United States
Environmental Protection
Agency

November
1990

Air

EPA

Cooperative Testing Program Draft Report

ECTD
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DRAFT

EPA-AA-TSS-I/M-90-X

Draft
v 1.5

Technical Report

Report on the EPA/Manufacturer Cooperative I/M Testing Program

By

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September 1990

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SECTION 1: EXECUTIVE SUMMARY

1.1 Program Summary

The EPA/Manufacturer Cooperative Test Program (CTP) recruited private-owner vehicles based on failure of the Michigan Auto Exhaust Testing (AET) Program for testing at laboratory facilities of the EPA and seven major motor vehicle manufacturers. The program focused on closed-loop light-duty vehicles and light-duty trucks from model years 1981-1986. The test protocols included the Federal Test Procedure (FTP) and a new short test procedure with segments simulating a variety of field test conditions. The remedial maintenance procedure called for incremental repairs and retests to meet both FTP and short test criteria.

Data from the program were analyzed with the following objectives in mind:

(1) Developing advice to I/M programs on improvements to preconditioning methods and formal I/M test procedures.

(2) Seeking, and assessing the potential of, a limited diagnosis and repair sequence as a remedy for a significant portion of the in-use emissions excess.

(3) Improving methods and models for estimating I/M effectiveness in reducing emissions.

(4) Providing feedback to the manufacturers on particular malfunction or malmaintenance types.

1.2 Results

The following results from analysis of the CTP data are significant:

(1) Eighty-six percent of the 239 vehicles in the CTP base sample failed their HC or CO certification standards in the as-received condition, with HC+CO failures being the most prevalent. Of the failures, one vehicle was a super emitter and 70% were high emitters, by the MOBILE4 definitions. The worst 40% of the vehicles accounted for 90% of the fleet excess HC and 83% of the fleet excess CO. [Sections 4.2 and 4.3]

(2) The mean excess HC and CO emissions of the MY1981-82 vehicle group exceeded the mean excess emissions for

the MY1983-86 group by about half. Discounting the impact of the one super emitter, the fuel-injected and carbureted vehicles had roughly comparable excess emissions, within the model year groups. The percentage of high emitters varied considerably across the manufacturers. [Section 4.2.4]

(3) Excess emissions were not well correlated with mileage; however, successively higher MOBILE4 emitter categories showed successively higher mean mileages. [Section 4.4.2]

(4) Of the 40% of the CTP fleet that were normal emitters, almost 80% failed their recruitment short test for only one pollutant; HC-only failures outnumbered CO-only failures by two to one. The data show no reasonable alternative cutpoints for excluding large numbers of normal emitters from AET failure without inappropriately converting many high emitters to AET passes. [Section 4.4.2]

(5) When tested in a fully-warmed condition with either loaded or extended-2500rpm preconditioning, the second-chance idle failure rate of the CTP fleet was only about 40%. Up to an additional 20% of the fleet failed second-chance idle tests under a variety of conditions on warmed-up vehicles. Only on vehicles that were idle tested immediately after an extended soak did the second chance failure rate exceed 60%. [Section 4.5.2]

(6) Vehicles that were combined HC+CO failures on their AET tests were not also prone to be HC+CO failures during second-chance testing. [Section 4.5.2]

(7) The second-chance idle tests at fully warmed condition, with loaded or extended 2500rpm preconditioning, reduced the error of commission rate to zero or near zero, and passed 78% or more of the marginal emitters as well. The failure rate of the high emitters under the same second-chance test conditions was 60%-65%. [Section 4.5.4]

(8) Correlation between the two idle modes of a two-mode idle test was relatively high (R^2 values of close to 90%) when the vehicles were fully warmed and preconditioned with loaded or extended-2500rpm operation. Poorer correlation (R^2 values between 31% and 85%) was shown under less ideal test conditions. For all test conditions, the effect of the intervening 2500rpm mode was generally to reduce the failure rate on the second idle. [Section 4.5.5]

(9) All but two of the 33 as-received error of commission vehicles had elevated or failing HC scores on the Michigan AET test; slightly over one-third failed the AET for CO. One-quarter of the E_c vehicles fell in one GM engine displacement. Only one of the E_c vehicles had a repeatable short test exceedance that was diagnosed and resolved through repair. Most E_c's were attributed to the response of the engine and control system to vehicle preconditioning. [Section 4.6]

(10) Repairs eliminated 99% of the excess HC and CO emissions in the CTP fleet; one fifth of the overall HC reduction and one third of the overall CO reduction were due to oxygen sensor replacement. Catalyst and fuel injector replacements also each contributed more than 10% to the total HC reduction, while no other repair type contributed more than 10% to the CO reduction. The average vehicle had 1.8 g/mi HC and 28 g/mi CO eliminated in 2.6 repair steps. [Sections 5.2.1 and 5.3.4]

(11) The most frequent repair types were oxygen sensor replacements (45% of repaired vehicles), catalyst replacements (30%), and ignition tune-ups (spark plug/wire replacement, initial timing adjustment, idle speed adjustment) (29%). [Appendix G]

(12) The most effective repair type on a per-vehicle basis was fuel injector replacement. This eliminated an average 2.4 g/mi HC and 24 g/mi CO. Other statistically significant effective HC repairs were to the catalyst (1.1 g/mi), carburetor (1.0 g/mi), oxygen sensor (0.8 g/mi) and fuel meter tune-ups (0.6 g/mi). For CO, the significant effective repairs were to the load sensor (23 g/mi), oxygen sensor (21 g/mi), carburetor (12 g/mi), fuel metering system tune-ups (12 g/mi), ECU (12 g/mi), and catalyst (7 g/mi). The average reduction per repair step for all repair types was 0.7 g/mi HC and 11 g/mi CO. [Section 5.3.3]

(13) Vehicles required an average of 1.5 repairs to switch from high emitter to marginal or passing emitter status on the FTP, with emitter categories as defined by MOBILE4. The same number of steps was needed to change from failing to passing on an idle I/M test performed under ideal conditions. [Section 5.6.1]

(14) Marginal emitters (as defined by MOBILE4) were not worthy repair targets in the CTP. Their emission

reductions were negligible, with high emitters achieving reductions 15 times as large. [Section 5.5.1]

(15) Repairs targeted at the most likely malfunctioning component resulted in the early repairs being more effective than later repairs; the first repair on a vehicle achieved an average reduction five times that of the third repair. [Section 5.6.1]

(16) Second-chance I/M tests apparently reduced the incidence of unnecessary repairs to normal emitters without greatly reducing the benefit due to repairing high emitters. Sixty percent of the fleet passed a second-chance I/M test performed under ideal conditions; this 60% would have achieved less than 25% of the total fleet repair reduction. [Section 5.4.5]

(17) Repair types that were consistently effective at reducing FTP emissions were also the most reliable at correcting I/M-failed vehicles to passes. At the system level, these were the exhaust, fuel metering, and 3-way control systems. Subsystems included the catalyst, carburetor, oxygen sensor, fuel metering system tune-ups, and fuel injectors. [Sections 5.3.2 and 5.3.3]

(18) Repairing until vehicles passed I/M reduced emission levels by approximately 75% and eliminated over half of the FTP excess. However, this was only about two thirds of the reduction that could be realized with more complete repair. [Section 5.4.6]

(19) Replacement of the catalytic convertor resulted in average g/mi reductions twice that of all other repair types for HC and 3/4 that of all other repair types for CO, even though catalyst repairs were generally withheld until the last repair. Evidence of tampering or misfueling occurred on only 20% of the vehicles that received catalyst repairs. [Section 5.3.5]

(20) Estimates of average emission reductions due to repair to I/M passing status are lower in the MOBILE4 model than those seen in the CTP, particularly for HC on fuel injected vehicles. [Section 5.4.3}

(21) Ninety-four percent of vehicles that were repaired from high to normal emitter levels on a transient test could also, at that repair stage, pass an I/M test performed under optimum conditions (57% from

I/M fail to pass, 37% already passing) [Section 5.4.4]

SECTION 2: BACKGROUND AND PROGRAM SUMMARY

2.1 Program Overview

The Cooperative EPA/Manufacturer I/M Test Program (CTP) was a joint effort by the Environmental Protection Agency and seven of the major domestic and imported vehicle manufacturers to recruit failed vehicles from an official state Inspection/Maintenance (I/M) program for study in a laboratory environment. The intent of the program was to gather data that could be combined with the results from a number of other studies, contributing to accomplishing several objectives. Among these were the following:[1]

- Develop advice to I/M programs on improvements to preconditioning methods and formal I/M test procedures.
- Seek, and assess the potential of, a limited diagnosis and repair sequence as a remedy for a significant portion of the in-use emissions excess.
- Improve methods and models for estimating I/M effectiveness in reducing emissions.
- Provide feedback to the manufacturers on particular malfunction or malmaintenance types.

The study focused on 1981-86 model-year vehicles with closed-loop engine control that failed the idle test under Michigan's decentralized Auto Exhaust Testing (AET) program. The EPA solicited owners just prior to their expected AET test date by direct mail for participation in the program and also coordinated initial recruitment efforts. Each of the participating manufacturers -- Chrysler, Ford, General Motors, Honda, Nissan, Mitsubishi, and Toyota -- completed the recruitment process and performed the laboratory work on its own vehicles, at its own facilities.

Vehicles of some additional manufacturers, which had no appropriate testing facilities in Southeast Michigan available during the program, were recruited to the EPA Motor Vehicle Emissions Laboratory in Ann Arbor, Michigan for testing and repair. This group included vehicles from American Motors, Mazda, Subaru, and Volkswagen. Facilities for Toyota were under construction at the outset of the program, and testing of the first ten Toyota vehicles consequently took place at MVEL; work on the remaining six Toyota vehicles was completed by the manufacturer.

According to the CTP program plan, recruited vehicles first underwent a series of emissions tests, including short cycles and the Federal Test Procedure (FTP), in the as-received condition. Each vehicle was diagnosed for causes of any excess emissions; it was then repaired, and retested. At least two features distinguished the program protocols from those in previous in-use studies conducted by EPA and others. First, the remedial maintenance and retest steps were incremental; that is, mass-emission and raw-gas tests were executed following each "significant" repair. Second, the program's short cycles incorporated a new Basic I/M Test Procedure (BITP) that was designed to simulate vehicle response under a variety of field I/M test conditions.

Recruitment for the Cooperative Test Program began in February 1987, and testing continued through May 1988. Data from the participants was collected, quality checked and organized in a common database through the EPA facility in Ann Arbor. Final data submissions and major corrections to the databases were completed in May 1989.

The remainder of this section summarizes portions of the CTP program plan that will aid the reader in understanding the analysis to follow.

2.2 Recruitment Quotas

The Cooperative Test Program vehicles were not a random sample from among all those that failed the Michigan Auto Exhaust Test. Quotas on recruitment were established according to a number of variables: manufacturer, model-year group, fuel-metering strategy, presence of tampering or misfueling, and presence of a pattern failure.

The manufacturer quotas distributed the testing obligation based on the relative percentages of each manufacturer's fleet in a 140,000-vehicle sample of failures from the Seattle I/M program. This program was selected because of the availability of detailed data, its procedural similarity to the Michigan program, and its use of a keyoff/restart step for Ford vehicles.[2]

Regardless of its share in the Seattle failures, each participant agreed to test a minimum of ten vehicles; this minimum was applied to Mitsubishi and Honda. General Motors, Ford, and EPA each entered the program with testing targets of 60 vehicles. Nissan was allocated 30 vehicles, Toyota 16, and Chrysler, 15. Thus the program plan target was 261 vehicles.

Only closed-loop vehicles from the 1981 through 1986 model years were recruited. By definition, manufacturers producing no closed-loop vehicles in the earlier model years necessarily met their recruitment goals from the later years. In order to further focus on technologies likely to dominate I/M fleets in the 1990s, carbureted vehicles were targeted to be less than half of each organization's basic quota, and at the manufacturer's option, post-1983MY carbureted vehicles could be excluded from recruitment.

For manufacturers with closed-loop production across the model years, some additional considerations applied: half of the quota was to be filled by vehicles from the 1981 or 1982 model years, the other half from the 1983 or later model years. Some additional considerations applied, in order to ensure a sample with current technology, as well as age-related malperformances.

In order to preclude domination of the sample by certain important forms of tampering, the number of vehicles with fuel inlet tampering, Plumbtesmo test failure, or catalyst removal was limited to the greater of one vehicle or ten percent of a manufacturer's overall CTP quota. Finally, the participants were also expected to limit recruitment of so-called "pattern failures" from the sample, under the principle that limited information of value would be obtained if a manufacturer's sample were heavily biased towards one (or a few) vehicle groups once a pattern of problems had been adequately diagnosed and remedied.

Because the primary recruitment quotas were based upon model year and fuel metering strategy, four "quota groups" were defined for each manufacturer: fuel-injected MY1981-82, carbureted 1981-82MY, fuel-injected MY1983+, and carbureted MY1983+. The quota groups will be referred to frequently in the remainder of this report.

2.3 Procurement

Each week over the course of the program, EPA culled a list of potential owners from a tape provided by the Michigan Department of State, containing registration data for owners of vehicles due to receive notices of their AET test requirement in that week. Decoders based on the Vehicle Identification Number (VIN) were employed to screen out ineligible vehicles. A mailing label was generated for eligible owners, and a direct-mail solicitation was conducted. The solicitation letter contained boilerplate language on the program and incentives for the owner to participate, as well as manufacturer-specific information. The letter emphasized that only those owners who failed their subsequent AET test would be eligible, and it provided instructions for interested owners to contact the appropriate participating CTP test site or its representative.

The size of a week's mailing was determined by each site's throughput and progress towards meeting the recruitment quotas. Where more eligible owners existed than CTP testing capacity for the likely respondents, the pool was reduced by randomly selecting owners from all those in the same quota group.

Once an owner contacted a CTP recruitment site, a telephone screening was conducted to verify eligibility. This screening verified the Michigan AET test failure, the timeliness of the owner response, the absence of any owner action to remedy the failure, and set of safety and outlier rejection criteria.[3] Conformance to the any late-breaking changes in the manufacturer's progress towards recruitment quotas was also taken into account. Owners not excluded during the telephone screening were scheduled for intake to the appropriate test site. A final safety and outlier screening was performed at the time of vehicle intake, including a road test to project safe dynamometer operation.

2.4 <u>As-Received Testing Protocols</u>

2.4.1 Introduction

The CTP program plan called for each vehicle to receive four short-cycle sequences, collectively referred to as the Basic I/M Testing Procedure (BITP), on tank fuel (Table 1).[4] The BITP was then followed by the Federal Test Procedure (FTP) on Indolene. If the vehicle was recruited with insufficient fuel to complete BITP testing, the program plan called for substitution of a commercial fuel. An RVP and lead-in-fuel analysis was performed on the tank fuel.

TABLE 1

<u>As-Received Emissions Testing Outline</u>

Procedure	Fuel	Sequence	Prior Base Operation
BITP	Tank/Commercial	Cold Start Extended Loaded Extended Idle Restart	75° Soak, 1 hr minimum LA4 continuous 20-min idle LA4 + Restart
FTP	Indolene	N/A	LA4 Prep, overnight 75° Soak, No heat build

2.4.2 Basic I/M Test Procedure

The Basic I/M Test Procedure attempted to replicate unloaded field I/M tests under a variety of controlled conditions, and thereby provide possible explanations for the Michigan AET results that were the basis for CTP vehicle recruitment. These controlled conditions included the prior ("base") operation of the vehicle and any conditioning that occurred immediately prior to the pass/fail test modes. Examination of other factors that might have affected the Michigan AET results, such as AET analyzer calibration variables or operator fraud, was not in the scope of the program.

The four sequences that make up the BITP corresponded to (and were named after) four different types of preceding, or "base" operation: a cold start, extended operation under load, extended operation at idle, and execution of an engine keyoff/restart. The base operation was then followed by one or more simulated Two-Speed Idle tests, each with a controlled conditioning mode. Raw-gas emission values and engine RPM measurements were gathered throughout the BITP, but attention was focused on seven "core" two-speed tests, spread through the procedure. No loaded short testing (either transient or steady-state) was included in the BITP.

Table 2 summarizes the modes of the Basic I/M Test Procedure. The core sampling periods, which will serve as the basis for much of the short-test analysis that is to follow, are shaded. Certain parameters -- HC, CO, CO_2, and engine RPM, -- were sampled throughout the procedure. During the core sampling periods, these parameters were measured at 15 and 30 seconds into each mode, and at 60, 90 and 120 seconds of the second idle-neutral mode as well. Coolant temperature was monitored during the entire cold start sequence, and at other points (such as the extended idles), where some significant variation might occur.

Sampling intervals outside of the core sampling period varied according to the purpose of the mode. For a more detailed description of the sampling procedure, refer to the program plan.[5]

The selection, order, and duration of the modes reflects a desire to test the vehicles under both ideal and non-ideal conditions. The purpose of the Cold Start sequence, for example, is to characterize the emissions of each vehicle at abnormal (low) operating temperature, and then to determine the effectiveness of various conditioning modes at achieving normal operating temperature, and the emissions impacts of such conditioning

The Extended Loaded sequence was the hypothetical "ideal" test condition in the procedure; its purpose was to measure vehicle emissions immediately following an extended period of loaded operation. The Extended Idle sequence presumes that the vehicle has prior loaded operation that had achieved normal operating condition in the recent past, but that a period of extended idle may have caused the vehicle's condition (and therefore its emissions) to deviate from its ideal levels.

Finally, the Restart sequence examines the non-ideal aspects of a keyoff/restart on vehicle emissions. For most vehicles, the ideal condition was presumed to not involve a restart, and to isolate the effects of the restart from other conditioning variables, these vehicles were not restarted during the Cold Start, Extended Loaded, and Extended Idle sequences, but were restarted during the Restart sequence. On the other hand, Ford vehicles from the 1981 model year onward were generally designed with the assumption that a keyoff/restart would precede any idle short test.[6] Use of the restart for Fords in the CTP was therefore the opposite of the case for non-Fords (see Table 2).

2.4.3 Applicability of the BITP Model

It is important to note that in the Cooperative Test Program the BITP simulates field test conditions but not a field sample. The program recruited initial idle-test failures only; no AET-passing vehicles underwent the BITP or other procedures from the CTP protocol.

The seven core sampling periods in the BITP thus represent second-chance I/M tests on failed vehicles. Without the analogous data on the passing vehicles, care must be taken when interpreting failure rates, excess emissions identified, variability results, and other analyses on the BITP data. This caution applies as well when examining parts of the BITP that had no direct analog in the Michigan AET test, such as 2500rpm pass/fail results.

2.4.4 As-Received FTP Test

The FTP used in the Cooperative Test Program was a standard three-bag cycle performed on Indolene (Table 1, above). The CTP version of the test omitted the heat build and the Highway Fuel Economy Test.

2.4.5 Tank Fuel Analysis

Lead-in-fuel analysis was performed using x-ray flourescence and targeted at designating the fuel as either above or below a 0.05 g/gal standard. Reid Vapor Pressure testing was conducted using the ASTM D323 protocol.

TABLE 2

Modes of the Basic I/M Test Procedure

SEQUENCE	MODE#	MODE NAME	DURATION	FUNCTION
Cold Start (CS)	0 1	75° Soak	>60 min	Base Operation
	0 2	Engine Start	n/a	Base Operation
	0 3	Idle-neutral	30 sec	Core Sampling
	0 4	2500rpm	30 sec	Core Sampling
	0 5	Idle-neutral	120 sec	Core Sampling
	0 6	2500rpm	180 sec	Conditioning
	0 7	Idle-neutral	30 sec	Core Sampling
	0 8	Keyoff/Restart	n/a	Ford Vehicles Only
	0 9	2500rpm	30 sec	Core Sampling
	1 0	Idle-neutral	120 sec	Core Sampling
	1 1	Idle-neutral	10 min	Conditioning
	1 2	Idle-neutral	30 sec	Core Sampling
	1 3	Keyoff/Restart	n/a	Ford Vehicles Only
	1 4	2500rpm	30 sec	Core Sampling
	1 5	Idle-neutral	120 sec	Core Sampling
Extended Loaded (XL)	0 1	LA 4	1372 sec	Base Operation
	0 2	Idle-neutral	30 sec	Core Sampling
	0 3	Keyoff/Restart	n/a	Ford Vehicles Only
	0 4	2500rpm	30 sec	Core Sampling
	0 5	Idle-neutral	120 sec	Core Sampling
Extended Idle (XI)	0 1	Idle-neutral	20 min	Base Operation
	0 2	Idle-neutral	30 sec	Core Sampling
	0 3	Keyoff/Restart	n/a	Ford Vehicles Only
	0 4	2500rpm	30 sec	Core Sampling
	0 5	Idle-neutral	120 sec	Core Sampling
	0 6	2500rpm	180 sec	Conditioning
	0 7	Idle-neutral	30 sec	Core Sampling
	0 8	Keyoff/Restart	n/a	Ford Vehicles Only
	0 9	2500rpm	30 sec	Core Sampling
	1 0	Idle-neutral	120 sec	Core Sampling
Restart (RS)	0 1	LA4	1372 sec	Base Operation
	0 2	Idle-neutral	30 sec	Core Sampling
	0 3	Keyoff/Restart	n/a	Non-Ford Vehicles Only
	0 4	2500rpm	30 sec	Core Sampling
	0 5	Idle-neutral	120 sec	Core Sampling

2.5 As-Received Diagnosis

The last step in characterizing the as-received condition of the CTP vehicles was a diagnosis of the engine and emission control systems. The primary purpose of this inspection was to identify system and component malperformances that might explain FTP or short-test noncompliances of the vehicles. An established protocol was then followed for performing remedial maintenance and retests to measure the impacts of the repairs.

In order to permit organization of the data from the eight participating sites in a common database, a uniform format was devised for reporting the results of the engine/emissions system diagnosis. The format was based largely on the ECOMP file employed by the EPA Emission Factors testing program, the largest mainframe EPA database on in-use vehicles. Both the CTP and ECOMP formats divide the engine and emissions components of the vehicle into systems and subsystems, and then code the presence and type of malperformance detected during the vehicle inspection. The coding is supplemented by narrative comments of the technicians. In the CTP, an additional data recording system was developed for coding the repair actions that were taken on the basis of the ECOMP diagnosis (see Section 5.3.1).

2.6 Selection of Vehicles for Remedial Maintenance

Before being released to its owner, each CTP vehicle was required to satisfy criteria in three categories: FTP performance, variability of the short test scores, and short test performance relative to the 207(b) emission standards. Table 3 summarizes these criteria.[7] Information from the as-received characterization (test results and diagnostic data) were used to identify all vehicles that would require remedial maintenance steps in order to meet the criteria.

2.7 Remedial Maintenance Protocols and Post-Repair Testing

The remedial maintenance philosophy in the CTP was (to the extent feasible) to measure the emissions impacts of individual repairs. Repairs and follow-up testing were therefore executed in steps, with the minimum number of repairs conducted at each step that would be expected to generate significant emissions impacts. The priority order of repairs was determined by the exit criteria remaining to be satisfied at that step -- targeting FTP compliance first, I/M variability second, and basic I/M conformance third. If multiple repair options were available that could reasonably satisfy the highest priority criterion, the repair with the biggest projected impact was conducted first (followed by the appropriate test sequence, to quantify the impact of the repair.[8]

TABLE 3

Allowable Exit Criteria in the Remedial Maintenance Phase

CATEGORY	MILEAGE	ALLOWABLE EXIT CRITERIA
FTP	<50K	HC & CO <1.5 * cert standard AND
	>50K	HC & CO <2.0 * cert standard
I/M Variability	N/A	Analogous sampling points between sequences show comparable values AND successive sampling points within a test mode show comparalbe values; OR
	N/A	Observed variability traced to unrepairable element of design OR
	N/A	Variability cannot be repeatably triggered OR
	N/A	All reasonable repair efforts completed
I/M Basic	N/A	Core sampling emissions in extended loaded sequence pass 207(b) OR
	N/A	Observed 207(b) failure traced to unrepairable element of design OR
	N/A	All reasonable repair efforts completed

The one exception to the above guideline was catalyst replacement. Dramatic emissions improvements would normally be expected with installation of any "green" catalyst, even if performance of the original catalyst was acceptable. Such replacements could mask the importance of other important malfunctions in the engine or other emission control devices. On-vehicle diagnosis was also anticipated to be difficult in some cases, except where overt signs of damage to the container or the the substrate existed. Thus, catalyst replacement was treated as the repair of last resort.

As a guide for decision-making when faced with multiple repair options, the CTP program plan established a guideline for the priority order of repair, as follows:

1. *Computer control and feedback system repairs,* including most repairs indicated by onboard diagnostic systems and repairs to electronic fuel metering components;

2. *Primary emission controls other than those in the feedback system,* including exhaust aftertreatment, secondary air, PCV, and EGR systems;

3. *Idle mixture adjustment,* on vehicles with missing limiter devices.

4. *Other basic engine components.*

In general, post-repair testing was conducted after each repair step in the CTP. The test procedures employed were all those necessary to track the vehicle's performance relative to *each* of the outstanding failed exit criteria. Thus, a repair targeted at an FTP failure on a vehicle with remaining short test noncompliance would be followed by I/M testing as well as FTP testing.

As a cost-saving measure, both the FTP and short test protocols could be shortened during post-repair testing. Test sites could perform an LA4 cycle in place of the FTP, until a significant improvement in emissions was exhibited between the post-repair LA4 and the weighted bag two and three results from the previous FTP. At that point, however, a full FTP was to be conducted before proceeding with further repairs. For short testing, abbreviated versions of the BITP were available that consisted of the extended loaded sequence, plus remaining sequences showing violations of the variability or basic I/M criteria.

2.8 Database Structures

Data from all of the important aspects of the program described in the above sections were recorded in a relational database (MICRO) on the Michigan Terminal System (MTS) and were also downloaded to microcomputers for analysis. The file structure of the CTP MICRO database mimics that of the EPA Emissions Factors database, with additional datasets and fields for the information that is unique to the CTP. A new repair database format was constructed to categorize repair actions and facilitate analysis. CTP program participants were afforded access to these data through MTS accounts and through copies of the subset microcomputer databases.

2.9 Program Nonconformities

By and large, the participating organizations in the CTP operated independently, under the guidelines of the CTP program plan. There was, for example, no real-time coordination between the participants during vehicle testing or when short turnaround decisions on repair protocols needed to be made. Thus, each testing organization exercised its own judgment in unusual or borderline cases. Some nonconformity in the data results, which complicated some of the analytical tasks. Relevant and significant examples will be identified in the sections that follow.

SECTION 3: BASIC VEHICLE CHARACTERISTICS OF THE CTP FLEET

3.1. Introduction and Overview

The participating organizations recruited 245 vehicles for study in the Cooperative Test Program. A detailed breakdown of the vehicle identifying information for all of these vehicles appears in Appendix B.

Malfunctions in two of the 245 vehicles prevented gathering sufficient as-received or post-repair data to justify inclusion in the base analytical sample.[9] Four additional vehicles received no initial FTP, and had no post-repair FTP that could be reasonably substituted for the missing as-received test.[10] These four vehicles are only included in a limited number of analyses in the sections that follow. The bulk of this report focuses on the remaining 239 vehicles, hereafter referred to as the base CTP sample.

3.2. Profile by Manufacturer and Quota Group

By and large, the actual CTP vehicle sample met the intent of the program plan targets described in Section 2.2. Table 4 and Figure 1 show the breakdown of the 239-vehicle sample by manufacturer and quota group.[11] As anticipated in

TABLE 4

CTP Base Sample by Manufacturer Share

Manufacturer	Vehicles	Sample %
General Motors	58	24.3
Ford	57	23.8
Nissan	20	8.4
Toyota*	16	6.7
Chrysler	15	6.3
American Motors**	15	6.3
Volkswagen**	14	5.9
Mazda**	12	5.0
Subaru**	12	5.0
Mitsubishi	10	4.2
Honda	10	4.2
TOTAL	239	100.0

* Testing split between EPA and manufacturer
** Testing performed by EPA

the project plan, General Motors, Ford, Nissan, Chrysler, Mitsubishi, and Honda tested their own vehicles. Testing of Toyota vehicles was divided between EPA and the manufacturer. Vehicles of the remaining manufacturers were tested by EPA at MVEL.

In general, the CTP recruitment reflects patterns one would have expected from the actual vehicle fleet. Ford and General Motors, which together comprise half of the CTP sample, are each dominated in the earlier model years by carbureted vehicles, and in the later model years, by fuel injection. Some manufacturers produced no closed-loop vehicles in a given quota group, and thus none were present in the program. Examples include fuel-injected 1981-82 Mazda and Subaru. In other cases, vehicles in the quota group were produced, but none was recruited in the CTP. Examples here were the fuel-injected MY1981-1982 Toyotas, and carbureted MY1983-1986 Subarus.

FIGURE 1

Fleet Profile by Quota Group and Manufacturer

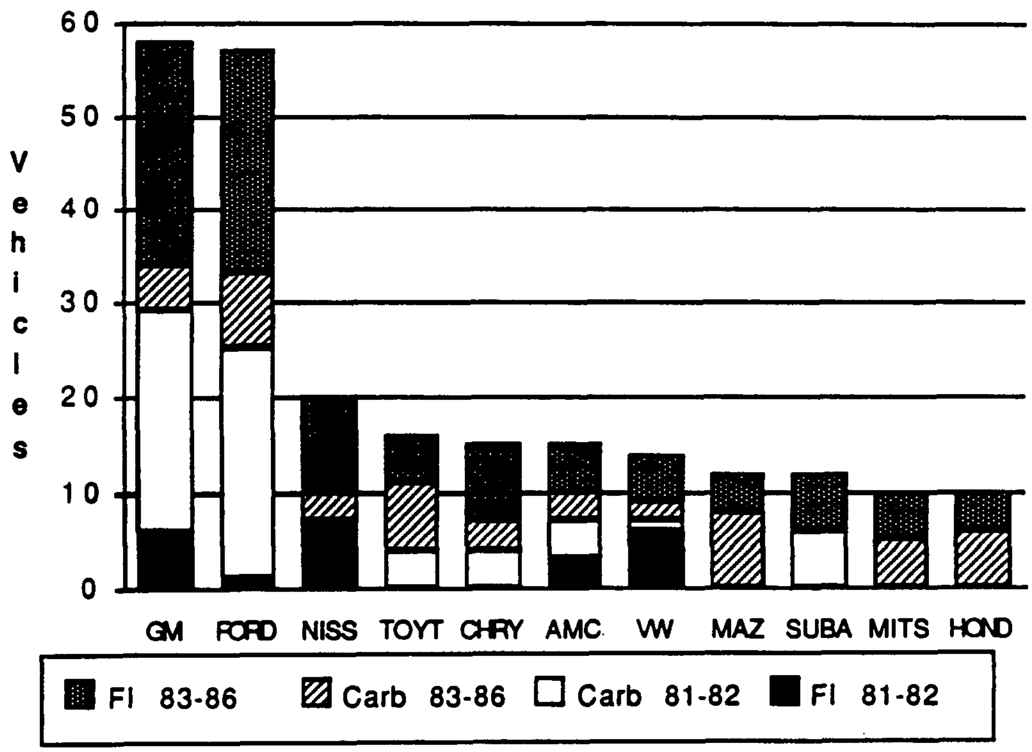


Table 5 shows the 239-vehicle fleet distribution by quota group. The fleet comes quite close to the planned target of 50% each for fuel injection and carburetion. Manufacturers who have unusual representation in a quota group are Volkswagen, with one-quarter of the fuel-injected 1981-82 vehicles, and Subaru and Toyota, whose total of ten carbureted 1981-82 vehicles were the only contributions by Japanese manufacturers to that quota group. Interestingly, three of Volkswagen's fourteen vehicles were carbureted.

Although no specific recruitment targets existed for individual model years, the sample was well-distributed across the 1981-86 range. Of the six model years represented, none comprised greater than 23% of the sample, and none was less than 11%.

TABLE 5

Fleet Breakdown by Quota Group

Quota Group	Vehicles	Fleet %
Fuel-Injected 1981-82	23	9.6
Carbureted 1981-82	66	27.6
Carbureted 1983-86	50	20.9
Fuel-Injected 1983-86	100	41.8
TOTALS	239	100.0

3.3. Mileage Profile

The CTP sample was also well-distributed by mileage (Figures 2 - 3), again without an explicit recruitment criterion. The median mileage was close to 50,000 miles. Not surprisingly, few (in fact only 15) of the under-50K vehicles were in the 1981-82 quota groups. Conversely, only 14 vehicles exceeded 100,000 miles, with only one from the 1983-86 model years.

The fleets of six of the eleven CTP manufacturers were composed entirely of vehicles with accumulated mileage under 100,000 (Figure 4). Of these, Volkswagen is notable for having close to 80% of its vehicles in the range 50,000 to 100,000 miles. Subaru and Toyota both had significant numbers of very high mileage vehicles in their samples, with 25% and 18%, respectively, over 100,000 miles. Toyota weighed in with the highest mileage vehicle, a 1982 Toyota Corolla with 234,000 miles.

FIGURE 2

Mileage Profile by Quota Group

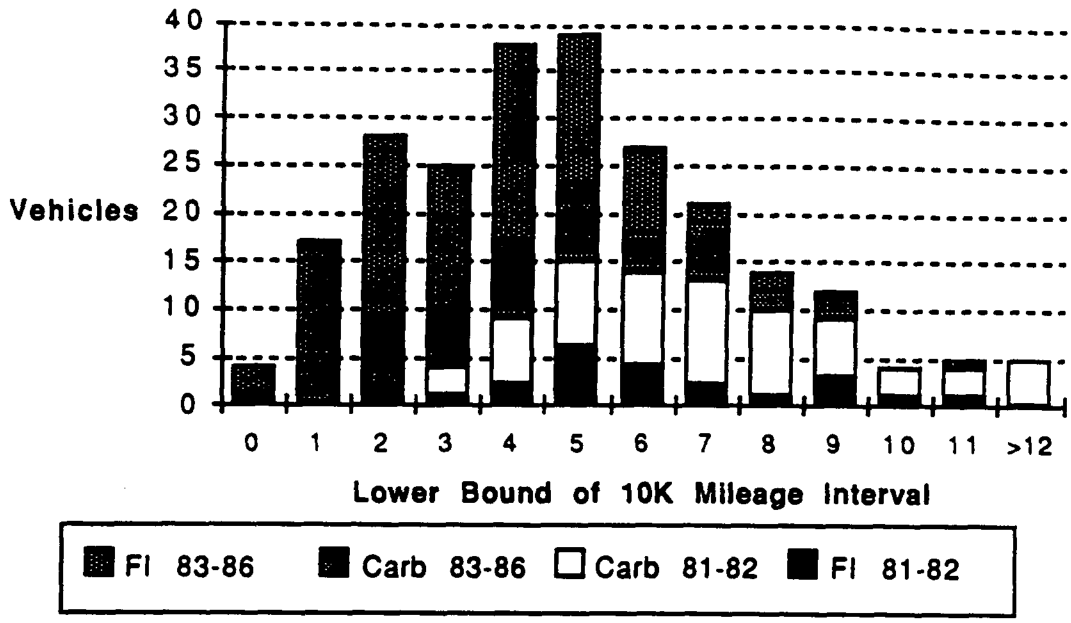


FIGURE 3

Cumulative Mileage Profile by Quota Group

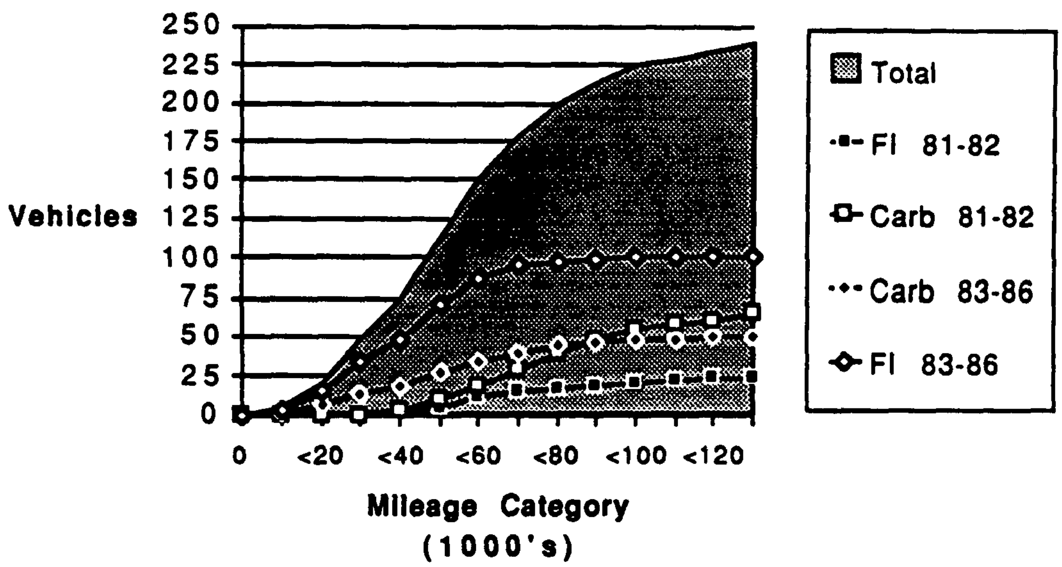


FIGURE 4

Mileage Distribution by Manufacturer

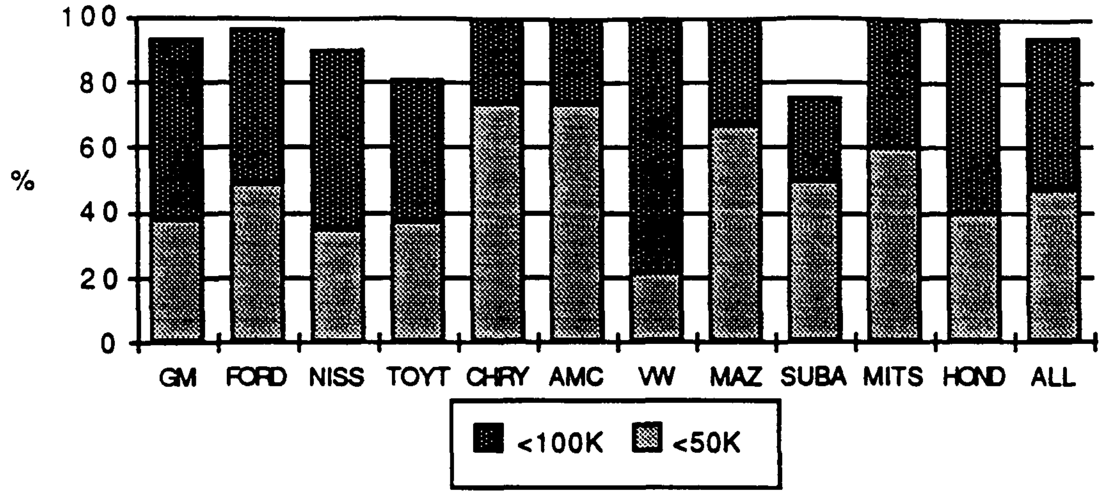
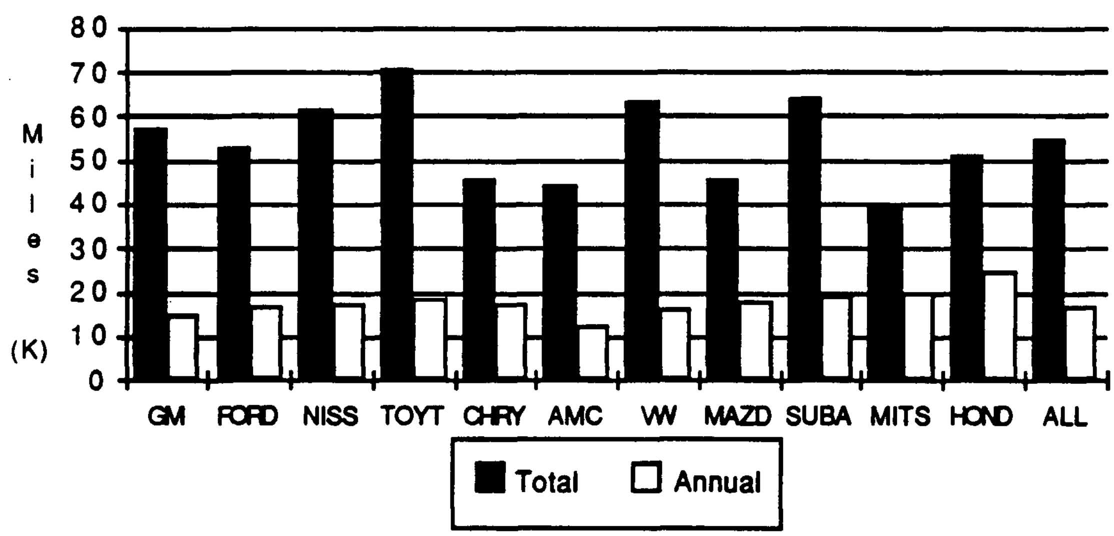


Figure 5 shows the mean mileages by manufacturer for the base CTP fleet. The "total" entries represent mean odometer miles; the "annual" entries are estimates of annual mileage accumulation, derived for each vehicle by subtracting the model year from 1987, dividing by the odometer miles, and then averaging across the given manufacturer.

FIGURE 5

Mean Mileage Accumulation by Manufacturer



The fleet mean odometer was 55,000 miles, and the calculated mean annual mileage accumulation was just under

17,000 miles. The high-mileage Toyota helped drive that manufacturer's mean odometer reading over 70,000 miles, highest among the participants; Mitsubishi (with no vehicles in the 1981-82 category) yielded the lowest mean odometer reading, 40,000 miles. Honda vehicles displayed the highest annual mileage accumulation (24,400 miles), almost twice that of AMC, whose 12,300-mile annual pace was the lowest among the participants.

3.4. Profile by Vehicle Type

Overall, eight percent of the 239-vehicle CTP sample were light-duty trucks (Table 6). Two participating manufacturers, General Motors and Chrysler, elected not to recruit LDTs. Two others, Mazda and Honda, produced no closed-loop LDTs in the model years covered by the program, and thus had none in their CTP samples. Of the remaining manufacturers, only American Motors had an LDT percentage of greater than 25% (from the Jeep line). Most of the trucks in the CTP sample fell in the later model years, probably reflecting the slower penetration of closed-loop technology in trucks relative to that in LDVs.

TABLE 6

Fleet Breakdown by Vehicle Type

Category	LDV	LDT	LDT %
General Motors	58	0	0.0
Ford	48	9	15.8
Nissan	19	1	5.0
Toyota	15	1	6.3
Chrysler	15	0	0.0
American Motors	11	4	26.7
Volkswagen	13	1	7.1
Mazda	12	0	0.0
Subaru	11	1	8.3
Mitsubishi	8	2	20.0
Honda	10	0	0.0
Fuel-Injected 1981-82	23	0	0.0
Carbureted 1981-82	64	2	3.0
Carbureted 1983-86	40	10	20.0
Fuel-Injected 1983-86	93	7	7.0
SAMPLE	220	19	7.9

3.5. Additional Comments on the Base Sample

Some manufacturers showed unusual concentrations of selected engine displacements in their samples. For example, fourteen of the fifteen Chrysler vehicles (or 93%) were 135CID engines. In the national fleet, this displacement accounted for between 64% and 74% of Chrysler's production of closed-loop vehicles in model years 1981-86. Close to three-fifths of the 57 Ford CTP vehicles were 140CID, a displacement that was only 19% to 28% of Ford's closed-loop production in the model years covered by the CTP. Finally, thirteen of the 30 fuel-injected GM vehicles (or 43%) were 151CID, compared to between 10% and 20% of GM's closed-loop production in the given model years.

Higher I/M failure rates are one possible cause, but not the only one, for the greater representation of these families; AET failure rates by manufacturer and displacement are not available from Michigan.

SECTION 4: AS-RECEIVED EMISSIONS ANALYSIS

4.1. Introduction

This section analyzes the emission results from testing of the CTP fleet in the as-received condition. The FTP results are analyzed first, including an analysis based on the "excess emissions" concept and emitter categories employed in EPA's MOBILE4 computer model. The short test results from both the Michigan AET test and the CTP's own short tests are analyzed and compared to the FTP results.

4.2. FTP Results

4.2.1. Sample Description

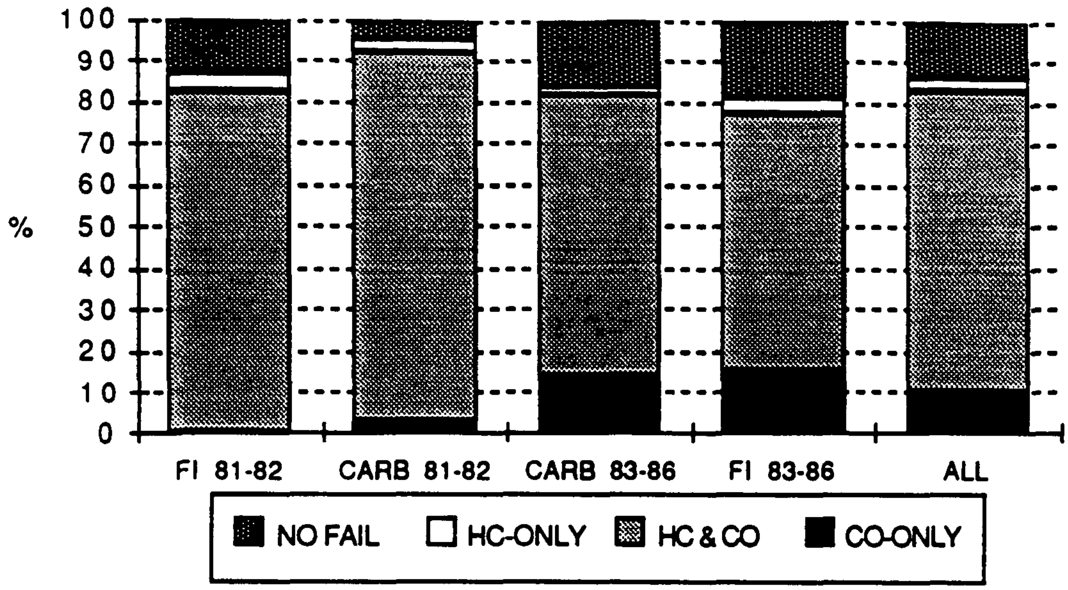
All but two of the 239 vehicles in the base CTP sample underwent an FTP on Indolene in the as-received condition. For the two exceptions (vehicles 257 and 337), post-repair FTP results were substituted for the missing as-received tests, based on the conclusion that the repairs performed were likely to have had negligible impact on each vehicle's emissions. (As discussed in Section 3.1, such substitutions were unavailable or unjustified for six additional vehicles, accounting for the difference between the 245 vehicles recruited for the program, and the 239 vehicles used for the bulk of this analysis.)

4.2.2. Pass/Fail Results at Certification Standards

Of the 239 vehicles in the base sample, 206 (or 86%) exceeded their certification standards for HC, CO, or both. The remaining 33 vehicles thus represent errors of commission (E_c) by the original AET short test. As Figure 6 shows, combined HC-CO FTP failures dominated the CTP sample. Only in the later model years were there significant numbers of CO-only failures, and few HC-only failures occurred, regardless of model year.[12]

FIGURE 6

As-Received FTP Failure Type by Quota Group



4.2.3. Excess Emissions Analysis

A more illuminating view of FTP emissions in the CTP sample arises from analyzing "excess" emissions, which is the difference between each vehicle's FTP performance and its emission standard, for a given pollutant. Figures 7 - 10 scatter plot the excess HC and CO emissions of the base sample, stratified by quota group. Identical scales have been used in the figures to ease comparisons between the groups; note, however, that the resolution does not permit display of the individual vehicles concentrated very close to the origin.

The total HC excess emissions in the 239-vehicle base sample was 334 g, or 1.4 g per average vehicle. The total CO excess was 5155 g, or 21.6 g average excess. As the scatter plots show, however, the fleet displayed a broad spread of excess emission values for both HC and CO. The total excess values include 57 vehicles that passed their HC standard and 41 that passed their CO standard, and thus contributed negative "excess" emissions. Cleanest relative to its certification standards for both HC and CO was vehicle 249, a carbureted 1982 Ford LDT, which was 0.8 g below its 1.7 g HC standard and 12.9 g below its 18 g CO standard.

FIGURE 7

As-Received FTP Excess Emissions:
Fuel-Injected 1981-82 Vehicles

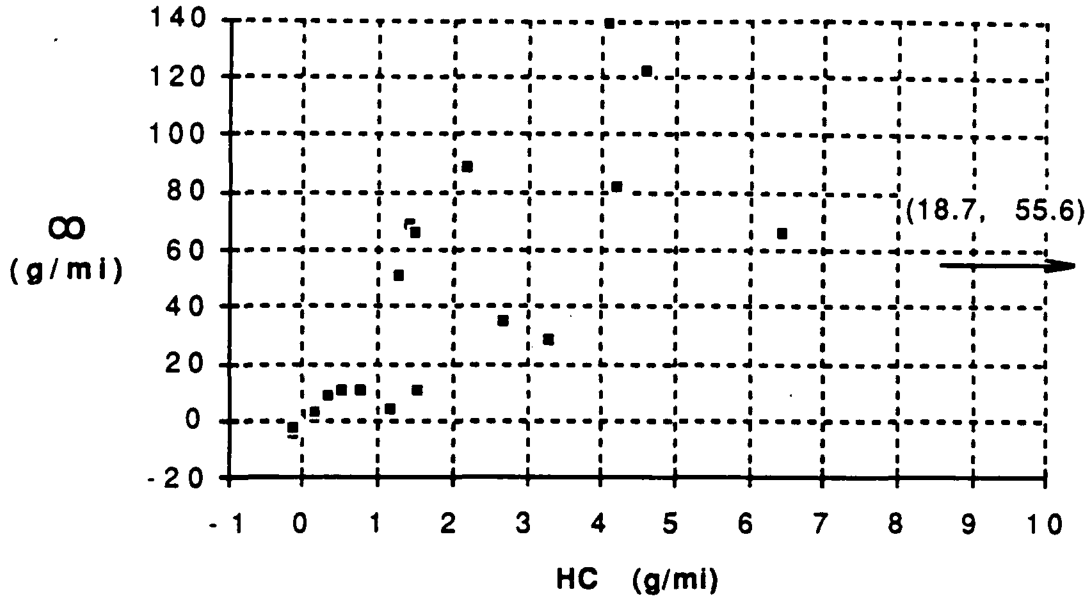


FIGURE 8

As-Received FTP Excess Emissions:
Carbureted 1981-82 Vehicles

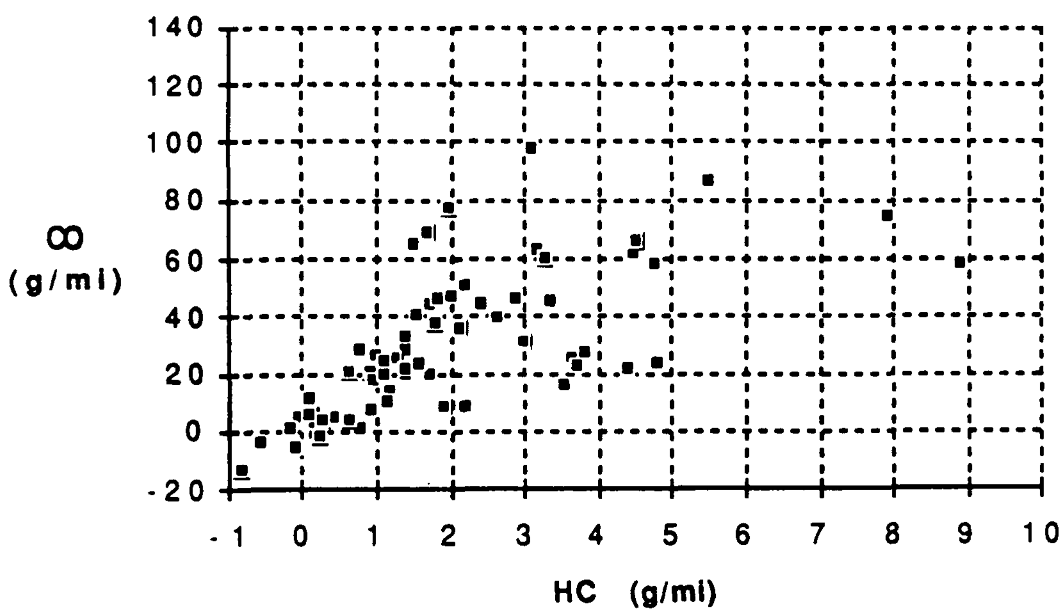


FIGURE 9

As-Received FTP Excess Emissions:
Carbureted 1983-86 Vehicles

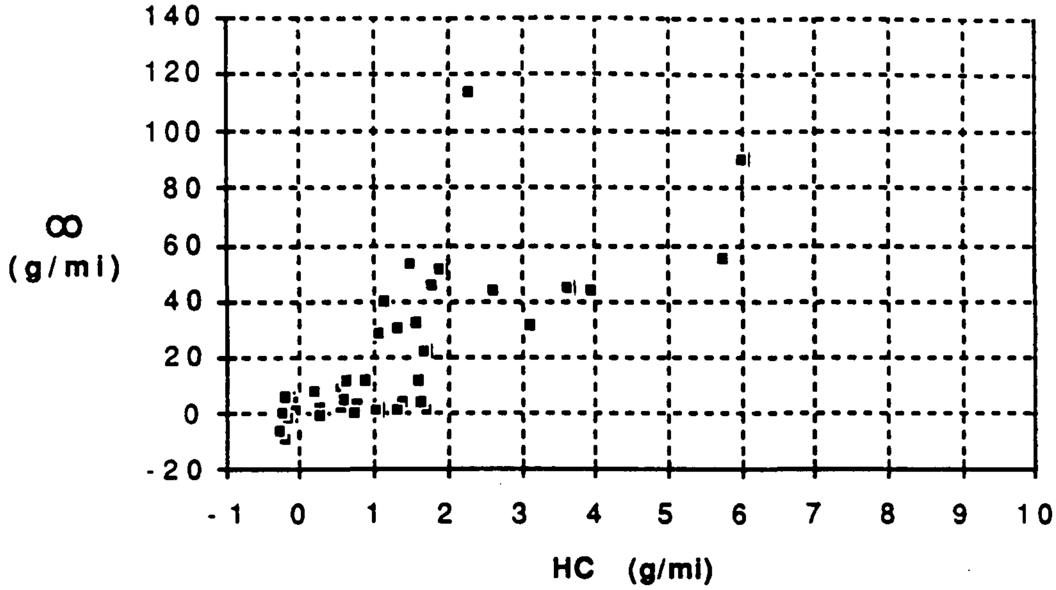
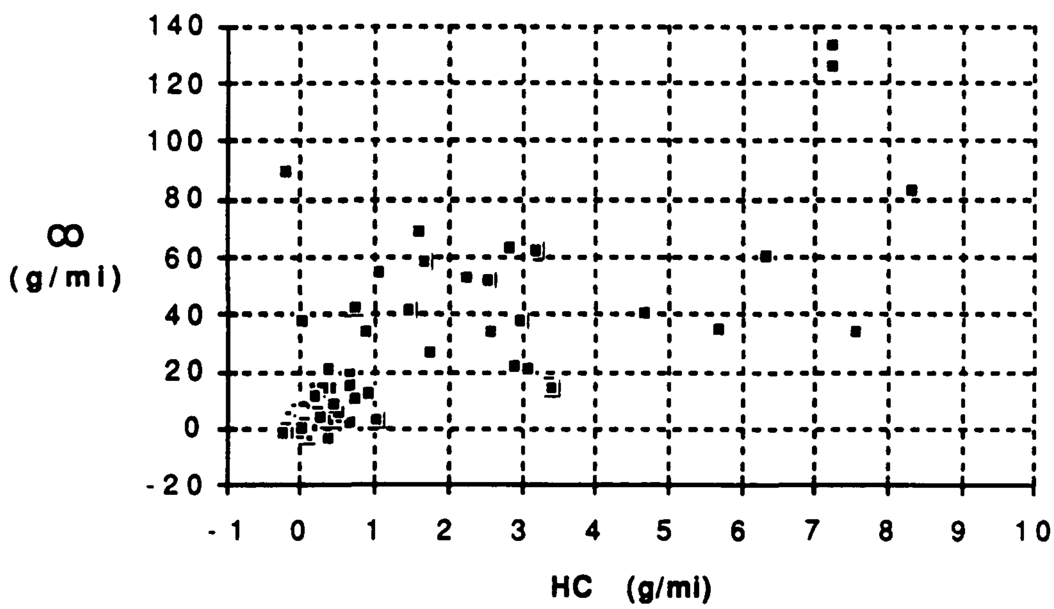


FIGURE 10

As-Received FTP Excess Emissions:
Fuel-Injected 1983-86 Vehicles

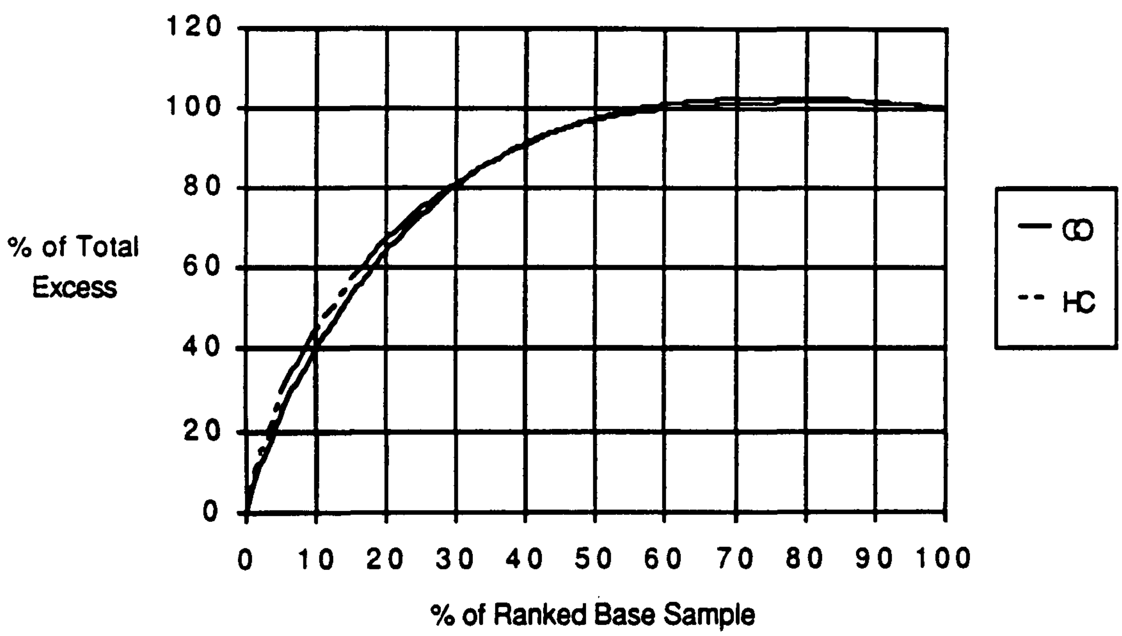


On the opposite extreme was vehicle 202, another 1982 Ford, which was a sizable 18.7 g above its 0.41 g HC standard. (This fuel-injected LDV was also the only super emitter in the as-received CTP sample; see section x.x.x below). On its own, #202 accounted for almost 6% of the total HC excess emissions in the 239-vehicle sample. Highest in the ranking of excess CO emissions was vehicle 605, a fuel-injected 1982 Nissan LDV, which was 139 g above its 3.4 g standard, or close to 3% of the total excess CO from the sample.

When the CTP vehicles are ranked by excess FTP emissions, and the excess is accumulated as a percent of the total excess for a given pollutant, Figure 11 results. The curves for HC and CO were determined independently. For each pollutant, the dirtiest 40% of the vehicles accounts for 90% of the excess from the sample. The leveling of the curve above 100% and eventual decline to 100% reflects the portion of the ranked sample that was very close to, and then below, the certification standards.

FIGURE 11

Excess Emissions in the Ranked As-Received Fleet



As the scatter plots and judgment would indicate, considerable overlap exists between the vehicles with large excesses for HC and CO. The ninety vehicles with the worst

HC excess emissions together account for 90% of the fleet excess HC; the identical 90 vehicles account for 83% of the fleet excess CO.

4.2.4. Analysis Using MOBILE4 Emitter Categories

The EPA MOBILE4 emissions model classifies light-duty vehicles into four categories, from lowest to highest emitters: passing, marginal failure, high failure and super.emitter. The passing and marginal emitters, when taken together as a single group, are frequently referred to as "normal" emitters.[13] Boundaries between emitter categories are defined separately for HC and CO. The pollutant with the highest emitter category determines the category of the vehicle; thus, a vehicle that is a high emitter on HC and a marginal emitter on CO is referred to as a high emitter.

Table 7 shows the upper bounds of the emitter categories for HC and CO. Note that the boundaries between the marginal- and high-emitter categories are technology and model-year-group specific.[14] Passing emitters have HC and CO values that are each below their respective certification standards. A vehicle with either an HC reading or a CO reading exceeding the respective upper bound of the high-emitter category is classified as a super emitter.

TABLE 7

Upper Bounds of the MOBILE4 Emitter Categories

	HC			CO		
Technology Group	Pass	Marginal	High	Pass	Marginal	High
Carbureted 1981-82	cert std	1.175	10.0	cert std	17.411	150
Fuel-Injected 1981-82	cert std	0.725	10.0	cert std	10.499	150
Carbureted 1983+	cert std	0.815	10.0	cert std	10.398	150
Fuel-Injected 1983+	cert std	0.965	10.0	cert std	10.558	150

Figure 12 shows the breakdown of the base CTP sample by the MOBILE4 approach, giving the percent of the sample in the four quota groups (and the entire sample) that fell in each emitter category.[15] Thus, approximately 15% of the CTP fleet were passing emitters, 25% were marginals, 60% were highs, and less than 1% -- that is, one vehicle -- was a super emitter. In simpler terms, 60% of the sample showed significant HC or CO FTP noncompliance, while the remaining 40% could be considered "normal" emitters.

The figure shows that the fuel-injected 1983-86 group was distinctive for containing a disproportionately large percentage of marginal emitters and fewer high emitters.

Carbureted vehicles were more likely to be high emitters than were their fuel-injected counterparts of the same model year. Similarly, vehicles from the earlier model year grouping were more likely to be high emitters than their counterparts in the later model-year grouping.

FIGURE 12
As-Received FTP Profile by Quota Group and Emissions Category

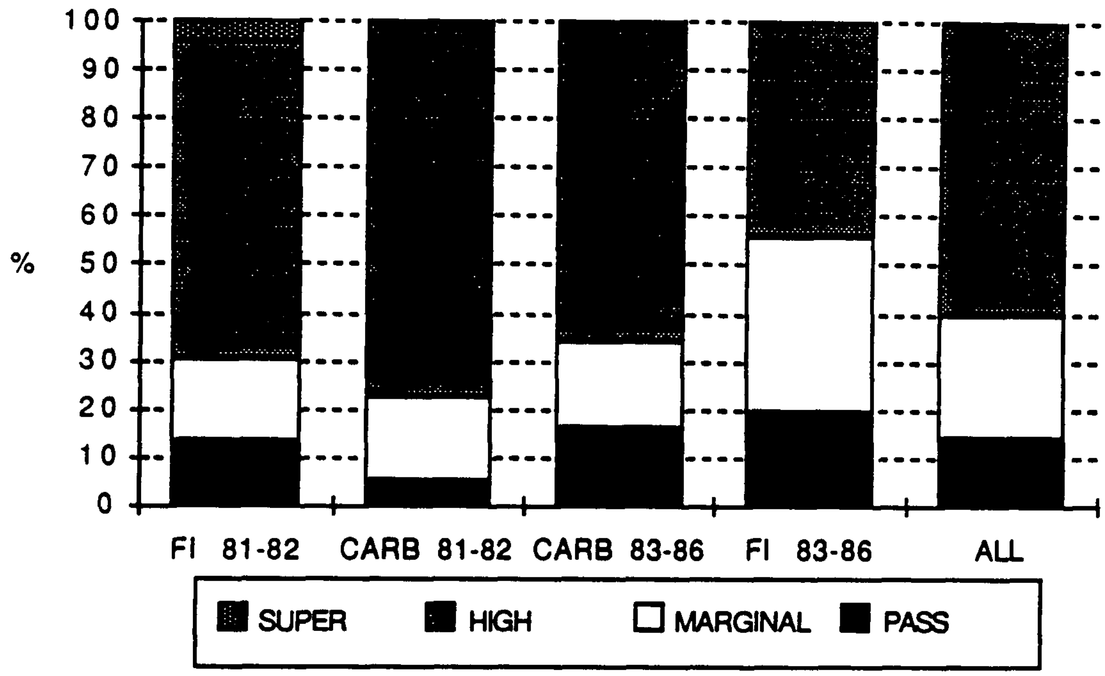


Table 8 shows the mean excess HC and CO emissions for all 206 FTP failures (including the one super emitter), and then isolates the mean excess HC and CO for the 62 marginal emitters and the 143 high emitters. Thus, for example, the mean excess for fuel-injected 1983-86 high-emitters was 2.21 g/mi HC and 35.4 g/mi CO. The mean excesses for the marginal emitters are quite small, implying that most of the marginals were in the lower part of the marginal range. The mean excess HC for the carbureted 1983-86 group is actually negative, indicating that the CO values for those vehicles were driving the classification. One implication of these low values for the marginal emitters is that the emissions repair benefit to be derived from them is quite small.

The relatively high values in the "all fails" category show the effects of the large number of high emitters in the sample. Thus, for example, the 2.07 g/mi HC excess and 30.5 g/mi CO excess for the carbureted 1981-82 vehicles are several times greater than the standards applicable to those vehicles. The mean excess for all failures in the fuel-injected 1981-82 group is sensitive to the presence of the single super emitter: the HC value would drop from 2.77 g/mi to 1.93 g/mi if the super-emitter were to be removed.

Because of the large impact of the single super emitter and the low mean excess displayed by the marginals, the analysis below will in most instances focus on the high-emitter category.

The mean excess HC values for the high emitters in the four quota groups were comparable to the mean for all high emitters of 2.22 g/mi, although the carbureted 1983-86 value was somewhat lower. For mean excess CO, the fuel-injected 1981-82 category was considerably dirtier than the mean, and the carbureted 1983-86 group was once again somewhat cleaner.

TABLE 8

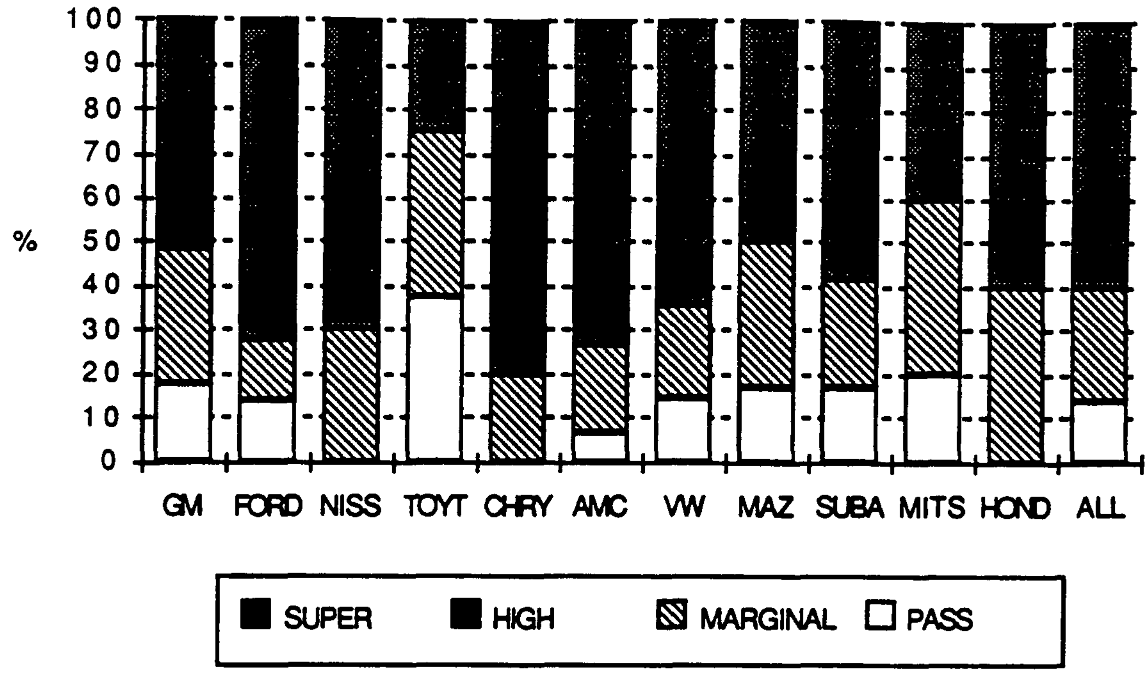
Mean Excess Emissions of Failures by Quota Group

	Excess HC (g/mi)			Excess CO (g/mi)		
Quota Group	All Fails	Marginal	High	All Fails	Marginal	High
Fuel-Injected 81-82	2.77	0.14	2.41	42.4	1.4	52.5
Carbureted 81-82	2.07	0.19	2.51	30.5	3.5	36.8
Carbureted 83-86	1.31	-0.01	1.67	19.8	2.3	24.6
Fuel-Injected 83-86	1.24	0.07	2.21	20.2	2.2	35.4
ALL	1.66	0.09	2.22	25.4	2.4	35.2

The MOBILE4 emitter categories were also used to generate Figure 13, which shows the proportion of each manufacturer's fleet that fell in each category. Although the data in Figure 13 have not been adjusted for mileage, model year, or technology factors, such factors do not necessarily explain the differences between manufacturers. Chrysler, for example, has the highest percentage of its fleet (80%) in the high-emitter category, yet it was the manufacturer with the highest percentage of its fleet under 50,000 miles (see Figure 4). The Chrysler fleet also contained an above-average percentage of late-model vehicles, and no fuel-injected 1981-82 vehicles (Figure 1). Toyota, on the other hand, shows the smallest percentage of vehicles in the high-emitter category (as well as the highest percentage of "passes,") yet its fleet had the highest average odometer reading of any manufacturer in the sample (Figure 5).

FIGURE 13

As-Received FTP Profile by Manufacturer and Emissions Category



4.2.5. Correlation of Excess Emissions, Emitter Category, and Odometer

Linear regressions on odometer against excess emissions in the as-received fleet yielded essentially no correlation. The degree to which dirty cars are dirty seems not to depend much on their age. Figure 14, for example, shows the wide scatter when excess HC is plotted against odometer for the carbureted 1981-82 group; plots for the other groups and for CO are similar. The R-squared values for the linear fits performed on each quota group ranged from 0.2% to 5.2% for both HC and CO, with similar poor correlation shown for the fleet as a whole.

On the other hand, the mean mileages increase across the MOBILE4 pass, marginal, and high categories for the technology and model year groups with significant sample sizes in each emitter category (Figure 15). This is consistent with an hypothesis that greater numbers of vehicles move into the failing emitter categories with increased mileage, although the actual excess emissions of vehicles within a category may not be linearly related to mileage.

FIGURE 14

Mileage vs. Excess HC in the Carbureted 1981-82 Quota Group

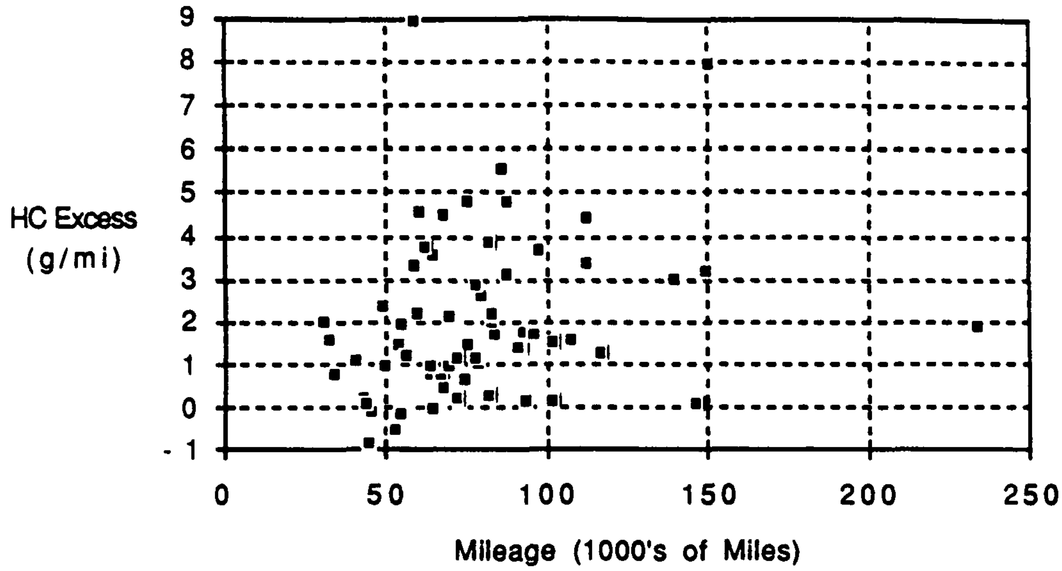
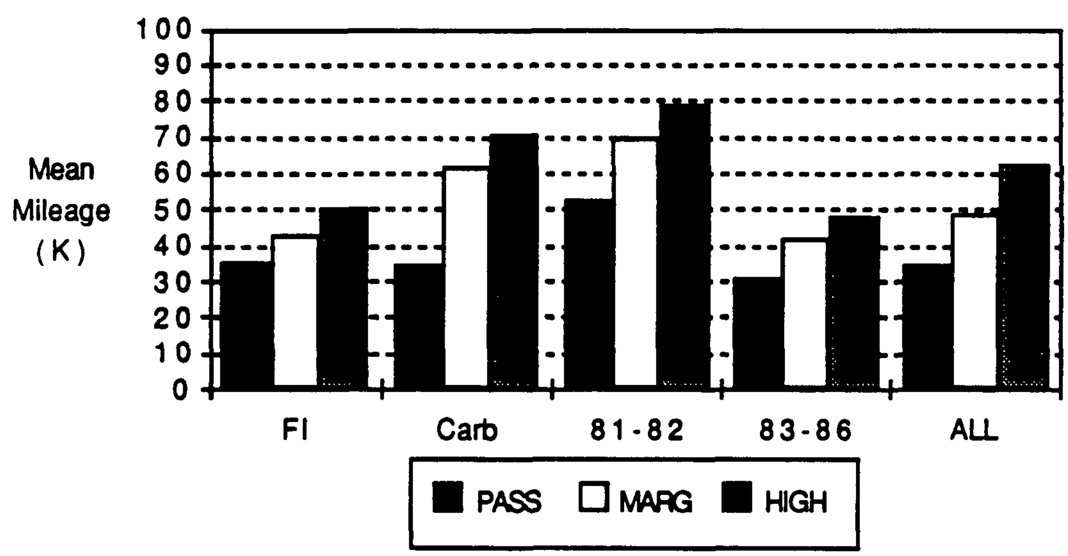


FIGURE 15

Mean Mileage of Model Year and Fuel-Metering Groups by MOBILE4 Emitter Category



4.3. Michigan AET Test Results

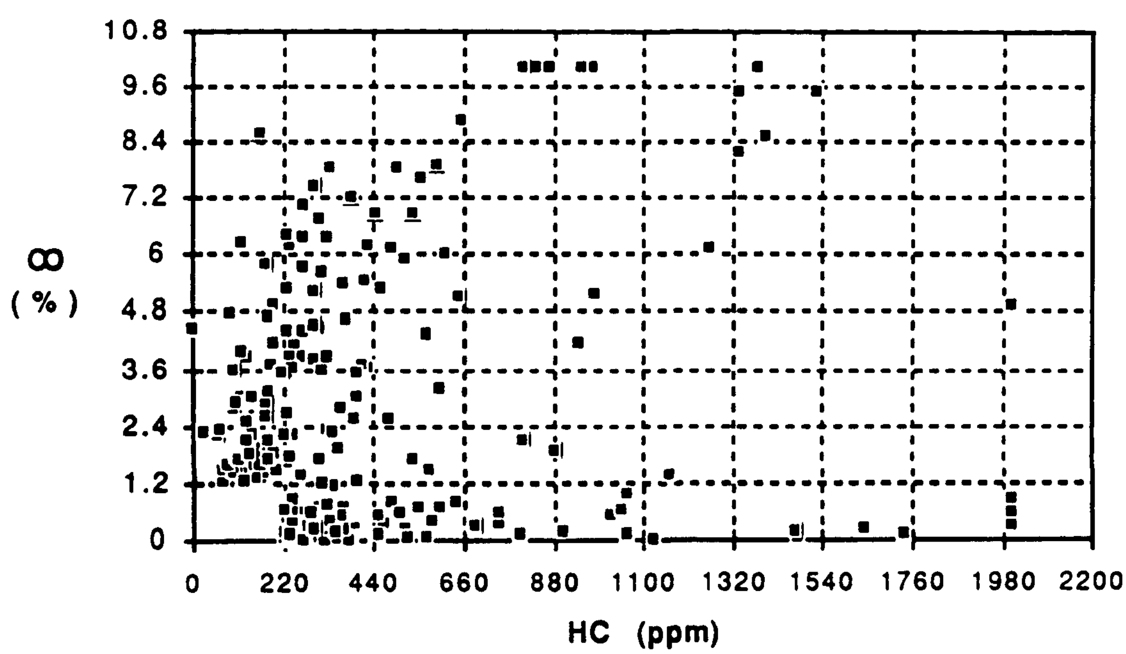
4.3.1. Profile of the Base Sample

As mentioned in Section 2.1 above, vehicles were recruited for the Cooperative Test Program on the basis of failing their official I/M short test under the Michigan Automobile Emission Testing (AET) program. The AET test makes a pass/fail determination at idle, following a short period of 2500rpm preconditioning.

A scatter plot of the HC and CO scores on the AET screening test for the 239-vehicle sample appears in Figure 16. The major divisions in the figure represent multiples of the 207(b) cutpoints. Values that fall on the 10% CO horizontal and the 2000ppm HC vertical are vehicles whose emissions exceeded the maximum ends of the analyzer ranges. Vehicles that passed the AET cutpoints of 1.2% CO and 220ppm HC were not recruited for the program, which accounts for the empty range in the lower left corner of the plot.

FIGURE 16

Results of the I/M Screening Test (AET Test) for the Base Sample



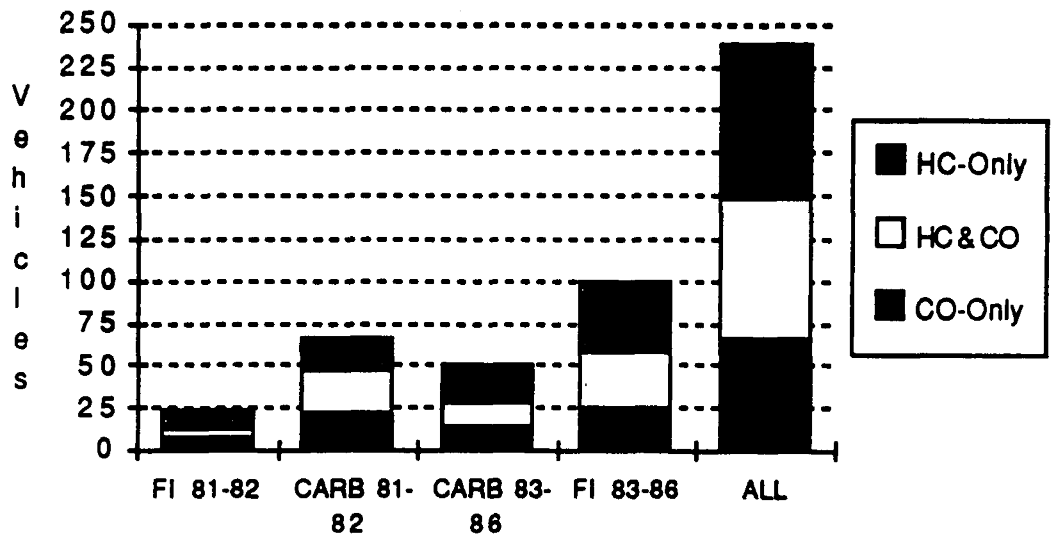
Noteworthy in Figure 16 is the large number of vehicles that failed one pollutant (particularly in the first "cell" above the cutpoint), but passed the other pollutant. Similarly, note the relatively small number of vehicles that failed both pollutants in the area just in excess of the cutpoints. On the other hand, 30% of the base sample (74 vehicles) had either HC emissions above 800ppm or CO emissions above 4%. Twenty-two of these vehicles with extremely high short test scores were single-pollutant failures, including the three 2000ppm HC vehicles at the extreme bottom right of Figure 16.

The distribution by failed pollutant is reasonably consistent with an hypothesis that some emission control failures (or AET test irregularities) cause high idle HC, and others cause high idle CO, but few cause both high HC and high CO. The vehicles seen to have high HC and CO are approximately accountable in terms of random simultaneous occurrence of two failures.

4.3.2. Stratifications by Manufacturer and Quota Group

The frequent pattern of AET failure for a single pollutant was maintained across quota groups as well as for the entire base sample (Figure 17). For each group, the sum of HC-only and CO-only failures exceeded the number of combined HC/CO failures. In the two 1983-86 groups and the fleet as a whole, the number of HC-only failures was itself almost equivalent to the number of combined HC+CO failures.

FIGURE 17

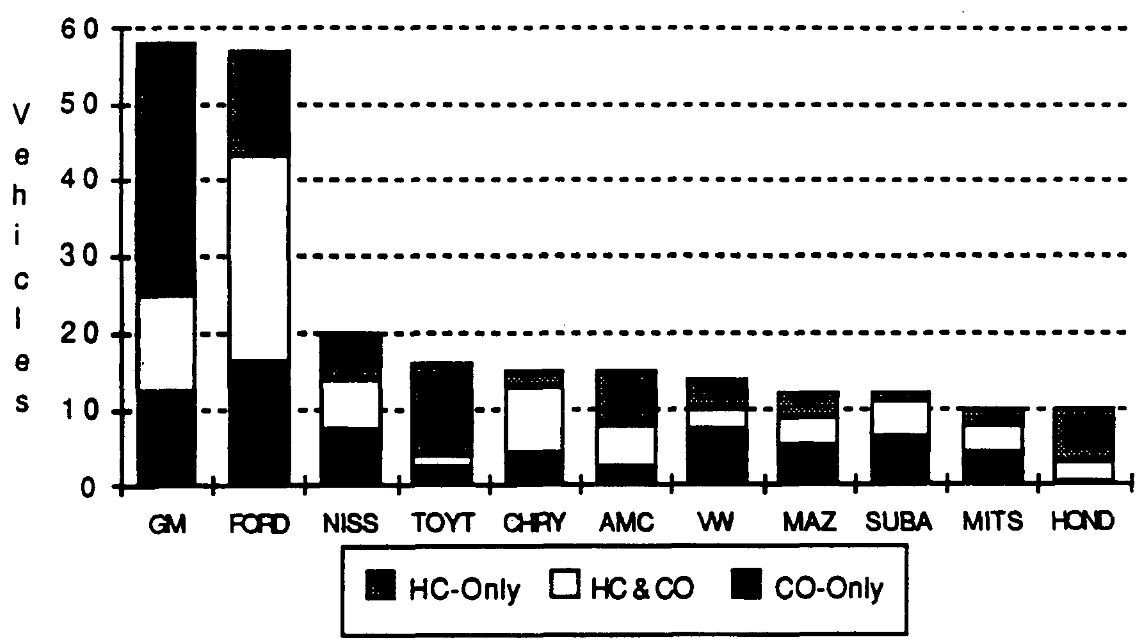


These observations on the Michigan AET results contrast with the results on the as-received FTP test, presented in Figure 6. There, HC-only failures were the rarity across all quota groups; CO-only failures occurred at a somewhat higher rate in the 1983-86 model year groups, and combined HC/CO failures dominated the sample. This trend is not simply an artifact of the cutpoints used to define FTP failure; that is, there is not a disproportionate number of combined HC+CO failures right above the standards, in the "marginal" failure category. In fact, of the 144 highest emitters in the sample (the 143 highs, plus the one super emitter), 141 were combined HC+CO failures.

In further analyzing the types of AET failure, what was true for the quota groups was not true for the manufacturers; different manufacturers showed different proportions of HC-only, CO-only and combined HC/CO failures. In Figure 18, each manufacturer's CTP sample is divided according to the number of vehicles that fell in each of the AET failure types. Better than 70% of the Honda and Toyota vehicles were HC-only failures, as were 57% of the GM vehicles. Together, these three manufacturers accounted for almost three-fifths of the HC-only failures in the base sample.

FIGURE 18

AET Failure Types by Manufacturer



Chrysler and Ford, on the other hand, showed higher proportions of their samples (60% and 47%, respectively) in the combined HC/CO failure category. Subaru and Volkswagen had close to half of their samples failing CO only, while Honda had no CO-only failures at all.

4.3.3. Stratification by Mileage and Vehicle Type

Two other brief analyses were performed on the relationship between the AET failure type and basic vehicle characteristics. Analysis of the numerical relationship between vehicle mileage and the AET scores showed essentially no useful correlation. Finally, no qualitative difference in the AET failure types was noticed when the base sample was disaggregated by vehicle type.

4.4. Correlation Between the FTP and Michigan AET Results

4.4.1. Introduction

Section 4.2.2 mentioned that 206 of the 239 vehicles (86%) in the base CTP sample failed their as-received FTP tests at certification standards. Because all vehicles recruited for the CTP had failed their initial Michigan AET test, the remaining 33 vehicles that passed their as-received FTP are considered errors of commission (E_c) by the AET short test. This section examines more closely the relationships between the AET test results and the as-received FTP test results for both the FTP failures and the E_c vehicles.

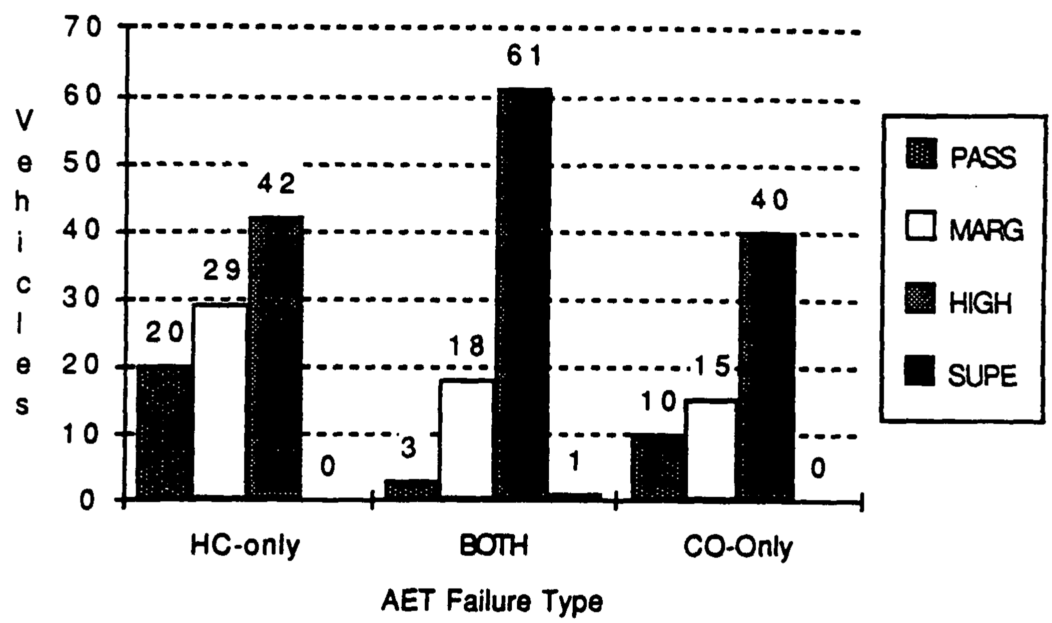
4.4.2. Excess Emissions and Emitter Categories of the AET Failure Types

Figure 19 stratifies the sample by the type of AET failure (HC-only, CO-only, or combined HC/CO) and the MOBILE4 emitter categories. As shown in the figure, the greatest number of vehicles fell in the high emitter category for each of the types of AET failure. Of the vehicles that failed their AET tests for both pollutants, for example, 61 of 83 (or 73%) were high emitters -- making the HC+CO failure type the most productive at identifying vehicles with significant FTP nonconformity. Next-most productive were the CO-only AET failures, where 62% were FTP high emitters. Least effective were the HC-only failures. While these failures were the most prevalent (38% of the sample), it was the only AET failure type where more normal FTP emitters were identified than high emitters.

Figure 19 also shows a correlation between the type of AET failure and whether or not the vehicle was an error of commission. Of the 33 E_c vehicles in the sample, only three failed their AET short test for both HC and CO. Of the remainder, E_c's among the HC-only failures outnumber those in the CO-only failures by two to one.

FIGURE 19

Breakdown of FTP Emitter Types by Type of AET Failure



As shown in Table 9, vehicles in the high-emitter category accounted for 93% of the excess HC and 96% of the excess CO from among the 206 failures in the base sample. Each type of AET failure contributed significantly to that total, but the combined HC+CO AET failures accounted for nearly half of the total excess (48.8% of the HC and 48.4% of the CO). This reflects both the larger number of HC+CO failures among the high emitters, as well as a generally larger mean excess per vehicle -- 2.73 g/mi for HC, and 41.6 g/mi CO.

On a per-vehicle basis, the CO-only AET failures matched the HC+CO failures in their ability to identify excess CO emissions among the high emitters. The CO-only failures even identified a respectable percentage of the excess HC emissions, with a mean excess HC of 1.7 g/mi, not far below the 2.0 g/mi mean from the HC-only AET failures. In spite of the high percentage of error of commission vehicles among the HC-only failures, the group nevertheless identifies nearly one quarter of the HC excess emissions among the failed vehicles in the sample, as well as 14% of the excess CO.

TABLE 9

Relationship Between AET Failure Type and Excess Emissions for the High Emitter Category

AET Failure Type	Mean Excess Emissions		% of Failed-Vehicle Excess	
	HC (g/mi)	CO (g/mi)	HC	CO
HC-only	1.97	17.8	24.3%	14.3%
HC and CO	2.73	41.6	48.8%	48.4%
CO-only	1.69	43.7	19.9%	33.4%
All Fail Types	2.22	35.2	93.0%	96.1%

Because no vehicles were recruited into the CTP with short test scores lower than the 207(b) cutpoints, the data cannot be used to evaluate the effectiveness of tighter standards on the excess emissions identified by the AET test. However, because so little of the excess apparently arises from the marginal emitters (and by definition, none arises from the passing vehicles), it is worth asking what impact raising the cutpoints might have had on the number of normal emitters identified by the test. Reducing the number of E_c vehicles, or perhaps even marginal emitters, while maintaining acceptable rates for identification of high emitters, would presumably be a desirable goal.

A scatter plot of the AET scores for the normal emitters appears in Figure 20, and Figure 21 shows the analogous data for the high emitters. The format is similar to that employed earlier in Figure 16, except that each of the axes has been truncated at four times the applicable 207(b) standard. Clearly, many of the normal emitters fall in the zone between the 100% and 200% of the HC and CO standards. Not surprisingly, however, many of the high emitters do precisely the same thing. Together, the plots show that there is no natural break in either the HC or the CO distribution that would suggest short test standards for excluding large numbers of the normal emitters from AET failure, without inappropriately converting many of the high emitters to AET passes.

FIGURE 20

<u>AET Scores of the Normal Emitters Lying Near the 207(b) Standards</u>

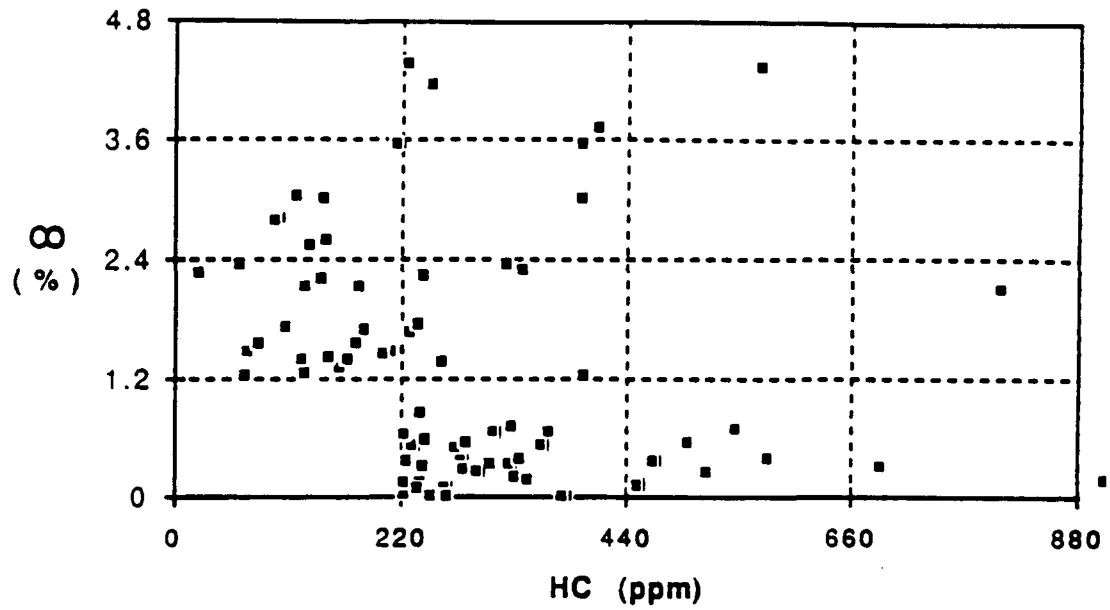
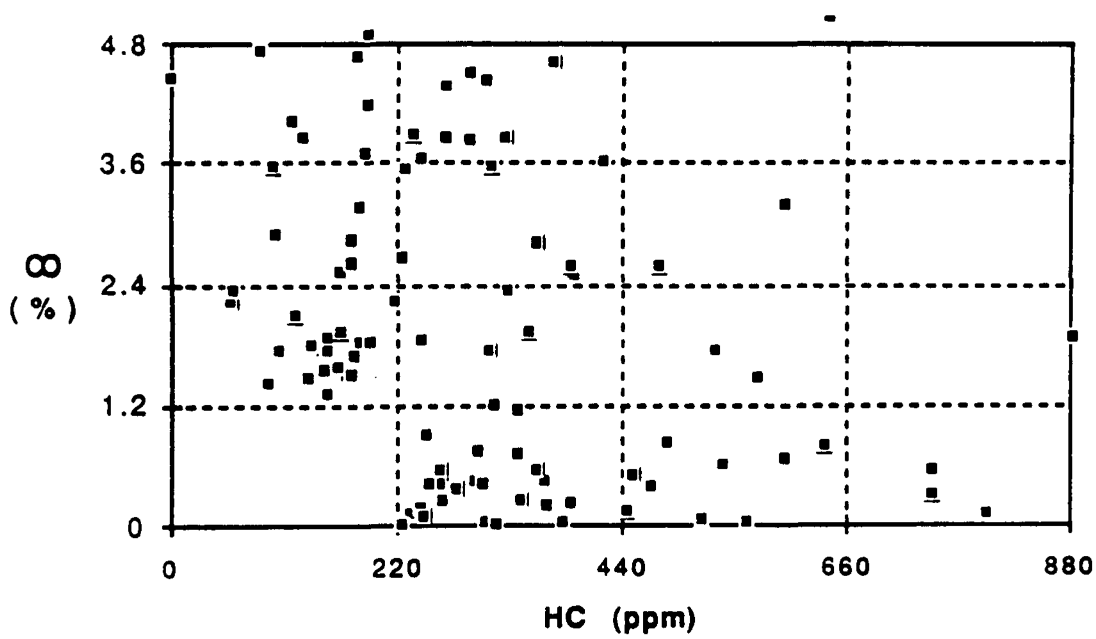


FIGURE 21

<u>AET Scores of the High Emitters Lying Near the 207(b) Standards</u>



4.5. Laboratory Short Test Results

4.5.1. Sample Description

For a variety of reasons, not all of the 239 vehicles in the base CTP sample completed short cycle testing with the Basic I/M Test Procedure on their tank fuel. Six of the vehicles were found to have insufficient tank fuel for the BITP after the procedure was underway; consistent with the program plan, the procedure was completed on these vehicles with commercial fuel.

Equipment and vehicle problems, as well as deviations from the program plan, led to omitted core sampling periods during parts of the BITP on seventeen vehicles. For all but eight of the vehicles, as-received indolene BITP testing was available for the missing tank/commercial modes, and the indolene values have been substituted for the purposes of the analysis below. Only one vehicle from the original 239 (vehicle 104) was missing enough data to be eliminated from the short cycle analysis entirely.

In summary, tank fuel values were available for all but a few vehicles, and all but a few modes. Where they were not, commercial fuel values were used; where commercial fuel values were unavailable, Indolene values were used. Sample sizes that are less than 239 for particular modes result when no substitute data (regardless of fuel type) were available.

4.5.2. Second-Chance Failure Rates of the As-Received Base Sample

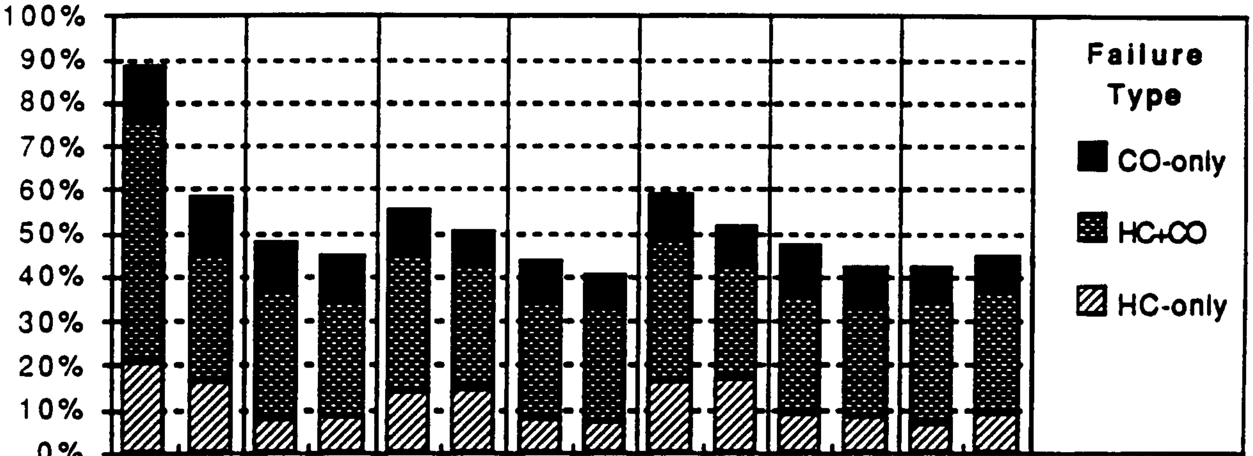
Recall from Section 2.4.2 that the Basic I/M Test Procedure includes seven "core" sampling periods, each consisting of a 30-second first-idle mode, a 30-second 2500rpm mode, and a 120-second second-idle mode. Thus, the core sampling periods closely resemble the EPA Two-Speed Idle Test. However, because all CTP vehicles had already failed one short test (the AET idle test) prior to recruitment, the core sampling periods in the BITP procedure represent "second-chance" short tests.

Figure 22 analyzes the as-received failure rates for fourteen of the idle modes found in the BITP, grouped as the paired first- and second-idle readings of the seven core sampling periods. The 30-second point in the modes were used in all cases, and failure type was determined by comparing those readings to the 207(b) HC and CO cutpoints. The numerical data on which the figure is based are provided in Appendix C.

The order of the modes in the figure duplicates the order in which they were performed during testing. Within each pair in the figure, the only difference between the two idles is an intervening 2500rpm mode, with the exception of the restart (RS) pair, which had both an intervening 2500rpm and a keyoff/restart. Between pairs, the difference between the idles is the intervening conditioning (shown in the bottom row of the table) that preceded the second pair.[16]

FIGURE 22

Failure Rates of the BITP Idle Modes



CS 03, CS 05	CS 07, CS 10	CS 12, CS 15	XL 02, XL 05	XI 02, XI 05	XI 07, XI 10	RS 02, RS 05	Idle Mode
75° Soak	75° Soak	75° Soak	Extended Loaded	Extended Idle	Extended Idle	Extended Loaded	Base Operation
None	Extended 2500rpm	Extended 2500rpm & Ext Idle	None	None	Extended 2500rpm	Restart	Conditioning

Each stacked column in Figure 22 gives the percent of the base sample that failed the given mode for CO-only (solid portion), HC-only (striped), and HC+CO (crosshatched). The total height of the column therefore gives the overall failure rate for the mode. The base operation and conditioning for the modes are provided below the horizontal axis. Thus, for example, 89% of the sample failed the first idle mode of the BITP (CS-03), which was an unconditioned idle following a minimum one-hour soak. Following 30 seconds of 2500rpm operation (CS-04), the failure rate dropped to 58% during the second idle (CS-05).

Figure 22 shows that considerable variability existed between the original Michigan Auto Exhaust Test results that were the basis for recruitment into the CTP and the simulated field short tests of the Basic I/M Test Procedure. With the exception of the very first mode of the procedure (following a "cold" start), the idle failure rates ranged between 40% and 60%. This indicates that a second-chance short test, almost regardless of how poorly it is performed, will reduce the idle-test failure rate substantially.

By examining the adjacent idle modes in Figure 22, one sees that the consistent impact of 2500rpm operation (both 30-second and 180-second) was to lower the idle failure rate. Focusing just on the core sampling periods, the failure rate for the second idle of each core sampling period was lower than the rate for the first, attributable to the intervening 30-second 2500rpm mode. The magnitude of the reduction between idles was greatest when the initial operating condition was furthest from ideal: the 31-point drop following the soak at the very beginning of the procedure, and an eight-point drop following the 20-minute extended idle in the middle of the procedure. Even in the conditions considered more ideal, however, failure rates for the second idle were three to four points lower than the first.

The impact of loaded operation was to reduce the failure rate as well. In fact, extended 2500rpm and loaded operation were apparently responsible for achieving the lowest failure rates among the 14 modes in the procedure; these are the values in the low 40's for XL-05, XL-10, and RS-02.[17]

On the other hand, the failure rate increased following extended idles: the ten-minute idle before CS-12 generated a ten-point rise, and the 20-minute idle at XI-02 led to an eighteen-point rise. In each of these cases, the accumulation of 2500rpm operation (including some extended 2500rpm modes) in succeeding modes eventually reversed the effects of the long idles.

Not surprisingly, the idle immediately following the initial soak period showed the highest failure rates of all. Interestingly, only extended 2500rpm and idle operation were then necessary to bring the failure rate down within a few points of the rates achieved by extended loaded operation later in the procedure.

Considering the effect of 2500rpm operation elsewhere in the procedure, the apparent rise from the combined effect of 2500rpm and restart operation between the last two idle modes (RS-02 and RS-05) implies that the restart alone might increase the failure rate somewhat.

The Michigan AET test and the BITP idle modes showed differences in the types of failure as well as in the overall failures rates. Recall from Section 4.3.1 that single-pollutant failures were frequent in the AET results. As shown in Figure 22, however, combined HC+CO failures were the rule in the BITP idle modes, outnumbering the other two failure types in every one of the modes. In fact, the HC+CO failures outnumbered the sum of the HC-only and CO-only failures in all of the idle modes except two: CS-05 and XI-02. These two modes represented non-ideal test conditions: one soon after the soak at the beginning of the procedure, and the other following a 20-minute idle.

Of the three failure types, the CO-only group had the most consistent failure rates across the different idle modes: all fell in the range from 7% to 13%. The four highest CO-only rates all came at the beginning of the procedure, before the first extended 2500rpm operation had occurred. Past that point, the CO-only failure rate never exceeded 10% of the sample. The HC-only failure rate, on the other hand, was apparently more sensitive to the type of prior operation. All of the modes preceded by extended 2500rpm or loaded operation had HC-only failure rates of 7%-9%; all the modes that immediately followed extended idle or a soak had failure rates twice that high.

The above observations support the hypothesis that many of the vehicles recruited for the CTP program were poorly preconditioned in their original Michigan AET test. Roughly one-half of the failures might have been avoided by better preconditioning.

In each idle mode in Figure 22 where the vehicles appear to have received adequate preconditioning (e.g., CS-10, XL-02, XI-10), approximately 20% to 25% of the sample failed the mode for both HC and CO. The possibility exists that these vehicles also failed the AET test for both HC and CO, and that they could represent a consistent set of failures across the various short test conditions encountered in the initial test (AET) and second chance tests. Table 10 compares the AET failure types to the failure types on on the first idle of the extended loaded sequence (XI-02). The data show considerable migration among the failure types between the initial test and this second-chance test. Of the 83 vehicles that failed both HC and CO on the AET test, for example, only 39 were of the same failure type on the second-chance test; 38 of the 83 changed from an HC+CO failure to a pass. The fact that the second-chance test shows the 25% HC+CO failure rate is due largely to the migration into that category of 17 vehicles from the AET CO-only category.

Given the earlier analysis of the AET HC-only failures, it is perhaps less surprising that more than two-thirds of these vehicles passed the second-chance test. Almost half of the AET CO-only failures passed the second-chance test as well.

TABLE 10

Comparison of Failure Types Between the AET Test and the First Idle-Neutral of the Extended Loaded Sequence

Second-Chance Failure Type	AET Failure Type			
	HC-Only	Both	CO-Only	Total
HC-Only	15	3	1	19
Both	8	39	17	64
CO-Only	2	3	16	21
Pass	66	38	31	135
Total	91	83	65	239

4.5.3. Idle-Mode Short Test Variability Due to Fuels

One-hundred, ninety-six of the vehicles in the base sample underwent as-received Extended Loaded short cycles on both Indolene and tank fuels.[18] The HC and CO values for the second idle (mode 5) of these sequences were compared to determine the effect of fuel type. For 169 of these (or 86%) there was no change in the 207(b) pass/fail status for either HC or CO between the tests on the different fuels; this is shown by the sum of the bold-print numbers in Table 11. Of the 27 remaining vehicles, there was an essentially negligible trend to more frequently pass the tank fuel test (a net increase of three failures occurred on Indolene). Although there were six more HC failures on tank fuel than Indolene, most of these vehicles were already consistent CO failures, so their overall pass/fail status did not change.

TABLE 11

Changes in Pass/Fail Status for HC and CO Between Tank and Indolene Idle Tests

	HC Pass/Fail Status (Tank-Indolene)				
CO Status	P-P	P-F	F-P	F-F	Total
P-P	**108**	2	3	11	124
P-F	5	**3**	0	0	8
F-P	0	0	**4**	2	6
F-F	12	2	6	**38**	58
Total	125	7	13	51	196

Were there to be a fuels-related impact on the idle test scores, the volatility difference between the tank and Indolene fuels would be the most obvious explanation. Fuel RVP levels were available for 189 of the 196 tank fuel tests used in the above comparison. The range in RVPs of this sample was 5.0 to 15.6, with a mean of 11.7.[19] One-third of the RVP levels were above 12.0. The 27-vehicle sample that showed variable pass/fail results on HC, CO or both, had RVP's in the range 9.3 to 15.6, and also had a mean RVP of 11.7. Thus no volatility-related fuel variability was evident in the first-idle neutral of the "ideal" short cycle from the as-received laboratory testing.

The group of 27 vehicles that change pass/fail status on either HC or CO between the Indolene and tank-fuel tests was divided into three roughly equal-sized groups. Eight vehicles had small score differences (changes in HC of less than 50ppm and in CO of less than 1.0%) that nevertheless overlap the 207(b) cutpoint. Eleven had extreme differences (changes in HC of more than 400 ppm or in CO of more than 4%). The remaining eight vehicles had moderate changes. For these groups, there was no correlation between the magnitude and the sign of the change in scores (i.e., no trends for one fuel being more failure-prone at idle), or between the magnitude of the change in scores and the RVP of the tank-fuel test.

4.5.4. Correlating the Laboratory Short Tests with the MOBILE4 Emitter Categories

Based on the results of the previous subsection, the question arises whether there are patterns to the FTP emissions of the vehicles that changed pass/fail status between the Michigan AET test and the various short cycles in the Basic I/M Test Procedure. Figure 19 begins this analysis with the laboratory short test results for the vehicles that were either passing emitters or marginal emitters on their as-received FTP tests, as well as the passing and marginal emitters taken together as a group. Thus, these are the vehicles that would presumably show minimal impacts from I/M-instigated repair.

Each collection of three bars in Figure 23 represents the percentage of the given MOBILE4 emitter category that passed a particular core sampling mode from the Basic I/M Test Procedure. Again, the horizontal axis gives the significant vehicle operation that preceded the sampling period. In each case, the data were from the second idle mode of the core sampling period. Based on the discussion in Section 23, the second idle of each period showed almost uniformly higher pass rates than did the first idle.

Thus, for example, the middle set of bars shows the rates for the fifth mode of the Extended Loaded sequence (XL-05), which was the second idle-neutral following an extended stretch of loaded operation. From the figure, 100% of the passing emitters passed this "second-chance" idle test. For the marginal emitters, the comparable figure on XL-05 was 85%, and for the passing and marginal emitters taken together, 91%.

FIGURE 23

Response of the Normal FTP Emitters to Second-Chance Short Testing

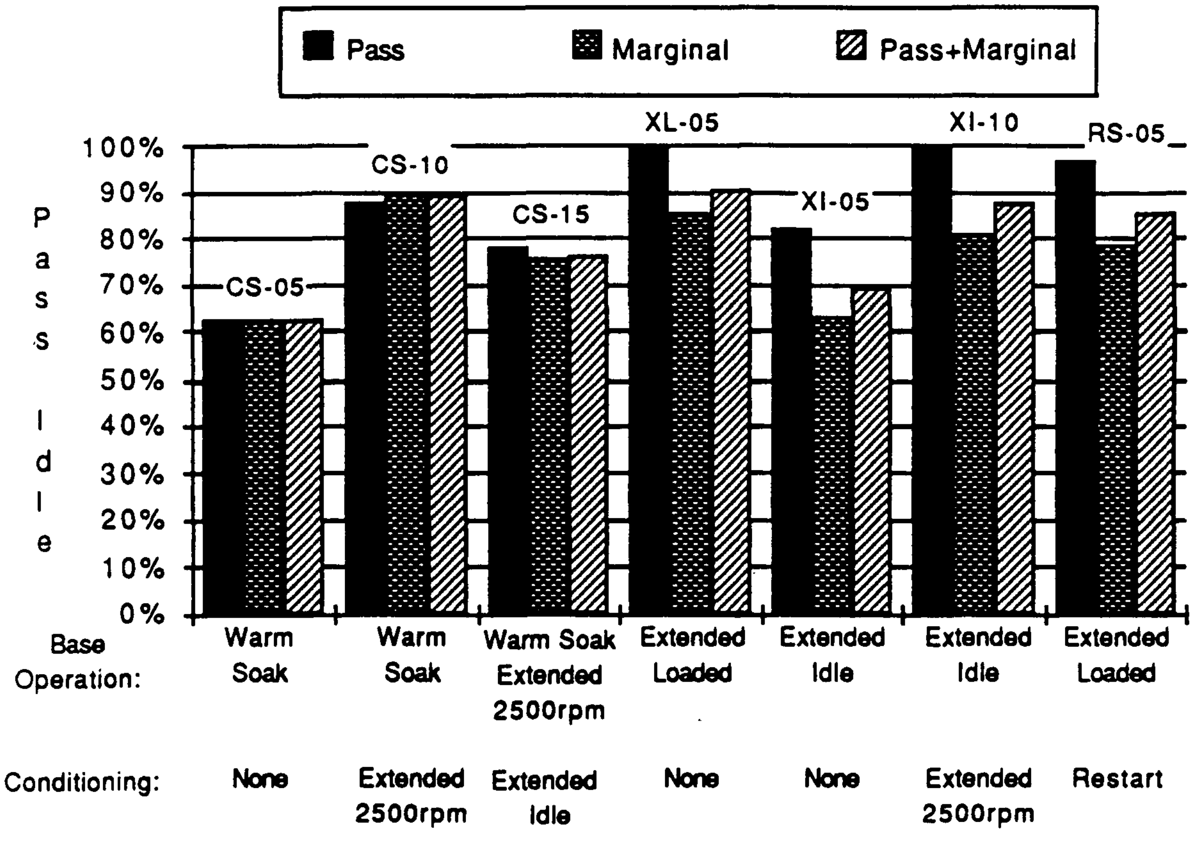
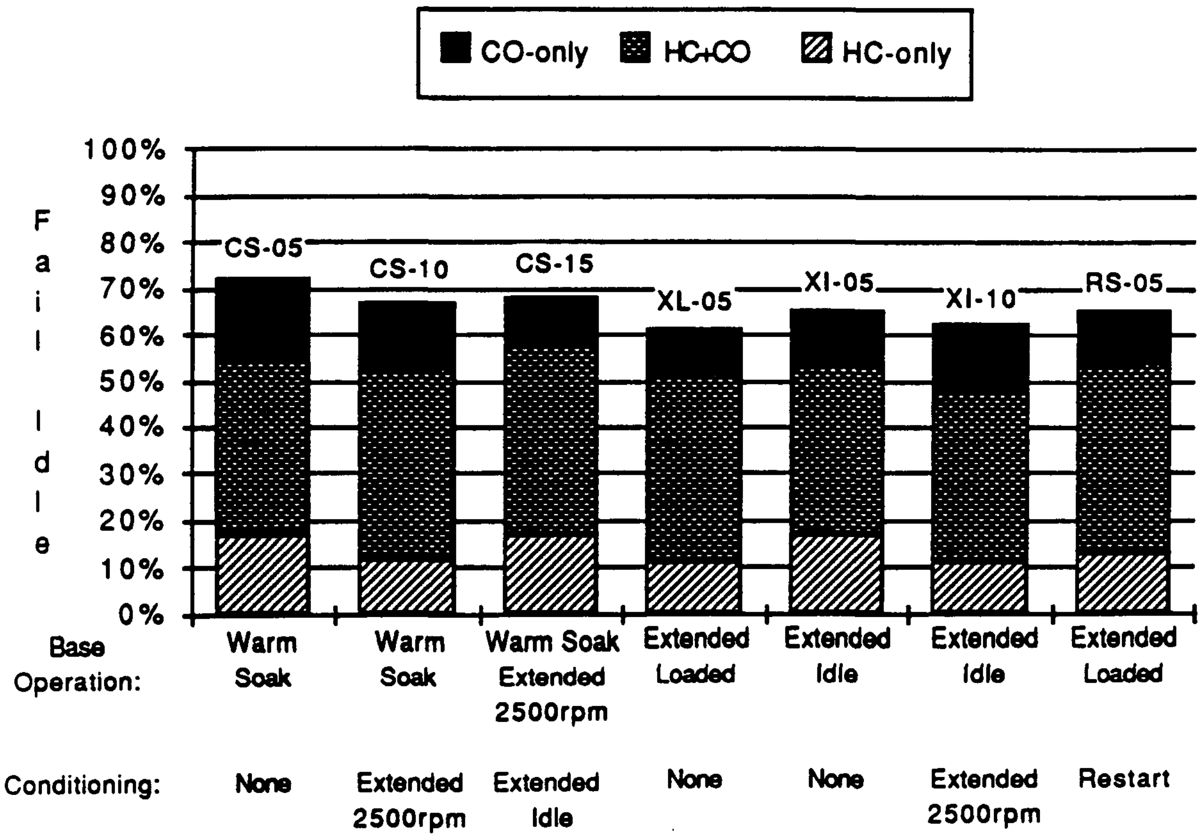


Figure 23 illustrates the significant reduction in failure rates of the normal FTP emitters that would probably have accompanied any of the sequences, had one been employed as a second-chance test in the Michigan AET program. Five of the seven sequences show pass rates for the normal emitters that are above 75%. For the three fully-warmed sequences preceded by extended loaded or extended 2500rpm base operation, the error of commission rate would have been at or near zero.

The apparent success of second-chance testing at passing normal emitters does not come without cost, however. Second-chance testing also reduces significantly the failure rates among the FTP high emitters, and consequently reduces the available emissions benefit to be gained by repair efforts. Figure 24 presents the response of the FTP high emitters in the base sample to the various second-chance tests of the Basic I/M Test Procedure. Each column in the chart corresponds to the percentage of the original 239 vehicles that failed the second idle-neutral of the indicated sequence. For example, somewhat over 70% of the vehicles failed their second-chance cold start test, with HC+CO failures being the largest group.

FIGURE 24

Response of the High Emitters to
Second-Chance Short Testing



The effect of the various types of vehicle operation on the failure rates of the high emitters was less severe than was seen earlier in the normal emitters, but was directionally the same. Between 28% and 39% of the original failures fell away, depending on the second-chance test. The lowest second-chance failure rates occurred after extended loaded operation (XL-05 and RS-05), followed closely by the rates on fully warmed vehicles with extended 2500rpm operation (XI-10). Thus, if one were to address the error of commission problem through such preconditioning and second-chance testing, between 35% and 40% of the high emitters captured by the initial test might be lost. The highest failure rate occurred on the vehicle with the worst conditioning -- the cold start sequence -- which was shown earlier in Figure 23 to exhibit the worst error of commission rate.

4.5.5. Variability Between Adjacent Idle Modes

Table 12 uses linear regression on the HC and CO emission values to analyze the variability between the first-idle and second-idle short test modes in the seven core sampling sequences of the Basic I/M Test Procedure. Recall from Section x.x that these two modes are separated by a 30-second 2500rpm no-load mode, making the core sampling sequence roughly equivalent to a two-mode idle test. Once again, the base operation and conditioning modes are provided for each of the modes as a guide to the I/M test conditions that each simulates.

TABLE 12

Regressions on the First and Second Idle Modes of the Core Sampling Periods

	MODE						
	CS-03/05	CS-07/10	CS-012/15	XL-O2/05	XI-02/05	XI-07/10	RS-02/05
Base Operation	Warm Soak	Warm Soak	Warm Soak Extended 2500rpm	Extended Loaded	Extended Idle	Extended Idle	Extended Loaded
Conditioning	None	Extended 2500rpm	Extended Idle	None	None	Extended 2500rpm	Restart
Sample Size	237	238	237	238	237	237	231
HC							
Slope	0.69	0.99	0.97	0.97	0.94	1.00	1.03
Intercept	252	25	51	19	57	22	5
R-squared	25.8%	88.5%	72.8%	85.5%	69.7%	90.7%	90.0%
CO							
Slope	0.65	0.95	0.89	0.96	0.89	0.95	0.97
Intercept	2.03	0.27	0.57	0.18	0.60	0.29	0.12
R-squared	30.9%	85.6%	70.4%	91.1%	69.2%	88.0%	88.7%

For a variety of reasons, not all vehicles were tested with each of the sequences in the Basic I/M Test Procedure. The sample sizes in Table 12 reflect the number of vehicles in the 239-vehicle sample where paired first-idle and second-idle modes were available for the given segment of the procedure.

The regressions are least-squares fits to lines of the form y = mx + b, where m is the slope and b is the y-intercept. In each case, the x-values were taken to be the first idle of the pair, and the y-values were the second idle. If there were no variability between the first- and second-idle modes, the relationship between the emission scores for each pollutant would be a line with slope of one, intercept of zero, and 100% R-squared value.

As shown in the table, four segments of the procedure showed slopes greater than 0.95 and correlation greater than 85% for both HC and CO; these were the Cold Start modes 7/10, Extended Loaded modes 2/5, Extended Idle modes 7/10, and the Restart modes 2/5. In two of these segments (CS-07/10 and XI-07/10), the short test was immediately preceded by three minutes of 2500rpm conditioning. In the other two segments (XL-02/05 and RS-02/05), the short test was preceded by an LA4 prep cycle.

Not surprisingly, the worst correlation (R^2 values below 30% for both HC and CO) was shown by the paired values for the Cold Start modes 2/5, which came at the very beginning of the procedure, following an extended soak and no conditioning. The fact that the slope of the HC and CO regression lines for this comparison are well below one shows that even the short period of 2500rpm operation between the two idle modes was sufficient to reduce emissions considerably on many vehicles.

The two remaining segments, which also showed poorer correlation, were the Cold Start modes 7/10 and the Extended Idle modes 2/5. These short tests immediately followed periods of extended idle: 10 minutes in the case of the Cold Start, and 20 minutes in the case of the Extended Idle.

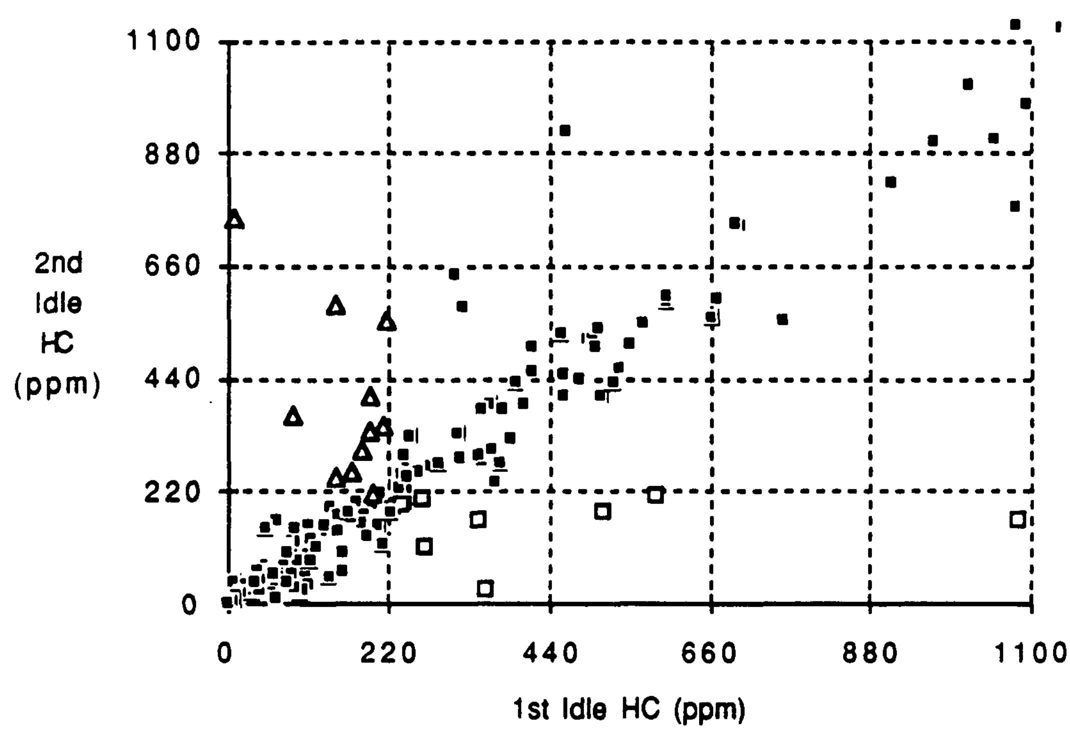
Based on the preceding discussion, periods of extended no-load off-idle operation and extended loaded operation can reduce the variability in short test scores that might result from periods of extended idle operation or from testing a vehicle too promptly after soak periods.

Figure 25 shows the actual scatter for one of the pairs of idles with good correlation: the first- and second-idle HC values from the extended loaded sequence. Recall that the base operation before the first idle mode in this sequence is an LA-4 prep cycle. In this case, the scatter was responsible for reducing the correlation coefficient to 85.5%. The maximum values for each axis have been set below the actual maximums in the sample in order to allow examination of the region around the 207(b) HC cutpoint of 220 ppm, where a number of vehicles changed pass/fail status; no actual data point that falls beyond the range of the graph passed HC on either idle mode.

The plot clearly shows that a number of vehicles had significant differences between their first-idle and second-idle HC scores, even though the 30 seconds of 2500rpm that separated the two idles might seem inconsequential compared to the LA-4 that preceded the first idle. Because of their variability, some of these changed pass/fail status for HC: data points with the open-square symbol are vehicles that failed the first idle, but changed to pass on the second; points marked with an open triangle passed the first idle but failed the second.

FIGURE 25

<u>Scatter Between First Idle and Second Idle</u>
<u>Following Extended Loaded Operation</u>



When both HC and CO are considered, 12% of the base sample -- 29 vehicles -- changed failure type (pass, HC-only, CO-only, HC+CO) between the two idle modes of the Extended Loaded sequence (the sum of the bold entries in Table 13). Twenty-three of the 29 also changed their overall idle test status: 15 failed the first idle and passed the second, and the balance did the reverse. As the table shows, however, most of this difference came from CO-only failures that were cleaner following the 2500rpm mode; the changes in other failure types for the most part offset each other.

TABLE 13

Distribution of the Base Sample by Failure Type on Idle Modes Following Extended Loaded Operation

Second Idle (XL-05)	First Idle (XL-02)				
	Pass	HC-only	HC+CO	CO-only	All
Pass	126	7	3	5	141
HC-only	6	11	1	0	18
HC+CO	2	1	58	2	63
CO-only	0	0	2	14	16
All	134	19	64	21	238

TABLE 14

Distribution of the Base Sample by Failure Type on Idle Modes Following Extended Idle Operation

	First Idle (XI-02)				
Second Idle (XI-05)	Pass	HC-only	HC+CO	CO-only	All
Pass	89	10	12	4	115
HC-only	4	28	9	0	41
HC+CO	2	1	52	4	59
CO-only	2	0	5	15	22
All	97	39	78	23	237

Table 14 makes a similar comparison for the idle modes in a sequence with poor preconditioning, the first and second idle modes of the extended idle sequence. Here, the base operation before the first idle test is a twenty-minute idle; the intervening mode between the two idle tests is once again 30 seconds of 2500rpm operation. The number of vehicles that change their failure type in this case rises to 53, or 22% of the base sample. Note, however, that almost three quarters of these were more serious failures on the first idle; for example, 26 vehicles changed from first idle failures of one type or another to passes on the second idle. This is consistent with the information presented in Figure X above, in that even a brief stretch of 2500rpm operation appears to compensate for extended periods of idle operation.

4.6 Supplemental Analysis of the AET Errors of Commission

As discussed previously in this section, 33 of the 239 vehicles in the CTP base sample were errors of commission by the Michigan AET test. A table of basic emissions data and vehicle identifying information for these vehicles appears in Appendix D.

Figure 19 above showed that the E_c vehicles were not randomly distributed by AET failure type; a disproportionate number were HC-only AET failures. The distribution of E_c vehicles also varied by basic vehicle characteristics. All but six of the 33 vehicles fell in the 1983-86 model years; the fuel-injected 1983-86 vehicles were the most heavily represented quota group, with 19 vehicles (53%) of the total E_c fleet. Differences were also evident between manufacturers. Six of the sixteen Toyota vehicles were errors of commission, while there were no Chrysler E_c's. Trucks were over-represented; there were eight LDT E_c's out of the 33 total (24%), while trucks only represented eight percent of the base sample. Five out of the eight LDT E_c's were Fords, all of them carbureted.

One particular engine stands out in the error of commission fleet: the GM 151 CID fuel-injected LDV. Eight of these vehicles appear in the list of E_c's, representing all but two of GM's total E_c's, and almost one-quarter of the total number of E_c's in the CTP fleet. Notably, all of the eight vehicles failed the AET test for HC.

As shown in the data of Appendix D, almost all of the AET errors of commission in the CTP fleet had elevated AET HC scores; a surprising number were above 400ppm HC, and three exceeded 1000ppm. The sample included thirteen AET errors of commission for CO, with the highest showing a 6.7% CO score.

Appendix D also provides data from the 30-second point of the first idle-neutral from the extended loaded sequence (XL30HC and XL30CO), performed on the as-received vehicles. Recall that these values represent idles following an extended period of loaded preconditioning (an LA4). In most cases, the HC values during this mode of the extended loaded sequence were much lower than the comparable values from the AET test. However, the XL30HC values for five of the 33 were still elevated from normal levels, and three continued to be

E_c's. None of the vehicles that was a CO error of commission on the AET test showed failing XL30CO values during its as-received testing, although a handful exceeded 0.5% CO.

With only a few exceptions, no component problems were identified during the as-received diagnosis that might have explained elevated values for the E_c vehicles on the AET test. Thus, only five of the 33 E_c vehicles had repair efforts, and only one of those could be considered successful in resolving observed emissions anomalies. This was vehicle 21, a 1984 Toyota, whose malperforming oxygen sensor was replaced, leading to normal HC and CO levels.

For most of these E_c vehicles, no specific explanation for the elevated AET scores was available. GM attributed elevated AET HC values in its E_c fleet to inadequate preconditioning during the AET test. Nevertheless, two of GM's vehicles (338 and 347) that were HC errors of commission by the AET test also showed failing values on the extended loaded sequence, in spite of the LA4 preconditioning. These and others of GM's E_c group did show elevated HC values during other idle modes of their as-received short testing. For one AMC vehicle (31), the AET failure was probably attributable to an air diversion timer tied to the elapsed time at idle.

SECTION 5: EMISSION EFFECTS OF REMEDIAL MAINTENANCE

5.1 Introduction and Sample Descriptions

Prior to any repair, each vehicle underwent an as-received characterization to aid in the decision of which repairs were necessary, if any. This characterization included the BITP, FTP, and a complete diagnosis of the vehicle's engine and emission control systems. If the results from this characterization indicated that repairs were necessary to meet the criteria for vehicle release, a repair sequence was designed. The first criterion was a reduction in FTP emissions to a target based on the vehicle's certification standards. Once this criterion had been met, repairs targeted emission levels and variability on the I/M test. The vehicle was released when all criteria had been met or all reasonable repair efforts were completed.

Of the 239-vehicle sample, 184 vehicles received a total of 479 remedial maintenance (RM) steps for which mass emissions data were collected. Of these steps, 372 were single, isolatable repairs; the remaining 107 RM steps included 258 repairs, for a total of 630 repairs. Each vehicle therefore received an average of 3.4 repairs in 2.6 RM steps.

The design of the CTP dictated that catalyst replacement be a last resort repair so that the high conversion efficiency of a new catalyst would not mask the necessity of other repairs; under certain conditions, the CTP program plan did not then require a final mass emissions test. Therefore, much of the following analysis is focussed on pre-catalyst repairs only. This included 413 RM steps on 175 vehicles. Vehicles that passed the CTP standards (150% of cert standards for mileage <=50K; 200% for mileage >50K) of the as-received FTP as well as the ideal I/M portion of the BITP, with little variability throughout the BITP, did not undergo repair.

5.2 Total Mass Emission Reductions from the CTP Fleet

5.2.1 Net Benefit of Repairs -- FTP-Based

The reduction in emissions of the CTP due to repair was substantial, with nearly all of the emissions in excess of certification standards being eliminated. The net emissions benefit achieved from the repairs on these 184 vehicles was 339 g/mi HC and 5193 g/mi CO, for an average reduction per vehicle of 1.8 g/mi HC and 28.2 g/mi CO. (The certification standard for the majority of these vehicles is 0.41 g/mi HC and 3.4 g/mi CO). On a percentage basis, HC emissions were reduced by slightly over 80%, and CO emissions by over 85% for these 184 vehicles. These reductions eliminated almost 99% of the excess HC and CO FTP emissions, relative to individual vehicles' certification standards, of the entire CTP fleet.[20] See Tables 15 and 16 for breakdowns by manufacturer and quota group. Note that greater than 100% of a group's excess can be eliminated; this is caused by vehicles that are repaired to levels cleaner than their certification standard.

TABLE 15

FTP Emission Reductions (g/mi) for All Repairs -- by Manufacturer

HC	number of vehicles	emissions reduction	% reduction	average reduction	total excess*	% excess reduced
GM	46	86.56	83.6%	1.88	85.60	101.1%
FORD	47	105.18	83.3%	2.24	105.82	99.4%
NISS	17	25.66	77.8%	1.51	25.96	98.9%
TOYT	8	4.68	42.3%	0.58	8.36	55.9%
CHRY	15	24.44	79.3%	1.63	24.68	99.0%
AMC	13	25.07	71.0%	1.93	27.74	90.4%
VW	10	17.24	71.4%	1.72	20.55	83.9%
MAZD	7	9.24	80.6%	1.32	8.72	106.0%
SUBA	8	20.58	87.6%	2.57	19.06	108.0%
MITS	6	10.08	84.1%	1.68	8.98	112.3%
HOND	7	10.24	91.2%	1.46	8.65	118.4%
ALL	184	338.98	80.3%	1.84	344.12	98.5%

CO	number of vehicles	emissions reduction	% reduction	average reduction	total excess*	% excess reduced
GM	46	1091.3	86.4%	23.7	1051.8	103.8%
FORD	47	1374.1	87.1%	29.2	1378.5	99.7%
NISS	17	763.6	91.4%	44.9	770.1	99.1%
TOYT	8	103.9	57.9%	13.0	147.8	70.3%
CHRY	15	395.4	85.9%	26.4	394.9	100.1%
AMC	13	384.2	78.4%	29.6	404.8	94.9%
VW	10	327.6	83.1%	32.8	359.5	91.1%
MAZD	7	220.0	84.9%	31.4	241.5	91.1%
SUBA	8	356.6	87.6%	44.6	344.5	103.5%
MITS	6	113.1	82.1%	18.9	106.4	106.3%
HOND	7	62.9	89.2%	9.0	50.8	123.8%
ALL	184	5192.6	85.5%	28.2	5250.7	98.9%

* excess is based on entire 239-vehicle sample

TABLE 16

FTP Emission Reductions (g/mi) for All Repairs -- by Quota Group

HC	number of vehicles	emissions reduction	% reduction	average reduction	total excess*	% excess reduced
FI 81-82	18	52.00	83.6%	2.89	55.42	93.8%
Carb 81-82	62	122.84	78.7%	1.98	130.60	94.1%
Carb 83-86	36	58.44	80.4%	1.62	56.12	104.1%
FI 83-86	68	105.71	80.5%	1.55	101.97	103.7%
ALL	184	338.98	80.3%	1.84	344.12	98.5%

CO	number of vehicles	emissions reduction	% reduction	average reduction	total excess*	% excess reduced
FI 81-82	18	830.7	90.1%	46.1	849.0	97.8%
Carb 81-82	62	1869.3	82.6%	30.2	1921.8	97.3%
Carb 83-86	36	829.7	84.0%	23.0	834.0	99.5%
FI 83-86	68	1662.8	87.5%	24.5	1645.8	101.0%
ALL	184	5192.6	85.5%	28.2	5250.7	98.9%

* excess is based on entire 239-vehicle sample

Because of the special treatment of catalyst repairs in the CTP, they are here separated from the analysis. Of the 184-vehicle sample, 175 vehicles received non-catalyst repairs; for 168 of these, both pre- and post-repair FTP data is available. This includes tests on vehicles that received a catalyst change at a later RM stage. The net emissions benefit from these non-catalyst repairs was 264 g/mi HC and 4544 g/mi CO, for an average reduction per vehicle of 1.6 g/mi HC and 27.1 g/mi CO. On a percentage basis, HC emissions were reduced by over 67%, and CO emissions by almost 80%. These reductions eliminated at least 76% of the excess HC and 86% of the excess CO emissions of the entire CTP fleet, and 84% and 92% of the excess HC and CO, respectively, of this 168-vehicle sample; more reductions may have occurred for which both pre- and post-repair data is not available.

Obviously, catalyst repairs had a significant impact on the overall emission reductions even though they were usually the final repair to be performed, occurring when emission levels had already been significantly decreased. Their contribution to the total emissions benefit was due to the unusually low FTP levels after a catalyst repair rather than to excessively high levels prior to that repair; emissions were lower, on average, prior to a catalyst replacement than before other types of repair.

Catalyst replacements for which FTP data is available accounted for 10% of the RM steps that occurred; their repair eliminated 17% of the excess HC and 8% of the excess CO of the entire CTP fleet. An additional 1% of the RM steps also involved catalyst replacements, but lack of data does not allow an assessment of their emissions impact. Final emission levels following a catalyst replacement averaged 0.33 g/mi HC and 4.2 g/mi CO -- approximately half the levels of the final non-catalyst repairs, at 0.76 g/mi HC and 7.1 g/mi CO. The average reduction for a single catalyst repair eliminated 77% of the HC and 65% of the CO emissions occurring just prior to the repair, and 44% and 32%, respectively, of the vehicle's entire as-received HC and CO emissions. In contrast, the average non-catalyst repair eliminated 38% of the HC and 51% of the CO emissions occurring just prior to the repair, and 29% and 39%, respectively, of the vehicle's as-received HC and CO emissions. Thus, catalyst repairs were somewhat more productive in eliminating HC than were repairs to other components, while CO was approximately in the same range.

5.2.2 FTP versus LA4 values

One purpose of the CTP was to obtain emission benefits of individual repairs, as measured by the FTP. However, in order to streamline the testing process, labs were not required to perform an entire FTP after a repair if there was reason to believe that there had been no effective emission benefit. In case of uncertainty, the lab could perform an LA4 (bags 1 and 2 of the FTP), without the extended vehicle preconditioning required in a complete FTP. Results of the LA4 were to be used to decide if the FTP was needed; significant emission decreases would mean that it was. Unfortunately, this process was not always followed, with the follow-up FTP sometimes eliminated. For this reason, FTP data is not available before and after each obviously significant repair.

Rather than eliminate these repairs from the analysis -- a significant proportion for at least one manufacturer -- it was judged better to retain all the data and perform the analysis on an LA4 basis. For repairs without an LA4, FTP data was converted to LA4 data by using results from bags 2 and 3; bag 3 has the same driving cycle as bag 1, and approximates the warmed-up vehicle condition seen in the LA4-only tests.

It was important to determine the effectiveness of thus modelling FTP emission reductions with LA4-derived values, and, if effective, the approximate shift in values one could expect. As a first step to accomplish this, FTP values were compared to the LA4 values derived from the FTP scores on those same vehicles. The scatterplots in Figures 26 and 27 show that FTP-derived LA4 values tracked FTP values quite consistently for both HC and CO, indicating that derived LA4 values are generally an effective approximation of FTP scores.

FIGURE 26

FTP vs FTP-Derived LA4 Emission Values -- HC

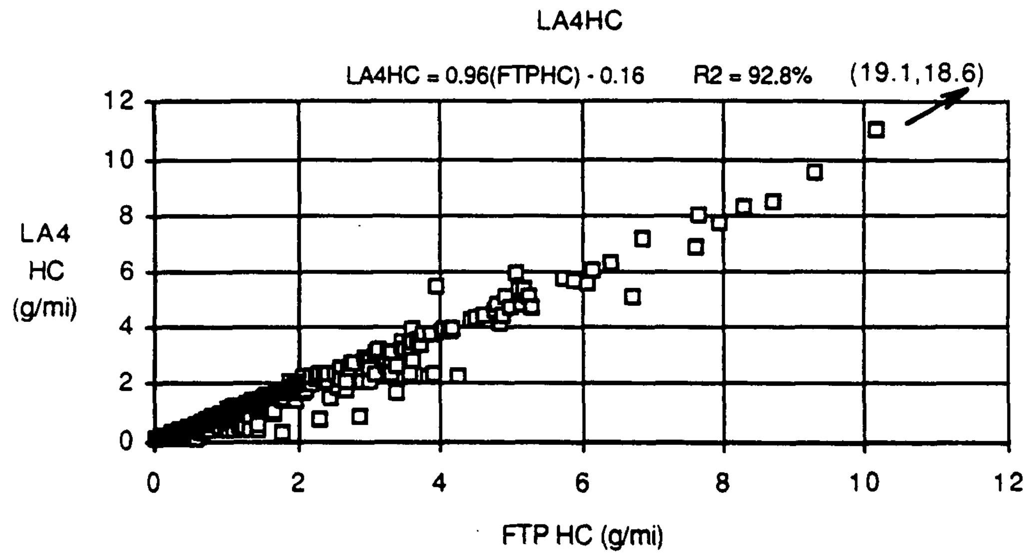


FIGURE 27

FTP vs FTP-Derived LA4 Emission Values -- CO

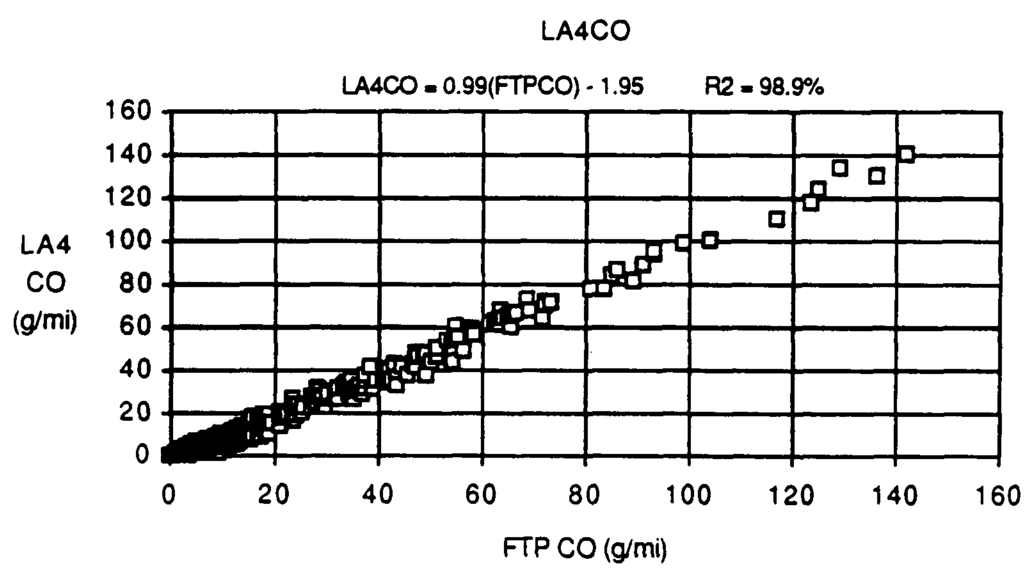


Table 17 shows the total and average FTP as-received emissions and emission reductions for all vehicles that received repairs, and the LA4 values derived from those same FTP results. It also gives the ratio of the derived LA4 to FTP values, shown as a percentage in the last row of each section of the table. Figures 28 and 29 show the scatter in g/mi reduction per RM as measured by the two methods. Derived LA4 emission values and g/mi emission reductions generally were somewhat lower than FTP values, as illustrated in Figure 30; derived LA4 values values are the lower of each set of lines, with dotted lines showing HC and solid indicating CO. On the other hand, the percent reductions as measured by the derived LA4 were several percentage points greater than as measured by the FTP.

The similarity of the FTP and derived-LA4 values indicate that any conclusions that would be drawn from FTP data would not be significantly altered by the use of derived-LA4 values. Therefore, much of the remaining analysis is performed using derived-LA4 and actual LA4 data as an FTP substitute. The emission impact of thus using LA4 rather than FTP values can be illustrated by repeating some of the information found in Section 5.2.1 above, describing net emission reductions due to repairs; this time, LA4 rather than FTP values are used. A comparison of the two reveals little difference in the substance of the findings.

TABLE 17

Emission Values as Measured by the FTP and FTP-Derived LA4

HC	number vehicles	total as-rcvd	total reduction	average as-rcvd	average reduction	% reduction
FTP	184	422.34	338.98	2.30	1.84	80.3%
LA4	184	382.99	321.91	2.08	1.75	84.1%
LA4/FTP	-	90.7%	95.0%	90.7%	95.0%	104.7%

CO	number vehicles	total as-rcvd	total reduction	average as-rcvd	average reduction	% reduction
FTP	184	6074.3	5192.6	33.0	28.2	85.5%
LA4	184	5665.9	5063.0	30.8	27.5	89.4%
LA4/FTP	-	93.3%	97.5%	93.3%	97.5%	104.5%

FIGURE 28

FTP vs FTP-Derived LA4 Emission Reductions -- HC

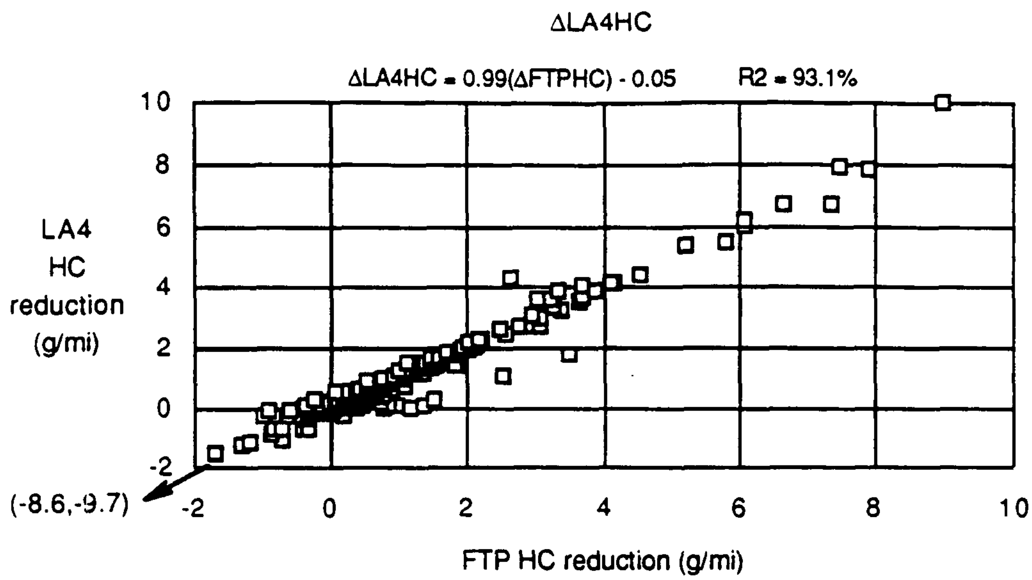


FIGURE 29

FTP vs FTP-Derived LA4 Emission Reductions -- CO

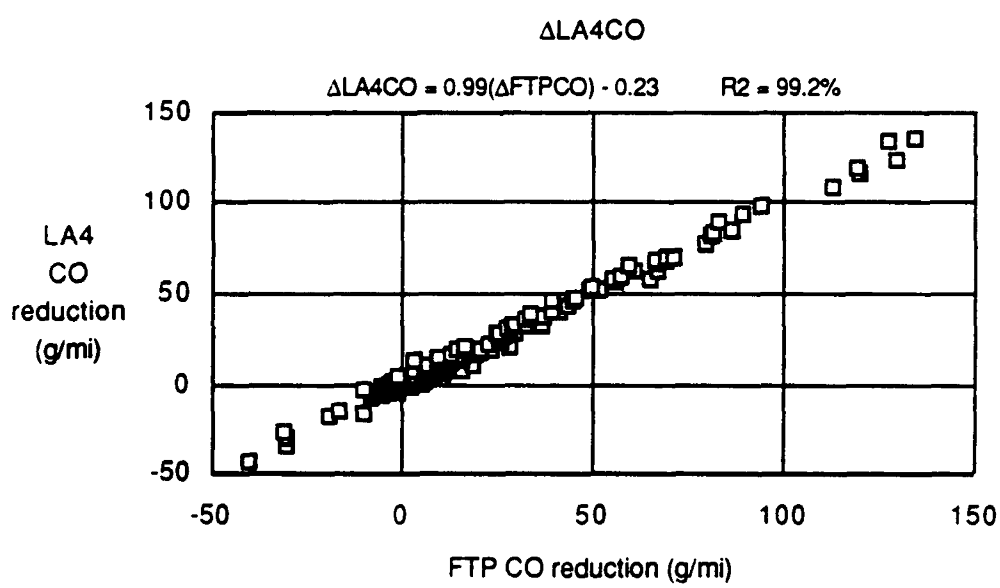
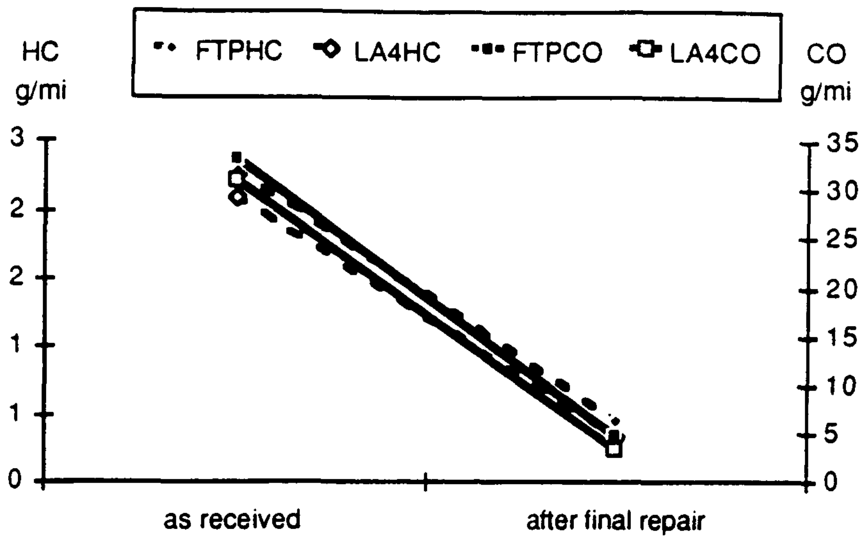


FIGURE 30

Average Emission Reductions Due to Repair: FTP and FTP-Derived LA4



5.2.3 Net Benefit of Repairs -- LA4-Based

The net emissions benefit achieved from the repairs on these 184 vehicles was 322 g/mi HC and 5063 g/mi CO, for an average reduction per vehicle of 1.7 g/mi HC and 27.5 g/mi CO. On a percentage basis, HC emissions were reduced by slightly over 84%, and CO emissions by almost 89% for these 184 vehicles. These reductions -- as measured by the LA4 -- eliminated approximately 95% of the excess HC and CO FTP emissions, relative to certification standards, of the entire CTP fleet.

Of the 184-vehicle sample, 175 vehicles received non-catalyst repairs for which pre- and post-repair LA4 data is available. This includes tests on vehicles that received a catalyst change at a later RM stage. The net emissions benefit from these non-catalyst repairs was 255 g/mi HC and 4575 g/mi CO, for an average reduction per vehicle of 1.5 g/mi HC and 26.1 g/mi CO. On a percentage basis, HC emissions were reduced by over 69%, and CO emissions by almost 83%. These reductions eliminated at least 74% of the excess HC and 87% of the excess CO emissions of the entire CTP fleet, and 78% and 90% of the excess HC and CO, respectively, of this 175-vehicle sample; more reductions may have occurred for which both pre- and post-repair data is not available.

5.3 Overview of the Repairs Conducted

5.3.1 System and Subsystem Repair Categories

Repairs were categorized by the testing organizations, with some advice from EPA staff, into the following systems and subsystems.

1. induction system
   - heated air door assembly
   - temperature sensors
   - air filter element
   - hoses
   - other (e.g., gaskets)

2. fuel metering system
   - carburetor assembly
   - idle mixture adjustment limiter
   - idle mixture adjustment
   - idle speed
   - idle speed solenoid
   - fuel injection components
   - hoses, lines, wires
   - choke adjustment -- notches
   - choke adjustment -- vacuum break
   - choke adjustment limiter
   - fast idle speed
   - vacuum diaphragms
   - electrical controls
   - exhaust heat control valve assembly
   - hoses, lines, wires
   - other (e.g., fuel filter, float level)

3. ignition system
   - distributor assembly
   - initial timing
   - initial timing limiter
   - spark plugs and wires
   - vacuum advance assembly
   - spark delay devices
   - spark knock detector
   - electronic timing module
   - coolant temperature sensors
   - hoses, lines, wires
   - other (e.g., points, distributor cap)

4. EGR system
   - egr valve assembly
   - back pressure transducer
   - delay solenoid
   - vacuum amplifier
   - vacuum reservoir
   - coolant temperature sensor

- hoses, lines, wires
- other (e.g., gaskets, plugged manifold)

5. air injection system
   - air injection assembly
   - bypass valve, dump valve -- air pump system
   - air diverter valve
   - check valve
   - drive belt
   - hoses, lines, wires
   - other (e.g., air filter, stuck valves)

6. PCV system
   - pcv valve assembly
   - filters
   - hoses and lines
   - other (e.g., vent tube seal)

7. exhaust system
   - exhaust manifold, tailpipe, muffler
   - catalytic converter
   - other (e.g., mixture set tube)

8. evaporative system
   - evaporative canister
   - canister filter
   - canister purge solenoid/valve
   - hoses, lines, wires
   - other (e.g., gas cap, gaskets)

9. engine assembly
   - engine assembly
   - cooling system
   - valve adjustment
   - belt tensions
   - hoses, lines, wires
   - other (e.g., battery, transmission fluid)

10. three-way catalyst system
    - electrical control unit
    - oxygen sensor
    - barometric pressure sensor
    - load sensor (throttle position, manifold vacuum)
    - engine speed sensor
    - coolant temperature sensor
    - crankshaft position sensor
    - egr position sensor
    - egr control solenoids
    - air/fuel control actuator
    - air bypass solenoid/valve
    - air diverter solenoid/valve
    - throttle kicker/actuator
    - idle speed control system
    - hoses, lines, wires

- diagnostic bulb check
- diagnostic warning
- other (e.g., switches)

In addition to these categories of systems and subsystems repaired, the CTP database includes a code listing the nature of repair -- replaced, adjusted, cleaned, reconnected, restored, or rebuilt. Narrative comments, filled out for each RM step, elaborated on the exact components, diagnostic techniques, and other details judged relevant by the technician but not covered by the coding system.

5.3.2 Emission Benefits per System Repair

According to the CTP program plan, repairs were to be done one at a time, with mass emission tests before and after each repair, and in decreasing order of their likely impact on emission reductions. In fact, this happened much of the time, resulting in a substantial database of isolatable repairs with bracketing mass emission tests. For these cases, the emissions reductions can be simply averaged over all of the occurrences of a particular repair. Attention must be paid to the possibility that some repair types with apparently low average benefits were the result of misdiagnosis as to what needed repair.

However, in a number of cases, more than one repair occurred prior to a post-repair emission test being performed, resulting in a number of non-isolatable repairs. For these, simple averages for each repair type would have resulted in counting the <u>entire</u> emission reduction of the grouped repairs for <u>each</u> of the repairs in the group.

To overcome this problem, multiple linear regressions were performed, using the systems listed in Section 5.3.1 as variables. The change in emission levels for each pollutant was regressed across the ten systems, resulting in the emission reduction for each pollutant to due repairs to each system. The regression for HC reduction took the form

$$\Delta LA4HC = 0 + \sum_{i=1}^{10} (\Delta LA4HC)_i \times (\text{indicator for system}_i \text{ repair})$$

A similar regression was performed for CO reduction. Note that regressions were calculated with zero as a constant term; that is, the results were forced through the origin, so that if no repair occurred, the result would be no emission reduction.

The following table lists repair results at the system level. Included are both the simple averages of the repairs which occurred singly, and the results of the multiple regression for all repairs. All emission values are in grams per mile, as measured by the LA4. See Appendix E for breakdowns by quota group.

TABLE 18

Emission Reductions per System Repair

SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Induction	14	0.33	0.0	28	0.27	0.64	1.4	0.28
Fuel Meter	94	1.07	13.2	117	0.98	5.12	12.8	5.70
Ignition	63	0.19	-1.4	78	0.23	0.95	-0.7	-0.26
EGR	19	0.11	1.5	27	-0.16	-0.40	-3.6	-0.78
Air Injection	77	0.41	6.7	93	0.30	1.20	4.5	1.53
PCV	4	-2.51	-9.4	11	-1.25	-2.01	-6.5	-0.89
Exhaust	60	1.20	7.3	68	1.16	4.51	8.0	2.65
Evap	4	0.31	3.0	8	0.75	1.07	10.7	1.31
Engine	10	0.90	6.8	21	0.53	1.13	5.9	1.08
3-Way	156	0.55	17.8	179	0.62	4.03	17.8	9.78
All	501	0.62	9.9	-	-	-	-	-

A stepwise regression was then performed, successively eliminating the system with the lowest t-ratio (correlation coefficient relative to standard error). This method eliminated the systems which had the least statistically significant repairs; that is, the systems whose repairs were the least useful at explaining an emission reduction were eliminated. The systems with the most significant repair benefits were the fuel metering, exhaust, and three-way systems. For these, the two approaches give similar reduction estimates, as shown in the following table. See Appendix F for breakdowns by quota group.

TABLE 19

Emission Reductions per Repair to Statistically Significant Systems

SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS OF THESE SYSTEMS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Fuel Meter	94	1.07	13.2	117	1.01	5.30	13.0	5.85
Exhaust	60	1.20	7.3	68	1.20	4.68	8.4	2.80
3-Way	156	0.55	17.8	179	0.64	4.16	17.9	9.89

These statistically significant systems are highlighted in dark grey in the following graphs of average emission reductions for isolatable repairs. The light grey bars must be taken cautiously, since the values that created these averages are highly variable. See Appendix E for individual figures per quota group.

FIGURE 31

Average HC Reductions per Isolatable System Repair

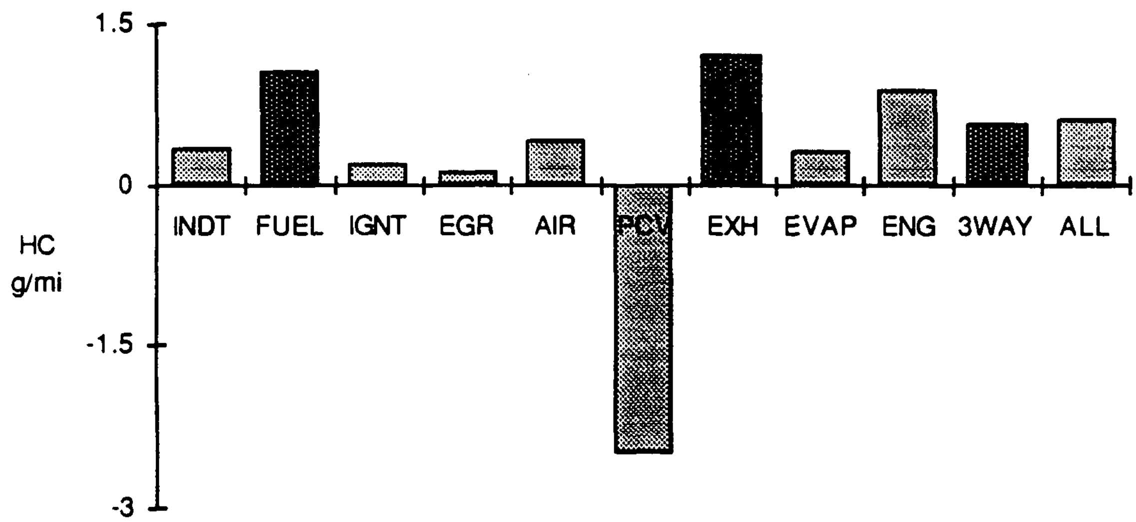
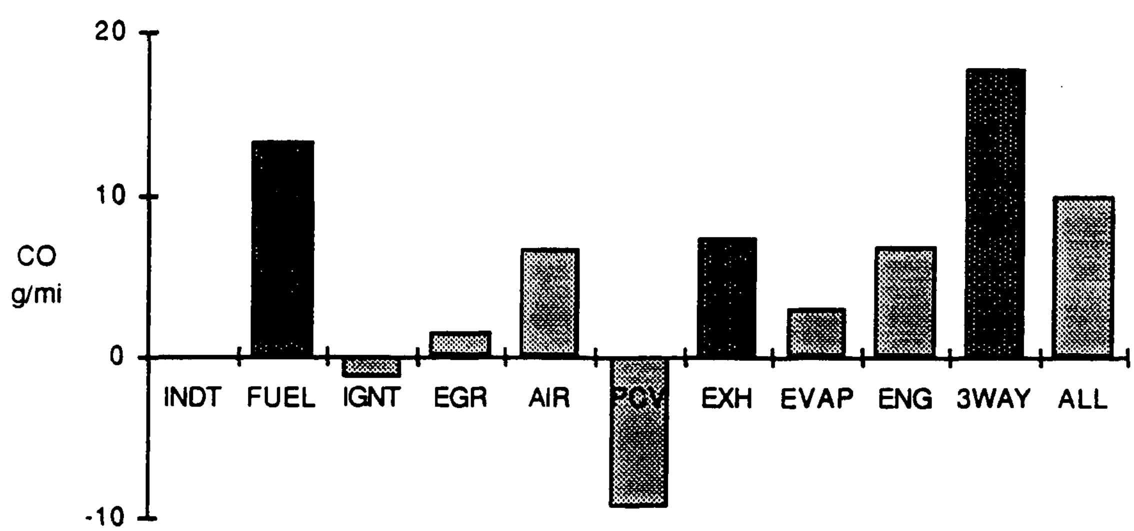


FIGURE 32

Average CO Reductions per Isolatable System Repair

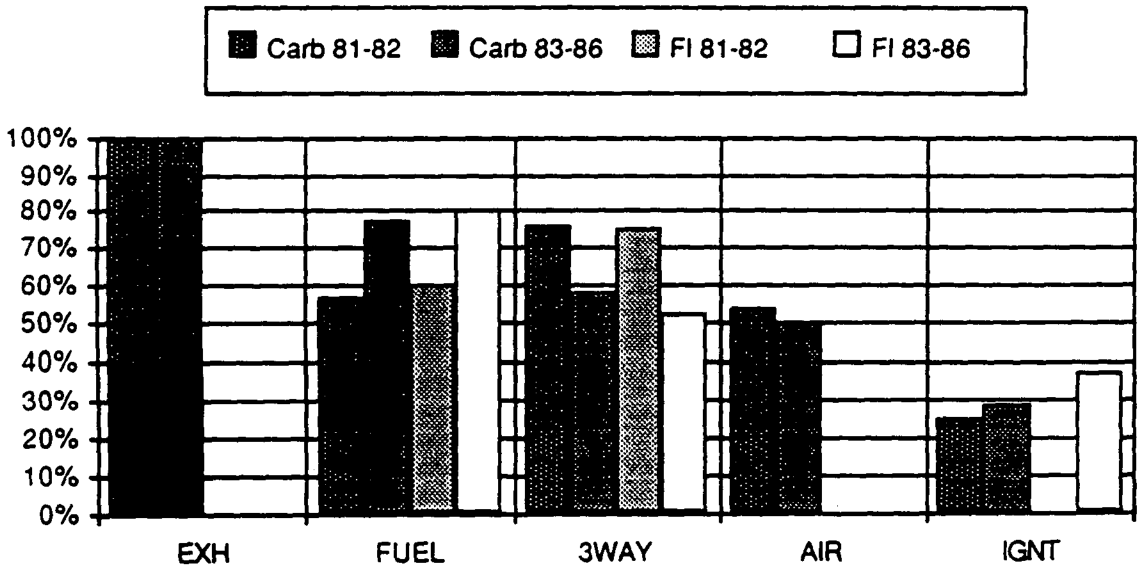


In general, calculating emission repair reductions at the system level, as just done, is not illuminating, since the repairs varied widely within the general system category. An examination by subsystem appears in Section 5.3.3 below.

Nevertheless, some additional information can be drawn from the analysis at the system level. As clearly shown in Figure 29, repairs to those systems with the least variability in FTP repair reductions were much more effective than others at consistently getting I/M failing vehicles to pass the I/M test. For instance, exhaust system repairs were effective 89% of the time, due almost entirely to catalytic convertor replacements. The excellent convertor efficiency of brand new catalysts may be responsible, and this result should be considered cautiously. Repairs to the fuel metering and three-way systems turned I/M fails into I/M passes 66 and 64% of the time, respectively. Fuel system repairs usually entailed replacing the carburetor or fuel injectors (nearly all injector replacements were on a single basic engine model) or tuning the system (largely on carbureted vehicles) -- that is, adjusting idle mix, idle speed and/or initial timing . Three-way system repairs were mostly oxygen sensor or, less frequently, ECU replacements.

FIGURE 33

I/M Pass Rates Due to System Repair -- by Quota Group



Repairs to those systems with greater variability in FTP repair reductions were, at the same time, less consistent in reducing the I/M failure rate. Air injection system repairs, effective at eliminating I/M failures 52% of the time, varied among various valve replacements and repairs to the pump assembly, while repairs of the ignition system were overwhelmingly tune-ups, and succeeding in getting failing vehicles to pass I/M only 30% of the time. The missing systems -- induction, EGR, PCV, evap, and engine -- had too few vehicles failing I/M at the time of the repair to include in the analysis. In general, quota group had little impact on the effectiveness of a certain repair. Figure 33 and the values cited above include only isolatable repairs. Missing data indicates small sample size, rather than 0% effectiveness.

5.3.3 Emission Benefits per Subsystem Repair

An analysis by subsystem is essentially an analysis by component or component group. Results at this finer level of detail can be used to better pinpoint those specific components that have the greatest impact on emissions. The same technique used above -- simple averages of emission reductions for isolatable repairs, coupled with a stepwise multiple linear regression for all repairs -- was repeated, this time using subsystems as variables.

Many subsystems were eliminated from the results due to a low occurrence of repairs. This is presumably because these components were not often diagnosed as emission control problems in need of repair, either because they were, in fact, not in need of repair, or because their malfunction was judged to not significantly affect emissions (see Appendix G for a count of repairs per subsystem). Of the remaining subsystems, a step-wise multiple regression yielded seven with statistically significant emission reductions due to their repair. Those with more than seven cases and a t-ratio greater than 2.0 for one or both pollutants are considered significant.

Table 20 lists the simple averages and the results of this step-wise regression. As with repairs categorized by system, the most consistently effective repair types were to the fuel system, the exhaust system -- mainly the catalyst -- and the electronic controls for the three-way system. Not surprisingly, some of the most important emission control components -- the catalyst and oxygen sensor -- are consistently effective at cleaning up both HC and CO emissions.

Note that, of the seven repair types, five were effective for both HC and CO; two were consistently effective on CO only (the ECU and load sensor). Recall from section 4.2.3 that most vehicles that were high emitters on one pollutant were also high on the other, so that repairs were often targeted, effectively so, at reducing both HC and CO. All emission values in the table are in grams per mile, as measured by the LA4. See Appendix G for results for all subsystems, and Appendix H for breakdowns of the statistically significant subsystems by quota group.

TABLE 20

Emission Reductions per Subsystem Repair

SUBSYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS OF THESE SUBSYSTEMS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Carburetor	22	1.03	11.9	27	1.02	2.7	12.6	2.9
FuelMtr Tune	30	0.61	11.6	43	0.63	2.1	11.8	3.4
Fuel Injector	19	2.35	24.2	20	2.22	5.1	22.5	4.4
Catalyst	43	1.11	7.0	56	1.20	4.7	8.5	2.8
ECU	14	0.40	10.7	19	0.67	1.5	13.4	2.5
O2 Sensor	69	0.80	20.7	82	0.94	4.4	22.9	9.0
Load Sensor	11	0.61	23.2	22	-0.27	-0.7	11.2	2.3
All	372	0.70	10.7	-	-	-	-	-

The method of repair which most often occurred on these seven important subsystems was replacement of the main component -- carburetor, fuel injectors, catalytic converter, oxygen sensor, load sensor (manifold air pressure or throttle position sensor), or electronic control unit. The other frequent subsystem repair was a fuel metering tune-up, which included adjustments to idle speed, idle mix, and/or initial timing.

A comparison of the simple averages with the regression correlation coefficients reveals reasonably consistent results, except for one case -- the load sensor. This subsystem yields an average CO reduction of 23.2 g/mi when repairs limited to the load sensor are averaged, in contrast to an 11.2 g/mi reduction projected by the regression. Further investigation reveals that when all repairs to the load sensor are averaged, including those lumped with other repairs, the average reduction drops to 11.2 g/mi, identical to that predicted by the regression. Of the 22 load sensor repairs, 11 were lumped with another repair -- hoses, lines, and wires; these were all Ford vehicles undergoing a recall procedure to clean out the line leading to the map sensor, regardless of a diagnosis indicating its necessity. These 11 repairs actually increased CO emissions by an average of 0.9 g/mi, presumably because they were often unnecessary, while the 11 isolatable repairs decreased CO by 23.2 g/mi, on average. This is an unusual instance, in which two repair types were repeatedly performed together, with consistent emission effects. In this case, the multiple regression was not able to separate out the effects of the single repair type. In most other cases for which we have a reasonable sample size, the multiple regression tracked the averages of isolatable repairs closely.

Figures 34 and 35 chart the average emission reductions from the preceding table. Dark columns indicate those subsystems that have statistically significant reductions for that pollutant. The average reduction for all repairs -- not just the seven major ones -- is also included in the figures. See Appendix H for breakdowns of these figures by quota group.

FIGURE 34

Average HC Reduction per Isolatable Subsystem Repair

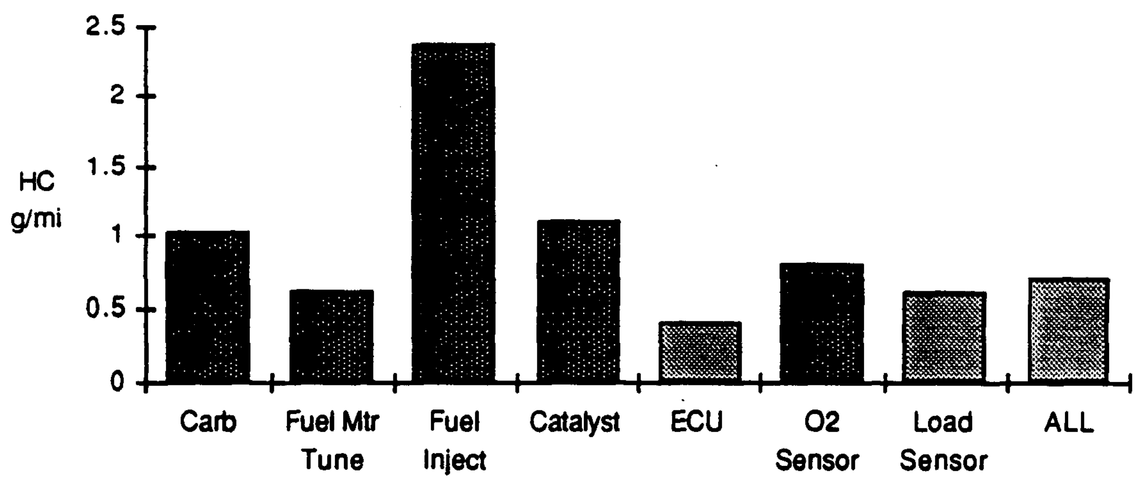
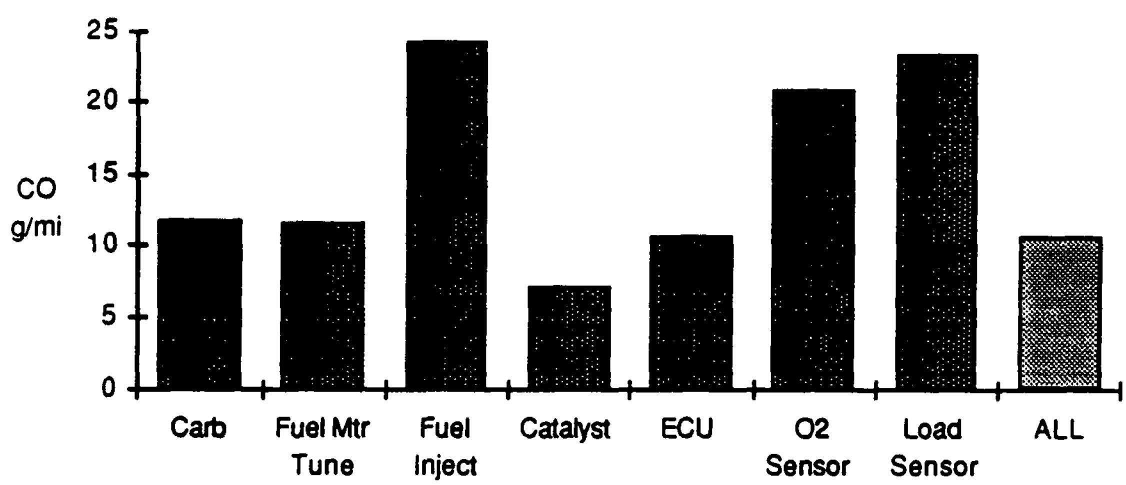


FIGURE 35

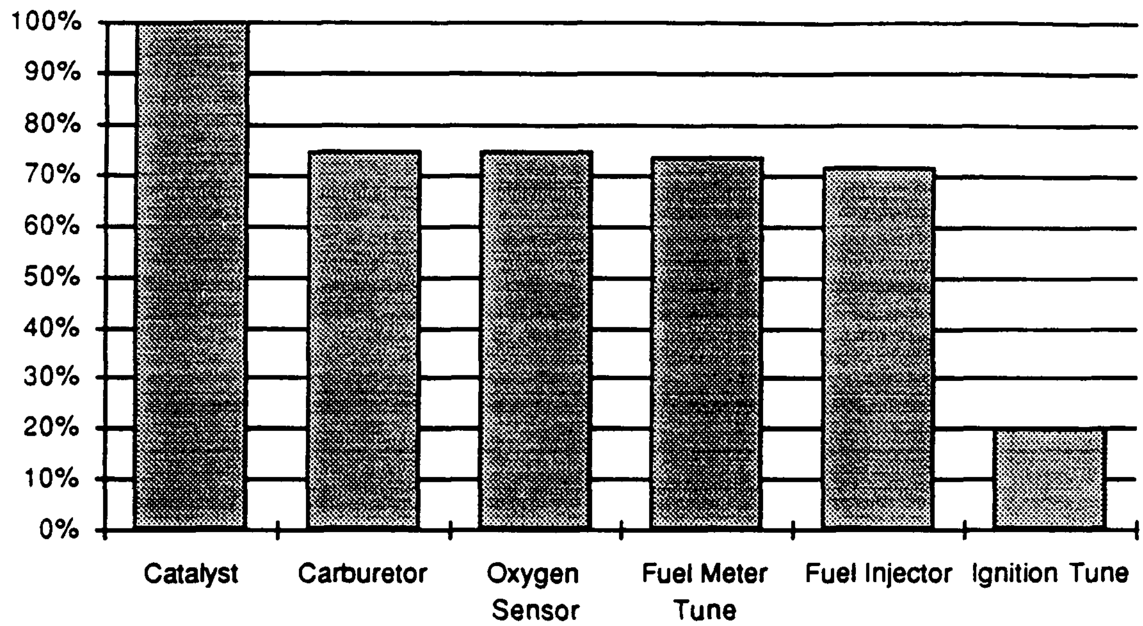
Average CO Reduction per Isolatable Subsystem Repair



Many of the same seven subsystems are consistently effective at reducing the I/M failure rate. Figure 36 illustrates the effectiveness of repairs to certain subsystems at allowing an I/M failing vehicle to pass the I/M test.

FIGURE 36

I/M Pass Rates Due to Subsystem Repair

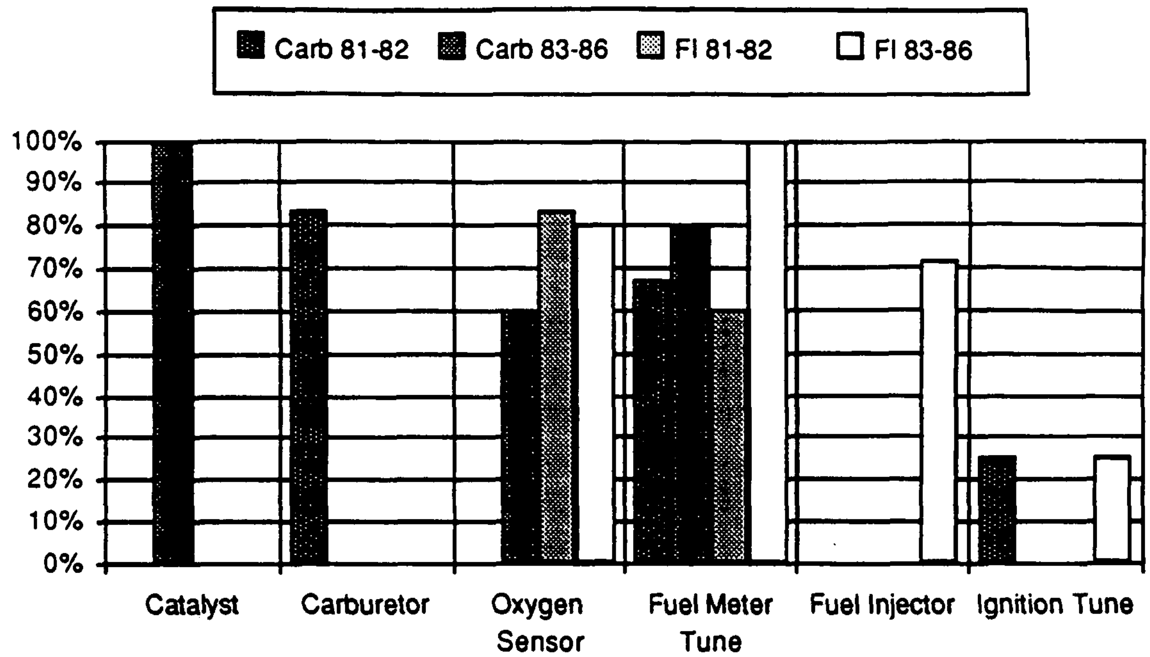


Catalytic convertor replacements were effective in this task 100% of the time, while replacement of the carburetor or fuel injectors, fuel metering system tune-ups, and oxygen replacement sensor replacements allowed I/M fails to pass approximately 75% of the time. On the other hand, ignition system tune-ups (i.e., spark plug or plug wire replacements or initial timing adjustments), which did not appear earlier as statistically significant, were effective only 20% of the time at turning I/M fails into I/M passes. The remaining subsystems had repairs on I/M failing vehicles too infrequently to be included in the analysis.

Figure 37 presents the same data split according to quota group. Note that missing data indicates small sample size (fewer than five cases), rather than 0% effectiveness. Both figures and the values cited in the previous paragraph include only isolatable repairs.

FIGURE 37

I/M Pass Rates Due to Subsystem Repair -- by Quota Group



5.3.4 Total Benefit per Subsystem

Many of these same subsystem repair types not only are consistently effective at reducing emissions on individual vehicles, but also contribute greatly to the total emission reduction of all repairs in the CTP. Figures 38 and 39 show the subsystem repairs that contributed greater than 5% of the overall CTP repair reduction. These values were derived by multiplying the average emission reduction per quota group for a subsystem repair type (calculated with isolatable repairs only) by the number of times a repair occurred to that subsystem in that quota group (all occurrences -- isolatable or not). This estimate of the total contribution of that subsystem was then divided by the total benefit realized by all repairs, generating percent contribution per subsystem. See Appendix I for a listing of results for all subsystems; this table is not stratified by quota. Note that the totals do not equal 100%, due to the combining of isolatable averages with all repair occurrences.

The most important repair at reducing fleet emissions was the oxygen sensor, for both HC and CO. This was not only the most frequently repaired component, being replaced on 1/3 of the repaired vehicles, but also contributed a fairly large reduction when replaced -- 0.80 g/mi HC and 20.7 g/mi CO. The catalyst was also very important, being replaced on 30%

of the repaired vehicles. It was even more effective than the oxygen sensor at reducing HC per vehicle, at 1.11 g/mi, but only about 1/3 as effective at reducing CO.

FIGURE 38

Contribution of Subsystems to Total HC Repair Benefit -- by Quota Group

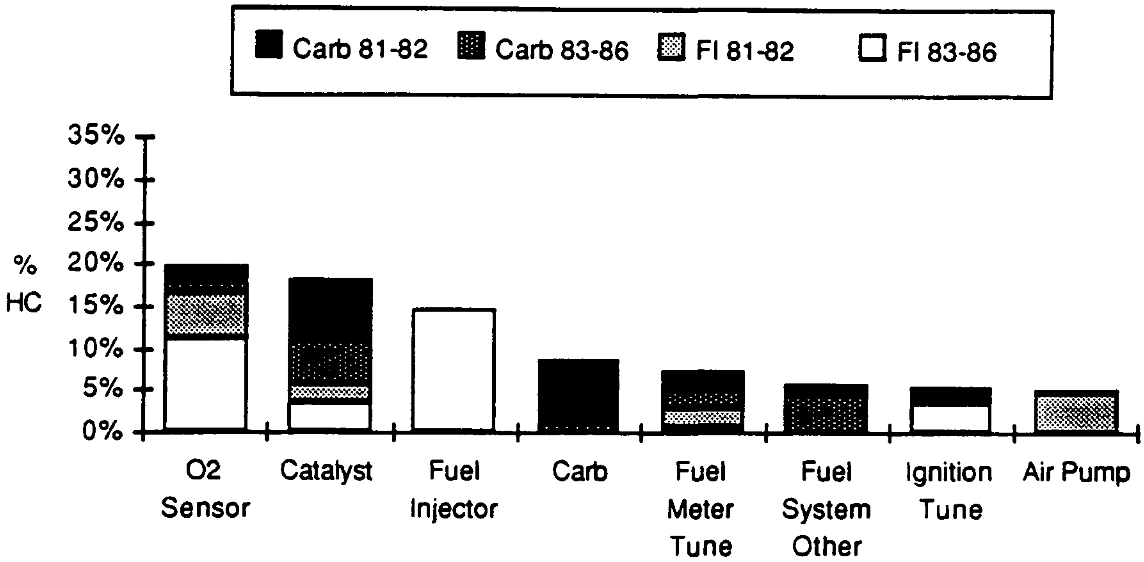
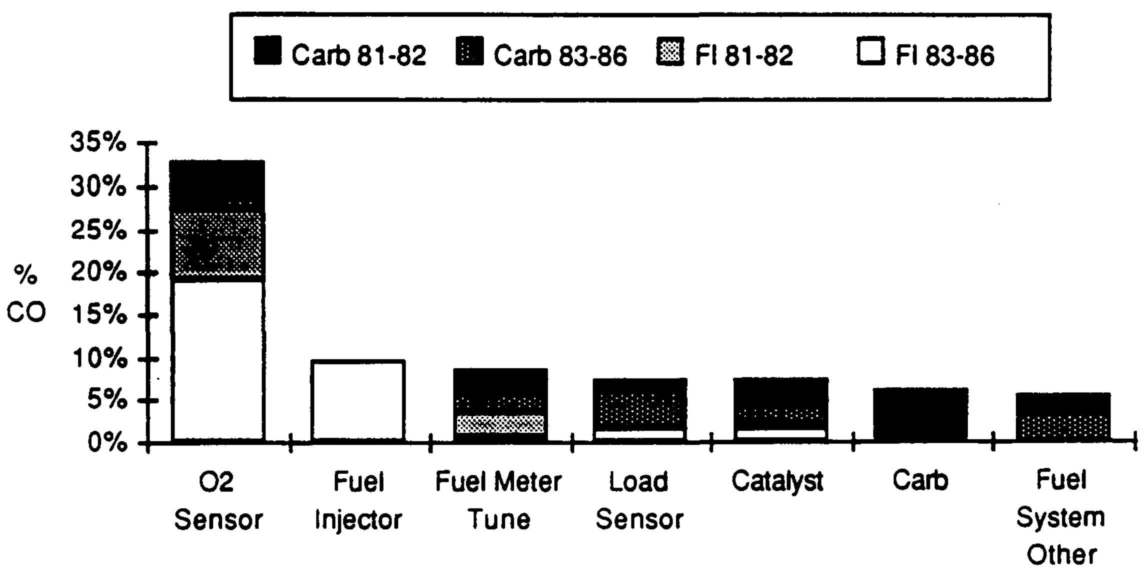


FIGURE 39

Contribution of Subsystems to Total CO Repair Benefit -- by Quota Group



Fuel system repairs of many kinds, including fuel injector replacements, catalyst replacements, tune ups, and miscellaneous repairs to other fuel system components were also extremely effective at reducing fleet emissions of both HC and CO. The fuel meter tune items -- idle speed, idle mix, and initial timing adjustments -- had an impact based largely on their frequency of occurrence, being performed on almost 25% of the repaired vehicles, but with a per-vehicles reduction of only 0.61 g/mi HC and 11.6 g/mi CO. Fuel injector replacements occurred somewhat less frequently, on only about 10% of the repaired vehicles, but had extremely high levels of reduction per repair, at 2.35 g/mi HC and 24.2 g/mi CO. Carburetors were replaced about as often as fuel injectors, but were only about half as effective per repair.

Repairs to other fuel system components were not particularly frequent, occurring on only 6% of the repaired vehicles, but they had extremely high average reductions per repair, on the order of those seen for fuel injectors. About half of these repairs to miscellaneous fuel system components had a negative or negligible emissions benefit, including carburetor mixture adjustments, cleaning deposits from the throttle body, and repairing the accelerator pump or linkage; those repairs that were effective consisted of replacing the air cleaner vacuum line, adjusting the float level and M/C solenoid, and replacing the jet mixture solenoid.

The air pump and ignition tune-ups both had large impacts on the overall HC reduction, but for opposite reasons. The air pump was repaired -- invariably this involved replacement -- on only 3% of the repaired vehicles, but had very large HC reductions upon repair, averaging 7.9 g/mi. Its repair also resulted in very large CO reductions of 41.1 g/mi, but not large enough to overcome the small frequency of occurrence. Ignition tune items, on the other hand -- spark plug or plug wire replacements or an initial timing adjustment, followed by an idle speed adjustment if needed -- were only marginally effective per repair, at 0.34 g/mi HC reduction, but their frequency -- performed on 30% of all repaired vehicles -- caused them to have a large HC impact overall.

5.3.5 Effect of Deteriorated Catalysts on Emissions

Because of the significant role catalytic converters play in emission control and because of their susceptibility to damage through tampering and misfueling, an analysis was conducted focusing on their role in emission levels when malfunctioning. In the CTP fleet, 55 catalysts were replaced on 53 vehicles (two vehicles had both an oxidation and a three-way catalyst replaced), accounting for 11% of the RMs that occurred. Table 21 details the emission reductions for catalyst replacements and for all other RM types. Catalyst replacements eliminated slightly less than 20% of the CTP fleet's excess HC, and slightly less than 9% of its excess CO. Percent reductions in emission levels per RM were significantly higher for catalyst replacements than for the other RM types, even though, since catalyst repairs were generally withheld until the last repair, the pre-RM emission levels were lower on average at the time they occurred.

TABLE 21

LA4 Emission Reductions -- Catalyst Replacements and All Other Repairs

HC	number of RMs	average pre-RM emissions	average reduction per RM	percent reduction per RM	total reduction	% total excess reduced
catalyst	55	1.38	1.23	89.0%	67.48	19.6%
other	413	1.82	0.62	33.8%	254.74	74.0%
all	479	1.74	0.67	38.5%	321.91	93.5%
CO	**number of RMs**	**average pre-RM emissions**	**average reduction per RM**	**percent reduction per RM**	**total reduction**	**% total excess reduced**
catalyst	55	10.9	8.5	78.1%	468.5	8.9%
other	413	23.0	11.1	48.1%	4575.3	87.1%
all	479	21.3	10.6	49.5%	5063.0	96.4%

note: 55+413=468; 10 of the missing repairs were post-catalyst replacement, excluded due to potential masking effect of new catalyst on subsequent repair reductions; 1 was catalyst diagnostic rather than repair

The correctness of the diagnosis that a particular catalyst was malfunctioning is important to this analysis. Most vehicles -- 95% -- were released from the test program with normal emission levels, suggesting that those that did not receive catalyst replacements probably did not require them. Also, catalyst replacements were normally withheld until all other repair options were exhausted. Therefore, it can be assumed that catalysts repairs were generally applied only when needed, and avoided when not.

Evidence of misfueling or tampering did not play a significant role in identifying vehicles which required a catalyst replacement to achieve normal emission levels. For catalyst replacement vehicles, the average lead level in the as-received tank fuel was 0.0037 g/gal; for all CTP vehicles, it was 38% higher, at 0.0051 g/gal. Of the 81 vehicles with above-average lead-in-fuel levels, only 9, or 11%, received catalyst replacements; 84% of the catalyst changes occurred on vehicles with below-average lead-in-fuel levels. Also, of the ten vehicles with the highest lead-in-fuel levels (0.015

-- 0.05 g/gal), only two received catalyst changes. Thus, fuel lead level is not a reliable predictor of the necessity of a catalyst replacement.

Additionally, only two of the 53 catalyst replacement vehicles were noted to have signs of fuel inlet restrictor damage. Two vehicles which did not receive cat replacements also had such damage; one was nevertheless released from the CTP with normal emitter levels achieved via other repairs, while the other remained a high emitter due to obvious tampering -- a missing catalyst. This vehicle certainly would have had drastic emission reductions had a new catalyst been installed. Thus, evidence of fuel inlet restrictor tampering may be a reliable sign of the necessity of catalyst replacement, but occurs infrequently.

Two-thirds of the as-received fleet underwent the Plumbtesmo test for tailpipe lead residues; only three failures occurred, and none of these required catalyst changes to achieve normal emission levels. Overall, only 20% of the vehicles that had their catalysts replaced had evidence of misfueling or tampering, as indicated by the Plumbtesmo test, fuel inlet restrictor damage, or above-average fuel lead levels.

5.4 Analysis of Incremental Repairs

5.4.1 Sample Description

The focus will now move from a discussion of the repair types that affected emission levels to the benefits actually achieved under different circumstances of test procedure, vehicle emitter category and repair target.

Recall that 630 repairs were performed in 479 remedial maintenance (RM) steps on 184 vehicles. The sequence of the RM steps on each vehicle was based on the as-received vehicle characterization, with the repairs judged most likely to reduce FTP emissions performed first. Once FTP values were sufficiently low, any vehicle that still had difficulty consistently passing the I/M test was repaired to eliminate that problem. Transient and I/M tests performed both before and after each repair allow a comparison of repairs that helped the vehicle pass I/M with those that actually cleaned up the vehicle, as measured by the FTP or LA4.

Recall from Section 4.5.2 that the core sampling period of the BITP which followed extended loaded preconditioning had the lowest failure rate, with approximately 40% of the CTP sample failing. This is considered to be the BITP sampling period which is closest to the "ideal" I/M test condition. Analysis of the effects of repair on the I/M test focuses exclusively on this sampling period. The following sections focus exclusively on non-catalyst repairs.

5.4.2 Benefits of Repairing to Pass I/M

The purpose of I/M is to determine which vehicles have high emission levels, so that their emissions can then be reduced through repair; an adequate repair should not only allow a vehicle to pass a subsequent I/M test, but also clean up its actual in-use emissions. It is therefore important to determine if those repairs that allow an I/M failing vehicle to pass are also the ones that actually clean up the emissions, as measured by a mass emissions test. This section investigates the mass emissions benefits that are realized by repairing vehicles to pass the I/M test.

One hundred vehicles -- 54% of those that received repair -- were failing their ideal I/M test at the time of first repair. Eighty-four of these vehicles received a non-catalyst repair at some point that allowed a passing I/M score, while 11 required a catalyst replacement to pass I/M, three never passed the ideal I/M test (these three never received catalyst repairs, and were high or marginal emitters at the time of release), and the remaining two had no post-repair I/M test data. Overall, it took an average of 1.5 remedial maintenance steps to get a failing vehicle to pass I/M.

Both I/M scores and mass emissions data are available for the non-catalyst repairs on 83 of the 84 vehicles which were initially failing I/M. The net LA4-measured emissions benefit achieved from these RMs -- those that first allowed an I/M pass without a catalyst change -- was 178 g/mi HC and 2651 g/mi CO. Average reductions per RM per vehicle were therefore 2.14 g/mi HC and 31.9 g/mi CO, over twice as large as the average reduction per RM for all repairs. This single RM step reduced as-received HC and CO emissions by about 75% for these 83 vehicles, eliminating approximately 80% of their as-received excess. This high level of reduction on these vehicles eliminated over 50% of the excess HC and CO emissions of the entire CTP fleet and achieved close to 60% of the entire reduction seen by that fleet, although the repairs occurred on only 47% of the vehicles, and represented only 20% of the non-catalyst RMs performed. Additionally, the number of high and super emitters in this group dropped from 83% to 25% due to this single RM. Therefore, the repairs that worked in terms of I/M pass/fail were also apparently well suited to reduce FTP emissions.

Table 22 gives values for these vehicles at their first I/M pass, broken down by the emitter categories before and after the repair that caused the passing test. The reduction is that caused by the single RM that caused the vehicle to go from I/M fail to I/M pass; mean emissions are those after the repair -- that is, at first I/M pass. Percent excess is of failed vehicles in the entire CTP fleet.

TABLE 22

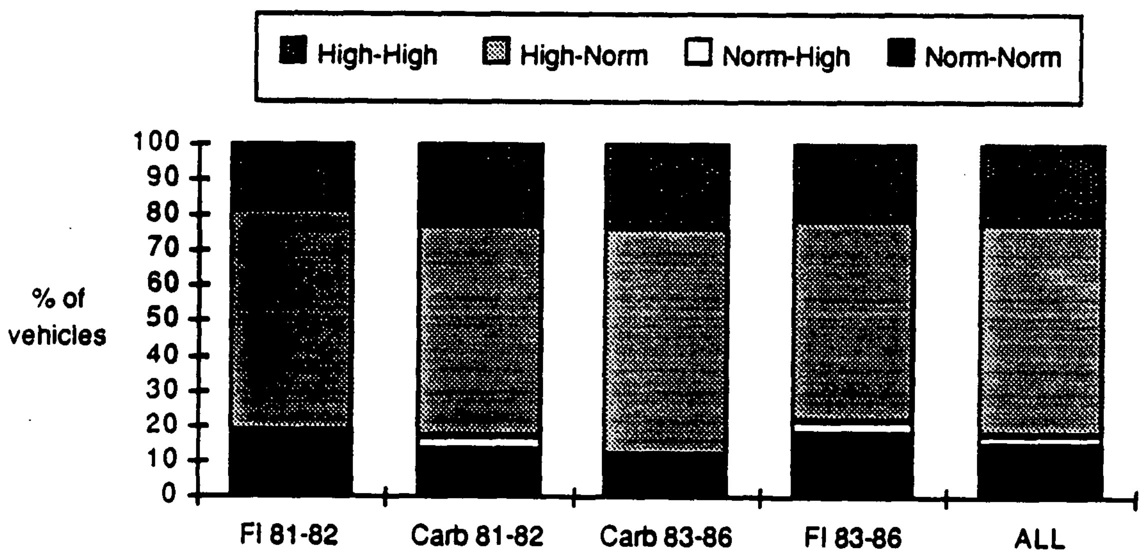
FTP Benefits of Repairing to Pass I/M

MOBILE4 Emitter Category	Number of Vehicles	Mean LA4 Reduction		% of FTP Excess		Mean LA4 Emissions	
		HC	CO	HC	CO	HC	CO
Normal to Normal	12	0.03	1.4	0.1%	0.3%	0.39	4.5
Normal to High	2	-0.64	-15.5	-0.4%	-0.6%	1.31	19.1
High to Normal	49	2.38	47.2	33.9%	44.1%	0.37	4.2
High to High	18	1.74	12.9	9.1%	4.4%	1.96	27.2
Super to Normal	1	15.69	62.9	4.6%	1.2%	0.28	2.2
Super to High	1	15.12	57.2	4.4%	1.1%	3.11	8.2
TOTAL	83	2.14	31.9	51.7%	50.5%	0.77	9.6

The FTP benefits of repairing to pass I/M were not dependent on fuel meter type or model year group. As Figure 40 illustrates, about 60% of the vehicles changed from high to normal emitters after the repair to passing I/M status, independent of quota group.

FIGURE 40

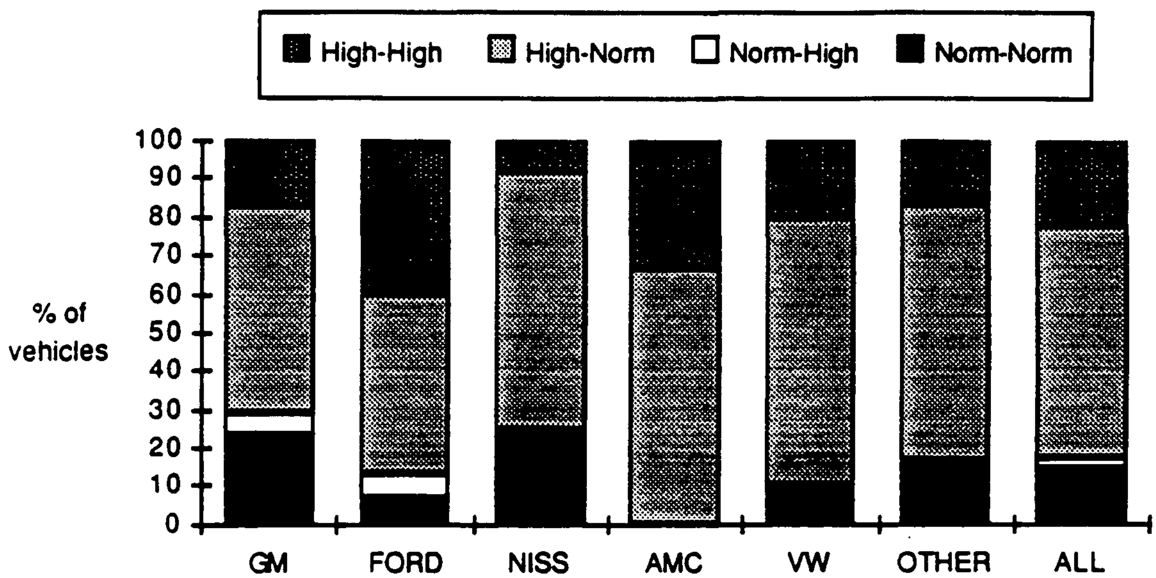
Changes in Emitter Group Due to Repair from I/M Fail to I/M Pass -- by Quota Group



Manufacturers were slightly more variable in their success, but this was to an extent due to the number of high versus normal emitters in their original sample. Overall, repairs that turned normal emitters into high emitters while allowing the vehicle to pass I/M were quite rare -- approximately 2%. Super emitters are included with highs in the following two figures. Note that several manufacturers are grouped together; this is due to their small sample size (fewer than seven vehicles) in this subset of data.

FIGURE 41

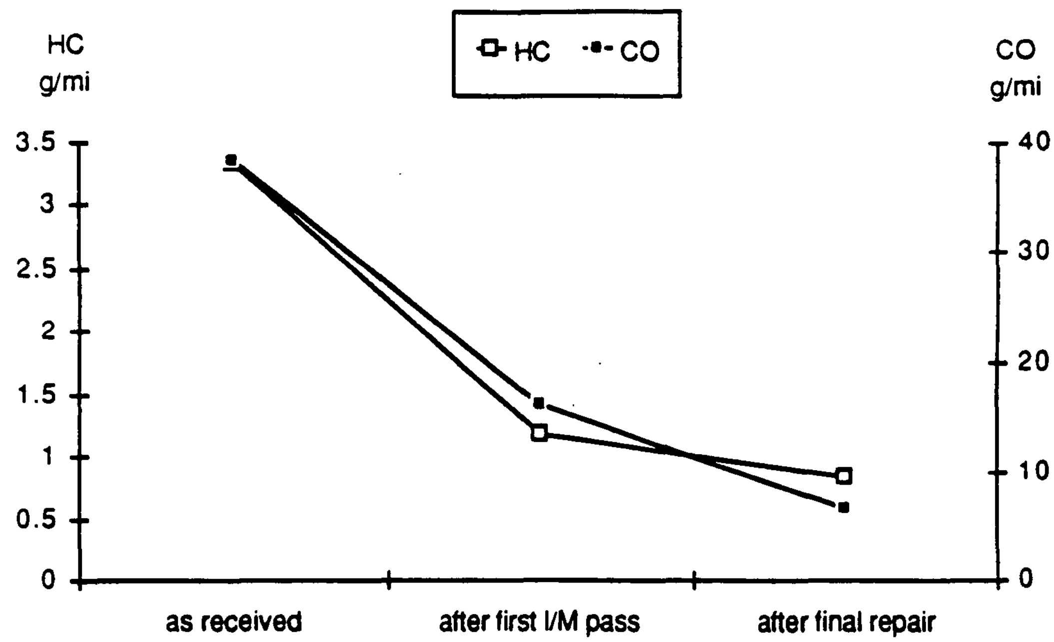
Changes in Emitter Group Due to Repair from I/M Fail to I/M Pass -- by Manufacturer



There is some additional FTP reduction available from more complete repair even after vehicles pass I/M. The CTP test sequence did not specifically address this issue, but the program nevertheless collected data on 39 vehicles that received additional repair and mass emission testing after they were passing I/M. These vehicles achieved an additional LA4 reduction of 0.33 g/mi HC and 9.5 g/mi CO, on average, as shown in Figure 42. These reductions were achieved in an average of two additional remedial maintenance steps per vehicle.

FIGURE 42

Average LA4 Emissions for Vehicles with Additional Repair After Passing I/M



5.4.3 Comparison to MOBILE4 Repair Estimates

The MOBILE4 emissions model uses emission benefits realized from repairing failing I/M vehicles to pass the I/M test as part of its calculations for I/M credits.[21] The values used are derived from test programs conducted by EPA and the California Air Resources Board, in which vehicles underwent the I/M process and failures were repaired by either commercial garage mechanics or EPA contractors instructed not to continue repairs past the point of passing I/M. Table 23 below compares the MOBILE4 average repair reductions -- for MY 80-86 vehicles with closed-loop control which initially failed an idle test -- to CTP values for a similar set of vehicles. (The MY 80 vehicles in the MOBILE4 dataset are California only, with technology similar to that used on Federally certified MY 81 vehicles). All vehicles included in these tables passed the I/M test following repair. Reductions are calculated from as-received values, and are those realized through the RM step which took the vehicle from I/M failing to I/M passing status. CTP reduction values are LA4-based; MOBILE4 values are FTP-based.

TABLE 23

MOBILE4 vs CTP Average Emission Reductions
Due to Repair to I/M Pass

Carbureted Vehicles										
	CTP					MOBILE4				
HC		As-Rcvd		Reduction			As-Rcvd	Reduction		
	N	FTP	LA4	g/mi	%	N	FTP	g/mi	%	
Normal	7	1.33	1.11	0.54	48.2%	38	0.76	0.14	18.7%	
High	40	3.50	3.30	2.46	74.6%	53	2.86	1.46	51.1%	
Super	0	-	-	-	-	9	13.81	11.67	84.5%	
ALL	47	3.18	2.97	2.17	73.1%	100	3.05	1.88	61.6%	
CO		As-Rcvd		Reduction			As-Rcvd	Reduction		
	N	FTP	LA4	g/mi	%	N	FTP	g/mi	%	
Normal	7	22.9	20.8	12.1	58.4%	38	8.8	1.8	20.8%	
High	40	50.9	48.8	38.0	77.9%	53	50.9	29.0	57.0%	
Super	0	-	-	-	-	9	190.2	174.0	91.5%	
ALL	47	46.8	44.6	34.1	76.5%	100	47.5	31.7	66.9%	

Fuel Injected Vehicles									
	CTP					MOBILE4			
HC		As-Rcvd		Reduction			As-Rcvd	Reduction	
	N	FTP	LA4	g/mi	%	N	FTP	g/mi	%
Normal	7	1.29	1.16	0.69	59.9%	12	0.41	0.08	20.0%
High	27	3.20	3.04	2.31	76.0%	24	2.36	1.42	60.3%
Super	2	12.91	11.87	10.18	85.7%	4	6.41	4.48	69.9%
ALL	36	3.36	3.16	2.43	76.9%	40	2.18	1.33	60.9%
CO		As-Rcvd		Reduction			As-Rcvd	Reduction	
	N	FTP	LA4	g/mi	%	N	FTP	g/mi	%
Normal	7	28.0	5.5	1.4	25.8%	12	5.8	1.3	23.4%
High	27	56.2	54.1	44.3	82.0%	24	47.9	32.7	68.3%
Super	2	62.9	62.0	56.8	91.6%	4	184.1	139.0	75.5%
ALL	36	51.1	45.1	36.7	81.4%	40	49.0	33.9	69.5%

When vehicles in all emitter categories are combined, the MOBILE4 percent reduction values undershoot those seen in the CTP by 2-40%; this gap would probably be several percent greater if the CTP values were FTP-based. The gram per mile reduction used by MOBILE4 is also generally lower than that seen in the CTP, partially due to lower as-received levels in the MOBILE4 sample. It can be argued that the MOBILE4 values are more realistic since many of the vehicles were repaired in commercial facilities rather than emission laboratories. On the other hand, the CTP values can be considered the level of reduction that could be attained given improved mechanic training in diagnosis and repair.

5.4.4 Benefits of Repairing to pass the FTP

One hundred thirty-two vehicles -- 72% of those receiving repair -- were high or super emitters at some point during their repair cycle. Almost 3/4 of these -- 98 vehicles -- received a non-catalyst repair that turned them into normal emitters, while 20% required a catalyst repair to be cleaned up, and the remaining 6% never were repaired to normal emitter levels, never having received a catalyst replacement.

The net LA4-measured emissions benefit achieved from these RMs -- the non-catalyst repairs that cleaned up a vehicle to normal emitter levels -- was 202 g/mi HC and 3722 g/mi CO. Average reductions per RM per vehicle were therefore 2.06 g/mi HC and 38.0 g/mi CO, almost three times as large as the average reduction per RM for all repairs. This single RM step reduced as-received HC and CO emissions by about 85% for these 98 vehicles, eliminating over 90% of their as-received excess. This very high level of reduction on these vehicles eliminated approximately 60% of the excess HC and 70% of the excess CO emissions of the entire CTP fleet and achieved close to 2/3 of the entire reduction seen by that fleet, although the repairs occurred on only 40% of the vehicles, and represented only 20% of the RMs performed.

Ideal I/M tests were performed on most of these high or super emitters. Of those that were cleaned up to normal emitting levels, 57% became I/M passes after the repair. Another 37% had previously been passing I/M and continued to pass, while 6% continued to fail I/M even though they had achieved normal emitter levels. Therefore, a total of 94% of the vehicles that were repaired from high to normal levels on a transient test could also, at that repair stage, pass an I/M test performed under optimum conditions.

Table 24 gives values for these vehicles for the repair which took them from high (or super) to normal emitter status, broken down by the I/M pass/fail category before and after the repair. The reduction is that caused by the single RM that caused the vehicle to become a normal emitter; mean emissions are those after the repair -- that is, for the first time at normal levels. Percent excess is of FTP-failed vehicles in the entire CTP fleet.

TABLE 24

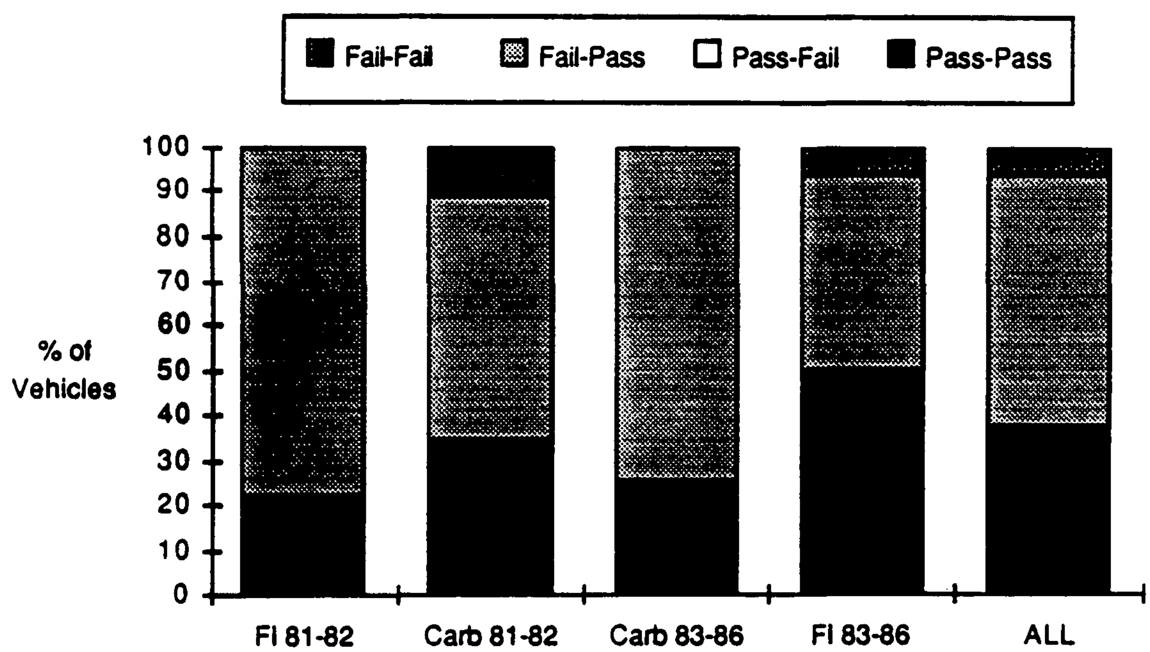
I/M Benefits of Repairing to FTP Normal Emitter Levels

Ideal I/M Pass/Fail Status	Number of Vehicles	Mean LA4 Reduction		% of FTP Excess		Mean LA4 Emissions	
		HC	CO	HC	CO	HC	CO
Pass to Pass	34	1.01	24.4	9.9%	15.8%	0.45	5.4
Pass to Fail	0	-	-	-	-	-	-
Fail to Pass	53	2.75	46.9	42.4%	47.3%	0.39	4.2
Fail to Fail	6	0.99	19.4	1.7%	2.2%	0.57	5.0
Unknown	5	3.18	58.5	4.6%	5.6%	0.57	4.3
TOTAL	98	2.06	38.0	58.7%	70.9%	0.43	4.7

The change in I/M pass/fail status once a vehicle was repaired to normal emitter levels was somewhat dependent on model year and fuel metering system, but largely as a result of variations in the I/M pass-fail levels prior to the repair. Overall, getting vehicles to pass I/M once their FTP or LA4 levels were low was not difficult for any quota group, with 94% of the vehicles passing overall, and no quota group doing worse than 88%.

FIGURE 43

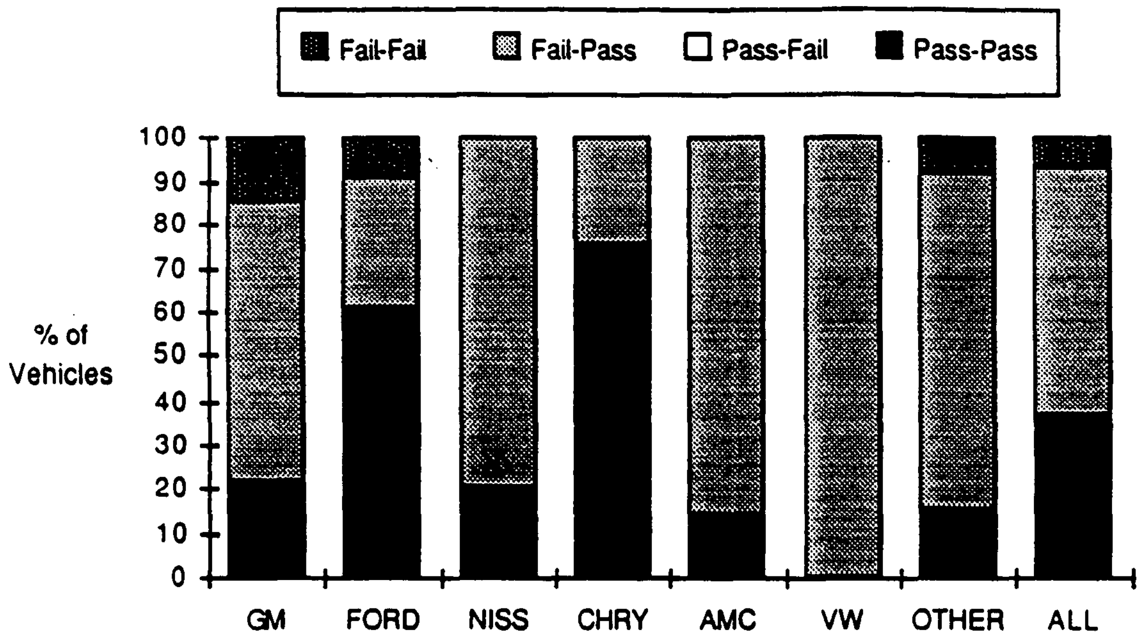
Changes in I/M Pass/Fail Status Due to Repair from High to Normal Emitter -- by Quota



Manufacturers were significantly more variable in their I/M status changes, but again, this was almost entirely due to the differences in pre-repair I/M status. GM and Ford had the most difficulty in obtaining passing I/M scores when vehicles were cleaned up on transient tests, with 14% and 9% failure rates, respectively.

FIGURE 44

Changes in I/M Pass/Fail Status Due to Repair from High to Normal Emitter -- by Manufacturer



5.4.5 Emission Benefits "Lost" through Second-Chance

I/M tests do not have perfect pass/fail correlation with the FTP. Vehicles that fail I/M with passing FTP emissions are considered false failures; their repair is unnecessary from a clean air standpoint and undesired from a consumer cost and inconvenience standpoint. One strategy to reduce the number of false I/M failures is to give all failing vehicles a second-chance I/M test. Presumably, clean vehicles that fail I/M due to inadequate preconditioning and/or canister purge during the idle test would have a good chance of passing an immediate second-chance test if preceded by sufficient preconditioning, and would not have to be repaired or retested later. Conversely, vehicles that are truly dirty under normal operating conditions should continue to fail. However, the second-chance test still being a short test, some dirty vehicles would pass along with those that are clean; it is important to determine the potential repair benefits from these vehicles that would be lost by applying the second chance test.

In the CTP, 138 vehicles -- almost 60% of the fleet -- passed an ideal I/M test in as-received condition (52 highs, 53 marginals, and 33 passes). Recall that all CTP vehicles failed their field I/M test, so that this lab test can be considered second-chance. We can assume that a fairly large proportion of these CTP second-chance passes would have also passed a second-chance test in the field, even under non-ideal conditions. These vehicles would then not be repaired.

It would be interesting to calculate the total emissions benefit due to repairing these vehicles -- that which would be lost if they all passed second-chance. However, we do not have repair data on all 138 of the vehicles, since a number were released from the CTP without repair and others did not receive mass emissions tests after repair. Mass emissions data for post-repair tests (including catalyst repairs) is available on 82 vehicles that passed second-chance (48 highs, 30 marginals, 4 passes). We can calculate the average emission reduction per vehicle (from as-received to release), with per-vehicle averages based on the as-received MOBILE4 emitter category. Summing these averages according to the weighting of the emitter categories of the 138 vehicles provides an estimate of the total emissions reduction that would not be realized: 68 g/mi HC and 1211 g/mi CO, or between 20 and 25% of the total LA4-based emission reduction of the entire CTP fleet. This estimate is an upper bound, since not all 138 vehicles would have passed second-chance given the non-ideal conditions in the field, and since the CTP per-vehicle repair benefits are probably higher than those in commercial facilities.

Thus, repairs to 60% of the CTP fleet provided less than 25% of the reduction, as an upper bound estimate. Over 60% of these CTP second-chance passes were normal emitters (pass or marginal) -- much higher than the general CTP fleet at 40% normal emitters -- and therefore are not desirable candidates for repair. This supports the theory that second-chance tests can reduce the incidence of unnecessary or detrimental repairs to cleaner vehicles without greatly reducing the emission benefit due to repairs to those that are dirty.

5.4.6 Benefits of Repairing to Different Targets

"Repair benefit" can be defined many different ways, based on the target which a vehicle is being repaired to meet. I/M programs, of course, use a passing score on a I/M test as the target; after this point is reached, there are no further emission control repairs. The CTP database provides information on the extent of excess emissions eliminated via I/M-targetted repairs, and whether a substantial portion of "repairable" emissions remain after an I/M test is passed. As the following table shows, repairs to I/M targets reduce as-received emission levels by about 75%, eliminating over half of the FTP excess. However, this is only about 2/3 of the total reduction that can be realized with more complete repair.

TABLE 25

Reduction in LA4 Emissions Due to Repair to Different Targets

TOTAL REDUCTION (g/mi)	# vehicles	as-received	after repairs	reduction	% reduction	% excess reduced
HC						
to first I/M pass -- non-cat	83	253.56	63.83	189.73	74.8%	55.1%
to first I/M pass -- all	94	281.59	65.87	215.71	76.6%	62.7%
all non-catalyst repairs	175	367.51	112.77	254.74	69.3%	74.0%
all repairs	184	382.99	61.08	321.91	84.1%	93.5%
CO						
to first I/M pass -- non-cat	83	3862.2	797.1	3065.1	79.4%	58.4%
to first I/M pass -- all	94	4115.7	820.8	3294.8	80.1%	62.8%
all non-catalyst repairs	175	5538.9	963.5	4575.3	82.6%	87.1%
all repairs	184	5665.9	603.0	5063.0	89.4%	96.4%
AVERAGE REDUCTION (g/mi)	**# vehicles**	**as-received**	**after repairs**	**reduction**	**% reduction**	**% excess reduced**
HC						
to first I/M pass -- non-cat	83	3.05	0.77	2.29	74.8%	55.1%
to first I/M pass -- all	94	3.00	0.70	2.29	76.6%	62.7%
all non-catalyst repairs	175	2.10	0.64	1.46	69.3%	74.0%
all repairs	184	2.08	0.33	1.75	84.1%	93.5%
CO						
to first I/M pass -- non-cat	83	46.5	9.6	36.9	79.4%	58.4%
to first I/M pass -- all	94	43.8	8.7	35.1	80.1%	62.8%
all non-catalyst repairs	175	31.7	5.5	26.1	82.6%	87.1%
all repairs	184	30.8	3.3	27.5	89.4%	96.4%

5.5 Repairs to High Emitters

5.5.1 Effectiveness of Repair on Marginals vs. Highs

It is important, first, to determine the effectiveness of repairs on marginal emitters versus high emitters. Is it worth it to capture and repair the marginals, or would the effort be better spent focussed entirely on the highs? Sixty percent of the CTP sample were high emitters (143 vehicles), while 26% were marginals (62 vehicles). As shown in Figures 45 and 46, the emissions benefit of non-catalyst repairs to the marginal emitters is negligible, whereas the high emitters have substantial LA4 reductions -- 1.8 g/mi HC and 33 g/mi CO. In fact, the average emission reduction on high emitters is over 15 times as great as that seen on marginals, for both HC and CO. These figures include non-catalyst repairs on only those vehicles that eventually received repair (all of the highs, and three-fourths of the marginals) and for which we have complete mass emissions data.

FIGURE 45

Average HC Repair Benefit -- Marginal vs High Emitters

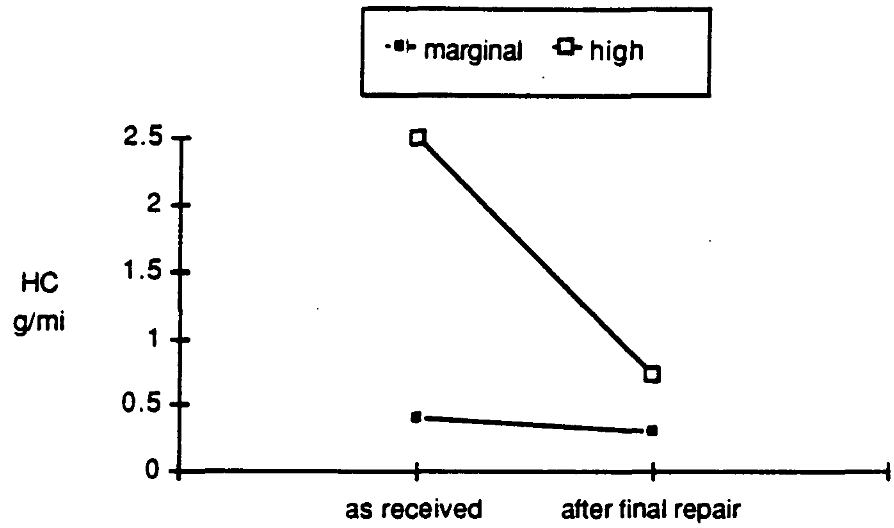
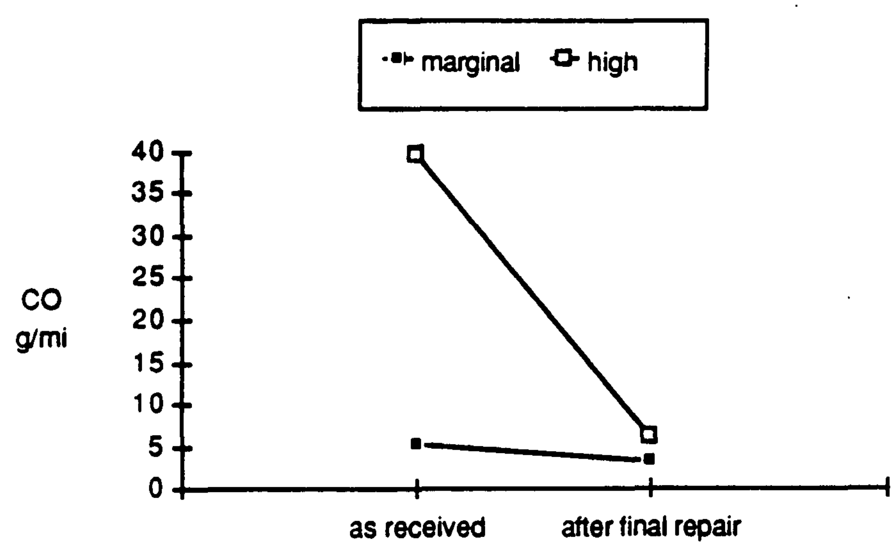


FIGURE 46

Average CO Repair Benefit -- Marginal vs High Emitters



The following table simply tallies the number of vehicles which were dirtier on the LA4 after all repairs than as-received, on at least one pollutant. The breakdown into high and marginal emitters indicates that a much higher percentage of the marginals than highs were dirtier after repair, although catalyst changes helped clean up both marginal and high emitters. Thus, repairs to marginal emitters generally result in negligible repair benefits and are much more likely to be detrimental than repairs to high emitters; therefore, marginal emitters are not a worthy target for I/M programs.

TABLE 26

Vehicles Dirtier After All Repairs

EMITTER	NON-CATALYST REPAIRS			ALL REPAIRS		
CATEGORY	N cleaner	N dirtier	% dirtier	N cleaner	N dirtier	% dirtier
High	123	11	8%	137	5	4%
Marginal	26	11	30%	31	7	18%

5.5.2 Benefit of Repairing Highs only

We now focus on high emitters, as both the most prevalent portion of the CTP sample and the most important segment relative to emission reductions. This section supplies FTP as well as LA4 values, to provide data that can be more easily compared to that from other programs.

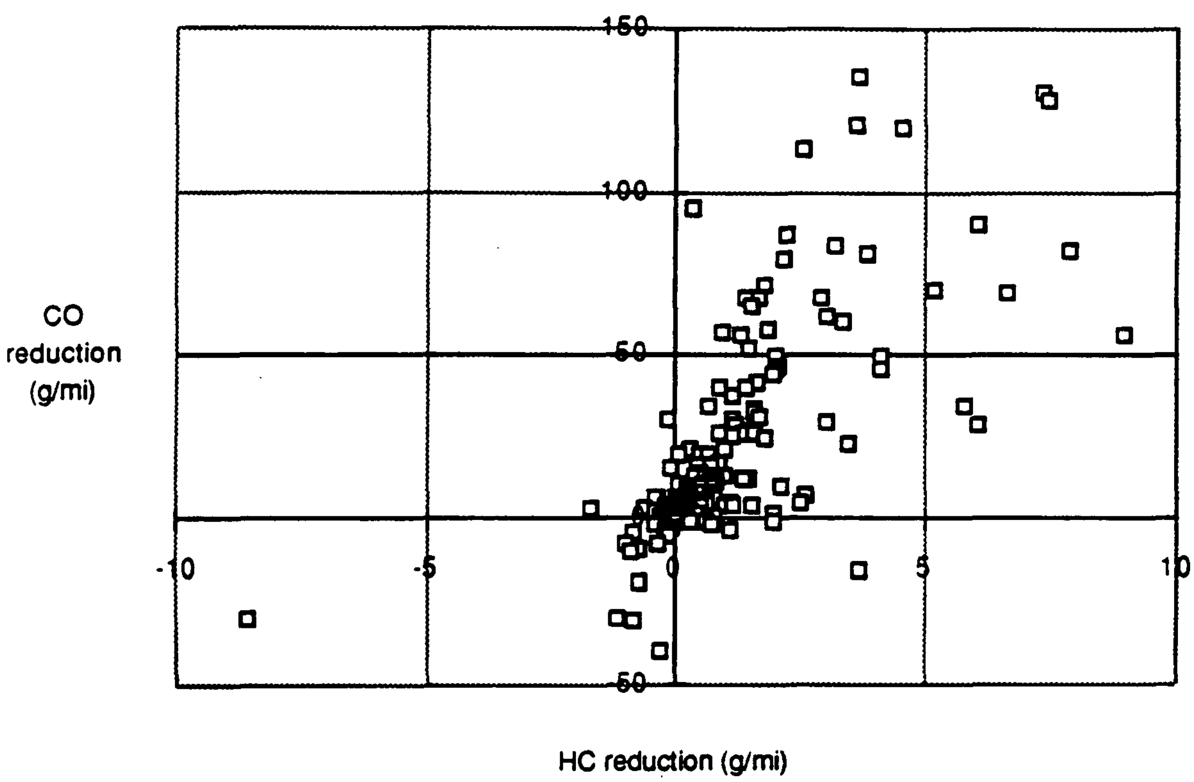
FTP emission benefits in a single non-catalyst RM step ranged from a reduction of more than 7 g/mi HC and 125 g/mi CO at the high end (from installation of a new oxygen sensor on a 1985 fuel injected Oldsmobile Firenza, and replacement of the ECU and oxygen sensor on a 1984 fuel injected Chevrolet Cavalier), to an emissions increase of 8.6 g/mi HC and 30 g/mi CO (from replacement of a PCV fitting on a 1982 carbureted Mercury Marquis). As Figure 47 shows, a large reduction in one pollutant did not necessarily correlate with a large reduction in the other, although there were relatively few cases in which one pollutant increased while the other decreased.

Overall, the average FTP benefit of non-catalyst repairs to high emitters, per RM, was 0.83 g/mi HC and 15.8 g/mi CO. This reduced HC by 41% and CO by 54% from the levels immediately prior to the RM, and eliminated 31% of the vehicle's as-received HC and 41% of its as-received CO, on average. Each high emitter received an average of 2.3 non-catalyst RMs, and eventually had 83% and 92% of its excess HC and CO eliminated. This reduced each high emitter's as-received emissions by 69% for HC and 81% for CO, or a total of 1.86 g/mi HC and 34.5 g/mi CO, from average levels of 2.70 g/mi HC and 42.4 g/mi CO.

With the inclusion of catalyst repairs, 98% of the excess HC and 99% of the excess CO from the high emitters was eliminated, in an average of 2.6 RMs per vehicle. This entailed reducing each high emitter's as-received FTP emissions by 81% for HC and 87% for CO, or 2.19 g/mi HC and 35.3 g/mi CO, from average levels of 2.69 g/mi HC and 40.6 g/mi CO.

FIGURE 47

FTP Benefit per RM of Non-Catalyst Repair to High Emitters



The average LA4 benefit of non-catalyst repairs to high emitters, per RM, was 0.71 g/mi HC and 13.4 g/mi CO. This reduced HC by 36% and CO by 50% from the levels immediately prior to the RM, and eliminated 28% of the vehicle's as-received HC and 34% of its as-received CO, on average. Each high emitter received an average of 2.5 non-catalyst RMs, and eventually had 78% and 90% of its excess HC and CO eliminated. This reduced each high emitter's as-received emissions by 71% for HC and 85% for CO, or a total of 1.77 g/mi HC and 33.4 g/mi CO, from average levels of 2.50 g/mi HC and 39.5 g/mi CO.

With the inclusion of catalyst repairs, 94% of the excess HC and 97% of the excess CO from the high emitters was eliminated, in an average of 2.8 RMs per vehicle. This entailed reducing each high emitter's as-received LA4 emissions by 86% for HC and 91% for CO, or a total of 2.11 g/mi HC and 34.7 g/mi CO, from average levels of 2.46 g/mi HC and 38.1 g/mi CO.

5.5.3 Catalyst Repairs Performed on Highs

Of the 143 vehicles that were high emitters as-received, 48 eventually received catalyst replacements; mass emissions data is available on all but one. These 47 vehicles had achieved, on average, an LA4-based emission reduction of 0.95 g/mi HC and 15.7 g/mi CO prior to replacement of the catalyst, reducing HC emissions 40% and CO 58% from as-received levels. These vehicles required an average of 2.9 non-catalyst RM steps to achieve these relatively small reductions. A single catalyst repair, on the other hand, allowed an additional 1.29 g/mi HC and 8.8 g/mi CO, eliminating an additional 54% and 33%, respectively, of the vehicle's as-received emissions. This resulted in an total reduction of 95% of the vehicle's as-received HC and CO, bringing levels lower than certification requirements, thus eliminating the entire excess for the vehicle.

Vehicles that never received a catalyst repair, however, had total reductions of 81% HC and 91% CO, in only 2.1 RMs, partly as a result of higher initial emission levels. This eliminated 90% of the excess HC and 95% of the excess CO for these vehicles. Non-catalyst repair vehicles never attained emission levels as low as catalyst-replacement vehicles, with final values approximately twice as high. Nevertheless, most of these vehicles were brought to normal emitter levels even without the benefit of a new catalyst, while over half of the catalyst-repair vehicles were still high emitters until the catalyst was replaced, despite almost three attempts at repairing other components. In all, over 15% of the high emitters could not be brought to normal levels by any means of repair other than catalyst replacement.

The following two figures and table illustrate the emission levels as-received, following all non-catalyst repairs, and finally after catalyst replacements, for vehicles that had no catalyst replacement and those that did. Only vehicles that were high emitters as-received are shown. Values are LA4-based.

FIGURE 48

Average HC Benefit of Repair to High Emitters -- Catalyst vs Other Repairs

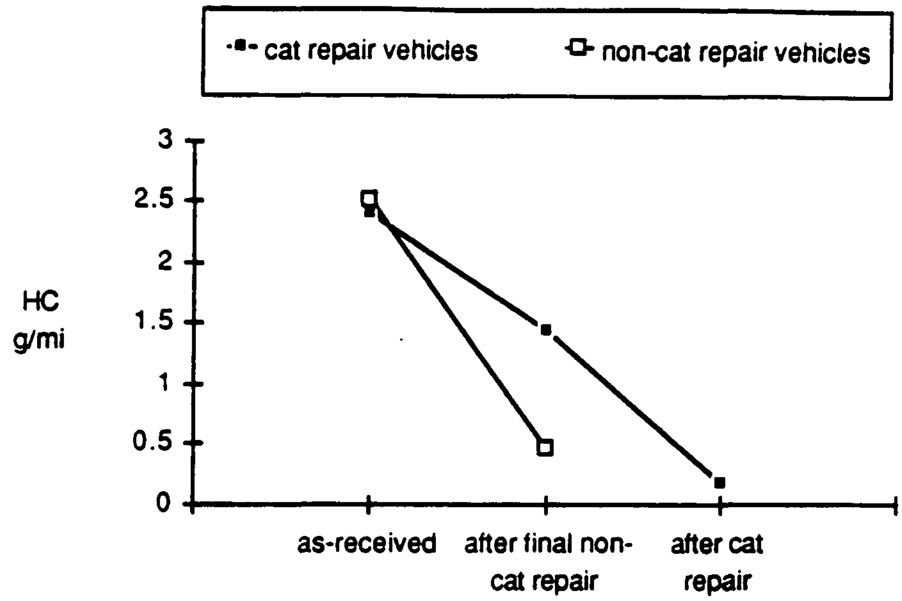


FIGURE 49

Average CO Benefit of Repair to High Emitters -- Catalyst vs Other Repairs

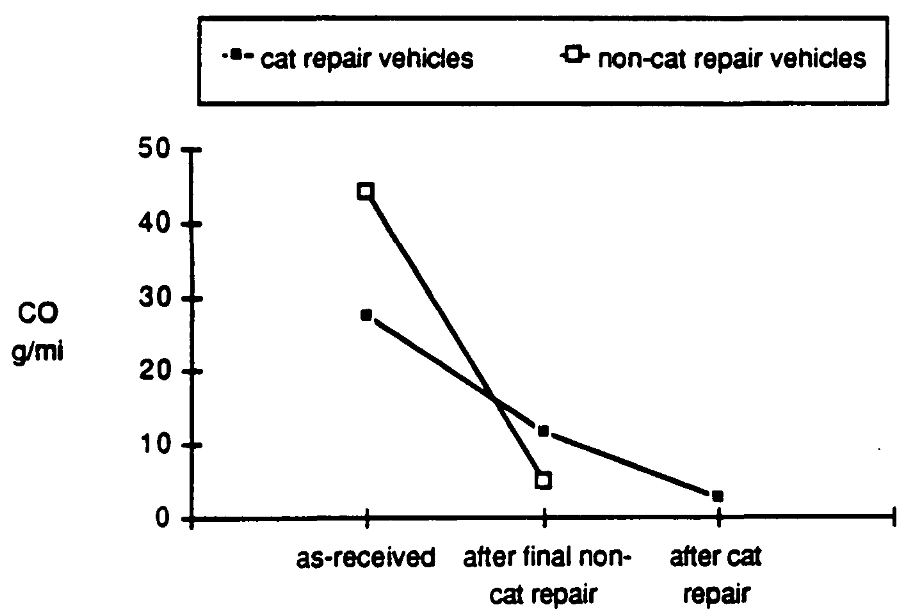


TABLE 27

Average Benefit of Repair to High Emitters -- Catalyst vs Other Repairs

HC	number of vehicles	as-received emissions	after final non-cat repair	after cat repair
cat repair vehicles	47	2.40	1.45	0.16
non-cat repair vehs	95	2.50	0.47	-
CO	number of vehicles	as-received emissions	after final non-cat repair	after cat repair
cat repair vehicles	47	27.1	11.4	2.6
non-cat repair vehs	95	43.9	4.5	-

Catalyst replacement was the second most frequent repair performed on high emitters, done on 1/3 of them. The most common was replacement of the oxygen sensor, performed on 43% of the high emitters. This repair was highly successful at reducing emissions, at an average LA4 reduction for the highs of 1.23 g/mi HC and 10.1 g/mi CO, eliminating almost 1/2 of the excess HC and 1/4 of the excess CO for the affected vehicles. Other repairs done frequently on high emitters included various ignition tune items and fuel metering tune items, and repair or replacement of carburetor assemblies, air injection system check valves and hoses, fuel injection components, and three-way control system components such as load sensors, hoses, and the ECU. Repairs to the induction, EGR, PCV, evaporative, and engine assembly systems were relatively infrequent.

5.6 Difficulty of Repair

5.6.1 Difficulty of Repair to Passing Levels

Another aspect of vehicle repair is the difficulty of diagnosing and performing the repair(s) that will actually reduce emissions. In the CTP, diagnosed problems were ranked according to their likely impact on FTP levels and performed in that order. Therefore, the earlier RMs should have had a greater emissions benefit than those performed later. If this holds true, we can assume that diagnosis was generally correct, and therefore was not a major inhibiting factor in reducing FTP levels. The remainder of this section investigates this issue.

The following table and figure indicate, for each repair step, the vehicles that changed MOBILE4 emitter status at each RM stage. The "high" grouping includes high and super emitters, while the "norm" grouping includes passes and marginals, as previously defined. All values are based on the LA4, and only repairs performed prior to catalyst replacement are included. Some totals are not equal to 100% due to occasionally missing data.

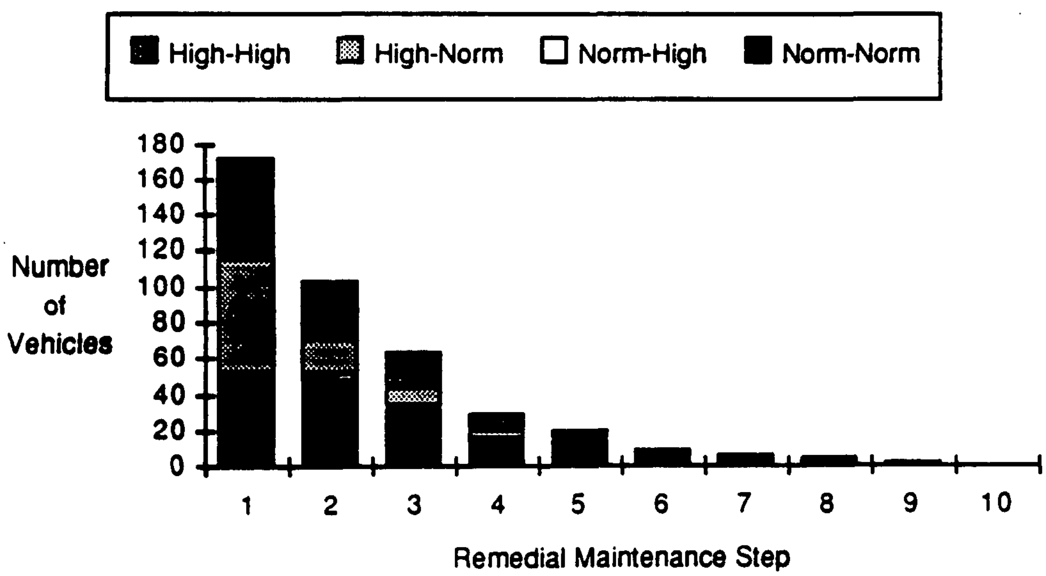
TABLE 28

Emitter Category Changes per RM Step

RM Step	MOBILE4 Emitter Category Change			
	Norm-Norm	Norm-High	High-Norm	High-High
1	30%	0%	37%	32%
2	45%	5%	18%	30%
3	49%	3%	15%	31%
4	52%	0%	14%	34%
5	65%	0%	10%	25%
6	63%	0%	25%	13%
7	67%	17%	0%	17%
8	75%	0%	25%	0%
9	100%	0%	0%	0%
10	-	-	-	-
ALL	42%	2%	24%	30%
	HIGH includes highs and supers NORM includes passes and marginals			

FIGURE 50

Emitter Category Changes Due to Remedial Maintenance

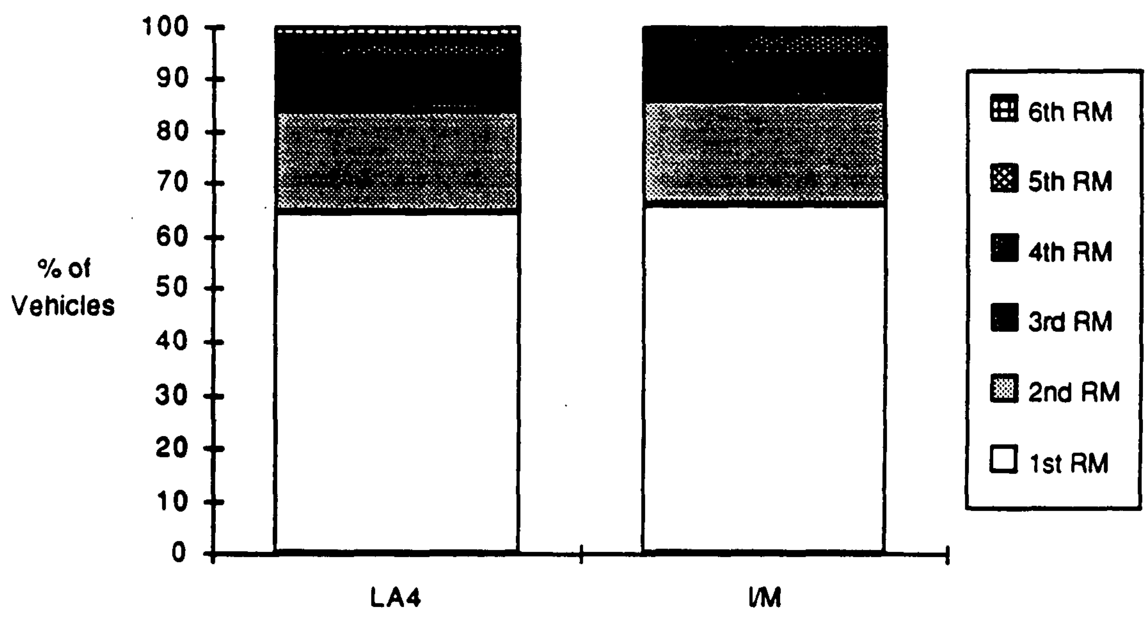


In general, earlier repairs were more successful than later repairs at reducing high emission levels to normal levels, as anticipated. This is partly because, at later RM steps, a greater percentage of vehicles had moved into the normal emitter category prior to that repair, thus reducing the number available to be cleaned from high to normal levels. Additionally, however, those that were high emitters at a later RM step were less likely than earlier repairs to have substantially reduced emission levels (enough to drop them into normal emitter status) due to that repair, dropping from a 53% chance at the first repair to a 29% chance at the fourth and fifth. The balance of these two effects is that each time a car is repaired, there is a two-thirds chance it will be at normal emitting levels after the repair.

It took approximately 1.5 RM steps, on average, to clean up an FTP- or I/M-failing vehicle to passing levels. Figure 51 gives a breakdown of the repair step after which high or super emitters became passing or marginal emitters, as measured by the LA4, and the step after which I/M failures became I/M passes.

FIGURE 51

RM Step that Cleaned Up Emissions --
LA4 from High to Normal Emitter; I/M Score from Fail to Pass

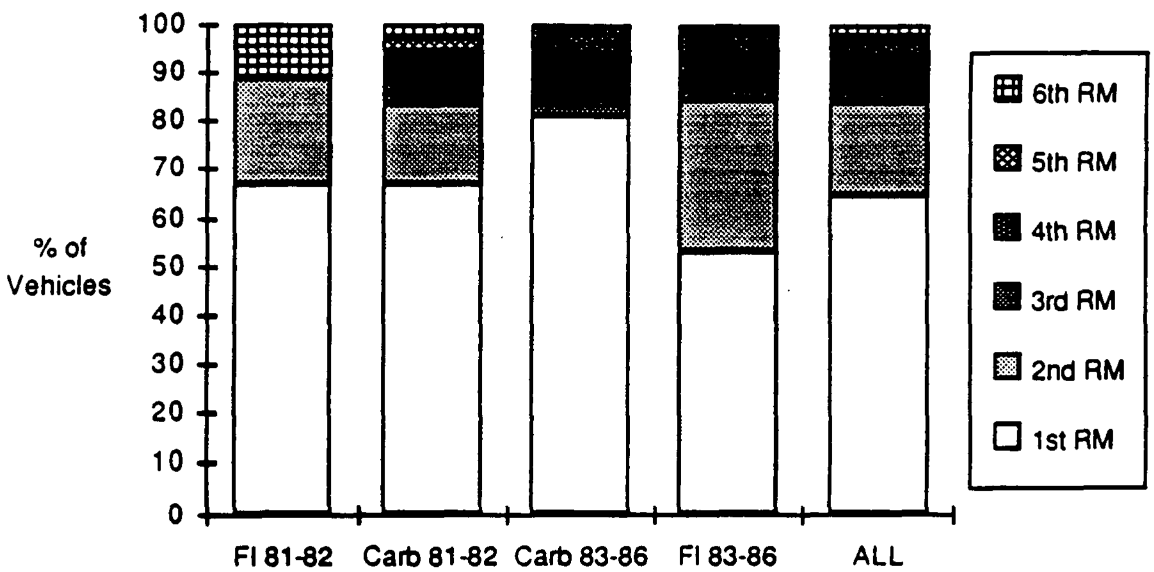


There is very little difference between the two cases; in fact, the two bars represent many of the same vehicles moving into passing status for both tests at the same RM stage. There is a 57% overlap between the two bars; that is, of the vehicles that were either high/super emitters as-received or were failing I/M as-received, 57% were both. Of this overlapping group, 72% passed both test types at the same RM step, 21% passed I/M while remaining high emitters, and 7% became normal emitters prior to passing I/M.

Quota group had a minor impact on the number of repair steps required to turn a vehicle from a high to normal emitter. While the MY 81-82 vehicles had nearly identical results regardless of fuel metering type, the MY 83-86 group showed a marked difference between carbureted and fuel injected models. Carbureted vehicles were repaired to normal emitter levels in only one repair 81% of the time, whereas only 53% of the fuel injected vehicles were successfully repaired in a single RM step. Nevertheless, each quota group was able to achieve a success rate of 80-90% after only two RMs, as illustrated in Figure 52.

FIGURE 52

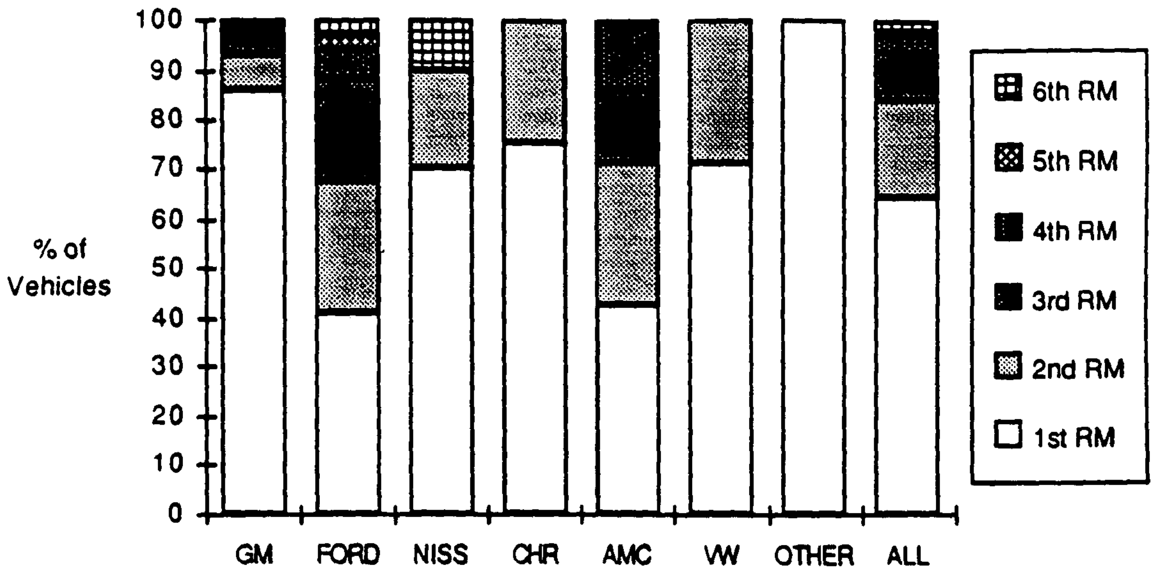
RM Step that Cleaned Up Emissions --
LA4 from High to Normal Emitter -- by Quota Group



Manufacturers were varied in their success at reducing high emitters to normal emitters in the first repair, with Ford and AMC having the most trouble -- a success rate of only slightly over 40% -- and the "other" group -- Toyota, Mazda, Subaru, Mitsubishi, and Honda -- successful 100% of the time. (These manufacturers were grouped to achieve a sufficient sample size). Nevertheless, at least 85% of the high emitters had been cleaned to normal emitting levels by the third repair, regardless of manufacturer.

FIGURE 53

RM Step that Cleaned Up Emissions --
LA4 from High to Normal Emitter -- by Manufacturer



5.6.2 Effectiveness of Repair at Successive RM Steps

The emission benefits of each repair also decreased, in general, as the number of RMs increased, as shown in Figures 54 and 55. Step four is out of line with the trend, particularly for HC. This is due to a single repair on the super emitter, which accounts for 2/3 of the total reduction for that repair step. When this vehicle is eliminated, the total HC reduction plummets from 23.4 to 8.2 g/mi, and the average drops from 0.81 g/mi to 0.29 g/mi, which is consistent with the trend across all RM steps.

Similarly, four vehicles had a large impact on the excessive reduction in CO seen in repair step four. These four vehicles had an average reduction of 42.6 g/mi, while the remaining 25 had an average reduction of 3.2 g/mi. The repairs to these four vehicles were dissimilar (rerouting lines to the air bypass and diverter valves, or replacing the carburetor, fuel injectors or air pump), with no apparent reason for such large reductions all occurring at RM step four. Elimination of them from the analysis allows the general trend to become more clear. The undue impact of a few vehicles can be attributed to the reduction in sample size at later repairs; this also affects steps five through ten.

FIGURE 54

Total and Average HC Reductions per RM Step

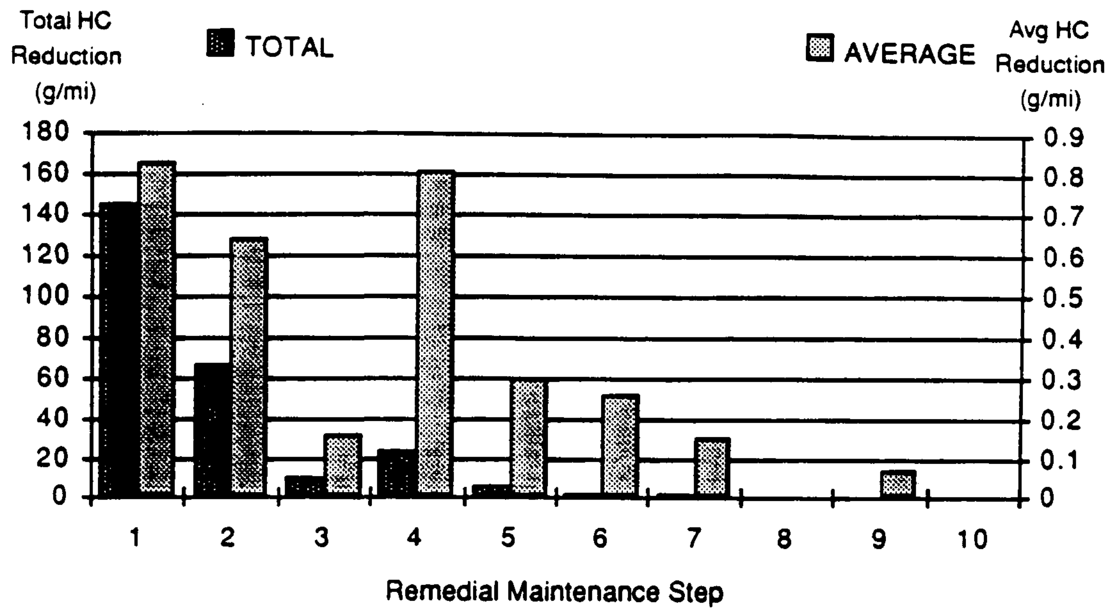
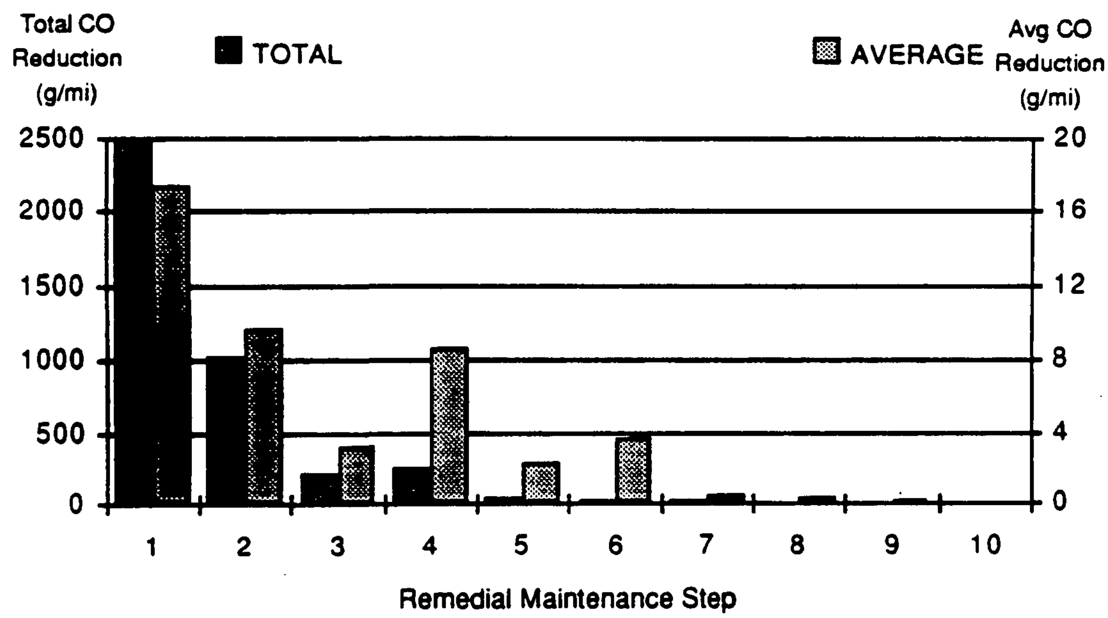


FIGURE 55

Total and Average CO Reductions per RM Step



In general, the early repairs were quite successful at reducing emissions, with the first repair generating an average reduction five times greater than the third repair, despite the fact that each RM step usually included a repair to only a single component. This is encouraging, in that it indicates both that technicians were quite successful in identifying the required repair, and that a single malfunctioning component, rather than a complex set of problems, is often the cause of high emissions.

Another way to approach the issue of repair difficulty is to look at the number of RM steps required to reduce high emission levels by a certain percentage. The following table lists the first RM step in which the total emission reduction to that point exceeded 80%, from original levels of HC>2 or CO>20 g/mi. The average number of repair steps to achieve this reduction was 1.8 Quota group was not a factor in the ability to reduce high emissions by 80%, as illustrated in Figure 52.

Again, however, manufacturer had an effect, with the seven Subaru and two Mitsubishi vehicles at these emission levels reduced by 80% in a single repair, while the three Toyota vehicles never achieved this reduction even after multiple repairs. GM and VW were never able to reduce 40% of their vehicles by this amount, while Ford and Chrysler were unsuccessful about 20% of the time. Overall, approximately 75% of the vehicles with HC>2 or CO>20 g/mi eventually received repairs which were able to reduce the high pollutant by 80% or more.

TABLE 29

RMs Needed to Reduce LA4 Emissions by >80% -- for Vehicles with FTP HC>2 or CO>20 g/mi

RM step	Number with >80% reduction	Total Number	Percent with >80% reduction
1	46	106	43.4%
2	18	75	24.0%
3	8	49	16.3%
4	5	27	18.5%
5	1	21	4.8%
6	1	15	6.7%
7	1	8	12.5%
8	0	7	0.0%
9	0	5	0.0%
10	0	1	0.0%
ALL	80	106	75.5%

FIGURE 56

RMs Needed to Reduce LA4 Emissions by >80% -- for Vehicles with FTP HC>2.0 and/or CO>20 g/mi -- by Quota

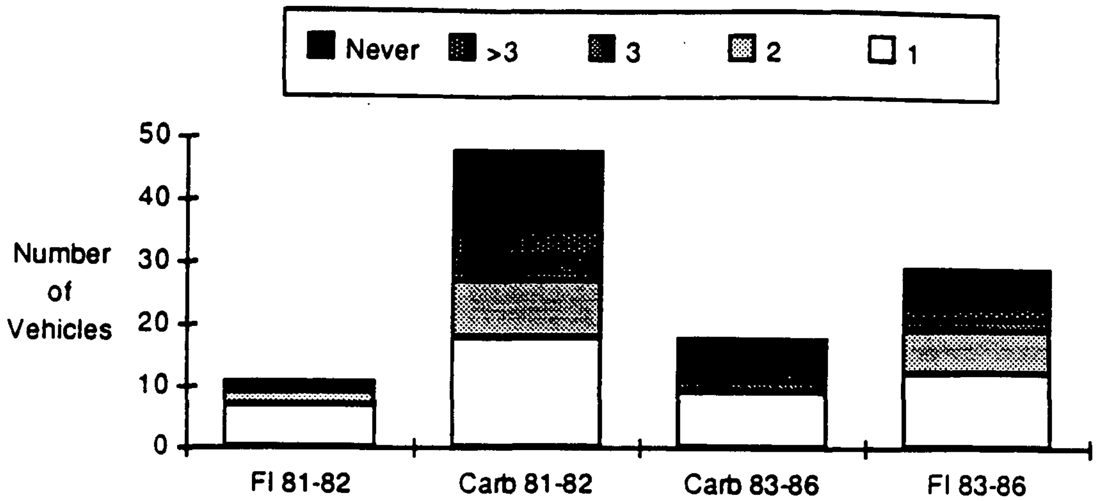
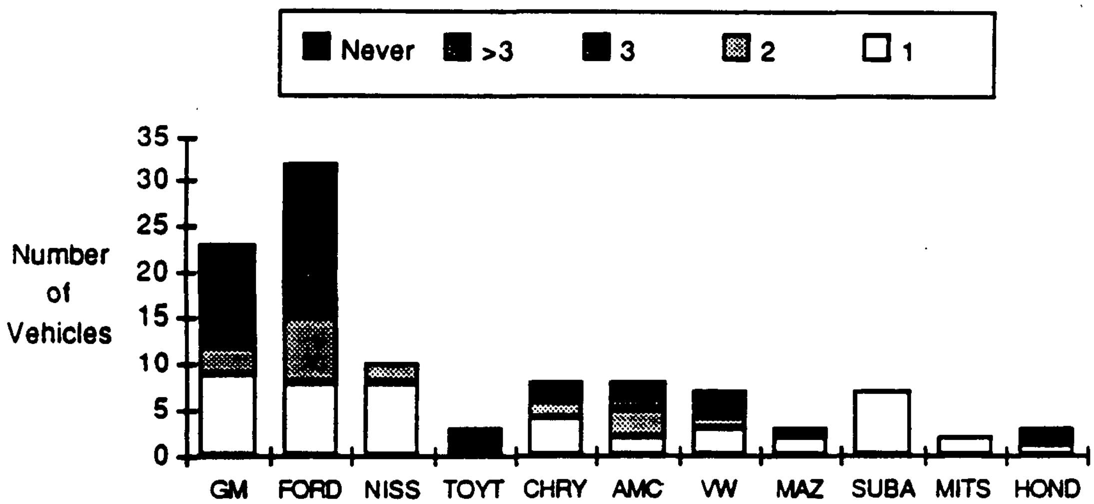


FIGURE 57

RMs Needed to Reduce LA4 Emissions by >80% -- for Vehicles with FTP HC>2.0 and/or CO>20 g/mi -- by Manufacturer



The sum of these various approaches to the question of diagnostic difficulty is that diagnosis was generally not an impediment to emission reduction. Fewer than two RMs were required, on average, to clean up an FTP- or I/M-failing vehicle to passing levels and to reduce high emission levels by 80% or more. This is despite the fact that each RM normally included only a single repair. Additionally, earlier repairs were twice as likely as later repairs to turn a high emitter into a normal emitter, and also had substantially larger average emission reductions. Of course, some vehicles were more difficult to diagnose and repair; five percent of the repaired vehicles were released as high emitters, never having achieved normal emitter status. Also, 15% of the repaired vehicles received more than four RM steps, and 4% needed more than six. However, most of these vehicles eventually had their catalysts replaced; the design of the CTP to delay these repairs until all other options had been exhausted contributed to the high number of RMs in most of these cases.

APPENDICES

APPENDIX A: FAILURE RATES IN THE MICHIGAN AET PROGRAM

The following table provides initial-test failure rates (in percent) for all valid inspections performed in the Michigan AET program in the first quarter of 1986. Data are provided by model year, and by the aggregate of the 1981 through 1986 model years. Available fields in the raw data did not permit isolating light-duty vehicle and light-duty truck failures.

Table 30: Michigan AET Failure Rates by Model Year and Manufacturer

	1981	1982	1983	1984	1985	1986	1981-86
AMC	17.8	15.3	16.4	9.9	10.8	n/a	14.7
CHRY	21.2	20.6	14.4	13.7	5.3	10.5	14.9
FORD	25.0	25.1	14.0	9.9	6.6	8.5	14.4
GM	15.9	13.1	8.3	9.0	5.4	6.1	10.3
HOND	3.8	6.0	11.3	10.3	11.6	0.0	9.0
MITS*	50.0	66.7	15.4	10.0	15.4	n/a	26.0
NISS	48.3	28.6	15.2	16.9	4.4	0.0	17.4
TOYT	10.4	5.7	8.5	5.1	4.2	n/a	7.0
VW	25.5	12.5	10.8	4.0	1.5	n/a	11.5

* Small sample size

APPENDIX B
Vehicle Identifying Information for the CTP Base Sample

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
001	SUBA	DL	CARB	81	109	LDV	102	534	1.7	1.94	71.6	0.41	7.0	33	0.0
002	AMC	JEEP	CARB	83	258	LDT	16	1335	9.5	4.84	49.0	1.70	18.0	1096	10.0
003	AMC	ALLI	TBI	85	85	LDV	32	327	6.3	1.08	21.9	0.41	3.4	527	8.6
004	SUBA	WAGO	CARB	82	109	LDV	151	839	10.0	8.32	81.3	0.41	7.0	738	10.0
005	AMC	ALLI	TBI	85	85	LDV	40	273	0.5	0.60	4.3	0.41	3.4	44	0.1
006	VW	JETT	PFI	85	109	LDV	27	88	4.7	1.47	58.2	0.41	3.4	320	10.0
007	AMC	JEEP	CARB	84	150	LDT	41	317	0.0	0.74	10.8	0.80	10.0	13	0.0
008	VW	JETT	PFI	84	105	LDV	66	268	5.7	0.73	6.3	0.41	3.4	581	0.6
009	SUBA	BRAT	TBI	83	109	LDT	38	104	2.9	1.71	55.5	1.70	18.0	272	9.7
010	SUBA	GLF	CARB	81	109	LDV	54	387	7.2	2.44	54.2	0.41	7.0	389	7.7
011	VW	GTI	TBI	85	109	LDV	27	82	1.6	0.31	2.9	0.41	3.4	1	0.0
012	AMC	JEEP	CARB	85	258	LDT	29	190	3.7	1.35	18.4	0.80	10.0	167	3.2
013	AMC	181	PFI	81	100	LDV	29	611	6.0	4.63	85.1	0.41	3.4	292	6.7
014	TOYT	TERC	CARB	85	89	LDV	23	176	1.6	0.23	1.4	0.41	3.4	6	0.0
015	AMC	ALLI	TBI	83	85	LDV	47	356	0.6	3.78	18.9	0.41	3.4	1742	3.4
016	VW	RABB	PFI	81	105	LDV	64	2000	0.5	6.87	69.3	0.41	3.4	1763	10.0
017	SUBA	SUBA	PFI	86	109	LDV	17	168	1.4	0.14	2.1	0.41	3.4	1	0.0
018	MAZD	GLC	CARB	85	91	LDV	23	71	1.5	0.28	8.9	0.41	3.4	7	0.0
019	MAZD	626	CARB	84	120	LDV	37	181	4.7	2.71	117.0	0.41	3.4	87	2.1
020	MAZD	GLC	CARB	85	91	LDV	13	63	2.4	0.10	3.1	0.41	3.4	0	0.0
021	TOYT	VAN	PFI	84	122	LDT	59	337	2.3	0.58	8.4	0.80	10.0	190	0.4
022	MAZD	GLC	CARB	83	91	LDV	49	97	2.8	0.31	7.7	0.41	3.4	1418	6.9
023	TOYT	CORO	CARB	84	97	LDV	70	382	0.0	0.66	6.0	0.41	3.4	34	0.2
024	TOYT	TERC	CARB	84	95	LDV	27	231	0.5	0.23	1.7	0.41	3.4	14	0.0
025	TOYT	STAR	PFI	83	79	LDV	54	225	0.3	0.47	6.0	0.41	3.4	99	0.1
026	SUBA	GL	CARB	81	109	LDV	60	180	1.7	2.60	57.7	0.41	7.0	328	4.7
027	TOYT	CORO	CARB	81	108	LDV	113	392	0.2	3.77	48.7	0.41	3.4	389	0.2
028	TOYT	CORO	CARB	83	97	LDV	53	978	5.1	0.68	5.1	0.41	3.4	61	0.0
029	AMC	SPIR	CARB	81	258	LDV	31	130	3.9	2.40	83.5	0.41	7.0	96	2.4

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
030	VW	RABB	PFI	82	105	LDV	44	150	1.4	0.45	5.4	0.41	3.4	130	1.2
031	AMC	EAGL	CARB	82	258	LDT	53	578	0.4	1.13	14.4	1.70	18.0	26	0.0
032	AMC	SPIR	CARB	82	151	LDV	88	232	6.2	3.50	104.3	0.41	7.0	196	4.8
033	VW	RABB	PFI	81	105	LDV	66	223	0.0	0.60	3.1	0.41	3.4	139	0.0
034	VW	RABB	PFI	84	109	LDV	69	119	4.0	1.33	15.2	0.41	3.4	231	8.6
035	MAZD	GLC	CARB	85	91	LDV	49	228	6.4	2.30	54.9	0.41	3.4	598	9.5
036	AMC	SPIR	CARB	82	151	LDV	49	237	3.9	1.35	28.8	0.41	7.0	266	3.8
037	SUBA	GL10	PFI	85	109	LDV	29	465	0.4	0.20	2.6	0.41	3.4	53	0.3
038	MAZD	323	PFI	86	98	LDV	37	236	0.1	0.43	3.0	0.41	3.4	143	0.2
039	MAZD	RX7	PFI	85	80	LDV	18	1743	0.1	0.26	1.6	0.41	3.4	2	0.0
040	VW	RABB	PFI	81	105	LDV	84	95	1.4	0.95	13.9	0.41	3.4	150	3.8
041	VW	RABB	CARB	82	105	LDV	76	1478	0.1	5.21	30.3	0.41	7.0	1131	0.2
042	AMC	18I	PFI	81	101	LDV	36	338	0.7	1.93	14.0	0.41	3.4	299	0.7
043	VW	QUAN	PFI	82	105	LDV	70	163	8.5	1.85	72.2	0.41	3.4	216	10.0
044	MAZD	GLC	CARB	83	91	LDV	92	350	1.9	1.08	13.7	0.41	3.4	53	0.1
045	VW	RABB	TBI	82	105	LDV	56	114	6.2	1.92	69.0	0.41	3.4	142	5.0
046	AMC	ALLI	TBI	83	85	LDV	72	541	0.6	7.98	37.5	0.41	3.4	2000	3.3
047	VW	RABB	CARB	83	105	LDV	93	364	0.4	2.11	25.6	0.41	3.4	520	0.9
048	AMC	18I	PFI	81	101	LDV	58	376	0.0	0.57	4.5	0.41	3.4	17	0.0
049	AMC	ENCO	TBI	85	85	LDV	47	486	6.1	0.74	10.1	0.41	3.4	518	9.8
050	VW	VANO	TBI	84	117	LDT	81	225	4.4	0.71	7.9	0.80	10.0	2	0.0
051	VW	RABB	CARB	84	105	LDV	66	423	6.2	1.98	35.2	0.41	3.4	98	1.6
052	SUBA	GL	CARB	82	109	LDV	82	294	5.2	4.24	34.1	0.41	7.0	540	8.4
053	SUBA	GL	TBI	86	109	LDV	43	179	2.1	0.16	3.6	0.41	3.4	21	0.1
054	SUBA	DL	CARB	82	109	LDV	108	0	4.5	1.97	47.8	0.41	7.0	746	10.0
055	MAZD	626	CARB	84	122	LDV	71	176	1.5	0.62	10.6	0.41	3.4	37	0.0
056	SUBA	GL10	PFI	85	109	LDV	39	141	2.2	0.27	4.9	0.41	3.4	19	0.2
057	SUBA	GL10	PFI	85	109	LDV	45	802	2.1	0.20	4.1	0.41	3.4	35	0.1
058	MAZD	RX7	PFI	84	80	LDV	84	477	2.6	3.40	40.9	0.41	3.4	201	0.8
059	MAZD	323	PFI	86	98	LDV	16	1047	0.6	0.28	4.0	0.41	3.4	111	0.2
060	MAZD	626	CARB	83	122	LDV	55	417	5.4	1.05	14.5	0.41	3.4	23	0.0
101	CHRY	FIFT	CARB	83	318	LDV	69	244	3.6	1.31	14.5	0.41	3.4	55	0.8
102	CHRY	ARIE	CARB	81	135	LDV	79	228	3.5	1.42	33.1	0.41	7.0	20	0.0

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
103	CHRY	CHAR	CARB	85	135	LDV	29	292	3.8	1.49	31.8	0.41	3.4	231	4.0
104	CHRY	OMNI	CARB	84	135	LDV	44	391	2.6	1.14	6.3	0.41	3.4	#N/A	#N/A
105	CHRY	CARA	TBI	85	135	LDV	29	150	1.5	3.63	63.7	0.41	3.4	406	7.1
107	CHRY	RELI	CARB	81	135	LDV	64	267	6.3	1.19	8.1	0.41	7.0	26	0.2
109	CHRY	DAYT	PFI	84	135	LDV	41	152	1.3	1.17	14.0	0.41	3.4	136	1.0
110	CHRY	LEBA	PFI	86	135	LDV	41	364	0.7	0.51	4.8	0.41	3.4	48	0.0
111	CHRY	600	TBI	84	135	LDV	54	537	6.8	3.00	37.5	0.41	3.4	2024	7.1
112	CHRY	RELI	TBI	85	135	LDV	32	175	2.8	2.10	61.4	0.41	3.4	34	0.4
113	CHRY	LANC	PFI	85	135	LDV	41	242	2.2	0.51	5.3	0.41	3.4	20	0.0
114	CHRY	LEBA	PFI	86	135	LDV	36	306	0.3	0.65	7.1	0.41	3.4	165	0.2
115	CHRY	NEWY	PFI	85	135	LDV	40	872	10.0	8.73	86.3	0.41	3.4	502	7.1
116	CHRY	ARIE	CARB	81	135	LDV	34	100	3.6	1.19	35.4	0.41	7.0	44	0.6
117	CHRY	RELI	CARB	81	135	LDV	49	334	7.8	2.81	51.3	0.41	7.0	345	6.8
201	FORD	LINC	CARB	82	302	LDV	59	881	1.9	9.33	65.2	0.41	7.0	165	2.0
202	FORD	TOWN	TBI	82	302	LDV	66	975	10.0	19.07	62.6	0.41	7.0	910	8.3
203	FORD	LINC	TBI	83	302	LDV	68	575	1.5	3.31	24.9	0.41	3.4	75	0.1
204	FORD	CAPR	CARB	81	140	LDV	75	321	2.3	1.04	7.5	0.41	3.4	109	0.0
205	FORD	MUST	CARB	81	140	LDV	150	187	3.7	3.57	66.5	0.41	3.4	461	7.8
206	FORD	F150	CARB	86	300	LDT	16	250	0.0	0.62	0.9	0.80	10.0	60	0.0
207	FORD	RANG	TBI	85	140	LDT	61	600	0.7	1.79	10.5	0.80	10.0	380	0.0
208	FORD	TEMP	CARB	84	140	LDV	53	244	0.2	3.02	47.3	0.41	3.4	279	0.0
209	FORD	MARQ	CARB	81	302	LDV	67	230	5.2	1.04	23.6	0.41	3.4	38	0.0
210	FORD	TEMP	TBI	85	140	LDV	33	518	5.9	2.68	56.3	0.41	3.4	43	0.0
211	FORD	TOPA	CARB	84	140	LDV	68	1382	10.0	6.17	58.7	0.41	3.4	300	2.6
212	FORD	RANG	TBI	85	140	LDT	49	744	0.6	1.18	5.9	0.80	10.0	500	0.0
213	FORD	TOPA	TBI	86	140	LDV	13	292	4.5	0.65	17.0	0.41	3.4	58	0.0
214	FORD	TEMP	TBI	86	140	LDV	15	105	1.8	0.80	23.7	0.41	3.4	43	0.0
216	FORD	TEMP	TBI	85	140	LDV	58	1333	8.1	2.15	30.1	0.41	3.4	1205	7.7
217	FORD	MARQ	CARB	82	302	LDV	92	147	1.7	1.81	34.9	0.41	7.0	211	4.9
218	FORD	LTD	CARB	81	302	LDV	70	640	0.8	2.53	39.3	0.41	3.4	25	0.0
219	FORD	MUST	CARB	81	140	LDV	68	422	3.6	4.90	64.9	0.41	3.4	557	3.4
220	FORD	ZEPH	CARB	81	140	LDV	117	183	3.2	1.66	28.3	0.41	3.4	155	0.7
221	FORD	RANG	CARB	84	140	LDT	44	124	1.4	0.54	4.1	0.80	10.0	40	0.0

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
222	FORD	LTD	CARB	81	255	LDV	80	293	5.2	3.03	42.9	0.41	3.4	72	0.1
223	FORD	MARQ	CARB	82	302	LDV	46	161	1.3	0.33	1.8	0.41	7.0	71	0.0
224	FORD	MARQ	TBI	86	302	LDV	28	449	0.1	0.39	2.0	0.41	3.4	40	0.0
225	FORD	MUST	CARB	81	140	LDV	93	327	2.3	2.14	23.4	0.41	3.4	588	0.3
226	FORD	MARQ	CARB	82	302	LDV	54	153	1.9	1.82	27.1	0.41	7.0	63	0.0
227	FORD	MUST	CARB	81	140	LDV	59	132	1.5	3.71	63.9	0.41	3.4	144	1.2
228	FORD	SABL	PFI	86	183	LDV	47	459	5.2	0.25	4.2	0.41	3.4	176	0.0
229	FORD	TOPA	TBI	86	140	LDV	5	144	3.0	0.36	10.2	0.41	3.4	27	0.1
230	FORD	LTD	CARB	81	302	LDV	41	1400	8.5	1.51	27.4	0.41	3.4	28	0.0
231	FORD	TOPA	CARB	84	140	LDV	55	1020	0.5	1.54	42.9	0.41	3.4	87	0.0
232	FORD	TEMP	TBI	85	140	LDV	25	312	3.5	0.47	10.8	0.41	3.4	26	0.0
233	FORD	MARQ	CARB	82	302	LDV	88	596	7.9	5.19	65.6	0.41	7.0	452	6.2
234	FORD	TEMP	TBI	85	140	LDV	58	326	3.9	3.84	17.5	0.41	3.4	409	0.1
235	FORD	TEMP	TBI	85	140	LDV	21	946	10.0	0.82	17.3	0.41	3.4	926	6.6
236	FORD	LTD	CARB	82	302	LDV	33	268	3.9	1.98	30.4	0.41	7.0	29	0.0
237	FORD	TEMP	TBI	85	140	LDV	43	485	0.8	0.60	17.3	0.41	3.4	14	0.0
238	FORD	TEMP	TBI	86	140	LDV	16	313	3.6	6.75	63.2	0.41	3.4	147	0.1
239	FORD	F150	CARB	86	300	LDT	36	58	2.2	2.30	63.4	0.80	10.0	50	1.1
240	FORD	RANG	TBI	86	177	LDT	27	309	0.7	0.91	7.1	0.80	10.0	974	7.8
241	FORD	TEMP	TBI	85	140	LDV	21	411	3.7	0.29	6.7	0.41	3.4	34	0.2
242	FORD	COUN	CARB	81	302	LDV	73	117	3.0	0.57	9.5	0.41	3.4	0	0.0
243	FORD	TEMP	TBI	85	140	LDV	45	938	4.2	3.49	24.0	0.41	3.4	965	5.1
244	FORD	MUST	CARB	81	140	LDV	76	312	5.6	1.83	36.2	0.41	3.4	436	5.5
245	FORD	TAUR	TBI	86	150	LDV	17	373	4.6	0.73	17.1	0.41	3.4	51	0.0
246	FORD	TEMP	TBI	85	140	LDV	42	644	5.1	3.23	65.9	0.41	3.4	164	0.8
247	FORD	MUST	CARB	81	140	LDV	70	306	0.0	1.33	23.8	0.41	3.4	31	0.0
248	FORD	TEMP	TBI	85	140	LDV	25	262	0.5	0.61	14.7	0.41	3.4	62	0.0
249	FORD	F250	CARB	82	351	LDT	45	1126	0.0	0.88	5.1	1.70	18.0	147	0.0
250	FORD	RANG	CARB	83	122	LDT	70	214	3.5	1.44	11.8	1.70	18.0	64	0.0
251	FORD	SABL	TBI	86	183	LDV	14	126	1.3	0.16	2.2	0.41	3.4	21	0.0
252	FORD	EXP	TBI	84	98	LDV	46	164	1.6	1.07	18.0	0.41	3.4	122	0.0
253	FORD	TEMP	TBI	86	140	LDV	10	651	8.8	3.60	65.2	0.41	3.4	826	8.7
254	FORD	MUST	CARB	81	140	LDV	65	102	2.8	0.38	8.2	0.41	3.4	84	0.0

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
257	FORD	MUST	CARB	81	140	LDV	78	366	5.4	3.30	49.2	0.41	3.4	450	5.7
258	FORD	MUST	CARB	81	140	LDV	94	263	0.0	0.57	4.6	0.41	3.4	61	0.0
259	FORD	CAPR	CARB	81	140	LDV	83	233	0.1	2.20	41.4	0.41	3.4	49	0.0
260	FORD	RANG	CARB	84	122	LDT	35	146	2.6	0.73	8.0	0.80	10.0	80	0.0
301	GM	RIVI	CARB	85	307	LDV	10	570	4.4	0.70	2.1	0.41	3.4	11	0.0
302	GM	REGA	CARB	82	231	LDV	98	298	0.4	4.06	32.3	0.41	7.0	254	2.3
304	GM	MALI	CARB	82	229	LDV	83	263	0.4	2.61	15.9	0.41	7.0	200	0.4
305	GM	BONN	CARB	82	231	LDV	65	341	0.3	3.97	22.5	0.41	7.0	754	0.3
306	GM	CELE	TBI	86	151	LDV	5	225	0.4	0.21	1.8	0.41	3.4	14	0.1
307	GM	MALI	CARB	81	229	LDV	102	399	1.2	0.56	5.7	0.41	7.0	19	0.0
308	GM	RIVI	CARB	81	250	LDV	68	805	10.0	0.84	8.4	0.41	3.4	151	0.6
309	GM	CIER	TBI	84	151	LDV	61	500	0.5	0.25	3.3	0.41	3.4	84	0.2
310	GM	PHOE	CARB	81	151	LDV	64	184	1.8	1.37	20.9	0.41	3.4	219	6.5
311	GM	MALI	CARB	81	229	LDV	43	502	0.6	0.59	9.8	0.41	7.0	338	0.3
312	GM	SKYH	TBI	83	110	LDV	58	357	0.5	0.93	6.5	0.41	3.4	87	0.0
313	GM	FIER	TBI	84	151	LDV	49	265	0.3	1.29	37.3	0.41	3.4	45	0.1
314	GM	SEVI	TBI	81	368	LDV	54	1167	1.4	3.72	35.3	0.41	7.0	1125	1.5
315	GM	CORV	TBI	82	350	LDV	49	306	4.4	3.11	42.0	0.41	7.0	261	1.4
316	GM	CUTL	CARB	81	231	LDV	57	602	3.2	1.59	20.9	0.41	7.0	57	0.2
317	GM	FIER	TBI	84	151	LDV	44	227	1.7	0.55	3.8	0.41	3.4	29	0.1
318	GM	FIRE	TBI	85	110	LDV	27	167	2.5	7.65	129.2	0.41	3.4	643	10.2
319	GM	CENT	CARB	81	231	LDV	62	1639	0.2	4.13	29.4	0.41	7.0	870	0.2
320	GM	CELE	CARB	83	173	LDV	116	309	1.7	1.82	7.3	0.41	3.4	102	0.0
321	GM	DEVI	TBI	82	250	LDV	60	264	0.0	0.33	5.2	0.41	7.0	18	0.0
322	GM	CAVA	TBI	86	121	LDV	18	239	0.9	0.16	1.8	0.41	3.4	9	0.0
323	GM	RIVI	CARB	81	250	LDV	72	249	0.9	1.52	23.4	0.41	3.4	556	7.2
324	GM	REGA	CARB	82	231	LDV	113	2000	0.3	4.83	28.2	0.41	7.0	1885	2.1
325	GM	CIER	TBI	84	151	LDV	35	244	0.6	0.85	6.4	0.41	3.4	121	0.3
326	GM	CITA	CARB	81	151	LDV	140	157	1.6	3.40	34.8	0.41	3.4	507	9.1
327	GM	BONN	CARB	82	231	LDV	55	172	1.5	2.32	15.7	0.41	7.0	19	0.0
328	GM	2000	TBI	83	110	LDV	59	367	0.2	0.97	7.4	0.41	3.4	173	0.3
329	GM	GRAN	CARB	84	305	LDV	37	252	0.4	2.01	15.1	0.41	3.4	196	0.5
330	GM	CIER	TBI	84	151	LDV	60	325	0.3	0.24	2.9	0.41	3.4	41	0.1

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
331	GM	MONT	CARB	83	229	LDV	46	1261	6.1	6.42	93.2	0.41	3.4	774	10.4
332	GM	OMEG	CARB	81	151	LDV	44	209	1.5	0.51	14.3	0.41	3.4	20	0.0
333	GM	CELE	CARB	82	173	LDV	82	248	4.2	0.70	10.6	0.41	7.0	379	6.5
334	GM	REGA	CARB	81	231	LDV	50	304	0.4	1.34	14.3	0.41	7.0	155	0.2
335	GM	CIMA	CARB	82	112	LDV	78	174	5.8	1.56	16.9	0.41	7.0	405	9.6
336	GM	GRAN	CARB	81	231	LDV	86	557	7.6	5.92	93.2	0.41	7.0	1927	8.6
337	GM	CITA	CARB	81	173	LDV	72	904	0.2	0.64	5.0	0.41	7.0	34	0.0
338	GM	OMEG	TBI	82	151	LDV	53	517	0.2	0.28	2.7	0.41	7.0	179	0.2
339	GM	REGA	CARB	83	231	LDV	84	134	1.5	0.98	5.7	0.41	3.4	181	1.1
340	GM	SKYL	CARB	81	173	LDV	55	68	1.2	0.25	8.0	0.41	7.0	26	0.1
341	GM	CITA	CARB	81	151	LDV	84	193	4.9	2.12	72.2	0.41	3.4	230	5.6
342	GM	DEVI	TBI	81	368	LDV	29	331	0.2	0.57	9.6	0.41	7.0	22	0.0
343	GM	CENT	TBI	86	151	LDV	37	452	0.5	1.10	5.2	0.41	3.4	287	0.3
345	GM	RIVI	CARB	81	307	LDV	61	393	2.5	4.94	68.9	0.41	3.4	214	0.4
346	GM	J200	CARB	82	112	LDV	91	192	4.2	1.81	28.6	0.41	7.0	274	5.7
347	GM	CITA	TBI	84	151	LDV	25	331	0.7	0.21	2.6	0.41	3.4	205	0.3
348	GM	GRAN	TBI	86	151	LDV	17	223	0.1	0.40	1.2	0.41	3.4	123	0.1
349	GM	SUNB	TBI	86	110	LDV	27	240	0.3	0.28	3.9	0.41	3.4	39	0.1
350	GM	SUNB	TBI	84	110	LDV	47	237	0.1	0.38	8.4	0.41	3.4	153	0.6
351	GM	DEVI	TBI	83	249	LDV	54	277	0.4	0.45	7.0	0.41	3.4	192	0.2
352	GM	CELE	TBI	85	151	LDV	52	284	0.6	0.34	4.3	0.41	3.4	13	0.0
353	GM	CITA	PFI	85	173	LDV	23	687	0.3	0.64	6.1	0.41	3.4	10	0.1
354	GM	CAVA	TBI	84	121	LDV	51	177	2.6	7.64	136.5	0.41	3.4	260	6.1
355	GM	SKYH	TBI	84	110	LDV	66	218	2.2	2.96	55.0	0.41	3.4	435	9.1
356	GM	CAVA	TBI	85	121	LDV	42	395	3.5	0.43	7.6	0.41	3.4	133	0.6
357	GM	GRAN	TBI	86	151	LDV	37	548	0.7	0.35	3.3	0.41	3.4	36	0.1
358	GM	CAVA	TBI	84	121	LDV	8	315	1.2	6.09	38.4	0.41	3.4	236	1.5
359	GM	DEVI	TBI	83	249	LDV	92	520	0.1	1.44	5.8	0.41	3.4	53	0.0
360	GM	CIER	TBI	82	151	LDV	56	1062	1.0	0.29	4.2	0.41	7.0	33	0.2
401	HOND	CIVI	PFI	86	91	LDV	41	259	1.4	0.35	3.5	0.41	3.4	44	0.1
402	HOND	CIVI	PFI	85	91	LDV	58	327	0.7	0.93	8.6	0.41	3.4	371	4.3
403	HOND	CIVI	CARB	84	91	LDV	53	227	0.0	1.46	4.5	0.41	3.4	160	0.1
404	HOND	CIVI	CARB	84	91	LDV	71	383	0.0	1.19	6.5	0.41	3.4	172	0.1

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
405	HOND	CIVI	CARB	84	91	LDV	85	798	0.1	2.14	4.7	0.41	3.4	123	0.2
406	HOND	CIVI	CARB	84	91	LDV	77	565	0.0	2.05	7.4	0.41	3.4	500	0.1
407	HOND	CIVI	CARB	85	91	LDV	13	248	0.1	1.73	4.8	0.41	3.4	348	0.2
408	HOND	CIVI	PFI	86	91	LDV	35	396	3.0	0.43	4.0	0.41	3.4	48	0.1
409	HOND	ACCO	CARB	85	112	LDV	22	244	1.8	1.75	34.0	0.41	3.4	291	1.8
410	HOND	CIVI	PFI	85	91	LDV	53	224	0.6	0.68	6.8	0.41	3.4	65	0.1
502	MITS	COLT	CARB	84	86	LDV	65	1061	0.1	1.00	8.2	0.41	3.4	250	0.7
503	MITS	RAM	CARB	85	122	LDT	50	493	7.8	4.77	53.3	0.80	10.0	593	7.6
504	MITS	COLT	CARB	85	90	LDV	34	24	2.3	0.21	9.3	0.41	3.4	35	1.9
505	MITS	COLT	CARB	84	98	LDV	59	746	0.3	1.18	6.6	0.41	3.4	114	0.1
506	MITS	RAM	CARB	85	122	LDT	28	227	2.7	4.44	54.2	0.80	10.0	600	8.0
507	MITS	COLT	TBI	85	98	LDV	21	2000	4.9	0.22	4.8	0.41	3.4	0	0.0
508	MITS	COLT	TBI	84	98	LDV	58	108	1.7	0.39	6.3	0.41	3.4	28	0.1
509	MITS	COLT	TBI	85	97	LDV	26	307	6.7	0.24	1.4	0.41	3.4	2	0.1
510	MITS	COLT	TBI	86	98	LDV	39	203	1.5	0.23	4.3	0.41	3.4	42	0.2
511	MITS	COLT	TBI	86	98	LDV	16	127	2.1	0.20	3.0	0.41	3.4	0	0.0
601	NISS	STAN	PFI	86	120	LDV	33	269	7.0	1.15	45.8	0.41	3.4	276	2.9
602	NISS	200S	PFI	82	134	LDV	95	194	1.8	2.61	91.5	0.41	3.4	1013	8.0
603	NISS	PULS	CARB	85	98	LDV	50	279	0.4	2.20	48.7	0.41	3.4	904	1.7
604	NISS	SENT	CARB	84	98	LDV	35	228	0.1	0.36	4.8	0.41	3.4	65	0.0
605	NISS	MAXI	PFI	82	146	LDV	91	357	2.8	4.52	142.2	0.41	3.4	167	3.3
606	NISS	MAXI	PFI	83	146	LDV	69	132	2.5	0.66	9.1	0.41	3.4	130	2.5
607	NISS	200S	PFI	81	119	LDV	119	122	2.1	1.20	16.9	0.41	7.0	35	0.2
608	NISS	200S	PFI	81	119	LDV	90	469	0.4	1.60	6.8	0.41	3.4	433	0.4
609	NISS	280Z	PFI	82	171	LDV	73	299	0.7	0.74	12.1	0.41	3.4	19	0.1
610	NISS	300Z	PFI	84	181	LDV	42	184	1.7	0.57	4.3	0.41	3.4	0	0.0
611	NISS	300Z	PFI	84	181	LDV	24	237	1.7	0.46	5.3	0.41	3.4	0	0.0
612	NISS	280Z	PFI	81	171	LDV	57	268	4.4	5.02	125.1	0.41	3.4	332	6.0
613	NISS	TRUC	TBI	86	146	LDT	28	61	2.3	0.61	98.9	0.80	10.0	60	3.8
614	NISS	PULS	PFI	83	91	LDV	55	1527	9.5	5.09	43.7	0.41	3.4	561	5.8
615	NISS	280Z	PFI	82	168	LDV	102	152	1.7	1.69	54.2	0.41	3.4	181	2.3
616	NISS	SENT	CARB	84	98	LDV	48	239	0.2	0.16	3.6	0.41	3.4	50	0.1
617	NISS	280Z	PFI	83	168	LDV	74	138	1.8	0.86	11.7	0.41	3.4	226	4.3

Veh	Mfr	Model	F/M	MY	CID	Type	KMile	AETHC	AETCO	FTPHC	FTPCO	HCstd	COstd	XL05HC	XL05CO
618	NISS	PULS	PFI	83	91	LDV	59	446	6.9	1.88	44.4	0.41	3.4	547	5.6
619	NISS	MAXI	PFI	83	146	LDV	61	281	0.3	0.68	7.0	0.41	3.4	17	0.0
620	NISS	200S	PFI	84	120	LDV	28	293	7.4	2.01	72.3	0.41	3.4	250	6.0
701	TOYT	TERC	CARB	86	91	LDV	5	262	0.1	0.24	1.9	0.41	3.4	7	0.0
702	TOYT	TERC	CARB	84	91	LDV	77	339	1.2	1.14	3.8	0.41	3.4	45	0.0
703	TOYT	CORO	CARB	81	108	LDV	96	167	1.9	2.12	47.2	0.41	3.4	128	0.8
704	TOYT	CELI	PFI	86	122	LDV	32	335	0.4	0.26	1.7	0.41	3.4	0	0.0
705	TOYT	CELI	PFI	83	144	LDV	59	293	0.2	0.44	3.0	0.41	3.4	141	0.1
706	TOYT	CORO	CARB	82	108	LDV	234	445	0.1	2.26	49.2	0.41	3.4	109	1.1
707	TOYT	CORO	CARB	82	108	LDV	147	1473	0.2	0.51	8.9	0.41	3.4	1	0.0
708	TOYT	CAMR	PFI	84	122	LDV	32	344	0.2	0.16	1.9	0.41	3.4	0	0.0
709	TOYT	CELI	CARB	83	144	LDV	49	2000	0.8	0.19	3.5	0.41	3.4	0	0.0

Appendix C
As Received Failure Rates for Selected Modes of the Basic I/M Test Procedure

VEHICLE COUNT				
BITP	Failure Type			
Mode	HC-only	HC+CO	CO-only	Pass
CS 03	49	131	29	27
CS 05	39	68	31	98
CS 07	19	68	26	124
CS 10	20	61	25	131
CS 12	33	74	24	106
CS 15	35	65	20	117
XL 02	19	64	21	134
XL 05	18	63	16	141
XI 02	39	78	23	97
XI 05	41	59	22	115
XI 07	22	63	27	125
XI 10	20	58	23	136
RS 02	16	64	18	134
RS 05	21	64	19	128

VEHICLE PERCENT				
BITP	Failure Type			
Mode	HC-only	HC+CO	CO-only	Pass
CS 03	21%	56%	12%	11%
CS 05	17%	29%	13%	42%
CS 07	8%	29%	11%	52%
CS 10	8%	26%	11%	55%
CS 12	14%	31%	10%	45%
CS 15	15%	27%	8%	49%
XL 02	8%	27%	9%	56%
XL 05	8%	26%	7%	59%
XI 02	16%	33%	10%	41%
XI 05	17%	25%	9%	49%
XI 07	9%	27%	11%	53%
XI 10	8%	24%	10%	57%
RS 02	7%	28%	8%	58%
RS 05	9%	28%	8%	55%

APPENDIX C

Emission Values for Calculating As Received Failure Rates for Selected Modes of the Basic I/M Test Procedure

HC values in ppm; failure >=220 ppm
CO values in % concentration; failure >=1.2%

	CS 03		CS 05		CS 07		CS 10		CS 12		CS 15		XL 02		XL 05		XI 02		XI 05		XI 07		XI 11		RS 02		RS 05	
Veh	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
001	247	6.4	163	6.7	15	0.0	20	0.0	53	0.0	63	0.0	21	0.0	33	0.0	118	0.1	56	0.0	23	0.0	28	0.0	51	0.1	100	0.2
002	2000	8.4	848	6.3	1255	10.0	1202	10.0	1537	10.0	1414	10.0	1203	10.0	1096	10.0	1686	10.0	1343	10.0	1293	10.0	1564	10.0	1363	10.0	1383	4.0
003	715	7.4	565	8.8	356	5.8	471	5.8	439	6.4	429	6.2	453	8.5	527	8.6	472	7.6	813	6.9	487	8.0	509	8.3	431	9.3	446	9.3
004	282	8.2	615	10.0	565	10.0	584	10.0	727	10.0	727	10.0	700	10.0	738	10.0	847	10.0	701	10.0	695	10.0	718	10.0	1015	10.0	1051	10.0
005	1386	6.7	729	5.2	143	0.1	86	0.1	159	0.1	163	0.1	8	0.0	44	0.1	203	1.2	169	0.2	58	0.0	71	0.1	14	0.0	13	0.0
006	323	5.8	142	2.0	197	7.4	200	7.5	234	8.4	246	8.5	386	10.0	320	10.0	632	10.0	710	10.0	277	9.5	435	10.0	581	10.0	428	10.0
007	278	5.2	182	4.4	9	0.0	8	0.0	4	0.0	8	0.0	15	0.0	13	0.0	1	0.0	11	0.0	6	0.0	8	0.0	3	0.0	5	0.0
008	829	6.6	148	0.3	29	0.5	26	0.1	26	0.1	24	0.0	319	0.5	581	0.6	776	0.3	326	0.6	68	0.0	58	0.1	432	2.0	722	0.4
009	326	5.4	143	3.5	127	3.4	130	3.5	131	3.1	122	2.8	277	9.7	272	9.7	110	3.1	104	2.7	106	3.1	108	3.1	109	3.1	99	2.9
010	299	4.3	211	3.9	545	8.0	517	7.9	471	7.5	470	7.6	402	7.6	389	7.7	389	6.8	349	6.2	275	5.3	290	5.3	271	5.6	267	5.6
011	498	5.3	133	0.4	9	0.0	8	0.0	7	0.0	8	0.0	3	0.0	1	0.0	214	4.9	164	3.4	11	0.0	11	0.0	0	0.0	2	0.0
012	571	0.3	65	0.0	169	3.2	9	0.3	96	1.6	251	5.4	177	2.6	167	3.2	141	1.5	169	1.9	110	1.5	195	2.6	1	0.0	126	0.6
013	936	10.0	356	4.8	242	2.6	231	2.3	192	1.1	222	1.4	239	6.9	292	6.7	152	1.2	184	0.8	282	6.0	265	6.0	254	6.6	273	6.2
014	200	1.3	135	1.2	59	0.1	47	0.0	41	0.0	33	0.0	8	0.0	6	0.0	30	0.0	146	0.2	135	0.6	69	0.2	35	0.0	54	0.0
015	533	1.0	288	2.6	2058	3.2	1955	3.2	2005	3.7	2002	3.5	1602	3.3	1742	3.4	2000	5.6	1821	3.8	1819	3.7	1753	3.5	1690	3.6	1744	3.5
016	2000	9.3	625	10.0	1259	10.0	1014	10.0	2000	10.0	2000	10.0	2000	10.0	1763	10.0	1100	10.0	1219	10.0	1164	10.0	1274	10.0	1794	10.0	2000	10.0
017	818	7.6	377	8.7	151	0.1	54	0.1	13	0.0	12	0.0	1	0.0	1	0.0	351	6.9	57	0.0	4	0.0	3	0.0	6	0.0	6	0.0
018	963	10.3	182	0.1	6	0.1	4	0.1	0	0.1	1	0.1	5	0.0	7	0.0	9	0.0	8	0.0	2	0.0	3	0.0	4	0.0	2	0.0
019	503	8.0	480	8.7	140	2.6	136	2.6	116	1.0	112	1.4	99	1.6	87	2.1	88	0.5	49	0.9	55	1.8	67	2.1	89	1.5	82	2.0
020	647	9.2	44	0.0	4	0.0	5	0.0	3	0.0	2	0.0	1	0.0	0	0.0	1	0.0	15	0.0	6	0.0	5	0.0	1	0.0	0	0.0
021	462	1.6	214	0.3	49	0.0	74	0.1	438	6.3	290	0.3	226	0.7	190	0.4	353	5.5	386	5.7	204	0.9	193	0.6	185	0.6	192	0.5
022	530	10.0	56	0.1	13	0.0	16	0.0	309	5.4	92	3.7	1019	5.4	1418	6.9	889	6.1	197	5.5	808	6.2	894	6.2	663	6.6	444	6.7
023	242	2.1	214	1.8	142	0.7	118	0.5	162	0.9	193	1.1	38	0.2	34	0.2	127	0.8	176	1.1	105	0.4	73	0.3	27	0.1	64	0.2
024	256	1.3	207	0.3	72	0.0	56	0.0	57	0.0	80	0.0	22	0.0	14	0.0	264	0.7	330	1.2	99	0.1	53	0.3	6	0.0	33	0.0
025	1038	5.0	519	2.8	150	0.1	187	0.1	261	0.0	213	0.0	157	0.1	99	0.1	266	0.2	217	0.1	169	0.1	142	0.1	133	0.1	100	0.0
026	202	3.9	180	3.1	261	3.1	238	4.0	301	4.7	301	4.4	247	5.5	328	4.7	329	3.7	260	4.5	285	5.0	246	5.8	280	3.3	322	5.2
027	616	1.8	301	2.3	218	0.2	274	0.2	323	0.2	363	0.2	357	0.2	389	0.2	335	0.2	407	0.2	325	0.2	311	0.2	443	0.2	393	0.2
028	277	1.0	436	2.8	370	3.0	326	2.4	298	2.2	303	2.3	56	0.1	61	0.0	43	0.0	52	0.0	77	0.2	58	0.0	38	0.0	37	0.0
029	518	2.6	307	4.4	139	4.4	133	4.0	135	3.3	127	3.6	99	2.4	96	2.4	105	3.0	104	3.1	99	3.4	102	3.1	103	3.2	100	3.2
030	441	9.7	112	0.4	118	0.5	148	0.9	162	1.1	160	1.2	98	0.8	130	1.2	165	2.3	137	2.1	140	1.2	131	1.1	131	2.7	153	2.4
031	343	5.6	133	0.7	16	0.0	18	0.2	340	3.6	290	1.1	20	0.0	26	0.0	775	1.8	477	0.4	27	0.0	24	0.0	137	0.3	15	0.0
032	1902	10.0	698	9.3	293	8.0	309	8.0	251	5.8	247	6.3	196	4.8	196	4.8	203	4.2	211	4.4	211	5.2	225	5.1	228	5.1	220	5.4
033	700	2.7	633	0.4	131	0.0	137	0.0	70	0.0	145	0.0	138	0.0	139	0.0	63	0.0	168	0.0	201	0.0	200	0.0	112	0.0	208	0.0
034	532	10.0	104	0.6	118	3.2	116	3.5	142	3.9	132	3.9	230	8.4	231	8.6	174	7.2	167	7.0	140	6.2	152	6.5	733	9.6	660	10.0
035	396	5.5	264	2.3	1024	10.0	748	9.4	1270	10.0	806	10.0	669	10.0	598	9.5	525	9.3	169	2.4	594	9.2	614	10.4	653	10.2	643	10.0
036	414	4.0	370	3.0	229	3.5	222	3.5	196	2.3	191	2.8	242	4.0	266	3.8	281	3.7	267	4.0	250	3.3	258	3.5	216	3.6	246	3.5
037	1956	2.2	69	0.1	39	0.2	50	0.2	62	0.1	204	0.3	105	0.3	53	0.3	182	0.2	164	0.3	61	0.2	57	0.2	57	0.3	3	0.0
038	718	1.4	280	0.9	96	0.0	81	0.0	36	0.0	102	0.1	190	0.2	143	0.2	1	0.0	325	0.2	192	0.1	282	0.2	110	0.2	165	0.2
039	192	0.6	31	0.0	10	0.0	11	0.0	11	0.0	11	0.0	3	0.0	2	0.0	4	0.0	6	0.0	5	0.0	5	0.0	3	0.0	3	0.0
040	479	2.7	209	1.7	150	1.6	148	1.8	142	2.1	144	2.0	129	3.6	150	3.8	156	3.5	151	3.5	163	3.8	164	4.0	241	9.4	246	9.1
041	903	0.2	859	0.2	2000	0.0	1539	0.2	752	0.3	844	0.2	1079	0.2	1131	0.2	1304	0.2	1090	0.2	1224	0.2	1136	0.2	1338	0.2	1123	0.2
042	464	4.3	227	0.8	351	0.8	280	0.8	133	0.7	172	0.7	182	0.6	299	0.7	165	0.7	162	0.6	203	0.7	166	0.7	169	0.7	245	0.7

Veh	CS 03		CS 05		CS 07		CS 10		CS 12		CS 15		XL 02		XL 05		XI 02		XI 05		XI 07		XI 11		RS 02		RS 05	
	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
043	554	10.0	291	8.0	274	9.7	274	9.9	248	10.0	248	10.0	209	9.9	216	10.0	202	10.0	199	9.6	204	9.4	211	9.5	181	10.0	189	9.4
044	2000	6.6	1752	0.0	62	0.0	54	0.0	67	0.0	41	0.0	60	0.3	53	0.1	109	0.1	52	0.0	64	0.0	57	0.1	41	0.0	29	0.0
045	517	10.0	202	3.8	140	4.0	147	4.2	140	4.7	154	4.8	136	5.5	142	5.0	136	6.0	131	4.9	120	4.6	127	3.9	135	6.1	134	4.6
046	2000	4.7	2000	4.8	2000	2.8	2000	2.9	2000	2.7	2000	2.9	1884	3.7	2000	3.3	2000	2.7	2000	3.0	2000	3.6	2000	2.9	1875	4.8	2000	4.6
047	379	1.2	455	1.2	430	1.3	376	1.1	823	0.3	798	0.3	491	1.0	520	0.9	756	0.8	526	1.0	276	1.4	362	1.4	486	1.3	359	1.4
048	444	1.7	152	0.1	0	0.0	0	0.0	0	0.0	0	0.0	14	0.0	17	0.0	26	0.0	31	0.0	12	0.0	11	0.0	3	0.0	9	0.0
049	1121	9.9	873	8.3	353	4.2	319	3.0	305	2.7	293	2.5	497	9.8	518	9.8	369	7.0	327	4.7	270	4.9	285	5.0	1146	10.0	1170	10.0
050	332	7.8	187	4.9	114	0.2	99	0.1	43	0.0	22	0.0	3	0.0	2	0.0	14	0.0	16	0.0	12	0.0	12	0.0	13	0.0	14	0.0
051	709	5.8	650	5.7	379	4.2	192	1.7	117	0.9	144	1.1	89	1.9	98	1.6	98	0.9	114	1.2	98	1.0	87	0.9	#N/A	#N/A	#N/A	#N/A
052	2000	6.8	197	3.2	412	6.2	296	6.2	239	4.1	314	6.5	505	7.9	540	8.4	233	5.1	338	7.1	315	6.9	303	6.9	351	7.1	335	7.1
053	273	0.4	118	0.3	132	0.2	65	0.2	22	0.0	102	0.1	32	0.1	21	0.1	381	3.6	273	1.0	87	0.2	77	0.2	577	8.3	487	7.1
054	167	3.8	99	2.1	298	7.8	273	7.4	301	7.6	324	8.0	693	10.0	746	10.0	390	8.8	387	8.8	404	9.1	396	8.8	333	6.3	298	5.6
055	543	8.8	246	2.4	59	0.1	60	0.0	55	0.1	57	0.0	36	0.0	37	0.0	47	0.1	44	0.0	44	0.1	42	0.0	22	0.0	22	0.0
056	419	2.6	58	0.1	13	0.0	14	0.0	58	0.0	41	0.0	20	0.1	19	0.2	272	4.0	157	0.1	24	0.0	21	0.0	17	0.1	26	0.1
057	434	2.3	103	0.4	17	0.0	19	0.0	35	0.0	84	0.2	109	0.2	35	0.1	64	0.0	81	0.1	46	0.2	28	0.2	72	0.2	11	0.1
058	680	3.2	452	2.3	216	0.7	217	0.7	247	0.6	245	0.6	173	0.8	201	0.8	221	0.5	219	0.6	183	0.7	178	0.7	193	0.8	311	1.5
059	368	2.7	140	0.1	278	0.4	120	0.2	169	0.1	141	0.2	270	0.4	111	0.2	158	0.2	104	0.2	62	0.2	63	0.2	531	0.8	118	0.3
060	377	2.9	361	5.7	45	0.0	33	0.0	63	0.0	35	0.0	64	0.0	23	0.0	53	0.0	45	0.0	36	0.0	54	0.0	28	0.0	33	0.0
101	342	7.1	72	1.3	25	0.0	20	0.0	10	0.0	6	0.0	46	0.9	55	0.8	29	0.5	48	0.9	38	2.0	43	1.9	78	3.0	71	1.3
102	185	4.2	94	0.0	12	0.0	11	0.0	38	0.0	10	0.1	34	0.0	20	0.0	28	0.0	6	0.0	8	0.0	7	0.0	39	0.1	18	0.0
103	502	7.1	437	1.0	274	5.3	251	4.9	280	4.4	283	4.7	225	3.5	231	4.0	260	3.6	252	3.7	194	4.1	192	4.0	216	3.6	217	3.7
105	220	3.3	226	6.0	387	7.1	502	7.1	502	7.1	502	7.1	192	4.4	406	7.1	21	0.0	151	1.7	153	3.0	173	2.9	96	0.5	348	7.0
107	502	7.1	121	0.3	124	3.4	79	1.6	21	0.9	46	0.1	11	0.1	26	0.2	26	0.7	80	0.4	179	3.1	62	0.5	24	0.9	14	0.1
109	105	0.7	114	1.5	87	0.8	91	0.7	132	1.0	119	0.9	144	1.6	136	1.0	128	0.8	121	0.9	108	1.0	112	1.0	130	1.1	122	1.0
110	206	0.2	233	1.0	34	0.0	31	0.0	44	0.1	28	0.0	82	0.1	48	0.0	195	0.3	157	0.6	30	0.1	28	0.0	42	0.0	51	0.0
111	270	6.2	266	5.9	461	7.1	406	7.1	337	6.7	438	7.1	1692	6.7	2024	7.1	312	6.1	437	7.1	338	7.1	284	7.0	295	5.9	313	6.7
112	502	7.0	308	7.1	33	0.1	22	0.2	7	0.1	19	0.2	61	0.5	34	0.4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	22	0.4	36	0.3
113	154	0.3	105	1.5	65	0.3	12	0.1	82	0.1	36	0.0	98	0.2	20	0.0	86	0.2	58	0.1	11	0.1	8	0.1	11	0.2	13	0.2
114	295	0.5	76	0.1	49	0.2	207	0.4	74	0.2	282	0.3	67	0.1	165	0.2	24	0.2	187	0.2	50	0.1	28	0.0	162	0.1	189	0.2
115	243	4.7	502	7.1	502	7.1	502	7.1	502	7.1	502	7.1	502	7.1	502	7.1	466	7.1	502	7.1	502	7.1	502	7.1	502	7.1	502	7.1
116	460	5.0	123	1.2	41	1.6	42	1.7	26	1.1	85	2.4	37	0.8	44	0.6	45	1.6	89	2.6	62	1.9	53	1.7	53	1.6	68	1.8
117	502	6.9	189	1.2	282	5.4	286	5.7	251	6.5	378	6.8	1343	6.2	345	6.8	218	6.2	475	6.9	325	6.5	356	6.7	214	5.6	248	6.0
201	288	4.3	102	1.1	959	8.7	88	1.6	1343	8.7	165	2.4	1082	8.7	165	2.0	1348	8.7	229	2.5	1111	8.7	135	2.3	1115	8.7	1083	8.7
202	507	7.6	1131	8.3	1298	8.3	890	8.3	1168	8.3	972	8.1	1049	8.3	910	8.3	1258	8.3	1580	8.2	1536	8.3	1153	8.3	1177	8.2	1088	8.3
203	77	2.5	80	0.6	56	0.3	57	0.1	71	0.1	74	0.1	76	0.1	75	0.1	83	0.1	81	0.1	73	0.1	66	0.1	263	0.4	84	0.1
204	167	3.2	128	0.3	142	0.0	134	0.0	696	7.0	356	1.5	109	0.0	109	0.0	621	6.7	333	1.4	254	0.1	211	0.0	167	0.0	189	0.0
205	325	7.1	293	6.0	435	7.9	436	8.1	440	7.9	405	7.6	534	8.4	461	7.8	372	7.0	376	6.9	370	7.2	427	7.5	572	8.4	444	8.0
206	956	1.5	163	0.0	32	0.0	57	0.0	120	0.0	116	0.0	67	0.0	60	0.0	214	0.0	158	0.0	65	0.0	59	0.0	93	0.0	94	0.0
207	317	1.5	257	0.7	300	0.1	370	0.1	997	4.6	697	0.7	347	0.0	380	0.0	769	0.7	631	0.7	462	0.0	484	0.0	382	0.1	358	0.0
208	1851	6.6	387	0.1	290	0.0	302	0.0	79	0.1	733	0.0	344	0.0	279	0.0	449	2.1	286	0.1	180	0.1	201	0.1	201	0.1	154	0.1
209	43	1.0	0	0.0	420	6.5	32	0.0	201	2.3	36	0.0	36	0.0	38	0.0	171	1.6	38	0.0	218	2.3	44	0.0	35	0.0	160	2.3
210	206	2.0	155	0.5	26	0.1	18	0.0	68	0.0	35	0.0	54	0.0	43	0.0	47	0.0	57	0.0	57	0.0	39	0.0	76	0.0	48	0.0
211	367	2.9	166	2.2	417	4.3	285	2.5	649	4.1	322	2.3	361	2.3	300	2.6	241	2.9	146	1.5	722	4.1	467	2.5	#N/A	#N/A	#N/A	#N/A
212	657	0.5	562	0.5	386	0.0	401	0.0	750	0.1	818	0.7	414	0.0	500	0.0	960	1.3	794	0.7	576	0.0	544	0.0	572	0.1	421	0.0
213	271	2.0	366	4.3	50	0.0	53	0.0	269	3.5	95	0.0	59	0.0	58	0.0	228	1.9	88	0.0	70	0.0	81	0.3	47	0.0	46	0.0
214	537	6.5	213	0.3	41	0.0	115	0.6	462	4.8	192	0.5	71	0.0	43	0.0	327	2.7	97	0.0	68	0.0	55	0.0	48	0.1	41	0.0
216	305	1.7	60	0.0	1161	8.3	1139	8.3	1887	8.3	1342	8.3	1754	8.3	1205	7.7	1887	8.2	926	4.4	807	6.8	985	5.9	703	7.2	750	5.7
217	93	1.3	270	6.2	1018	3.1	201	4.7	269	4.1	228	4.2	263	5.1	211	4.9	267	5.1	203	4.3	260	5.6	224	4.5	238	4.8	274	5.5
218	48	0.6	12	0.2	77	2.3	15	0.0	81	2.4	72	0.0	57	0.6	25	0.0	63	1.2	27	0.0	66	1.3	27	0.0	54	0.5	50	0.5

	CS 03		CS 05		CS 07		CS 10		CS 12		CS 15		XL 02		XL 05		XI 02		XI 05		XI 07		XI 11		RS 02		RS 05	
Veh	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
219	632	8.3	743	7.5	439	3.3	612	3.5	528	3.2	610	2.8	759	3.5	557	3.4	869	2.8	767	2.6	826	3.2	657	3.3	579	3.5	671	3.1
220	259	3.2	308	1.6	217	2.8	243	2.8	76	0.0	193	2.3	209	1.8	155	0.7	57	0.0	118	0.6	86	0.6	77	0.3	199	1.1	154	0.8
221	206	3.3	235	0.3	55	0.1	49	0.0	161	1.8	110	1.1	32	0.0	40	0.0	123	1.4	93	0.8	44	0.1	41	0.0	32	0.0	39	0.0
222	451	2.4	1248	7.2	56	0.4	138	1.8	97	0.2	155	1.1	52	0.0	72	0.1	236	1.8	149	0.7	474	8.0	94	0.1	37	0.0	21	0.0
223	266	0.3	239	0.0	594	5.9	296	0.0	555	3.9	314	0.0	67	0.0	71	0.0	278	2.6	108	0.0	325	4.5	103	0.0	85	0.0	86	0.0
224	238	0.1	87	0.2	8	0.0	8	0.0	846	1.0	41	0.0	43	0.0	40	0.0	604	0.6	75	0.0	37	0.0	87	0.0	21	0.0	46	0.0
225	222	1.2	154	0.5	122	1.0	128	1.0	144	1.1	113	0.8	147	0.8	588	0.3	221	0.9	133	0.7	106	0.7	123	0.6	200	0.6	236	0.3
226	875	2.7	191	0.6	219	2.7	185	0.0	162	1.4	70	0.0	156	2.6	63	0.0	132	1.3	46	0.0	101	0.4	49	0.0	125	0.4	102	0.0
227	259	3.7	208	2.4	201	1.5	206	1.6	367	2.6	225	1.3	149	1.5	144	1.2	283	2.1	139	1.0	132	1.1	132	1.1	137	1.2	130	0.9
228	678	8.4	49	0.0	50	0.0	78	0.0	144	0.0	164	0.0	170	0.0	176	0.0	212	0.1	185	0.0	140	0.0	152	0.0	104	0.0	107	0.0
229	115	2.0	50	0.1	14	0.0	16	0.0	154	2.5	131	1.3	19	0.0	27	0.1	68	0.6	25	0.0	19	0.0	18	0.0	30	0.1	15	0.0
230	817	2.0	28	0.0	433	7.3	38	0.0	312	6.3	40	0.0	352	7.1	28	0.0	262	4.8	40	0.0	433	7.4	54	0.1	344	7.1	385	7.2
231	127	4.4	102	0.0	68	0.0	93	0.0	116	0.0	98	0.0	114	0.0	87	0.0	228	3.0	107	1.9	43	0.0	36	0.6	90	0.0	64	0.0
232	312	2.7	218	0.4	59	0.0	33	0.0	99	0.0	79	0.0	97	0.0	26	0.0	356	2.0	158	0.0	30	0.0	30	0.0	78	0.0	25	0.0
233	421	1.6	323	3.0	380	5.4	398	6.0	476	6.0	463	6.3	413	5.6	452	6.2	474	6.1	419	5.2	404	5.8	415	5.7	#N/A	#N/A	#N/A	#N/A
234	248	0.2	263	0.3	344	1.9	355	2.1	664	5.0	1005	6.2	510	4.0	409	0.1	539	4.2	500	1.7	361	0.0	329	0.1	463	4.0	387	0.7
235	565	5.5	759	7.9	576	5.7	634	6.0	875	6.9	614	6.0	462	4.9	926	6.6	601	5.6	1091	6.9	485	5.4	962	7.1	418	4.3	303	3.8
236	32	0.0	20	0.0	107	1.8	30	0.0	118	1.3	48	0.0	102	1.1	29	0.0	121	1.0	51	0.0	109	1.3	49	0.0	96	1.1	90	1.0
237	81	1.3	86	0.6	19	0.0	17	0.0	20	0.0	26	0.0	17	0.0	14	0.0	37	0.1	80	0.0	45	0.0	24	0.0	14	0.0	25	0.0
238	382	3.5	157	0.0	48	0.0	39	0.0	719	6.8	500	3.4	91	0.0	147	0.1	771	8.9	469	4.0	124	0.1	239	1.0	607	6.4	458	6.7
239	54	2.2	115	2.7	61	1.7	61	1.5	53	0.8	58	1.0	43	0.8	50	1.1	53	0.8	54	0.9	40	0.8	44	0.8	44	0.8	49	0.9
240	125	1.9	31	0.0	100	0.0	82	0.0	667	5.8	363	0.3	1094	7.9	974	7.8	1068	7.9	1004	7.8	1274	7.9	851	7.9	1114	7.8	1144	7.9
241	97	1.3	100	0.7	63	0.7	62	0.7	88	1.1	51	0.2	19	0.0	34	0.2	70	0.7	69	0.4	42	0.3	46	0.3	22	0.0	33	0.1
242	356	3.2	13	0.0	2	0.0	3	0.0	7	0.0	3	0.0	5	0.0	0	0.0	4	0.0	0	0.0	59	1.7	3	0.0	5	0.0	0	0.0
243	361	5.5	509	0.8	998	4.8	989	5.2	1583	7.2	1061	4.7	1309	5.4	965	5.1	1651	6.7	832	4.6	1731	0.3	1731	0.5	#N/A	#N/A	#N/A	#N/A
244	354	4.6	167	3.1	326	6.2	334	6.2	398	6.0	340	5.6	479	6.0	436	5.5	643	5.4	629	5.1	610	5.3	612	5.3	1205	5.5	1192	4.9
245	404	5.9	636	8.4	44	0.0	150	0.9	375	3.8	91	0.0	140	1.2	51	0.0	269	1.8	91	0.0	60	0.0	71	0.0	78	0.2	59	0.0
246	450	5.4	396	5.3	715	7.0	577	5.7	929	8.3	392	5.5	341	3.5	164	0.8	646	7.1	306	0.6	454	5.0	90	0.0	440	4.0	267	3.2
247	97	2.1	92	1.9	3	0.0	1	0.0	3	0.0	5	0.0	8	0.0	31	0.0	27	0.0	18	0.0	8	0.0	10	0.0	28	0.0	20	0.0
248	79	0.0	222	0.0	67	0.0	75	0.0	163	0.0	187	0.0	59	0.0	62	0.0	336	0.5	79	0.1	78	0.0	90	0.0	50	0.0	49	0.0
249	110	1.4	52	0.0	144	0.0	78	0.0	308	3.1	113	0.0	53	0.0	147	0.0	270	2.7	101	0.0	166	0.0	92	0.0	65	0.0	73	0.0
250	112	2.1	44	0.0	120	1.2	132	1.6	220	2.7	124	1.5	64	0.1	64	0.0	193	2.3	117	1.2	81	0.6	102	1.2	62	0.0	62	0.1
251	199	0.3	11	0.0	0	0.0	5	0.0	11	0.0	19	0.0	17	0.0	21	0.0	101	0.0	136	0.1	103	0.0	125	0.0	95	0.0	97	0.0
252	175	3.0	206	2.6	452	0.2	280	1.6	321	1.1	303	1.2	110	0.0	122	0.0	448	0.0	267	0.7	166	0.0	172	0.0	98	0.0	134	0.0
253	727	7.0	514	3.0	804	8.7	781	8.7	1015	8.7	1071	8.7	908	8.7	826	8.7	1128	8.7	955	7.9	784	7.5	754	7.6	895	8.7	869	8.7
254	109	1.0	28	0.0	28	0.0	37	0.0	467	8.6	177	0.0	86	0.0	84	0.0	634	7.8	330	0.0	263	0.0	264	0.0	241	0.0	231	0.0
257	2098	2.3	859	4.3	565	6.7	555	6.8	467	5.4	463	5.8	458	6.1	450	5.7	403	4.3	398	5.0	407	5.4	425	5.4	463	5.8	424	5.5
258	90	0.4	41	0.0	49	0.0	59	0.0	127	0.0	111	0.0	74	0.0	61	0.0	160	0.0	66	0.0	62	0.0	67	0.0	61	0.0	67	0.0
259	363	7.0	339	4.2	67	0.0	57	0.0	159	0.2	103	0.0	62	0.0	49	0.0	171	0.2	126	0.1	52	0.0	46	0.0	59	0.0	50	0.0
260	265	0.3	116	0.1	46	0.0	46	0.0	84	0.8	74	0.3	72	0.0	80	0.0	65	0.4	99	0.2	62	0.0	70	0.0	39	0.0	40	0.0
301	105	0.9	23	0.0	537	5.0	4	0.0	162	0.3	33	0.0	15	0.0	11	0.0	278	1.4	273	1.1	638	5.3	255	1.7	184	0.2	12	0.0
302	477	3.1	472	2.0	312	3.5	268	1.3	217	0.6	236	0.8	236	2.4	254	2.3	248	1.1	218	0.6	236	1.6	237	1.6	242	3.2	472	3.5
304	1970	9.5	304	0.3	169	0.3	168	0.4	234	0.4	184	0.4	240	0.5	200	0.4	204	0.5	281	0.5	217	0.5	208	0.5	196	0.3	287	0.8
305	678	4.2	1266	0.1	627	0.4	973	0.6	1588	1.1	1111	0.5	6	0.1	754	0.3	42	0.4	48	0.2	29	0.0	11	0.1	4	0.1	43	0.1
306	234	0.2	231	0.1	23	0.1	5	0.0	22	0.1	22	0.2	19	0.1	14	0.1	9	0.0	36	0.1	59	0.2	25	0.1	18	0.1	13	0.1
307	302	0.2	232	0.7	39	0.0	28	0.0	46	0.0	37	0.0	20	0.0	19	0.0	66	0.1	64	0.1	20	0.0	19	0.0	21	0.0	247	3.4
308	199	0.2	212	0.4	76	0.2	27	0.0	78	0.1	44	0.0	204	1.1	151	0.6	172	0.3	132	0.2	225	1.8	201	1.3	101	0.2	243	1.3
309	340	0.3	207	0.6	156	0.2	126	0.2	150	0.2	173	0.1	95	0.1	84	0.2	115	0.0	106	0.0	141	0.1	59	0.1	28	0.1	57	0.2
310	96	2.8	209	3.7	154	3.7	157	3.1	176	3.5	171	3.6	197	5.4	219	6.5	184	4.7	234	6.9	235	7.9	215	7.0	297	8.7	324	9.6

Veh	CS 03 HC	CS 03 CO	CS 05 HC	CS 05 CO	CS 07 HC	CS 07 CO	CS 10 HC	CS 10 CO	CS 12 HC	CS 12 CO	CS 15 HC	CS 15 CO	XL 02 HC	XL 02 CO	XL 05 HC	XL 05 CO	XI 02 HC	XI 02 CO	XI 05 HC	XI 05 CO	XI 07 HC	XI 07 CO	XI 11 HC	XI 11 CO	RS 02 HC	RS 02 CO	RS 05 HC	RS 05 CO
311	190	0.9	54	0.1	200	0.3	167	0.4	25	0.0	26	0.0	192	0.1	338	0.3	24	0.0	82	0.1	142	0.4	208	0.4	420	0.2	38	0.0
312	310	0.1	189	0.2	194	0.3	158	0.1	182	0.1	193	0.2	76	0.0	87	0.0	287	0.4	291	0.5	277	0.2	230	0.2	111	0.1	97	0.1
313	452	0.7	371	1.4	72	0.2	83	0.8	842	6.5	58	0.0	30	0.1	45	0.1	56	0.4	32	0.1	50	0.3	45	0.2	32	0.0	46	0.1
314	662	1.0	958	1.0	920	1.3	879	1.3	1965	0.4	1097	1.3	1141	1.1	1125	1.5	1965	0.6	1123	1.2	804	1.2	547	1.2	1149	0.9	999	1.5
315	1913	2.9	830	2.6	332	2.7	106	0.2	421	1.2	313	3.9	167	0.2	261	1.4	322	2.1	412	2.3	103	0.7	57	0.0	304	1.9	332	4.7
316	205	1.8	79	0.0	46	0.2	38	0.1	195	2.5	92	0.2	87	0.4	57	0.2	101	0.2	67	0.1	132	1.9	132	1.6	66	0.6	39	0.1
317	236	1.1	278	0.6	40	0.1	98	0.2	18	0.0	25	0.0	103	0.1	29	0.1	21	0.0	81	0.1	117	0.2	47	0.1	11	0.0	89	0.6
318	194	3.5	144	0.6	226	5.2	315	8.3	315	5.3	597	10.2	309	7.4	643	10.2	377	6.9	611	10.2	764	10.2	689	10.1	388	8.5	699	10.1
319	94	1.7	403	3.9	666	0.4	699	0.3	1080	0.2	1045	0.2	1483	0.2	870	0.2	1332	0.2	1183	0.2	821	0.3	715	0.2	661	0.3	579	0.3
320	201	1.9	125	0.2	63	0.0	99	0.0	213	1.2	228	1.5	80	0.0	102	0.0	258	1.4	265	1.4	108	0.0	81	0.0	74	0.0	84	0.0
321	345	0.2	104	0.1	18	0.0	21	0.0	33	0.0	24	0.0	18	0.0	18	0.0	26	0.0	23	0.0	20	0.0	20	0.0	20	0.0	24	0.0
322	307	0.1	158	0.4	20	0.0	20	0.0	14	0.0	17	0.0	11	0.0	9	0.0	28	0.0	37	0.2	16	0.0	18	0.2	13	0.0	25	0.2
323	166	0.4	128	0.5	311	2.4	309	2.3	112	0.1	129	0.4	214	2.8	556	7.2	68	0.3	131	1.5	546	7.6	618	10.2	535	6.4	179	1.8
324	614	0.6	154	0.4	1870	2.1	1885	1.9	155	0.8	1755	2.1	1885	2.7	1885	2.1	184	0.5	1885	2.2	1885	1.9	1306	1.4	1885	2.9	1259	1.7
325	162	0.3	219	0.8	153	0.1	119	0.1	223	0.5	204	0.4	110	0.3	121	0.3	216	0.5	211	0.5	163	0.3	154	0.3	113	0.3	117	0.3
326	1885	4.6	499	0.9	353	5.6	336	5.7	352	4.8	371	5.2	550	9.3	507	9.1	303	4.0	498	6.9	1885	10.1	1885	10.1	802	9.2	566	8.4
327	307	0.1	312	0.0	132	0.1	58	0.2	48	0.0	39	0.1	15	0.0	19	0.0	25	0.0	24	0.0	191	0.3	21	0.1	27	0.0	17	0.0
328	1116	0.1	1101	0.1	235	0.4	230	0.5	219	0.1	199	0.4	186	0.4	173	0.3	277	0.2	393	0.3	241	0.3	198	0.3	139	0.1	101	0.1
329	103	0.2	1553	0.1	384	0.5	283	0.5	447	0.3	317	0.3	235	0.4	196	0.5	641	0.2	279	0.5	235	0.4	240	0.5	279	0.4	268	0.5
330	331	0.3	313	0.5	107	0.1	107	0.1	53	0.0	68	0.1	39	0.1	41	0.1	100	0.1	152	0.2	114	0.1	87	0.1	42	0.1	39	0.1
331	450	5.2	414	7.3	703	10.4	996	10.4	721	8.6	633	8.6	1079	10.4	774	10.4	510	7.1	453	6.7	706	10.4	656	10.4	907	10.4	558	10.4
332	236	8.1	88	0.1	19	0.0	17	0.0	24	0.0	21	0.0	18	0.0	20	0.0	30	0.0	27	0.1	23	0.0	22	0.1	77	0.4	165	3.9
333	#N/A	#N/A	#N/A	#N/A	64	0.1	65	0.1	184	1.5	174	1.1	375	6.6	379	6.5	60	1.2	311	7.4	330	5.2	342	5.5	#N/A	#N/A	#N/A	#N/A
334	266	0.2	282	0.8	176	0.4	154	0.4	182	0.2	164	0.3	130	0.3	155	0.2	172	0.3	188	0.3	137	0.6	113	0.4	130	0.4	165	0.4
335	260	4.0	260	4.1	137	0.9	126	0.5	429	8.0	249	3.5	458	10.2	405	9.6	320	8.8	287	7.7	328	8.8	326	8.8	400	9.9	358	9.5
336	470	3.6	127	0.1	1682	7.5	1927	6.7	1927	7.9	1662	7.5	1927	7.8	1927	8.6	1927	7.9	1927	6.6	1927	8.4	1927	8.4	1927	8.6	1037	0.5
337	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	30	0.0	34	0.0	50	0.0	81	0.6	37	0.0	34	0.0	29	0.0	64	0.3
338	477	0.8	1037	0.1	350	0.6	293	0.3	928	0.3	348	0.2	512	0.6	179	0.2	541	0.2	816	0.2	274	0.7	135	0.4	454	0.3	149	0.3
339	245	0.2	58	0.0	162	2.4	188	1.9	208	0.1	258	0.8	221	0.9	181	1.1	239	0.3	205	0.6	186	1.6	179	1.6	196	1.5	36	0.0
340	142	0.2	67	0.1	24	0.0	27	0.0	30	0.0	29	0.1	29	0.0	26	0.1	79	0.0	36	0.1	37	0.2	37	0.1	22	0.0	22	0.0
341	279	2.6	266	3.2	186	2.7	186	2.7	210	3.3	184	2.9	244	6.0	230	5.6	233	5.4	221	5.1	233	5.5	250	6.0	276	7.4	521	7.6
342	327	0.1	78	0.1	18	0.0	18	0.0	32	0.0	31	0.0	18	0.0	22	0.0	82	0.0	35	0.0	39	0.1	19	0.0	17	0.0	22	0.0
343	206	0.2	423	0.6	331	0.3	308	0.3	493	0.6	421	0.5	315	0.3	287	0.3	453	0.6	374	0.6	343	0.5	335	0.4	260	0.3	283	0.3
345	426	0.3	506	2.8	362	1.8	324	1.6	233	0.9	218	0.4	586	2.7	214	0.4	393	1.2	201	0.2	193	0.9	187	0.9	485	2.4	467	2.5
346	248	3.4	252	2.6	303	2.4	354	2.9	318	5.6	239	4.4	289	6.4	274	5.7	363	6.3	320	5.9	510	5.3	553	5.5	255	5.6	261	4.5
347	259	0.5	704	0.8	243	0.4	151	0.2	109	0.7	238	0.1	265	0.5	205	0.3	196	0.6	262	0.5	152	0.4	128	1.0	176	0.4	261	0.7
348	503	1.5	575	0.5	268	0.1	200	0.0	125	0.0	219	0.0	100	0.1	123	0.1	145	0.0	135	0.0	248	0.1	193	0.1	170	0.1	90	0.0
349	183	0.4	125	0.5	14	0.0	12	0.0	81	0.1	21	0.0	3	0.0	39	0.1	434	5.3	168	0.1	95	0.2	63	0.1	13	0.1	73	0.1
350	311	7.2	171	1.2	69	0.4	150	0.6	250	2.7	162	0.6	108	1.3	153	0.6	277	4.7	270	1.3	180	1.0	148	0.4	151	2.3	92	0.6
351	269	0.9	413	0.4	176	0.5	156	0.5	163	0.1	246	0.4	139	0.1	192	0.2	102	0.1	235	0.1	218	0.6	153	0.2	109	0.1	183	0.2
352	238	0.5	207	0.6	36	0.1	26	0.1	29	0.1	34	0.1	10	0.0	13	0.0	26	0.0	28	0.1	15	0.0	13	0.0	5	0.0	4	0.0
353	378	0.9	94	0.3	6	0.0	38	0.2	12	0.0	37	0.1	66	0.2	10	0.1	188	0.5	40	0.1	15	0.1	6	0.1	44	0.2	141	0.2
354	636	0.1	158	0.1	686	8.3	746	8.5	205	2.3	265	4.6	259	6.0	260	6.1	215	4.4	198	4.7	214	5.6	214	5.5	255	6.3	250	6.2
355	557	9.1	412	3.8	498	4.8	555	5.6	720	10.0	613	6.8	527	10.0	435	9.1	779	10.0	621	8.0	525	8.4	573	7.7	594	10.0	507	10.0
356	305	0.7	212	0.4	131	0.4	135	0.8	399	5.5	165	0.4	190	0.9	133	0.6	678	8.1	317	1.2	161	0.7	157	0.5	252	1.6	135	0.5
357	209	0.5	462	0.6	142	0.2	135	0.2	26	0.0	52	0.1	43	0.1	36	0.1	25	0.0	66	0.0	158	0.2	120	0.2	43	0.2	32	0.1
358	841	0.1	1897	3.0	368	1.3	280	1.0	749	1.3	354	1.4	363	1.7	236	1.5	532	0.8	335	1.1	179	1.4	220	1.5	#N/A	#N/A	#N/A	#N/A
359	1576	0.1	957	0.1	73	0.0	67	0.0	97	0.0	81	0.0	60	0.0	53	0.0	274	0.0	188	0.0	65	0.0	56	0.0	94	0.0	96	0.1
360	88	0.2	103	0.1	53	0.0	39	0.0	20	0.0	22	0.0	92	0.2	33	0.2	15	0.0	20	0.0	58	0.3	18	0.0	19	0.0	19	0.0

Veh	CS 03		CS 05		CS 07		CS 10		CS 12		CS 15		XL 02		XL 05		XI 02		XI 05		XI 07		XI 11		RS 02		RS 05	
	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO	HC	CO
401	330	5.0	408	3.0	136	1.0	141	1.0	153	0.2	135	0.8	79	0.1	44	0.1	62	0.1	92	0.1	56	0.1	50	0.1	77	0.1	47	0.1
402	493	1.3	363	5.0	70	0.1	65	0.1	356	2.1	100	0.1	86	0.1	371	4.3	307	0.8	299	0.8	87	0.1	77	0.0	79	0.1	320	2.9
403	329	0.2	277	0.1	344	0.1	322	0.1	500	0.2	314	0.1	181	0.1	160	0.1	463	0.2	302	0.1	240	0.1	251	0.1	174	0.1	198	0.1
404	277	2.5	213	0.3	180	0.1	203	0.1	350	0.3	271	0.1	149	0.1	172	0.1	448	0.1	307	0.0	201	0.0	189	0.0	146	0.1	186	0.1
405	185	0.2	500	0.1	500	0.1	297	0.2	292	0.2	500	0.2	111	0.2	123	0.2	140	0.2	186	0.2	163	0.2	234	0.2	158	0.2	240	0.2
406	277	0.2	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1	500	0.1
407	225	1.1	216	0.2	215	0.2	212	0.1	269	0.2	231	0.2	211	0.2	348	0.2	254	0.3	254	0.2	251	0.2	339	0.2	482	0.3	443	0.2
408	306	2.9	237	2.0	63	0.0	62	0.1	263	0.4	104	0.1	48	0.1	48	0.1	239	0.4	289	0.9	108	0.1	69	0.1	49	0.1	53	0.1
409	500	5.0	394	5.0	323	3.1	334	3.0	250	0.4	226	0.5	341	3.1	291	1.8	276	1.3	264	1.2	274	1.4	289	1.8	391	4.5	369	4.3
410	297	3.3	232	2.1	73	0.0	93	0.1	130	0.1	153	0.1	49	0.1	65	0.1	228	0.4	206	0.1	121	0.1	107	0.1	89	0.1	88	0.1
502	487	5.5	192	0.3	444	1.4	522	2.5	334	0.5	307	0.4	145	0.2	250	0.7	520	1.2	371	1.2	413	1.3	409	1.5	205	0.3	304	0.8
503	600	10.6	600	7.0	600	7.7	600	7.8	581	7.0	536	6.2	600	8.2	593	7.6	600	8.1	589	7.5	534	7.1	585	7.5	582	7.8	389	5.7
504	217	2.9	94	2.9	52	2.0	56	2.5	38	1.5	48	1.5	38	2.4	35	1.9	43	2.4	61	1.7	83	3.0	77	2.6	30	1.8	28	1.6
505	357	0.5	199	0.1	53	0.0	48	0.0	267	0.4	276	0.5	210	0.3	114	0.1	240	0.3	261	0.4	261	0.5	219	0.4	67	0.3	114	0.4
506	600	11.2	600	8.0	600	9.6	600	9.0	600	9.4	600	8.3	600	8.9	600	8.0	600	9.2	600	8.6	600	9.2	600	8.8	600	8.4	554	7.8
507	309	5.9	158	2.4	9	0.1	5	0.0	38	0.0	48	0.0	0	0.0	0	0.0	62	0.1	59	0.1	25	0.1	13	0.1	0	0.0	0	0.0
508	369	1.7	256	3.9	215	1.1	211	1.5	234	2.2	224	2.1	45	0.1	28	0.1	57	0.0	104	0.1	67	0.2	81	0.1	30	0.0	31	0.0
509	412	5.4	347	4.6	282	3.1	269	3.1	243	1.5	265	2.7	0	0.0	2	0.1	40	0.0	45	0.2	41	0.2	101	0.3	13	0.2	11	0.2
510	1080	0.1	126	0.0	166	0.5	91	1.1	313	1.2	301	3.0	8	0.1	42	0.2	769	0.6	438	5.8	211	0.4	144	0.3	77	0.8	66	0.2
511	322	4.7	276	3.9	10	0.0	13	0.0	73	0.0	20	0.1	0	0.0	0	0.0	74	0.0	26	0.1	0	0.0	0	0.0	0	0.0	0	0.0
601	570	4.2	414	3.1	423	4.1	453	4.1	459	2.8	432	3.0	372	2.9	276	2.9	492	3.7	546	3.2	402	3.2	399	3.1	378	3.1	312	3.1
602	739	4.1	548	2.2	1013	8.2	1013	8.2	669	1.8	665	2.2	1013	8.0	1013	8.0	598	1.5	609	1.8	713	4.7	804	5.7	1013	8.4	1013	8.4
603	552	2.6	202	0.0	27	0.0	42	0.0	563	0.0	378	0.1	968	2.2	904	1.7	1015	1.1	1015	1.1	1013	1.4	963	1.6	901	1.8	832	1.2
604	429	0.5	211	0.2	118	0.0	90	0.0	577	0.2	472	0.1	41	0.0	65	0.0	585	0.1	551	0.1	287	0.0	242	0.0	43	0.0	95	0.0
605	425	4.4	192	2.6	199	2.7	199	2.9	195	2.7	203	2.7	168	3.4	167	3.3	165	2.3	235	2.0	165	2.4	163	2.2	160	2.8	171	3.3
606	315	2.9	136	1.3	144	2.0	147	2.2	172	1.9	166	2.1	110	1.9	130	2.5	156	2.4	150	2.3	142	2.4	146	2.2	136	2.3	123	2.2
607	103	0.3	82	0.3	52	0.2	56	0.2	132	0.2	133	0.3	25	0.1	35	0.2	141	0.7	113	0.3	46	0.2	40	0.2	26	0.2	44	0.3
608	324	1.4	178	0.3	551	0.5	546	0.4	733	0.2	575	0.6	392	0.4	433	0.4	511	0.2	524	0.6	512	0.4	525	0.4	381	0.4	406	0.4
609	267	3.4	105	0.8	30	0.1	25	0.1	31	0.1	41	0.1	19	0.1	19	0.1	43	0.1	67	0.2	21	0.0	19	0.1	32	0.2	30	0.2
610	337	3.2	177	0.5	10	0.0	7	0.0	22	0.0	24	0.0	0	0.0	0	0.0	249	0.8	224	0.3	18	0.0	17	0.0	135	0.1	119	0.2
611	412	3.3	254	2.7	9	0.0	7	0.0	43	0.0	60	0.0	0	0.0	0	0.0	21	0.0	72	0.0	8	0.0	7	0.0	0	0.0	0	0.0
612	269	0.6	246	6.3	366	6.5	373	6.4	384	5.1	399	6.0	314	5.8	332	6.0	340	5.5	497	6.0	360	6.1	352	5.8	340	6.0	340	6.0
613	203	2.5	97	1.5	183	4.5	144	4.3	151	4.4	155	3.8	61	3.7	60	3.8	183	6.3	185	6.7	140	5.6	166	6.8	102	5.8	110	6.6
614	505	7.9	384	6.8	406	5.1	501	4.3	418	3.2	855	8.8	663	8.5	561	5.8	333	2.5	497	8.4	419	3.5	429	3.2	379	3.4	426	3.4
615	330	3.4	155	2.5	188	2.3	199	2.4	190	1.6	206	1.9	164	2.3	181	2.3	185	2.6	346	2.4	219	2.7	232	2.6	181	2.8	211	3.3
616	254	1.0	113	0.1	114	0.2	158	0.2	469	0.4	234	0.0	45	0.0	50	0.1	548	1.0	394	0.2	140	0.1	218	0.2	80	0.2	93	0.2
617	254	2.1	201	3.4	253	4.2	239	4.1	280	4.3	262	3.0	232	4.4	226	4.3	285	4.9	345	4.5	243	4.4	247	4.3	252	5.2	205	4.9
618	804	10.0	628	10.0	634	7.5	596	7.2	629	6.1	603	6.2	566	6.4	547	5.6	541	5.2	559	5.3	516	5.5	520	5.3	489	5.9	454	5.6
619	321	3.6	84	0.5	25	0.0	26	0.0	73	0.0	108	0.1	10	0.0	17	0.0	108	0.2	143	0.1	36	0.0	31	0.1	8	0.0	15	0.0
620	95	0.3	36	0.1	217	6.3	229	6.2	265	6.1	277	5.7	243	5.8	250	6.0	257	6.1	286	5.9	26	0.0	14	0.0	1	0.0	6	0.0
701	178	0.7	128	0.4	16	0.0	19	0.0	39	0.0	96	0.0	6	0.0	7	0.0	120	0.1	152	0.1	39	0.0	21	0.0	4	0.0	5	0.0
702	117	0.9	100	0.6	56	0.0	53	0.0	146	0.7	131	0.3	35	0.0	45	0.0	142	0.5	138	0.4	67	0.0	68	0.0	36	0.0	41	0.0
703	380	9.4	182	3.2	152	0.8	147	0.8	130	0.5	137	0.8	112	0.5	128	0.8	27	0.0	92	0.5	112	0.8	112	0.7	76	0.1	118	0.9
704	176	2.2	103	0.6	18	0.0	9	0.0	16	0.0	23	0.0	2	0.0	0	0.0	50	0.1	85	0.2	11	0.0	8	0.0	2	0.0	2	0.0
705	646	0.2	371	0.3	180	0.1	279	0.1	333	0.0	352	0.0	148	0.1	141	0.1	214	0.1	197	0.0	214	0.1	184	0.1	160	0.1	151	0.1
706	352	3.9	123	1.6	140	1.3	143	1.2	152	0.9	145	1.1	122	0.9	109	1.1	127	0.6	121	0.8	119	1.1	121	1.0	98	0.6	105	0.8
707	302	5.1	59	0.3	27	0.0	34	0.0	102	0.0	98	0.0	0	0.0	1	0.0	30	0.0	33	0.0	3	0.0	3	0.0	0	0.0	0	0.0
708	246	0.9	152	0.4	3	0.0	0	0.0	5	0.0	2	0.0	0	0.0	0	0.0	6	0.0	3	0.0	3	0.0	0	0.0	0	0.0	0	0.0
709	138	1.9	152	0.6	30	0.0	17	0.0	38	0.1	43	0.1	0	0.0	0	0.0	9	0.0	13	0.0	1	0.0	2	0.0	0	0.0	1	0.0

APPENDIX D
AET Errors of Commission in the CTP Sample

Veh	MY	MFR	CID	Type	KMile	Quota Grp	HCCert	FTPHC	COCert	FTPCO	AET HC	AET CO	XL30HC	XL30CO
31	82	AMC	258	LDT	53	Carb 81-82	1.70	1.13	18.0	14.4	578	0.4	20	0.0
223	82	FORD	302	LDV	46	Carb 81-82	0.41	0.33	7.0	1.8	161	1.3	67	0.0
249	82	FORD	351	LDT	45	Carb 81-82	1.70	0.88	18.0	5.1	1126	0.0	53	0.0
14	85	TOYT	89	LDV	23	Carb 83-86	0.41	0.23	3.4	1.4	176	1.6	8	0.0
20	85	MAZD	91	LDV	13	Carb 83-86	0.41	0.10	3.4	3.1	63	2.4	1	0.0
24	84	TOYT	95	LDV	27	Carb 83-86	0.41	0.23	3.4	1.7	231	0.5	22	0.0
206	86	FORD	300	LDT	16	Carb 83-86	0.80	0.62	10.0	0.9	250	0.0	67	0.0
221	84	FORD	140	LDT	44	Carb 83-86	0.80	0.54	10.0	4.1	124	1.4	32	0.0
250	83	FORD	122	LDT	70	Carb 83-86	1.70	1.44	18.0	11.8	214	3.5	64	0.1
260	84	FORD	122	LDT	35	Carb 83-86	0.80	0.73	10.0	8.0	146	2.6	72	0.0
701	86	TOYT	91	LDV	5	Carb 83-86	0.41	0.24	3.4	1.9	262	0.1	6	0.0
321	82	GM	250	LDV	60	FI 81-82	0.41	0.33	7.0	5.2	264	0.0	18	0.0
338	82	GM	151	LDV	53	FI 81-82	0.41	0.28	7.0	2.7	517	0.2	512	0.6
360	82	GM	151	LDV	56	FI 81-82	0.41	0.29	7.0	4.2	1062	1.0	92	0.2
11	85	VW	109	LDV	27	FI 83-86	0.41	0.31	3.4	2.9	82	1.6	3	0.0
17	86	SUBA	109	LDV	17	FI 83-86	0.41	0.14	3.4	2.1	168	1.4	1	0.0
21	84	TOYT	122	LDT	59	FI 83-86	0.80	0.58	10.0	8.4	337	2.3	226	0.7
37	85	SUBA	109	LDV	29	FI 83-86	0.41	0.20	3.4	2.6	465	0.4	105	0.3
39	85	MAZD	80	LDV	18	FI 83-86	0.41	0.26	3.4	1.6	1743	0.1	3	0.0
50	84	VW	117	LDT	81	FI 83-86	0.80	0.71	10.0	7.9	225	4.4	3	0.0
224	86	FORD	302	LDV	28	FI 83-86	0.41	0.39	3.4	2.0	449	0.1	43	0.0
251	86	FORD	183	LDV	14	FI 83-86	0.41	0.16	3.4	2.2	126	1.3	17	0.0
306	86	GM	151	LDV	5	FI 83-86	0.41	0.21	3.4	1.8	225	0.4	19	0.1
309	84	GM	151	LDV	61	FI 83-86	0.41	0.25	3.4	3.3	500	0.5	95	0.1
322	86	GM	121	LDV	18	FI 83-86	0.41	0.16	3.4	1.8	239	0.9	11	0.0
330	84	GM	151	LDV	60	FI 83-86	0.41	0.24	3.4	2.9	325	0.3	39	0.1
347	84	GM	151	LDV	25	FI 83-86	0.41	0.21	3.4	2.6	331	0.7	265	0.5
348	86	GM	151	LDV	17	FI 83-86	0.41	0.40	3.4	1.2	223	0.1	100	0.1
357	86	GM	151	LDV	37	FI 83-86	0.41	0.35	3.4	3.3	548	0.7	43	0.1
509	85	MITS	97	LDV	26	FI 83-86	0.41	0.24	3.4	1.4	307	6.7	0	0.0
511	86	MITS	98	LDV	16	FI 83-86	0.41	0.20	3.4	3.0	127	2.1	0	0.0
704	86	TOYT	122	LDV	32	FI 83-86	0.41	0.26	3.4	1.7	335	0.4	2	0.0
708	84	TOYT	122	LDV	32	FI 83-86	0.41	0.16	3.4	1.9	344	0.2	0	0.0

APPENDIX E: PER-REPAIR EMISSION REDUCTIONS FOR ALL SYSTEMS: BY QUOTA GROUP

These tables summarize the HC and CO emission reductions per repair, due to repairs to the systems on vehicles in the quota groups listed, in g/mi, as measured by the LA4 transient cycle. Figures indicate averages derived from isolatable repairs.

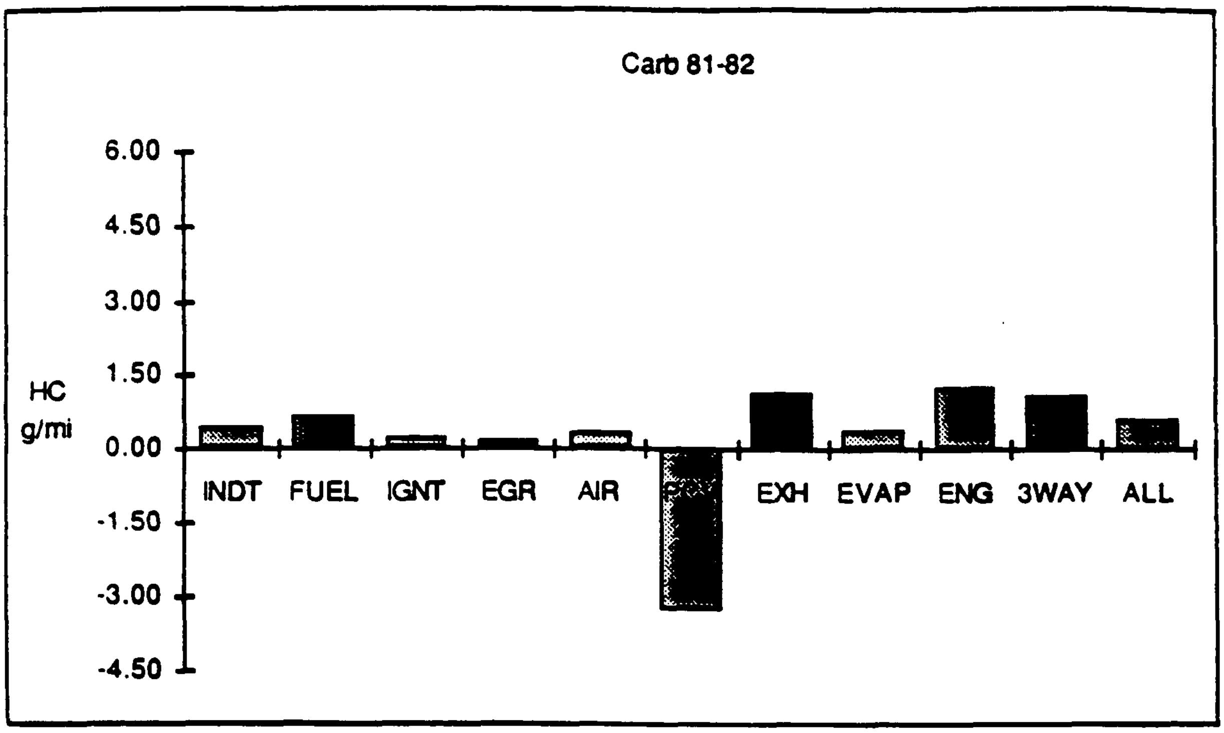
Carbureted 1981-1982 Vehicles								
SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Induction	11	0.41	-0.7	18	0.72	1.6	0.6	0.1
Fuel Meter	46	0.67	8.8	53	0.60	2.6	9.1	3.4
Ignition	18	0.24	0.0	24	0.11	0.3	-0.3	-0.1
EGR	11	0.18	2.6	18	-0.24	-0.6	-5.4	-1.1
Air Injection	55	0.31	6.8	70	0.18	0.8	4.2	1.5
PCV	3	-3.31	-11.0	8	-1.65	-2.8	-4.7	-0.7
Exhaust	30	1.12	7.7	35	1.00	3.5	9.1	2.7
Evap	3	0.39	3.9	3	0.39	0.4	3.9	0.4
Engine	1	1.23	30.9	6	-0.05	-0.1	2.4	0.3
3-Way	42	1.06	22.3	56	0.90	4.1	19.4	7.6
ALL	220	0.59	9.0	291	-	-	-	-

Carbureted 1983-1986 Vehicles								
SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Induction	3	0.02	2.4	5	0.45	1.0	12.8	1.4
Fuel Meter	20	0.87	11.1	29	0.92	4.4	13.0	3.1
Ignition	12	-0.20	-6.5	17	-0.33	-1.1	-7.3	-1.2
EGR	4	0.08	0.3	5	-0.06	-0.1	-1.0	-0.1
Air Injection	8	0.16	4.1	9	0.16	0.5	3.9	0.6
PCV	1	-0.11	-4.7	2	-0.24	-0.3	-7.6	-0.5
Exhaust	10	1.32	6.9	13	1.53	5.1	8.0	1.3
Evap	0	-	-	3	1.44	2.3	24.8	2.0
Engine	2	-0.01	0.3	4	-0.12	-0.2	-3.9	-0.4
3-Way	25	0.42	13.2	26	0.42	2.0	13.5	3.2
ALL	85	0.47	6.8	113	-	-	-	-

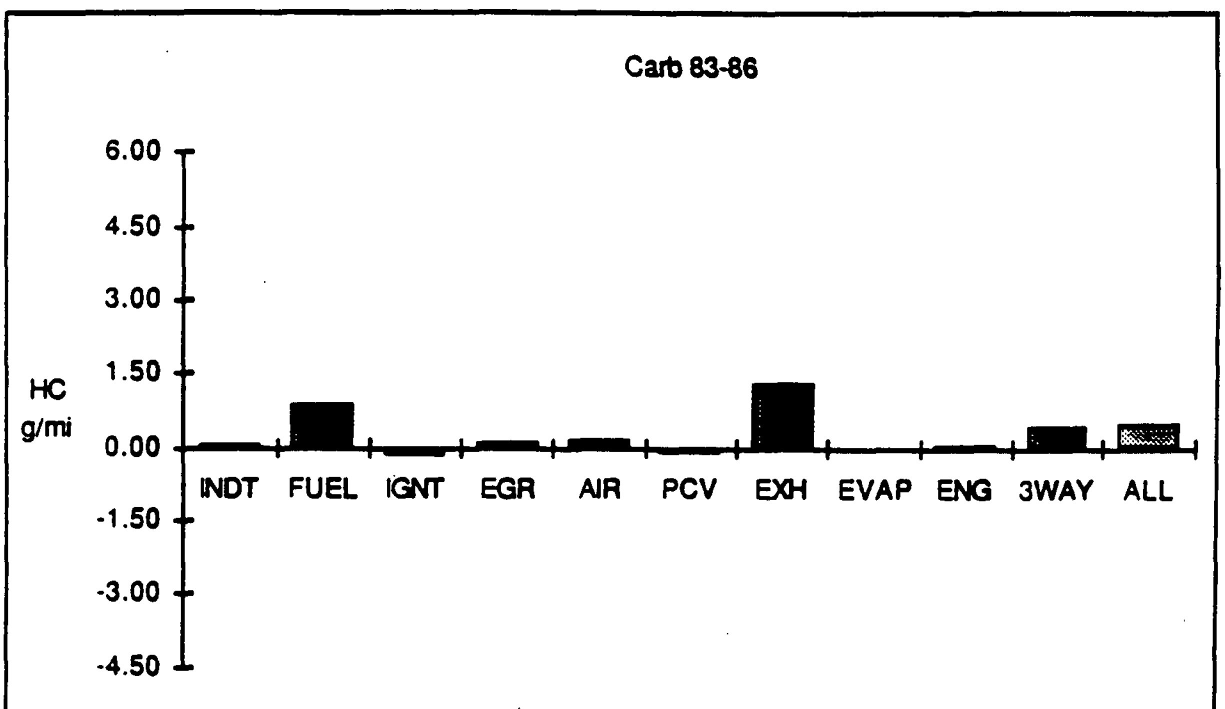
Fuel Injected 1981-1982 Vehicles									
SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS					
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio	
Induction	0	-	-	1	0.02	0.0	-0.2	0.0	
Fuel Meter	6	1.10	22.8	6	1.11	1.1	22.8	1.7	
Ignition	7	0.06	0.1	8	0.06	0.1	0.1	0.0	
EGR	2	-0.06	0.0	2	-0.06	0.0	0.0	0.0	
Air Injection	4	4.85	28.3	4	8.27	4.9	38.0	1.6	
PCV	0	-	-	0	-	-	-	-	
Exhaust	5	2.11	6.2	5	2.28	1.9	8.6	0.5	
Evap	0	-	-	0	-	-	-	-	
Engine	2	-0.02	0.4	4	1.04	0.8	27.9	1.4	
3-Way	14	1.06	32.0	15	1.21	2.0	35.9	4.1	
ALL	40	1.29	18.3	45	-	-	-	-	

Fuel Injected 1983-1986 Vehicles								
SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Induction	0	-	-	4	-1.77	-1.2	-14.0	-0.8
Fuel Meter	22	2.07	21.6	29	1.78	3.6	17.2	3.2
Ignition	26	0.37	-0.3	29	0.72	1.4	1.9	0.3
EGR	2	0.00	-0.1	2	0.00	0.0	-0.1	0.0
Air Injection	10	-0.65	-0.3	10	-0.82	-0.9	-1.0	-0.1
PCV	0	-	-	1	1.77	0.5	13.3	0.3
Exhaust	15	0.98	7.2	15	0.94	1.4	6.8	0.9
Evap	1	0.08	0.3	2	0.08	0.0	0.3	0.0
Engine	5	1.57	7.1	7	1.53	1.5	6.4	0.6
3-Way	75	0.22	14.2	82	0.33	1.1	14.1	4.3
ALL	156	0.56	10.7	181	-	-	-	-

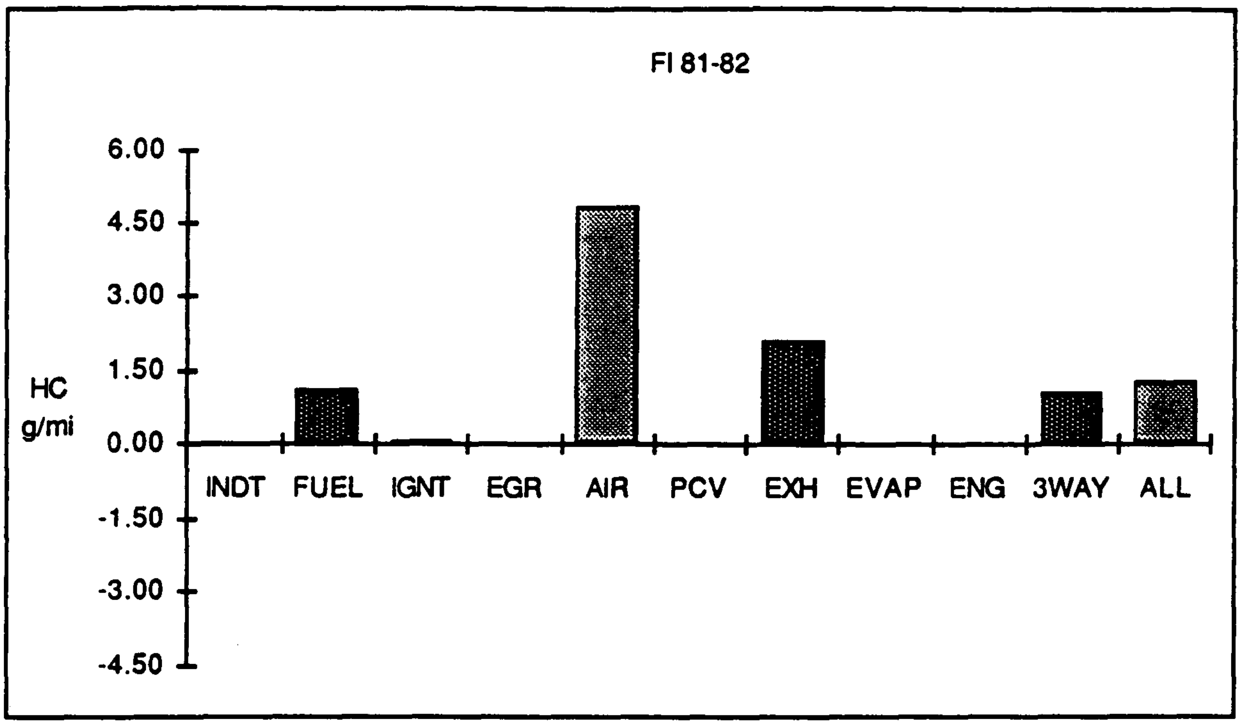
Average HC Benefit per System Repair --
Carbureted MY 81-82 Vehicles



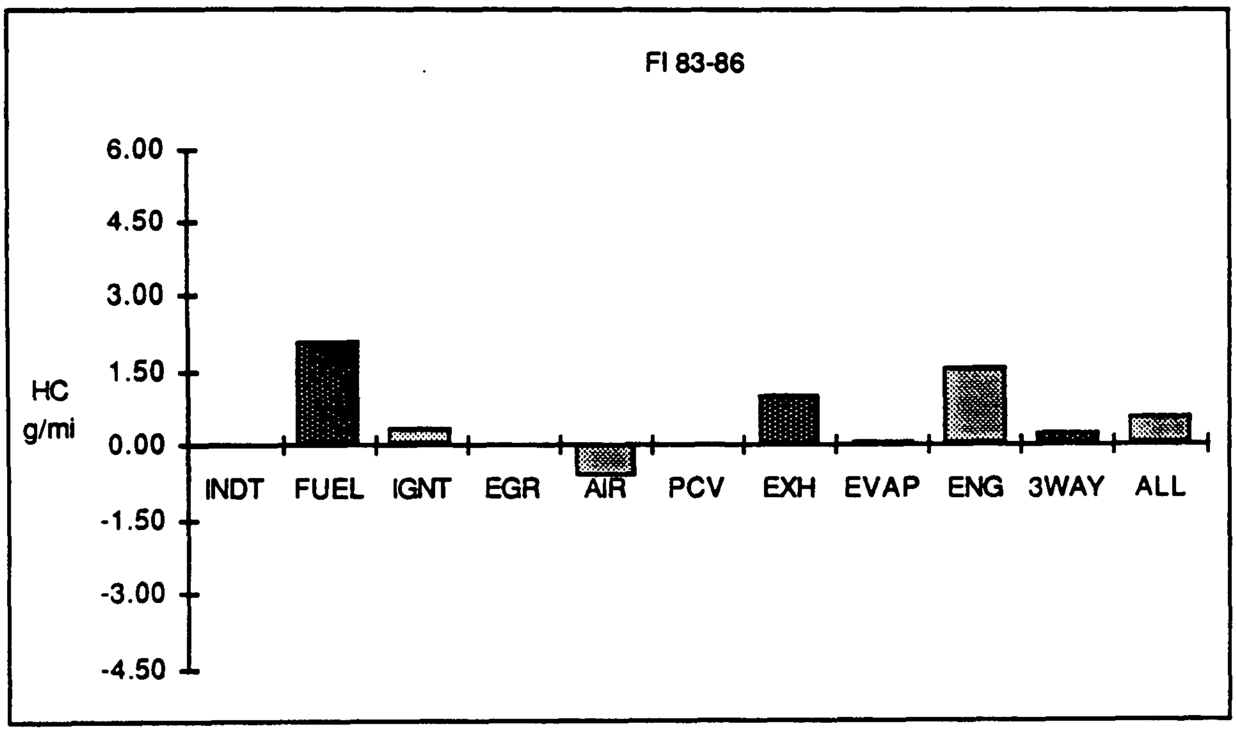
Average HC Benefit per System Repair --
Carbureted MY 83-86 Vehicles



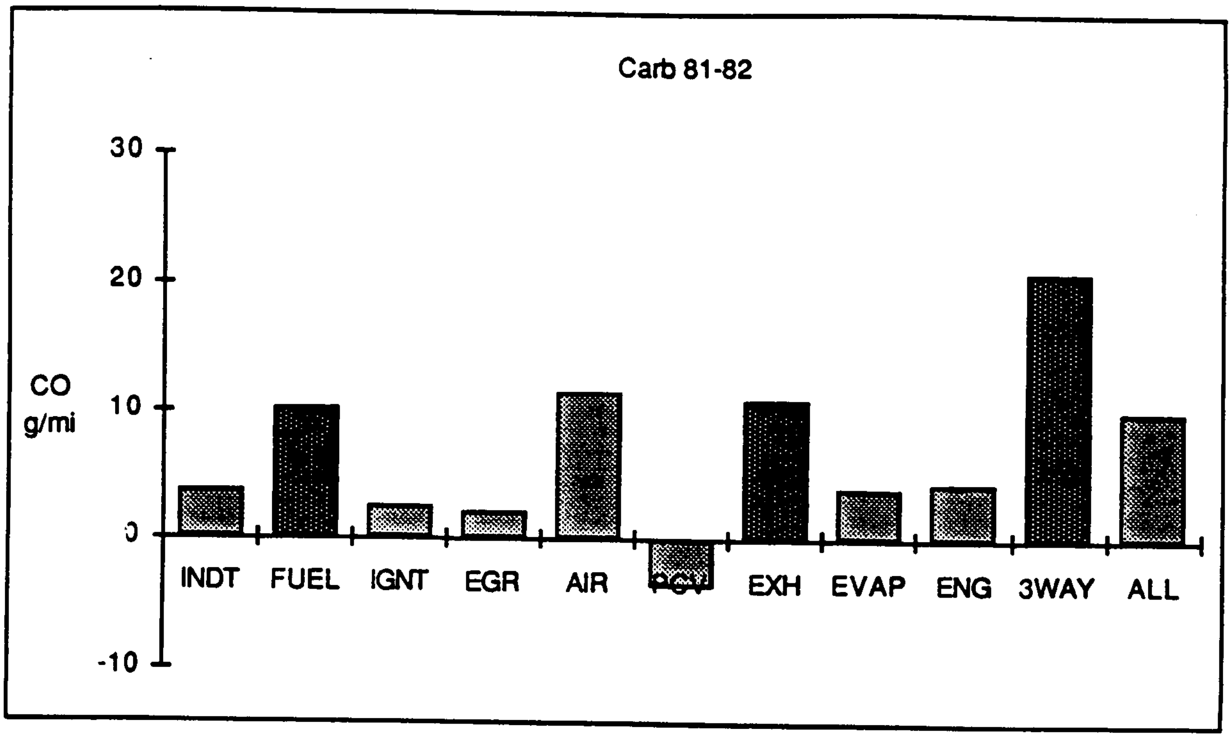
Average HC Benefit per System Repair --
Fuel Injected MY 81-82 Vehicles



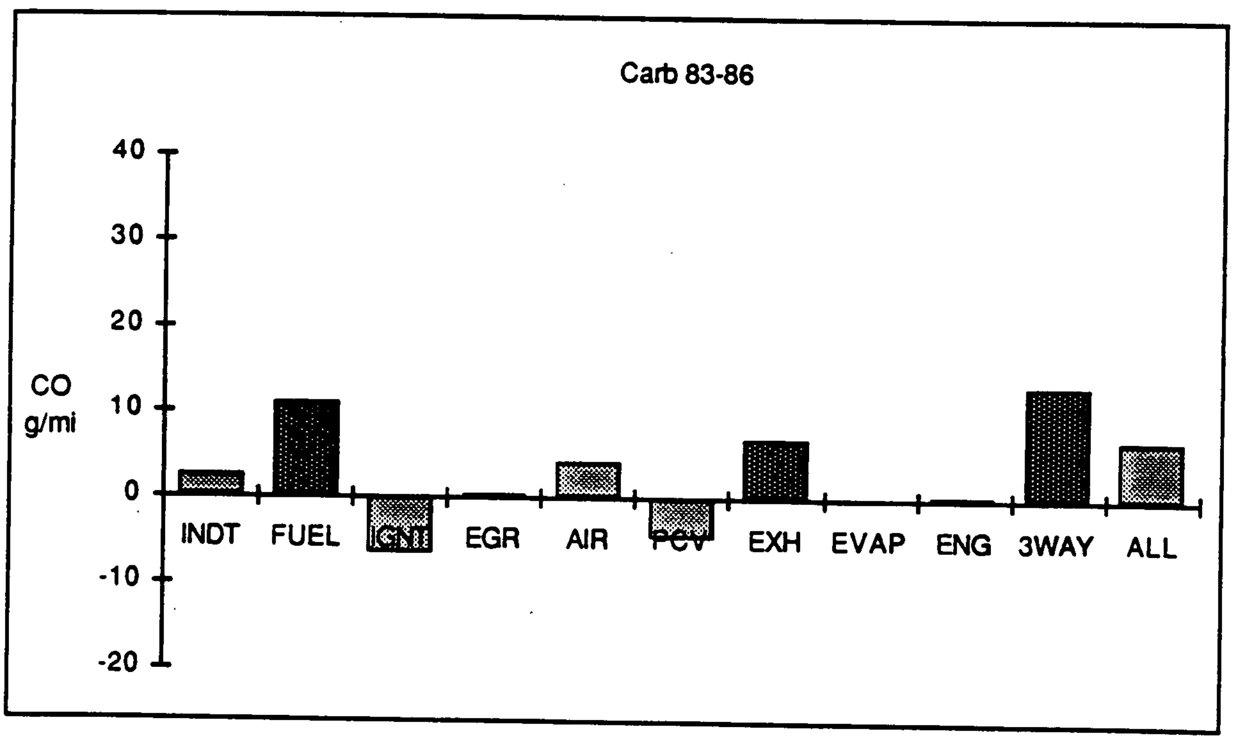
Average HC Benefit per System Repair --
Fuel Injected MY 83-86 Vehicles



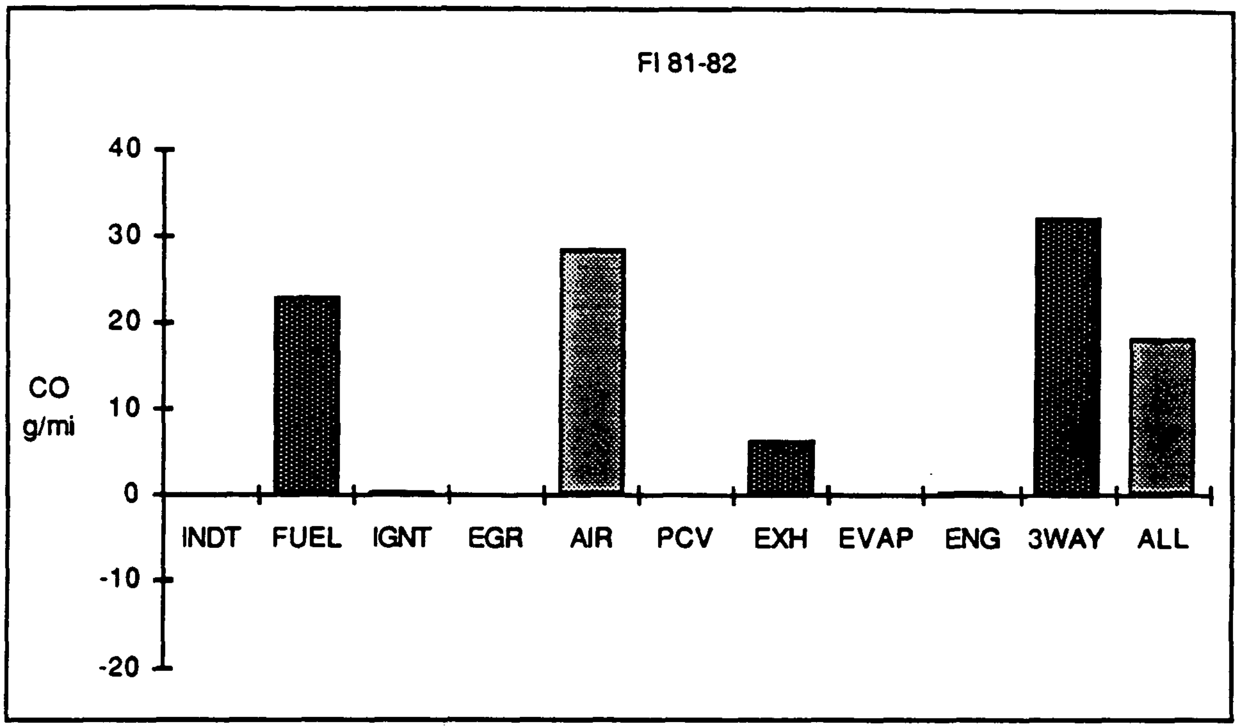
Average CO Benefit per System Repair --
Carbureted MY 81-82 Vehicles



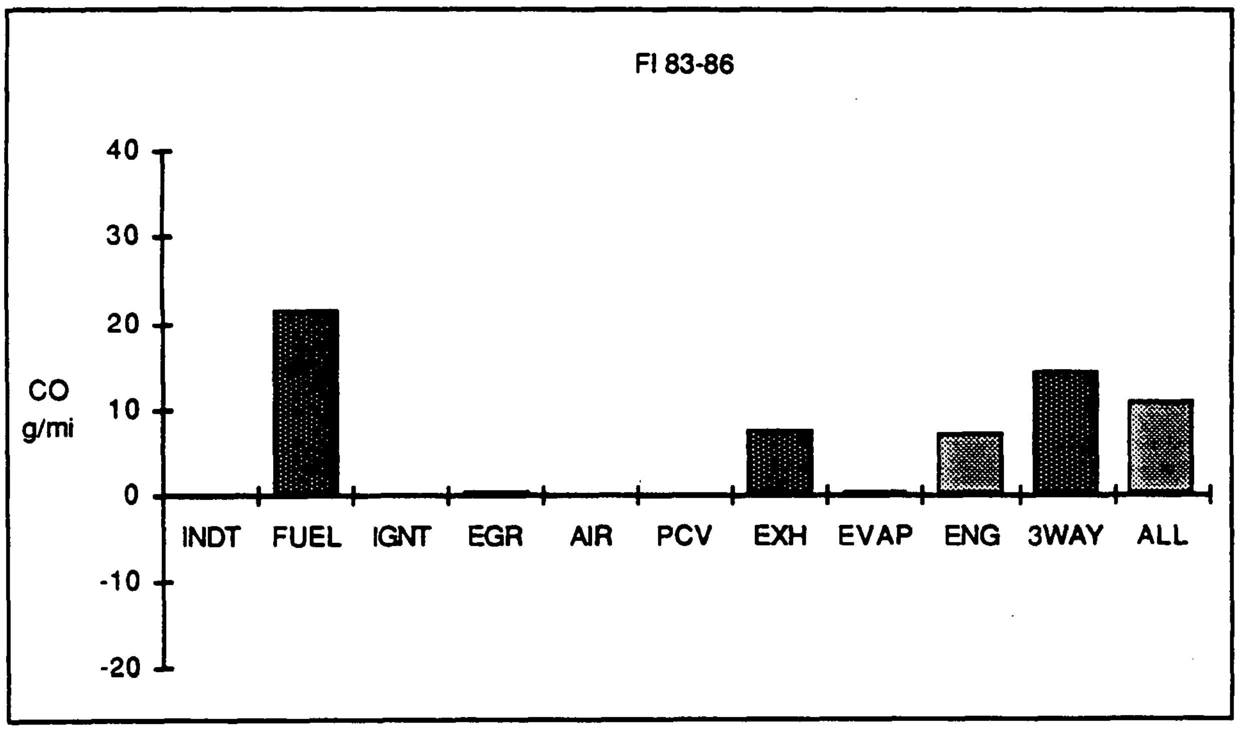
Average CO Benefit per System Repair --
Carbureted MY 83-86 Vehicles



Average CO Benefit per System Repair --
Fuel Injected MY 81-82 Vehicles



Average CO Benefit per System Repair --
Fuel Injected MY 83-86 Vehicles



APPENDIX F: PER-REPAIR EMISSION REDUCTIONS FOR STATISTICALLY SIGNIFICANT SYSTEMS: BY QUOTA GROUP

This table summarizes the HC and CO emission reductions per repair, due to repairs to the systems on vehicles in the quota groups listed, in g/mi, as measured by the LA4 transient cycle.

SYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS OF THESE SYSTEMS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Carbureted 1981-1982 Vehicles								
Fuel Meter	46	0.67	8.8	53	0.61	2.7	9.2	3.5
Exhaust	30	1.12	7.7	35	1.05	3.6	9.6	2.9
3-Way	42	1.06	22.3	56	0.91	4.2	19.2	7.7
Carbureted 1983-1986 Vehicles								
Fuel Meter	20	0.87	11.1	29	1.01	5.0	14.6	3.6
Exhaust	10	1.32	6.9	13	1.51	5.1	7.4	1.2
3-Way	25	0.42	13.2	26	0.42	2.0	13.3	3.2
Fuel Injected 1981-1982 Vehicles								
Fuel Meter	6	1.10	22.8	6	1.11	0.9	22.8	1.7
Exhaust	5	2.11	6.2	5	2.28	1.5	8.6	0.5
3-Way	14	1.06	32.0	15	1.28	1.7	37.8	4.4
Fuel Injected 1983-1986 Vehicles								
Fuel Meter	22	2.07	21.6	29	1.67	3.5	16.2	3.2
Exhaust	15	0.98	7.2	15	0.94	1.4	6.8	0.9
3-Way	75	0.22	14.2	82	0.38	1.3	14.3	4.5

APPENDIX G: PER-REPAIR EMISSION REDUCTIONS FOR ALL SUBSYSTEMS

This table summarizes the HC and CO emission reductions per repair, due to repairs to the subsystems listed, in g/mi, as measured by the LA4 transient cycle.

SUBSYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
INDUCTION SYSTEM								
Htd Air Door	1	0.06	-1.6	2	-0.65	-0.4	-6.0	-0.31
Temp Sensors	0	–	–	2	-0.40	-0.2	3.3	0.16
Air Filter	3	-0.01	2.2	15	-0.57	-0.9	-2.8	-0.38
Hoses	4	1.13	-2.3	6	1.16	1.4	7.7	0.77
Other (Indt)	1	0.00	-0.2	3	1.18	0.8	3.2	0.19
FUEL METERING SYSTEM								
Carb Assembly	22	1.03	11.9	27	0.89	2.3	10.8	2.41
Fuel Meter Tune	30	0.61	11.6	43	0.49	1.6	10.0	2.78
Idl Spd Sole	0	–	–	1	-0.65	-0.3	-14.1	-0.61
Fuel Inj	19	2.35	24.2	20	2.22	5.2	22.2	4.40
Hoses	3	-0.09	0.2	7	0.08	0.1	-5.8	-0.66
Other	4	2.35	29.7	11	0.70	1.1	10.7	1.47
Chk Adj Vacm	1	0.01	0.5	1	0.01	0.0	0.5	0.02
Vac Diaphrms	2	-0.06	-1.0	5	0.10	0.1	1.5	0.14
Other (Chk)	1	-0.01	-0.4	2	1.51	1.0	20.9	1.13
IGNITION SYSTEM								
Dist Assembly	3	0.00	-0.5	11	-0.22	-0.4	-3.6	-0.50
Igni Tune Items	38	0.34	0.4	54	0.46	1.7	0.5	0.16
Vac Adv Assmb	2	-0.19	-1.2	5	-0.15	-0.1	-0.6	-0.05
Spk Delay Dev	1	0.28	10.4	1	0.28	0.1	10.4	0.46
Elect Tim Mod	0	–	–	1	0.56	0.3	1.2	0.05
Hoses	2	0.01	-0.5	2	0.01	0.0	-0.6	-0.04
Wir/Hrns/Fuse	0	–	–	2	-0.53	-0.3	-4.2	-0.23
Other	0	–	–	2	-0.48	-0.3	-5.8	-0.32
EGR SYSTEM								
Valv Assembly	8	-0.01	0.6	12	-0.01	0.0	-1.0	-0.15
Delay Solnoid	0	–	–	1	-0.89	-0.4	-16.3	-0.60
Cool Temp Sen	1	-0.02	0.3	1	-0.02	0.0	0.3	0.01
Hoses	4	0.05	-1.4	8	-0.05	-0.1	-1.5	-0.18
Other	2	0.62	11.3	5	0.41	0.4	7.0	0.60
AIR INJECTION SYSTEM								
Pump Assembly	2	7.93	41.1	5	5.31	4.7	22.6	1.70
Byps/Dump Vlv	0	–	–	3	-0.31	-0.2	12.3	0.71
Diverter Vlv	5	-1.45	-3.4	13	-0.67	-1.0	-1.3	-0.17

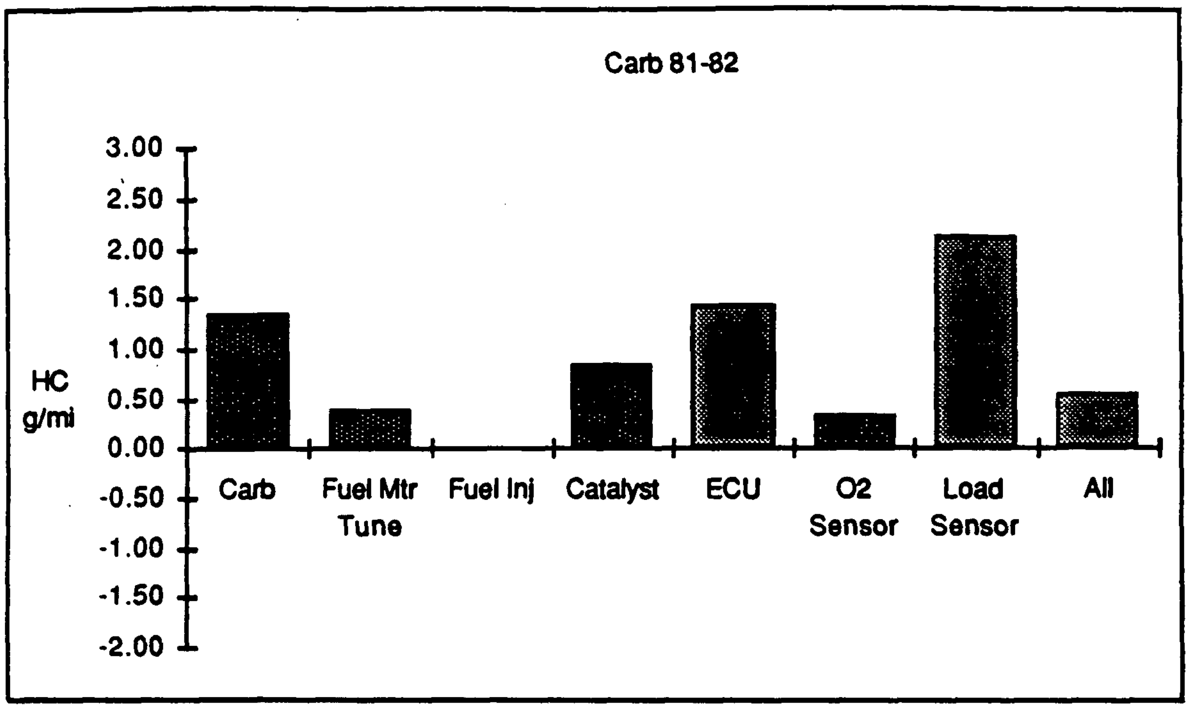
SUBSYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
AIR INJECTION SYSTEM (continued)								
Check Valve	14	0.35	3.8	31	0.33	0.8	4.3	0.88
Drive Belt	1	-0.04	0.1	5	-2.01	-1.8	-3.7	-0.28
Hoses	9	-0.24	0.5	27	-0.06	-0.1	1.0	0.20
Wir/Hrns/Fuse	1	0.02	0.4	2	1.39	1.0	17.8	1.09
Other	4	-0.30	-3.7	7	-0.46	-0.6	-6.4	-0.67
PCV SYSTEM								
Valv Assembly	3	-0.12	-0.8	3	-0.12	-0.1	-0.8	-0.06
Filters	0	–	–	4	0.54	0.4	3.9	0.27
Hoses/Lines	1	-9.68	-35.3	3	-3.55	-2.9	-10.8	-0.73
Other	0	–	–	1	-0.34	-0.2	-8.2	-0.36
EXHAUST SYSTEM								
Exh Manifold	0	–	–	10	0.42	0.6	0.8	0.10
Catalyst	43	1.11	7.0	56	1.09	3.9	7.8	2.36
Other	1	0.50	12.3	2	0.77	0.6	4.1	0.25
EVAPORATIVE SYSTEM								
Evap Canister	1	0.08	0.3	1	0.08	0.0	0.3	0.01
Canister Purg	2	0.58	5.8	2	0.58	0.4	5.8	0.37
Hoses	1	0.02	0.2	3	0.56	0.5	-0.6	-0.05
Other	0	–	–	2	1.04	0.7	19.8	1.06
ENGINE ASSEMBLY								
Eng Assembly	2	0.63	16.6	3	0.66	0.6	14.0	1.03
Cooling Sys	1	-0.06	-1.5	7	-0.24	-0.3	-8.2	-0.83
Valve Adj	1	0.11	1.5	4	-0.27	-0.2	-7.4	-0.57
Belt Tension	0	–	–	1	3.72	1.8	105.1	4.28
Hoses	1	5.99	28.7	1	5.99	3.2	28.7	1.28
Eng Oil	1	-0.16	-0.8	2	-0.14	-0.1	2.9	0.16
Other	2	0.46	1.9	3	0.36	0.3	0.2	0.02
THREE-WAY CATALYST SYSTEM								
ECU	14	0.40	10.7	19	0.67	1.5	14.0	2.59
O2 Sen	69	0.80	20.7	82	0.91	4.2	21.9	8.60
Load Sensor	11	0.61	23.2	22	0.02	0.0	17.1	2.98
Eng Spd Sen	1	0.53	3.4	2	0.27	0.2	-3.7	-0.24
Cool Temp Sen	4	0.86	27.4	8	0.24	0.4	11.4	1.42
EGR Postn Sen	1	0.06	-12.8	1	0.06	0.0	-12.8	-0.57
A/F Cntrl Act	5	2.46	32.6	5	2.46	2.9	32.6	3.25
Air Bypas Sen	1	2.76	28.2	3	1.77	1.3	21.8	1.36
Air Divrt Act	1	0.12	-0.4	4	-0.33	-0.3	-4.4	-0.32
ISC Sys	1	0.20	2.0	1	0.20	0.1	2.0	0.09
Hoses	6	0.37	-3.7	18	-0.58	-1.1	-11.9	-1.86
MAT Sen	3	-0.55	10.2	3	-0.55	-0.5	10.1	0.78
Wir/Hrns/Fuse	6	0.43	26.7	9	0.48	0.7	26.2	3.27
Other	1	-0.02	-0.7	2	0.45	0.3	20.5	1.25
ALL	372	0.70	10.7	630	–	–	–	–

APPENDIX H: PER-REPAIR EMISSION REDUCTIONS FOR STATISTCALLY SIGNIFICANT SUBSYSTEMS: BY QUOTA GROUP

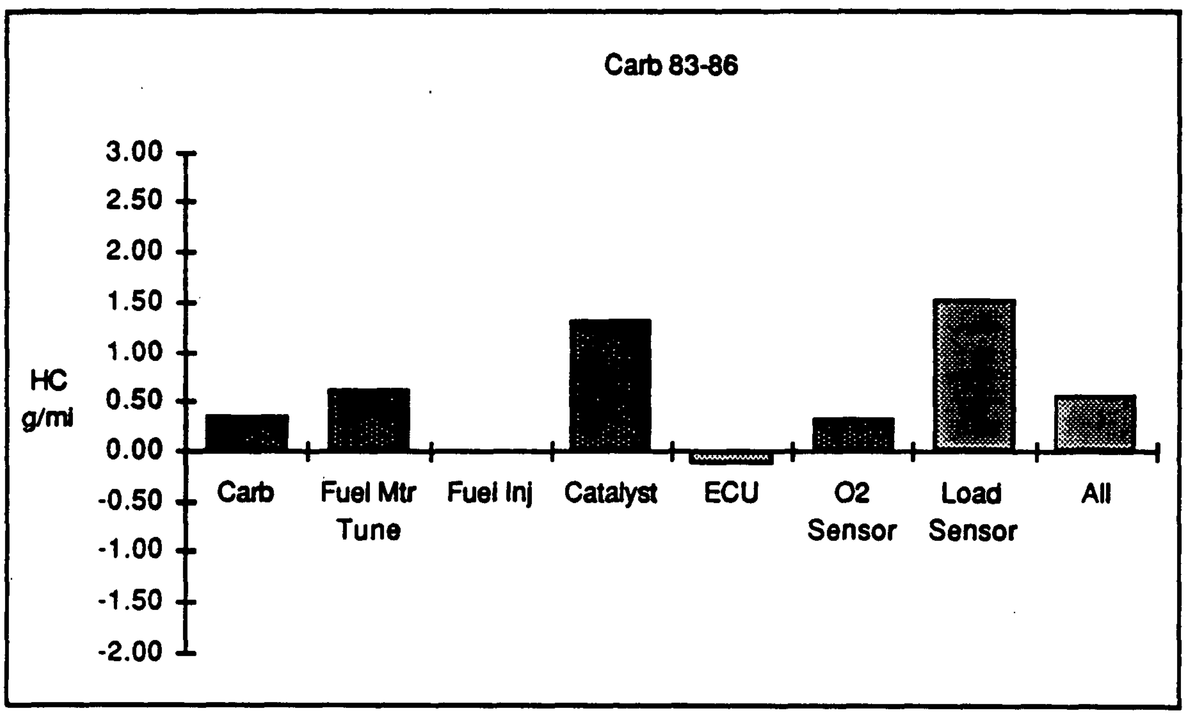
This table summarizes the HC and CO emission reductions per repair, due to repairs to the subsystems on vehicles in the quota groups listed, in g/mi, as measured by the LA4 transient cycle. Figures indicate the averages derived from isolatable repairs.

SUBSYSTEM REPAIRED	SIMPLE AVERAGES ISOLATABLE REPAIRS			MULTIPLE LINEAR REGRESSION ALL REPAIRS OF THESE SUBSYSTEMS				
	N	Δ HC	Δ CO	N	Δ HC	t-ratio	Δ CO	t-ratio
Carbureted 1981-1982 Vehicles								
Carburetor	15	1.34	16.2	18	1.06	2.8	13.1	3.0
FuelMtr Tune	12	0.37	7.6	19	0.61	1.7	11.5	2.7
Fuel Injector	0	-	-	0	-	-	-	-
Catalyst	19	0.85	6.2	28	1.07	3.6	9.6	2.7
ECU	9	1.42	21.9	11	1.17	2.5	17.9	3.2
O2 Sensor	15	0.32	9.6	21	0.38	1.1	12.8	3.2
Load Sensor	1	2.13	76.7	1	2.13	1.3	76.7	4.1
ALL	149	0.55	8.3	291	-	-	-	-
Carbureted 1983-1986 Vehicles								
Carburetor	7	0.36	2.6	9	0.92	2.5	10.9	1.6
FuelMtr Tune	10	0.63	10.5	12	0.93	3.0	15.7	2.6
Fuel Injector	0	-	-	0	-	-	-	-
Catalyst	10	1.32	6.9	12	1.51	4.8	7.4	1.2
ECU	1	-0.13	0.6	1	-0.13	-0.1	0.6	0.0
O2 Sensor	12	0.31	5.2	13	0.29	1.0	5.0	0.9
Load Sensor	2	1.53	73.7	3	1.05	1.7	48.8	4.1
ALL	75	0.57	9.1	113	-	-	-	-
Fuel Injected 1981-1982 Vehicles								
Carburetor	0	-	-	0	-	-	-	-
FuelMtr Tune	5	1.35	27.3	5	1.35	1.0	27.4	1.9
Fuel Injector	0	-	-	0	-	-	-	-
Catalyst	3	2.55	12.6	3	2.55	1.5	12.6	0.7
ECU	0	-	-	0	-	-	-	-
O2 Sensor	9	1.77	42.5	10	2.03	2.2	50.1	5.0
Load Sensor	2	0.16	0.8	2	0.16	0.1	0.8	0.0
ALL	35	1.27	19.5	45	-	-	-	-
Fuel Injected 1983-1986 Vehicles								
Carburetor	0	-	-	0	-	-	-	-
FuelMtr Tune	3	0.30	5.0	7	-0.30	-0.3	-4.4	-0.5
Fuel Injector	19	2.35	24.2	20	2.26	4.2	23.3	4.3
Catalyst	11	0.87	6.3	13	0.94	1.4	6.8	1.0
ECU	4	-1.75	-12.0	7	-0.05	-0.1	7.3	0.8
O2 Sensor	33	0.93	25.5	38	1.24	3.2	27.9	7.1
Load Sensor	6	0.19	5.0	16	-0.72	-1.2	1.3	0.2
ALL	113	0.80	12.1	181	-	-	-	-

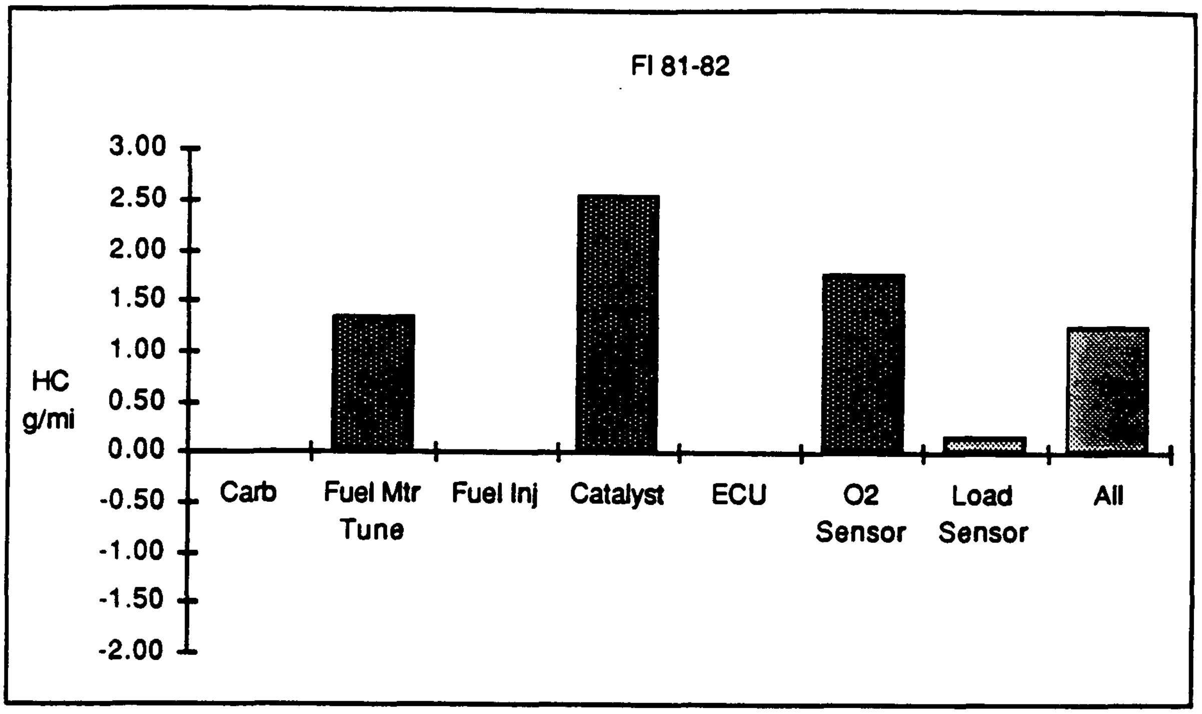
Average HC Benefit per Subsystem Repair --
Carbureted MY 81-82 Vehicles



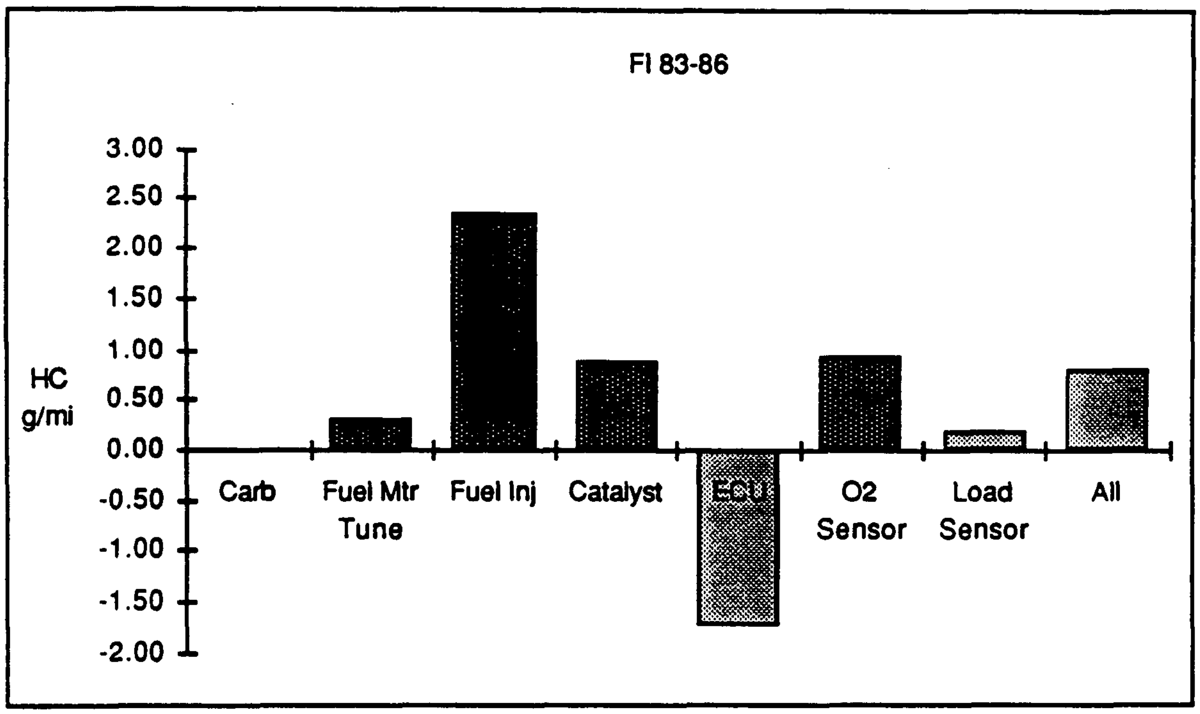
Average HC Benefit per Subsystem Repair --
Carbureted MY 83-86 Vehicles



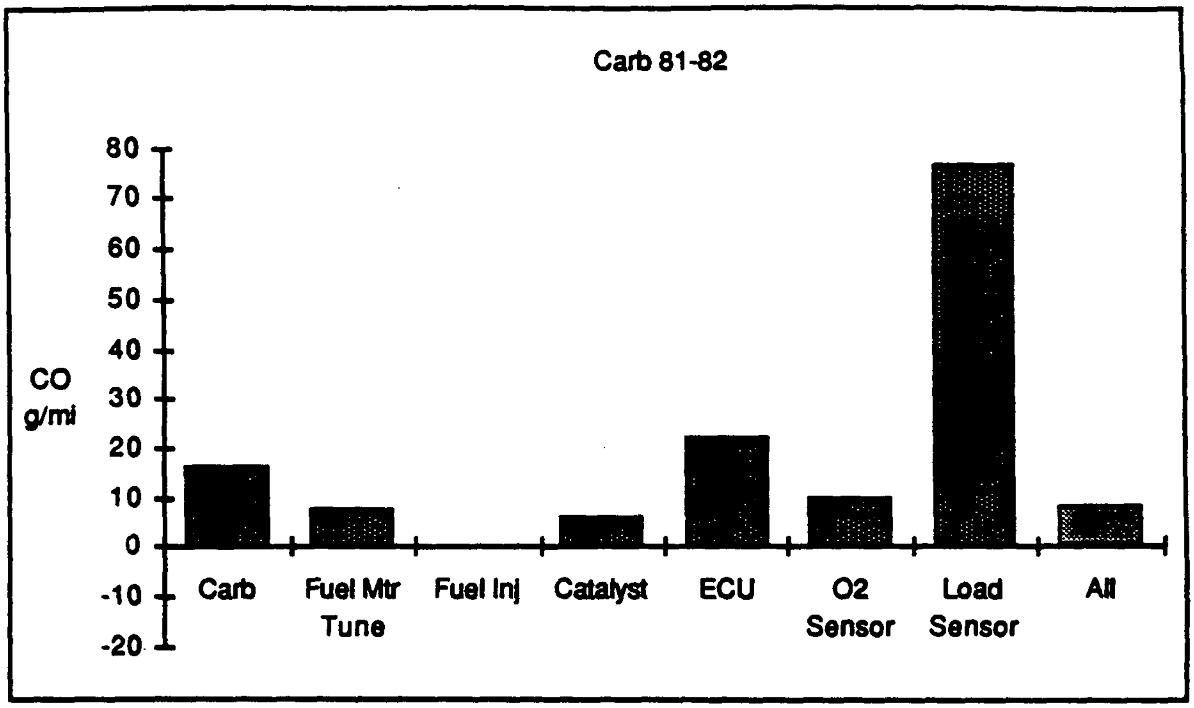
Average HC Benefit per Subsystem Repair --
Fuel Injected MY 81-82 Vehicles



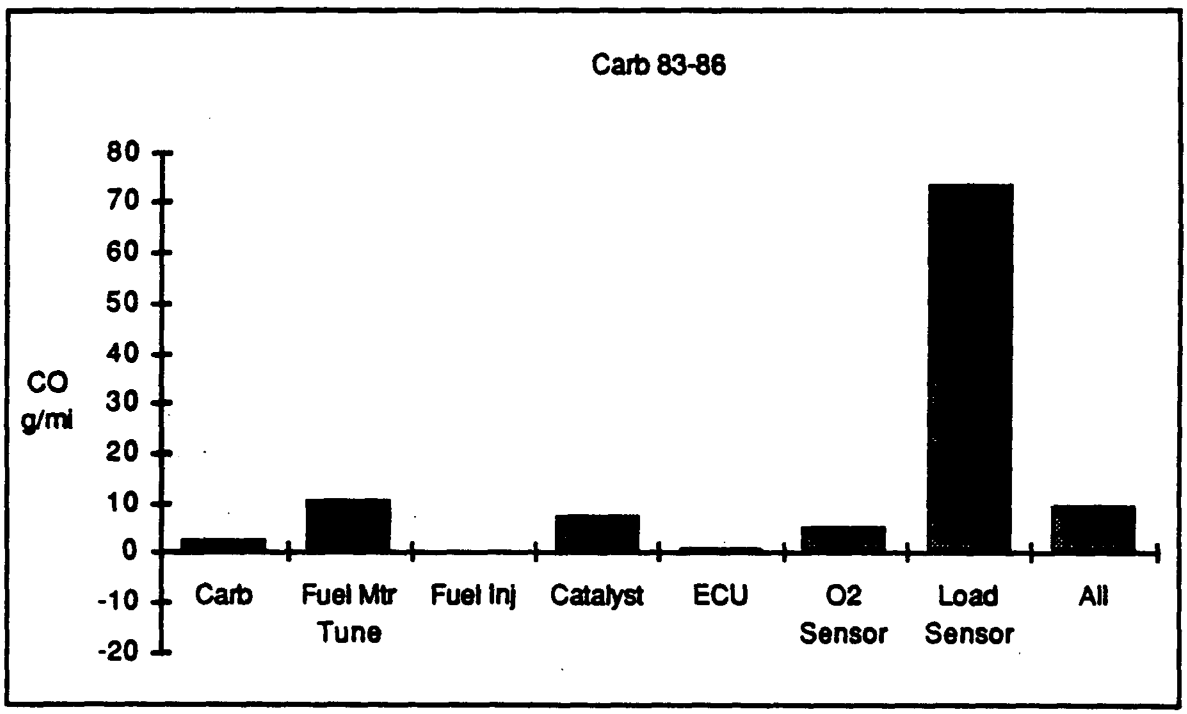
Average HC Benefit per Subsystem Repair --
Fuel Injected MY 83-86 Vehicles



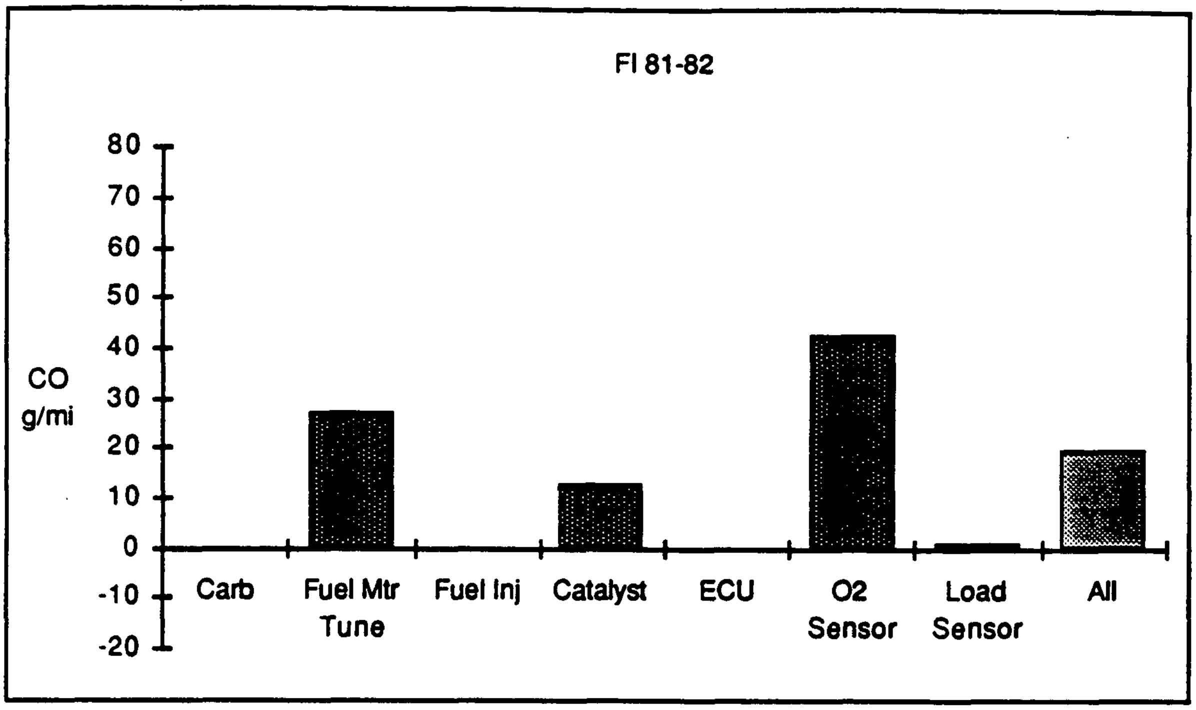
Average CO Benefit per Subsystem Repair --
Carbureted MY 81-82 Vehicles



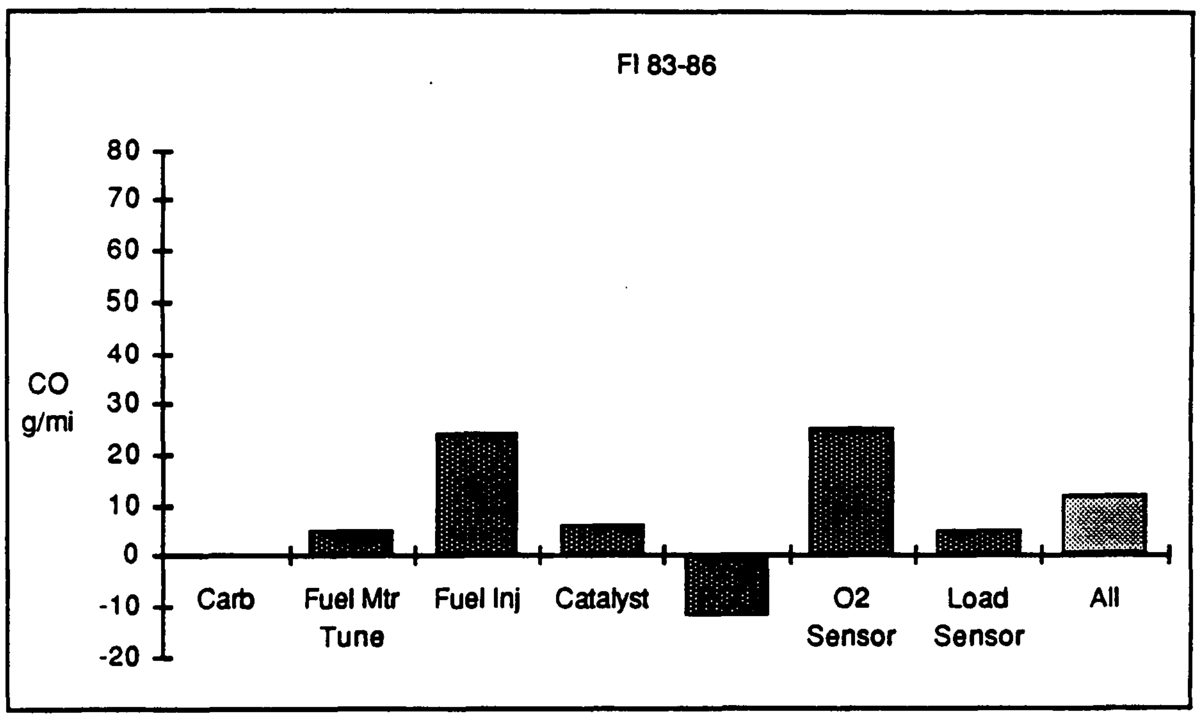
Average CO Benefit per Subsystem Repair --
Carbureted MY 83-86 Vehicles



Average CO Benefit per Subsystem Repair --
Fuel Injected MY 81-82 Vehicles



Average CO Benefit per Subsystem Repair --
Fuel Injected MY 81-82 Vehicles



Appendix I: Total Estimated Emission Reductions for All Subsystems

This table summarizes estimates of the total emission reductions, in g/mi and percent of overall CTP fleet reduction, realized by repairs to specific subsystems, as measured by the LA4. Average reductions per repair are calculated from isolatable repairs only. Number of repairs includes all repairs to that subsystem, whether or not isolatable. Totals greater than 100% are due to the combination of isolatable averages with all repairs.

SUBSYSTEM REPAIRED		AVG REDUCTION PER REPAIR		ESTIMATE OF TOTAL REDUCTION		% OF ENTIRE CTP REDUCTION	
	N	HC	CO	HC	CO	HC	CO
INDUCTION SYSTEM							
Htd Air Door	2	0.06	-1.6	0.12	-3.1	0.0%	-0.1%
Temp Sensors	2	-	-	-	-	-	-
Air Filter	15	-0.01	2.2	-0.17	33.2	-0.1%	0.7%
Hoses	6	1.13	-2.3	6.79	-13.8	2.1%	-0.3%
Other (Indt)	3	0.00	-0.2	0.01	-0.5	0.0%	0.0%
FUEL METERING SYSTEM							
Carb Assmbly	27	1.03	11.9	27.73	320.5	8.6%	6.3%
Fuel Meter Tune	43	0.61	11.6	26.29	498.8	8.2%	9.9%
Idl Spd Sole	1	-	-	-	-	-	-
Fuel Inj	20	2.35	24.2	47.09	484.3	14.6%	9.6%
Hoses	7	-0.09	0.2	-0.64	1.3	-0.2%	0.0%
Other	11	2.35	29.7	25.82	327.2	8.0%	6.5%
Chk Adj Vacm	1	0.01	0.5	0.01	0.5	0.0%	0.0%
Vac Diaphrms	5	-0.06	-1.0	-0.30	-5.0	-0.1%	-0.1%
Other (Chk)	2	-0.01	-0.4	-0.02	-0.9	0.0%	0.0%
IGNITION SYSTEM							
Dist Assembly	11	0.00	-0.5	-0.02	-5.2	0.0%	-0.1%
Igni Tune Items	54	0.34	0.4	18.59	19.8	5.8%	0.4%
Vac Adv Assmb	5	-0.19	-1.2	-0.95	-6.0	-0.3%	-0.1%
Spk Delay Dev	1	0.28	10.4	0.28	10.4	0.1%	0.2%
Elect Tim Mod	1	-	-	-	-	-	-
Hoses	2	0.01	-0.5	0.02	-1.1	0.0%	0.0%
Wir/Hrns/Fuse	2	-	-	-	-	-	-
Other	2	-	-	-	-	-	-
EGR SYSTEM							-
Valv Assembly	12	-0.01	0.6	-0.11	6.7	0.0%	0.1%
Delay Solnoid	1	-	-	-	-	-	-
Cool Temp Sen	1	-0.02	0.3	-0.02	0.3	0.0%	0.0%
Hoses	8	0.05	-1.4	0.37	-10.9	0.1%	-0.2%
Other	5	0.62	11.3	3.09	56.4	1.0%	1.1%
AIR INJECTION SYSTEM							
Pump Assembly	5	7.93	41.1	39.66	205.6	12.3%	4.1%
Byps/Dump Vlv	3	-	-	-	-	-	-
Diverter Vlv	13	-1.45	-3.4	-18.87	-43.7	-5.9%	-0.9%

SUBSYSTEM REPAIRED		AVG REDUCTION PER REPAIR		ESTIMATE OF TOTAL REDUCTION		% OF ENTIRE CTP REDUCTION	
	N	HC	CO	HC	CO	HC	CO
AIR INJECTION SYSTEM (continued)							
Check Valve	31	0.35	3.8	10.77	117.6	3.3%	2.3%
Drive Belt	5	-0.04	0.1	-0.18	0.7	-0.1%	0.0%
Hoses	27	-0.24	0.5	-6.41	12.3	-2.0%	0.2%
Wir/Hrns/Fuse	2	0.02	0.4	0.04	0.8	0.0%	0.0%
Other	7	-0.30	-3.7	-2.08	-25.9	-0.6%	-0.5%
PCV SYSTEM							
Valv Assembly	3	-0.12	-0.8	-0.35	-2.4	-0.1%	0.0%
Filters	4	-	-	-	-	-	-
Hoses/Lines	3	-9.68	-35.3	-29.05	-105.8	-9.0%	-2.1%
Other	1	-	-	-	-	-	-
EXHAUST SYSTEM							
Exh Manifold	10	-	-	-	-	-	-
Catalyst	56	1.11	7.0	62.18	393.0	19.3%	7.8%
Other	2	0.50	12.3	1.01	24.6	0.3%	0.5%
EVAPORATIVE SYSTEM							
Evap Canister	1	0.08	0.3	0.08	0.3	0.0%	0.0%
Canister Purg	2	0.58	5.8	1.16	11.6	0.4%	0.2%
Hoses	3	0.02	0.2	0.06	0.5	0.0%	0.0%
Other	2	-	-	-	-	-	-
ENGINE ASSEMBLY							
Eng Assembly	3	0.63	16.6	1.89	49.7	0.6%	1.0%
Cooling Sys	7	-0.06	-1.5	-0.41	-10.8	-0.1%	-0.2%
Valve Adj	4	0.11	1.5	0.46	6.1	0.1%	0.1%
Belt Tension	1	-	-	-	-	-	-
Hoses	1	5.99	28.7	5.99	28.7	1.9%	0.6%
Eng Oil	2	-0.16	-0.8	-0.32	-1.6	-0.1%	0.0%
Other	3	0.46	1.9	1.39	5.7	0.4%	0.1%
THREE-WAY CATALYST SYSTEM							
ECU	19	0.40	10.7	7.68	203.5	2.4%	4.0%
O2 Sen	82	0.80	20.7	65.61	1698.0	20.4%	33.5%
Load Sensor	22	0.61	23.2	13.35	510.6	4.1%	10.1%
Eng Spd Sen	2	0.53	3.4	1.07	6.8	0.3%	0.1%
Cool Temp Sen	8	0.86	27.4	6.91	218.8	2.1%	4.3%
EGR Postn Sen	1	0.06	-12.8	0.06	-12.8	0.0%	-0.3%
A/F Cntrl Act	5	2.46	32.6	12.32	163.1	3.8%	3.2%
Air Bypas Sen	3	2.76	28.2	8.28	84.5	2.6%	1.7%
Air Divrt Act	4	0.12	-0.4	0.49	-1.6	0.2%	0.0%
ISC Sys	1	0.20	2.0	0.20	2.0	0.1%	0.0%
Hoses	18	0.37	-3.7	6.73	-66.5	2.1%	-1.3%
Other	2	-0.02	-0.7	-0.04	-1.4	0.0%	0.0%
MAT Sensor	3	-0.55	10.2	-1.65	30.5	-0.5%	0.6%
Wir/Hrns/Fuse	9	0.43	26.7	3.89	240.3	1.2%	4.7%
ALL	630	0.70	10.7	345.89	5455.8	107.5%	107.8%

[1] For a more complete description of the CTP program objectives, refer to "Program Plan: A Cooperative EPA/Manufacturer I/M Testing Program," U.S. EPA, Office of Mobile Sources, ECTD/TSS, January 1987.

[2] At the time the CTP was being designed, the Michigan AET database did not include fields for vehicle type (LDT or LDV), fuel metering type, and other vehicle identifiers that were factors in the CTP recruitment. Consequently, Michigan AET program statistics available to EPA were not specific enough to set the program quotas. Nevertheless, some summary information from those data are provided in Appendix A. For more details on the recruitment quotas, refer to the CTP program plan *op. cit.*.

[3] The safety and outlier rejection criteria were based upon the EPA Emissions Factors recruitment criteria, and included off-road use, major engine modifications, and excessive towing. Other such criteria were evaluated at the time of vehicle intake at the test site.

[4] Some manufacturers chose to begin their as-received testing with a simulation of the original AET test. Such a test was not part of the program plan, however, and data for these tests are not stored in the common CTP database.

[5] CTP Program Plan, *op. cit.*, pp. 21-25.

[6] This fact is the basis for including a restart requirement in the testing of Ford vehicles with unloaded versions of the EPA-approved performance warranty short tests (40 CFR 85.2201-2212)

[7] The criteria in the I/M Variability category actually involve a set of numerical comparisons between the emission results in the various modes and sequences of the Basic I/M Test Procedure. Details may be found in the CTP Program Plan *op. cit*.

[8] A generalized flow diagram of decision making in the CTP remedial maintenance phase appears in Figure 3 of the program plan, *op. cit*.

[9] Vehicle 256, a Ford Topaz, suffered a transmission failure during as-received testing and was removed from the program by the manufacturer. Vehicle 344, an Buick Electra, had a substantial leak in the catalyst as-received, and was not FTP tested for safety reasons; post-repair FTP testing was not performed due to the lack of an emissions baseline for the vehicle.

[10] Initial testing for three of the four (vehicles 215, 255, and 303)was terminated for safety reasons due to catalyst overtemperature, traced to malperformance of other components; the fourth had an ECM failure traced to a disconnected coolant temperature sensor.

[11] Unless otherwise specified, "AMC" encompasses AMC, Jeep, and Renault nameplates and "VW" encompasses VW of America and VW of Germany. Divisions of other manufacturers are grouped under the principal manufacturer name (e.g., Chrysler, Dodge, and Plymouth are grouped under Chrysler).

[12] Unless otherwise noted, the term "CO-only failure" refers to a vehicle that fails the relevant procedure (FTP, short cycle) for CO but passes HC; i.e., NO_x is ignored in the failure-type classification. Failures for "HC-only" are handled analogously. If no suffix appears on the failure type (e.g., "CO failure"), the classification was made blind to the pass/fail status of other pollutants. To simplify the tables and figures in this report, the "blind" category is rarely presented on its own, but the ordering of the other failure types has been chosen to permit easy summing of the HC-only or CO-only category with the HC+CO category, yielding the failures for one pollutant that are blind to the other.

[13] See, for example, Glover, E. L., and Brzezinski, D. J., MOBILE4 Exhaust Emission Factors and Inspection/Maintenance Benefits for Passenger Cars, US E.P.A technical report EPA-AA-TSS-I/M-89-3 (1989).

[14] The upper bounds for marginal emitters in MOBILE4 were determined by projecting a log-normal distribution onto the emissions of a large sample of in-use vehicles in each of several technology categories, applying a two-standard-deviation cutoff, and then back-calculating the emission values that corresponded to the cutoff.

[15] Limited sample sizes prevented application of the four emitter categories to light-duty trucks in the development of the MOBILE4 model. We have applied the categories to both LDVs and LDTs in the CTP analysis, however.

[16] Recall from Section 2.4 that Ford vehicles alone received a keyoff/restart step between idles in the core sampling periods throughout all sequences of the BITP except the Restart sequence. Because this was the baseline condition for Fords, the effect of the procedure design is still to isolate the impact of the intervening engine operation, which is the significant point for the analysis to follow.

[17] Note by recalling Table2 in Section 2.4 that because the restart step follows the RS-02 mode, XL-05 and RS-02 are procedurally identical.

[18] Almost all of the vehicles that were lost to this analysis were ones that received no Indolene Extended Loaded sequence following the as-received FTP. Such exclusions included all of the Chryslers and scattered cases from the other participants. Low incoming fuel levels in two vehicles (33 and 240) prompted substitution of commercial fuel during the Extended Loaded sequences of the tank BITP.

[19] The anomolous RVP of 5.0 for vehicle 613 was verified with the manufacturer (Nissan) but remains unexplained.

[20] "Excess" emissions are defined as that portion of the emissions above the certification level for the vehicle, with HC and CO treated separately. "Total excess" is the sum of the individual excess emissions of each vehicle. At this point and for the remainder of this report, the excess is set to zero for clean vehicles -- those whose emissions are below the certification standard. Earlier analyses in this report treated clean vehicles as negative excess.

[21] Glover, E. L., and Brzezinski, D. J., *op. cit.*