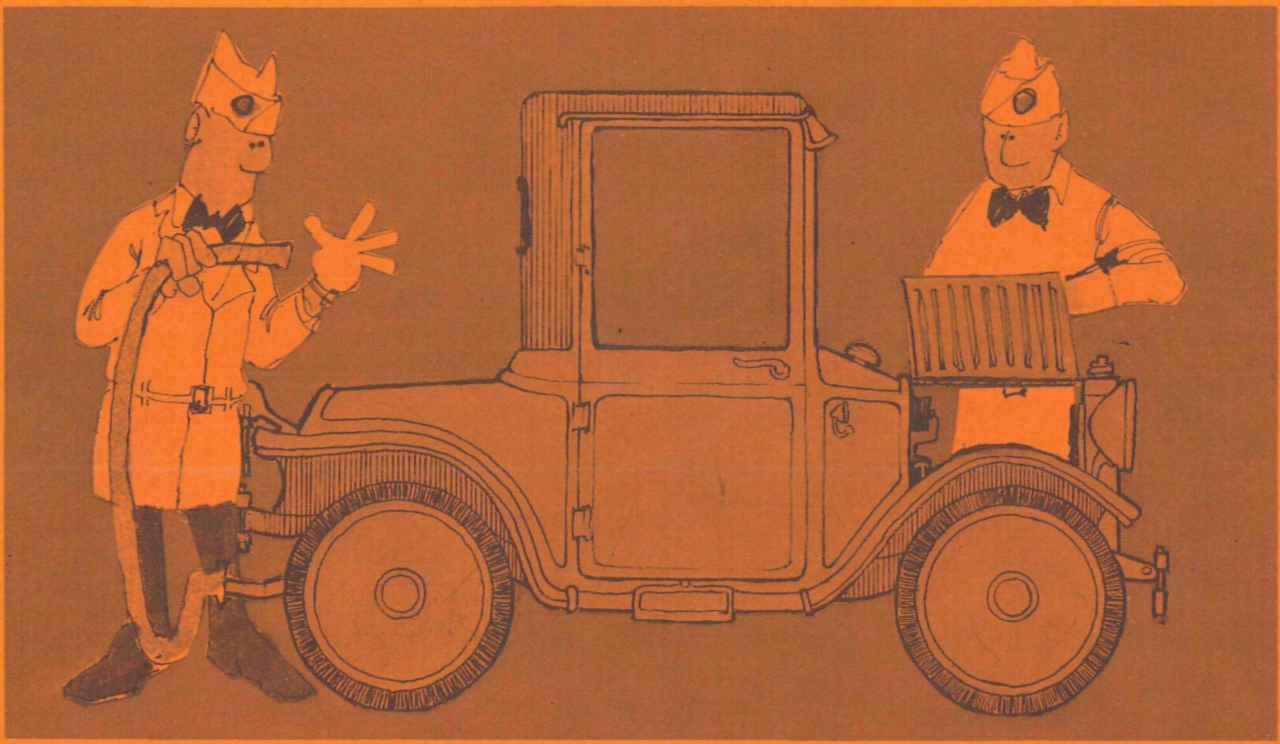
A Study of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions

Volume VIII. Experimental Characterization of Vehicle Emissions and Maintenance States



FINAL REPORT

July 1973

In Support of:
APRAC Project Number CAPE-13-68

for

Coordinating Research Council, Inc.
Thirty Rockefeller Plaza
New York, New York 10020

and

Environmental Protection Agency
Air Pollution Control Office
5600 Fishers Lane
Rockville, Maryland 20852

TRW. TRANSPORTATION & ENVIRONMENTAL OPERATIONS
ONE SPACE PARK • REDONDO BEACH CALIFORNIA 90278

SCOTT RESEARCH LABORATORIES, INC.
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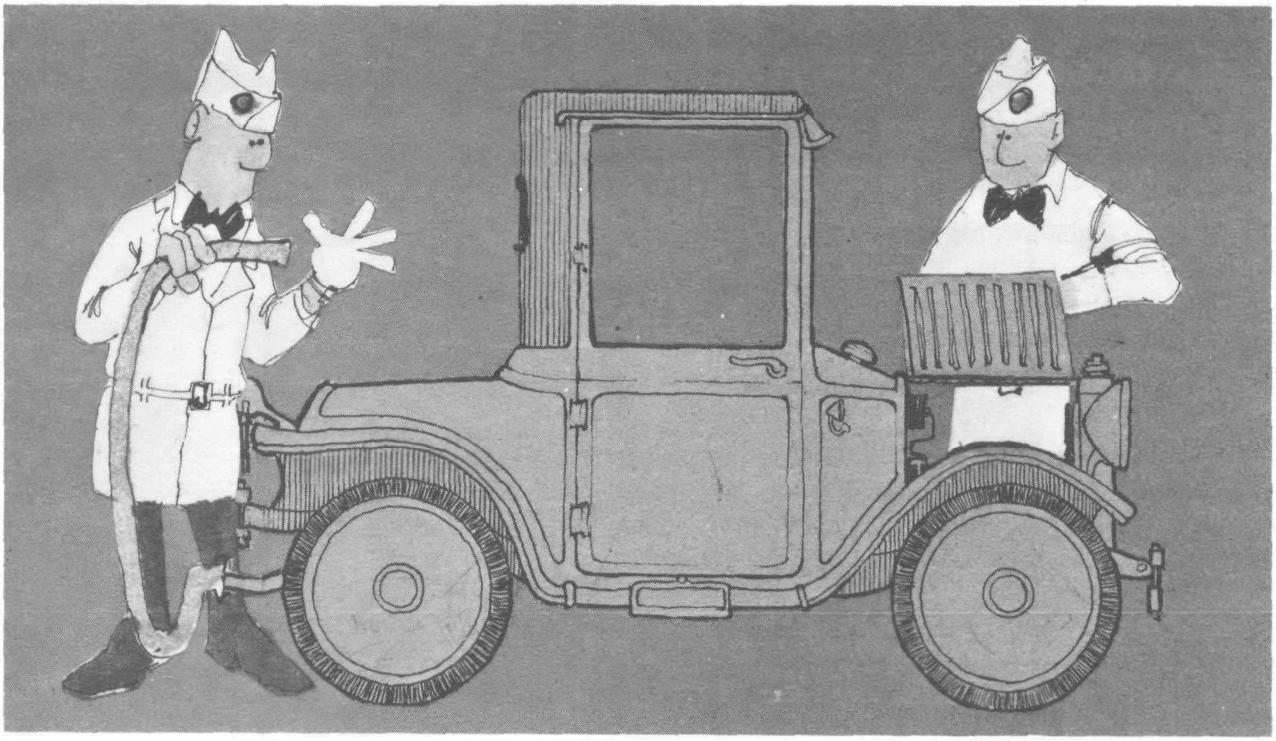

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PREFACE

This report, "A Study of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions," consists of eight volumes. The following are the subtitles given for each volume:

- Executive Summary, Volume I, Final Report, July 1973
- Mandatory Inspection/Maintenance Systems Study, Volume II, Final Report, July 1973
- A Documentation Handbook for the Economic Effectiveness Model, Volume III, Final Report, July 1972
- Experimental Characterization of Vehicle Emissions and Maintenance Studies, Volume IV, Year End Report, July 1972
- Experimental Characterization of Service Organization Maintenance Performance, Volume V, Final Report, July 1972
- A Comparison of Oxides of Nitrogen Measurements Made with Chemiluminescent and Non-Dispersive Radiation Analyzers, Volume VI, Final Report, July 1972
- A User's Manual and Guide to the Economic Effectiveness Computer Program, Volume VII, Final Report, July 1973
- Experimental Characterization of Vehicle Emissions and Maintenance States, Volume VIII, Final Report, July 1973

The first volume summarizes the general objectives, approach and results of the study. The second volume presents the results of a mandatory inspection/maintenance system study conducted with a computerized system model which is described in Volume III. The experimental programs conducted to develop input data for the model are described in Volume IV (Interim Report of 1971-72 Test Effort), V, VI, and VIII. Volume VII is a user's manual for the computer code and Volume VIII reports the experimental program and data obtained in the final test phase of the investigation.

The work presented herein is the product of a joint effort by TRW Systems Group and its subcontractor, Scott Research Laboratories. TRW, as the prime contractor, was responsible for overall program management, experimental design, data management and analysis, and the economic effectiveness study. Scott acquired and tested all of the study vehicles. Scott also provided technical assistance in selecting emission test procedures and in evaluating the test results.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONT'D.)

LIST OF FIGURES (CONT'D.)

LIST OF TABLES

LIST OF TABLES (CONT'D.)

LIST OF TABLES (CONT'D.)

LIST OF TABLES (CONT'D.)

1.0 INTRODUCTION

A twenty month vehicle emission and related engine tune-up parameter deterioration investigation was performed to provide empirical data for the Economic Effectiveness Model which was developed in the Study of Mandatory Engine Maintenance for Reducing Vehicle Emissions. This was the most recently completed in a series of experimental studies that were conducted as part of the Vehicle Inspection and Maintenance Study.

The "Experimental Characterization of Vehicle Emission and Tune-Up Parameter Deterioration" involved a large scale fleet evaluation to determine vehicle tune-up setting and component deterioration characteristics with time and mileage. The results of the first year of this program were reported in Volume IV, "Experimental Characterization of Vehicle Emissions and Maintenance States," Year End Report, July 1972 (Reference 1). This report presents the procedures, data, and results for the entire twenty month program.

Interim analyses of data suggested that two sub-experiments were necessary to properly interpret the data taken during this experiment. One consisted of the development of the run-to-run repeatability of emission measurements and the other was the characterization of emissions measured using 1972 Federal Procedure as a function of the cold soak temperature.

The Deterioration Experiment is presented in Section 2.0, and the two sub-experiments investigating measurement repeatability and the effect of cold soak temperature on emissions are respectively presented in Sections 3.0 and 4.0.

2.0 EXPERIMENTAL CHARACTERIZATION OF VEHICLE EMISSIONS AND TUNE-UP PARAMETER DETERIORATION

2.1 INTRODUCTION

The objective of this program was to determine the deterioration rates of engine tune-up settings and components and the corresponding emissions of privately owned and operated vehicles. The deterioration of emissions and adjustments with both time and mileage were studied for a period covering sixteen months of typical driving. These deterioration rates were required to provide a more accurate data base in the Economic Effectiveness model for the model's predictive output.

The tune-up settings and components that were to be evaluated consisted of the following:

1. Basic ignition timing
2. Idle speed
3. Idle air/fuel ratio (% CO)
4. PCV valve and system performance
5. Air filter restriction
6. Primary ignition system condition
7. Secondary ignition system condition
8. NO_x control system operation
9. Choke diaphragm or piston setting
10. Heat riser valve operation
11. Air injection system performance

The exhaust emission data that were required included measurement of unburned hydrocarbons, carbon monoxide, and oxides of nitrogen. Exhaust gas mass emissions were measured using both the current Federal test procedure and a short cycle. Emission concentration measurements were also made in selected engine operating modes.

2.2 TEST PROCEDURE

Four hundred fifty (450) vehicles were initially obtained from private owners for testing. The vehicles were subsequently recalled for testing at scheduled four-month time intervals. Four recalls were scheduled, thus providing five test periods covering sixteen months of owner operation for each vehicle. Of the original 450 vehicles, 413, 392, 367, and 330 were obtained for each subsequent test. Testing was initiated in May of 1971 and completed in January of 1973.

Engine tune-up adjustments and component replacements as well as vehicle exhaust emissions were quantitatively measured at each scheduled test. The following measurements were made on each vehicle at the four-month intervals:

- Quantitative measurement of engine components, parameters, and settings that were shown in Phase One of the CAPE-13-68 Program to be significant in an emission control program.
- Exhaust emissions using the 1972 Federal test procedure and the Federal short cycle. During the eighth month of the program the 1972 Federal test procedure was replaced with the 1975 procedure.
- Closed, hot seven-mode cycle CVS mass emissions, at the time of the first test.
- Concentration of exhaust emissions at idle and under loaded engine operating conditions.

The total fleet was divided equally into three groups of 150 vehicles based upon model years which reflected the extent of their emission control equipment. The basic description of the fleets were Pre-Emission Controlled Vehicles (pre 1966), Vehicles with HC and CO exhaust emission controls (1966-1970), and NO_x Emission Controlled Vehicles sold in California during the 1971 model year.

To characterize deterioration of engine parameters with both time and mileage accumulation, it was necessary to establish a baseline from which deterioration could be monitored. This was accomplished by adjusting or replacing components in accordance to the manufacturer's specifications at the beginning of the deterioration test period. The emission and engine diagnostic tests were made both before and after the initial tune-up. After the vehicles received their last test for deterioration, they were again returned to specifications and retested.

2.2.1 Vehicle Sample Identification and Acquisition Procedures

Fleet Acquisition

Three fleets of 150 vehicles were each selected and acquired by Scott. Candidate vehicles were first identified from a file of Scott questionnaires. Only the questionnaires returned by owners who indicated an interest in participating in an experimental program were considered. During the first four months of initial vehicle acquisition, the owners of needed vehicles were contacted, given an explanation of the program and incentive provided, and if they were willing to participate, their vehicle was scheduled for testing.

The owners of vehicles used in the program were always supplied with a 1971 loan vehicle while their car was under test. In addition, maintenance of their vehicle was performed at the beginning and end of the program at no cost. A cash and gasoline incentive was also given to owners at each test interval when no tune-up was performed. The cash incentive was $15 for 1971 model year vehicles and $10 for all earlier model year vehicles. Each owner's vehicle received five gallons of premium grade gasoline upon completion of tests.

The vehicles that were supplied as loan vehicles were new, major manufacturer, 1971 intermediate size vehicles, equipped with standard V-8 engines and automatic transmissions. There were twenty of these loan vehicles and they were included in the California NO_x Controlled vehicle fleet.

Fleet Identification and Description

Vehicles included in the experimental program were limited to passenger vehicles and light duty trucks which were classified in one of three categories. Each category consisted of 150 vehicles at the initial implementation of the program (test phase 1). The specific classifications of each category were:

Fleet I - Vehicles with no exhaust emission controls (pre-emission controlled vehicles), which included all 1960 through 1965 model year vehicles and 1966 and 1967 model year vehicles that were originally purchased outside California. (The majority of vehicles were originally purchased in California and were equipped with Positive Crankcase Ventilation Systems.)

Fleet II - Vehicles equipped with exhaust emission controls (emission controlled vehicles), which included California vehicles from model years 1966 through 1970 and out-of-state purchased vehicles from model years 1968 through 1970.

Fleet III - Vehicles originally sold in California for the 1971 model year (NO_x controlled vehicles), which were required to meet NO_x emission standards.

Vehicles of various manufacture were obtained in proportion to the national in-use population, within the fleet groupings, as determined by vehicle registration data provided in the most recent Automotive News Almanac, (Reference 2). The proportioning was based on vehicle make and model year and within attainable goals; vehicle size, transmission type and number of engine cylinders. A description of the initial program goals for the distribution of makes within each fleet is presented in Table 2.1.

The distribution of vehicle makes was controlled for only U.S. makes and Volkswagens. All other foreign vehicles were combined into the miscellaneous category. The percentage of foreign vehicles (Volkswagens included) was to be limited to 10 percent of Fleets I and II and to 20 percent of Fleet III. Deviations from the above criteria were required due to the low number of available 1960 through 1962 vehicles as well as the low availability of American Motors Corporation and Oldsmobile vehicles for most years.

Table 2.1

In-Use Percent of Vehicle Population by Make and Number Desired for Each Fleet Classification

	Fleet #1		Fleet #2		Fleet #3	
	Uncontrolled		Controlled		1971 California	
Vehicle Make	%	Number	%	Number	%	Number
Buick	5.6	9	6.1	11	5.8	10
Cadillac	2.0	4	2.1	4	1.9	3
Chevrolet	24.8	41	20.1	35	20.2	33
Chrysler	1.8	3	2.0	3	2.5	4
Dodge	4.8	8	5.6	10	6.3	10
Ford	19.8	33	18.3	31	22.8	37
Mercury	3.8	6	3.4	6	4.2	7
Oldsmobile	6.0	10	5.9	10	6.1	10
Plymouth	5.6	9	7.0	12	8.5	14
Pontiac	7.7	13	7.8	13	6.0	10
Rambler	4.2	7	2.6	4	3.3	5
Volkswagen	4.0	7	6.3	11	4.2	7
Miscellaneous	9.9	0	12.2	0	8.2	0
TOTAL	100	150	100	150	100	150

The ratio of automatic to manual transmissions was matched to production statistics for each fleet. The percentage of six cylinder and V-8 engines was maintained only across the entire 450 vehicles sample. The number of vehicles in Fleet II that were equipped with Air Injection emission control systems was limited to 20 percent of that fleet.

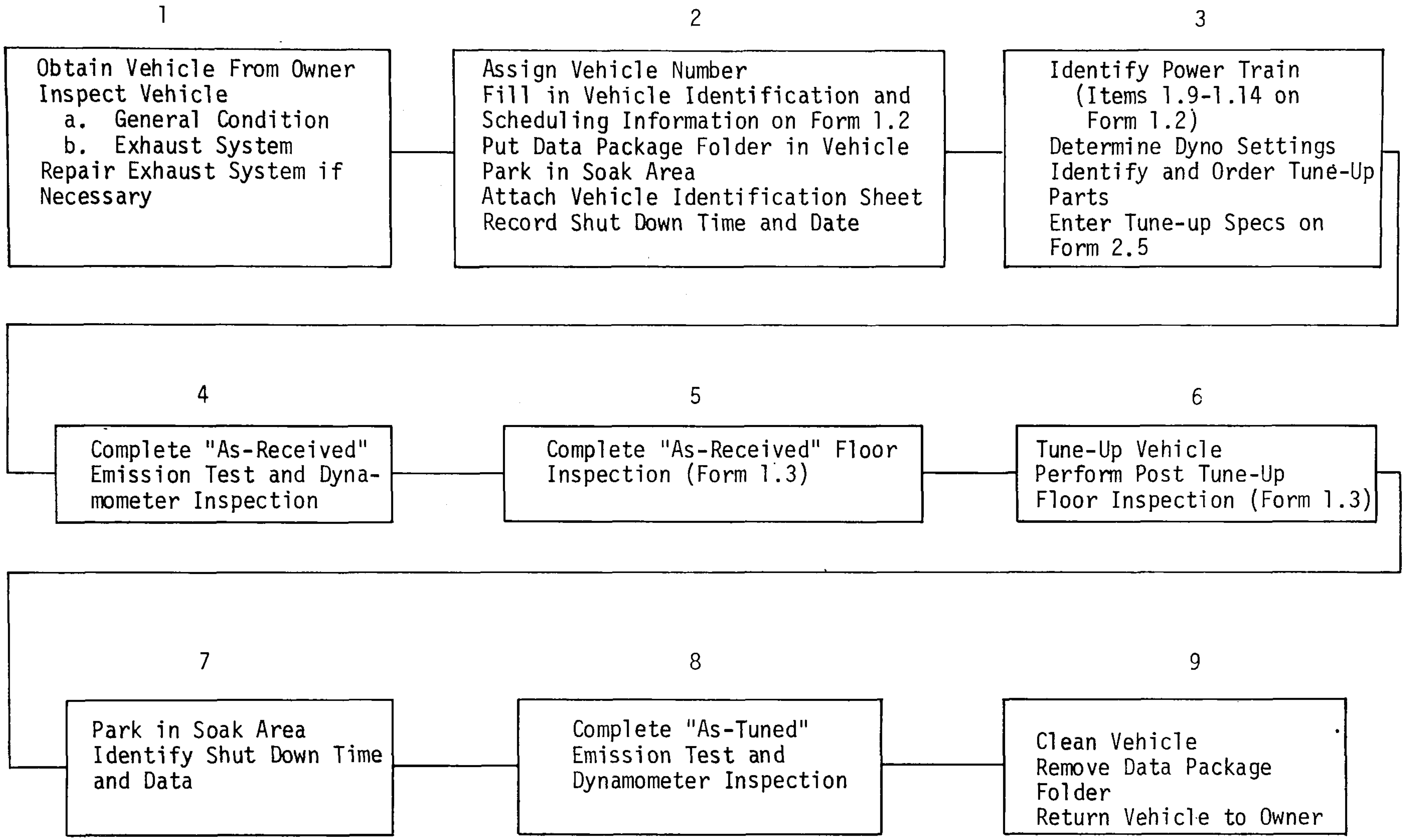
Initial Vehicle Scheduling and Control

Vehicles were scheduled for testing on a continuous basis during the first four months of testing. Once these vehicles were obtained they were processed according to the Test Vehicle Processing Sequence illustrated in Figure 2.1. The specific details of the sequence elements are described as follows:

Sequence Element 1 - Owners were contacted as vehicles were required and appointments were made for delivery of the vehicles to the Scott facility. Each vehicle was inspected by Scott personnel to determine the condition of the body sheet metal, interior trim and mechanical items. The exhaust system of the vehicle was leak checked by blocking the tail pipe outlet. Repairs were made if leaks were detected in the exhaust system.

Sequence Element 2 - Vehicle numbers were assigned on the following basis: Fleet I - 1 through 150, Fleet II - 151 through 300, and Fleet III - 301 through 450. A data package folder was placed in and remained with the vehicle during test and inspection. This folder was kept on file until the next time the vehicle was recalled for testing. The Vehicle Control Log, Figure 2.2, was included in the folder. The vehicle identification items 1.1 through 1.8 and scheduling information items 2.3 and 2.4 were filled out. The Engine Parameter Inspection Forms, described in Section 2.2.2 were also included. All forms were identified with the vehicle and test numbers. The vehicle was then parked in a designated cold soak area. A Vehicle Identification Sheet was placed in the vehicle to identify the vehicle and test number along with the date and starting time of the soak period.

Sequence Element 3 - While the vehicle was being cold soaked, the power train was identified by use of engine codes and carburetor numbers. Items 1.9 through 1.14 of the



- Elements Required for Recall Tests Except Test 5

FIGURE 2.1 TEST VEHICLE PROCESSING SEQUENCE

Figure 2.2 Vehicle Control Log

FLEET DETERIORATION PROGRAM
FORM 1.2

Vehicle Control Log

Test No. 1 [1A]
Car No. 2 [205]

Curb Weight 3750 + 300 lbs = 3 [4050]

Inertia Weight 4000   Indicated HP 8.0

1. Vehicle Identification

1.1	Year	4 [68]	1.9	Engine Size, CID	6	383
1.2	Make	5 [Plymouth]	1.10	Horse power	7	330
1.3	Model	Road Runner	1.11	Carb Make and Bbls	8	Holley , 4
1.4	Color	Blue	1.12	Transmission Type	9	Auto
1.5	License No.	ZZT 088	1.13	Exh. Emiss. Sys.	10	C.A.P.
1.6	Owner's Name	J. Welstand	1.14	Crankcase Emiss. Sys.	11	4
1.7	Telephone No.	862-7757				

1.8 Address 26021 18th Street, San Bernardino, California

2. SCHEDULING INFORMATION

2.1	Next Due Date				10/28/71	2/28/72	6/28/72	____	
2.2	Test No.		1A	1B	2	3	4	5A	5B
2.3	Odometer Reading	12	35414		38185	40327			
2.4	Date Obtained	13	6-22-71		11-1-71	2-24-72			
2.5	Vehicle Checked		M.Y.		B.B.	M.Y.			
2.6	Tune-Up Completed			JW					
2.7	Inspection Completed		JW	JW	LA	KRT			
2.8	Test Completed		JC	JC	BS	MM			
2.9	Date Returned								
2.10	Incentive/Vehicle								
	o Received by								

3. OWNER INQUIRY   Response

Type of Repair

__ Minor

14 __ Major (REL)

__ General

Minor - Ignition tune-up only

Major - Ignition tune-up and carburetor rebuild or replace

General - All other

Table 2.2

Crankcase Ventilation System Type Codes

1.	PCV Valve Only - Controlled by Manifold Vacuum (Open System)
2.	Valve Only - Controlled by Crankcase Vacuum
3.	Hose from Crankcase to Air Cleaner Only (Like VW)
4.	Combination System - PCV Valve and Hose to Air Cleaner (Closed System)

Vehicle Control Log were completed. The crankcase emission system type was identified and coded as described in Table 2.2. The codes, 1 through 4, are consistent with the nomenclature used for California vehicle emission installation and inspection stations, (Reference 3). The vehicle curb weight was determined from specifications listed in the Automotive News Almanac. The appropriate dynamometer inertia and indicated horsepower setting was then determined in accordance with the 1972 Federal test procedure. These settings were entered at the top of the Vehicle Control Log. The vehicle drive train description was used to identify and order the basic tune-up parts. The tune-up specifications were also determined and entered on the Engine Parameter Inspection Forms (Section 2.2.2).

Sequence Elements 4, 5, 6, 7, and 8 - The required emission tests, parameter inspections and tune-up were then performed in the sequence depicted in Figure 2.1. The details of these elements are fully described in Sections 2.2.2 and 2.2.3.

Sequence Element 9 - Upon completion of all required testing, the vehicle was washed, the data package folder was removed, and the owner was contacted to arrange for the return of the vehicle.

Recall Scheduling and Control

The first test sequence was designated as Test 1A and Test 1B for the "as-received" and "post tune-up" tests, respectively. The four month recall tests were sequentially numbered Tests 2 through 5. The recall tests 2 through 4 required only the elements 1, 2, 4, 5, and 9 of the Test Vehicle Processing Sequence, Figure 2.1. The final test sequence designated as Test 5A and 5B was performed in a manner similar to the first test sequence.

Vehicle recalls were scheduled at approximate four-month intervals from the initial test date. Minor deviations from the four-month interval were required due to the specific availability of vehicles from their owners and for efficient usage of facilities and time. At each recall the vehicle information such as mileage and owner maintenance was recorded on the appropriate forms. Additional procedures were implemented during the program because an increasing number of vehicles received owner provided maintenance as the program progressed. The procedures for identifying unscheduled maintenance and repairs are presented in Section 2.2.2.

The additional procedures which were implemented during the test program for vehicles that received unscheduled maintenance were designed to maximize the useful data obtained for the basic program. During Tests 2 and 3 those vehicles receiving minor tune-up repairs and adjustments were processed according to the basic test plan. The repairs and adjustments were documented for future data analysis. Those vehicles that received major or extensive engine maintenance were reinitialized. Reinitialization consisted of assigning a new number to the test vehicle, performing an initial tune-up and/or inspection, and starting the test series over, beginning with Test 1.

At Test 4 it was found that a substantial number of vehicles were requiring tune-ups after twelve months of operation. It was deemed advisable on these vehicles to perform the deterioration test, the tune-up, and "post tune-up" test at this time. The vehicles were assigned new numbers as in the previous cases. In addition, these vehicles were recalled at the fifth test period for one additional test which would be similar to Test 2 of the original sequence. This was possible since the tune-up and emission test at Test 4 served as an initialization. Also, vehicles that had received unauthorized maintenance since the previous test were processed in the same manner - "as-received" test, tune-up, "post tune-up" test, assignment of a new vehicle number, and scheduled recall for one additional Test 2. A Fleet Deterioration Vehicle Scheduling Control, Form 1.5 (Figure 2.3) was used at Test 4 to facilitate decision making by test personnel, assure proper handling as outlined above, and document the work performed. At test period 5, a similar form was used as a follow-up and for the same purposes as at Test 4. This Form is shown in Figure 2.4.

FLEET DETERIORATION VEHICLE SCHEDULING CONTROL
FORM 1.5

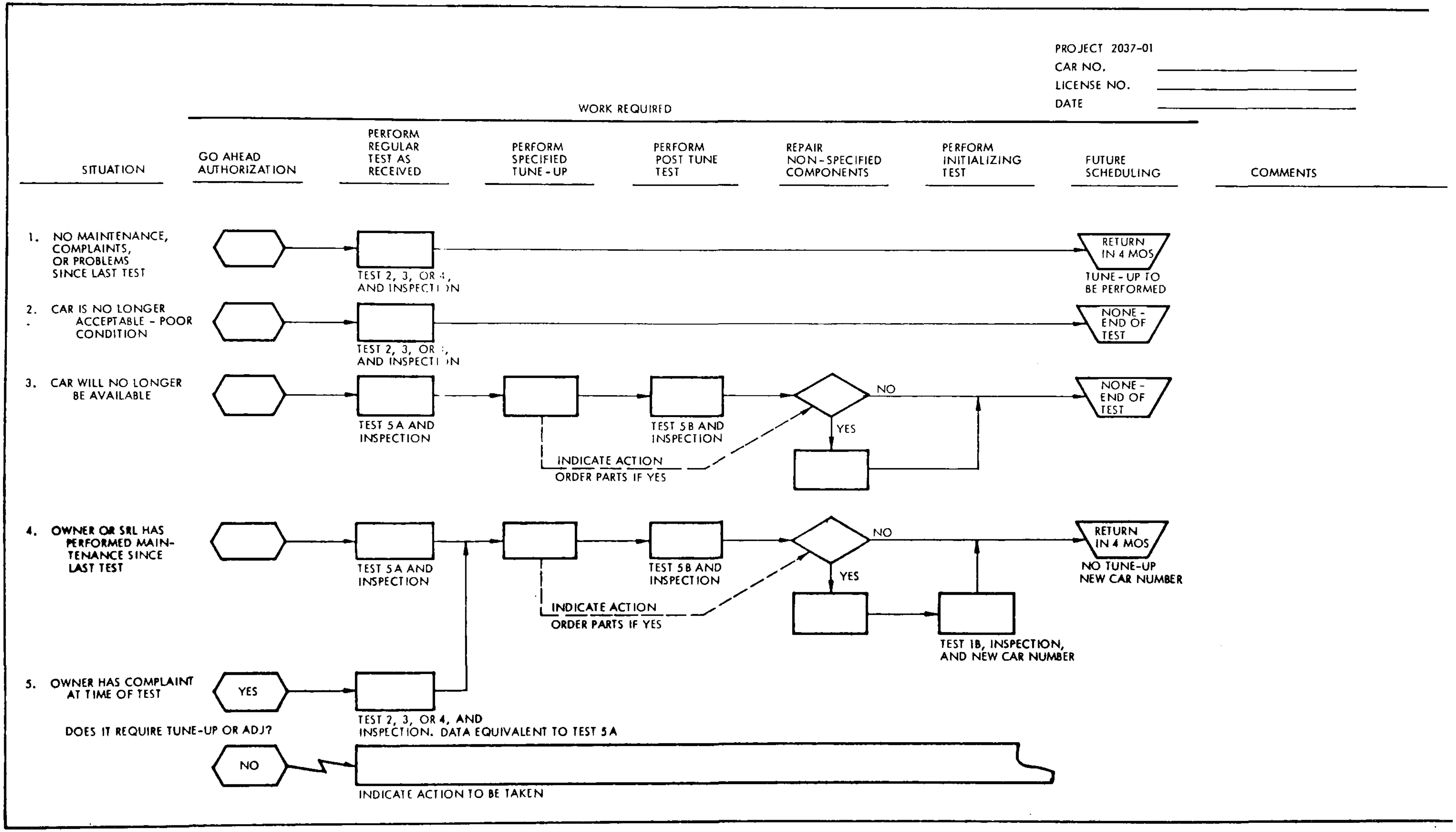


Figure 2.3 Test 4 Vehicle Scheduling Control

FLEET DETERIORATION VEHICLE SCHEDULING CONTROL

FORM 1.5

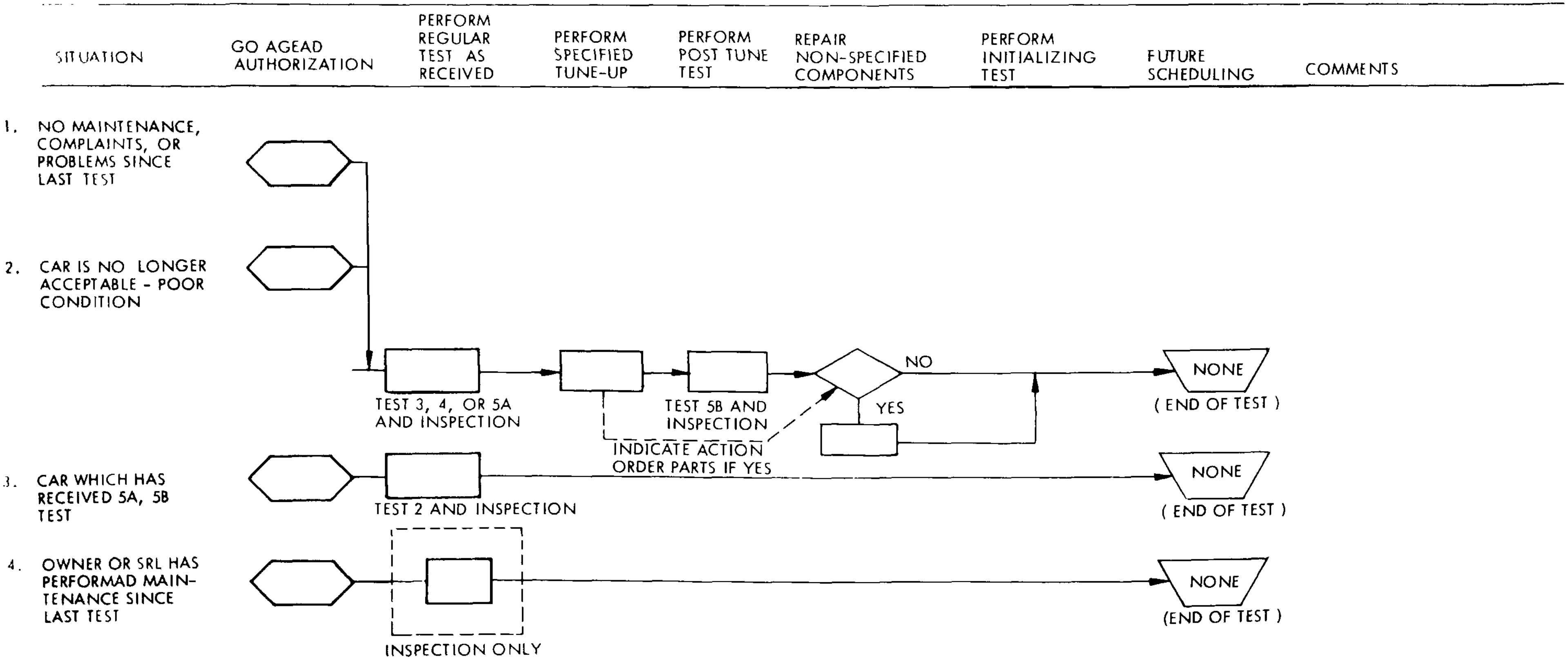
PROJECT 2037-01

CAR NO. ____________

LICENSE NO. ____________

DATE ____________

WORK REQUIRED



NOTE: OWNER COMPLAINTS WILL BE CORRECTED AFTER TEST 5B OR 2.

Figure 2.4 Test 5 Vehicle Scheduling Control

2.2.2 Vehicle Inspection and Tune-Up Procedures

Inspection Procedures

A comprehensive engine parameter adjustment and component inspection was performed in conjunction with each scheduled emission test. The engine inspection was designed to quantitatively evaluate those engine settings and components that affect vehicle emissions. The inspection covered the ignition system, induction system, and emission control devices. Measurements of ignition misfire, air cleaner blockage, PCV system performance and air injection pump system performance were made with the engine under load on a chassis dynamometer. Figure 2.5, Engine Parameter Inspection, was used to record all engine inspection information.

The procedures used for obtaining the measurements recorded on the Engine Parameter Inspection form are outlined below and relate to the item numbers on Figure 2.5. Figure 2.6 shows an acceptable ignition pattern and its nomenclature.

(2.) Ignition System Inspection

(2.1) Required Voltage

The parade display of the ignition scope is selected with the engine operating at 1500 rpm, no load. The minimum and maximum firing line voltage readings are recorded.

(2.2) Coil Available Voltage

The same operating conditions as described in item 2.1 are employed, except one secondary ignition wire is disconnected for an open ignition circuit condition. The maximum voltage output that is observed for the open circuit cylinder is recorded.

(2.3) Spark Line

With the engine still operating at 1500 rpm and the transmission set in neutral, the scope is set for stacked or raster display. The spark lines are rated OK if they are generally clean and level. Excessive slope or noise for any cylinder is rated NO (no good).

FLEET DETERIORATION PROGRAM

FORM 1.3

Engine Parameter Inspection
Performed By
SCOTT RESEARCH LABORATORIES, INC.

1. Vehicle Identification

- 1.1 Test No. 1 1A
- 1.2 Car No. 2 205
- 1.3 License No. ZZT 088
- 1.4 Inspected By JH
- 1.5 Date 6-24-71

2. Ignition System Inspection

Item		Measurement or Analysis			Manufacturer's Specification	
2.1 Required Voltage, kv at 1500 rpm	3	5-8	kv	4		kv
2.2 Coil Available Voltage, kv at 1500 rpm	5	36	kv	6		kv
2.3 Spark Line (OK, NG)	7	NG				
2.4 Coil Oscillations (OK, NG)	8	NG				
2.5 Point Opening Variation, degrees	9	2	°			
2.6 Coil Polarity (OK, NG)	10	OK				
2.7 Ignition Point Dwell, degrees	11	35	°	12	27-32	°
2.8 Condenser Oscillations (OK, NG)	13	OK				
2.9 Basic Ignition Timing, degrees	14	BTDC	°	15	BTDC	°
2.10 Total Advance at 2500 rpm, degrees	16	50	°	17	41-50 1/2	°
2.11 Mechanical Advance, at 2500 rpm, degrees	18	28	°	19	23-26 1/2	°
2.12 Vacuum Advance at 2500 rpm, degrees	20	22	°	21	18-24	°

3. Induction System

REL

Item		Measurement or Analysis			Manufacturer's Specification	
3.1 Idle Speed, rpm (Chrys. in Neutral) N__ Dr X	1	650	rpm	2	600	rpm
3.2 Manifold Vacuum, in. Hg.	3	15	"	4		"
3.3 Air Cleaner Angle, degrees	5	0	°	6		°
3.4 Float Level, inches*	7	X	"	8		"
3.5 Choke, Vacuum Kick, inches	9	.081	"	10	.081	"
3.6 Choke Vacuum Diaphragm (OK, NG, None)	11	OK				
3.7 Heat Riser Valve (None, Free, Frozen)	12	FREE				

* On parking lot survey only

Figure 2.5 Engine Parameter Inspection

FLEET DETERIORATION PROGRAM

FORM 1.3 (Continued)

		Measurement or Analysis		Manufacturer's Specification
4. Emission Control				
4.1 PCV Perf. at Idle, inches H_2O**	13	-.1	"	
4.2 Vacuum Leaks (Yes or No)	14	NO		
4.3 Idle rpm change (Leaks Eliminated)	15	X	rpm	
4.4 NO_x Control Device (Ok, NG, None)	16	NONE		
4.5 Timing Retard Mechanism (OK, NG, None)	17	NONE	REL	

5. Keymode Diagnostic Inspection

Dyno Load Set to 30 HP at 50 MPH

5.1 49/45 MPH Cruise				
o Plug Req'd Volt, kv	1	7-9	kv	
o Misfire Rate, %	2	0	%	
o Air Cleaner Restriction, in H_2O	3	.2	"	
o PCV Flow, inches	4	.40	"	
o Air Pump Disconnected, Emissions		Completed By ______________		
5.2 33.5/30 MPH Cruise				
o Plug Req's Volt, kv	5	8-10	kv	
o Misfire Rate, %	6	0	%	
o Air Cleaner Restriction, in H_2O	7	.1	"	
o PCV Flow, inches	8	.40	"	
o Air Pump Disconnected, Emissions		Completed By ______________		
5.3 Idle (in Drive)				
o Plug Req'd Volt, kv	9	12-15	kv	
o Misfire Rate, %	10	0	% REL	
o Air Pump Disconnected, Emissions		Completed By ______________		

REMARKS: High point resistance

** Vacuum is minus (-), and Pressure is plus (+)

Figure 2.5 Engine Parameter Inspection (Continued)

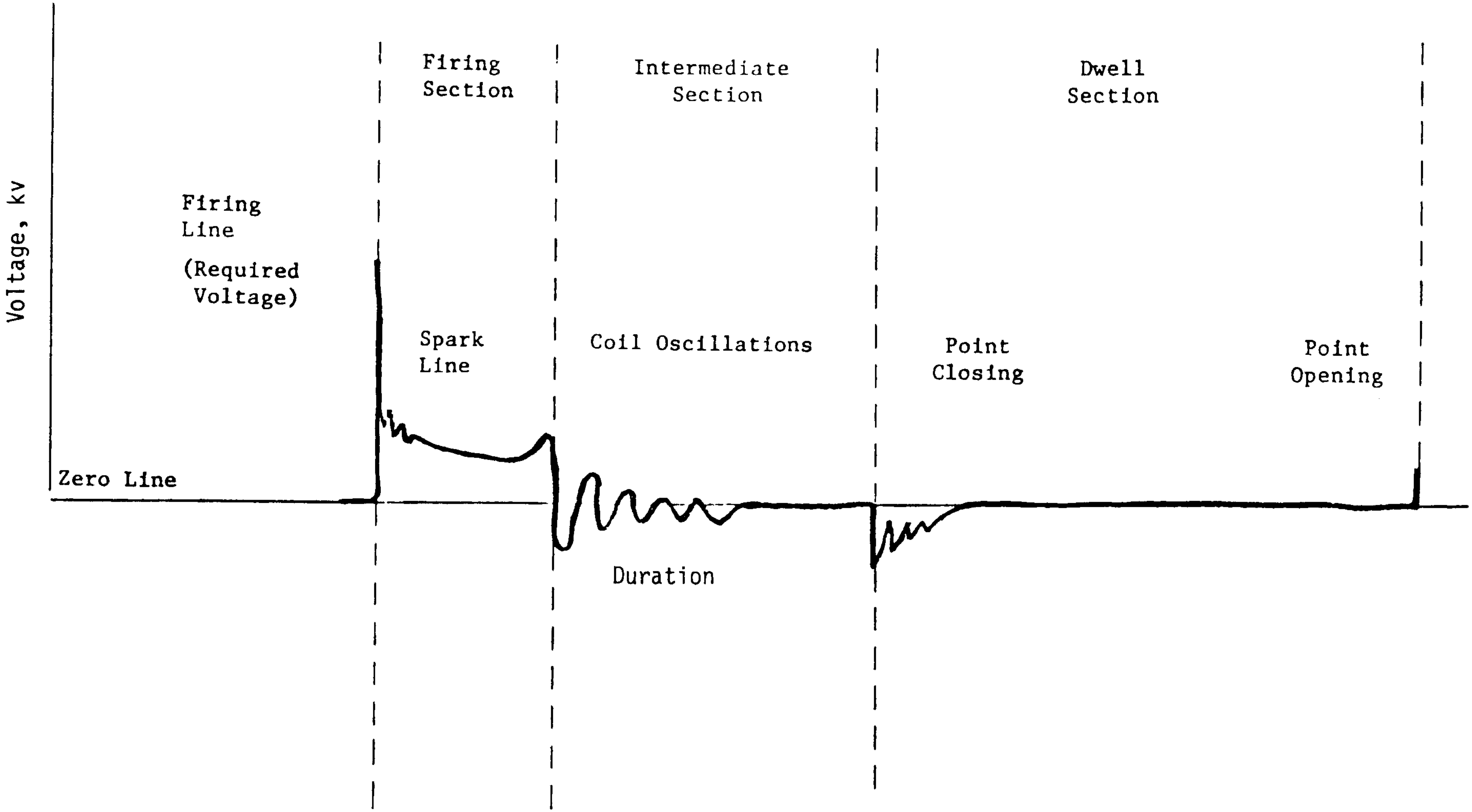


Figure 2.6 Engine Analyzer Ignition Pattern

(2.4) Coil Oscillations

Four or more oscillations are required for an OK rating. The ignition scope and engine rpm are set as described for item 2.3.

(2.5) Point Opening Variation

The engine is operated as described above and the scope is set for a superimposed display of cylinder ignition patterns. The difference in timing (point opening) between the cylinder with the earliest timing and the cylinder with the latest timing is recorded.

(2.6) Coil Polarity

If the ignition pattern is reversed on the vertical scale (upside-down), the coil polarity is reversed and rated NG.

(2.7) Ignition Point Dwell

The conventional (average point) dwell is recorded with the engine at idle.

(2.8) Condenser Oscillations

Oscillations must be observed and the first oscillation must have the greatest magnitude for an (OK) rating.

(2.9) Basic Ignition Timing

The distributor vacuum line is disconnected and the timing is recorded in accordance with the manufacturer's specified procedure.

(2.10) Total Advance at 2500 rpm

The engine is run at 2500 rpm in neutral and the total advance in ignition timing from the basic timing is recorded.

(2.11) Mechanical Advance at 2500 rpm

The same operating conditions as 2.10 are employed, except that the distributor vacuum line is disconnected. The advance in ignition timing from the basic timing is recorded.

(2.12) Vacuum Advance at 2500 rpm

The reading for 2.11 is subtracted from the reading for 2.10 to obtain the value for the vacuum advance.

(3.) Induction System

(3.1) Idle Speed

The idle rpm is measured with a tachometer according to the manufacturer's specified procedure (includes proper operation of transmission, air conditioning, evaporative control system, headlights, etc.).

(3.2) Manifold Vacuum

The manifold vacuum is obtained with the engine idling and the transmission set in neutral.

(3.3) Air Cleaner Angle

The vehicle's air cleaner element is placed on a commercial air cleaner tester and the relative restriction is indicated in angular degrees.

(3.4) Float Level

Not measured

(3.5) Choke Vacuum Kick

The choke vacuum diaphragm or piston setting is measured according to the manufacturer's procedure with a gauge pin. Various nomenclatures for this setting are Vacuum Kick, Vacuum Break, Choke Plate or Valve Pulldown, Choke Opening, Choke Vacuum Piston, Intermediate Choke Rod and Initial Choke Opening.

(3.6) Choke Vacuum Diaphragm

On those vehicles equipped with a choke vacuum diaphragm, vacuum is applied to the diaphragm. If the diaphragm does not retract, it is failed and NG is recorded. OK is recorded if it is operational.

(3.7) Heat Riser Valve

On vehicles equipped with an exhaust heat riser valve the valve is inspected manually for freeness of operation. If the operation is not free, a FROZEN rating is entered. Acceptable operation is rated OK.

(4.) Emission Control

(4.1) PCV Performance at Idle

With all the vehicle's PCV system components properly installed, the crankcase vacuum is measured at the oil dipstick tube. The vacuum or pressure is recorded in inches of water. The fresh air inlet to the PCV system is not blocked off with this procedure.

(4.2) Vacuum Leaks

Accessory vacuum hose leaks are diagnosed at idle by pinching off each hose individually near its source of vacuum. A leak is detected if the idle quality changes noticeably (or the idle rpm changes).

(4.3) Idle rpm Change

If an idle rpm change is detected in item 4.2, the difference in rpm is recorded.

(4.4) NO_x Control Device

Vehicles that have a distributor vacuum advance that is controlled by either speed or transmission gear engagement are evaluated for proper operation of the vacuum advance control. The vehicle is gradually accelerated from idle to about 40 mph on the chassis dynamometer. If the vacuum advance control does not operate according to the manufacturer's specifications within reasonable limits, the device is rated NG.

(4.5) Timing Retard Mechanism

Dual diaphragm distributors and solenoid operated retard mechanisms are evaluated for proper operation. Either the retard side vacuum hose or electrical connection is disconnected and the change in ignition timing is observed. If there is a shift in ignition timing in the correct direction, the unit is rated OK.

(5.) Keymode Diagnostic Inspection

An evaluation of firing voltage, ignition misfire, air cleaner restriction, PCV system flow, and air injection pump performance is made using the Clayton Keymode Cycle diagnostic modes, (Reference 4). The Clayton Keymode Cycle consists of steady state cycles at high engine load, moderate engine load and idle. The Keymode cycle is described in Table 2.4, Section 2.2.3. All of the performance evaluations are made during the high and low cruise. In addition, the ignition system, firing voltage and air injection performance measurements are performed at idle. The measurement techniques that are employed are described as follows:

a) Spark Plug Required Voltage

The ignition analyzer scope is connected and set to the parade display. The minimum and maximum observed firing voltage readings are recorded.

b) Misfire Rate

With the same ignition scope set-up that is described in a), misfire is considered to be present if an open circuit is observed in the firing line and no spark line is present. The percentage is based on the total number of spark plug firings that are available, i.e., if one spark plug in an eight cylinder engine is misfiring all of the time the misfire rate is 12.5%.

c) Air Cleaner Restriction

The complete air cleaner assembly and attachments are installed in their normal arrangement. The air cleaner hold-down wing nut is removed and the end of a hose is butt connected at the air cleaner housing opening around the attachment stud. The other end of the hose is connected to a "U" tube water manometer. The air cleaner housing vacuum that is observed is recorded for the two loaded engine conditions.

d) PCV Flow

A laminar element flow gauge is connected to the upstream side of the Positive Crankcase Ventilation Valve and hose. The downstream side of the PCV Valve is connected in its normal operating configuration. The flow rate is recorded for the two loaded engine conditions.

e) Air Pump Disconnected

The air injection pump is disconnected from the air distribution manifold and the manifold inlets are plugged. The direct concentration exhaust emissions of carbon monoxide, carbon dioxide, and hydrocarbons for the three operating modes are monitored and recorded on standard strip charts. The exhaust emissions at this condition are compared to the exhaust emissions obtained during the standard emission test sequence when the air injection pump is normally connected.

Any deficiencies and pertinent items that are observed beyond those recorded on the standard inspections sheet are recorded under "Comments."

The vehicle parameter inspection was expanded during the seventh month of the experimental program (midway through the first recall). The measurement of idle carbon monoxide emissions during the engine parameter inspection (floor inspection) was added. This measurement was performed on Vehicle Fleets II and III to verify the fuel/air mixture adjustments made during initialization of the vehicles to manufacturers' specifications.

This additional measurement was initiated to establish the relationship between the Keymode idle CO and the idle CO obtained during a garage floor measurement. The original initialization of idle CO was made under the garage conditions.

The other parameter diagnostic procedure that was added was the performance of a cylinder balance check. The cylinder balance check is performed with the ignition analyzer scope by sequentially shorting ignition of individual cylinders, i.e., there is no ignition spark for a selected cylinder. The ignition scope provides a reading of percent loss of engine speed for each cylinder shorting. This test was performed at the low speed cruise of the Keymode Cycle and at 1500 rpm in neutral during the floor inspection. This procedure was undertaken due to the indication that ignition misfire was not being accurately detected by the previously discussed procedure.

Vehicle Initialization Procedures

Each vehicle in the fleet received a comprehensive engine tune-up after the "as-received" emission test and parameter inspection had been performed. This tune-up was performed in order to initialize the vehicle so that the deterioration of new components and adjustments with mileage and time could be monitored. The baseline or reference emission level prior to deterioration was measured in test 1B which was performed immediately after vehicle initialization.

Regardless of their condition, each vehicle was equipped with new spark plugs, ignition condenser, PCV valve and air cleaner element. In every case, idle rpm, idle fuel/air ratio, basic timing, ignition point dwell and the choke vacuum kick were set to manufacturers' specification. In many cases, failed distributor and choke vacuum diaphragms were detected and therefore replaced. All stuck heat riser valves were freed. The secondary ignition components, i.e., high tension cables, rotors, and distributor caps were replaced whenever they were found to be in poor condition. Occasional major carburetor and distributor repairs were performed in order to obtain acceptable vehicle operation. The tune-up parts used were major Original Equipment Manufacturer (OEM) brands.

All of the mechanical settings were accomplished using conventional mechanical and electrical equipment and standard garage procedures. The distributor advance specifications were obtained from the Sun Specification Service Manual, (Reference 5), and all other tune-up specifications were obtained from National Service Data manuals, (Reference 6). The settings of idle rpm and basic timing were made in strict compliance with the manufacturers' published procedures. The idle mixture settings were set for "best lean idle" on the vehicles with no emission controls (Pre-Emission Controlled Vehicles, Fleet I). "Best lean idle" was accomplished by leaning the mixture until a lean engine roll or rpm drop was observed and then just richening the mixture to return the idle rpm back to the value prior to the drop. Emission Controlled Vehicles (Fleet II and Fleet III) idle settings were made using the most definitive procedures known. These procedures resulted in either a % CO setting or best idle rpm drop setting. The specifications that were employed are listed in Table 2.3.

Table 2.3

Idle CO % Specifications for
Vehicles Equipped with Exhaust Emission Controls

General Motors - Follow engine compartment or tune-up manual procedures.

These procedures are based on rpm drop with the mixture screw. 1971 Chevrolet, Pontiac and Oldsmobile have % CO specifications listed in the tune-up manual.

Chrysler Corporation - Set 1.0% CO at the specified rpm with transmission set in neutral.

Ford Motor Company - Set the idle % CO at the specified rpm with the transmission in neutral.

The % CO specifications are listed in the Ford (Reference) Emissions Analyzer Manual. The specifications listed for 1968 model vehicles are applicable to 1967 and 1966 California Vehicles. The idle % CO setting for 1971 vehicles is listed in the tune-up manual.

American Motors - 1968 through 1971 vehicles are set from 1.0 to 1.5 % CO.

1966 and 1967 California vehicles are set for best lean idle.

All Others - Set to whatever specifications are available in the tune-up manual.

Unscheduled Maintenance and Repairs

The program goal was that a minimum number of vehicles would receive additional tune-up maintenance during the course of the vehicle deterioration test program. All participating vehicle owners were informed at the beginning of the program that their vehicles would undergo an additional major tune-up at the end of the test series, sixteen months from the time of their vehicle's first test. It was anticipated that the vehicle owner would therefore tend to delay his routine, periodic tune-up maintenance until the end of the test series. During the period of the first recall testing (Test 2), it was discovered that some owners had obtained various and sometimes extensive tune-up related repairs. Therefore, at the beginning of the second recall testing (Test 3) a letter was sent to the vehicle owners reminding them of the scheduled tune-up at Test 5. However, extensive maintenance and even complete tune-ups continued to be performed on many of the vehicles. Vehicles were also returned to Scott at either the scheduled recall or between tests with various performance complaints. These complaints, however, were corrected only when judged to be necessary. A coding system was established to maintain a complete record of all unscheduled maintenance and to facilitate automatic data processing. The Engine Parameter Adjustment/Repair Record (Figure 2.7) was used to document parameter adjustments and repairs that were performed at the Scott Research Laboratories facilities.

Due to this greater than expected degree of unscheduled maintenance, additional procedures were instituted in order to maximize the usefulness of data obtained from vehicles which received unscheduled maintenance. As described in Section 2.2.1, during the first and second recalls (Tests 2 and 3) the vehicles that had received excessive maintenance were reinitialized and retested. In cases where only minor adjustments were required, the adjustments were documented along with the corresponding before and after diagnostic readings. Reinitialization involved retuning the vehicle as described in Section 2.2.1, assigning a new vehicle number

Fleet Deterioration Program

Form 1.4

Engine Parameter Adjustment/Repair Record

1. Vehicle Identification

1.1 Last Test No. 3

1.2 Car No. 313

1.3 License No. 347 DJC

1.4 Repaired by K.T.

1.5 Date 4-22-72

1.6 Odometer

2. Complaint or Problem

Misses and poor acceleration

3. Repair(s) or Adjustment(s) Made

Re-set timing

4. Diagnostic Readings

	Item Adjusted	Measurement Before Adjustment	Measurement After Adjustment
1	Timing	TDC	6° BTDC
2			
3			
4			
5			

Figure 2.7 Engine Parameter Adjustment/Repair Record

to that vehicle, and reinstituting the vehicle in the program at Test 1B. At Test 4, vehicles that had received any tune-up related maintenance since Test 3, and those vehicles that required maintenance due to owner complaints were given their final "as-received" test, the specified tune-up, and their "post tune-up" test. Since this procedure was equivalent to reinitialization, these vehicles were assigned a new number and recalled at the fifth test period for an additional Test 2.

Those vehicles that required testing under the alternate procedures due to excessive maintenance were identified by owner volunteered information or from records of Scott performed interim maintenance. An inquiry was made of each owner at the scheduled recalls to determine whether he had any tune-up related work performed on his vehicle since the last test. All positive responses were recorded on appropriate forms. It was apparent that complete identification of interim maintenance was not being obtained by owner inquiries. Additional techniques were instituted throughout the test program to identify additional maintenance as often as possible.

At the beginning of the third test period the carburetor mixture and speed screws were painted with nail polish to identify their position. At the subsequent recalls the mechanics inspected the screws during the floor diagnosis. The results of this inspection were recorded. At the beginning of the fourth test period the replaceable tune-up parts were color coded with paint. These parts were retained after their removal at the final tune-up for evaluation. The evaluation of the tune-up parts was made by inspecting them for paint coding, their condition, and their part number and manufacturer's brand. Most of the original parts were listed by manufacturer and part number on individual requisitions by car number. All probable discrepancies were noted.

In addition to these parts inspections the tune-up parameter inspection sheets for each individual vehicle were screened. Pertinent parameters such as timing, dwell, idle rpm, idle CO, air cleaner measurements, and spark plug required voltage were compared for the sequential tests. Suspicious discrepancies were noted and occasionally a follow-up inquiry was made of the owner. When unscheduled maintenance was detected, the results were recorded as additional tune codes for data processing. Only those determinations of unreported maintenance that were considered to be positive were recorded. There were approximately 100 vehicles where additional maintenance was suspected, but where the probability was not considered to be high. Tune codes were not entered for these vehicles.

Final Tune-Up Procedures

At the time of the final tune-up the same procedures used for the original vehicle initialization were employed except for the postponement of some maintenance. Only those tune-up adjustments and component replacements that are characterized in the Economic Effectiveness Model were made. These characterized tune-up elements are described as follows:

1. Basic ignition timing
2. Idle speed
3. Idle air/fuel ratio (% CO)
4. PCV valve and system
5. Air filter element
6. Primary ignition system
7. Secondary ignition system
8. NO_x control system
9. Choke piston setting
10. Heat riser valve
11. Air injection system

Only those NO_x system components were maintained that controlled vacuum spark advance and only when replacement parts were immediately available. The air injection system performance was not diagnosed at Scott and was not repaired, if defective.

The failed components that did not fall into the above categories were repaired after the performance of the "post tune-up" emission test. These repairs included such items as carburetor overhaul or replacement, distributor replacement, replacement of failed choke and distributor vacuum advance diaphragms, and other choke mechanism repairs or adjustments. An additional "non-specified maintenance" emission test and engine diagnosis was performed after repair of these maintenance items for information. The application of these procedures would allow for comparison of actual versus the Economic Effectiveness Model prediction of emission response to tune-up.

2.2.3 Exhaust Emission Tests

Exhaust emission measurements were performed on each vehicle before and after the initial tune-up and at each scheduled four-month recall. The "as received" and "post tune-up" tests were designated Tests 1A and 1B, respectively. The first recall test, conducted four months after Test 1, was identified as Test 2 and the second recall test, after an additional four-month period, was identified as Test 3, etc.

Exhaust Emission Test Procedures

The exhaust emission tests were made in accordance with applicable Federal Register test procedures and instrumentation specification (References 7 and 8). The exhaust emission tests involved both Constant Volume Sampling mass emission and direct, tail pipe concentration measurements. The mass emission, dilute exhaust bag samples were analyzed with non-dispersive infrared instrumentation for carbon monoxide (CO) carbon dioxide (CO_2) and nitric oxide (NO). Flame ionization detection instrumentation was used for the analysis of total unburned hydrocarbon (HC), and non-dispersive ultraviolet instrumentation was used for the analysis of nitrogen dioxide (NO_2). The direct exhaust emission concentrations were analyzed for carbon monoxide, carbon dioxide, n-hexane equivalent unburned hydrocarbons, and nitric oxide with non-dispersive infrared instrumentation. In addition, for both mass and concentration measurements, a chemiluminescence analyzer, i.e., converter and chemiluminescent NO analyzer system, was incorporated during the third month of the testing program and was used for the analysis of total oxides of nitrogen. The NDIR/NDUV NO_x measurements were deleted during the fourteenth month of testing.

Since all of the emission tests involved either the 1972 or 1975 Federal Procedure, the vehicles were soaked for the minimum twelve hour time period before conducting the cold start tests. The program was initiated using the 1972 Federal Procedure but a change to the 1975 Federal Procedure was incorporated at the end of the first recall period (Test 2). Indolene 30 test fuel, which meets the Federal test requirements, was used whenever possible, during all of the emission test cycles. Vehicles that were equipped with in-tank fuel pumps and foreign and U.S. vehicles having fuel lines that were difficult to disconnect were consistently tested using the vehicle's tank fuel. Approximately 10 to 13% of the vehicles were tested on tank fuel. The dynamometer inertia weight and road load horsepower were set according to the 1972 Federal Test Procedure.

Exhaust Emission Test Cycles

Each vehicle test incorporated the measurements of the exhaust emission using the 1972 or 1975 Federal Test Procedure from a cold start, the Federal Short Cycle and the short diagnostic cycles. The Federal Test Procedure and the Federal Short Cycle tests require CVS mass emission measurements. The short diagnostic cycle emissions were measured on a direct concentration basis. Only the Federal Test Procedure was run from a cold start, the other two test cycles were run with a warmed-up engine. The emission testing was performed using the following sequence:

a) Federal 1972 or 1975 Cold Start
b) Two hot 7-mode cycles (CVS test at 1A only)
c) Federal Short cycle
d) Clayton Keymode cycles while performing parameter inspection
e) Short Diagnostic cycles while measuring exhaust emissions (which included the 49/45 mph, 33/30 mph aNd idle Clayton Keymodes).

As indicated above, at the time of the "as-received" test (Test 1A) an additional emission test was run. Two 7-mode cycles, the 1968-71 Federal Test Procedure driving cycle, were run and the closed cycle, Constant Volume Sample mass emissions were determined. In addition, the direct concentration readings were recorded simultaneously over the 7-mode cycle.

The 1975 Federal Test Procedure was substituted for the 1972 Federal Test Procedure at the beginning of the eighth month of testing. The Federal Short Cycle driving scheduled is presented in Figure 2.8. The short diagnostic cycles which include the Clayton Keymode Cycles are illustrated in Figure 2.9. The specifications used for the Keymode cycles are shown in Table 2.4.

2.2.4 Instrumentation and Test Equipment

Whenever possible, conventional equipment was used to obtain both the engine parameter and emission measurements. A brief description of all equipment that was employed is given below.

Engine Parameter Inspection Equipment

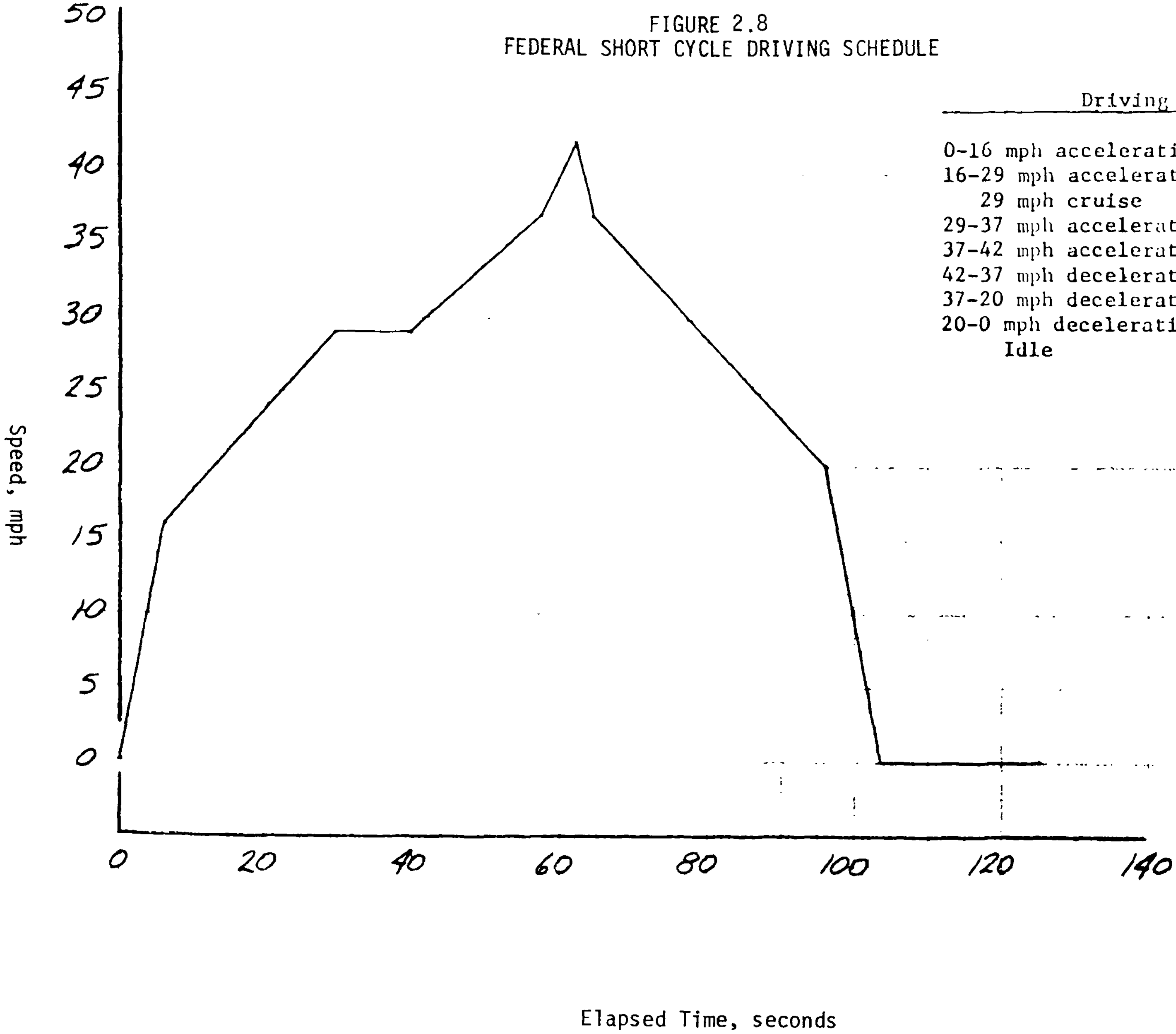
The measurements described in Section 2.2.1 and the tune-up adjustments described in Section 2.2.2 were performed with the following equipment:

A) Engine Analyzer with Ignition Scope
An Autoscan Model 4000 Series Diagnostic System was used. This engine analyzer included the ignition oscilloscope, tachometer, dwell meter, vacuum gauge, % speed power change test meter, timing advance meter, and timing light.

B) Air Filter Tester
The air cleaner element tester was an AC Model 0 air filter tester. A protractor was installed on the face of the tester in order to obtain the readings in angular degrees from 0 to 180.

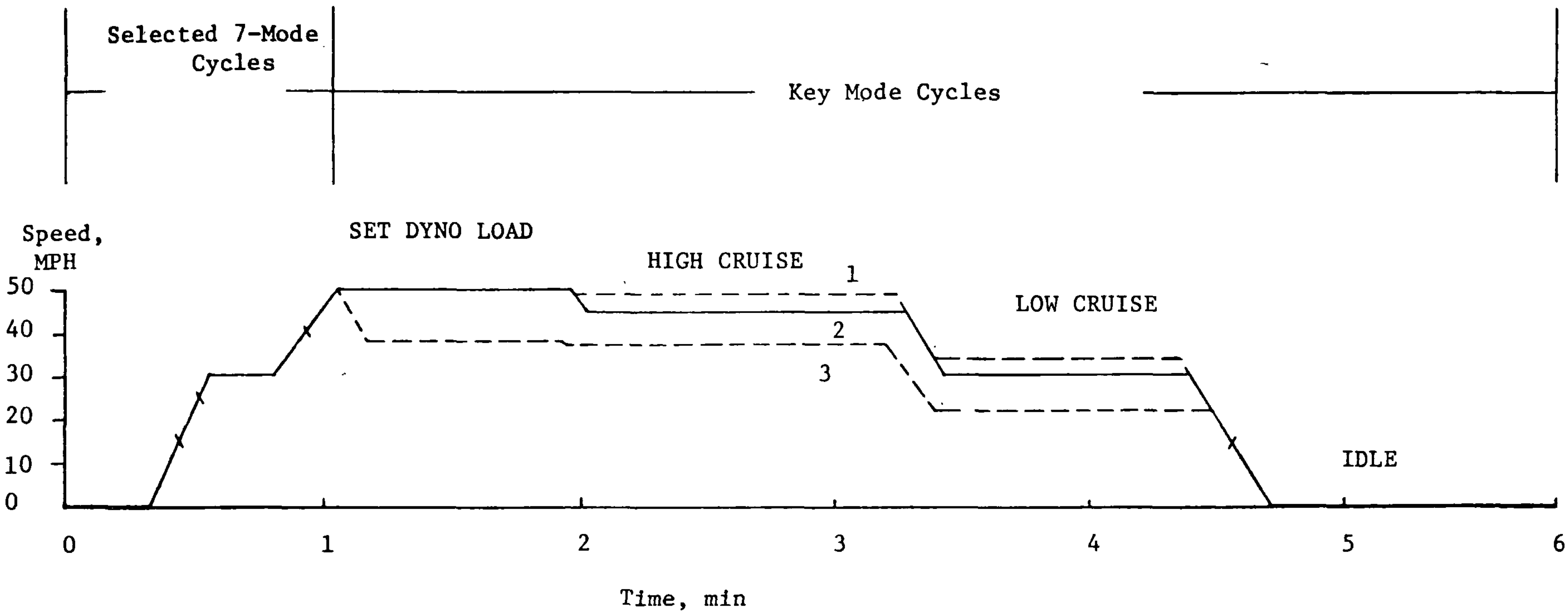
C) Garage Carbon Monoxide Meter
An Horiba, Type MEXA-200 Motor Vehicle Exhaust Gas Analyzer was used to set and measure the garage floor idle CO concentration. This is a non-dispersive infrared instrument, with 0 to 5 Volume % range and claimed accuracy of $\pm 5\%$ of full scale.

FIGURE 2.8
FEDERAL SHORT CYCLE DRIVING SCHEDULE



Driving Mode	Time in Mode, Seconds
0-16 mph acceleration	6
16-29 mph acceleration	23
29 mph cruise	10
29-37 mph acceleration	18
37-42 mph acceleration	4.5
42-37 mph deceleration	2.5
37-20 mph deceleration	32
20-0 mph deceleration	7.5
Idle	21.5
	125 sec.
	.7536
	21.7 mph

Figure 2.9
SHORT DIAGNOSTIC CYCLES



Driving Schedules for Vehicles vs. Inertia Weight Settings

1. 4000 lbs and heavier Inertia
2. 3000 - 4000 lbs Inertia
3. 2500 lbs and lighter Inertia

Table 2.4

KEY MODE CYCLES

Vehicle Inertia Weight	Horsepower Setting	Driving Cycles		
		High Cruise	Low Cruise	Idle
4,000 lbs. & up	30 HP @ 50 MPH	49 MPH	33 MPH	0
3,000-3,500 lbs.	30 HP @ 50 MPH	45 MPH	30 MPH	0
2,000-2,500 lbs.	15 HP @ 38 MPH	37 MPH	23 MPH	0

Notes:

1. 2,000-2,500 lb. vehicles with four speed transmissions are driven in third gear.

2. Automatic transmissions are set in neutral at idle.

D) PCV Flow Rate Meter

A Model 50 Vol-0-Flow meter, manufactured by National Instrument Laboratories, Inc. was used to measure the PCV system flow rate. This is a laminar flow meter with a differential pressure gauge and has a nominal flow range of 0 to 10 CFM.

E) Crankcase Pressure Gauge

A "U" Tube water manometer was employed to determine the crankcase pressure in inches of water.

F) Choke Vacuum Kick Gauges

The choke vacuum kick settings were measured with a Kent-Moore J-9789-01 plug gauge set.

Emission Test Equipment

The equipment used for the exhaust emission measurements was constructed with standard commercial components in accordance with the Federal Test Procedure requirements. The several instrument systems were combined so that direct concentration samples could be taken simultaneously with the CVS bag samples. The direct concentration samples were returned to the dilution duct so that they would not bypass the bag collection. Dual range instrumentation was also employed whenever possible and all standard operating modes such as calibration, sampling, and analysis and purging were semiautomatically controlled from a single, push button operated control panel for simplicity and speed of operation. The specific instrument units are described below.

a) Non-Dispersive Infrared System for Measurement of CO, CO_2, and HC

A Scott Research Laboratories Model 103-11X instrument system employing Beckman 315A analyzers was used for the analysis of Carbon Monoxide, Carbon Dioxide and n-hexane equivalent Hydrocarbons. Two ranges of HC analyzers were used for direct concentration readings: 1,500 ppm and 10,000 ppm full scale. The CO_2 analyzer had a full scale range of 16% and was used for all analyses. A stacked cell CO analyzer was used. The direct concentration measurements required the full scale range of 12% and the bag sample analysis required the 1% of full scale range. The low range cell was operated on two ranges, 0.4% and 2.0% full scale when the 1975 Federal Test Procedure was implemented.

b) FID Analyzer for Measurement of Total Hydrocarbons

A Beckman Instrument Model 108A Flame Ionization Detection hydrocarbon analyzer was used to measure the dilute bag sample total hydrocarbons. Multirange attenuation was used to set the appropriate full scale values of from 30 to 1000 ppm C_b.

c) NDIR/NDUV Analyzer for Measurement of NO and NO_2

A Scott Research Laboratories Model 107-2 NO_x analyzer was used to measure both nitric oxide and nitrogen dioxide emissions. A Beckman Instrument Model 315-A, non-dispersive infrared analyzer was used to measure NO tailpipe concentration and dilute bag sample emissions. The full scale ranges were 5000 ppm and 500 ppm, respectively. A Beckman Instrument 315-A, non-dispersive ultraviolet analyzer was used to measure the dilute bag sample emissions of NO_2 with a full scale range of 200 ppm.

d) Mass Sampling System

A Scott Research Laboratories Model 301 Constant Volume Sampler was used to collect the mass emission samples. Five sample bags were incorporated in the system, with the ability to analyze one bag sample while collecting another.

e) Chemiluminescence NO_x Analyzer

A government furnished Chemiluminescence analyzer (NO_2 Converter/Chemiluminescent NO analyzer system) was incorporated for the analysis of oxides of nitrogen during the third month of the testing program. This unit was operated in conjunction with the NDIR/NDUV analyzer until the fourteenth month of the program. This unit was a Thermo Electron

Corporation Model 10A Analyzer. The Chemiluminescence analyzer and thermal converter were assembled in a sample train which was operated independently of the above described emission equipment. The NO_x exhaust emission samples were always analyzed concurrently with the other instruments. The CVS bag samples were analyzed in the NO_x mode (converter on) with range attenuation set for 250 ppm full scale. Direct concentration NO emissions were analyzed with the converter bypassed and the attenuator set to 5500 ppm full scale. The results of data obtained with the two different sets of NO_x instruments were compared and evaluated. A special detailed evaluation was performed. The results of this evaluation were published in Volume VI, "A Comparison of Oxides of Nitrogen Measurements Made with Chemiluminescent and Non-Dispersive Radiation Analyzers," Year End Report, 1972.

f) Chassis Dynamometer

A Clayton Manufacturing CT-200 Chassis Dynamometer was used for all emission tests. The dynamometer had a 2000 to 5000 pound inertia system, adjustable in 500 pound increments. A 50 horsepower torque bridge was used for the road load horsepower settings.

Instrument Maintenance and Calibration

The emission analysis equipment received preventive maintenance on a bi-weekly basis. The emission instruments were calibrated monthly. Most of the instruments were calibrated with at least a five point curve plus zero. All of the calibration gases, including the span gases used to set the instruments for each test were ±2% tolerance. A system start-up procedure which included an instrument curve verification and leak check was followed every day. Engine tachometer calibrations were checked on a weekly basis, at the beginning of the program and monthly in the second year.

2.3 DATA REDUCTION AND ANALYSIS SYSTEM

A detailed description of the system developed for processing and analyzing all of the data taken in the various experiments conducted in support of surveillance, inspection, and maintenance for minimization of vehicle emissions was presented in the report presenting the first year's activities (Reference 1). Only an overview of the system is therefore presented. For further information, the reader is referred to Reference 1.

Review of the requirements of the program indicated that in order to properly process data for publication and to obtain the maximum amount of information from the experimental program, a system which would provide the following capabilities would be required:

- reduce test data
- store test data
- retrieve data
- compute statistics
- develop graphical presentations
- develop regression equations
- perform analyses of variance

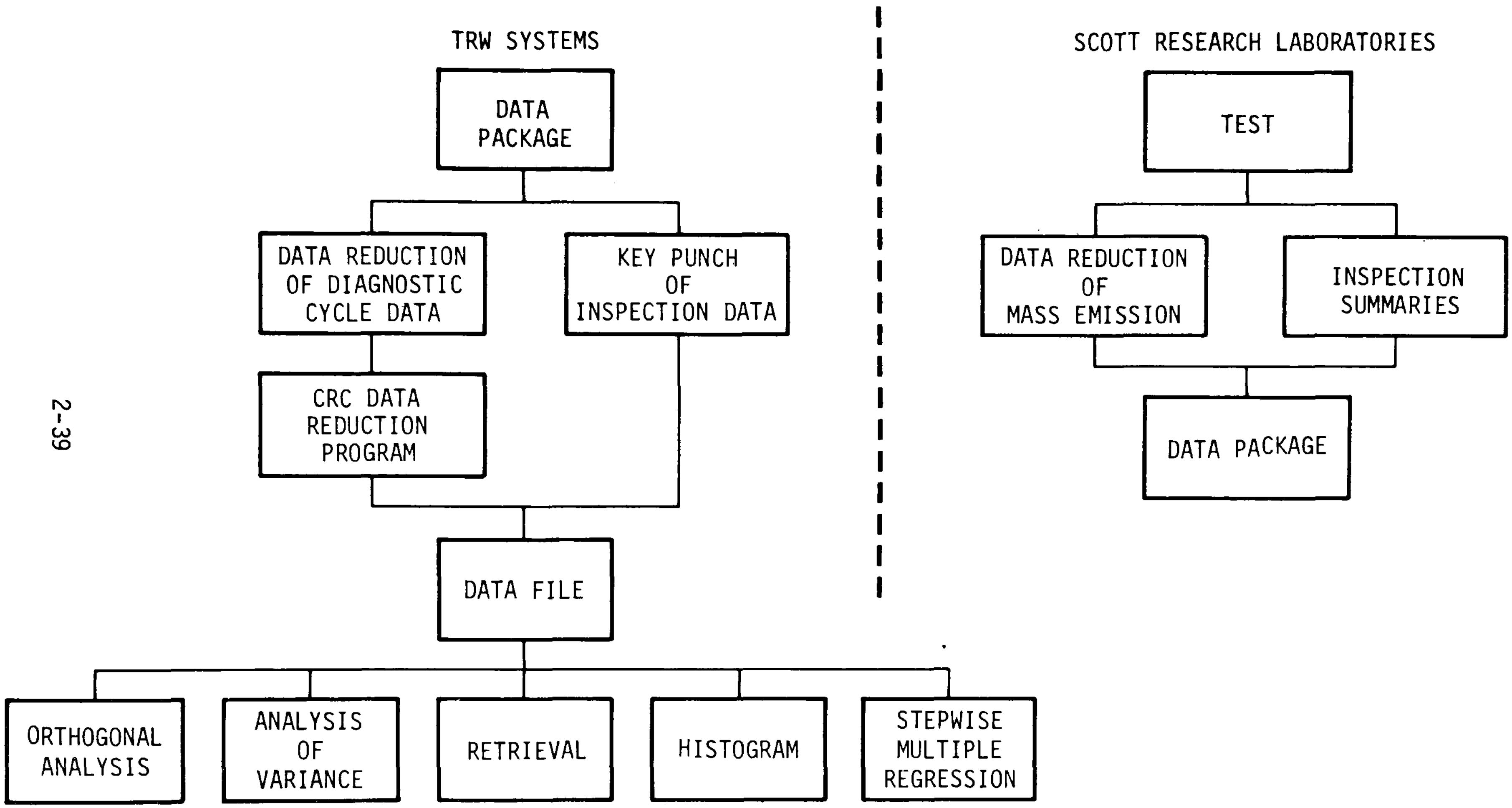
A system was therefore developed which made maximum use of the capabilities of Scott Research Laboratories (SRL) and TRW Systems. The partitioning of the activities is illustrated in Figure 2.10. Since all of the testing was to be undertaken by SRL, all of the recorded emission data and the reduced CVS data were combined to form a total data package that was to be submitted to TRW. TRW, in turn, was charged with the responsibility for systematically processing the data for further analysis and publication.

The program required that a large amount of data be recorded by the technicians on the test floor. Because the information was to be submitted to the computer, special forms were developed which constituted a compromise between the specific formats required for computer processing and the descriptive information that is customarily acquired by technicians. A sample of the types of forms that were used is presented in Section 2.2.

The completed forms, as previously discussed, together with strip chart records and the computed results of the mass emission tests, were submitted to TRW as a data package. The inspection data was submitted to

Figure 2.10

DATA REDUCTION AND ANALYSIS SYSTEM

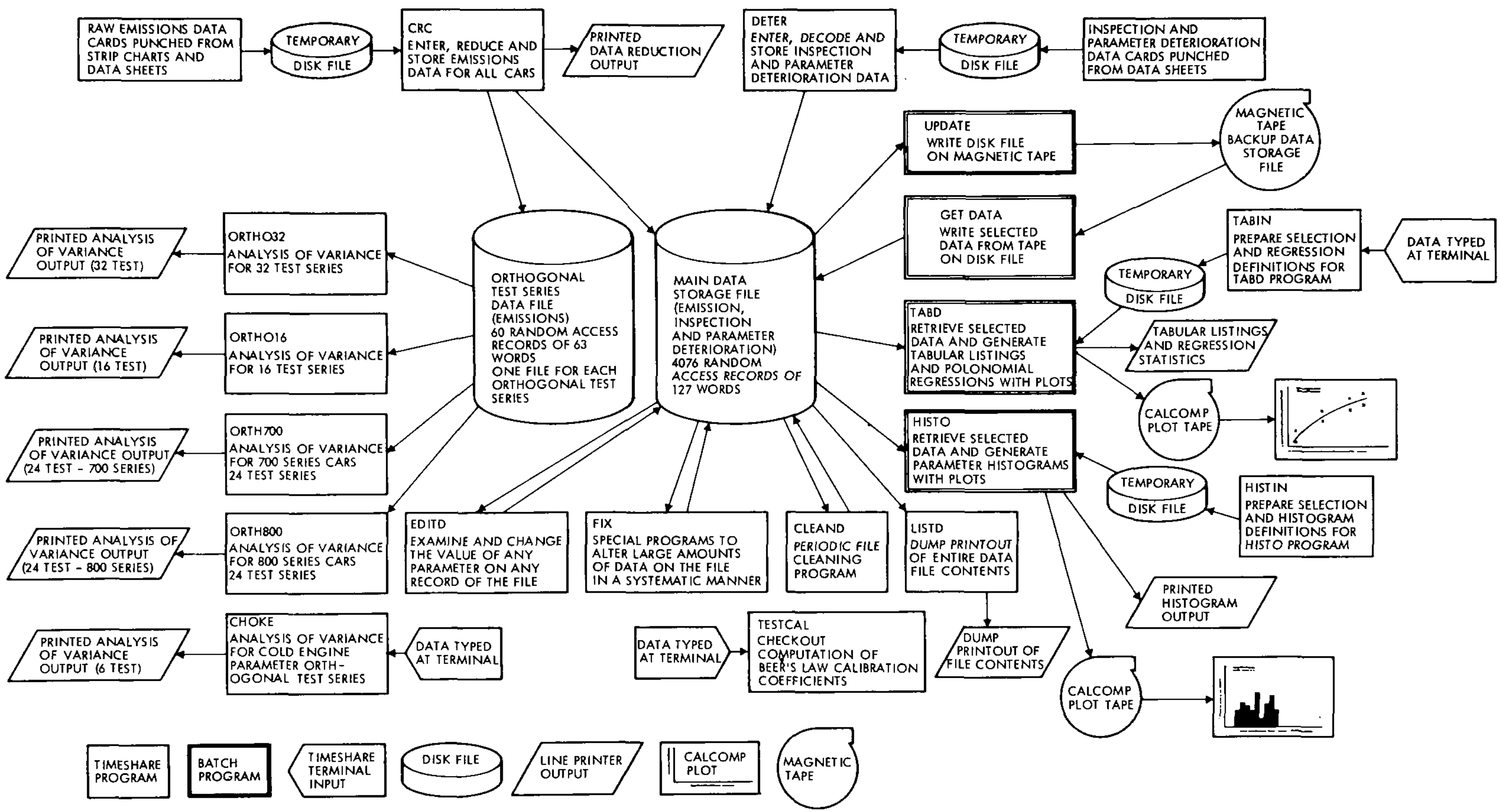


keypunch and the mass emissions data was merged with the diagnostic cycle emission test data processed by TRW.

To reduce transportation and procedural errors, a system of data formatting, editing and review was initiated. The data were initially keypunched and submitted to the computer in a batch mode. Data listings were reviewed and corrections were made by editing the data bank using the remote terminal, TRW Time Share System. Review of the data and editing of the data was therefore performed on a real time basis, on the computer, with full control by the data processing technician. All of the process computer programs are also controlled by teletype terminal control and large data outputs are developed on a batch mode with the high speed printer. The program therefore has the capability of submitting large banks of data to the computer in batch mode with total control of storage, retrieval and analyses on a demand basis by use of the remote terminal, Time Share System.

A very extensive computer oriented analysis system was developed to support all of the experiments of the Emissions Program. The total system is depicted in Figure 2.11. The system was designed to facilitate efficient processing and analysis of the large amount of data taken in the Parameter Deterioration Experiment. Description of each of the computer codes is presented in Reference 1.

Figure 2.11
COMPUTER PROGRAM INTERFACES



2.4 ANALYSIS OF TEST DATA

2.4.1 Discussion of Results

The objective of the Parameter Deterioration Experiment was to: 1) determine the rate (change per mile of vehicle use) of variation of emission and continuous engine tune parameters and 2) for those parameters which were discontinuous, i.e., either operative or non-operative, determine failure rates. Review of the data developed over a sixteen month test period indicated that statistically significant deterioration rates for Cold 1972 Federal Emissions were obtained. In contrast, for many of the key mode emissions, as well as the engine parameters, very few cases of statistically significant deterioration rates were obtained from the experimental data.

The tangible results of the experimental program are therefore the mean value of the deterioration rates (regardless of whether or not statistically significant regressions were obtained) and upper and lower limits at the 95 percent confidence level. The results therefore establish the limits to which parameter deteriorations can be expected to occur. It is speculated that the many cases of non-significant deterioration rates resulted because: 1) the sixteen month driving period was not sufficiently long to result in parameter malfunctions or variations, and 2) sample size was too low at the completion of the program.

This section presents a summary of the results of analyses performed with data taken in the Deterioration Experiment. The best estimates of the parameter deterioration rates and the parameter failure rates are summarized, and a comparison of predicted emission deterioration rates using the empirically derived parameter variation rates ($\Delta P/\Delta Miles$) and influence coefficients ($\Delta E/\Delta P$), with the empirically derived emission deterioration rates ($\Delta E/\Delta Miles$) are presented. A comparison of predicted and measured changes in emissions prior to and following vehicle initialization is also presented.

Fleet Attrition

One of the reasons for the resulting low number of statistically significant parameter deterioration rates was the small sample size of vehicles which received no maintenance that remained at the end of the experiment. An overview of the vehicle population at the end of the sixteen month test program is illustrated in Table 2.5. The program was initiated with 150 vehicles in each of three fleets, which represented vehicles with different degrees of emission control equipment. These were: Pre-Emission Controlled Vehicles (Fleet 1), Emission Controlled Vehicles (Fleet 2), and NO_x Controlled Vehicles (Fleet 3); a very detailed presentation of this distribution of the vehicle make and model year of the vehicles which were included in each of the vehicle fleets is presented in Reference 1. At the end of the test program there were 24, 27, and 29 vehicles, respectively, in Fleet 1, Fleet 2, and Fleet 3, which had not received any maintenance throughout the program. There were 43, 38, and 43 vehicles, respectively, which had received minor adjustments. Another 20 to 30 percent of the vehicles in each fleet required major adjustments and finally, approximately 30 percent of the vehicles were lost due to attrition.

A very salient conclusion with regard to a program of this type which makes use of in-field vehicles driven by owners is that the vehicles cannot be adequately controlled to obtain a data set of vehicles which will not be maintained over a prolonged (greater than six month) test program. Another observation is that owners are either (1) unaware that their vehicles are being maintained, (2) not aware of the nature or extent of maintenance, or (3) are unwilling to report repairs even though specific questions regarding maintenance are asked of them. As is indicated in Table 2.5, of the vehicles which had minor adjustments, respectively 49%, 32%, and 19% of these vehicles of the three fleets, which received maintenance were not reported. The number of unreported cases of vehicle maintenance was obtained either by examining the parts at the completion of the program (manufacture of component parts were examined for consistency)

Table 2.5

FLEET DISTRIBUTION OVER 16 MONTH TEST PROGRAM

SUBSET DESCRIPTION	PRE-EMISSION CONTROLLED FLEET 1		EMISSION CONTROLLED FLEET 2		NO_X CONTROLLED FLEET 3	
	NO.	%	NO.	%	NO.	%
VEHICLES WITH NO MAINTENANCE	24	16	27	18	29	19
VEHICLES WITH MINOR ADJUSTMENTS	43	29	38	25	43	29
REPORTED	(22)	(51)	(26)	(68)	35	(81)
UNREPORTED	(21)	(49)	(12)	(32)	8	(19)
VEHICLES REQUIRING MAJOR ADJUSTMENTS	38	25	43	29	46	31
VEHICLES LOST DUE TO ATTRITION	45	30	42	28	32	21
TOTAL	150		150		150	

or examination of parts that were painted. The very important unanswered question is the number of additional cases of maintenance that were unreported. Examination of emission and parameter measurements, in many cases, very definitely suggested additional cases in which vehicles were maintained.

Deterioration Rates

Several methods were employed to develop estimates of deterioration rates. A summary of the deterioration rates that are considered to be the best estimates is presented in Tables 2.6, 2.7, and 2.8, respectively, for the Pre-Emission, Emission, and NO_x Controlled Vehicles. As was previously described, the mean and the upper and lower 95 percent confidence limits are summarized. The results are also graphically depicted in the Figures 2.12 to 2.50. A cursory review of the data indicates that statistically significant deterioration rates were consistently obtained for only the Cold 1972 Federal Emissions and Air Cleaner Restrictions. There are only three additional cases in which statistically significant results were obtained. These were HC emissions during 49/45 mph Cruise and PCV flow rates with Emission Controlled Vehicles and NO_x emissions during 49/45 mph Cruise with NO_x Controlled Vehicles. It is concluded that the meaningful results obtained from this experimental investigation are the establishment of the upper and lower limits of the rates at which emission and engine tune parameters can deteriorate. In most cases it is concluded that the results tend to be conservative, in that for a deterioration period of approximately sixteen months, the deterioration rates would be expected to be less in magnitude than is indicated by the limits.

Parameter Failure Rates

In addition to the deterioration rates of parameters, the data taken in the Deterioration Experiment was analyzed to develop the failure rates of discrete parameters. Summaries of the parameter failure rates of interest for vehicles which were not maintained at any point during the deterioration phase of the program are respectively presented in Tables 2.9, 2.10, and 2.11, for the three test fleets.

Table 2.6

SUMMARY OF DETERIORATION RATES (CHANGE PER MILE)

PRE-EMISSION CONTROLLED VEHICLES

FLEET 1

PARAMETER	UPPER LIMIT $\overline{X} + kS$	MEAN $\overline{X}$	LOWER LIMIT $\overline{X} - kS$
COLD 1972 FEDERAL HC, gm/mi^2	9.332×10^{-4}	5.740×10^{-4}*	2.148×10^{-4}
COLD 1972 FEDERAL CO, gm/mi^2	7.569×10^{-3}	4.673×10^{-3}*	1.477×10^{-3}
COLD 1972 FEDERAL NO_x, gm/mi^2	-1.230×10^{-4}	-2.327×10^{-4}*	-3.354×10^{-4}
49/45 MPH CRUISE HC, ppm/mi	3.176×10^{-3}	-0.978×10^{-3}	-5.132×10^{-3}
49/45 MPH CRUISE CO, % v/mi	4.725×10^{-5}	-1.610×10^{-5}	-7.945×10^{-5}
49/45 MPH CRUISE NO_x, ppm/mi	6.053×10^{-2}	2.306×10^{-2}	-1.441×10^{-2}
IDLE HC, ppm/mi	3.174×10^{-2}	-0.382×10^{-2}	-3.938×10^{-2}
IDLE CO, % v/mi	3.202×10^{-4}	1.334×10^{-4}	-0.534×10^{-4}
IDLE NO_x, ppm/mi	-1.561×10^{-3}	-3.140×10^{-3}	-7.841×10^{-3}
TIMING, degrees/mi	1.131×10^{-4}	-1.481×10^{-4}	-4.093×10^{-4}
IDLE RPM, rpm/mi	10.715×10^{-3}	3.766×10^{-3}	-3.183×10^{-3}
AIR CLEANER, degree/mi	7.729×10^{-3}	5.307×10^{-3}*	2.885×10^{-3}
PCV FLOW (33/30), cfm/mi	3.513×10^{-5}	-1.424×10^{-5}	-6.361×10^{-5}

*Statistically significant at the 90% confidence level.

Table 2.7

SUMMARY OF DETERIORATION RATES (CHANGE PER MILE)

EMISSION CONTROLLED VEHICLES

FLEET 2

PARAMETER	UPPER LIMIT $\bar{X} + kS$	MEAN $\bar{X}$	LOWER LIMIT $\bar{X} - kS$
COLD 1972 FEDERAL HC, gm/mi^2	2.570×10^{-4}	1.333×10^{-4}*	0.096×10^{-4}
COLD 1972 FEDERAL CO, gm/mi^2	4.054×10^{-3}	2.351×10^{-3}*	0.648×10^{-3}
COLD 1972 FEDERAL NO_x, gm/mi^2	-2.636×10^{-4}	-3.744×10^{-4}*	-4.852×10^{-4}
49/45 MPH CRUISE HC, ppm/mi	0.334×10^{-3}	-2.444×10^{-3}*	-5.222×10^{-3}
49/45 MPH CRUISE CO, % v/mi	2.568×10^{-5}	-0.278×10^{-5}	-3.124×10^{-5}
49/45 MPH CRUISE NO_x, ppm/mi	2.137×10^{-2}	-1.203×10^{-2}	-4.543×10^{-2}
IDLE HC, ppm/mi	0.629×10^{-2}	0.046×10^{-2}	-0.537×10^{-2}
IDLE CO, % v/mi	1.062×10^{-4}	0.274×10^{-4}	-0.514×10^{-4}
IDLE NO_x, ppm/mi	2.267×10^{-3}	-1.088×10^{-3}	-4.443×10^{-3}
TIMING, degrees/mi	1.240×10^{-4}	-0.409×10^{-4}	-2.058×10^{-4}
IDLE RPM, rpm/mi	4.011×10^{-3}	0.053×10^{-3}	-3.905×10^{-3}
AIR CLEANER, degrees/mi	3.426×10^{-3}	2.555×10^{-3}*	1.684×10^{-3}
PCV FLOW (33/30), cfm/mi	-1.946×10^{-5}	-4.758×10^{-5}*	-7.570×10^{-5}

*Statistically significant at the 90% confidence level.

Table 2.8

SUMMARY OF DETERIORATION RATES (CHANGE PER MILE)

NO_x CONTROLLED VEHICLES

FLEET 3

PARAMETER	UPPER LIMIT $\bar{X} + kS$	MEAN $\bar{X}$	LOWER LIMIT $\bar{X} - kS$
COLD 1972 FEDERAL HC, gm/mi^2	1.191×10^{-4}	0.703×10^{-4}*	0.215×10^{-4}
COLD 1972 FEDERAL CO, gm/mi^2	1.474×10^{-3}	0.810×10^{-3}*	0.147×10^{-3}
COLD 1972 FEDERAL NO_x, gm/mi^2	0.653×10^{-5}	-3.381×10^{-5}*	-7.415×10^{-5}
49/45 MPH CRUISE HC, ppm/mi	1.598×10^{-3}	-0.228×10^{-3}	-2.054×10^{-3}
49/45 MPH CRUISE CO, % v/mi	0.320×10^{-5}	-0.716×10^{-5}	-1.752×10^{-5}
49/45 MPH CRUISE NO_x, ppm/mi	0.271×10^{-2}	-3.002×10^{-2}*	-6.275×10^{-2}
IDLE HC, ppm/mi	0.260×10^{-2}	-0.013×10^{-2}	-0.286×10^{-2}
IDLE CO, % v/mi	0.493×10^{-4}	-0.115×10^{-4}	-0.723×10^{-4}
IDLE NO_x, ppm/mi	2.762×10^{-3}	0.200×10^{-3}	-2.362×10^{-3}
TIMING, degrees/mi	1.117×10^{-4}	0.345×10^{-4}	-0.427×10^{-4}
IDLE RPM, rpm/mi	0.856×10^{-3}	-1.510×10^{-3}	-3.876×10^{-3}
AIR CLEANER, degrees/mi	2.711×10^{-3}	2.093×10^{-3}*	1.475×10^{-3}
PCV FLOW (33/30), cfm/mi	2.199×10^{-5}	0.970×10^{-5}	-0.259×10^{-5}

*Statistically significant at the 90% confidence level.

Table 2.9

FAILURE RATES OF ENGINE PARAMETERS

PRE-EMISSION CONTROLLED VEHICLES

FLEET 1

PARAMETER		1A	1B	2	3	4	5A	5B
Heat Riser, % failed	failed	51.8	7.0	33.3	38.5	40.9	40.0	40.0
	N	85	86	66	39	22	15	15
Vacuum Diaphragm, % failed	failed	21.4	0	0	0	0	20.0	20.0
	N	28	28	19	12	5	5	5
No_x Control Dev., % failed	failed	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-
Air Pump, % failed	failed	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-
Misfire, 49/45 Cruise %	$\overline{X}$	0.505	0	0	0	0	1.472	0
	n	5	0	0	0	0	2	0
	N	150	150	100	67	43	24	24
Misfire, 33/30 Cruise %	$\overline{X}$	0.560	0	0	0	0	1.312	0
	n	5	0	0	0	0	2	0
	N	150	150	100	67	43	24	24
Misfire, Idle %	$\overline{X}$	0.732	0	0	0	0	1.292	0
	n	5	0	0	0	0	2	0
	N	150	150	100	67	43	24	24
Mileage, Miles		0	0	3500	5900	8600	10200	10200

n = Number of cases in which misfire was detected

N = Samples in experimental test set

Table 2.10

FAILURE RATES OF ENGINE PARAMETERS

EMISSION CONTROLLED VEHICLES

FLEET 2

PARAMETER		1A	1B	2	3	4	5A	5B
Heat Riser,	failed	43.8	4.1	27.1	21.9	57.9	45.4	0
% failed	N	73	73	59	32	19	11	12
Vacuum Diaphragm,	failed	20.6	0	1.4	8.7	7.4	5.3	0
% failed	N	92	92	70	46	27	19	19
NO_x Control Dev.,	failed	0	0	0	0	20.0	16.7	16.7
% failed	N	12	14	13	12	10	6	6
Air Pump,	failed	7.7	2.6	3.6	0	0	0	0
% failed	N	39	39	28	15	5	3	3
Misfire, 49/45 Cruise	$\overline{X}$	.0750	0	0	0	0	0	0
%	n	2	0	0	0	0	0	0
	N	148	148	105	67	40	27	27
Misfire, 33/30 Cruise	$\overline{X}$	.0818	0	0	0	0	0	0
%	n	2	0	0	0	0	0	0
	N	148	148	105	67	40	27	27
Misfire, Idle	$\overline{X}$	.208	0	0	.188	0	0	0
%	n	2	0	0	1	0	0	0
	N	148	148	105	67	40	27	27
Mileage, Miles		0	0	4700	7500	10900	13400	13400

n = Number of cases in which misfire was detected

N = Samples in experimental test set

Table 2.11

FAILURE RATES OF ENGINE PARAMETERS

NO_X CONTROLLED VEHICLES

FLEET 3

PARAMETER		1A	1B	2	3	4	5A	5B
Heat Riser, % failed	failed	3.6	0	0	0	0	0	0
	N	28	28	20	11	5	0	0
Vacuum Diaphragm, % failed	failed	0	0	1.1	1.5	4.8	3.8	4.0
	N	122	122	91	65	42	26	25
No_x Control Dev., % failed	failed	4.8	2.4	8.1	6.8	6.9	11.1	11.8
	N	84	85	62	44	29	18	17
Air Pump, % failed	failed	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-
Misfire, 49/45 Cruise %	$\overline{X}$	0	0	0	0	0	0	0
	n	0	0	0	0	0	0	0
	N	150	150	113	75	48	29	28
Misfire, 33/30 Cruise %	$\overline{X}$	0	0	0	0	0	0	0
	n	0	0	0	0	0	0	0
	N	150	150	113	75	48	29	28
Misfire, Idle %	$\overline{X}$	0	0	0	0	0	0	0
	n	0	0	0	0	0	0	0
	N	150	150	113	75	48	29	28
Mileage, Miles		0	0	5600	9300	12900	18000	18000

n = Number of cases in which misfire was detected

N = Samples in experimental test set

As has been consistently observed throughout the program, the heat riser has a high frequency of failure. Vacuum diaphragms have comparatively low rates of failure. In contrast, NO_x controlled devices have a surprisingly large number of failures. The sample size of vehicles equipped with an air pump was comparatively small. During the initialization, the one vehicle with a failed air pump was not corrected. This vehicle is the only one in which a measured air pump failure was observed.

Engine misfire is a very major cause for high HC emissions and it was an objective of this experiment to develop the frequency of occurrence. It was, however, concluded early in the program that no reliable method for determining misfire existed. A method which utilized HC emission measurements was therefore adopted to measure misfire (a discussion of the method is presented in Reference 1). This approach was selected even though confounding with other malfunction, i.e., valve failure, flooding carburetor, etc., could occur and errors of commission could result. There were very few cases of misfire detected with those vehicles which were not maintained during the course of the Deterioration Experiment. In fact, during the entire experimental program only two vehicles were observed to have misfire. These two vehicles were Pre-Emission Controlled Vehicles and the misfire rate occurred after approximately 10,000 miles of use. No measureable amount of misfire was observed in the vehicles of the two other fleets.

The failure fractions presented in Tables 2.9, 2.10, and 2.11 were developed from inspections of vehicles which did not receive maintenance during the deterioration period. The failure fractions could therefore be misleadingly low because only those vehicles which were inherently more stable were left in the fleet. Secondly, because of the high number of vehicles which received maintenance, the fleet sample sizes were greatly reduced. In order to develop more representative estimates of failure fractions, the failure fractions of discrete parameters of vehicles which received minor maintenance were developed. These results are presented in Tables 2.12, 2.13, and 2.14. Particular emphasis should be placed on the number of misfirings that occurred with the vehicles that had received minor maintenance. It is speculated that: 1) many cases of misfire were

Table 2.12

FAILURE RATES OF ENGINE PARAMETERS

VEHICLES WITH MINOR ADJUSTMENTS

PRE-EMISSION CONTROLLED VEHICLES
(FLEET 1)

PARAMETER	TEST	1A	1B	2	3	4	5A	5B
HEAT RISER, % FAILED	failed	51.8	7.0	38.4	49.2	48.3	52.7	5.4
	N	85	86	73	65	60	38	55
VACUUM DIAPHRAGM, % FAILED	failed	21.4	0	0	0	0	16.7	10.5
	N	28	28	22	19	19	12	19
NO_x CONTROL DEV., % FAILED	failed	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-
AIR PUMP, % FAILED	failed	-	-	-	-	-	-	-
	N	-	-	-	-	-	-	-
MISFIRE, 49/45 Cruise %	$\overline{X}$	.508	0	.638	.307*	0.133*	0.914*	0
	n	5	0	4	2	1	3	0
	N	150	150	126	110	105	81	97
MISFIRE, 33/30 Cruise %	$\overline{X}$	.564	0	.739	.350*	0	0.899*	0
	n	5	0	4	3	0	3	0
	N	150	150	126	110	105	81	97
MISFIRE, Idle %	$\overline{X}$	.737	0	.574	.354*	0.217*	0.545*	0
	n	5	0	4	3	2	3	0
	N	150	150	126	110	104	80	97
MILEAGE, miles		0	0	3600	6200	9100	11200	11200

n = Number of cases in which misfire was detected

N = Samples in experimental test set

*Distributive values

Table 2.13

FAILURE RATES OF ENGINE PARAMETERS

VEHICLES WITH MINOR ADJUSTMENTS

EMISSION CONTROLLED VEHICLES

(FLEET 2)

PARAMETER	TEST	1A	1B	2	3	4	5A	5B
HEAT RISER,	failed	43.8	4.1	25.0	35.9	48.1	48.7	0
% FAILED	N	73	73	72	64	52	35	53
VACUUM DIAPHRAGM,	failed	20.6	0	2.4	5.6	4.8	9.3	6.6
% FAILED	N	92	92	85	72	63	43	61
NO_x CONTROL DEV.,	failed	0	0	0	0	13.3	11.1	8.3
% FAILED	N	12	13	15	15	15	9	12
AIR PUMP,	failed	7.7	2.6	2.8	3.1	0	0	0
% FAILED	N	39	39	35	32	27	25	25
MISFIRE,49/45 Cruise	$\overline{X}$	.0750	0	0	0	.300	0	0
%	n	2	0	0	0	2	0	0
	N	148	148	130	112	98	85	95
MISFIRE,33/30 Cruise	$\overline{X}$	.0818	0	0	0	.304	0	0
%	n	2	0	0	0	2	0	0
	N	148	148	130	112	98	85	95
MISFIRE, Idle	$\overline{X}$	.208	0	0	.112	.247	0	0
	n	2	0	0	1	2	0	0
	N	148	148	130	112	98	85	95
MILEAGE, miles		0	0	5000	8100	11700	14600	14600

n = Number of cases in which misfire was detected

N = Samples in experimental test set

Table 2.14

FAILURE RATES OF ENGINE PARAMETERS

VEHICLES WITH MINOR ADJUSTMENTS

NO_x CONTROLLED VEHICLES
(FLEET 3)

PARAMETER	TEST	1A	1B	2	3	4	5A	5B
HEAT RISER,	failed	3.6	0	0	4.8	0	0	0
% FAILED	N	28	28	25	21	21	10	19
VACUUM DIAPHRAGM,	failed	0	0	1.8	4.1	2.1	1.6	2.2
% FAILED	N	122	122	113	98	96	61	90
NO_x CONTROL DEV.,	failed	4.8	2.4	6.8	4.4	10.4	13.0	14.3
% FAILED	N	84	85	74	68	67	46	63
AIR PUMP,	failed	-	-	-	-	-	-	-
% FAILED	N	-	-	-	-	-	-	-
MISFIRE,49/45 Cruise	$\overline{X}$	0	0	.0544	0	0	.165*	0
%	n	0	0	1	0	0	1	0
	N	150	150	136	114	111	86	106
MISFIRE,33/30 Cruise	$\overline{X}$	0	0	.0434	0	0	.173*	0
%	n	0	0	1	0	0	1	0
	N	150	150	136	114	111	86	106
MISFIRE, Idle	$\overline{X}$	.0993	0	.0301	0	0	.153*	0
%	n	1	0	1	0	0	1	0
MILEAGE, miles		0	0	5700	9600	13900	17400	17400

n = Number of cases in which misfire was detected
N = Samples in experimental test set

*Distributive values.

not detected due to the lack of sensitivity of misfire measurements, and 2) those vehicles which resulted in significant misfire may have been repaired in the field with no record of maintenance. It is therefore concluded that the failure rates measured with vehicles which received minor maintenance are better representations of the expected frequencies of occurrence of misfire of vehicles in the field. It should be noted that the misfire rates, expressed in percentage of the total vehicle fleet, are given as a distributive value. A cumulative frequency of misfire would therefore be a summation of the values presented in the Tables. Effort to quantify the deterioration characteristics of the continuous parameters for vehicles which received minor adjustments was not pursued because it was speculated that in addition to the minor adjustment performed, other parameters would be maintained with no record of the degree of maintenance. This consideration further supports the observation that the frequency of misfire detected in this program is low.

Comparison of Predicted and Measured Emission Deterioration Rates

Two important phases of the Emissions Test Program were the development of experimental data to: 1) determine the deterioration rate of engine tune components and settings and exhaust emission parameters (Cold 1972 Federal emissions or concentration measurements for the 49/45 mph loaded mode or idle mode) and, 2) the influence coefficients which relate changes in parameters to changes in emissions. Since both the emissions as well as the engine tune parameters were measured during the Parameter Deterioration Experiment, a direct comparison of how well variations in emissions can be accounted for by changes in the selected parameters monitored during the experiment could be made. The primary parameters which were considered to influence emissions were basic timing, idle rpm, air cleaner restriction, PCV flow restriction, and idle CO. Cold engine parameters were not considered and misfire was treated separately. Certainly there are other parameters that would influence emissions; however, these other parameters were considered to be either too costly to repair (carburetor, valves, rings, etc.) or on an individual basis were concluded to effect small changes in emissions. In addition, misfire was not included in these analyses because within the scope of this experimental program the number of cases of misfire with unmaintained vehicles was so small that the results were not considered statistically meaningful.

The comparison was made to determine the degree to which the deterioration rates on engine parameters would account for the deterioration rate of cold emissions as measured by the 1972 Federal Procedure. The results are summarized in Table 2.15. The measured and predicted values using the mean and the upper 95 percent confidence limits of the deterioration rates and influence coefficients (the change in emission with change in parameter as developed in the analysis of variance of data taken in the Orthogonal Test Program, Reference 1) are given. Further discussion, which presents the development of the confidence limits of both the deterioration rates and the influence coefficients, is presented in Section 2.4.3.

The data presented in Table 2.15 clearly indicate that as is the case for comparisons of predicted and measured changes that occurred during the initialization phase (initial and final tune-up) the best agreement between predicted and measured values is obtained with CO emissions. Clearly, an intercept of the predicted value with the measured value within the range of variation of the experimentally measured rates resulted; e.g., with the Emission Controlled Vehicles the maximum predicted value or the maximum predicted deterioration rate is 1.762×10^{-3} gm/mi^2, and the measured values resulted in a lower limit of 0.648×10^{-3} gm/mi, and an upper limit of 4.054×10^{-3} gm/mi. The results with the Pre-Emission Controlled Vehicles, as well as with the NO_x Controlled Vehicles, are comparable. Comparison of measured and predicted values for Cold 1972 Federal HC Emissions resulted in an intercept of limits with Pre-Emission Controlled and Emission Controlled Vehicles. In contrast, with the NO_x Controlled Vehicles, the predicted upper limit of 0.190×10^{-4} gm/mi^2 was less than the lower limit of the measured HC emission deterioration rate. For these 1971 NO_x Controlled Vehicles both the emission rates and the engine tune parameter

Table 2.15

COMPARISON OF MEASURED AND PREDICTED EMISSION VARIATION RATES

STATISTIC	PRE-EMISSION CONTROLLED MEASURED	PRE-EMISSION CONTROLLED PREDICTED	EMISSION CONTROLLED MEASURED	EMISSION CONTROLLED PREDICTED	NO_x CONTROLLED MEASURED	NO_x CONTROLLED PREDICTED
	COLD 1972 FEDERAL HC EMISSIONS					
	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2
MEAN	$5.740x10^{-4}$	$0.676x10^{-4}$	$1.333x10^{-4}$	$0.048x10^{-4}$	$0.703x10^{-4}$	$0.027x10^{-4}$
UPPER LIMIT	$9.332x10^{-4}$	$2.533x10^{-4}$	$2.570x10^{-4}$	$0.498x10^{-4}$	$1.191x10^{-4}$	$0.190x10^{-4}$
LOWER LIMIT	$2.148x10^{-4}$	-	$0.096x10^{-4}$	-	$0.215x10^{-4}$	-
	COLD 1972 FEDERAL CO EMISSIONS					
	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2
MEAN	$4.673x10^{-3}$	$1.408x10^{-3}$	$2.351x10^{-3}$	$0.543x10^{-3}$	$0.810x10^{-3}$	$-0.081x10^{-3}$
UPPER LIMIT	$7.869x10^{-3}$	$3.787x10^{-3}$	$4.054x10^{-3}$	$1.762x10^{-3}$	$1.474x10^{-3}$	$0.734x10^{-3}$
LOWER LIMIT	$1.477x10^{-3}$	-	$0.648x10^{-3}$	-	$0.147x10^{-3}$	-
	COLD 1972 FEDERAL NO_x EMISSIONS					
	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2	gm/mi^2
MEAN	$-2.327x10^{-4}$	$-0.079x10^{-4}$	$-3.744x10^{-4}$	$-0.126x10^{-4}$	$-0.3381x10^{-4}$	$-0.139x10^{-4}$
UPPER LIMIT	$-1.230x10^{-4}$	$-1.081x10^{-4}$	$-2.636x10^{-4}$	$-0.424x10^{-4}$	$0.0653x10^{-4}$	$-0.628x10^{-4}$
LOWER LIMIT	$-3.354x10^{-4}$	-	$-4.852x10^{-4}$	-	$-0.7415x10^{-4}$	-

deterioration rates were extremely small, and therefore resulted in the lack of agreement between measured and predicted results. Furthermore, the HC deterioration rates with the NO_x Controlled Vehicles were more repeatable than with the other fleets, and therefore resulted in a much tighter band of variation of measured emission deterioration rates. The inclusion of Misfire should greatly improve the correlation.

The predicted values of NO_x emission deterioration rates on the basis of five engine tune parameters clearly did not account for the experimentally measured emission deterioration rate. In all cases the upper 95 percent confidence limit of the predicted emission rate was smaller in magnitude than the upper limit of measured deterioration rates. (It should be noted that NO_x deterioration rates are negative). Additional experimental data are required to determine the reasons for the discrepancy between measured and predicted NO_x emission deterioration rates. The method selected to develop the deterioration rate weights high values heavily, and therefore may have resulted in an overestimation of the rate. Although the approach gives reasonable results with HC and CO emissions, the NO_x emissions appear large. The use of alternate approaches for development of deterioration rates of different parameters could not be justified. The same approach was therefore applied to all parameters. Clearly, further review of the existing data or development of additional test data is required.

As a part of the effort to verify the experimentally developed deterioration rates and influence coefficients, a measure of the degree to which the combined effects of the magnitude of the deterioration rate and the magnitude of the influence coefficient contributes to the total emission, was developed. The fraction of total emissions was developed using the predicted values, for both the cases in which predictions were made using 1) the mean values and 2) the upper 95 percent confidence limits (values selected to obtain the largest magnitude of emission change). The fraction of total emissions for the two cases studied are presented in Tables 2.16 and 2.17. Although there are some cases of differences between the two cases examined, there are some fairly consistent indications. In all cases, as would be expected, idle CO greatly influences the Cold 1972 Federal CO emission deterioration rate. Air cleaner restriction is a strong influence on the CO deterioration rate. Both idle CO and air cleaner restriction greatly affect the deterioration rate of HC emissions for Pre-Emission Controlled and NO_x Controlled Vehicles. For Cold 1972 NO_x emission deterioration rates, timing appears to be the strongest influence, with air cleaner also being a very strong influence. These data appear consistent with opinions generally accepted in the industry and therefore tend to further establish credibility of the data developed in this program. One inconsistency of a prior concept which resulted from the detailed experimentation conducted during the deterioration experiment is the low deterioration of PCV flow rate, together with the very minor influence of PCV flow rate variations on emissions. The other is that, surprisingly, idle rpm appears to deteriorate at a lower rate than anticipated prior to the experimental program. It should be emphasized, however, that as summarized in Tables 2.6, 2.7, and 2.8, timing, idle rpm, PCV, and flowrate resulted in low deterioration rates which were not statistically significant. It is speculated that these parameters operate in a non-linear manner and the length of the program was not sufficient to result in real physical changes in these parameters.

Comparison of Predicted and Measured Changes in Emissions due to Engine Tune

The influence coefficients which will be used in the Economic Effectiveness Model to predict a change in emissions, on the basis of a known or predicted change in parameter, were developed experimentally (Orthogonal Experiments). The results of the Analysis of Variance (AOV) conducted with the test data are presented in Reference 1. Coefficients were developed for General Motors, Ford, Chrysler, American Motors, and other categories of vehicle make. All the data clearly indicated that

Table 2.16

FRACTION OF PREDICTED EMISSION DETERIORATION RATE (SLOPE)

BASIS MEAN RATE

PARAMETER	PRE-EMISSION CONTROLLED (FLEET 1)			EMISSION CONTROLLED (FLEET 2)			NO_x CONTROLLED (FLEET 3)		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
TIMING	-0.1472	0.0888	2.5988	-0.4280	0.0258	0.3088	0.9655	0.4355	-5.5375
IDLE RPM	-0.1632	0.0773	-0.3463	-0.0612	0.0020	-0.0011	0.2372	0.4846	1.7971
AIR CLEANER	0.4449	0.4226	2.0369	0.4832	0.3595	0.4294	0.6932	-1.7759	6.4033
PCV FLOW	-0.0048	0.0247	0.3546	0.8413	0.2506	0.3265	-0.5560	0.8936	-1.2440
IDLE CO	0.8703	0.3866	-3.6440	0.1647	0.3621	-0.0636	-0.3399	0.9622	-0.4189

Table 2.17

FRACTION OF PREDICTED EMISSION DETERIORATION RATE

BASIS MAXIMUM RATE (UPPER LIMIT)

PARAMETER	PRE-EMISSION CONTROLLED (FLEET 1)			EMISSION CONTROLLED (FLEET 2)			NO_x CONTROLLED (FLEET 3)		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
TIMING	0.0371	0.1180	0.6314	0.1526	0.0536	0.5386	0.4841	0.0669	0.2842
IDLE RPM	0.0509	0.1132	0.0323	0.5462	0.0618	0.0320	0.0604	0.0395	0.1919
AIR CLEANER	0.2385	0.2933	0.2890	0.0743	0.1737	0.2217	0.1631	0.3214	0.4121
PCV FLOW	0.0043	0.0579	0.0473	0.1486	0.1419	0.2077	0.0268	0.0318	0.0168
IDLE CO	0.6692	0.4176	0	0.0783	0.5690	0	0.2656	0.5404	0.0949

the coefficients were both repeatable for like power trains, and in most parameters, similar for all power trains. It was considered necessary to apply these coefficients to the measured changes in parameter to determine how well the change in emissions could be predicted. This section presents the methods used to compute the predictions and to determine whether or not the differences were statistically different.

Influence Coefficients

The influence coefficients developed from the data obtained for each vehicle tested in the Orthogonal Experiments were used to develop a weighted value for each class of major vehicle manufacturer. Also, the estimates for each vehicle make were weighted by using the National Distribution of Vehicles to develop a weighted average coefficient representing the in-field population of vehicles. Results of the weighted values for the parameters timing, idle rpm, air cleaner restrictions, PCV flow restriction (measured in the 33/30 keymode) and idle CO were developed. These values were reported in Reference 1.

It was noted that in the testing of the Emission Controlled Vehicles (Fleet 2, 1966-1970 Vehicles) that there were very few cases of two-factor interactions. In contrast, in the testing of the Pre-Emission Controlled Vehicles (Fleet 1, Pre-1966 Vehicles), and the NO_x Controlled Vehicles (Fleet 3, 1971 Vehicles), the analyses presented many cases of two-factor interactions which, although small in comparison to the main effects, were considered significant. For use in predictions, it was therefore necessary to make use of the two-factor interactions.

Although two-factor interactions can be included in a computer model, for use in quick or hand calculations in predicting emission changes, it was decided that main effects would be adjusted for two-factor interactions. For those parameters which varied both in a positive and negative direction from mean values, it was decided that the two-factor interaction could be ignored. This decision is considered valid because predictions are made on the basis of an average set of data and the effect of a two-factor interaction would be negligible if the parameter varies both in a positive and negative direction. In contrast, there are some parameters which, in general, did not vary in a positive and negative direction. For example, the Orthogonal Experiment was conducted measuring the influence of a change in Air Cleaner from a fully restricted Air Cleaner to a new, unused Air Cleaner (approximately 180° change using the Air Cleaner Tester). Examination of the average value of Air Cleaner Restriction in the test data, in contrast, suggested that the mean value of Air Cleaner Restriction was approximately 20 degrees. Since there was an apparent bias in Air Cleaner Restriction from the median value of the change imposed in the Orthogonal Experiment, the effect of a two-factor interaction which involved Air Cleaner and a second parameter was used to adjust the main effect of the second parameter. This adjustment was used to nullify the bias that existed in the Air Cleaner Restriction in comparison to the restriction used in the Orthogonal Experiment. A similar correction was used for two-factor interactions which involved PCV flow rates and NO_x control devices. The investigation of the effects in variations in these two parameters in the Orthogonal Experiment consisted of examining a fully operative or non-operative system (failed or operative). In a deterioration experiment very few cases of PCV valve failure or NO_x control system failure resulted. The effect of two-factor interactions was therefore eliminated by imposing the effect of fully operative PCV valve and NO_x control devices.

The coefficients that resulted following the adjustments described in the previous paragraph are summarized in Table 2.18. It should be emphasized that no two-factor interactions are included in the Table. The influence coefficients for changes in the parameters indicated are representative of the change that would be expected to result for a given change in the main parameter, given that the air cleaner restriction is approximately 20 degrees and the PCV valve and NO_x control valve are operative. Since these coefficients are used primarily to predict the change in emissions that would result in an average change in a given parameter for a fleet of vehicles, they are considered the best estimates and most easily usable influence coefficients. To obtain a more exact

Table 2.18

EMISSION RESPONSE COEFFICIENTS HOT 1972 FEDERAL CVS PROCEDURE

TIMING, gram/mile/degree

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	.06788	.0742	.1087	-1.234	-.5128	-.5659	.09036	.1041	.1631
FORD	.06173	.0604	.06898	-.3661	-.1575	-1.513	.2257	.1126	.09282
CHRYSLER	.07457	.0180	.04618	-.2972	-.2011	-1.880	.1579	.1030	.1403
AMC	-	-	.01581	-	-	-1.388	-	-	.1080
OTHER	-	0	.04000	-	-.3299	-.1327	-	.0480	.09501
COMPOSITE	.06710	.0498	.07558	-.8444	-.3423	-1.022	.1394	.09524	.1299

IDLE CO (- TO 0), g/mi/% v

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	.2018	-	-	7.877	-	-	-.4582	-	-
FORD	-.008467	-	-	3.355	-	-	-1.200	-	-
CHRYSLER	0	-	-	2.381	-	-	.01786	-	-
AMC	-	-	-	-	-	-	-	-	-
OTHER	-	-	-	-	-	-	-	-	-
COMPOSITE	.1112	-	-	5.756	-	-	-.6011	-	-

IDLE RPM, gram/mile/rpm

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	-.005205	-.00584	-.001747	.01191	.00541	.01216	.001298	.00062	.003639
FORD	0	-.00711	.001227	.05264	.03256	.07750	0	0	-.001820
CHRYSLER	0	-.00354	0	.04704	.03618	0	0	0	0
AMC	-	-	-.0002768	-	-	0	-	-	-.00002991
OTHER	-	-.00346	-.0003846	-	.02979	.001572	-	0	0
COMPOSITE	-.002930	-.00550	-.0004243	.02888	.02120	.02598	.0007306	.000255	.0009632

IDLE CO (0 TO +), gram/mile/% v

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	.4171	.0696	-	3.295	9.66	-	-.03805	-.0489	-
FORD	.4122	0	-	4.365	6.01	-	.8272	.1702	-
CHRYSLER	.5880	0	-	6.506	9.31	-	0	0	-
AMC	-	-	-	-	-	-	-	-	-
OTHER	-	0	-	-	2.71	-	-	0	-
COMPOSITE	.4411	.02860	-	4.081	7.177	-	.2170	.02926	-

PCV, gram/mile/cfm

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	0	-.08332	-.1126	-3.355	-5.476	-6.561	.1029	.06041	.01232
FORD	.07922	-.1114	-.2047	-1.167	-.7393	-8.164	0	.1035	.2348
CHRYSLER	0	-.1785	-.1439	-1.454	-3.979	-9.591	0	.3217	.5361
AMC	-	-	-.1025	-	-	-1.182	-	-	.1692
OTHER	-	0	-.2116	-	0	-7.508	-	0	-.5069
COMPOSITE	.02283	-.08415	-.1548	-2.441	-2.861	-7.458	.05792	.08654	.1038

IDLE CO (- TO +), gram/mile/% v

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	-	-	.09530	-	-	9.927	-	-	-.1564
FORD	-	-	.04900	-	-	6.744	-	-	0
CHRYSLER	-	-	.1450	-	-	8.351	-	-	.1912
AMC	-	-	-.03225	-	-	3.380	-	-	0
OTHER	-	-	.03600	-	-	2.337	-	-	0
COMPOSITE	-	-	.07983	-	-	6.773	-	-	-.02948

AIR CLEANER, gram/mile/degree

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	.007773	.00297	.0006598	.1482	.1091	.05896	-.003286	-.00258	-.001500
FORD	.003819	0	.001076	.07568	.0525	.07879	-.003069	-.00157	-.003482
CHRYSLER	.001293	0	.001733	.04606	.0501	.1105	-.002113	-.00298	-.004896
AMC	-	-	.001152	-	-	.05317	-	-	-.002694
OTHER	-	-.00161	.00001800	-	.0570	.02390	-	-.00157	0
COMPOSITE	.005668	.000900	.0008945	.1121	.07642	.06869	-.003049	-.00212	-.002476

NOX CONTROL DEVICE, gram/mile/unit

MANUFACTURER	HC EMISSIONS FLEET 1	HC EMISSIONS FLEET 2	HC EMISSIONS FLEET 3	CO EMISSIONS FLEET 1	CO EMISSIONS FLEET 2	CO EMISSIONS FLEET 3	NOX EMISSIONS FLEET 1	NOX EMISSIONS FLEET 2	NOX EMISSIONS FLEET 3
GM	-	-	.8491	-	-	-6.876	-	-	.3311
FORD	-	-	0	-	-	0	-	-	0
CHRYSLER	-	-	0	-	-	-3.423	-	-	.8375
AMC	-	-	.07562	-	-	-12.62	-	-	1.209
OTHER	-	-	.6560	-	-	3.104	-	-	2.081
COMPOSITE	-	-	.4235	-	-	-3.374	-	-	.5753

functional relationship of emissions with parameter changes, the full change of main effects and two-factor interactions can be obtained from the Tables presented in Reference 1.

An initial attempt to develop an indication of how well predictions of Cold 1972 Federal Emissions could be made on the basis of measured changes in parameters was made using the test data developed in the final vehicle initialization process performed at the end of the Parameter Deterioration Experiment (Tests 5A and 5B). Calculations were made on the basis of average changes that were calculated for each fleet of vehicles. The weighted influence coefficients representative of all in-field vehicles were therefore used. The method used to apply the coefficients and to indicate the general agreement of the results is illustrated in the calculation sheets respectively representing the results with each of the three test fleets (Tables 2.19, 2.20, and 2.21). It should be emphasized that the estimates presented in these tables are the results developed following elimination of emission values greater than two times the estimate of standard deviation obtained in an initial retrieval of all of the data. This smoothing of the data was considered necessary because of the existence of the resulting large changes in some of the vehicles. For example, these were in the order of magnitude of 20, 120, and 3 gm/mi, respectively, for HC, CO, and NO_x emissions as measured using the Cold 1972 Federal Procedure. Changes of this magnitude were considered beyond expected changes that would result from minor variations in parameters.

A cursory review of the results obtained by applying the influence coefficients using average changes per fleet indicates the best agreement between predictions and measured changes in CO. In general, the coefficients resulted in larger predictions than measured. In contrast, the predictions for HC changes were markedly smaller than measured. For predictions of NO_x changes, there appeared to be no correlation between measured and predicted results. A cursory conclusion was that the predictions of CO would be expected within the experimental uncertainty of

Table 2.19

CALCULATION OF AVERAGE CHANGE IN EMISSIONS
PRE-EMISSION CONTROLLED VEHICLES
(FLEET 1)

PARAMETER		CHANGE	COLD 1972 FEDERAL HC		COLD 1972 FEDERAL CO		COLD 1972 FEDERAL NOx	
			ΔE/ΔP	ΔE gm/mi	ΔE/ΔP	ΔE gm/mi	ΔE/ΔP	ΔE gm/mi
TIMING, degrees		-.2037	.06710	-.013	-.8444	0.17	.1394	-0.028
IDLE RPM, rpm		61.71	-.002930	0.181	.02888	1.78	.0007306	0.045
PCV, cfm		-.1306	.02283	-0.003	-2.441	0.32	.05792	-0.008
A/C, degree		18.24	.005668	0.103	.1121	2.04	-.003049	-0.056
ICO, % v		0.5700	.4411	0.251	4.081	2.32	.2170	0.124
PREDICTED VALUES	$\bar{X}$			0.519		6.63		0.077
MEASURED VALUES	$\bar{X}$			1.212		5.34		0.026
	s			3.6		35		0.91
	d.f.			81		81		81
	t			3.07		1.40		0.26

Table 2.20

CALCULATION OF AVERAGE CHANGE IN EMISSIONS

EMISSION CONTROLLED VEHICLES

(FLEET 2)

PARAMETER		CHANGE	COLD 1972 FEDERAL HC $\Delta E/\Delta P$	COLD 1972 FEDERAL HC ΔE gm/mi	COLD 1972 FEDERAL CO $\Delta E/\Delta P$	COLD 1972 FEDERAL CO ΔE gm/mi	COLD 1972 FEDERAL NO_x $\Delta E/\Delta P$	COLD 1972 FEDERAL NO_x ΔE gm/mi
TIMING, degrees		-0.5488	0.0498	-0.027	-0.3423	0.19	0.09524	-0.052
IDLE RPM, rpm		- 11.12	-0.00550	0.061	0.02120	-0.24	0.000255	-0.003
PCV, cfm		-0.1193	-0.08415	0.010	-2.861	0.34	0.08654	-0.010
A/C, degrees		17.07	0.00090	0.015	0.07642	1.30	-0.00212	-0.036
ICO, % v		1.174	0.02860	0.034	7.177	8.42	0.02926	0.034
PREDICTED VALUES	$\bar{X}$			0.093		10.01		-0.067
MEASURED VALUES	$\bar{X}$			0.72		9.00		-0.222
	s			1.8		28		0.90
	d.f.			81		81		81
	t			3.54		2.88		-2.23

Table 2.21

CALCULATION OF AVERAGE CHANGE IN EMISSIONS

NO_X CONTROLLED VEHICLES

(FLEET 3)

PARAMETER		CHANGE	COLD 1972 FEDERAL HC ΔE/ΔP	COLD 1972 FEDERAL HC ΔE gm/mi	COLD 1972 FEDERAL CO ΔE/ΔP	COLD 1972 FEDERAL CO ΔE gm/mi	COLD 1972 FEDERAL NO_X ΔE/ΔP	COLD 1972 FEDERAL NO_X ΔE gm/mi
TIMING, degrees		-0.1686	0.07558	-0.013	-1.022	0.17	0.1299	-0.022
IDLE RPM, rpm		1.977	-0.0004243	-0.001	0.02598	0.05	0.0009632	0.019
PCV, cfm		-0.1598	-0.1548	0.025	-7.458	1.19	0.1038	-0.016
A/C, degrees		26.12	0.0008945	0.023	0.06869	1.79	-0.002476	-0.065
ICO, % v		0.8568	0.07983	0.068	6.773	5.80	-0.02948	-0.025
PREDICTED VALUES	$\bar{X}$			0.102		9.00		-0.109
MEASURED VALUES	$\bar{X}$			0.345		6.70		-0.07
	s			1.6		17		0.67
	d.f.			87		87		87
	t			2.06		3.64		-1.03

the data, but that the HC and NO_x emissions predictions would result in poor predictions of emissions. In order to further investigate the validity of the influence coefficients, computer runs were made applying the coefficients developed for each major manufacturer to the corresponding change measured in the test program. A corresponding comparison was made using the major change in Hot 1972 Federal emissions. In addition, predictions were made using results obtained in the first vehicle initialization period (Test 1A and 1B). The results of the computer runs are summarized in Tables 2.22, 2.23, and 2.24. These results agree with the comparisons developed using average changes in parameters. The best agreement was obtained for CO emission measurements; HC emission measurements correlated, but the predicted values were markedly smaller than the measured values. The statistics, however, did not show significant differences in many cases. For the data obtained for NO_x emission changes, there appeared to be a great deal of scatter between predicted and measured changes in emissions. In some cases there was a lack of agreement in direction between predicted and measured quantities. The predictions were also both larger and smaller than the measured quantities for the different cases considered. There appears to be a general lack of agreement between predicted and measured values of NO_x emissions.

Development of Uncertainty of the Influence Coefficients

In order to facilitate the statistical comparison of major changes in emissions and predicted changes, a measure of uncertainty of the influence coefficients was developed. The primary source of uncertainty was obtained from the residual variance estimates developed in the analysis of variance of test data. The uncertainty of the coefficient was developed by applying the following relationship:

Table 2.22

COMPARISON OF PREDICTED AND MEASURED COLD 1972 FEDERAL EMISSIONS
FINAL INITIALIZATION PERIOD (TEST 5A, 5B)

VEHICLE FLEETS		COLD 1972 FEDERAL HC PREDICTED* gm/mi	COLD 1972 FEDERAL HC MEASURED gm/mi	COLD 1972 FEDERAL CO PREDICTED* gm/mi	COLD 1972 FEDERAL CO MEASURED gm/mi	COLD 1972 FEDERAL NO_x PREDICTED* gm/mi	COLD 1972 FEDERAL NO_x MEASURED gm/mi
PRE-EMISSION CONTROLLED VEHICLES (FLEET 1)	$\bar{X}$	0.563	1.062	7.658	5.412	0.221	-0.020
	$S_{\bar{X}}$	0.048	0.47	0.55	4.7	0.060	0.12
	n	-	62	-	62	-	62
	t	-1.05		0.47		1.98	
	d.f.	61		61		61	
	Conf.	70		<50		95	
EMISSION CONTROLLED VEHICLES (FLEET 2)	$\bar{X}$	0.125	0.738	10.19	9.33	-0.095	-0.260
	$S_{\bar{X}}$	0.018	0.20	0.93	3.5	0.013	0.11
	n	-	67	-	67	-	67
	t	-3.00		0.23		1.44	
	d.f.	66		66		66	
	Conf.	>99		<40		85	
NO_x CONTROLLED VEHICLES (FLEET 3)	$\bar{X}$	0.095	0.242	8.61	6.68	-0.111	-0.051
	$S_{\bar{X}}$	0.010	0.57	0.58	1.9	0.012	0.077
	n	-	75	-	75	-	75
	t	-0.84		0.95		-0.74	
	d.f.	74		74		74	
	Conf.	60		70		60	

* PREDICTIONS MADE ON THE BASIS OF INFLUENCE COEFFICIENTS DEVELOPED BY MAKE

Table 2.23

COMPARISON OF PREDICTED AND MEASURED HOT 1972 FEDERAL EMISSIONS

FINAL INITIALIZATION PERIOD (TEST 5A, 5B)

VEHICLE FLEETS		HOT 1972 FEDERAL HC PREDICTED* gm/mi	HOT 1972 FEDERAL HC MEASURED gm/mi	HOT 1972 FEDERAL CO PREDICTED* gm/mi	HOT 1972 FEDERAL CO MEASURED gm/mi	HOT 1972 FEDERAL NO_x PREDICTED* gm/mi	HOT 1972 FEDERAL NO_x MEASURED gm/mi
PRE-EMISSION CONTROLLED VEHICLES (FLEET 1)	$\bar{X}$	0.591	1.533	8.14	10.24	0.243	-0.089
	$S_{\bar{X}}$	0.051	0.314	1.59	3.24	0.066	0.104
	n	-	59	-	59	-	59
	t	-2.93		-0.60		3.10	
	d.f.	58		58		58	
	Conf.	>99		50		>99	
EMISSION CONTROLLED VEHICLES (FLEET 2)	$\bar{X}$	0.115	0.502	9.61	10.08	-0.096	-0.298
	$S_{\bar{X}}$	0.016	0.170	0.87	2.78	0.013	0.117
	n	-	67	-	67	-	67
	t	-2.26		-0.15		1.71	
	d.f.	66		66		66	
	Conf.	97		<40		91	
NO_x CONTROLLED VEHICLES (FLEET 3)	$\bar{X}$	0.074	0.264	8.192	8.129	-0.144	-0.055
	$S_{\bar{X}}$	0.008	0.095	0.557	1.63	-0.016	0.079
	n	-	74	-	74	-	74
	t	-1.98		0.04		-1.10	
	d.f.	73		73		73	
	Conf.	95		<40		96	

* PREDICTIONS MADE ON THE BASIS OF INFLUENCE COEFFICIENTS DEVELOPED BY MAKE

Table 2.24

COMPARISON OF PREDICTED AND MEASURED COLD 1972 FEDERAL EMISSIONS

PRE-DETERIORATION EXPERIMENT INITIALIZATION PERIOD (TEST 1A, 1B)

VEHICLE FLEETS		COLD 1972 FEDERAL HC PREDICTED* gm/mi	COLD 1972 FEDERAL HC MEASURED gm/mi	COLD 1972 FEDERAL CO PREDICTED* gm/mi	COLD 1972 FEDERAL CO MEASURED gm/mi	COLD 1972 FEDERAL NO_x PREDICTED* gm/mi	COLD 1972 FEDERAL NO_x MEASURED gm/mi
PRE-EMISSION CONTROLLED VEHICLES (FLEET 1)	$\overline{X}$	0.215	0.608	5.48	6.691	0.088	-0.240
	$S_{\overline{X}}$	0.020	0.279	0.39	3.32	0.024	0.126
	n	-	74	-	74	-	74
	t	-1.40		-0.35		2.59	
	d.f.	73		73		73	
	Conf.	85		<40		99	
EMISSION CONTROLLED VEHICLES (FLEET 2)	$\overline{X}$	0.250	0.395	12.02	7.58	-0.016	-0.230
	$S_{\overline{X}}$	0.035	0.176	1.09	2.47	-0.002	0.167
	n	-	100	-	100	-	100
	t	-0.82		1.49		1.27	
	d.f.	99		99		99	
	Conf.	59		86		80	
NO_x CONTROLLED VEHICLES (FLEET 3)	$\overline{X}$	0.082	0.395	5.50	8.07	0.009	0.056
	$S_{\overline{X}}$	0.009	0.122	0.37	2.02	0.001	0.102
	n	-	104	-	104	-	104
	t	-2.53		-1.24		-0.46	
	d.f.	103		103		103	
	Conf.	99		80		<40	

* PREDICTIONS MADE ON THE BASIS OF INFLUENCE COEFFICIENTS DEVELOPED BY MAKE

$$S_B = S_R \sqrt{DF}/S_X$$

where;

S_B = Estimate of standard deviation of the influence coefficients

S_R = Square root of the residual variance

DF = Degrees of Freedom associated with the residual variance

S_X = Estimate of standard deviation of the variations imposed on the parameters

Estimates were obtained for each parameter and each vehicle tested. Since the emission levels of the vehicles tested were different, even though they were representative of vehicles within the same test fleet, i.e., Fleet 1, 2, or 3, the estimate of uncertainty of the coefficient was divided by the measured effect and adjusted to give an estimate presented as a percent of uncertainty. Estimates were developed only when the effects were statistically significant. These estimates were subsequently pooled to develop an overall estimate of uncertainty for each main effect. The resulting estimates of uncertainty are presented in Table 2.25.

In order to develop the functional relationship of the uncertainty in the coefficient and the uncertainty of the final predicted result, a measure of the fraction of total emission change that results from the change in a given tune parameter was developed, using the data presented in Tables 2.19, 2.20, and 2.21. Although it is realized that the distribution of changes in parameters will vary, depending on the particular set of vehicles tested, it was considered that the sample sizes were sufficiently large to give valid estimates of the changes in parameters. It is assumed the mean change in parameters would result regardless of the group of vehicles tested. This assumption is certainly acceptable for

Table 2.25

ESTIMATE OF STANDARD DEVIATION OF INFLUENCE COEFFICIENTS

PARAMETER	PRE-EMISSION CONTROLLED FLEET 1			EMISSION CONTROLLED FLEET 2			NO_X CONTROLLED FLEET 3		
	HC %	CO %	NO_X %	HC %	CO %	NO_X %	HC %	CO %	NO_X %
TIMING, deg	11.8	17.0	8.33	12.1	14.8	9.86	4.6	6.38	5.28
IDLE RPM, rpm	13.4	14.0	18.3	19.4	19.4	25.3	15.2	15.4	10.8
PCV FLOW, cfm	8.86	7.76	17.3	20.5	20.8	18.0	13.7	10.5	17.4
AIR CLEANER, deg	11.5	8.48	14.8	19.1	14.2	16.4	14.1	13.5	16.3
IDLE CO, % v	14.3	15.8	14.0	10.1	10.6	11.6	14.3	9.52	20.5
NO_X CONTROL, units	-	-	-	-	-	-	9.90	14.8	11.4
DEGREES OF FREEDOM	60			120			150		

use in prediction of overall uncertainties. These results also give an indication of the combined influence of the magnitude of the parameter change and the influence coefficients. The fraction of the changes that are expected as a result in change of parameter is summarized in Table 2.26. These results clearly suggest the importance of idle CO and air cleaner performance for control of emissions. Idle RPM appears significant in some cases, and PCV and basic timing appear least important. This latter conclusion is consistent with the observation that basic timing and PCV performance are somewhat invariant in vehicle use.

The overall uncertainty of the predictions ($S_{\overline{X}}$), as was summarized in Tables 2.22, 2.23, and 2.24, was developed by statistically summing the uncertainties of each of the coefficients and the fraction of total emission change as summarized in Table 2.26. These uncertainties, expressed in percent of measured values, are given in Table 2.27.

The values presented in Table 2.27 represent the uncertainty of predicted changes in emissions associated with changes only in the five parameters under consideration, i.e., timing, idle rpm, idle CO, air cleaner restriction, and PCV valve restriction. Variabilities in emissions of vehicle fleets in the field will be greater because other parameters will malfunction. The magnitude of the uncertainties do, however, suggest that within the limitations of the test program, the uncertainties are consistent with test measurement uncertainties. Repeatability tests conducted with NO_x Controlled Vehicles (Section 3.0) resulted in test-to-test estimates of standard deviation of 8.6%, 12%, and 4%, respectively, for HC, CO, and NO_x emissions measured using the Cold 1972 Federal Procedure. These can be compared with 10.6%, 6.8%, and 11.3%, respectively, for uncertainties of predictions. The uncertainty of predictions of NO_x emissions is the only case that appears excessively large. The uncertainty is great for this case because the tune-up parameters considered did not correlate well with the NO_x emissions.

Table 2.26

FRACTION OF TOTAL EMISSION CHANGE DUE TO CHANGE IN TUNE PARAMETER

PARAMETER	COLD 1972 FEDERAL HC			COLD 1972 FEDERAL CO			COLD 1972 FEDERAL NO_x		
	FLEET 1	FLEET 2	FLEET 3	FLEET 1	FLEET 2	FLEET 3	FLEET 1	FLEET 2	FLEET 3
TIMING, deg	-0.0250	-0.2903	-0.1274	0.0256	0.0190	0.0189	-0.3636	-0.7761	-0.2018
IDLE RPM, rpm	0.3487	0.6559	-0.0098	0.2685	-0.0240	0.0056	0.5844	-0.0448	0.1743
PCV, cfm	-0.0058	0.1075	0.2451	0.0483	0.0340	0.1322	-0.1039	-0.1492	-0.1468
AIR CLEANER, deg	0.1984	0.1613	0.2255	0.3077	0.1299	0.1989	-0.7273	-0.5373	-0.5963
ICO, % v	0.4836	0.3656	0.6667	0.3499	0.8412	0.6444	1.6104	0.5075	-0.2294
PREDICTED, gm/mi	0.519	0.093	0.102	6.63	10.01	9.00	0.077	-0.067	-0.109

Table 2.27

SUMMARY OF ESTIMATE OF UNCERTAINTY (STANDARD DEVIATION)
OF AVERAGE PREDICTED EMISSIONS

EMISSION	PRE-EMISSION CONTROLLED (FLEET 1) %	EMISSION CONTROLLED (FLEET 2) %	NO_x CONTROLLED (FLEET 3) %
COLD 1972 FEDERAL HC	8.7	14.2	10.6
COLD 1972 FEDERAL CO	7.2	9.1	6.8
COLD 1972 FEDERAL NO_x	27.4	13.4	11.3

Maintenance Effects on Emissions and Engine Parameters

The vehicles selected for the Parameter Deterioration Experiment were restored to manufacturers' specifications prior to release in the field. In this initial engine tune process all engine tune related components, including carburetor replacement on some vehicles, were replaced or repaired. At the completion of the deterioration phase of the experiment, vehicles were again restored to manufacturers' specifications. In this final engine tune, misfire related parameters, i.e., spark plugs, wires, etc., and parameters for which response coefficients were developed in the Orthogonal Experiments (Reference 1) were repaired. In both engine tune processes, emission and parameter inspections were made prior to and following the engine tune.

The average state of parameters prior to and following the tune process at the beginning and end of the Deterioration Experiment are presented in Tables 2.28 through 2.33. The tune parameters for the three test fleets are respectively presented in Tables 2.28 through 2.30 and the average emission levels as measured with the 1972 Federal Procedure are presented in Tables 2.31 through 2.33.

The data given as Test 1 are indicative of the tests prior to (Test 1A) and following (Test 1B) engine tune-up performed at the beginning of the test program. For most vehicles Test 5 was performed prior to release of the vehicles following the deterioration phase of the experiment. A few vehicles which required major repair during the deterioration phase of the program were also tested prior to and following repair. These tests were also designated as Test 5.

Although the data were indicative of the state following different time periods of deterioration, a large number of parameters were at a state close to the "as received" condition (Test 1A) when Test 5A was performed. Timing varied non-systematically. However, the agreement of the state of idle rpm, idle CO, and PCV flow rate, and air cleaner restriction for Pre-Emission Controlled Vehicles (Fleet 1) and Emission

Table 2.28
EFFECT OF RE-INITIALIZATION
TUNE PARAMETERS

PRE-EMISSION CONTROLLED VEHICLES

FLEET 1

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
TIMING, degrees	$\overline{X}$	0.44	0.014	0.47	-0.39	-0.24	-0.16
	s	5.8	0.28	5.8	6.2	2.2	4.7
	d.f.	148	146	147	96	96	95
	t	-	-	0.97	-	-	-0.34
	Conf.	-	-	67	-	-	< 40
IRPM, rpm	$\overline{X}$	81.2	12.4	67.1	63.5	4.3	56.5
	s	141	45	138	150	18	144
	d.f.	148	142	145	94	96	93
	t	-	-	5.86	-	-	3.79
	Conf.	-	-	99	-	-	99
ICO, % v	$\overline{X}$	6.08	5.86	0.27	6.50	6.12	0.39
	s	3.0	2.6	3.2	2.8	2.7	3.0
	d.f.	147	148	147	96	96	95
	t	-	-	1.04	-	-	1.27
	Conf.	-	-	69	-	-	78
AIR CLN, degrees	$\overline{X}$	60.0	31.7	28.4	61.1	40.5	19.3
	s	53	44	51	41	35	31
	d.f.	137	136	133	91	87	87
	t	-	-	6.43	-	-	5.79
	Conf.	-	-	99	-	-	99
PCV FLO D1, cfm (49/45 Cruise)	$\overline{X}$	2.87	2.93	-0.09	3.09	3.32	-0.22
	s	1.3	1.1	1.4	1.5	1.3	1.3
	d.f.	126	126	124	83	83	82
	t	-	-	-0.72	-	-	-1.52
	Conf.	-	-	52	-	-	86
MILEAGE		83248	83438	0	93038	93233	0
TEST DATE		202	204	0	634	635	0

Table 2.29

EFFECT OF RE-INITIALIZATION TUNE PARAMETERS

EMISSION CONTROLLED VEHICLES

FLEET 2

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
TIMING, degrees	$\overline{X}$	0.53	0.063	0.33	-0.32	0.19	-0.51
	s	4.7	0.88	4.5	3.4	1.2	3.5
	d.f.	147	141	141	94	94	94
	t	-	-	0.87	-	-	-1.43
	Conf.	-	-	61	-	-	84
IRPM, rpm	$\overline{X}$	-17.3	-1.5	-17.4	-15.2	-0.54	-12.8
	s	108	12	109	89	6.4	91
	d.f.	147	145	145	94	92	92
	t	-	-	-1.92	-	-	-1.36
	Conf.	-	-	94	-	-	82
ICO, % v	$\overline{X}$	3.98	3.15	0.83	3.67	2.50	1.17
	s	2.5	2.2	2.7	2.8	1.7	2.6
	d.f.	147	147	147	94	94	94
	t	-	-	3.77	-	-	4.48
	Conf.	-	-	99	-	-	99
AIR CLN, degrees	$\overline{X}$	45.9	21.7	22.5	43.1	23.2	20.0
	s	53	37	49	40	31	34
	d.f.	136	137	133	88	84	84
	t	-	-	5.36	-	-	5.43
	Conf.	-	-	99	-	-	99
PCV FLO DI, cfm (49/45 Cruise)	$\overline{X}$	2.619	2.619	0	2.872	3.093	-0.227
	s	0.97	0.80	1.0	0.88	0.89	0.80
	d.f.	136	136	136	89	88	88
	t	-	-	0	-	-	-2.66
	Conf.	-	-	<40	-	-	99
MILEAGE		43357	43357	0	53809	53826	0
TEST DATE		187	189	0	622	622	0

Table 2.30

EFFECT OF RE-INITIALIZATION
TUNE PARAMETERS

NOX CONTROLLED VEHICLES

FLEET 3

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
TIMING, degrees	$\overline{X}$	0.19	0.04	0.24	0.14	0	0.16
	s	3.5	1.2	3.2	4.6	0.55	4.5
	d.f.	147	145	145	104	104	103
	t	-	-	0.91	-	-	0.36
	Conf.	-	-	68	-	-	<40
IRPM, rpm	$\overline{X}$	-5.7	1.8	-14.2	10.6	1.00	11.1
	s	138	35	94	136	8.2	138
	d.f.	149	148	148	105	103	103
	t	-	-	-1.84	-	-	0.82
	Conf.	-	-	93	-	-	58
ICO, % v	$\overline{X}$	3.34	2.81	0.52	3.00	1.76	1.24
	s	2.7	2.5	2.5	2.6	1.8	2.4
	d.f.	149	148	148	104	105	104
	t	-	-	2.52	-	-	5.32
	Conf.	-	-	98	-	-	99
AIR CLN, degrees	$\overline{X}$	28.8	16.0	13.2	42.3	17.8	24.5
	s	43	32	34	38	22	31
	d.f.	130	133	128	98	98	97
	t	-	-	4.39	-	-	7.86
	Conf.	-	-	99	-	-	99
PCV FLO DI, cfm (49/45 Cruise)	$\overline{X}$	2.574	2.63	-0.057	2.82	3.04	-0.219
	s	0.90	1.1	0.82	1.0	1.2	0.95
	d.f.	135	134	133	97	97	97
	t	-	-	-0.81	-	-	-2.27
	Conf.	-	-	58	-	-	97
MILEAGE		8059	8059	0	24221	24345	0
TEST DATE		215	217	0	642	643	0

Table 2.31

EFFECT OF RE-INITIALIZATION
EMISSION PARAMETERS

PRE-EMISSION CONTROLLED VEHICLES

FLEET 1

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
72 COLD HC,	$\overline{X}$	12.48	11.17	1.41	16.0	12.62	3.34
gm/mi	s	6.9	4.6	5.5	12	9.3	9.5
	d.f.	147	148	147	96	96	95
	t	-	-	3.11	-	-	3.46
	Conf.	-	-	99	-	-	99
72 COLD CO,	$\overline{X}$	135.4	125.3	10.6	146.0	137.9	7.7
gm/mi	s	63	53	49	84	85	59
	d.f.	147	148	147	96	96	95
	t	-	-	2.61	-	-	1.29
	Conf.	-	-	99	-	-	80
72 COLD NOXP,	$\overline{X}$	3.68	3.88	-0.24	3.40	3.62	-0.22
gm/mi	s	1.7	1.9	1.4	1.6	1.8	1.5
	d.f.	146	148	146	96	96	95
	t	-	-	-2.07	-	-	-1.39
	Conf.	-	-	96	-	-	83
MILEAGE		83248	83438	0	93038	93233	0
TEST DATE		202	204	0	634	635	0

Table 2.32

EFFECT OF RE-INITIALIZATION
EMISSION PARAMETERS

EMISSION CONTROLLED VEHICLES

FLEET 2

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
72 COLD HC,	$\overline{X}$	7.39	6.55	0.84	8.65	6.40	2.25
gm/mi	s	3.8	2.2	3.4	10	3.1	9.1
	d.f.	147	147	147	94	94	94
	t	-	-	3.01	-	-	2.42
	Conf.	-	-	99	-	-	98
72 COLD CO,	$\overline{X}$	93.5	84.6	9.0	96.6	82.4	14.2
gm/mi	s	44	35	34	60	34	51
	d.f.	147	147	147	94	94	94
	t	-	-	3.18	-	-	2.70
	Conf.	-	-	99	-	-	99
72 COLD NOXP,	$\overline{X}$	5.80	5.91	-0.11	4.72	5.02	-0.30
gm/mi	s	2.2	2.0	2.0	1.5	1.6	1.1
	d.f.	145	144	143	94	94	94
	t	-	-	-0.69	-	-	-2.54
	Conf.	-	-	51	-	-	98
MILEAGE		43357	43357	0	53809	53826	0
TEST DATE		187	189	0	622	622	0

Table 2.33

EFFECT OF RE-INITIALIZATION
EMISSION PARAMETERS

NOX CONTROLLED VEHICLES

FLEET 3

PARAMETER		1A	1B	1A-1B	5A	5B	5A-5B
72 COLD HC,	$\overline{X}$	4.98	4.60	0.37	5.80	4.63	1.16
gm/mi	s	1.8	2.3	2.0	4.7	1.5	4.3
	d.f.	149	148	148	104	105	104
	t	-	-	2.29	-	-	2.74
	Conf.	-	-	97	-	-	99
72 COLD CO,	$\overline{X}$	71.0	61.0	10.0	71.1	57.7	13.1
gm/mi	s	37	32	28	44	29	26
	d.f.	149	147	147	104	105	104
	t	-	-	4.32	-	-	5.15
	Conf.	-	-	99	-	-	99
72 COLD NOXP,	$\overline{X}$	5.40	5.27	0.12	4.45	4.65	-0.193
gm/mi	s	1.7	1.7	1.4	1.1	1.3	0.88
	d.f.	149	148	148	104	105	104
	t	-	-	1.07	-	-	-2.24
	Conf.	-	-	70	-	-	97
MILEAGE		8059	8059	0	24221	24345	0
TEST DATE		215	217	0	642	643	0

Controlled Vehicles (Fleet 2) was extremely close. With the NO_x Controlled Vehicles (Fleet 3) the state of idle CO and PCV flow rate at Test 1A and 5A showed fair agreement. As expected, since the Fleet 3 vehicles were fairly new (8,000 miles) at the time of initial tune process, air cleaner restriction measured at Test 5 was greater than measured at Test 1A.

The average HC and CO emissions tended to be larger, and the NO_x emissions smaller, at TEst 5A than at Test 1A. Normal wear of all components other than those repaired would be expected to cause these differences. In all cases, however, emission levels following the two tune-up processes showed extremely good agreement. The magnitude of the changes in emissions that were measured at the completion of the program (after 10,000 to 15,000 miles of use) were consequently larger in magnitude.

The data taken prior to and following the tune-up process appear consistent. Attempts made to correlate predicted changes in emissions as developed on the basis of measured changes in parameters and response coefficients did not fully account for the changes observed in the emission levels (this effort is described in Section 3.1.5). The magnitude of the changes should, however, be considered as best estimates for the changes in emissions that could be expected by restoring vehicles to manufacturers' specifications.

2.4.2 Analysis Method

Comparison of Approach

Several approaches for developing the parameter deterioration rates of continuous functions were investigated prior to the selection of the method ultimately used to develop the rates. The final method used to compute the parameter deterioration rates was one in which the slope, i.e., change in parameter with change in mileage, was calculated using the data taken in two consecutive tests with a given vehicle. Averages for each pair of test periods were computed, e.g., Test 2 - Test 1, Test 3 - Test 2, etc. The average values for each pair of test periods were ultimately statistically pooled to develop the finalized deterioration rates. A detailed description of the procedure is further described later in this Section.

The initial approach used to develop the deterioration rates was development of a linear regression of the change in emissions with mileage accumulation from the values that existed following initialization of the vehicles (Test 1B). The results of this initial effort indicate, with the exception of the NO_x Controlled Vehicles, a very low number of statistically significant relationships, particularly with the Cold 1972 Federal Emissions. The results of the repeatability tests, which were described in Section 3.0, suggested that particularly with HC emissions a systematically lower value will be obtained if two consecutive tests are conducted using the Cold 1972 Federal Procedure. Therefore, on the basis of the assumption that deterioration rates are linear, linear regressions were developed using Test 2 measured values as the reference condition. These results gave more cases of statistically significant results.

It was speculated that if the changes in emissions were expressed as a fraction of the value obtained following the initialization of the vehicles, a more meaningful result would be obtained. This speculation had been previously suggested by members of the CRC CAPE-13 Committee. Therefore, in an attempt to further improve the results, linear regressions were developed using the changes expressed as a fraction of the Test 1B measured values, or the Test 2 measured values (two cases were investigated). This approach further improved the correlations in that the Index of Determinations improved for most cases considered.

A careful review of the data suggested that systematic biases in the difference from the reference test values (either Test 1B or Test 2) resulted in the data. This would be caused by a high or low reference value that could result from random variations of measured emissions. In order to eliminate these systematic biases the slope, i.e., change in emissions with change in parameter, was calculated on the basis of two consecutive tests. As would be expected, in many cases close examination of the results for a given vehicle indicated that slopes varied both in a positive and negative manner. This random variability could, however, be reduced by averaging the data. The arithmetic average of the data for each of the vehicles between two adjacent tests was calculated to develop an estimate of the deterioration rate between two discrete measurement points. These results were further examined for consistency and those values which were statistically different from the remaining set at the 95 percent confidence level were rejected. The remaining estimates were finally pooled to develop the best estimate of the deterioration rate.

The results of all of the investigations conducted to determine the deterioration rates of Cold 1972 Federal Emissions are presented in Tables 2.34, 2.35, and 2.36. In addition to the results of regressions described in the previous discussion, the statistics for linear regressions of the measured emissions, i.e., no reference value subtracted, are included in the tables. The results, also summarized in Tables 2.34 through 2.36 indicate fairly consistent results between vehicle fleets. It is apparent that the data obtained with the Pre-Emission Controlled Vehicles exhibited the greatest amount of scatter, and the results with the 1971 NO_x Controlled Vehicles resulted in the least amount of scatter in the data. With the exception of this trend, a comparison of the different approaches shows comparable results. The significance levels, using Test 2 as a reference, tend to be higher than those obtained using the Test 1B values as a reference. The regressions were better, as indicated by the larger student(t)values. The correlations were further improved when the regressions were developed using the fractional (ratio) change in emissions. In contrast, due to the large variability in emission levels of vehicles in a given fleet, linear regressions using the "as measured" values (in contrast to using the change in emissions) resulted in statistically significant correlations (greater than 90 percent confidence) with only

Table 2.34

COMPARISON OF SLOPES - COLD 1972 FEDERAL EMISSIONS

PRE-EMISSION CONTROLLED VEHICLES
(FLEET 1)

PARAMETER		REGRESSION RESULTS					
		MEASURED CHANGE FROM REFERENCE TEST		FRACTIONAL CHANGE FROM REFERENCE TEST		MEASURED	RETRIEVAL RESULTS
		TEST 1B gm/mi^2	TEST 2 gm/mi^2	TEST 1B gm/mi	TEST 2 gm/mi	gm/mi^2	gm/mi^2
COLD 1972 FEDERAL HC	Slope	$2.695x10^{-5}$	$1.759x10^{-4}$	$5.103x10^{-6}$	$2.080x10^{-5}$	$5.537x10^{-5}$	$5.740x10^{-4}$
	SEE	2.83	3.185	0.284	0.256	4.93	$22.7x10^{-4}$
	t	0.83	2.60	1.56	3.83	1.01	3.15
	d.f.	384	235	384	235	389	154
	Conf.	59	99	90	99	70	99
COLD 1972 FEDERAL CO	Slope	$4.221x10^{-4}$	$1.643x10^{-3}$	$5.992x10^{-6}$	$1.857x10^{-5}$	$3.922x10^{-5}$	$4.673x10^{-3}$
	SEE	28.5	28.9	0.297	0.261	52.6	$23.2x10^{-3}$
	t	1.28	2.68	1.75	3.36	0.65	2.85
	d.f.	384	235	384	235	389	154
	Conf.	80	99	93	99	47	99
COLD 1972 FEDERAL NO_x	Slope	$-2.608x10^{-5}$	$-1.571x10^{-5}$	$-4.345x10^{-5}$	$6.559x10^{-7}$	$-4.035x10^{-5}$	$2.327x10^{-4}$
	SEE	0.891	0.766	0.232	0.537	1.66	$6.78x10^{-4}$
	t	2.54	0.97	1.63	0.06	2.18	4.51
	d.f.	382	229	382	229	387	168
	Conf.	99	76	90	<40	97	99

Table 2.35

COMPARISON OF SLOPES - COLD 1972 FEDERAL EMISSIONS

EMISSION CONTROLLED VEHICLES
(FLEET 2)

PARAMETER		REGRESSION RESULTS: MEASURED CHANGE FROM REFERENCE TEST, TEST 1B gm/mi^2	MEASURED CHANGE FROM REFERENCE TEST, TEST 2 gm/mi^2	FRACTIONAL CHANGE FROM REFERENCE TEST, TEST 1B gm/mi	FRACTIONAL CHANGE FROM REFERENCE TEST, TEST 2 gm/mi	MEASURED gm/mi^2	RETRIEVAL RESULTS gm/mi^2
COLD 1972 FEDERAL HC	Slope	-9.240×10^{-6}	3.784×10^{-5}	1.987×10^{-6}	9.660×10^{-6}	-2.781×10^{-5}	1.333×10^{-4}
	SEE	1.88	1.33	0.278	0.206	2.54	8.28×10^{-4}
	t	0.52	1.77	0.77	2.91	1.19	2.12
	d.f.	393	244	393	244	395	173
	Conf.	40	92	60	99	76	95
COLD 1972 FEDERAL CO	Slope	2.448×10^{-4}	5.255×10^{-4}	1.429×10^{-5}	1.184×10^{-5}	1.643×10^{-4}	2.351×10^{-3}
	SEE	22.6	18.1	0.354	0.226	34.0	11.4×10^{-3}
	t	1.17	1.80	4.37	3.25	0.52	2.72
	d.f.	393	244	393	244	395	173
	Conf.	75	92	99	99	40	99
COLD 1972 FEDERAL NO_x	Slope	-1.114×10^{-4}	-3.756×10^{-5}	-1.439×10^{-5}	-4.600×10^{-6}	-8.763×10^{-5}	-3.744×10^{-4}
	SEE	1.49	0.961	0.203	0.179	1.74	7.59×10^{-4}
	t	8.07	2.25	7.62	1.48	5.50	181
	d.f.	383	233	383	233	387	6.65
	Conf.	99	97	99	85	>99	99

Table 2.36

COMPARISON OF SLOPES - COLD 1972 FEDERAL EMISSIONS

NO_x CONTROLLED VEHICLES
(FLEET 3)

PARAMETER		REGRESSION RESULTS: MEASURED CHANGE FROM REFERENCE TEST, TEST 1B gm/mi	MEASURED CHANGE FROM REFERENCE TEST, TEST 2 gm/mi	FRACTIONAL CHANGE FROM REFERENCE TEST, TEST 1B 1/mi	FRACTIONAL CHANGE FROM REFERENCE TEST, TEST 2 1/mi	MEASURED gm/mi	RETRIEVAL RESULTS gm/mi^2
COLD 1972 FEDERAL HC	Slope	$2.990x10^{-5}$	$8.392x10^{-5}$	$9.619x10^{-6}$	$2.132x10^{-5}$	$2.146x10^{-5}$	$0.703x10^{-4}$
	SEE	1.11	1.05	0.316	0.226	1.84	$3.73x10^{-4}$
	t	3.53	6.04	4.00	7.13	1.56	2.83
	d.f.	412	265	412	265	426	186
	Conf.	99	99	99	99	87	99
COLD 1972 FEDERAL CO	Slope	$4.065x10^{-4}$	$6.101x10^{-4}$	$1.339x10^{-5}$	$1.540x10^{-5}$	$3.788x10^{-4}$	$0.8105x10^{-3}$
	SEE	15.7	15.8	0.344	0.296	37.2	$4.57x10^{-3}$
	t	3.39	2.92	5.09	3.95	1.57	2.40
	d.f.	407	265	407	265	425	183
	Conf.	99	99	99	99	87	98
COLD 1972 FEDERAL NO_x	Slope	$-6.689x10^{-5}$	$-1.823x10^{-5}$	$-1.030x10^{-5}$	$-2.651x10^{-6}$	$-3.940x10^{-5}$	$-1.803x10^{-4}$
	SEE	0.998	0.685	0.171	0.169	1.39	$3.40x10^{-4}$
	t	8.80	2.00	7.90	1.18	3.80	7.45
	d.f.	410	260	410	260	424	207
	Conf.	99	96	99	78	>99	99

NO_x emissions. The approach using the overall pooled value of the slope of the emission between tests (indicated as Retrieval Results in Tables 2.34 through 2.36) resulted in statistically significant values in all cases. It should be emphasized that in many cases the approach in which the slope between adjacent tests is used resulted in a higher magnitude for the overall deterioration rate. As will be explained later in detail, some of the results are due to the rejection of data between given tests. The corresponding results obtained for the other parameters of interest are presented in Tables 2.37, 2.38, and 2.39, for the three test fleets.

Selection of Method

The different deterioration rates that would result, depending upon the method used to analyze the data, are very vividly illustrated in Figures 2.12, 2.13, and 2.14. The three figures respectively represent the plots of the change in Cold 1972 Federal HC, CO, and NO_x emissions for the Pre-Emission Controlled Vehicle Fleet after vehicle initialization. The various plots presented in each figure illustrate the different deterioration rates of emissions developed by alternative methods for analyzing the test data. The data points presented are those that represent the change from the measurements taken following vehicle initialization. The mean values obtained following each test during the deterioration phase of the program are respectively represented with triangles and circles for the total data set (Δ) and the set that would result with only vehicles that completed the entire program with no maintenance (O). Review of these discrete average values suggests and "s" shaped non-linear deterioration with a net effect of marginal change in emissions at the end of the deterioration program, with approximately 10 to 17,000 miles of average mileage accumulated on the vehicles. It should be observed that the agreement of both the results with the total data set and the constant n data set illustrate the validity of including all of the data in the analysis regardless of whether or not the test vehicle remained non-maintained throughout the deterioration experiment.

TABLE 2.37

COMPARISON OF SLOPES - ENGINE TUNE AND KEY MODE PARAMETERS

PRE-EMISSION CONTROLLED VEHICLES
FLEET 1

PARAMETER	REGRESSION RESULTS				RETRIEVAL RESULTS
	MEASURED CHANGE FROM REFERENCE TEST		FRACTIONAL CHANGE FROM REFERENCE TEST		
	TEST 1B	TEST 2	TEST 1B	TEST 2	
TIMING, degrees/mi	3.107×10^{-5}	-6.606×10^{-5}	-	-	-1.481×10^{-4}
IDLE RPM, rpm/mi	4.540×10^{-3}*	1.838×10^{-3}	-	-	3.766×10^{-3}
AIR CLEANER, deg./mi	1.064×10^{-3}*	9.509×10^{-4}*	-	-	5.307×10^{-3}
PCV FLOW, cfm/mi	-1.619×10^{-5}*	-3.241×10^{-5}*	-	-	-1.424×10^{-5}
CHOKE KICK, in/mi	-4.828×10^{-7}*	-2.303×10^{-7}	-	-	-1.889×10^{-7}
49/45 MPH HC, ppm/mi	-1.295×10^{-3}*	2.306×10^{-3}*	-2.503×10^{-6}	1.753×10^{-5}*	-0.978×10^{-3}
49/45 MPH CO, % v/mi	-2.820×10^{-5}*	4.062×10^{-5}*	-8.169×10^{-6}*	2.652×10^{-5}*	-3.366×10^{-5}
49/45 MPH NO_x, ppm/mi	2.685×10^{-2}*	-2.473×10^{-2}*	2.060×10^{-5}	-6.638×10^{-6}	5.644×10^{-2}
IDLE HC, ppm/mi	6.621×10^{-4}	8.871×10^{-3}	1.149×10^{-5}*	2.138×10^{-5}*	-0.382×10^{-2}
IDLE CO, % v/mi	2.414×10^{-5}	3.647×10^{-5}	2.256×10^{-5}	3.448×10^{-5}*	1.334×10^{-4}
IDLE NO_x, ppm/mi	7.715×10^{-4}	3.887×10^{-4}	6.343×10^{-5}*	2.837×10^{-5}*	-3.140×10^{-3}

*Regression significant at 90% confidence level.

Table 2.38

COMPARISON OF SLOPES - ENGINE TUNE AND KEY MODE PARAMETERS

EMISSION CONTROLLED VEHICLES
FLEET 2

PARAMETER	REGRESSION RESULTS: MEASURED CHANGE FROM REFERENCE TEST		REGRESSION RESULTS: FRACTIONAL CHANGE FROM REFERENCE TEST		RETRIEVAL RESULTS
	TEST 1B	TEST 2	TEST 1B	TEST 2	
TIMING, degrees/mi	-4.114×10^{-5}*	-1.214×10^{-5}	-	-	-0.409×10^{-4}
IDLE RPM, rpm/mi	-2.207×10^{-4}	1.689×10^{-3}	-	-	3.766×10^{-3}
AIR CLEANER, deg./mi	1.820×10^{-3}*	2.016×10^{-3}*	-	-	5.307×10^{-3}
PCV FLOW, cfm/mi	5.746×10^{-7}	-1.342×10^{-5}	-	-	-1.424×10^{-5}
CHOKE KICK, in/mi	-4.929×10^{-7}*	-1.198×10^{-6}	-	-	-1.889×10^{-7}
49/45 MPH HC, ppm/mi	-1.210×10^{-3}*	1.032×10^{-3}*	-6.064×10^{-6}*	8.790×10^{-6}*	-2.444×10^{-3}
49/45 MPH CO, % v/mi	5.769×10^{-6}	1.210×10^{-5}*	1.676×10^{-5}*	1.860×10^{-5}*	-0.278×10^{-5}
49/45 MPH NO_x, ppm/mi	-1.198×10^{-2}*	-2.877×10^{-2}*	3.052×10^{-4}	3.125×10^{-5}	-1.203×10^{-2}
IDLE HC, ppm/mi	2.267×10^{-4}	5.252×10^{-3}*	1.039×10^{-5}*	3.954×10^{-5}*	0.046×10^{-2}
IDLE CO, % v/mi	5.358×10^{-5}*	4.161×10^{-5}*	6.879×10^{-5}*	5.904×10^{-5}	0.274×10^{-4}
IDLE NO_x, ppm/mi	-5.845×10^{-4}	-2.279×10^{-3}*	1.786×10^{-5}	-7.928×10^{-6}	-1.088×10^{-3}

*Regression significant at 90% confidence level.

Table 2.39

COMPARISON OF SLOPES - ENGINE TUNE AND KEY MODE PARAMETERS

NO_X CONTROLLED VEHICLES
FLEET 3

PARAMETER	REGRESSION RESULTS: MEASURED CHANGE FROM REFERENCE TEST		REGRESSION RESULTS: FRACTIONAL CHANGE FROM REFERENCE TEST		RETRIEVAL RESULTS
	TEST 1B	TEST 2	TEST 1B	TEST 2	
TIMING, degrees/mi	-3.187×10^{-5}	-7.051×10^{-5}*	-	-	0.345×10^{-4}
IDLE RPM, rpm/mi	-4.645×10^{-4}	2.345×10^{-4}	-	-	-1.510×10^{-3}
AIR CLEANER, deg./mi	1.895×10^{-3}*	2.205×10^{-3}*	-	-	2.093×10^{-3}
PCV FLOW, cfm/mi	8.467×10^{-6}*	6.650×10^{-6}	-	-	0.9700×10^{-5}
CHOKE KICK, in/mi	-4.959×10^{-8}	-5.283×10^{-8}	-	-	-3.310×10^{-7}
49/45 MPH HC, ppm/mi	4.681×10^{-4}	-4.302×10^{-4}	6.551×10^{-6}	2.916×10^{-6}	-0.228×10^{-3}
49/45 MPH CO, % v/mi	-6.270×10^{-7}	6.193×10^{-6}*	9.456×10^{-6}	1.458×10^{-5}*	-0.716×10^{-5}
49/45 MPH NO_X, ppm/mi	8.168×10^{-3}*	-1.572×10^{-2}*	3.705×10^{-6}*	-6.631×10^{-6}*	-3.002×10^{-2}
IDLE HC, ppm/mi	2.413×10^{-3}*	3.303×10^{-3}*	1.681×10^{-5}*	2.177×10^{-5}*	-0.013×10^{-2}
IDLE CO, % v/mi	3.437×10^{-5}*	2.870×10^{-5}*	6.362×10^{-5}*	1.400×10^{-4}*	-0.115×10^{-4}
IDLE NO_X, ppm/mi	-2.529×10^{-4}	-1.888×10^{-3}*	1.141×10^{-5}	-3.502×10^{-6}	0.200×10^{-3}

*Regression significant at 90% confidence level.

Figure 2.12

COLD 1972 FEDERAL HC EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

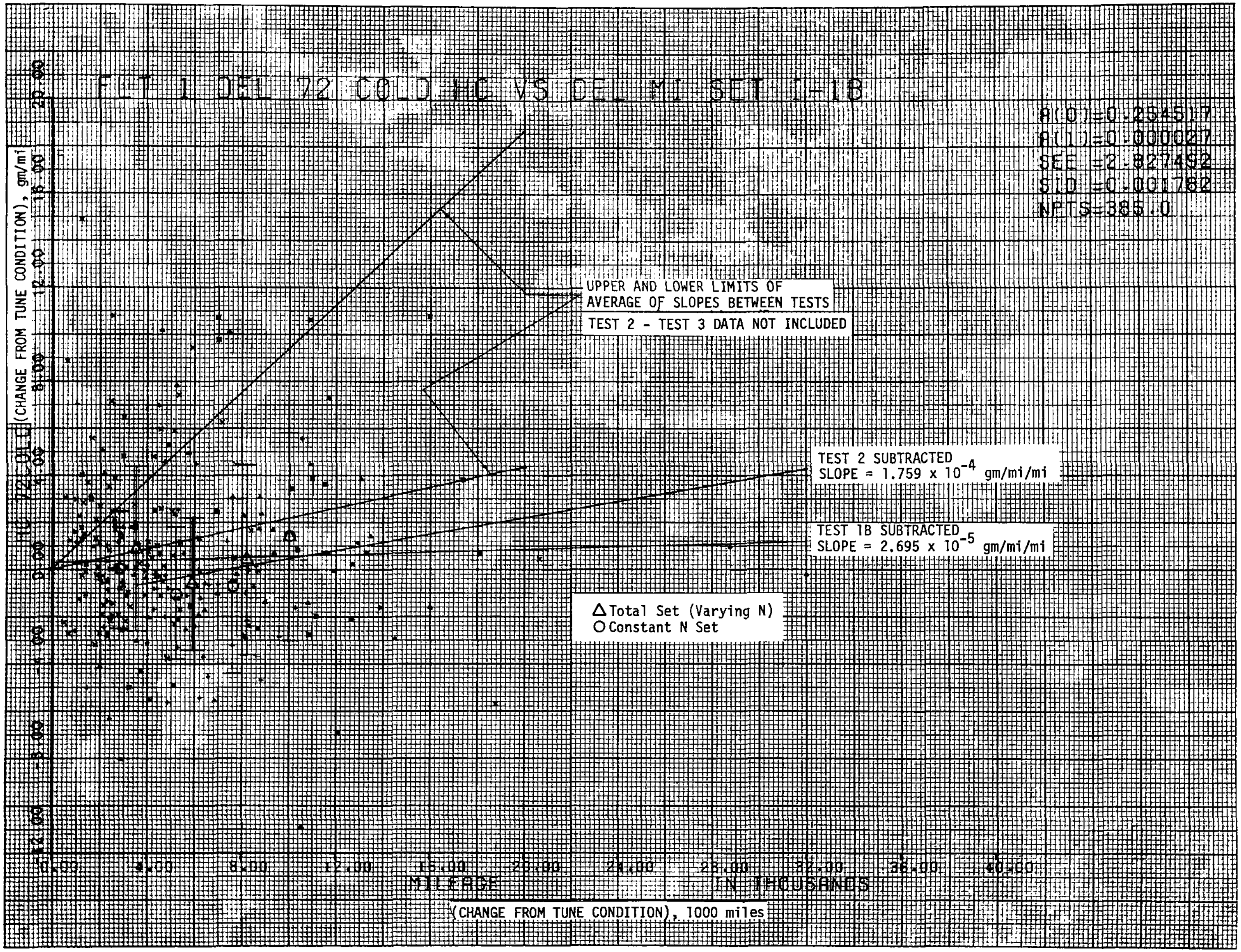


Figure 2.13

COLD 1972 FEDERAL CO EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

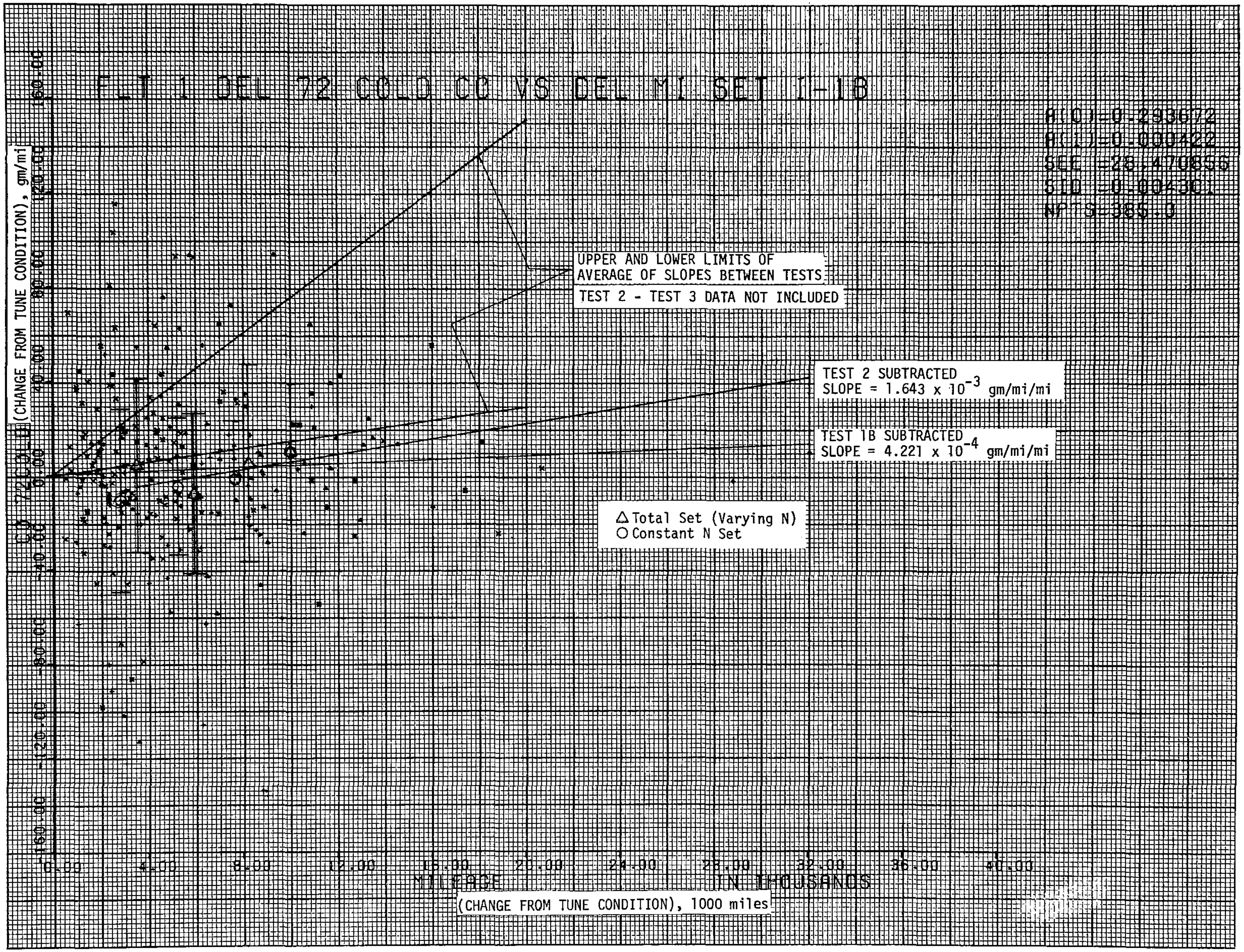
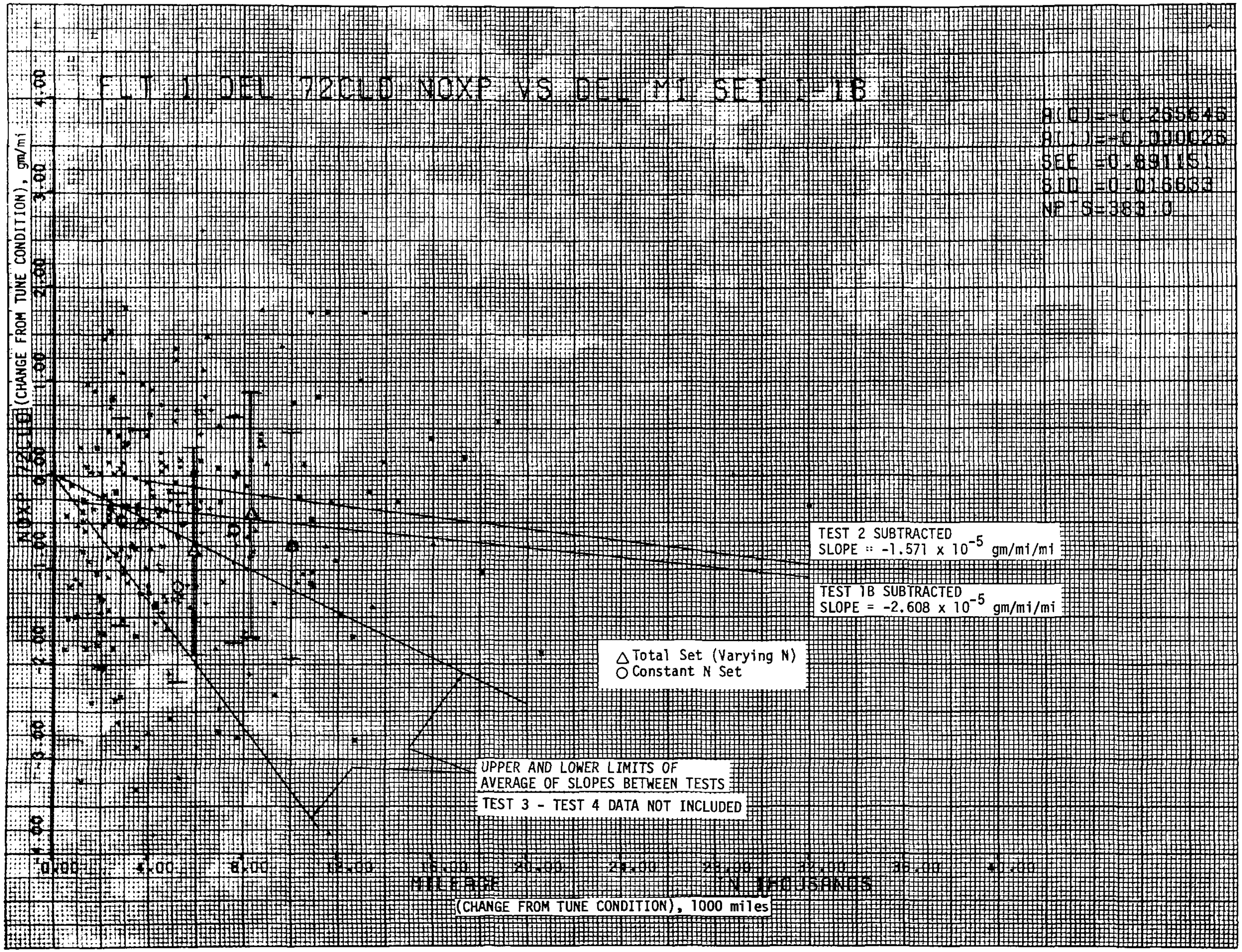


Figure 2.14

COLD 1972 FEDERAL NO_X EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES



The deterioration rate of Cold 1972 Federal HC (gm/mi^2) as is illustrated in Figure 2.12, is representative of all of the figures. For this case the slope of the linear regression developed using all of the points plotted in the graph resulted in a slope of $2.695x10^{-5}$ gm/mi^2. As depicted in Figure 2.12, this slope represents a negligible deterioration rate and is indicated to be negligible by the low value of index of determination given in the regression results (summary of the results of regressions are presented in Section 2.4.4). As is discussed in the analysis of repeatability test data because there was some question as to the validity of the test following vehicle initialization, a regression was developed using the data taken at Test 2 as a reference. The resulting linear curve is presented in Figure 2.12 with a slope of $1.759x10^{-4}$ gm/mi^2. Finally, by taking the difference between adjacent tests and developing the arithmetic mean of all slopes calculated using each pair of tests resulted in an average value of $5.74x10^{-4}$ gm/mi^2 (not plotted). The curves presented in Figure 2.12 give the upper and lower 95 percent confidence limits of this mean value. The upper and lower limits are, respectively, $9.32x10^{-4}$ gm/mi^2 and $2.148x10^{-4}$ gm/mi^2.

In the development of the slopes by using the calculated slope between adjacent tests, clear indications of differences in average values for given pairs of tests which were statistically different were observed (Test 2 - Test 2). This difference is apparent in the plot of the average values for Tests 2 and 3, presented in Figure 2.12. The upper and lower limits indicated in the figure represent the results obtained following rejection of the statistically significant outlier set. The rejection of the outlier set is the primary reason why the slopes obtained by the averaging method are markedly different than those obtained by the regressions.

Clearly, the different approaches give different results. The best method for developing the deterioration rate is not apparent. There is a large amount of data scatter and the linear regressions obtained are not statistically significant when the total data set is used. In contrast, if data subsequent to Test 2 are used, a statistically significant (99 percent) regression is obtained. However, the data used in regressions were in some cases obviously biased by the fact that subtracting a given reference value from all subsequent values, a systematic bias in all of the data points would result because of the random variation that resulted in the data measured at the reference point. Review of computer listings clearly indicated positive and negative deviations for certain vehicles. For example, with some vehicles negative deviations resulted at every test and therefore suggested an erroneously high value for the reference test. The calculation of individual slopes between adjacent tests and averaging of the data tends to eliminate systematic biases. Random variations will, however, exist in all of the data and the development of the arithmetic average will tend to eliminate the effects of random variation. The averaging technique was therefore selected as the best method for developing the deterioration rates.

It should be emphasized that the averaging method tends to result in high values if a situation in which large changes resulted due to random variations of measurements and low mileage was accumulated between tests. Obvious outliers have been rejected during the computational process; however, this approach will weight the data in favor of the high deterioration rate values. Consistency of the standard deviations of all the individual pairs of tests, however, suggests that the overall data set was consistent. Further improvement may possibly be made by further rejecting extreme values.

The results of the analyses conducted using the data taken with Emission Controlled Vehicles and the NO_x Controlled Vehicles, respectively presented in Figures 2 and 3, illustrate comparable results. The format described in Figures 2.12, 2.13, and 2.14 is maintained throughout all of the figures and is presented in the data summary in Section 2.4.4. Plots representing the Federal Emissions of all the vehicle fleets, together with the five continuous parameters considered most important to emissions control, e.g., timing, idle rpm, air cleaner, PCV flow (33/30 mph cruise), and choke kick, and the emissions measured in the 49/45 mph cruise and idle modes of the Clayton keymode cycle, are included in Section 2.4.4.

2.4.3 Variability of Coefficients

In addition to the development of the influence coefficients and the deterioration rates in order to meaningfully make use of the Economic Effectiveness model, it was necessary to develop a measure of uncertainty of the coefficients in the model. The final approach selected to develop the deterioration rates, i.e., values obtained as the weighted overall pooled value of individual slopes between adjacent tests readily allowed development of the confidence limits of the values. The statistics associated with each of the deterioration rates, together with the upper and lower 95 percent confidence limits of all coefficients, are presented in Tables 2.40 through 2.44.

The statistics associated with the emissions, as measured using the Cold 1972 Federal Procedure, are presented in Table 2.40. The results, in general, appear consistent between the three test fleets. As a whole, the deterioration rates of HC and CO emissions decreased from the older Pre-Emission Controlled Vehicles (Fleet 1) to the newer 1971 NO_x Controlled Vehicles (Fleet 3). In contrast, the variation rate of NO_x emissions was largest with the Emission Controlled Vehicles (Fleet 2) as would be expected and substantially smaller with the NO_x Controlled Vehicles (Fleet 3).

From an engineering standpoint rather than differential changes in emissions with mileage, it could be more practical to explain the change as a fraction of the value that would be obtained with an initialized vehicle. The deterioration rates, expressed in terms of a fractional change from a reference value, are therefore presented in Table 2.41. To illustrate the magnitude of the changes that would result by using a hot cycle method for determining emissions, the deterioration rates obtained using the Federal Short Emission Cycle are presented in Table 2.42. The deterioration rates of the emissions using the High Speed

Table 2.40

PARAMETER VARIATION RATE

CHANGE IN COLD 1972 FEDERAL EMISSION WITH MILEAGE

PARAMETER		PRE-EMISSION CONTROLLED (FLEET 1)	EMISSION CONTROLLED (FLEET 2)	NO_x CONTROLLED (FLEET 3)
COLD 1972 FEDERAL HC, 10^{-4} gm/mi^2	$\bar{X}$	5.740	1.333	0.703
	S_X	22.7	8.28	3.39
	d.f.	154	173	186
	$S_{\bar{X}}$	1.82	0.628	0.248
	t	3.15	2.12	2.84
	$\bar{X}+kS_{\bar{X}}$	9.332	2.570	1.191
	$\bar{X}-kS_{\bar{X}}$	2.148	0.096	0.215
	Conf.	99	95	99
COLD 1972 FEDERAL CO, 10^{-3} gm/mi^2	$\bar{X}$	4.673	2.351	0.8105
	S_X	20.2	11.4	4.57
	d.f.	154	173	183
	$S_{\bar{X}}$	1.622	0.864	0.337
	t	2.88	2.72	2.40
	$\bar{X}+kS_{\bar{X}}$	7.869	4.054	1.474
	$\bar{X}-kS_{\bar{X}}$	1.477	0.648	0.147
	Conf.	99	99	98
COLD 1972 FEDERAL NO_x, 10^{-4} gm/mi^2	$\bar{X}$	-2.586	-3.744	-0.3381
	S_X	7.49	7.59	3.27
	d.f.	171	181	254
	$S_{\bar{X}}$	0.571	0.563	0.205
	t	-4.53	-6.65	-1.65
	$\bar{X}+kS_{\bar{X}}$	-1.461	-2.636	0.0653
	$\bar{X}-kS_{\bar{X}}$	-3.711	-4.852	-0.7415
	Conf.	99	99	90

Table 2.41

PARAMETER VARIATION RATE

FRACTIONAL CHANGE IN COLD 1972 FEDERAL EMISSION WITH MILEAGE

PARAMETER		PRE-EMISSION CONTROLLED (FLEET 1)	EMISSION CONTROLLED (FLEET 2)	NO_x CONTROLLED (FLEET 3)
COLD 1972 FEDERAL HC, 10^{-5} mi^{-1}	$\overline{X}$	6.617	2.553	2.825
	S_X	20.1	12.8	9.87
	d.f.	155	173	186
	$S_{\overline{X}}$	1.61	0.970	0.722
	t	4.11	2.63	3.91
	$\overline{X}+kS_{\overline{X}}$	9.787	4.465	4.247
	$\overline{X}-kS_{\overline{X}}$	3.447	0.641	1.403
	Conf.	99	99	99
COLD 1972 FEDERAL CO, 10^{-5} mi^{-1}	$\overline{X}$	5.56	3.739	2.270
	S_X	18.8	14.3	9.42
	d.f.	155	173	183
	$S_{\overline{X}}$	1.51	1.08	0.694
	t	3.69	3.45	3.27
	$\overline{X}+kS_{\overline{X}}$	8.525	5.875	3.638
	$\overline{X}-kS_{\overline{X}}$	2.595	1.603	0.902
	Conf.	99	99	99
COLD 1972 FEDERAL NO_x, 10^{-5} mi^{-1}	$\overline{X}$	-5.092	-5.073	-0.884
	S_X	16.9	9.12	5.58
	d.f.	172	181	254
	$S_{\overline{X}}$	1.28	0.676	0.349
	t	- 3.96	- 7.50	-2.529
	$\overline{X}+kS_{\overline{X}}$	-2.561	-3.741	-0.196
	$\overline{X}-kS_{\overline{X}}$	-7.623	-6.405	-1.572
	Conf.	99	99	99

Table 2.42

PARAMETER VARIATION RATE

CHANGE IN FEDERAL SHORT EMISSION WITH MILEAGE

PARAMETER		PRE-EMISSION CONTROLLED (FLEET 1)	EMISSION CONTROLLED (FLEET 2)	NO_x CONTROLLED (FLEET 3)
FEDERAL SHORT HC, 10^{-4} gm/mi^2	$\bar{X}$	1.503	0.2546	0.3427
	S_X	13.5	3.60	2.14
	d.f.	214	239	250
	$S_{\bar{X}}$	0.921	0.232	0.135
	t	1.63	1.10	2.54
	$\bar{X}+kS_{\bar{X}}$	3.317	0.712	0.609
	$\bar{X}-kS_{\bar{X}}$	-0.311	-0.203	0.077
	Conf.	85	70	98
FEDERAL SHORT CO, 10^{-3} gm/mi^2	$\bar{X}$	4.068	1.218	0.2951
	S_X	13.8	6.48	4.77
	d.f.	149	238	248
	$S_{\bar{X}}$	1.13	0.419	0.302
	t	3.61	2.90	0.98
	$\bar{X}+kS_{\bar{X}}$	6.29	2.044	0.890
	$\bar{X}-kS_{\bar{X}}$	1.85	0.392	-0.300
	Conf.	99	99	70
FEDERAL SHORT NO_x, 10^{-4} gm/mi^2	$\bar{X}$	-0.3118	-2.287	-0.3076
	S_X	4.44	5.19	2.54
	d.f.	195	180	240
	$S_{\bar{X}}$	0.317	0.386	0.164
	t	-0.983	-5.929	-1.880
	$\bar{X}+kS_{\bar{X}}$	0.313	-1.527	0.015
	$\bar{X}-kS_{\bar{X}}$	-0.937	-3.047	-0.630
	Conf.	70	99	90

Cruise Mode (49/45 mph cruise) of the Clayton keymode cycle and the idle mode, are presented in Table 2.43. Deterioration rates of engine tune parameters, which are primarily used in controlling emissions, are presented in Table 2.44.

In addition to the upper and lower 95 percent confidence levels of the deterioration rates the corresponding limits of the influence coefficients, i.e., change in emission with change in parameter, were computed and are presented in Table 2.45. The estimate of standard deviation used to develop the confidence limits was obtained as previously described in Section 2.4.1.

The approach in which individual slopes were calculated and ultimately pooled to develop the overall deterioration rate is considered to be the most appropriate because it eliminates the systematic biases that might occur as a result of a random variation in the measurement of a parameter during the reference test. The additional advantage of utilizing this approach is that the statistical limits of the deterioration rate can easily be developed. In particular, in most of the engine tune parameters, statistically significant values for deterioration rates were not obtained (Air Cleaner Restriction was the only parameter that resulted in significant deterioration rates). The results, however, clearly establish the upper and lower bounds at which parameter deteriorations can be expected. Investigations with the Economic Effectiveness Model can therefore be made to determine the maximum and minimum expected effect of mandatory inspection and maintenance of specific parameters.

2.4.4 Summary of Data

As was described in this section, a large amount of effort has been directed in the analysis of data to develop the deterioration rates. A method was ultimately chosen which is considered to be the most consistent and meaningful. However, in order to present all of the information developed in the course of the analysis, data summaries as well as graphical

Table 2.43

PARAMETER VARIATION RATE

CHANGE IN KEY MODE EMISSION WITH MILEAGE

PARAMETERS		PRE-EMISSION CONTROLLED (FLEET 1)	EMISSION CONTROLLED (FLEET 2)	NO_x CONTROLLED (FLEET 3)
49/45 MPH CRUISE HC, 10^{-3} ppm/mi	$\bar{X}$	-0.978	-2.444	-0.228
	S_X	30.7	21.8	14.8
	d.f.	211	238	254
	$S_{\bar{X}}$	2.11	1.410	0.927
	t	-0.46	-1.73	-0.25
	X+ks	3.176	0.334	1.598
	X-ks	-5.132	-5.222	-2.054
	Conf.	<50	90	<50
49/45 MPH CRUISE CO, 10^{-5} % v/mi	$\bar{X}$	-1.610	-0.278	-0.716
	S_X	46.6	22.1	8.43
	d.f.	209	233	256
	$S_{\bar{X}}$	3.22	1.44	0.526
	t	-0.50	-0.19	-1.36
	X+ks	4.725	2.568	0.320
	X-ks	-7.945	-3.124	-1.752
	Conf.	<50	<50	80
49/45 MPH CRUISE NO_x, 10^{-2} ppm/mi	$\bar{X}$	2.306	-1.203	-3.002
	S_X	26.9	24.8	19.8
	d.f.	199	213	141
	$S_{\bar{X}}$	1.90	1.70	1.66
	t	1.21	-0.71	-1.81
	X+ks	6.053	2.137	0.271
	X-ks	-1.441	-4.543	-6.275
	Conf.	80	50	90
IDLE HC, 10^{-2} ppm/mi	$\bar{X}$	-0.382	0.046	-0.013
	S_X	26.1	4.55	2.22
	d.f.	208	235	256
	$S_{\bar{X}}$	1.805	0.296	0.134
	t	-0.21	0.16	-0.09
	X+ks	3.174	0.629	0.260
	X-ks	-3.938	-0.537	-0.286
	Conf.	90	<50	<50
IDLE CO, 10^{-4} % v/mi	$\bar{X}$	1.334	0.274	-0.115
	S_X	14	6.18	4.93
	d.f.	217	238	254
	$S_{\bar{X}}$	0.948	0.400	0.309
	t	1.41	0.68	0.37
	X+ks	3.202	1.062	0.493
	X-ks	-0.534	-0.514	-0.723
	Conf.	70	50	<50
IDLE NO_x, 10^{-3} ppm/mi	$\bar{X}$	-3.14	-1.088	0.200
	S_X	24.1	18.5	20.4
	d.f.	101	117	245
	$S_{\bar{X}}$	2.39	1.70	1.30
	t	-1.32	0.64	0.15
	X+ks	1.561	2.267	2.762
	X-ks	-7.841	-4.443	-2.362
	Conf.	80	<50	<50

Table 2.44

PARAMETER VARIATION RATE

CHANGE IN ENGINE TUNE PARAMETERS WITH MILEAGE

PARAMETER		PRE-EMISSION CONTROLLED (FLEET 1)	EMISSION CONTROLLED (FLEET 2)	NO_X CONTROLLED (FLEET 3)
	$\bar{X}$	-1.481	-0.409	0.345
TIMING,	S_X	19.8	12.3	6.20
10^{-4} degrees/mi	d.f.	222	215	249
	$S_{\bar{X}}$	1.32	0.837	0.392
	t	- 1.12	-0.489	0.880
	$\bar{X}+kS_{\bar{X}}$	1.131	1.240	1.117
	$\bar{X}-kS_{\bar{X}}$	-4.093	-2.058	-0.427
	Conf.	70	<50	60
	$\bar{X}$	3.766	0.053	-1.510
	S_X	52.2	29.8	19.1
IDLE RPM,	d.f.	218	219	253
10^{-3} rpm/mi	$S_{\bar{X}}$	3.53	2.01	1.20
	t	1.07	0.03	- 1.26
	$\bar{X}+kS$	10.715	4.011	0.856
	$\bar{X}-kS$	-3.183	-3.905	-3.876
	Conf.	70	<50	75
	$\bar{X}$	5.307	2.555	2.093
	S_X	14.7	6.14	4.60
AIR CLEANER,	d.f.	142	192	214
10^{-3} degrees/mi	$S_{\bar{X}}$	1.23	0.442	0.314
	t	4.32	5.78	6.67
	$\bar{X}+kS$	7.729	3.426	2.711
	$\bar{X}-kS$	2.885	1.684	1.475
	Conf.	99	99	99
	$\bar{X}$	-1.424	-4.758	0.970
PCV FLOWRATE	S_X	31.8	15.7	9.38
(33/30 MPH	d.f.	160	120	225
CRUISE),	$S_{\bar{X}}$	2.51	1.43	0.624
10^{-5} cfm/mi	t	- 0.57	- 3.33	1.55
	$\bar{X}+kS_{\bar{X}}$	3.513	-1.946	2.199
	$\bar{X}-kS_{\bar{X}}$	-6.361	-7.570	-0.259
	Conf.	<50	99	85
	$\bar{X}$	-1.889	- 5.87	- 3.31
CHOKE KICK,	S_X	67.2	132	70.4
10^{-7} in/mi	d.f.	215	155	193
	$S_{\bar{X}}$	4.57	10.57	5.05
	t	- 0.41	- 0.56	- 0.65
	$\bar{X}+kS_{\bar{X}}$	7.118	14.950	6.647
	$\bar{X}-kS_{\bar{X}}$	-10.896	-26.690	-13.267
	Conf.	<50	<50	<50

Table 2.45

SUMMARY OF MEAN AND 95% CONFIDENCE LIMITS OF INFLUENCE FACTORS

		PRE-EMISSION CONTROLLED (FLEET 1)			EMISSION CONTROLLED (FLEET 2)			NO_x CONTROLLED (FLEET 3)		
		HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
PARAMETERS		gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP	gm/mi/ΔP
TIMING, degrees	$\bar{X}$+ks	0.08321	-0.5964	0.1667	0.06155	-0.2259	0.1111	0.08248	-0.893	0.1435
	$\bar{X}$	0.06710	-0.8444	0.1394	0.04980	-0.3423	0.09524	0.07558	-1.022	0.1299
	$\bar{X}$-ks	0.05099	-1.0923	0.1121	0.03805	-0.4587	0.07937	0.06869	-1.151	0.1163
IDLE RPM, rpm	$\bar{X}$+ks	-0.001802	0.04000	0.001097	-0.004026	0.02714	0.0003483	-0.0002964	0.03392	0.0010670
	$\bar{X}$	-0.002930	0.02888	0.0007306	-0.005500	0.02120	0.0002550	-0.0004243	0.02598	0.0009632
	$\bar{X}$-ks	-0.004058	0.01776	0.0003639	-0.006974	0.01526	0.0001617	-0.0005522	0.01804	0.0008592
AIR CLEANER, degrees	$\bar{X}$+ks	0.007816	0.1437	-0.002057	0.001107	0.08938	-0.001492	0.001145	0.08709	-0.001675
	$\bar{X}$	0.005668	0.1121	-0.003049	0.0009000	0.07642	-0.002120	0.0008945	0.06869	-0.002476
	$\bar{X}$-ks	0.003520	0.0805	-0.004041	0.0006930	0.06346	-0.002748	0.0006443	0.05029	-0.003277
PCV(33/30), cfm	$\bar{X}$+ks	0.03212	-1.434	0.08034	-0.06924	2.417	0.1165	-0.1127	-5.904	0.1396
	$\bar{X}$	0.02283	-2.441	0.05920	-0.08415	-2.861	0.08654	-0.1548	-7.458	0.1038
	$\bar{X}$-ks	0.01354	-3.448	0.03806	-0.09906	-3.305	0.0566	-0.1969	-9.012	0.0680
IDLE CO, % v	$\bar{X}$+ks	0.5295	4.939	0.2669	0.03678	9.445	0.03745	0.1025	8.052	-0.01749
	$\bar{X}$	0.4411	4.081	0.2170	0.02860	7.177	0.02926	0.07983	6.773	-0.02948
	$\bar{X}$-ks	0.3527	3.223	0.1670	0.02042	4.909	0.02107	0.05718	5.494	-0.04147

plots are presented in this section to illustrate the various methods used to develop indicators of the deterioration rates.

Graphical presentations of all the data points given as a change from the Reference 1B Test, are presented for each of the parameters considered in the investigation. Graphs of the emissions as measured using the Cold 1972 Federal Procedure and the emissions measured using the 49/45 mph cruise and the idle mode, are presented for each of the vehicle test fleets. In addition, data of changes in timing, idle rpm, air cleaner restriction, PCV flow rate (33/30 mph cruise) and the choke kick are presented. The plots of all parameters for the three test fleets are presented in Figures 2.15 to 2.50.

On each plot the linear regressions obtained using Test 1B for a reference, or using Test 2 as a reference, are indicated. In order to further illustrate the consistency of the data when averages are obtained for each test period, discrete data points are plotted to indicate the change that was observed in each test phase. Plots representing the total data set (data set in which vehicle number varied throughout the program) and the constant n set (n equal to the number of vehicles remaining at the end of the program) are included in the graphs. Also, the upper and lower limits as obtained by calculating the slope between tests and ultimately pooling the results are included in the graphs.

The summary of the data of all of the curves and points included in the graphs is included in Tables 2.46 to 2.61. These tables represent:

1) Summaries of all of the statistical regressions conducted;

2) The average changes that occurred during each test phase, and

3) The average slope and pooled value obtained by calculating the slope between adjacent tests.

Figure 2.15

COLD 1972 FEDERAL HC EMISSIONS - EMISSION CONTROLLED VEHICLES

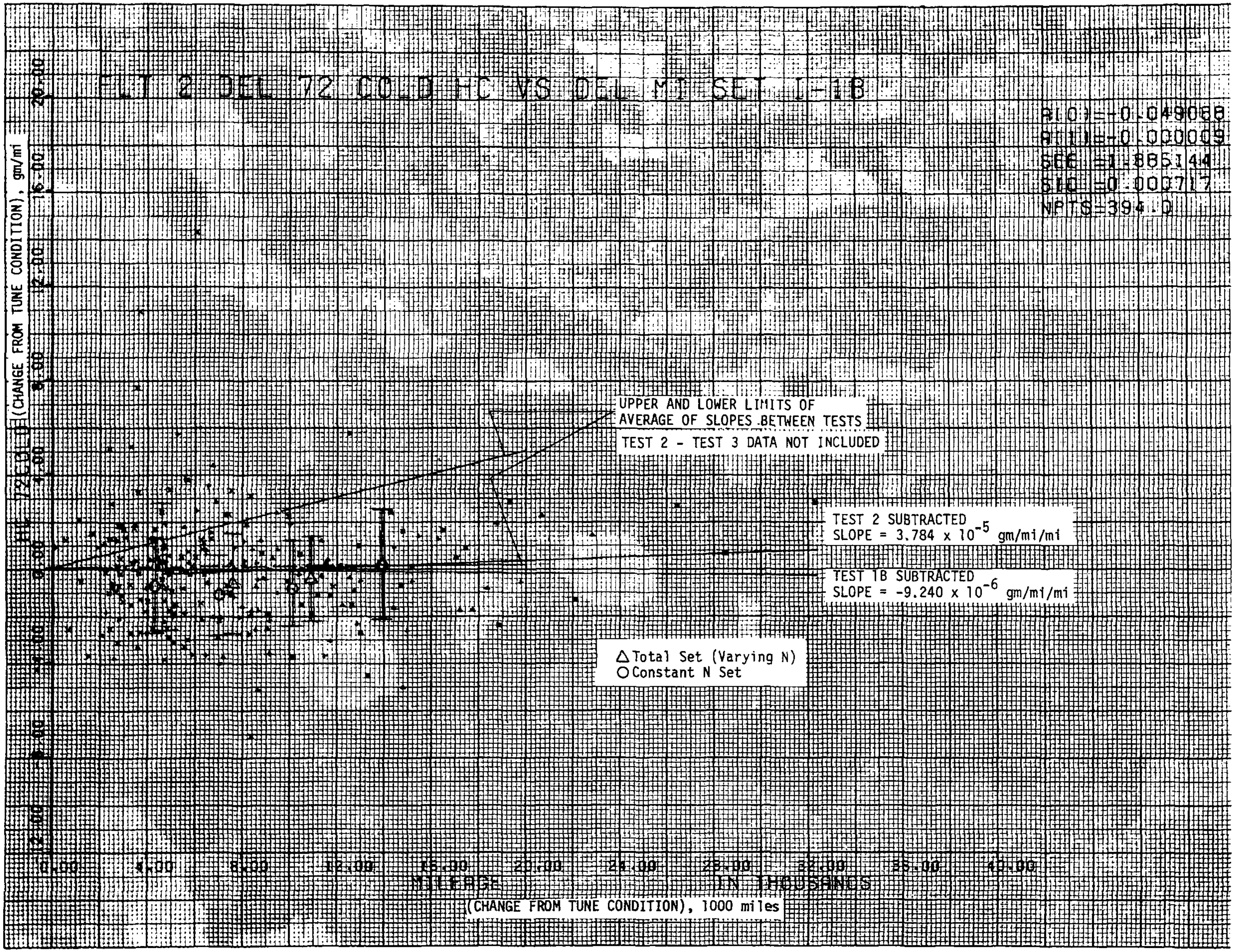


Figure 2.16

COLD 1972 FEDERAL CO EMISSIONS - EMISSION CONTROLLED VEHICLES

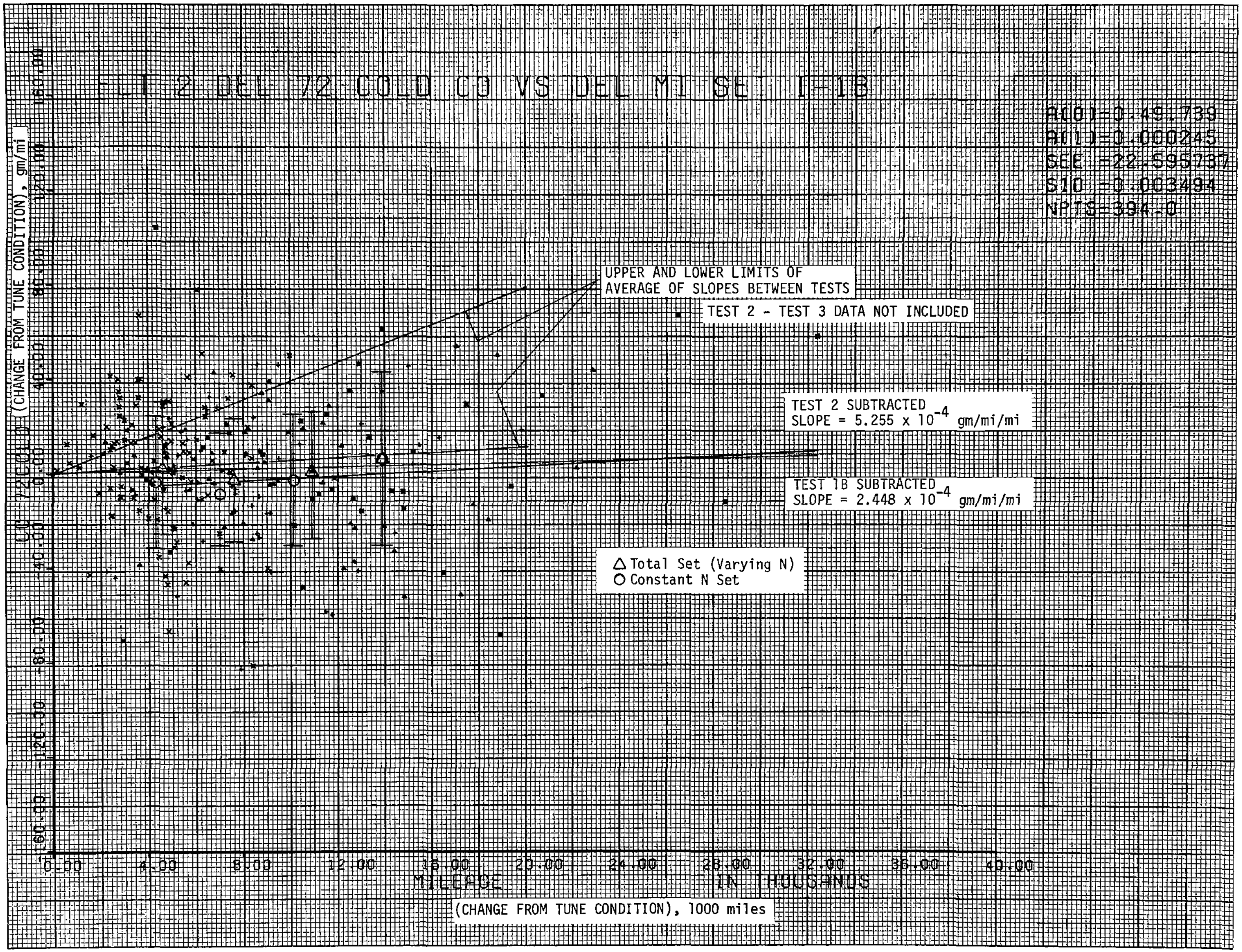


Figure 2.17

COLD 1972 FEDERAL NO_X EMISSIONS - EMISSION CONTROLLED VEHICLES

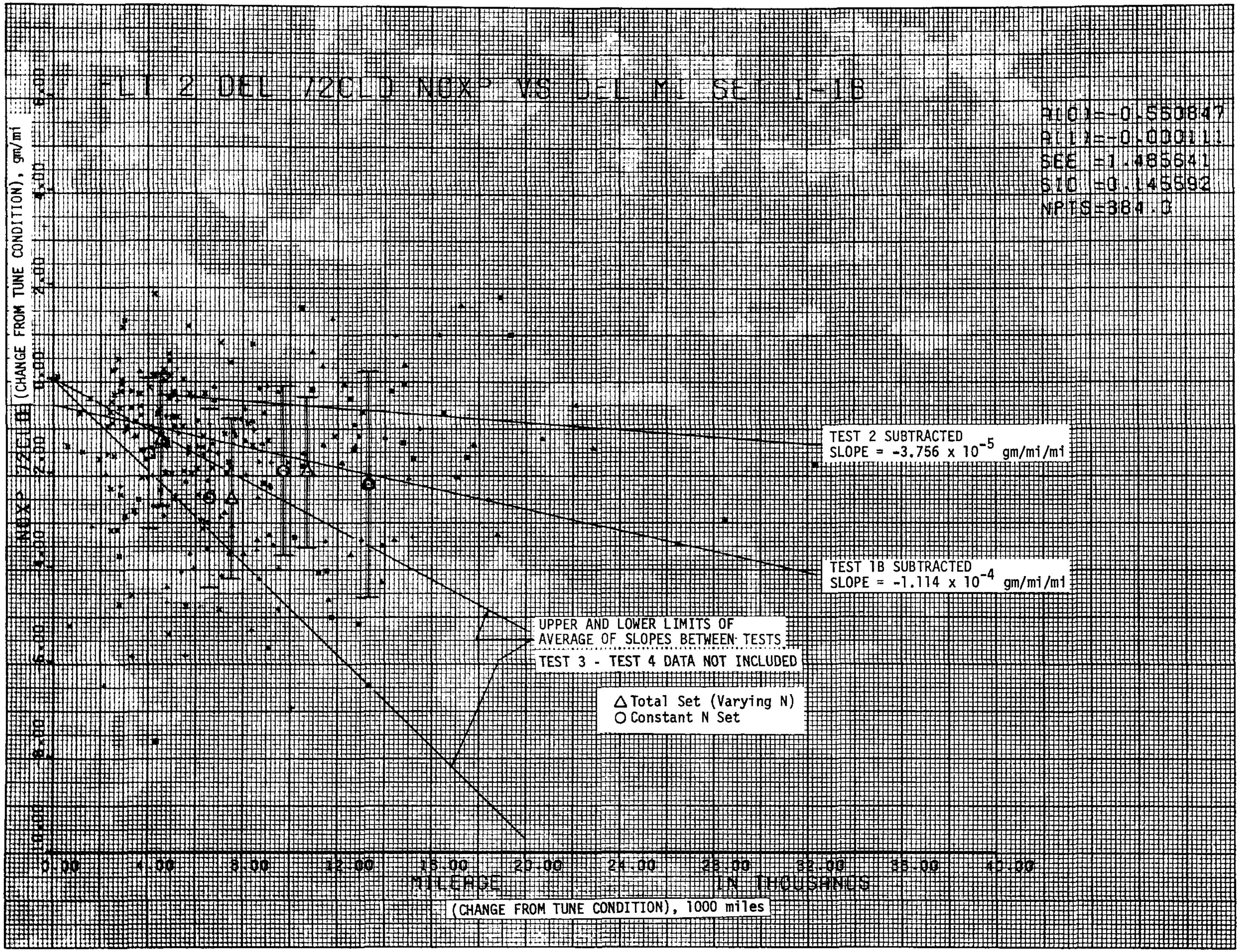


Figure 2.18

COLD 1972 FEDERAL HC EMISSIONS - NO_X CONTROLLED VEHICLES

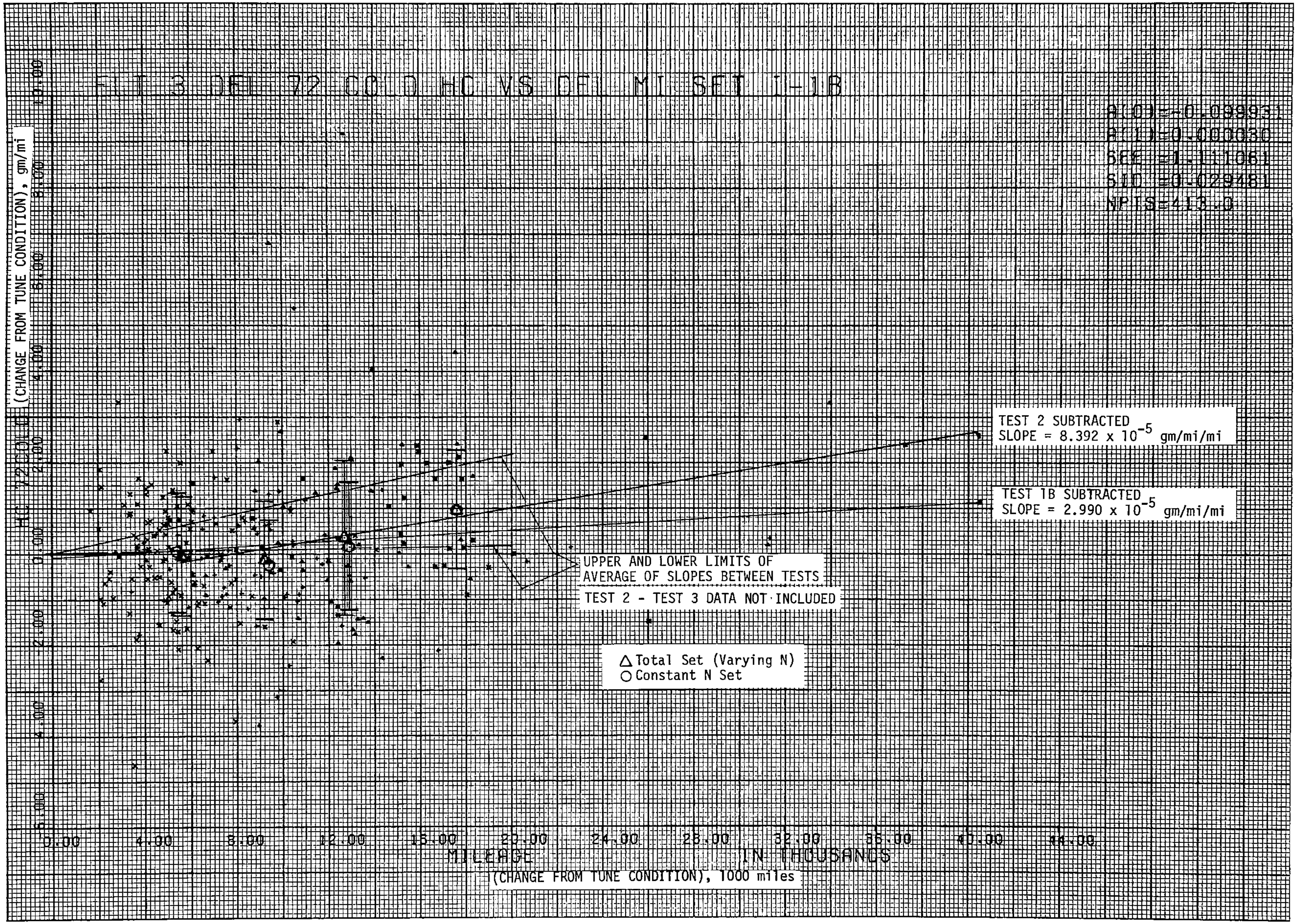


Figure 2.19

COLD 1972 FEDERAL CO EMISSIONS - NO_X CONTROLLED VEHICLES

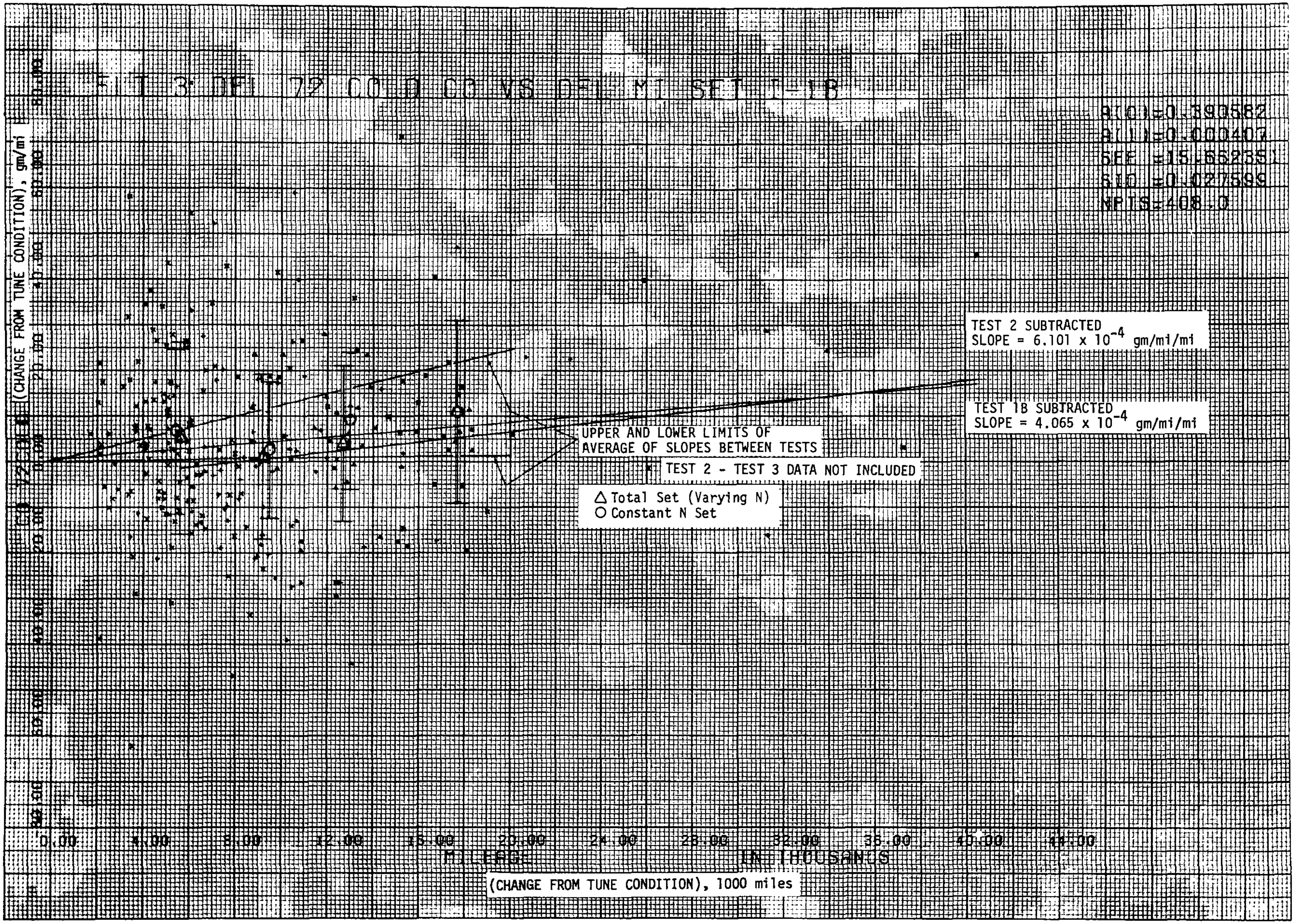


Figure 2.20

COLD 1972 FEDERAL NO_X EMISSIONS - NO_X CONTROLLED VEHICLES

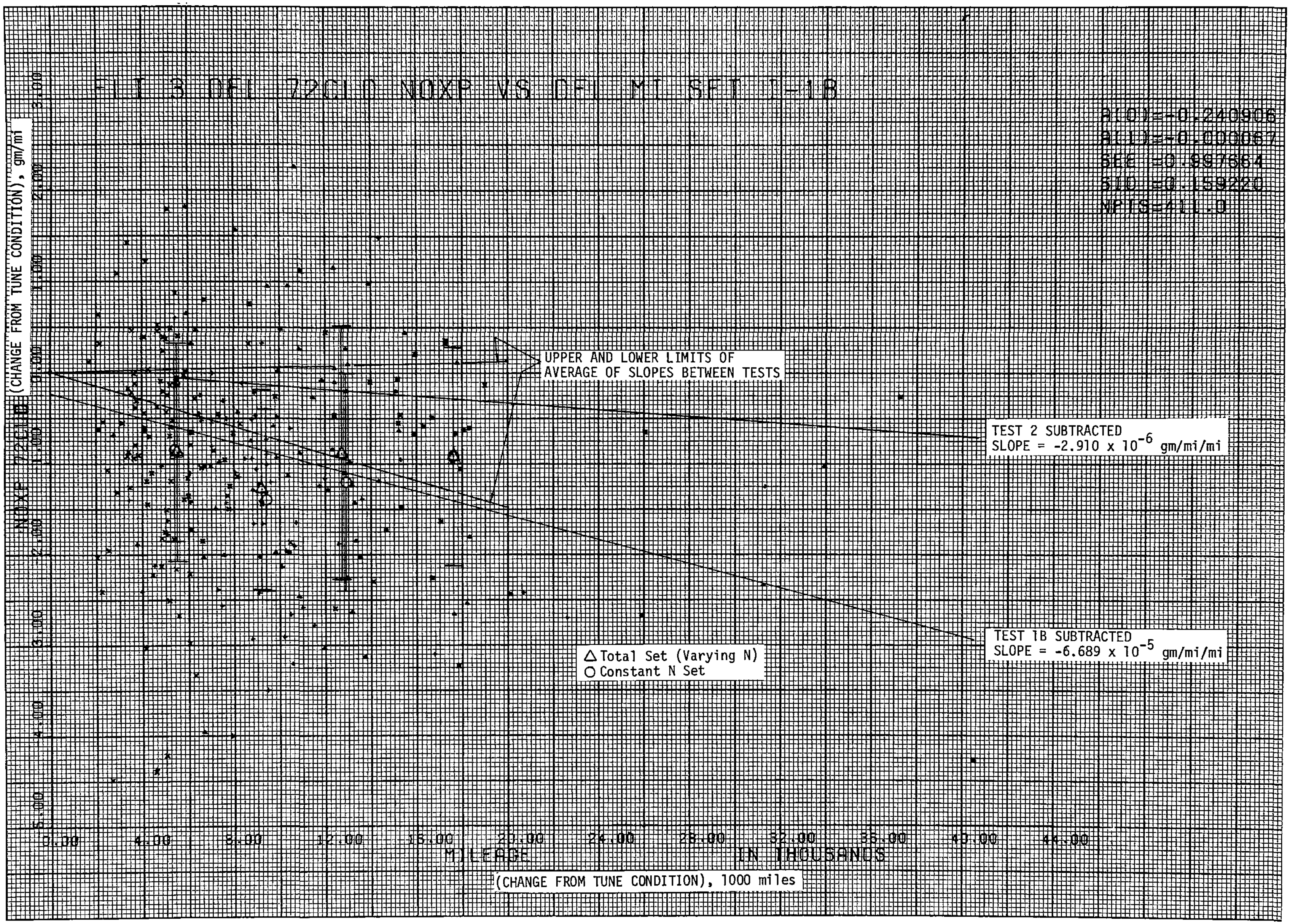


Figure 2.21

BASIC TIMING - PRE-EMISSION CONTROLLED VEHICLES

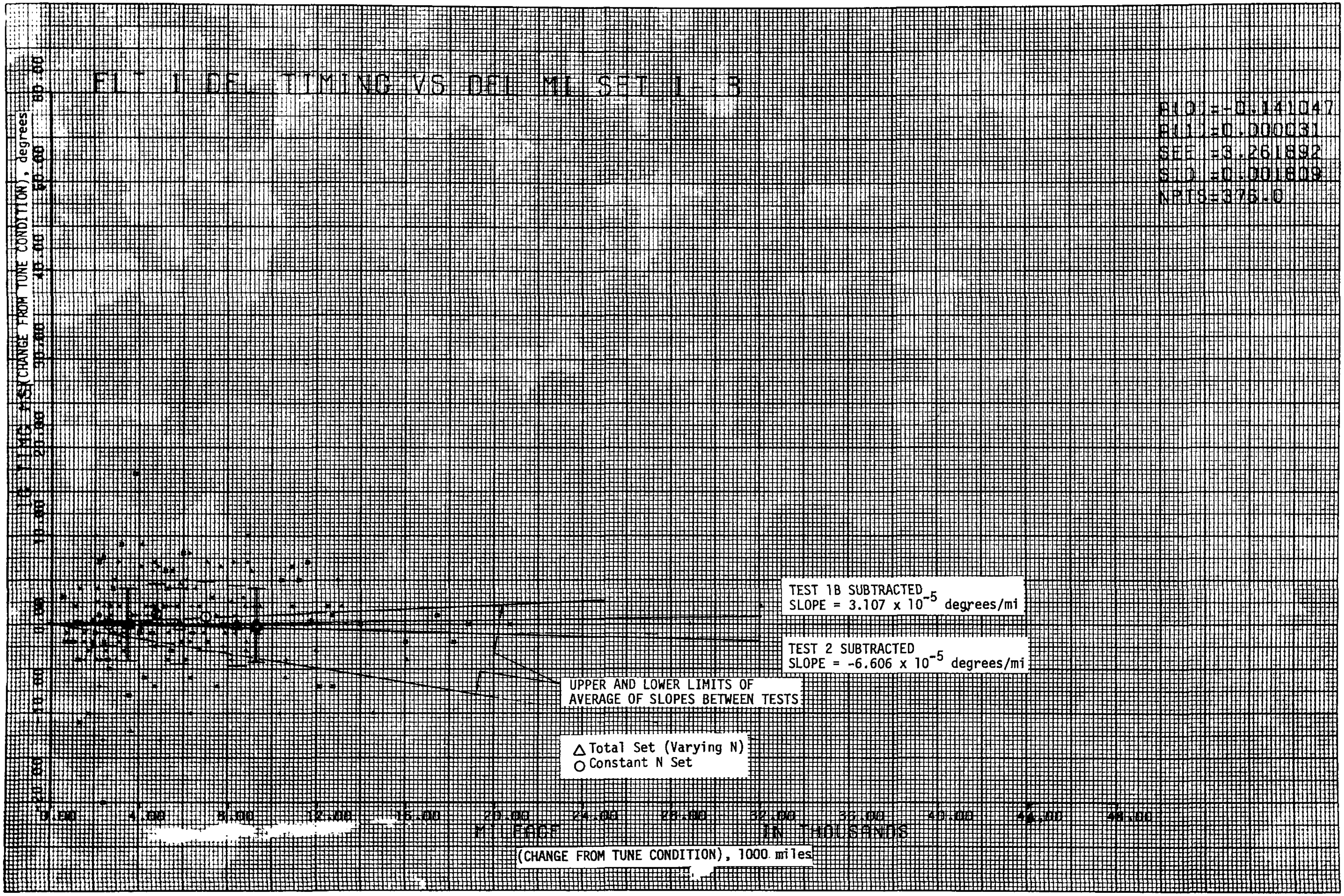


Figure 2.22

BASIC TIMING - EMISSION CONTROLLED VEHICLES

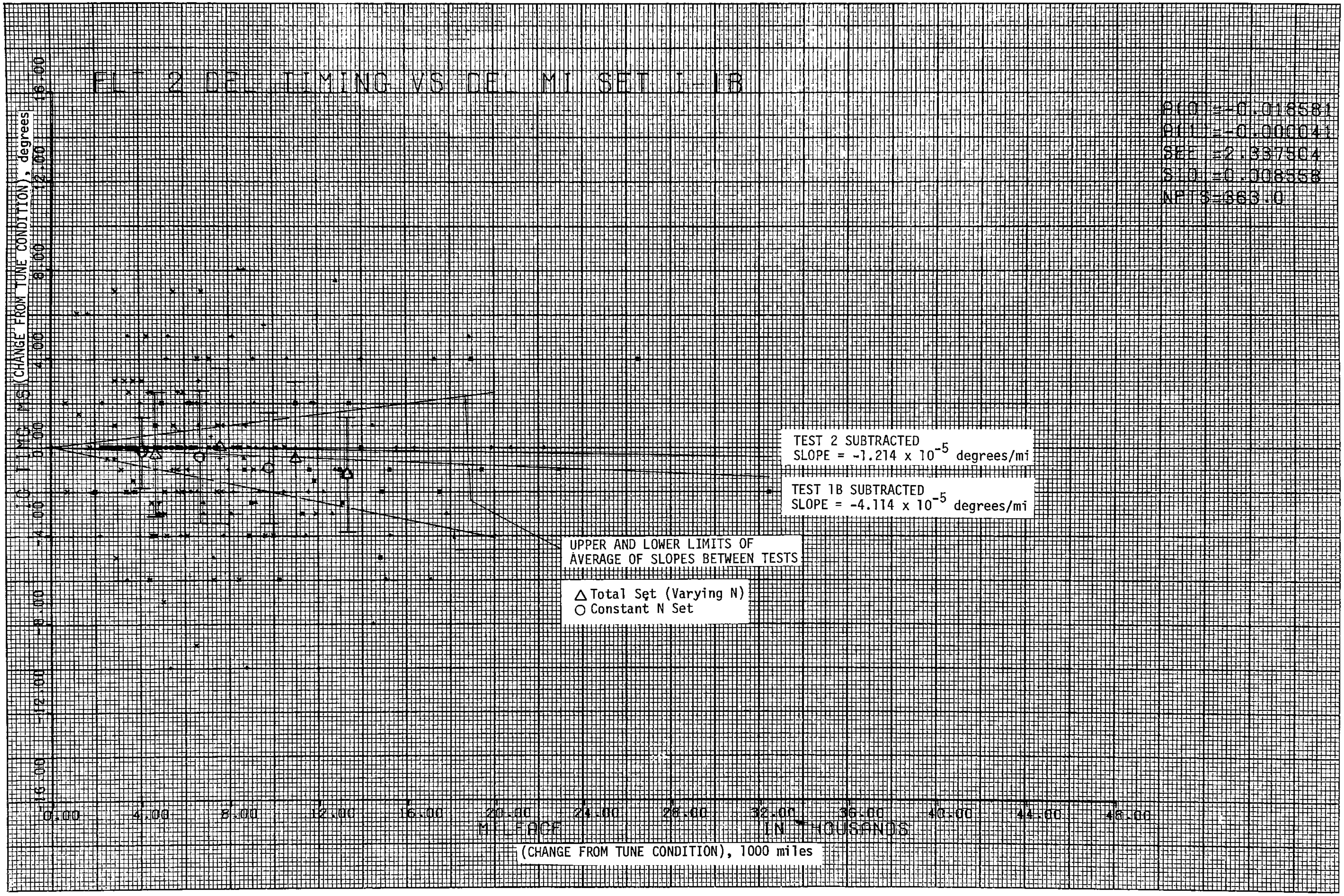


Figure 2.23

BASIC TIMING - NO_X CONTROLLED VEHICLES

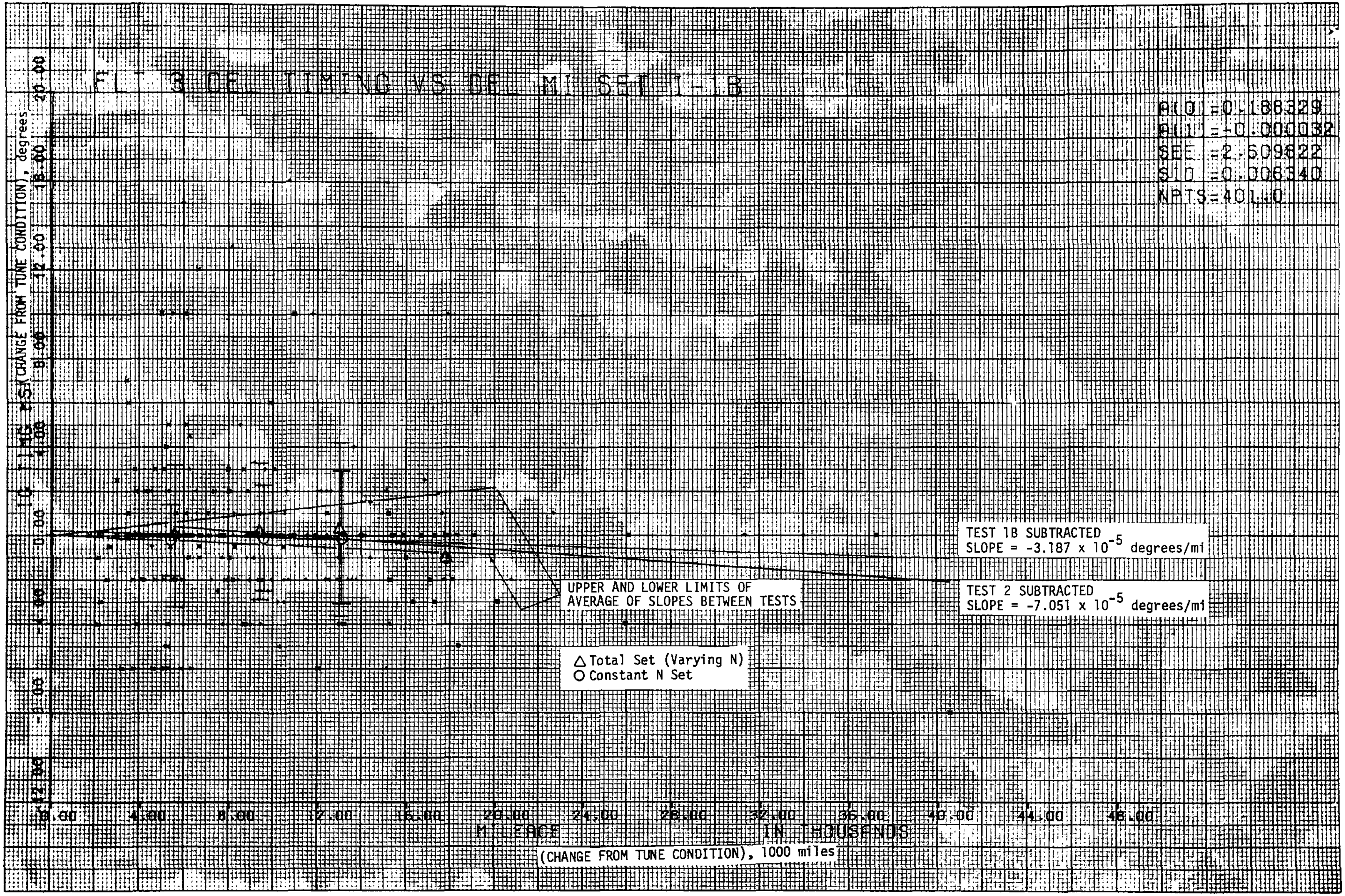


Figure 2.24

IDLE SPEED - PRE-EMISSION CONTROLLED VEHICLES

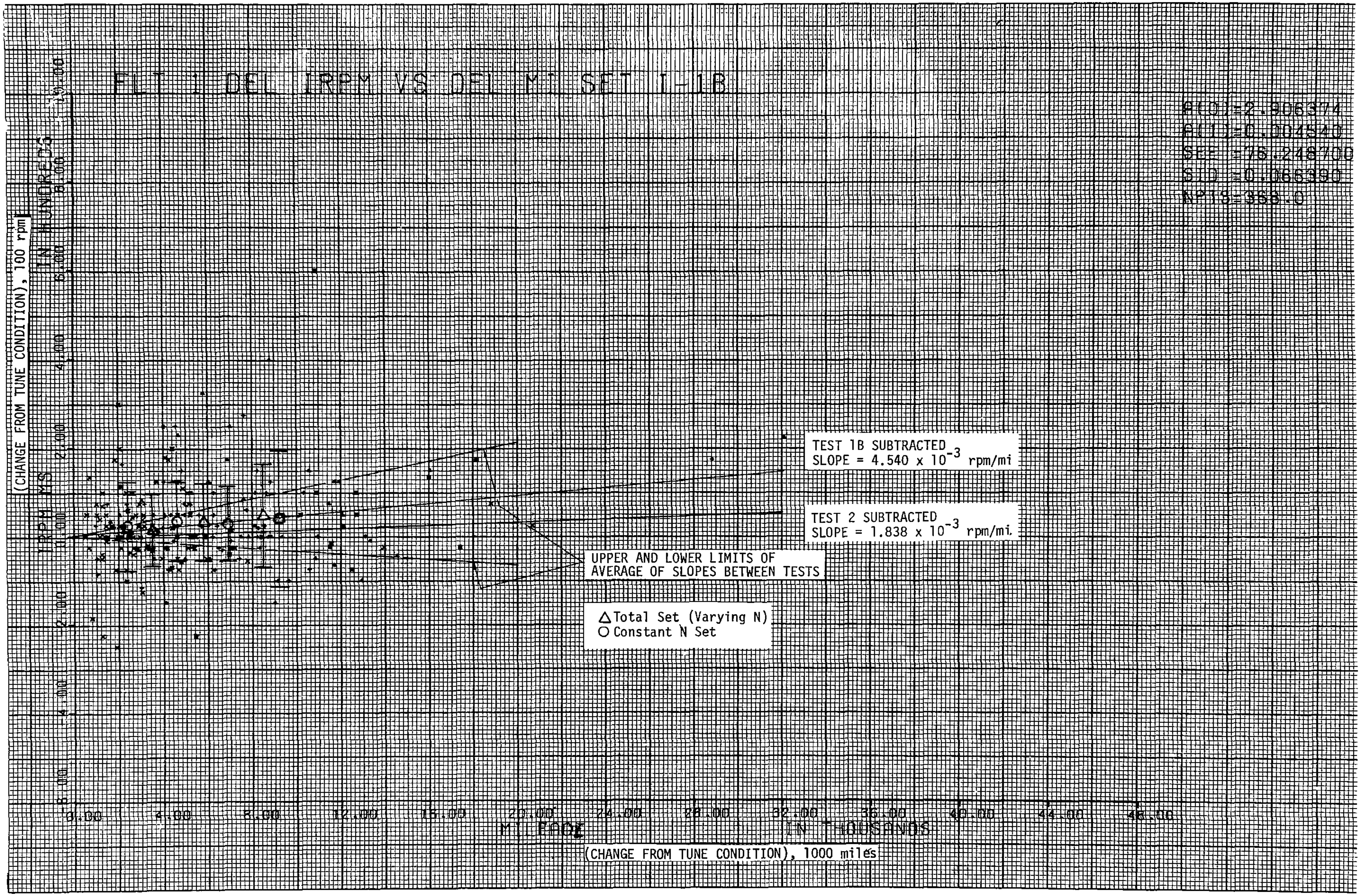


Figure 2.25

IDLE SPEED - EMISSION CONTROLLED VEHICLES

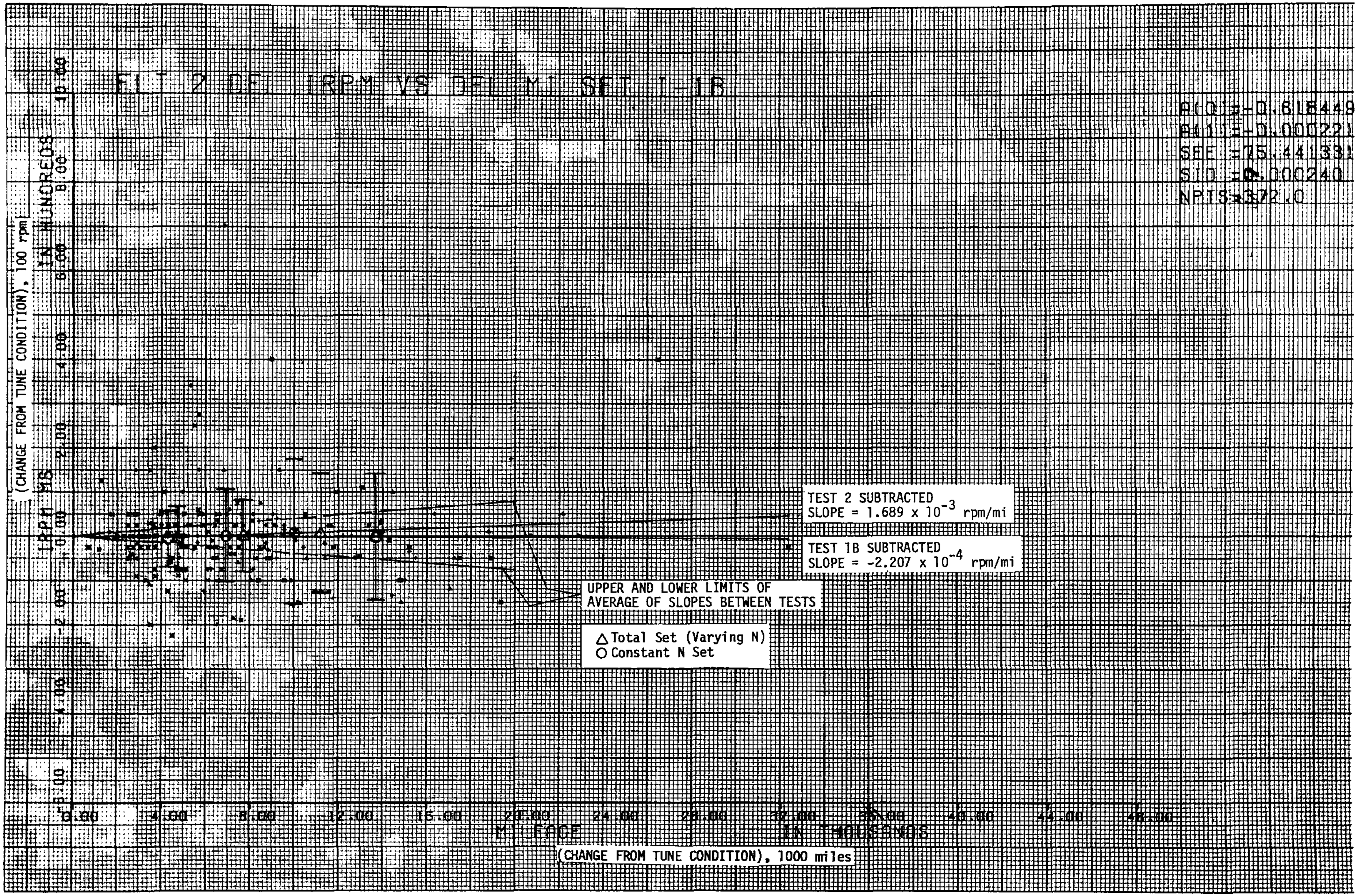


Figure 2.26

IDLE SPEED - NO_X CONTROLLED VEHICLES

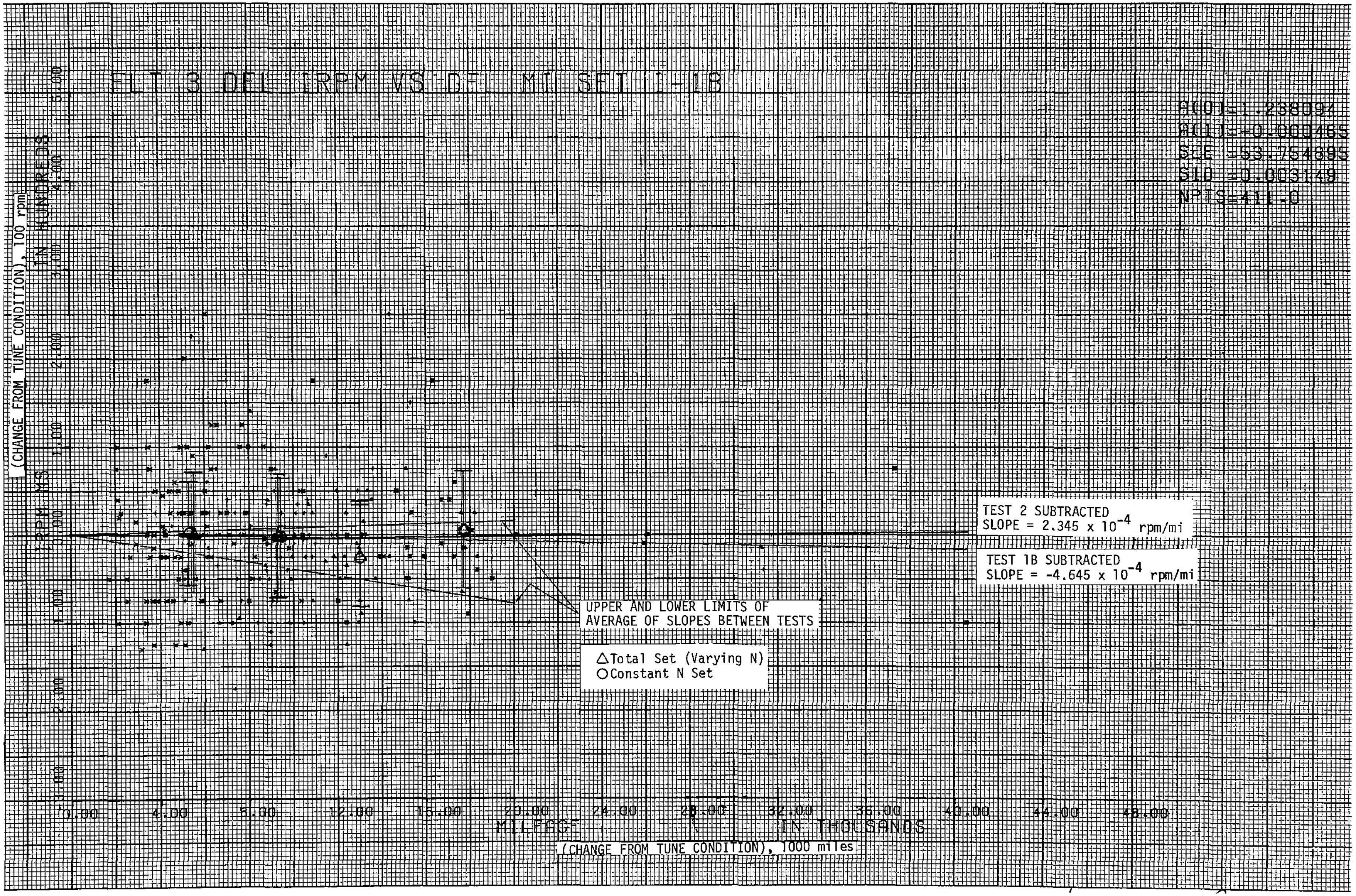


Figure 2.27

AIR CLEANER RESTRICTION - PRE-EMISSION CONTROLLED VEHICLES

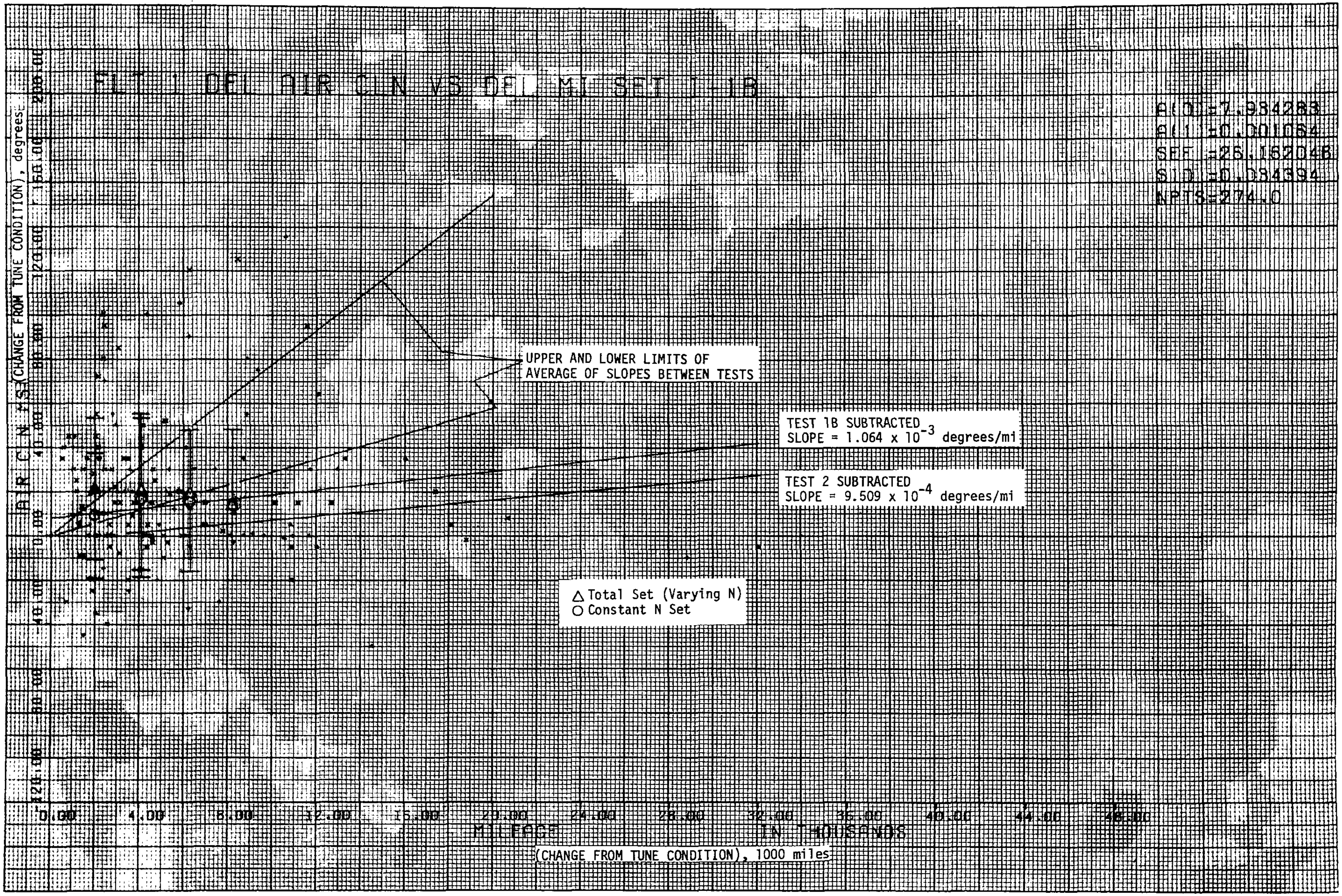


Figure 2.28

AIR CLEANER RESTRICTION - EMISSION CONTROLLED VEHICLES

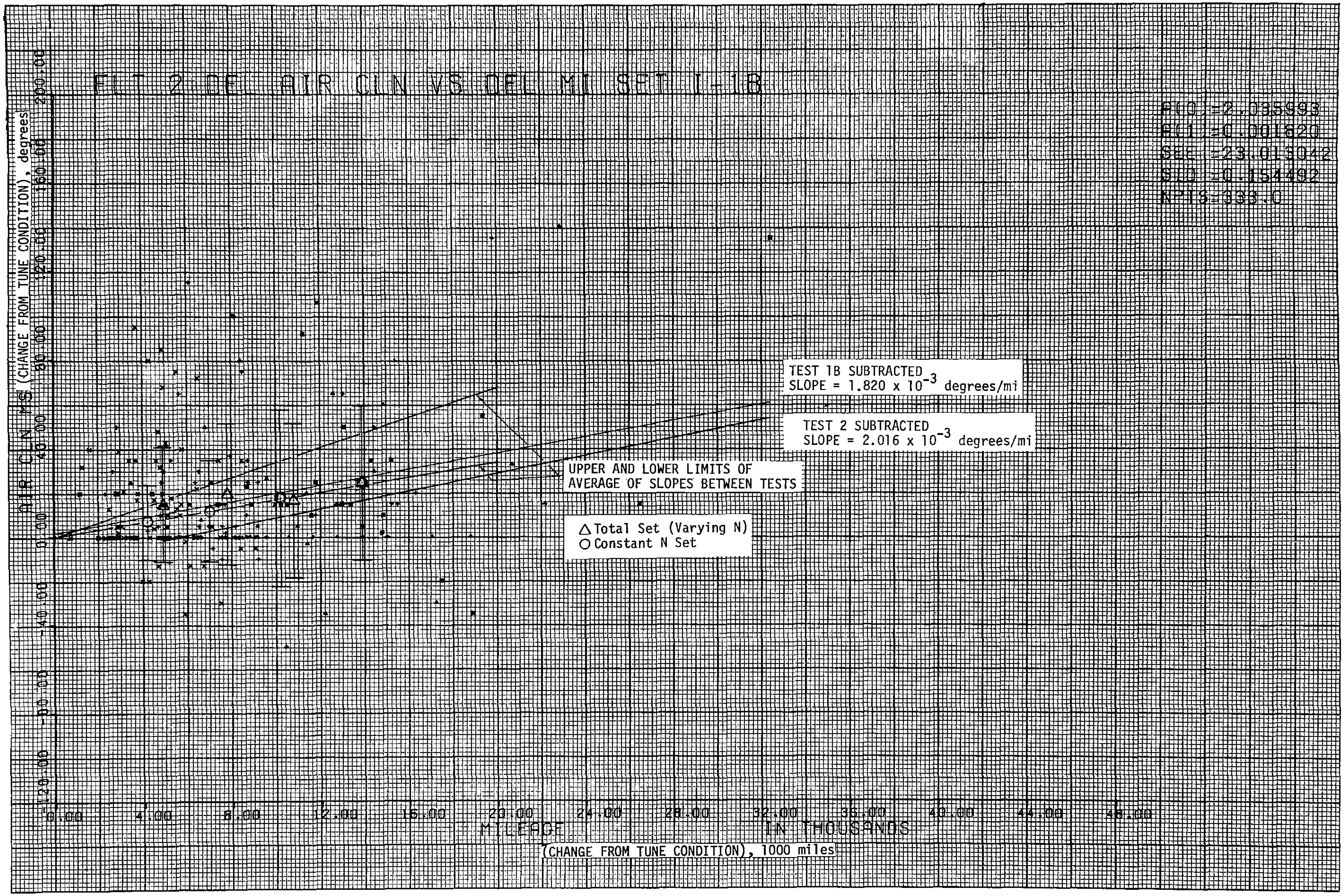


Figure 2.29

AIR CLEANER RESTRICTION - NO_X CONTROLLED VEHICLES

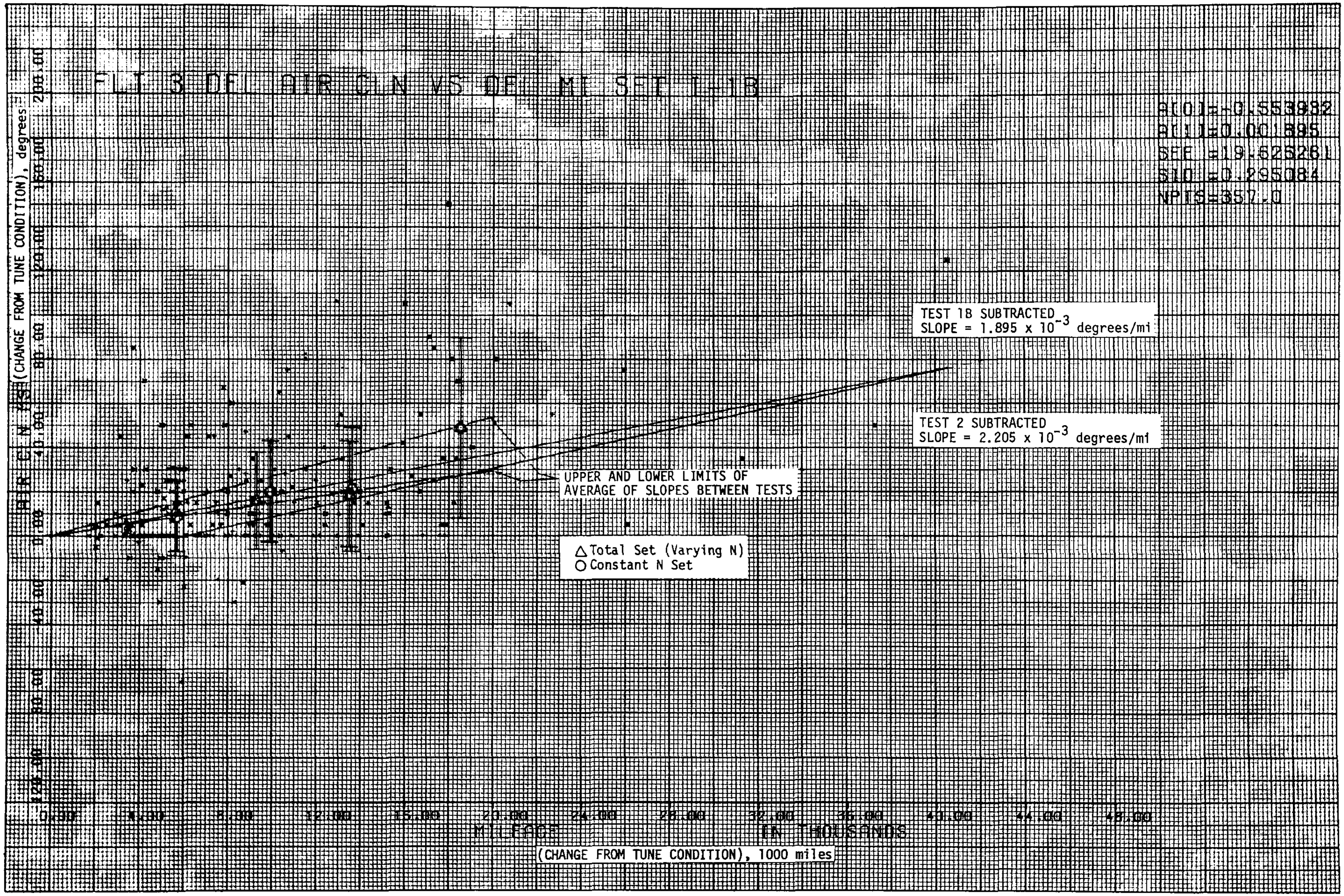


Figure 2.30

PCV VALVE RESTRICTION (33/30 MPH CRUISE) - PRE-EMISSION CONTROLLED VEHICLES

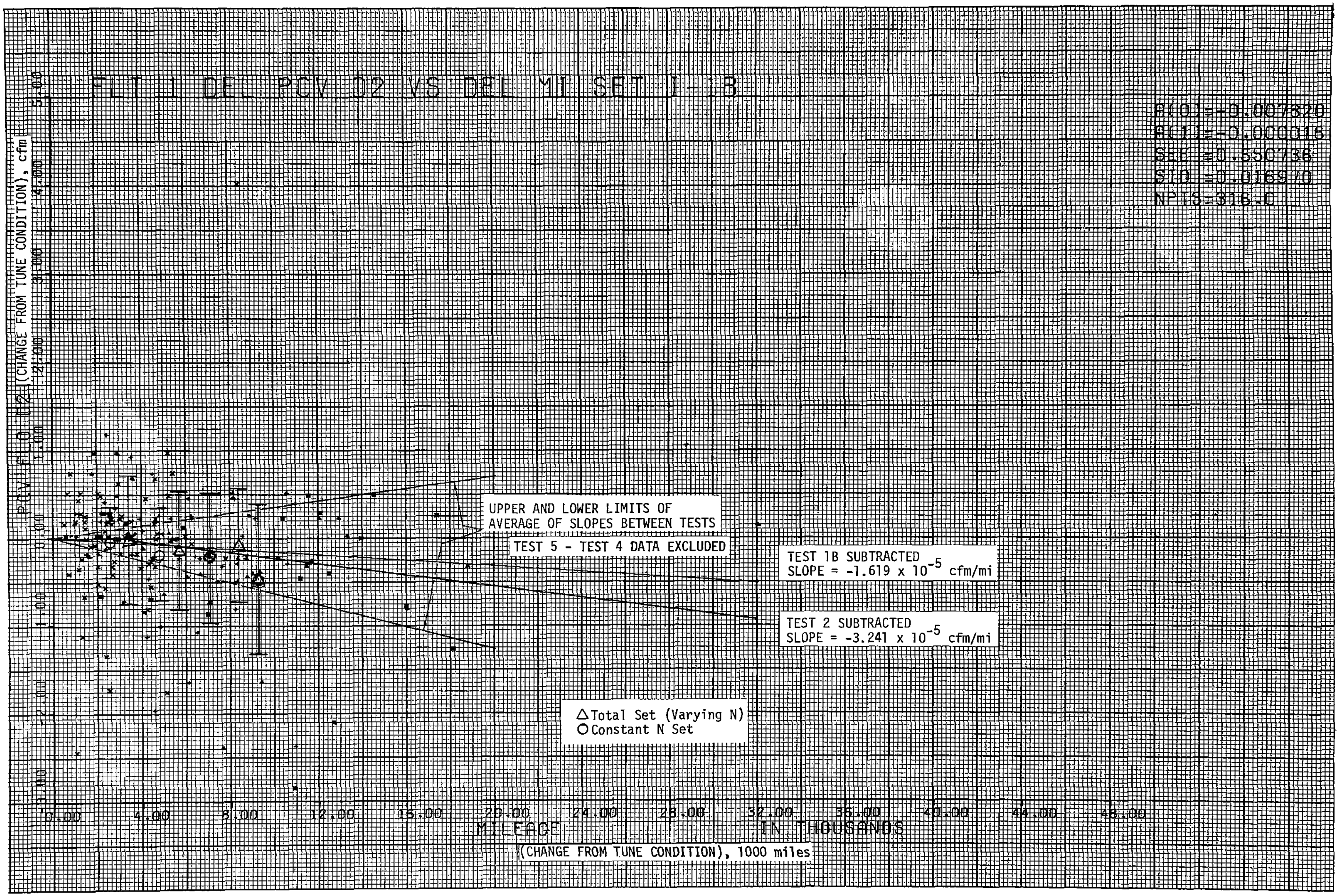


Figure 2.31

PCV VALVE RESTRICTION (33/30 MPH CRUISE) - EMISSION CONTROLLED VEHICLES

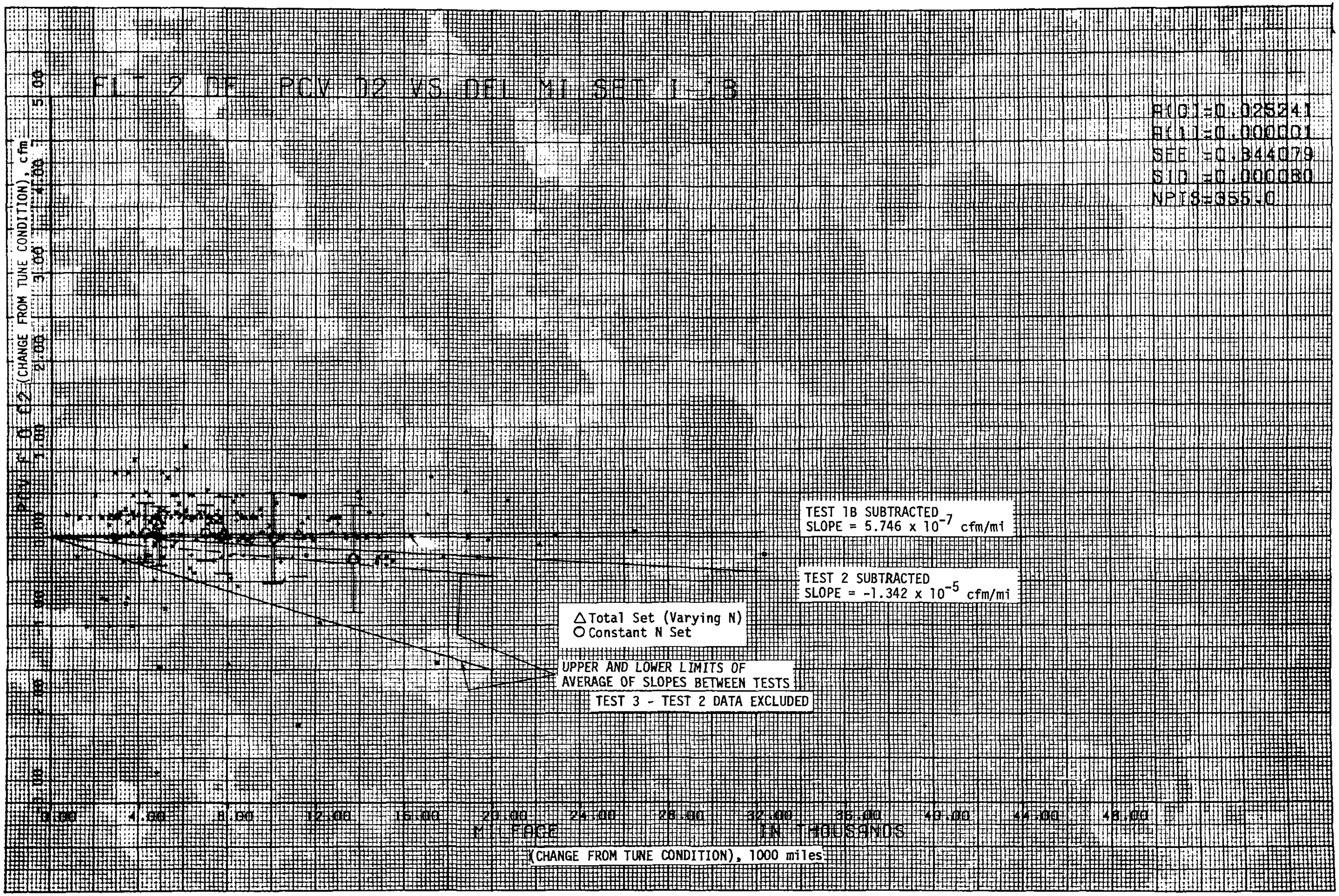


Figure 2.32

PCV VALVE RESTRICTION (33/30 MPH CRUISE) - NO_X CONTROLLED VEHICLES

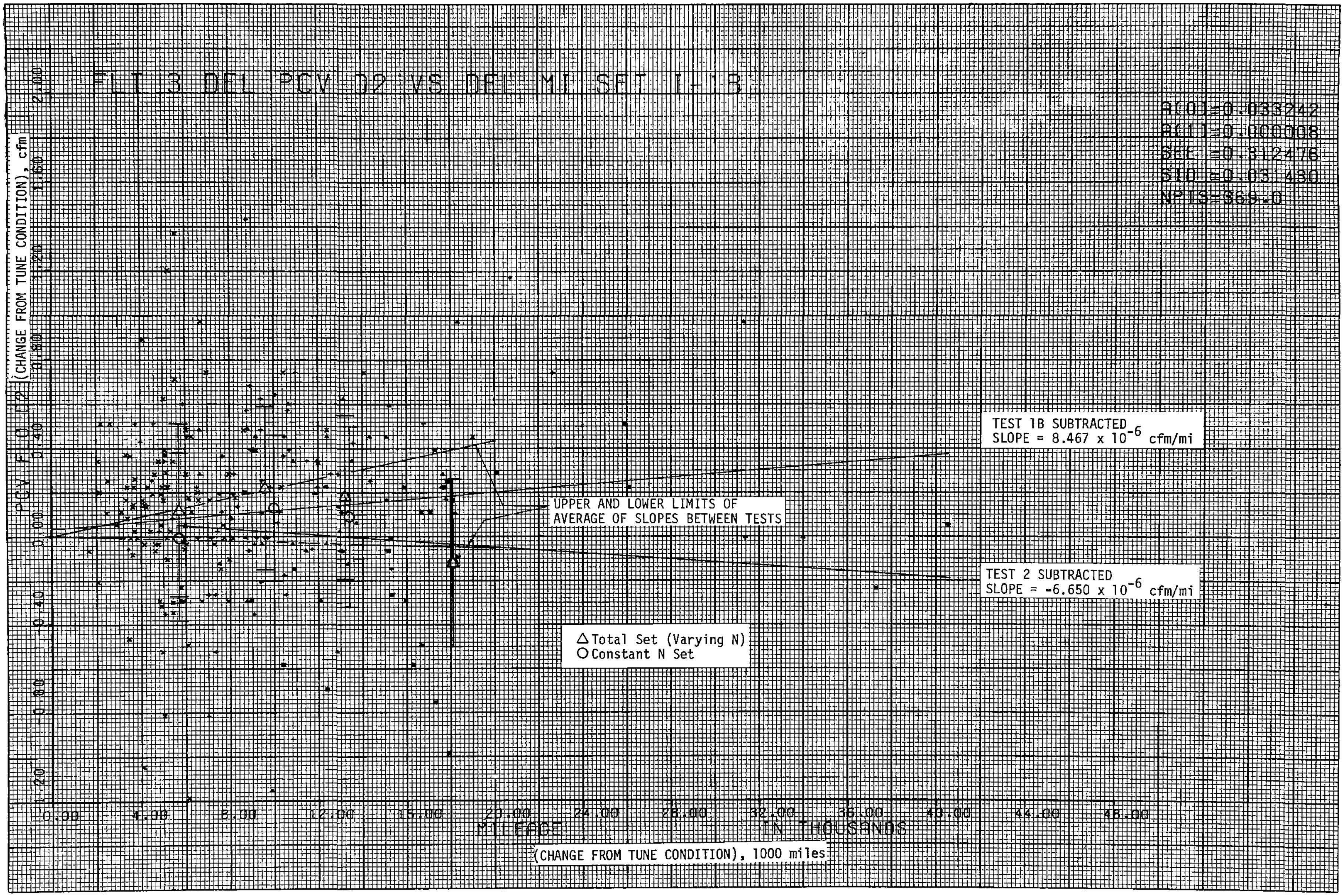


Figure 2.33

IDLE MODE HC EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

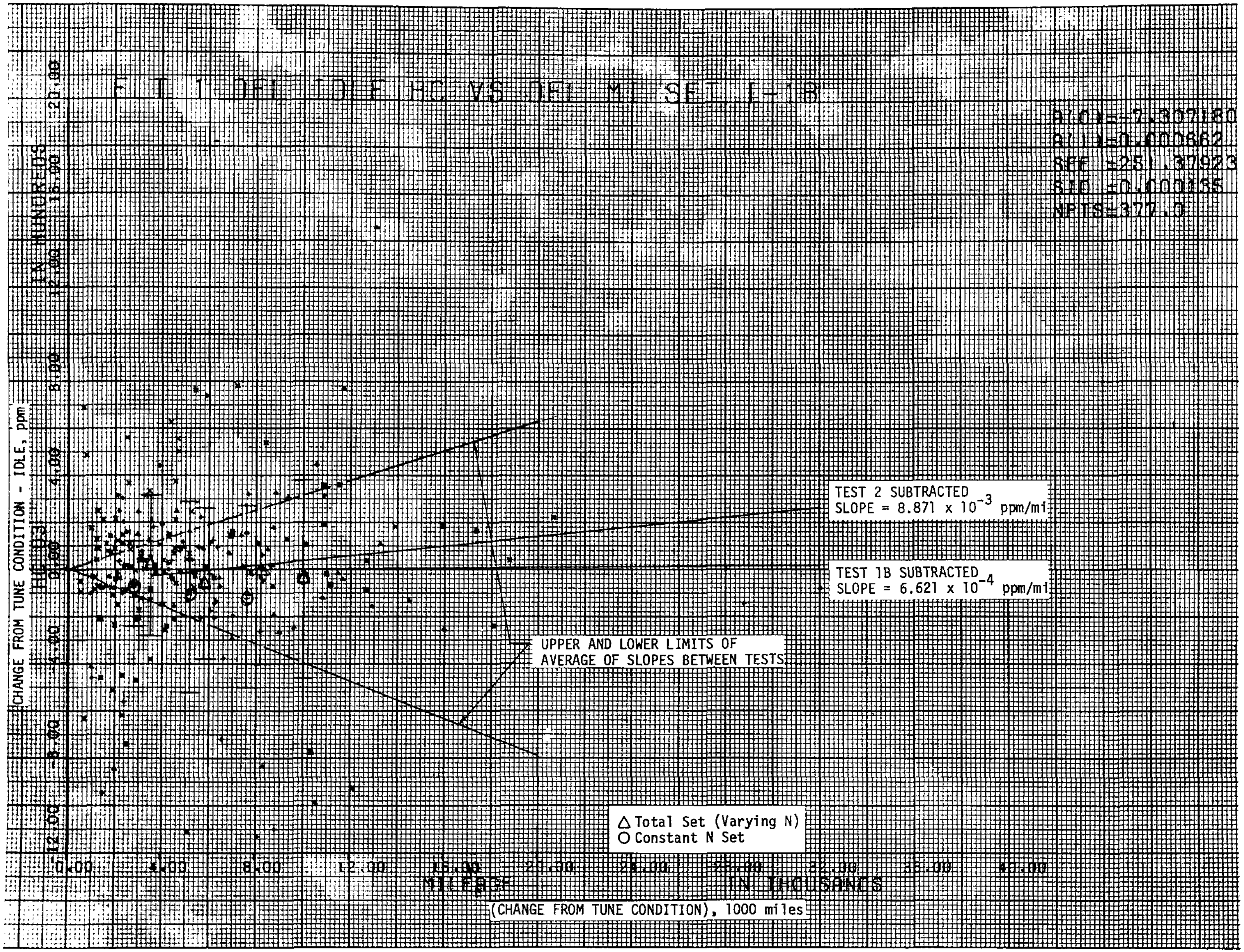


Figure 2.34

IDLE MODE HC EMISSIONS -EMISSION CONTROLLED VEHICLES

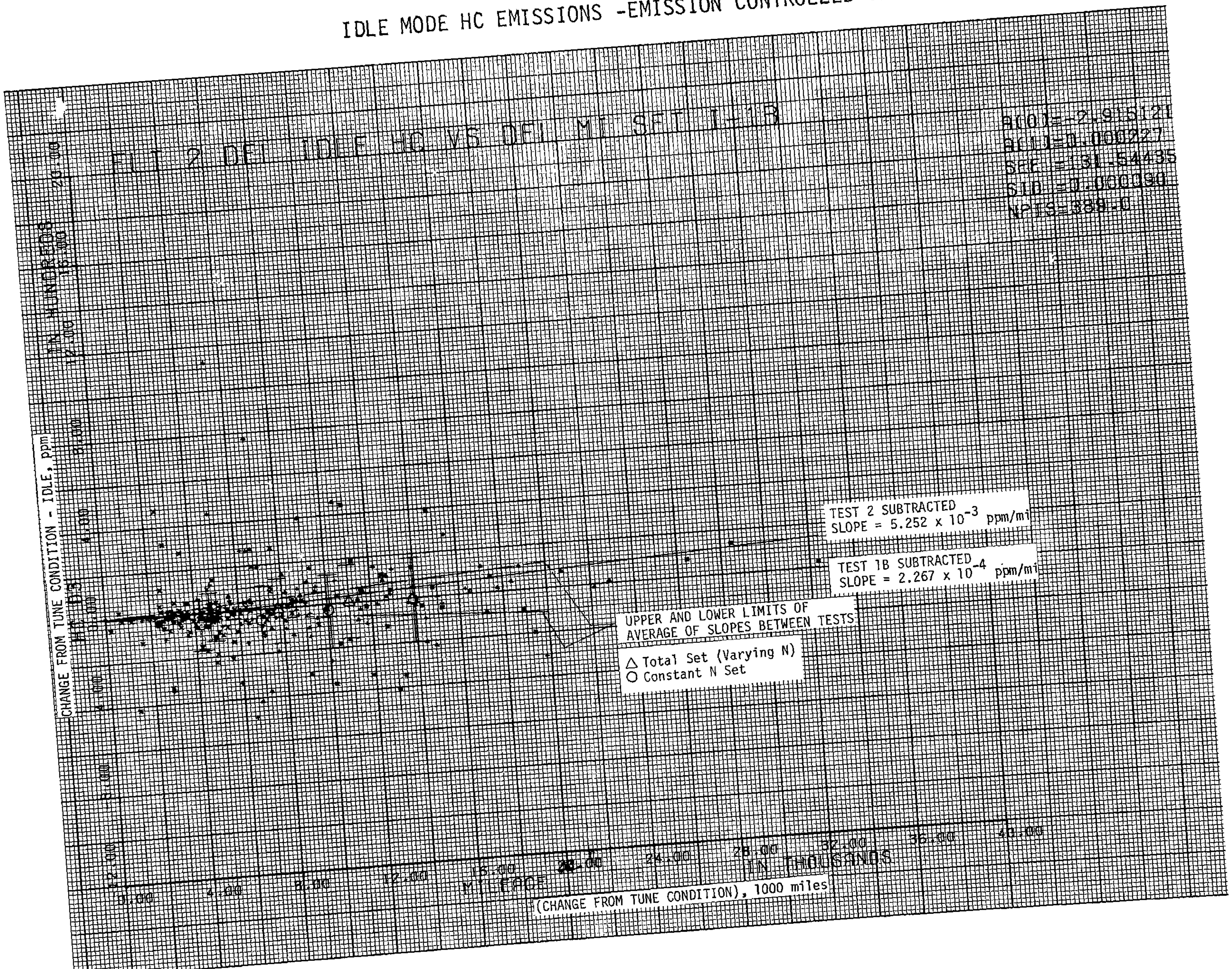


Figure 2.35

IDLE MODE HC EMISSIONS - NO_X CONTROLLED VEHICLES

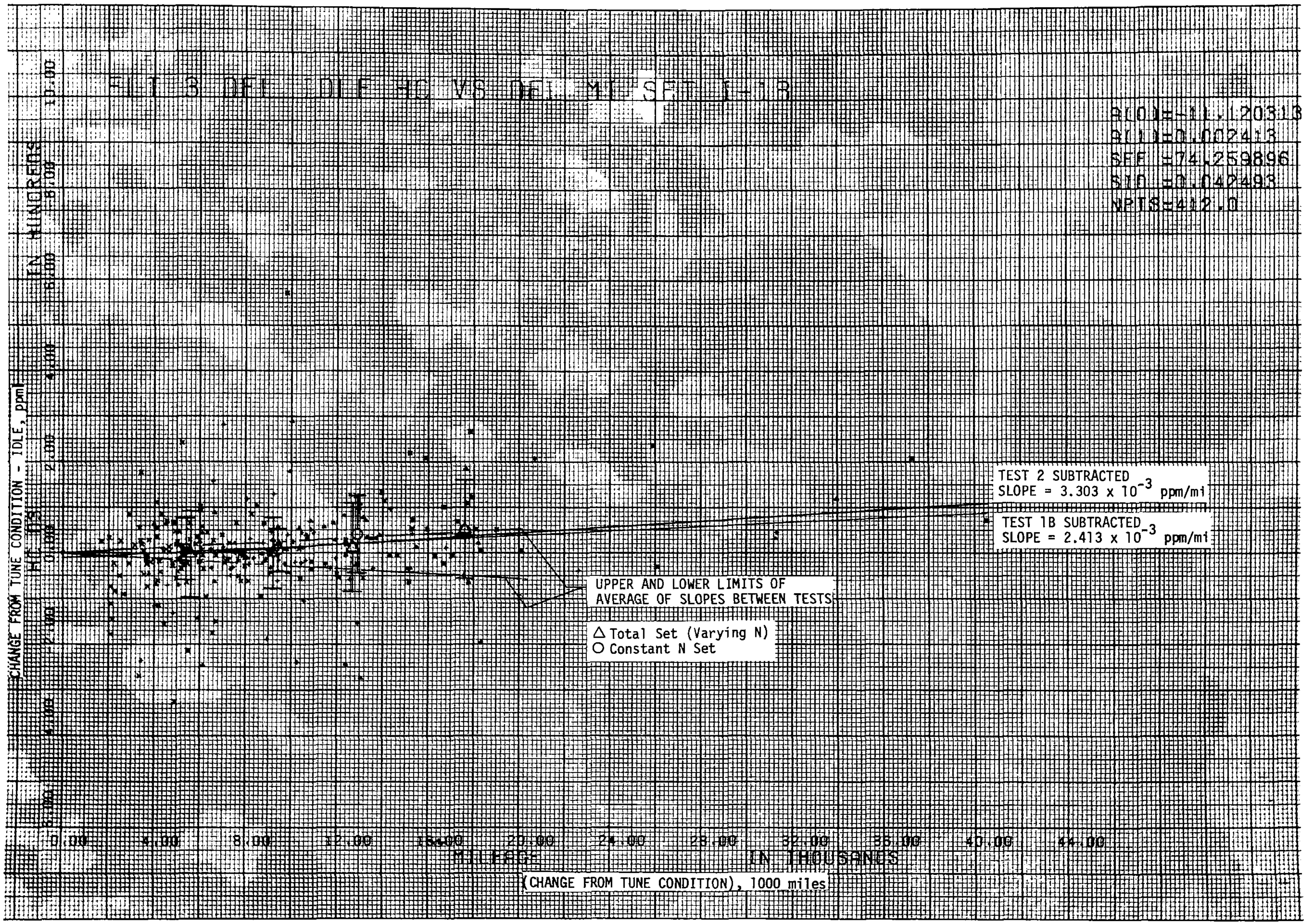


Figure 2.36

IDLE MODE CO EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

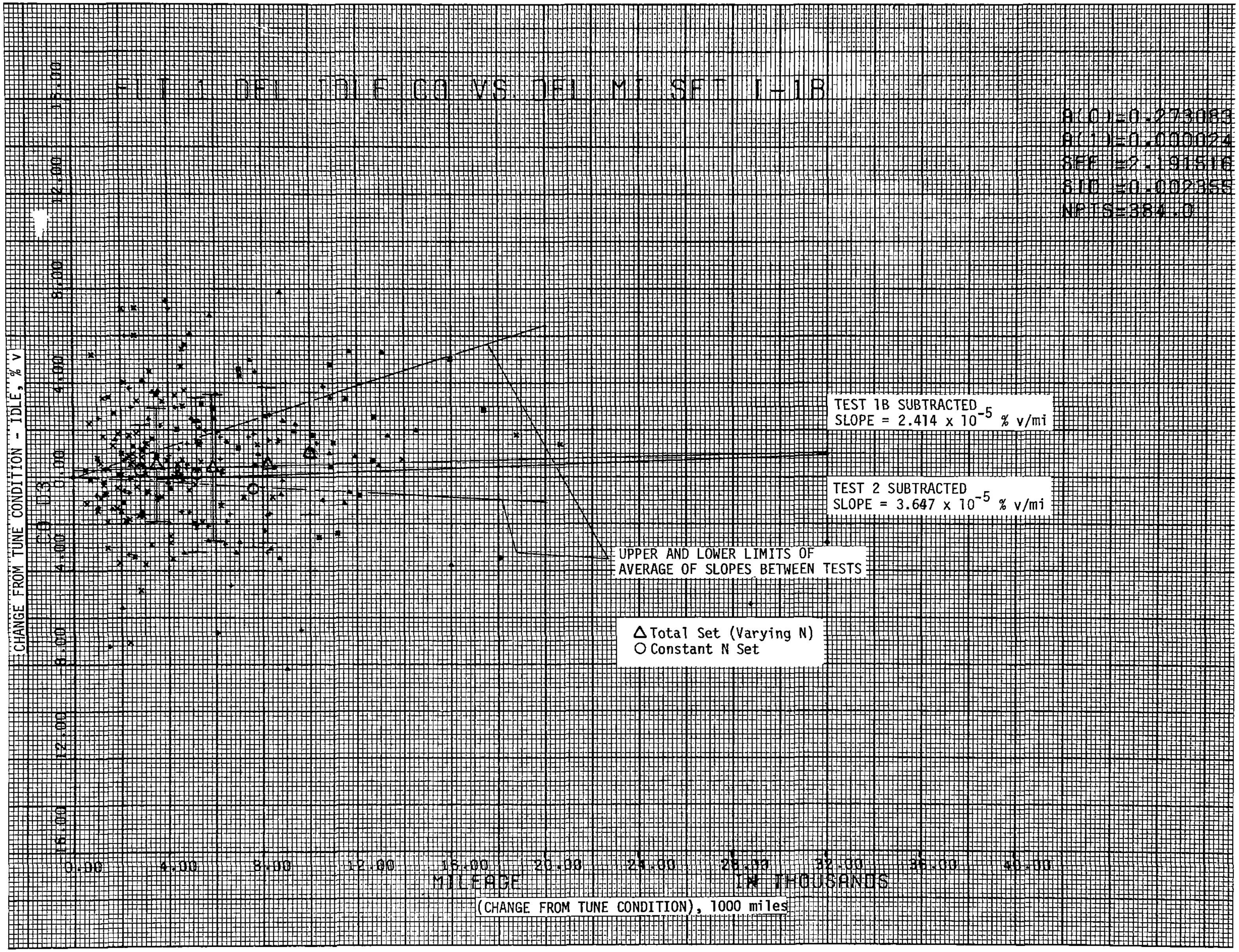


Figure 2.37

IDLE MODE CO EMISSIONS - EMISSION CONTROLLED VEHICLES

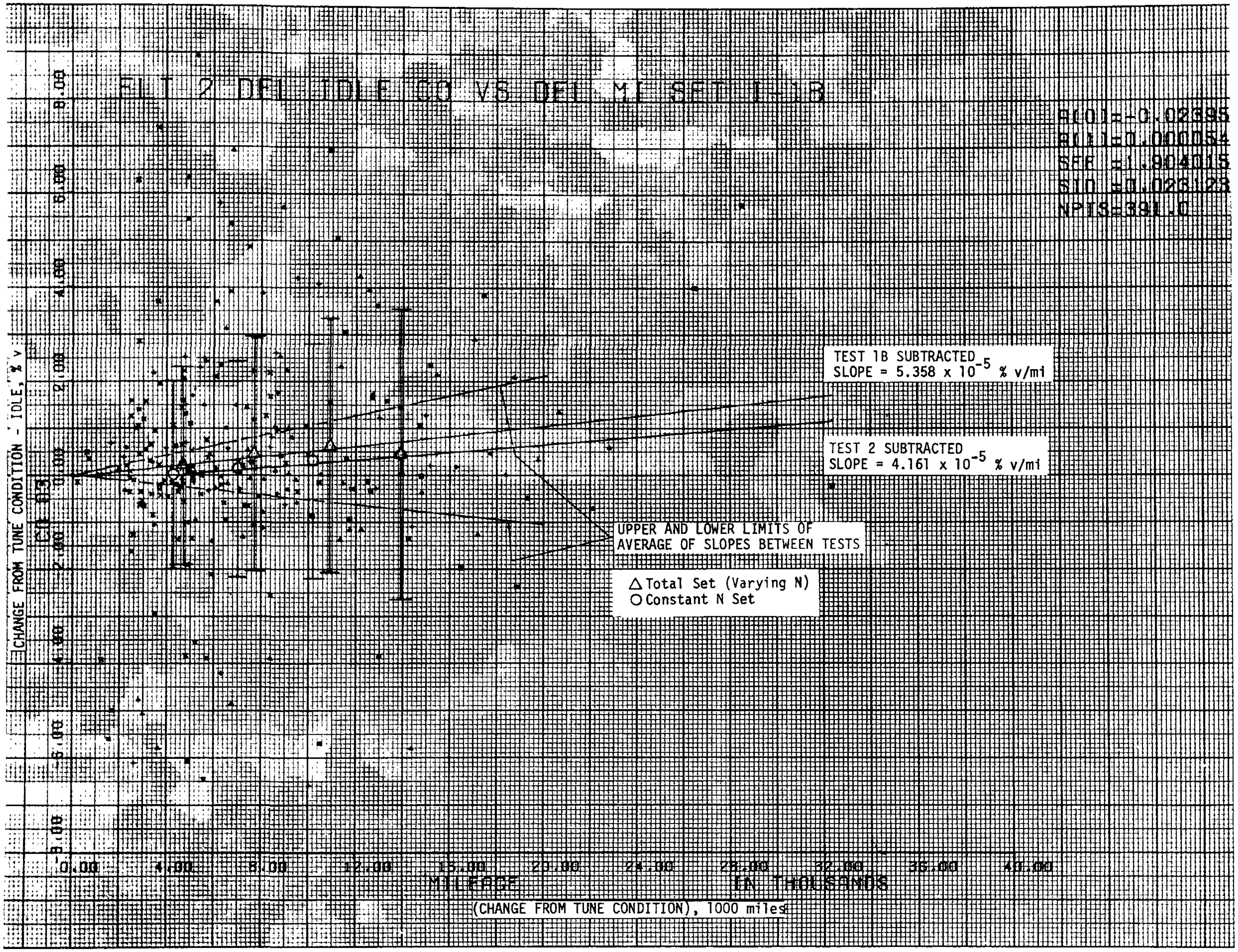
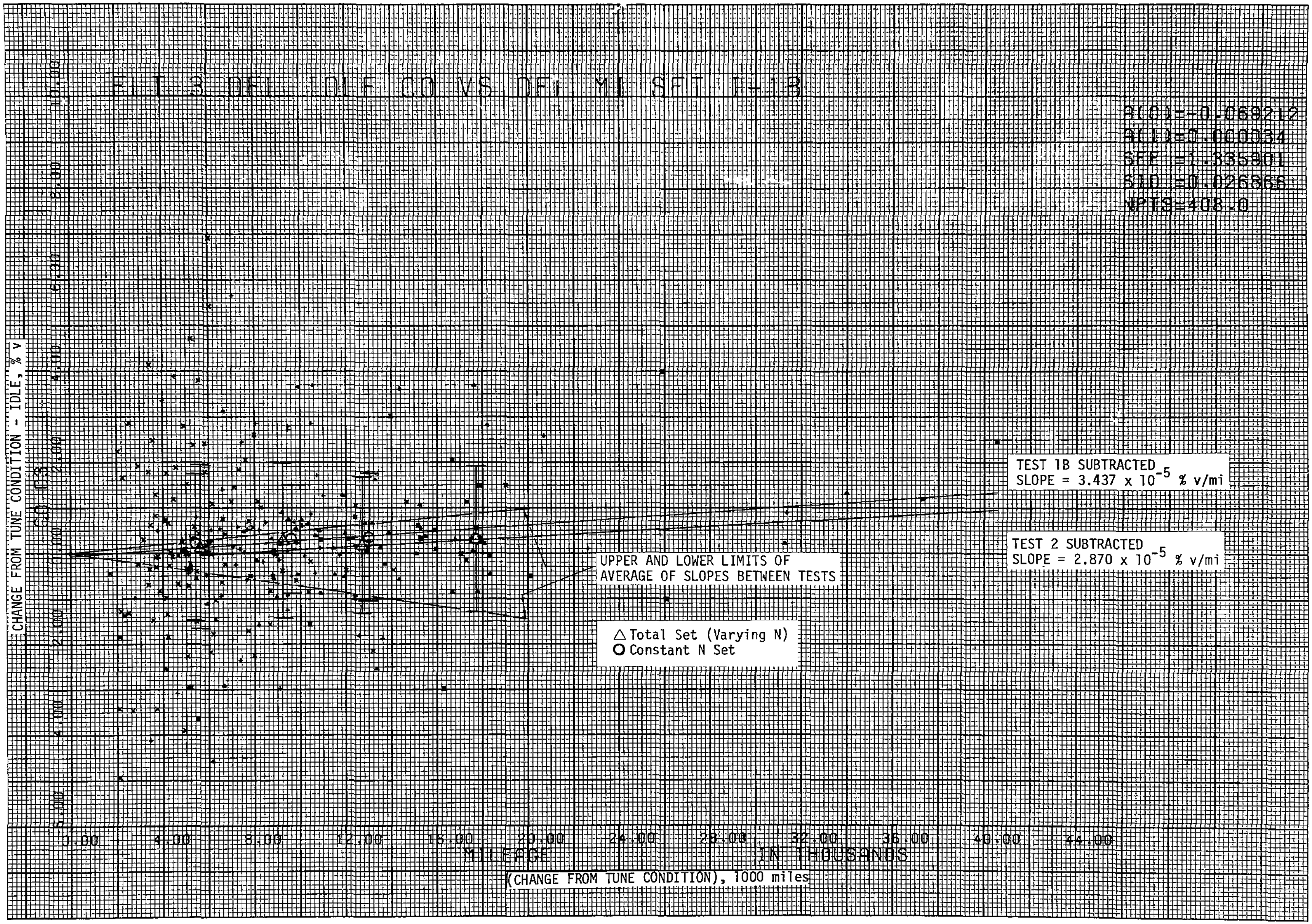


Figure 2.38

IDLE MODE CO EMISSIONS - NO_X CONTROLLED VEHICLES



IDLE MODE NO_X EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

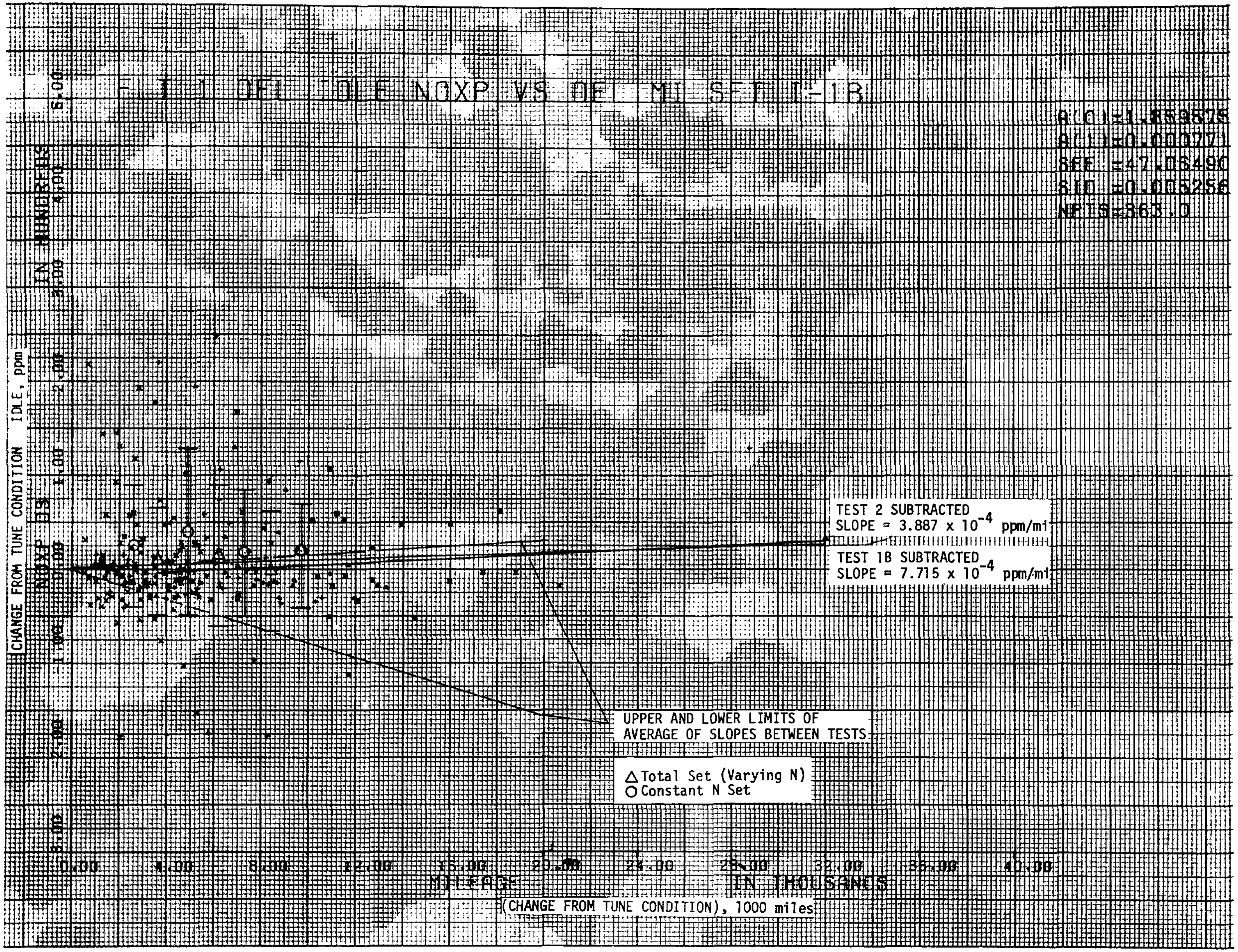
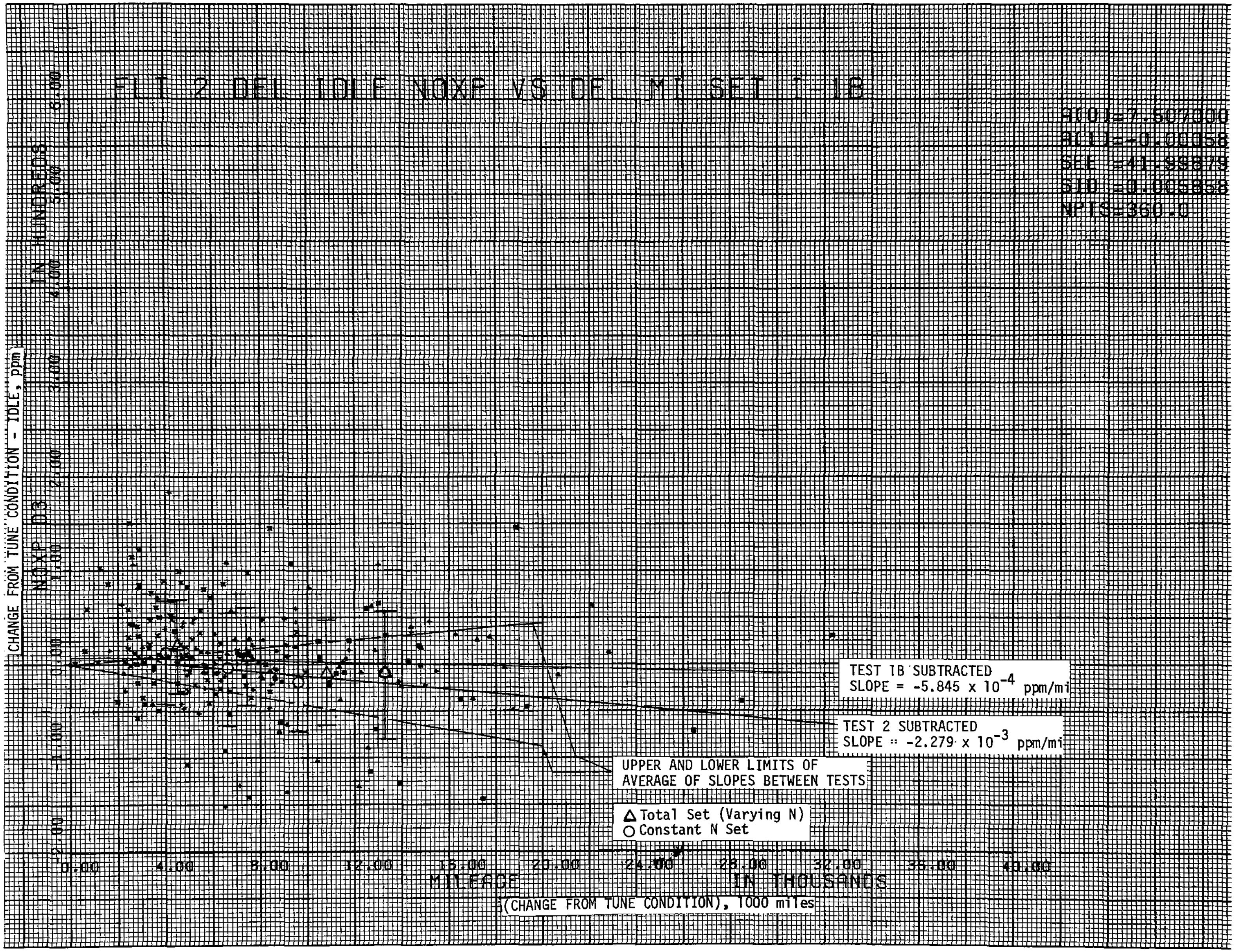


Figure 2.40

IDLE MODE NO_X EMISSIONS - EMISSION CONTROLLED VEHICLES



IDLE MODE NO_X EMISSIONS - NO_X CONTROLLED VEHICLES

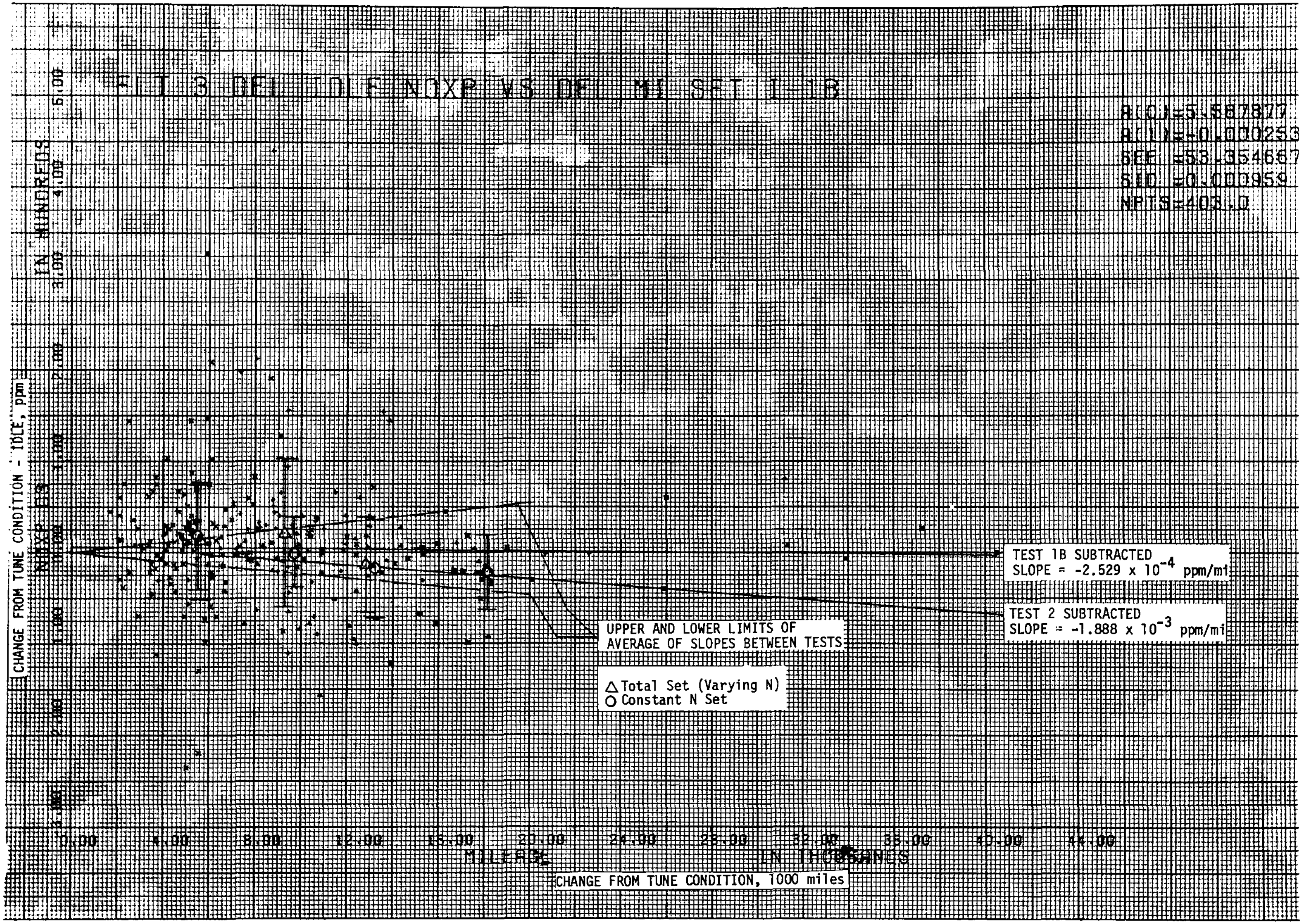


Figure 2.42

49/45 MPH CRUISE MODE HC EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

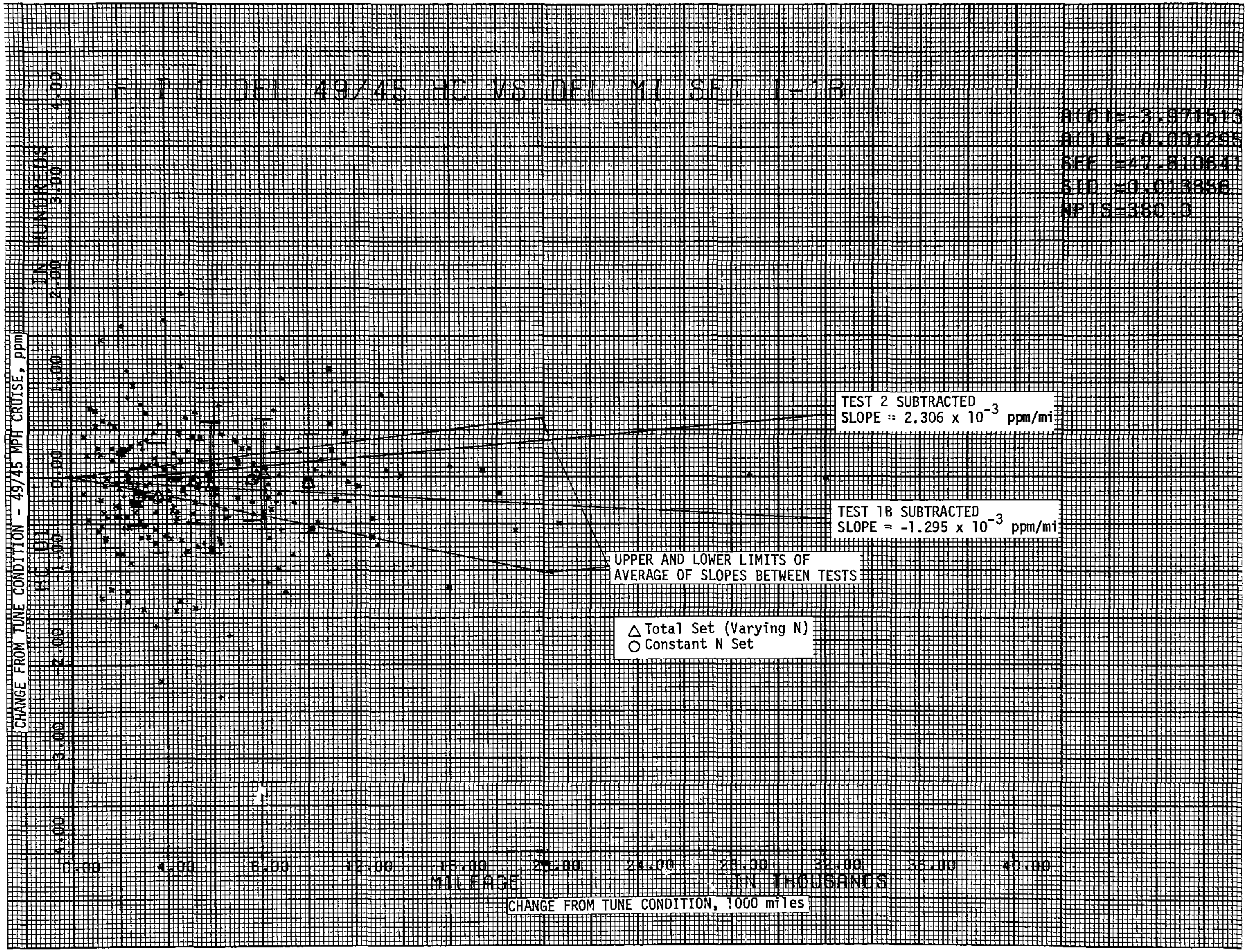


Figure 2.43

49/45 MPH CRUISE MODE HC EMISSIONS - EMISSION CONTROLLED VEHICLES

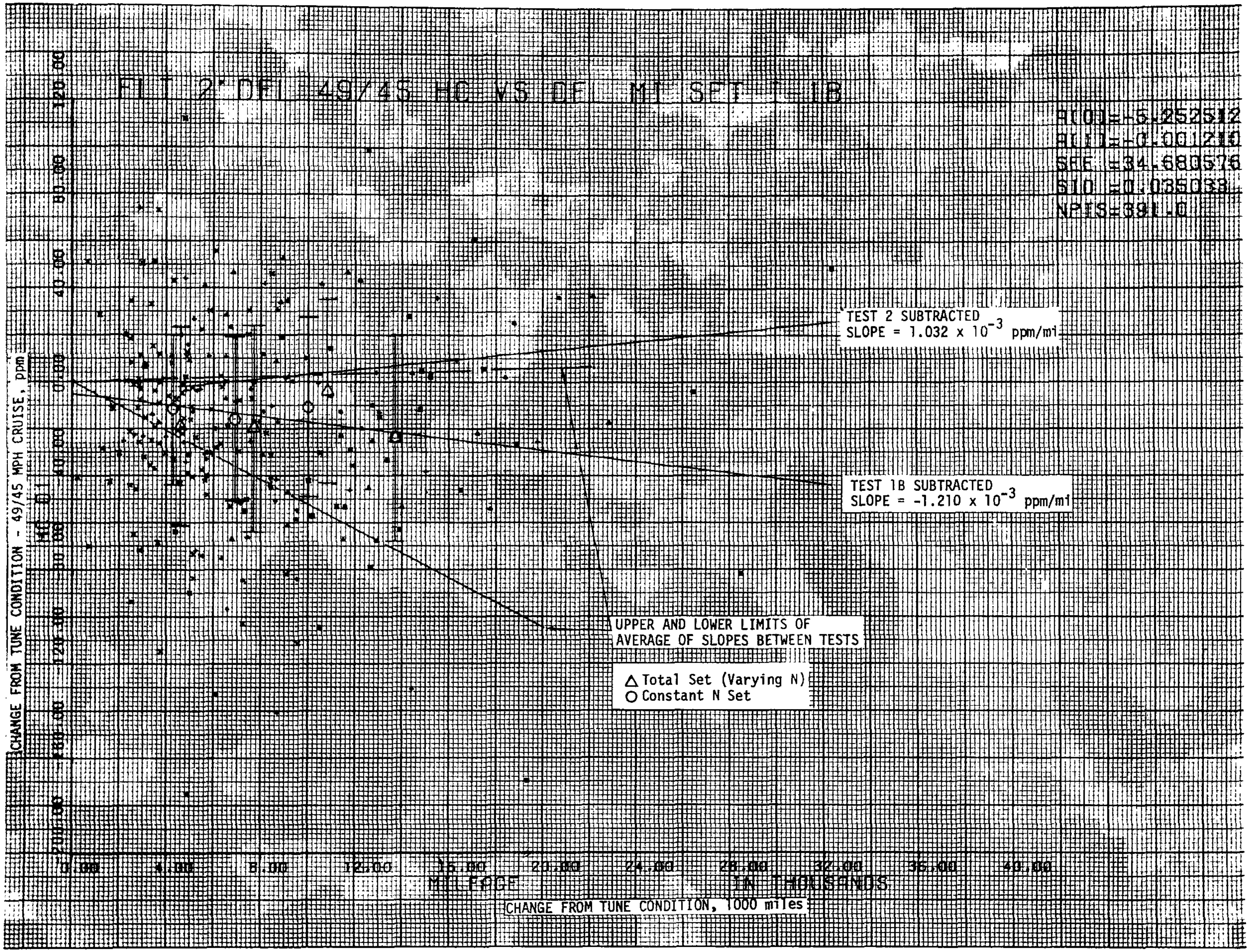


Figure 2.44

49/45 MPH CRUISE MODE HC EMISSIONS - NO_X CONTROLLED VEHICLES

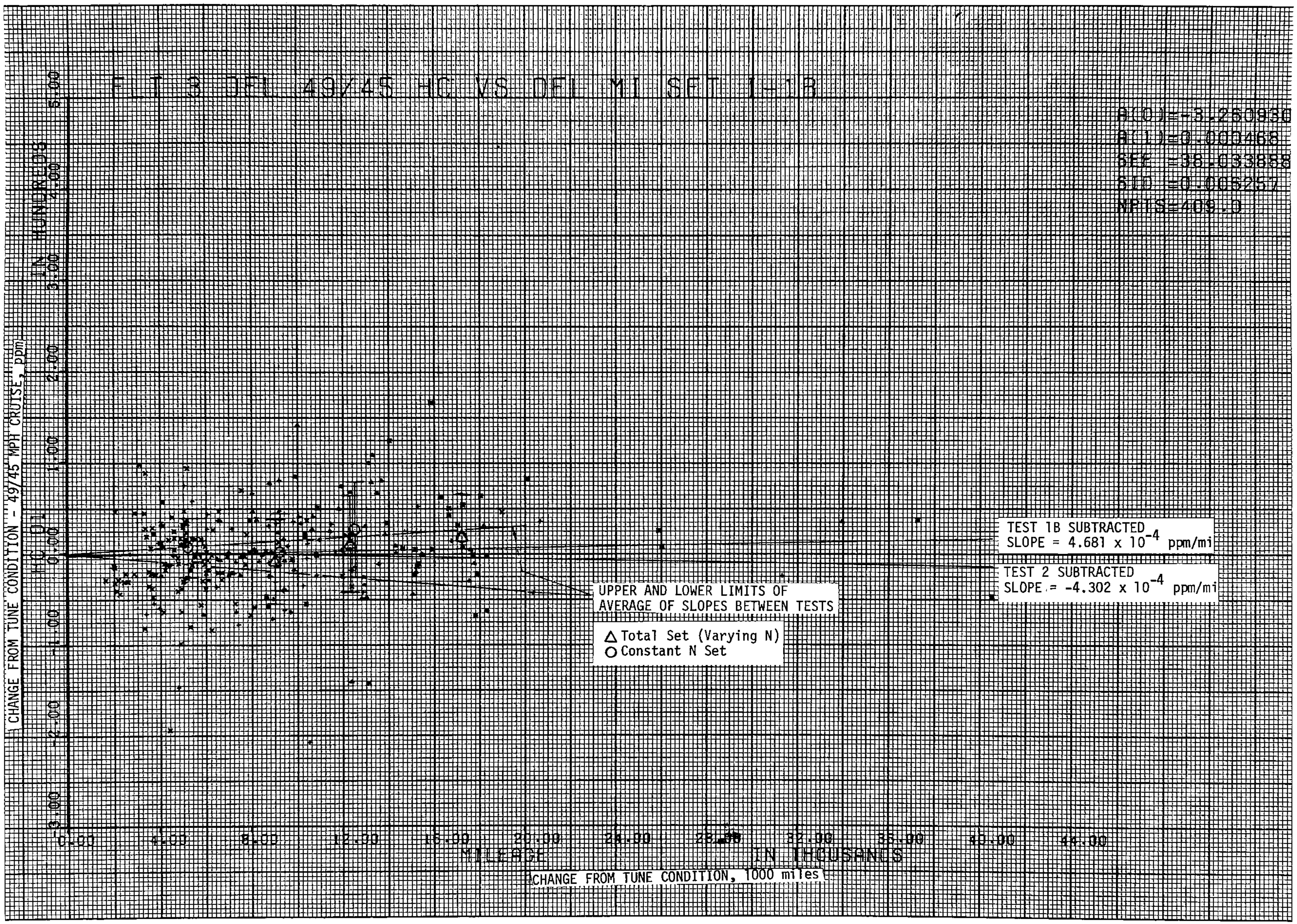


Figure 2.45

49/45 MPH CRUISE MODE CO EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

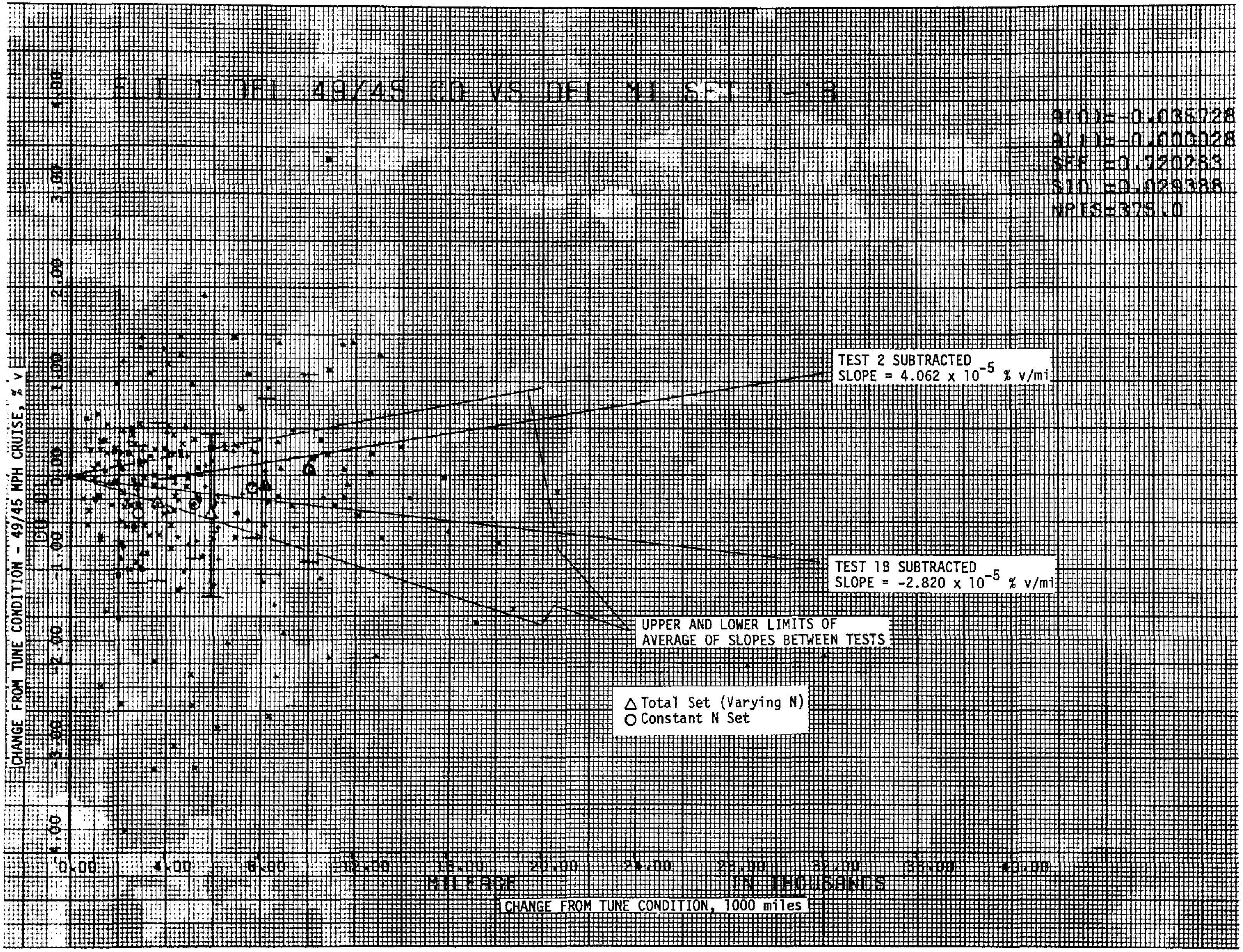


Figure 2.46

49/45 MPH CRUISE MODE CO EMISSIONS - EMISSION CONTROLLED VEHICLES

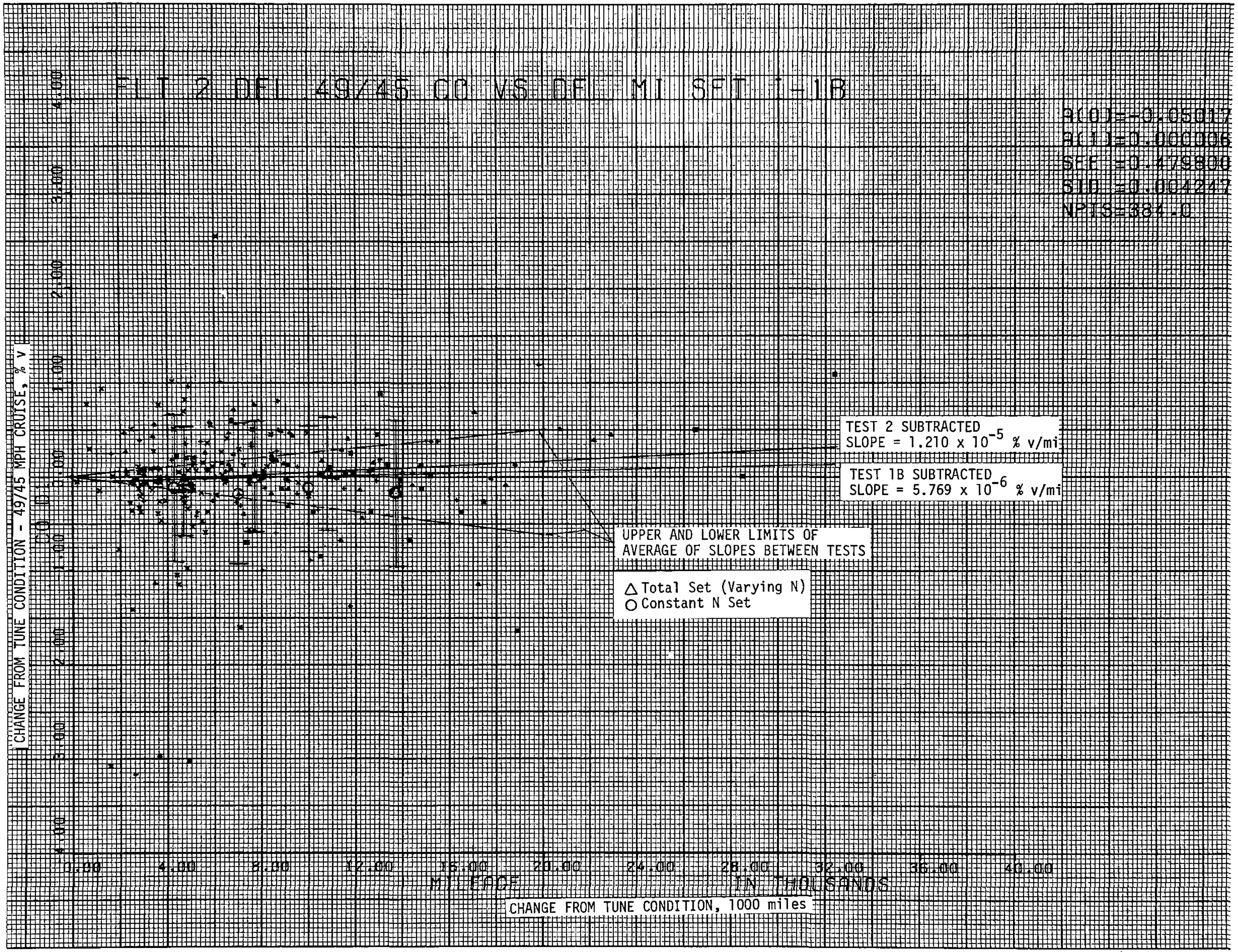


Figure 2.47

49/45 MPH CRUISE MODE CO EMISSIONS - NO_X CONTROLLED VEHICLES

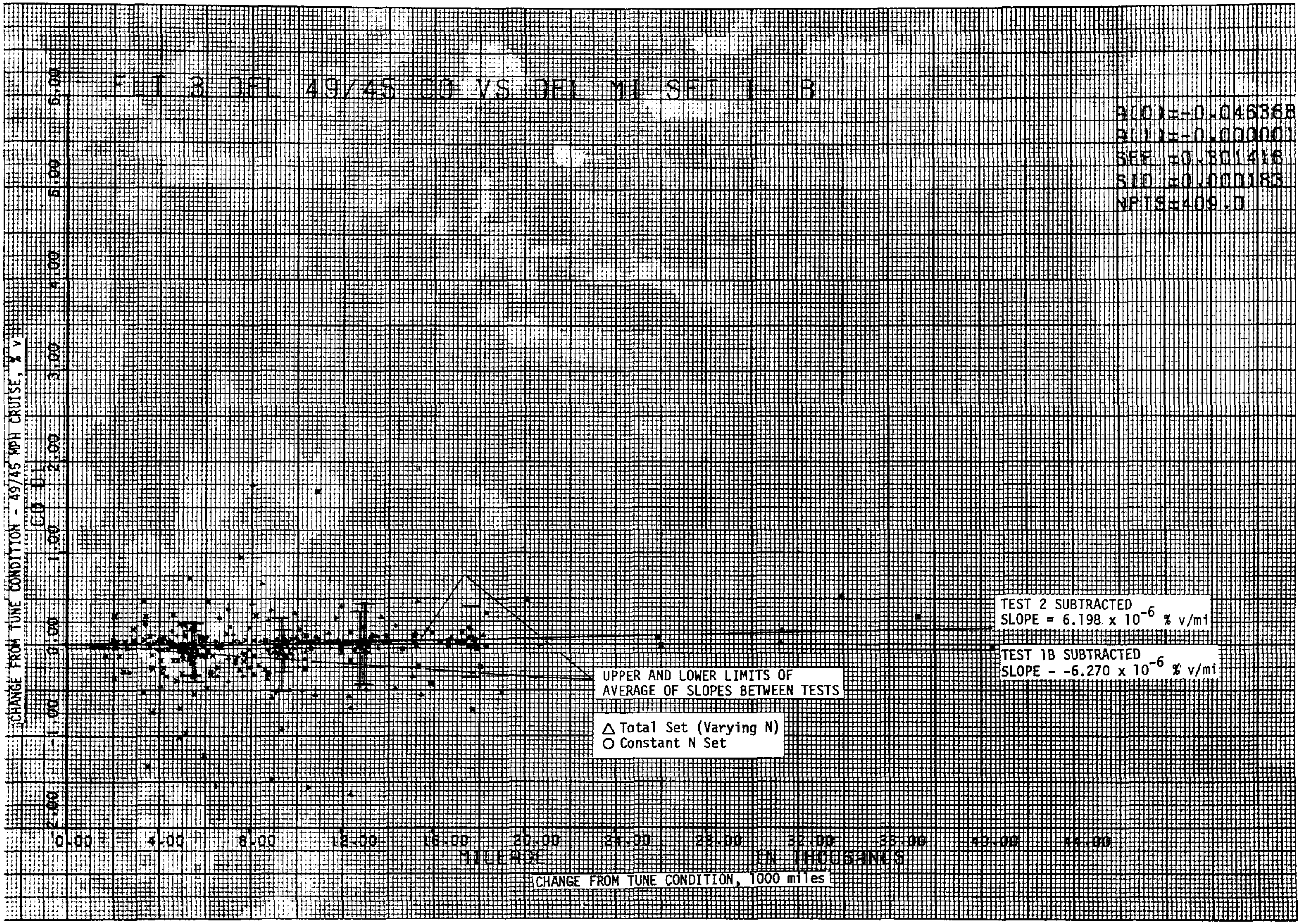


Figure 2.48

49/45 MPH CRUISE MODE NO_X EMISSIONS - PRE-EMISSION CONTROLLED VEHICLES

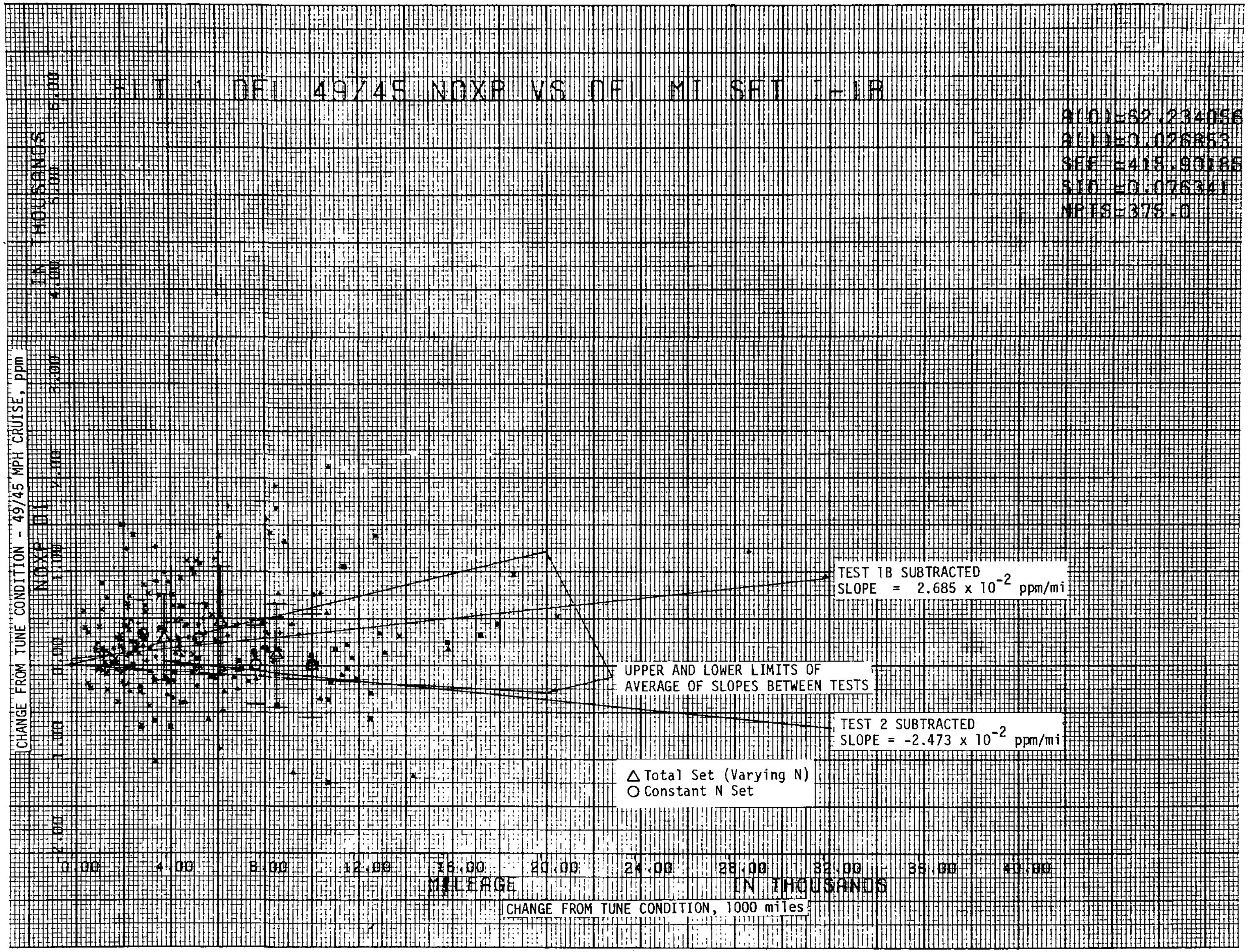


Figure 2.49

49/45 MPH CRUISE MODE NO_X EMISSIONS - EMISSION CONTROLLED VEHICLES

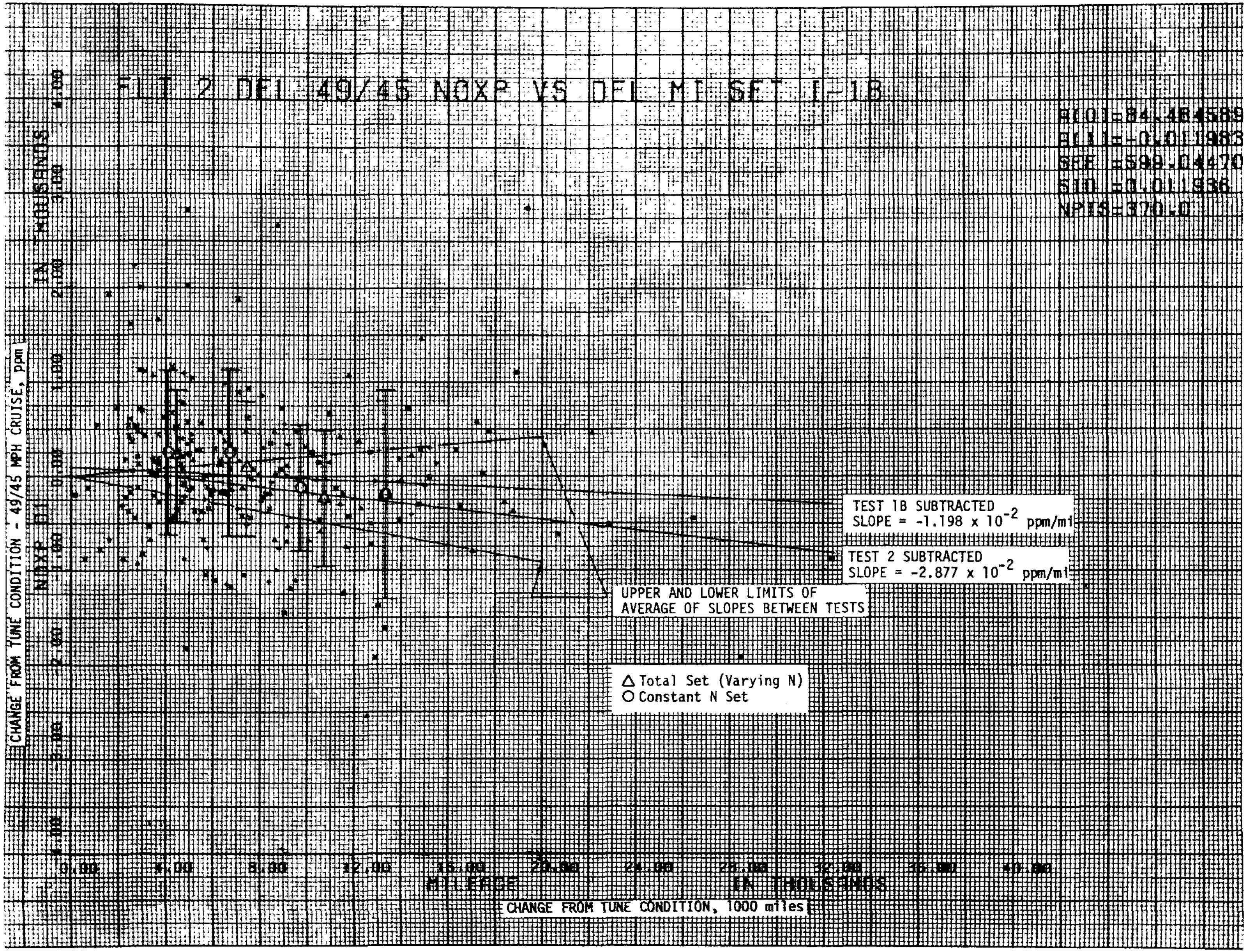


Figure 2.50

49/45 MPH CRUISE MODE NO_X EMISSIONS - NO_X CONTROLLED VEHICLES

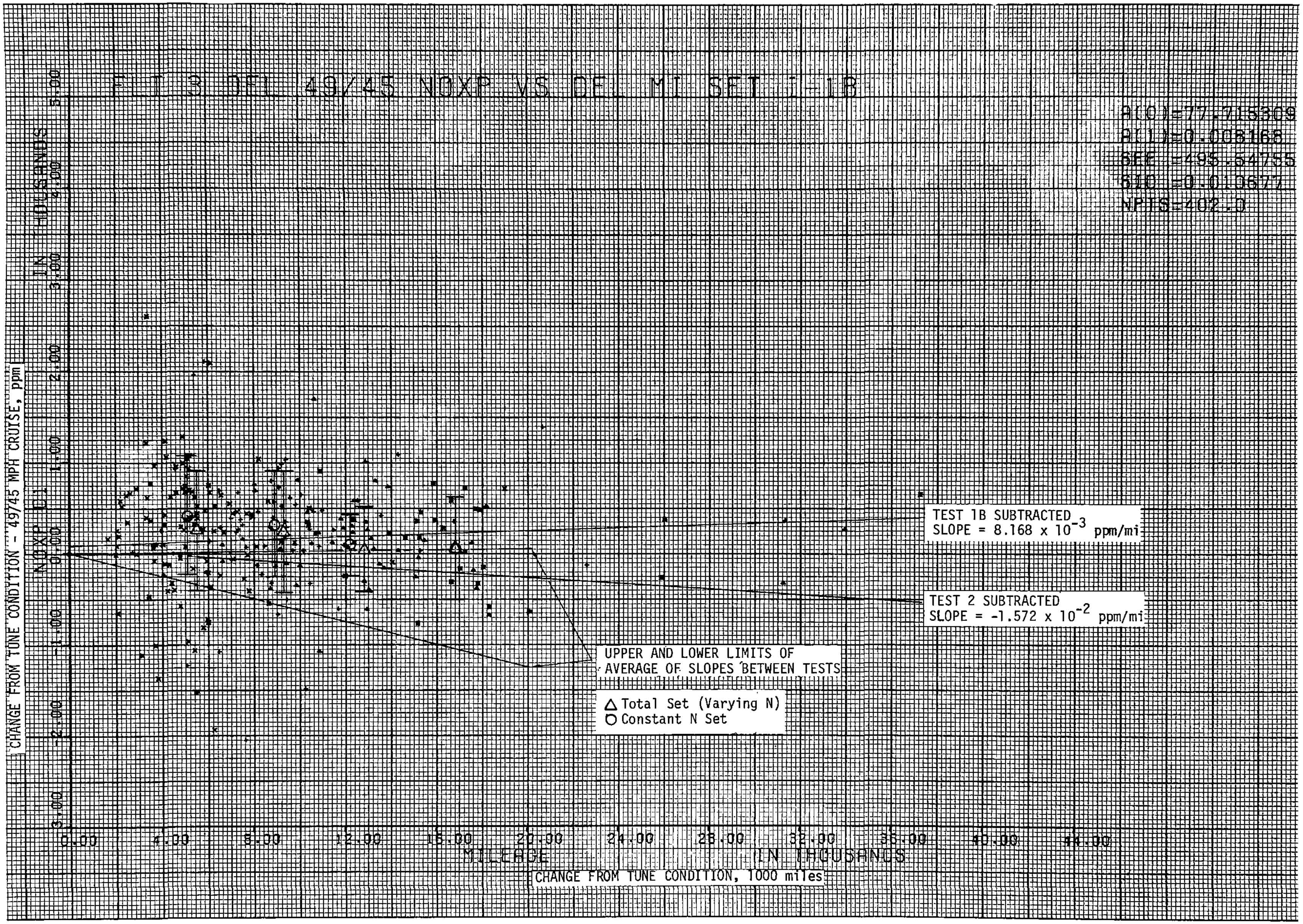


Table 2.46

AVERAGE COLD 1972 FEDERAL EMISSION

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
COLD 1972	$\bar{X}$	11.46	10.95	11.48	10.21	11.50	12.69	11.27	7.26	6.50	6.71	5.81	6.02	6.62	5.86	4.98	4.60	4.26	4.17	4.62	5.50	4.94
FEDERAL	S	4.9	4.6	5.2	4.6	4.4	4.9	3.5	3.7	2.2	3.4	2.2	1.5	2.6	1.6	1.8	2.3	1.2	1.5	1.8	2.0	1.3
HC, gm/mi	d.f	140	140	95	64	46	19	19	145	104	102	68	43	29	28	148	148	110	77	53	30	30
	t	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL SET	Conf.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	MILEAGE	83438	83438	87105	89542	92209	93841	93841	43357	43357	48104	51392	55256	57117	57117	8059	8059	13730	17629	21912	25443	25443
COLD 1972																						
FEDERAL	$\bar{X}$	133.3	122.9	125.4	114.7	133.6	141.8	132.4	92.0	83.6	90.9	81.4	85.6	91.8	73.7	71.0	61.0	63.5	58.5	59.8	64.3	50.9
	S	59	53	52	42	45	47	42	40	33	36	28	29	40	23	37	32	31	33	35	31	20
CO, gm/mi	d.f	140	140	95	64	46	19	19	145	145	102	68	43	29	28	147	147	109	76	52	29	29
	t	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL SET	Conf.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	MILEAGE	83438	83438	87105	89542	92209	93841	93841	43357	43357	48104	51392	55256	57117	57117	8059	8059	13730	17629	21912	25443	25443
COLD 1972	$\bar{X}$	3.74	4.01	3.46	3.23	3.52	3.39	3.43	5.85	5.96	4.82	4.08	4.89	4.67	5.47	5.40	5.27	4.39	4.11	4.52	4.67	4.94
FEDERAL	S	1.7	1.9	1.5	1.4	1.5	1.5	1.4	2.2	2.0	1.4	1.4	1.4	1.4	1.5	1.8	1.7	1.2	1.0	1.1	1.0	1.2
NO_x, gm/mi	d.f	139	139	93	62	44	18	18	141	141	95	62	40	26	25	148	148	108	76	52	29	29
	t	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOTAL SET	Conf.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	MILEAGE	83438	83438	87105	89542	92209	93841	93841	43357	43357	48104	51392	53256	57117	57117	8059	8059	13730	17629	21912	25443	25443
COLD 1972																						
FEDERAL	$\bar{X}$		10.96	11.42	10.27	10.89	12.69	11.27		6.49	5.74	5.32	5.79	6.62	5.86		4.30	4.29	4.06	4.32	5.50	4.94
	S		4.4	6.6	4.0	4.2	4.9	3.5		2.1	1.9	1.7	1.3	2.6	1.6		1.3	1.1	1.0	1.4	2.0	1.3
HC, gm/mi	d.f.		19	19	19	19	19	19		29	29	29	29	29	28		30	30	30	30	30	30
	t		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
CONSTANT	Conf.		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
N SET	MILEAGE		83438	86093	88423	90720	93841	93841		43357	47648	50310	53405	57117	57117		8059	13337	17324	20717	25443	25443
COLD 1972																						
FEDERAL	$\bar{X}$		129.0	125.8	127.9	131.6	141.8	132.4		85.1	81.9	76.7	83.8	91.7	73.7		53.1	58.5	55.4	60.2	64.3	50.9
	S		40	55	44	46	47	42		34	32	31	28	40	23		26	26	26	30	31	20
CO, gm/mi	d.f.		19	19	19	19	19	19		29	29	29	29	29	28		29	29	29	29	29	29
CONSTANT	t		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
	Conf.		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
N SET	MILEAGE		83438	86093	88423	90720	93841	93841		43357	47648	50310	53405	57117	57117		8059	13337	17324	20717	25443	25443
COLD 1972																						
FEDERAL	$\bar{X}$		4.08	3.55	2.91	3.48	3.38	3.43		6.87	5.39	4.41	5.00	4.67	5.47		5.58	4.72	4.19	4.44	4.67	4.94
	S		1.7	1.8	1.2	1.6	1.5	1.4		2.4	1.6	1.5	1.3	1.4	1.5		1.6	1.1	1.0	1.0	1.0	1.2
NO_x, gm/mi	d.f.		18	18	18	18	18	18		26	26	26	26	26	25		29	29	29	29	29	29
	t		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
CONSTANT	Conf.		—	—	—	—	—	—		—	—	—	—	—	—		—	—	—	—	—	—
N SET	MILEAGE		83438	86093	88423	90720	93841	93841		43357	47648	50310	53405	57117	57117		8059	13337	17324	20717	25443	25443

Table 2.47

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - COLD 1972 FEDERAL EMISSIONS

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO.	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B
COLD 1972 FEDERAL HC, gm/mi TOTAL SET	x̄	0.51	11.1	0.87	-0.59	0.45	1.41	0.005	0.76	6.55	0.14	-0.58	-0.43	0.17	-0.66	0.37	4.60	-0.04	-0.12	0.36	0.97	0.82
	s	3.4	4.6	3.5	2.8	4.0	4.4	3.7	3.3	2.2	2.7	2.1	1.8	2.3	1.8	2.0	2.3	1.3	1.3	1.7	1.3	1.5
	d.f	140	149	95	63	42	17	17	145	147	102	67	43	28	27	148	148	110	73	48	28	28
	t	1.77	—	2.47	-1.69	0.74	1.36	0.005	2.77	—	0.50	-2.24	-1.58	0.41	-1.95	2.29	—	-0.34	-0.83	1.46	4.09	2.86
	Conf.	92	—	98	90	55	81	<40	>99	—	<40	97	89	<40	95	97	—	<40	59	86	>99	>99
	MILEAGE	0	—	3532	5866	8180	10044	10044	0	—	4632	7553	10908	13865	13913	0	—	5561	9208	12689	17606	17606
COLD 1972 FEDERAL CO, gm/mi TOTAL SET	x̄	10.4	124.8	5.1	-7.4	5.7	11.3	1.6	8.4	84.6	4.5	-1.9	1.5	7.6	-10.8	10.0	61.0	5.1	1.1	4.0	11.0	0.4
	s	48	53	37	34	12	29	32	34	35	28	26	27	37	[illegible]	28	32	21	18	17	20	20
	d.f	140	149	95	63	42	17	17	145	147	102	67	43	[illegible]	[illegible]	147	147	109	72	47	27	27
	t	2.58	—	1.36	-1.72	0.89	1.65	[illegible]	2.99	—	1.63	-0.43	0.36	[illegible]	1.70	4.32	—	2.50	0.52	1.66	2.86	0.09
	Conf.	99	—	86	91	62	88	<40	>99	—	89	<40	<40	73	90	>99	—	99	40	90	>99	<40
	MILEAGE	0	—	3532	5866	8180	10044	10044	0	—	4632	7553	10908	13865	13913	[illegible]	—	5585	9224	12746	17736	17736
COLD 1972 FEDERAL NO_x, gm/mi TOTAL SET	x̄	-0.26	3.91	-0.511	-0.80	-0.42	-0.74	-0.68	-0.12	5.91	-1.25	-2.49	-1.92	-2.19	-1.51	0.12	5.27	-0.87	-1.28	-0.88	-0.92	-0.70
	s	1.4	1.9	0.99	1.1	1.3	1.2	1.1	2.0	2.0	1.4	1.7	1.6	2.4	2.1	1.4	1.7	1.2	1.1	1.4	1.2	1.0
	d.f	139	149	93	61	40	17	17	141	144	95	61	40	25	24	148	148	108	72	47	27	27
	t	-2.20	—	-5.02	-5.71	-2.11	-2.57	-2.66	-0.70	—	-8.55	-11.63	-7.52	-4.69	-3.53	1.07	—	-7.60	-9.61	-9.53	-3.90	-3.66
	Conf.	97	—	>99	>99	96	98	98	55	—	>99	>99	>99	>99	>99	78	—	>99	>99	>99	>99	>99
	MILEAGE	0	—	3569	5940	8282	10044	10044	0	—	4535	7469	10666	13266	13296	0	—	5544	9199	12695	17601	17601

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - FEDERAL SHORT EMISSIONS

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B
FEDERAL SHORT HC, gm/mi TOTAL SET	x̄	0.32	7.19	0.002	-0.33	0.55	0.92	-0.13	0.30	3.88	-0.06	-0.07	0.34	0.49	0.08	0.230	2.472	0.004	0.077	0.312	1.17	1.05
	s	2.6	3.2	2.1	2.2	2.8	3.2	2.9	2.8	1.8	1.1	1.2	1.2	1.2	0.92	0.92	0.87	0.71	0.69	0.89	1.1	1.7
	d.f	140	149	94	62	41	17	17	145	147	102	68	42	27	26	148	148	107	70	46	27	27
	t	1.48	—	0.01	-1.16	1.26	1.22	-0.19	1.28	—	-0.57	-0.51	1.88	2.08	0.43	3.05	—	0.05	0.94	2.41	5.43	3.22
	Conf.	89	—	<40	78	80	78	<40	80	—	45	<40	94	96	<40	>99	—	<40	65	98	>99	>99
	MILEAGE	0	—	3532	5847	8076	10044	10044		—	4666	7652	10954	13970	14023	[illegible]	—	5579	9228	12751	17517	17517
FEDERAL SHORT CO, gm/mi TOTAL SET	x̄	7.9	76.6	5.6	3.8	15.4	15.2	7.8	6.2	40.8	2.7	5.0	10.5	8.9	-3.1	4.4	29.3	1.5	2.2	5.1	11.9	1.2
	s	29	36	24	27	24	16	22	29	24	22	20	22	25	24	15	20	14	13	15	22	11
	d.f	139	148	94	62	39	16	16	145	147	102	67	42	27	26	147	147	106	70	46	26	26
	t	3.23	—	2.26	1.13	4.00	3.79	1.47	2.56	—	1.28	2.07	3.10	1.77	-0.69	3.49	—	1.12	1.41	2.35	2.85	0.54
	Conf.	>99	—	97	75	>99	>99	82	99	—	80	95	>99	92	58	>99	—	78	86	98	>99	41
	MILEAGE	0	—	3513	5830	7931	9921	9921	0	—	4628	7525	10630	13204	13229	0	—	5588	9207	12725	17648	17648
FEDERAL SHORT NO_x, gm/mi TOTAL SET	x̄	-0.08	2.96	-0.261	-0.298	-0.129	-0.166	-0.133	0.08	4.24	-0.67	-1.22	-0.92	-0.81	-0.02	0.28	3.84	-0.51	-0.66	-0.25	-0.36	-0.19
	s	1.3	1.5	0.74	0.84	0.90	0.77	0.74	1.5	1.7	1.2	1.2	1.4	1.6	1.8	1.2	1.3	1.1	1.2	1.1	1.2	1.1
	d.f	138	147	88	56	36	15	15	140	143	95	61	39	24	23	147	147	105	67	43	25	25
	t	-0.71	—	-3.60	-2.67	-0.87	-0.86	-0.76	0.68	—	-5.30	-7.97	-9.06	-6.98	-0.05	2.30	—	-4.76	-4.69	-1.50	-1.55	-0.86
	Conf.	52	—	>99	>99	61	61	59	51	—	>99	>99	>99	99	<40	>99	—	>99	>99	88	88	61
	MILEAGE	0	—	3606	6046	8579	10398	10398	0	—	4596	7614	10713	13280	13311	0	—	5562	9252	12799	17555	17555

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - COLD 1972 EMISSIONS

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO.	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
COLD 1972 FEDERAL HC, gm/mi CONSTANT N SET																						
	$\bar{x}$	0.31		0.003	-0.97	-0.70	1.41	0.005	1.02		-0.67	-1.09	-0.65	0.17	-0.66	0.91		0.02	-0.230	0.166	0.770	0.820
	s	3.5		2.5	2.8	3.7	4.4	3.7	4.4		2.6	1.7	1.8	2.3	1.8	1.4		1.3	0.97	1.4	1.3	1.5
	d.f.	17		17	17	17	17	17	28		28	28	28	28	27	28		28	28	28	28	28
	t	0.37		0.005	-1.46	-0.80	1.36	0.005	1.23		-1.84	-3.40	-1.90	0.41	-1.95	3.38		0.10	-1.29	0.64	4.07	2.86
	Conf.	<40		<40	85	57	81	<40	78		92	>99	94	<40	95	>99		<40	80	55	>99	>99
	MILEAGE	0		2757	5173	7606	10044	10044			4317	6999	10124	13865	13913	0		5360	9447	12887	17606	17606
COLD 1972 FEDERAL CO, gm/mi CONSTANT N SET																						
	$\bar{x}$	-5.9		-10.0	-4.0	-0.82	11.3	1.61	8.6		-2.3	-7.2	-0.6	7.6	-10.8	17.6		6.6	2.6	9.0	11.0	0.4
	s	35		39	29	25	29	32	36		28	26	28	37	34	20		18	15	15	20	20
	d.f.	17		17	17	17	17	17	28		28	28	28	28	27	27		27	27	27	27	27
	t	-0.70		-1.09	-0.58	-0.14	1.65	0.21	1.27		-0.44	-1.48	-0.12	1.09	-1.70	4.63		1.99	0.91	3.11	2.86	0.09
	Conf.	55		79	45	<40	88	<40	79		<40	85	<40	73	90	>99		95	68	>99	>99	<40
	MILEAGE	0		2757	5173	7606	10044	10044	0		4317	6999	10124	13685	13913			5447	9496	12992	17736	17736
COLD 1972 FEDERAL NO_x, gm/mi CONSTANT N SET																						
	$\bar{x}$	-0.15		-0.48	-1.18	-0.58	-0.74	-0.68	-0.66		-1.51	-2.48	-1.89	-2.19	-1.51	-0.14		-0.85	-1.40	-1.20	-0.92	-0.70
	s	1.2		1.1	1.0	1.2	1.2	1.1	2.1		1.6	1.9	1.8	2.4	2.1	1.0		1.0	1.0	1.2	1.2	1.0
	d.f.	17		17	17	17	17	17	25		25	25	25	25	24	27		27	27	27	27	27
	t	-0.54		-1.80	-4.89	-2.05	-2.57	-2.66	-1.60		-4.75	-6.57	-5.29	-4.69	-3.53	-0.71		-4.39	7.12	-5.29	-3.90	-3.66
	Conf.	41		92	>99	94	98	98	88		>99	>99	>99	>99	>99	58		>99	>99	>99	>99	>99
	MILEAGE	0		2757	5173	7606	10044	10044	0		4042	6640	9652	13266	13296	0		5373	9432	12904	17601	17601

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - FEDERAL SHORT EMISSIONS

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO.	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
FEDERAL SHORT HC, gm/mi CONSTANT N SET																						
	$\bar{x}$	0.13		-0.50	-0.93	-0.19	0.92	-0.13	0.08		-0.137	-0.280	0.040	0.491	0.076	0.268		0.003	0.126	.460	1.17	1.05
	s	3.4		1.4	2.6	3.2	3.2	2.9	1.4		0.72	0.88	0.92	1.2	0.92	0.92		0.71	0.63	0.92	1.1	1.7
	d.f.	17		17	17	17	17	17	27		27	27	27	27	26	27		27	27	27	27	27
	t	0.16		-1.50	-1.51	-0.26	1.22	-0.19	0.30		-1.01	-1.69	0.23	2.08	0.43	1.53		0.02	1.06	2.65	5.43	3.22
	Conf.	<40		87	87	<40	78	<40	<40		75	90	<40	96	<40	88		<40	78	99	>99	>99
	MILEAGE	0		2757	5173	7606	10044	10044	0		4383	7078	10167	13970	14023	0		5367	9420	12857	17517	17517
FEDERAL SHORT CO, gm/mi CONSTANT N SET																						
	$\bar{x}$	0.76		0.31	-1.3	7.0	15.2	7.8	8.4		-1.7	-0.46	7.0	8.4	-3.1	6.2		2.2	3.7	7.7	11.9	1.2
	s	22		18	22	17	16	22	24		16	17	22	25	24	17		14	10	13	22	11
	d.f.	16		16	16	16	16	16	27		27	27	27	27	26	26		26	26	26	26	26
	t	0.14		0.07	-0.24	1.65	3.79	1.47	1.83		-0.54	-0.14	1.69	1.77	-0.69	1.92		0.85	1.91	2.99	2.85	0.54
	Conf.	<40		<40	<40	88	>99	82	92		40	<40	90	92	58	94		60	94	>99	>99	41
	MILEAGE	0		2602	4999	7430	9921	9921	0		4114	6666	4669	13204	13229	0		5457	9470	12965	17648	17648
FEDERAL SHORT NO_x, gm/mi CONSTANT N SET																						
	$\bar{x}$	0.041		-0.28	-0.3[illegible]	-0.168	-0.166	-0.133	-0.11		-0.62	-1.01	-0.67	-0.81	-0.02	0.075		-0.531	-0.820	-0.459	-0.363	-0.191
	s	0.73		1.0	0.80	0.80	0.77	0.74	1.5		1.2	1.3	1.4	1.6	1.8	1.2		1.2	1.2	1.1	1.2	1.1
	d.f.	15		15	15	15	15	15	24		24	24	24	24	23	25		25	25	25	25	25
	t	0.22		-1.11	-1.99	-0.84	-0.86	-0.72	-0.37		-2.53	-3.91	-2.34	-2.48	-0.05	0.32		-2.21	-3.48	-2.12	-1.55	-0.86
	Conf.	<40		77	93	61	61	59	<40		99	>99	97	99	<40	<40		97	>97	96	88	61
	MILEAGE	0		2896	5377	7943	10398	10398	0		4055	6689	9686	13280	13311	0		5394	9415	12855	17555	17555

Table 2.49

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - 49/45 MPH CRUISE MODE

	TEST NO	PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
		1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B
49/45 MPH CRUISE	x̄	50.9	259.8	-22.4	-12.4	2.8	-7.2	-18.0	35.8	180.5	-19.1	-19.5	-3.6	-24.3	-29.6	7.2	127.7	-5.0	-7.9	10.6	18.3	20.6
HC, ppm	s	90	107	58	70	59	52	35	334	137	42	44	39	41	29	47	53	45	46	53	48	41
	d.f	140	149	94	62	38	17	17	143	146	101	68	42	27	26	147	147	109	72	47	26	26
TOTAL SET	t	6.72	—	-3.76	-1.40	0.30	-0.59	2.18	1.29	—	4.63	-3.71	-0.61	-2.92	-5.27	1.85	—	-1.18	-1.47	1.39	2.00	2.60
	Conf.	>99	—	>99	85	<40	50	96	80	—	>99	>99	50	>99	>99	92	—	78	88	88	94	99
	MILEAGE	0	—	3548	5894	8086	10044	10044	0	—	4646	7652	10817	13669	13711	0	—	5555	9024	12302	17205	17205
49/45 MPH CRUISE	x̄	0.23	3.09	-0.29	-0.43	-0.12	0.07	-0.306	-0.094	1.14	-0.052	-0.002	0.029	-0.173	-0.194	0.062	0.816	-0.088	-0.118	-0.065	0.034	0.010
CO, %	s	1.7	2.2	0.84	0.86	0.94	1.0	0.51	0.68	1.0	0.58	0.59	0.60	0.78	0.75	0.96	0.84	0.32	0.40	0.43	0.39	0.33
	d.f	137	146	91	60	41	17	17	143	145	100	66	41	26	26	147	147	108	72	48	28	28
TOTAL SET	t	1.58	—	-3.31	-3.95	-0.80	0.30	-2.53	-0.77	—	-0.90	0.03	0.32	-1.15	-1.34	0.79	—	-2.86	-2.54	-1.05	0.47	0.16
	Conf.	89	—	>99	>99	59	<40	98	58	—	71	<40	<40	78	80	59	—	>99	99	75	<40	<40
	MILEAGE	0	—	3579	5886	8236	10044	10044	0	—	4674	7660	10849	13711	13711	0	—	5539	9264	12689	17606	17606
49/45 MPH CRUISE	x̄	-97.5	1675.5	293.8	474.2	108.0	-0.82	110.4	-36.3	2587.5	209.6	81.4	-226.6	-196.4	18.6	-4.5	2445.3	257.4	242.3	52.1	63.0	233.6
NO_x, ppm	s	622	876	462	579	556	559	356	707	965	699	708	719	1106	1050	568	766	653	664	462	558	486
	d.f	137	147	88	57	37	17	17	136	139	91	59	39	24	24	146	146	105	70	45	26	26
TOTAL SET	t	-1.89	—	6.00	6.23	1.20	-0.01	1.32	-0.60	—	2.88	0.89	-1.99	-0.89	0.09	-0.10	—	4.06	3.07	0.76	0.58	2.50
	Conf.	94	—	>99	>99	78	<40	80	50	—	>99	62	95	63	<40	<40	—	>99	>99	59	42	>99
	MILEAGE	0	—	3664	6090	8506	10044	10044	0	—	4495	7382	10696	13296	13296	0	—	5502	9273	12829	16752	16752

AVERAGE CHANGE IN PARAMETER FROM TEST 1B- IDLE MODE

	TEST NO	PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
		1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B	1A	MEAS 1B	2	3	4	5A	5B
IDLE MODE	x̄	34.1	715.8	18.4	-60.3	-4.1	-37.6	-88.2	51.4	291.0	-19.3	-13.7	4.6	-8.0	-82.8	40.4	198.7	-2.2	-0.001	12.1	51.8	76.1
HC, ppm	s	540	583	293	315	401	422	285	416	273	111	141	168	187	165	194	90	94	77	96	108	272
	d.f	137	147	92	60	39	17	17	143	146	99	66	42	28	27	148	148	109	72	47	28	28
TOTAL SET	t	0.74	—	0.60	-1.50	-0.66	-0.38	-1.31	1.48	—	-1.74	-0.80	0.18	-0.63	-4.16	2.55	—	-0.25	0	0.87	2.60	1.51
	Conf.	59	—	55	88	<40	<40	80	88	—	92	58	<40	<40	>99	98	—	<40	<40	62	98	85
	MILEAGE	0	—	3534	5837	8162	10044	10044	0	—	4658	7672	11004	13865	13913	0	—	5554	9193	12681	17606	17606
IDLE MODE	x̄	0.299	5.86	0.536	0.429	0.487	0.493	0.275	0.87	3.15	0.21	0.46	0.64	0.44	-0.97	0.52	2.81	0.14	0.29	0.18	0.31	-0.86
CO, %	s	3.1	2.6	2.4	3.1	3.3	2.6	3.4	2.7	2.2	2.1	2.5	2.7	3.1	2.3	2.5	2.5	1.8	1.7	1.5	1.6	2.4
	d.f	140	149	95	63	42	17	17	145	147	102	67	42	27	26	148	148	109	72	47	26	26
TOTAL SET	t	1.13	—	2.13	1.12	0.98	1.62	0.34	3.92	—	1.04	1.54	1.58	0.75	-2.17	2.52	—	0.80	1.50	0.84	1.01	-1.90
	Conf.	78	—	97	78	65	87	<40	>99	—	78	87	89	56	96	99	—	59	88	60	62	93
	MILEAGE	0	—	3532	5866	8180	10044	10044	0	—	4663	7669	10949	13864	13913	0	—	5554	9193	12681	17683	17683
IDLE MODE	x̄	23.1	49.4	9.5	13.7	-1.5	18.7	13.9	-5.1	77.4	19.1	8.3	-8.9	-11.8	6.7	-2.8	109.3	13.2	21.8	-14.2	-22.1	25.5
NO_x, ppm	s	101	41	57	75	64	60	42	75	60	50	52	56	68	75	68	79	64	81	52	41	96
	d.f	138	147	88	55	32	14	14	132	136	88	57	37	23	22	147	147	106	70	44	25	25
TOTAL SET	t	2.70	—	1.56	1.38	-0.14	1.20	1.27	-0.79	—	3.63	1.21	-0.99	-0.85	0.43	-0.50	—	2.13	2.27	-1.89	-2.77	1.35
	Conf.	>99	—	90	88	<40	78	79	58	—	>99	78	72	60	<40	<40	—	97	98	92	>99	82
	MILEAGE	0	—	3598	6167	8272	9745	9745	0	—	4499	7390	10804	13314	13348	0	—	5574	9273	12818	18117	18117

Table 2.50

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - 49/45 MPH CRUISE MODE

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO.	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
49/45 MPH CRUISE																						
HC, ppm	$\bar{x}$	42.9		-22.2	-4.7	-2.8	7.2	-18.0	132.9		-12.4	16.0	-10.9	-24.3	-29.6	8.3		7.2	3.0	27.1	18.3	20.6
	s	59		30	44	44	52	35	650		32	35	38	44	29	44		33	42	52	48	41
CONSTANT	d.f.	17		17	17	17	17	17	27		27	27	27	27	26	26		26	26	26	26	26
N SET	t	3.08		-3.16	0.45	-0.26	-0.59	-2.18	1.08		-2.09	-2.90	-1.53	-2.52	-5.27	0.99		1.14	0.37	2.73	2.00	2.60
	Conf.	>99		>99	<40	<40	50	96	72		96	97	88	>99	>99	75		77	<40	99	44	99
	MILEAGE	0		2757	5173	7606	10044	10044	0		4297	6938	9956	13669	13711	0		5158	9206	12531	17205	17205
49/45 MPH CRUISE																						
CO, %	$\bar{x}$	-0.186		-0.418	-0.316	-0.138	0.07	-0.306	-0.154		-0.175	-0.177	-0.130	-0.173	-0.194	0.051		-0.092	-0.068	0.014	0.039	0.010
	s	0.92		0.73	0.57	0.53	1.0	0.51	0.74		0.78	0.75	0.67	0.78	0.75	0.21		0.24	0.23	0.44	0.39	0.33
CONSTANT	d.f.	17		17	17	17	17	17	26		26	26	26	26	26	28		28	28	28	28	28
N SET	t	-0.86		-2.43	-2.36	-1.11	0.30	-2.53	-1.08		0.83	-1.23	-1.01	-1.15	-1.34	1.28		-2.06	-1.58	0.18	0.97	0.16
	Conf.	60		97	97	78	<40	98	77		59	78	76	78	80	80		95	88	<40	<40	<40
	MILEAGE	0		2757	5173	7606	10044	10044	0		4332	6968	9973	13711	13711	0		5360	9447	12887	17606	17606
49/45 MPH CRUISE																						
NO_x, ppm	$\bar{x}$	75.8		318.4	282.6	2.7	-0.8	110.4	31.0		252.6	251.9	-122.6	-196.9	18.6	-89.7		423.3	329.2	95.3	63.0	233.6
	s	471		376	379	423	559	356	748		874	880	669	1106	1050	446		646	579	338	558	486
CONSTANT	d.f.	17		17	17	17	17	17	24		24	24	24	24	24	26		26	26	26	26	26
N SET	t	0.68		3.60	3.16	0.03	-0.01	1.32	0.21		1.44	1.43	-0.92	-0.89	0.09	-1.04		3.41	2.96	1.46	0.58	2.50
	Conf.	58		>99	>99	<40	<40	80	<40		81	81	61	63	<40	75		>99	>99	85	42	>99
	MILEAGE	0		2757	5173	7606	10044	10044	0		4070	6661	9659	13296	13296	0		5051	8943	12223	16752	16752

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - IDLE MODE

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
IDLE MODE																						
HC, ppm	$\bar{x}$	-12.7		-56.4	-112.0	-116.6	-37.6	-88.2	129.8		-54.4	-48.2	-32.2	-8.0	-82.8	23.4		9.4	6.5	41.4	51.8	76.1
	s	264		179	405	387	422	285	689		112	148	165	187	105	94		67	48	84	108	272
CONSTANT	d.f.	17		17	17	17	17	17	28		28	28	28	28	27	28		28	28	28	28	28
N SET	t	-0.20		-1.34	-1.17	-1.28	-0.38	-1.31	0.97		-2.61	-1.75	-1.05	-0.23	-4.16	1.34		0.76	0.73	2.64	2.60	1.51
	Conf.	<40		80	79	80	<40	80	78		98	93	78	<40	>99	80		59	59	98	98	85
	MILEAGE	0		2757	5173	7606	10044	10044	0		4317	6999	10124	13865	13913	0		5360	9447	12887	17606	17606
IDLE MODE																						
CO, %	$\bar{x}$	0.36		0.30	0.05	-0.50	0.99	0.28	0.87		0.04	0.13	0.30	0.49	-0.97	0.44		0.13	0.32	0.36	0.31	-0.86
	s	3.8		1.9	3.3	2.5	2.6	3.4	2.7		2.0	2.3	2.5	3.1	2.3	2.5		1.6	1.2	1.4	1.6	2.4
CONSTANT	d.f.	17		17	17	17	17	17	27		27	27	27	27	26	26		26	26	26	26	26
N SET	t	0.40		0.67	0.06	-0.84	1.62	0.34	1.73		0.12	0.31	0.63	0.75	-2.17	0.92		0.42	1.39	1.34	1.01	-1.90
	Conf.	<40		57	<40	66	87	<40	91		<40	<40	50	74	96	88		<40	82	80	62	93
	MILEAGE	0		2757	5173	7606	10044	10044	0		4320	7016	10159	13864	13913	0		5909	9633	12993	17683	17683
IDLE MODE																						
NO_x, ppm	$\bar{x}$	22.2		24.8	39.5	17.0	18.7	13.9	-18.4		12.3	-5.0	-20.5	-11.8	6.7	-24.3		17.5	-0.45	-18.3	-22.1	25.5
	s	78		65	88	67	60	42	80		55	60	51	68	75	55		57	38	53	41	96
CONSTANT	d.f.	14		14	14	14	14	14	23		23	23	23	23	22	25		25	25	25	25	25
N SET	t	1.10		1.47	1.73	0.99	1.20	1.27	-1.12		1.08	-0.41	-1.98	-0.85	0.43	-2.26		1.57	-0.06	-1.78	-2.77	1.35
	Conf.	71		85	90	70	78	79	78		78	<40	95	60	<40	96		88	<40	92	>99	82
	MILEAGE	0		2627	4928	7319	9745	9745	0		3968	6564	9625	13314	13348	0		5512	9701	13225	18117	18117

Table 2.51

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - TUNE PARAMETERS

	TEST NO.	PRE-EMISSION CONTROLLED FLEET 1 1A	1B	2	3	4	5A	5B	EMISSION CONTROLED FLEET 2 1A	1B	2	3	4	5A	5B	NOX CONTROLLED FLEET 3 1A	1B	2	3	4	5A	5B
Timing, degrees	x̄	0.47		0.01	-.10	-.17	-.06	-.043	.33		-.32	0.09	-.49	-1.23	-.104	0.24		0.005	0.20	0.32	-1.00	-.04
	s	5.8		4.1	4.3	4.6	4.2	0.21	4.5		2.8	3.5	2.0	2.6	0.51	3.2		3.2	3.1	3.9	3.0	1.3
	d.f	147		97	63	40	22	22	141		97	60	35	23	23	145		107	70	45	27	25
Total Set	t	0.97		0.02	-.19	-.24	-.08	-1.00	0.67		-1.16	0.20	-.97	-2.30	-1.00	0.91		0.02	0.53	0.55	-1.77	-.15
	Conf.	70		<40	<40	<40	<40	70	63		78	<40	70	97	78	64		<40	40	40	91	<40
	MILEAGE	0		3519	5792	8359	9309	9309	[illegible]		4746	7575	11000	13325	13325	0		5638	9447	13015	17836	17088
IRPM, rpm																						
	x̄	67.1		16.3	35.3	50.0	42.6	-0.7	-17.4		-7.8	2.4	7.0	-0.7	16.8	-14.2		3.2	-0.9	-23.6	6.3	-3.2
	s	138		83	87	117	154	10	10[illegible]		75	62	136	14[illegible]	62	94		69	70	58	67	21
	d.f	145		96	62	40	20	20	145		100	61	36	22	21	148		111	71	45	26	24
Total Set	t	5.86		1.94	3.20	2.73	1.27	-.33	-1.92		-1.05	0.23	0.31	-.02	1.28	-1.84		0.49	-.11	-2.77	0.49	-.77
	Conf.	>99		96	>99	>99	98	<40	94		75	<40	<40	<40	79			<40	<40	>99	<40	56
	MILEAGE	0		3536	5824	8507	9166	9166	0		4749	[illegible]	11235	[illegible]	13839	0		5548	9347	12974	17713	17699
PCV Flow (33/30 MPH) cfm																						
	x̄	-.39		-.015	-.137	-.084	-.466	-.128	-.236		0.141	0.019	0.021	-.242	-.022	-.149		0.124	0.218	0.176	-.124	-.018
	s	1.2		0.73	0.67	0.65	0.85	0.50	0.71		0.34	0.44	0.46	0.60	0.38	0.52		0.39	0.37	0.37	0.38	0.37
	d.f	122		79	50	31	19	19	135		25	62	36	22	22	133		98	64	40	23	21
Total Set	t	-3.55		-.18	-1.47	-.73	-2.45	-1.16	-4.72		4.04	0.34	0.28	-1.92	-.28	-3.28		3.16	4.69	3.04	-1.58	-.23
	Conf.	>99		<40	85	56	97	72	>99		>99	<40	<40	94	<40	>99		>99	>99	>99	85	<40
	MILEAGE	0		3386	5668	8391	9252	9252	0		4778	7778	11249	13742	13742	0		5662	9619	13155	18138	18286
Air Cleaner, degrees																						
	x̄	24.0		20.9	19.7	18.6	14.2	5.0	20.0		14.6	19.7	17.4	24.9	-.82	10.7		10.7	16.5	19.2	49.2	5.2
	s	48		32	35	29	34	24	48		26	32	35	35	20	30		20	22	24	41	8.2
	d.f	113		71	40	20	11	9	127		25	56	30	21	21	124		94	61	36	23	22
Total Set	t	5.39		5.60	3.58	2.90	1.45	0.65	4.73		5.20	4.57	2.73	3.31	-.19	4.02		5.17	5.78	4.84	5.83	3.03
	Conf.	>99		>99	>99	>99	82	47	>99		>99	>99	99	>99	<40	>99		>99	>99	>99	>99	>99
	MILEAGE	0		3498	5942	8295	8202	6937	0		4877	7764	10848	13904	13904	0		5605	9323	13520	18483	18510
Choke Kick inches																						
	x̄	.0081		-.00015	-.0044	-.0074	.0043	.00020	-.0024		.0026	-.0107	-.0004	-.0043	0	-.0102		-.0036	-.0041	-.0030	.00357	.0028
	s	.049		.0066	.022	.031	.021	.00063	.047		.042	.026	.014	.0025	0	.040		.022	.030	.021	.0084	.010
	d.f	82		52	35	21	9	9	116		73	44	25	13	13	121		85	53	35	20	19
Total Set	t	1.51		-.17	-1.19	-1.10	0.63	1.00	-.54		0.52	-2.77	-.14	-.63	0	-2.83		-1.47	-1.02	-.87	1.95	1.21
	Conf.	85		<40	76	70	45	70	40		40	>99	<40	45	<40	>99		85	70	62	92	74
	MILEAGE	0		3942	6699	10418	10668	10668	0		4826	7400	10806	11567	11567	0		5717	9775	13153	17220	17188

Table 2.52

AVERAGE CHANGE IN PARAMETER FROM TEST 1B - TUNE PARAMETERS

		PRE-EMISSION CONTROLLED FLEET 1							EMISSION CONTROLED FLEET 2							NOX CONTROLLED FLEET 3						
	TEST NO	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B	1A	1B	2	3	4	5A	5B
TIMING, degrees CONSTANT N SET	$\bar{x}$	0.56		0.11	1.15	0.87	-.06	-.043	-.50		-.19	-.3c	-.92	-1.23	-.104	-.11		-.25	-.11	-.14	-1.00	-.04
	s	5.2		2.5	3.5	3.9	4.2	0.21	3.7		1.6	3.0	2.5	2.6	0.51	2.4		1.6	2.4	3.0	3.0	1.3
	d.f.	22		22	22	22	22	22	23		23	23	23	23	23	27		27	27	27	27	25
	t	0.52		0.21	1.58	1.08	-.08	-1.00	-.66		-.56	-.62	-1.79	-2.30	-1.00	-.24		-.80	-.24	-.25	-1.77	-.15
	Conf.	40		<40	87	75	<40	70	57		45	50	91	97	78	<40		59	<40	<40	90	<40
	MILEAGE	0		2553	4753	7022	9309	9309	0		4104	6739	9759	13325	13325	0		5401	9550	13070	17836	17088
IRPM, rpm CONSTANT N SET																						
	$\bar{x}$	122.0		25.0	36.0	31.2	42.6	-0.7	5.8		-6.6	3.4	10.0	-0.7	16.8	-16.7		1.7	-1.8	-22.0	6.3	-3.2
	s	158		101	91	84	154	10	125		63	104	165	143	62	83		59	67	60	67	21
	d.f.	20		20	20	20	20	20	22		22	22	22	22	21	26		26	26	26	26	24
	t	3.53		1.13	1.81	1.70	1.27	-.33	0.22		-.50	0.16	0.29	-.02	1.28	-1.04		0.15	-.14	-1.92	0.49	-.77
	Conf.	>99		95	92	89	78	<40	<40		40	<40	<40	<40	79	70		<40	<40	93	<40	56
	MILEAGE	0		2448	4599	6876	9166	9166	0		4261	6937	10035	13693	13839	0		5328	9433	12971	17713	17699
PCV FLOW (30 MPH) cfm CONSTANT N SET																						
	$\bar{x}$	-.21		-.038	-.179	-.225	-.466	-.128	-.332		.047	.047	-.014	-.242	-.022	-.246		-.002	.126	.086	-.124	-.018
	s	1.2		0.40	0.53	0.74	0.85	0.50	0.49		0.33	0.32	0.52	0.60	0.38	0.46		0.38	0.33	0.41	0.38	0.37
	d.f.	19		19	19	19	19	19	22		22	22	22	22	22	23		23	23	23	23	21
	t	-.80		-.42	-1.50	-1.36	-2.45	-1.16	-3.23		0.68	0.71	-.13	-1.92	-.28	-2.61		-.03	1.84	1.04	-1.58	-.23
	Conf.	58		<40	85	80	97	74	>99		<40	56	<40	94	<40	98		<40	92	70	85	<40
	MILEAGE	0		2604	4800	7133	9252	9252	0		4272	6972	10057	13742	13742	0		5733	9953	13423	18138	18286
AIR CLEANER degrees CONSTANT N SET																						
	$\bar{x}$	34.8		8.7	17.2	15.8	14.2	5.0	11.1		7.3	11.8	17.5	24.9	-.82	12.0		9.2	20.2	21.4	49.2	5.17
	s	58		28	36	32	34	24	17		17	23	40	35	20	26		16	23	28	41	8.2
	d.f.	11		11	11	11	11	9	21		21	21	21	21	21	23		23	23	23	23	23
	t	2.07		1.08	1.68	1.73	1.45	0.65	3.02		2.04	2.39	2.06	3.31	-.19	2.25		2.84	4.35	3.80	5.83	3.03
	Conf.	93		76	86	88	85	44	>99		95	97	95	>99	<40	97		99	>99	>99	>99	>99
	MILEAGE	0		2013	4113	6271	8202	6937	0		4236	7020	10185	13904	13904	0		5660	9938	13586	18483	18510
CHOKE KICK inches CONSTANT N SET																						
	$\bar{x}$	-.0002		-.00020	-.0077	.0018	.0043	.000200	-.0146		.0171	-.0050	.0005	-.0043	0	-.0136		-.0024	-.0011	.0047	.00357	.0028
	s	.031		.0059	.016	.018	.021	.00063	.031		.080	.0055	.015	.0025	0	.045		.012	.027	.019	.0084	.010
	d.f.	9		9	9	9	9	9	13		13	13	13	13	13	20		20	20	20	20	19
	t	-.02		-.11	-1.51	0.31	0.63	1.00	-1.79		0.80	-1.01	0.12	-.63	0	-1.37		-.92	-.19	1.17	1.95	1.21
	Conf.	<40		<40	85	<40	44	68	90		60	70	<40	45	<40	80		65	<40	75	93	74
	MILEAGE	0		2914	5566	8417	10668	10668	0		3662	5912	8554	11567	11567	0		5453	9734	12921	17220	17188

Table 2.53

AVERAGE SLOPE OF FRACTIONAL CHANGE OF COLD 1972 FEDERAL EMISSIONS WITH MILEAGE

AVERAGE SLOPE OF FRACTIONAL CHANGE OF COLD 1972 FEDERAL EMISSIONS WITH MILEAGE

PRE-EMISSION CONTROLLED FLEET 1

		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TOTAL
COLD 1972 FEDERAL HC, 10^{-5} gm/mi^2	$\bar{X}$	5.514	-6.342*	7.665	9.939	6.617	2.840
	S	18.9	21.7	24.8	12.7	20.1	20.6
	d.f	95	64	43	17	155	219
	t	2.89	-2.35	2.65	3.33	4.11	
	Conf.	>99	97	96	>99	99	
	MILEAGE	3532	2682	2642	2439	8613	11295
COLD 1972 FEDERAL CO, 10^{-5} gm/mi^2							
	$\bar{X}$	4.122	-4.56*	7.186	9.259	5.560	2.623
	S	18.0	25.8	20.2	19.5	18.8	21.1
	d.f.	95	64	43	17	155	219
	t	2.24	-1.41	2.36	2.02	3.69	
	Conf.	96	85	97	94	99	
	MILEAGE	3532	2682	2642	2439	8613	11295
COLD 1972 FEDERAL NO_x, 10^{-5} gm/mi^2							
	$\bar{X}$	-5.867	-3.594	9.487*	-6.292	-5.092	-2.271
	S	15.8	17.1	26.5	21.2	16.9	19.1
	d.f	93	62	41	17	172	213
	t	-3.59	-1.67	2.32	-1.26	-3.96	
	Conf.	>99	90	97	79	99	
	MILEAGE	3569	2712	2647	2439	8720	11367

EMISSION CONTROLED FLEET 2

		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TOTAL
COLD 1972 FEDERAL HC, 10^{-5} gm/mi^2	$\bar{X}$	2.194	-3.672*	1.935	4.765	2.553	0.8181
	S	14.8	10.6	7.5	11.4	12.8	12.2
	d.f	102	67	43	28	173	240
	t	1.51	-2.84	1.71	2.26	2.63	
	Conf.	88	>99	91	96	99	
	MILEAGE	4632	3010	3375	3741	11748	14758
COLD 1972 FEDERAL CO, 10^{-5} gm/mi^2							
	$\bar{X}$	3.326	-3.312*	3.259	5.928	3.739	1.774
	S	10.2	10.9	11.3	26.3	14.3	13.4
	d.f.	102	67	43	28	173	240
	t	3.31	-2.50	1.92	1.21	3.45	
	Conf.	>99	99	94	76	99	
	MILEAGE	4632	3010	3375	3741	11748	14758
COLD 1972 FEDERAL NO_x, 10^{-5} gm/mi^2							
	$\bar{X}$	-5.145	-6.655	4.400*	-1.037	-5.073	-3.346
	S	9.4	9.6	6.7	6.5	9.1	8.7
	d.f	95	61	40	25	181	221
	t	-5.38	-5.43	4.18	-0.81	-7.50	
	Conf.	>99	>99	>99	58	99	
	MILEAGE	4535	3025	3321	3614	11174	14495

NOX CONTROLLED FLEET 3

		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TOTAL
COLD 1972 FEDERAL HC, 10^{-5} gm/mi^2	$\bar{X}$	1.41	-3.573*	4.568	5.276	2.825	1.025
	S	9.2	11.-	12.9	5.4	9.9	10.4
	d.f	110	73	48	28	186	259
	t	1.62	-2.67	2.48	5.21	3.91	
	Conf.	89	>99	99	>99	99	
	MILEAGE	5561	3888	3708	4719	13988	17876
COLD 1972 FEDERAL CO, 10^{-5} gm/mi^2							
	$\bar{X}$	3.502	-5.139*	0.000381	1.319	2.270	0.[illegible]
	S	9.1	15.1	11.4	6.9	9.4	11.3
	d.f.	109	72	47	27	183	255
	t	4.05	-2.91	0	1.10	3.27	
	Conf.	>99	>99	0	72	99	
	MILEAGE	5585	3871	3746	4744	14075	17946
COLD 1972 FEDERAL NO_x, 10^{-5} gm/mi^2							
	$\bar{X}$	-2.634	-1.421	2.299	1.869	-0.884	-0.0843
	S	5.2	7.3	4.1	3.7	5.6	5.6
	d.f	108	72	47	27	254	254
	t	-5.30	-1.66	3.89	2.66	-2.53	
	Conf.	>99	90	>99	99	99	
	MILEAGE	5544	3875	3732	4498	17849	17849

* DATA NOT INCLUDED IN POOLED ESTIMATE

AVERAGE SLOPE OF COLD 1972 FEDERAL EMISSIONS WITH MILEAGE

		PRE-EMISSION CONTROLLED FLEET 1					EMISSION CONTROLED FLEET 2					NOX CONTROLLED FLEET 3				
		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED
[illegible]	$\bar{X}$	5121	-8[illegible]*	4930	1096	5740	[illegible]	-2.941*	1.360	3.262	1.333	-0.0051	-.144*	1.556	[illegible]	[illegible]
	S	21.9	22.9	272	127	[illegible]	9.13	7.56	4.75	9.21	8.28	[illegible]	4.65	4.30	[illegible]	[illegible]
	d.f	95	63	42	17	154	103	67	43	28	173	110	73	48	[illegible]	156
	t	2.29	[illegible]	.9	[illegible]	[illegible]	2.865	-3.21	1.90	1.91	2.12	-0.02	[illegible]	2.48	[illegible]	[illegible]
	Conf.	97	99	76	[illegible]	77	99	99	94	93	95	40	96	98	[illegible]	99
	MILEAGE	[illegible]	2687	2513	[illegible]		[illegible]	[illegible]	3375	3741		5561	3888	3708	[illegible]	
Cold 1972 Federal CO, 10^{-3} gm/mi^2	$\bar{X}$	2.466	-8.911*	7.972	9.761	[illegible]	1.599	[illegible]*	2.637	4.630	2.351	1.045	-2.275*	5.084	[illegible]	2.3105
	S	18.7	44.7	23.6	19.5	[illegible]	7.60	9.75	[illegible]	[illegible]	[illegible]	[illegible]	7.74	4.80	[illegible]	4.57
	d.f.	95	63	42	17	[illegible]	[illegible]	67	43	28	173	109	72	47	27	183
	t	1.29	-1.59	2.08	2.12	[illegible]	[illegible]	[illegible]	1.89	1.15	2.72	[illegible]	-2.51	0.73	0.75	2.40
	Conf.	82	88	96	95	[illegible]	[illegible]	[illegible]	94	78	99	97	98	55	58	98
	MILEAGE	[illegible]	2687	2513	[illegible]		[illegible]	[illegible]	3375	3741		[illegible]	3871	3746	4744	
Cold 1972 Federal NOx, 10^{-4} gm/mi^2	$\bar{X}$	-2.944	-1.942	3.788*	-0.049	[illegible]	[illegible]	4.745	[illegible]	-1.340	[illegible]	-1.803	-0.644	1.018	0.948	[illegible]
	S	6.45	7.80	9.50	[illegible]	6.78	[illegible]	[illegible]	4.87	[illegible]	1.59	[illegible]	4.48	2.06	1.98	[illegible]
	d.f	93	61	40	14	168	[illegible]	61	40	[illegible]	191	[illegible]	72	47	27	[illegible]
	t	-4.43	-1.96	2.55	[illegible]	-4.51	[illegible]	-4.91	3.76	-1.30	-6.65	[illegible]	[illegible]	[illegible]	2.53	[illegible]
	Conf.	99	95	98	50	99	[illegible]	[illegible]	99	79	99	[illegible]	79	99	99	70
	MILEAGE	3569	2717	2512	2439		4535	[illegible]	3521	[illegible]		5544	3875	3732	4678	

AVERAGE SLOPE OF FEDERAL SHORT EMISSIONS WITH MILEAGE

		PRE-EMISSION CONTROLLED FLEET 1					EMISSION CONTROLED FLEET 2					NOX CONTROLLED FLEET 3				
		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED
FEDERAL SHORT HC, 10^{-4} gm/mi^2	$\bar{X}$	0.516	-1.762	6.082	7.455	1.503	-.033	-.621	1.592	1.416	0.255	0.030	-.041	0.815	1.729	0.343
	S	12.8	13.6	14.1	15.3	13.5	3.70	4.06	3.06	2.65	3.60	1.69	2.96	1.59	1.99	2.14
	d.f	94	62	41	17	214	102	63	42	27	237	107	70	46	27	250
	t	0.39	-1.03	2.80	2.07	1.63	-0.09	-1.23	3.42	2.82	1.10	0.18	-0.12	3.52	4.59	2.54
	Conf.	<40	70	>99	95	85	<40	81	>99	>99	70	<40	<40	>99	>99	98
	MILEAGE	3532	2674	2462	2437		4666	3037	3357	3803		5579	3890	3745	4660	
FEDERAL SHORT CO, 10^{-3} gm/mi^2	$\bar{X}$	3.182	0.257*	5.694	5.193	4.062	0.335	1.000	3.204	0.107	1.218	0.262	-.244	0.650	1.226	0.295
	S	13.7	14.9	14.4	12.6	13.3	6.64	5.81	8.14	4.10	6.48	3.83	6.36	3.62	5.03	4.77
	d.f.	94	62	39	16	149	102	67	42	27	238	106	70	46	26	248
	t	2.27	0.14	2.49	1.69	3.61	1.28	1.42	2.58	0.14	2.90	0.71	-0.32	1.23	1.27	0.98
	Conf.	97	<40	98	89	99	81	85	98	<40	99	50	<40	78	79	70
	MILEAGE	3513	2686	2365	2491		4628	2987	3301	3535		5588	3850	3751	4684	
FEDERAL SHORT NOx, gm/mi^2	$\bar{X}$	-1.534	0.353	1.633	-.379	-.312	-2.213	-2.144	1.718*	-2.929	-2.287	-.960	-.557	1.305	0.275	-.308
	S	3.82	5.40	4.70	3.03	4.44	5.09	6.06	4.32	2.53	5.19	2.37	3.01	2.37	2.15	2.54
	d.f	88	56	36	15	195	95	61	39	24	180	105	67	43	25	240
	t	-3.78	0.49	2.11	-0.50	-0.98	-4.26	-2.78	2.51	-0.58	-5.92	-4.17	-1.52	3.65	0.65	-1.88
	Conf.	>99	<40	96	<40	70	>99	>99	99	50	99	>99	88	>99	50	90
	MILEAGE	3606	2440	2533	1819		4596	3018	3099	2567		5562	3690	3547	4756	

* DATA NOT INCLUDED IN POOLED ESTIMATES

Table 2.55

AVERAGE SLOPE OF 49/45 MPH CRUISE EMISSIONS WITH MILEAGE

		PRE-EMISSION CONTROLLED FLEET 1					EMISSION CONTROLED FLEET 2					NOX CONTROLLED FLEET 3				
		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED
49/45 MPH CRUISE HC, 10^{-3} ppm/mi^2	$\bar{X}$	-6.372	5.171	[illegible]	-5.945	-.978	-6.311	-0.331	6.259	-6.129	-2.444	-1.404	-0.437	3.856	2.130	-.228
	s	31.5	30.3	32.2	23.8	30.7	25.2	18.8	18.5	19.7	21.8	10.0	10.7	15.0	11.7	14.8
	d.f	94	62	38	17	211	101	68	42	27	238	109	72	47	26	254
	t	-1.97	1.36	0.88	-1.06	-0.46	2.53	-0.15	2.21	-1.86	-1.73	-1.48	-0.18	1.78	-0.94	-.25
	Conf.	95	85	63	75	<50	99	<40	97	94	90	87	<40	92	75	<50
	MILEAGE	3548	2648	2444	2439		4656	3037	3311	3714		5555	3824	3606	4674	
49/45 MPH CRUISE CO, 10^{-5} %v/mi^2	$\bar{X}$	-9.186	-8.804	15.19	20.63	[illegible]	-1.591	0.347	5.384	-5.721	-.278	-1.858	-0.776	1.257	0.346	-0.716
	s	32.2	49.0	40.2	13.5	46.6	27.2	18.0	18.1	19.2	22.1	7.3	9.4	10.9	[illegible]	8.4
	d.f.	91	60	41	17	209	100	66	41	26	233	108	72	48	28	256
	t	-2.73	1.40	2.45	0.94	-0.50	-0.58	0.16	1.92	-2.09	-0.19	-2.66	-0.71	0.81	0.57	-1.36
	Conf.	>99	85	18	68	<50	55	<40	93	96	<50	>99	57	60	52	80
	MILEAGE	3579	2709	2530	2938		4674	3029	3309	3738		5539	3915	3708	4719	
49/45 MPH CRUISE NO_x, 10^{-2} ppm/mi^2	$\bar{X}$	11.014	2.986	16.581	-3.064	2.306	4.490	3.281	12.788	.367	-1.203	5.662*	0.911	-6.300	-2.881	-3.002
	s	21.9	31.4	32.3	22.6	[illegible]	29.3	20.9	20.6	21.1	24.8	15.3	21.0	17.2	20.4	19.8
	d.f	88	57	37	17	[illegible]	91	59	39	24	213	105	70	45	26	141
	t	4.86	0.72	-3.17	-0.57	1.21	1.47	-1.22	-3.92	0.32	-0.72	3.80	-0.36	-2.49	-0.73	-1.82
	Conf.	>99	57	>99	50	80	88	79	>99	<40	50	>99	<40	98	58	90
	MILEAGE	3664	2778	2570	2439		4495	2963	3320	3647		5502	3910	3763	4529	

AVERAGE SLOPE OF IDLE EMISSIONS WITH MILEAGE

		PRE-EMISSION CONTROLLED FLEET 1					EMISSION CONTROLED FLEET 2					NOX CONTROLLED FLEET 3				
		TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED	TEST 2	TEST 3	TEST 4	TEST 5A	POOLED
IDLE MODE HC, 10^{-2} ppm/mi^2	$\bar{X}$	-0.117	-5.813	4.515	5.769	-.382	-0.816	0.366	1.344	0.356	0.046	-0.252	0.111	0.380	-0.072	-0.013
	s	18.4	40.6	14.4	14.3	26.1	5.2	4.6	3.6	3.0	4.6	2.1	2.3	2.2	2.5	2.2
	d.f	92	60	39	17	203	99	66	42	28	235	109	72	47	28	256
	t	-0.06	-1.12	1.99	1.71	1.85	-1.57	0.69	2.43	0.63	0.16	-1.26	0.42	1.20	-0.15	-0.09
	Conf.	<40	76	95	90	70	89	50	99	55	<50	80	<40	79	<40	<50
	MILEAGE	3534	2658	2553	2439		4658	3044	3418	3741		5554	3887	3728	4719	
IDLE MODE CO, 10^{-4} %v/mi^2	$\bar{X}$	2.030	-0.971	-0.296	9.710	1.334	0.043	0.726	0.820	-0.497	0.274	0.018	-0.122	-0.202	-0.980	-.115
	s	12.1	16.0	15.1	13.2	14.0	7.3	5.1	5.8	4.3	6.2	4.9	6.6	2.5	2.3	4.9
	d.f.	95	63	42	17	217	102	67	42	27	238	109	72	47	26	254
	t	1.64	-0.48	-0.13	3.12	1.41	0.06	1.17	0.92	-0.61	0.68	0.09	-0.16	-0.55	-1.10	-.37
	Conf.	89	<40	<40	>99	70	<40	76	67	54	50	<40	<40	50	95	<50
	MILEAGE	3532	2687	2513	2439		4663	3048	3392	3705		5554	3887	3728	4690	
IDLE MODE NO_x, 10^{-3} ppm/mi^2	$\bar{X}$	6.979*	-0.909	-7.954	-0.894	-3.140	7.441†	-0.229	-7.339	6.731	-1.088	3.048	1.001	-8.058	0.583	0.200
	s	42.2	26.6	23.8	10.4	24.1	18.2	20.4	16.2	17.2	18.5	14.0	26.8	24.8	12.7	20.4
	d.f	88	55	32	14	101	88	57	37	23	117	106	70	44	25	245
	t	1.56	-0.26	-1.92	-0.33	-1.32	3.86	-0.08	-2.78	1.92	-0.64	2.24	0.32	-2.18	0.23	0.15
	Conf.	89	<40	94	<40	80	>99	<40	>99	94	<50	97	<40	96	<40	<50
	MILEAGE	3598	2800	2483	2427		4499	2994	3416	3689		5574	3910	3753	4891	

* DATA NOT INCLUDED IN POOLED ESTIMATE

Table 2.56

AVERAGE SLOPE OF TUNE PARAMETERS WITH MILEAGE

PRE-EMISSION CONTROLLED FLEET 1

Parameter		TEST 2	TEST 3	TEST 4	TEST [illegible]	POOLED
TIMING, 10^{-4} deg/mi^2	$\bar{x}$	-1.549	-2.326	3.112	-7.029	-1.481
	s	19.2	20.5	12.9	28.4	19.8
	d.f	97	63	40	22	222
	t	-.80	-.91	1.54	-1.19	-1.12
	Conf.	59	78	86	75	73
	MILEAGE	3519	2633	2572	2287	
IRPM, 10^{-3} rpm/mi^2	$\bar{x}$	6.053	0.153	7.033	-2.334	3.766
	s	49.4	56.0	50.9	55.8	52.2
	d.f.	76	62	40	20	213
	t	1.20	0.02	0.78	-.19	[illegible]
	Conf.	79	<40	70	<40	73
	MILEAGE	3536	2657	2656	2290	
AIR CLEANER, 10^{-3} deg/mi^2	$\bar{x}$	9.150	2.616	-1.352	3.09[illegible]	5.307
	s	17.1	9.3	14.6	14.0	4.7
	d.f	71	40	20	11	142
	t	4.53	1.80	-.42	0.08	4.32
	Conf.	>99	93	<40	<40	97
	MILEAGE	3498	2743	2432	1732	
PCV FLOW (33/30 MPH), 10^{-5} cfm/mi^2	$\bar{x}$	-1.677	-1.790	-.209	-18.9[illegible]*	-.424
	s	37.6	23.8	26.4	43.2	31.8
	d.f	79	50	31	12	160
	t	-.40	-.54	-.04	-1.76	-0.57
	Conf.	<40	42	<40	95	<50
	MILEAGE	3386	2538	2612	2119	
CHOKE KICK, 10^{-7} cmdeg/mi^2	$\bar{x}$	1.873	-13.335	4.206	5.968	-1.887
	s	34.4	93.3	65.0	32.9	67.2
	d.f.	52	35	21	9	215
	t	0.40	-.86	0.23	0.57	-0.41
	Conf.	<40	65	<40	50	<50
	MILEAGE	3942	3016	3273	2251	

EMISSION CONTROLED FLEET 2

Parameter		TEST [illegible]	TEST [illegible]	TEST [illegible]	TEST [illegible]	POOLED
TIMING	$\bar{x}$	[illegible]	[illegible]	-3.021	-.594	-.409
	s	[illegible]	[illegible]	[illegible]	4.5	12.3
	d.f	27	[illegible]	[illegible]	23	215
	t	0.12	[illegible]	-.93	-.64	-.49
	Conf.	<40	<40	68	45	<50
	MILEAGE	474[illegible]	[illegible]	[illegible]	356[illegible]	
IRPM	$\bar{x}$	-1.331	[illegible]	[illegible]	-7.704	.353
	s	[illegible]	26.2	[illegible]	33.4	[illegible]
	d.f.	10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	t	[illegible]	[illegible]	[illegible]	-1.11	0.[illegible]
	Conf.	50	76	<40	75	<50
	MILEAGE	474[illegible]	[illegible]	3473	3657	
AIR CLEANER	$\bar{x}$	[illegible]	[illegible]	1.422	2.754	2.555
	s	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	d.f	35	[illegible]	[illegible]	[illegible]	72
	t	[illegible]	[illegible]	43	[illegible]	5.79
	Conf.	>9[illegible]	95	82	74	99
	MILEAGE	[illegible]	[illegible]	[illegible]	37[illegible]	
PCV FLOW	$\bar{x}$	3.[illegible]	-5.252	-1.303	-3.143	-4.753
	s	11.4	.71	14.0	[illegible]	[illegible]
	d.f	35	62	36	22	120
	t	[illegible]	-2.44	-.79	-2.74	-3.33
	Conf.	>99	78	58	98	99
	MILEAGE	4873	3140	347[illegible]	369[illegible]	
CHOKE KICK	$\bar{x}$	2.035	-41.133	39.26[illegible]	-16.[illegible]35	-5.87
	s	10[illegible]	173	1[illegible]	66.0	132
	d.f.	73	44	25	13	155
	t	[illegible]	-1.55	1.60	-.72	-.56
	Conf.	<40	89	88	62	<50
	MILEAGE	4326	[illegible]	33[illegible]	3012	

NOX CONTROLLED FLEET 3

Parameter		TEST 2	TEST 3	TEST 4	TEST 5[illegible]	POOLED
TIMING	$\bar{x}$	[illegible]	[illegible]382	[illegible]	-1.35[illegible]	.345
	s	[illegible]	7.5	[illegible]	4.2	6.2
	d.f	[illegible]	[illegible]	45	[illegible]	142
	t	[illegible]	[illegible].44	2.57	[illegible]	2.11
	Conf.	<40	98	45	46	60
	MILEAGE	[illegible]	4017	3792	4705	
IRPM	$\bar{x}$	[illegible]	-4.077	-7.39[illegible]	3.437	-1.51[illegible]
	s	[illegible].4	22.6	10.3	[illegible]	19.1
	d.f.	111	71	45	26	253
	t	0.10	-1.53	-2.74	2.0[illegible]	1.26
	Conf.	<40	86	>99	96	75
	MILEAGE	5[illegible]43	[illegible]	3326	4742	
AIR CLEANER	$\bar{x}$	1.972	[illegible].028	0.149	5.74[illegible]	2.0[illegible]
	s	4.2	4.1	5.7	5.4	4.[illegible]
	d.f	74	[illegible]	36	[illegible]	[illegible]19
	t	4.5[illegible]	3.21	0.16	5.21	6.67
	Conf.	>99	>99	<40	>99	99
	MILEAGE	[illegible]	[illegible]	3[illegible]	4397	
PCV FLOW	$\bar{x}$	2.448	7.192	-.910	-5.0[illegible]	[illegible]
	s	[illegible]	10.4	9.3	11.[illegible]	9.4
	d.f	[illegible]	64	40	23	225
	t	[illegible]	1.66	-.59	-2.25	[illegible]
	Conf.	>99	90	45	97	65
	MILEAGE	5062	4063	376[illegible]	4715	
CHOKE KICK	$\bar{x}$	-10.373	-10.5[illegible]	21.649	1.3[illegible]	-3.310
	s	52.0	67.5	113	44.1	70.4
	d.f.	85	53	35	20	173
	t	-1.35	-1.15	1.15	0.14	-.65
	Conf.	44	78	76	<40	<50
	MILEAGE	57[illegible]	41[illegible]	3670	4299	

* DATA NOT INCLUDED IN POOLED ESTIMATES

Table 2.57

LINEAR REGRESSION OF COLD 1972 FEDERAL EMISSIONS WITH MILEAGE

PRE-EMISSION CONTROLLED FLEET 1

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]	MEASURED [5]
COLD 1972 FEDERAL HC, gm/mi	A (1)	5.103×10^{-6}	2.080×10^{-5}	2.695×10^{-5}	1.759×10^{-4}	5.537×10^{-5}
	A (0)	0.0339	-.0354	0.254	-.676	11.7
	SEE	0.294	0.256	2.53	3.185	4.22
	R^2	.0063	.0511	.0018	.0282	.0026
	d.f.	334	235	334	235	337
	t	1.56	3.33	0.83	2.60	1.31
	Conf.	90	>99	59	99	70
COLD 1972 FEDERAL CO, gm/mi	A (1)	5.992×10^{-6}	1.857×10^{-5}	4.221×10^{-4}	1.643×10^{-3}	3.322×10^{-4}
	A (0)	.0295	-.0105	0.294	-4.255	125.6
	SEE	.297	.261	23.5	26.7	52.6
	R^2	.0079	.0460	.0043	.0299	.0011
	d.f.	384	235	384	235	387
	t	1.75	3.36	1.28	2.68	0.65
	Conf.	93	>99	80	>99	47
COLD 1972 FEDERAL NOx, gm/mi	A (1)	-4.345×10^{-5}	6.559×10^{-7}	-2.608×10^{-5}	-1.571×10^{-5}	-4.235×10^{-5}
	A (0)	-.0550	.0455	-0.266	-0.052	3.654
	SEE	.232	.537	.891	.766	1.66
	R^2	.0067	.0001	.0166	.0041	.0121
	d.f.	382	229	382	229	387
	t	1.63	0.06	2.54	0.97	2.13
	Conf.	90	<40	99	76	97

EMISSION CONTROLLED FLEET 2

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]	MEASURED [5]
COLD 1972 FEDERAL HC, gm/mi	A (1)	[illegible]	9.40×10^{-6}	-9.240×10^{-6}	3.784×10^{-5}	-2.791×10^{-5}
	A (0)	-.0714	-.0195	-.049	-.2254	6.561
	SEE	.273	.226	1.53	1.33	1.54
	R^2	.0015	.0337	.0007	.0127	.0036
	d.f.	313	244	313	244	395
	t	0.77	2.71	.52	1.77	1.19
	Conf.	60	>99	40	92	76
COLD 1972 FEDERAL CO, gm/mi	A (1)	[illegible]	1.184×10^{-5}	2.448×10^{-4}	5.255×10^{-4}	[illegible]
	A (0)	.0312	-.0215	.492	-2.573	85.55
	SEE	.354	226	22.6	15.03	34.0
	R^2	.0465	.0416	.0035	.0132	.0007
	d.f.	392	244	392	244	395
	t	4.37	3.35	1.17	1.30	0.52
	Conf.	>99	>99	75	92	40
COLD 1972 FEDERAL NOx, gm/mi	A (1)	-1.439×10^{-5}	-4.620×10^{-6}	-1.114×10^{-4}	-3.256×10^{-5}	-8.763×10^{-5}
	A (0)	-.0772	-.0477	-.561	-.2607	5.504
	SEE	.203	.179	1.49	.961	1.74
	R^2	.1313	.0024	.1456	.0214	.0724
	d.f.	383	233	383	233	387
	t	7.62	1.48	8.07	2.25	5.50
	Conf.	>99	85	>99	97	>99

NOX CONTROLLED FLEET 3

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]	MEASURED [5]
COLD 1972 FEDERAL HC, gm/mi	A (1)	9.614×10^{-6}	2.132×10^{-5}	2.990×10^{-5}	8.392×10^{-5}	2.146×10^{-5}
	A (0)	-.0022	-.0333	-.0771	-.1337	4.374
	SEE	.315	.227	1.11	1.054	1.34
	R^2	.0375	.1615	.0295	.1216	.0057
	d.f.	412	265	412	265	426
	t	4.00	7.13	3.53	6.04	1.56
	Conf.	>99	>99	>99	>99	87
COLD 1972 FEDERAL CO, gm/mi	A (1)	1.339×10^{-5}	1.540×10^{-5}	4.065×10^{-4}	6.101×10^{-4}	3.788×10^{-4}
	A (0)	.0177	-.0454	0.31	-2.741	[illegible]
	SEE	.344	.296	15.7	15.8	32.3
	R^2	.0600	.0558	.0276	.0314	.0053
	d.f.	407	265	407	265	425
	t	5.09	3.95	3.39	2.92	1.57
	Conf.	>99	>99	>99	>99	37
COLD 1972 FEDERAL NOx, gm/mi	A (1)	-1.030×10^{-5}	-2.651×10^{-6}	-6.689×10^{-5}	-1.823×10^{-5}	-3.740×10^{-5}
	A (0)	-.0366	-.0056	-0.241	-.0597	4.921
	SEE	.171	.169	.993	.685	1.39
	R^2	.1325	.0053	.1592	.0152	.0330
	d.f.	410	260	410	260	424
	t	7.90	1.18	8.80	2.90	3.80
	Conf.	>99	79	>99	96	>99

1) Change from test 1B expressed as fraction of test 1B value
2) Change from test 2 expressed as fraction of test 2 value
3) Change from test 1B
4) Change from test 2
5) As Measured

Table 2.58

LINEAR REGRESSION OF FEDERAL SHORT EMISSIONS WITH MILEAGE

PRE-EMISSION CONTROLLED FLEET 1

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]
[illegible] HC, gm/mi	A (1)	9.485×10^{-6}	2.274×10^{-5}	3.306×10^{-5}	1.564×10^{-4}
	A (0)	0.0226	-0.0082	0.0349	-.1068
	SEE	0.296	0.232	1.92	1.59
	R^2	0.0198	0.0839	.0054	.0836
	d.f.	384	235	380	225
	t	2.78	4.63	1.43	4.51
	Conf.	>99	>99	83	>99
[illegible] CO, gm/mi	A (1)	1.090×10^{-5}	2.664×10^{-5}	4.415×10^{-4}	9.978×10^{-4}
	A (0)	0.08741	-0.0030	3.069	-.1546
	SEE	0.401	0.254	19.2	15.2
	R^2	0.0143	0.0951	.0076	.0367
	d.f.	384	235	374	226
	t	2.36	4.96	1.92	2.92
	Conf.	>99	>99	95	>99
[illegible] NO_x, gm/mi	A (1)	1.546×10^{-6}	1.188×10^{-5}	2.223×10^{-6}	1.819×10^{-5}
	A (0)	-0.0626	0.0014	-.1759	.0123
	SEE	0.237	0.261	.651	.575
	R^2	0.0008	0.0197	.0002	.0105
	d.f.	380	229	370	217
	t	0.55	2.14	0.27	1.51
	Conf.	43	96	<40	84

EMISSION CONTROLLED FLEET 2

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]
HC	A (1)	$8.328 \times 10^{-?}$ [illegible]	[illegible]	[illegible] $\times 10^{-5}$	7.087×10^{-5}
	A (0)	0.0012	-0.0198	[illegible]	-.0963
	SEE	0.275	[illegible]	[illegible]	.650
	R^2	0.0266	0.1660	.0114	.1580
	d.f.	399	246	[illegible]	244
	t	3.28	[illegible]	2.12	6.79
	Conf.	>99	[illegible]	[illegible]	>99
CO	A (1)	5.675×10^{-5}	$1.908 \times 10^{-?}$	6.966×10^{-4}	1.204×10^{-3}
	A (0)	0.0044	[illegible]	.3325	.5428
	SEE	0.535	0.561	17.2	13.1
	R^2	0.1236	0.04	.0466	.0764
	d.f.	399	246	393	242
	t	7.44	3.22	4.37	4.46
	Conf.	>99	>99	>99	>99
NO_x	A (1)	-7.632×10^{-6}	[illegible] $\times 10^{-4}$	-4.208×10^{-5}	1.288×10^{-7}
	A (0)	-0.0528	0.012	-.2764	-.1579
	SEE	0.255	0.227	1.06	.870
	R^2	[illegible]	0.0039	.0505	.0000
	d.f.	384	235	377	235
	t	3.22	0.96	4.76	0
	Conf.	>99	78	>99	0

NO_x CONTROLLED FLEET 3

		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]
HC	A (1)	[illegible] $\times 10^{-5}$	3.073×10^{-5}	3.147×10^{-5}	7.072×10^{-5}
	A (0)	-0.0070	-0.0282	-.0636	-.0664
	SEE	[illegible]	[illegible]	.668	.524
	R^2	0.1081	0.1868	.0856	.2841
	d.f.	410	259	407	256
	t	9.04	10.18	[illegible]	10.06
	Conf.	>99	>99	>99	>99
CO	A (1)	[illegible] $\times 10^{-5}$	[illegible] $\times 10^{-5}$	4.507×10^{-4}	7.879×10^{-4}
	A (0)	0.0144	[illegible]	-.5693	-1.111
	SEE	0.662	0.810	11.9	11.4
	R^2	[illegible]	0.0960	.0578	.0945
	d.f.	405	259	[illegible]	258
	t	4.85	5.23	4.97	5.18
	Conf.	>99	>99	>99	>99
NO_x	A (1)	-5.652×10^{-6}	5.608×10^{-6}	-5.119×10^{-5}	5.130×10^{-6}
	A (0)	-0.0098	[illegible]	-.1134	-.0005
	SEE	[illegible]	[illegible]	.297	.676
	R^2	0.0251	[illegible]	.0511	.0013
	d.f.	404	[illegible]	404	249
	t	3.22	1.74	4.66	0.57
	Conf.	>99	92	>99	40

1. Change from test 1B, expressed as fraction of test 1B value
2. Change from test 2, expressed as fraction of test 2 value
3. Change from test 1B
4. Change from test 2

Table 2.59

LINEAR REGRESSION OF 49/45 MPH CRUISE EMISSIONS WITH MILEAGE

		PRE-EMISSION CONTROLLED FLEET 1					
		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]		
49/45 MPH CRUISE HC, ppm	A (1)	-2.503×10^{-4}	1.753×10^{-5}	-1.295×10^{-3}	2.306×10^{-3}		
	A (0)	0.0048	0.0074	-3.972	.6938		
	SEE	0.251	0.274	47.8	31.6		
	R^2	0.0020	0.0375	.0139	.0457		
	d.f.	389	235	379	227		
	t	0.88	3.02	2.31	3.29		
	Conf.	62	>99	98	>99		
49/45 MPH CRUISE CO, %	A (1)	-8.169×10^{-6}	2.652×10^{-5}	2.820×10^{-5}	4.062×10^{-5}		
	A (0)	0.0149	-0.0326	-.0357	-.0623		
	SEE	0.374	0.271	.720	.650		
	R^2	0.0097	0.0836	.0294	.0357		
	d.f.	389	235	374	229		
	t	1.95	4.62	3.36	2.90		
	Conf.	95	>99	>99	>99		
49/45 MPH CRUISE NO_x, ppm	A (1)	2.060×10^{-5}	-6.638×10^{-6}	2.685×10^{-2}	-2.493×10^{-2}		
	A (0)	0.0210	0.1804	62.23	41.2		
	SEE	1.46	1.69	416	422		
	R^2	0.0041	0.0002	.0763	.0321		
	d.f.	386	226	374	221		
	t	1.26	0.21	5.55	2.69		
	Conf.	79	<40	>99	>99		

		EMISSION CONTROLLED FLEET 2					
		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]		
49/45 MPH CRUISE HC, ppm	A (1)	-6.064×10^{-6}	8.790×10^{-6}	-1.210×10^{-5}	1.032×10^{-3}		
	A (0)	-0.0273	-0.0005	-5.252	-2.452		
	SEE	0.201	0.239	34.7	30.2		
	R^2	0.0269	0.0208	0.0350	.0180		
	d.f.	392	244	390	244		
	t	3.29	2.27	3.76	2.11		
	Conf.	>99	98	>99	96		
49/45 MPH CRUISE CO, %	A (1)	1.696×10^{-5}	1.860×10^{-5}	5.769×10^{-6}	1.210×10^{-5}		
	A (0)	-0.0133	0.0176	-.0502	-.0167		
	SEE	0.464	0.351	.480	.297		
	R^2	0.0381	0.0423	.0042	.0256		
	d.f.	395	245	383	241		
	t	3.95	3.28	1.27	2.51		
	Conf.	>99	>99	80	99		
49/45 MPH CRUISE NO_x, ppm	A (1)	3.052×10^{-4}	3.125×10^{-5}	-1.198×10^{-2}	2.877×10^{-2}		
	A (0)	1.5788	0.2688	84.98	-9.265		
	SEE	3.94	3.92	599	520		
	R^2	0.0018	0.0009	0.0119	.0419		
	d.f.	396	234	369	234		
	t	0.82	0.46	2.10	3.19		
	Conf.	61	40	96	>99		

		NOX CONTROLLED FLEET 3					
		$\Delta 1B/1B$ [1]	$\Delta 2/2$ [2]	$\Delta 1B$ [3]	$\Delta 2$ [4]		
49/45 MPH CRUISE HC, ppm	A (1)	6.551×10^{-6}	2.916×10^{-6}	4.681×10^{-4}	-4.302×10^{-4}		
	A (0)	0.0406	0.0280	-3.26	1.905		
	SEE	0.751	0.317	38.0	34.5		
	R^2	0.0032	0.0018	.0063	.0034		
	d.f.	422	264	408	263		
	t	1.16	0.69	1.61	0.94		
	Conf.	75	53	89	64		
49/45 MPH CRUISE CO, %	A (1)	9.456×10^{-6}	1.458×10^{-5}	-6.270×10^{-7}	6.193×10^{-6}		
	A (0)	0.0265	0.0033	-.0464	-.0206		
	SEE	0.993	0.439	.301	.261		
	R^2	0.0038	0.0235	.0002	.0122		
	d.f.	423	265	408	263		
	t	1.27	2.52	0.28	1.80		
	Conf.	79	99	<40	93		
49/45 MPH CRUISE NO_x, ppm	A (1)	3.706×10^{-6}	-6.631×10^{-6}	8.168×10^{-3}	-1.572×10^{-2}		
	A (0)	0.0505	0.0025	77.72	-29.65		
	SEE	0.242	0.172	496	427		
	R^2	0.0100	0.0317	.0107	.0264		
	d.f.	415	257	401	256		
	t	2.04	2.89	2.08	2.63		
	Conf.	96	>99	96	99		

1. Change from test 1B, expressed as fraction of test 1B value
2. Change from test 2, expressed as fraction of test 2 value
3. Change from test 1B
4. Change from test 2

Table 2.60

LINEAR REGRESSION OF IDLE KEY MODE EMISSIONS WITH MILEAGE

PRE-EMISSION CONTROLLED FLEET 1

Mode	Statistic	$\Delta IE/IE$ [1]	$\Delta Z/Z$ [2]	ΔIE [3]	ΔZ [4]
Idle Mode [illegible]	A (1)	1.149×[illegible]	[illegible]	[illegible]21×10^{-4}	8.271×10^{-3}
	A (0)	[illegible]	0.0011	-7.307	-28.74
	SEE	.532	0.292	251	281
	R^2	[illegible]	[illegible]	.0001	.0092
	d.f.	384	233	376	232
	t	1.15	2.58	0.17	1.47
	Conf.	94	99	<40	85
Idle Mode [illegible]	A (1)	1.156×10^{-5}	1.445×10^{-5}	2.44×10^{-5}	3.649×10^{-5}
	A (0)	0.1693	0.1544	.273	-.0253
	SEE	1.30	0.816	2.19	[illegible]
	R^2	0.0062	0.0161	.0024	.0038
	d.f.	389	235	355	233
	t	1.56	2.00	[illegible]	0.94
	Conf.	88	96	<4[illegible]	64
Idle Mode [illegible]	A (1)	1.[illegible]×10^{-5}	2.637×10^{-5}	7.715×10^{-4}	3.887×10^{-4}
	A (0)	0.0386	0.0262	1.260	-3.380
	SEE	2.11	0.754	47.1	37.9
	R^2	0.0184	0.0144	.0053	.0010
	d.f.	375	214	362	209
	t	2.65	1.76	1.39	0.46
	Conf.	>99	94	83	<40

EMISSION CONTROLLED FLEET 2

Mode	Statistic	$\Delta IE/IE$ [1]	$\Delta Z/Z$ [2]	ΔIE [3]	ΔZ [4]
Idle Mode [illegible]	A (1)	1.019×10^{-5}	2.954×10^{-5}	2.267×10^{-4}	5.252×10^{-3}
	A (0)	-0.0080	0.0124	-2.915	-2.50
	SEE	0.534	0.552	132	67.8
	R^2	0.0114	0.0[illegible]	.0001	.0540
	d.f.	395	245	388	241
	t	2.13	4.44	0.20	3.70
	Conf.	97	>99	<40	>99
Idle Mode [illegible]	A (1)	1.879×10^{-5}	5.904×10^{-5}	1.35[illegible]×10^{-5}	4.161×10^{-5}
	A (0)	0.0821	0.1816	-0.0240	.0138
	SEE	1.62	2.55	1.90	1.16
	R^2	0.0519	0.0084	0.0231	.0199
	d.f.	395	245	390	242
	t	4.64	1.44	3.03	2.21
	Conf.	>99	8[illegible]	>99	97
Idle Mode [illegible]	A (1)	1.786×10^{-5}	7.928×10^{-6}	-5.845×10^{-4}	-2.277×10^{-3}
	A (0)	-0.0133	0.0117	7.507	-1.354
	SEE	4.36	0.396	42.0	43.6
	R^2	0.0005	0.00[illegible]7	.0057	.0379
	d.f.	374	231	357	227
	t	0.43	1.19	1.46	2.96
	Conf.	<40	80	85	>99

NOX CONTROLLED FLEET 3

Mode	Statistic	$\Delta IE/IE$ [1]	$\Delta Z/Z$ [2]	ΔIE [3]	ΔZ [4]
Idle Mode [illegible]	A (1)	1.581×10^{-5}	3.177×10^{-5}	2.413×10^{-3}	3.303×10^{-3}
	A (0)	-0.0277	-0.0082	-11.12	-3.951
	SEE	0.370	0.304	74.3	54.5
	R^2	0.0803	0.1004	.0425	.0747
	d.f.	423	265	411	262
	t	6.07	5.43	4.26	4.59
	Conf.	>99	>99	>99	>99
Idle Mode [illegible]	A (1)	1.462×10^{-5}	1.400×10^{-4}	3.437×10^{-5}	2.870×10^{-5}
	A (0)	0.0701	-0.0664	-.0692	-.0532
	SEE	1.99	2.69	1.34	.892
	R^2	0.0413	0.0558	.0269	.0219
	d.f.	422	264	407	260
	t	4.26	3.94	3.35	2.41
	Conf.	>99	>99	>99	98
Idle Mode [illegible]	A (1)	1.141×10^{-5}	-3.502×10^{-6}	-2.529×10^{-4}	-1.888×10^{-3}
	A (0)	0.2392	0.1588	5.588	-1.720
	SEE	2.18	2.00	53.4	56.8
	R^2	0.0012	0.0001	.0010	.0238
	d.f.	415	257	402	255
	t	0.70	0.16	0.63	2.49
	Conf.	56	<40	46	99

1. Change from test 1B, expressed as fraction of test 1B value
2. Change from test 2, expressed as fraction of test 2 value
3. Change from test 1B
4. Change from test 2

Table 2.61

LINEAR REGRESSION OF TUNE PARAMETERS WITH MILEAGE

Linear Regression of Tune Parameters with Mileage

		PRE-EMISSION CONTROLLED FLEET 1		EMISSION CONTROLLED FLEET 2		NOX CONTROLLED FLEET 3	
		Δ/B[1]	ΔZ[2]	Δ/B[1]	ΔZ[2]	Δ/B[1]	ΔZ[2]
Timing, degrees	A (1)	3.107x10^{-5}	-6.606x10^{-5}	-4.119x10^{-5}	-1.214x10^{-5}	-3.189x10^{-5}	-7.051x10^{-5}
	A (0)	-0.1410	0.0712	-0.0186	-0.0915	0.1883	0.4074
	SEE	3.26	2.62	2.34	2.00	2.61	1.57
	R^2	0.0018	0.0062	0.0086	0.0005	0.0063	0.0427
	d.f.	375	229	362	231	400	257
	t	0.82	1.20	1.77	0.39	1.59	3.38
	Conf.	59	78	93	<40	89	>99
IRPM, rpm							
	A (1)	4.540x10^{-3}	1.838x10^{-3}	-2.207x10^{-4}	1.689x10^{-3}	-4.645x10^{-4}	2.345x10^{-4}
	A (0)	2.9064	3.5404	-0.6189	0.0942	1.2381	-5.1170
	SEE	76.2	67.6	75.4	62.1	53.8	48.3
	R^2	0.0664	0.0071	0.0002	0.0107	0.0031	0.0005
	d.f.	367	231	371	230	410	258
	t	5.11	1.28	0.27	1.58	1.13	0.36
	Conf.	>99	81	<40	89	76	<40
Air Cleaner, degrees							
	A (1)	1.064x10^{-3}	9.509x10^{-4}	1.820x10^{-3}	2.016x10^{-3}	1.895x10^{-3}	2.205x10^{-3}
	A (0)	7.9393	0.7463	2.0360	-1.1768	-0.5539	-1.2098
	SEE	26.2	14.0	23.0	14.5	19.6	18.1
	R^2	0.0344	0.0415	0.1595	0.2230	0.2951	0.2550
	d.f.	273	196	332	217	356	238
	t	3.12	2.91	7.79	7.89	12.21	9.02
	Conf.	>99	>99	>99	>99	>99	>99
PCV Flow (32/3.. mph), cfm							
	A (1)	-1.619x10^{-5}	-3.241x10^{-5}	5.746x10^{-7}	-1.342x10^{-5}	8.467x10^{-6}	-6.650x10^{-6}
	A (0)	-0.0078	-0.0187	0.0252	-0.0293	0.0332	0.0497
	SEE	0.551	0.433	0.344	0.271	0.312	0.304
	R^2	0.0170	0.0523	0.0001	0.0353	0.0314	0.0101
	d.f.	315	196	354	218	368	239
	t	2.33	3.29	0.19	2.82	3.45	1.56
	Conf.	98	>99	<40	>99	>99	88
Choke Kick, inches							
	A (1)	-4.828x10^{-7}	-2.303x10^{-7}	-4.929x10^{-6}	-1.198x10^{-6}	-4.959x10^{-8}	-5.283x10^{-8}
	A (0)	0.0007	-0.0018	0.0005	-0.0013	-0.0021	0.0006
	SEE	0.014	0.018	0.025	0.090	0.019	0.018
	R^2	0.0266	0.0019	0.0111	0.0106	0.0003	0.0002
	d.f.	223	140	310	182	326	210
	t	2.47	0.52	1.86	1.40	0.31	0.20
	Conf.	99	<40	94	85	<40	<40

1. Change from test 1B
2. Change from test 2

3.0 EXPERIMENT TO DETERMINE THE EFFECT OF REPEATED TESTING

3.1 INTRODUCTION

The variation of HC and CO emissions as periodically measured in the Emission Test Program using the 1972 Federal Procedure following operation in the field did not follow a smooth predictable function. The data clearly indicated variabilities that were both random within each test period and systematic over certain periods within the test program. Increases in emissions after the first four month operating interval resulted in average emission increases that were approximately as large as the decrease in emissions that were measured when the vehicles were tested after initialization to manufacturers' specifications. The subsequent deterioration periods over the remaining eight months of the year resulted in deteriorations that were on the average negative during the second period and positive during the third period. Although the general deterioration rate over the year of operation appeared reasonable, the individual results over each operational period appeared anomalous. The variabilities of measured emissions precluded precise interpretations of experimental results. An experimental investigation was therefore performed to determine the test-to-test variability of emission measurements.

Certainly, the variabilities were caused by a variety of influences. The influences that are hypothesized to influence emissions are the following:

- length of cold soak
- temperature at which the cold soak is made
- test sequence (effect of repeated testing)
- preconditioning prior to cold soak
- previous driving history
- fuel type
- climate during previous driving
- post tune-up conditioning

The study of influences was not within the scope of this investigation. A cursory study was made however to determine the effects of test sequence on emissions. Repeat emission tests were made using 1971 vehicles used in the NO_x Controlled Vehicle Fleet.

3.2 OBJECTIVE

The objective of the experiment was to characterize the test-to-test variability of emission measurements using the 1972 Federal Procedure.

3.3 TEST PROCEDURE

3.3.1 Test Vehicle and Preparation

Nine vehicles were selected for the repeatability experiments. All of the vehicles were the Scott leased loan cars which were supplied to the owners of the vehicles used on the Deterioration Experiment. Six of the vehicles were 1971 Ford Torinos equipped with 302 cubic inch engines with two barrel carburetors and automatic transmissions. The other three vehicles were 1971 Chevrolet Malibus equipped with 307 cubic inch engines with two barrel carburetors and automatic transmissions. The vehicles had been driven by many individuals and therefore represented usage under all types of driving conditions.

The vehicles were not given any special maintenance or preconditioning treatment prior to these tests. However, all of the vehicles had received manufacturer's recommended, periodic maintenance and a complete tune-up about four months previously. They were processed directly from normal service to the test series. This procedure was equivalent to that used during the Deterioration Experiment for the recall tests.

3.3.2 Test Sequence and Measurements

The vehicles were brought off normal service and initially stored in the soak area for a minimum of twelve hours. The next day they were installed on the chassis dynamometer, and Indolene fuel was connected for a cold start emission test. The emission test sequence was similar to that used for the Deterioration Experiments. A 1975 Federal Test Procedure exhaust emission test was conducted followed by the performance of the Clayton Keymode Cycle emission tests. The vehicle was then returned to the soak area and shut down. The vehicle would then be emission tested on the following day, approximately twenty-two hours later, except over weekends.

The above sequence of daily testing was repeated until a total of five to six tests had been made on each vehicle. The majority of the vehicles were started on this test sequence so that the first weekend-long soak occurred after the first three to five tests had been conducted using the one day soak period.

3.4 ANALYSIS OF TEST DATA

3.4.1 Summary of Results

The analysis of the data indicated a systematic bias in the cold or hot HC emission levels measured between the first and second test when the 1972 Federal Procedure was used to measure emissions. Statistically significant differences of 0.68 gm/mi and 0.26 gm/mi, respectively, for the cold and hot HC emissions at the 95 percent confidence level resulted. Comparable results were not obtained with CO or NO_x emissions.

The test-to-test repeatability of emission measurement made using the 1972 Federal Procedures and representative of data taken in the Parameter Deterioration Experiment are as follows:

	COLD 1972 PROCEDURE				HOT 1972 PROCEDURE			
Emission Specie	$\overline{X}$ gm/mi	Estimate of Standard Deviation gm/mi	%	d.f.	X gm/mi	Estimate of Standard Deviation gm/mi	%	d.f.
HC	4.202	0.362	8.6	14	3.423	0.217	6.3	14
CO	31.27	3.79	12.1	23	18.65	1.49	8.0	23
NO_x	4.349	0.174	4.0	23	4.443	0.150	3.4	23

3.4.2 Discussion of Analysis

The set of data analyzed consisted of from five to seven 1972 Federal Hot and Cold Cycle emission response tests conducted on a fleet of nine vehicles. The vehicles were selected to represent a homogeneous fleet (i.e., same engine and drive train configuration for each vehicle). Each emission test was conducted after a cold soak period of sufficient length such that the vehicle was at or near 70°F. The data set, then, was assumed to be representative of a single vehicle undergoing repeated tests at the same starting conditions with all other factors (e.g., variations between test cells and test crews) removed which could contribute to variations in emissions. A summary of all the test data is presented in Table 3.1.

In order to verify this assumption, the mean and standard deviation statistics for each vehicle and for each emission specie, i.e., hydrocarbon, carbon monoxide, and mixed oxides of nitrogen, were developed for both the Cold and Hot Cycle 1972 Federal Emission measurements. Review of statistics presented in Table 3.1 indicated that for Vehicle 302, both the mean level of hydrocarbon emissions and the scatter of emissions were grossly larger in comparison to the rest of the fleet. On the basis of a Cochran's test for homogeniety of variances, the precision of the hydrocarbon measurements for hydrocarbon emissions were determined to be significantly different (95 percent confidence level) and therefore the data from these tests were removed from the overall data set and not used during any of the subsequent analyses.

In order to verify that the remaining data set was homogeneous (i.e., no significant differences between vehicles), an analysis of variance was conducted for each emission specie on the data acquired with the Cold 1972 Federal Procedure. The results indicated that there were significant differences (i.e., at the 95 percent confidence level) between vehicles for all emission species. Since the scatter of the emission data from the tests conducted on the eight remaining vehicles was approximately the same, the between vehicle effect was removed by subtracting the mean value of each test series from the raw values for that series. Further, it was observed by plotting the emission data (mean values subtracted out) versus test

Table 3.1

SUMMARY OF REPEATABILITY EXPERIMENT EMISSION RESPONSE

Vehicle No.	Test Number	1972 Cold Cycle HC gm/mile	1972 Cold Cycle CO gm/mile	1972 Cold Cycle NOx gm/mile	1972 Hot Cycle HC gm/mile	1972 Hot Cycle CO gm/mile	1972 Hot Cycle NOx gm/mile
302	1	9.07	47.50	4.83	8.01	15.17	5.02
	2	4.86	36.13	4.96	6.19	14.20	5.02
	3	10.73	29.22	4.69	11.63	10.47	5.10
	4	9.75	35.23	5.26	11.16	14.63	5.13
	5	5.16	36.96	4.91	5.39	16.52	5.16
	Mean	7.91	37.01	4.93	8.59	14.20	5.09
	Std Dev	2.7	6.6	0.21	3.3	2.3	.06
	d.f.	4	4	4	4	4	4
305	1	4.66	34.10	4.84	4.31	25.07	4.79
	2	5.26	49.79	5.01	4.19	28.13	4.96
	3	4.95	43.75	4.90	4.34	31.20	4.91
	4	4.55	40.31	4.71	4.02	27.96	4.80
	5	4.44	40.24	4.53	4.46	27.96	4.46
	6	4.39	39.07	4.81	4.09	31.08	4.86
	7	4.89	40.94	4.88	3.70	22.04	4.93
	Mean	4.73	41.17	4.81	4.16	27.89	4.82
	Std Dev	0.31	4.8	0.15	0.25	3.36	0.17
	d.f.	6	6	6	6	6	6
306	1	4.29	44.18	4.16	4.35	26.64	4.37
	2	4.56	45.15	4.57	4.35	29.80	4.58
	3	4.22	41.84	3.98	4.21	27.26	4.33
	4	4.26	40.62	4.28	3.88	26.10	4.43
	5	4.48	40.82	4.13	4.47	25.63	4.28
	6	5.11	50.05	4.28	4.01	29.28	4.37
	Mean	4.50	43.78	4.23	4.21	27.45	4.39
	Std Dev	0.32	3.6	0.20	0.23	1.71	0.10
	d.f.	5	5	5	5	5	5
307	1	5.30	32.53	3.96	3.69	18.01	4.18
	2	4.19	27.39	4.07	3.42	17.50	4.28
	3	3.90	22.61	4.14	3.15	14.58	4.13
	4	4.61	29.04	4.69	3.33	15.63	4.92
	5	4.10	24.22	4.14	3.38	14.50	4.21
	Mean	4.42	27.16	4.20	3.39	16.04	4.34
	Std Dev	0.56	3.9	0.20	0.20	1.6	0.33
	d.f.	4	4	4	4	4	4
309	1	4.49	28.30	4.22	3.69	19.32	4.09
	2	4.12	23.32	4.04	3.34	16.05	3.94
	3	3.82	23.31	4.09	3.35	17.71	4.00
	4	3.64	23.47	3.72	3.27	17.84	3.73
	5	4.20	27.90	4.14	4.54	20.90	4.01
	6	4.11	30.42	4.37	3.21	19.99	4.16
	Mean	4.06	26.12	4.10	3.57	18.64	3.99
	Std Dev	0.30	3.1	0.22	0.50	1.8	0.15
	d.f.	5	5	5	5	5	5

Table 3.1 (Continued)

SUMMARY OF REPEATABILITY EXPERIMENT EMISSION RESPONSE

Vehicle No.	Test Number	1972 Cold Cycle HC gm/mile	1972 Cold Cycle CO gm/mile	1972 Cold Cycle NOx gm/mile	1972 Hot Cycle HC gm/mile	1972 Hot Cycle CO gm/mile	1972 Hot Cycle NOx gm/mile
310	1	3.47	27.09	4.14	3.21	14.94	4.11
	2	3.13	24.57	3.93	2.92	12.94	4.00
	3	3.33	27.19	4.21	3.61	14.86	4.30
	4	3.27	25.42	3.69	3.21	14.97	3.57
	5	3.40	28.42	4.55	3.74	19.54	4.27
	6	3.51	31.99	4.40	3.75	16.97	4.38
	Mean	3.35	27.45	4.15	3.41	15.70	4.10
	Std Dev	0.14	2.6	0.31	0.34	2.3	0.30
	d.f.	5	5	5	5	5	5
313	1	4.26	22.51	4.62	3.80	14.03	4.59
	2	3.44	21.75	4.40	2.94	14.38	4.44
	3	3.46	19.79	4.42	3.10	12.95	4.55
	4	3.40	23.51	4.39	3.04	14.53	4.43
	5	3.23	20.81	4.39	3.97	15.01	4.25
	6	3.60	23.34	4.85	3.26	16.42	4.72
	Mean	3.56	21.95	4.51	3.35	14.55	4.50
	Std Dev	0.36	1.5	0.19	0.43	1.2	0.16
	d.f.	5	5	5	5	5	5
317	1	5.54	35.22	4.98	3.61	15.81	5.18
	2	4.08	27.09	4.75	3.33	12.74	4.91
	3	4.13	33.42	4.24	3.31	12.66	4.40
	4	3.98	32.25	4.49	2.77	20.75	4.67
	5	4.09	28.86	4.57	3.31	15.02	4.69
	6	4.41	30.76	4.85	3.40	17.24	4.89
	Mean	4.37	31.27	4.65	3.29	15.70	4.79
	Std Dev	0.59	3.0	0.27	0.28	3.04	0.26
	d.f.	5	5	5	5	5	5
320	1	4.76	44.84	4.52	2.83	18.72	4.78
	2	3.70	33.34	4.08	2.71	16.34	4.39
	3	3.37	26.85	4.41	2.67	16.06	4.57
	4	4.27	30.58	4.76	3.40	17.19	4.96
	5	3.78	31.23	4.30	2.62	17.64	4.78
	6	3.62	27.24	4.75	2.62	18.81	4.82
	Mean	3.92	32.35	4.47	2.81	17.46	4.71
	Std Dev	0.51	6.6	0.26	0.30	1.16	0.20
	d.f.	5	5	5	5	5	5

number that an increase in the scatter of the data occurred after the third test. More importantly, however, abrupt shifts in emission levels for specific vehicles occurred following the third test in most of the cases. A typical example for this phenomena is shown in Figure 3.1 for HC emissions. Comparable figures presenting data typical of CO and NO_x emissions are presented, respectively, in Figures 3.2 and 3.3. In particular, the reader should note the change in emission level for Vehicles 307 and 320 between the third and fourth test. A review of the conduct of the experiment, i.e., date of test and crew used, did not reveal any reasonable systematic cause for either the increased scatter or the emission level shifts. Without attempting to further explore the reason for this observed characteristic, it was decided to remove the data after the third test from the data set and recalculate the differences from the average, based on the first three tests.

This final data set, including both cold and hot cycle data, was then subjected to an analysis of variance. The results of this analysis, shown in Table 3.4, indicated that for HC emissions a statistically significant difference between tests was present. Further comparisons by means of the Duncan Multiple Range test indicated that the first tests for both 1972 Federal Procedures (Cold and Hot) were significantly different (95 percent confidence level) from the second and third tests. The second and third tests, however, were not found to be significantly different. The net effects (differences between the first test and the average of the second and third test) are, respectively, 0.68 gm/mi and 0.26 gm/mi for the cold and hot cycles. The significance levels for between test effect of cold CO emissions was 75 percent and was less than 50 percent for hot emissions. The significance levels of repeat test effects of hot and cold NO_x emissions were approximately 50 percent.

The natural product of repeat emission testing was the development of run-to-run variability of vehicle emission measurements. The results summarized in Table 3.1 are representative of the random uncertainty of emission measurements caused by pure vehicle non-repeatability (excluding fuel, climate, preconditioning, etc.) and measurement system uncertainty.

Table 3.2

REPEATABILITY TEST ANALYSIS OF VARIANCE SUMMARY

TEST CYCLE	EMISSION SPECIE	SOURCE OF VARIATION	DEGREES OF FREEDOM	TEST STATISTIC*	SIGNIFICANCE LEVEL %
1972 COLD	HC	Between Vehicles	7	0	0
		Between Tests	2	9.70	99.5
	CO	Between Vehicles	7	0	0
		Between Tests	2	1.63	75+
	NO_X	Between Vehicles	7	0	0
		Between Tests	2	1.12	50+
1972 HOT	HC	Between Vehicles	7	0	0
		Between Tests	2	3.92	95
	CO	Between Vehicles	7	0	0
		Between Tests	2	0.78	<50
	NO_X	Between Vehicles	7	0	0
		Between Tests	2	1.01	50+

*Ratio of Source of Variation Mean Square to Residual Mean Square. Significance determined by comparison of Test Statistic to Standard "F" distribution value. Degrees of Freedom for Residual Mean Square is equal to 14 for all cases.

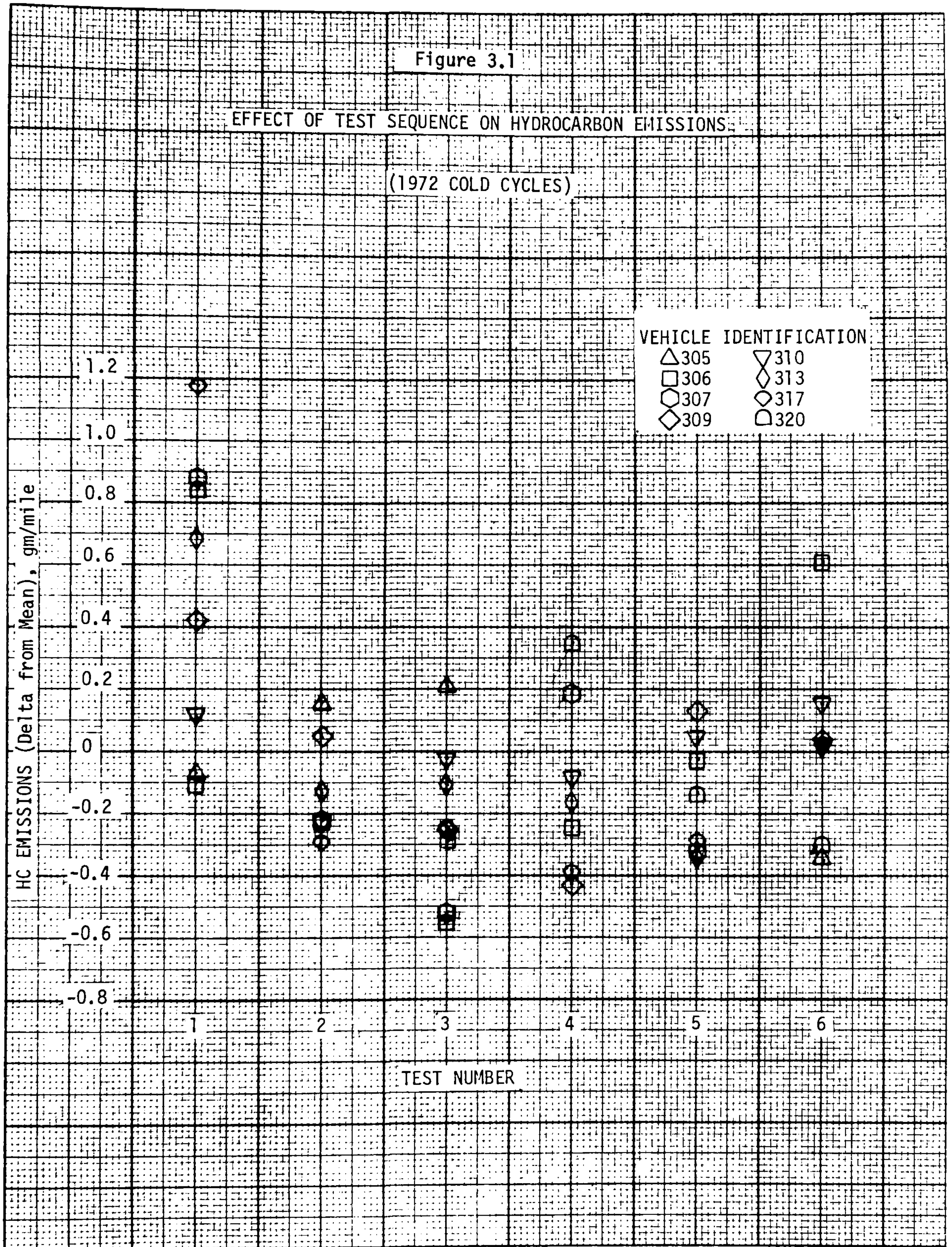


Figure 3.1
EFFECT OF TEST SEQUENCE ON HYDROCARBON EMISSIONS
(1972 COLD CYCLES)
VEHICLE IDENTIFICATION
305
306
307
309
310
313
317
320
HC EMISSIONS (Delta from Mean), gm/mile
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1
2
3
4
5
6
TEST NUMBER

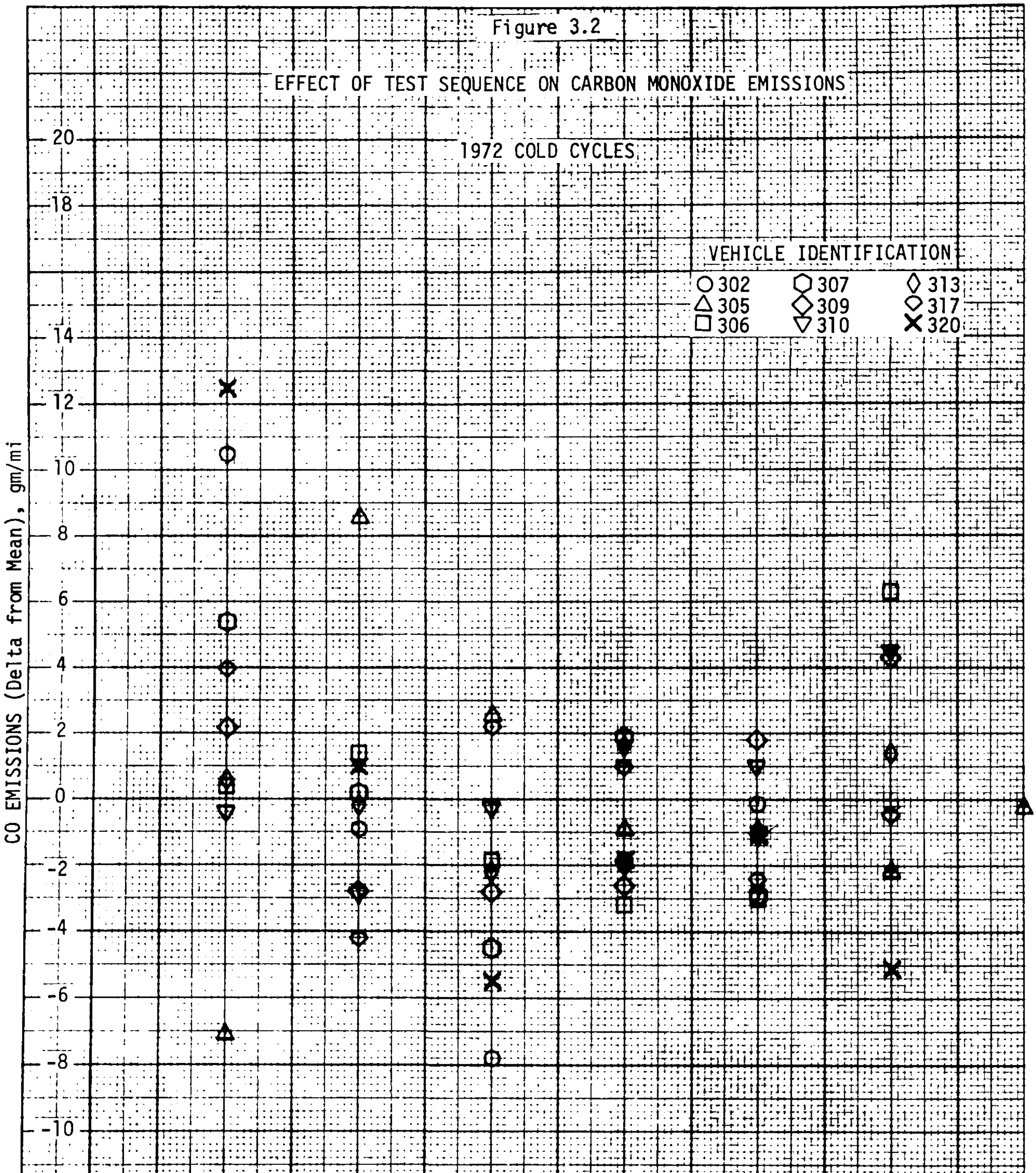


Figure 3.2
EFFECT OF TEST SEQUENCE ON CARBON MONOXIDE EMISSIONS
1972 COLD CYCLES
VEHICLE IDENTIFICATION
302
307
313
305
309
317
306
310
320
CO EMISSIONS (Delta from Mean), gm/mi
20
18
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
0
1
2
3
4
5
6
7
TEST NUMBER

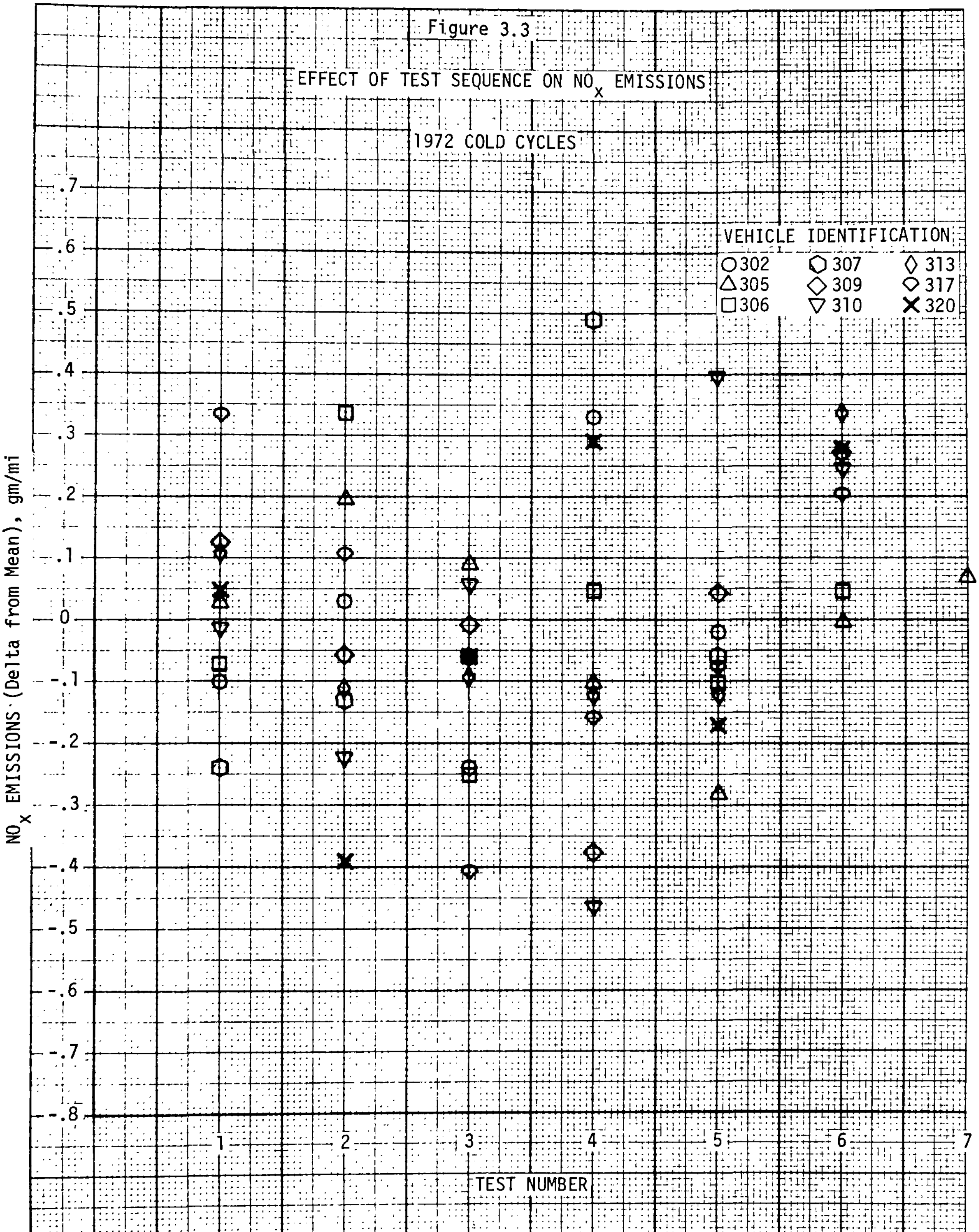


Figure 3.3
EFFECT OF TEST SEQUENCE ON NO_x EMISSIONS
1972 COLD CYCLES
VEHICLE IDENTIFICATION
302
307
313
305
309
317
306
310
320
NO_x EMISSIONS (Delta from Mean), gm/mi
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
1
2
3
4
5
6
7
TEST NUMBER

4.0 EFFECT OF COLD SOAK TEMPERATURE ON EXHAUST EMISSIONS

4.1 INTRODUCTION

A series of experimental tests was performed in which eight vehicles were emission tested after being soaked at different ambient temperatures. The soak temperature is the ambient temperature at which a motor vehicle is stored prior to conducting a Federal exhaust emission test on that vehicle. The soak temperature was varied over a range of 60°F. Other test variables were held as constant as possible. The 1972 and 1975 Federal Test Procedures were employed to determine the CVS mass emission response.

4.2 OBJECTIVE

The objective of these experiments was to develop the response of automobile exhaust emissions to variations in soak temperature. This characterization was made for three classes of vehicles; 1) vehicles with no exhaust emission controls, 2) vehicles with controls of HC and CO, and 3) 1971 California vehicles having controls of HC, CO, and NO_x. These three classes can be related directly to the three fleets that were tested in the Deterioration Experiment. The emission responses developed for this experiment could then be used to correct data from the Deterioration Experiment where soak temperatures were not controlled within specified limits.

4.3 TEST PROCEDURE

4.3.1 Test Vehicles

Eight vehicles were selected to approximately represent the three classes of emission controls. Two and three vehicles per class do not provide a firm base for representing populations. However, an understanding of the possible lack of correlation to a population could be assessed by observing the variabilities between vehicles in the same class. Only popular makes of vehicles with the most commonly employed driveline options were used. This selection provided for the best possible correlation to the populations being evaluated. Table 4.1 presents the description of the eight vehicles.

TABLE 4.1

TEST VEHICLE DESCRIPTION

Fleet Represented	Year	Make/Model	Engine/ Carburetor	Repairs
I	1964	Ford/Galaxie	289/2 bbl.	Installed correct model year carburetor
I	1964	Chevrolet/Impala	327/4 bbl.	Replaced flooding carburetor
I	1965	Dodge/Dart	273/2 bbl.	None
II	1967	Ford/Mustang	289/2 bbl.	None
II	1968	Pontiac/Tempest	350/2 bbl.	Replaced ignition wires and vacuum advance
II	1969	Chevrolet/Impala	427/4 bbl.	Connect and adjust choke linkage
III	1971	Ford/LTD	351/2 bbl.	None
III	1971	Chevrolet/Camaro	350/2 bbl.	Installed new distributor

4.3.2 Vehicle Preparation

Vehicle preparation was limited to making repairs on components that would effect the stability of emissions or grossly effect emission levels relative to their nominal level. No other tune-up repairs or settings were made as it was desired that these vehicles approximate the in-use condition of vehicles. Table 4.1 above describes those repairs that were made.

4.3.3 Vehicle Soak Temperature and Sequence

Soak temperature experiments on two vehicles were first completed covering a temperature range of 40 to 90°F in ten degree increments. Based on the data obtained from these two vehicles the soak temperatures were set at 50, 65, 85, and 100°F for the remaining six vehicles. Apparent outlying test results occasionally occurred at these temperatures. In these cases the tests were repeated. If no repeat tests were required an additional test was run at 75°F. The soak temperatures for each vehicle were randomized (not statistically) to preclude any bias due to prior soak temperature from affecting the data. The vehicle soak temperature was maintained by storing the test vehicle in Scott's All-Weather Room facility. Heating and air conditioning equipment and controls in this facility allowed for maintaining the desired soak temperature within ± 2° during the soak period.

In order to eliminate any influence due to the length of time of the soak period, the time of each test was regulated. After the first two vehicles mentioned above were tested, a twenty-four hour test cycle was instituted. The vehicle was brought out of soak between 9:00 and 10:00 p.m. to receive its emission test. The emission test took approximately one hour to perform and the vehicle was returned to the soak facility. The vehicle was allowed to stand overnight at nominal temperature as the air conditioning equipment could not be operated overnight. The temperature controls were set and the air conditioning equipment was turned on at 8:00 a.m. the next morning. By no later than 10:00 a.m. the desired temperature was reached. Thus, the vehicles were soaked for at least twenty-two hours, the last eleven being at the desired soak temperature. This precise routine was violated only on weekends when the vehicle was soaked for three days.

4.3.4 Exhaust Emission Test

After completing the soak described above, the vehicle was installed on a chassis dynamometer at a test station that was immediately adjacent to the All-Weather Room facility. A 1975 Federal Test Procedure exhaust emission test was then conducted from a cold engine start. As three sample bags are collected on this test, the equivalent 1972 Federal test results could be obtained from the first two sample bags. The 1972 test was of primary concern in this experiment. The emission tests were conducted within the nominal ambient temperatures of 68 - 86°F.

The vehicle tail pipe pressures, mixing chamber pressure, and CO analyzer were compliant with the 1972 Federal Test Procedure but were not up-to-date with respect to the 1975 Procedure. The instrumentation employed was also compliant with Federal test regulations. Both Chemiluminescence and NDIR/NDLN NO_x instrumentation was used to determine the NO_x emissions. The three bag data was converted to mass emission results using the 1975 procedure. A dilution factor is used for correcting the background level to obtain the net vehicle emissions.

4.4 ANALYSIS OF TEST DATA

4.4.1 Summary of Results

The analysis of data taken in the Cold Soak Temperature Experiment indicated significant dependency (greater than 99 percent) of CO emissions with soak temperature with vehicles representative of all three vehicle fleets tested in the Parameter Deterioration Experiment. A comparable highly significant dependency (98 percent) of HC emissions with Emission Controlled Vehicles (Fleet 2) and NO_x Controlled Vehicles (Fleet 3) was noted. Dependency of NO_x emissions was observed only with Emission Controlled Vehicles.

4.4.2 Discussion of Analyses

The set of data which was obtained from the Soak Temperature Experiments consisted of from five to seven emission tests using the Cold 1972 Federal Procedure with eight vehicles which had been cold soaked at temperatures ranging from 50 to 100°F. The overall fleet in this case was selected to be representative of the general population and was partitioned into three subsets (Pre-Emission Controlled, Emission Controlled, and NO_x Controlled Vehicles).

It was assumed for the purpose of analysis of these data that all testing associated variables which could affect the emission response other than pre-emission test soak temperature, were closely controlled and could be ignored. It was also assumed that the three subsets were significantly different and should be analyzed separately.

Based on the analysis of the data obtained from the Repeatability Experiment, two operations were performed on the Soak Temperature Experiment data set. The first was to remove from the data set the HC emissions from the first test conducted on each vehicle. This operation was conducted on the basis that the first test had been shown to be significantly different for HC emissions during the Repeatability Experiment. The second operation was to subtract the average emission response of the remaining tests for all emission species and within each vehicle test series from the raw test values. This was done to remove the between vehicle effect from each subset. The resulting delta emission values for each emission specie and for each subset of vehicles are shown in Figures 4.1 through 4.9.

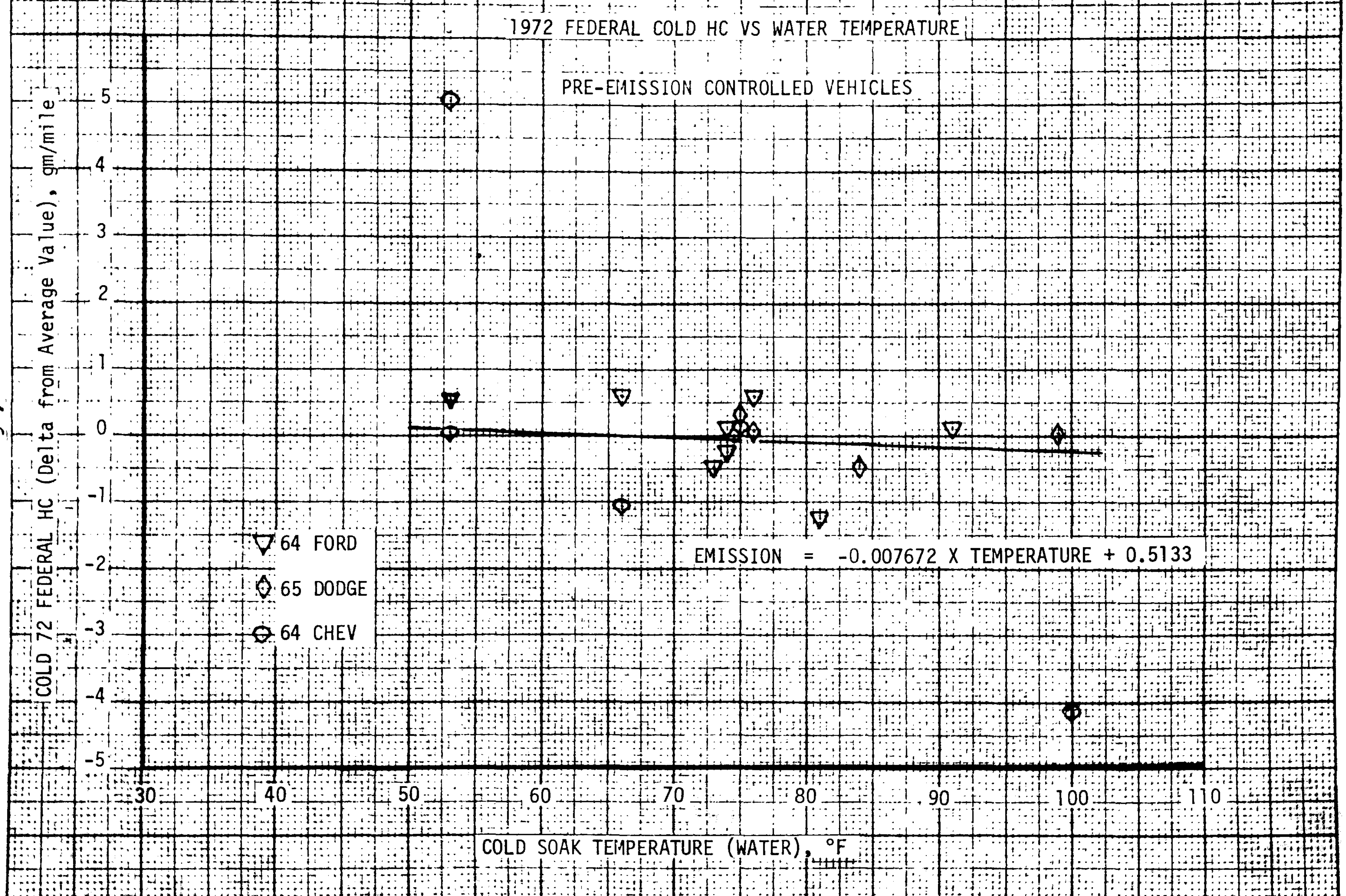
A set of regressions was then conducted on the adjusted data set to determine the effect of soak temperature on emission response. A cursory review of the delta emission levels following the regression analysis indicated that, for the pre-emission controlled set, the significance of the HC response was largely dependent upon two extreme values from one vehicle. This particular case was then re-analyzed without these two data points.

The final set of regression results, shown in Table 4.2, are summarized by the following.

1) A highly significant dependency (greater than 99 percent) of CO emission response with soak temperature across all three fleets.

2) A significant dependency (98 percent) of HC emission response with soak temperature for the emission controlled fleet and a highly significant dependency for the NO_x controlled fleet.

Figure 4.1

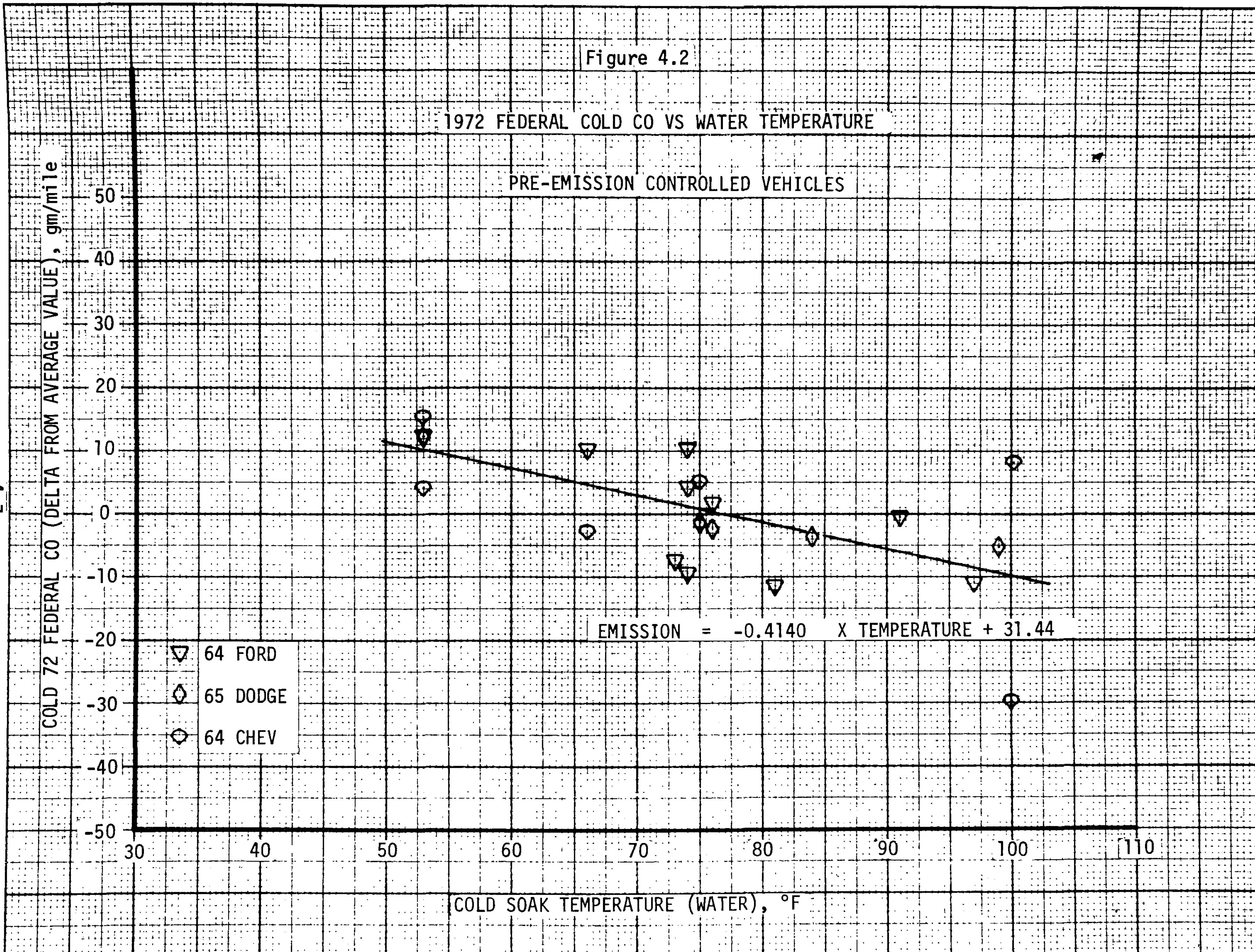


1972 FEDERAL COLD HC VS WATER TEMPERATURE
PRE-EMISSION CONTROLLED VEHICLES
COLD 72 FEDERAL HC (Delta from Average Value), gm/mile
5
4
3
2
1
0
-1
-2
-3
-4
-5
30
40
50
60
70
80
90
100
110
COLD SOAK TEMPERATURE (WATER), °F
64 FORD
65 DODGE
64 CHEV
EMISSION = -0.007672 X TEMPERATURE + 0.5133

Figure 4.2

1972 FEDERAL COLD CO VS WATER TEMPERATURE

PRE-EMISSION CONTROLLED VEHICLES



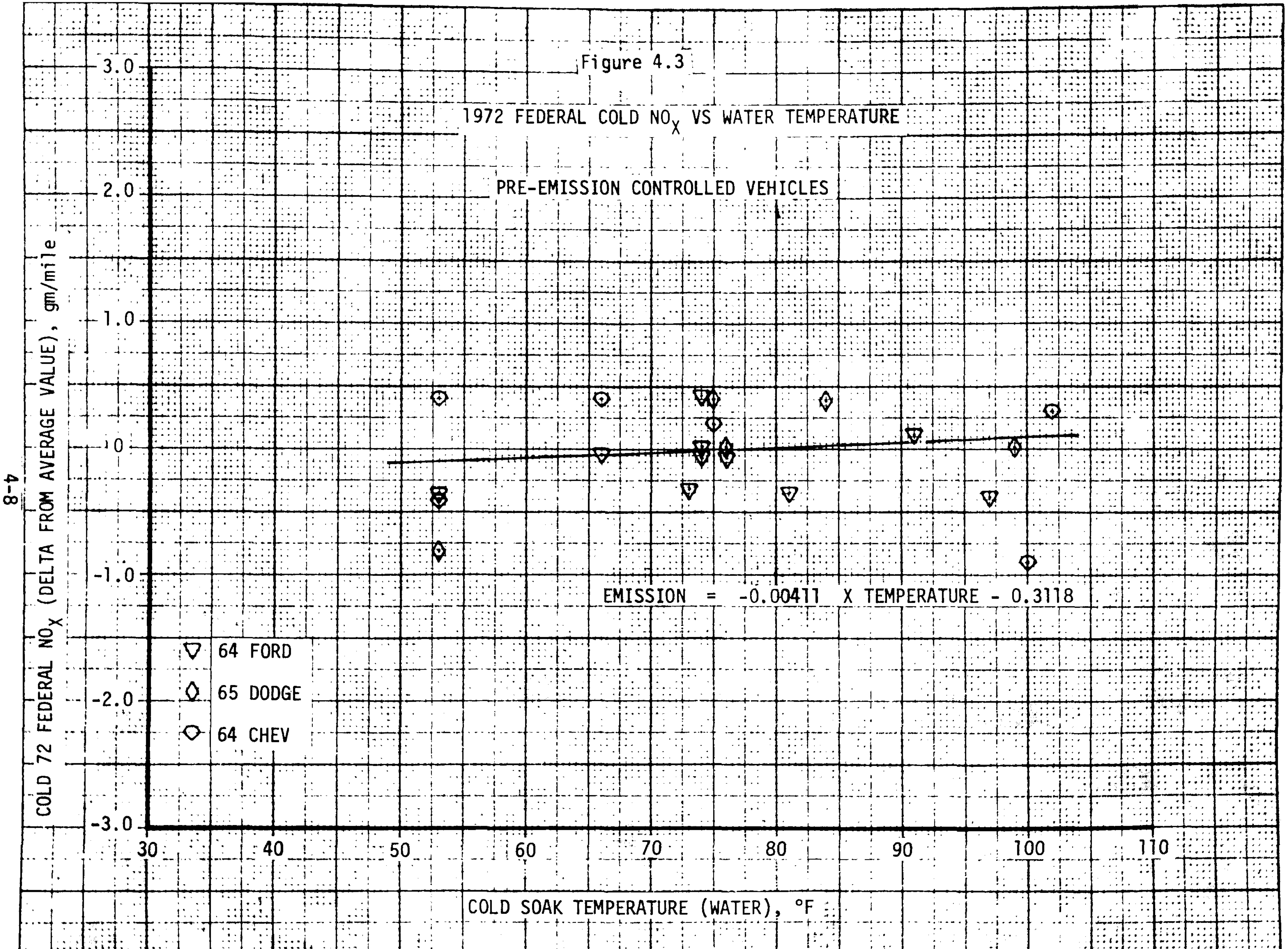


Figure 4.3
1972 FEDERAL COLD NO$_X$ VS WATER TEMPERATURE
PRE-EMISSION CONTROLLED VEHICLES
EMISSION = -0.00411 X TEMPERATURE - 0.3118
64 FORD
65 DODGE
64 CHEV
COLD 72 FEDERAL NO$_X$ (DELTA FROM AVERAGE VALUE), gm/mile
COLD SOAK TEMPERATURE (WATER), °F
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
30
40
50
60
70
80
90
100
110

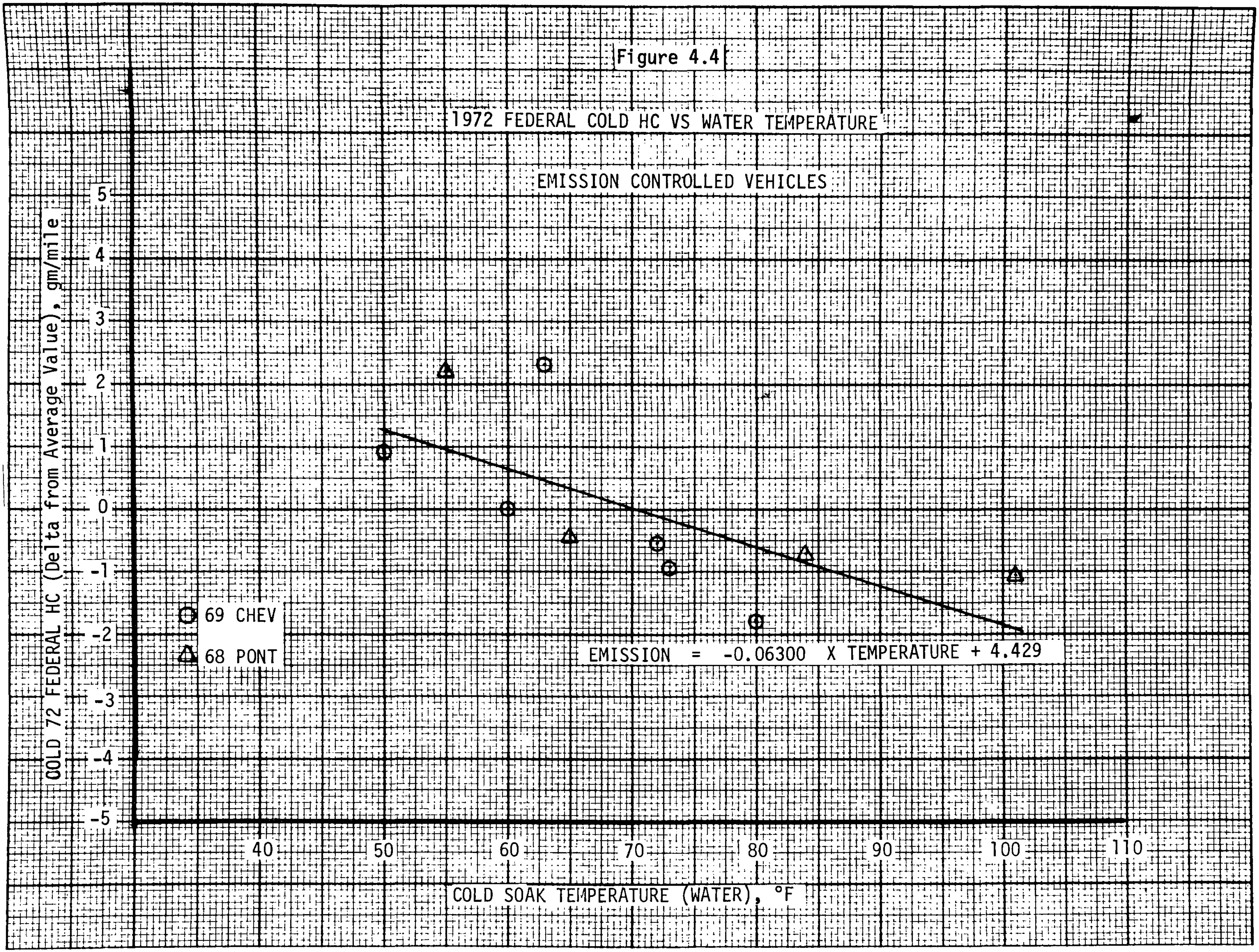


Figure 4.4
1972 FEDERAL COLD HC VS WATER TEMPERATURE
EMISSION CONTROLLED VEHICLES
COLD 72 FEDERAL HC (Delta from Average Value), gm/mile
5
4
3
2
1
0
-1
-2
-3
-4
-5
69 CHEV
68 PONT
EMISSION = -0.06300 X TEMPERATURE + 4.429
40
50
60
70
80
90
100
110
COLD SOAK TEMPERATURE (WATER), °F

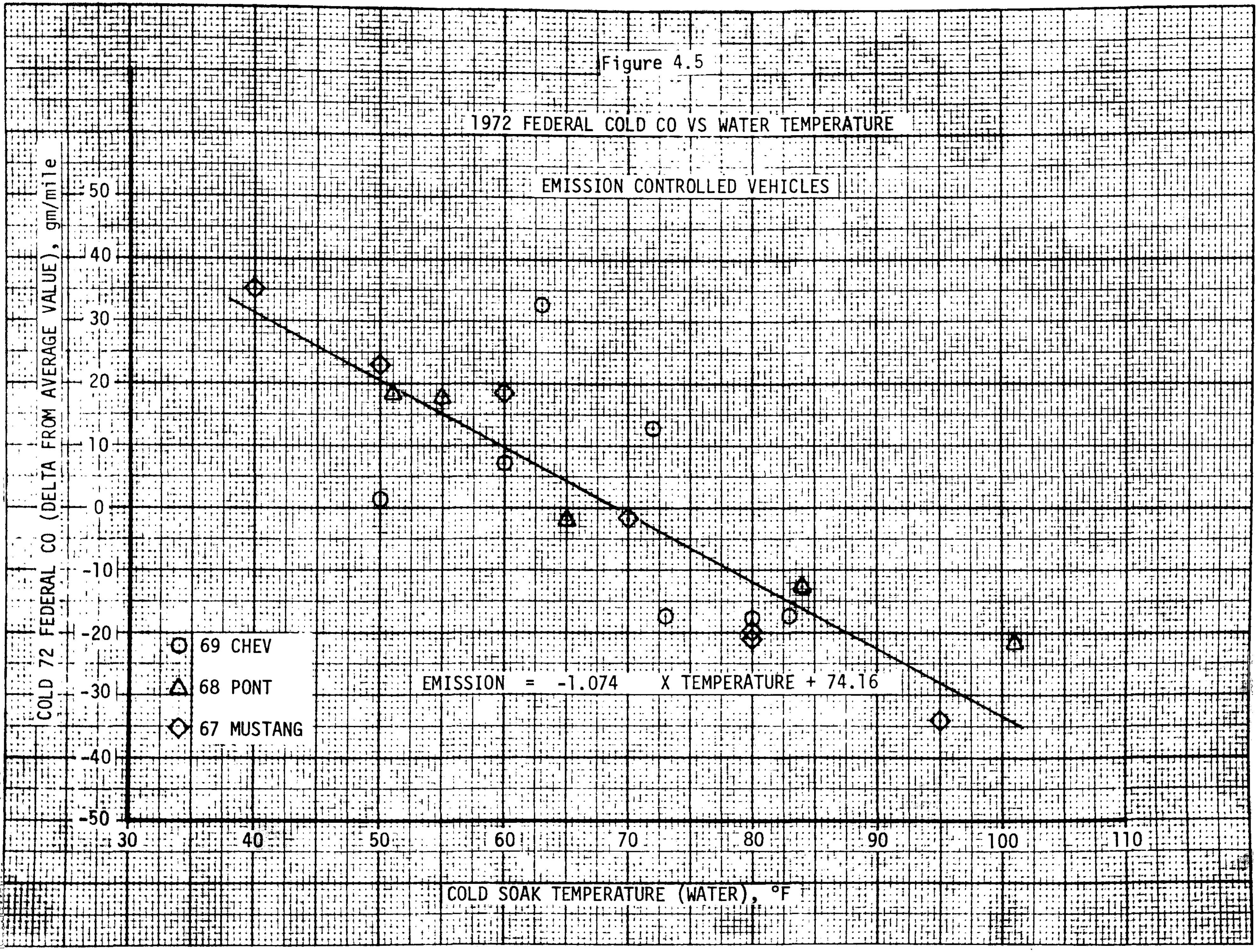


Figure 4.5
1972 FEDERAL COLD CO VS WATER TEMPERATURE
EMISSION CONTROLLED VEHICLES
COLD 72 FEDERAL CO (DELTA FROM AVERAGE VALUE), gm/mile
50
40
30
20
10
0
-10
-20
-30
-40
-50
30
40
50
60
70
80
90
100
110
COLD SOAK TEMPERATURE (WATER), °F
69 CHEV
68 PONT
67 MUSTANG
EMISSION = -1.074 X TEMPERATURE + 74.16

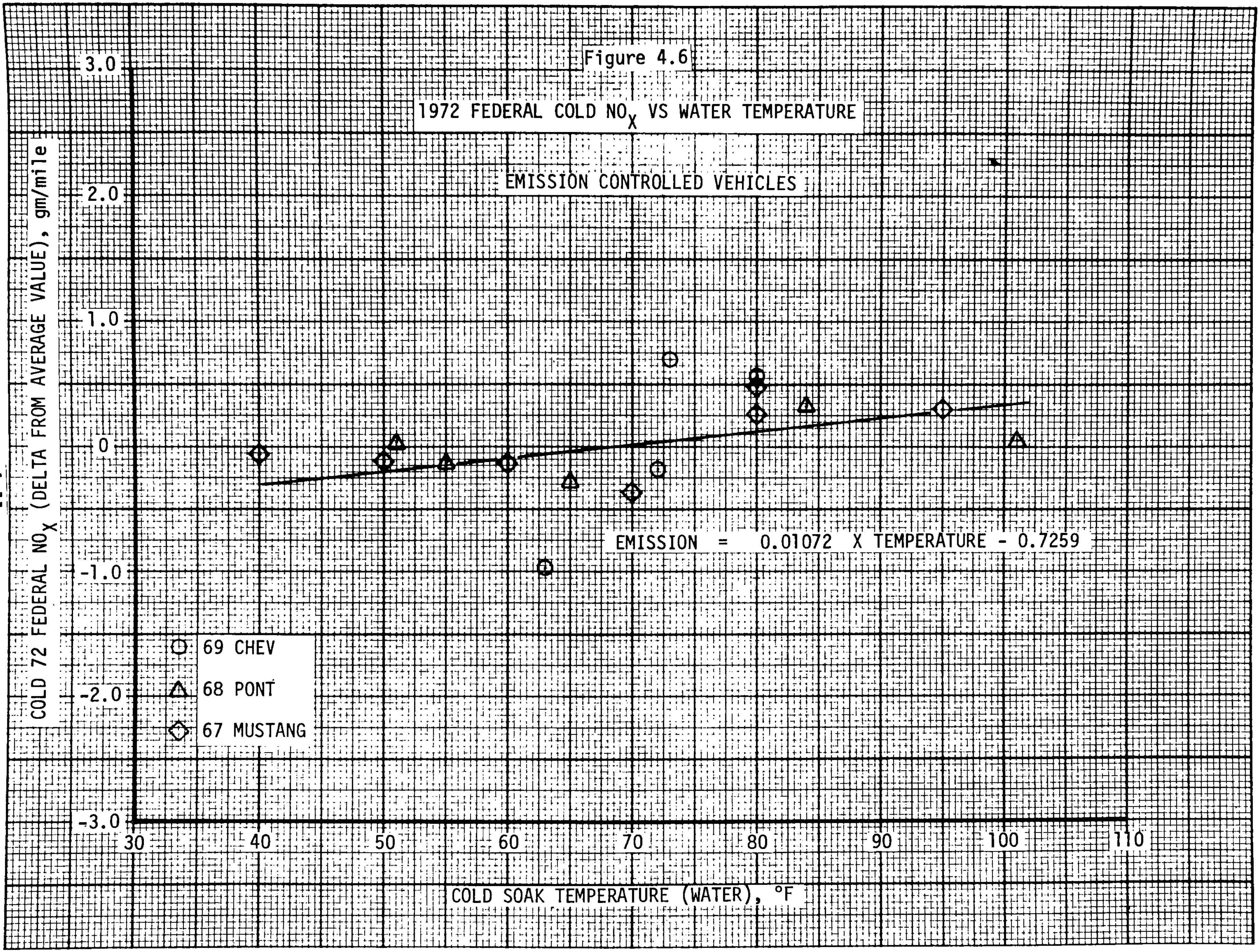

1972 FEDERAL COLD NO_X VS WATER TEMPERATURE
EMISSION CONTROLLED VEHICLES
COLD 72 FEDERAL NO_X (DELTA FROM AVERAGE VALUE), gm/mile
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
30
40
50
60
70
80
90
100
110
EMISSION = 0.01072 X TEMPERATURE - 0.7259
69 CHEV
68 PONT
67 MUSTANG
COLD SOAK TEMPERATURE (WATER), °F

Figure 4.6

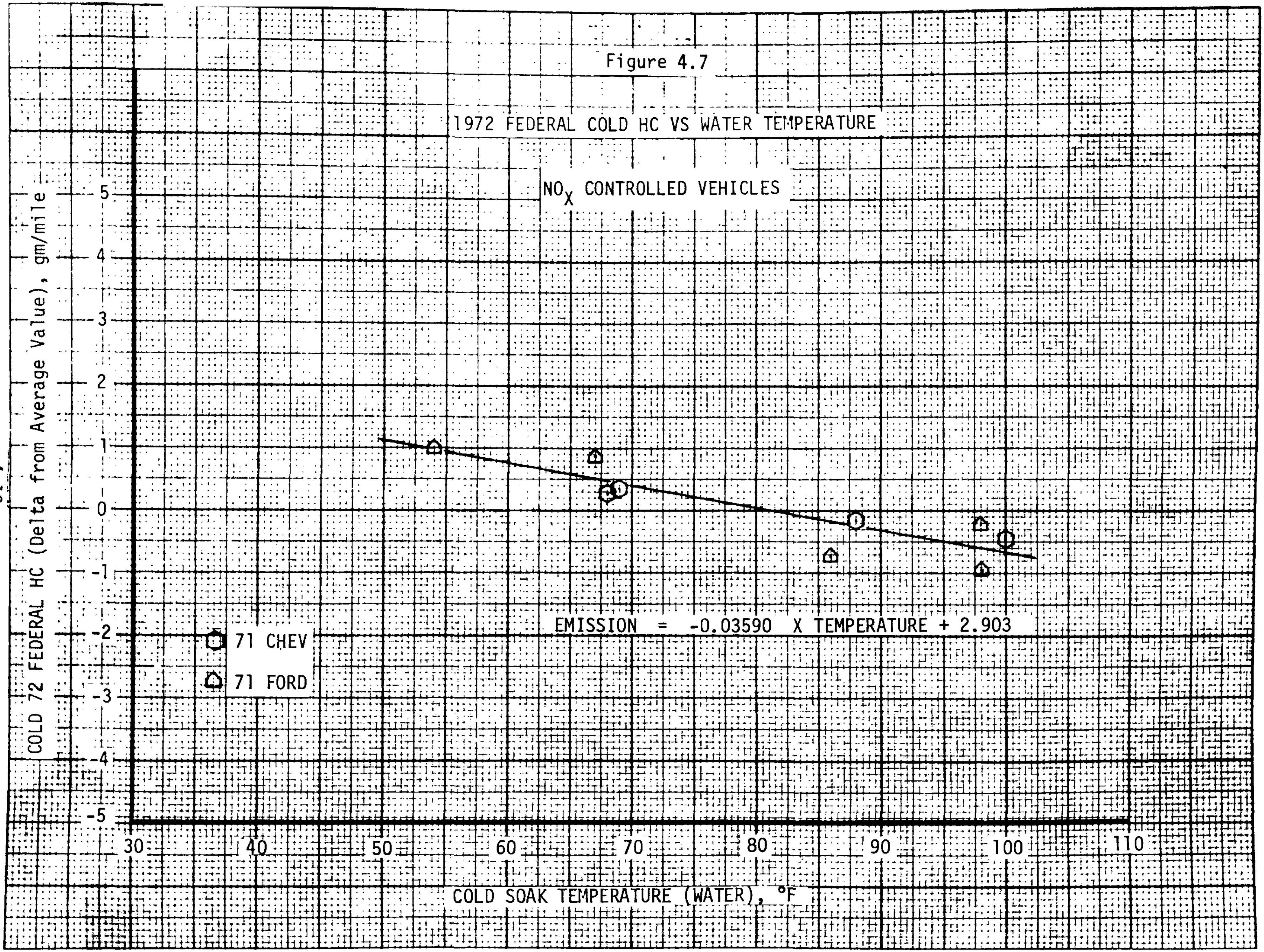


Figure 4.7
1972 FEDERAL COLD HC VS WATER TEMPERATURE
NOX CONTROLLED VEHICLES
COLD 72 FEDERAL HC (Delta from Average Value), gm/mile
5
4
3
2
1
0
-1
-2
-3
-4
-5
30
40
50
60
70
80
90
100
110
COLD SOAK TEMPERATURE (WATER), °F
EMISSION = -0.03590 X TEMPERATURE + 2.903
71 CHEV
71 FORD

Figure 4.8

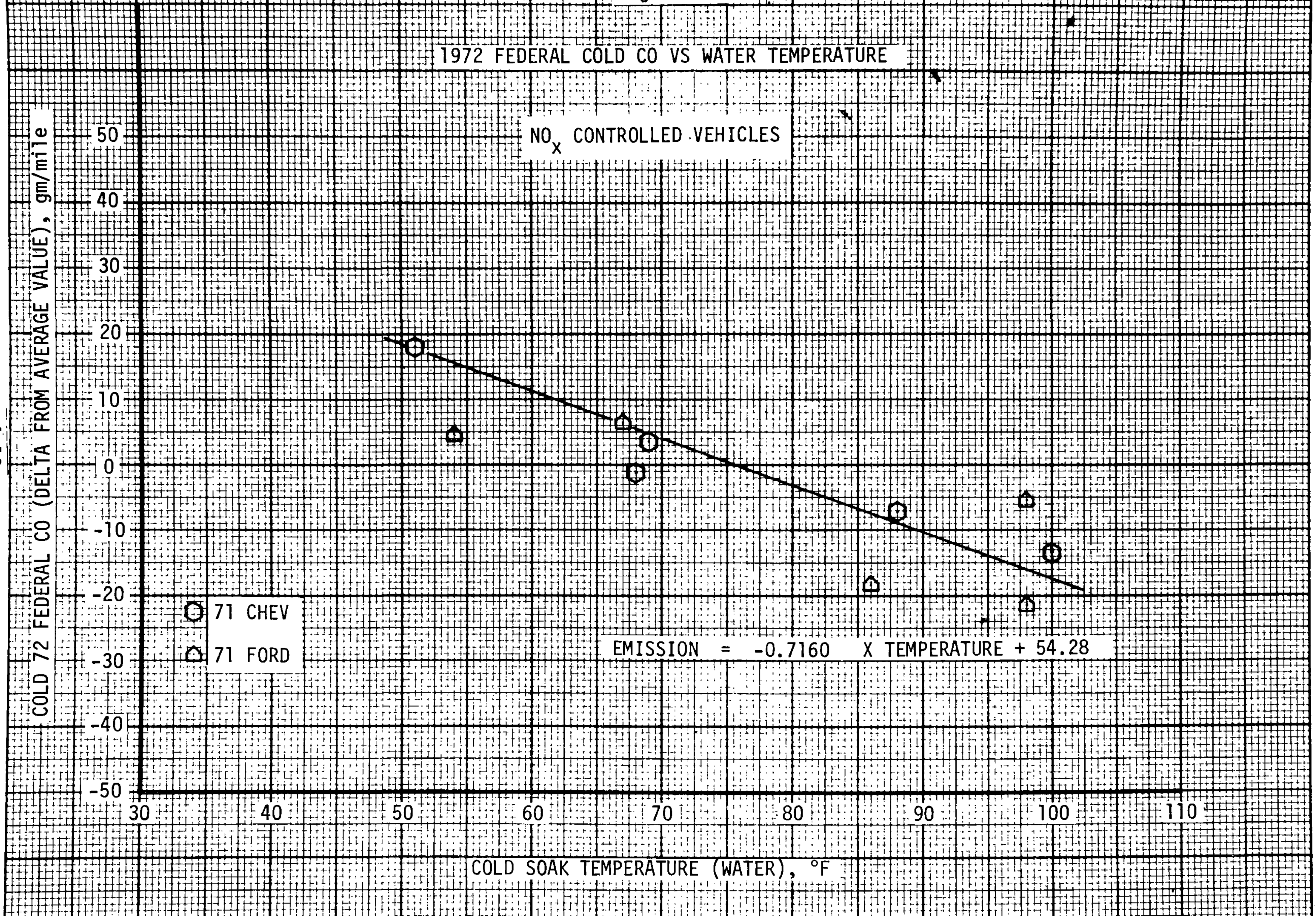
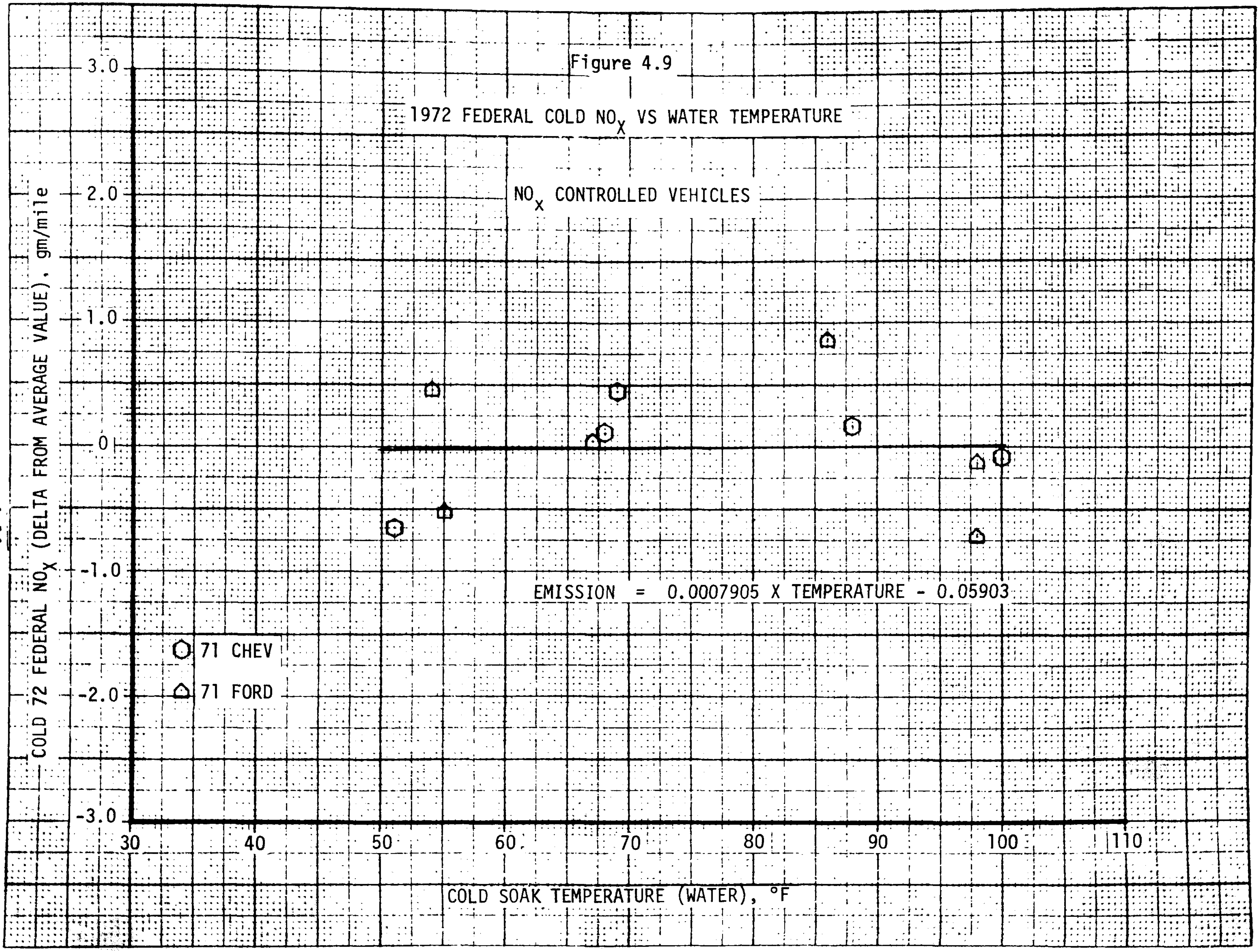

1972 FEDERAL COLD CO VS WATER TEMPERATURE
NOx CONTROLLED VEHICLES
COLD 72 FEDERAL CO (DELTA FROM AVERAGE VALUE), gm/mile
50
40
30
20
10
0
-10
-20
-30
-40
-50
30
40
50
60
70
80
90
100
110
71 CHEV
71 FORD
EMISSION = -0.7160 X TEMPERATURE + 54.28
COLD SOAK TEMPERATURE (WATER), °F

Figure 4.9



1972 FEDERAL COLD NOX VS WATER TEMPERATURE
NOX CONTROLLED VEHICLES
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
COLD 72 FEDERAL NOX (DELTA FROM AVERAGE VALUE), gm/mile
30
40
50
60
70
80
90
100
110
COLD SOAK TEMPERATURE (WATER), °F
EMISSION = 0.0007905 X TEMPERATURE - 0.05903
71 CHEV
71 FORD

3) A significant dependency (95 percent) of NO_x emission response for the emission controlled fleet.

The response coefficients of emissions with cold soak temperature of the three vehicle fleets are presented in Table 4.3.

Table 4.2

STATISTICAL SUMMARY OF THE EFFECT OF SOAK TEMPERATURE ON 1972 FEDERAL EMISSIONS

VEHICLE FLEET	PARAMETER	STANDARD ERROR gm/mile	DEGREES OF FREEDOM	INDEX OF DETERMINATION	t	SIGNIFICANCE %
PRE-EMISSION CONTROLLED VEHICLES	HC	0.56	14	0.029	0.619	70.5
	CO	8.50	20	0.380	3.410	99.5
	NO_x	0.48	20	0.019	0.607	70.0
EMISSION CONTROLLED VEHICLES	HC	1.10	9	0.475	2.690	98.0
	CO	11.10	18	0.725	6.690	99.9
	NO_x	0.38	16	0.188	1.860	95.0
NO_x CONTROLLED VEHICLES	HC	0.34	8	0.783	5.020	99.9
	CO	9.60	10	0.688	4.450	99.9
	NO_x	0.52	10	0.001	0.095	<50.0

Table 4.3

COMPARISON OF RESPONSE COEFFICIENTS

VEHICLE FLEET	PARAMETER	RESPONSE COEFFICIENT g/mile/degree
PRE-EMISSION CONTROLLED VEHICLES	HC	-.00767
	CO	-.4140 *
	NO_X	0.0041
EMISSION CONTROLLED VEHICLES	HC	-.06300 *
	CO	- 1.074 *
	NO_X	0.01072
NO_X CONTROLLED VEHICLES	HC	-.03590 *
	CO	-.7160
	NO_X	0.0008

*Statistically significant with confidence greater than 95 percent.

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