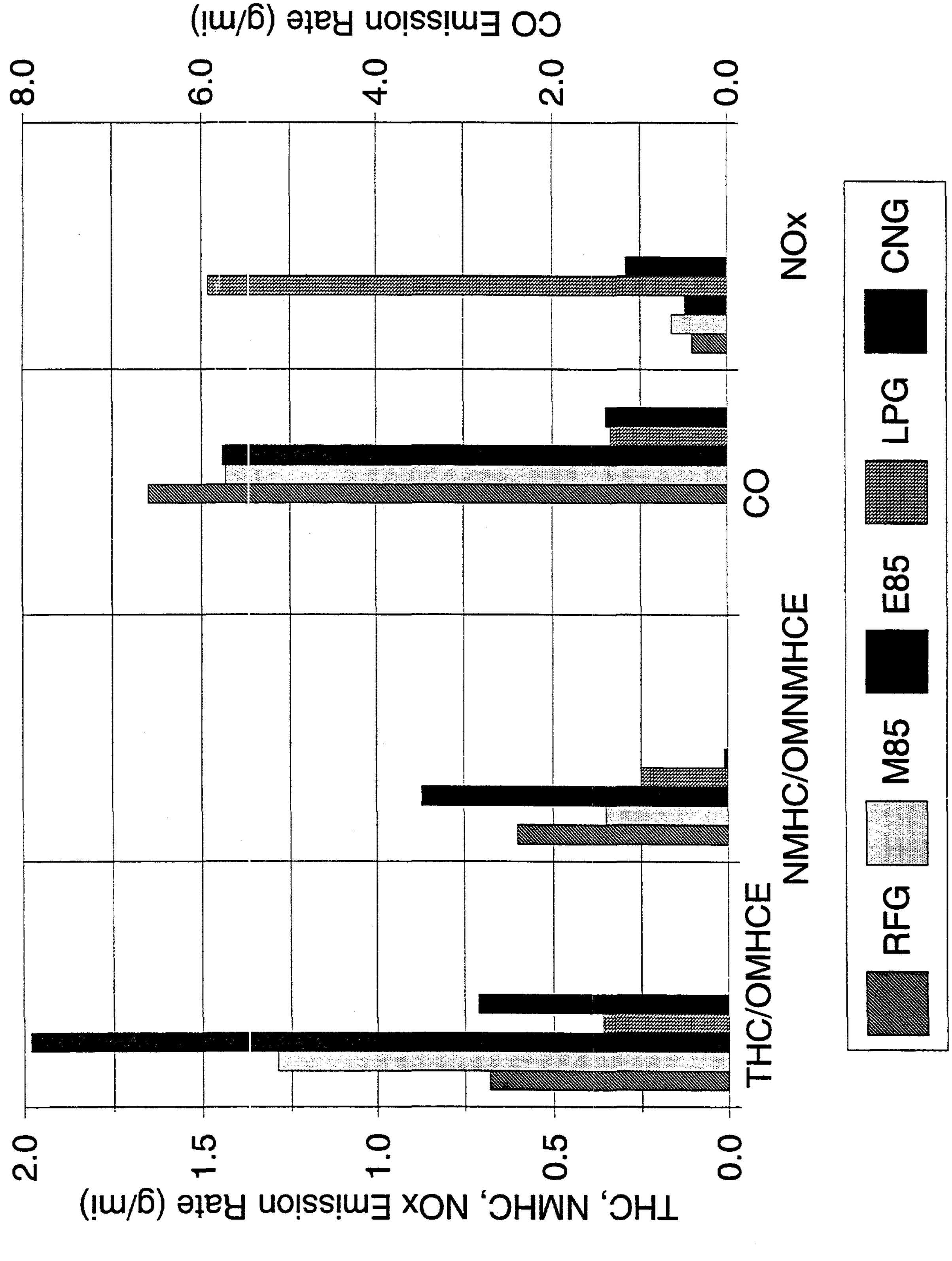

Figure 8. Average FTP Gaseous Exhaust Emissions at 20°F

Emissions from this TLEV-certified vehicle are generally close to TLEV levels (although the hydrocarbon standard for TLEV is based on NMOG rather than NMHC or OMNMHCE). The vehicle was originally designed to operate on blends of gasoline and methanol up to M85. However, this vehicle has also run on E85, CNG, and LPG during Phase II and Phase III of the overall program. Phase II testing included operation in a fuel-rich failure mode that required installing a custom-made fuel controller. Some rough operation and misfiring occurred while tuning this system. In Phases II and III, lean operation also occurred during installation and tuning of the gaseous conversion kits. Possibly, these instances of rough operation and misfire accelerated deterioration of the catalytic converters, which were not replaced during testing. Given its history, the test vehicle's exhaust emissions seemed reasonable.

Total hydrocarbon and OMHCE exhaust emissions from tests conducted with RFG, E85, and M85 at 20°F were four to nine times higher than tests at 72°F. CO emissions were two to three times higher for the three liquid fuels compared to 72°F FTPs. Command fuel enrichment needed to compensate for the difficulty in volatizing these fuels in the engine intake at cold temperature could account for differences in emission rates. Fuel enrichment was especially apparent during operation on the alcohol fuels, when the vehicle required extensive cranking to fire during 20°F cold starts.

A comparison of emissions at 72°F and 20°F while operating on LPG is somewhat inconclusive. During the third of the three tests at 72°F, the vehicle operated poorly and produced higher emissions throughout the cycle compared to the two previous runs. During the 20°F tests on LPG, the vehicle seemed to operate very lean, and misfire somewhat. This resulted in higher HC and substantially higher NO_x at 20°F compared to 72°F. Given the difficulty in tuning this conversion kit to operate satisfactorily on the vehicle (see Section II), further investigation into the poor operation of this kit on LPG was outside the scope of this project. Exhaust emissions while operating the vehicle on CNG were fairly consistent between 72°F and 20°F. However, the conversion kit did tend to operate slightly lean at 20°F, causing an increase in NO_x emissions. It is not known whether the increased NO_x was due to system calibration or the effect of cold temperature on the kit components.

Repeatability ratios for each exhaust constituent during each set of tests are given in Table 13. The repeatability ratio for each exhaust constituent is the ratio of the high and low values obtained from the replicate tests, and provides a way to characterize test-to-test repeatability. For comparison, the test-to-test repeatability criteria used for replicate tests during the Auto/Oil Air Quality Improvement Research Program (SAE Paper 920319) are also given. Although there is no direct correlation between gaseous and particulate emissions, these repeatability ratios might serve as some indication of the particulate test-to-test variability for this vehicle. These data illustrate the high degree of variability in the operation of the LPG conversion kit, especially at 75°F.

TABLE 13. TEST REPEATABILITY RATIOS

Pollutant	Repeatability Ratio by Fuel and Temperature										
	RFG		E85		M85		LPG		CNG		Auto/ Oil, max
	72°F[a]	20°F[b]	72°F[a]	20°F[b]	72°F[a]	20°F[b]	72°F[a]	20°F[b]	72°F[a]	20°F[b]	
THC/ OMHCE	1.07	1.04	1.29	1.21	1.24	1.05	1.70	1.42	1.09	1.15	1.33
CO	1.25	1.06	1.20	1.30	1.04	1.07	3.32	1.99	1.09	1.16	1.70
NO_x	1.40	1.19	1.08	1.02	1.14	1.17	1.36	1.10	1.11	1.07	1.29

[a] triplicate tests
[b] duplicate tests

B. Particulate Mass Emissions

Particulate mass emission rates during operation on the five fuels at different temperatures are give in Table 14 and Figure 9. These rates were determined by passing a proportional amount of the dilute vehicle exhaust through 47-mm Pallflex® fluorocarbon-coated glass fiber filters. Mass increases were determined by weighing with a microbalance. Mass emission rates of particulate samples collected for additional analyses were also measured. Particulate samples for elemental analysis using the proton-induced x-ray emission technique were collected on 47-mm Nuclepore® polycarbonate filters. For analysis of particle-bound polynuclear aromatic hydrocarbons, particulate samples were collected by passing the total dilute exhaust flow from each test through a 20-inch × 20-inch Pallflex® fluorocarbon-coated glass fiber filter. Particle size distribution measurements were performed using an MSP Model 100 MOUDI using 47-mm aluminum foil substrates. Comparing the particulate sampling characteristics of different filter media was not the intention for this study. However, these additional data provided a cross-check of the mass emission rates determined by 47-mm fluorocarbon-coated glass fiber filters. Data in Appendix D indicate that the particulate mass emission rate obtained with 47-mm fluorocarbon-coated glass fiber filters during the hot-start UDDS on RFG could be an outlier. Therefore, Table 14 shows the result obtained with a 47-mm Nuclepore filter. The Nuclepore filter sample was collected from the same zone in the dilution tunnel, and at the same flow rate as the fluorocarbon-coated glass fiber filter. Differences in particulate mass on the 47-mm Pallflex and Nuclepore filters were generally less than 25 percent. However, for particulate emission rates of less than 5 mg/mi, the filters sometimes differed by more than a factor of two.

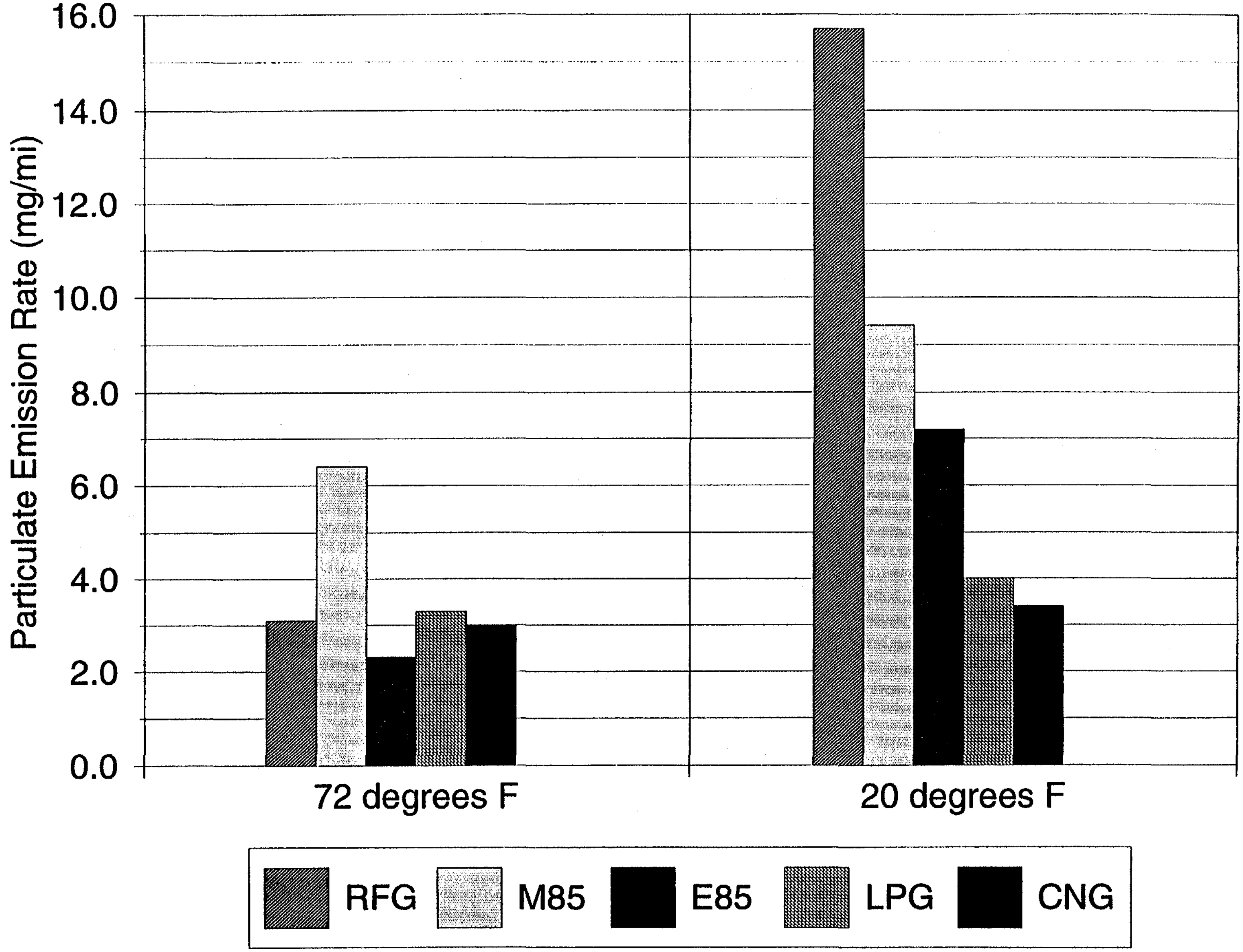

Figure 9. Average FTP Particulate Exhaust Emissions

TABLE 14. AVERAGE PARTICULATE MASS EMISSIONS

Temperature	Phase	Fuel				
		RFG	E85	M85	LPG	CNG
72°F	Cold UDDS	5.0	3.4	8.1	4.0	4.2
	Hot UDDS	1.6[a]	1.5	5.2	2.8	2.1
	4-Bag FTP [b]	3.1	2.3	6.4	3.3	3.0
20°F	Cold UDDS	32.6	15.6	18.6	5.2	5.2
	Hot UDDS	3.0	0.9	2.5	3.2	2.1
	4-Bag FTP [b]	15.7	7.2	9.4	4.0	3.4

[a] data from 47-mm Nuclepore filter
[b] (0.43 × Cold UDDS) + (0.57 × Hot UDDS)

For all fuels except M85, the room temperature particulate emission rate from this vehicle appeared to be on the order of 2 to 3 mg/mile. With M85, the particulate emission rate was more than 6 mg/mile, or about twice as high. This higher emission rate was observed over the filter sets collected for a variety of particulate analyses (see Appendix D), and occurred during both the cold-and the hot-start phases of the FTP. This result was not expected, and the explanation is uncertain. Further investigation is needed to determine whether the higher particulate rate with M85 occurs with other methanol-fueled vehicles, or if it is due to this specific vehicle and/or M85 blend. A discussion on possible causes of the higher particulate rate with M85 follows.

Visual inspection of the particulate filters revealed that the M85 particulate samples were different than those from RFG and E85. Although it was difficult to observe any differences in the 72°F samples for these fuels, the 20°F samples had very visible differences. The particulate samples collected from RFG and E85 exhaust were very black and dry, while the particulate from M85 was grey and oily. In addition, elemental analysis data presented in Section III.D show an order of magnitude more sulfur and calcium in the M85 samples compared to all other samples. These elements are likely from the engine lubricating oil, which could have caused the higher particulate rate from M85. Further investigation will be necessary, however, to confirm this possible explanation.

The data generated at 72°F demonstrate that a properly operating modern fuel-injected gasoline vehicle has particulate emissions that are as low as those operating with carbureted gaseous fuels systems. This observation is not surprising, considering that modern vehicles use sophisticated fuel control strategies to minimize cold-start fuel enrichment. In addition, modern fuel injectors provide fine sprays that quickly vaporize at room temperature. With these technologies, there is little particulate generated from a gasoline vehicle operating over a low-load driving cycle like the FTP.

However, testing at 20°F demonstrated large differences in particulate emissions between liquid and gaseous fuels. For RFG, cold-start particulate emission rates at 20°F were more than six times higher than at room temperature. For the alcohol fuels, cold-start rates were two to three times more than at room temperature. For CNG and LPG, however, particulate emissions measurements were nearly the same in both 72°F and 20°F tests. These results were expected since gaseous fuels do not require cold-start enrichment, while liquid fuels do require enrichment.

During the first 20°F test, which was on gasoline, the CVS pressure drop across the 20-inch by 20-inch filter changed by over 50 inches of water during the first few minutes of the FTP. During tests at ambient temperatures, the pressure drop typically changes by less than 5 inches of water over the entire FTP. This dramatic change in pressure in the CVS suggested that the 20-inch by 20-inch in-line filter was loading up with particulate. Researchers decided this situation merited further investigation. Therefore, a Tapered Element Oscillating Microbalance (TEOM) was used during the second 20°F cold-start UDDS on RFG. The TEOM continuously monitored the particulate emission rate and showed when particulate was being produced. Exhaust sample flow for the TEOM came from the same zone in the CVS as the filter and MOUDI samples. The TEOM was used to observe trends in particulate emissions rather than actual mass; therefore, no effort was made to correlate the TEOM with other particulate measurement methods.

Figure 10 shows continuous particulate emission as measured by TEOM, percent of accumulated particulate, and vehicle dynamometer speed for the first 1,200 seconds of the 1,372-second cold-start UDDS. These data indicate that more than 50 percent of particulate mass emitted during the 20°F cold-start UDDS with RFG occurred during the first 90 seconds of the cycle. In addition, there appears to be a strong correlation between particulate generation and vehicle acceleration. As was the case with RFG, a large drop in CVS pressure during the first few minutes of the FTP was observed during 20°F tests with the E85 and M85 fuels, indicating particulate emission trends similar to RFG. However, TEOM data was not available from the tests with the alcohol fuels.

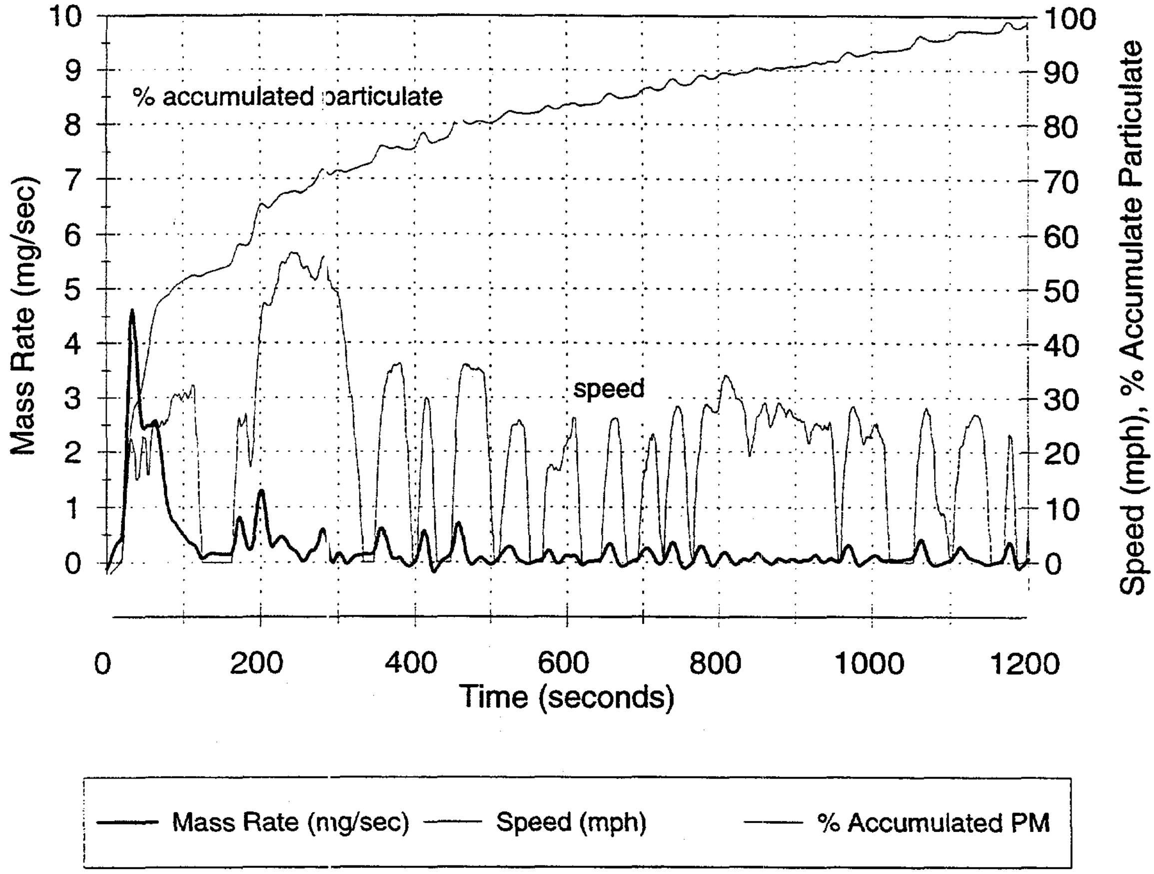

Figure 10. Continuous Particulate Mass Emissions on RFG at 20°F

C. Size Distribution

Figures 11 through 14 show MOUDI particle size distribution data for each of the fuels tested. Figures 15 and 16 show composite FTP size distributions for all fuels at 72°F and 20°F, respectively. Particle size distribution measurements made during operation on LPG were unexpectedly variable and even included some negative weight measurements. Because of this variability, the LPG data are not presented here.

Figure 15 shows that RFG, CNG, and E85 had similar particulate size distributions at 72°F. A major portion of the combustion-related particulate appears to be between 0.54 and 0.06 µm for these three fuels. The percentage of total particulate measured in this size range is given in Table 15. This size range accounted for at least one-half of the particulate for RFG and E85, and nearly one-half for CNG. There was also an increase in particle mass above about 3 µm for these three fuels during the hot-start UDDS, which was likely due to particle agglomeration. In addition, more than 90 percent of the overall increase in particulate mass from 72°F to 20°F for RFG and E85 was due to an increase in mass of particles between 0.54 and 0.06 µm in size.

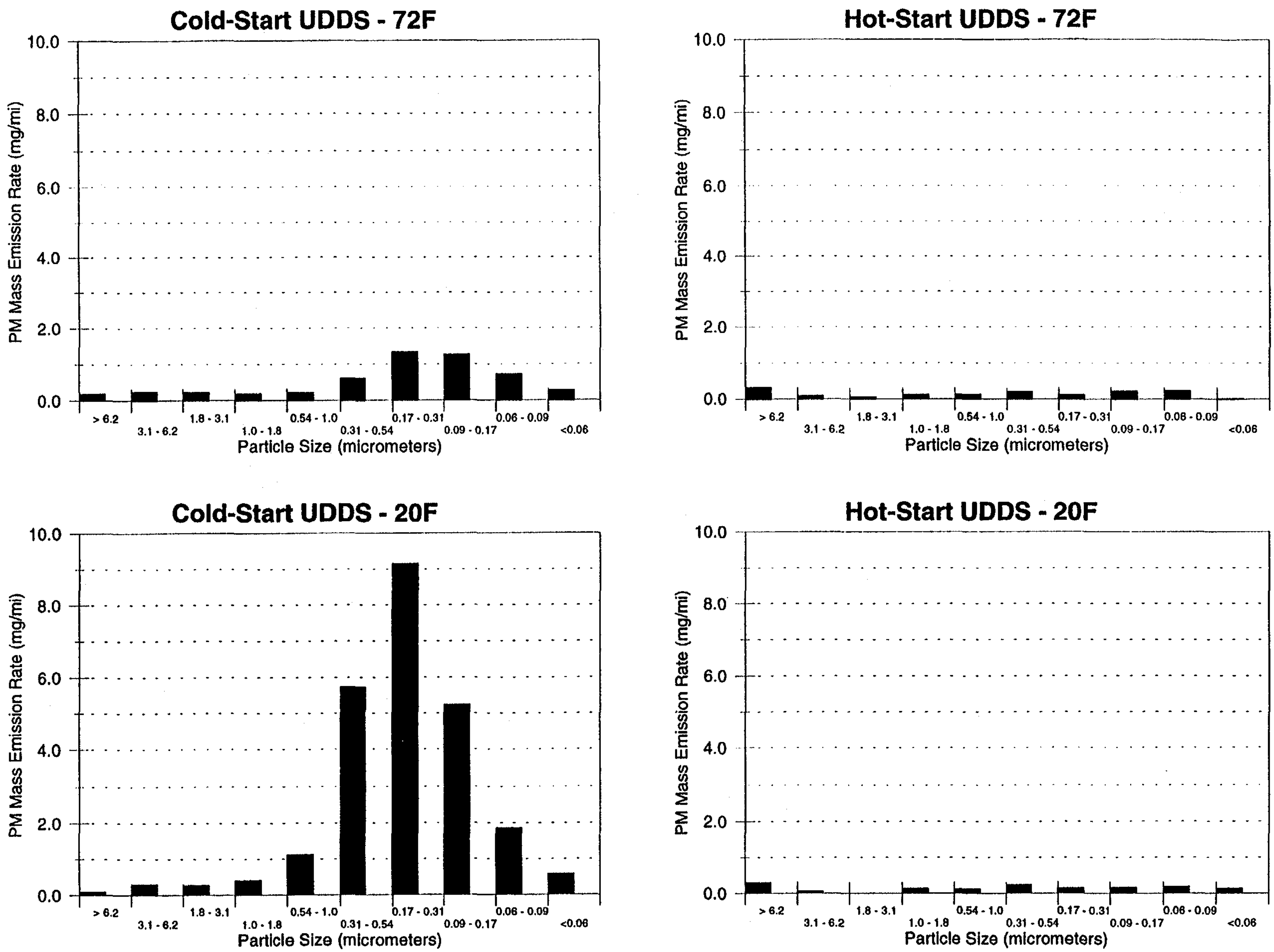

Figure 11. Average Particle Size Distribution While Operating on RFG

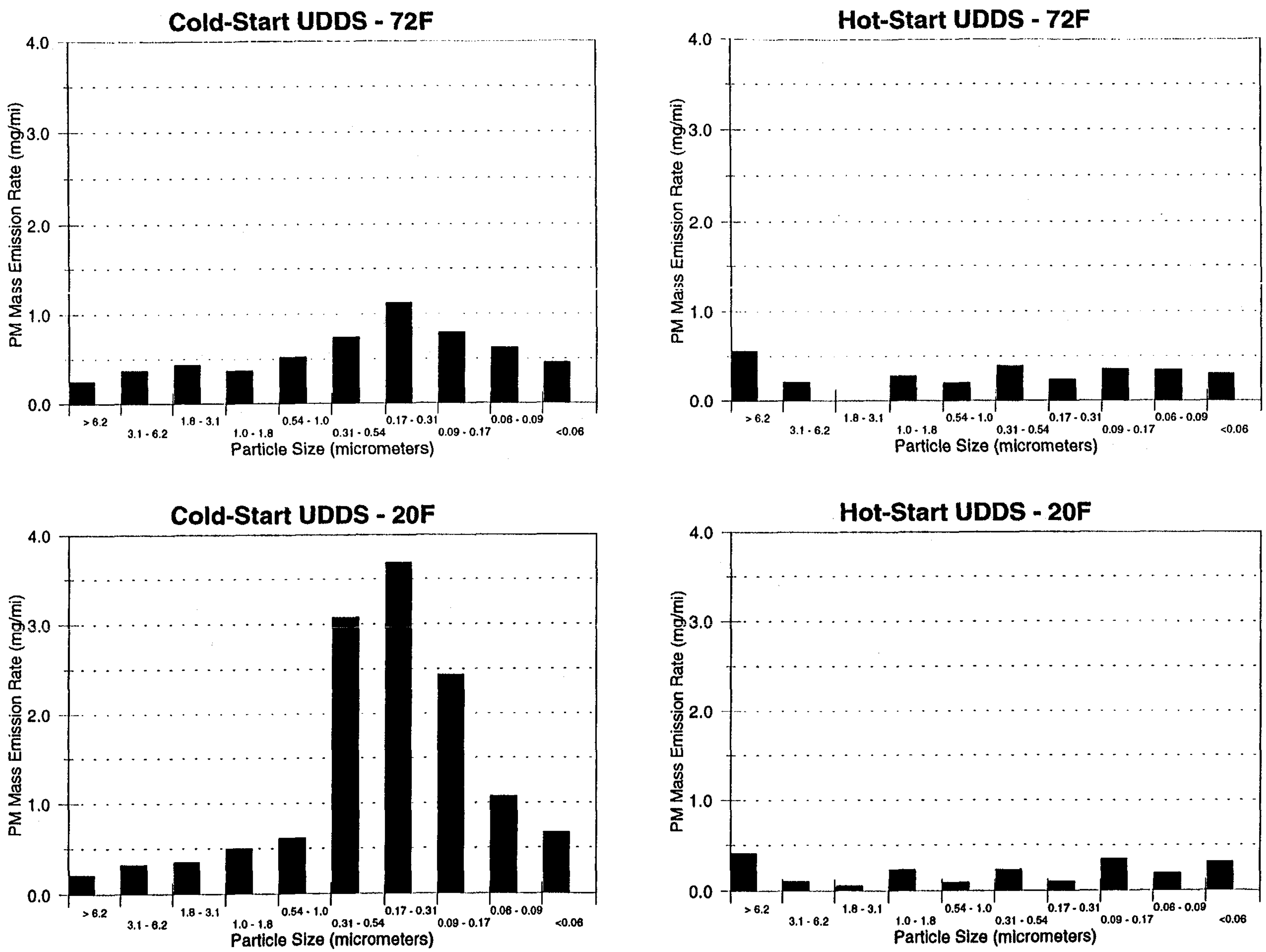

Figure 12. Average Particle Size Distribution While Operating on E85

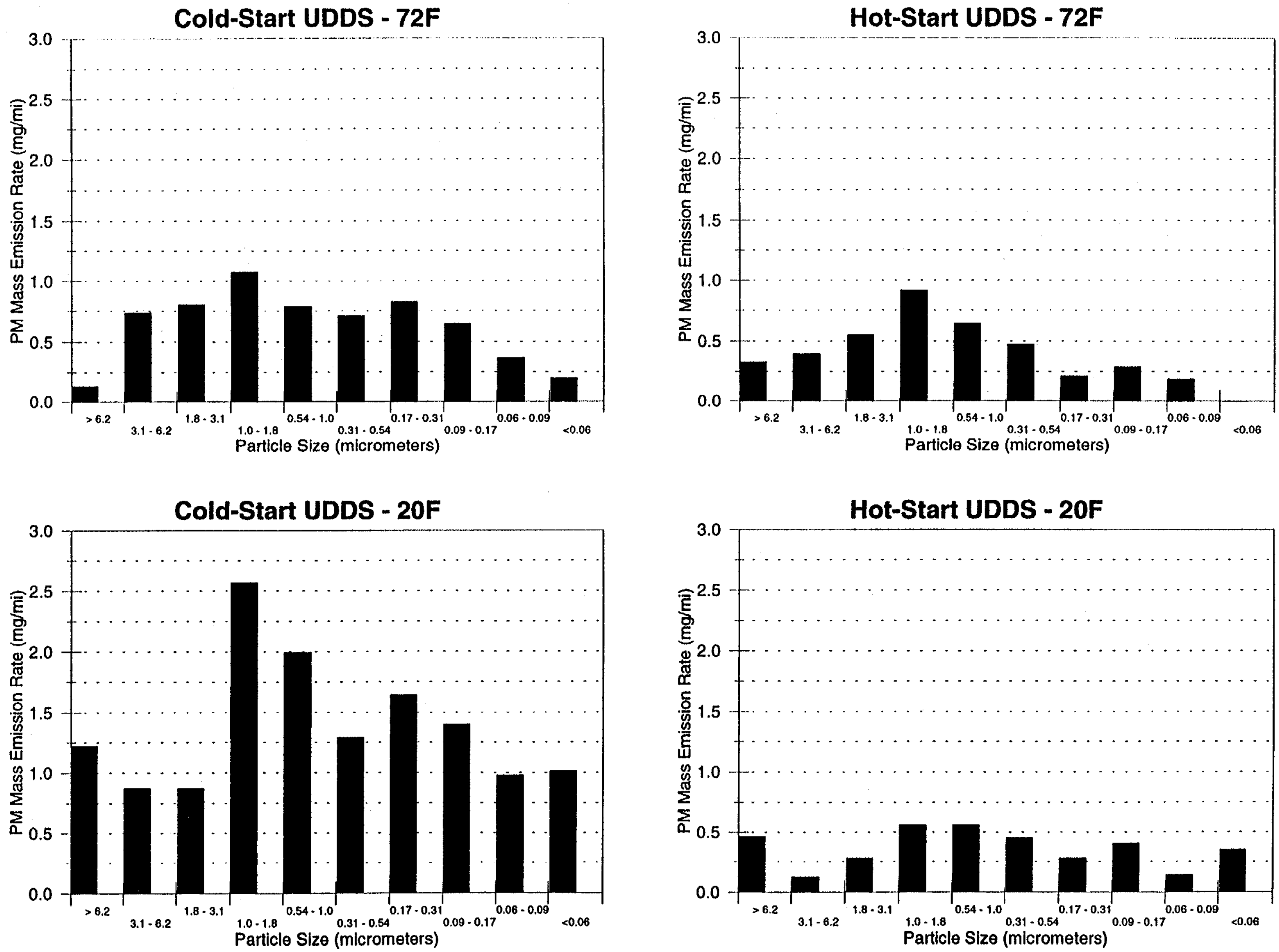

Figure 13. Average Particle Size Distribution While Operating on M85

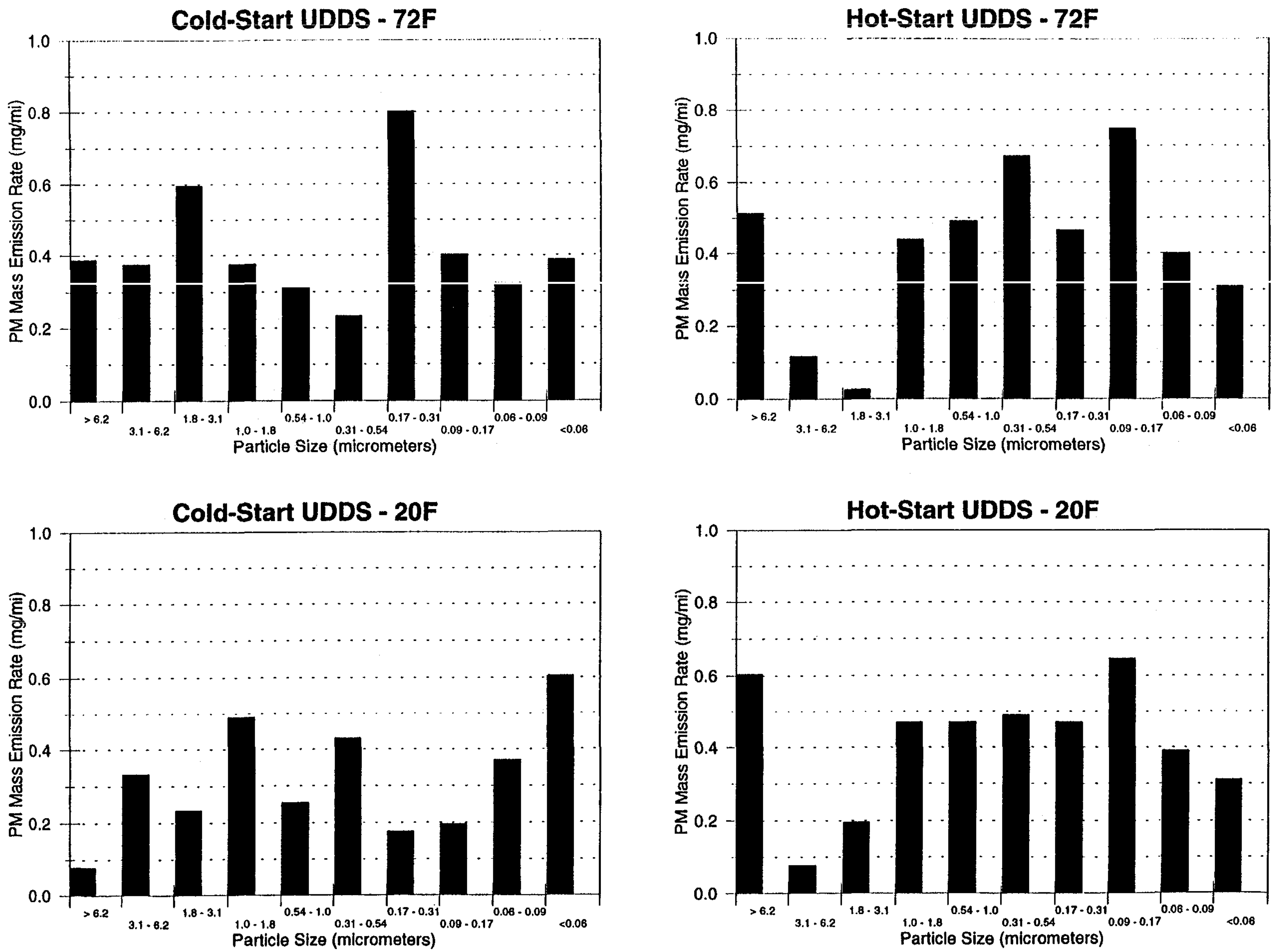

Figure 14. Particle Size Distribution Data While Operating on CNG

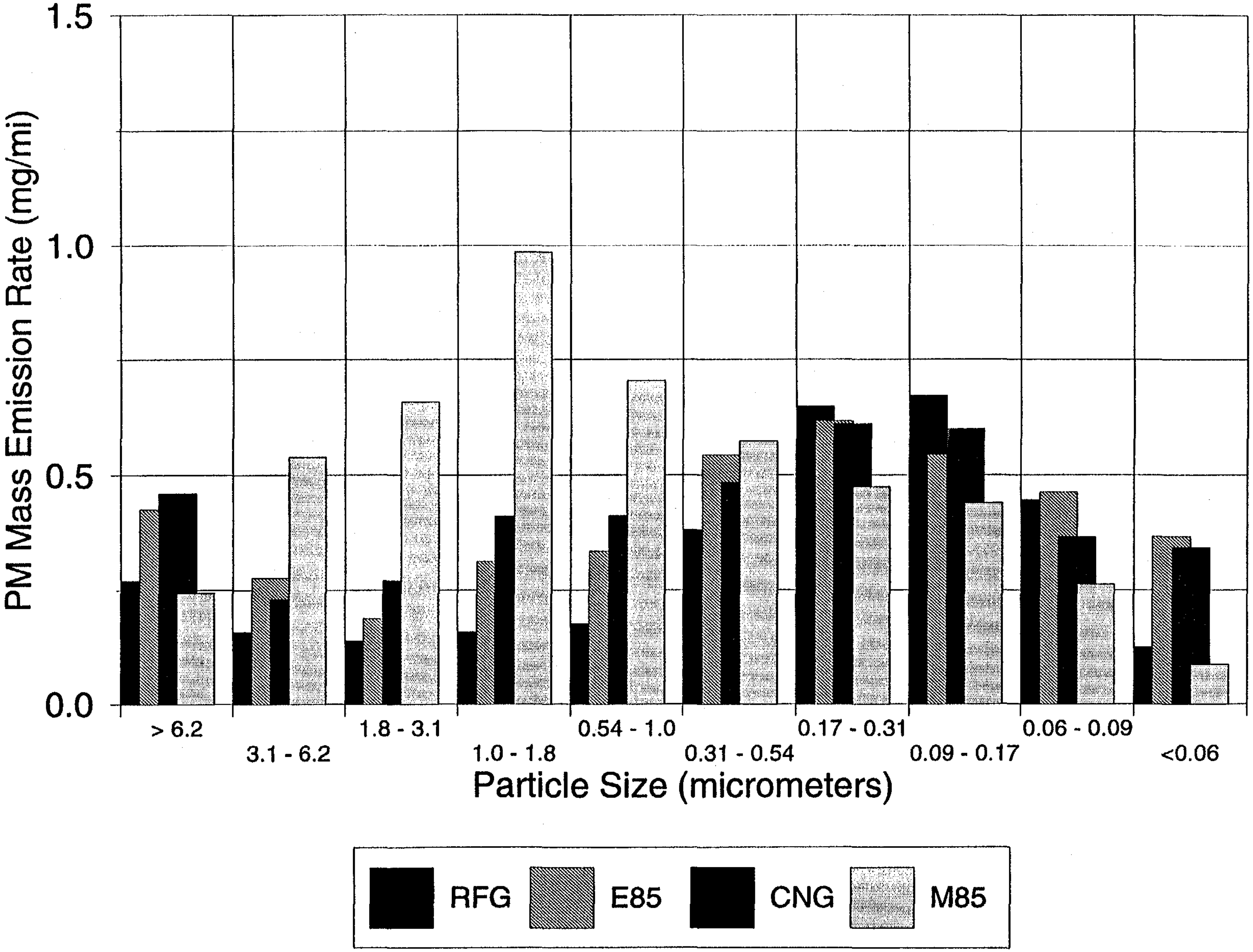

Figure 15. 72°F FTP Particle Size Distribution

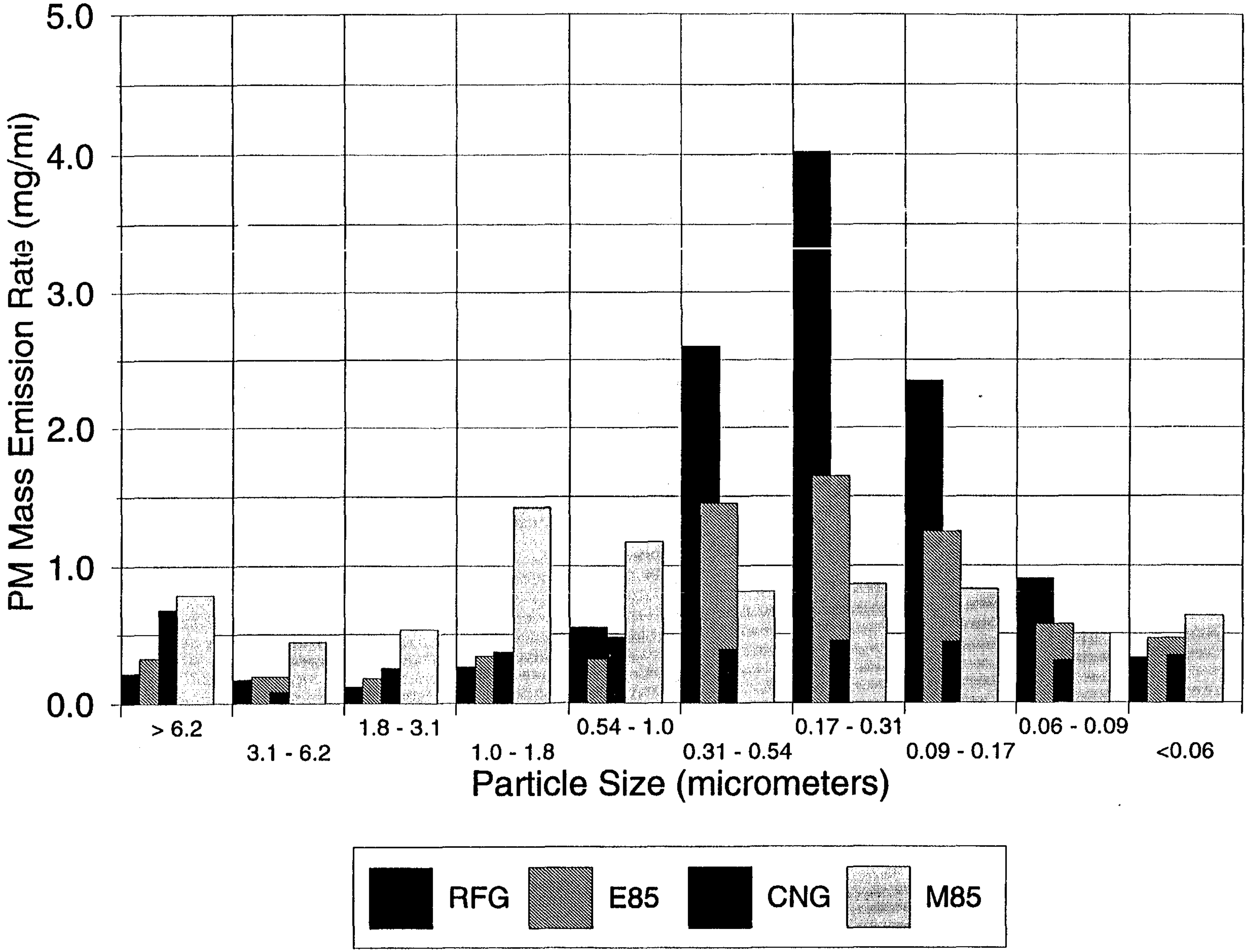

Figure 16. 20°F FTP Particle Size Distribution

TABLE 15. PERCENTAGE OF PARTICULATE MASS BETWEEN 0.54 AND 0.06 μM

Fuel	72°F FTP	20°F FTP
RFG	68%	86%
E85	53%	73%
M85	35%	38%
LPG	NA[a]	NA
CNG	49%	42%
[a] data not available		

Compared to RFG and E85, particle mass from CNG was distributed more evenly over the range of sizes. The CNG particulate mass was fairly evenly distributed among all size categories below 1.8 μm, with mass emission rates ranging from 0.2 to 0.8 mg/mi. This difference is size distribution indicates there may be more than one pathway in the formation of particles (one for CNG and another for RFG and E85).

M85 showed a completely different size distribution than the other fuels. Although, like the other fuels, there appears to be a similar distribution of particles between 0.54 and 0.06 μm, the mass of these particles was less than 40 percent of the total mass. The majority of the particulate mass from M85 at 72°F was between 0.54 and 6.2 μm mean aerodynamic diameter. Particulate increased at 20°F across all size ranges, but was most significant between 0.54 and 1.8 μm and above 6.2 μm. It is thought that the larger mass of particles found in larger aerodynamic diameter size ranges may be due to the greater fraction of lubricating oil in the particulate matter.

Sampled filters obtained to measure LPG particle size distribution had little or no weight gain, and showed no discernable differences in mass among stages. Particulate mass emission rates on individual stages were generally less than 0.4 mg/mi for those stages that showed a weight gain. It is unknown whether these results are due to the nature of particulate from LPG, or a result of sampling.

D. Elemental Analysis

Results from the analysis of particulate filters for the presence of select elements are given in Figure 17. Detailed results are given in Appendix E. Separate filters samples were collected and analyzed over each cold- and hot-start UDDS; therefore, these FTP results are properly weighted and directly comparable to other FTP data. Figure 17 shows an order of magnitude more sulfur and calcium from M85 than any other fuel. A possible source of these elements is engine lubricating oil, as discussed previously in Section III.B. Also present in exhaust from all fuels were silicon and chlorine. The silicon might have come from dust in the exhaust dilution air or ambient air. The source of the chlorine is unknown. There are higher amounts of chromium, aluminum, and iron in samples from LPG and CNG than from the liquid fuels. This is a likely indication of additional engine wear during operation on the gaseous fuels. There was also a small amount of unexplained lead (less than 0.01 mg/mi) in the exhaust from LPG.

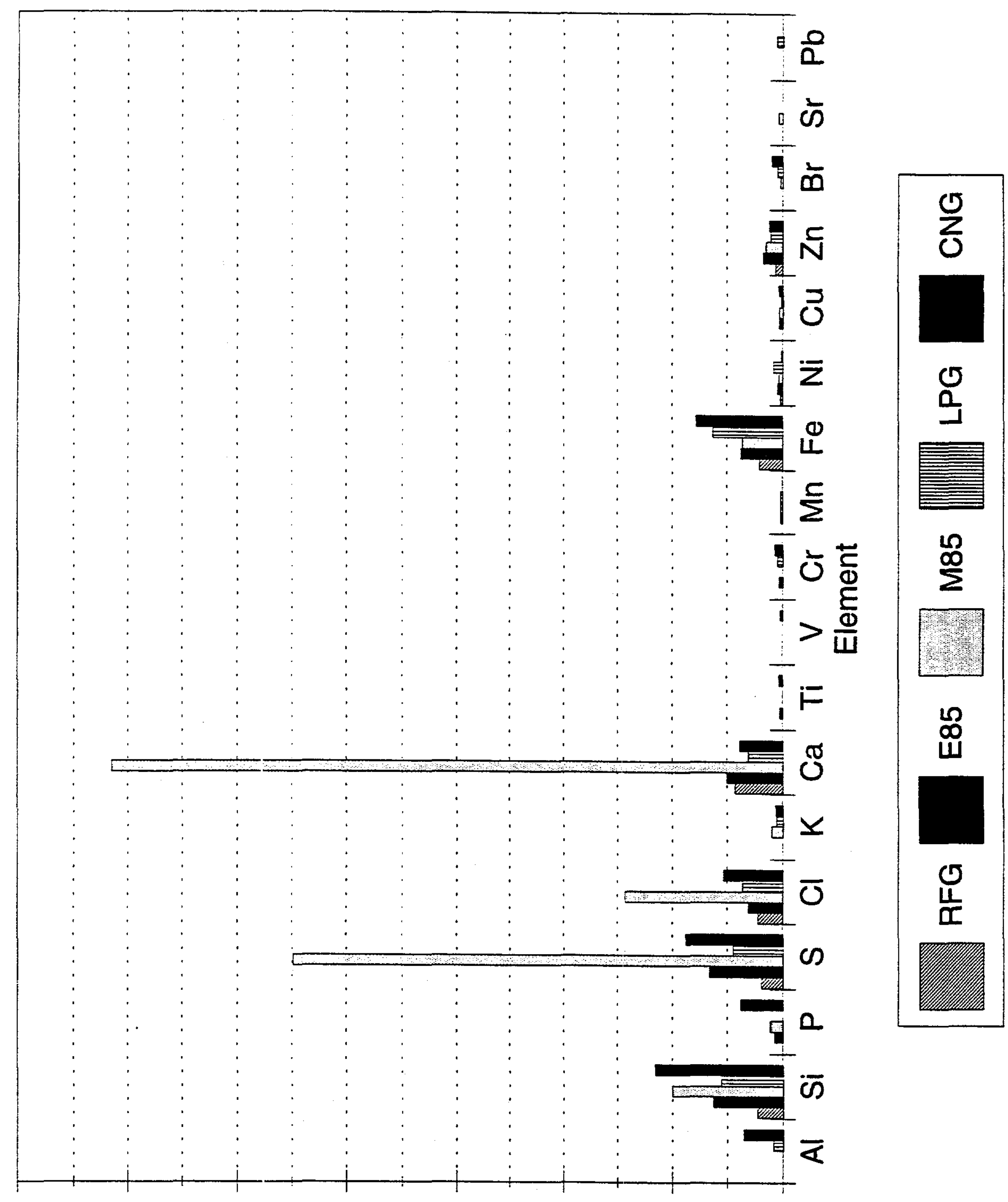

Figure 17. Average FTP Elemental Analysis

E. PAH Analyses

Results from analyses of filter extracts for the presence of select PAH compounds are given in Figure 18. Detailed results are in Appendix F. Separate filters samples were collected and analyzed over each cold- and hot-start UDDS; therefore, these results are also properly weighted and directly comparable to other FTP data. Limits of detection were less than 0.001 µg/mile.

Measured particle-bound PAH emissions ranged from 2.1 to 2.8 µg/mile for the alcohol and gaseous fuels. PAH emissions from RFG were 5.2 µg/mile, or about twice as high as the other fuels. The higher levels of the PAHs in RFG particulate compared to the alcohol fuels may be expected if the PAH precursors are thought to originate from the gasoline components. However, both CNG and LPG had much higher amounts of pyrene, and its nitrated analog 1-nitropyrene, than expected if the PAHs actually originated from gasoline components. In addition, there were unexpectedly high amounts of benzo(g,h,i)perylene in the gaseous fuel filter extracts. These results were unexpected given the simple molecular structure of CNG and LPG. Further investigation of PAH emissions from gaseous fuels is necessary to determine if these results are consistent with other vehicles and fuel blends.

F. Trace Species

In addition to the PAH analyses of 20-inch × 20-inch filter extracts, experimental analyses were performed on these extracts to identify (but not quantitate) trace exhaust species. These analyses positively identified all the PAH compounds reported in Section III.E., as well as a variety of glycols, ethers, phthalates, organic acids, and alkanes. The compounds identified are listed in Table 16.

Examination of the identified trace species yields no distinct trends. The lighter PAHs up to the benzopyrenes were detected in every fuel, with the exception of naphthalene and methyl naphthalene in CNG. These compounds were found primarily in the cold-start samples. Ethyl benzene and xylene showed up in almost every sample. These compounds are common solvents and may be artifacts from background conditions. A number of glycols and glycol ethers were found in samples from operation on each of the fuels, but again, there was no distinct pattern. Several phthalates were found for each fuel. Phthalates are commonly used as plasticizers; however, the source for these compounds is uncertain.

G. Determination of Volatile Organic Fraction

For the 72°F tests, attempts were made to characterize the volatile organic fraction of the particulate and the percent of oil in the VOC using DFI/GC analysis. However, due to the low particulate loading on the filter media, results were near the detection limits of this instrument. Because of this low loading, it was not practical to draw any firm conclusions from these data.

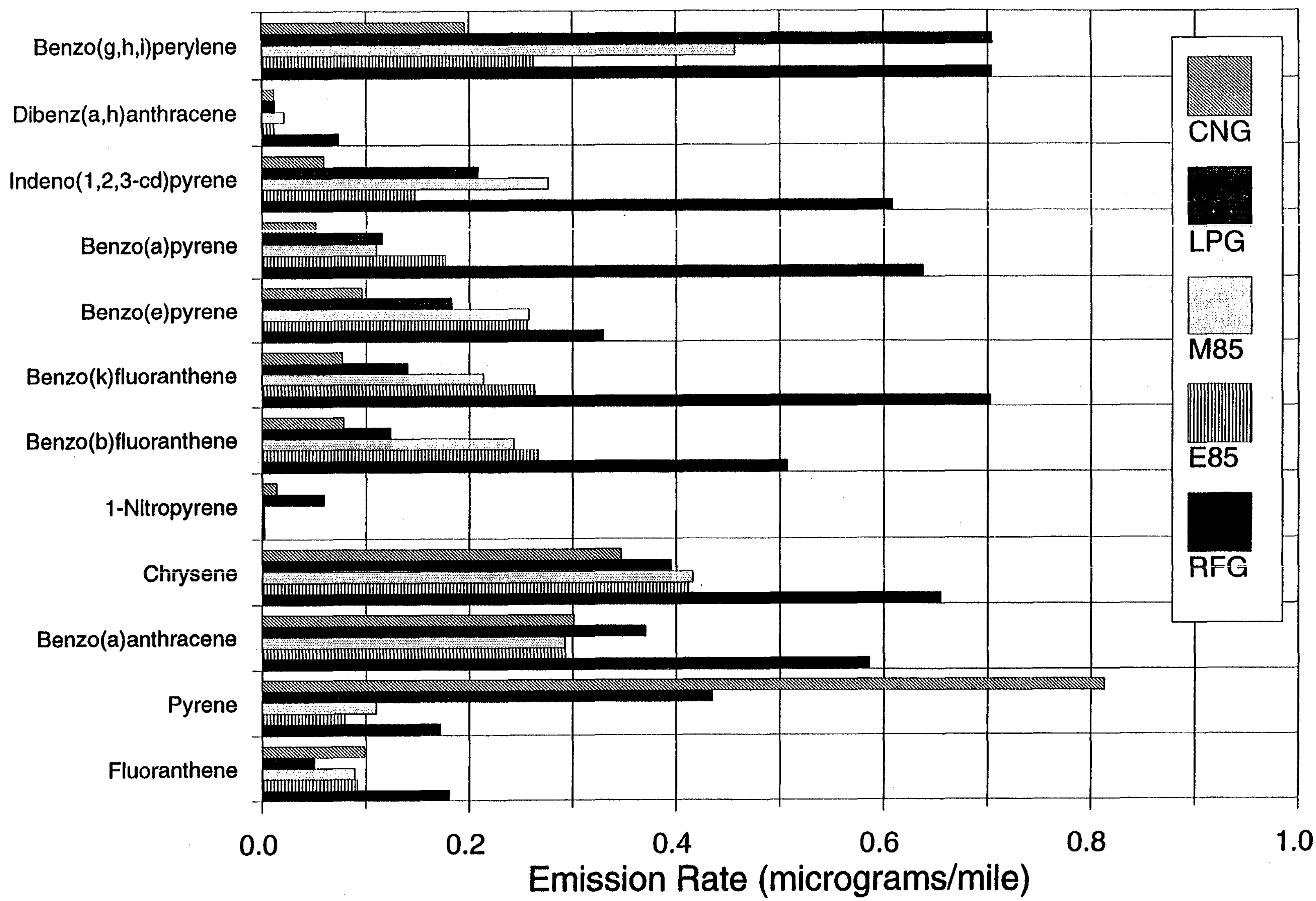

Figure 18. Average FTP PAH Emissions

Table 16. Trace Species Identified by GC/MS Analysis

COMPOUND	Fuel	RFG		E85	
	Test Condition	Cold UDDS	Hot UDDS	Cold UDDS	Hot UDDS
Naphthalene		✓		✓	✓
Methyl naphthalene		✓		✓	✓
Biphenyl		✓			
Phenanthrene		✓	✓	✓	
Anthracene		✓	✓	✓	
Fluoranthene		✓	✓	✓	
Pyrene		✓	✓	✓	
Benzo(a)Anthracene		✓		✓	
Chrysene		✓		✓	
Benzo(b)Fluoranthene		✓		✓	
Benzo(k)Fluoranthene		✓		✓	
Benzo(e)Pyrene		✓			
Benzo(a)Pyrene		✓		✓	
Benzo(c)fluorene-7-one		✓			
Benzo(g,h,i)fluoranthene					
Isochrysene					
Ethyl benzene		✓	✓	✓	✓
Xylene		✓		✓	✓
Triethylene glycol		✓	✓		✓
Tetraethylene glycol			✓		
Triethylene glycol monomethyl ether		✓			✓
Diethylene glycol butyl ether					✓
Triethylene glycol butyl ether		✓			✓
hexanedioic acid, bis(1-methyethyl)ester (Adipic Acid)		✓	✓		✓
Tetraethylene glycol		✓	✓		
Dibutylphthalate (1,2-Benzendicarboxilic acid, dibutyl)		✓	✓	✓	✓
3-nitrophthalic acid		✓	✓	✓	
Butyl benzyl phthalate		✓		✓	
Various normal alkanes, C22 - C36		✓		✓	
ethanol,2[2[4(1,1,3,3-tetramethyl butyl)phenoxy]ethoxy]-		✓	✓	✓	
ethanol 2,2[2[4(1,1,3,3-tetramethyl butyl phenoxy)ethoxy]ethoxy]-		✓	✓	✓	
4-nitro-1-methylimidazole (tentative)					
(+)-Cularcine		✓			
3-methyl-1-nitropyrozole (tentative)		✓		✓	

Table 16 (Cont'd). Trace Species Identified by GC/MS Analysis

COMPOUND	Fuel	M85		LPG	
	Test Condition	Cold UDDS	Hot UDDS	Cold UDDS	Hot UDDS
Naphthalene		✓	✓	✓	✓
Methyl naphthalene		✓		✓	
Biphenyl					
Phenanthrene		✓		✓	
Anthracene		✓		✓	
Fluoranthene		✓		✓	✓
Pyrene		✓		✓	✓
Benzo(a)Anthracene		✓	✓	✓	✓
Chrysene		✓	✓	✓	✓
Benzo(b)Fluoranthene		✓	✓	✓	✓
Benzo(k)Fluoranthene		✓	✓	✓	✓
Benzo(e)Pyrene					
Benzo(a)Pyrene		✓	✓	✓	✓
Benzo(c)fluorene-7-one					
Benzo(g,h,i)fluoranthene					
Isochrysene				✓	
Ethyl benzene		✓	✓	✓	✓
Xylene		✓	✓	✓	
Triethylene glycol			✓		
Tetraethylene glycol		✓			✓
Triethylene glycol monomethyl ether			✓		
Diethylene glycol butyl ether			✓		
Triethylene glycol butyl ether			✓		✓
hexanedioic acid, bis(1-methyethyl)ester (Adipic Acid)			✓		
Tetraethylene glycol			✓		
Dibutylphthalate (1,2-Benzendicarboxilic acid, dibutyl)		✓	✓	✓	✓
3-nitrophthalic acid		✓	✓	✓	✓
Butyl benzyl phthalate				✓	
Various normal alkanes, C22 - C36		✓		✓	✓
ethanol,2[2[4(1,1,3,3-tetramethyl butyl)phenoxy]ethoxy]-		✓		✓	✓
ethanol 2,2[2[4(1,1,3,3-tetramethyl butyl phenoxy)ethoxy]ethoxy]-		✓			
4-nitro-1-methylimidazole (tentative)				✓	
(+)-Cularcine		✓		✓	✓
3-methyl-1-nitropyrozole (tentative)					

Table 16 (Cont'd). Trace Species Identified by GC/MS Analysis

COMPOUND	Fuel	CNG	
	Test Condition	Cold UDDS	Hot UDDS
Naphthalene			
Methyl naphthalene			
Biphenyl			
Phenanthrene		✓	✓
Anthracene		✓	
Fluoranthene		✓	✓
Pyrene		✓	✓
Benzo(a)Anthracene		✓	✓
Chrysene		✓	✓
Benzo(b)Fluoranthene		✓	✓
Benzo(k)Fluoranthene		✓	✓
Benzo(e)Pyrene			
Benzo(a)Pyrene		✓	✓
Benzo(c)fluorene-7-one			
Benzo(g,h,i)fluoranthene		✓	
Isochrysene			
Ethyl benzene		✓	✓
Xylene		✓	✓
Triethylene glycol			
Tetraethylene glycol			
Triethylene glycol monomethyl ether			
Diethylene glycol butyl ether			
Triethylene glycol butyl ether		✓	✓
hexanedioic acid, bis(1-methyethyl)ester (Adipic Acid)			
Tetraethylene glycol			✓
Dibutylphthalate (1,2-Benzendicarboxilic acid, dibutyl)		✓	✓
3-nitrophthalic acid		✓	✓
Butyl benzyl phthalate		✓	
Various normal alkanes, C22 - C36		✓	✓
ethanol,2[2[4(1,1,3,3-tetramethyl butyl)phenoxy]ethoxy]-		✓	✓
ethanol 2,2[2[4(1,1,3,3-tetramethyl butyl phenoxy) ethoxy]ethoxy]-			
4-nitro-1-methylimidazole (tentative)		✓	✓
(+)-Cularcine		✓	✓
3-methyl-1-nitropyrozole (tentative)			

IV. Summary of Results

Particulate and gaseous exhaust emissions were characterized for a 1994 Ford Taurus FFV while operating on alternative fuels and gasoline. Tests were conducted at room temperature (nominally 72°F) and 20°F using the chassis dynamometer portion of the FTP for light-duty vehicles. Fuels included Federal RFG, LPG meeting HD-5 specifications, a national average blend of CNG, E85, and M85. Exhaust particulate generated at room temperature was further characterized to determine polynuclear aromatic content, volatile organic fraction, and trace organic constituents. Some notable findings of this study are listed below.

- The vehicle's particulate emission rate while operating on M85 at 72°F was more than 6 mg/mile. This rate was more than twice as high as with the other fuels. This higher emission rate may be due to the presence of more engine lubricating oil in the particulate emissions.

- For RFG, cold-start particulate emission rates at 20°F were more than six times higher than at room temperature. For alcohol fuels, cold-start rates were two to three times higher than at room temperature. These results are consistent with cold-start fuel enrichment used at cold temperatures for liquid fuel-injected engines.

- For all fuels, most particulate emissions occurred during the cold-start portion of the FTP. For the gaseous fuels, where cold-start fuel enrichment is not required, the higher particulate rates during cold-start, as compared to hot-start, indicate that a hot catalytic converter may play a part in reducing exhaust particulate.

- Particulate emissions measured from CNG and LPG were virtually the same at both 72°F and 20°F, demonstrating that gaseous fuel vehicles may provide a means of reducing winter-time ambient particulate in cold climates.

- TEOM data indicated that more than 50 percent of particulate mass emitted during the 20°F cold-start UDDS on RFG occurred during the first 90 seconds of the cycle. In addition, there was strong correlation between particulate generation and vehicle acceleration.

- For RFG and E85, roughly two-thirds of the particulate mass measured between 0.54 and 0.06 µm equivalent aerodynamic diameter. For CNG, less than one-half the particulate was in this size range.

- For M85, a majority of the particulate mass was between 0.54 and 6.2 µm mean aerodynamic diameter. The particulate in this size range may have come from the engine lubricating oil.

- During operation with CNG, the particulate mass was fairly evenly distributed among all size categories less than 1.8 μm, indicating there may be more than one pathway in the formation of particulate among the different fuels.

- Particle-bound PAH levels from the alcohol and gaseous fuels were one-half of those found in RFG exhaust particulate. However, PAH emissions from CNG and LPG, while lower than those from RFG, were still higher than expected. Emissions from both gaseous fuels had higher amounts of pyrene, 1-nitropyrene, and benzo(g,h,i)perylene than the other fuels. These results were unexpected, and need to be confirmed in future studies.

- PIXE analysis revealed an order of magnitude more sulfur and calcium in particulate from M85 than for any other fuel. These elements are probably from engine lubricating oil.

V. Conclusions and Recommendations

The primary objective of this program was to characterize particulate matter emissions from one passenger vehicle operating on Federal RFG, LPG, CNG, E85, and M85. Particulate mass emission measurements were achieved for all fuels, even at rates as low as 2 to 3 mg/mile. However, the accumulation of particulate on filters over replicate tests was required. These accumulated samples provided a sufficiently measurable mass on the filter media.

Low particulate rates made the measurement of particle size distribution difficult, especially in the use of LPG. Low overall mass emission rates meant filter loading on individual MOUDI stages was sometimes less than 0.01 percent of the original weight of the foil filters. Determining proper size distribution data required isokinetic sampling of the exhaust. Thus, increasing the flow rate through the MOUDI was not a viable means of improving filter loading. Size distribution measurement could be improved in the future by operating the vehicle over additional driving cycles with the filter sets, or by investigating different filter media with lower tare weights. These methods might also improve the sensitivity of VOF measurement at these low particulate emission rates.

Analyses in this study to characterize particulate emissions provided only a partial account of particulate composition. This partial accounting made it difficult to conclusively identify the source of additional particulate for M85. Additional analyses that may have provided more information on the composition of the particulate include sulfate, nitrate, chloride ions, ash, and soot. Fully understanding the origin of particulate from alternative fuel vehicles will require additional compositional analyses.

The relatively high particulate mass emission rates with M85 were not expected. It is thought that this higher particulate emission rate, as well as the relatively high levels of sulfur and calcium in the particulate, and the different particulate size distribution, were related to the presence of engine lubricating oil in the exhaust. However, further studies are needed to confirm if this is an isolated observation or typical of M85-fueled vehicles. In addition, the higher than expected PAH levels with the CNG and LPG fuel also need to be confirmed in future studies.

Future research to characterize and analyze exhaust emissions from alternative fuel vehicles should avoid aftermarket gaseous-fuel conversion kits. This program demonstrated that conversion kits are difficult to tune properly to provide the repeatability necessary for an emissions characterization study. In this Phase III study, using the same vehicle to investigate emissions from gaseous and alcohol fuels was appropriate. However, this approach is not recommended for future studies. Future programs might focus on OEM-certified vehicles, which tend to have more robust and reliable fuel control systems. In addition, more data needs to be generated on a variety of alternative fuel vehicles to determine whether the findings of this study are fuel related or vehicle related.

APPENDIX A

DETECTION LIMITS OF PIXE ANALYSIS FOR SELECT ELEMENTS

Appendix Table A-1. Detection Limits of PIXE Analysis for Select Elements

Element	Detection Limit, ug/mile	Element	Detection Limit, ug/mile
Na	150	In	75
Mg	75	Sn	100
Al	50	Sb	100
Si	50	Te	50
P	50	I	50
S	50	Cs	50
Cl	25	Ba	25
K	25	La	25
Ca	25	Ce	25
Sc	10	Pr	25
Ti	10	Nd	25
V	10	Pm	25
Cr	10	Sm	25
Mn	10	Eu	25
Fe	10	Gb	25
Co	10	Tb	25
Ni	10	Dy	25
Cu	10	Ho	25
Zn	10	Er	25
Ga	10	Tm	25
Ge	10	Yb	25
As	10	Lu	10
Se	10	Hf	10
Br	10	Ta	10
Rb	10	W	10
Sr	10	Re	10
Y	10	Os	10
Zr	15	Ir	10
Nb	15	Pt	10
Mo	20	Au	10
Tc	20	Hg	10
Ru	30	Tl	10
Rh	30	Pb	10
Pd	40	Bi	10
Ag	40	Th	10
Cd	60	U	25

APPENDIX B

BASELINE TESTS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.5-R — 3-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST FT-1213-CK	GASOLINE EM-2350-F
VEHICLE MODEL	94 FORD TAURUS	DATE 12/13/96 RUN	FUEL DENSITY 6.201 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .135 C .865 O .000 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	20364 MILES (32765 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.20 IN HG (741.7 MM HG) — DRY BULB TEMPERATURE 76.0°F (24.4°C) — NOX HUMIDITY C.F. .942

RELATIVE HUMIDITY 45.1 PCT.

BAG NUMBER	1	2	3
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)
RUN TIME SECONDS	505.2	865.9	504.9
DRY/WET CORRECTION FACTOR, SAMP/BACK	.974/.986	.978/.986	.976/.986
MEASURED DISTANCE MILES (KM)	3.64 (5.86)	3.96 (6.37)	3.64 (5.86)
BLOWER FLOW RATE SCFM (SCMM)	308.1 (8.73)	307.2 (8.70)	307.5 (8.71)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2594. (73.5)	4434. (125.6)	2587. (73.3)
HC SAMPLE METER/RANGE/PPM (BAG)	50.7/ 2/ 50.67	7.7/ 2/ 7.70	10.0/ 2/ 9.99
HC BCKGRD METER/RANGE/PPM	6.1/ 2/ 6.10	6.2/ 2/ 6.20	5.7/ 2/ 5.70
CO SAMPLE METER/RANGE/PPM	54.0/ 14/ 237.71	31.5/ 12/ 31.57	38.8/ 12/ 38.65
CO BCKGRD METER/RANGE/PPM	.2/ 14/ .80	.8/ 12/ .86	.5/ 12/ .54
CO2 SAMPLE METER/RANGE/PCT	67.5/ 1/ 1.2454	90.0/ 14/ .8673	60.6/ 1/ 1.1154
CO2 BCKGRD METER/RANGE/PCT	2.7/ 1/ .0500	13.2/ 14/ .0429	2.5/ 1/ .0463
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	21.7/ 1/ 5.56	2.4/ 1/ .63	14.6/ 1/ 3.76
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .10	.5/ 1/ .13	.5/ 1/ .13
DILUTION FACTOR	10.56	15.43	12.00
HC CONCENTRATION PPM	45.15	1.90	4.77
CO CONCENTRATION PPM	227.82	29.79	36.77
CO2 CONCENTRATION PCT	1.2001	.8272	1.0729
NOX CONCENTRATION PPM	5.47	.50	3.64
HC MASS GRAMS	1.914	.138	.202
CO MASS GRAMS	19.485	4.355	3.137
CO2 MASS GRAMS	1614.17	1901.77	1439.41
NOX MASS GRAMS	.724	.114	.481
FUEL MASS KG	.521	.603	.456
FUEL ECONOMY MPG (L/100KM)	19.66 (11.96)	18.48 (12.73)	22.48 (10.47)

3-BAG COMPOSITE RESULTS

HC	G/MI	.142
CO	G/MI	1.910
NOX	G/MI	.092
FUEL ECONOMY MPG (L/100KM)		19.70 (11.94)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.5-R   3-BAG CARB FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-400

VEHICLE NUMBER 90X
VEHICLE MODEL 94 FORD TAURUS
ENGINE 3.0 L (181 CID)- A4
TRANSMISSION A4
ODOMETER 19420 MILES (31246 KM)

TEST FT-RFG-BASE
DATE 10/12/95 RUN
DYNO 3 BAG CART 2
ACTUAL ROAD LOAD 6.80 HP (5.07 KW)
TEST WEIGHT 3500 LBS (1587 KG)

GASOLINE RFG EM-2060-F
FUEL DENSITY 6.291 LB/GAL
H .135 C .849 O .016 X .000

BAROMETER 29.19 IN HG (741.4 MM HG) DRY BULB TEMPERATURE 74.0°F (23.3°C) NOX HUMIDITY C.F. .918
RELATIVE HUMIDITY 43.7 PCT.

BAG NUMBER	1	2	3
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)
RUN TIME SECONDS	505.2	867.0	505.1
DRY/WET CORRECTION FACTOR, SAMP/BACK	.977/.987	.980/.987	.978/.987
MEASURED DISTANCE MILES (KM)	3.60 (5.80)	3.83 (6.17)	3.59 (5.78)
BLOWER FLOW RATE SCFM (SCMM)	307.8 (8.72)	310.1 (8.78)	309.4 (8.76)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2592. (73.4)	4481. (126.9)	2604. (73.8)
HC SAMPLE METER/RANGE/PPM (BAG)	46.7/ 2/ 46.67	62.5/ 1/ 6.29	88.9/ 1/ 8.95
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40	49.7/ 1/ 5.00	46.3/ 1/ 4.66
CO SAMPLE METER/RANGE/PPM	73.8/ 13/ 176.83	22.3/ 12/ 21.61	33.2/ 12/ 32.31
CO BCKGRD METER/RANGE/PPM	.5/ 13/ 1.10	.8/ 12/ .77	.5/ 12/ .48
CO2 SAMPLE METER/RANGE/PCT	61.4/ 1/ 1.1304	85.1/ 14/ .7555	94.5/ 14/ .9872
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0519	13.7/ 14/ .0448	13.5/ 14/ .0441
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	38.7/ 1/ 9.70	7.5/ 1/ 1.88	16.8/ 1/ 4.21
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .20	.7/ 1/ .18	.5/ 1/ .13
CH4 SAMPLE PPM (1.150)	5.11	2.98	3.35
CH4 BCKGRD PPM	2.29	2.14	2.25
DILUTION FACTOR	11.63	17.68	13.52
HC CONCENTRATION PPM	41.74	1.57	4.63
CO CONCENTRATION PPM	169.45	20.27	30.79
CO2 CONCENTRATION PCT	1.0830	.7132	.9464
NOX CONCENTRATION PPM	9.52	1.72	4.10
CH4 CONCENTRATION PPM	3.02	.96	1.26
NMHC CONCENTRATION PPM	38.27	.47	3.18
FIDHC MASS GRAMS	1.801	.117	.201
CO MASS GRAMS	14.480	2.995	2.644
CO2 MASS GRAMS	1455.37	1657.01	1278.02
NOX MASS GRAMS	1.227	.382	.531
CH4 MASS GRAMS	.148	.081	.062
NMHC MASS GRAMS (FID)	1.620	.034	.135
FUEL MASS KG	.477	.534	.412
FUEL ECONOMY MPG (L/100KM)	21.55 (10.92)	20.46 (11.50)	24.85 (9.46)

3-BAG COMPOSITE RESULTS

FIDHC G/MI	.135	CH4 G/MI	.024
CO G/MI	1.444	NMHC G/MI	.109
NOX G/MI	.163		
FUEL ECONOMY MPG (L/100KM)	21.77 (10.80)		

APPENDIX C

DETAILED COMPUTER PRINTOUTS OF FTP RESULTS

Test No.	Fuel	Temperature	Page
RFG-75F-1	RFG	72°F	C-1
RFG-75F-2	RFG	72°F	C-2
RFG-75F-3	RFG	72°F	C-3
RFG-20F-1	RFG	20°F	C-4
RFG-20F-2	RFG	20°F	C-5
M85-75F-1	M85	72°F	C-6
M85-75F-2	M85	72°F	C-7
M85-75F-3	M85	72°F	C-8
M85-20F-1	M85	20°F	C-9
M85-20F-2	M85	20°F	C-10
E85-75F-4	E85	72°F	C-11
E85-75F-5	E85	72°F	C-12
E85-75F-6	E85	72°F	C-13
E85-20F-3	E85	20°F	C-14
E85-20F-4	E85	20°F	C-15
LPG-75F-1	LPG	72°F	C-16
LPG-75F-2	LPG	72°F	C-17
LPG-75F-3	LPG	72°F	C-18
LPG-20F-1	LPG	20°F	C-19
LPG-20F-2	LPG	20°F	C-20
CNG-75F-1	CNG	72°F	C-21
CNG-75F-2	CNG	72°F	C-22
CNG-75F-3	CNG	72°F	C-23
CNG-20F-1	CNG	20°F	C-24
CNG-20F-2	CNG	20°F	C-25

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.5-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X		TEST RFG-75F-1	GASOLINE RFG EM-2352-F
VEHICLE MODEL	94 FORD TAURUS	DATE 12/16/96 RUN	FUEL DENSITY 6.210 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .130 C .847 O .022 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	20400 MILES (32823 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.16 IN HG (740.7 MM HG) — DRY BULB TEMPERATURE 73.0°F (22.8°C) — NOX HUMIDITY C.F. .821

RELATIVE HUMIDITY 23.1 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	502.8	865.4	504.7	866.2
DRY/WET CORRECTION FACTOR, SAMP/BACK	.983/.993	.986/.993	.984/.993	.987/.993
MEASURED DISTANCE MILES (KM)	3.57 (5.75)	3.88 (6.25)	3.60 (5.79)	3.91 (6.29)
BLOWER FLOW RATE SCFM (SCMM)	305.0 (8.64)	307.2 (8.70)	307.9 (8.72)	310.5 (8.79)
20X20 FLOW RATE SCFM (SCMM)	.0 (.00)	.0 (.00)	.0 (.00)	.0 (.00)
GAS METER FLOW RATE SCFM (SCMM)	2.90 (.08)	2.90 (.08)	2.90 (.08)	2.90 (.08)
TOTAL FLOW SCF (SCM)	2580. (73.1)	4473. (126.7)	2614. (74.0)	4524. (128.1)
HC SAMPLE METER/RANGE/PPM (BAG)	61.1/ 2/ 61.06	63.8/ 1/ 6.42	83.8/ 1/ 8.44	59.8/ 1/ 6.02
HC BCKGRD METER/RANGE/PPM	4.1/ 2/ 4.10	40.6/ 1/ 4.09	38.2/ 1/ 3.85	36.6/ 1/ 3.68
CO SAMPLE METER/RANGE/PPM	57.2/ 14/ 254.22	31.5/ 12/ 31.57	38.0/ 12/ 37.87	29.2/ 12/ 29.34
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.0/ 12/ .00	.0/ 12/ .00	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	63.6/ 1/ 1.1718	86.0/ 14/ .7748	95.0/ 14/ 1.0018	83.9/ 14/ .7306
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0482	3.3/ 14/ .0094	13.1/ 14/ .0425	13.0/ 14/ .0421
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	51.4/ 1/ 13.04	4.8/ 1/ 1.25	23.9/ 1/ 6.12	4.6/ 1/ 1.20
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .16	.5/ 1/ .13	.4/ 1/ .10	.3/ 1/ .08
CH4 SAMPLE PPM (1.175)	6.36	2.96	3.45	2.97
CH4 BCKGRD PPM	1.99	1.96	1.94	1.95
DILUTION FACTOR	11.30	17.46	13.51	18.52
HC CONCENTRATION PPM	57.33	2.57	4.88	2.53
CO CONCENTRATION PPM	246.62	30.87	36.87	28.71
CO2 CONCENTRATION PCT	1.1279	.7659	.9624	.6907
NOX CONCENTRATION PPM	12.89	1.13	6.02	1.12
CH4 CONCENTRATION PPM	4.55	1.12	1.66	1.13
NMHC CONCENTRATION PPM	51.99	1.26	2.93	1.21
HC MASS GRAMS	2.469	.192	.213	.191
CO MASS GRAMS	20.980	4.552	3.178	4.282
CO2 MASS GRAMS	1508.90	1776.44	1304.59	1620.07
NOX MASS GRAMS	1.479	.224	.700	.226
CH4 MASS GRAMS	.221	.094	.082	.096
NMHC MASS GRAMS ( )	2.190	.092	.125	.089
FUEL MASS KG	.499	.574	.422	.524
FUEL ECONOMY MPG (L/100KM)	20.16 (11.67)	19.04 (12.35)	24.04 (9.79)	21.01 (11.20)

4-BAG COMPOSITE RESULTS

HC	G/MI	.184	CH4	G/MI	.032
CO	G/MI	2.039	NMHC	G/MI	.148
NOX	G/MI	.168			

FUEL ECONOMY MPG (L/100KM) 21.16 (11.12)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST RFG-75F-2		GASOLINE RFG	EM-2352-F
VEHICLE MODEL	94 FORD TAURUS	DATE 12/17/96	RUN	FUEL DENSITY 6.210 LB/GAL	
ENGINE	3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .130 C .847 O .022 X .000	
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)			
ODOMETER	20415 MILES (32847 KM)	TEST WEIGHT 3500 LBS (1587 KG)			

BAROMETER 29.17 IN HG (740.9 MM HG) DRY BULB TEMPERATURE 70.0°F (21.1°C) NOX HUMIDITY C.F. .824

RELATIVE HUMIDITY 26.5 PCT.

BAG NUMBER	1*	2*	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	515.1	890.5	501.4	866.7
DRY/WET CORRECTION FACTOR, SAMP/BACK	.983/.993	.986/.993	.984/.993	.987/.993
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.87 (6.23)	3.61 (5.80)	3.88 (6.24)
BLOWER FLOW RATE SCFM (SCMM)	303.0 (8.58)	304.2 (8.62)	309.6 (8.77)	308.6 (8.74)
20X20 FLOW RATE SCFM (SCMM)	.0 (.00)	.0 (.00)	.0 (.00)	.0 (.00)
GAS METER FLOW RATE SCFM (SCMM)	2.89 (.08)	2.89 (.08)	2.96 (.08)	2.96 (.08)
TOTAL FLOW SCF (SCM)	2626. (74.4)	4558. (129.1)	2612. (74.0)	4500. (127.4)
HC SAMPLE METER/RANGE/PPM (BAG)	51.1/ 2/ 51.07	70.3/ 1/ 7.03	10.0/ 2/ 9.99	66.8/ 1/ 6.72
HC BCKGRD METER/RANGE/PPM	4.4/ 2/ 4.40	41.5/ 1/ 4.18	3.8/ 2/ 3.80	37.7/ 1/ 3.80
CO SAMPLE METER/RANGE/PPM	70.5/ 13/ 167.65	35.5/ 12/ 35.45	36.3/ 12/ 36.22	33.3/ 12/ 33.31
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00	.0/ 12/ .00	.0/ 12/ .00	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	61.3/ 1/ 1.1285	86.0/ 14/ .7748	94.6/ 14/ .9901	84.0/ 14/ .7326
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0445	12.9/ 14/ .0418	12.8/ 14/ .0414	12.8/ 14/ .0414
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	39.9/ 1/ 10.15	4.0/ 1/ 1.04	21.1/ 1/ 5.41	4.3/ 1/ 1.12
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .16	.5/ 1/ .13	.3/ 1/ .08	.4/ 1/ .10
DILUTION FACTOR	11.82	17.45	13.67	18.46
HC CONCENTRATION PPM	47.04	3.14	6.47	3.14
CO CONCENTRATION PPM	162.59	34.62	35.23	32.56
CO2 CONCENTRATION PCT	1.0878	.7354	.9518	.6935
NOX CONCENTRATION PPM	10.00	.92	5.34	1.02
HC MASS GRAMS	2.062	.239	.282	.235
CO MASS GRAMS	14.078	5.202	3.034	4.831
CO2 MASS GRAMS	1481.27	1738.03	1289.07	1618.09
NOX MASS GRAMS	1.173	.187	.623	.205
FUEL MASS KG	.486	.563	.417	.524
FUEL ECONOMY MPG (L/100KM)	20.84 (11.29)	19.38 (12.14)	24.37 (9.65)	20.88 (11.27)

4-BAG COMPOSITE RESULTS

HC	G/MI	.172
CO	G/MI	1.709
NOX	G/MI	.141
FUEL ECONOMY MPG (L/100KM)		21.41 (10.99)

* Vehicle idled approximately an additional 30 seconds following the cold-start crank due to a problem with the driver's aid. Subsequently, switching between bags 1 and 2 did not occur properly, causing a discrepancy in the sampling times. Although individual data for Bag 1 and Bag 2 are not accurate, weighted exhaust emissions for the cold-start UDDS are calculated properly.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST	RFG-75F-3	GASOLINE	RFG EM-2352-F
VEHICLE MODEL	94 FORD TAURUS	DATE	12/18/96 RUN	FUEL DENSITY	6.210 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO	3 BAG CART 2	H .130 C .847 O .022 X .000	
TRANSMISSION	A4	ACTUAL ROAD LOAD	6.80 HP (5.07 KW)		
ODOMETER	20430 MILES (32871 KM)	TEST WEIGHT	3500 LBS (1587 KG)		

BAROMETER 29.51 IN HG (749.6 MM HG)   DRY BULB TEMPERATURE 68.0°F (20.0°C)   NOX HUMIDITY C.F. .768

RELATIVE HUMIDITY 10.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.1	866.7	504.7	867.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.987/.998	.990/.998	.989/.998	.991/.998
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.91 (6.28)	3.59 (5.77)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	296.1 (8.39)	294.4 (8.34)	315.7 (8.94)	320.5 (9.08)
20X20 FLOW RATE SCFM (SCMM)	.0 (.00)	.0 (.00)	.0 (.00)	.0 (.00)
GAS METER FLOW RATE SCFM (SCMM)	2.88 (.08)	2.88 (.08)	2.89 (.08)	2.89 (.08)
TOTAL FLOW SCF (SCM)	2517. (71.3)	4294. (121.6)	2680. (75.9)	4674. (132.4)
HC SAMPLE METER/RANGE/PPM (BAG)	56.6/ 2/ 56.57	62.5/ 1/ 6.29	85.0/ 1/ 8.56	62.7/ 1/ 6.31
HC BCKGRD METER/RANGE/PPM	3.7/ 2/ 3.70	32.2/ 1/ 3.24	33.5/ 1/ 3.37	33.3/ 1/ 3.35
CO SAMPLE METER/RANGE/PPM	57.7/ 14/ 256.84	39.4/ 12/ 39.23	39.9/ 12/ 39.72	33.0/ 12/ 33.02
CO BCKGRD METER/RANGE/PPM	.1/ 14/ .40	.0/ 12/ .00	.0/ 12/ .00	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	64.7/ 1/ 1.1925	86.9/ 14/ .7946	93.7/ 14/ .9645	83.5/ 14/ .7224
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0445	12.5/ 14/ .0402	12.9/ 14/ .0418	13.2/ 14/ .0429
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	36.6/ 1/ 9.32	2.9/ 1/ .76	18.7/ 1/ 4.80	4.0/ 1/ 1.04
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .03	.1/ 1/ .03	.0/ 1/ .00	.0/ 1/ .00
DILUTION FACTOR	11.11	17.01	14.02	18.71
HC CONCENTRATION PPM	53.20	3.24	5.43	3.14
CO CONCENTRATION PPM	249.74	38.50	38.85	32.46
CO2 CONCENTRATION PCT	1.1521	.7567	.9257	.6818
NOX CONCENTRATION PPM	9.30	.73	4.80	1.04
HC MASS GRAMS	2.235	.232	.243	.245
CO MASS GRAMS	20.726	5.451	3.433	5.001
CO2 MASS GRAMS	1503.63	1684.85	1286.31	1652.22
NOX MASS GRAMS	.973	.131	.536	.202
FUEL MASS KG	.497	.545	.416	.535
FUEL ECONOMY MPG (L/100KM)	20.41 (11.52)	20.17 (11.66)	24.28 (9.69)	20.50 (11.48)

4-BAG COMPOSITE RESULTS

HC	G/MI	.179
CO	G/MI	2.142
NOX	G/MI	.120
FUEL ECONOMY MPG (L/100KM)		21.35 (11.02)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.5-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST RFG-20F-1		GASOLINE RFG EM-2352-F
VEHICLE MODEL 94 FORD TAURUS	DATE 12/19/96	RUN	FUEL DENSITY 6.210 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .130 C .847 O .022 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20452 MILES (32907 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.59 IN HG (751.6 MM HG)   DRY BULB TEMPERATURE 69.0°F (20.6°C)   NOX HUMIDITY C.F. .763

RELATIVE HUMIDITY 8.5 PCT.

BAG NUMBER	1	2	3*	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	504.8	866.6	540.3	866.8
DRY/WET CORRECTION FACTOR, SAMP/BACK	.984/.998	.989/.998	.989/.998	.991/.998
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.91 (6.29)	3.60 (5.79)	3.93 (6.32)
BLOWER FLOW RATE SCFM (SCMM)	270.1 (7.65)	266.5 (7.55)	314.3 (8.90)	323.0 (9.15)
20X20 FLOW RATE SCFM (SCMM)	.0 (.00)	.0 (.00)	.0 (.00)	.0 (.00)
GAS METER FLOW RATE SCFM (SCMM)	2.24 (.06)	2.24 (.06)	2.20 (.06)	2.21 (.06)
TOTAL FLOW SCF (SCM)	2291. (64.9)	3881. (109.9)	2850. (80.7)	4698. (133.1)
HC SAMPLE METER/RANGE/PPM (BAG)	27.7/ 3/ 276.38	11.1/ 2/ 11.09	17.8/ 2/ 17.79	80.8/ 1/ 8.13
HC BCKGRD METER/RANGE/PPM	.9/ 3/ 8.98	7.0/ 2/ 7.00	5.8/ 2/ 5.80	51.7/ 1/ 5.20
CO SAMPLE METER/RANGE/PPM	55.3/ 2/1247.21	42.7/ 12/ 42.45	73.4/ 12/ 73.13	36.4/ 12/ 36.32
CO BCKGRD METER/RANGE/PPM	.2/ 2/ 3.07	2.1/ 12/ 2.25	1.9/ 12/ 2.04	1.4/ 12/ 1.50
CO2 SAMPLE METER/RANGE/PCT	84.1/ 1/ 1.5596	50.9/ 1/ .9339	54.6/ 1/ 1.0029	85.2/ 14/ .7576
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0445	2.5/ 1/ .0463	2.6/ 1/ .0482	13.8/ 14/ .0452
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	38.3/ 1/ 9.75	3.6/ 1/ .94	12.1/ 1/ 3.13	2.9/ 1/ .76
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .21	.6/ 1/ .16	.5/ 1/ .13	.5/ 1/ .13
CH4 SAMPLE PPM (1.175)	19.52	3.98	3.55	4.65
CH4 BCKGRD PPM	3.24	2.95	2.82	2.59
DILUTION FACTOR	7.96	14.47	13.43	17.84
HC CONCENTRATION PPM	268.53	4.58	12.42	3.22
CO CONCENTRATION PPM	1203.85	39.48	69.65	34.28
CO2 CONCENTRATION PCT	1.5207	.8908	.9583	.7149
NOX CONCENTRATION PPM	9.56	.79	3.00	.63
CH4 CONCENTRATION PPM	16.69	1.24	.94	2.20
NMHC CONCENTRATION PPM	248.93	3.12	11.32	.63
HC MASS GRAMS	10.270	.297	.591	.253
CO MASS GRAMS	90.951	5.053	6.544	5.310
CO2 MASS GRAMS	1806.76	1792.77	1416.21	1741.65
NOX MASS GRAMS	.906	.127	.354	.123
PM MASS GRAMS	.000	.000	.000	.000
CH4 MASS GRAMS	.722	.091	.051	.195
NMHC MASS GRAMS ( )	9.315	.198	.527	.048
FUEL MASS KG	.638	.580	.460	.564
FUEL ECONOMY MPG (L/100KM)	15.89 (14.81)	18.99 (12.39)	22.05 (10.67)	19.61 (11.99)

4-BAG COMPOSITE RESULTS

HC	G/MI	.669	CH4	G/MI	.065
CO	G/MI	6.395	NMHC	G/MI	.588
NOX	G/MI	.095			
PM	G/MI	.000			

FUEL ECONOMY MPG (L/100KM) 19.27 (12.21)

* Vehicle idled approximately an additional 30 seconds following the hot-start crank due to a problem with the driver's aid.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.5-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST RFG-20F-2	GASOLINE RFG	EM-2352-F
VEHICLE MODEL 94 FORD TAURUS	DATE 12/20/96 RUN	FUEL DENSITY 6.210 LB/GAL	
ENGINE 3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .130 C .847 O .022 X .000	
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20467 MILES (32931 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.47 IN HG (748.5 MM HG)   DRY BULB TEMPERATURE 70.0°F (21.1°C)   NOX HUMIDITY C.F. .834

RELATIVE HUMIDITY 29.7 PCT.

BAG NUMBER	1	2*	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	504.5	884.9	505.1	866.5
DRY/WET CORRECTION FACTOR, SAMP/BACK	.978/.993	.984/.993	.983/.993	.985/.993
MEASURED DISTANCE MILES (KM)	3.59 (5.78)	3.89 (6.25)	3.60 (5.79)	3.90 (6.27)
BLOWER FLOW RATE SCFM (SCMM)	264.0 (7.48)	262.0 (7.42)	311.6 (8.83)	314.8 (8.92)
20X20 FLOW RATE SCFM (SCMM)	.0 (.00)	.0 (.00)	.0 (.00)	.0 (.00)
GAS METER FLOW RATE SCFM (SCMM)	2.29 (.06)	2.28 (.06)	2.28 (.06)	2.28 (.06)
TOTAL FLOW SCF (SCM)	2239. (63.4)	3897. (110.4)	2643. (74.8)	4580. (129.7)
HC SAMPLE METER/RANGE/PPM (BAG)	29.3/ 3/ 292.35	11.0/ 2/ 10.99	16.1/ 2/ 16.09	92.6/ 1/ 9.32
HC BCKGRD METER/RANGE/PPM	.7/ 3/ 6.98	6.9/ 2/ 6.90	5.7/ 2/ 5.70	52.3/ 1/ 5.27
CO SAMPLE METER/RANGE/PPM	57.8/ 2/1326.59	50.5/ 12/ 50.10	82.4/ 12/ 82.35	51.4/ 12/ 50.99
CO BCKGRD METER/RANGE/PPM	.2/ 2/ 3.07	1.7/ 12/ 1.82	1.9/ 12/ 2.04	2.4/ 12/ 2.57
CO2 SAMPLE METER/RANGE/PCT	88.3/ 1/ 1.6389	51.7/ 1/ .9488	58.0/ 1/ 1.0666	86.3/ 14/ .7813
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0482	2.8/ 1/ .0519	3.0/ 1/ .0556	14.6/ 14/ .0484
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	40.3/ 1/ 10.25	3.6/ 1/ .94	17.0/ 1/ 4.37	3.9/ 1/ 1.02
NOX BCKGRD METER/RANGE/PPM	1.2/ 1/ .31	1.4/ 1/ .37	1.2/ 1/ .31	1.0/ 1/ .26
CH4 SAMPLE PPM (1.175)	20.94	3.72	4.34	3.85
CH4 BCKGRD PPM	2.53	2.51	2.44	2.43
DILUTION FACTOR	7.57	14.24	12.63	17.27
HC CONCENTRATION PPM	286.29	4.58	10.84	4.36
CO CONCENTRATION PPM	1269.61	47.03	78.02	47.34
CO2 CONCENTRATION PCT	1.5970	.9006	1.0154	.7358
NOX CONCENTRATION PPM	9.98	.60	4.08	.77
CH4 CONCENTRATION PPM	18.74	1.39	2.10	1.55
NMHC CONCENTRATION PPM	264.26	2.95	8.38	2.54
HC MASS GRAMS	10.699	.298	.478	.333
CO MASS GRAMS	93.727	6.043	6.798	7.148
CO2 MASS GRAMS	1854.13	1819.84	1391.30	1747.10
NOX MASS GRAMS	1.010	.105	.488	.159
CH4 MASS GRAMS	.792	.102	.105	.134
NMHC MASS GRAMS ( )	9.663	.188	.362	.190
FUEL MASS KG	.655	.589	.452	.567
FUEL ECONOMY MPG (L/100KM)	15.45 (15.22)	18.58 (12.66)	22.41 (10.50)	19.39 (12.13)

4-BAG COMPOSITE RESULTS

HC	G/MI	.694	CH4	G/MI	.070
CO	G/MI	6.795	NMHC	G/MI	.608
NOX	G/MI	.113			
FUEL ECONOMY MPG (L/100KM)		19.10 (12.32)			

* CVS ran an additional 18 seconds following vehicle shut-down.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST M85-75F-1		METHANOL M85 EM-2422-F
VEHICLE MODEL 94 FORD TAURUS	DATE 2/13/97	RUN	FUEL DENSITY 6.623 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .127 C .431 O .442 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20730 MILES (33354 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.14 IN HG (740.2 MM HG)   DRY BULB TEMPERATURE 72.0°F (22.2°C)   NOX HUMIDITY C.F. .932

RELATIVE HUMIDITY 49.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.2	866.2	505.0	865.8
DRY/WET CORRECTION FACTOR, SAMP/BACK	.967/.986	.973/.986	.969/.986	.973/.986
MEASURED DISTANCE MILES (KM)	3.61 (5.81)	3.89 (6.27)	3.61 (5.81)	3.91 (6.29)
BLOWER FLOW RATE SCFM (SCMM)	310.4 (8.79)	312.2 (8.84)	310.2 (8.78)	311.4 (8.82)
GAS METER FLOW RATE SCFM (SCMM)	2.82 (.08)	1.10 (.03)	2.84 (.08)	1.05 (.03)
TOTAL FLOW SCF (SCM)	2638. (74.7)	4523. (128.1)	2635. (74.6)	4508. (127.7)
HC SAMPLE METER/RANGE/PPM (EAG)	74.7/ 2/ 74.66	80.1/ 1/ 8.06	11.3/ 2/ 11.29	84.7/ 1/ 8.53
HC BCKGRD METER/RANGE/PPM	8.0/ 2/ 8.00	62.6/ 1/ 6.30	6.7/ 2/ 6.70	69.3/ 1/ 6.98
CO SAMPLE METER/RANGE/PPM	85.9/ 14/ 418.49	44.7/ 12/ 44.54	47.9/ 13/ 109.87	37.5/ 12/ 37.68
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.3/ 12/ .37	.0/ 13/ .00	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	59.7/ 1/ 1.0985	84.8/ 14/ .7492	94.1/ 14/ .9758	84.9/ 14/ .7513
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0463	12.7/ 14/ .0410	13.3/ 14/ .0433	13.3/ 14/ .0433
NOX SAMPLE METER/RANGE/PPM (EAG) (D)	27.7/ 1/ 7.08	4.8/ 1/ 1.25	12.6/ 1/ 3.25	4.9/ 1/ 1.27
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .03	.3/ 1/ .08	.2/ 1/ .05	.3/ 1/ .08
CH4 SAMPLE PPM (1.185)	7.16	3.22	4.07	3.12
CH4 BCKGRD PPM	2.02	2.08	2.06	2.10
DILUTION FACTOR	10.42	15.84	12.10	15.81
HC CONCENTRATION PPM	67.43	2.16	5.15	1.99
CO CONCENTRATION PPM	399.13	42.57	105.16	36.30
CO2 CONCENTRATION PCT	1.0566	.7108	.9361	.7107
NOX CONCENTRATION PPM	7.06	1.18	3.20	1.20
CH4 CONCENTRATION PPM	5.34	1.27	2.18	1.15
RHC CONCENTRATION PPM	28.75	2.16	4.00	1.94
OMHCE MASS GRAMS	3.395	.163	.238	.149
CO MASS GRAMS	34.710	6.349	9.134	5.395
CO2 MASS GRAMS	1445.03	1666.88	1278.69	1661.35
NOX MASS GRAMS	.940	.268	.426	.273
CH4 MASS GRAMS	.266	.109	.108	.098
RHC MASS GRAMS ( )	1.238	.160	.172	.143
FUEL MASS KG	.957	1.062	.820	1.058
FUEL ECONOMY MPG (L/100KM)	11.34 (20.75)	11.01 (21.36)	13.24 (17.76)	11.09 (21.20)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.233	CH4	G/MI	.037
CO	G/MI	3.454	NMHC	G/MI	.104
NOX	G/MI	.122			

FUEL ECONOMY MPG (L/100KM) 11.66 (20.18)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST M85-75F-2		METHANOL M85	EM-2422-F
VEHICLE MODEL	94 FORD TAURUS	DATE 2/14/97	RUN	FUEL DENSITY 6.623 LB/GAL	
ENGINE	3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .127 C .431 O .442 X .000	
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)			
ODOMETER	20745 MILES (33378 KM)	TEST WEIGHT 3500 LBS (1587 KG)			

BAROMETER 29.36 IN HG (745.7 MM HG)   DRY BULB TEMPERATURE 79.0°F (26.1°C)   NOX HUMIDITY C.F. .939

RELATIVE HUMIDITY 40.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.4	866.2	505.0	865.9
DRY/WET CORRECTION FACTOR, SAMP/BACK	.966/.986	.973/.986	.969/.986	.973/.986
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.92 (6.30)	3.61 (5.80)	3.90 (6.27)
BLOWER FLOW RATE SCFM (SCMM)	309.4 (8.76)	310.1 (8.78)	310.1 (8.78)	311.1 (8.81)
GAS METER FLOW RATE SCFM (SCMM)	2.85 (.08)	1.07 (.03)	2.83 (.08)	1.06 (.03)
TOTAL FLOW SCF (SCM)	2630. (74.5)	4492. (127.2)	2634. (74.6)	4505. (127.6)
HC SAMPLE METER/RANGE/PPM (BAG)	67.0/ 2/ 66.96	81.4/ 1/ 8.19	11.6/ 2/ 11.59	86.6/ 1/ 8.72
HC BCKGRD METER/RANGE/PPM	5.8/ 2/ 5.80	59.5/ 1/ 5.99	6.1/ 2/ 6.10	66.6/ 1/ 6.70
CO SAMPLE METER/RANGE/PPM	78.3/ 14/ 372.27	46.7/ 12/ 46.47	49.8/ 13/ 114.47	53.6/ 12/ 53.22
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.0/ 12/ .00	.0/ 13/ .00	.4/ 12/ .49
CO2 SAMPLE METER/RANGE/PCT	61.9/ 1/ 1.1398	85.0/ 14/ .7534	93.5/ 14/ .9589	83.6/ 14/ .7245
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0445	12.6/ 14/ .0406	12.3/ 14/ .0395	12.5/ 14/ .0402
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	28.6/ 1/ 7.31	7.0/ 1/ 1.82	13.1/ 1/ 3.38	6.2/ 1/ 1.61
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ .08	.3/ 1/ .08	.1/ 1/ .03	.3/ 1/ .08
CH4 SAMPLE PPM (1.185)	6.56	5.24	3.98	3.52
CH4 BCKGRD PPM	2.25	3.36	2.13	2.20
DILUTION FACTOR	10.10	15.75	12.30	16.36
HC CONCENTRATION PPM	61.74	2.58	5.99	2.42
CO CONCENTRATION PPM	355.70	44.90	109.95	51.01
CO2 CONCENTRATION PCT	1.0997	.7153	.9226	.6867
NOX CONCENTRATION PPM	7.24	1.74	3.36	1.54
CH4 CONCENTRATION PPM	4.53	2.09	2.03	1.45
RHC CONCENTRATION PPM	25.15	2.58	5.20	2.42
OMHCE MASS GRAMS	3.124	.193	.268	.180
CO MASS GRAMS	30.845	6.650	9.547	7.576
CO2 MASS GRAMS	1499.72	1666.18	1259.89	1603.88
NOX MASS GRAMS	.968	.398	.450	.352
CH4 MASS GRAMS	.225	.178	.101	.124
RHC MASS GRAMS ( )	1.080	.190	.223	.178
FUEL MASS KG	.987	1.062	.808	1.024
FUEL ECONOMY MPG (L/100KM)	10.96 (21.47)	11.08 (21.23)	13.40 (17.55)	11.44 (20.57)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.224	CH4	G/MI	.040
CO	G/MI	3.445	NMHC	G/MI	.103
NOX	G/MI	.139			

FUEL ECONOMY MPG (L/100KM) 11.75 (20.02)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST M85-75F-3		METHANOL M85 EM-2422-F
VEHICLE MODEL 94 FORD TAURUS	DATE 2/15/97	RUN	FUEL DENSITY 6.623 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .127 C .431 O .442 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20759 MILES (33401 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.54 IN HG (750.3 MM HG) — DRY BULB TEMPERATURE 74.0°F (23.3°C) — NOX HUMIDITY C.F. .915

RELATIVE HUMIDITY 43.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.6	866.1	504.6	865.9
DRY/WET CORRECTION FACTOR, SAMP/BACK	.968/.987	.974/.987	.971/.987	.975/.987
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.88 (6.25)	3.61 (5.82)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	311.7 (8.83)	313.8 (8.89)	313.4 (8.88)	314.6 (8.91)
GAS METER FLOW RATE SCFM (SCMM)	2.84 (.08)	1.07 (.03)	2.84 (.08)	1.03 (.03)
TOTAL FLOW SCF (SCM)	2650. (75.1)	4545. (128.7)	2659. (75.3)	4556. (129.0)
HC SAMPLE METER/RANGE/PPM (BAG)	61.4/ 2/ 61.36	10.8/ 2/ 10.79	13.3/ 2/ 13.29	10.9/ 2/ 10.89
HC BCKGRD METER/RANGE/PPM	10.0/ 2/ 9.99	10.0/ 2/ 9.99	9.1/ 2/ 9.09	9.8/ 2/ 9.79
CO SAMPLE METER/RANGE/PPM	45.5/ 1/ 400.01	34.8/ 12/ 35.13	48.8/ 13/ 112.05	38.0/ 12/ 38.15
CO BCKGRD METER/RANGE/PPM	.1/ 1/ .74	.5/ 12/ .61	.2/ 13/ .49	.6/ 12/ .73
CO2 SAMPLE METER/RANGE/PCT	98.1/ 14/ 1.0984	85.4/ 14/ .7619	93.4/ 14/ .9562	83.7/ 14/ .7265
CO2 BCKGRD METER/RANGE/PCT	13.0/ 14/ .0421	13.1/ 14/ .0425	13.1/ 14/ .0425	13.2/ 14/ .0429
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	29.1/ 1/ 7.43	5.7/ 1/ 1.48	13.2/ 1/ 3.41	5.5/ 1/ 1.43
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .16	.5/ 1/ .13	.6/ 1/ .16	.5/ 1/ .13
CH4 SAMPLE PPM (1.185)	10.06	6.03	5.92	4.47
CH4 BCKGRD PPM	5.40	5.19	4.07	3.57
DILUTION FACTOR	10.45	15.59	12.34	16.34
HC CONCENTRATION PPM	52.33	1.44	4.93	1.70
CO CONCENTRATION PPM	381.63	33.34	107.08	36.18
CO2 CONCENTRATION PCT	1.0603	.7221	.9171	.6862
NOX CONCENTRATION PPM	7.29	1.36	3.26	1.31
CH4 CONCENTRATION PPM	5.18	1.17	2.18	1.12
RHC CONCENTRATION PPM	21.73	1.40	4.28	1.69
OMHCE MASS GRAMS	2.669	.108	.245	.135
CO MASS GRAMS	33.347	4.996	9.389	5.434
CO2 MASS GRAMS	1457.01	1701.74	1264.60	1620.91
NOX MASS GRAMS	.957	.306	.430	.295
CH4 MASS GRAMS	.259	.101	.110	.096
RHC MASS GRAMS ( )	.941	.104	.186	.126
FUEL MASS KG	.961	1.083	.811	1.032
FUEL ECONOMY MPG (L/100KM)	11.25 (20.91)	10.77 (21.85)	13.39 (17.57)	11.33 (20.77)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.188	CH4	G/MI	.036
CO	G/MI	3.329	NMHC	G/MI	.084
NOX	G/MI	.128			
FUEL ECONOMY MPG (L/100KM)		11.70 (20.10)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.7-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST M85-20F-1	METHANOL M85 EM-2422-F
VEHICLE MODEL 94 FORD TAURUS	DATE 2/11/97 RUN	FUEL DENSITY 6.623 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .127 C .431 O .442 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER 20693 MILES (33295 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.38 IN HG (746.3 MM HG) — DRY BULB TEMPERATURE 75.0°F (23.9°C) — NOX HUMIDITY C.F. .877

RELATIVE HUMIDITY 34.3 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	508.9	866.7	506.2	866.4
DRY/WET CORRECTION FACTOR, SAMP/BACK	.963/.990	.974/.990	.969/.990	.975/.990
MEASURED DISTANCE MILES (KM)	3.61 (5.80)	3.89 (6.25)	3.59 (5.77)	3.90 (6.27)
BLOWER FLOW RATE SCFM (SCMM)	279.2 (7.91)	278.2 (7.88)	275.1 (7.79)	275.7 (7.81)
GAS METER FLOW RATE SCFM (SCMM)	2.86 (.08)	.73 (.02)	2.89 (.08)	1.05 (.03)
TOTAL FLOW SCF (SCM)	2392. (67.8)	4029. (114.1)	2345. (66.4)	3997. (113.2)
HC SAMPLE METER/RANGE/PPM (BAG)	45.0/ 3/ 449.00	12.9/ 2/ 12.89	16.1/ 2/ 16.09	10.0/ 2/ 9.99
HC BCKGRD METER/RANGE/PPM	1.0/ 3/ 9.98	7.3/ 2/ 7.30	7.5/ 2/ 7.50	7.6/ 2/ 7.60
CO SAMPLE METER/RANGE/PPM	86.3/ 1/ 877.81	64.3/ 12/ 63.96	74.7/ 13/ 178.43	71.4/ 12/ 71.22
CO BCKGRD METER/RANGE/PPM	.0/ 1/ .00	.7/ 12/ .85	.0/ 13/ .00	.3/ 12/ .37
CO2 SAMPLE METER/RANGE/PCT	82.6/ 1/ 1.5312	90.5/ 14/ .8798	62.7/ 1/ 1.1549	88.8/ 14/ .8383
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0519	14.3/ 14/ .0472	2.9/ 1/ .0537	14.6/ 14/ .0484
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	46.2/ 1/ 11.73	7.1/ 1/ 1.84	15.9/ 1/ 4.09	6.7/ 1/ 1.74
NOX BCKGRD METER/RANGE/PPM	1.0/ 1/ .26	.7/ 1/ .18	.6/ 1/ .16	.5/ 1/ .13
CH4 SAMPLE PPM (1.185)	21.05	3.73	5.07	3.86
CH4 BCKGRD PPM	2.37	2.33	2.33	2.27
DILUTION FACTOR	7.17	13.47	10.18	14.12
HC CONCENTRATION PPM	440.41	6.14	9.33	2.94
CO CONCENTRATION PPM	831.05	60.92	170.78	68.45
CO2 CONCENTRATION PCT	1.4866	.8361	1.1064	.7934
NOX CONCENTRATION PPM	11.51	1.67	3.95	1.62
CH4 CONCENTRATION PPM	19.00	1.58	2.97	1.75
RHC CONCENTRATION PPM	129.31	2.70	5.73	2.24
OMHCE MASS GRAMS	20.447	.473	.401	.205
CO MASS GRAMS	65.548	8.092	13.205	9.020
CO2 MASS GRAMS	1843.93	1746.46	1345.41	1644.17
NOX MASS GRAMS	1.307	.320	.440	.307
CH4 MASS GRAMS	.858	.120	.132	.132
RHC MASS GRAMS ( )	5.052	.177	.219	.146
FUEL MASS KG	1.274	1.115	.866	1.051
FUEL ECONOMY MPG (L/100KM)	8.50 (27.66)	10.47 (22.47)	12.45 (18.90)	11.14 (21.11)

4-BAG COMPOSITE RESULTS

OMHCE G/MI	1.247	CH4 G/MI	.076
CO G/MI	5.918	NMHC G/MI	.328
NOX G/MI	.150		
FUEL ECONOMY MPG (L/100KM)	10.74 (21.91)		

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.7-R 4-BAG EPA FTP VEHICLE EMISSION RESULTS PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X
VEHICLE MODEL 94 FORD TAURUS
ENGINE 3.0 L (181 CID)-6
TRANSMISSION A4
ODOMETER 20708 MILES (33319 KM)

TEST M85-20F-2
DATE 2/12/97 RUN
DYNO 3 BAG CART 2
ACTUAL ROAD LOAD 6.80 HP (5.07 KW)
TEST WEIGHT 3500 LBS (1587 KG)

METHANOL M85 EM-2422-F
FUEL DENSITY 6.623 LB/GAL
H .127 C .431 O .442 X .000

BAROMETER 28.99 IN HG (736.3 MM HG) DRY BULB TEMPERATURE 75.0°F (23.9°C) NOX HUMIDITY C.F. .995
RELATIVE HUMIDITY 55.1 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	506.8	866.6	509.2	861.5
DRY/WET CORRECTION FACTOR, SAMP/BACK	.956/.983	.967/.983	.965/.983	.970/.983
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.89 (6.27)	3.61 (5.81)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	273.4 (7.74)	272.3 (7.71)	304.2 (8.62)	305.3 (8.65)
GAS METER FLOW RATE SCFM (SCMM)	2.83 (.08)	.62 (.02)	1.75 (.05)	1.79 (.05)
TOTAL FLOW SCF (SCM)	2333. (66.1)	3942. (111.6)	2597. (73.5)	4410. (124.9)
HC SAMPLE METER/RANGE/PPM (BAG)	49.0/ 3/ 488.91	11.4/ 2/ 11.39	13.5/ 2/ 13.49	9.2/ 2/ 9.19
HC BCKGRD METER/RANGE/PPM	1.1/ 3/ 10.98	7.2/ 2/ 7.20	7.4/ 2/ 7.40	7.0/ 2/ 7.00
CO SAMPLE METER/RANGE/PPM	85.9/ 1/ 872.46	56.2/ 12/ 55.80	33.3/ 14/ 138.88	62.2/ 12/ 61.83
CO BCKGRD METER/RANGE/PPM	.0/ 1/ .00	.2/ 12/ .24	.0/ 14/ .00	.2/ 12/ .24
CO2 SAMPLE METER/RANGE/PCT	83.6/ 1/ 1.5501	91.1/ 14/ .8949	56.0/ 1/ 1.0291	85.4/ 14/ .7619
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0463	13.0/ 14/ .0421	2.6/ 1/ .0482	13.1/ 14/ .0425
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	51.2/ 1/ 12.99	7.4/ 1/ 1.92	12.7/ 1/ 3.28	5.5/ 1/ 1.43
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .05	.2/ 1/ .05	.1/ 1/ .03	.0/ 1/ .00
CH4 SAMPLE PPM (1.185)	20.68	3.42	3.53	3.61
CH4 BCKGRD PPM	2.09	2.03	2.07	2.07
DILUTION FACTOR	7.07	13.26	11.45	15.54
HC CONCENTRATION PPM	479.49	4.74	6.74	2.65
CO CONCENTRATION PPM	819.67	53.21	132.47	59.21
CO2 CONCENTRATION PCT	1.5103	.8560	.9851	.7221
NOX CONCENTRATION PPM	12.94	1.87	3.25	1.43
CH4 CONCENTRATION PPM	18.89	1.55	1.64	1.68
RHC CONCENTRATION PPM	153.74	2.64	4.66	2.19
OMHCE MASS GRAMS	21.559	.346	.320	.202
CO MASS GRAMS	63.047	6.915	11.341	8.608
CO2 MASS GRAMS	1826.97	1749.40	1326.40	1651.03
NOX MASS GRAMS	1.627	.397	.455	.340
CH4 MASS GRAMS	.832	.115	.080	.140
RHC MASS GRAMS ( )	5.857	.170	.198	.158
FUEL MASS KG	1.263	1.116	.852	1.055
FUEL ECONOMY MPG (L/100KM)	8.56 (27.47)	10.49 (22.43)	12.72 (18.49)	11.09 (21.22)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	1.297	CH4	G/MI	.071
CO	G/MI	5.530	NMHC	G/MI	.373
NOX	G/MI	.177			

FUEL ECONOMY MPG (L/100KM) 10.81 (21.77)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST E85-75F-4	ETHANOL E85 EM-2154-F
VEHICLE MODEL	94 FORD TAURUS	DATE 1/27/97 RUN	FUEL DENSITY 6.480 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .132 C .600 O .268 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	20588 MILES (33126 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.11 IN HG (739.4 MM HG)   DRY BULB TEMPERATURE 76.0°F (24.4°C)   NOX HUMIDITY C.F. 1.009

RELATIVE HUMIDITY 55.6 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.5	866.9	506.1	866.4
DRY/WET CORRECTION FACTOR, SAMP/BACK	.968/.983	.973/.983	.969/.983	.973/.983
MEASURED DISTANCE MILES (KM)	3.61 (5.80)	3.90 (6.27)	3.62 (5.82)	3.93 (6.32)
BLOWER FLOW RATE SCFM (SCMM)	305.9 (8.66)	305.4 (8.65)	305.3 (8.65)	305.7 (8.66)
GAS METER FLOW RATE SCFM (SCMM)	2.88 (.08)	1.03 (.03)	2.83 (.08)	1.04 (.03)
TOTAL FLOW SCF (SCM)	2602. (73.7)	4427. (125.4)	2599. (73.6)	4429. (125.4)
HC SAMPLE METER/RANGE/PPM (BAG)	53.3/ 2/ 53.27	10.8/ 2/ 10.79	16.1/ 2/ 16.09	11.3/ 2/ 11.29
HC BCKGRD METER/RANGE/PPM	7.8/ 2/ 7.80	7.9/ 2/ 7.90	7.6/ 2/ 7.60	8.7/ 2/ 8.69
CO SAMPLE METER/RANGE/PPM	56.5/ 14/ 250.58	31.6/ 12/ 31.67	58.8/ 12/ 58.35	24.2/ 12/ 24.49
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.1/ 12/ .11	.0/ 12/ .00	.2/ 12/ .22
CO2 SAMPLE METER/RANGE/PCT	61.0/ 1/ 1.1229	85.3/ 14/ .7597	95.0/ 14/ 1.0018	84.8/ 14/ .7492
CO2 BCKGRD METER/RANGE/PCT	2.7/ 1/ .0500	12.9/ 14/ .0418	13.1/ 14/ .0425	13.1/ 14/ .0425
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	24.6/ 1/ 6.30	1.3/ 1/ .34	10.2/ 1/ 2.64	1.8/ 1/ .47
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .05	.0/ 1/ .00	.2/ 1/ .05	.1/ 1/ .03
CH4 SAMPLE PPM (1.175)	9.73	4.51	6.76	4.44
CH4 BCKGRD PPM	2.11	2.10	2.09	2.10
DILUTION FACTOR	10.99	16.56	12.54	16.81
HC CONCENTRATION PPM	46.18	3.38	9.10	3.12
CO CONCENTRATION PPM	239.58	30.44	55.95	23.42
CO2 CONCENTRATION PCT	1.0774	.7205	.9627	.7092
NOX CONCENTRATION PPM	6.25	.34	2.59	.45
CH4 CONCENTRATION PPM	7.81	2.54	4.84	2.47
RHC CONCENTRATION PPM	26.49	3.37	8.58	3.09
OMHCE MASS GRAMS	2.322	.246	.403	.227
CO MASS GRAMS	20.551	4.444	4.795	3.420
CO2 MASS GRAMS	1453.44	1653.81	1297.36	1628.55
NOX MASS GRAMS	.888	.082	.368	.108
CH4 MASS GRAMS	.384	.213	.237	.206
RHC MASS GRAMS ( )	1.126	.244	.364	.223
FUEL MASS KG	.681	.756	.595	.744
FUEL ECONOMY MPG (L/100KM)	15.57 (15.11)	15.16 (15.52)	17.89 (13.15)	15.51 (15.17)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.195	CH4	G/MI	.068
CO	G/MI	2.053	NMHC	G/MI	.123
NOX	G/MI	.092			

FUEL ECONOMY MPG (L/100KM) 16.04 (14.66)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST E85-75F-5	ETHANOL E85 EM-2154-F
VEHICLE MODEL	94 FORD TAURUS	DATE 1/28/97 RUN	FUEL DENSITY 6.480 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .132 C .600 O .268 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	20602 MILES (33148 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.52 IN HG (749.8 MM HG) DRY BULB TEMPERATURE 77.0°F (25.0°C) NOX HUMIDITY C.F. .835

RELATIVE HUMIDITY 23.7 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.5	867.0	504.9	867.3
DRY/WET CORRECTION FACTOR, SAMP/BACK	.978/.992	.983/.992	.979/.992	.983/.992
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.91 (6.30)	3.59 (5.78)	3.91 (6.29)
BLOWER FLOW RATE SCFM (SCMM)	310.7 (8.80)	315.1 (8.92)	312.3 (8.84)	314.4 (8.90)
GAS METER FLOW RATE SCFM (SCMM)	2.86 (.08)	1.04 (.03)	2.88 (.08)	1.02 (.03)
TOTAL FLOW SCF (SCM)	2642. (74.8)	4568. (129.4)	2652. (75.1)	4559. (129.1)
HC SAMPLE METER/RANGE/PPM (BAG)	52.1/ 2/ 52.07	90.7/ 1/ 9.13	16.8/ 2/ 16.79	93.5/ 1/ 9.41
HC BCKGRD METER/RANGE/PPM	5.1/ 2/ 5.10	58.7/ 1/ 5.91	6.3/ 2/ 6.30	64.5/ 1/ 6.49
CO SAMPLE METER/RANGE/PPM	59.5/ 14/ 266.32	25.4/ 12/ 25.65	64.4/ 12/ 63.98	25.3/ 12/ 25.56
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.0/ 12/ .00	.2/ 12/ .22	.1/ 12/ .11
CO2 SAMPLE METER/RANGE/PCT	60.0/ 1/ 1.1041	85.1/ 14/ .7555	94.6/ 14/ .9901	84.2/ 14/ .7367
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0463	13.5/ 14/ .0441	13.8/ 14/ .0452	13.7/ 14/ .0448
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	26.4/ 1/ 6.75	1.6/ 1/ .42	10.8/ 1/ 2.79	2.9/ 1/ .76
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .13	.3/ 1/ .08	.4/ 1/ .10	.2/ 1/ .05
CH4 SAMPLE PPM (1.175)	9.46	4.01	6.44	4.06
CH4 BCKGRD PPM	2.06	1.98	2.02	2.03
DILUTION FACTOR	11.15	16.67	12.68	17.09
HC CONCENTRATION PPM	47.43	3.58	10.99	3.30
CO CONCENTRATION PPM	257.48	25.01	61.83	24.83
CO2 CONCENTRATION PCT	1.0619	.7141	.9485	.6945
NOX CONCENTRATION PPM	6.63	.34	2.70	.71
CH4 CONCENTRATION PPM	7.58	2.14	4.58	2.14
RHC CONCENTRATION PPM	31.87	3.56	10.79	3.29
OMHCE MASS GRAMS	2.386	.268	.495	.247
CO MASS GRAMS	22.426	3.767	5.406	3.732
CO2 MASS GRAMS	1454.54	1691.38	1304.15	1641.72
NOX MASS GRAMS	.793	.071	.324	.146
CH4 MASS GRAMS	.378	.185	.229	.184
RHC MASS GRAMS ( )	1.375	.265	.467	.245
FUEL MASS KG	.683	.773	.598	.750
FUEL ECONOMY MPG (L/100KM)	15.50 (15.18)	14.89 (15.80)	17.66 (13.32)	15.31 (15.37)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.208	CH4	G/MI	.064
CO	G/MI	2.193	NMHC	G/MI	.148
NOX	G/MI	.085			

FUEL ECONOMY MPG (L/100KM) 15.85 (14.85)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R 4-BAG EPA FTP VEHICLE EMISSION RESULTS PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST E85-75F-6		ETHANOL E85 EM-2154-F
VEHICLE MODEL 94 FORD TAURUS	DATE 1/29/97	RUN	FUEL DENSITY 6.480 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .132 C .600 O .268 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20617 MILES (33172 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.52 IN HG (749.8 MM HG) DRY BULB TEMPERATURE 77.0°F (25.0°C) NOX HUMIDITY C.F. .787

RELATIVE HUMIDITY 12.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	506.7	866.7	504.6	866.8
DRY/WET CORRECTION FACTOR, SAMP/BACK	.981/.996	.986/.996	.983/.996	.986/.996
MEASURED DISTANCE MILES (KM)	3.60 (5.80)	3.89 (6.27)	3.61 (5.80)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	311.0 (8.81)	311.2 (8.81)	311.3 (8.81)	312.2 (8.84)
GAS METER FLOW RATE SCFM (SCMM)	2.76 (.08)	.94 (.03)	2.74 (.08)	.93 (.03)
TOTAL FLOW SCF (SCM)	2650. (75.0)	4509. (127.7)	2641. (74.8)	4524. (128.1)
HC SAMPLE METER/RANGE/PPM (BAG)	58.4/ 2/ 58.37	9.2/ 2/ 9.19	29.8/ 2/ 29.78	10.6/ 2/ 10.59
HC BCKGRD METER/RANGE/PPM	6.2/ 2/ 6.20	6.4/ 2/ 6.40	7.1/ 2/ 7.10	7.7/ 2/ 7.70
CO SAMPLE METER/RANGE/PPM	63.2/ 14/ 286.17	31.3/ 12/ 31.38	85.7/ 12/ 85.74	24.5/ 12/ 24.78
CO BCKGRD METER/RANGE/PPM	.1/ 14/ .40	.4/ 12/ .43	.4/ 12/ .43	.5/ 12/ .54
CO2 SAMPLE METER/RANGE/PCT	61.1/ 1/ 1.1248	85.2/ 14/ .7576	54.4/ 1/ .9992	84.5/ 14/ .7429
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0482	13.8/ 14/ .0452	2.7/ 1/ .0500	14.1/ 14/ .0464
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	29.7/ 1/ 7.58	2.5/ 1/ .65	13.1/ 1/ 3.38	2.5/ 1/ .65
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .21	.6/ 1/ .16	.7/ 1/ .18	1.2/ 1/ .31
CH4 SAMPLE PPM (1.175)	9.99	4.16	8.68	8.68
CH4 BCKGRD PPM	2.06	2.06	2.11	2.08
DILUTION FACTOR	10.93	16.61	12.52	16.95
HC CONCENTRATION PPM	52.74	3.18	23.25	3.35
CO CONCENTRATION PPM	277.21	30.30	83.01	23.75
CO2 CONCENTRATION PCT	1.0810	.7151	.9532	.6993
NOX CONCENTRATION PPM	7.39	.50	3.21	.36
CH4 CONCENTRATION PPM	8.11	2.23	6.74	6.72
RHC CONCENTRATION PPM	32.95	3.18	23.04	3.35
OMHCE MASS GRAMS	2.497	.234	1.005	.248
CO MASS GRAMS	24.220	4.504	7.228	3.542
CO2 MASS GRAMS	1485.29	1671.83	1305.06	1640.10
NOX MASS GRAMS	.835	.097	.362	.069
CH4 MASS GRAMS	.406	.190	.336	.574
RHC MASS GRAMS ( )	1.426	.234	.993	.248
FUEL MASS KG	.698	.764	.601	.749
FUEL ECONOMY MPG (L/100KM)	15.18 (15.50)	14.98 (15.71)	17.64 (13.34)	15.25 (15.42)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	.252	CH4	G/MI	.103
CO	G/MI	2.466	NMHC	G/MI	.190
NOX	G/MI	.086			

FUEL ECONOMY MPG (L/100KM) 15.78 (14.91)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST E85-20F-3	ETHANOL E85 EM-2154-F
VEHICLE MODEL	94 FORD TAURUS	DATE 1/30/97 RUN	FUEL DENSITY 6.480 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 3 BAG CART 2	H .132 C .600 O .268 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	20639 MILES (33208 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.52 IN HG (749.8 MM HG)   DRY BULB TEMPERATURE 77.0°F (25.0°C)   NOX HUMIDITY C.F. .835

RELATIVE HUMIDITY 23.7 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	518.7	864.9	504.8	867.3
DRY/WET CORRECTION FACTOR, SAMP/BACK	.972/.992	.981/.992	.979/.992	.982/.992
MEASURED DISTANCE MILES (KM)	3.61 (5.80)	3.91 (6.28)	3.60 (5.79)	3.88 (6.25)
BLOWER FLOW RATE SCFM (SCMM)	277.2 (7.85)	275.4 (7.80)	310.4 (8.79)	310.1 (8.78)
GAS METER FLOW RATE SCFM (SCMM)	2.68 (.08)	.92 (.03)	2.73 (.08)	.92 (.03)
TOTAL FLOW SCF (SCM)	2420. (68.5)	3983. (112.8)	2634. (74.6)	4495. (127.3)
HC SAMPLE METER/RANGE/PPM (BAG)	68.0/ 3/ 678.49	11.4/ 2/ 11.39	18.6/ 2/ 18.59	10.4/ 2/ 10.39
HC BCKGRD METER/RANGE/PPM	.9/ 3/ 8.98	7.9/ 2/ 7.90	7.7/ 2/ 7.70	7.3/ 2/ 7.30
CO SAMPLE METER/RANGE/PPM	87.2/ 1/ 889.91	31.5/ 12/ 31.57	88.0/ 12/ 88.09	31.7/ 12/ 31.76
CO BCKGRD METER/RANGE/PPM	.1/ 1/ .74	.5/ 12/ .54	.5/ 12/ .54	.1/ 12/ .11
CO2 SAMPLE METER/RANGE/PCT	82.8/ 1/ 1.5350	91.0/ 14/ .8924	57.0/ 1/ 1.0478	85.5/ 14/ .7640
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0519	14.1/ 14/ .0464	2.7/ 1/ .0500	13.7/ 14/ .0448
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	58.4/ 1/ 14.79	3.2/ 1/ .83	8.1/ 1/ 2.10	2.0/ 1/ .52
NOX BCKGRD METER/RANGE/PPM	1.4/ 1/ .37	1.9/ 1/ .50	.9/ 1/ .24	.7/ 1/ .18
CH4 SAMPLE PPM (1.175)	48.22	4.01	6.84	4.38
CH4 BCKGRD PPM	2.09	2.16	2.08	2.08
DILUTION FACTOR	7.55	14.11	11.96	16.47
HC CONCENTRATION PPM	670.70	4.06	11.54	3.54
CO CONCENTRATION PPM	850.89	30.18	84.79	30.86
CO2 CONCENTRATION PCT	1.4900	.8493	1.0020	.7219
NOX CONCENTRATION PPM	14.47	.37	1.88	.35
CH4 CONCENTRATION PPM	46.40	2.00	4.93	2.42
RHC CONCENTRATION PPM	316.89	2.75	9.74	3.37
OMHCE MASS GRAMS	30.010	.285	.516	.263
CO MASS GRAMS	67.880	3.964	7.364	4.574
CO2 MASS GRAMS	1869.30	1754.12	1368.48	1682.60
NOX MASS GRAMS	1.585	.067	.225	.071
CH4 MASS GRAMS	2.120	.151	.245	.205
RHC MASS GRAMS ( )	12.521	.179	.419	.247
FUEL MASS KG	.959	.802	.629	.769
FUEL ECONOMY MPG (L/100KM)	11.05 (21.28)	14.32 (16.42)	16.82 (13.98)	14.83 (15.86)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	1.793	CH4	G/MI	.164
CO	G/MI	5.022	NMHC	G/MI	.778
NOX	G/MI	.117			
FUEL ECONOMY MPG (L/100KM)		14.36 (16.38)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST E85-20F-4		ETHANOL E85 EM-2154-F
VEHICLE MODEL 94 FORD TAURUS	DATE 1/31/97	RUN	FUEL DENSITY 6.480 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 3	BAG CART 2	H .132 C .600 O .268 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 20654 MILES (33232 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.27 IN HG (743.5 MM HG)   DRY BULB TEMPERATURE 77.0°F (25.0°C)   NOX HUMIDITY C.F. .837

RELATIVE HUMIDITY 23.9 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	513.7	866.9	505.3	866.6
DRY/WET CORRECTION FACTOR, SAMP/BACK	.972/.992	.981/.992	.978/.992	.982/.992
MEASURED DISTANCE MILES (KM)	3.58 (5.76)	3.85 (6.19)	3.60 (5.80)	3.89 (6.25)
BLOWER FLOW RATE SCFM (SCMM)	274.0 (7.76)	272.1 (7.71)	306.4 (8.68)	308.3 (8.73)
GAS METER FLOW RATE SCFM (SCMM)	2.86 (.08)	1.05 (.03)	2.91 (.08)	1.05 (.03)
TOTAL FLOW SCF (SCM)	2371. (67.1)	3946. (111.8)	2605. (73.8)	4467. (126.5)
HC SAMPLE METER/RANGE/PPM (BAG)	81.6/ 3/ 814.19	11.8/ 2/ 11.79	17.1/ 2/ 17.09	10.7/ 2/ 10.69
HC BCKGRD METER/RANGE/PPM	1.0/ 3/ 9.98	7.4/ 2/ 7.40	7.4/ 2/ 7.40	7.2/ 2/ 7.20
CO SAMPLE METER/RANGE/PPM	55.7/ 2/1259.76	28.6/ 12/ 28.76	75.3/ 12/ 75.08	35.5/ 12/ 35.45
CO BCKGRD METER/RANGE/PPM	.0/ 2/ .00	.7/ 12/ .75	.9/ 12/ .97	.7/ 12/ .75
CO2 SAMPLE METER/RANGE/PCT	83.0/ 1/ 1.5388	91.1/ 14/ .8949	57.4/ 1/ 1.0553	85.3/ 14/ .7597
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0482	13.1/ 14/ .0425	2.6/ 1/ .0482	13.2/ 14/ .0429
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	48.4/ 1/ 12.28	3.1/ 1/ .81	10.3/ 1/ 2.66	1.8/ 1/ .47
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .05	.1/ 1/ .03	.1/ 1/ .03	.0/ 1/ .00
CH4 SAMPLE PPM (1.175)	71.53	3.72	6.68	4.41
CH4 BCKGRD PPM	2.06	2.01	2.04	2.01
DILUTION FACTOR	7.33	14.07	11.89	16.55
HC CONCENTRATION PPM	805.57	4.92	10.32	3.93
CO CONCENTRATION PPM	1205.23	27.25	71.78	33.85
CO2 CONCENTRATION PCT	1.4972	.8554	1.0112	.7194
NOX CONCENTRATION PPM	12.24	.78	2.64	.47
CH4 CONCENTRATION PPM	69.76	1.85	4.81	2.52
RHC CONCENTRATION PPM	401.46	3.86	9.29	3.54
OMHCE MASS GRAMS	36.245	.338	.463	.297
CO MASS GRAMS	94.200	3.545	6.164	4.986
CO2 MASS GRAMS	1840.26	1750.42	1365.62	1666.41
NOX MASS GRAMS	1.316	.140	.312	.095
CH4 MASS GRAMS	3.122	.138	.236	.213
RHC MASS GRAMS ( )	15.542	.249	.395	.258
FUEL MASS KG	.977	.800	.627	.762
FUEL ECONOMY MPG (L/100KM)	10.77 (21.83)	14.15 (16.62)	16.90 (13.92)	14.99 (15.70)

4-BAG COMPOSITE RESULTS

OMHCE	G/MI	2.175	CH4	G/MI	.223
CO	G/MI	6.504	NMHC	G/MI	.963
NOX	G/MI	.115			

FUEL ECONOMY MPG (L/100KM) 14.32 (16.43)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
COMPUTER PROGRAM LDT 1.6-R 4-BAG EPA FTP VEHICLE EMISSION RESULTS PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST LPG-75F-1		PROPANE LPG LPG
VEHICLE MODEL 94 FORD TAURUS	DATE 5/29/97	RUN	FUEL DENSITY 5.729 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5	BAG CART 2	H .183 C .817 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 21072 MILES (33904 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.17 IN HG (740.9 MM HG) DRY BULB TEMPERATURE 74.0°F (23.3°C) NOX HUMIDITY C.F. .957
RELATIVE HUMIDITY 50.8 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	507.0	867.2	504.6	866.8
DRY/WET CORRECTION FACTOR, SAMP/BACK	.970/.985	.975/.985	.972/.985	.976/.985
MEASURED DISTANCE MILES (KM)	3.59 (5.78)	3.90 (6.28)	3.61 (5.81)	3.94 (6.35)
BLOWER FLOW RATE SCFM (SCMM)	306.1 (8.67)	307.7 (8.71)	306.5 (8.68)	306.6 (8.68)
GAS METER FLOW RATE SCFM (SCMM)	2.51 (.07)	.72 (.02)	2.50 (.07)	.74 (.02)
TOTAL FLOW SCF (SCM)	2608. (73.8)	4458. (126.2)	2599. (73.6)	4440. (125.7)
HC SAMPLE METER/RANGE/PPM (BAG)	47.0/ 2/ 46.97	85.1/ 1/ 8.57	19.4/ 2/ 19.39	8.7/ 2/ 8.69
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40	52.0/ 1/ 5.23	5.2/ 2/ 5.20	5.4/ 2/ 5.40
CO SAMPLE METER/RANGE/PPM	44.3/ 13/ 100.86	24.8/ 12/ 24.90	49.4/ 12/ 48.59	20.8/ 12/ 21.05
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .47	.5/ 12/ .54	.4/ 12/ .44	.6/ 12/ .65
CO2 SAMPLE METER/RANGE/PCT	62.1/ 1/ 1.1436	84.3/ 14/ .7388	94.4/ 14/ .9844	83.3/ 14/ .7184
CO2 BCKGRD METER/RANGE/PCT	2.7/ 1/ .0500	13.1/ 14/ .0425	13.0/ 14/ .0421	12.9/ 14/ .0418
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	32.3/ 1/ 8.24	14.5/ 1/ 3.74	19.7/ 1/ 5.06	17.3/ 1/ 4.45
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .00	.0/ 1/ .00	.3/ 1/ .08	.2/ 1/ .05
CH4 SAMPLE PPM (1.185)	5.29	4.26	5.12	4.47
CH4 BCKGRD PPM	2.22	2.23	2.19	2.16
DILUTION FACTOR	10.04	15.67	11.73	16.12
HC CONCENTRATION PPM	42.11	3.67	14.63	3.63
CO CONCENTRATION PPM	96.10	23.56	46.29	19.75
CO2 CONCENTRATION PCT	1.0985	.6990	.9458	.6793
NOX CONCENTRATION PPM	8.24	3.74	4.99	4.40
CH4 CONCENTRATION PPM	3.29	2.18	3.11	2.45
NMHC CONCENTRATION PPM	38.22	1.09	10.94	.73
HC MASS GRAMS	1.900	.283	.658	.279
CO MASS GRAMS	8.262	3.463	3.966	2.892
CO2 MASS GRAMS	1485.22	1615.56	1274.59	1563.75
NOX MASS GRAMS	1.113	.863	.672	1.012
CH4 MASS GRAMS	.162	.183	.153	.205
NMHC MASS GRAMS ( )	1.409	.069	.402	.046
FUEL MASS KG	.503	.542	.429	.524
FUEL ECONOMY MPG (L/100KM)	18.56 (12.67)	18.71 (12.58)	21.88 (10.75)	19.55 (12.03)

4-BAG COMPOSITE RESULTS

HC	G/MI	.196	CH4	G/MI	.047
CO	G/MI	1.191	NMHC	G/MI	.119
NOX	G/MI	.241			

FUEL ECONOMY MPG (L/100KM) 19.75 (11.91)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST LPG-75F-2	PROPANE LPG LPG
VEHICLE MODEL 94 FORD TAURUS	DATE 5/30/97 RUN	FUEL DENSITY 5.729 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5 BAG CART 2	H .183 C .817 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER 21086 MILES (33927 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.12 IN HG (739.6 MM HG)   DRY BULB TEMPERATURE 75.0°F (23.9°C)   NOX HUMIDITY C.F. .971

RELATIVE HUMIDITY 51.4 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.4	866.7	505.1	866.5
DRY/WET CORRECTION FACTOR, SAMP/BACK	.969/.984	.975/.984	.971/.984	.975/.984
MEASURED DISTANCE MILES (KM)	3.58 (5.77)	3.90 (6.28)	3.61 (5.80)	3.90 (6.27)
BLOWER FLOW RATE SCFM (SCMM)	304.0 (8.61)	307.3 (8.70)	305.2 (8.64)	306.5 (8.68)
GAS METER FLOW RATE SCFM (SCMM)	2.54 (.07)	.74 (.02)	2.54 (.07)	.74 (.02)
TOTAL FLOW SCF (SCM)	2582. (73.1)	4449. (126.0)	2591. (73.4)	4437. (125.7)
HC SAMPLE METER/RANGE/PPM (BAG)	55.5/ 2/ 55.47	86.5/ 1/ 8.71	23.5/ 2/ 23.49	88.2/ 1/ 8.88
HC BCKGRD METER/RANGE/PPM	4.9/ 2/ 4.90	51.4/ 1/ 5.17	5.2/ 2/ 5.20	50.0/ 1/ 5.03
CO SAMPLE METER/RANGE/PPM	50.3/ 13/ 115.24	28.2/ 12/ 28.16	92.9/ 12/ 92.28	26.1/ 12/ 26.15
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00	.3/ 12/ .33	.0/ 12/ .00	.3/ 12/ .33
CO2 SAMPLE METER/RANGE/PCT	62.6/ 1/ 1.1530	84.0/ 14/ .7326	94.5/ 14/ .9872	83.1/ 14/ .7144
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0463	13.1/ 14/ .0425	13.2/ 14/ .0429	13.4/ 14/ .0437
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	36.3/ 1/ 9.24	16.4/ 1/ 4.22	15.0/ 1/ 3.86	15.2/ 1/ 3.92
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .00	.0/ 1/ .00	.1/ 2/ .10	1.9/ 1/ .50
CH4 SAMPLE PPM (1.185)	5.34	4.38	5.59	4.78
CH4 BCKGRD PPM	2.09	2.11	2.09	2.10
DILUTION FACTOR	9.94	15.79	11.64	16.19
HC CONCENTRATION PPM	51.06	3.86	18.74	4.16
CO CONCENTRATION PPM	110.23	26.91	88.62	24.97
CO2 CONCENTRATION PCT	1.1113	.6928	.9480	.6734
NOX CONCENTRATION PPM	9.24	4.22	3.77	3.45
CH4 CONCENTRATION PPM	3.46	2.40	3.68	2.81
NMHC CONCENTRATION PPM	46.96	1.01	14.38	.82
HC MASS GRAMS	2.282	.297	.840	.319
CO MASS GRAMS	9.384	3.947	7.569	3.653
CO2 MASS GRAMS	1487.92	1598.21	1273.42	1549.33
NOX MASS GRAMS	1.255	.987	.514	.805
CH4 MASS GRAMS	.169	.202	.180	.236
NMHC MASS GRAMS ( )	1.714	.064	.527	.052
FUEL MASS KG	.504	.536	.430	.520
FUEL ECONOMY MPG (L/100KM)	18.47 (12.74)	18.90 (12.44)	21.77 (10.81)	19.47 (12.08)

4-BAG COMPOSITE RESULTS

HC	G/MI	.236	CH4	G/MI	.053
CO	G/MI	1.619	NMHC	G/MI	.146
NOX	G/MI	.229			

FUEL ECONOMY MPG (L/100KM) 19.73 (11.92)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X		TEST LPG-75F-3	PROPANE LPG LPG
VEHICLE MODEL 94 FORD TAURUS		DATE 6/ 2/97 RUN	FUEL DENSITY 5.729 LB/GAL
ENGINE 3.0 L (181 CID)-6		DYNO 5 BAG CART 2	H .183 C .817 O .000 X .000
TRANSMISSION A4		ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER 21108 MILES (33962 KM)		TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 28.96 IN HG (735.6 MM HG)   DRY BULB TEMPERATURE 74.0°F (23.3°C)   NOX HUMIDITY C.F. .939

RELATIVE HUMIDITY 47.3 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.7	866.4	505.0	851.2
DRY/WET CORRECTION FACTOR, SAMP/BACK	.971/.986	.977/.986	.973/.986	.976/.986
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.89 (6.26)	3.83 (6.17)	3.94 (6.34)
BLOWER FLOW RATE SCFM (SCMM)	307.7 (8.71)	307.8 (8.72)	305.3 (8.65)	306.2 (8.67)
GAS METER FLOW RATE SCFM (SCMM)	2.60 (.07)	.74 (.02)	2.59 (.07)	.79 (.02)
TOTAL FLOW SCF (SCM)	2615. (74.1)	4455. (126.2)	2591. (73.4)	4355. (123.3)
HC SAMPLE METER/RANGE/PPM (BAG)	63.9/ 2/ 63.86	12.5/ 2/ 12.49	34.8/ 2/ 34.78	16.0/ 2/ 15.99
HC BCKGRD METER/RANGE/PPM	5.8/ 2/ 5.80	6.0/ 2/ 6.00	6.1/ 2/ 6.10	6.3/ 2/ 6.30
CO SAMPLE METER/RANGE/PPM	49.0/ 14/ 212.35	80.5/ 12/ 79.85	78.0/ 13/ 186.09	50.8/ 13/ 116.46
CO BCKGRD METER/RANGE/PPM	.0/ 14/ .00	.4/ 12/ .44	.1/ 13/ .23	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	60.4/ 1/ 1.1116	83.0/ 14/ .7124	95.3/ 14/ 1.0106	83.8/ 14/ .7285
CO2 BCKGRD METER/RANGE/PCT	2.7/ 1/ .0500	13.7/ 14/ .0448	13.8/ 14/ .0452	13.8/ 14/ .0452
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	36.6/ 1/ 9.32	24.2/ 1/ 6.20	20.4/ 1/ 5.24	27.2/ 1/ 6.95
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ .08	.4/ 1/ .10	.5/ 1/ .13	.4/ 1/ .10
CH4 SAMPLE PPM (1.185)	7.48	6.33	7.18	7.07
CH4 BCKGRD PPM	2.51	2.48	2.50	2.48
DILUTION FACTOR	10.21	16.11	11.26	15.68
HC CONCENTRATION PPM	58.63	6.87	29.22	10.10
CO CONCENTRATION PPM	203.60	76.90	178.64	112.70
CO2 CONCENTRATION PCT	1.0665	.6704	.9694	.6862
NOX CONCENTRATION PPM	9.25	6.10	5.12	6.86
CH4 CONCENTRATION PPM	5.21	4.00	4.90	4.75
NMHC CONCENTRATION PPM	52.46	2.13	23.42	4.47
HC MASS GRAMS	2.653	.529	1.310	.761
CO MASS GRAMS	17.555	11.295	15.262	16.181
CO2 MASS GRAMS	1446.18	1548.45	1302.49	1549.40
NOX MASS GRAMS	1.231	1.382	.675	1.519
CH4 MASS GRAMS	.257	.337	.240	.391
NMHC MASS GRAMS ( )	1.939	.134	.858	.275
FUEL MASS KG	.495	.524	.445	.527
FUEL ECONOMY MPG (L/100KM)	18.90 (12.45)	19.31 (12.18)	22.42 (10.49)	19.44 (12.10)

4-BAG COMPOSITE RESULTS

HC	G/MI	.334	CH4	G/MI	.080
CO	G/MI	3.960	NMHC	G/MI	.202
NOX	G/MI	.311			

FUEL ECONOMY MPG (L/100KM) 20.08 (11.72)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST LPG-20F-1	PROPANE LPG LPG
VEHICLE MODEL	94 FORD TAURUS	DATE 6/ 4/97 RUN	FUEL DENSITY 5.729 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 5 BAG CART 2	H .183 C .817 O .000 X .000
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	21138 MILES (34011 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.03 IN HG (737.4 MM HG)   DRY BULB TEMPERATURE 75.0°F (23.9°C)   NOX HUMIDITY C.F. .951

RELATIVE HUMIDITY 47.9 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	504.9	866.9	505.6	866.6
DRY/WET CORRECTION FACTOR, SAMP/BACK	.967/.985	.975/.985	.971/.985	.975/.985
MEASURED DISTANCE MILES (KM)	3.59 (5.78)	3.90 (6.27)	3.59 (5.78)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	302.7 (8.57)	304.3 (8.62)	302.3 (8.56)	304.3 (8.62)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2548. (72.1)	4397. (124.5)	2547. (72.1)	4395. (124.5)
HC SAMPLE METER/RANGE/PPM (BAG)	73.1/ 2/ 73.06	81.9/ 1/ 8.24	33.6/ 2/ 33.58	8.7/ 2/ 8.69
HC BCKGRD METER/RANGE/PPM	6.1/ 2/ 6.10	58.8/ 1/ 5.92	5.9/ 2/ 5.90	6.0/ 2/ 6.00
CO SAMPLE METER/RANGE/PPM	62.6/ 13/ 145.82	1.9/ 12/ 2.05	36.3/ 12/ 35.91	.5/ 12/ .54
CO BCKGRD METER/RANGE/PPM	.4/ 13/ .93	.5/ 12/ .54	.4/ 12/ .44	.3/ 12/ .33
CO2 SAMPLE METER/RANGE/PCT	76.5/ 1/ 1.4157	87.3/ 14/ .8036	59.0/ 1/ 1.0853	85.7/ 14/ .7683
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0482	13.6/ 14/ .0444	2.6/ 1/ .0482	13.4/ 14/ .0437
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	28.0/ 2/ 28.10	29.2/ 2/ 29.30	34.8/ 2/ 34.92	27.7/ 2/ 27.80
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .20	.2/ 2/ .20	.1/ 2/ .10	.2/ 2/ .20
CH4 SAMPLE PPM (1.185)	5.18	3.94	4.43	4.23
CH4 BCKGRD PPM	2.32	2.35	2.25	2.29
DILUTION FACTOR	8.09	14.45	10.64	15.11
HC CONCENTRATION PPM	67.71	2.74	28.24	3.10
CO CONCENTRATION PPM	137.94	1.48	34.05	.23
CO2 CONCENTRATION PCT	1.3735	.7622	1.0417	.7275
NOX CONCENTRATION PPM	27.92	29.12	34.83	27.61
CH4 CONCENTRATION PPM	3.14	1.75	2.39	2.08
NMHC CONCENTRATION PPM	64.00	.66	25.40	.63
HC MASS GRAMS	2.985	.208	1.244	.235
CO MASS GRAMS	11.586	.215	2.860	.033
CO2 MASS GRAMS	1814.24	1737.80	1375.64	1657.82
NOX MASS GRAMS	3.665	6.596	4.571	6.252
CH4 MASS GRAMS	.151	.145	.115	.173
NMHC MASS GRAMS ( )	2.305	.041	.915	.039
FUEL MASS KG	.615	.581	.462	.554
FUEL ECONOMY MPG (L/100KM)	15.18 (15.49)	17.43 (13.49)	20.18 (11.66)	18.25 (12.89)

4-BAG COMPOSITE RESULTS

HC	G/MI	.296	CH4	G/MI	.039
CO	G/MI	.898	NMHC	G/MI	.207
NOX	G/MI	1.413			

FUEL ECONOMY MPG (L/100KM) 17.90 (13.14)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X
VEHICLE MODEL 94 FORD TAURUS
ENGINE 3.0 L (181 CID)-5
TRANSMISSION A4
ODOMETER 21153 MILES (34035 KM)

TEST LPG-20F-2
DATE 6/ 5/97 RUN
DYNO 5 BAG CART 2
ACTUAL ROAD LOAD 6.80 HP (5.07 KW)
TEST WEIGHT 3500 LBS (1587 KG)

PROPANE LPG LPG
FUEL DENSITY 5.729 LB/GAL
H .183 C .817 O .000 X .000

BAROMETER 28.93 IN HG (734.8 MM HG)   DRY BULB TEMPERATURE 75.0°F (23.9°C)   NOX HUMIDITY C.F. .973
RELATIVE HUMIDITY 51.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	503.9	866.7	505.0	865.7
DRY/WET CORRECTION FACTOR, SAMP/BACK	.966/.984	.974/.984	.969/.984	.974/.984
MEASURED DISTANCE MILES (KM)	3.60 (5.79)	3.92 (6.31)	3.62 (5.82)	3.91 (6.29)
BLOWER FLOW RATE SCFM (SCMM)	301.6 (8.54)	299.6 (8.49)	300.6 (8.51)	302.6 (8.57)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2533. (71.7)	4328. (122.6)	2530. (71.7)	4366. (123.6)
HC SAMPLE METER/RANGE/PPM (BAG)	85.8/ 2/ 85.75	10.0/ 2/ 9.99	61.7/ 2/ 61.66	11.8/ 2/ 11.79
HC BCKGRD METER/RANGE/PPM	7.0/ 2/ 7.00	6.8/ 2/ 6.80	6.7/ 2/ 6.70	8.6/ 2/ 8.60
CO SAMPLE METER/RANGE/PPM	65.0/ 14/ 295.19	1.3/ 12/ 1.41	75.3/ 12/ 74.56	.5/ 12/ .54
CO BCKGRD METER/RANGE/PPM	.3/ 14/ 1.21	.7/ 12/ .76	.5/ 12/ .54	.3/ 12/ .33
CO2 SAMPLE METER/RANGE/PCT	75.3/ 1/ 1.3930	87.4/ 14/ .8058	60.5/ 1/ 1.1135	85.6/ 14/ .7661
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0519	13.7/ 14/ .0448	2.8/ 1/ .0519	13.9/ 14/ .0456
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	32.9/ 2/ 33.02	32.1/ 2/ 32.21	30.5/ 2/ 30.61	33.3/ 2/ 33.42
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30	.3/ 2/ .30	.2/ 2/ .20	.2/ 2/ .20
CH4 SAMPLE PPM (1.185)	8.42	4.49	8.06	4.34
CH4 BCKGRD PPM	2.48	2.46	2.35	2.37
DILUTION FACTOR	8.13	14.41	10.32	15.15
HC CONCENTRATION PPM	79.61	3.67	55.62	3.77
CO CONCENTRATION PPM	279.63	.66	70.90	.23
CO2 CONCENTRATION PCT	1.3475	.7641	1.0666	.7235
NOX CONCENTRATION PPM	32.75	31.93	30.43	33.23
CH4 CONCENTRATION PPM	6.24	2.20	5.94	2.13
NMHC CONCENTRATION PPM	72.21	1.06	48.58	1.24
HC MASS GRAMS	3.489	.275	2.435	.284
CO MASS GRAMS	23.350	.095	5.914	.032
CO2 MASS GRAMS	1769.46	1714.92	1399.30	1637.89
NOX MASS GRAMS	4.373	7.287	4.059	7.649
CH4 MASS GRAMS	.299	.180	.284	.176
NMHC MASS GRAMS ( )	2.586	.065	1.738	.077
FUEL MASS KG	.607	.573	.473	.548
FUEL ECONOMY MPG (L/100KM)	15.40 (15.28)	17.77 (13.24)	19.88 (11.83)	18.56 (12.67)

4-BAG COMPOSITE RESULTS

HC	G/MI	.421	CH4	G/MI	.062
CO	G/MI	1.791	NMHC	G/MI	.289
NOX	G/MI	1.553			

FUEL ECONOMY MPG (L/100KM) 18.04 (13.04)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER	90X	TEST CNG-75-1	NAT GAS CNG
VEHICLE MODEL	94 FORD TAURUS	DATE 7/21/97 RUN	FUEL DENSITY 5.570 LB/GAL
ENGINE	3.0 L (181 CID)-6	DYNO 5 BAG CART 1	H .238 C .726 O .018 X .017
TRANSMISSION	A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)	
ODOMETER	21302 MILES (34274 KM)	TEST WEIGHT 3500 LBS (1587 KG)	

BAROMETER 29.11 IN HG (739.4 MM HG) DRY BULB TEMPERATURE 76.0°F (24.4°C) NOX HUMIDITY C.F. .964

RELATIVE HUMIDITY 48.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.3	866.5	505.6	866.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.965/.985	.971/.985	.967/.985	.971/.985
MEASURED DISTANCE MILES (KM)	3.63 (5.84)	3.93 (6.33)	3.61 (5.80)	3.92 (6.31)
BLOWER FLOW RATE SCFM (SCMM)	308.5 (8.74)	308.6 (8.74)	305.6 (8.65)	306.8 (8.69)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2598. (73.6)	4457. (126.2)	2575. (72.9)	4429. (125.4)
HC SAMPLE METER/RANGE/PPM (BAG)	93.6/ 2/ 93.62	42.7/ 2/ 42.71	74.9/ 2/ 74.91	51.1/ 2/ 51.11
HC BCKGRD METER/RANGE/PPM	6.3/ 2/ 6.30	6.6/ 2/ 6.60	7.0/ 2/ 7.00	7.6/ 2/ 7.60
CO SAMPLE METER/RANGE/PPM	93.9/ 12/ 94.47	39.6/ 12/ 38.70	37.1/ 12/ 36.22	34.2/ 12/ 33.33
CO BCKGRD METER/RANGE/PPM	1.1/ 12/ 1.04	.8/ 12/ .76	.8/ 12/ .76	.6/ 12/ .57
CO2 SAMPLE METER/RANGE/PCT	59.1/ 3/ 1.0375	79.6/ 11/ .7046	95.6/ 11/ .9251	78.2/ 11/ .6865
CO2 BCKGRD METER/RANGE/PCT	3.7/ 3/ .0585	8.7/ 11/ .0510	8.8/ 11/ .0516	8.7/ 11/ .0510
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	37.3/ 1/ 9.32	3.1/ 1/ .77	22.7/ 1/ 5.67	3.7/ 1/ .92
NOX BCKGRD METER/RANGE/PPM	.7/ 1/ .17	.4/ 1/ .10	.8/ 1/ .20	.6/ 1/ .15
CH4 SAMPLE PPM (1.160)	78.70	34.24	63.13	40.80
CH4 BCKGRD PPM	2.66	2.60	2.71	2.69
DILUTION FACTOR	9.16	13.57	10.33	13.92
HC CONCENTRATION PPM	88.01	36.59	68.59	44.05
CO CONCENTRATION PPM	89.18	36.60	33.99	31.62
CO2 CONCENTRATION PCT	.9855	.6574	.8785	.6392
NOX CONCENTRATION PPM	9.16	.68	5.49	.79
CH4 CONCENTRATION PPM	76.33	31.83	60.68	38.31
NMHC CONCENTRATION PPM	-.54	-.33	-1.80	-.39
THC MASS GRAMS	3.744	2.679	2.951	3.203
CO MASS GRAMS	7.639	5.379	2.886	4.617
CO2 MASS GRAMS	1327.42	1519.33	1172.97	1467.64
NOX MASS GRAMS	1.242	.159	.738	.182
CH4 MASS GRAMS	3.744	2.679	2.951	3.203
NMHC MASS GRAMS ( )	.000	.000	.000	.000
FUEL MASS KG	.498	.567	.438	.548
FUEL ECONOMY MPG (L/100KM)	18.41 (12.78)	17.53 (13.42)	20.81 (11.30)	18.08 (13.01)

4-BAG COMPOSITE RESULTS

THC	G/MI	.831	CH4	G/MI	.831
CO	G/MI	1.309	NMHC	G/MI	.000
NOX	G/MI	.149			

FUEL ECONOMY MPG (L/100KM) 18.71 (12.57)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST CNG-75F-2		NAT GAS CNG
VEHICLE MODEL 94 FORD TAURUS	DATE 7/22/97	RUN	FUEL DENSITY 5.570 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5	BAG CART 1	H .238 C .726 O .018 X .017
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 21317 MILES (34299 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.17 IN HG (740.9 MM HG)   DRY BULB TEMPERATURE 73.0°F (22.8°C)   NOX HUMIDITY C.F. .985

RELATIVE HUMIDITY 57.6 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.3	866.7	505.6	866.7
DRY/WET CORRECTION FACTOR, SAMP/BACK	.963/.984	.970/.984	.965/.984	.970/.984
MEASURED DISTANCE MILES (KM)	3.61 (5.82)	3.89 (6.26)	3.62 (5.83)	3.94 (6.34)
BLOWER FLOW RATE SCFM (SCMM)	310.5 (8.79)	310.3 (8.79)	307.9 (8.72)	307.6 (8.71)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2615. (74.1)	4482. (126.9)	2595. (73.5)	4443. (125.8)
HC SAMPLE METER/RANGE/PPM (BAG)	91.2/ 2/ 91.22	42.1/ 2/ 42.11	69.6/ 2/ 69.61	41.9/ 2/ 41.91
HC BCKGRD METER/RANGE/PPM	5.5/ 2/ 5.50	5.9/ 2/ 5.90	6.5/ 2/ 6.50	6.8/ 2/ 6.80
CO SAMPLE METER/RANGE/PPM	46.5/ 13/ 107.36	38.9/ 12/ 38.01	31.6/ 12/ 30.75	27.0/ 12/ 26.20
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .44	.3/ 12/ .28	.2/ 12/ .19	.3/ 12/ .28
CO2 SAMPLE METER/RANGE/PCT	61.0/ 3/ 1.0743	79.5/ 11/ .7033	96.3/ 11/ .9352	79.1/ 11/ .6981
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .0489	8.4/ 11/ .0492	8.4/ 11/ .0492	8.4/ 11/ .0492
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	30.4/ 1/ 7.60	3.6/ 1/ .90	28.9/ 1/ 7.22	3.5/ 1/ .87
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .05	.3/ 1/ .07	.5/ 1/ .12	.6/ 1/ .15
CH4 SAMPLE PPM (1.160)	75.30	34.18	56.72	32.77
CH4 BCKGRD PPM	2.56	2.51	2.51	2.52
DILUTION FACTOR	8.84	13.60	10.23	13.72
HC CONCENTRATION PPM	86.34	36.64	63.75	35.60
CO CONCENTRATION PPM	101.58	36.25	29.17	24.92
CO2 CONCENTRATION PCT	1.0309	.6578	.8908	.6525
NOX CONCENTRATION PPM	7.55	.83	7.11	.74
CH4 CONCENTRATION PPM	73.03	31.85	54.45	30.43
NMHC CONCENTRATION PPM	1.63	-.30	.58	.30
THC MASS GRAMS	3.677	2.695	2.693	2.575
CO MASS GRAMS	8.757	5.357	2.495	3.649
CO2 MASS GRAMS	1397.71	1528.53	1198.49	1503.12
NOX MASS GRAMS	1.054	.199	.984	.174
CH4 MASS GRAMS	3.605	2.695	2.668	2.552
NMHC MASS GRAMS ( )	.072	.000	.026	.023
FUEL MASS KG	.525	.570	.447	.560
FUEL ECONOMY MPG (L/100KM)	17.40 (13.52)	17.24 (13.64)	20.50 (11.48)	17.79 (13.23)

4-BAG COMPOSITE RESULTS

THC	G/MI	.762	CH4	G/MI	.754
CO	G/MI	1.272	NMHC	G/MI	.008
NOX	G/MI	.159			

FUEL ECONOMY MPG (L/100KM) 18.27 (12.87)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST CNG-75F-3		NAT GAS CNG
VEHICLE MODEL 94 FORD TAURUS	DATE 7/23/97	RUN	FUEL DENSITY 5.570 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5	BAG CART 1	H .238 C .726 O .018 X .017
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 21332 MILES (34323 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.19 IN HG (741.4 MM HG)   DRY BULB TEMPERATURE 74.0°F (23.3°C)   NOX HUMIDITY C.F. 1.000

RELATIVE HUMIDITY 58.1 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.7	866.2	506.8	866.5
DRY/WET CORRECTION FACTOR, SAMP/BACK	.963/.983	.969/.983	.964/.983	.969/.983
MEASURED DISTANCE MILES (KM)	3.59 (5.77)	3.90 (6.28)	3.61 (5.81)	3.91 (6.29)
BLOWER FLOW RATE SCFM (SCMM)	309.2 (8.76)	309.8 (8.77)	307.1 (8.70)	308.0 (8.72)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2606. (73.8)	4472. (126.6)	2594. (73.5)	4448. (126.0)
HC SAMPLE METER/RANGE/PPM (BAG)	86.0/ 2/ 86.02	38.8/ 2/ 38.81	71.8/ 2/ 71.81	47.5/ 2/ 47.51
HC BCKGRD METER/RANGE/PPM	4.9/ 2/ 4.90	5.4/ 2/ 5.40	5.9/ 2/ 5.90	6.1/ 2/ 6.10
CO SAMPLE METER/RANGE/PPM	88.2/ 12/ 88.27	37.6/ 12/ 36.71	40.2/ 12/ 39.30	41.7/ 12/ 40.79
CO BCKGRD METER/RANGE/PPM	.5/ 12/ .47	.3/ 12/ .28	.2/ 12/ .19	.3/ 12/ .28
CO2 SAMPLE METER/RANGE/PCT	59.6/ 3/ 1.0472	80.7/ 11/ .7190	97.1/ 11/ .9467	80.0/ 11/ .7098
CO2 BCKGRD METER/RANGE/PCT	2.8/ 3/ .0441	8.4/ 11/ .0492	8.3/ 11/ .0485	8.0/ 11/ .0467
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	32.6/ 1/ 8.15	3.2/ 1/ .80	29.5/ 1/ 7.37	3.7/ 1/ .92
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .12	.7/ 1/ .17	.7/ 1/ .17	.7/ 1/ .17
CH4 SAMPLE PPM (1.160)	69.32	30.23	56.53	37.00
CH4 BCKGRD PPM	2.35	2.31	2.42	2.44
DILUTION FACTOR	9.09	13.31	10.10	13.46
HC CONCENTRATION PPM	81.66	33.81	66.50	41.86
CO CONCENTRATION PPM	83.47	34.99	37.30	38.92
CO2 CONCENTRATION PCT	1.0079	.6735	.9030	.6666
NOX CONCENTRATION PPM	8.03	.64	7.21	.76
CH4 CONCENTRATION PPM	67.23	28.09	54.35	34.74
NMHC CONCENTRATION PPM	3.66	1.23	3.45	1.56
THC MASS GRAMS	3.470	2.465	2.814	3.036
CO MASS GRAMS	7.172	5.158	3.190	5.707
CO2 MASS GRAMS	1361.85	1561.72	1214.68	1537.46
NOX MASS GRAMS	1.134	.154	1.013	.184
CH4 MASS GRAMS	3.308	2.372	2.662	2.918
NMHC MASS GRAMS ( )	.162	.093	.152	.118
FUEL MASS KG	.510	.582	.453	.574
FUEL ECONOMY MPG (L/100KM)	17.74 (13.26)	16.93 (13.90)	20.14 (11.68)	17.19 (13.68)

4-BAG COMPOSITE RESULTS

THC	G/MI	.784	CH4	G/MI	.749
CO	G/MI	1.383	NMHC	G/MI	.035
NOX	G/MI	.165			

FUEL ECONOMY MPG (L/100KM) 17.99 (13.08)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R   4-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST CNG-20F-1		NAT GAS CNG
VEHICLE MODEL 94 FORD TAURUS	DATE 7/25/97	RUN 2	FUEL DENSITY 5.570 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5	BAG CART 2	H .238 C .726 O .018 X .017
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 21362 MILES (34371 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.19 IN HG (741.4 MM HG)   DRY BULB TEMPERATURE 74.0°F (23.3°C)   NOX HUMIDITY C.F. .977

RELATIVE HUMIDITY 54.4 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	507.6	866.4	506.0	865.8
DRY/WET CORRECTION FACTOR, SAMP/BACK	.960/.984	.970/.984	.965/.984	.971/.984
MEASURED DISTANCE MILES (KM)	3.61 (5.80)	3.91 (6.30)	3.62 (5.82)	3.90 (6.28)
BLOWER FLOW RATE SCFM (SCMM)	310.6 (8.80)	311.2 (8.81)	311.4 (8.82)	309.4 (8.76)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2628. (74.4)	4493. (127.3)	2626. (74.4)	4465. (126.5)
HC SAMPLE METER/RANGE/PPM (BAG)	9.8/ 3/ 97.78	32.5/ 2/ 32.48	77.0/ 2/ 76.96	40.6/ 2/ 40.58
HC BCKGRD METER/RANGE/PPM	.7/ 3/ 6.98	6.8/ 2/ 6.80	6.3/ 2/ 6.30	6.1/ 2/ 6.10
CO SAMPLE METER/RANGE/PPM	86.1/ 12/ 85.29	48.9/ 12/ 47.05	54.6/ 12/ 52.75	37.8/ 12/ 36.11
CO BCKGRD METER/RANGE/PPM	.6/ 12/ .57	.5/ 12/ .47	.6/ 12/ .57	.5/ 12/ .47
CO2 SAMPLE METER/RANGE/PCT	66.8/ 1/ 1.2322	83.5/ 14/ .7224	51.8/ 1/ .9507	81.5/ 14/ .6832
CO2 BCKGRD METER/RANGE/PCT	2.7/ 1/ .0500	13.7/ 14/ .0448	2.7/ 1/ .0500	13.7/ 14/ .0448
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	77.7/ 1/ 19.60	4.8/ 1/ 1.25	35.9/ 1/ 9.14	5.9/ 1/ 1.53
NOX BCKGRD METER/RANGE/PPM	1.3/ 1/ .34	1.4/ 1/ .37	.9/ 1/ .24	.9/ 1/ .24
CH4 SAMPLE PPM (1.160)	83.36	25.48	62.54	32.25
CH4 BCKGRD PPM	2.80	2.66	2.61	2.51
DILUTION FACTOR	7.74	13.24	10.04	14.00
HC CONCENTRATION PPM	91.70	26.20	71.29	34.92
CO CONCENTRATION PPM	80.20	44.78	49.84	34.32
CO2 CONCENTRATION PCT	1.1886	.6810	.9056	.6416
NOX CONCENTRATION PPM	19.30	.91	8.93	1.31
CH4 CONCENTRATION PPM	80.91	23.02	60.19	29.92
NMHC CONCENTRATION PPM	-2.16	-.51	1.47	.21
THC MASS GRAMS	4.014	1.953	3.050	2.538
CO MASS GRAMS	6.947	6.635	4.315	5.052
CO2 MASS GRAMS	1619.31	1586.63	1233.19	1485.43
NOX MASS GRAMS	2.684	.217	1.242	.311
CH4 MASS GRAMS	4.014	1.953	2.984	2.522
NMHC MASS GRAMS ( )	.000	.000	.065	.016
FUEL MASS KG	.606	.592	.461	.554
FUEL ECONOMY MPG (L/100KM)	15.03 (15.65)	16.71 (14.08)	19.83 (11.86)	17.80 (13.22)

4-BAG COMPOSITE RESULTS

THC	G/MI	.765	CH4	G/MI	.759
CO	G/MI	1.487	NMHC	G/MI	.006
NOX	G/MI	.284			

FUEL ECONOMY MPG (L/100KM) 17.49 (13.45)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 1.6-R — 4-BAG EPA FTP VEHICLE EMISSION RESULTS — PROJECT NO. 08-6068-410

VEHICLE NUMBER 90X	TEST CNG-20F-2		NAT GAS CNG
VEHICLE MODEL 94 FORD TAURUS	DATE 7/28/97	RUN 2	FUEL DENSITY 5.570 LB/GAL
ENGINE 3.0 L (181 CID)-6	DYNO 5	BAG CART 2	H .238 C .726 O .018 X .017
TRANSMISSION A4	ACTUAL ROAD LOAD 6.80 HP (5.07 KW)		
ODOMETER 21384 MILES (34406 KM)	TEST WEIGHT 3500 LBS (1587 KG)		

BAROMETER 29.16 IN HG (740.7 MM HG) DRY BULB TEMPERATURE 73.0°F (22.8°C) NOX HUMIDITY C.F. 1.008
RELATIVE HUMIDITY 61.5 PCT.

BAG NUMBER	1	2	3	4
BAG DESCRIPTION	COLD TRANSIENT (0-505 SEC.)	STABILIZED (505-1372 SEC.)	HOT TRANSIENT (0- 505 SEC.)	HOT STABILIZED (505-1372 SEC.)
RUN TIME SECONDS	505.8	867.3	505.5	867.7
DRY/WET CORRECTION FACTOR, SAMP/BACK	.958/.983	.969/.983	.964/.983	.969/.983
MEASURED DISTANCE MILES (KM)	3.62 (5.82)	3.87 (6.23)	3.61 (5.81)	3.89 (6.26)
BLOWER FLOW RATE SCFM (SCMM)	311.4 (8.82)	311.0 (8.81)	308.6 (8.74)	309.1 (8.75)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
TOTAL FLOW SCF (SCM)	2625. (74.3)	4496. (127.3)	2600. (73.6)	4470. (126.6)
HC SAMPLE METER/RANGE/PPM (BAG)	93.5/ 2/ 93.45	26.9/ 2/ 26.88	67.4/ 2/ 67.36	33.0/ 2/ 32.98
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40	5.3/ 2/ 5.30	5.3/ 2/ 5.30	5.9/ 2/ 5.90
CO SAMPLE METER/RANGE/PPM	65.6/ 12/ 63.92	46.3/ 12/ 44.46	46.0/ 12/ 44.17	34.6/ 12/ 33.00
CO BCKGRD METER/RANGE/PPM	.3/ 12/ .28	.3/ 12/ .28	.3/ 12/ .28	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	68.1/ 1/ 1.2567	82.9/ 14/ .7104	93.0/ 14/ .9452	82.4/ 14/ .7006
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0519	13.2/ 14/ .0429	13.4/ 14/ .0437	12.6/ 14/ .0406
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	77.9/ 1/ 19.65	4.4/ 1/ 1.15	37.5/ 1/ 9.55	7.0/ 1/ 1.82
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .03	.1/ 1/ .03	1.3/ 1/ .34	1.3/ 1/ .34
CH4 SAMPLE PPM (1.160)	74.77	21.05	55.91	26.13
CH4 BCKGRD PPM	2.55	2.51	2.53	2.53
DILUTION FACTOR	7.60	13.47	10.11	13.67
HC CONCENTRATION PPM	88.76	21.98	62.59	27.52
CO CONCENTRATION PPM	60.04	42.39	41.81	31.66
CO2 CONCENTRATION PCT	1.2117	.6707	.9058	.6630
NOX CONCENTRATION PPM	19.62	1.12	9.24	1.50
CH4 CONCENTRATION PPM	72.55	18.72	53.63	23.78
NMHC CONCENTRATION PPM	4.60	.26	.38	-.07
THC MASS GRAMS	3.800	1.609	2.649	2.007
CO MASS GRAMS	5.196	6.283	3.584	4.666
CO2 MASS GRAMS	1649.02	1563.48	1221.02	1536.67
NOX MASS GRAMS	2.813	.275	1.312	.367
CH4 MASS GRAMS	3.595	1.589	2.632	2.007
NMHC MASS GRAMS ( )	.205	.020	.017	.000
FUEL MASS KG	.616	.583	.456	.572
FUEL ECONOMY MPG (L/100KM)	14.85 (15.84)	16.80 (14.00)	20.01 (11.76)	17.18 (13.69)

4-BAG COMPOSITE RESULTS

THC	G/MI	.664	CH4	G/MI	.650
CO	G/MI	1.286	NMHC	G/MI	.014
NOX	G/MI	.305			

FUEL ECONOMY MPG (L/100KM) 17.30 (13.60)

APPENDIX D

COMPARISON OF PARTICULATE EMISSION RATES MEASURED WITH VARIOUS FILTER MEDIA

Appendix Table D-1. Comparison of Particulate Emission Rates Measured with Various Filter Media

Fuel	Temp.	Filter Type	Particulate Emission Rate (mg/mi)				
			Pallflex 20" x 20"	Pallflex 47 mm	Nuclepore 47 mm	MOUDI	TEOM[a]
RFG	72°F	Cold UDDS	4.40	5.03	5.43	5.31	
		Hot UDDS	0.78	4.25[a]	1.55	1.58	
		FTP[b]	2.33	4.58	3.22	3.19	
	20°F	Cold UDDS	30.37	32.57	36.14	24.69	43.77
		Hot UDDS	0.81	2.99	2.18	1.76	
		FTP[b]	13.52	15.71	16.78	11.62	
E85	72°F	Cold UDDS	2.53	3.35	3.88	5.69	
		Hot UDDS	1.12	1.50	4.27[a]	2.86	
		FTP[b]	1.72	2.30	4.10	4.07	
	20°F	Cold UDDS	11.05	15.60	14.90	12.91	
		Hot UDDS	0.97	0.93	1.91	2.27	
		FTP[b]	5.30	7.24	7.49	6.85	
M85	72°F	Cold UDDS	7.38	8.08	6.45	6.27	
		Hot UDDS	4.76	5.19	5.57	3.99	
		FTP[b]	5.89	6.43	5.95	4.97	
	20°F	Cold UDDS	21.52	18.55	12.07	13.85	
		Hot UDDS	1.92	2.48	3.52	3.77	
		FTP[b]	10.35	9.39	7.20	8.10	
LPG	72°F	Cold UDDS	2.97	4.03	3.94	1.53	
		Hot UDDS	1.36	2.81	2.08	1.95	
		FTP[b]	2.05	3.34	2.88	1.77	
	20°F	Cold UDDS	2.79	5.17	3.87	2.41	
		Hot UDDS	1.41	3.16	2.39	3.39	
		FTP[b]	2.00	4.02	3.03	2.97	
CNG	72°F	Cold UDDS	2.37	4.20	5.29	4.20	
		Hot UDDS	1.06	2.05	2.33	4.16	
		FTP[b]	1.62	2.97	3.60	4.17	
	20°F	Cold UDDS	1.89	5.21	4.43	3.35	
		Hot UDDS	0.85	2.09	2.12	4.11	
		FTP[b]	1.30	3.43	3.12	3.78	

[a] possible outlier
[b] FTP = 0.47 (cold UDDS) + 0.53 (hot UDDS)

APPENDIX E

AVERAGE PIXE FTP EMISSIONS

Appendix Table E-1. Average FTP PAH Emissions

	RFG			E85			M85			LPG			CNG		
	Cold Start UDDS (ng)	Hot Start UDDS (ng)	FTP[a] (ng/mi)	Cold Start UDDS (ng)	Hot Start UDDS (ng)	FTP[a] (ug/mi)	Cold Start UDDS (ng)	Hot Start UDDS (ng)	FTP[a] (ug/mi)	Cold Start UDDS (ng)	Hot Start UDDS (ng)	FTP[a] (ug/mi)	Cold Start UDDS (ng)	Hot Start UDDS (ng)	FTP[a] (ug/mi)
Fluoranthene	4,200	1,600	181	2,200	740	91	2,100	750	89	1,000	570	50	2,200	930	98
Pyrene	3,900	1,600	173	2,000	590	80	2,600	930	110	4,700	7,900	435	9,800	14,000	813
Benzo(a)anthracene	19,000	1,100	586	5,300	3,700	293	4,900	4,000	292	6,300	5,000	371	5,600	3,700	301
Chrysene	21,000	1,400	655	7,200	5,400	412	6,400	6,100	415	6,500	5,500	395	6,400	4,300	347
1-Nitropyrene	66	17	3	42	20	2	40	19	2	66	1,500	59	310	120	13
Benzo(b)fluoranthene	17,000	530	507	4,800	3,400	267	4,500	3,000	243	2,600	1,300	124	2,100	480	78
Benzo(k)fluoranthene	24,000	390	703	4,800	3,300	263	4,000	2,600	213	2,900	1,500	140	2,000	520	77
Benzo(e)pyrene	11,000	370	329	4,400	3,400	255	4,200	3,600	257	3,200	2,400	183	2,200	860	96
Benzo(a)pyrene	22,000	200	638	3,500	2,000	176	2,100	1,300	110	2,300	1,300	115	1,300	370	51
Indeno(1,2,3-cd)pyrene	21,000	180	609	2,500	2,000	148	3,000	5,000	276	1,700	4,200	208	840	920	59
Dibenz(a,h)anthracene	2,500	40	73	210	150	12	270	360	21	150	210	12	340	48	12
Benzo(g,h,i)perylene	24,000	430	704	4,500	3,500	262	4,800	8,400	457	4,700	15,000	705	1,800	3,800	196
Total	169,666	7,857	5,162	41,452	28,200	2,260	38,910	36,059	2,486	36,116	46,380	2,798	34,890	30,048	2,142

[a] FTP = 0.43(Cold-start UDDS) + 0.57 (Hot-start UDDS)

APPENDIX F

AVERAGE FTP PAH EMISSIONS

Appendix Table F-1. Average PIXE FTP Emissions

	RFG			E85			M85			LPG			CNG		
	Cold Start UDDS (µg)	Hot Start UDDS (µg)	FTP[a] (µg/mi)	Cold Start UDDS (µg)	Hot Start UDDS (µg)	FTP[a] (µg/mi)	Cold Start UDDS (µg)	Hot Start UDDS (µg)	FTP[a] (µg/mi)	Cold Start UDDS (µg)	Hot Start UDDS (µg)	FTP[a] (µg/mi)	Cold Start UDDS (µg)	Hot Start UDDS (µg)	FTP[a] (µg/mi)
Na	ND[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mg	ND	ND	ND	ND	ND	ND	ND	4.898	0.186	ND	ND	ND	ND	1.425	0.054
Al	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.583	ND	0.017	ND	1.842	0.070
Si	0.568	0.761	0.045	1.436	2.210	0.125	2.138	3.640	0.200	1.410	1.857	0.111	2.886	3.873	0.230
P	ND	ND	ND	ND	0.357	0.014	ND	0.561	0.021	ND	ND	ND	0.696	1.459	0.075
S	0.917	0.314	0.038	2.157	1.840	0.132	12.805	13.970	0.898	1.841	0.968	0.090	3.278	2.104	0.174
Cl	0.668	0.656	0.044	0.807	1.030	0.062	2.260	5.788	0.285	1.231	0.963	0.072	2.097	1.223	0.107
K	ND	ND	ND	ND	ND	ND	0.692	ND	0.020	0.384	ND	0.011	0.425	ND	0.012
Ca	1.197	1.360	0.086	1.185	1.755	0.101	7.467	26.732	1.230	1.360	0.607	0.062	1.450	0.951	0.078
Ti	ND	ND	ND	ND	0.124	0.005	ND	ND	ND	ND	ND	ND	0.189	ND	0.005
V	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.133	ND	0.004
Cr	ND	ND	ND	0.063	0.097	0.005	ND	ND	ND	0.105	0.144	0.008	0.132	0.239	0.013
Mn	ND	ND	ND	ND	0.075	0.003	0.105	ND	0.003	0.094	ND	0.003	ND	ND	ND
Fe	0.665	0.590	0.041	0.951	1.257	0.075	0.533	1.504	0.072	3.023	1.028	0.126	2.415	2.259	0.155
Ni	0.101	ND	0.003	0.074	0.146	0.008	0.077	0.108	0.006	0.556	ND	0.016	0.064	ND	0.002
Cu	ND	ND	ND	0.081	0.098	0.006	0.071	0.099	0.006	ND	0.056	0.002	0.113	0.062	0.006
Zn	0.231	0.142	0.012	0.407	0.597	0.034	0.387	0.478	0.029	0.463	0.183	0.020	0.520	0.230	0.024
Br	ND	ND	ND	ND	ND	ND	0.078	0.052	0.004	0.152	0.127	0.009	0.383	0.215	0.019
Sr	ND	ND	ND	ND	ND	ND	ND	0.170	0.006	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.207	0.111	0.010	ND	ND	ND
Total	4.348	3.822	0.270	7.161	9.585	0.570	26.612	58.000	2.967	11.409	6.045	0.557	14.779	15.882	1.027

[a] FTP = 0.43(Cold-start UDDS) + 0.57 (Hot-start UDDS)
[b] not detected

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13. ABSTRACT *(Maximum 200 words)* This report describes the laboratory efforts to characterize particulate and gaseous exhaust emissions from a passenger vehicle operating on alternative fuels. Tests were conducted at room temperature (nominally 72°F) and 20°F utilizing the chassis dynamometer portion of the Federal Test Procedure for light-duty vehicles. Fuels evaluated included Federal reformulated gasoline, liquefied petroleum gas, a national average blend of compressed natural gas, E85, and M85.

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