IX. TOYOTA CELICA CONVERSION AND EMISSIONS ANALYSIS

The 1990 Toyota Celica was factory equipped with a close-coupled catalytic converter plus a relatively small underbody catalyst. There is no air injection with the original catalyst configuration. This vehicle has two oxygen sensors, one located immediately upstream and the other immediately downstream of the stock (original) close-coupled catalyst. Photographs of the original Toyota Celica catalysts are shown in Figure 15. An electrically-heated catalyst was mounted just upstream of the original underbody catalyst as shown in Figure 16. A blank "spool" replaces the electrically-heated catalyst for original configuration tests. The Celica provided an opportunity to study the emission control potential of an electrically-heated catalyst located downstream of a close-coupled catalyst. In this downstream location, the electrically-heated catalyst would be expected to operate at lower overall temperatures than if located first in the exhaust stream, close to the engine. Therefore, long-term durability for the heated catalyst may be enhanced in this cooler location.

Take-apart flanges were fitted to the exhaust pipe and electrically-heated catalyst so that emission tests could be performed easily with or without the preheated catalyst. An on-vehicle air injection pump was mounted behind the front bumper, along with the solenoid-operated air control valve. The original Toyota battery was replaced with the strongest battery available that would fit into the underhood location. For emission tests at SwRI, the catalyst power controller was located behind the right-front seat, as shown previously (Figure 7).

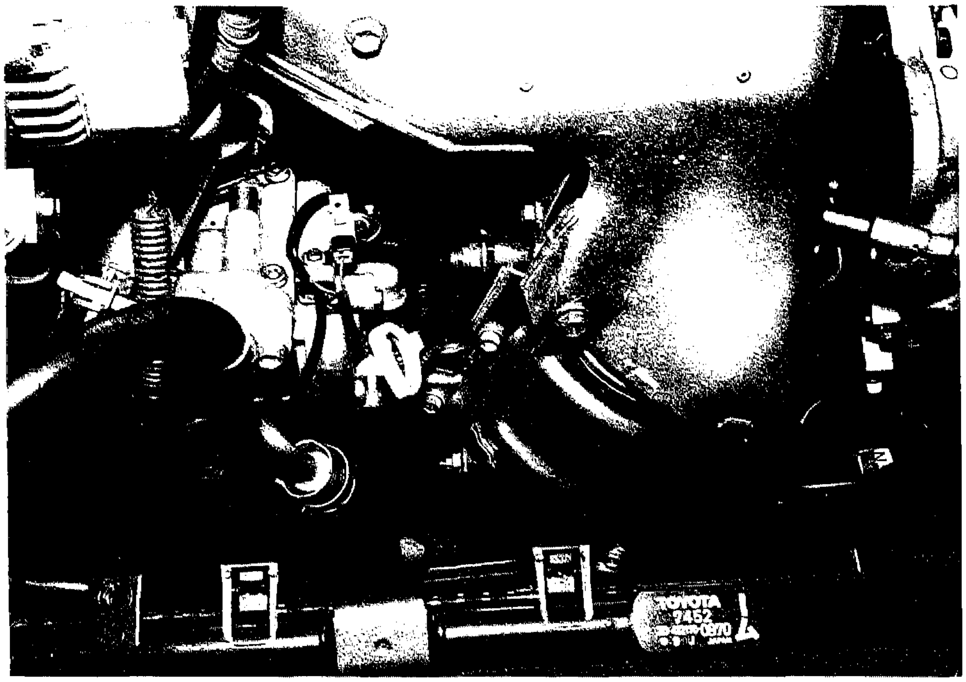
A total of 27 FTP emission tests were performed on the Toyota Celica while at SwRI. Studies were performed on air injection flowrate and duration, battery configurations, alternator recharge loads, and fuel economy penalties. Electrically-heated catalyst emissions were compared with baseline (stock) catalyst emission results. During the course of Celica emission testing, it was determined that cables carrying high pulse-width modulated heating currents can cause engine control interference if not routed properly. A summary of the emission results for each test configuration is given in Appendix L. Toyota Celica FTP emission results for each test are located in Appendix M.

A. Air Injection Flowrate Calibration

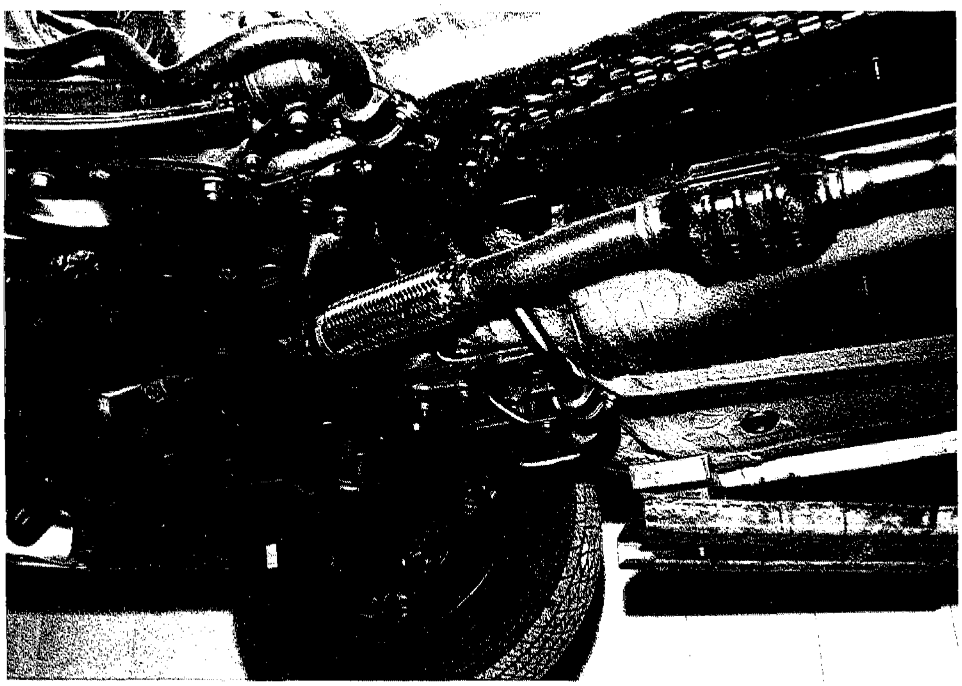
An air injection calibration verification was performed on the Toyota Celica with the electrically-heated catalyst installed. FTP cold-start and hot-start emissions were measured with air injection flowrates of 0, 85, 140, and 300 L/min (0, 3.0, 5.0, and 10.7 CFM). Cold-start air injection began at engine cranking and stopped 65 seconds into the FTP, while hot-start air injection lasted 20 seconds. Air was injected with the same laboratory pump (Figure 14) used to determine the optimal flowrate on the Buick. Celica FTP emissions at the various air injection flowrates are given in Table 33. Note that air injection significantly improved control of HC and CO, although NO_X emissions were higher when air was injected.

1. Cold-Start

Celica cold-start emissions for each of the air injection flowrates are given in Table 34. Air injection provided the lowest cold-start HC and CO emissions at a rate of 170 L/min (5.9 CFM) for the Celica, and this flow was used for other tests. This flowrate

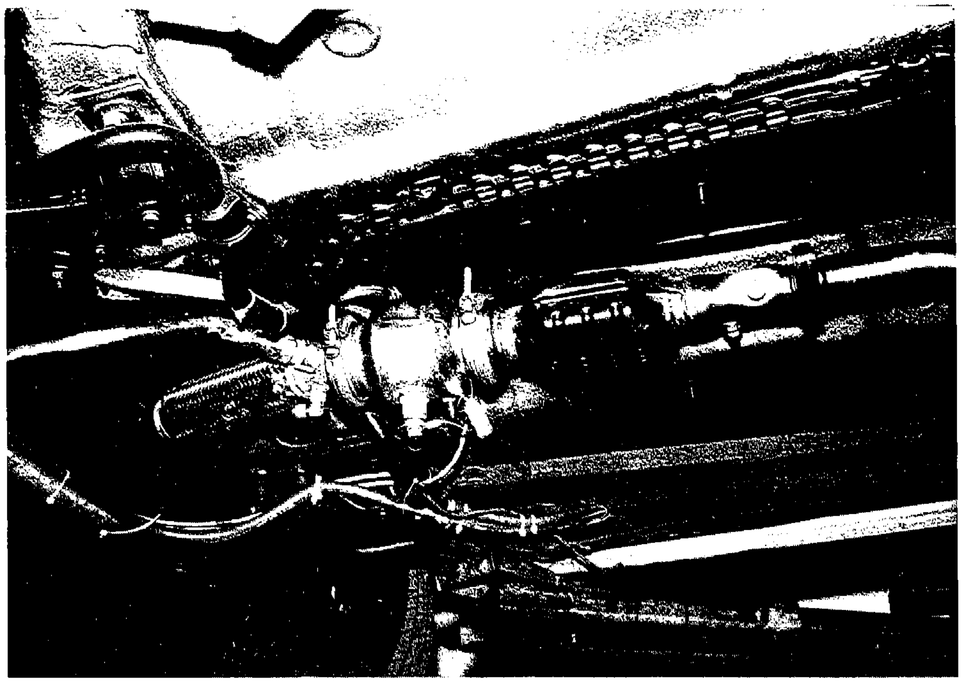


Catalyst Close-coupled to Exhaust Manifold

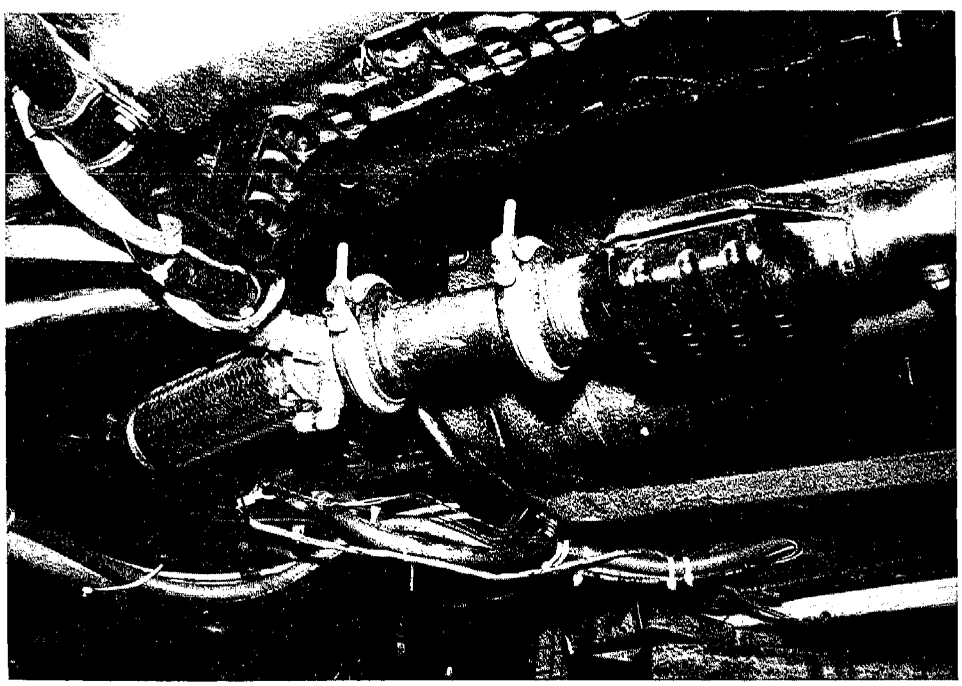


Underbody Catalyst

FIGURE 15. TOYOTA CELICA STOCK CATALYSTS



Electrically-Heated Catalyst



Blank "Spool"

FIGURE 16. TOYOTA CELICA EXHAUST SYSTEM CONVERSION

TABLE 33. TOYOTA CELICA FTP EMISSIONS WITH PREHEATED CATALYST AND AIR INJECTION

FTP Emissions	Air Injection Flowrate, L/min			
	No Air[a]	85	170	300
HC, g/mi	0.08	0.05	0.05	0.14
CO, g/mi	0.84	0.43	0.49	0.69
NO_x, g/mi	0.14	0.20	0.24	0.15

[a]Heat only.
Air Injection: Cold-start 65 sec.; hot-start 20 sec.

TABLE 34. TOYOTA CELICA COLD-START EMISSIONS WITH PREHEATED CATALYST AND AIR INJECTION

Bag 1A Emissions	Air Injection Flowrate, L/min			
	No Air[a]	85	170	300
HC, g/mi	1.21	0.74	0.56	2.88
CO, g/mi	9.12	5.12	3.71	15.64
NO_x, g/mi	2.08	2.66	3.44	2.20

[a]Heat only.
Air injection for 65 seconds.

TABLE 35. TOYOTA CELICA HOT-START EMISSIONS WITH PREHEATED CATALYST AND AIR INJECTION

Bag 3 Emissions	Air Injection Flowrate, L/min			
	No Air[a]	85	170	300
HC, g/mi	0.07	0.07	0.07	0.10
CO, g/mi	0.09	0.10	0.14	0.18
NO_x, g/mi	0.07	0.11	0.12	0.11

[a]Heat only.
Air injection for 20 seconds.

corresponds to that measured for the vehicle-mounted electric air pump. Future "official" Toyota Celica tests incorporated the vehicle air pump instead of the experimental laboratory air injection pump.

2. Hot-Start

Toyota Celica hot-start emissions at the various air flowrates are given in Table 35. This table shows that all air flow increases caused slightly higher emissions rather than lower ones. Hot-start hydrocarbon emissions were relatively constant from the "no air" configuration up through the highest flowrate of 300 L/min (10.7 CFM). The CO emissions, which have typically demonstrated more sensitively to the secondary air, show a continuously increasing trend. Hot-start NO_x emissions also suffered with the introduction of air. Toyota Celica air injection during the FTP hot-start was discontinued because it provided no emission benefit.

B. Air Injection Duration Study

The air injection duration for the Toyota Celica was also evaluated. It was expected that moderate air injection flowrates would improve control of HC and CO with increased duration. Conversely, NO_x emission control would be expected to suffer with longer periods of air injection. Automotive catalytic converters will not control NO_x emissions in the presence of excess oxygen, therefore NO_x control is favored by short air injection periods.[20] A review of the HC, CO, and NO_x emissions at the various air injection periods tested suggests that the expectations were loosely realized. There was some scatter in the emission data as the injection duration increased from zero to 140 seconds (in six steps). Emissions of HC and CO generally tended downward, and NO_x tended upward as air injection duration increased. It was difficult to experimentally ascertain the precise air injection cut-off point (duration) that provided the maximum emission benefit. The cold-start air injection period was originally determined, therefore, based on the open-loop air-fuel ratio period (65 seconds). Subsequent experiments demonstrated no emission control loss with shorter injection duration. Final air injection duration for the Toyota Celica at SwRI was 50 seconds for the cold-start and zero (no air injection) for the hot-start.

C. Battery Recharging Configuration Study

Toyota Celica battery recharging modes were examined to determine the effect of alternator recharge load on FTP emissions and fuel economy. An FTP emission test was run on the Toyota with an unloaded alternator (Configuration A). This alternator configuration is unrealistic, but was performed to establish a best case FTP emission and fuel economy test result. FTP emission test results are given in Table 36 along with results of other battery recharging strategies and battery configurations. Configuration B was a dual-battery system where only the vehicle battery is recharged in order to isolate the effect on emissions of normal recharging loads. The second battery, which is used to preheat the catalyst, is not recharged in this configuration. Configuration C is a single battery system in which the vehicle battery is used to preheat the catalyst as well as start the vehicle. In this configuration, the alternator charges the battery. The final two configurations (D and E) recharge the batteries over the entire FTP except for the periods noted (all of segment 1A and the heating period only).

Battery and alternator configurations were analyzed to determine their effect on FTP emissions and fuel economy. Nitrogen oxide emissions (Table 17) increased with alternator recharge load as seen from battery recharging configurations A, B, and C. In Configuration A, the alternator produces no power and the FTP NO_X emission rate is 0.08 grams/mile (g/mi). In Configuration B, the engine starting battery is charged, but not the electrically-heated catalyst battery; and the NO_X emission rate is 0.15 g/mi. Finally (Configuration C), the entire load of the engine starting and catalyst heating energy is replaced by the alternator, and the engine produces a NO_X emission rate of 0.23 g/mi. For each step, the fuel economy drops by slightly more than one mile per gallon. (Note that the emission tests incorporated a long post-start heating time, up to 60 seconds. This energy drain, which was later reduced, resulted in an unnecessarily lengthy battery recharging time). The HC and CO emissions tended to decrease when the alternator recharge load was removed from the system. This suggests that alternator recharge load has an effect on all emissions. These conclusions are preliminary and would have to be verified by a larger number of tests on several vehicles.

TABLE 36. TOYOTA CELICA BATTERY RECHARGING CONFIGURATIONS AND EMISSIONS

Configuration Identification	Battery Recharging Strategy	Battery Configuration	FTP Emissions, g/mi			Fuel Economy, mi/gal
			HC	CO	NO_X	
A	No recharging	Dual batteries in parallel	0.03	0.11	0.08	26.89
B	No recharging of EHC battery	Dual batteries separated	0.03	0.08	0.15	25.74
C	Recharging	Vehicle battery only	0.06	0.11	0.23	24.33
D	Recharging except for Segment 1A	Dual batteries in parallel	0.05	0.19	0.19	24.58
E	Recharging except for heating period	Vehicle battery only	0.05	0.16	0.23	24.62

EHC - electrically-heated catalyst

D. Electrically-Heated Catalyst Replacement

The electrically-heated catalyst was replaced with a larger unit, and further improvement in emissions was observed. Emissions from the Toyota Celica with the electrically-heated catalyst are then compared to the original stock configuration emissions.

1. Larger Heated Catalyst

Toyota Celica FTP emissions were improved by exchanging the electrically-heated catalyst for a larger unit. The larger heated catalyst had a volume of 460 cubic centimeters (28.0 cubic inches) as compared to the 240 cubic centimeter (14.5 cubic inches) of the previous unit. Precious metal loadings of both catalysts were the same, namely 40 grams per cubic foot; and both had platinum to rhodium ratios of 5 to 1 (Table 25). The new electrically-heated catalyst was operated using a dual battery configuration. A second battery was placed in parallel with the first so that both batteries supply power to the catalyst during preheating. Both batteries were recharged by the alternator during the emission test. The emission tests performed on the Toyota Celica in the dual (parallel) battery configuration with the larger electrically-heated catalyst had the lowest overall emissions of HC and CO. The larger catalyst controlled the increase in NO_x emissions associated with alternator loading. These tests were performed with the on-vehicle air pump supplying 170 L/min (5.9 CFM) of air ahead of the preheated catalyst. No electrical heating or air injection was used on the hot-start position of these final Celica emission tests.

2. Comparison to Stock Configuration

Baseline emissions from the Celica were already low, meeting the 1990 U.S. EPA and California emission standards easily. The electrically-heated catalyst conversion reduced these emissions even further with the air and heating calibrations developed in this program. These emissions are compared to the original baseline emissions in Table 37. Emissions of HC and CO were reduced about 50 percent. Emissions of NO_x were lowered about 40 percent with the final (larger) heated catalyst. The original heated catalyst was of insufficient volume to control the increased engine-out NO_x emissions associated with the battery recharging load. In the final configuration, the larger electrically-heated catalyst was able to control NO_x emissions to levels lower than the stock configuration (Table 18).

TABLE 37. TOYOTA CELICA EMISSIONS WITH LARGER ELECTRICALLY-HEATED CATALYST COMPARED TO STOCK

Catalyst Configuration	FTP Emissions, g/mi			Fuel Economy, mi/gal
	NMHC	CO	NO_x	
Stock	0.08	0.66	0.09	25.4
EHC w/Air	0.02	0.30	0.05	24.3
Air Injection: 170 L/min; 50 sec. for cold-start, no air during hot-start. Larger volume EHC, Camet Model 10-10 Extended post-start heating (~60 sec.) Conducted at SwRI.				

E. Difficulties Encountered

Difficulties were encountered while performing the electrically-heated catalyst conversion on the Toyota Celica. Some difficulties stem from the layout of the exhaust system and others from the conversion itself.

1. Close-Coupled Catalyst Configuration

In an absolute sense, the emission benefit for this vehicle was less than for the Buick LeSabre. As already mentioned, the Celica had good control of emissions in stock form due to an effective close-coupled catalyst. This close-coupled catalyst presented additional problems for the installation of an electrically-heated catalyst system. Since the electrically-heated catalyst was placed downstream of the close-coupled Toyota catalyst, the close-coupled catalyst (being the first catalyst in the exhaust stream), acted as a heat sink. This reduced the heat available to the electrically-heated catalyst, causing excessively long post-start heating times. The extended low temperature period of the electrically-heated catalyst caused the heating controller to supply power to the catalyst for up to 60 seconds following the cold-start. This excessively long heating period consumed electrical energy from the battery that subsequently had to be replaced by the alternator, increasing engine load. The increased alternator load has been shown to increase emissions (HC, CO, and NO_X) and decrease fuel economy. Based on the Buick LeSabre conversion and on previous studies[20], it would appear that the electrically-heated catalyst performs best when it is the first (upstream) catalyst in the exhaust system, although close-coupling of an electrically-heated catalyst may reduce its long-term durability. (Another approach would be to reduce the Toyota's electrically-heated catalyst energy consumption by limiting the post-start heating time to 20 seconds. This approach was investigated by ARB following this program.)

2. Electrical Interference

While investigating multiple battery configurations, the effect of high current cabling on engine calibration was discovered. Electrically-heated catalyst cables were inadvertently placed near engine sensors or electronics during preliminary emissions tests. These cables carried approximately 600 to 700 amperes of current to the electrically-heated catalyst. A magnetic field, caused by the pulse width modulation of the current, apparently caused the engine to run rich, increasing HC and CO emissions. This problem was discovered and corrected by rerouting the catalyst cables along a path previously determined successful. Another possible approach could have been to use shielded cables for catalyst power. Celica FTP emission tests that exhibited this electrical interference are so labeled in Appendix O.

X. BUICK LESABRE AND TOYOTA CELICA EXHAUST HYDROCARBON SPECIATION

Hydrocarbon speciation of exhaust emissions from selected Buick LeSabre and Toyota Celica FTP emission tests, in both stock (original) and electrically-heated catalyst configurations, was performed for the ARB. This speciation work was based on ARB Contract No. A996-204, "Measurement of Emissions from Advanced Technology Vehicles," and identified within SwRI as Project 08-3734. The speciation measurements for the LeSabre and Celica are given in this report for completeness, and include C_1 to C_{10} hydrocarbons, aldehydes, and ketones for several Buick and Toyota tests. Emission tests were performed using two different test fuels.

A. Test Fuels

Two test fuels were used in this study, Howell EEE emissions test fuel and Phillips RF-A "national average" gasoline. Phillips RF-A is currently being used by the Coordinating Research Council (CRC) in the Auto/Oil program. The Auto/Oil program is a cooperative research study to determine the effect of fuel composition on exhaust and evaporative emissions. It is being conducted by the automobile manufacturers and the oil companies. A wide variety of vehicle models, vehicle model years, and fuel formulations are being studied. The Howell EEE emissions test fuel was identified by fuel codes EM-1035-F and EM-995-F. The Phillips RF-A "national average" gasoline was identified by fuel code EM-1026-F. Analyses of the Howell EEE test fuels and the Phillips RF-A national average fuel are provided in Appendix A.

B. Speciation Measurements

The Buick LeSabre and Toyota Celica catalyst configurations and FTP emissions are given in Table 38. FTP hydrocarbon speciation measurements for the Buick LeSabre are given in Appendix N. Buick LeSabre cold-start (Bag 1) hydrocarbon speciation measurements are divided further into segments 1A (0-140 seconds) and 1B (140-505 seconds), and are located in Appendix O. FTP hydrocarbon speciation measurements for the Toyota are given in Appendix P. Toyota Celica cold-start (Bag 1) hydrocarbon speciation measurements are further divided into Bags 1A and 1B and are located in Appendix Q. Note that the Celica emission speciation tests numbered CS-VAH-12-2 and CS-VAH-15 were those tests that experienced electrical interference during the heating sequence. These speciation test results, along with the results of CS-VAH-12 (which was performed with the smaller volume heated catalyst), are included in the appropriate appendices.

Speciation procedures identified and quantified over 106 individual hydrocarbons and aldehydes and ketones in the exhaust from selected FTP tests conducted in this study.[24] Electrically-heated catalyst emissions for selected hydrocarbons were examined and compared to the stock catalyst emissions. The hydrocarbons examined in some detail included methane, 1,3-butadiene, benzene, toluene, formaldehyde, p-xylene/m-xylene, and o-xylene. These compounds are of interest due to their reactivity and/or toxicity.

FTP benzene emissions were generally lowered by 40 to 75 percent with the preheated catalyst, except for one Celica emissions test using Howell EEE gasoline where emissions

TABLE 38. BUICK LESABRE AND TOYOTA CELICA CATALYST CONFIGURATIONS AND FTP EMISSIONS

Test Date	Test No.	Odometer Miles	Test Description	Airflow Rate, cfm	Air Injection Duration, sec. Bag 1A	Air Injection Duration, sec. Bag 3	Fuel	FTP Emissions, g/mile CO_2	FTP Emissions, g/mile HC	FTP Emissions, g/mile CO	FTP Emissions, g/mile NO_x	Fuel Eco. mi/gal
1990 BUICK LESABRE												
7-10-90	LS-AH-11	404	Heat & Air	10.7	75	30	EEE	446.4	0.06	0.41	0.23	19.86
7-11-90	LS-AH-12	417	Heat & Air	10.7	75	30	EEE	453.5	0.05	0.41	0.21	19.55
7-12-90	LS-OE-13	437	Stock Catalyst	--	--	--	EEE	438.4	0.15	1.10	0.15	20.15
7-13-90	LS-OE-14	475	Stock Catalyst	--	--	--	RF-A	429.2	0.15	0.85	0.18	20.59
7-14-90	LS-AH-15	488	Heat & Air	10.7	75	30	RF-A	447.6	0.06	0.45	0.20	19.78
7-18-90	LS-AH-16	523	Heat & Air	10.7	75	30	RF-A	445.0	0.07	0.45	0.20	19.92
1990 TOYOTA CELICA												
9-13-90	CS-VAH-26	681	Heat & Air	V5.9	50	None	EEE	366.7	0.03	0.30	0.05	24.27
7-12-90	CS-OE-13	326	Stock Catalyst	--	--	--	EEE	349.0	0.09	0.66	0.09	25.40
7-15-90	CS-OE-14	396	Stock Catalyst	--	--	--	RF-A	338.1	0.07	0.48	0.10	26.21
9-14-90	CS-VAH-27	716	Heat & Air	V5.9	50	None	RF-A	357.7	0.04	0.24	0.06	24.89

OE -Original Equipment
A -Air
H -Heat
V -Vehicle Air
EEE -Howell EEE
RF-A -National Average

were increased. Toluene and formaldehyde emissions were lowered by 30 to 100 percent using the preheated catalyst system on both the LeSabre and Celica. Cold transient (bag 1) emission rates (grams/mile) of toluene and formaldehyde were actually lower than cold stabilized (Bag 2) rates on the Buick LeSabre equipped with the electrically-heated catalyst (Appendices N and P).

The xylenes, which have a high reactivity related to ozone formation, were reduced by 50 to 90 percent with the electrically-heated catalyst. Emissions of 1,3-butadiene were below the measurement detection limits when the heated catalyst and air injection were employed. The effect of fuel formation on electrically-heated catalyst emission results could not be evaluated in any detail due to the limited number of tests conducted in this study. When available, results from the CRC Auto/Oil cooperative research study on the effects of fuel properties on emissions may provide information that can be extended to the heated catalyst application.

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APPENDIX A

FUEL ANALYSES

- Howell EEE Emissions Test Fuel, Code EM-780-F
- Howell EEE Emissions Test Fuel, Code EM-1035-F
- Howell EEE Emissions Test Fuel, Code EM-995-F
- Phillips 66 RF-A Fuel, Code EM-1026-F

DEPT. OF EMISSIONS RESEARCH

GASOLINE EMISSIONS FUEL SPECIFICATIONS
QUALITY ASSURANCE

LEADED ________ UNLEADED X SUPPLIER HOWELL HYDROCARBONS

LOT NO. B-87-155 SwRI CODE EM-780-F X CERTIFICATION
____ SERVICE ACCUMULATION

Item	CFR Specification ASTM	Leaded	Unleaded	Supplier Analyses	SwRI Analyses
Octane, research, min.	D2699	98	93	96.7	96.4
Sensitivity (min.)		7.5	7.5	8.9	7.7
Pb(organic), gm/U.S., gal		1.4[a]	0.00-0.05	0.001	<0.001
Distillation range:					
IBP °F	D86	75-95	75-95	90	87
10% Point, °F	D86	120-135	120-135	128	124
50% Point, °F	D86	200-230	200-230	214	215
90% Point, °F	D86	300-325	300-325	317	320
EP, °F (max.)	D86	415	415	375	388
Sulfur, wt. % (max.)	D1266	0.10	0.10	0.004	0.016
Phosphorus, gm/U.S., gal (max.)		0.01	0.005	0.0005	0.0014
RVP, psi	D323	8.7-9.2	8.7-9.2	9.0	9.2
Hydrocarbon Composition:					
Olefins, %, (max.)	D1319	10	10	1.7	1.0
Aromatics, % (max.)	D1319	35	35	33.2	31.1
Saturates	D1319	b	b	65.1	67.9

[a]Minimum
[b]Remainder

Supplier Analyses
Date Nov. , 1987

SwRI Analyses
by Kathy Olsen

Date 11-20-87

SOUTHWEST RESEARCH INSTITUTE

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TABLE 1. GASOLINE EMISSIONS FUEL SPECIFICATIONS QUALITY ASSURANCE

UNLEADED __X__ LOW-LEADED ______ SUPPLIER HOWELL HYDROCARBONS

LOT NO. 89S-24 SwRI CODE EM-995-F __X__ Certification
_____ Service Accumulation

Item	CFR Specification[a]		Supplier Analysis	SwRI Analyses
	ASTM	Unleaded		
Octane, research, min.	D2699	93	96.4	95.8
Sensitivity (min.)		7.5	8.4	
Pb (organic), gm/U.S., gal		0.05[b]	0.002	<0.001
Distillation Range:				
IBP°F	D86	75-95	90	88
10% Point, °F	D86	120-135	128	123
50% Point, °F	D86	200-230	222	221
90% Point, °F	D86	300-325	318	319
EP, °F (max.)	D86	415	379	372
Sulfur, wt. % (max.)	D1266	0.10	0.004	0.013
Phosphorus, gm/U.S.,gal (max.)	D3231	0.005	0.0	0.0002
RVP, psi	D323	8.0-9.2[d]	9.1	9.1
Hydrocarbon Composition:				
Olefins, %, (max.)	D1319	10	1.0	1.2
Aromatics, % (max.)	D1319	35	31.7	28.9
Saturates, %	D1319	c	67.3	69.2

[a]Gasoline fuel specification as in CFR 86.113-90(a)(1) for light-duty gasoline vehicles and CFR 86.1313-90(a)(1) for heavy-duty gasoline engines.
[b]Maximum
[c]Remainder
[d]For testing unrelated to evaporative emissions control.

Supplier Analyses
Date: 10/26/89

SwRI Analyses
by: Karen Kohl
Date: 1/23/90

SAN ANTONIO, TEXAS
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S O U T H W E S T   R E S E A R C H   I N S T I T U T E

6220 CULEBRA ROAD • POST OFFICE DRAWER 28510 • SAN ANTONIO, TEXAS, USA 78228-0510 • (512) 684-5111 • TELEX 244846

TABLE. GASOLINE EMISSIONS FUEL SPECIFICATIONS QUALITY ASSURANCE

UNLEADED _X_ LOW-LEADED ___ SUPPLIER _HOWELL HYDROCARBONS_

LOT NO. _90S-8_ SwRI CODE _EM-1035-F_ _X_ Certification

___ Service Accumulation

Item	CFR Specification[a]			Supplier Analysis	SwRI Analyses
	ASTM	Leaded	Unleaded		
Octane, research, min.	D2699	98	93	96.4	96.6
Sensitivity (min.)		7.5	7.5	8.4	8.5
Pb (organic), gm/U.S., gal		0.10[b]	0.05[b]	0.001	<0.001
Distillation Range:					
IBP°F	D86	75-95	75-95	92	90
10% Point, °F	D86	120-135	120-135	131	131
50% Point, °F	D86	200-230	200-230	219	220
90% Point, °F	D86	300-325	300-325	312	306
EP, °F (max.)	D86	415	415	406	395
Sulfur, wt. % (max.)	D1266	0.10	0.10	0.004	0.025
Phosphorus, gm/U.S.,gal (max.)	D3231	0.01	0.005	0	0.0001
RVP, psi	D323	8.0-9.2	8.0-9.2	9.2	9.1
Hydrocarbon Composition:					
Olefins, %, (max.)	D1319	10	10	3.0	5.7
Aromatics, % (max.)	D1319	35	35	30.0	31.4
Saturates	D1319	c	c	67.0	62.9

[a]Gasoline fuel specification as in CFR 86.113-87(b)(2) for light-duty gasoline vehicles and CFR 86.113-87(b)(2) for heavy-duty gasoline engines.
[b]Maximum
[c]Remainder

Supplier Analyses
Date: 4/25/90

SwRI Analyses
by: Karen Kohl
Date: 5/9/90

Laboratory Report

PHILLIPS 66 COMPANY
A SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT

CUSTOMER ORDER NO.

INV./REQN. NO.

CODE EM-1026-F

REFORMULATED FUEL RF-A

LOT K-579

TESTS	RESULTS	SPECIFICATIONS
API Gravity	57.4	Report
Sulfur, ppm	339	300 ± 50
Color	Purple	Report
Benzene, Vol. %	1.53	1.6 ± 0.3
Reid Vapor Pressure	8.7	8.7 ± 0.3
Driveability	1195	1250 Max.
Antiknock Index	87.3	87.3 Min.
Distillation, D-86 °F		
IBP	91	
10%	128	
50%	218	240 Max.
90%	330	323 - 333
EP	415	
Hydrocarbon Type, Vol.% FIA		
Aromatics	32.0	32 ± 3.0
Olefins	9.2	12 ± 3.0
Saturates	58.8	Report

BGL:LK:gao
10-05-90

FORM 684

APPENDIX B

ARB LETTER REQUESTING A CHANGE OF CONTROL TECHNOLOGY

STATE OF CALIFORNIA—RESOURCES AGENCY GEORGE DEUKMEJIAN, *Governor*

AIR RESOURCES BOARD
HAAGEN-SMIT LABORATORY
528 TELSTAR AVENUE
EL MONTE 91731
PHONE: (213) 575-6800

Reference No. Z-88-02

MAR 23 1988

Mr. Lawrence R. Smith
Department of Emissions Research
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78284

Dear Mr. Smith:

This is a follow-up to your February 22, 1988, and March 8, 1988, telephone conversations with Mr. Jack Kitowski, of my staff regarding our contract for the control of benzene from light-duty motor vehicles.

You had indicated the two prototype demonstration vehicles would be equipped with an air pump and dual-bed catalyst. The staff recognizes that an air pump and dual-bed catalyst may provide a greater HC and benzene control than a single-bed catalyst. However, we are concerned about the compatibility of this technology with California's 0.4 g/mile NOx certification standard. The injection of air significantly inhibits the reduction of NOx emissions and can actually generate NOx emissions by the oxidation of ammonia. In order to meet our low NOx standard, the vast majority of new-vehicle manufacturers no longer use air pumps or dual-bed catalysts. Therefore, your use of test vehicles with air pump and dual-bed catalyst technology would provide only minimal benefit to us. We strongly urge you to reconsider your choice of control technology.

You also indicated that your cold storage device (CSD) may not be effectively used without an air pump to purge the stored hydrocabons/ benzene. Several alternative systems may be available which would inject/ induct the purged hydrocarbons into the intake system, including systems analogous to the evaporative canister and to the PCV system. Please submit a progress report which considers these options in your choice of control systems.

If you have any questions, please contact Mr. Jack Kitowski, Air Resources Engineer, at (818) 575-6675.

Sincerely,

K. D. Drachand, Chief
Mobile Source Division

cc: Manjit Ahuja

APPENDIX C

COLD-START DEVICE EXPERIMENT
REGULATED EMISSION AND FUEL ECONOMY RESULTS

TABLE C-1. EMISSIONS TEST RESULTS WITHOUT COLD-START HYDROCARBON COLLECTION

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - OEM CAT, CSD EXH SYS
PROJECT 08-1815-001

TEST NO. 3 RUN 1
VEHICLE MODEL 86 HONDA ACCORD
ENGINE 1.9 L(119. CID) -4
TRANSMISSION M5

VEHICLE NO.535
DATE 5/24/88
BAG CART NO. 1 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1304. KG(2875. LBS)
ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
GASOLINE EM-788-F
ODOMETER 37578. KM(23350. MILES)

BAROMETER 741.93 MM HG(29.21 IN HG)
RELATIVE HUMIDITY 62. PCT

DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)
ABS. HUMIDITY 11.4 GM/KG

NOX HUMIDITY CORRECTION FACTOR 1.02

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT		COLD TRANSIENT	STABILIZED		HOT TRANSIENT
	0-140 SEC		140-505 SEC			
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		43.3 (110.0)	43.3 (110.0)		43.3 (110.0)
BLOWER REVOLUTIONS	11337.		29183.	69591.		40231.
TOT FLOW STD. CU. METRES(SCF)	21.1 (745.)		54.3 (1918.)	129.5 (4572.)		74.9 (2643.)
THC SAMPLE METER/RANGE/PPM	15.1/ 3/ 148.		29.5/ 2/ 30.	11.9/ 2/ 12.		13.5/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		7.2/ 2/ 7.	7.3/ 2/ 7.		6.9/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	34.3/ 3/ 808.		81.1/ 13/ 80.	56.2/ 13/ 53.		42.2/ 13/ 39.
CO BCKGRD METER/RANGE/PPM	.1/ 3/ 2.		1.0/ 13/ 1.	1.1/ 13/ 1.		.9/ 13/ 1.
CO2 SAMPLE METER/RANGE/PCT	86.1/ 11/ .8291		96.4/ 11/ .9950	73.6/ 11/ .6543		87.1/ 11/ .8442
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0483		7.4/ 11/ .0440	7.4/ 11/ .0440		7.8/ 11/ .0465
NOX SAMPLE METER/RANGE/PPM	93.7/ 1/ 23.4		81.3/ 1/ 20.4	6.9/ 1/ 1.8		46.1/ 1/ 11.6
NOX BCKGRD METER/RANGE/PPM	.9/ 1/ .2		.7/ 1/ .2	.0/ 1/ .0		.5/ 1/ .1
DILUTION FACTOR	14.54		13.32	20.28		15.78
THC CONCENTRATION PPM	141.		23.	5.		7.
CO CONCENTRATION PPM	777.		76.	51.		37.
CO2 CONCENTRATION PCT	.7841		.9544	.6125		.8007
NOX CONCENTRATION PPM	23.2		20.2	1.8		11.5
THC MASS GRAMS	1.72		.72	.37		.30
CO MASS GRAMS	19.09		4.82	7.62		3.22
CO2 MASS GRAMS	302.8		948.9	1452.1		1097.3
NOX MASS GRAMS	.96		2.15	.45		1.68
THC GRAMS/MI	2.52		.25	.09		.08
CO GRAMS/MI	27.95		1.66	1.95		.89
CO2 GRAMS/MI	443.4		327.2	371.8		303.7
NOX GRAMS/MI	1.40		.74	.12		.46
FUEL ECONOMY IN MPG	17.90	24.50	26.82	23.64	25.96	29.04
RUN TIME SECONDS	141.		364.	869.		503.
MEASURED DISTANCE MI	.68	3.58	2.90	3.91	7.52	3.61
SCF, DRY	.972	.971	.971	.974	.973	.972
DFC, WET (DRY)		.927(.908)			.946(.927)	
TOT VOL (SCM) / SAM BLR (SCM)		75.4/ .00			204.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		3
BAROMETER	MM HG	741.9
HUMIDITY	G/KG	11.4
TEMPERATURE	DEG C	23.3

		3-BAG
CARBON DIOXIDE	G/MI	348.5
FUEL ECONOMY	MPG	25.13
HYDROCARBONS (THC)	G/MI	.21
CARBON MONOXIDE	G/MI	2.63
OXIDES OF NITROGEN	G/MI	.37

TABLE C-2. EMISSIONS TEST RESULTS WITH CSD HYDROCARBON COLLECTION FOR 140 SECONDS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - HC COLLECTION - 140 SEC
PROJECT 08-1815-001

TEST NO. 1 RUN 1	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 5/20/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37552. KM(23334. MILES)
	CVS NO. 2	

BAROMETER 738.38 MM HG(29.07 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 46. PCT	ABS. HUMIDITY 9.8 GM/KG	NOX HUMIDITY CORRECTION FACTOR .97

BAG RESULTS

BAG NUMBER / DESCRIPTION	1A COLD TRANSIENT 0-140 sec	1B COLD TRANSIENT 140-505 sec
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)	762.0 (30.0)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)	762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)	42.8 (109.0)
BLOWER REVOLUTIONS	11266.	29410.
TOT FLOW STD. CU. METRES(SCF)	20.9 (736.)	54.5 (1924.)
THC SAMPLE METER/RANGE/PPM	98.9/ 2/ 99.	24.4/ 2/ 25.
THC BCKGRD METER/RANGE/PPM	6.7/ 2/ 7.	6.4/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	76.7/ 1/ 739.	53.2/ 13/ 125.
CO BCKGRD METER/RANGE/PPM	.4/ 1/ 3.	.9/ 13/ 2.
CO2 SAMPLE METER/RANGE/PCT	87.6/ 14/ .8124	95.1/ 14/1.0004
CO2 BCKGRD METER/RANGE/PCT	13.0/ 14/ .0456	13.0/ 14/ .0456
NOX SAMPLE METER/RANGE/PPM	78.8/ 1/ 19.7	51.2/ 1/ 12.8
NOX BCKGRD METER/RANGE/PPM	1.0/ 1/ .3	.5/ 1/ .1
DILUTION FACTOR	14.99	13.20
THC CONCENTRATION PPM	93.	19.
CO CONCENTRATION PPM	714.	119.
CO2 CONCENTRATION PCT	.7698	.9582
NOX CONCENTRATION PPM	19.5	12.7
THC MASS GRAMS	1.11	.59
CO MASS GRAMS	17.33	7.53
CO2 MASS GRAMS	293.9	956.1
NOX MASS GRAMS	.75	1.29
THC GRAMS/MI	1.64	.20
CO GRAMS/MI	25.55	2.58
CO2 GRAMS/MI	433.4	327.3
NOX GRAMS/MI	1.11	.44
FUEL ECONOMY IN MPG	18.52	26.71
RUN TIME SECONDS	140.	366.
MEASURED DISTANCE MI	.68	2.92
SCF, DRY	.977	.976

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	738.4
HUMIDITY	G/KG	9.8
TEMPERATURE	DEG C	25.6

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI		
FUEL ECONOMY	MPG		
HYDROCARBONS (THC)	G/MI		
CARBON MONOXIDE	G/MI		
OXIDES OF NITROGEN	G/MI		

TABLE C-3. EMISSIONS TEST RESULTS WITH CSD COLLECTION FOR 70 SECONDS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - HC COLLECTION - 70 SEC
PROJECT 08-1815-001

TEST NO. 2 RUN 1	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 5/23/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37565. KM(23342. MILES)
	CVS NO. 2	

BAROMETER 741.93 MM HG(29.21 IN HG)	DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)	
RELATIVE HUMIDITY 52. PCT	ABS. HUMIDITY 10.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR .98

BAG RESULTS

BAG NUMBER DESCRIPTION	1A COLD TRANSIENT 0-140 sec	1B COLD TRANSIENT 140-505 sec
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)	774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)	774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)	42.8 (109.0)
BLOWER REVOLUTIONS	11314.	29189.
TOT FLOW STD. CU. METRES(SCF)	21.1 (744.)	54.3 (1917.)
THC SAMPLE METER/RANGE/PPM	98.8/ 2/ 99.	20.7/ 2/ 21.
THC BCKGRD METER/RANGE/PPM	7.6/ 2/ 8.	7.2/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	83.3/ 1/ 829.	52.0/ 12/ 52.
CO BCKGRD METER/RANGE/PPM	1.0/ 1/ 7.	5.1/ 12/ 5.
CO2 SAMPLE METER/RANGE/PCT	88.4/ 14/ .8303	93.1/ 14/ .9455
CO2 BCKGRD METER/RANGE/PCT	13.7/ 14/ .0485	14.0/ 14/ .0497
NOX SAMPLE METER/RANGE/PPM	91.4/ 1/ 22.8	59.0/ 1/ 14.8
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1	.5/ 1/ .1
DILUTION FACTOR	14.56	14.07
THC CONCENTRATION PPM	92.	14.
CO CONCENTRATION PPM	795.	46.
CO2 CONCENTRATION PCT	.7852	.8993
NOX CONCENTRATION PPM	22.7	14.7
THC MASS GRAMS	1.11	.44
CO MASS GRAMS	19.49	2.88
CO2 MASS GRAMS	302.7	893.7
NOX MASS GRAMS	.90	1.50
THC GRAMS/MI	1.63	.15
CO GRAMS/MI	28.56	.99
CO2 GRAMS/MI	443.5	307.2
NOX GRAMS/MI	1.32	.51
FUEL ECONOMY IN MPG	17.97	28.68
RUN TIME SECONDS	141.	363.
MEASURED DISTANCE MI	.68	2.91
SCF, DRY	.976	.974

MPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	741.9
HUMIDITY	G/KG	10.2
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI		
FUEL ECONOMY	MPG		
HYDROCARBONS (THC)	G/MI		
CARBON MONOXIDE	G/MI		
OXIDES OF NITROGEN	G/MI		

APPENDIX D

BASELINE REGULATED EMISSION AND FUEL ECONOMY RESULTS FOR THE DEMONSTRATION VEHICLE USED FOR COLD-START HYDROCARBON COLLECTION

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - OEM CATALYST

TEST NO. 1 RUN 1	VEHICLE NO. 535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/12/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 35999. KM(22369. MILES)
	CVS NO. 2	

BAROMETER 740.66 MM HG(29.16 IN HG)	DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)	
RELATIVE HUMIDITY 67. PCT	ABS. HUMIDITY 13.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.09

BAG RESULTS

BAG NUMBER	1	2	3
DESCRIPTION	COLD TRANSIENT	STABILIZED	HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	767.1 (30.2)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	767.1 (30.2)
BLOWER INLET TEMP. DEG. C(DEG. F)	40.6 (105.0)	40.0 (104.0)	40.6 (105.0)
BLOWER REVOLUTIONS	40555.	69580.	40551.
TOT FLOW STD. CU. METRES(SCF)	75.6 (2668.)	129.8 (4583.)	75.6 (2671.)
THC SAMPLE METER/RANGE/PPM	79.3/ 2/ 80.	15.1/ 2/ 15.	14.0/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	7.8/ 2/ 8.	8.1/ 2/ 8.	7.0/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	43.5/ 1/ 359.	9.6/ 1/ 69.	6.2/ 1/ 44.
CO BCKGRD METER/RANGE/PPM	.4/ 1/ 3.	.3/ 1/ 2.	.1/ 1/ 1.
CO2 SAMPLE METER/RANGE/PCT	92.6/ 14/ .9323	80.5/ 14/ .6680	88.9/ 14/ .8411
CO2 BCKGRD METER/RANGE/PCT	12.4/ 14/ .0415	12.3/ 14/ .0411	12.3/ 14/ .0411
NOX SAMPLE METER/RANGE/PPM	56.6/ 1/ 14.2	5.5/ 1/ 1.4	25.7/ 1/ 6.5
NOX BCKGRD METER/RANGE/PPM	.7/ 1/ .2	.7/ 1/ .2	.6/ 1/ .2
DILUTION FACTOR	13.75	19.82	15.83
THC CONCENTRATION PPM	72.	8.	8.
CO CONCENTRATION PPM	342.	64.	41.
CO2 CONCENTRATION PCT	.8939	.6290	.8026
NOX CONCENTRATION PPM	14.0	1.3	6.4
THC MASS GRAMS	3.15	.56	.33
CO MASS GRAMS	30.08	9.71	3.65
CO2 MASS GRAMS	1236.7	1494.6	1111.5
NOX MASS GRAMS	2.20	.34	1.00
THC GRAMS/MI	.88	.15	.09
CO GRAMS/MI	8.45	2.53	1.02
CO2 GRAMS/MI	347.3	389.6	311.4
NOX GRAMS/MI	.62	.09	.28
FUEL ECONOMY IN MPG	24.40	22.51	28.31
RUN TIME SECONDS	505.	868.	506.
MEASURED DISTANCE MI	3.56	3.84	3.57
SCF, DRY	.970	.972	.971

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	740.7
HUMIDITY	G/KG	13.2
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	359.3	(.0)
FUEL ECONOMY	MPG	24.26	(.00)
HYDROCARBONS (THC)	G/MI	.28	(.00)
CARBON MONOXIDE	G/MI	3.34	(.00)
OXIDES OF NITROGEN	G/MI	.25	(.00)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - OEM CATALST

TEST NO. 2 RUN 1	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/18/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 1 / CVS NO. 2	GASOLINE ~~EM-780-F~~
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37721. KM(23439. MILES)

BAROMETER 743.71 MM HG(29.28 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 62. PCT	ABS. HUMIDITY 11.8 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.04

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		784.9 (30.9)	787.4 (31.0)		784.9 (30.9)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		784.9 (30.9)	787.4 (31.0)		784.9 (30.9)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		41.7 (107.0)	40.0 (104.0)		41.1 (106.0)
BLOWER REVOLUTIONS	11219.		29371.	69611.		40539.
TOT FLOW STD. CU. METRES(SCF)	21.0 (740.)		54.8 (1935.)	130.2 (4598.)		75.7 (2673.)
THC SAMPLE METER/RANGE/PPM	16.7/ 3/ 164.		31.6/ 2/ 32.	11.4/ 2/ 11.		13.2/ 2/ 13.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		8.2/ 2/ 8.	7.4/ 2/ 7.		7.1/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	34.2/ 3/ 806.		51.7/ 12/ 108.	26.0/ 12/ 50.		21.7/ 12/ 41.
CO BCKGRD METER/RANGE/PPM	.0/ 3/ 0.		4.8/ 12/ 9.	4.3/ 12/ 8.		2.8/ 12/ 5.
CO2 SAMPLE METER/RANGE/PCT	85.6/ 11/ .8216		94.3/ 11/ .9593	73.8/ 11/ .6569		86.2/ 11/ .8306
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0458		7.7/ 11/ .0458	7.7/ 11/ .0458		7.7/ 11/ .0458
NOX SAMPLE METER/RANGE/PPM	86.5/ 1/ 21.7		57.2/ 1/ 14.4	4.5/ 1/ 1.2		26.7/ 1/ 6.8
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.7/ 1/ .2	.0/ 1/ .0		.3/ 1/ .1
DILUTION FACTOR	14.63		13.77	20.22		16.03
THC CONCENTRATION PPM	157.		24.	4.		7.
CO CONCENTRATION PPM	777.		96.	41.		35.
CO2 CONCENTRATION PCT	.7789		.9168	.6133		.7876
NOX CONCENTRATION PPM	21.6		14.2	1.2		6.7
THC MASS GRAMS	1.90		.76	.33		.29
CO MASS GRAMS	18.96		6.12	6.20		3.08
CO2 MASS GRAMS	298.9		919.7	1462.1		1091.5
NOX MASS GRAMS	.90		1.54	.30		1.01
THC GRAMS/MI	2.81		.26	.09		.08
CO GRAMS/MI	28.02		2.11	1.61		.87
CO2 GRAMS/MI	441.8		316.7	380.6		307.2
NOX GRAMS/MI	1.33		.53	.08		.28
FUEL ECONOMY IN MPG	17.93	25.07	27.64	23.13	25.52	28.72
RUN TIME SECONDS	140.		366.	867.		505.
MEASURED DISTANCE MI	.68	3.58	2.90	3.84	7.40	3.55
SCF, DRY	.972	.971	.971	.974	.973	.972
DFC, WET (DRY)		.929(.910)			.946(.927)	
TOT VOL (SCM) / SAM BLR (SCM)		75.7/ .00			205.9/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	743.7
HUMIDITY	G/KG	11.8
TEMPERATURE	DEG C	23.9

		3-BAG
CARBON DIOXIDE	G/MI	352.1
FUEL ECONOMY	MPG	24.88
HYDROCARBONS (THC)	G/MI	.22
CARBON MONOXIDE	G/MI	2.53
OXIDES OF NITROGEN	G/MI	.26

APPENDIX E

REGULATED EMISSION AND FUEL ECONOMY RESULTS FOR EXPERIMENTAL LOW BENZENE CATALYST EXPERIMENTS

FTP - VEHICLE EMISSIONS RESULTS - CATALYST PZM-3292

TEST NO. 1 RUN 1	VEHICLE NO. 535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/13/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 1	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37639. KM(23388. MILES)
	CVS NO. 2	

BAROMETER 741.68 MM HG(29.20 IN HG)	DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)	
RELATIVE HUMIDITY 62. PCT	ABS. HUMIDITY 11.4 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.02

BAG RESULTS

BAG NUMBER	1	2	3
DESCRIPTION	COLD TRANSIENT	STABILIZED	HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	767.1 (30.2)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	767.1 (30.2)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)	40.0 (104.0)	40.6 (105.0)
BLOWER REVOLUTIONS	40707.	69622.	40516.
TOT FLOW STD. CU. METRES(SCF)	75.9 (2680.)	130.1 (4593.)	75.7 (2673.)
THC SAMPLE METER/RANGE/PPM	80.6/ 2/ 81.	32.6/ 2/ 33.	32.6/ 2/ 33.
THC BCKGRD METER/RANGE/PPM	7.3/ 2/ 7.	7.0/ 2/ 7.	6.9/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	65.9/ 11/ 262.	57.9/ 13/ 55.	47.3/ 13/ 44.
CO BCKGRD METER/RANGE/PPM	.4/ 11/ 1.	.1/ 13/ 0.	.5/ 13/ 0.
CO2 SAMPLE METER/RANGE/PCT	90.4/ 11/ .8956	73.3/ 11/ .6504	85.1/ 11/ .8141
CO2 BCKGRD METER/RANGE/PCT	7.8/ 11/ .0465	7.2/ 11/ .0427	6.6/ 11/ .0390
NOX SAMPLE METER/RANGE/PPM	79.4/ 1/ 19.9	8.4/ 1/ 2.2	56.7/ 1/ 14.2
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1	.8/ 1/ .2	.5/ 1/ .1
DILUTION FACTOR	14.42	20.33	16.31
THC CONCENTRATION PPM	74.	26.	26.
CO CONCENTRATION PPM	252.	53.	42.
CO2 CONCENTRATION PCT	.8524	.6098	.7775
NOX CONCENTRATION PPM	19.8	2.0	14.1
THC MASS GRAMS	3.23	1.95	1.14
CO MASS GRAMS	22.23	8.04	3.71
CO2 MASS GRAMS	1184.4	1452.2	1077.4
NOX MASS GRAMS	2.94	.50	2.09
THC GRAMS/MI	.90	.50	.32
CO GRAMS/MI	6.21	2.08	1.04
CO2 GRAMS/MI	330.8	375.3	301.2
NOX GRAMS/MI	.82	.13	.58
FUEL ECONOMY IN MPG	25.82	23.33	29.18
RUN TIME SECONDS	507.	868.	505.
MEASURED DISTANCE MI	3.58	3.87	3.58
SCF, DRY	.972	.974	.972

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	741.7
HUMIDITY	G/KG	11.4
TEMPERATURE	DEG C	23.3

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	345.8	(.0)
FUEL ECONOMY	MPG	25.22	(.00)
HYDROCARBONS (THC)	G/MI	.54	(.00)
CARBON MONOXIDE	G/MI	2.65	(.00)
OXIDES OF NITROGEN	G/MI	.40	(.00)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

FTP - VEHICLE EMISSIONS RESULTS - CATALYST PZM-3292

TEST NO. 2 RUN 1
VEHICLE MODEL 86 HONDA ACCORD
ENGINE 1.9 L(119. CID) L-4
TRANSMISSION M5

VEHICLE NO.535
DATE 7/14/88
BAG CART NO. 2
DYNO NO. 3
CVS NO. 2

TEST WEIGHT 1304. KG(2875. LBS)
ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
GASOLINE EM-780-F
ODOMETER 37663. KM(23403. MILES)

BAROMETER 743.46 MM HG(29.27 IN HG)
RELATIVE HUMIDITY 59. PCT

DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
ABS. HUMIDITY 11.1 GM/KG

NOX HUMIDITY CORRECTION FACTOR 1.01

BAG RESULTS

BAG NUMBER	1	2	3
DESCRIPTION	COLD TRANSIENT	STABILIZED	HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)	774.7 (30.5)	774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	39.4 (103.0)	37.8 (100.0)	40.0 (104.0)
BLOWER REVOLUTIONS	40538.	69536.	40481.
TOT FLOW STD. CU. METRES(SCF)	76.0 (2684.)	130.8 (4620.)	75.8 (2677.)
THC SAMPLE METER/RANGE/PPM	86.2/ 2/ 87.	33.1/ 2/ 33.	32.3/ 2/ 33.
THC BCKGRD METER/RANGE/PPM	6.9/ 2/ 7.	6.4/ 2/ 7.	6.8/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	34.9/ 1/ 277.	58.6/ 12/ 59.	38.3/ 12/ 38.
CO BCKGRD METER/RANGE/PPM	.1/ 1/ 1.	.6/ 12/ 1.	.6/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	91.1/ 14/ .8940	78.8/ 14/ .6376	87.5/ 14/ .8092
CO2 BCKGRD METER/RANGE/PCT	12.7/ 14/ .0426	12.8/ 14/ .0430	13.1/ 14/ .0442
NOX SAMPLE METER/RANGE/PPM	84.8/ 1/ 21.2	9.5/ 1/ 2.5	39.5/ 1/ 9.9
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1	.5/ 1/ .1	.5/ 1/ .1
DILUTION FACTOR	14.42	20.72	16.42
THC CONCENTRATION PPM	80.	27.	26.
CO CONCENTRATION PPM	266.	56.	37.
CO2 CONCENTRATION PCT	.8543	.5966	.7677
NOX CONCENTRATION PPM	21.1	2.3	9.8
THC MASS GRAMS	3.50	2.05	1.14
CO MASS GRAMS	23.56	8.58	3.22
CO2 MASS GRAMS	1189.0	1429.0	1065.8
NOX MASS GRAMS	3.11	.59	1.44
THC GRAMS/MI	.98	.53	.32
CO GRAMS/MI	6.61	2.23	.91
CO2 GRAMS/MI	333.8	372.2	299.3
NOX GRAMS/MI	.87	.15	.40
FUEL ECONOMY IN MPG	25.53	23.49	29.39
RUN TIME SECONDS	506.	868.	505.
MEASURED DISTANCE MI	3.56	3.84	3.56
SCF, DRY	.973	.975	.974

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	743.5
HUMIDITY	G/KG	11.1
TEMPERATURE	DEG C	23.9

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	344.3	(.0)
FUEL ECONOMY	MPG	25.30	(.00)
HYDROCARBONS (THC)	G/MI	.57	(.00)
CARBON MONOXIDE	G/MI	2.78	(.00)
OXIDES OF NITROGEN	G/MI	.37	(.00)

APPENDIX F

REGULATED EMISSION AND FUEL ECONOMY RESULTS FOR THE HIGH-TEMPERATURE CATALYST EXPERIMENTS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - HI TEMP & OEM CAT

TEST NO. 1 RUN 1	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/19/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 1 / CVS NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37752. KM(23458. MILES)

BAROMETER 742.19 MM HG(29.22 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 59. PCT	ABS. HUMIDITY 11.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.01

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		41.7 (107.0)	39.4 (103.0)		40.6 (105.0)
BLOWER REVOLUTIONS	11225.		29305.	69581.		40481.
TOT FLOW STD. CU. METRES(SCF)	21.0 (741.)		54.7 (1932.)	130.5 (4607.)		75.7 (2675.)
THC SAMPLE METER/RANGE/PPM	10.1/ 3/ 99.		12.7/ 2/ 13.	9.0/ 2/ 9.		9.6/ 2/ 10.
THC BCKGRD METER/RANGE/PPM	.9/ 3/ 9.		8.9/ 2/ 9.	9.4/ 2/ 9.		9.7/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	26.1/ 3/ 606.		22.2/ 13/ 20.	23.9/ 13/ 22.		13.8/ 13/ 12.
CO BCKGRD METER/RANGE/PPM	.1/ 3/ 2.		.3/ 13/ 0.	.6/ 13/ 1.		.9/ 13/ 1.
CO2 SAMPLE METER/RANGE/PCT	88.3/ 11/ .8627		93.8/ 11/ .9510	74.3/ 11/ .6634		86.7/ 11/ .8381
CO2 BCKGRD METER/RANGE/PCT	6.9/ 11/ .0409		6.9/ 11/ .0409	7.2/ 11/ .0427		7.3/ 11/ .0433
NOX SAMPLE METER/RANGE/PPM	21.2/ 1/ 5.4		41.0/ 1/ 10.3	2.3/ 1/ .6		1.9/ 1/ .5
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .0		.1/ 1/ .0	.0/ 1/ .0		.1/ 1/ .0
DILUTION FACTOR	14.39		14.04	20.11		15.95
THC CONCENTRATION PPM	91.		4.	0.		1.
CO CONCENTRATION PPM	582.		19.	20.		11.
CO2 CONCENTRATION PCT	.8246		.9130	.6228		.7975
NOX CONCENTRATION PPM	5.4		10.3	.6		.5
THC MASS GRAMS	1.10		.14	.01		.02
CO MASS GRAMS	14.22		1.21	3.09		.98
CO2 MASS GRAMS	316.8		914.7	1487.8		1105.9
NOX MASS GRAMS	.22		1.09	.15		.07
THC GRAMS/MI	1.63		.05	.00		.01
CO GRAMS/MI	21.08		.42	.80		.27
CO2 GRAMS/MI	469.4		315.7	386.1		309.1
NOX GRAMS/MI	.32		.38	.04		.02
FUEL ECONOMY IN MPG	17.47	25.15	28.02	22.89	25.35	28.65
RUN TIME SECONDS	140.		365.	867.		505.
MEASURED DISTANCE MI	.67	3.57	2.90	3.85	7.43	3.58
SCF, DRY	.973	.972	.972	.975	.974	.973
DFC, WET (DRY)		.929(.912)			.946(.928)	
TOT VOL (SCM) / SAM BLR (SCM)		75.7/ .00			206.2/ .00	

COMPOSITE RESULTS

TEST NUMBER		1	
BAROMETER	MM HG	742.2	
HUMIDITY	G/KG	11.1	
TEMPERATURE	DEG C	23.9	

		3-BAG
CARBON DIOXIDE	G/MI	356.4
FUEL ECONOMY	MPG	24.74
HYDROCARBONS (THC)	G/MI	.07
CARBON MONOXIDE	G/MI	1.39
OXIDES OF NITROGEN	G/MI	.10

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - HI TEMP & OEM CAT.

TEST NO. 2 RUN 1	VEHICLE NO. 535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/20/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37770. KM(23469. MILES)

BAROMETER 744.73 MM HG(29.32 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 59. PCT	ABS. HUMIDITY 11.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.01

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		41.1 (106.0)	40.6 (105.0)		40.6 (105.0)
BLOWER REVOLUTIONS	11252.		29362.	69635.		40527.
TOT FLOW STD. CU. METRES(SCF)	21.1 (744.)		55.0 (1942.)	130.6 (4610.)		76.0 (2683.)
THC SAMPLE METER/RANGE/PPM	10.0/ 3/ 101.		11.1/ 2/ 11.	7.7/ 2/ 8.		7.8/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		7.1/ 2/ 7.	7.7/ 2/ 8.		7.2/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	97.8/ 14/ 489.		25.9/ 12/ 26.	21.5/ 12/ 22.		8.7/ 12/ 9.
CO BCKGRD METER/RANGE/PPM	.0/ 14/ 0.		.0/ 12/ 0.	.0/ 12/ 0.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	88.4/ 14/ .8295		92.0/ 14/ .9168	78.6/ 14/ .6341		88.0/ 14/ .8204
CO2 BCKGRD METER/RANGE/PCT	11.3/ 14/ .0372		11.2/ 14/ .0369	11.5/ 14/ .0380		11.8/ 14/ .0391
NOX SAMPLE METER/RANGE/PPM	2.8/ 1/ .7		36.9/ 1/ 9.3	1.7/ 1/ .4		6.6/ 1/ 1.7
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.5/ 1/ .1	.5/ 1/ .1		.6/ 1/ .2
DILUTION FACTOR	15.11		14.56	21.04		16.30
THC CONCENTRATION PPM	93.		5.	0.		1.
CO CONCENTRATION PPM	472.		25.	21.		9.
CO2 CONCENTRATION PCT	.7948		.8824	.5979		.7837
NOX CONCENTRATION PPM	.6		9.2	.3		1.6
THC MASS GRAMS	1.13		.14	.03		.05
CO MASS GRAMS	11.59		1.61	3.19		.76
CO2 MASS GRAMS	306.6		888.5	1429.1		1090.1
NOX MASS GRAMS	.03		.98	.08		.23
THC GRAMS/MI	1.69		.05	.01		.01
CO GRAMS/MI	17.23		.55	.83		.21
CO2 GRAMS/MI	455.8		306.6	372.0		305.1
NOX GRAMS/MI	.04		.34	.02		.06
FUEL ECONOMY IN MPG	18.16	25.96	28.83	23.75	26.03	29.03
RUN TIME SECONDS	140.		366.	868.		505.
MEASURED DISTANCE MI	.67	3.57	2.90	3.84	7.41	3.57
SCF, DRY	.973	.973	.973	.975	.975	.973
DFC, WET (DRY)		.932(.914)			.947(.929)	
TOT VOL (SCM) / SAM BLR (SCM)		76.1/ .00			206.5/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	744.7
HUMIDITY	G/KG	11.1
TEMPERATURE	DEG C	23.9

		3-BAG
CARBON DIOXIDE	G/MI	345.9
FUEL ECONOMY	MPG	25.49
HYDROCARBONS (THC)	G/MI	.08
CARBON MONOXIDE	G/MI	1.25
OXIDES OF NITROGEN	G/MI	.09

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - HI TEMP & OEM CAT.

TEST NO. 2 RUN 2	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/21/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37794. KM(23484. MILES)

BAROMETER 746.25 MM HG(29.38 IN HG)	DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)	
RELATIVE HUMIDITY 54. PCT	ABS. HUMIDITY 9.9 GM/KG	NOX HUMIDITY CORRECTION FACTOR .97

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	784.9 (30.9)		784.9 (30.9)	787.4 (31.0)		784.9 (30.9)
BLOWER INLET P MM. H2O(IN. H2O)	784.9 (30.9)		784.9 (30.9)	787.4 (31.0)		784.9 (30.9)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		40.0 (104.0)	38.3 (101.0)		40.6 (105.0)
BLOWER REVOLUTIONS	11228.		29339.	69639.		40571.
TOT FLOW STD. CU. METRES(SCF)	21.0 (743.)		55.1 (1946.)	131.2 (4632.)		76.1 (2688.)
THC SAMPLE METER/RANGE/PPM	10.1/ 3/ 102.		10.5/ 2/ 11.	7.8/ 2/ 8.		7.9/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		7.5/ 2/ 8.	7.6/ 2/ 8.		7.5/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	98.7/ 14/ 495.		20.1/ 12/ 20.	16.1/ 12/ 16.		7.8/ 12/ 8.
CO BCKGRD METER/RANGE/PPM	.1/ 14/ 0.		.3/ 12/ 0.	.0/ 12/ 0.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	90.0/ 14/ .8671		92.0/ 14/ .9168	79.0/ 14/ .6411		87.8/ 14/ .8159
CO2 BCKGRD METER/RANGE/PCT	12.4/ 14/ .0415		12.5/ 14/ .0418	12.6/ 14/ .0422		12.6/ 14/ .0422
NOX SAMPLE METER/RANGE/PPM	26.3/ 1/ 6.7		32.6/ 1/ 8.2	2.6/ 1/ .7		9.9/ 1/ 2.6
NOX BCKGRD METER/RANGE/PPM	1.2/ 1/ .3		.9/ 1/ .2	.8/ 1/ .2		.9/ 1/ .2
DILUTION FACTOR	14.49		14.57	20.83		16.39
THC CONCENTRATION PPM	94.		4.	1.		1.
CO CONCENTRATION PPM	478.		19.	16.		8.
CO2 CONCENTRATION PCT	.8285		.8778	.6009		.7763
NOX CONCENTRATION PPM	6.4		8.0	.5		2.3
THC MASS GRAMS	1.14		.11	.04		.04
CO MASS GRAMS	11.71		1.24	2.41		.68
CO2 MASS GRAMS	319.2		885.7	1443.2		1081.9
NOX MASS GRAMS	.25		.82	.12		.33
THC GRAMS/MI	1.70		.04	.01		.01
CO GRAMS/MI	17.38		.43	.63		.19
CO2 GRAMS/MI	474.0		306.5	375.7		304.8
NOX GRAMS/MI	.37		.28	.03		.09
FUEL ECONOMY IN MPG	17.50	25.70	28.85	23.54	25.90	29.06
RUN TIME SECONDS	140.		365.	868.		506.
MEASURED DISTANCE MI	.67	3.56	2.89	3.84	7.39	3.55
SCF, DRY	.974	.974	.974	.977	.976	.975
DFC, WET (DRY)		.931(.915)			.947(.931)	
TOT VOL (SCM) / SAM BLR (SCM)		76.2/ .00			207.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	746.3
HUMIDITY	G/KG	9.9
TEMPERATURE	DEG C	23.3

		3-BAG
CARBON DIOXIDE	G/MI	348.5
FUEL ECONOMY	MPG	25.31
HYDROCARBONS (THC)	G/MI	.08
CARBON MONOXIDE	G/MI	1.13
OXIDES OF NITROGEN	G/MI	.10

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

FTP - VEHICLE EMISSIONS RESULTS - HI TEMP CAT ONLY

TEST NO. 1 RUN 1	VEHICLE NO.535	TEST WEIGHT 1304. KG(2875. LBS)
VEHICLE MODEL 86 HONDA ACCORD	DATE 7/22/88	ACTUAL ROAD LOAD 5.7 KW(7.7 HP)
ENGINE 1.9 L(119. CID) L-4	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-780-F
TRANSMISSION M5	DYNO NO. 3	ODOMETER 37818. KM(23499. MILES)

BAROMETER 745.24 MM HG(29.34 IN HG)	DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)	
RELATIVE HUMIDITY 53. PCT	ABS. HUMIDITY 9.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR .95

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		41.1 (106.0)	40.0 (104.0)		40.6 (105.0)
BLOWER REVOLUTIONS	11294.		29342.	69613.		40533.
TOT FLOW STD. CU. METRES(SCF)	21.1 (747.)		55.0 (1942.)	130.8 (4617.)		76.1 (2685.)
THC SAMPLE METER/RANGE/PPM	9.6/ 3/ 97.		17.0/ 2/ 17.	11.1/ 2/ 11.		13.2/ 2/ 13.
THC BCKGRD METER/RANGE/PPM	1.0/ 3/ 10.		9.7/ 2/ 10.	10.2/ 2/ 10.		10.4/ 2/ 11.
CO SAMPLE METER/RANGE/PPM	96.1/ 14/ 479.		42.9/ 12/ 43.	34.6/ 12/ 35.		28.8/ 12/ 29.
CO BCKGRD METER/RANGE/PPM	.0/ 14/ 0.		.6/ 12/ 1.	1.2/ 12/ 1.		2.4/ 12/ 2.
CO2 SAMPLE METER/RANGE/PCT	89.2/ 14/ .8481		90.9/ 14/ .8890	75.9/ 14/ .5887		84.1/ 14/ .7371
CO2 BCKGRD METER/RANGE/PCT	12.3/ 14/ .0411		12.4/ 14/ .0415	12.9/ 14/ .0434		13.5/ 14/ .0458
NOX SAMPLE METER/RANGE/PPM	35.0/ 1/ 8.8		91.9/ 1/ 23.0	25.8/ 1/ 6.5		73.1/ 1/ 18.3
NOX BCKGRD METER/RANGE/PPM	1.3/ 1/ .3		.9/ 1/ .2	.9/ 1/ .2		1.1/ 1/ .3
DILUTION FACTOR	14.82		14.97	22.59		18.08
THC CONCENTRATION PPM	87.		8.	1.		3.
CO CONCENTRATION PPM	463.		41.	33.		26.
CO2 CONCENTRATION PCT	.8098		.8504	.5472		.6939
NOX CONCENTRATION PPM	8.5		22.7	6.3		18.0
THC MASS GRAMS	1.07		.26	.10		.15
CO MASS GRAMS	11.40		2.62	4.96		2.28
CO2 MASS GRAMS	313.5		856.2	1309.9		966.1
NOX MASS GRAMS	.33		2.27	1.50		2.49
THC GRAMS/MI	1.58		.09	.03		.04
CO GRAMS/MI	16.87		.92	1.30		.64
CO2 GRAMS/MI	464.0		299.0	343.2		271.9
NOX GRAMS/MI	.48		.79	.39		.70
FUEL ECONOMY IN MPG	17.90	26.25	29.49	25.68	28.56	32.48
RUN TIME SECONDS	141.		365.	867.		505.
MEASURED DISTANCE MI	.68	3.54	2.86	3.82	7.37	3.55
SCF, DRY	.975	.975	.975	.977	.977	.976
DFC, WET (DRY)		.933(.917)			.952(.935)	
TOT VOL (SCM) / SAM BLR (SCM)		76.1/ .00			206.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	745.2
HUMIDITY	G/KG	9.1
TEMPERATURE	DEG C	22.2

		3-BAG
CARBON DIOXIDE	G/MI	321.0
FUEL ECONOMY	MPG	27.44
HYDROCARBONS (THC)	G/MI	.10
CARBON MONOXIDE	G/MI	1.67
OXIDES OF NITROGEN	G/MI	.55

APPENDIX G

BET SURFACE AREA ANALYSIS

MICROMERITICS INSTRUMENT CORPORATION
FlowSorb 2300

BET SURFACE AREA ANALYSIS
REPORT DATE: 8/20/88

SAMPLE I.D.: GM Charcoal
SAMPLE WEIGHT: 0.0782 g
MOL. CROSS-SECTIONAL AREA: 0.162 nm^2
AMBIENT TEMPERATURE: 0.00 C

ADSORBATE: Nitrogen
BAROMETRIC PRESSURE: 760 mmHg
SATURATION PRESSURE: 775 mmHg

EXPERIMENTAL DATA (%)	(VOL)	VOL ADSORBED (cm^3/g AT STP)	X=P/Po	Y=X/[(1-X)V]
5.010	23.47	*300.13	0.0491	0.00017
10.000	25.64	*327.88	0.0981	0.00033
14.900	28.04	*358.57	0.1461	0.00048
22.000	30.96	*395.91	0.2157	0.00069

BET SURFACE AREA: 1382.97 +/- 12.21 m^2/g
SLOPE: 0.0031 +/- 0.0000
INTERCEPT: 0.0000 +/- 0.0000
C: 149.55
Vm: 317.69 cm^3/g
CORRELATION COEFFICIENT 0.9999

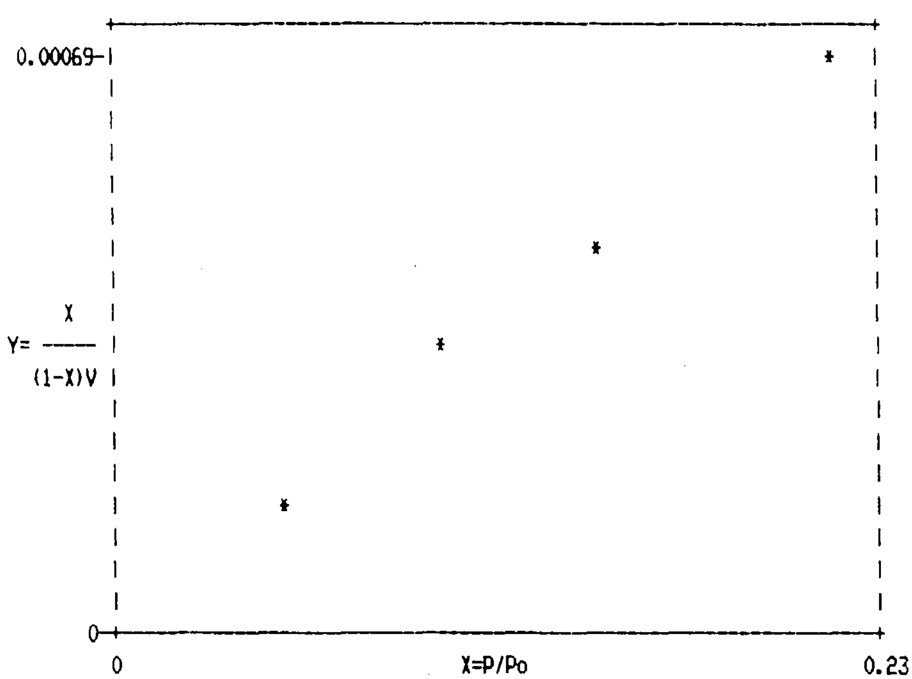

FIGURE G-1. BET SURFACE AREA ANALYSIS FOR GM CHARCOAL

MICROMERITICS INSTRUMENT CORPORATION
FlowSorb 2300

BET SURFACE AREA ANALYSIS
REPORT DATE: 8/20/88

SAMPLE I.D.: FORD charcoal
SAMPLE WEIGHT: 0.0728 g
MOL. CROSS-SECTIONAL AREA: 0.162 nm^2
AMBIENT TEMPERATURE: 0.00 C

ADSORBATE: Nitrogen
BAROMETRIC PRESSURE: 760 mmHg
SATURATION PRESSURE: 775 mmHg

EXPERIMENTAL DATA (%)	(VOL)	VOL ADSORBED (cm^3/g AT STP)	X=P/Po	Y=X/[(1-X)V]
5.010	20.14	%276.65	0.0491	0.00019
10.000	22.68	%311.54	0.0981	0.00035
14.900	24.69	%339.15	0.1461	0.00050
22.000	27.40	%376.37	0.2157	0.00073

BET SURFACE AREA: 1323.12 +/- 4.54 m^2/g
SLOPE: 0.0033 +/- 0.0000
INTERCEPT: 0.0000 +/- 0.0000
C: 119.17
Vm: 303.94 cm^3/g
CORRELATION COEFFICIENT 1.0000

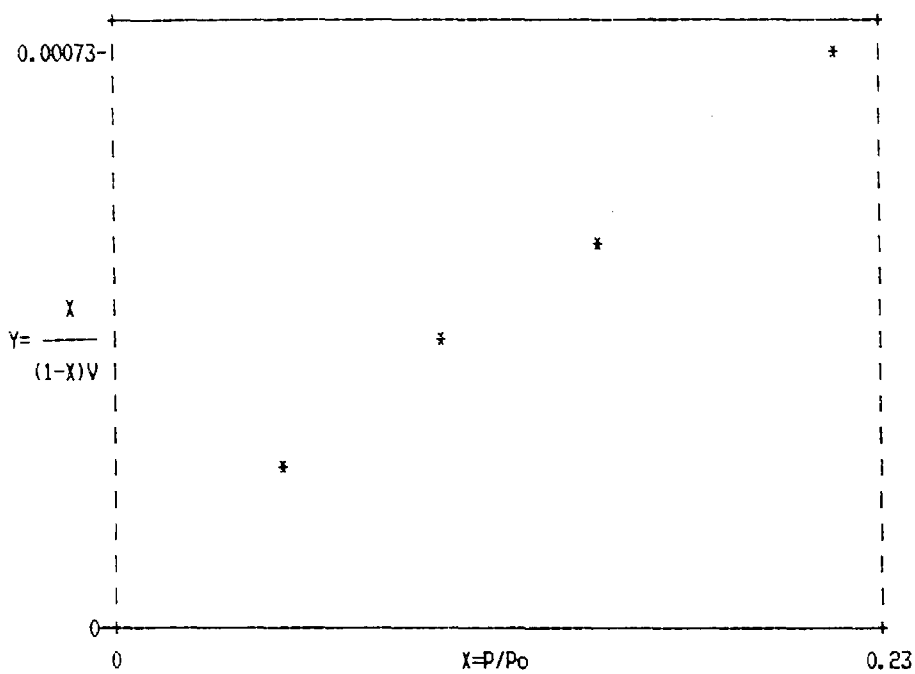

FIGURE G-2. BET SURFACE AREA ANALYSIS FOR FORM CHARCOAL

APPENDIX H

AIR INJECTION TO AN ELECTRICALLY-HEATED CATALYST FOR REDUCING COLD-START BENZENE EMISSIONS FROM GASOLINE VEHICLES

by

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Based on Work Performed

for

Advisory Committee for Research
Southwest Research Institute
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Presented at

Society of Automotive Engineers
International Fuels and Lubricants
Meeting and Exposition
Tulsa, Oklahoma
October 22-25, 1990

ABSTRACT

This paper describes the laboratory effort to determine the emissions benefit of cold-start air injection to a preheated automotive catalyst. Previous experimentation with an electrically-heated catalyst on a gasoline-fueled vehicle with no supplemental air showed little improvement in hydrocarbon emission control.

In this study, air was injected ahead of an electrically-heated catalyst during cold-start operation. Analysis of continuously recorded raw exhaust emissions were used to determine air injection calibrations and oxidation-reduction trade-offs. Improved control of non-methane hydrocarbons (NMHC), benzene, and carbon monoxide (CO) emissions was observed. Nitrogen oxides (NO_x) emission control was maintained by the use of a carefully controlled air injection flowrate and schedule.

This study determined that heating an automotive exhaust emission catalyst prior to cold-start operation may not be sufficient in itself. Supplemental oxygen may be required for improved emissions control. Finally, it was demonstrated that the gasoline vehicle used in this study, equipped with an electrically-heated catalyst and air injection, provided FTP emission rates of non-methane organic gases (NMOG), CO, and NO_x near or at the California standards for the ultra-low emission vehicle (ULEV).

COLD-START EMISSIONS represent the greatest concentration of emissions from today's catalyst-equipped vehicles. A cold-start is defined by the Code of Federal Regulations (CFR) as an engine start following a 12- to 36-hour continuous vehicle soak in a constant temperature environment of 20°C to 30°C.(1)* The catalyst is not active during this period due to its low operating temperature. Depending on the particular engine, vehicle tailpipe emissions can be excessive for a period of one to two minutes following the cold-start. Any strategy to significantly reduce vehicle emissions, therefore, needs to address the cold-start.

One strategy to reduce the quantity of pollutants emitted during the cold-start operation is to have the catalyst active at the time the engine starts. Electrically heating the catalyst prior to cold engine cranking can help achieve catalyst activity during the cold-start.(2,3,4,5,6) The goal is to have an active catalyst capable of controlling cold-start emissions to the levels achieved during hot starting.

A gasoline-fueled vehicle was equipped with an electrically-heated catalyst at Southwest Research Institute (SwRI). This experiment produced the initial finding that heating alone did not significantly improve emission control over an unheated catalyst baseline vehicle test.(7) With only electrical preheating, cold-start catalyst activity is still impaired because of a lack of oxygen in the engine-out exhaust. In many vehicle fuel system calibrations, a cold engine is run fuel-rich to maintain driveability. Rich fuel-air ratios result in insufficient oxygen levels in the raw exhaust, limiting the oxidation of hydrocarbons and carbon monoxide.

One of the objectives of the gasoline-fueled vehicle study was to reduce the quantity of total hydrocarbon emissions through the development of a total emission control system, without sacrificing control of other pollutants such as nitrogen oxides (NO_x). The maintenance of NO_x emission control was of special interest because of the NO_x contribution to smog formation. Benzene emission control was also of special interest. The vehicle was equipped with an electrically-heated catalyst for cold-start control of total hydrocarbons and benzene emissions. A prototype cold-start air injection system was developed. This paper describes the results of an effort to improve cold-start emission control from a gasoline-fueled vehicle by introducing secondary air ahead of an electrically-heated catalyst. The emission data generated in this program has contributed to the establishment of future vehicle emission standards by the State of California Air Resources Board (ARB).

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*Numbers in parentheses designate references at the end of the paper.

CALIFORNIA PROPOSED VEHICLE STANDARDS

In California, hydrocarbon emissions from motor vehicles have traditionally been represented in terms of non-methane hydrocarbons (NMHC). Instead of a NMHC standard, the ARB is currently considering a non-methane organic gases (NMOG) standard for the vehicle and its fuel. NMOG consists of all measurable reactive hydrocarbons: NMHC, aldehydes and ketones, and alcohols containing 12 or fewer carbon atoms.(8)

Light-duty gasoline vehicle emission standards being considered by ARB are given in Table 1. This table provides the certification standards for Transitional Low-Emission Vehicles (TLEVs), Low-Emission Vehicles (LEVs), and Ultra-Low-Emission Vehicles (ULEVs) at 50,000 miles.(8) In addition, the State of California is proposing that all vehicles certified for sale in California must meet specified fleet average NMOG standards starting in 1994. In this paper, the emission results achieved by a gasoline-fueled vehicle equipped with an electrically-heated catalyst will be compared to the proposed California emission standards.

Table 1 - Proposed California Vehicle Exhaust Emission Standards For Light-Duty Vehicles

Vehicle Category	Exhaust Emissions, g/mi		
	NMOG	CO	NO_x
TLEV	0.125	3.4	0.40
LEV	0.075	3.4	0.20
ULEV	0.040	1.7	0.20
Proposed standards as of July 1990			

TEST VEHICLE AND GASOLINE

A gasoline-fueled 1986 Toyota Camry was used for experimentation. This vehicle was equipped with electronic port fuel injection and a three-way (only) catalytic converter. The 1986 Toyota Camry was 50-state emissions certified. At the start of the air injection experiments, the vehicle odometer read 21,835 miles. A vehicle description is given in Table 2. The original underbody stock catalyst was removed and replaced with an electrically-heated catalyst, a three-way formulation designed as a total replacement for the stock catalyst. The front face of the underbody electrically-heated catalyst was located a distance of 76 centimeters (30 inches) from the exit of the exhaust manifold. This replacement catalyst was evaluated with and without air injection and electrical heating. A photograph of the Camry is given in Figure 1. The test fuel was a Chevron regular unleaded gasoline, and was shipped from California to SwRI. Test fuel composition was typical of unleaded gasolines sold in California. Fuel analysis results are given in Table 3.

ELECTRICALLY-HEATED CATALYST AND POWER CONTROL DESCRIPTION

The electrically-heated catalyst used in these experiments was composed of two separate sections. The larger downstream section was a metal substrate catalyst without heating capability. The smaller upstream section was a catalyzed metal substrate with the ability to be heated electrically. Figure 2 shows a schematic of the electrically-heated catalyst. The catalytic converter was installed on the vehicle with the heated catalyst portion upstream (toward the engine). A description of the electrically-heated converter is given in

Table 2 - Demonstration Vehicle Description
1986 Toyota Camry

Item	Toyota Camry
Model Year	1986
Body Style	4-Door Sedan
Odometer[a]	35,140 km (21,835 miles)
Transmission	Automatic
No. of Gears	4
VIN	JT25V16E3G0486387
Texas License No.	860-NJF
Tires	185/70SR13
Accessories	Air Conditioning Overdrive Transmission Power Steering Power Brakes
Engine Family	GTY2.0V5FBB3
Engine Displacement	2.0 Liter
No. of Cylinders	4
Fuel System	Electronic Port Fuel Injection
Ignition System	Electronic Ignition
Emission Control	Three-way Catalyst
Evaporative Family	EV - E
Chassis Dynamometer: Inertia Setting Road Load @ 50 mph	 1304 kg (2875 lb) 6.0 kW (8.1 hp)

[a]Odometer mileage as of September 28, 1989.

Table 3 - Fuel Analysis of Unleaded Gasoline

Measurement	Results
Distillation, D-86, °F	
IBP	95
5% Point	118
10% Point	132
20% Point	158
30% Point	184
40% Point	208
50% Point	231
60% Point	255
70% Point	280
80% Point	300
90% Point	332
95% Point	352
End Point	399
Recovery, %	98.3
Residue, %	0.9
Loss, %	0.8
Hydrocarbon Types	
Aromatics, L.V. %	37.0
Olefins, L.V. %	7.9
Saturates, L.V. %	55.1
Manganese Content, g/gal	<0.001
Motor Octane Number, Clear	83.2
Research Octane Number, Clear	93.0
(R+M)/2	88.1
Oxygenates, L.V. %	
Methanol	<0.1
Tertiary butyl alcohol	<0.1
Methyl tertiary butyl ether (MTBE)	<0.1
Ethanol	<0.1
Lead Content, D-3237, g/gal	<0.002
Phosphorus Content, D-3231, g/gal	0.0006
Reid Vapor Pressure, D-323, psi @ 100°F	8.4
Total Sulfur, D-3246, Wt. %	0.002
API gravity @ 60°F	53.6
Density, g/mL @ 81°F	0.756
Benzene, Vol. %	2.44
Toluene, Vol. %	9.74
Xylene, Vol. %	9.41

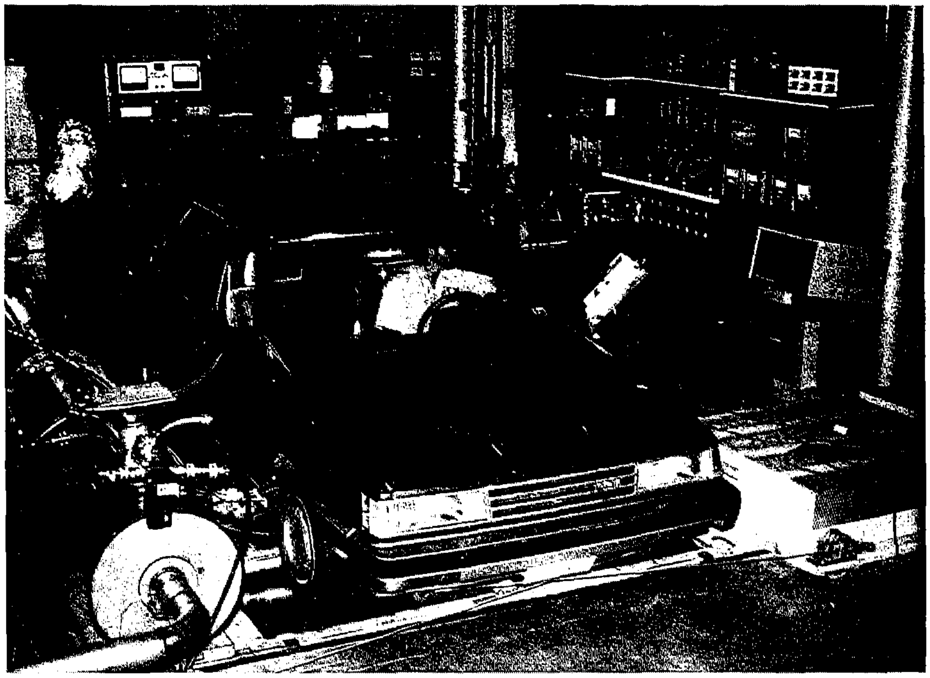


Figure 1 - 1986 Toyota Camry Demonstration Vehicle

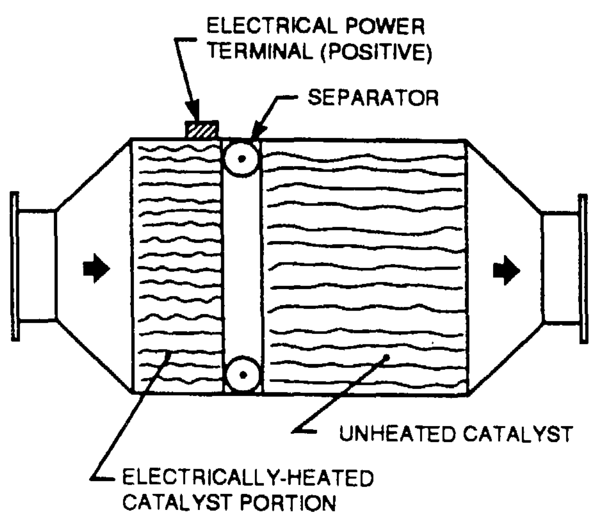


Figure 2 - Schematic of Electrically-Heated Catalyst

Table 4. A photograph of the actual demonstration electrically-heated catalyst unit is given in Figure 3.

Table 4 - Description of Electrically-Heated Catalytic Converter Used on the Toyota Camry

Item	Electrically-Heated Catalytic Converter	
	Heated Segment	**Unheated Segment**
Piece Dimensions, in.: (W × H × L)	5.5 × 2.87 × 1	6 × 3.37 × 3.5
Percent Open Area, %	61	85
Heating Element Voltage (nominal):	24 volts	--
Substrate Type:	Stainless Steel Foil	Stainless Steel Foil
Wall Thickness, inch	0.002	0.002
Metal Loading, g/ft^3 Type Ratio	35-40 Pt/Rh 7:1	35-40 Pt/Rh 7:1
Description provided by Camet Co.		

Prior to the experimentation, the electrically-heated catalyst was initially aged on the vehicle for 805 kilometers (500 miles) using the Alternate Mileage Accumulation (AMA) driving schedule. The AMA driving schedule was based on a 10-kilometer driving route. Each lap had a maximum speed between 48 and 80 kilometers per hour (30 and 55 miles per hour). AMA vehicle driving incorporated stops, decelerations from lap speed, and accelerations to lap speed. This preliminary catalyst aging was performed to remove the initial high level of catalytic activity associated with fresh catalysts.

A small 12-volt (motorcycle) battery was placed in series with the original vehicle battery to provide a maximum of 24 volts to the catalyst. Power to the electrically-heated catalyst was controlled with on-vehicle solenoids.(9) For recharging, solenoids placed the second battery in parallel with the original battery (when the catalyst was not being electrically heated). A timer was built into this solenoid-based controller to provide a 15-second cold-start- and a 5-second hot-start-precrank heating time. For our experiments, the catalyst electrical heating resumed immediately for 30 seconds following cold-starts and for 10 seconds following hot-starts.

EMISSION TEST PROCEDURES

The Toyota Camry with the electrically-heated catalyst was evaluated with experimental air injection strategies using the Federal Test Procedure (FTP). The FTP is an emissions certification test procedure used for light-duty vehicles. It uses the Urban Dynamometer Driving Schedule (UDDS), which is 1372 seconds in duration. The UDDS is divided into two segments; the first consisting of 505 seconds and the second consisting of 867 seconds. An FTP is composed of a cold transient 505 and a cold stabilized 867 portion followed by a ten-minute soak and then a hot transient 505.

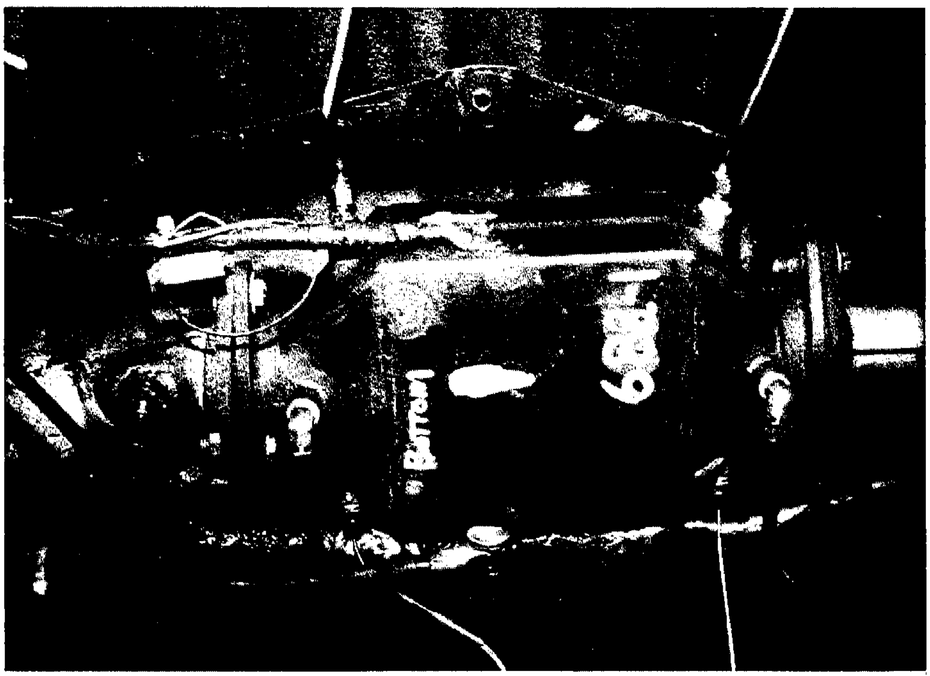


Figure 3 - Prototype Electrically-Heated Catalyst on the Toyota Camry

For use in studying cold-start exhaust emissions, the first segment (Bag 1) of the UDDS was divided into two parts. Bag 1A was defined as the first 140 seconds of the cold-transient portion of the UDDS. This segment contains the majority of the cold-start emissions produced by the test vehicle. The remainder of the cold-transient segment is designated as Bag 1B (140-505 seconds). The sum of the mass emissions produced in Bags 1A and 1B is equal to the emissions generated during a conventional FTP Bag 1. The FTP driving schedule with the cold and hot transient test segments identified is given in Figure 4.

LABORATORY EMISSION MEASURING EQUIPMENT AND INSTRUMENTATION

This section briefly describes some of the emission measuring equipment and laboratory instrumentation used to conduct the experimentation. Laboratory equipment such as the chassis dynamometer, exhaust sampling system, instrumentation for determining mass emissions, and instrumentation for measuring raw exhaust constituent concentrations is discussed.

DYNAMOMETER, CVS, AND EXHAUST SAMPLING SYSTEM - A Clayton Model ECE-50 chassis dynamometer with a direct drive variable inertia system was used for all testing. The inertia system simulates equivalent vehicle test weights from 1,000 lb to 4,750 lb in 125 lb increments. A nominal 18-inch diameter by 16-foot length dilution tunnel was used in conjunction with a constant volume sampler (CVS). The CVS used for these evaluations has a nominal capacity of 315 SCFM. A Hartzell vehicle cooling fan of 5,000 CFM capacity was used in front of the test vehicles during all tests. Vehicle hoods were fully open during engine operation and closed during soak periods. Both the dynamometer and the CVS were calibrated, maintained, and operated in accordance with manufacturers' instructions and the appropriate sections of the Code of Federal Regulations applicable to light-duty vehicles.(1) Gaseous emissions samples were taken in Tedlar bags. Photographs of the dynamometer, CVS, and dilute exhaust sampling system are shown in Figures 5 and 6.

INSTRUMENTATION FOR REGULATED EMISSIONS - Regulated exhaust emissions of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and oxides of nitrogen (NO_x) were measured using continuous proportional bag samples of dilute exhaust. Dilute exhaust emission measuring instruments were calibrated and operated in accordance with the appropriate sections of the Code of Federal Regulations applicable to the light-duty vehicles. Fuel consumption was calculated based on the carbon balance method.

INDIVIDUAL HYDROCARBON ANALYSIS - An individual hydrocarbon analysis was performed to measure quantities of methane, benzene, and toluene exhaust emissions. Measurement of individual hydrocarbons in dilute exhaust was conducted with a gas chromatography technique.(10) Tedlar film bags were filled with dilute exhaust during each driving cycle. Sample concentrations were determined by comparison to a calibration blend of hydrocarbons.

CONTINUOUS RAW EXHAUST EMISSION MEASUREMENT - Continuous raw exhaust emissions were monitored during the experimentation. Raw exhaust concentrations of HC, CO, O_2, and NO_x were measured before and after the catalytic converter. The continuous raw exhaust emission traces were used to examine emission characteristics during cold-start and hot-start modes. The continuous raw exhaust emission sampling cart is shown in Figure 7.

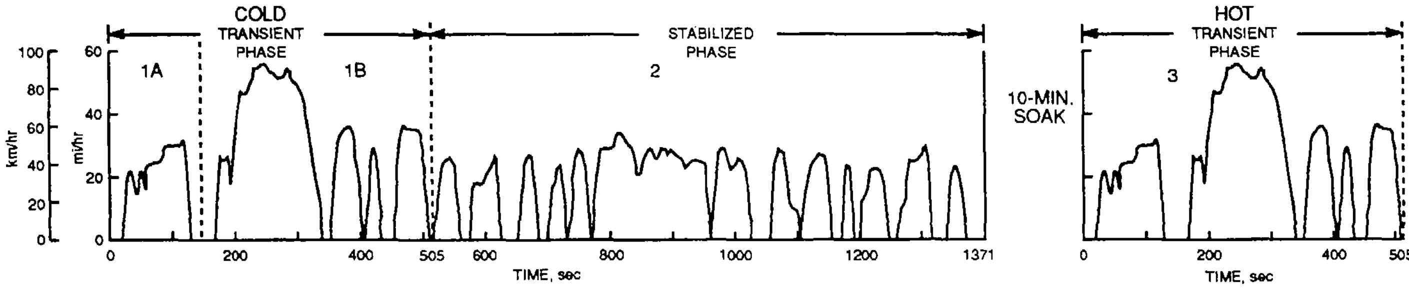


Figure 4. FTP Driving Schedule Showing Test Segments

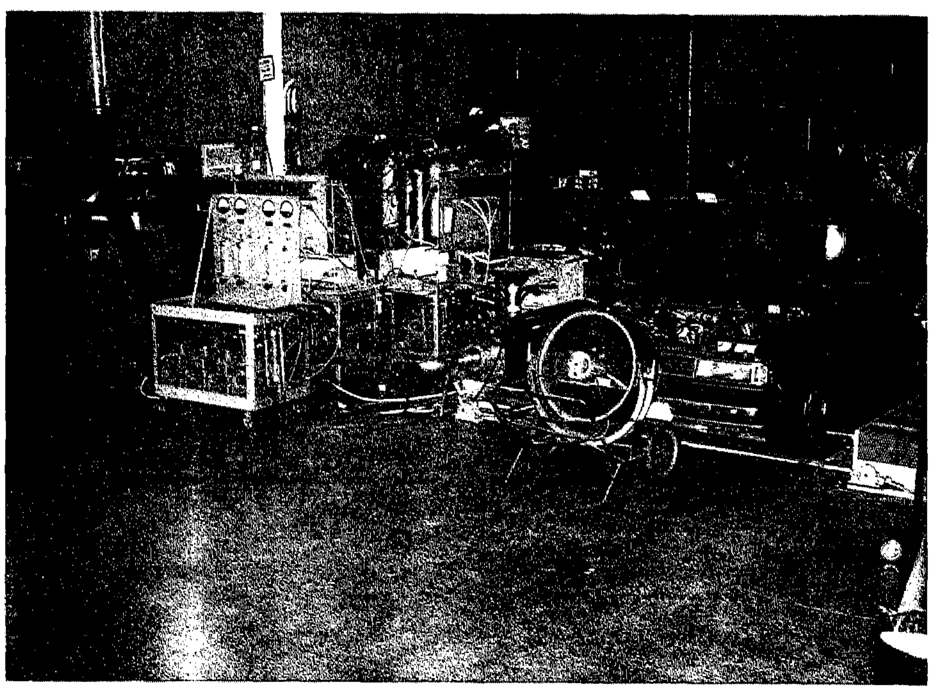


Figure 5 - Vehicle Dynamometer and Dilution Tunnel

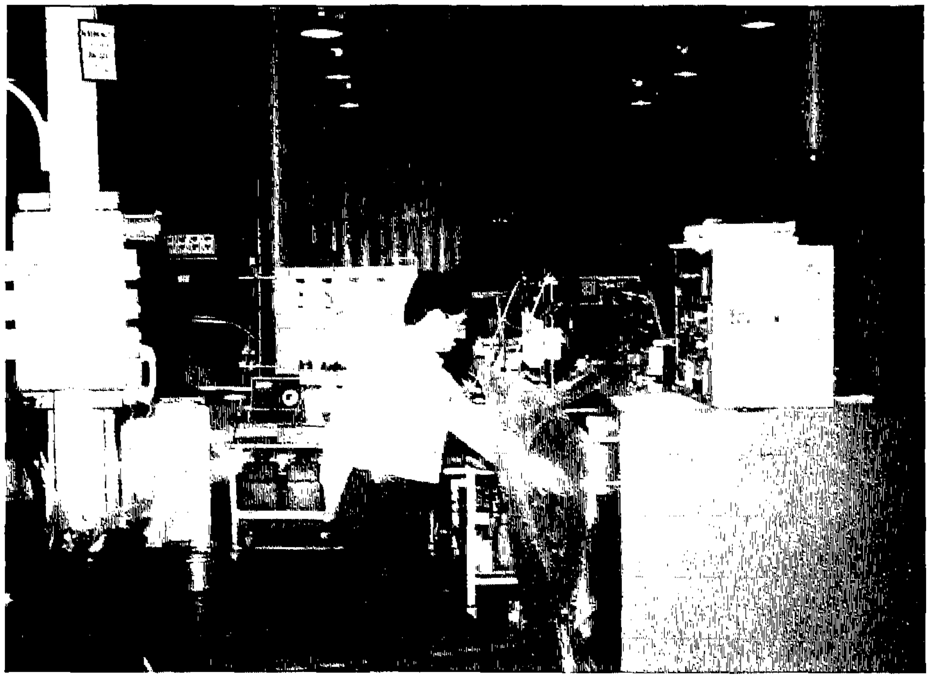


Figure 6 - Dilute Exhaust Emission Collection in Tedlar Bags

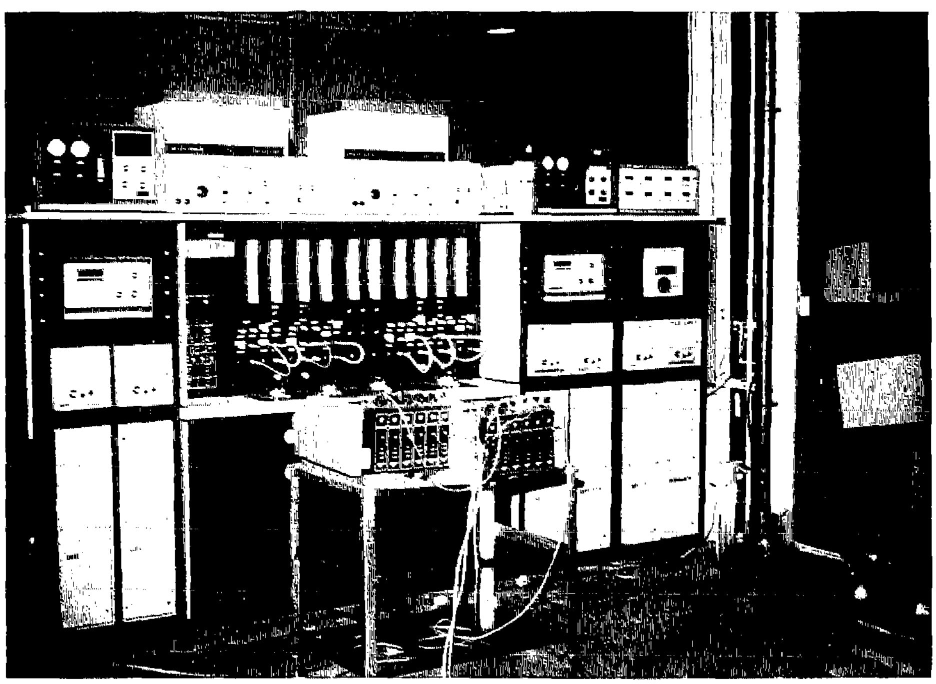


Figure 7 - Continuous Raw Exhaust Emission Sampling Cart

THREE-WAY CATALYST TECHNOLOGY AND EMISSION CONTROL BACKGROUND

A basic review of three-way catalyst technology is required to follow the emission reduction strategy of the electrically-heated catalyst. The three most influential factors affecting catalyst performance, other than the catalyst design itself, are exhaust composition (air-fuel ratio), catalyst temperature, and engine fuel control characteristics.

Three desirable chemical reactions occur in an active three-way catalyst. These three reactions are the oxidation of HC, the oxidation of CO, and the reduction of NO_x. Principal equations for the reactions are given below.

$$2HC + 5/2\ O_2 \rightarrow 2CO_2 + H_2O \qquad [1]$$

$$CO + 1/2\ O_2 \rightarrow CO_2 \qquad [2]$$

$$NO + CO \rightarrow CO_2 + 1/2\ N_2 \qquad [3]$$

$$10\ NO + 4HC \rightarrow 4CO_2 + 2H_2O + 5N_2 \qquad [4]$$

$$NO + H_2 \rightarrow 1/2\ N_2 + H_2O \qquad [5]$$

HC represents unburned fuel.

A three-way catalyst is so named because it is designed to simultaneously convert HC, CO, and NO_x to CO_2, N_2, and H_2O.

The conversion characteristics of a three-way catalyst are a strong function of the air-fuel ratio. Ideally, for complete combustion of a fuel with a hydrogen to carbon (H to C) ratio of 1.85 to 1 and without oxygenates, a stoichiometric air-fuel (mass) ratio of approximately 14.56 to 1 is required. With stoichiometric exhaust constituents, the catalyst has the correct proportions of HC, CO, NO_x and O_2 available for optimal three-way control. Note that in equation 2, CO is a controlled emission and, in equation 3, a reducing agent for NO_x.

Combustion air-fuel ratio affects catalyst conversion efficiency. If the air-fuel ratio (AFR) is fuel-rich (AFR less than stoichiometric), there is insufficient oxygen in the exhaust stream for maximum conversion of HC and CO. Therefore, more CO is available for the reduction of NO_x, and catalyst conversion efficiency for NO_x is improved (refer to Equations 2 and 3). When lean air-fuel ratios prevail, oxygen is available for the oxidation of HC and CO, but NO_x conversion suffers without a sufficient supply of CO. A well controlled stoichiometric air-fuel ratio affords the best simultaneous control of HC, CO, and NO_x. A diagram of catalyst conversion efficiency versus air-fuel ratio for HC, CO, NO_x is given in Figure 8.

Temperature is also a critical factor in catalyst performance. Immediately following the cold start, an unheated catalyst is not active because it is not up to temperature. An automotive catalyst needs to be at a temperature of approximately 500°F to 600°F (260°C to 320°C) before catalyst "light-off" can occur. Catalyst light-off is often defined as the occurrence of a 50- percent conversion efficiency.

Catalyst efficiency and emission control is strongly affected by the control of the fuel delivery system. Today, in modern technology vehicles, electronic port fuel injection is used. Fuel control is achieved with exhaust gas oxygen content feedback. An oxygen sensor in the exhaust system relays exhaust gas oxygen concentrations to a computerized fuel control system. The air-fuel ratio of the engine cycles from slightly rich to slightly lean with a characteristic frequency and amplitude. Each vehicle model has its own unique fuel system calibration. The characteristics of this fuel calibration ultimately influence the characteristic of the exhaust emissions.

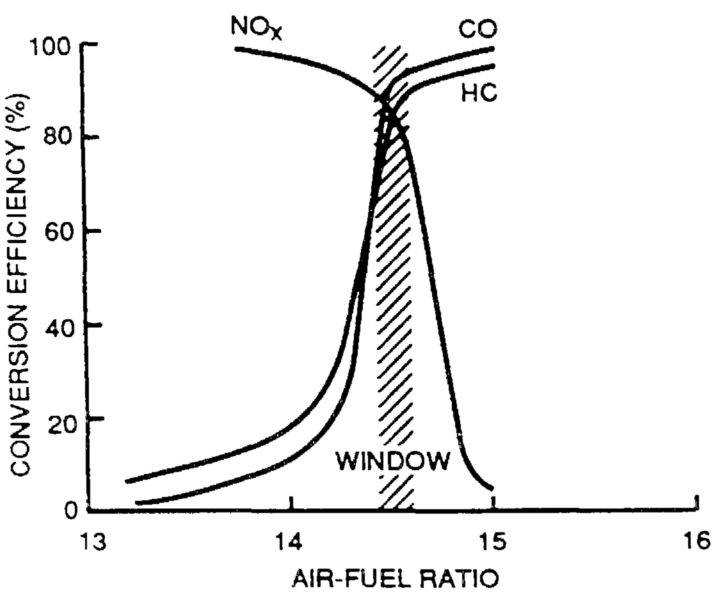


Figure 8 - Three-Way Catalyst Conversion Efficiency

DEVELOPMENT OF THE AIR INJECTION STRATEGY

It was thought that air injection ahead of the preheated catalyst would provide the required oxygen for more complete oxidation of exhaust hydrocarbons and carbon monoxide. In order to demonstrate the feasibility of secondary air, an air injection system consisting of a constant-speed rotary vane air pump driven by an off-vehicle electric motor was constructed. The air pump was an automotive production pump typical of what is used on gasoline engines equipped with three-way plus oxidation catalyst systems. The experimental pump assembly had a four-belt pulley so that four separate flowrates could be achieved. Manually operated gate valves were used to fine tune the air injection flowrate and pump backpressure. A one-way check valve was located in the line supplying air to the vehicle exhaust system. A laminar flow element (LFE) was used to measure air injection rates during vehicle emission experiments. The experimental air injection pump is shown in Figure 9.

AIR INJECTION FLOWRATE - The air injection flowrate was determined such that the exhaust gas ahead of the electrically-heated underbody catalyst contained a sufficient amount of oxygen. It was hypothesized that at some point, an increased rate of air injection would not contribute to improved emission control, but rather would tend to saturate the exhaust and possibly cool the preheated catalyst, inhibiting further emission control. To this end, several quick experiments were performed to determine the effects of different rates of air injection. A summary of the air injection experiments is given in Table 5.

Table 5 - FTP Cold-Start Air Injection Flowrate Experiments

Description	Bag 1A Emissions, grams		
	HC	CO	NO_x
No Air - No Heat (Baseline)	1.68	16.77	1.89
Air (3.8 CFM, 70 seconds) - Heat	1.38	15.40	1.74
Air (5.0 CFM, 140 seconds) - Heat	0.70	1.95	2.03
Air (5.0 CFM, 140 seconds) - Heat	0.28	1.34	2.07
Air (5.0 CFM, 140 seconds) - Heat	0.23	0.93	1.79
Air (5.0 CFM, 140 seconds) - Heat	0.22	0.21	2.45
Heat - 15 seconds pre-crank, 30 seconds post-start			

Based on the results of these tests, an air injection rate of approximately 140 liters per minute (5 cubic feet per minute) was selected. It is recognized that the flowrate selected is dependent upon the flowrate-backpressure characteristics of the experimental air pump. Engine-out emission rates of HC and CO are also a factor in selecting the air injection flowrate.

AIR INJECTION DURATION - Once the air injection flowrate was selected, the duration of air injection needed to be determined. The duration of the flow can have a trade-off effect on HC and NO_x emissions. Hydrocarbon (and carbon monoxide) exhaust emissions are easily controlled in a lean (oxygen-rich) exhaust gas environment within an active catalytic converter. Oxides of nitrogen exhaust emissions, on the other hand, are controlled

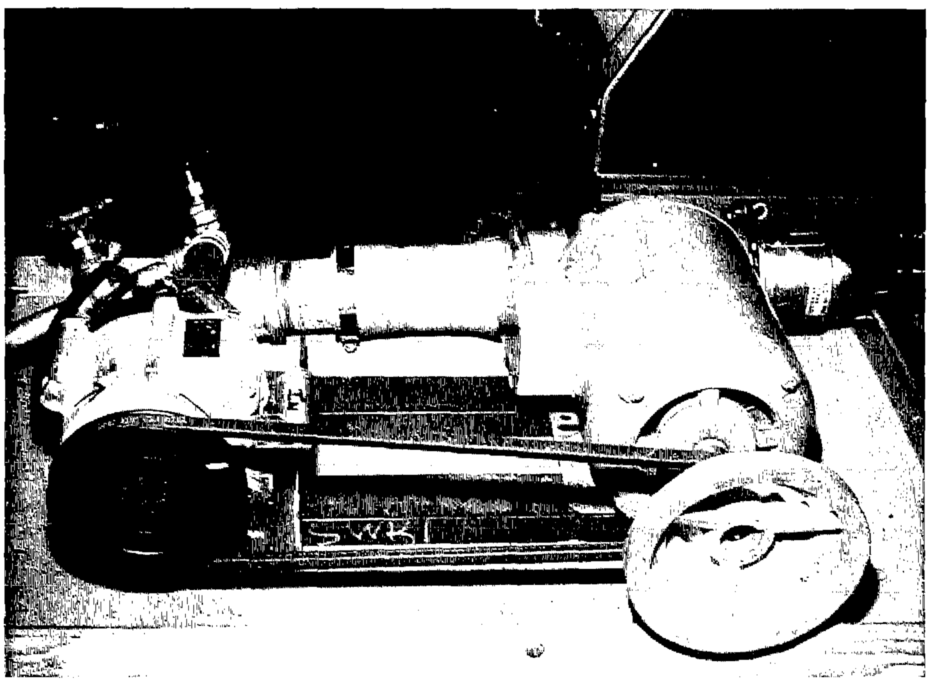


Figure 9 - Developmental Air Injection Pump

best in a fuel-rich exhaust gas environment. In keeping with the objective of this demonstration, the HC emissions (specifically benzene) could not be controlled at the expense of a NO_x emission increase. Air injection could not be continued beyond the point where NO_x emissions would normally be controlled with the original catalyst. It was found that air-fuel ratio does not come into control (initially) until about 130 to 160 seconds into the cold-transient segment of the FTP. It is hypothesized that NO_x control was not fully achieved during the first 140 seconds of the FTP, because the original catalyst was not up to efficient operating temperature during this time. In addition, the uncontrolled open-loop fluctuations in exhaust gas air-fuel ratio during the first 140 seconds would not provide an environment for steady control of NO_x. Based on these experiments, a cold-start air injection duration was set for a time of 140 seconds. A limited number of hot-start air injection experiments appeared to result in an increase in NO_x emissions and only a minimal reduction of HC emissions for this vehicle. There was, therefore, no air injection during hot-starts for this demonstration. (Other electrically-heated catalyst applications have shown emission benefits with the use of hot-start air injection.(7)).

CATALYST POWER CONSUMPTION AND TEMPERATURE

The electrical function of the heated catalyst was monitored during a cold-start FTP. During this test, catalyst bed temperature, voltage drop across the catalyst, voltage at the battery, and catalyst electrical current were continuously recorded. Cold-start pre-crank and post-start heating times were 15 seconds and 30 seconds, respectively. As shown in Figure 10, battery-supplied catalyst power drops almost 50 percent by the end of the 30-second post-start heating period. The extreme power loss is most likely due to the undersized second battery placed in series with the original vehicle battery. Table 6 contains the catalyst voltage and current at the start and end of the cold-start heating periods. The catalyst was preheated to a temperature of 520°C in 15 seconds prior to engine starting. The catalyst power is turned off at this time. After about 10-13 seconds (during which time the engine is started) the catalyst bed drops to a temperature of 225°C. At this time, the post-start electrical catalyst heating begins and the temperature of the catalyst bed begins to rise (again). It is noted that the engine-out exhaust gas initially cools the preheated catalyst. This cooling effect is temporary. At some point, the engine-out exhaust gas temperature is able to maintain sufficient catalyst temperature and activity.

Table 6 - Catalyst Power Consumption During Cold-Start

Catalyst Heating	Time, sec.	Catalyst Voltage Drop, volts		Catalyst Current, amps		Power Consumption, watts	
		Max.	Min.	Max.	Min.	Max.	Min.
Pre-Crank[a]	15	18.5	17.3	210	190	3890	3290
Post-Start	30	18.8	13.5	210	150	3950	2030

[a]Maximum pre-crank catalyst temperature is 520°C.

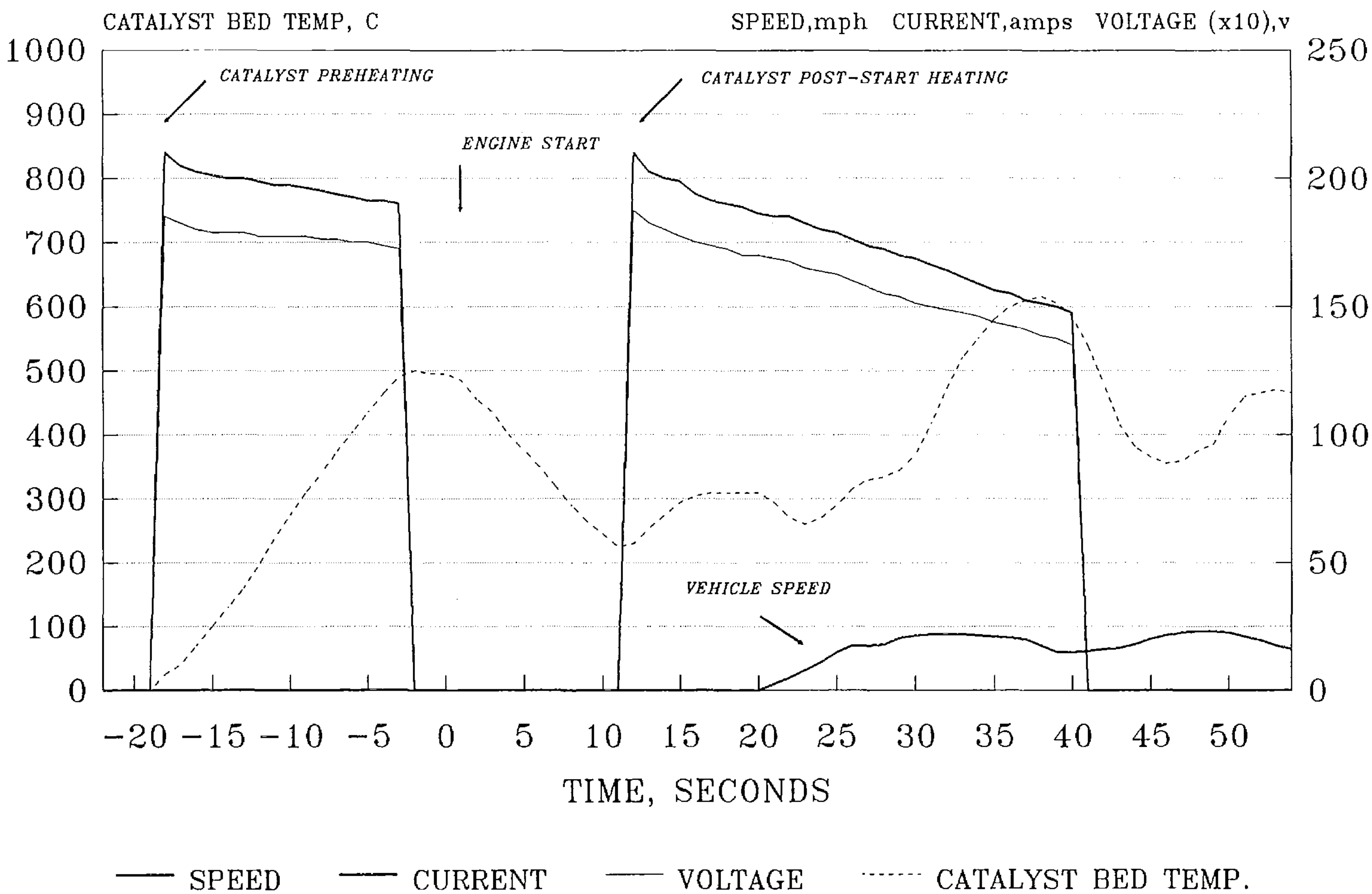


Figure 10 - Catalyst Power Consumption and Temperature

RESULTS AND DISCUSSION

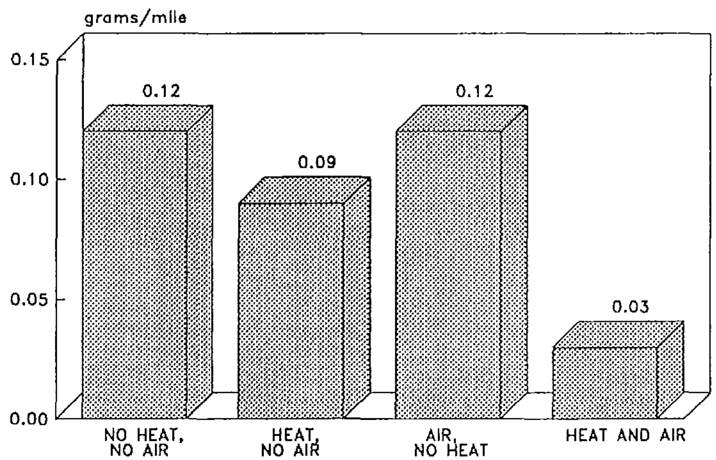
Following the determination of an optimal air injection strategy, final FTP emission tests were conducted on the gasoline-fueled Camry. Benzene and toluene emissions were measured in addition to the regulated emissions (HC, CO, NO_X). FTP emissions for each of the four catalyst preheating and air injection configurations are given in Table 7. The proposed California Emission standards for the ultra-low emission vehicle (ULEV) are also listed in the table. Catalyst preheating combined with air injection produced emissions that were near or at the proposed ULEV standards.

Table 7 - FTP Air Injection and Heated Catalyst Experiments on a Gasoline-Fueled Camry

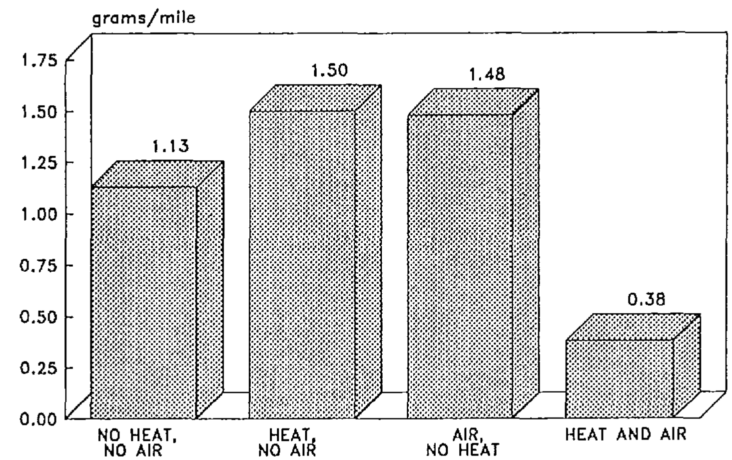
Test Description	FTP Emissions, g/mile					
	THC	NMHC	CO	NO_X	Benzene	Toluene
No Heat, No Air	0.12	0.12	1.13	0.22	0.0078	0.0140
Heat, No Air	0.10	0.09	1.50	0.12	0.0066	0.0091
Air, No Heat	0.13	0.12	1.48	0.23	0.0071	0.0113
Heat and Air	0.07	--	0.40	0.25	--	--
Heat and Air	0.05	0.03	0.35	0.22	0.0017	0.0012
Heat and Air	0.04	0.03	0.49	0.25	0.0038	0.0018
Heat and Air	0.04	0.03	0.26	0.27	0.0022	0.0026
(Average)	**0.05**	**0.03**	**0.38**	**0.25**	**0.0026**	**0.0019**
Proposed California ULEV Standards	--	0.04[a]	1.70	0.20	--	--
[a]Proposed NMOG Standard						

As depicted in Figure 11, the lowest FTP emission rates for HC, CO, benzene, and toluene were achieved with catalyst preheating and secondary air injection. NO_X emissions, however, were minimized with the catalyst preheating alone (no air injection). This is because the heated catalyst was an active NO_X reduction catalyst without the addition of air. The continuous raw exhaust measurements show cold-start engine-out exhaust gas air-fuel ratio to be rich (oxygen low), which is ideal for NO_X conversion in an active catalyst. The NO_X emissions during the air injection experiments (air alone; heat and air) were slightly higher than the no-air baseline. This slight increase in NO_X emissions occurred during the cold transient portion of the FTP, when the secondary air was injected.

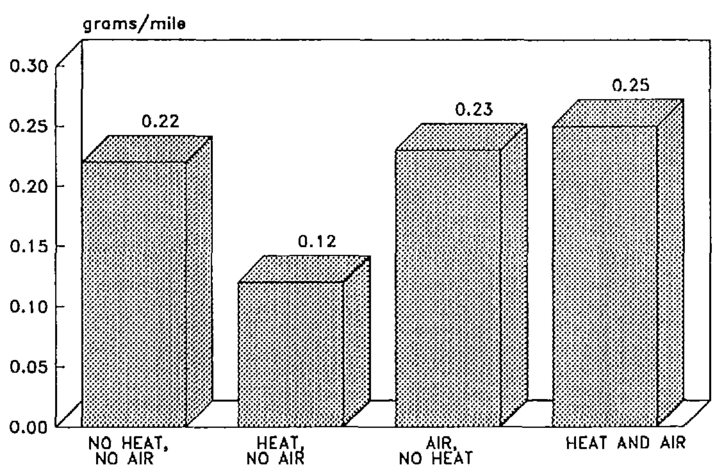
Continuous raw exhaust emissions were monitored for the no-heat-no-air, heat only, air only, and the heat-plus-air catalyst configurations. Raw exhaust hydrocarbon concentrations were of particular interest here. Figure 12 (Graphs A-D) compares the raw tailpipe hydrocarbon concentrations for the four catalyst configurations over the cold-start portion of the FTP (Bag 1A). The hydrocarbon emissions come into control when the catalyst becomes sufficiently active, depicted by a quick (and lasting) decrease in the hydrocarbon tailpipe emission level. Note that the vehicle cold-start with catalyst heating plus air injection (Graph D of Figure 12) resulted in the earliest drop in raw hydrocarbon level (after



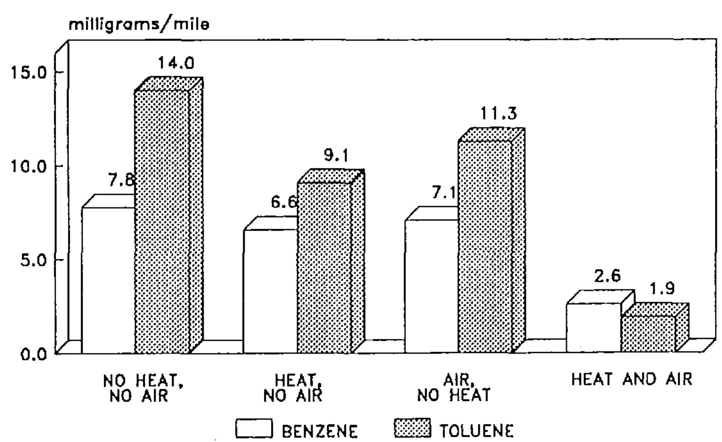
FTP CAMRY NON-METHANE HYDROCARBON EXHAUST EMISSIONS
Air Injection and Preheated Catalyst Experiments



FTP CAMRY CARBON MONOXIDE EXHAUST EMISSIONS
Air Injection and Preheated Catalyst Experiments



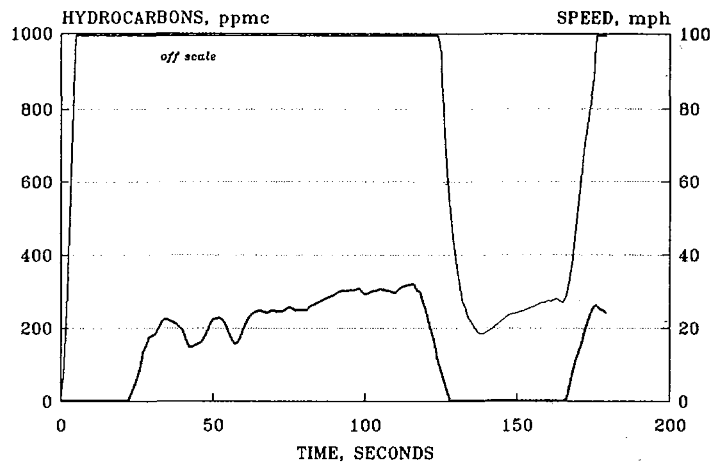
FTP CAMRY NITROGEN OXIDES EXHAUST EMISSIONS
Air Injection and Preheated Catalyst Experiments



FTP CAMRY BENZENE AND TOLUENE EXHAUST EMISSIONS
Air Injection and Preheated Catalyst Experiments

Figure 11 - FTP Camry Exhaust Emissions

TEST NO. TCCAM08U

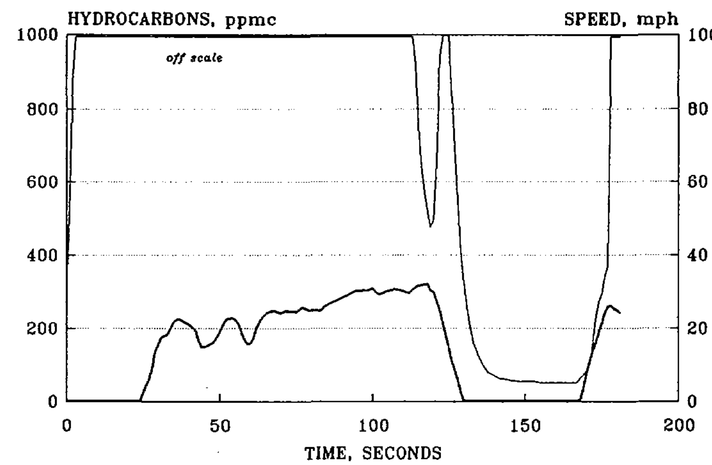


— HC — VEHICLE SPEED
COLD-START RAW EXHAUST HYDROCARBON EMISSIONS
NO HEAT - NO AIR

10/31/89

GRAPH A

TEST NO. TCCAM13H

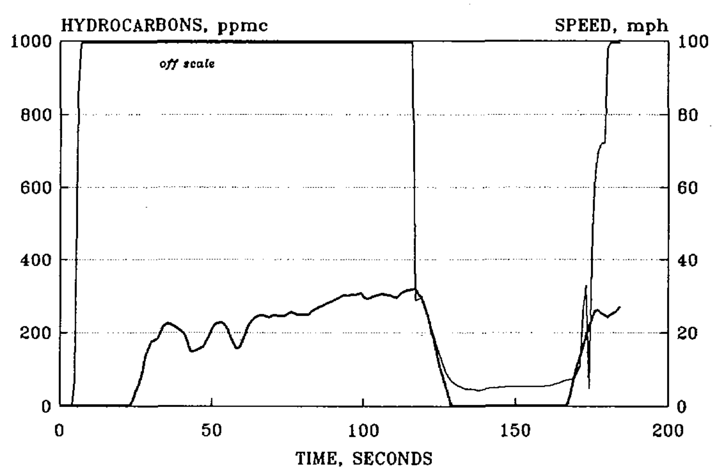


— HC — VEHICLE SPEED
COLD-START RAW EXHAUST HYDROCARBON EMISSIONS
HEAT - NO AIR

11/09/89

GRAPH B

TEST NO. TCCAM08U

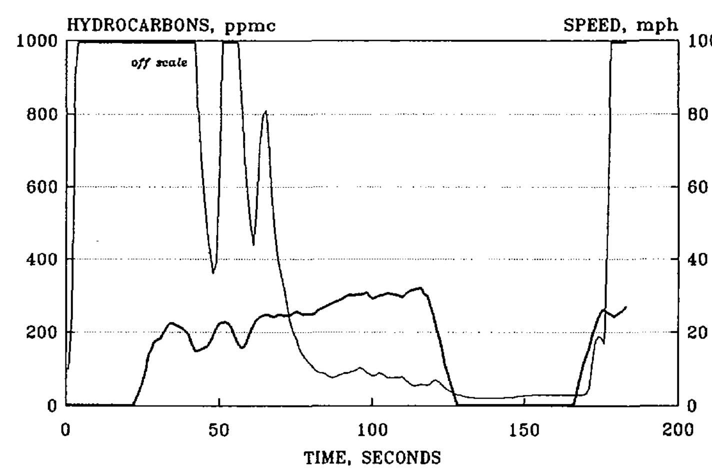


— HC — VEHICLE SPEED
COLD-START RAW EXHAUST HYDROCARBON EMISSIONS
AIR - NO HEAT

11/02/89

GRAPH C

TEST NO. TCCAM07H



— HC — VEHICLE SPEED
COLD - START RAW EXHAUST HYDROCARBON EMISSIONS
HEAT AND AIR

11/01/89

GRAPH D

Figure 12 - Cold-Start Raw Exhaust Hydrocarbon Emissions

the catalyst). The times at which each catalyst configuration came into (subjective) hydrocarbon control are given Table 8. These times correspond to the mass emission rates of the Bags 1A. That is, the longer the time required for the hydrocarbons to come into control, the greater the mass emission rate.

Table 8 - Hydrocarbon Emission Control

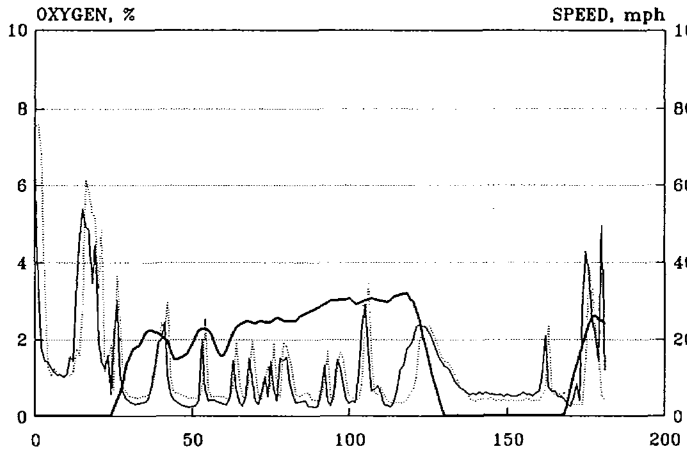
Electrically-Heated Catalyst Configuration	Hydrocarbon Emission Control[a] First Achieved at (sec)
No Heat - No Air	204
Heat Only	134
Air Only	120
Heat plus Air	75
[a]Catalyst-out HC concentration controlled to 150 ppmC	

Oxygen concentrations were measured before and after the underbody electrically-heated catalyst unit for each catalyst configuration and are shown in Figures 13 (Graphs A-D). Recall that during the air injection experiments (air only; heat plus air), the air was injected ahead of the electrically-heated catalyst for 140 seconds into the cold-start. The no-heat-no-air oxygen traces before and after the electrically-heated catalyst (Graph A of Figure 13) show that the exhaust oxygen concentration ranges from 0.5% to 2% for the majority of Bag 1A. By comparison, this range (and mean) is greater than the heat-no-air test in Graph B of Figure 13. It is believed that the lower concentrations of catalyst-out oxygen indicates a consumption of oxygen within the catalyst, probably due to an increase in catalyst activity, following preheating.

Graph C of Figure 13 shows the before and after catalyst oxygen concentration for the air-no-heat experiment. This figure shows the before and after oxygen concentration traces following each other very closely, indicating little consumption of oxygen during most of Bag 1A. This suggests that air injection alone does not significantly increase catalyst activity.

Catalyst preheating plus air injection, shown in Graph D of Figure 13, realizes the greatest gain in catalyst activity, as seen by the oxygen consumption within the catalyst. The difference in oxygen levels between the inlet and outlet of the catalyst indicates oxidation (of hydrocarbons and carbon monoxide) during this period. This is supported by substantially lower hydrocarbon and carbon monoxide mass emissions in Figure 11. A summary of the oxygen content observations is given in Table 9.

TEST NO. TCCAM06U



— O2 BEFORE ····· O2 AFTER — SPEED

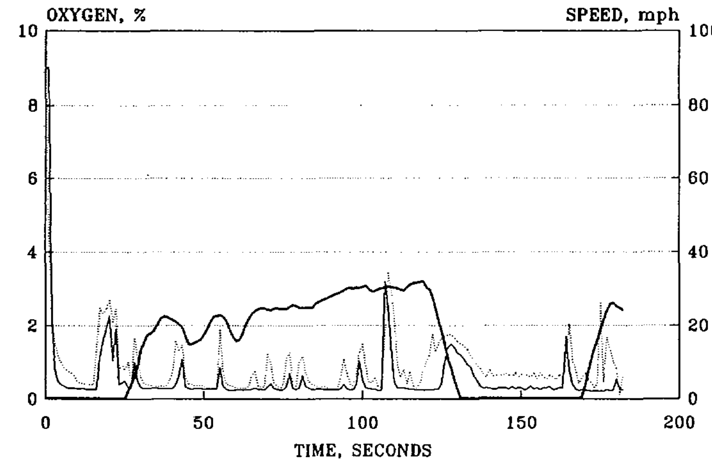
COLD-START OXYGEN BEFORE AND AFTER CATALYST

NO HEAT - NO AIR

10/31/89

GRAPH A

TEST NO. TCCAM13H



— O2 BEFORE ····· O2 AFTER — SPEED

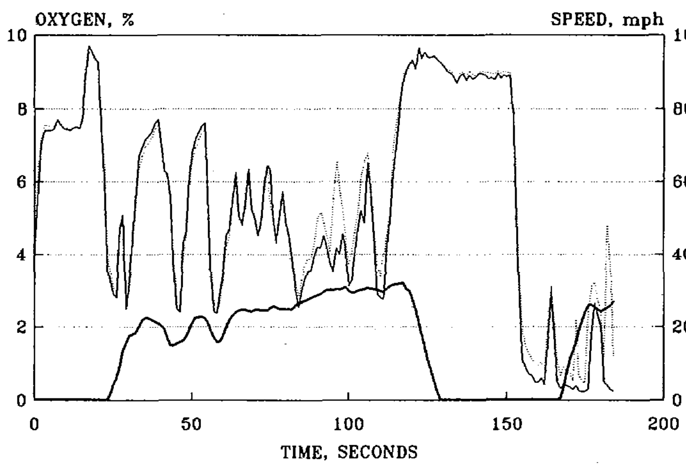
COLD-START OXYGEN BEFORE AND AFTER CATALYST

HEAT - NO AIR

11/09/89

GRAPH B

TEST NO. TCCAM08U



— O2 BEFORE ····· O2 AFTER — SPEED

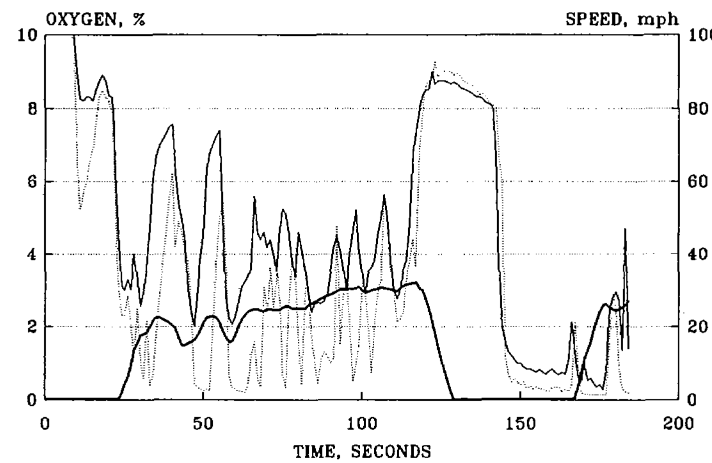
COLD-START OXYGEN BEFORE AND AFTER CATALYST

AIR - NO HEAT

11/02/89

GRAPH C

TEST NO. TCCAM07H



— O2 BEFORE ····· O2 AFTER — SPEED

COLD-START OXYGEN BEFORE AND AFTER CATALYST

HEAT AND AIR

11/01/89

GRAPH D

Figure 13 - Cold-Start Oxygen Before and After the Catalyst

Table 9 - Oxygen Before and After Catalyst Observations

Electrically-Heated Catalyst Configuration	Oxygen Level	Observable Oxygen Consumption	Significant Improvement in Bag 1A Mass Emissions
No Heat - No Air	Low	No	--
Heat - No Air	Low	Possible	No
Air - No Heat	High	No	No
Heat plus Air	High	Yes	Yes

SUMMARY

Based on the results of the gasoline-fueled vehicle experiments, the electrically-heated catalyst with air injection represents a possible control technology for meeting future California emission standards. This study concludes that air injection is required with the electrically-heated catalyst for improved HC and CO control in some applications. Some issues, however, have yet to be studied. For each vehicle application, catalyst heating and air injection strategies will need to be optimized. Battery-related issues such as recharging times and the effect of this energy replacement on fuel economy and exhaust emissions need to be addressed. Vehicle battery specifications are likely to limit heating times and catalyst preheat temperatures. Long-term durability of the preheated catalyst and associated heat and air controls will have to be studied. Development will be necessary to optimize the system for cold-ambient starting conditions. Finally, a consumer-acceptable preheating time will be crucial to the commercial success of such an emission control system.

Emissions from current gasoline-fueled vehicles, although improved greatly over the years, still remain a concern. The electrically-heated catalyst has successfully demonstrated proof-of-concept in the laboratory, but much development work remains to be done. The future of electrically-heated catalyst technology will be determined by emission regulations, and conversely, the future of emission regulations may depend on the electrically-heated catalyst and other cold-start emission control strategies.

ACKNOWLEDGEMENTS

This paper is based on work performed by the Department of Emissions Research at Southwest Research Institute for the SwRI Advisory Committee for Research. The study was titled, "Experimentation to Determine the Feasibility of Air Injection on an Electrically-Heated Catalyst for Reducing Cold-Start Benzene Emissions from Gasoline Vehicles," and identified as SwRI Project No. 08-9574. Need for the SwRI internal research on this subject was identified while performing a program for the State of California Air Resources Board entitled, "Control of Benzene Emissions from Light-Duty Motor Vehicles," SwRI Project No. 08-1815, under ARB Contract No. A732-148. The electrically-heated catalyst was provided by Camet Co. of Hiram, Ohio. The author would like to thank the SwRI personnel who were instrumental in the success of this demonstration.

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APPENDIX I

ELECTRIC AIR PUMP PERFORMANCE DATA

Colt Automotive Products

Electric Air Pump Performance Data

Colt part number: X030174D   Customer part number:

Serial #: 439   Run date: 2/15/90

Volts	Amps	Discharge (in. H_2O)	Pressure (kPa)	Flow (SCFM)	Flow (SLPM)	Discharge Temperature (°F)	Discharge Temperature (°C)	Sound Level 0.0-12.8 kHz (dBa)
13.50	5.30	10.00	2.49	6.79	192.2	108	42	
13.50	5.30	10.00	2.49	6.79	192.2	108	42	
13.50	5.90	20.00	4.98	5.22	147.8	114	46	
13.50	5.90	20.00	4.98	5.22	147.8	114	46	
13.50	6.30	25.00	6.23	4.40	124.7	117	47	61.4
13.50	6.30	25.00	6.23	4.40	124.7	117	47	62.3
13.50	6.50	30.00	7.47	3.67	103.9	122	50	
13.50	6.50	30.00	7.47	3.67	103.9	122	50	
13.50	7.00	40.00	9.97	1.39	39.4	135	57	
13.50	7.00	40.00	9.97	1.39	39.4	135	57	

Colt Automotive Products

Electric Air Pump Performance Data

Colt part number: X030174D

Customer part number:

Serial #: 460

Run date: 2/27/90

Volts	Amps	Discharge (in. H_2O)	Pressure (kPa)	Flow (SCFM)	Flow (SLPM)	Discharge Temperature (°F)	Discharge Temperature (°C)	Sound Level 0.0-12.8 kHz (dBa)
13.50	5.30	10.00	2.49	7.05	199.6	107	42	
13.50	6.10	20.00	4.98	5.53	156.6	113	45	
13.50	6.30	25.00	6.23	4.90	138.6	115	46	55.1
13.50	6.60	30.00	7.47	3.96	112.2	121	49	
13.50	7.30	40.00	9.97	2.03	57.4	134	57	

APPENDIX J

1990 BUICK LESABRE CATALYST CONFIGURATION AND EMISSIONS

TABLE J-1. BUICK LESABRE CATALYST CONFIGURATIONS AND FTP EMISSIONS

TEST DATE	TEST NO.	ODOMETER MILES	TEST DESCRIPTION	AIRFLOW RATE, cfm	AIR INJECTION DURATION, sec.		FUEL	FTP EMISSIONS, g/mile				FUEL ECO. mi/gal	NOTES
					BAG 1A	BAG 3		CO2	HC	CO	NOx		
CARB BASELINE TESTING													
03-09-90	L-OE-0	100	OE-STOCK CATALYST	--	--	--		463.4	0.17	1.36	0.18	19.05	CARB BASELINE TEST
03-13-90	L-OE-00	119	OE-STOCK CATALYST	--	--	--		466.8	0.15	1.08	0.19	18.93	CARB BASELINE TEST
SWRI BASELINE STUDY													
04-18-90	L-OE-01	209	OE-STOCK CATALYST	--	--	--	AS REC'D.	443.2	0.18	1.53	0.15	19.90	SWRI BASELINE TEST
ELECTRICALLY - HEATED CATALYST													
05-16-90	L-H-02	229	HEAT ONLY	--	--	--	EEE	446.9	0.12	1.06	0.13	19.78	OFF-VEHICLE HEAT
05-22-90	L-AH-03	248	HEAT AND AIR	4.7	100	None	EEE	452.8	0.07	0.83	0.15	19.54	OFF-VEHICLE HEAT AND AIR
06-26-90	L-H-04	276	HEAT ONLY	--	--	--	RF-A	435.9	0.07	0.45	0.19	20.33	ON-VEHICLE HEAT
06-27-90	L-VAH-05	296	HEAT AND AIR	V5.9	75	None	RF-A	427.0	0.07	0.33	0.19	20.76	ON-VEHICLE HEAT AND AIR
AIR INJECTION STUDY													
06-29-90	L-AH-06	334	HEAT AND AIR	10.7	75	30	EEE	444.5	0.04	0.18	0.21	19.96	OFF-VEHICLE AIR
06-30-90	L-AH-07	345	HEAT AND AIR	13.0	75	30	EEE	447.2	0.03	0.22	0.18	19.83	OFF-VEHICLE AIR
07-01-90	L-AH-08	358	HEAT ONLY	--	--	--	EEE	459.0	0.08	0.63	0.18	19.31	N0 AIR
07-02-90	L-AH-09	369	HEAT AND AIR	5.9	75	30	EEE	446.5	0.03	0.26	0.21	19.87	OFF-VEHICLE AIR
07-03-90	L-AH-10	382	HEAT AND AIR	10.7	75	30	EEE	447.9	0.04	0.21	0.19	19.80	OFF-VEHICLE AIR
FUEL AND SPECIATION STUDY													
07-10-90	LS-AH-11	404	HEAT AND AIR	10.7	75	30	EEE	446.4	0.06	0.41	0.23	19.86	OFF-VEHICLE AIR
07-11-90	LS-AH-12	417	HEAT AND AIR	10.7	75	30	EEE	453.5	0.05	0.41	0.21	19.55	OFF-VEHICLE AIR
07-12-90	LS-OE-13	437	STOCK CATALYST	--	--	--	EEE	438.4	0.15	1.10	0.15	20.15	STOCK CATALYST ONLY
07-13-90	LS-OE-14	475	STOCK CATALYST	--	--	--	RF-A	429.2	0.15	0.85	0.18	20.59	STOCK CATALYST ONLY
07-14-90	LS-AH-15	488	HEAT AND AIR	10.7	75	30	RF-A	447.6	0.06	0.45	0.20	19.78	OFF-VEHICLE AIR
07-18-90	LS-AH-16	523	HEAT AND AIR	10.7	75	30	RF-A	445.0	0.07	0.45	0.20	19.92	OFF-VEHICLE AIR
VEHICLE SHIPPED TO CARB													

OE - ORIGINAL EQUIPMENT
A - AIR
H - HEAT

V - VEHICLE AIR

EEE - HOWELL EEE
RF-A - NATIONAL AVERAGE

TABLE J-2. BUICK LESABRE TEST SEGMENT EMISSIONS

TEST DATE	TEST NUMBER	TOTAL HYDROCARBONS, g/mi				CARBON MONOXIDE, g/mi				NITROGEN OXIDES, g/ mi				FUEL ECONOMY, mi/gal			
		BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3
CARB BASELINE TESTING																	
03-09-90	L-OE-0																
03-13-90	L-OE-00																
SWRI BASELINE STUDY																	
04-18-90	L-OE-01	2.06	0.08	0.10	0.11	12.74	0.34	1.12	1.44	1.99	0.05	0.00	0.22	14.29	21.26	18.78	22.71
ELECTRICALLY - HEATED CATALYST																	
05-16-90	L-H-02	1.39	0.06	0.05	0.09	8.97	0.17	0.68	1.20	1.55	0.01	0.00	0.26	14.34	21.42	18.58	22.62
05-22-90	L-AH-03	0.39	0.03	0.04	0.10	2.39	0.13	0.77	1.15	2.15	0.01	0.00	0.23	14.10	21.18	18.41	22.16
06-26-90	L-H-04	0.75	0.05	0.03	0.05	7.60	0.10	0.14	0.24	1.77	0.01	0.01	0.44	14.16	21.44	19.33	23.18
06-27-90	L-VAH-05	0.25	0.06	0.06	0.06	0.79	0.21	0.34	0.34	2.34	0.02	0.01	0.32	14.01	21.98	19.81	23.60
AIR INJECTION STUDY																	
06-29-90	L-AH-06	0.29	0.04	0.02	0.03	1.09	0.12	0.17	0.13	2.53	0.02	0.00	0.40	13.43	21.07	19.11	22.57
06-30-90	L-AH-07	0.42	0.03	0.00	0.02	2.92	0.10	0.11	0.11	1.80	0.02	0.00	0.40	13.64	21.20	18.93	22.32
07-01-90	L-AH-08	1.05	0.04	0.02	0.06	9.68	0.13	0.15	0.50	2.24	0.01	0.00	0.32	13.40	19.97	18.39	22.15
07-02-90	L-AH-09	0.36	0.03	0.01	0.03	1.96	0.12	0.22	0.19	2.80	0.01	0.00	0.36	13.68	21.15	18.89	22.61
07-03-90	L-AH-10	0.50	0.03	0.01	0.03	1.22	0.14	0.13	0.28	2.69	0.02	0.00	0.31	13.31	21.15	18.97	22.22
FUEL AND SPECIATION STUDY																	
07-10-90	LS-AH-11	0.46	0.06	0.03	0.07	1.28	0.18	0.27	0.68	2.79	0.02	0.00	0.41	13.07	20.86	19.15	22.29
07-11-90	LS-AH-12	0.42	0.05	0.02	0.04	1.28	0.25	0.39	0.42	2.78	0.01	0.01	0.33	13.46	20.65	18.72	21.99
07-12-90	LS-OE-13	2.40	0.07	0.04	0.10	13.82	0.15	0.45	1.12	2.17	0.02	0.00	0.24	14.60	21.13	19.09	23.06
07-13-90	LS-OE-14	2.03	0.10	0.07	0.07	9.43	0.18	0.56	0.63	1.69	0.04	0.01	0.35	15.09	21.87	19.51	23.34
07-14-90	LS-AH-15	0.48	0.05	0.04	0.04	0.95	0.51	0.33	0.56	2.00	0.07	0.01	0.37	13.92	21.25	19.07	21.65
07-18-90	LS-AH-16	0.37	0.06	0.06	0.06	0.32	0.23	0.52	0.46	2.48	0.02	0.00	0.34	13.45	21.35	18.86	22.81
VEHICLE SHIPPED TO CARB																	

TABLE J-3. BUICK LESABRE—METHANE, BENZENE, AND TOLUENE EMISSIONS

TEST DATE	TEST NUMBER	ODOMETER MILES	TEST DESCRIPTION	METHANE, mg/mi					BENZENE, mg/mi					TOLUENE, mg/mi				
				1A	1B	2	3	FTP	1A	1B	2	3	FTP	1A	1B	2	3	FTP
SWRI BASELINE TESTING																		
04-19-90	L-OE-01	209	OE-STOCK CATALYST	126.4	15.8	22.7			78.7	5.4	6.1			273.9	7.1	6.7		
ELECTRICALLY - HEATED CATALYST																		
05-16-90	L-H-02	229	HEAT ONLY	110.4	10.8				93.5	7.3				176.8	3.7			
05-22-90	L-AH-03	248	HEAT AND AIR	117.8	11.6	16.8	21.9	21.2	15.5	2.2	2.9	9.0	4.9	46.3	5.1	5.4	12.0	8.7

APPENDIX K

1990 BUICK LESABRE
VEHICLE EMISSION RESULTS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS -AS RECD BASELINE
PROJECT 08-1815-001

TEST NO. L-OE-01 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 4/18/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-995-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 336. KM(209. MILES)

BAROMETER 743.46 MM HG(29.27 IN HG)	DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)	
RELATIVE HUMIDITY 61. PCT	ABS. HUMIDITY 10.4 GM/KG	NOX HUMIDITY CORRECTION FACTOR .99

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	787.4 (31.0)		789.9 (31.1)	789.9 (31.1)		789.9 (31.1)
BLOWER INLET P MM. H2O(IN. H2O)	787.4 (31.0)		789.9 (31.1)	789.9 (31.1)		789.9 (31.1)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		41.7 (107.0)	40.0 (104.0)		39.4 (103.0)
BLOWER REVOLUTIONS	11225.		29232.	69329.		40364.
TOT FLOW STD. CU. METRES(SCF)	20.9 (737.)		54.5 (1923.)	129.6 (4575.)		75.5 (2666.)
THC SAMPLE METER/RANGE/PPM	12.4/ 3/ 124.		16.4/ 2/ 16.	14.5/ 2/ 14.		18.2/ 2/ 18.
THC BCKGRD METER/RANGE/PPM	1.0/ 3/ 10.		9.5/ 2/ 9.	10.0/ 2/ 10.		9.5/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	76.4/ 14/ 366.		17.6/ 12/ 17.	30.9/ 12/ 30.		62.5/ 12/ 62.
CO BCKGRD METER/RANGE/PPM	.0/ 14/ 0.		.6/ 12/ 1.	.6/ 12/ 1.		.5/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	59.0/ 1/1.0830		68.1/ 1/1.2537	87.2/ 14/ .8026		96.7/ 14/1.0475
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0459		2.6/ 1/ .0459	12.9/ 14/ .0434		13.1/ 14/ .0442
NOX SAMPLE METER/RANGE/PPM	33.9/ 2/ 33.9		6.1/ 1/ 1.6	.0/ 1/ .0		22.0/ 1/ 5.6
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .2		.3/ 1/ .1	.0/ 1/ .0		.3/ 1/ .1
DILUTION FACTOR	11.85		10.66	16.61		12.70
THC CONCENTRATION PPM	115.		8.	5.		9.
CO CONCENTRATION PPM	351.		16.	29.		59.
CO2 CONCENTRATION PCT	1.0410		1.2121	.7618		1.0067
NOX CONCENTRATION PPM	33.8		1.5	.0		5.5
THC MASS GRAMS	1.38		.24	.38		.41
CO MASS GRAMS	8.54		1.00	4.31		5.18
CO2 MASS GRAMS	398.0		1208.6	1806.9		1391.8
NOX MASS GRAMS	1.34		.16	.00		.79
THC GRAMS/MI	2.06		.08	.10		.11
CO GRAMS/MI	12.74		.34	1.12		1.44
CO2 GRAMS/MI	594.2		416.4	470.0		387.9
NOX GRAMS/MI	1.99		.05	.00		.22
FUEL ECONOMY IN MPG	14.29	19.47	21.26	18.78	20.49	22.71
RUN TIME SECONDS	140.		365.	867.		505.
MEASURED DISTANCE MI	.67	3.57	2.90	3.84	7.43	3.59
SCF, DRY	.970	.969	.969	.973	.972	.971
DFC, WET (DRY)		.909(.891)			.933(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		75.3/ .00			205.1/ .00	

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	743.5
HUMIDITY	G/KG	10.4
TEMPERATURE	DEG C	22.2

		3-BAG
CARBON DIOXIDE	G/MI	443.2
FUEL ECONOMY	MPG	19.90
HYDROCARBONS (THC)	G/MI	.18
CARBON MONOXIDE	G/MI	1.53
OXIDES OF NITROGEN	G/MI	.15

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS -
PROJECT 08-1815-001

TEST NO. L-H-02 RUN 1
VEHICLE MODEL 90 BUICK LESABRE
ENGINE 3.8 L(232. CID) V-6
TRANSMISSION A4

VEHICLE NO.88
DATE 5/16/90
BAG CART NO. 2 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1644. KG(3625. LBS)
ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
GASOLINE EM-995-F
ODOMETER 369. KM(229. MILES)

BAROMETER 736.85 MM HG(29.01 IN HG)
RELATIVE HUMIDITY 62. PCT

DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)
ABS. HUMIDITY 11.0 GM/KG

NOX HUMIDITY CORRECTION FACTOR 1.01

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	764.5 (30.1)		772.2 (30.4)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		769.6 (30.3)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		43.3 (110.0)	41.7 (107.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11207.		29228.	69450.		40470.
TOT FLOW STD. CU. METRES(SCF)	20.7 (731.)		54.0 (1906.)	128.6 (4541.)		74.7 (2638.)
THC SAMPLE METER/RANGE/PPM	90.8/ 2/ 90.		17.3/ 2/ 17.	13.9/ 2/ 14.		19.1/ 2/ 19.
THC BCKGRD METER/RANGE/PPM	12.4/ 2/ 12.		12.5/ 2/ 12.	11.9/ 2/ 12.		12.1/ 2/ 12.
CO SAMPLE METER/RANGE/PPM	58.5/ 14/ 266.		12.7/ 12/ 12.	21.8/ 12/ 21.		53.5/ 12/ 53.
CO BCKGRD METER/RANGE/PPM	1.1/ 14/ 4.		4.3/ 12/ 4.	3.0/ 12/ 3.		1.0/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	60.5/ 1/1.1111		68.8/ 1/1.2669	88.3/ 14/ .8273		97.2/ 14/1.0627
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0459		2.6/ 1/ .0459	12.6/ 14/ .0422		12.3/ 14/ .0411
NOX SAMPLE METER/RANGE/PPM	26.4/ 2/ 26.5		.8/ 1/ .2	.0/ 1/ .0		25.6/ 1/ 6.5
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .3		.1/ 1/ .0	.0/ 1/ .0		.1/ 1/ .0
DILUTION FACTOR	11.70		10.55	16.13		12.53
THC CONCENTRATION PPM	79.		6.	3.		8.
CO CONCENTRATION PPM	251.		8.	18.		50.
CO2 CONCENTRATION PCT	1.0691		1.2253	.7876		1.0249
NOX CONCENTRATION PPM	26.2		.2	.0		6.5
THC MASS GRAMS	.94		.18	.20		.34
CO MASS GRAMS	6.06		.51	2.66		4.33
CO2 MASS GRAMS	405.1		1210.8	1854.6		1401.9
NOX MASS GRAMS	1.05		.02	.00		.93
THC GRAMS/MI	1.39		.06	.05		.09
CO GRAMS/MI	8.97		.17	.68		1.20
CO2 GRAMS/MI	599.9		413.6	476.2		389.9
NOX GRAMS/MI	1.55		.01	.00		.26
FUEL ECONOMY IN MPG	14.34	19.60	21.42	18.58	20.32	22.62
RUN TIME SECONDS	140.		365.	868.		506.
MEASURED DISTANCE MI	.68	3.60	2.93	3.90	7.49	3.60
SCF, DRY	.970	.969	.968	.972	.972	.970
DFC, WET (DRY)		.908(.890)			.931(.913)	
TOT VOL (SCM) / SAM BLR (SCM)		74.7/ .00			203.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-H-02
BAROMETER	MM HG	736.9
HUMIDITY	G/KG	11.0
TEMPERATURE	DEG C	22.8

		3-BAG
CARBON DIOXIDE	G/MI	446.9
FUEL ECONOMY	MPG	19.78
HYDROCARBONS (THC)	G/MI	.12
CARBON MONOXIDE	G/MI	1.06
OXIDES OF NITROGEN	G/MI	.13

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PROJECT 08-1815-001

TEST NO. L-AH-03 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 5/22/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-995-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 399. KM(248. MILES)

BAROMETER 741.17 MM HG(29.18 IN HG) DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY 59. PCT ABS. HUMIDITY 11.2 GM/KG NOX HUMIDITY CORRECTION FACTOR 1.02

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	41.1 (106.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11256.		29309.	69445.		40438.
TOT FLOW STD. CU. METRES(SCF)	20.9 (737.)		54.4 (1922.)	129.4 (4567.)		75.1 (2651.)
THC SAMPLE METER/RANGE/PPM	34.3/ 2/ 34.		15.9/ 2/ 16.	14.6/ 2/ 14.		19.6/ 2/ 19.
THC BCKGRD METER/RANGE/PPM	13.9/ 2/ 14.		14.5/ 2/ 14.	13.2/ 2/ 13.		12.2/ 2/ 12.
CO SAMPLE METER/RANGE/PPM	72.1/ 12/ 72.		9.6/ 12/ 9.	22.6/ 12/ 22.		50.0/ 12/ 49.
CO BCKGRD METER/RANGE/PPM	3.7/ 12/ 4.		3.3/ 12/ 3.	2.0/ 12/ 2.		.6/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	61.4/ 1/1.1280		68.5/ 1/1.2612	87.6/ 14/ .8114		58.0/ 1/1.0643
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0423		2.6/ 1/ .0459	11.9/ 14/ .0395		2.3/ 1/ .0406
NOX SAMPLE METER/RANGE/PPM	35.9/ 2/ 35.9		1.8/ 1/ .5	.2/ 1/ .1		22.6/ 1/ 5.7
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ .5		.5/ 1/ .1	.0/ 1/ .0		.2/ 1/ .1
DILUTION FACTOR	11.77		10.60	16.44		12.51
THC CONCENTRATION PPM	21.		3.	2.		8.
CO CONCENTRATION PPM	66.		6.	19.		47.
CO2 CONCENTRATION PCT	1.0892		1.2197	.7743		1.0270
NOX CONCENTRATION PPM	35.5		.4	.1		5.7
THC MASS GRAMS	.26		.09	.16		.36
CO MASS GRAMS	1.59		.38	2.93		4.09
CO2 MASS GRAMS	416.4		1215.4	1833.7		1411.9
NOX MASS GRAMS	1.44		.04	.01		.83
THC GRAMS/MI	.39		.03	.04		.10
CO GRAMS/MI	2.39		.13	.77		1.15
CO2 GRAMS/MI	623.8		418.5	480.3		398.0
NOX GRAMS/MI	2.15		.01	.00		.23
FUEL ECONOMY IN MPG	14.10	19.36	21.18	18.41	20.05	22.16
RUN TIME SECONDS	141.		366.	868.		505.
MEASURED DISTANCE MI	.67	3.57	2.90	3.82	7.37	3.55
SCF, DRY	.971	.970	.969	.974	.973	.971
DFC, WET (DRY)		.908(.891)			.932(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		75.3/ .00			204.4/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-AH-03
BAROMETER	MM HG	741.2
HUMIDITY	G/KG	11.2
TEMPERATURE	DEG C	23.9

		3-BAG
CARBON DIOXIDE	G/MI	452.8
FUEL ECONOMY	MPG	19.54
HYDROCARBONS (THC)	G/MI	.07
CARBON MONOXIDE	G/MI	.83
OXIDES OF NITROGEN	G/MI	.15

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PROJECT 08-1815-001

TEST NO. L-H-04 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 6/26/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1026-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 444. KM(276. MILES)

BAROMETER 737.87 MM HG(29.05 IN HG) DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY 59. PCT ABS. HUMIDITY 11.2 GM/KG NOX HUMIDITY CORRECTION FACTOR 1.02

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.2 (108.0)	41.1 (106.0)		42.2 (108.0)
BLOWER REVOLUTIONS	11499.		29012.	69458.		40447.
TOT FLOW STD. CU. METRES(SCF)	21.3 (750.)		53.6 (1894.)	128.7 (4546.)		74.8 (2642.)
THC SAMPLE METER/RANGE/PPM	52.6/ 2/ 52.		15.8/ 2/ 16.	12.4/ 2/ 12.		14.2/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	10.8/ 2/ 11.		11.8/ 2/ 12.	11.4/ 2/ 11.		10.8/ 2/ 11.
CO SAMPLE METER/RANGE/PPM	50.2/ 14/ 223.		7.9/ 12/ 8.	6.2/ 12/ 6.		12.1/ 12/ 12.
CO BCKGRD METER/RANGE/PPM	.8/ 14/ 3.		2.8/ 12/ 3.	2.3/ 12/ 2.		1.6/ 12/ 2.
CO2 SAMPLE METER/RANGE/PCT	61.0/ 1/1.1205		69.5/ 1/1.2800	87.0/ 14/ .7982		96.6/ 14/1.0445
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0423		2.4/ 1/ .0423	12.8/ 14/ .0430		12.8/ 14/ .0430
NOX SAMPLE METER/RANGE/PPM	29.5/ 2/ 29.5		2.9/ 1/ .8	1.7/ 1/ .4		44.7/ 1/ 11.2
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .1		2.2/ 1/ .6	1.3/ 1/ .3		1.6/ 1/ .4
DILUTION FACTOR	11.68		10.45	16.75		12.80
THC CONCENTRATION PPM	42.		5.	2.		4.
CO CONCENTRATION PPM	211.		5.	4.		10.
CO2 CONCENTRATION PCT	1.0818		1.2418	.7577		1.0048
NOX CONCENTRATION PPM	29.5		.2	.1		10.8
THC MASS GRAMS	.52		.16	.12		.18
CO MASS GRAMS	5.22		.30	.56		.86
CO2 MASS GRAMS	420.9		1219.5	1785.9		1376.3
NOX MASS GRAMS	1.22		.02	.03		1.58
THC GRAMS/MI	.75		.05	.03		.05
CO GRAMS/MI	7.60		.10	.14		.24
CO2 GRAMS/MI	612.1		413.3	458.5		382.0
NOX GRAMS/MI	1.77		.01	.01		.44
FUEL ECONOMY IN MPG	14.16	19.54	21.44	19.33	21.01	23.18
RUN TIME SECONDS	140.		365.	867.		505.
MEASURED DISTANCE MI	.69	3.64	2.95	3.90	7.50	3.60
SCF, DRY	.971	.970	.969	.974	.973	.971
DFC, WET (DRY)		.907(.890)			.934(.916)	
TOT VOL (SCM) / SAM BLR (SCM)		74.9/ .00			203.6/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-H-04
BAROMETER	MM HG	737.9
HUMIDITY	G/KG	11.2
TEMPERATURE	DEG C	23.9

		3-BAG
CARBON DIOXIDE	G/MI	435.9
FUEL ECONOMY	MPG	20.33
HYDROCARBONS (THC)	G/MI	.07
CARBON MONOXIDE	G/MI	.45
OXIDES OF NITROGEN	G/MI	.19

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TEST NO. L-VAH-05 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 6/27/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1026-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 476. KM(296. MILES)
BAROMETER 737.11 MM HG(29.02 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 46. PCT	ABS. HUMIDITY 9.3 GM/KG	NOX HUMIDITY CORRECTION FACTOR .96

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	774.7 (30.5)		774.7 (30.5)	774.7 (30.5)		774.7 (30.5)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		42.2 (108.0)	41.7 (107.0)		42.2 (108.0)
BLOWER REVOLUTIONS	11209.		29279.	69516.		40498.
TOT FLOW STD. CU. METRES(SCF)	20.7 (731.)		54.1 (1910.)	128.6 (4540.)		74.8 (2642.)
THC SAMPLE METER/RANGE/PPM	23.4/ 2/ 23.		15.0/ 2/ 15.	12.7/ 2/ 13.		14.1/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	9.6/ 2/ 9.		10.1/ 2/ 10.	9.9/ 2/ 10.		10.0/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	24.7/ 12/ 24.		11.7/ 12/ 11.	10.2/ 12/ 10.		15.7/ 12/ 15.
CO BCKGRD METER/RANGE/PPM	.9/ 12/ 1.		1.3/ 12/ 1.	1.0/ 12/ 1.		.9/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	63.5/ 1/1.1673		66.6/ 1/1.2255	42.1/ 1/ .7679		55.5/ 1/1.0176
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0423		2.5/ 1/ .0441	2.4/ 1/ .0423		2.5/ 1/ .0441
NOX SAMPLE METER/RANGE/PPM	42.2/ 2/ 42.2		2.7/ 1/ .7	.7/ 1/ .2		33.6/ 1/ 8.5
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .4		.8/ 1/ .2	.2/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	11.43		10.91	17.40		13.13
THC CONCENTRATION PPM	14.		6.	3.		5.
CO CONCENTRATION PPM	22.		10.	9.		14.
CO2 CONCENTRATION PCT	1.1287		1.1854	.7280		.9769
NOX CONCENTRATION PPM	41.8		.5	.1		8.4
THC MASS GRAMS	.17		.18	.25		.21
CO MASS GRAMS	.54		.61	1.29		1.21
CO2 MASS GRAMS	427.5		1174.1	1713.5		1338.1
NOX MASS GRAMS	1.58		.05	.03		1.15
THC GRAMS/MI	.25		.06	.06		.06
CO GRAMS/MI	.79		.21	.34		.34
CO2 GRAMS/MI	630.7		402.9	447.0		375.1
NOX GRAMS/MI	2.34		.02	.01		.32
FUEL ECONOMY IN MPG	14.01	19.85	21.98	19.81	21.47	23.60
RUN TIME SECONDS	140.		365.	868.		506.
MEASURED DISTANCE MI	.68	3.59	2.91	3.83	7.40	3.57
SCF, DRY	.974	.974	.974	.978	.977	.976
DFC, WET (DRY)		.910(.896)			.936(.922)	
TOT VOL (SCM) / SAM BLR (SCM)		74.8/ .00			203.4/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-VAH05
BAROMETER	MM HG	737.1
HUMIDITY	G/KG	9.3
TEMPERATURE	DEG C	25.0

		3-BAG
CARBON DIOXIDE	G/MI	427.0
FUEL ECONOMY	MPG	20.76
HYDROCARBONS (THC)	G/MI	.07
CARBON MONOXIDE	G/MI	.33
OXIDES OF NITROGEN	G/MI	.19

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TEST NO. L-AH-06 RUN 1	VEHICLE NO. 88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 6/29/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-995-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 538. KM(334. MILES)

BAROMETER 739.39 MM HG(29.11 IN HG) — DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
RELATIVE HUMIDITY 45. PCT — ABS. HUMIDITY 8.9 GM/KG — NOX HUMIDITY CORRECTION FACTOR .94

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	767.1 (30.2)		767.1 (30.2)	769.6 (30.3)		769.6 (30.3)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	40.6 (105.0)		42.2 (108.0)	41.7 (107.0)		41.7 (107.0)
BLOWER REVOLUTIONS	11208.		29259.	69410.		40492.
TOT FLOW STD. CU. METRES(SCF)	20.9 (737.)		54.3 (1918.)	129.0 (4555.)		75.3 (2657.)
THC SAMPLE METER/RANGE/PPM	25.5/ 2/ 25.		12.5/ 2/ 12.	10.5/ 2/ 10.		11.8/ 2/ 12.
THC BCKGRD METER/RANGE/PPM	9.7/ 2/ 10.		9.8/ 2/ 10.	10.0/ 2/ 10.		9.8/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	32.3/ 12/ 32.		6.1/ 12/ 6.	4.9/ 12/ 5.		5.8/ 12/ 6.
CO BCKGRD METER/RANGE/PPM	.2/ 12/ 0.		.1/ 12/ 0.	.3/ 12/ 0.		.2/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	65.2/ 1/1.1992		69.2/ 1/1.2744	87.2/ 14/ .8026		97.1/ 14/1.0596
CO2 BCKGRD METER/RANGE/PCT	2.3/ 1/ .0406		2.5/ 1/ .0441	13.5/ 14/ .0458		12.0/ 14/ .0399
NOX SAMPLE METER/RANGE/PPM	45.8/ 2/ 45.8		3.0/ 1/ .8	.0/ 1/ .0		41.9/ 1/ 10.5
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .4		.6/ 1/ .2	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	11.12		10.50	16.67		12.63
THC CONCENTRATION PPM	16.		4.	1.		3.
CO CONCENTRATION PPM	30.		6.	4.		5.
CO2 CONCENTRATION PCT	1.1623		1.2345	.7595		1.0229
NOX CONCENTRATION PPM	45.4		.6	.0		10.5
THC MASS GRAMS	.20		.11	.08		.12
CO MASS GRAMS	.73		.35	.64		.45
CO2 MASS GRAMS	444.3		1228.0	1793.9		1409.4
NOX MASS GRAMS	1.71		.06	.00		1.43
THC GRAMS/MI	.29		.04	.02		.03
CO GRAMS/MI	1.09		.12	.17		.13
CO2 GRAMS/MI	657.5		420.5	463.8		392.6
NOX GRAMS/MI	2.53		.02	.00		.40
FUEL ECONOMY IN MPG	13.43	19.04	21.07	19.11	20.63	22.57
RUN TIME SECONDS	140.		366.	868.		506.
MEASURED DISTANCE MI	.68	3.60	2.92	3.87	7.46	3.59
SCF, DRY	.974	.974	.974	.978	.977	.976
DFC, WET (DRY)		.906(.893)			.933(.919)	
TOT VOL (SCM) / SAM BLR (SCM)		75.2/ .00			204.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-AH-06
BAROMETER	MM HG	739.4
HUMIDITY	G/KG	8.9
TEMPERATURE	DEG C	24.4

		3-BAG
CARBON DIOXIDE	G/MI	444.5
FUEL ECONOMY	MPG	19.96
HYDROCARBONS (THC)	G/MI	.04
CARBON MONOXIDE	G/MI	.18
OXIDES OF NITROGEN	G/MI	.21

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TEST NO. L-AH-07 RUN 1	VEHICLE NO. 88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 6/30/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-995-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 555. KM(345. MILES)

BAROMETER 742.70 MM HG(29.24 IN HG) DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)
RELATIVE HUMIDITY 58. PCT ABS. HUMIDITY 10.2 GM/KG NOX HUMIDITY CORRECTION FACTOR .98

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	767.1 (30.2)		774.7 (30.5)	777.2 (30.6)		782.3 (30.8)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		767.1 (30.2)	769.6 (30.3)		772.2 (30.4)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		41.7 (107.0)	40.0 (104.0)		41.7 (107.0)
BLOWER REVOLUTIONS	11240.		29328.	69571.		40487.
TOT FLOW STD. CU. METRES(SCF)	20.9 (739.)		54.7 (1933.)	130.2 (4598.)		75.5 (2666.)
THC SAMPLE METER/RANGE/PPM	34.0/ 2/ 34.		13.6/ 2/ 13.	11.6/ 2/ 11.		12.9/ 2/ 13.
THC BCKGRD METER/RANGE/PPM	11.7/ 2/ 12.		12.3/ 2/ 12.	12.1/ 2/ 12.		11.9/ 2/ 12.
CO SAMPLE METER/RANGE/PPM	84.1/ 12/ 84.		5.5/ 12/ 5.	3.4/ 12/ 3.		5.3/ 12/ 5.
CO BCKGRD METER/RANGE/PPM	.7/ 12/ 1.		.4/ 12/ 0.	.5/ 12/ 0.		.5/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	63.1/ 1/1.1598		67.6/ 1/1.2443	86.9/ 14/ .7960		97.3/ 14/1.0658
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0388		2.4/ 1/ .0423	11.9/ 14/ .0395		12.0/ 14/ .0399
NOX SAMPLE METER/RANGE/PPM	30.8/ 2/ 30.8		2.2/ 1/ .6	.0/ 1/ .0		39.9/ 1/ 10.0
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .3		.3/ 1/ .1	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	11.44		10.75	16.80		12.55
THC CONCENTRATION PPM	23.		2.	0.		2.
CO CONCENTRATION PPM	80.		5.	3.		4.
CO2 CONCENTRATION PCT	1.1244		1.2059	.7588		1.0290
NOX CONCENTRATION PPM	30.6		.5	.0		10.0
THC MASS GRAMS	.28		.08	.02		.08
CO MASS GRAMS	1.95		.30	.41		.39
CO2 MASS GRAMS	431.0		1208.7	1809.1		1422.7
NOX MASS GRAMS	1.20		.05	.00		1.42
THC GRAMS/MI	.42		.03	.00		.02
CO GRAMS/MI	2.92		.10	.11		.11
CO2 GRAMS/MI	644.4		418.0	468.4		397.1
NOX GRAMS/MI	1.80		.02	.00		.40
FUEL ECONOMY IN MPG	13.64	19.20	21.20	18.93	20.42	22.32
RUN TIME SECONDS	140.		366.	868.		505.
MEASURED DISTANCE MI	.67	3.56	2.89	3.86	7.45	3.58
SCF, DRY	.971	.970	.970	.974	.973	.972
DFC, WET (DRY)		.909(.892)			.933(.916)	
TOT VOL (SCM) / SAM BLR (SCM)		75.7/ .00			205.7/ .00	

COMPOSITE RESULTS

TEST NUMBER		L-AH-07
BAROMETER	MM HG	742.7
HUMIDITY	G/KG	10.2
TEMPERATURE	DEG C	22.8

		3-BAG
CARBON DIOXIDE	G/MI	447.2
FUEL ECONOMY	MPG	19.83
HYDROCARBONS (THC)	G/MI	.03
CARBON MONOXIDE	G/MI	.22
OXIDES OF NITROGEN	G/MI	.18

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TEST NO. L-AH-08 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/ 1/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1035-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 576. KM(358. MILES)
BAROMETER 743.71 MM HG(29.28 IN HG)	DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)	
RELATIVE HUMIDITY 65. PCT	ABS. HUMIDITY 11.6 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.03

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	769.6 (30.3)		772.2 (30.4)	772.2 (30.4)		772.2 (30.4)
BLOWER INLET P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		42.2 (108.0)	41.1 (106.0)		42.2 (108.0)
BLOWER REVOLUTIONS	11223.		29283.	69495.		40486.
TOT FLOW STD. CU. METRES(SCF)	21.0 (740.)		54.7 (1932.)	130.1 (4595.)		75.7 (2671.)
THC SAMPLE METER/RANGE/PPM	70.1/ 2/ 69.		12.8/ 2/ 13.	10.2/ 2/ 10.		14.1/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	9.6/ 2/ 9.		9.7/ 2/ 10.	9.7/ 2/ 10.		9.4/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	62.9/ 14/ 290.		6.8/ 12/ 7.	4.3/ 12/ 4.		22.9/ 12/ 22.
CO BCKGRD METER/RANGE/PPM	.0/ 14/ 0.		.2/ 12/ 0.	.0/ 12/ 0.		.2/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	65.8/ 1/1.2105		72.1/ 1/1.3290	88.0/ 14/ .8204		96.6/ 14/1.1069
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0441		2.5/ 1/ .0441	11.7/ 14/ .0388		11.8/ 14/ .0391
NOX SAMPLE METER/RANGE/PPM	38.0/ 2/ 38.0		1.5/ 1/ .4	.3/ 1/ .1		31.9/ 1/ 8.0
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .1		.0/ 1/ .0	.1/ 1/ .0		.3/ 1/ .1
DILUTION FACTOR	10.76		10.07	16.30		12.07
THC CONCENTRATION PPM	61.		4.	1.		5.
CO CONCENTRATION PPM	277.		6.	4.		21.
CO2 CONCENTRATION PCT	1.1705		1.2893	.7841		1.0710
NOX CONCENTRATION PPM	37.9		.4	.1		8.0
THC MASS GRAMS	.73		.13	.08		.24
CO MASS GRAMS	6.76		.38	.60		1.86
CO2 MASS GRAMS	449.0		1291.8	1868.0		1483.4
NOX MASS GRAMS	1.57		.04	.01		1.19
THC GRAMS/MI	1.05		.04	.02		.06
CO GRAMS/MI	9.68		.13	.15		.50
CO2 GRAMS/MI	643.0		443.8	482.0		399.3
NOX GRAMS/MI	2.24		.01	.00		.32
FUEL ECONOMY IN MPG	13.40	18.24	19.97	18.39	20.05	22.15
RUN TIME SECONDS	140.		366.	868.		506.
MEASURED DISTANCE MI	.70	3.61	2.91	3.88	7.59	3.71
SCF, DRY	.968	.967	.967	.971	.970	.969
DFC, WET (DRY)		.902(.883)			.931(.911)	
TOT VOL (SCM) / SAM BLR (SCM)		75.7/ .00			205.8/ .00	

COMPOSITE RESULTS

					3-BAG
TEST NUMBER		L-AH-08	CARBON DIOXIDE	G/MI	459.0
BAROMETER	MM HG	743.7	FUEL ECONOMY	MPG	19.31
HUMIDITY	G/KG	11.6	HYDROCARBONS (THC)	G/MI	.08
TEMPERATURE	DEG C	22.8	CARBON MONOXIDE	G/MI	.63
			OXIDES OF NITROGEN	G/MI	.18

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TEST NO. L-AH-09 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/ 2/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1035-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 594. KM(369. MILES)

BAROMETER 737.87 MM HG(29.05 IN HG)	DRY BULB TEMP. 27.2 DEG C(81.0 DEG F)	
RELATIVE HUMIDITY 39. PCT	ABS. HUMIDITY 9.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR .95

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	772.2 (30.4)		762.0 (30.0)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		756.9 (29.8)	762.0 (30.0)		756.9 (29.8)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	41.7 (107.0)		42.2 (108.0)
BLOWER REVOLUTIONS	11218.		29190.	69383.		40468.
TOT FLOW STD. CU. METRES(SCF)	20.8 (733.)		54.1 (1909.)	128.6 (4543.)		75.0 (2649.)
THC SAMPLE METER/RANGE/PPM	28.3/ 2/ 28.		12.0/ 2/ 12.	9.4/ 2/ 9.		11.2/ 2/ 11.
THC BCKGRD METER/RANGE/PPM	8.3/ 2/ 8.		9.7/ 2/ 10.	9.6/ 2/ 9.		9.3/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	26.2/ 13/ 60.		8.0/ 12/ 8.	7.9/ 12/ 8.		9.6/ 12/ 9.
CO BCKGRD METER/RANGE/PPM	1.0/ 13/ 2.		2.3/ 12/ 2.	1.9/ 12/ 2.		1.2/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	65.6/ 1/1.2067		70.2/ 1/1.2932	87.7/ 14/ .8137		97.1/ 14/1.0596
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0441		2.7/ 1/ .0476	12.0/ 14/ .0399		12.2/ 14/ .0407
NOX SAMPLE METER/RANGE/PPM	51.3/ 2/ 51.3		1.6/ 1/ .4	.3/ 1/ .1		38.0/ 1/ 9.6
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .1		.1/ 1/ .0	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	11.03		10.35	16.43		12.62
THC CONCENTRATION PPM	21.		3.	0.		3.
CO CONCENTRATION PPM	56.		5.	6.		8.
CO2 CONCENTRATION PCT	1.1666		1.2502	.7762		1.0222
NOX CONCENTRATION PPM	51.2		.4	.1		9.6
THC MASS GRAMS	.25		.10	.03		.11
CO MASS GRAMS	1.35		.34	.85		.69
CO2 MASS GRAMS	443.4		1237.5	1828.2		1404.1
NOX MASS GRAMS	1.93		.04	.02		1.30
THC GRAMS/MI	.36		.03	.01		.03
CO GRAMS/MI	1.96		.12	.22		.19
CO2 GRAMS/MI	643.9		419.0	469.2		391.8
NOX GRAMS/MI	2.80		.01	.00		.36
FUEL ECONOMY IN MPG	13.68	19.17	21.15	18.89	20.50	22.61
RUN TIME SECONDS	140.		365.	868.		506.
MEASURED DISTANCE MI	.69	3.64	2.95	3.90	7.48	3.58
SCF, DRY	.976	.976	.975	.980	.979	.978
DFC, WET (DRY)		.905(.894)			.932(.921)	
TOT VOL (SCM) / SAM BLR (SCM)		74.8/ .00			203.7/ .00	

MPOSITE RESULTS

TEST NUMBER		L-AH-09
BAROMETER	MM HG	737.9
HUMIDITY	G/KG	9.1
TEMPERATURE	DEG C	27.2

		3-BAG
CARBON DIOXIDE	G/MI	446.5
FUEL ECONOMY	MPG	19.87
HYDROCARBONS (THC)	G/MI	.03
CARBON MONOXIDE	G/MI	.26
OXIDES OF NITROGEN	G/MI	.21

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TEST NO. L-AH-10 RUN 1 | VEHICLE NO.88 | TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE | DATE 7/ 3/90 | ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6 | BAG CART NO. 2 / CVS NO. 2 | GASOLINE EM-1035-F
TRANSMISSION A4 | DYNO NO. 3 | ODOMETER 615. KM(382. MILES)

BAROMETER 736.85 MM HG(29.01 IN HG) | DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)
RELATIVE HUMIDITY 40. PCT | ABS. HUMIDITY 7.4 GM/KG | NOX HUMIDITY CORRECTION FACTOR .90

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		774.7 (30.5)	767.1 (30.2)		762.0 (30.0)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		767.1 (30.2)	762.0 (30.0)		756.9 (29.8)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		46.1 (115.0)	40.6 (105.0)		42.2 (108.0)
BLOWER REVOLUTIONS	11212.		29226.	69396.		40479.
TOT FLOW STD. CU. METRES(SCF)	20.8 (734.)		53.9 (1905.)	128.8 (4547.)		74.9 (2646.)
THC SAMPLE METER/RANGE/PPM	37.7/ 2/ 37.		12.5/ 2/ 12.	9.6/ 2/ 9.		12.2/ 2/ 12.
THC BCKGRD METER/RANGE/PPM	10.7/ 2/ 11.		11.0/ 2/ 11.	9.6/ 2/ 9.		10.3/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	36.2/ 12/ 35.		7.5/ 12/ 7.	4.3/ 12/ 4.		12.9/ 12/ 12.
CO BCKGRD METER/RANGE/PPM	.6/ 12/ 1.		.8/ 12/ 1.	.8/ 12/ 1.		.7/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	65.6/ 1/1.2067		69.0/ 1/1.2706	87.2/ 14/ .8026		97.3/ 14/1.0658
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0459		2.6/ 1/ .0459	12.8/ 14/ .0430		12.9/ 14/ .0434
NOX SAMPLE METER/RANGE/PPM	50.3/ 2/ 50.3		2.1/ 1/ .6	.0/ 1/ .0		33.3/ 1/ 8.4
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .2		.3/ 1/ .1	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	11.04		10.53	16.67		12.54
THC CONCENTRATION PPM	28.		3.	1.		3.
CO CONCENTRATION PPM	34.		6.	3.		11.
CO2 CONCENTRATION PCT	1.1650		1.2291	.7621		1.0258
NOX CONCENTRATION PPM	50.1		.5	.0		8.4
THC MASS GRAMS	.33		.08	.04		.12
CO MASS GRAMS	.81		.39	.49		1.00
CO2 MASS GRAMS	443.2		1214.0	1796.7		1407.4
NOX MASS GRAMS	1.80		.04	.00		1.09
THC GRAMS/MI	.50		.03	.01		.03
CO GRAMS/MI	1.22		.14	.13		.28
CO2 GRAMS/MI	663.0		419.0	467.1		398.6
NOX GRAMS/MI	2.69		.02	.00		.31
FUEL ECONOMY IN MPG	13.31	19.04	21.15	18.97	20.40	22.22
RUN TIME SECONDS	140.		365.	867.		506.
MEASURED DISTANCE MI	.67	3.57	2.90	3.85	7.38	3.53
SCF, DRY	.976	.975	.975	.980	.979	.977
DFC, WET (DRY)		.906(.894)			.933(.921)	
TOT VOL (SCM) / SAM BLR (SCM)		74.7/ .00			203.7/ .00	

COMPOSITE RESULTS

TEST NUMBER L-AH-10
BAROMETER MM HG 736.9
HUMIDITY G/KG 7.4
TEMPERATURE DEG C 23.3

		3-BAG
CARBON DIOXIDE	G/MI	447.9
FUEL ECONOMY	MPG	19.80
HYDROCARBONS (THC)	G/MI	.04
CARBON MONOXIDE	G/MI	.21
OXIDES OF NITROGEN	G/MI	.19

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TEST NO. LS-AH-11 RUN 1
VEHICLE MODEL 90 BUICK LESABRE
ENGINE 3.8 L(232. CID) V-6
TRANSMISSION A4

VEHICLE NO.88
DATE 7/10/90
BAG CART NO. 2 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1644. KG(3625. LBS)
ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
GASOLINE EM-995-F
ODOMETER 650. KM(404. MILES)

BAROMETER 739.65 MM HG(29.12 IN HG)
RELATIVE HUMIDITY 47. PCT

DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)
ABS. HUMIDITY 10.2 GM/KG

NOX HUMIDITY CORRECTION FACTOR .98

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	787.4 (31.0)		769.6 (30.3)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		759.5 (29.9)	762.0 (30.0)		759.5 (29.9)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	42.8 (109.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11210.		29218.	69410.		40447.
TOT FLOW STD. CU. METRES(SCF)	20.8 (734.)		54.2 (1915.)	128.7 (4545.)		75.1 (2651.)
THC SAMPLE METER/RANGE/PPM	35.9/ 2/ 36.		16.0/ 2/ 16.	11.6/ 2/ 12.		14.9/ 2/ 15.
THC BCKGRD METER/RANGE/PPM	11.0/ 2/ 11.		11.5/ 2/ 11.	10.9/ 2/ 11.		9.7/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	38.5/ 12/ 38.		9.6/ 12/ 9.	7.9/ 12/ 8.		30.0/ 12/ 29.
CO BCKGRD METER/RANGE/PPM	.8/ 12/ 1.		.5/ 12/ 0.	.3/ 12/ 0.		.5/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	67.1/ 1/1.2349		69.7/ 1/1.2838	87.0/ 14/ .7982		97.6/ 14/1.0751
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0423		2.6/ 1/ .0459	12.6/ 14/ .0422		12.5/ 14/ .0418
NOX SAMPLE METER/RANGE/PPM	48.4/ 2/ 48.4		2.5/ 1/ .7	.3/ 1/ .1		42.1/ 1/ 10.6
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .3		.6/ 1/ .2	.1/ 1/ .0		.3/ 1/ .1
DILUTION FACTOR	10.79		10.42	16.75		12.41
THC CONCENTRATION PPM	26.		6.	1.		6.
CO CONCENTRATION PPM	36.		8.	7.		28.
CO2 CONCENTRATION PCT	1.1965		1.2423	.7584		1.0366
NOX CONCENTRATION PPM	48.1		.5	.1		10.5
THC MASS GRAMS	.31		.18	.10		.26
CO MASS GRAMS	.86		.53	1.06		2.43
CO2 MASS GRAMS	455.6		1233.9	1787.3		1424.8
NOX MASS GRAMS	1.88		.05	.01		1.48
THC GRAMS/MI	.46		.06	.03		.07
CO GRAMS/MI	1.28		.18	.27		.68
CO2 GRAMS/MI	675.1		424.7	462.6		396.5
NOX GRAMS/MI	2.79		.02	.00		.41
FUEL ECONOMY IN MPG	13.07	18.75	20.86	19.15	20.54	22.29
RUN TIME SECONDS	140.		365.	868.		506.
MEASURED DISTANCE MI	.67	3.58	2.91	3.86	7.46	3.59
SCF, DRY	.973	.973	.973	.977	.976	.975
DFC, WET (DRY)		.905(.891)			.933(.918)	
TOT VOL (SCM) / SAM BLR (SCM)		75.0/ .00			203.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		LS-AH-11
BAROMETER	MM HG	739.6
HUMIDITY	G/KG	10.2
TEMPERATURE	DEG C	26.1

		3-BAG
CARBON DIOXIDE	G/MI	446.4
FUEL ECONOMY	MPG	19.86
HYDROCARBONS (THC)	G/MI	.06
CARBON MONOXIDE	G/MI	.41
OXIDES OF NITROGEN	G/MI	.23

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TEST NO. LS-AH-12 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/11/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-995-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 671. KM(417. MILES)
BAROMETER 739.14 MM HG(29.10 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 43. PCT	ABS. HUMIDITY 9.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR .95

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		767.1 (30.2)	762.0 (30.0)		764.5 (30.1)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		762.0 (30.0)	756.9 (29.8)		756.9 (29.8)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	42.8 (109.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11218.		29183.	69447.		40377.
TOT FLOW STD. CU. METRES(SCF)	20.8 (734.)		54.1 (1911.)	128.9 (4551.)		74.9 (2646.)
THC SAMPLE METER/RANGE/PPM	32.8/ 2/ 33.		13.5/ 2/ 13.	10.7/ 2/ 11.		12.0/ 2/ 12.
THC BCKGRD METER/RANGE/PPM	9.5/ 2/ 9.		9.9/ 2/ 10.	10.2/ 2/ 10.		9.3/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	40.5/ 12/ 40.		14.2/ 12/ 14.	12.3/ 12/ 12.		19.3/ 12/ 19.
CO BCKGRD METER/RANGE/PPM	2.3/ 12/ 2.		2.1/ 12/ 2.	1.6/ 12/ 2.		.9/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	66.6/ 1/1.2255		71.1/ 1/1.3102	88.3/ 14/ .8273		98.4/ 14/1.1004
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0494		2.7/ 1/ .0476	13.5/ 14/ .0458		12.9/ 14/ .0434
NOX SAMPLE METER/RANGE/PPM	51.0/ 2/ 51.0		2.8/ 1/ .7	1.3/ 1/ .3		35.1/ 1/ 8.8
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ .5		1.3/ 1/ .3	.8/ 1/ .2		.5/ 1/ .1
DILUTION FACTOR	10.87		10.21	16.15		12.14
THC CONCENTRATION PPM	24.		5.	1.		3.
CO CONCENTRATION PPM	36.		11.	10.		17.
CO2 CONCENTRATION PCT	1.1806		1.2672	.7843		1.0606
NOX CONCENTRATION PPM	50.5		.4	.1		8.7
THC MASS GRAMS	.29		.14	.08		.15
CO MASS GRAMS	.88		.72	1.51		1.51
CO2 MASS GRAMS	449.6		1255.6	1850.6		1454.8
NOX MASS GRAMS	1.91		.04	.03		1.19
THC GRAMS/MI	.42		.05	.02		.04
CO GRAMS/MI	1.28		.25	.39		.42
CO2 GRAMS/MI	655.4		428.8	473.0		402.5
NOX GRAMS/MI	2.78		.01	.01		.33
FUEL ECONOMY IN MPG	13.46	18.75	20.65	18.72	20.16	21.99
RUN TIME SECONDS	140.		364.	868.		505.
MEASURED DISTANCE MI	.69	3.61	2.93	3.91	7.53	3.61
SCF, DRY	.975	.974	.974	.978	.977	.976
DFC, WET (DRY)		.904(.891)			.931(.918)	
TOT VOL (SCM) / SAM BLR (SCM)		74.9/ .00			203.8/ .00	

COMPOSITE RESULTS

TEST NUMBER	LS-AH-12
BAROMETER MM HG	739.1
HUMIDITY G/KG	9.1
TEMPERATURE DEG C	25.6

		3-BAG
CARBON DIOXIDE	G/MI	453.5
FUEL ECONOMY	MPG	19.55
HYDROCARBONS (THC)	G/MI	.05
CARBON MONOXIDE	G/MI	.41
OXIDES OF NITROGEN	G/MI	.21

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TEST NO. LS-OE-13 RUN 1
VEHICLE MODEL 90 BUICK LESABRE
ENGINE 3.8 L(232. CID) V-6
TRANSMISSION A4

VEHICLE NO.88
DATE 7/12/90
BAG CART NO. 2 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1644. KG(3625. LBS)
ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
GASOLINE EM-1035-F
ODOMETER 703. KM(437. MILES)

BAROMETER 741.68 MM HG(29.20 IN HG)
RELATIVE HUMIDITY 61. PCT

DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)
ABS. HUMIDITY 10.9 GM/KG

NOX HUMIDITY CORRECTION FACTOR 1.01

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		762.0 (30.0)	762.0 (30.0)		767.1 (30.2)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		756.9 (29.8)	756.9 (29.8)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	42.8 (109.0)		43.3 (110.0)
BLOWER REVOLUTIONS	11212.		29213.	69433.		40431.
TOT FLOW STD. CU. METRES(SCF)	20.9 (737.)		54.4 (1922.)	129.3 (4567.)		75.2 (2655.)
THC SAMPLE METER/RANGE/PPM	14.2/ 3/ 142.		13.5/ 2/ 13.	9.6/ 2/ 10.		16.0/ 2/ 16.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		7.4/ 2/ 7.	8.1/ 2/ 8.		8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	82.3/ 14/ 400.		8.2/ 12/ 8.	13.0/ 12/ 13.		49.1/ 12/ 48.
CO BCKGRD METER/RANGE/PPM	.4/ 14/ 2.		.6/ 12/ 1.	.7/ 12/ 1.		.5/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	57.4/ 1/1.0531		67.8/ 1/1.2480	86.9/ 14/ .7960		96.2/ 14/1.0325
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0388		2.4/ 1/ .0423	11.8/ 14/ .0391		11.9/ 14/ .0395
NOX SAMPLE METER/RANGE/PPM	36.5/ 2/ 36.5		1.8/ 1/ .5	.0/ 1/ .0		23.2/ 1/ 5.9
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .2		.2/ 1/ .1	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	12.12		10.72	16.79		12.90
THC CONCENTRATION PPM	134.		7.	2.		9.
CO CONCENTRATION PPM	383.		7.	11.		46.
CO2 CONCENTRATION PCT	1.0175		1.2097	.7592		.9961
NOX CONCENTRATION PPM	36.3		.4	.0		5.9
THC MASS GRAMS	1.62		.21	.15		.37
CO MASS GRAMS	9.30		.44	1.73		4.03
CO2 MASS GRAMS	388.7		1205.3	1797.8		1371.2
NOX MASS GRAMS	1.46		.04	.00		.85
THC GRAMS/MI	2.40		.07	.04		.10
CO GRAMS/MI	13.82		.15	.45		1.12
CO2 GRAMS/MI	577.9		419.1	463.6		382.5
NOX GRAMS/MI	2.17		.02	.00		.24
FUEL ECONOMY IN MPG	14.60	19.48	21.13	19.09	20.81	23.06
RUN TIME SECONDS	140.		365.	867.		505.
MEASURED DISTANCE MI	.67	3.55	2.88	3.88	7.46	3.59
SCF, DRY	.970	.969	.969	.973	.972	.971
DFC, WET (DRY)		.910(.892)			.934(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		75.3/ .00			204.5/ .00	

COMPOSITE RESULTS

TEST NUMBER		LS-OE-13
BAROMETER	MM HG	741.7
HUMIDITY	G/KG	10.9
TEMPERATURE	DEG C	22.8

		3-BAG
CARBON DIOXIDE	G/MI	438.4
FUEL ECONOMY	MPG	20.15
HYDROCARBONS (THC)	G/MI	.15
CARBON MONOXIDE	G/MI	1.10
OXIDES OF NITROGEN	G/MI	.15

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PROJECT 08-1815-001

TEST NO. LS-OE-14 RUN 1	VEHICLE NO. 88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/13/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1026-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 764. KM(475. MILES)

BAROMETER 740.66 MM HG(29.16 IN HG)
DRY BULB TEMP. 27.8 DEG C(82.0 DEG F)
RELATIVE HUMIDITY 34. PCT
ABS. HUMIDITY 8.1 GM/KG
NOX HUMIDITY CORRECTION FACTOR .92

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	762.0 (30.0)		769.6 (30.3)	769.6 (30.3)		767.1 (30.2)
BLOWER INLET P MM. H2O(IN. H2O)	756.9 (29.8)		762.0 (30.0)	762.0 (30.0)		762.0 (30.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		43.3 (110.0)	42.8 (109.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11216.		29241.	69453.		40383.
TOT FLOW STD. CU. METRES(SCF)	20.8 (736.)		54.3 (1917.)	129.1 (4558.)		75.1 (2650.)
THC SAMPLE METER/RANGE/PPM	12.0/ 3/ 120.		15.0/ 2/ 15.	9.9/ 2/ 10.		14.0/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	.7/ 3/ 7.		6.5/ 2/ 6.	6.4/ 2/ 6.		8.9/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	58.9/ 14/ 268.		9.2/ 12/ 9.	15.4/ 12/ 15.		27.4/ 12/ 27.
CO BCKGRD METER/RANGE/PPM	.1/ 14/ 0.		.5/ 12/ 0.	.3/ 12/ 0.		.4/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	96.0/ 14/1.0266		66.4/ 1/1.2217	85.8/ 14/ .7723		95.6/ 14/1.0149
CO2 BCKGRD METER/RANGE/PCT	11.2/ 14/ .0369		2.2/ 1/ .0388	11.0/ 14/ .0361		11.5/ 14/ .0380
NOX SAMPLE METER/RANGE/PPM	31.1/ 2/ 31.1		4.7/ 1/ 1.2	1.0/ 1/ .3		37.7/ 1/ 9.5
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .3		.6/ 1/ .2	.1/ 1/ .0		.1/ 1/ .0
DILUTION FACTOR	12.59		10.95	17.30		13.15
THC CONCENTRATION PPM	113.		9.	4.		6.
CO CONCENTRATION PPM	260.		8.	14.		26.
CO2 CONCENTRATION PCT	.9927		1.1865	.7383		.9798
NOX CONCENTRATION PPM	30.9		1.1	.2		9.5
THC MASS GRAMS	1.36		.28	.29		.25
CO MASS GRAMS	6.30		.51	2.14		2.23
CO2 MASS GRAMS	378.8		1179.4	1744.6		1346.5
NOX MASS GRAMS	1.13		.10	.05		1.25
THC GRAMS/MI	2.03		.10	.07		.07
CO GRAMS/MI	9.43		.18	.56		.63
CO2 GRAMS/MI	566.3		405.0	453.5		378.8
NOX GRAMS/MI	1.69		.04	.01		.35
FUEL ECONOMY IN MPG	15.09	20.18	21.87	19.51	21.18	23.34
RUN TIME SECONDS	140.		365.	868.		505.
MEASURED DISTANCE MI	.67	3.58	2.91	3.85	7.40	3.55
SCF, DRY	.980	.978	.978	.982	.981	.980
DFC, WET (DRY)		.912(.902)			.935(.925)	
TOT VOL (SCM) / SAM BLR (SCM)		75.1/ .00			204.1/ .00	

COMPOSITE RESULTS

TEST NUMBER		LS-OE-14
BAROMETER	MM HG	740.7
HUMIDITY	G/KG	8.1
TEMPERATURE	DEG C	27.8

		3-BAG
CARBON DIOXIDE	G/MI	429.2
FUEL ECONOMY	MPG	20.59
HYDROCARBONS (THC)	G/MI	.15
CARBON MONOXIDE	G/MI	.85
OXIDES OF NITROGEN	G/MI	.18

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TEST NO. LS-AH-15 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/14/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1026-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 785. KM(488. MILES)

BAROMETER 742.19 MM HG(29.22 IN HG) DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)
RELATIVE HUMIDITY 46. PCT ABS. HUMIDITY 7.8 GM/KG NOX HUMIDITY CORRECTION FACTOR .91
BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	774.7 (30.5)		777.2 (30.6)	767.1 (30.2)		764.5 (30.1)
BLOWER INLET P MM. H2O(IN. H2O)	764.5 (30.1)		769.6 (30.3)	762.0 (30.0)		759.5 (29.9)
BLOWER INLET TEMP. DEG. C(DEG. F)	37.2 (99.0)		37.8 (100.0)	38.9 (102.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11224.		29292.	69443.		40475.
TOT FLOW STD. CU. METRES(SCF)	21.1 (746.)		55.0 (1943.)	130.3 (4602.)		75.4 (2664.)
THC SAMPLE METER/RANGE/PPM	34.0/ 2/ 34.		13.0/ 2/ 13.	10.3/ 2/ 10.		10.6/ 2/ 11.
THC BCKGRD METER/RANGE/PPM	8.3/ 2/ 8.		9.0/ 2/ 9.	8.7/ 2/ 9.		7.5/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	29.0/ 12/ 28.		25.9/ 12/ 25.	9.9/ 12/ 10.		24.8/ 12/ 24.
CO BCKGRD METER/RANGE/PPM	1.4/ 12/ 1.		1.5/ 12/ 1.	.9/ 12/ 1.		.3/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	62.2/ 1/1.1429		67.4/ 1/1.2405	86.6/ 14/ .7894		59.9/ 1/1.0999
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0423		2.5/ 1/ .0441	11.8/ 14/ .0391		2.3/ 1/ .0406
NOX SAMPLE METER/RANGE/PPM	36.9/ 2/ 36.9		9.4/ 1/ 2.4	1.1/ 1/ .3		40.5/ 1/ 10.2
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .4		1.1/ 1/ .3	.4/ 1/ .1		.8/ 1/ .2
DILUTION FACTOR	11.66		10.77	16.93		12.15
THC CONCENTRATION PPM	26.		5.	2.		4.
CO CONCENTRATION PPM	26.		23.	8.		23.
CO2 CONCENTRATION PCT	1.1042		1.2005	.7526		1.0626
NOX CONCENTRATION PPM	36.6		2.2	.2		10.0
THC MASS GRAMS	.32		.15	.16		.16
CO MASS GRAMS	.64		1.47	1.28		2.02
CO2 MASS GRAMS	427.1		1209.5	1795.7		1467.6
NOX MASS GRAMS	1.35		.21	.04		1.31
THC GRAMS/MI	.48		.05	.04		.04
CO GRAMS/MI	.95		.51	.33		.56
CO2 GRAMS/MI	634.0		416.4	464.5		408.5
NOX GRAMS/MI	2.00		.07	.01		.37
FUEL ECONOMY IN MPG	13.92	19.33	21.25	19.07	20.23	21.65
RUN TIME SECONDS	140.		366.	868.		505.
MEASURED DISTANCE MI	.67	3.58	2.90	3.87	7.46	3.59
SCF, DRY	.975	.974	.974	.978	.977	.975
DFC, WET (DRY)		.909(.896)			.932(.919)	
TOT VOL (SCM) / SAM BLR (SCM)		76.2/ .00			205.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		LS-AH-15
BAROMETER	MM HG	742.2
HUMIDITY	G/KG	7.8
TEMPERATURE	DEG C	22.2

		3-BAG
CARBON DIOXIDE	G/MI	447.6
FUEL ECONOMY	MPG	19.78
HYDROCARBONS (THC)	G/MI	.06
CARBON MONOXIDE	G/MI	.45
OXIDES OF NITROGEN	G/MI	.20

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PROJECT 08-1815-001

TEST NO. LS-AH-16 RUN 1	VEHICLE NO.88	TEST WEIGHT 1644. KG(3625. LBS)
VEHICLE MODEL 90 BUICK LESABRE	DATE 7/18/90	ACTUAL ROAD LOAD 5.4 KW(7.3 HP)
ENGINE 3.8 L(232. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1026-F
TRANSMISSION A4	DYNO NO. 3	ODOMETER 842. KM(523. MILES)

BAROMETER 742.19 MM HG(29.22 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 60. PCT	ABS. HUMIDITY 12.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

BAG NUMBER	1A		1B	2		3
DESCRIPTION	COLD TRANSIENT 0-140 SEC		COLD TRANSIENT 140-505 SEC	STABILIZED		HOT TRANSIENT
BLOWER DIF P MM. H2O(IN. H2O)	759.5 (29.9)		774.7 (30.5)	764.5 (30.1)		774.7 (30.5)
BLOWER INLET P MM. H2O(IN. H2O)	759.5 (29.9)		767.1 (30.2)	756.9 (29.8)		767.1 (30.2)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.8 (109.0)	42.8 (109.0)		42.8 (109.0)
BLOWER REVOLUTIONS	11225.		29233.	69472.		40449.
TOT FLOW STD. CU. METRES(SCF)	20.9 (738.)		54.4 (1921.)	129.5 (4573.)		75.3 (2659.)
THC SAMPLE METER/RANGE/PPM	29.7/ 2/ 30.		14.2/ 2/ 14.	12.4/ 2/ 12.		13.7/ 2/ 14.
THC BCKGRD METER/RANGE/PPM	9.5/ 2/ 9.		9.7/ 2/ 10.	10.1/ 2/ 10.		9.7/ 2/ 10.
CO SAMPLE METER/RANGE/PPM	10.3/ 12/ 10.		12.1/ 12/ 12.	14.9/ 12/ 14.		20.6/ 12/ 20.
CO BCKGRD METER/RANGE/PPM	.6/ 12/ 1.		.5/ 12/ 0.	.5/ 12/ 0.		.4/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	65.4/ 1/1.2030		68.3/ 1/1.2575	87.3/ 14/ .8048		96.9/ 14/1.0535
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0441		2.6/ 1/ .0459	12.2/ 14/ .0407		12.3/ 14/ .0411
NOX SAMPLE METER/RANGE/PPM	40.2/ 2/ 40.2		2.4/ 1/ .6	.2/ 1/ .1		32.3/ 1/ 8.1
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .3		.2/ 1/ .1	.0/ 1/ .0		.2/ 1/ .1
DILUTION FACTOR	11.10		10.64	16.60		12.68
THC CONCENTRATION PPM	21.		5.	3.		5.
CO CONCENTRATION PPM	9.		11.	13.		19.
CO2 CONCENTRATION PCT	1.1628		1.2159	.7665		1.0157
NOX CONCENTRATION PPM	39.9		.6	.1		8.1
THC MASS GRAMS	.25		.17	.22		.21
CO MASS GRAMS	.22		.68	2.03		1.65
CO2 MASS GRAMS	445.0		1211.4	1817.5		1400.1
NOX MASS GRAMS	1.67		.06	.01		1.22
THC GRAMS/MI	.37		.06	.06		.06
CO GRAMS/MI	.32		.23	.52		.46
CO2 GRAMS/MI	657.8		414.8	469.1		388.0
NOX GRAMS/MI	2.48		.02	.00		.34
FUEL ECONOMY IN MPG	13.45	19.22	21.35	18.86	20.58	22.81
RUN TIME SECONDS	140.		365.	868.		505.
MEASURED DISTANCE MI	.68	3.60	2.92	3.87	7.48	3.61
SCF, DRY	.970	.969	.969	.973	.972	.971
DFC, WET (DRY)		.907(.890)			.933(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		75.3/ .00			204.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		LS-AH-16
BAROMETER	MM HG	742.2
HUMIDITY	G/KG	12.1
TEMPERATURE	DEG C	25.0

		3-BAG
CARBON DIOXIDE	G/MI	445.0
FUEL ECONOMY	MPG	19.92
HYDROCARBONS (THC)	G/MI	.07
CARBON MONOXIDE	G/MI	.45
OXIDES OF NITROGEN	G/MI	.20

APPENDIX L

1990 TOYOTA CELICA CATALYST CONFIGURATION AND EMISSIONS

TABLE L-1. TOYOTA CELICA CATALYST CONFIGURATIONS AND FTP EMISSIONS

TEST DATE	TEST NUMBER	ODOMETER MILES	TEST DESCRIPTION	AIRFLOW RATE, cfm	AIR INJECTION DURATION, sec. BAG 1A	BAG 3	FUEL	FTP EMISSIONS, g/mile CO2	HC	CO	NOx	FUEL ECO. mi/gal	NOTES
CARB BASELINE TESTING													
03-08-90	C-OE-0	41	OE-STOCK CATALYST	--	--	--		335.3	0.11	0.68	0.05	26.37	CARB BASELINE TEST
03-09-90	C-OE-00	53	OE-STOCK CATALYST	--	--	--		356.6	0.13	1.10	0.04	24.75	CARB BASELINE TEST
SWRI BASELINE TESTING													
04-19-90	C-OE-01	90	OE-STOCK CATALYST	--	--	--	AS-REC'D.	352.3	0.08	0.52	0.09	25.14	SWRI BASELINE TEST
ELECTRICALLY - HEATED CATALYST													
05-18-90	C-AH-02	111	HEAT AND AIR	4.7	140	--	EEE	369.6	0.04	0.13	0.17	24.03	OFF-VEHICLE HEAT AND AIR
06-26-90	C-VAH-03	136	HEAT AND AIR	V5.9	65	--	RF-A	371.2	0.05	0.39	0.17	23.89	ON-VEHICLE HEAT AND AIR
06-27-90	C-VH-04	157	HEAT ONLY	--	--	--	RF-A	359.3	0.10	0.34	0.22	24.68	ON-VEHICLE HEAT
AIR INJECTION STUDY													
06-29-90	C-AH-05	194	HEAT AND AIR	10.7	65	20	EEE	390.7	0.14	0.69	0.15	22.65	OFF-VEHICLE AIR
06-30-90	C-AH-06	208	HEAT AND AIR	3.0	65	20	EEE	389.1	0.05	0.43	0.20	22.78	OFF-VEHICLE AIR
07-01-90	C-H-07	219	HEAT ONLY	--	--	--	EEE	380.9	0.08	0.84	0.14	23.25	NO AIR
07-02-90	C-AH-08	233	HEAT AND AIR	5.9	65	20	EEE	384.3	0.05	0.49	0.24	23.08	OFF-VEHICLE AIR
07-03-90	C-AH-09	248	HEAT AND AIR	5.9	85	None	EEE	376.6	0.05	0.22	0.18	23.57	OFF-VEHICLE AIR
07-06-90	C-AH-10	277	HEAT AND AIR	5.9	100	None	EEE	374.0	0.05	0.43	0.14	23.72	OFF-VEHICLE AIR
07-07-90	C-AH-11	290	HEAT AND AIR	5.9	140	None	EEE	375.7	0.05	0.29	0.19	23.62	OFF-VEHICLE AIR
FUEL AND SPECIATION STUDY													
07-11-90	CS-VAH-12	311	HEAT AND AIR	V5.9	85	None	EEE	369.9	0.05	0.24	0.18	24.00	ON-VEHICLE AIR
07-12-90	CS-OE-13	326	STOCK CATALYST	--	--	--	EEE	349.0	0.09	0.66	0.09	25.40	STOCK CATALYST ONLY
07-13-90	CS-VAH-12-2	343	HEAT AND AIR	V5.9	85	None	EEE	342.3	0.42	0.90	0.12	25.78	OFF-VEHICLE BAT.(ELECT. INTERFERENCE)
07-14-90	CS-VAH-15	369	HEAT AND AIR	V5.9	85	None	RF-A	344.5	0.25	0.70	0.07	25.66	OFF-VEHICLE BAT.(ELECT. INTERFERENCE)
07-15-90	CS-OE-14	396	STOCK CATALYST	--	--	--	RF-A	338.1	0.07	0.48	0.10	26.21	STOCK CATALYST ONLY
BATTERY CONFIGURATION STUDY													
07-18-90	C-VAH-16	438	HEAT AND AIR	V5.9	85	None	RF-A	347.1	0.23	0.42	0.11	25.51	OFF-VEHICLE BAT.(ELECT. INTERFERENCE)
07-19-90	C-VAH-16-3	473	HEAT AND AIR	V5.9	85	None	RF-A	371.4	0.05	0.15	0.18	23.92	ON-VEHICLE BATTERY ONLY
07-20-90	C-VAH-17	499	HEAT AND AIR	V5.9	85	None	RF-A	364.9	0.06	0.11	0.23	24.33	ON-VEHICLE BATTERY ONLY
08-02-90	C-AH-18	533	HEAT AND AIR	V5.9	85	None	RF-A	345.0	0.03	0.08	0.15	25.74	OFF-VEHICLE BAT.(INTERFERENCE CORRECTED)
08-03-90	C-AH-19	545	HEAT AND AIR	V5.9	50	None	RF-A	339.2	0.04	0.14	0.08	26.16	OFF-VEHICLE BATTERY
08-07-90	C-VAH-20	564	HEAT AND AIR	V5.9	60	None	RF-A	366.2	0.06	0.21	0.13	24.26	OFF-VEHICLE BATTERY IN PARALLEL
ALTERNATOR CONFIGURATION STUDY													
08-08-90	C-VAH-21	575	HEAT AND AIR	V5.9	50	None	RF-A	330.4	0.03	0.11	0.08	26.89	TWO BAT., NO ALT, CHARGER ON
08-10-90	C-VAH-22	596	HEAT AND AIR	V5.9	50	None	RF-A	347.8	0.08	0.43	0.11	25.52	VEH. BAT. ONLY, ALT. ON,(1),(2)
08-15-90	C-VAH-23	617	HEAT AND AIR	V5.9	50	None	RF-A	361.5	0.05	0.16	0.23	24.62	ON-VEHICLE BATTERY ONLY, (1),(3)
08-16-90	C-VAH-24	631	HEAT AND AIR	V5.9	50	None	RF-A	361.7	0.05	0.19	0.19	24.58	OFF-VEH. BAT. IN PARALLEL, (1),(4)
FINAL HYDROCARBON SPECIATION STUDY													
09-12-90	C-VAH-25	646	HEAT AND AIR	V5.9	50	None	RF-A	382.6	0.09	0.53	0.04	23.17	VEH. PREP - NEW LARGER EHC INSTALLED,(1)
09-13-90	CS-VAH-26	681	HEAT AND AIR	V5.9	50	None	EEE	366.7	0.03	0.30	0.05	24.27	OFF-VEH. BATTERY IN PARALLEL, (1)
09-14-90	CS-VAH-27	716	HEAT AND AIR	V5.9	50	None	RF-A	357.7	0.04	0.24	0.06	24.89	OFF-VEH. BATTERY IN PARALLEL, (1)
VEHICLE SHIPPED TO CARB													

OE - ORIGINAL EQUIPMENT
A - AIR
H - HEAT

V - VEHICLE AIR

EEE - HOWELL EEE
RF-A - NATIONAL AVERAGE

(1) NO HOT-START HEATING
(2) NO COLD-START POST-START HEATING
(3) ALTERNATOR OFF DURING HEATING

TABLE L-2. TOYOTA CELICA TEST SEGMENT EMISSIONS

TEST DATE	TEST NUMBER	TOTAL HYDROCARBONS, g/mi				CARBON MONOXIDE, g/mi				NITROGEN OXIDES, g/mi				FUEL ECONOMY, mi/gal			
		BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3	BAG 1A	BAG 1B	BAG 2	BAG 3
	CARB BASELINE TESTING																
03-08-90	C-OE-0																
03-09-90	C-OE-00																
	SWRI BASELINE TESTING																
04-19-90	C-OE-01	1.55	0.02	0.02	0.02	12.01	0.00	0.08	0.05	0.89	0.12	0.04	0.05	18.02	24.84	24.60	27.90
	ELECTRICALLY - HEATED CATALYST																
05-18-90	C-AH-02	0.53	0.02	0.01	0.02	2.78	0.01	0.03	0.02	2.69	0.16	0.04	0.09	17.35	23.52	23.21	27.46
06-26-90	C-VAH-03	0.41	0.05	0.01	0.06	1.87	1.50	0.07	0.11	2.82	0.17	0.02	0.09	17.25	23.34	23.33	26.74
06-27-90	C-VH-04	1.72	0.03	0.00	0.09	7.24	0.09	0.00	0.18	3.14	0.18	0.05	0.17	17.12	23.48	24.72	26.87
	AIR INJECTION STUDY																
06-29-90	C-AH-05	2.88	0.02	0.00	0.10	15.64	0.05	0.05	0.18	2.20	0.06	0.04	0.11	16.52	22.71	21.76	25.78
06-30-90	C-AH-06	0.74	0.00	0.00	0.07	5.12	1.12	0.02	0.10	2.66	0.32	0.03	0.11	16.84	22.47	22.29	25.16
07-01-90	C-H-07	1.21	0.05	0.01	0.07	9.12	2.26	0.17	0.09	2.08	0.06	0.06	0.07	16.54	21.93	23.19	25.51
07-02-90	C-AH-08	0.56	0.02	0.00	0.07	3.71	1.73	0.03	0.14	3.44	0.26	0.06	0.12	15.31	22.23	23.13	25.15
07-03-90	C-AH-09	0.52	0.01	0.01	0.07	3.91	0.04	0.05	0.13	2.67	0.18	0.05	0.07	17.22	22.75	23.13	26.25
07-06-90	C-AH-10	0.45	0.05	0.00	0.09	2.98	1.50	0.07	0.11	2.47	0.06	0.03	0.06	16.41	22.30	23.82	25.92
07-07-90	C-AH-11	0.62	0.01	0.00	0.10	4.18	0.29	0.05	0.19	2.83	0.14	0.04	0.11	16.66	22.61	23.53	25.83
	FUEL AND SPECIATION STUDY																
07-11-90	CS-VAH-12	0.51	0.03	0.00	0.10	2.85	0.21	0.02	0.31	3.41	0.06	0.04	0.07	16.67	22.72	24.04	26.17
07-12-90	CS-OE-13	1.81	0.05	0.02	0.03	13.43	0.55	0.05	0.09	0.85	0.12	0.04	0.05	17.39	24.45	24.78	28.99
07-13-90	CS-VAH-12-2	8.67	0.00	0.00	0.31	21.71	0.02	0.02	0.17	0.81	0.23	0.07	0.04	16.34	25.61	25.21	29.18
07-14-90	CS-VAH-15	3.75	0.06	0.00	0.35	11.07	0.98	0.05	0.28	0.65	0.09	0.03	0.04	17.66	25.23	25.08	28.84
07-15-90	CS-OE-14	1.61	0.04	0.00	0.02	11.41	0.08	0.02	0.04	0.43	0.20	0.07	0.05	18.16	25.81	25.56	29.52
	BATTERY CONFIGURATION STUDY																
07-18-90	C-VAH-16	2.07	0.03	0.03	0.48	7.96	0.01	0.03	0.32	1.49	0.12	0.03	0.06	17.70	25.62	24.52	29.21
07-19-90	C-VAH-16-3	0.62	0.03	0.03	0.04	1.52	0.09	0.07	0.17	3.03	0.12	0.03	0.09	16.99	22.30	23.98	26.19
07-20-90	C-VAH-17	0.88	0.02	0.02	0.03	1.68	0.01	0.05	0.08	2.97	0.30	0.06	0.12	17.30	23.12	24.34	26.48
08-02-90	C-AH-18	0.42	0.01	0.01	0.01	1.56	0.03	0.02	0.01	2.29	0.16	0.04	0.05	18.20	26.36	24.59	29.42
08-03-90	C-AH-19	0.52	0.02	0.02	0.02	1.93	0.03	0.07	0.08	0.76	0.10	0.03	0.05	18.13	26.36	25.54	29.01
08-07-90	C-VAH-20	0.69	0.06	0.03	0.04	3.21	0.13	0.04	0.14	1.23	0.22	0.06	0.07	17.35	22.55	23.96	27.41
	ALTERNATOR CONFIGURATION STUDY																
08-08-90	C-VAH-21	0.39	0.01	0.02	0.01	1.53	0.01	0.07	0.02	1.11	0.03	0.03	0.08	18.55	25.73	26.70	29.71
08-10-90	C-VAH-22	1.30	0.06	0.03	0.01	4.90	1.25	0.06	0.01	0.72	0.09	0.08	0.08	17.12	24.08	25.32	28.61
08-15-90	C-VAH-23	0.62	0.02	0.03	0.02	1.83	0.04	0.13	0.07	3.11	0.44	0.04	0.04	18.94	22.44	23.73	29.15
08-16-90	C-VAH-24	0.57	0.03	0.02	0.04	2.17	0.09	0.09	0.12	2.24	0.41	0.03	0.04	20.70	22.36	23.70	28.75
	FINAL HYDROCARBON SPECIATION STUDY																
09-12-90	C-VAH-25	1.60	0.08	0.03	0.01	11.37	0.39	0.05	0.03	0.16	0.04	0.03	0.06	15.48	23.02	22.51	26.31
09-13-90	CS-VAH-26	0.36	0.06	0.02	0.01	1.37	1.35	0.02	0.03	0.35	0.07	0.03	0.04	16.81	22.25	23.63	28.56
09-14-90	CS-VAH-27	0.47	0.06	0.02	0.01	1.64	0.74	0.07	0.05	0.54	0.06	0.02	0.01	16.55	22.55	24.69	28.63

TABLE L-3. TOYOTA CELICA—METHANE, BENZENE, AND TOLUENE EMISSIONS

TEST DATE	TEST NUMBER	ODOMETER MILES	TEST DESCRIPTION	METHANE, mg/mi					BENZENE, mg/mi					TOLUENE, mg/mi				
				1A	1B	2	3	FTP	1A	1B	2	3	FTP	1A	1B	2	3	FTP
SWRI BASELINE TESTING																		
04-19-90	C-OE-01	90	OE-STOCK CATALYST	106.9	3.63	3.74	2.36	7.37	59.9	0.62	2.41	0.65	3.87	207.2	2.91	1.81	1.62	9.96
ELECTRICALLY - HEATED CATALYST																		
05-18-90	C-AH-02	111	HEAT AND AIR	116.5	5.82	6.45	6.58	10.60	15.45	2.23	0.47	2.40	1.88	25.8	4	3.7	8.1	5.83