

AD-A211 300

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

A PROGRAM TO EVALUATE A VEHICLE TEST METHOD FOR PORT FUEL INJECTOR DEPOSIT-FORMING TENDENCIES OF UNLEADED BASE GASOLINES

DAAK-70-89-C-0022

DTIC
ELECTE
AUG 15 1989
S D D

February 1989

89 8 15 027

COORDINATING RESEARCH COUNCIL, INC.
219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

The Coordinating Research Council, Inc. (CRC) is a non-profit corporation supported by the petroleum and automotive equipment industries. CRC operates through committees made up of technical experts from industry and government who voluntarily participate. The four main areas of research within CRC are: air pollution (atmospheric and engineering studies); aviation fuels, lubricants, and equipment performance; heavy-duty vehicle fuels, lubricants, and equipment performance (e.g., diesel trucks); and light-duty vehicle fuels, lubricants, and equipment performance (e.g., passenger cars). CRC's function is to provide the mechanism for joint research conducted by the two industries that will help in determining the optimum combinations of petroleum products and automotive equipment. CRC's work is limited to research that is mutually beneficial to the two industries involved, and all information is available to the public.

COORDINATING RESEARCH COUNCIL

INCORPORATED

219 PERIMETER CENTER PARKWAY

ATLANTA, GEORGIA 30346

(404) 396-3400

A PROGRAM
TO EVALUATE A VEHICLE TEST METHOD
FOR PORT FUEL INJECTOR DEPOSIT-FORMING TENDENCIES
OF UNLEADED BASE GASOLINES
(CRC PROJECT No. CM-128-85)

IN FORMULATING AND APPROVING REPORTS, THE APPROPRIATE COMMITTEE OF THE COORDINATING RESEARCH COUNCIL, INC. HAS NOT INVESTIGATED OR CONSIDERED PATENTS WHICH MAY APPLY TO THE SUBJECT MATTER. PROSPECTIVE USERS OF THE REPORT ARE RESPONSIBLE FOR PROTECTING THEMSELVES AGAINST LIABILITY FOR INFRINGEMENT OF PATENTS.

Prepared by the
Fuel Injector Test Procedures Analysis Panel
of the
CRC Automotive Fuel Injector Deposit Group

February 1989



Accession For	
NTIS	CRA&I
DTIC	TAB
Unannounced	
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee
of the
Coordinating Research Council, Inc.

ABSTRACT

Car owners began complaining of operability problems with port fuel injector (PFI) systems late in 1984. Deposits within the tips of the pintle-type injectors of certain engines restricted fuel flow and caused misfiring. The automakers and gasoline marketers sought a test method that would enable determination of causative factors and consequent solutions. The Coordinating Research Council (CRC) Automotive Fuel Injector Deposit Group, organized in March 1986, developed a program which led to selection of a vehicle procedure for a round robin evaluation. The cycle involved 15 minutes operation at 88 kph (55 mph) followed by a 45 minute hot soak shutdown with total test durations of 4800 to 9600 km (3000 to 6000 miles). Twelve laboratories ran various combinations of three different base unleaded gasolines in five types of port fuel injected engines. From this set, data from 38 runs were analyzed, representing eleven laboratories and four engine types. Even though all test conditions were not tightly controlled, results showed statistically significant differences (at the 95% confidence level) in deposit-forming tendencies of the fuels as well as the vehicles. The test approach is useful for relative performance evaluations but more development effort is needed before it could serve as a quantitative measure.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT.....	i
I. INTRODUCTION.....	1
II. SUMMARY.....	2
III. TEST VEHICLES.....	4
IV. TEST FUELS.....	5
V. TEST PROCEDURES.....	6
VI. DISCUSSION OF RESULTS.....	8
A. Data Analysis Techniques.....	9
B. Multiple Linear Regression.....	10
C. Multiple Linear Regression of Exponentially Transformed Data.....	12
D. Data Variability.....	13
E. Average Versus Worst Injector Concepts.....	15
F. Fuel Stability.....	16
G. Temperature Data.....	18
H. Program Timing.....	18

LIST OF TABLES

<u>Table</u>	<u>Description</u>
I	Test Car Engine Configuration
II	Typical Test Fuel Inspections
III	Vehicle and Fuel Combinations Tested By Participating Laboratories
IV	Analysis of Exponentially Transformed Data - Estimated Flow Reduction At 4800 km

LIST OF FIGURES

<u>Figure</u>	<u>Description</u>
1	PFI Round Robin Summary - Least Squares Regression
2	Car Severity Related to Different Makes
3	Test Runs Showing Non-Linear Characteristics of Flow Rates Versus Distance Traveled
4	CAR D - Summary Based on Least Squares Regression
5	CAR G - Summary Based on Least Squares Regression
6	CARS F & L - Summary Based on Least Squares Regression
7A	FUEL A - Injector Set Average Flow Reduction
7B	FUEL A - Worst Injector Flow Reduction
8	FUEL B - Injector Set Average and Worst Injector Flow Reduction
9A	FUEL C - Injector Set Average Flow Reduction
9B	FUEL C - Worst Injector Flow Reduction
10	Program Timing

LIST OF APPENDICES

<u>Appendix</u>	<u>Description</u>
A	Program Participants and Membership
B	Test Program Plan for CRC Fuel Injector Deposit Evaluation in Vehicles and Injector Leak Rate Test Procedure
C	Vehicle Descriptions and Program Summary
D	Test Fuel Inspections
E	Laboratory Operating Conditions
F *	Injector Flow Data - Master Data Set
G *	Temperature Data
H	Statistical Analysis of Fuel Injector Flow Data

* Data presented in Appendices F and G are available on computer diskette in Lotus 1-2-3 Version 2.01 format. Contact the Coordinating Research Council, 219 Perimeter Center Parkway, Atlanta, Georgia, 30346.

I. INTRODUCTION

In the latter half of 1984 and progressing into 1985, there was an increasing number of car owner complaints of driveability problems with certain engines having port fuel injection systems. The injectors were of the same pintle design from a single source manufacturer.

Initially complaints developed in the Denver, Colorado area with some indication that certain unleaded gasolines were involved. With time, they spread to other geographical areas, particularly the southern states. Thus, a test method was needed to define the factors contributing to flow restricting deposits in the very close clearances between the injector pintle and body.

In October 1985, the Coordinating Research Council (CRC) held a forum in Tulsa, Oklahoma with open invitation to automaker, petroleum and supplier industry representatives to share information that might lead to defining a test. The CRC Automotive Fuel Injector Deposit Group was formally organized March 20, 1986, and divided into three subgroups. Two were assigned responsibilities for studying fuel composition and exploring possible laboratory bench tests to correlate with field performance. The third subgroup was charged with selecting a vehicle test procedure based upon field experience. This third group was called the Port Fuel Injector Test Procedure Subgroup.

Through individual member experience, a procedure was selected that could be applied to cars to generate injector deposits. There was sufficient indication that the procedure could be a useful tool to study factors affecting injector deposits, so a round robin program was conducted to explore repeatability and reproducibility. This report describes the program and results.

II. SUMMARY

Twelve laboratories participated as members of the CRC Automotive Fuel Injector Deposit Group in a round robin vehicle test program (Appendix A). The purpose was to evaluate a proposed technique for studying vehicle and fuel parameters leading to the formation of flow-restricting deposits within the critical metering area of pintle-type port fuel injectors (PFI). A copy of the test program is attached as Appendix B.

A prescribed test cycle was used by all participants. It consisted of a 15-minute running period at 88 kph (55 mph) followed by a 45-minute hot soak with the engine shut off. This was repeated for varying durations of typically 4000 to 9600 km (2500 to 6000 miles). Nominally, a test was ended when a set of fuel injectors suffered 20% or more average loss of flow due to deposits or when 9600 km was reached, whichever occurred first. Flow restriction was determined in a bench rig that accurately measured the quantity of fuel flowed through each injector when held open for precisely ten seconds. Flow measurements were made on injector sets initially and at 1600-km (1000-mile) intervals.

Based on field experience, three car makes were targeted for testing. However, participating laboratories also tested two other car makes. The test vehicles are described on Table I. All cars had automatic transmissions and the typical power accessories. Model years ranged from 1984 to 1986.

Three test fuels were provided from central sources so that each was common to all laboratories. The fuels were full boiling range unleaded base gasolines without any detergent, dispersant, or deposit control additives. The major compositional difference among them was in the olefin content, as shown below:

<u>Fuel Code</u>	<u>% Total Olefins</u>	<u>Deposit Severity</u>
CRC-9-86A	35	High
CRC-9-86B	5	Low
CRC-9-86C	12	Moderate

In total, the 12 laboratories tested 19 vehicles using the three fuels to yield 42 runs, including repeats. A summary of the runs is shown in Table III and also in Appendix C. In 38 of the 42 runs, the data were sufficiently complete to be included in the statistical analysis; data from the other four runs were omitted.*

Test results were expressed as percent flow restriction versus test duration in miles. For each injector set, data for the average injector and worst (most restricted) injector were

* Laboratory 12 did not conduct flow tests at intermediate intervals. Consequently, data from this laboratory were excluded from the data set which was analyzed.

analyzed. The rate of flow restriction increase was analyzed statistically using a linear model and an exponential model. Both approaches yielded the same conclusions which follow:

- The 15/45 minute vehicle test cycle can significantly discriminate among base gasolines and among cars for injector deposit forming tendencies.
- Unleaded base gasolines exhibit significant differences in their tendencies to form port fuel injector deposits (95% confidence level).
- Car makes differ significantly in their tendencies to form port fuel injector deposits (95% confidence level).
- Different car makes appear consistent in their relative ranking of the deposit forming tendencies of different unleaded base gasolines.
- Simple linear modeling of injector set flow rates versus distance is a suitable basis for screening fuel and vehicle tendencies to form injector deposits with test durations of 4800 to 8000 km (3000 to 5000 miles).
- Exponential modeling of injector set flow rates versus distance may be more suitable for longer term tests.
- Fuel and vehicle effects on injector deposits may be represented similarly by both average injector set flow restriction and worst (most restricted) injector in the set. However, average set restriction is preferred to offset the greater uncertainty of a single measurement.
- Further procedure development is necessary to determine the potential for use as a quantitative industry method for port fuel injector cleanliness performance of gasolines.

There was evidence of good repeatability within various laboratories, even though it was not possible to control major test parameters closely as would be required for a uniform test. Compromises were made to make the program practical and timely. In spite of these compromises, the results support the usefulness of the technique in studying parameters affecting injector deposits. Further testing has been commissioned by CRC at an independent testing laboratory to provide vehicle validation data for studying laboratory bench tests as a more cost-effective approach to fuel and fuel additive evaluation.

III. TEST VEHICLES

The test program specified testing of three vehicle/engine configurations known to be subject to fuel injector deposit restriction in the field. As mentioned earlier, two other vehicle/engine configurations were also tested by two participating laboratories. Table I describes the vehicle/engine configurations tested.

Car Make D was chosen due to its identification with the earliest reports of the port fuel injector fouling complaints. Car Make G was chosen because of its high sales volume; also, this engine was thought to have mild deposit-forming tendencies. Car Make F was later involved in owner complaints in several geographical areas. Car Makes S and L, though not associated with customer complaints in the field, were tested by one laboratory each as independent choices.

All cars were tuned to meet manufacturer's specifications. To avoid variability due to engine break-in effects, testing was done only after more than 6400 km (4000 miles) had been accumulated. Since many of the laboratories had previously been testing for their own purposes, vehicles were readily available for this program. Also, it is believed that injector fouling is generally dependent on both engine design and underhood temperatures rather than engine/body combinations. Consequently, no test restrictions were made pertaining to body style, optional equipment, model design, etc.

The test results from Lab 12 (Runs 39 to 42) were excluded from the data analyses because they were incomplete. The laboratory submitted only beginning and ending injector flow data; data at intermediate intervals were not available.

IV. TEST FUELS

Three full-boiling unleaded base gasolines were tested. These are identified as CRC-9-86A, CRC-9-86B, and CRC-9-86C. Each laboratory was requested to make a repeat run on CRC-9-86A in one test vehicle of its choice. Testing of fuel CRC-9-86B was suggested but not required.

Based on earlier experience by individual laboratories, fuel CRC-9-86A was projected to form the most deposits, CRC-9-86C intermediate, and CRC-9-86B was projected to form the least. None of the fuels contained injector detergent, dispersant, or deposit control additives. A summary of typical inspections is shown in Table II. Complete inspection data are contained in Appendix D. Hereinafter, these fuels are referred to as "Fuel A", "Fuel B", and "Fuel C".

V. TEST PROCEDURE

The program outline, including testing technique, is presented in Appendix B.

The test vehicles operated on a uniform cycle of 15 minutes operation at 88 kph (55 mph) followed by a 45-minute engine-off soak. The procedure specified port fuel injectors be flow tested initially and at 1600-km (1000-mile) intervals thereafter. Nineteen vehicles of five engine types were operated either over the road, on outdoor mileage accumulation dynamometers, or on indoor chassis dynamometers. The specific operating conditions at each laboratory are described in Appendix E.

Each test vehicle was to run on two or more of the three test fuels. The program description in Appendix B mentions that Fuel A was projected to be more severe than Fuel C. Fuel B, which had not been defined at the start of the program, was intended to be of intermediate severity to Fuels A and C. After obtaining preliminary data on Fuel C, it was decided that Fuel B should be less severe than Fuel C to broaden the range of data.

All fuel injectors were of the pintle-type, according to the original engine manufacturer specifications. Injector flow measurements were taken at the start of each test and every 1600 km (1000 miles). Flow rates were measured as grams of flow medium (Stoddard solvent or iso-octane) through the injector which was kept energized for ten seconds. Rates were then expressed as grams per second. The complete set of injector flow data is shown in Appendix F.

Additional measurements included ambient air, inlet air, coolant, and fuel tank temperatures. Typical maximum/minimum temperatures were recorded for each 24-hour test period. Furthermore, one or more of the injectors in each engine set were equipped with thermocouples (located at the injector tip) to determine peak injector tip temperatures during the engine-off soak period. Complete temperature data are shown in Appendix G.

Average vehicle fuel consumption was also recorded. These data are presented in Appendix C.

Injector leak rates were measured according to the procedure described at the end of Appendix B. Injectors with leak rates greater than 2 mL air per minute were rejected.

The test fuels were analyzed by each participating laboratory at the beginning and end of the program. Fuel analyses included existent and unwashed gums (ASTM D 381-86), oxidation stability (ASTM D 525-86), distillation (ASTM D 86-82), and Reid vapor pressure (ASTM D 2551-80, ASTM D 323-82, or automatic method). These data are tabulated in Appendix D.

Required information included measurement of injector flow rates and, where possible, injector tip temperature. Test duration was

targeted at 6400 to 9600 km (4000 to 6000 miles). Tests could be terminated early if one of the following conditions existed:

- (1) 20% average injector plugging, or
- (2) significant driveability disturbance.

VI. DISCUSSION OF RESULTS

Twelve participating laboratories submitted test data from nineteen vehicles but only results from eleven laboratories and seven-teen vehicles were analyzed. The distribution of valid test data was as follows:

<u>Car Make</u>	<u>Vehicle Engine Type</u>	<u>No. of Vehicles</u>
D	2.2L, I-4, Turbo	8
S	2.8L, I-6	0
G	3.8L, V-6	3
F	5.0L, V-8	4
L	5.0L, V-8	2

Although testing of Car Make L was outside the original program, it was included as additional information. Data for Car Make S were incomplete and were not part of the data set analyzed.

As described earlier in the report, three unleaded base gasolines were tested:

<u>Fuel</u>	<u>Deposit Forming Tendency</u>
A	High
B	Low
C	Moderate

Insofar as possible, all laboratories were requested to run Fuel A and Fuel C. Fuel B was an option supplied later in the program.

A. Data Analysis Techniques

Table III shows the combinations of cars and fuels tested by each participating laboratory. All laboratories ran Fuel A, nine laboratories ran Fuel C, and only three laboratories ran Fuel B. A few laboratories also were able to run repeat tests for some car-fuel combinations.

Presentation of the results are in terms of percent injector flow reduction (average of all injectors in an engine relative to new, clean injector flow) versus test duration in miles. This is a direct indication of a vehicle's tendency to form injector deposits on a particular fuel. The "percent reduction relative to new injector flow rate" parameter was selected to put all vehicles on a common basis since new injector flow can vary from engine to engine. Injectors which stayed clean would show no reduction in percent of new injector average flow rate. A high deposit forming fuel would show a rapid increase in percent reduction of flow rate after a relatively short duration (few test miles).

Prior experience by several participants with the 15/45 minute test cycle had shown that the injector flow rate change with test duration was essentially linear over 4800 to 8000 km (3000 to 5000 miles). Thus, each test could be fairly represented by a least squares straight line through the flow rate reduction measurements versus test duration. A more advanced method of data analysis, which will be discussed later, took into account possible curvature of the flow rate reduction response. However, both the simple and the more complex methods yielded the same conclusions. Detailed discussions of both methods of analysis are contained in Appendix H.

In addition, the data were analyzed using the worst (most restricted) injector in a set rather than the average level of injector restriction. Again, the same conclusions were reached.

B. Multiple Linear Regression Analysis

Results of the program are shown in a series of graphs of average percent flow reduction (relative to new injector flow) versus test duration. Each test curve (or least squares straight line) can be characterized by its slope. This yields a single value that can be treated by multiple regression analysis to determine car effects, fuel effects, and possible interactions.

On this basis, the round robin program showed:

- a) The three fuels are significantly different from each other (95% confidence level):

Fuel A - High Deposit Forming

Fuel C - Moderate Deposit Forming

Fuel B - Low Deposit Forming

- b) The four vehicle/engine configurations could be divided into three groups which are significantly different from each other (95% confidence level):

Car F (5.0L V-8) - High Severity

Car D (2.2L I-4 Turbo) - Moderate Severity

Car G (3.8L V-6) - Moderate Severity

Car L (5.0L V-8) - Low Severity

Additionally, the analysis showed the interaction of cars and fuels to be significant at the 95% confidence level. Therefore, the data are discussed for the three fuels in each of the car makes.

The most concise presentation of the overall results of the round robin program is given in Figure 1, which shows the percent flow reduction (relative to new injectors) versus test duration for the average of each fuel in each of the four car makes.* Fuel A is clearly the highest deposit-forming fuel in all cars. Responses in Car D and Car G are similar, whereas Car F forms deposits at about twice the rate of the other two and Car L forms deposits at about 1/4 the rate of the other two.

* Car Make L was only tested with Fuel A.

A similar picture is evident for Fuel C, which exhibits an intermediate deposit-forming tendency. Comparatively, Fuel B shows little deposit-forming tendency in all three cars. In 4800 km (3000 miles), only 3% or less average flow reduction occurred with Fuel B. The original program instructions were to extend any test run to an average flow reduction of 20% or to a test duration of 9600 km (6000 miles). Thus, all laboratories testing Fuel B ran the full test duration, at which point one laboratory reached 4.4% average flow reduction and the other two reached 2.3% and 2.0%.

On the basis of the above test results, it may be concluded that the 15/45 minute vehicle test procedure does significantly discriminate between base gasolines of different deposit-forming tendencies. As a corollary conclusion, unleaded base gasolines can differ significantly in their deposit forming tendencies. A further conclusion relative to car makes is that vehicle/engine configurations can differ significantly in severity or tendency to form deposits which restrict injector flow. It is also noteworthy that the distinctly different car makes ranked the test fuels in the same relative order of deposit forming tendencies. Hence, there appears to be a consistency among makes that are subject to field complaints.

As amplification of the car make severity question, recall that a fourth vehicle/engine combination, Car Make L, was tested outside the original program design but with the same test procedure and the same Fuel A. Although the engines in Car Makes F and L were both 5.0L V-8, they differed significantly in their sensitivity to deposit formation, as shown in Figure 2.

C. Multiple Linear Regression of Exponentially Transformed Data

About one-third of the test runs in the program showed evidence of some curvature. Without regard to car make or fuel type, those particular curves are plotted together in Figure 3. The extent of curvature appears to be greater with extended test duration. In addition, as one might expect, test variability increased with test duration (i.e. standard deviation was a function of test duration). Therefore, the data were subjected to more sophisticated exponential modeling suitable for this type of data versus the previous simple linear model.

First, the data were transformed exponentially, which linearized the data and "normalized" the standard deviations. Then, the transformed data were subjected to multiple linear regression. From the resulting least-squares best-fit model, parameter estimates were generated at 4800, 9600, and 16,000 km (3000, 6000, and 10,000 miles).* The parameter values at 4800 km (3000 miles) are listed in Table IV. The estimated flow reductions were calculated by using the equation shown at the bottom of the table using appropriate values for a fuel parameter (f), a car parameter (c), and the intercept (I). For example, the estimate of the flow reduction for Car D on Fuel A at 4800 km (3000 miles) was determined as follows:

$$\% \text{ Flow Reduction} = \frac{100}{1 + \exp[-(-4.046 + 0.774 + 1.292)]} = 12.1\%$$

The other values shown on the table were calculated in a similar manner.

Conclusions from this analysis of exponentially transformed data coincide with those from the simple linear analysis. The differences among Fuels A, B, and C and among Cars F, D & G, and L were significant at the 95% confidence level.

A more thorough discussion of this method and tabulations of the parameter values at other test length intervals is contained in Appendix H.

* The latter interval is a considerable extrapolation from the maximum actual test duration of 9600 km (6000 miles).

D. Data Variability

This round robin program was intended to give a general assessment of the feasibility of the 15/45 minute test cycle as a means for evaluating fuel deposition tendencies. A reasonable effort was made to control the major parameters believed to affect injector deposits, i.e. vehicle/engine configuration, fuel, and driving pattern. Other parameters, such as injector tip temperatures, coolant temperature, and ambient temperatures, were measured to help explain spurious results.

To minimize vehicle/engine effects, it was the intent to test only three vehicle/engine configurations (D, G, and F), but each laboratory could use the model year car already on hand. This resulted in a variation of up to three model years. However, all laboratories had to use the same batches of fuel and a common engine oil. No cars were exchanged among laboratories, so car and laboratory effects were confounded. Also each laboratory was free to run cars anytime during the year, and test operation could be either on the road or on a chassis dynamometer.

In spite of the freedom of approach in testing, the results proved the basic test approach is useful for fuel and/or car testing. However, the variability encountered limits the applicability of the round robin procedure as a method for quantifying injector fouling. A significant development program would be required to refine testing technique.

To illustrate the variability factors, the linear least squares regression lines are shown in Figures 4, 5, and 6.

Figure 4 shows results for all laboratories using Car D with each fuel. There is clearly much higher variability with Fuel A, the one most prone to form deposits. Reproducibility between car/laboratory combinations is poor, ranging up to 30 percentage points at 4000 km (2500 miles). For the three laboratories that made repeat runs (Labs 1, 8, and 11), the variability is somewhat lower. Tests within Lab 8 (Runs 27 and 28) were fairly close together, suggesting the possibility of more precise testing with some development effort. One possible reason for the high variability of results for Fuel A was the stability of the fuel. This issue will be discussed later in this report.

A similar presentation of results for Car G is shown in Figure 5. Here the number of runs is more limited. Note that the runs for Lab 2 with Fuel A (Runs 7 and 8) show relatively poor repeatability, while those for Lab 3 (Runs 10 and 11) are very good.

One of the reasons for differences between Runs 7 and 8 is that Lab 2 modified the car after Run 7. The laboratory observed that maximum injector tip temperatures in Run 7 were lower than expected. Consequently, for Run 8 the laboratory added a hood shield to elevate maximum injector tip temperature. In retrospect, it may have been technically justifiable to exclude Run 8 from the data set, but the differences between the two runs were

within the test precision observed in this program. Consequently, Run 8 was retained in the data set.

Figure 6 presents results for Cars F and L. Car F is clearly the most severe vehicle/engine configuration. Repeatability within Labs 7 and 9 for Car F with Fuel A was excellent. With Fuel C, repeatability was somewhat poorer, and Run 30 appears to be excessively severe relative to the rest of the tests with this fuel. The two tests by Lab 4 with Fuel A in Car L (Runs 14 and 15) repeated very well, especially considering that the tests were conducted in two different cars. Again, these results suggest that test variability may be controlled to yield a useful quantitative performance test method.

E. Average Versus Worst Injector Concepts

A characteristic observation of deposit formation in injector tips is that a set of injectors in an engine do not become uniformly restricted during a given vehicle test. There is usually a large spread between the cleanest and the most restricted injector.

Thus, there is a question of how best to represent quantitatively the performance of a fuel in an engine. Since there is a high variability in the behavior of individual injectors, it was considered that averaging the flow restriction for a complete set of injectors would tend to average out some of the variability and give a better estimate. In support of this concept, the raw test data were compared on the basis of the injector set averages versus the worst single injector in each set.

Figures 7, 8, and 9 provide a visual comparison for all of the program data. The data are separated by fuels and car makes. Figures 7A and 7B show the data for Fuel A in terms of the average and the worst injector, respectively. Similarly, Figures 9A and 9B show the data for Fuel C. In Figure 8, the comparable data for Fuel B are condensed into two plots because few data points were available. Note that the scale of the y-axis for the plots of average injector flow reduction differs from those for worst injector flow reduction.

A visual comparison of the plots of average versus worst injector results reveals a strikingly similar appearance. This is true for each fuel in each car. Consequently, the same general conclusions regarding the overall fuel and car effects can be drawn whether they are based on injector set averages or on the worst single injector in a set.

F. Fuel Stability

One of the possible causes of poor test precision was poor fuel stability. This issue was of great concern to the program panel because of the possible correlation between poor stability and high deposit formation and because of the extended time frame over which the tests would be conducted.

To determine whether fuel stability had changed during the program, inspections were conducted on each of the test fuels by each of the participating laboratories, both before and after the vehicle tests. These inspections included tests for unwashed and washed gums, induction period, Reid vapor pressure, and distillation. Appendix D contains a complete tabulation of the inspection results. An indication of the time frame over which these inspections were obtained is given in Figure 10.

For evaluating the significance of the results, reliance has been placed on the less stringent reproducibility criteria from the ASTM standards, rather than the repeatability standards, since the intra-laboratory measurements were made several months apart.

Fuel A - The ASTM D 381 gum results from Lab 5 differ significantly from those of the other laboratories, both before and after the vehicle test program. These results were probably due to differences in calibration or technique rather than real differences in fuel characteristics, because Lab 5 obtained vehicle test results which were similar to results obtained at other laboratories.

Labs 2 and 7 measured an increase in existent gum levels from the beginning to the end of the test. While these results are statistically significant and while they suggest that the fuel was changing, the changes could not be correlated with changes in the deposit-forming characteristics of the test fuel.

Labs 5, 9, and 11 measured a significant reduction in induction period over the course of the test program. These reductions may be due to storage conditions at these laboratories.

Lab 4 measured lower than average Reid vapor pressure (RVP) and greater than average reduction in RVP. These differences were probably due to storage practices or sampling techniques. The laboratory stored its fuel in an above-ground tank during the summer in the southern part of the country. Among the other laboratories, differences in RVP of minor significance were observed, both between laboratories and between initial and final inspections at individual laboratories.

Some minor differences in ASTM D 86 distillation characteristics were observed, particularly with respect to Lab 4. These differences were not of sufficient magnitude to cause concern.

Fuel B - The inspection data for this fuel were very limited; however, they did not indicate any significant change in the fuel over the course of the test program.

Fuel C - The variation in the inspection data for this fuel is much less than that for Fuel A. Perhaps the fuel was less sensitive to storage and handling practices because it had a lower volatility and it contained oxidation inhibitors.

With the exceptions noted above, the analysis of the fuel inspection data indicates that overall there were only minor differences in fuel characteristics, both among laboratories and between initial and final inspections by individual laboratories. These differences do not reveal contamination nor significant deterioration of the fuels during the program. It should be noted, however, that these inspections address only the macroscopic characteristics of the fuels. Changes in more subtle fuel characteristics which might be related to deposit-forming tendencies cannot be ruled out.

G. Injector Tip Temperatures

As mentioned earlier, part of the program included monitoring of ambient temperatures and injector tip temperatures, plus the option of monitoring a few other key temperatures. A tabulation of the data collected is given in Appendix G.

While much data were collected, the manner in which they were obtained was not sufficiently controlled to provide consistent data logging. A cursory analysis of the data did not reveal a strong relationship between the temperature data and deposit formation. Because of the inconsistencies, a thorough analysis of the temperature data was not possible.

H. Program Timing

While it was desirable for participants to run this program all in the same time frame, it was not possible due to other priorities within the various laboratories. Figure 10 shows the program duration for each participating laboratory. Some began the program early and finished in a short time (2 months), while others extended the program over 7 to 8 months.

Most participants ran 24 hours per day continuously while others had protracted shutdowns (weekends, evenings, etc.) No correlation could be made between length of test time in relation to injector deposit formation rates.

ACKNOWLEDGEMENT

The CRC PFI Round Robin Analysis Panel gratefully acknowledges the contributions of Mr. Louis J. Painter, a statistics consultant, who provided the statistical analyses of the data from this program.

TABLES AND FIGURES

TABLE I
TEST CAR ENGINE CONFIGURATIONS

<u>Car Make</u>	<u>Displacement (L)</u>	<u>Number of Cylinders</u>	<u>Turbocharged</u>
D	2.2	4	Yes
S *	2.8	6	No
G	3.8	6	No
F	5.0	8	No
L **	5.0	8	No

* Car Make S was not specified for the round robin program. However, it was tested by one laboratory, Lab 12. As mentioned in the report, data from Lab 12 were not included in the data analysis because the data were incomplete.

** Car Make L was not specified for the round robin program. However, it was tested by one laboratory, Lab 4, using the program procedure on one CRC fuel. Since the data reported were complete, they have been included in the analysis as supplemental information.

TABLE II
TYPICAL TEST FUEL INSPECTIONS

	FUEL A	FUEL B	FUEL C
	<u>CRC-9-86A</u>	<u>CRC-9-86B</u>	<u>CRC-9-86C</u>
Gravity, °API	59.9	62.3	54.8
Specific Gravity @ 15.6 °C	0.74	0.73	0.76
Distillation, °C			
Initial	33	38	37
10% Evaporated	48	58	55
50% Evaporated	106	108	108
90% Evaporated	188	172	171
End Point	218	204	223
Total Olefins, % Vol.	35	5	12
Induction Period, minutes	270	360+	360+
Reid Vapor Pressure, kPa (psi)	81 (11.8)	61 (8.9)	52 (7.5)
Gum, mg/100 mL			
Unwashed	7.0	2.6	2.0
Washed (Existent)	6.0	0.4	0.6
Sulfur, % Wt	0.08	0.01	0.03

TABLE III
VEHICLE AND FUEL COMBINATIONS TESTED
BY PARTICIPATING LABORATORIES

Lab	Fuel	Vehicle Make and Engine Type (Number in parentheses identifies Run Number)					Number of Runs per Test Fuel		
		D 2.2L I-4 Turbo	S 2.8L I-6	G 3.8L V-6	F 5.0L V-8	L 5.0L V-8	A	B	C
		(1) (2) (3)							
1	A B C	(4)					3		1
2	A B C	(5)		(7) (8)			3		
		(6)		(9)					2
3	A B C			(10) (11) (13) (12)			2	1	1
4	A B C					(14) (15)	2		
5	A B C			(16)			1		
				(17)					1
6	A B C	(18) (19)					1	1	
7	A B C				(20) (23) (24) (26) (21) (22) (25)		3	1	3
8	A B C	(27) (28)					2		
9	A B C				(29) (31) (30) (32)		2		2
10	A B C	(33) (34)					1		1
11	A B C	(35) (36) (37) (38)					3		1
12	A B C	(39)* (41)*	(40)* (42)*				2		2
* Excluded from analysis because data incomplete.							25	3	14
Total Runs per Car Make							=====		
							18	2	9
							11	2	
							=		
							42		Grand Total
							38		Runs Analyzed

TABLE IV
ANALYSIS OF EXPONENTIALLY-TRANSFORMED DATA

ESTIMATED FLOW REDUCTION @ 4800 KM (3000 MILES)
(Based on Least Square Means)

Intercept		Fuel A	Fuel B	Fuel C	Average Fuel
I = -4.046		0.774	-1.301	0.000	-0.176
		% Flow Reduction @ 4800 km *			
Car D	1.292	12.1	1.7	6.0	5.1
Car G	1.003	9.4	1.3	4.6	3.8
Car F	2.064	23.0	3.6	12.1	10.4
Car L	0.000	3.7	0.5	1.7	1.4
Average Car	1.090	10.1	1.4	4.9	4.2

(f)
Fitted
Effects

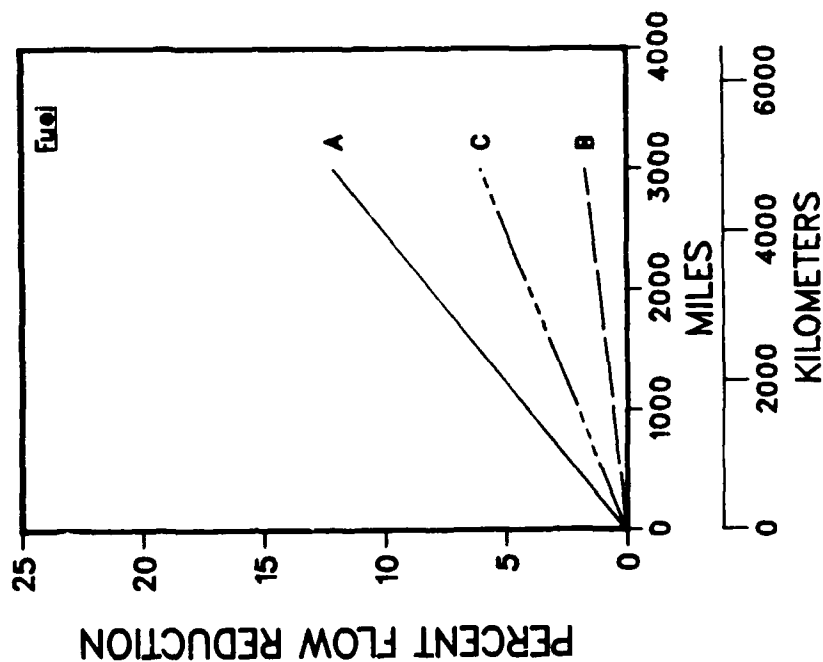
↑
(c)
Fitted
Effects

$$* \quad \% \text{ Flow Reduction} = \frac{100}{1 + \exp(-(I+f+c))}$$

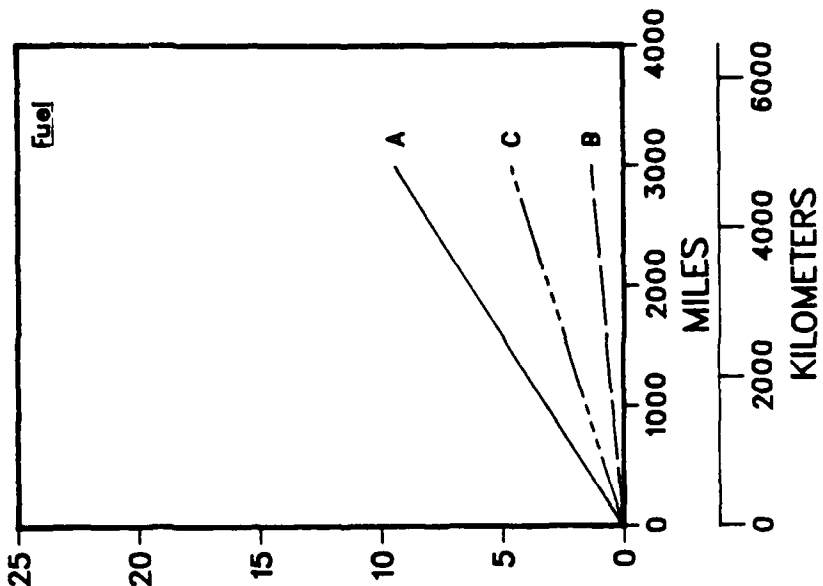
Figure 1
PFI ROUND ROBIN SUMMARY
LEAST SQUARES REGRESSION

Injector Set Average

CAR MAKE D
2.2 I-4 Turbo



CAR MAKE G
3.8L V-6



CAR MAKE F & L
5.0L V-8

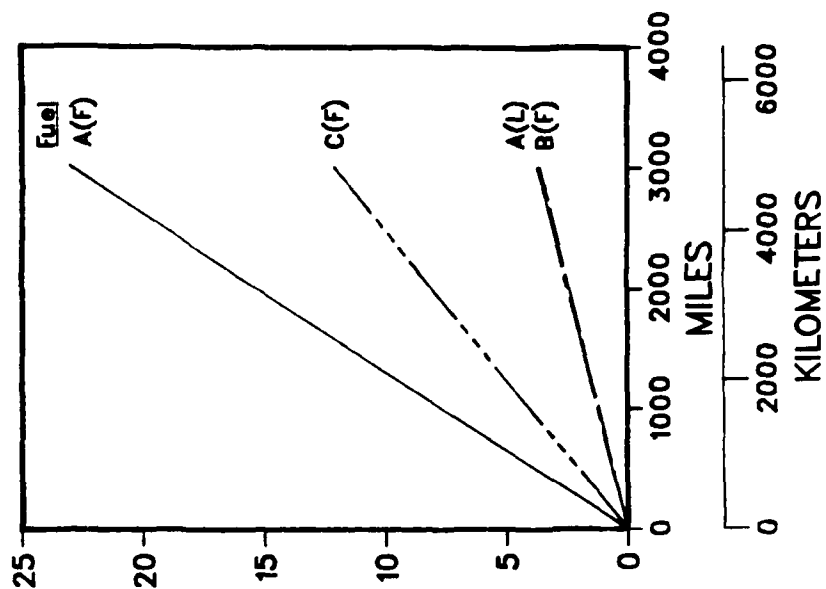


Figure 2
COMPARISON OF CAR SEVERITY
OF DIFFERENT MAKES
5.0L V-8

FUEL A

INJECTOR SET AVERAGE

WORST INJECTOR

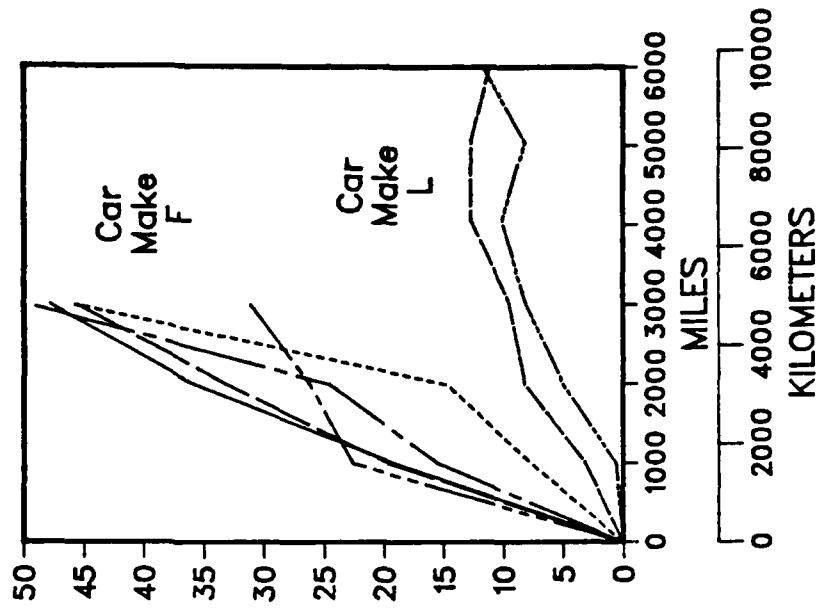
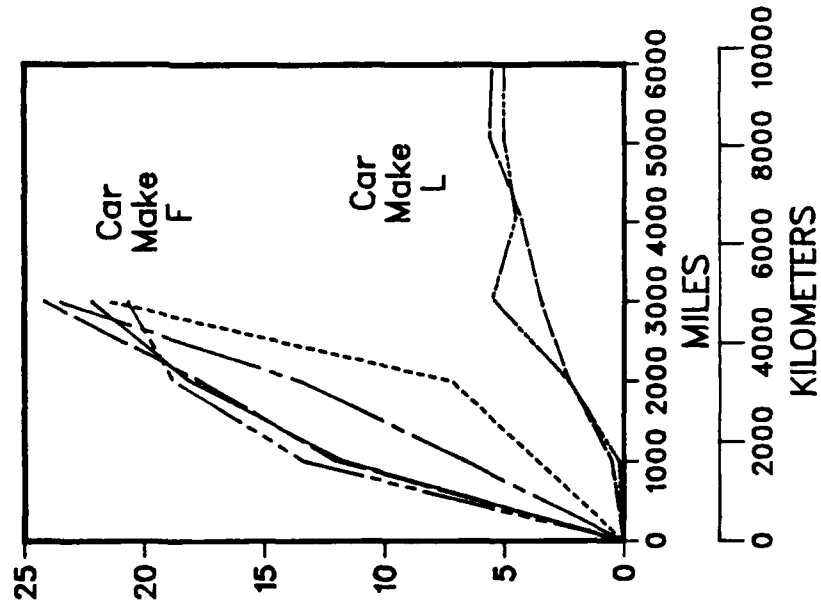


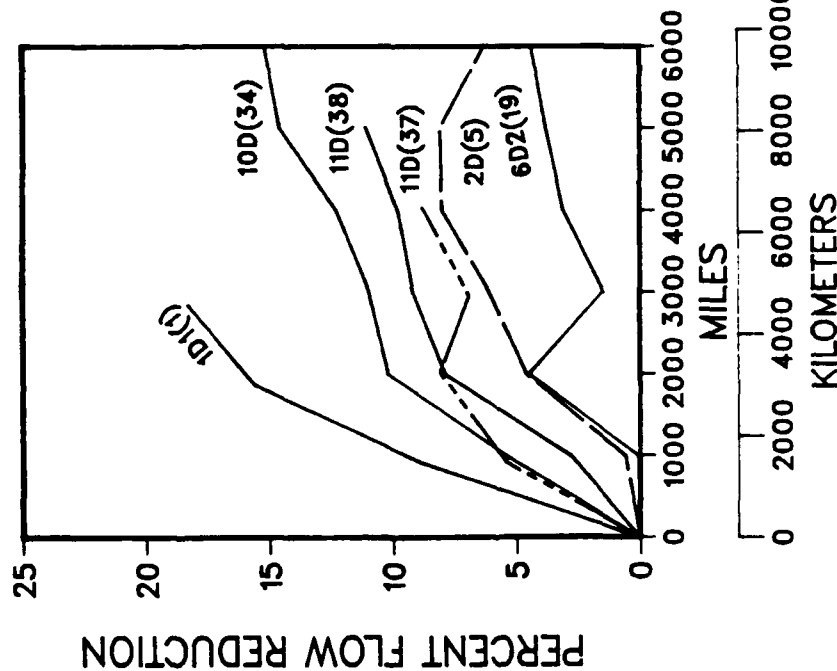
Figure 3

TEST RUNS SHOWING NON-LINEAR CHARACTERISTICS IN RATE OF FLOW REDUCTION

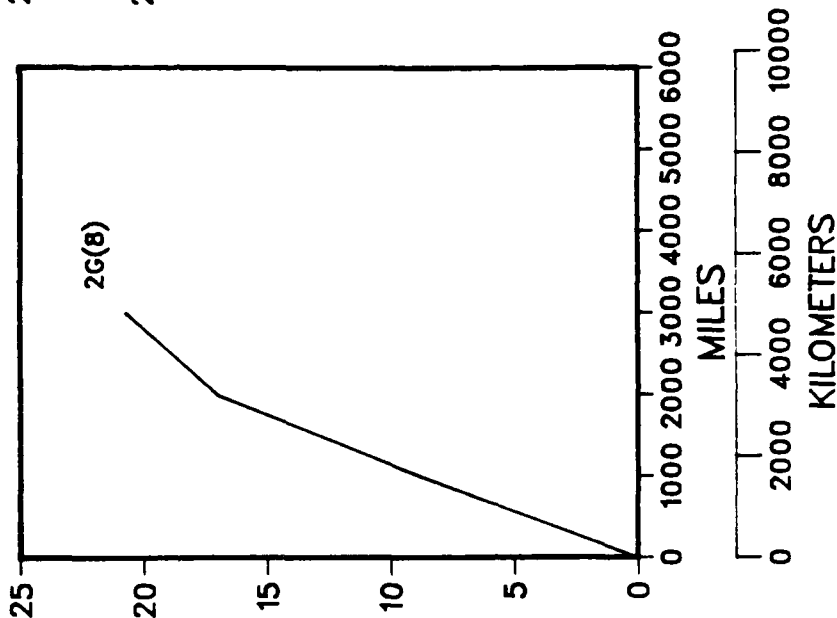
Various Fuels & Car Makes
Injector Set Averages

CODE: Lab,Car(Run)

CAR MAKE D 2.2 l-4 Turbo



CAR MAKE G 3.8L V-6



CAR MAKES F & L 5.0L V-8

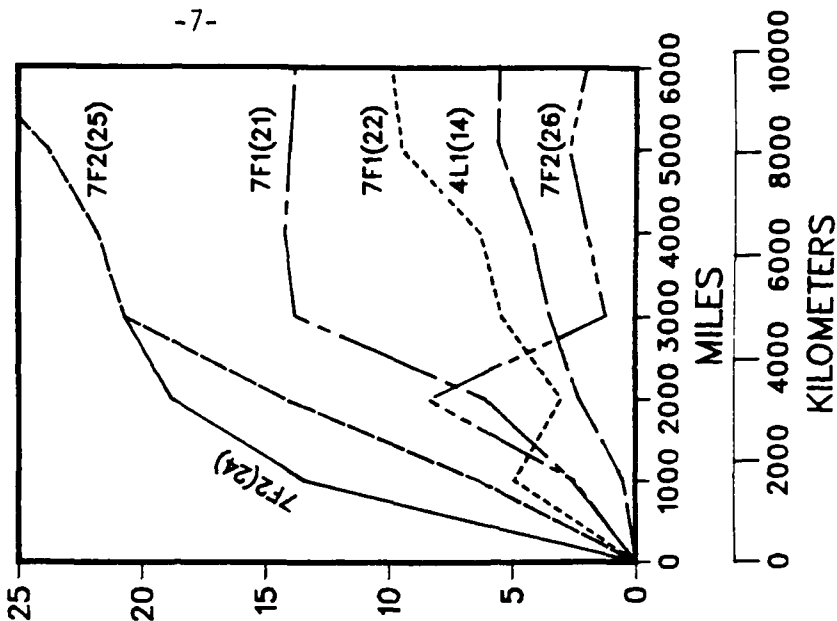


Figure 4

DATA SUMMARY
BASED ON
LEAST SQUARES REGRESSION

CODE: Lab,Car(Run)

CAR MAKE D: 2.2L I-4 Turbo
Injector Set Average

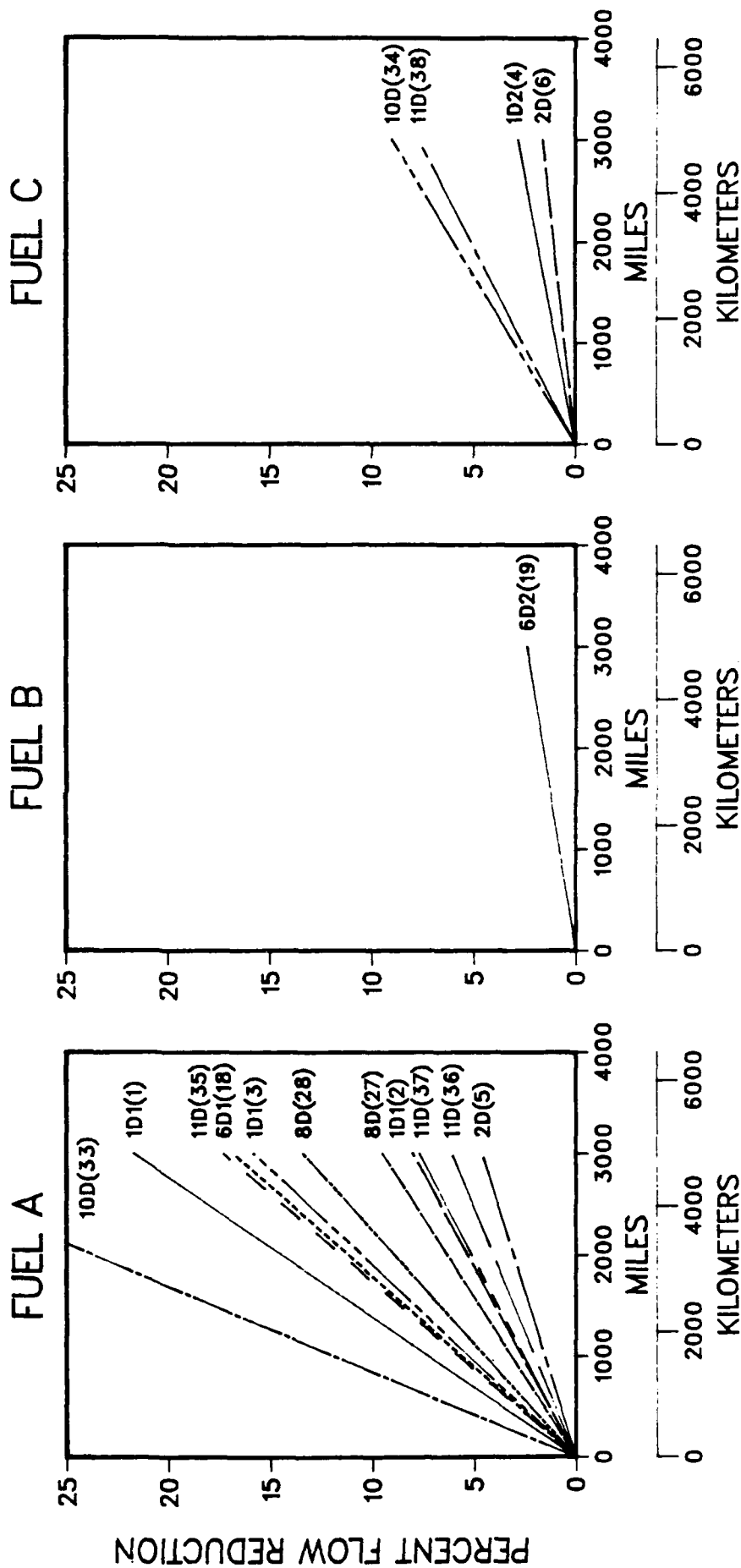


Figure 5
DATA SUMMARY
BASED ON
LEAST SQUARES REGRESSION

CODE: Lab,Car(Run)

CAR MAKE G: 3.8L V-6
Injector Set Average

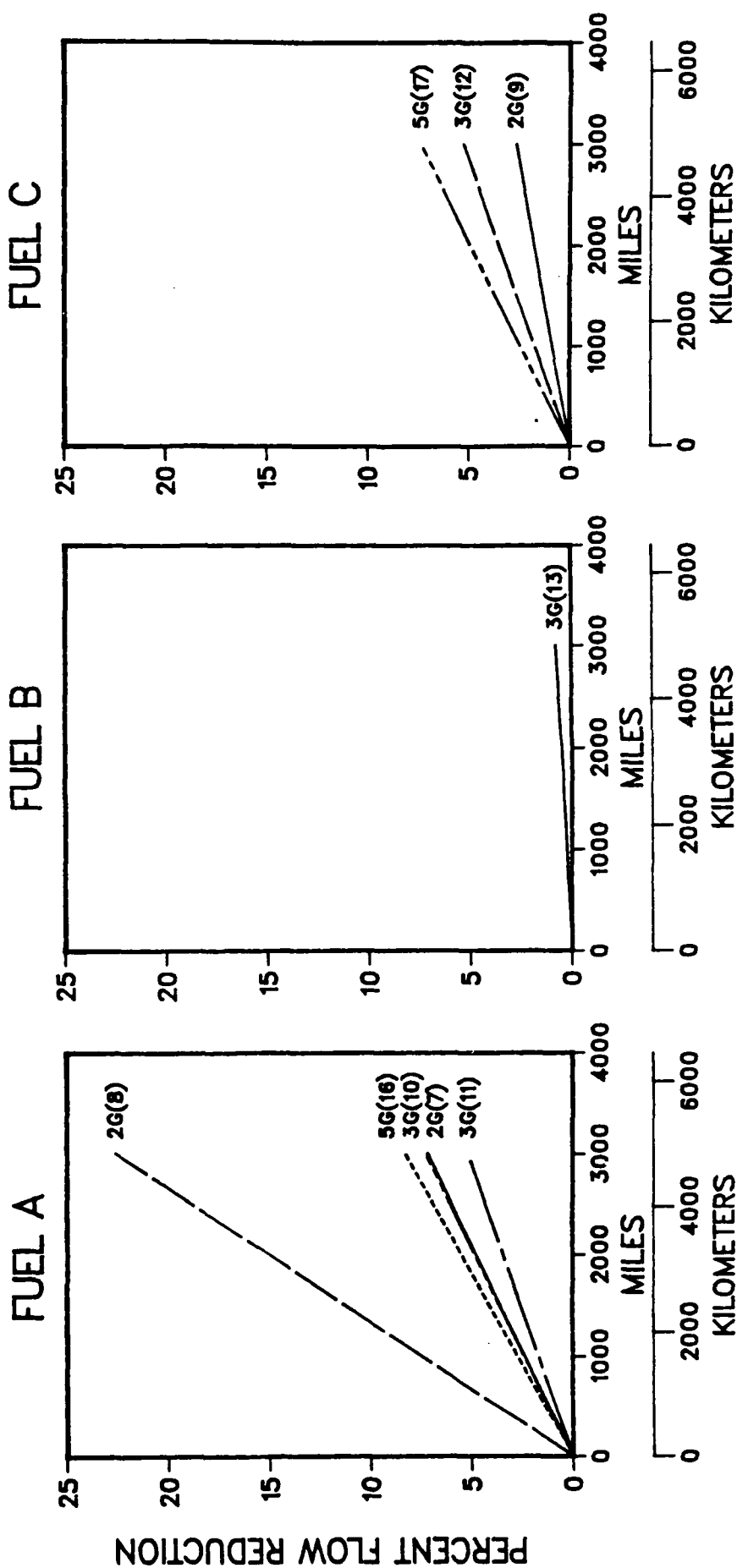


Figure 6
DATA SUMMARY
BASED ON
LEAST SQUARES REGRESSION

CODE: Lab,Car(Run)

CAR MAKES F & L: 5.0L V-8

Injector Set Average

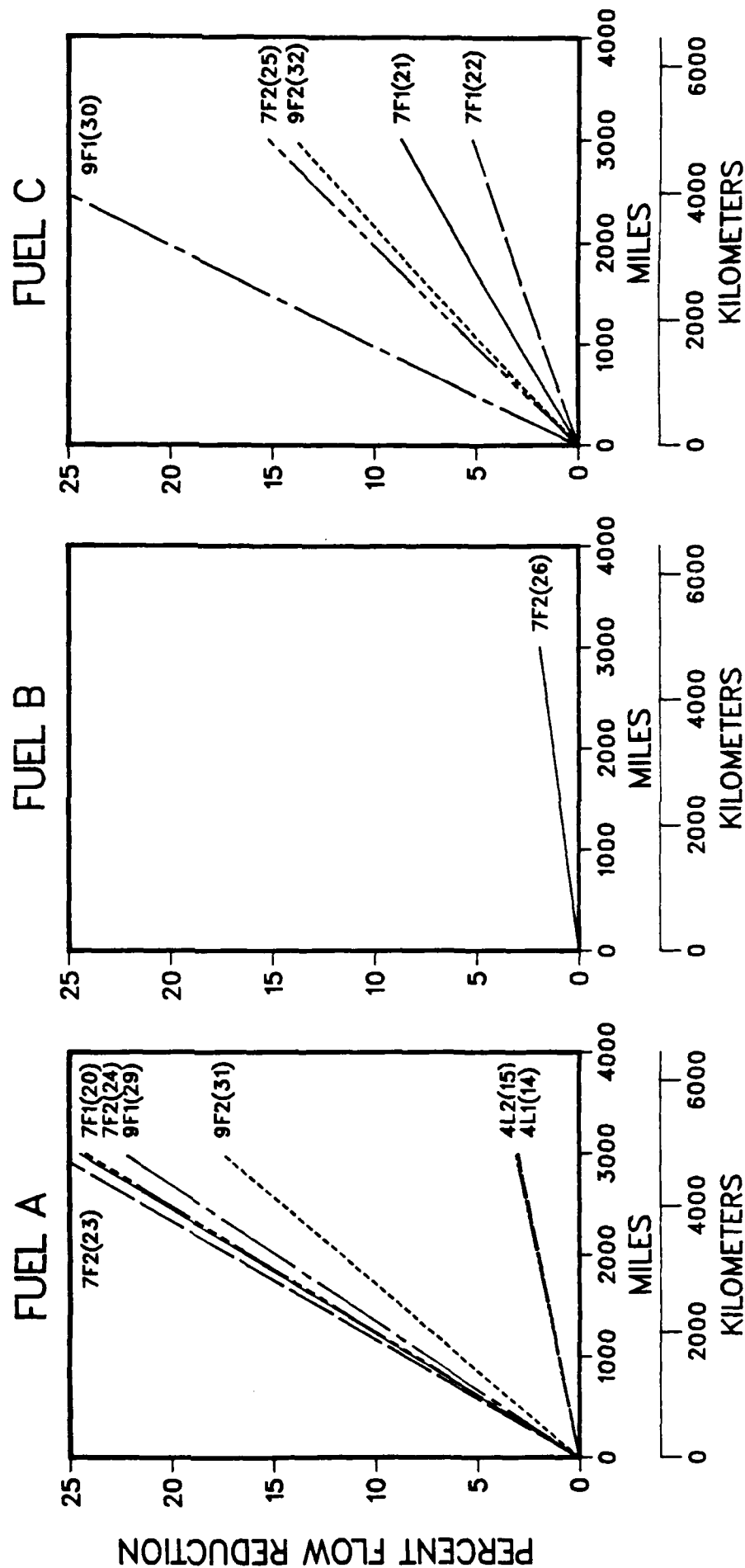


Figure 7A
FUEL A
Injector Set Average

CODE: Lab,Car(Run)

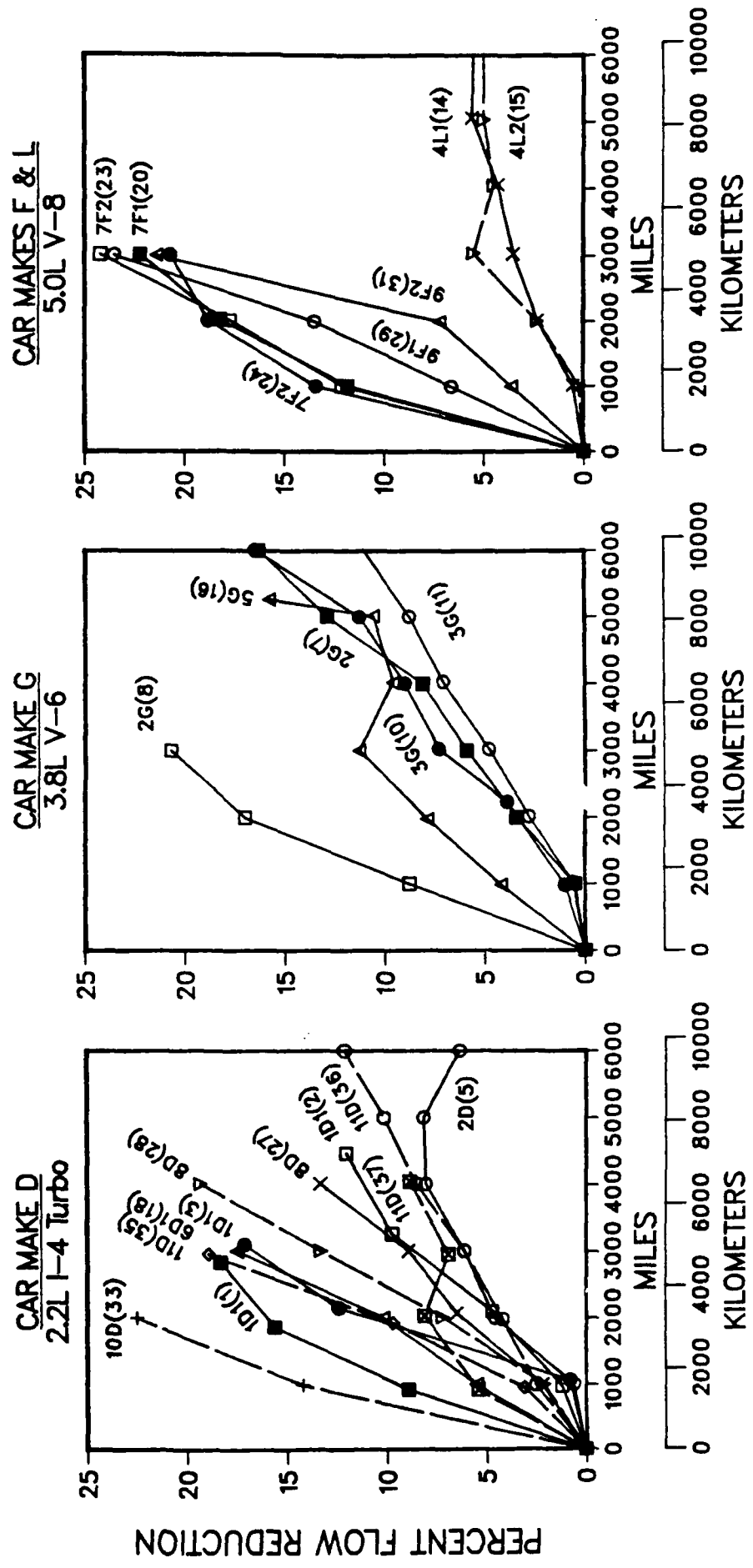


Figure 7B
FUEL A
Worst Injector

CODE: Lab,Car(Run)

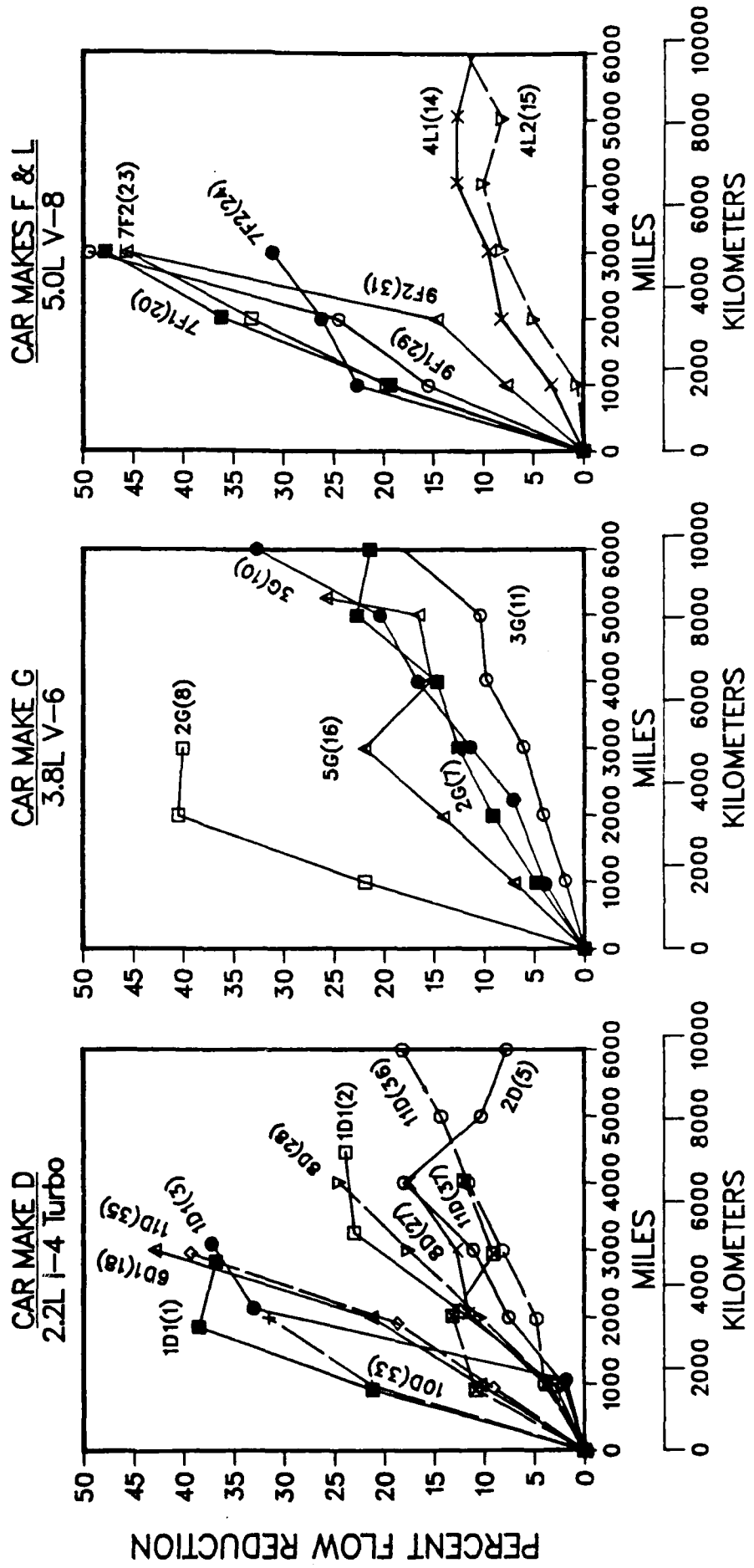
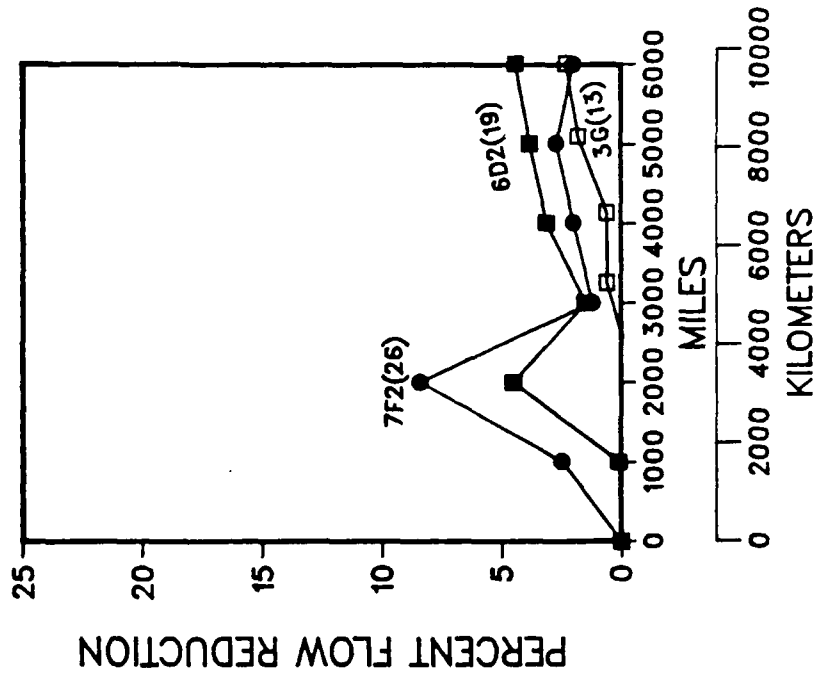


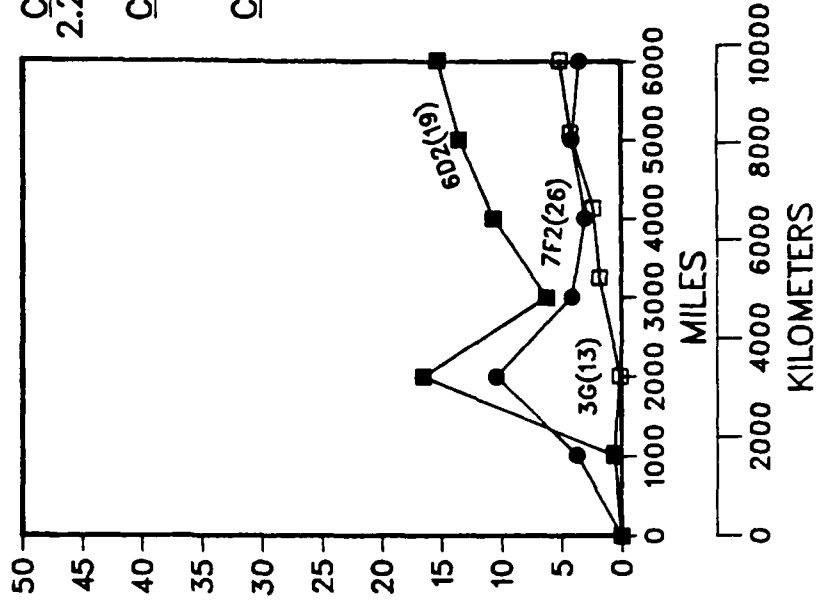
Figure 8
FUEL B

CODE: Lab,Car(Run)

INJECTOR SET AVERAGE



WORST INJECTOR



CAR MAKE D
2.2L I-4 Turbo

CAR MAKE G
3.8L V-6

CAR MAKE F
5.0L V-8

Figure 9A
FUEL C
Injector Set Average

CODE: Lab,Car(Run)

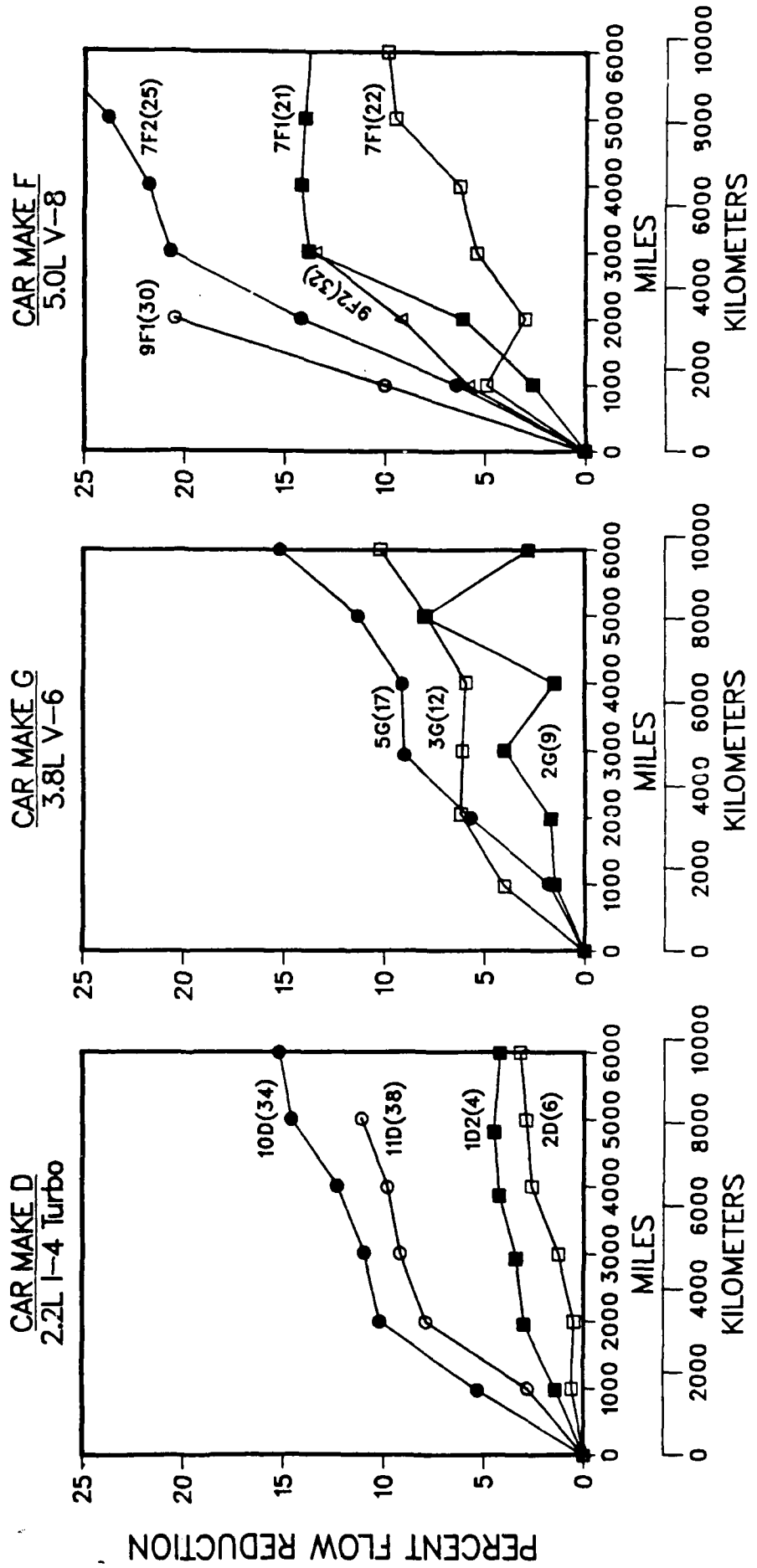


Figure 9B
FUEL C
Worst Injector

CODE: Lab,Car(Run)

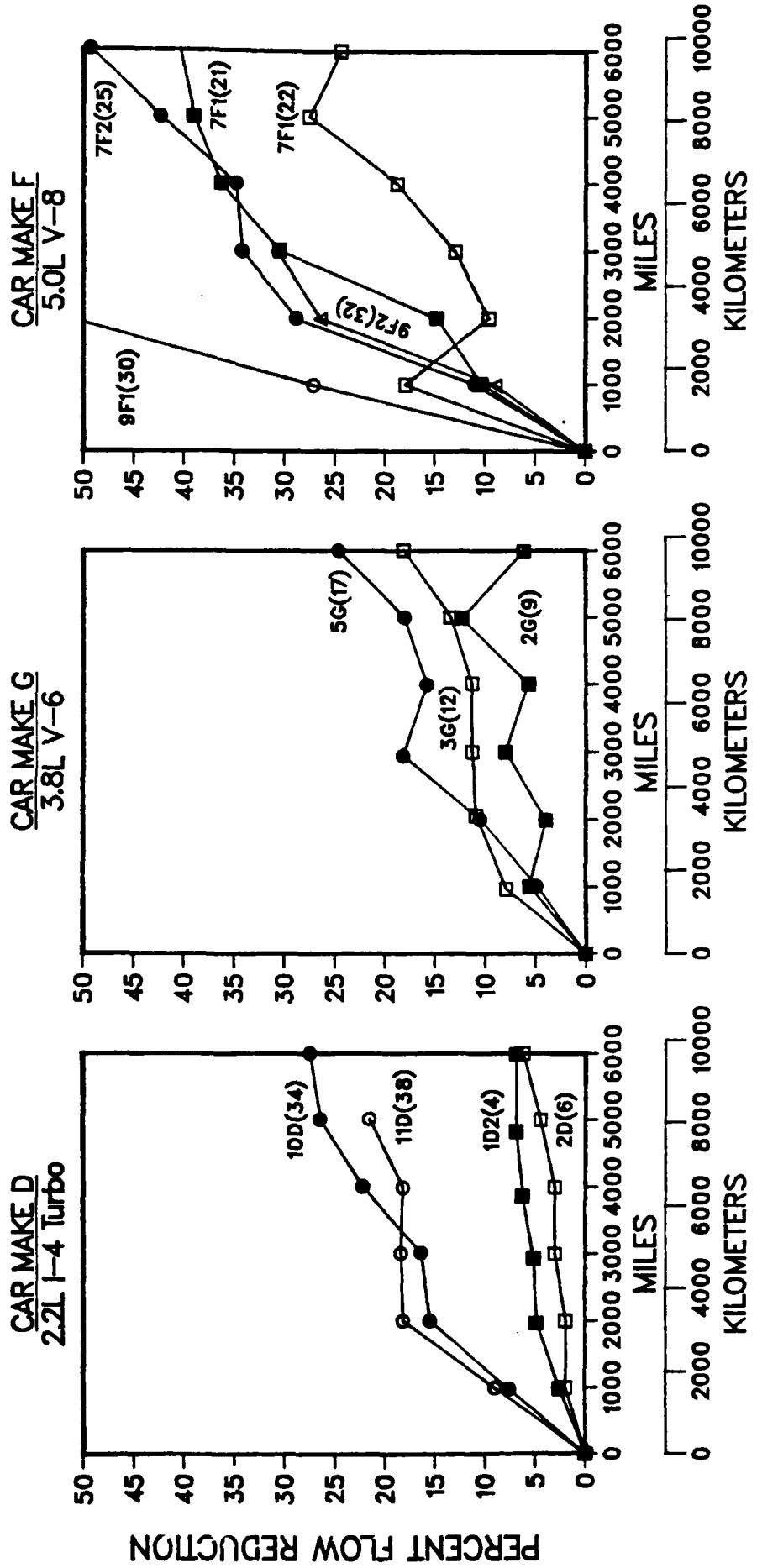
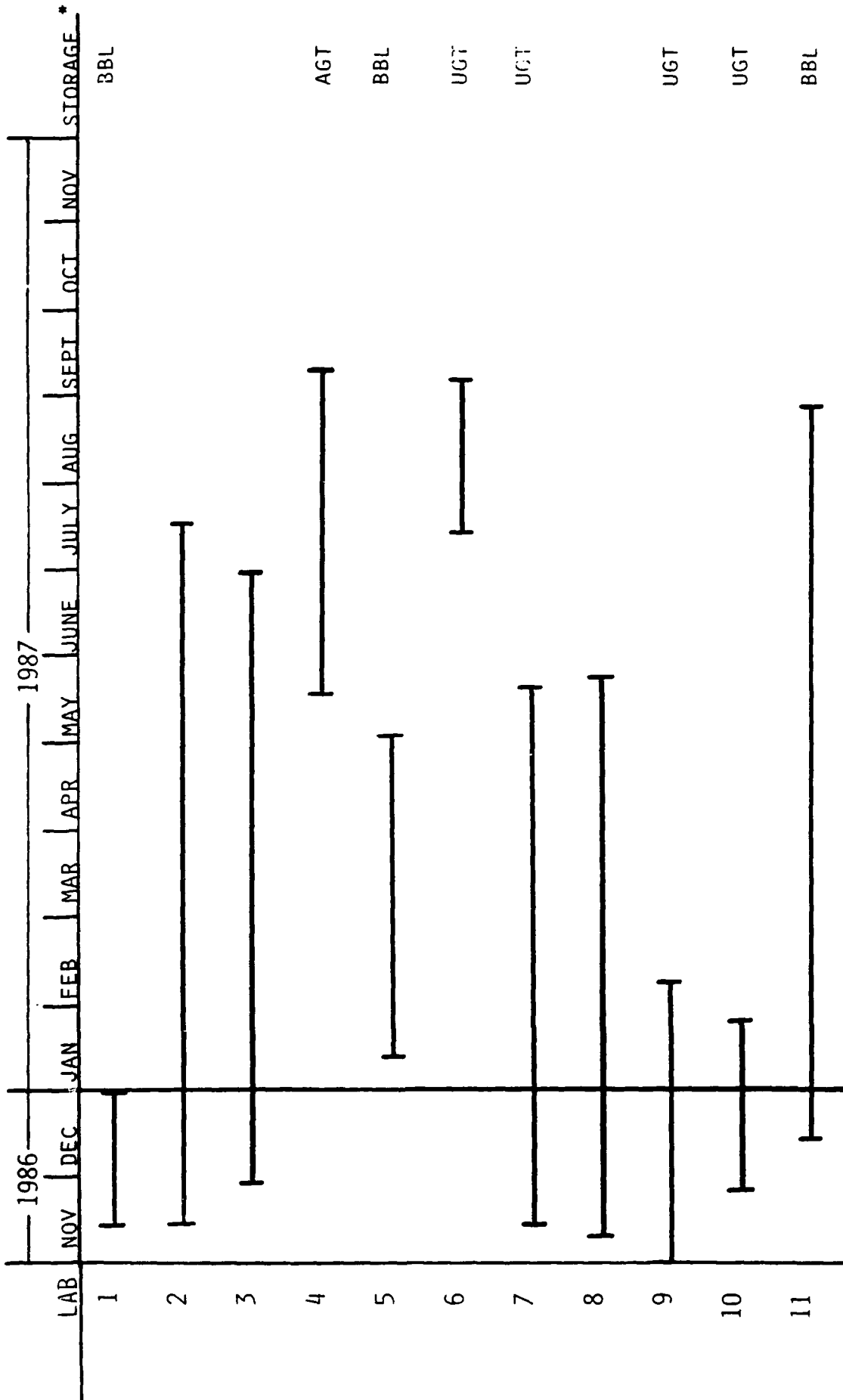


FIGURE 10

PROGRAM TIMING



* FUEL SUPPLY SYSTEM

BBL = 55 GALLON DRUM
 AGT = ABOVE GROUND TANK
 UGT = UNDER GROUND TANK

APPENDIX A

CRC PFI ROUND ROBIN PROGRAM PARTICIPANTS

Amoco Oil Company
Ashland Petroleum Company
Chevron Research Company
E. I. DuPont de Nemours & Co., Inc.
Exxon Research and Engineering Company
General Motors Research Laboratories
The Lubrizol Corporation
Mobil Research and Development Corporation
Nalco Chemical Company
Shell Development Company
Standard Oil Company
Unocal Corporation

CRC PFI ROUND ROBIN ANALYSIS PANEL MEMBERS

R. C. Tupa (Leader)	- The Lubrizol Corporation
L. Jokubaitis	
G. Abramo	- Mobil Research and Development Corp.
L. Beard	- Amoco Oil Company
J. D. Benson	- General Motors Research Laboratories
B. Y. Taniguchi	- Chevron Research Company
T. Wusz	- Unocal Corporation

APPENDIX B

**TEST PROGRAM PLAN FOR
CRC PORT FUEL INJECTOR
DEPOSIT EVALUATION IN VEHICLES

AND

INJECTOR LEAK RATE TEST PROCEDURE**

CRC ROUND ROBIN PFI PROGRAM

Project No. CM-128-85

TABLE OF CONTENTS

Purpose

Program Timing

Program Outline

Test Program

Measurements

Presentation of Data

CRC ROUND ROBIN PFI PROGRAMPURPOSE

The purpose of this program is to evaluate the port fuel injector deposit forming characteristics of test gasolines as a basis for correlation with fuel properties and simple bench screening tests.

Results are necessary to achieve the objectives of the CRC Fuels Task Force and the CRC Bench Test Task Force. The Program will provide a measure of test reproducibility among laboratories and provide the basis for development of a standard CRC test procedure to qualify future test fuels.

PROGRAM TIMING

The sooner the results of this program can be achieved, the greater their value. Questions of work priorities within the participating labs must be recognized. Nevertheless, the following timing targets are suggested as desirable:

- | | |
|---|--------------------|
| 1. Test fuels available to participants | September 15, 1986 |
| 2. Start of testing | October 1, 1986 |
| 3. End of testing | Jan. 2, 1987 |

PROGRAM OUTLINE

A common test procedure will be used to evaluate the deposit forming tendencies of two fuels in each of two port fuel injected cars. Beneficial to the program is a repeat run on one fuel in one car of each laboratory's choice. Any additional repeat runs, though optional, would be very valuable. A third fuel may be offered at a later date.

Required information is measurement of injector flow rates and, where possible, injector tip temperatures. Test duration is 4000 miles (minimum) to 6000 miles (maximum). Other criteria that may be used to determine end of test: 1) 20% avg. plugging or 2) significant driveability disturbance.

Chemical and physical data on the three test fuels will be provided.

TEST PROGRAM

Test Cycle

To minimize variability, all labs are requested to run the following operating conditions:

- 15 minutes at 55 mph (road load); specifics of operation should be the same as previously reported by the labs.
- 45 minutes hot soak - engine shut off.

Vehicle running conditions may be accomplished on a test track, road simulator or chassis dynamometer. It is important that the test vehicles be rapidly brought to 55 mph, as well as back to zero at the end. For open road operations, it is desirable to minimize the travel distance to reach the operating speed of 55 mph. --

For hot soak, no special options are needed, (e.g., blankets, engine shrouds, etc). (The intent is to run vehicles in a realistic way "simulating" customer experience.) Continue hot soaks indoors or outdoors, whatever the previous practice has been at each participating laboratory.

ALL TESTS, INCLUDING REPEAT RUNS, ARE TO START WITH NEW, FLOW-RATED INJECTORS.

Test Fuels

Two full boiling, commercial type unleaded base gasolines (identified as CRC-9-86A and CRC-9-86C) are to be tested in the order given. Each laboratory is requested to make a repeat run on CRC-9-86A in one test vehicle as chosen by each laboratory.

Based on limited vehicle testing, the above fuels have been selected to give high and low injector deposit forming tendencies. Fuel CRC-9-86A is projected to form the most deposits and CRC-9-86C the least.

A third fuel of intermediate deposit forming tendency was originally intended to be included. Variability of the third fuel created uncertainty about its selection. This is being further investigated with the intent of making such a fuel available in the near term. Until then, the program will be based on the high and low deposit fuels.

None of the fuels contain detergent/dispersant additives. Typical properties and analyses for each fuel will be provided to all participants when the fuel batches are made available. Ordering instructions are as follows:

Reference Fuel CRC-9-86A (High Deposit)

Contact: Ashland Petroleum Co.
Attn: L. M. Ferguson
APAL, P.O. Box 391
Ashland, Kentucky 41114

Phone: (606)329-5297

When ordering, refer to "Ashland PFI Reference Fuel, Batch Four" in all correspondence. Price is \$2.50 per gallon bulk, F.O.B. Ashland Terminal at Ironton, Ohio. Requests for drum quantities are discouraged, but can be made available at \$3.00 per gallon.

Reference Fuel CRC-9-85C (Low Deposit)

Contact: Phillips 66 Company
Attn: Linda Remke
6 B2 Adams Building
Bartlesville, Oklahoma 74004

Phone: (918)661-4479

This fuel is from Phillips Batch No. 26. Price at August 22, 1986 was \$1.82 per gallon in tank cars and tank trucks. The price for 55 gallon drums as of August 22 was \$2.43 per gallon, F.O.B. Sweeny, Texas. This fuel is also known, generically, as "Phillips J".

NOTE:

It is recommended that storage of fuels in 55 gallon drums be in a protected area to shield them from rain or other possible water contamination. Whenever possible, inside storage is preferred.

Engine Oil

The same engine oil should be used throughout the program. A single source supply has been arranged so that all participants can use the identical oil which is an SAE 10W-30 viscosity grade of API SE quality.

It was formulated as a standard reference and should be ordered from:

ASTM Test Monitoring Center
4400 Fifth Avenue
Pittsburgh, PA 15213
Attn: Paul R. Eisamann

Phone: (412)268-3314

The oil is referred to as "Oil 200" and is priced at \$35.00 per gallon, F.O.B. Pittsburgh. It will be billed and shipped freight collect against a purchase order from each participating company. When ordering, refer to:

CRC PFI Round Robin Program

For any participant company that is doing motor oil sequence testing, existing purchase order numbers may be used.

Fuel Injectors

OEM part number injectors ONLY are to be used as manufactured by Bosch.

MEASUREMENTSVehicle Performance

All test cars should be tuned and perform according to manufacturer's specifications. To avoid any variability due to engine break-in-effects, testing should begin only after 4000 or more odometer miles have been accumulated.

Test Fuels

Two full boiling, commercial type unleaded base gasolines are to be tested. Based on limited vehicle testing, they have been selected to give high and low injector deposit forming tendencies. Fuel A is projected to form the most deposits and Fuel C the least.

THE ORDER OF FUEL TESTING WILL BE: FUEL A FOLLOWED BY FUEL C.

The fuels do not contain detergent/dispersant additives. Typical properties and analyses are given for each fuel in the Appendix.

As a check on fuel uniformity, each lab is asked to run the following tests for each fuel upon shipment arrival and at the end of the test program:

- D381 (gum)
- D525 (stability)
- R.V.P.
- ASTM distillation

Engine Oil

The same crank case engine oil should be used throughout the program by all labs. Each test run should be flushed with fresh oil following an oil filter change. Drain the oil, change filter, and put in a fresh change of the same oil for the test.

Because of the limited mileage of each test, it is not considered necessary to save or analyze drain samples. Any such measurements are at the discretion of each participant.

Fuel Rail Pressure

The injector fuel rail pressure in the vehicle must be at manufacturer's specified level. A malfunctioning pressure regulator will cause decreasing rail pressure which can cause a decrease in deposit formation. Check this pressure at least once each day.

Injector Flow Ratings

1. The laboratory flow apparatus should deliver the same fuel rail pressure as specified for the vehicle.
2. A light hydrocarbon (isooctane, mineral spirits or Stoddard solvent) should be used for flow testing. The intent is for each lab to continue a consistent practice.
3. Hold the injector open wide for ten seconds. A longer time interval may risk overheating the injector solenoid. The timing interval must be precise, and reported to hundredths of a second. Bosch indicates injectors will open fully at 8 volts DC without risk of overheating, which would allow longer flow times to improve measurement accuracy.
4. A minimum of three repeat flow rate tests per injector are considered necessary. If necessary, additional tests must be run until repeat results have less than 1% variability. 1% variability is a reasonable expectation for new injectors. The average (to two decimal places) should be reported as the flow rate for that injector measurement.

An alternate technique that may improve measurement precision is to flow test injectors against a clean reference injector. Duplicate flow tests have shown standard deviations less than 0.1%. Also, the test injectors are subjected to less volume of testing fluids.

5. Injectors should be rated as soon as possible after removal from the vehicle to avoid drying out and possible effects on deposit stability. If any extended storage becomes necessary, the injectors should be put in a tightly sealed glass container.
6. For clean injectors at the start of each test, run the Injector Leak Rate Test to check for leaking, dribbling, etc. (See page B-9.)
As injectors become fouled, the probability of pintle leakage increases. Deposit formation may cause an improper seal between pintle and injector opening, thus causing leakage.

Upper production limit of leakage with air is 2cc per min. (at approx. 50 psig). Injectors above this rate should be rejected for test.

To avoid unnecessary rejection of new injectors due to dirt particles, the injectors should be first flowed with liquid. This will serve to flush the critical internal areas before leak testing with air.

7. Rate injectors every 1000 miles.
8. For new injectors, flow rates within a test set for an engine should fall within $\pm 2\%$ of each other.

Temperature Measurement

Each laboratory should measure:

1. Ambient at test site (maximum and minimum for every 24 hour time period).
2. Injector tips.
3. Inlet air, coolant, oil and fuel tank.

For items 2 and 3, report typical maximum temperatures during operations for each 24 hour test period.

Injectors with thermocouples should be installed as follows:

<u>No. of Engine Cylinders</u>	<u>Thermocouple Injector Location</u>
4	Cylinder #1
6 or 8	Cylinder #1 and a second cylinder as chosen by each test lab.

A service to install thermocouples on flowed injectors supplied by each participant is available through:

Mr. Earl Grates
13214 Culver
Utica, MI 48087

Phone: (313)986-1912 (call after 4:00 p.m.)

Cost is \$50/installation to be covered by each participant. A type K thermocouple will be used and a six inch lead with a connector will be attached.

Fuel Consumption

For each test, the fuel consumed per odometer miles traveled should be recorded with reasonable accuracy. Use of a standard gasoline dispensing pump is satisfactory. One Average per test program is a representative measurement.

PRESENTATION OF DATA

Each laboratory is requested to provide the following in their final report:

1. Total number of soak cycles.
2. Tabulation of raw flow rates for each injector by cylinder position.
3. Number of soak cycles for each 1000 mile interval.
4. Graphs of flow rates vs. vehicle miles per car per fuel. In order to expedite coordination of results, each laboratory is asked to plot graphs using the following coordinates:
 - a. X-axis (vehicle miles) - 0 to 6000 in increments of 1000.
 - b. Y-axis (flow rates - g/sec) - 3.6 to 2.0 in increments of 0.1 for Chryslers' cars, 2.9 to 1.8 in increments of 0.1 for GM cars. (Above subject to change only if results exceed specified values.)
5. Graphs of Σ flow restrictions for each injector per car per tankful.
 - a. X-axis - same as 2a.
 - b. Y-axis - 30 to 0 in increments of 1.

Standardized data sheets will be issued to the participants prior to testing. A Lotus spreadsheet for reporting of data will be available for those interested.

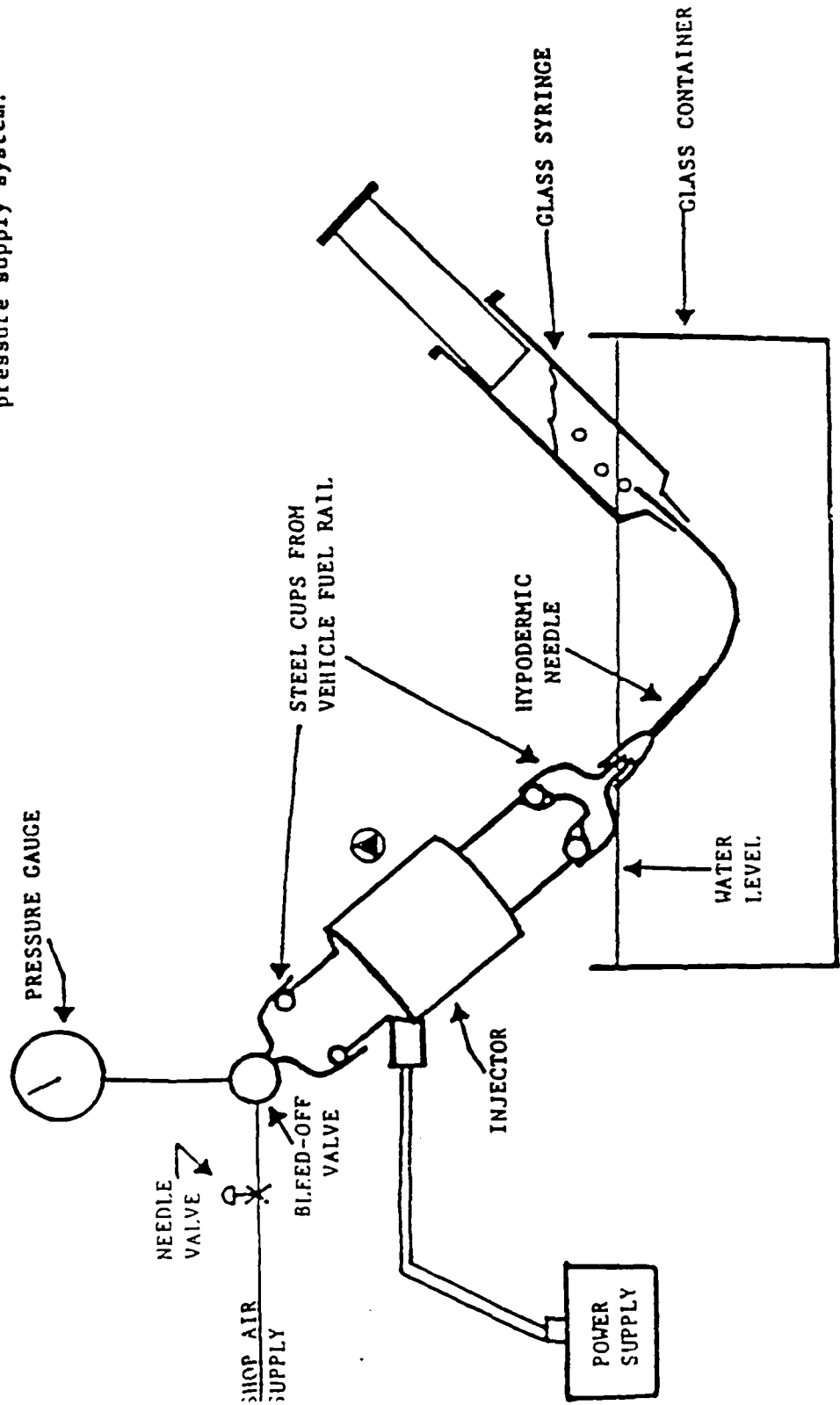
It is recognized that some companies desire to make interim injector pressure drop measurements without removing injectors. If a laboratory's experience shows a close correlation between these measurements and actual flow rates and vehicle performance, these supplemental data should be reported. However, the primary data required are actual injector flow rate measurements at the beginning, at each 1,000 mile interval and at the end of the testing.

INJECTOR LEAK RATE
TEST PROCEDURE

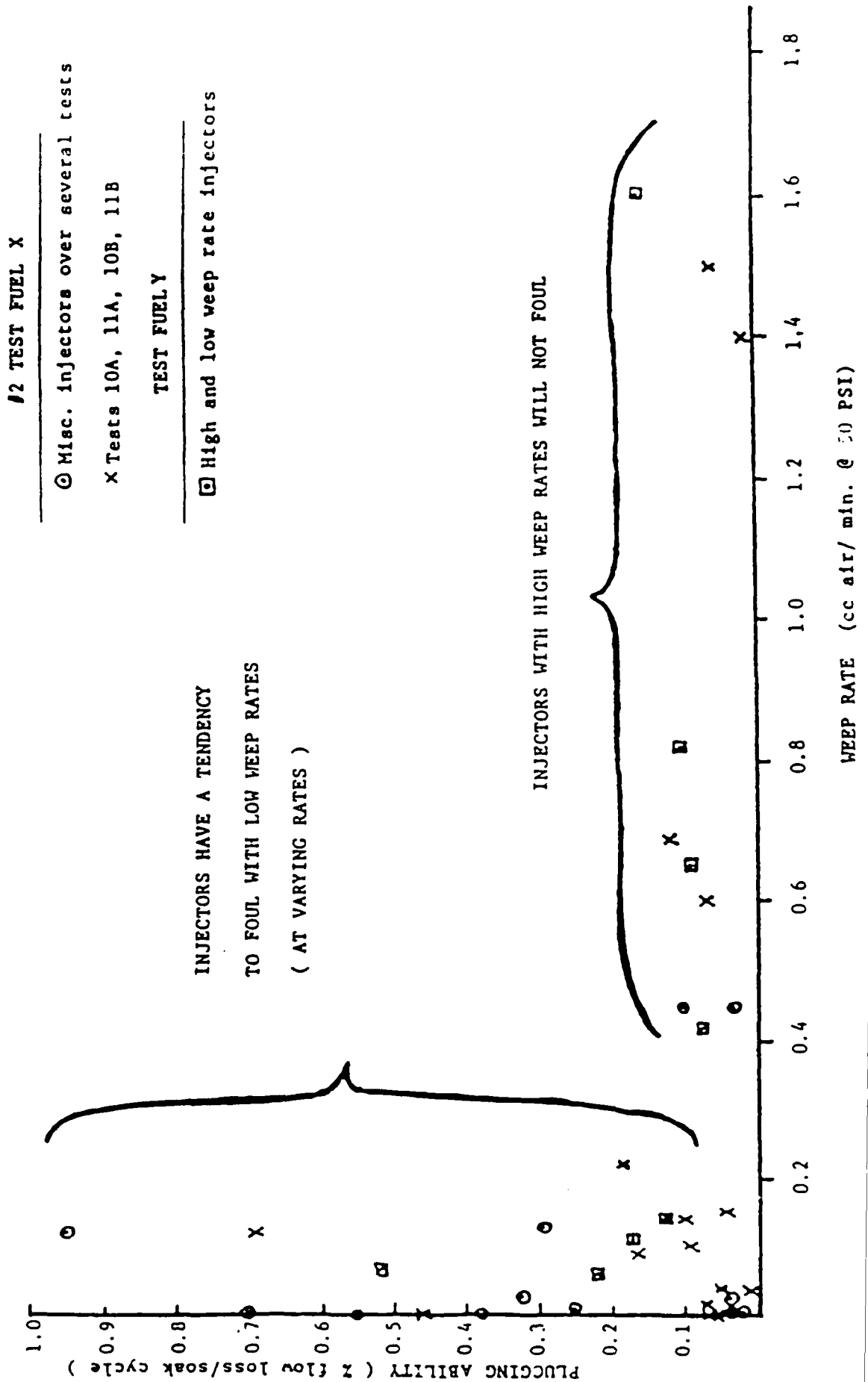
1. Blow any residual fluids out of the injector with clean, dry shop air while holding the injector open.
2. While the injector is still open, rinse with acetone and blow dry. Repeat.
3. Mount injector in rig and attach hypodermic needle assembly as in the diagram.
4. Place a 5 ml, water-filled syringe over the hypodermic needle tip for gas collection and volumetric measurements at 0.25, 1.0 and 5.0 ml. Immerse in bath as illustrated.
5. Apply 50 PSI air pressure and collect the air bubbles at the hypodermic needle tip using the 5 ml syringe measured over a suitable time period.
6. Record results as ml's of air collected per one minute time period.
7. Repeat until 3 consecutive results in the same range are obtained.

INJECTOR LEAK TEST APPARATUS

- Ⓐ NOT SHOWN: A clamping device which holds the injector body into the air pressure supply system.



INJECTOR PLUGGING VS. WEEP RATE



APPENDIX C

**VEHICLE DESCRIPTIONS
AND
PROGRAM SUMMARY**

Table C-1
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
VEHICLE DESCRIPTIONS AND PROGRAM SUMMARY

VEHICLE DESCRIPTION							VEHICLE DESCRIPTION										FUEL ECONOMY		FUEL CONSUMPTION				
Run	Lab	Car	Fuel	Reps	Code	Year	Make	Model	Trans	A/C?	Cyls	Disp. L	Turbo?	Comp. Ratio	Start Date	End Date	Days Run	Total Cycles	Total Miles	Cycles per 1000 mi.	Cycles per 1000 km	FUEL ECONOMY mi/gal.	FUEL CONSUMPTION L/100-km
(1)	1	D1	A	1/3	101-A1	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	10-Nov-86	03-Dec-86	24	236	2830	83.4	51.7	21.2	11.1
(2)	1	D1	A	2/3	101-A2	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	15-Dec-86	23-Jan-87	40	360	4455	80.8	50.1	21.4	10.9
(3)	1	D1	A	3/3	101-A3	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	15-Oct-87	08-Dec-87	55	309	3091	100.0	62.0		
(4)	1	D2	C	1/1	102-C	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	27-Oct-86	11-Dec-86	46	497	5987	83.0	51.5	21.8	10.8
(5)	2	D	A	1/1	20-A	1984	D	E	Auto	Yes	4	2.2	Yes	8.5				408	5995	68.1	42.2	31.9	7.4
(6)	2	D	C	1/1	20-C	1984	D	E	Auto	Yes	4	2.2	Yes	8.5				409	6000	68.2	42.3	31.3	7.5
(7)	2	G	A	1/2	26-A1	1985	G	O	Auto	Yes	6	3.8	No					415	6000	69.2	42.9	32.0	7.3
(8)	2	G	A	2/2	26-A2	1985	G	O	Auto	Yes	6	3.8	No					205	2994	68.5	42.5		
(9)	2	G	C	1/1	26-C	1985	G	O	Auto	Yes	6	3.8	No					423	5998	70.5	43.7		
(10)	3	G	A	1/2	36-A1	1986	G	T	Auto	Yes	6	3.8	No	8.5	04-Mar-87	25-Mar-87	22	445	6007	74.1	45.9		
(11)	3	G	A	2/2	36-A2	1986	G	T	Auto	Yes	6	3.8	No	8.5	11-Jun-87	22-Jul-87	42	451	6185	72.9	45.2		
(12)	3	G	C	1/1	36-C	1986	G	T	Auto	Yes	6	3.8	No	8.5	20-Apr-87	08-May-87	19	435	6014	72.3	44.8		
(13)	3	G	B	1/1	36-B	1986	G	T	Auto	Yes	6	3.8	No	8.5	23-Mar-87	16-Apr-87	25	431	6013	71.7	44.4		
(14)	4	L1	A	1/1	41-A	1986	L	P	Auto	Yes	8	5.0	No	8.9	26-May-87	17-Aug-87	84	607	6067	100.0	62.0	20.2	11.6
(15)	4	L2	A	1/1	41-A	1986	L	P	Auto	Yes	8	5.0	No	8.9	05-Sep-87	11-Oct-87	37	607	6068	100.0	62.0	19.7	11.9
(16)	5	G	A	1/1	56-A	1986	G	T	Auto	Yes	6	3.8	No	8.5	09-Apr-87	28-Apr-87	20	354	5262	67.3	41.7		
(17)	5	G	C	1/1	56-C	1986	G	T	Auto	Yes	6	3.8	No	8.5	29-Apr-87	22-May-87	24	411	6007	68.4	42.4		
(18)	6	D1	A	1/1	601-A	1984	D	Y	Auto	Yes	4	2.2	Yes	8.5	30-Jul-87	10-Aug-87	12	228	3000	76.0	47.1	13.2	17.8
(19)	6	D2	B	1/1	602-B	1984	D	Y	Auto	Yes	4	2.2	Yes	8.5	06-Aug-87	27-Aug-87	22	455	6008	75.7	47.0	13.2	17.8
(20)	7	F1	A	1/1	71-A	1985	F	R	Auto	Yes	8	5.0	No	9.5	12-Nov-86	08-Dec-86	27	219	3007	72.8	45.2	25.6	9.2
(21)	7	F1	C	1/2	71-C1	1985	F	R	Auto	Yes	8	5.0	No	9.5	05-Jan-87	19-Feb-87	46	438	6016	72.8	45.1	28.9	8.1
(22)	7	F1	C	2/2	71-C2	1985	F	R	Auto	Yes	8	5.0	No	9.5	24-Feb-87	13-Apr-87	49	436	6001	72.7	45.0	25.5	9.2
(23)	7	F2	A	1/2	71-A	1985	F	R	Auto	Yes	8	5.0	No	9.5	12-Nov-86	09-Dec-86	28	219	3013	72.7	45.1	25.8	9.1
(24)	7	F2	A	2/2	72-A	1985	F	R	Auto	Yes	8	5.0	No	9.5	24-Feb-87	13-Mar-87	18	218	3002	72.6	45.0	21.4	11.0
(25)	7	F2	C	1/1	72-C	1985	F	R	Auto	Yes	8	5.0	No	9.5	05-Jan-87	19-Feb-87	46	437	6010	72.7	45.1	28.6	8.2
(26)	7	F2	B	1/1	72-B	1985	F	R	Auto	Yes	8	5.0	No	9.5	02-Sep-87	12-Nov-87	72	436	6002	72.6	45.0	32.8	7.2
(27)	8	D	A	1/2	80-A1	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	15-Dec-86	04-Mar-87	80	321	4000	80.3	49.8	23.9	9.8
(28)	8	D	A	2/2	80-A2	1985	D	H	Auto	Yes	4	2.2	Yes	8.5	11-Mar-87	16-Apr-87	37	317	4001	79.2	49.1	24.9	9.4
(29)	9	F1	A	1/1	91-A	1986	F	R	Auto	Yes	8	5.0	No	9.3	Dec-86		31	231	3000	77.0	47.7	21.6	10.9
(30)	9	F1	C	1/1	91-C	1986	F	R	Auto	Yes	8	5.0	No	9.3	Jan-87		28	154	2000	77.0	47.7	22.4	10.5
(31)	9	F2	A	1/1	91-A	1986	F	R	Auto	Yes	8	5.0	No	9.3	Dec-86		23	231	3000	77.0	47.7	18.9	12.4
(32)	9	F2	C	1/1	91-C	1986	F	R	Auto	Yes	8	5.0	No	9.3	Jan-87		28	231	3000	77.0	47.7		
(33)	10	D	A	1/1	100-A	1985	D	J	Auto	Yes	4	2.2	Yes	8.5	01-Dec-86	09-Dec-86	9	143	1998	71.6	44.4	20.6	11.4
(34)	10	D	C	1/1	100-C	1985	D	J	Auto	Yes	4	2.2	Yes	8.5	09-Dec-86	12-Jan-87	35	430	6000	71.7	44.4	21.7	10.8
(35)	11	D	A	1/3	110-A1	1986	D	H	Auto	Yes	4	2.2	Yes	8.5	16-Jan-87	13-Feb-87	29	291	2954	98.5	61.1	23.8	9.9
(36)	11	D	A	2/3	110-A2	1986	D	H	Auto	Yes	4	2.2	Yes	8.5	13-May-87	13-Jul-87	62	579	5994	96.6	59.9	22.7	10.3
(37)	11	D	A	3/3	110-A3	1986	D	H	Auto	Yes	4	2.2	Yes	8.5	27-Oct-87	10-Dec-87	45	387	4029	96.1	59.6		
(38)	11	D	C	1/1	110-C	1986	D	H	Auto	Yes	4	2.2	Yes	8.5	26-Mar-87	12-May-87	48	485	5009	96.8	60.0	23.3	10.1

Table C-1
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
VEHICLE DESCRIPTIONS AND PROGRAM SUMMARY
(Continued)

Run		Lab	Car	Fuel	Reps	Code	Year	Make	Model	Trans	A/C?	Cyls	Disp. L	Turbo?	Comp. Ratio	Start Date	End Date	Days Run	Total Soak Cycles	Total Miles	Cycles per 1000 mi.	Cycles per 1000 km	FUEL ECONOMY mi/gal.	FUEL CONSUMP. L/100-km
(39)	12	D	A	1/1 EXCLUDED*			1985	D	J	Auto	Yes	4	2.2	Yes	8.5	06-Feb-87	24-Mar-87	47	401	6021	66.6	41.3		
(40)	12	D	C	1/1 EXCLUDED*			1985	D	J	Auto	Yes	4	2.2	Yes	8.5	24-Mar-87	24-Apr-87	32	400	6002	66.6	41.3		
(41)	12	S	A	1/1 EXCLUDED*			1986	S	W	Auto	Yes	6	2.8	No	9.2	07-Feb-87	20-Mar-87	42	400	6000	66.7	41.3		
(42)	12	S	C	1/1 EXCLUDED*			1986	S	W	Auto	Yes	6	2.8	No	9.2	26-Mar-87	07-May-87	43	400	6006	66.6	41.3		

* Data Incomplete

APPENDIX D

TEST FUEL INSPECTIONS

Table D-1
FUEL A ANALYSIS
(Start/End of Test)

Laboratory	Existent Gum, D 381		Induction Period D 525 minutes	Reid Vapor Pressure psi (kPa)	Distillation, D 86, C			
	Unwashed mg/100 mL	Washed mg/100 mL			IBP	10%	50%	90% EP
1	4.4 / -	3.8 / -	- / -	12.5 / - (86)/ -	28 / -	45 / -	104 / -	188 / - 221 / -
2	10.0 / 17.0	4.8 / 11.2	216 / -	12.6 / 12.0 (87)/ (82)	26 / 22	43 / 36	101 / 94	177 / 174 224 / 212
3	10.0 / 17.2	1.9 / 5.0	240 / 210	12.0 / 12.0 (82)/ (82)	31 / 33	46 / 47	103 / 103	180 / 184 226 / 219
4	9.0 / 5.8	4.0 / 5.6	255 / 255	10.1 / 8.1 (69)/ (56)	32 / 36	50 / 51	103 / 106	182 / 182 220 / 223
5	17.0 / 21.0	11.0 / 15.0	282 / 212	12.3 / 12.1 (85)/ (83)	27 / 29	43 / 44	102 / 101	182 / 184 218 / 222
6	14.8 / 15.6	3.4 / 3.8	290 / 295	- / -	30 / 32	44 / 47	103 / 101	192 / 196 215 / 217
7	5.2 / 11.2	3.0 / 9.2	- / -	- / -	31 / 29	47 / 47	105 / 105	185 / 185 222 / 223
8	8.8 / 8.3	2.4 / 4.6	240 / 265	12.0 / 12.0 (82)/ (82)	25 / 24	44 / 44	102 / 103	187 / 186 223 / 222
9	7.0 / 4.2	6.0 / 3.0	270 / 150	11.9 / 11.1 (82)/ (76)	32 / 28	48 / 46	106 / 108	188 / 192 218 / 218
10	13.8 / 14.2	4.1 / 3.8	285 / 300	12.3 / 11.6 (85)/ (80)	26 / 29	41 / 43	99 / 100	179 / 177 222 / 216
11	5.0 / 8.0	3.0 / 5.0	240 / 180	- / -	32 / 29	44 / 45	102 / 104	179 / 181 227 / 227

Table D-11
FUEL B ANALYSIS
(Start/End of Test)

Laboratory	Existent Gum, D 381		Induction Period D 525 minutes	Reid Vapor Pressure psi (kPa)	Distillation, D 86, C				
	Unwashed mg/100 mL	Washed mg/100 mL			18P	10%	50%	90%	EP
3	3.8 / -	0.6 / -	360+/-	8.9 / - (61)/ -	37 / -	57 / -	103 / -	162 / -	205 / -
6	2.2 / 2.6	0.2 / 0.6	- / -	- / -	39 / 37	59 / 61	111 / 112	175 / 177	202 / 204
7	3.8 / -	1.0 / -	- / -	- / -	33 / -	55 / -	104 / -	162 / -	199 / -

Table D-III
FUEL C ANALYSIS

(Start/End of Test)

Laboratory	Existent Gum, D 381		Induction Period D 525 minutes	Reid Vapor Pressure psi (kPa)	Distillation, D 86, C				
	Unwashed mg/100 mL	Washed mg/100 mL			IBP	10%	50%	90%	EP
1	0.4 / -	0.4 / -	- / -	7.7 / - (53)/	34 / -	54 / -	104 / -	157 / -	219 / -
2	0.4 / 0.8	0.3 / 0.6	1485 / -	7.5 / 7.6 (52)/ (52)	38 / 30	55 / 53	108 / 107	167 / 164	227 / 218
3	2.0 / 3.8	0.1 / 2.0	360+ / 360+	7.5 / 7.5 (52)/ (52)	35 / 39	53 / 57	106 / 109	180 / 170	214 / 217
5	2.0 / 2.0	1.0 / 1.0	1200 / 1200	8.1 / 8.0 (56)/ (55)	35 / 36	53 / 52	106 / 107	169 / 167	221 / 218
7	1.0 / 0.8	0.6 / 0.4	- / -	- / -	39 / 38	58 / 57	112 / 111	174 / 172	222 / 222
9	- / 6.0	- / 1.6	- / 1410+	- / 6.9 / (47)	- / 37	- / 56	- / 111	- / 177	- / 215
10	3.2 / 1.9	0.2 / 0.4	No / No Break Break	7.2 / 6.6 (49)/ (45)	36 / 36	53 / 56	105 / 108	166 / 168	218 / 211
11	2.0 / 2.0	1.0 / 2.0	1440+ / -	- / 6.3 (43)	34 / 37	57 / 60	109 / 111	165 / 169	229 / 226

APPENDIX E

LABORATORY OPERATING CONDITIONS

TABLE E-1
METHOD OF TESTING
BY PARTICIPATING LABORATORIES

LAB	LOCATION FOR ACCUMULATING CYCLES *		COMMENTS
	15-Minute Run Segment	45-Minute Soak Segment	
1	Outdoors on Road	Outdoors (Days) Indoors (Nights)	
2	Indoors on CD	Indoors	Used hood shield to elevate injector temperature (Run 8, Car Make G, Fuel A)
3	Outdoors on Sheltered MAD	Outdoors on Sheltered MAD	Rail pressure decreases were detected during Run (12). Regulator and fuel pump were replaced during next run (11) but min pressures remained low.
4	Outdoors on Road	Enclosure at 21 C	
5	Outdoors on MAD	Outdoors on MAD	
6	Outdoors on MAD	Outdoors on MAD	
7	Outdoors on MAD	Outdoors on MAD	
8	Outdoors on Road	Indoors (Heated Garage)	
9	Outdoors on MAD	Outdoors on MAD	
10	Outdoors on MAD	Outdoors on MAD	
11	Outdoors on Road	Outdoors	
12	Outdoors on MAD	Outdoors on MAD	

* CD = Chassis Dynamometer, Dual Roll Type
MAD = Mileage Accumulation Dynamometer, Single Roll Type

APPENDIX F

INJECTOR FLOW DATA

MASTER DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)										
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST
(1)	1	D1	A	1/3	Nov-86	24	0 1000 2000 3000 4000 5000 6000	0 919 1860 2830	3.49 3.29 3.06 2.77	3.53 2.78 2.17 2.23	3.50 3.41 3.36 3.27	3.50 3.29 3.24 3.18				3.51 3.19 2.96 2.86	0.0 5.7 12.3 20.6	0.0 21.2 38.5 36.8	0.0 2.6 4.0 6.6	0.0 6.0 7.4 9.1					0.0 8.9 15.6 18.3	0.0 21.2 38.5 36.8
							Leak Test, ml-air/min.																			
(2)	1	D1	A	2/3	Dec-86	40	0 1000 2000 3000 4000 5000 6000	0 978 2095 3251 4455	0.52 3.48 3.38 2.68 2.65	0.00 3.46 3.45 3.16 2.96	0.00 3.46 3.42 3.31 3.25	0.94 3.49 3.48 3.39 3.37				0.37 3.47 3.43 3.31 3.14 3.06	0.0 2.9 12.4 23.0 23.9	0.0 0.3 2.3 8.7 14.5	0.0 1.2 2.9 4.3 6.1	0.0 0.3 2.9 3.4					0.0 1.2 4.7 9.7 12.0	0.0 2.9 12.4 23.0 23.9
							Leak Test, ml-air/min.																			
(3)	1	D1	A	3/3	Oct-87	55	0 1000 2000 3000 4000 5000 6000	0 1063 2141 3091	0.84 3.51 3.48 3.19 2.96	0.00 3.52 3.48 3.34 3.09	0.00 3.43 3.44 3.35 3.31	0.00 3.45 3.38 2.31 2.16				0.21 3.48 3.45 3.05 2.88	0.0 0.7 9.2 15.6	0.0 1.0 5.1 12.2	0.0 -0.3 2.3 3.6	0.0 1.8 33.0 37.2					0.0 0.8 12.4 17.1	0.0 1.8 33.0 37.2
							Leak Test, ml-air/min.																			
(4)	1	D2	C	1/1	Oct-86	46	0 1000 2000 3000 4000 5000 6000	0 985 1963 2931 3864 4820 5987	0.00 3.48 3.43 3.37 3.31 3.26 3.26	0.00 3.49 3.48 3.47 3.49 3.46 3.47	0.00 3.50 3.41 3.29 3.28 3.25 3.22	0.00 3.41 3.38 3.38 3.36 3.37 3.39				0.00 3.48 3.43 3.38 3.34 3.33 3.34	0.0 1.4 3.2 4.9 6.3 6.3	0.0 0.3 0.6 0.0 0.6 0.9	0.0 1.4 4.9 5.2 6.1 6.9	0.0 2.6 3.4 3.4 4.0 3.7					0.0 1.4 3.0 3.4 4.2 4.5 4.2	0.0 2.6 4.9 5.2 6.3 6.9 6.9
							Leak Test, ml-air/min.																			

Table F-11
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)													
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST			
(5)	2	D	A	1/1			0	2.89	2.82	2.81	2.84					2.84	0.0	0.0	0.0	0.0							0.0	0.0	
							1000	998	67	2.83	2.82	2.83	2.81			2.82	2.1	0.0	-0.7	1.1							0.6	2.1	
							2000	2001	136	2.67	2.68	2.74	2.75			2.71	7.6	5.0	2.5	3.2							4.6	7.6	
							3000	3003	204	2.57	2.64	2.71	2.74			2.67	11.1	6.4	3.6	3.5							6.1	11.1	
							4000	3996	272	2.37	2.63	2.66	2.78			2.61	18.0	6.7	5.3	2.1							8.0	18.0	
							5000	4995	340	2.64	2.53	2.60	2.67			2.61	8.7	10.3	7.5	6.0							8.1	10.3	
							6000	5995	408	2.74	2.60	2.62	2.69			2.66	5.2	7.8	6.8	5.3							6.3	7.8	
						EOT	----->																						
Leak Test, ml-air/min.								0.30	0.05	0.10	1.70						0.54												
(6)	2	D	C	1/1			0	3.04	2.92	2.99	2.98					2.98	0.0	0.0	0.0	0.0							0.0	0.0	
							1000	1000	68	2.98	2.93	2.97	2.98			2.97	2.0	-0.3	0.7	0.0							0.6	2.0	
							2000	2000	136	2.98	2.95	2.97	2.97			2.97	2.0	-1.0	0.7	0.3							0.5	2.0	
							3000	3001	204	2.97	2.83	2.97	3.01			2.95	2.3	3.1	0.7	-1.0							1.3	3.1	
							4000	4000	272	2.98	2.83	2.91	2.90			2.91	2.0	3.1	2.7	2.7							2.6	3.1	
							5000	5000	340	2.91	2.79	2.94	2.95			2.90	4.3	4.5	1.7	1.0							2.9	4.5	
							6000	6000	409	2.85	2.83	2.91	2.96			2.89	6.2	3.1	2.7	0.7							3.2	6.2	
Leak Test, ml-air/min.																													
(7)	2	G	A	1/2			0	2.29	2.29	2.31	2.33	2.30	2.31			2.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
							1000	991	68	2.26	2.35	2.20	2.36	2.29	2.30	2.29	1.3	-2.6	4.8	-1.3	0.4	0.4	0.4	0.4	0.4	0.5	4.8		
							2000	1991	136	2.25	2.21	2.10	2.26	2.24	2.30	2.23	1.7	3.5	9.1	3.0	2.6	0.4	0.4	0.4	0.4	3.4	9.1		
							3000	2999	205	2.19	2.13	2.02	2.23	2.15	2.30	2.17	4.4	7.0	12.6	4.3	6.5	0.4	0.4	0.4	0.4	5.9	12.6		
							4000	3995	275	2.09	2.12	1.97	2.21	2.12	2.20	2.12	8.7	7.4	14.7	5.2	7.8	4.8	4.8	4.8	8.1	14.7			
							5000	4998	344	1.77	2.05	1.95	2.15	2.04	2.09	2.01	22.7	10.5	15.6	7.7	11.3	9.5	9.5	9.5	12.9	22.7			
							6000	6000	415	1.80	1.99	1.92	1.93	2.01	1.93	1.93	21.4	13.1	16.9	17.2	12.6	16.5	16.5	16.5	16.3	21.4			
Leak Test, ml-air/min.								0.01	0.01	0.03	0.05	0.01	0.01			0.02													
(8)	2	G	A	2/2			0	2.37	2.37	2.37	2.37	2.44	2.30			2.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
							1000	1000	68	2.05	1.85	2.05	2.37	2.30	2.34	2.16	13.5	21.9	13.5	0.0	5.7	-1.7	-1.7	-1.7	8.8	21.9			
							2000	1998	136	1.92	1.41	1.57	2.30	2.22	2.38	1.97	19.0	40.5	33.8	3.0	9.0	-3.5	-3.5	-3.5	17.0	40.5			
							3000	2994	205	1.71	1.42	1.48	2.26	2.08	2.32	1.88	27.8	40.1	37.6	4.6	14.8	-0.9	-0.9	-0.9	20.7	40.1			
							4000																						
							5000																						
							6000																						
Leak Test, ml-air/min.																													
(9)	2	G	C	1/1			0	2.36	2.44	2.50	2.43	2.44	2.37			2.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
							1000	1000	70	2.41	2.37	2.36	2.44	2.37	2.36	2.39	-2.1	2.9	5.6	-0.4	2.9	0.4	0.4	0.4	1.5	5.6			
							2000	1988	138	2.35	2.37	2.40	2.44	2.36	2.37	2.38	0.4	2.9	4.0	-0.4	3.3	0.0	0.0	0.0	1.7	4.0			
							3000	2999	210	2.31	2.30	2.30	2.40	2.30	2.34	2.33	2.1	5.7	8.0	1.2	5.7	1.3	1.3	1.3	4.0	8.0			
							4000	4002	280	2.43	2.37	2.43	2.43	2.30	2.36	2.39	-3.0	2.9	2.8	0.0	5.7	0.4	0.4	0.4	1.5	5.7			
							5000	4993	352	2.22	2.25	2.26	2.29	2.14	2.21	2.23	5.9	7.8	9.6	5.8	12.3	6.8	6.8	6.8	8.0	12.3			
							6000	5998	423	2.37	2.31	2.37	2.44	2.29	2.35	2.36	-0.4	5.3	5.2	-0.4	6.1	0.8	0.8	0.8	2.8	6.1			
Leak Test, ml-air/min.																													

Table F-111
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)											
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST	
(10)	3	G	A	1/2	Mar-87	17	0	2.11	2.07	2.12	2.09	2.13	2.09			2.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
							1000	2.11	1.99	2.10	2.05	2.14	2.10			2.08	0.0	3.9	0.9	1.9	-0.5	-0.5		1.0	3.9		
							2000	1.96	1.98	2.06	1.99	2.09	2.04			2.02	7.1	4.3	2.8	4.8	1.9	2.4		3.9	7.1		
							3000	1.87	1.90	1.99	1.92	2.04	1.97			1.95	11.4	8.2	6.1	8.1	4.2	5.7		7.3	11.4		
							4000	1.76	1.89	1.93	1.91	2.03	1.96			1.91	16.6	8.7	9.0	8.6	4.7	6.2		9.0	16.6		
							5000	1.68	1.88	1.86	1.85	1.98	1.94			1.87	20.4	9.2	12.3	11.5	7.0	7.2		11.3	20.4		
							6000	1.42	1.83	1.80	* 1.92	1.81			1.46	32.7	11.6	15.1	9.9	13.4		16.5	32.7				
					EOT	----->		* Injector Malfunction																			
							Leak Test, ml-air/min.	0.04	0.80	0.70	0.64	0.10	0.00			0.38											
(11)	3	G	A	2/2	Apr-87	19	0	2.29	2.21	2.21	2.22	2.23	2.21			2.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
							1000	2.30	2.17	2.23	2.20	2.19	2.20			2.21	-0.2	1.0	-1.0	0.7	1.8	0.6		0.6	1.9		
							2000	2.23	2.12	2.18	2.16	2.15	2.17			2.17	2.9	4.1	1.4	2.8	3.5	1.8		2.8	4.1		
							3000	2.19	2.09	2.11	2.11	2.09	2.14			2.12	4.5	5.8	4.6	4.8	6.1	3.2		4.8	6.1		
							4000	2.17	2.06	2.03	2.08	2.01	2.08			2.07	5.6	7.1	7.9	6.4	9.8	5.8		7.1	9.8		
							5000	2.13	2.03	1.98	2.08	2.00	1.99			2.03	7.1	8.5	10.4	6.4	10.1	10.2		8.8	10.4		
							6000	2.09	1.99	1.78	2.05	1.94	1.98			1.97	8.8	10.1	19.5	7.6	12.7	10.6		11.5	19.5		
					EOT	----->																					
							Leak Test, ml-air/min.	0.03	0.15	0.07	0.07	0.09	0.10			0.09											
(12)	3	G	C	1/1	Mar-87	25	0	2.39	2.42	2.33	2.33	2.32	2.33			2.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
							1000	2.20	2.31	2.24	2.30	2.25	2.25			2.26	7.9	4.4	3.9	1.3	2.9	3.3		4.0	7.9		
							2000	2.13	2.26	2.15	2.27	2.22	2.20			2.21	10.9	6.5	7.8	2.6	4.2	5.4		6.2	10.9		
							3000	2.12	2.27	2.13	2.26	2.23	2.24			2.21	11.3	6.0	8.7	3.0	3.8	3.7		6.1	11.3		
							4000	2.12	2.27	2.12	2.27	2.24	2.25			2.21	11.3	6.0	9.1	2.6	3.3	3.3		5.9	11.3		
							5000	2.07	2.23	2.03	2.26	2.22	2.18			2.17	13.4	7.7	13.0	3.0	4.2	6.3		7.9	13.4		
							6000	2.03	2.19	1.91	2.22	2.18	2.14			2.11	15.1	9.4	18.1	4.8	5.9	8.0		10.2	18.1		
					EOT	----->																					
							Leak Test, ml-air/min.	0.85	0.07	0.36	0.25	0.70	0.01			0.37											
(13)	3	G	B	1/1	Jun-87	27	0	2.26	2.23	2.18	2.27	2.25	2.25			2.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
							1000	2.27	2.22	2.19	2.27	2.25	2.25			2.24	-0.5	0.6	-0.5	0.0	0.3	-0.4		-0.1	0.6		
							2000	2.26	2.23	2.20	2.29	2.27	2.27			2.25	0.0	0.1	-1.0	-0.9	-0.9	-0.9		-0.6	0.1		
							3000	2.24	2.19	2.18	2.27	2.24	2.23			2.23	0.8	1.8	-0.1	-0.1	0.7	0.5		0.6	1.8		
							4000	2.21	2.19	2.19	2.26	2.24	2.27			2.23	2.3	1.7	-0.2	0.3	0.6	-1.1		0.6	2.3		
							5000	2.17	2.15	2.17	2.25	2.23	2.23			2.20	4.2	3.5	0.7	0.7	1.1	0.8		1.8	4.2		
							6000	2.15	2.15	2.16	2.26	2.18	2.24			2.19	5.1	3.7	1.1	0.3	3.2	0.5		2.3	5.1		
					EOT	----->																					
							Leak Test, ml-air/min.	0.67	0.94	0.82	0.75	0.72	0.73			0.77											

LAB 4

Table F-IV
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE		INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)														
							ACCUMULATION	Cycles	1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST				
(14)	4	L1	A	1/1	May-87	84	0	0	1.64	1.59	1.61	1.58	1.60	1.60	1.58	1.59	1.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
							1000	1011	1.62	1.61	1.60	1.59	1.60	1.59	1.53	1.59	1.59	1.2	-1.3	0.6	-0.6	0.0	0.6	3.2	0.0	0.5	3.2				
							2000	2011	1.58	1.60	1.58	1.56	1.60	1.55	1.45	1.58	1.56	3.7	-0.6	1.9	1.3	0.0	3.1	8.2	0.6	2.3	8.2				
							3000	3036	1.55	1.57	1.59	1.53	1.59	1.50	1.43	1.58	1.54	5.5	1.3	1.2	3.2	0.6	6.3	9.5	0.6	3.5	9.5				
							4000	4064	1.53	1.54	1.59	1.49	1.59	1.54	1.38	1.58	1.53	6.7	3.1	1.2	5.7	0.6	3.8	12.7	0.6	4.3	12.7				
							5000	5066	1.49	1.49	1.60	1.42	1.59	1.54	1.38	1.57	1.51	9.1	6.3	0.6	10.1	0.6	3.8	12.7	1.3	5.6	12.7				
							6000	6067	1.46	1.46	1.57	1.49	1.53	1.54	1.47	1.57	1.51	11.0	8.2	2.5	5.7	4.4	3.8	7.0	1.3	5.5	11.0				
EOT ----->							Leak Test, ml.-air/min.																								
(15)	4	L2	A	1/1	Sep-87	37	0	0	1.61	1.59	1.60	1.60	1.60	1.61	1.61	1.62	1.61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
							1000	1006	1.61	1.58	1.60	1.60	1.60	1.61	1.61	1.62	1.60	0.0	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.2	0.6				
							2000	2001	1.58	1.51	1.57	1.57	1.55	1.57	1.58	1.61	1.57	1.9	5.0	1.9	1.9	3.1	2.5	1.9	0.6	2.3	5.0				
							3000	3043	1.54	1.46	1.51	1.53	1.54	1.50	1.53	1.53	1.52	4.3	8.2	5.6	4.4	3.8	6.8	5.0	5.6	5.5	8.2				
							4000	4050	1.57	1.43	1.53	1.53	1.54	1.51	1.57	1.58	1.53	2.5	10.1	4.4	4.4	3.8	6.2	2.5	2.5	4.5	10.1				
							5000	5036	1.58	1.46	1.51	1.50	1.53	1.48	1.57	1.57	1.53	1.9	8.2	5.6	6.3	4.4	8.1	2.5	3.1	5.0	8.2				
							6000	6068	1.58	1.40	1.53	1.54	1.53	1.47	1.57	1.58	1.53	1.9	11.9	4.4	3.8	4.4	8.7	2.5	2.5	5.0	11.9				
EOT ----->							Leak Test, ml.-air/min.																								

Table F-V
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Date	Start Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)											
								1	2	3	4	5	6	7	8	Avg	1	2	3	4	5	6	7	8	Avg	WORST	
(16)	5	G	A	1/1	Apr-87	20	0	2.27	2.31	2.30	2.24	2.29	2.18	2.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
							983	2.11	2.27	2.24	2.12	2.14	2.14	2.17	7.0	1.7	2.6	5.4	6.6	1.8	4.2	7.0	1.8	4.2	7.0	1.8	
							1000	2.00	1971	133	1.95	2.23	2.18	2.10	1.99	2.06	2.09	14.1	3.5	5.2	6.3	13.1	5.5	7.9	14.1	7.9	
							Code = 56-A	3000	2999	201	1.77	2.15	2.17	2.03	1.90	2.03	2.01	22.0	6.9	5.7	9.4	17.0	6.9	11.3	22.0	11.3	
							4000	4018	270	1.95	2.16	2.24	1.97	1.94	2.03	2.05	14.1	6.5	2.6	12.1	15.3	6.9	9.6	15.3	9.6		
							5000	5010	338	1.96	2.13	2.20	1.97	1.91	1.98	2.03	13.7	7.8	4.3	12.1	16.6	9.2	10.6	16.6	10.6		
							EOT ----->	6000	5262	354	1.96	2.08	2.16	1.67	1.70	1.88	1.91	13.7	10.0	6.1	25.4	25.8	13.8	15.8	25.8	15.8	
							Leak Test, ml-air/min.	0.50	0.60	0.60	0.90	1.90	0.90	0.90	0.90		0.90										
(17)	5	G	C	1/1	Apr-87	24	0	2.25	2.29	2.31	2.27	2.28	2.23	2.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
							1009	2.14	2.28	2.28	2.24	2.23	2.21	2.23	4.9	0.4	1.3	1.3	2.2	0.9	1.8	4.9	1.8	4.9	1.8		
							Code = 56-C	2000	1999	69	2.04	2.26	2.24	2.14	2.04	2.14	2.14	9.3	1.3	3.0	5.7	10.5	4.0	5.7	10.5	5.7	
							3000	2945	206	1.84	2.24	2.22	2.08	1.94	2.09	2.07	18.2	2.2	3.9	8.4	14.9	6.3	9.0	18.2	9.0		
							4000	3996	274	1.94	2.20	2.25	2.03	1.92	2.05	2.07	13.8	3.9	2.6	10.6	15.8	8.1	9.1	15.8	9.1		
							5000	5004	343	1.93	2.09	2.22	1.98	1.87	2.00	2.02	14.2	8.7	3.9	12.8	18.0	10.3	11.3	18.0	11.3		
							EOT ----->	6000	6007	411	1.93	2.06	2.20	1.74	1.72	1.91	1.93	14.2	10.0	4.8	23.3	24.6	14.3	15.2	24.6	15.2	
							Leak Test, ml-air/min.	0.60	0.60	0.50	0.80	0.90	0.60	0.67		0.67											

LAB 5

LAB 6

Table F-VI
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)												
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST		
(18)	6	D1	A	1/1	Jul-87	12	0	3.35	3.38	3.39	3.38					3.38	0.0	0.0	0.0	0.0							0.0	0.0
							1000	76	3.23	3.16	3.34	3.03				3.19	3.6	6.5	1.5	10.4							5.5	10.4
							2000	152	3.13	3.09	3.24	2.66				3.03	6.6	8.6	4.4	21.3							10.2	21.3
							3000	228	3.03	2.99	3.19	1.93				2.79	9.6	11.5	5.9	42.9							17.5	42.9
							4000																					
							5000																					
							6000																					
Leak Test, ml.-air/min.																												
(19)	6	D2	B	1/1	Aug-87	22	0	3.37	3.36	3.40	3.31					3.36	0.0	0.0	0.0	0.0							0.0	0.0
							1000	76	3.35	3.36	3.39	3.32				3.36	0.6	0.0	0.3	-0.3							0.1	0.6
							2000	152	3.34	3.35	2.84	3.30				3.21	0.9	0.3	16.5	0.3							4.5	16.5
							3000	2998	227	3.37	3.36	3.19	3.31			3.31	0.0	0.0	6.2	0.0							1.5	6.2
							4000	4005	303	3.36	3.33	3.04	3.29			3.26	0.3	0.9	10.6	0.6							3.1	10.6
							5000	5004	379	3.35	3.33	2.94	3.31			3.23	0.6	0.9	13.5	0.0							3.8	13.5
							6000	6008	455	3.34	3.32	2.88	3.30			3.21	0.9	1.2	15.3	0.3							4.4	15.3
Leak Test, ml.-air/min.																												
							EOT																					

LAB 7 (Continued)

Table F-VIIb
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)												
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST		
(24)	7	F2	A	2/2	Feb-87	18	0	2.21	2.22	2.20	2.23	2.21	2.23	2.23	2.23	2.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
							1000	1.98	1.97	1.86	1.88	1.71	2.16	1.79	2.03	1.92	10.4	11.3	15.5	15.7	22.6	3.1	19.7	9.0	13.4	22.6	13.4	
							2000	2007	1.79	1.74	1.64	1.79	1.63	2.15	1.72	1.96	1.80	19.0	21.6	25.5	19.7	26.2	3.6	22.9	12.1	18.8	26.2	
							3000	3002	1.72	1.53	1.59	1.80	1.65	2.12	1.71	1.96	1.76	22.2	31.1	27.7	19.3	25.3	4.9	23.3	12.1	20.7	31.1	
							4000																					
							5000																					
							6000																					
							Code = 7F2-A2																					
							EOT ----->																					
							SOT																					
							EOT																					
(25)	7	F2	C	1/1	Jan-87	46	0	2.29	2.29	2.28	2.33	2.30	2.29	2.27	2.28	2.29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
							1000	1014	2.12	2.11	2.03	2.33	2.25	2.22	2.05	2.06	2.15	7.4	7.9	11.0	0.0	2.2	3.1	9.7	9.6	6.4	11.0	
							2000	2006	1.63	1.91	1.74	2.30	2.21	2.15	1.81	1.99	1.97	28.8	16.6	23.7	1.3	3.9	6.1	20.3	12.7	14.2	28.8	
							3000	3005	1.65	1.67	1.50	2.20	2.10	2.07	1.53	1.82	1.82	27.9	27.1	34.2	5.6	8.7	9.6	32.6	20.2	20.7	34.2	
							4000	4006	1.73	1.57	1.53	2.19	2.09	2.06	1.48	1.70	1.79	24.4	31.4	32.9	6.0	9.1	10.0	34.8	25.4	21.8	34.8	
							5000	5005	1.66	1.44	1.55	2.20	2.12	2.08	1.31	1.63	1.75	27.5	37.1	32.0	5.6	7.8	9.2	42.3	28.5	23.8	42.3	
							6000	6010	1.61	1.31	1.54	2.18	2.05	2.08	1.15	1.48	1.68	29.7	42.8	32.5	6.4	10.9	9.2	49.3	35.1	27.0	49.3	
							Code = 7F2-C																					
							EOT ----->																					
							SOT																					
							EOT																					
							Leak Test, ml-air/min.																					
							Leak Test, ml-air/min.																					
(26)	7	F2	B	1/1	Sep-87	72	0	2.24	2.22	2.25	2.22	2.23	2.22	2.20	2.22	2.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
							1000	1008	2.17	2.15	2.18	2.14	2.18	2.16	2.18	2.19	2.17	3.5	3.3	3.0	3.7	2.2	2.3	0.8	1.3	2.5	3.7	
							2000	2003	2.05	2.02	2.01	2.03	2.06	2.00	2.05	2.08	2.04	8.7	9.1	10.4	8.4	7.5	9.7	7.0	6.5	8.4	10.4	
							3000	3005	2.23	2.24	2.23	2.19	2.17	2.13	2.19	2.20	2.20	0.6	0.8	0.9	1.2	2.6	4.1	0.7	0.8	1.2	4.1	
							4000	4009	2.18	2.18	2.19	2.17	2.17	2.17	2.19	2.20	2.18	3.0	1.6	2.5	2.4	2.6	2.3	0.5	0.9	2.0	3.0	
							5000	5008	2.18	2.17	2.18	2.14	2.14	2.13	2.18	2.20	2.18	2.6	2.2	2.8	3.4	4.0	4.1	1.2	1.1	2.7	4.1	
							6000	6002	2.16	2.20	2.17	2.15	2.17	2.15	2.20	2.23	2.18	3.5	0.9	3.4	3.0	2.6	3.0	0.1	-0.4	2.0	3.5	
							Code = 7F2-B																					
							EOT ----->																					
							SOT																					
							EOT																					
							Leak Test, ml-air/min.																					
							Leak Test, ml-air/min.																					

LAB 8

Table F-VIII
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE		INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)								
							Target	Actual	Cycles	1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7
(27)	8	D	A	1/2	Dec-86	80	0	0	0	3.44	3.43	3.44	3.44				0.0	0.0	0.0	0.0				0.0	0.0
							1000	1001	80	3.41	3.38	3.31	3.35				0.9	1.5	3.8	2.6				3.36	2.2
							2000	2062	165	3.35	3.24	3.04	3.22				2.6	5.5	11.6	6.4				3.21	3.8
							3000	2999	241	3.26	3.07	3.00	3.20				5.2	10.5	12.8	7.0				3.13	6.5
							4000	4000	321	3.10	2.83	2.87	3.12				9.9	17.5	16.6	9.3				2.98	8.9
							5000																	13.3	
							6000																	17.5	
							Leak Test, ml-air/min.								1.05										
(28)	8	D	A	2/2	Mar-87	37	0	0	0	1.34	0.73	1.87	0.25				0.0	0.0	0.0	0.0				3.42	0.0
							1000	999	79	3.40	3.43	3.37	3.47				1.2	1.5	2.4	3.5				3.35	2.1
							2000	2003	159	3.36	3.38	3.29	3.35				5.9	6.4	6.2	10.4				3.17	3.5
							3000	3001	238	3.00	2.99	3.00	2.86				11.8	12.8	11.0	17.6				2.96	7.2
							4000	4001	317	2.84	2.78	2.79	2.62				16.5	19.0	17.2	24.5				2.76	13.3
							5000																	19.3	
							6000																	24.5	
							Leak Test, ml-air/min.								1.22										
							0	0	0	1.33	1.03	1.32	1.21												

Table F-1X
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run		Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)										
									1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST
(29)	9	F1	A	1/1	Dec-86		31	0	2.35	2.30	2.33	2.38	2.39	2.34	2.36	2.34	2.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								1000	2.30	2.27	1.97	2.34	2.10	2.31	2.09	2.17	2.19	2.1	1.3	15.5	1.7	12.1	1.3	11.4	7.3	6.6	15.5
								2000	2.26	2.00	1.76	2.22	1.83	2.26	1.97	1.96	2.03	3.8	13.0	24.5	6.7	23.4	3.4	16.5	16.2	13.5	24.5
								3000	2.28	1.54	1.18	2.18	1.68	2.22	1.68	1.62	1.80	3.0	33.0	49.4	8.4	29.7	5.1	28.8	30.8	23.5	49.4
								4000																			
								5000																			
								6000																			
								Leak Test, ml-air/min.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(30)	9	F1	C	1/1	Jan-87		28	0	2.25	2.27	2.28	2.32	2.32	2.33	2.31	2.31	2.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								1000	1.64	1.76	2.30	2.24	1.81	2.17	2.30	2.34	2.07	27.1	22.5	-0.9	3.4	22.0	6.9	0.4	-1.3	10.0	27.1
								2000	1.29	1.10	2.28	2.26	1.33	1.95	2.12	2.31	1.83	42.7	51.5	0.0	2.6	42.7	16.3	8.2	0.0	20.5	51.5
								3000																			
								4000																			
								5000																			
								6000																			
								Leak Test, ml-air/min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(31)	9	F2	A	1/1	Dec-86		23	0	2.32	2.34	2.33	2.31	2.33	2.33	2.40	2.41	2.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								1000	2.20	2.28	2.30	2.28	2.15	2.25	2.31	2.33	2.26	5.2	2.6	1.3	1.3	7.7	3.4	3.7	3.3	3.6	7.7
								2000	1.98	2.10	2.26	2.17	2.17	2.24	2.30	2.20	2.18	14.7	10.3	3.0	6.1	6.9	3.9	4.2	8.7	7.2	14.7
								3000	1.26	1.79	1.80	2.01	1.80	1.72	2.20	2.20	1.85	45.7	23.5	22.7	13.0	22.7	26.2	8.3	8.7	21.4	45.7
								4000																			
								5000																			
								6000																			
								Leak Test, ml-air/min.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(32)	9	F2	C	1/1	Jan-87		28	0	2.28	2.29	2.31	2.32	2.31	2.32	2.35	2.30	2.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								1000	2.19	2.18	2.24	2.18	2.12	2.17	2.14	2.19	2.18	3.9	4.8	3.0	6.0	8.2	6.5	8.9	4.8	5.8	8.9
								2000	2.20	2.15	2.29	2.12	1.70	2.04	2.11	2.17	2.10	3.5	6.1	0.9	8.6	26.4	12.1	10.2	5.7	9.2	26.4
								3000	2.25	2.11	2.31	2.10	1.60	1.62	1.86	2.12	2.00	1.3	7.9	0.0	9.5	30.7	30.2	20.9	7.8	13.5	30.7
								4000																			
								5000																			
								6000																			
								Leak Test, ml-air/min.																			

LAB 10

Table F-X
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

[illegible]

Table F-XI
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

Run	Lab	Car	Fuel	Reps	Start Date	Days Run	MILEAGE ACCUMULATION Target Actual Cycles	INJECTOR FLOW RATES (g/sec.)								PERCENT FLOW REDUCTION (FROM NEW)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
								1	2	3	4	5	6	7	8	AVG	1	2	3	4	5	6	7	8	AVG	WORST																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
(35)	11	D	A	1/3	Jan-87	29	0	3.46	3.45	3.46	3.46							0.0	0.0	0.0	0.0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							</

LAB 12

Table F-XII
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
MASTER FLOW DATA SET

[illegible]

APPENDIX G

TEMPERATURE DATA

LAB 1

Table G-1
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	Ambient		INJECTOR			TIP SOAK TEMPERATURES, C								Inlet		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		Ambient		Inj		Inlet		Coolant		Oil		Fuel Tank		Fuel Rail Pressure																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
					Max C	Min C	1	2	3	4	5	6	7	8	Max	Air C	C C	C C	C C	C C	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F

LAB 2

Table G-11
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	Ambient Max C	Ambient Min C	INJECTOR	TIP	SOAK	TEMPERATURES, C	Inlet Air C	Coolant C	Oil C	Fuel Tank C	Fuel Rail Pressure kPa	Ambient Max F	Ambient Min F	Inj Max F	Inlet Air F	Coolant F	Oil F	Fuel Tank F	Fuel Rail Pressure psi
(5)	2	D	A	20-A	28-Jan-87	21	19	1	2	3	4	5	6	7	8	91	32	96					
(6)	2	D	C	20-C																			
(7)	2	G	A	26-A1	10-Feb-87	22	21									56	48	96					
(8)	2	G	A	26-A2	24-Feb-87 (w/ shield)	21	21									82	52	97					
(9)	2	G	C	26-C																			

Table G-111a
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C								Ambient		Fuel Rail Pressure		Inlet		Inlet		Inlet		Coolant		Oil		Fuel Tank		Fuel Rail Pressure	
			1	2	3	4	5	6	7	8	Max	Min	Max	Min	Air	C	Air	F	Max	Min	F	F	F	F	Max	Min	psi	psi
(10)	3 G A 3G-A1	04-Mar-87									89	27	19		49	95	111	62	227	179	81	66	192	120	203	232	144	33
		05-Mar-87									88	26	14		51	94	110	62			79	57	190	124	201	230	144	33
		09-Mar-87									86	21			51	100	105	61			82	70	187	124	212	221	142	33
		10-Mar-87									89	24	16		49	98	111	59			75	61	192	120	208	232	138	33
		11-Mar-87									82	18	17		42	96	106	55			64	63	180	108	205	223	131	33
		12-Mar-87									85	21	12		44	98	105	57			70	54	185	111	208	221	135	33
		13-Mar-87									78	23	15		43	93	99	55			73	59	172	109	199	210	131	33
		16-Mar-87									88	24	21		49	101	110	62			75	70	190	120	214	230	144	33
		17-Mar-87									89	26	18		51	100	111	63			79	64	192	124	212	232	145	33
		18-Mar-87									93	29	15		67	102	113	66	220	179	84	59	199	153	216	235	151	32
		19-Mar-87									92	27	17		56	100	113	66			81	63	198	133	212	235	151	32
		20-Mar-87									88	28	20		53	99	112	65			82	68	190	127	210	234	149	33
(11)	3 G A 3G-A2	11-Jun-87									90	33	28		18	99	111	66			91	82	194	138	210	232	151	36
		12-Jun-87									95	33	28		59	100	112	66	247	62	91	82	203	142	212	237	154	34
		15-Jun-87									96	37	28		61	100	114	68	234	55	99	82	205	144	214	234	165	34
		16-Jun-87									97	35	28		62	101	112	74	234	55	95	82	205	144	214	234	160	38
		18-Jun-87									97	34	27		61	101	111	71	261	62	93	81	207	142	214	232	163	38
		19-Jun-87									97	34	27		62	102	111	73	227	34	93	81	207	144	216	232	163	33
		24-Jun-87									95	36	29		63	99	112	72	213		97	84	203	145	210	234	162	31
		25-Jun-87									97	40	29		63	102	112	73	206	82	104	84	207	145	216	234	163	30
		01-Jul-87									97	36	29		63	99	110	69	220		97	84	207	145	210	232	162	30
		02-Jul-87									96	36	29		62	100	110	68	213		95	84	205	144	212	230	156	32
		07-Jul-87									94	31	26		57	99	111	68	227		88	79	201	135	210	232	154	33
		08-Jul-87									94	31	26		57	100	112	68	220		88	79	201	135	212	234	154	33
		09-Jul-87									94	32	24		58	99	112	68	220		90	75	201	136	210	234	154	32
		10-Jul-87									93	33	28		59	99	107	70	206	76	91	82	199	138	210	235	158	30
		13-Jul-87									94	37	29		59	99	112	68	199	76	99	84	201	138	210	234	154	29
		14-Jul-87									92	36	29		58	102	112	65	199		97	84	198	136	216	234	149	29
		15-Jul-87									94	35	27		60	99	110	69	199		95	81	201	140	210	230	156	29
		16-Jul-87									95	34	29		59	99	110	67	206	62	93	84	203	138	210	230	153	30
		17-Jul-87									95	34	28		61	99	113	71	199		93	82	203	142	210	235	160	29
		21-Jul-87									94	28	34		58	100	110	67	192	41	93	82	201	136	212	230	153	28
		22-Jul-87									93	34	29		56	99	112	68	206	55	93	84	199	133	210	234	154	30

During Run 12, the rail pressures started to decrease more during the soak. Thus, the regulator and fuel pump were replaced on 6/18, but the minimum rail pressures remained low and sometimes were zero.

Lab 3 continued on next page

LAB 3 (continued)

Table G-111b
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C								Ambient		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pres. kPa		Inj Max		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pres. psi	
			1	2	3	4	5	6	7	8	Max	Min	C	C	C	C	C	C	Max	Min	F	F	Max	Min	F	F	Max	Min	F	F	Max	Min		
(12)	3 G C 3G-C	20-Apr-87								94	58	102	110	65							93	75	201	136	216	230	230	149						
		21-Apr-87								92	55	101	110	63							91	70	198	131	214	230	230	145						
		22-Apr-87								92	54	101	112	62							90	70	198	129	214	234	234	144						
		23-Apr-87								92	58	100	112	65							95	75	198	136	212	234	234	149						
		24-Apr-87								94	56	101	112	63	268 117						95	70	201	133	214	234	234	145						
		29-Apr-87								96	59	100	110	68							91	79	205	138	212	230	230	154						
		30-Apr-87								95	56	99	113	66							88	73	203	133	210	235	235	151						
		01-May-87								94	57	100	112	66							82	73	201	135	212	232	232	151						
		05-May-87								94	57	100	111	66							90	73	201	135	212	232	232	151						
		06-May-87								92	54	101	108	64							82	73	198	129	214	226	226	147						
07-May-87								94	55	100	111	64							88	73	201	131	212	232	232	147								
08-May-87								91	55	99	109	63							84	73	196	131	210	228	228	145								
(13)	3 G B 3G-B	23-Mar-87							85	49	99	112	61							81	68	185	120	210	234	234	142							
		24-Mar-87							85	51	98	111	63							79	55	185	124	208	232	232	145							
		25-Mar-87							86	50	98	112	63							82	63	187	122	208	234	234	145							
		02-Apr-87							85	48	100	109	58							77	62	185	118	212	228	236	136							
		03-Apr-87							96	41	97	88	51							72	61	205	106	207	190	190	124							
		06-Apr-87							102	47	100	108	58							73	68	216	117	212	226	226	136							
		07-Apr-87							104	50	101	109	61							79	63	219	122	214	228	228	142							
		08-Apr-87							94	51	99	107	62							81	63	201	124	210	225	225	144							
		09-Apr-87							94	55	99	112	66							84	59	201	131	210	234	234	151							
		10-Apr-87							94	46	101	106	57							81	61	201	115	214	223	223	135							
13-Apr-87							94	51	99	111	62							86	73	201	124	210	232	232	144									
14-Apr-87							93	51	99	109	60							82	61	199	124	210	228	228	140									
15-Apr-87							94	56	100	111	65							90	59	201	133	212	232	232	149									
16-Apr-87							94	56	101	110	63							95	66	201	133	214	230	230	145									

LAB 4

Table G-IV
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	Ambient		INJECTOR TIP SOAK TEMPERATURES, C										Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		
			Max C	Min C	1	2	3	4	5	6	7	3	Max	C	F	C	F	C	F	C	F	psi			
(14)	4 L1 A 4L1-A	26-May-87	33	25									87							220		92	77	188	32
		27-May-87	28	23									78							220		82	74	172	32
		28-May-87	30	18									79							220		86	65	172	32
		07-Jun-87	24	21									81							220		76	70	175	32
		08-Jun-87	29	21									82							220		85	70	178	32
		10-Jun-87	28	24									82							220		82	75	179	32
		02-Jul-87	35	23									87							220		95	73	188	32
		03-Jul-87	37	30									87							220		98	86	189	32
		17-Jul-87	35	24									84							220		95	75	183	32
		18-Jul-87	35	23									88							220		95	73	190	32
		19-Jul-87	35	21									83							220		95	70	182	32
		20-Jul-87	33	20									82							220		92	68	180	32
		21-Jul-87	34	24									84							220		93	75	183	32
		28-Jul-87	33	22									87							220		92	72	188	32
		29-Jul-87	35	22									86							220		95	71	187	32
		30-Jul-87	31	22									87							220		88	72	189	32
(15)	4 L2 A 4L2-A	31-Jul-87	36	23								90							220		96	73	194	32	
		01-Aug-87	36	24								87							220		97	76	189	32	
		02-Aug-87	36	26								86							220		96	78	187	32	
		04-Aug-87	28	22								81							220		83	72	178	32	
		06-Aug-87	37	23								87							220		99	74	188	32	
		07-Aug-87	37	23								89							220		99	73	193	32	
		08-Aug-87	36	24								87							220		97	76	188	32	
		09-Aug-87	36	23								88							220		97	73	190	32	
		10-Aug-87	37	23								88							220		98	74	190	32	
		16-Aug-87	38	26								88							220		100	78	190	32	
		17-Aug-87	38	24								90							220		100	75	194	32	
		05-Sep-87	32	22								84							220		90	72	184	32	
		06-Sep-87	32	22								85							220		89	72	185	32	
		08-Sep-87	34	21								86							220		93	69	186	32	
		09-Sep-87	33	21								88							220		92	69	190	32	
		10-Sep-87	34	20								87							179		94	68	189	26	
18-Sep-87	26	19								81							220		79	67	178	32			
19-Sep-87	29	19								83							213		85	67	182	31			
20-Sep-87	31	17								84							213		87	67	184	31			
25-Sep-87	32	17								85							179		89	62	185	26			
26-Sep-87	31	23								83							179		88	74	181	26			
27-Sep-87	33	23								86							179		92	74	186	26			
28-Sep-87	33	23								84							179		91	74	184	26			
29-Sep-87	31	13								82							179		87	55	179	26			
30-Sep-87	30	13								79							179		86	55	174	26			
07-Oct-87	30	13								83							179		86	55	182	26			
08-Oct-87	32	14								81							179		89	58	178	26			
09-Oct-87	32	16								80							206		90	60	176	30			
10-Oct-87	31	16								81							199		87	60	177	29			
11-Oct-87	30	13								81									86	55	177				

LAB 5

Table G-V
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	Ambient								INJECTOR TIP SOAK TEMPERATURES, C								Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
					Max	Min	1	2	3	4	5	6	7	8	Max	C	Air	C	Coolant	C	C	C	Max	Min	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F	Max	Min	Max	F	F

Table G-VI
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	Ambient		INJECTOR TIP SOAK TEMPERATURES, C								Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		psi					
			Max C	Min C	1	2	3	4	5	6	7	8	Max C	Min C	Max F	Min F	Max F	Min F	Max F	Min F	Max F	Min F						
(18)	6 D1 A 601-A	30-Jul-87	30	26								103	60	124	113					323	86	78	218	140	255	235		47
		31-Jul-87	30	21								103	54	128	113					330	86	70	218	130	262	235		48
		01-Aug-87	27	19								106	56	127	111					330	81	67	223	133	260	232		48
		02-Aug-87	29	23								102	52	127	112					337	85	74	215	125	260	233		49
		03-Aug-87	29	22								103	53	128	111					337	84	71	217	127	263	232		49
		04-Aug-87	30	21								104	50	129	111					323	86	69	220	122	265	232		47
		05-Aug-87	24	22								106	47	129	110					330	75	71	223	117	265	230		48
		06-Aug-87	26	16								104	61	131	110					330	78	61	220	142	268	230		48
		07-Aug-87	31	23								106	62	129	111					330	88	73	223	144	265	232		48
		08-Aug-87	26	22								106	52	131	109					323	79	71	223	125	268	228		47
09-Aug-87	29	20								102	60	131	113					337	85	68	215	140	268	235		49		
10-Aug-87	23	20								101	49	129	107					337	73	68	213	120	265	225		49		
(19)	6 D2 B 602-B	06-Aug-87	26	16								103	61	129	112					337	78	61	217	141	265	233		49
		07-Aug-87	31	23								105	62	129	113					337	88	73	221	143	265	235		49
		08-Aug-87	26	22								105	51	130	112					330	79	71	221	123	266	233		48
		09-Aug-87	29	20								100	61	126	110					330	85	68	212	141	258	230		48
		10-Aug-87	23	20								99	49	127	106					330	73	68	211	121	260	222		48
		11-Aug-87	27	16								102	47	124	113					337	80	61	216	117	255	236		49
		12-Aug-87	32	18								105	63	123	113					330	90	64	221	146	254	236		48
		13-Aug-87	33	22								103	64	123	113					330	92	71	218	148	254	236		48
		14-Aug-87	34	22								110	66	125	115					337	94	71	230	150	257	239		49
		15-Aug-87	35	22								112	67	126	113					337	95	73	225	152	258	236		49
		16-Aug-87	34	23								107	68	127	112					337	83	73	225	155	260	233		49
		17-Aug-87	28	26								102	63	126	112					330	83	78	216	146	258	233		48
		19-Aug-87	28	24								110	63	127	113					323	82	75	230	146	260	236		47
		20-Aug-87	24	19								110	63	123	113					330	76	67	230	145	254	236		48
		21-Aug-87	25	19								106	55	124	113					337	77	67	222	131	255	236		49
		22-Aug-87	25	19								100	57	127	113					337	77	67	212	134	260	236		49
		23-Aug-87	22	18								103	56	127	113					330	72	64	218	132	260	236		48
24-Aug-87	21	13								97	55	124	110					330	69	55	206	131	255	230		48		
25-Aug-87	22	12								98	58	124	112					330	72	54	209	137	255	233		48		
26-Aug-87	18	15								97	50	125	112					330	64	59	206	122	257	233		48		
27-Aug-87	22	18								102	122	124	112					323	72	65	215	252	256	234		47		

Table G-VII
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car	Fuel Code	Date	Ambient Max C	Min C	INJECTOR	1	2	3	4	5	6	7	8	Max	Inlet Air C	Coolant C	Oil C	Fuel Tank C	Fuel Rail Pressure kPa	Ambient Max F	Min F	Inj Max F	Inlet Air F	Coolant F	Oil F	Fuel Tank F	Fuel Rail Pressure psi
(20)	7	F1 A	7F1-A	Start 12-Nov-86	9	-13									85					300	48	9	185					44
			End 08-Dec-86																									
(21)	7	F1 C	7F1-C1	Start 05-Jan-87	7	-25									82					300	45	-13	180					44
			End 19-Feb-87																									
(22)	7	F1 C	7F1-C2	Start 24-Feb-87	11	-7									90					300	52	19	194					44
			End 13-Apr-87																									
(23)	7	F2 A	7F2-A1	Start 12-Nov-86	9	-13									85	65	100	110	25	300	48	9	185	149	212	230	77	44
			End 09-Dec-86																									
(24)	7	F2 A	7F2-A2	Start 24-Feb-87	8	-9									95	65	100	110	25	300	46	16	203	149	212	230	77	44
			End 13-Apr-87																									
(25)	7	F2 C	7F2-C	Start 05-Jan-87	7	-25									85	65	105	115	23	300	45	-13	185	149	221	239	73	44
			End 19-Feb-87																									
(26)	7	F2 B	7F2-B	Start 02-Sep-86	27	-4									87	65	100	105	20	300	81	25	189	149	212	221	68	44
			End 12-Nov-86																									

Table G-VIIia
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C								Ambient		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
					Max	Min	1	2	3	4	5	6	7	8	Max	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F

Lab 8, Run 27 continued on next page

Table G-VIIIb
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C										Ambient		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure	
			1	2	3	4	5	6	7	8	Max	C	Min	C	F	C	F	C	F	C	F	psi	psi	
(27)	8 D A 80-A1 (continued)	24-Feb-87	3	-3							44	119	118	29	350			111	247	244	85	51		
		25-Feb-87	5	-4							44	123	127	26	316			111	254	260	79	46		
		26-Feb-87	3	-2							44	118	123	29	344			111	251	253	85	50		
		27-Feb-87	5	-3							45	122	129	26	350			113	251	265	79	51		
		28-Feb-87	2	-2							44	123	118	23	344			112	253	244	73	50		
		02-Mar-87	13	6							46	121	127	32	330			115	250	261	89	48		
		03-Mar-87	9	-1							44	121	121	32	330			112	249	249	90	48		
		04-Mar-87	7	-1							44	121	123	21	344			111	249	254	69	50		
(28)	8 D A 80-A2	11-Mar-87	2	-4						81	118	118	26	344			111	244	244	78	50			
		12-Mar-87	8	-2						88	122	129	26	344			111	252	264	78	50			
		13-Mar-87	3	0						84	122	118	27	344			115	251	245	81	50			
		14-Mar-87	6	-2						84	118	118	32	344			113	244	244	90	50			
		16-Mar-87	7	-1						83	119	120	32	371			114	247	248	89	54			
		17-Mar-87	9	-2						87	123	121	32	350			115	254	249	90	54			
		18-Mar-87	9	1						96	124	128	37	350			123	256	263	98	51			
		19-Mar-87	13	0						87	126	118	32	357			118	258	244	90	52			
		20-Mar-87	12	1						86	126	118	32	350			114	258	244	90	51			
		21-Mar-87	12	2						92	124	124	29	316			117	256	256	85	46			
		23-Mar-87	88	48						88	126	123	33	344			119	258	254	91	50			
		24-Mar-87	88	50						88	119	118	38	344			122	246	245	101	50			
		25-Mar-87	18	2						90	122	124	39	344			122	251	256	103	50			
		26-Mar-87	17	8						92	124	126	46	350			127	255	259	114	51			
		27-Mar-87	7	6						92	123	123	44	344			131	254	259	111	50			
		28-Mar-87	9	7						90	119	126	38	357			121	246	253	101	52			
30-Mar-87	17	9						87	124	126	38	357			124	256	258	101	52					
31-Mar-87	14	10						86	116	121	35	371			116	240	250	95	54					
01-Apr-87	0	-4						84	118	116	29	344			116	244	240	85	54					
02-Apr-87	88	5	-1					88	117	118	34	357			120	243	245	94	52					
03-Apr-87	8	3						87	125	116	31	371			120	257	241	88	54					
04-Apr-87	19	3						88	118	116	29	371			115	245	240	85	54					
06-Apr-87	6	-2						86	117	115	27	364			116	243	239	80	53					
07-Apr-87	4	-1						87	126	116	33	364			120	258	241	91	53					
08-Apr-87	11	6						99	124	124	39	364			128	256	255	103	53					
09-Apr-87	18	7						91	121	118	34	357			119	249	244	94	52					
10-Apr-87	16	10						92	119	121	46	344			125	256	250	114	50					
11-Apr-87	19	4						91	124	117	43	357			125	256	243	110	52					
13-Apr-87	15	4						96	126	122	32	371			125	258	251	90	54					
14-Apr-87	11	2						90	121	117	39	357			124	244	243	103	52					
15-Apr-87	16	7						88	118	119	32	357			118	250	247	90	52					
16-Apr-87	6	4						94	126	124	29	344			118	259	256	85	50					

LAB 9

Table G-IX
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	Ambient		INJECTOR TIP SOAK TEMPERATURES, C								Inlet Air		Coolant C		Oil C		Fuel Tank C		Fuel Rail Pres. kpa		Ambient		Inj		Inlet Air		Coolant F		Oil F		Fuel Tank F		Fuel Rail Pres. psi				
					Max	Min	1	2	3	4	5	6	7	8	Max	C	C	C	C	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min				
(29)	9	F1	A	9F1-A																																					
(30)	9	F1	C	9F1-C			6	-11						93		87																									
(31)	9	F2	A	9F2-A			17	-3						93		86																									
(32)	9	F2	C	9F2-C			14	-11						97		83																									

Table G-X
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel	Code	Date	INJECTOR TIP SOAK TEMPERATURES, C								Ambient		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pressure		psi	
						1	2	3	4	5	6	7	8	Max	Max	Min	C	F	C	F	C	F	kPa	F	psi		
(33)	10	D	A	100-A	01-Dec-86	94	103	103						103		37	26	218					357		52		
					02-Dec-86	97	105	105						105		39	25	221					357		52		
					03-Dec-86	90	101	101						101		34	29	214					371		54		
					04-Dec-86	82	93	93						93		35	28	199					385		56		
					05-Dec-86	93	101	101						101		37	24	214					357		52		
					06-Dec-86	97	106	106						106		43	33	223					357		52		
					08-Dec-86	97	107	107						107		46	40	224					357		52		
					09-Dec-86	95	104	104						104		45	20	220					357		52		
(34)	10	D	C	100-C	09-Dec-86	90	99	99						99		45	20	210					357		52		
					10-Dec-86	90	98	98						98		25	15	208					357		52		
					11-Dec-86	90	98	98						98		35	20	208					357		52		
					12-Dec-86	87	97	97						97		23	10	207					357		52		
					13-Dec-86	93	102	102						102		30	10	215					350		51		
					15-Dec-86	96	106	106						106		50	35	223					344		50		
					16-Dec-86	97	107	107						107		45	40	224					344		50		
					17-Dec-86	92	102	102						102		45	39	216					344		50		
					18-Dec-86	93	103	103						103		38	35	218					344		50		
					19-Dec-86	97	107	107						107		46	30	225					337		49		
					20-Dec-86	94	105	105						105		43	32	221					344		50		
					22-Dec-86	93	102	102						102		39	27	216					337		49		
					23-Dec-86	94	105	105						105		38	34	221					344		50		
					24-Dec-86	93	107	107						107		39	33	224					344		50		
					29-Dec-86											39	33					344		50			
					30-Dec-86											45	35					344		50			
					31-Dec-86											37	35					344		50			
					02-Jan-87											41	35					344		50			
					03-Jan-87											43	33					344		50			
					05-Jan-87											45	34					344		50			
					06-Jan-87											50	35					344		50			
					07-Jan-87											43	37					357		52			
					11-Jan-87											37	34					364		53			
					07-Jan-87											41	33					364		53			
					10-Jan-87											46	33					344		50			
					12-Jan-87											45	30					344		50			

G-12

Lab 11, Run 36 continued on next page

Table G-XIb
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab Car Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C			Ambient		Inlet		Coolant		Oil		Fuel Tank		Pres. Psi		Fuel Rail				
			1	2	3	4	5	6	7	8	Max	Air	C	F	Max	Air	C	F	Max	Min		
(36)	11 D A 110-A2 (continued)	19-Jun-87	13	20	13	87					97	111	116	68	55	207	231	240	240	84	55	51
		22-Jun-87	29	14	101	104					104	116	117	84	57	219	240	243	240	99		
		23-Jun-87	21	14	97	101					101	114	116	70	57	213	237	240	240	90		
		24-Jun-87	24	13	99	102					102	114	116	76	56	216	237	240	240	93		
		25-Jun-87	20	13	96	99					99	112	116	68	55	210	234	240	240	90		
		26-Jun-87	19	14	96	97					97	111	114	66	57	207	231	237	237	84		
		29-Jun-87	21	14	92	96					96	111	114	70	57	204	231	237	237	75		
		30-Jun-87	20	14	94	97					97	111	114	68	58	207	231	237	237	84		
		01-Jul-87	21	14	94	96					96	111	112	69	58	204	231	234	234	78		
		02-Jul-87	23	13	96	97					97	112	112	74	56	207	234	237	237	90		
		06-Jul-87	23	14	99	102					102	112	114	74	58	216	234	237	237	93		
		07-Jul-87	31	15	101	104					104	116	117	87	59	219	240	243	243	105		
		08-Jul-87	24	15	96	99					99	112	114	75	59	210	234	237	237	90		
09-Jul-87	21	16	91	96					96	109	114	70	60	204	228	237	237	81				
10-Jul-87	19	14	92	96					96	112	114	67	57	204	234	237	237	78				
13-Jul-87	22	15	94	97					97	112	114	71	59	207	234	237	237	75				
(37)	11 D A 110-A3	26-Oct-87	16	5	102	102	92				102	117	121	60	41	216	243	249	234			
		27-Oct-87	14	4	92	99	101	91			101	116	119	58	40	213	240	246	234			
		28-Oct-87	17	8	99	101	89				101	116	117	62	47	213	240	243	240			
		29-Oct-87	15	9										59	49							
		30-Oct-87	13	10	91	99	92				99	116	117	55	50	210	240	243	240			
		02-Nov-87	23	15	86	92	87				92	111	114	73	59	198	231	237	237			
		03-Nov-87	30	14	91	97	92				97	114	119	86	58	207	237	246	240			
		04-Nov-87	39	16	91	97					97	112	114	102	60	207	234	237	237			
		05-Nov-87	40	19										104	66							
		06-Nov-87	34	19										94	66							
		09-Nov-87	22	16										72	60							
		10-Nov-87	22	16										72	61							
		12-Nov-87	22	17	89	96	96	87			96	112	116	71	62	204	234	240	237			
		13-Nov-87	19	15	86	92	92	86			92	112	117	66	59	198	234	243	234			
		16-Nov-87	21	14										69	58							
		17-Nov-87	28	12	84	91	87	84			91	109	111	82	54	195	228	231	234	72		
		18-Nov-87	24	12																		
19-Nov-87	20	13	87	94	91	86			94	111	114	76	53	201	231	237	234	84				
20-Nov-87	18	11	87	94	89	84			94	112	116	68	55	201	234	240	237	72				
23-Nov-87	21	16	91	97	99	87			99	116	119	69	60	210	240	246	240	85				
24-Nov-87	27	14	89	96	94	86			96	112	114	76	57	204	234	237	237	71				
25-Nov-87	27	14	91	96	91	86			96	112	116	81	57	204	234	240	237	78				
30-Nov-87	22	13	86	87	86	82			87	112	116	72	56	189	234	240	234	60				
01-Dec-87			89	94	91	84			94	112	116	72		201	234	240	231	69				
02-Dec-87			89	94	87	84			94	112	116	72		201	234	240	237	75				
03-Dec-87			91	96	92	87			96	112	114	72		204	234	237	234	81				
04-Dec-87			89	92	87	82			92	111	114	72		198	231	237	237	66				
07-Dec-87			91	94	96	84			96	112	114	72		204	234	237	237	78				
08-Dec-87			92	96	96	86			96	112	116	72		204	234	240	240	72				
09-Dec-87			90	94	82	81			94	112	114			201	234	237	237	69				
10-Dec-87																						
				</																		

Table G-X1c
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel Code	Date	INJECTOR TIP SOAK TEMPERATURES, C								Ambient		Fuel Rail Pres. kPa		Inlet Air		Coolant		Oil		Fuel Tank		Fuel Rail Pres. psi			
					1	2	3	4	5	6	7	8	Max	C	Max	Min	C	Max	Min	C	Max	Min	C	Max	Min	F	Max	Min
(38)	11	D	C	11D-C	26-Mar-87	94	103	103	97				103	116	118	114	33	371	344								54	50
				27-Mar-87	91	99	95	91				99	112	118	114	33												
				30-Mar-87	26	9																						
				31-Mar-87	26	10																						
				01-Apr-87	24	9																						
				02-Apr-87	20	16																						
				03-Apr-87	20	12																						
				06-Apr-87	22	9																						
				07-Apr-87	23	11																						
				08-Apr-87	24	12																						
				09-Apr-87	24	12																						
				10-Apr-87	23	13																						
				13-Apr-87	27	9																						
				14-Apr-87	24	11																						
				15-Apr-87	31	10																						
				16-Apr-87	27	13																						
				17-Apr-87	21	12																						
				20-Apr-87	28	10																						
				21-Apr-87	32	12																						
				22-Apr-87	27	13																						
				23-Apr-87	19	12																						
				24-Apr-87	21	12																						
				27-Apr-87	27	12																						
				28-Apr-87	20	12																						
				29-Apr-87	18	12																						
				30-Apr-87	18	12																						
				01-May-87	20	14																						
				04-May-87	27	13																						
				05-May-87	36	14																						
				06-May-87	33	16																						
				07-May-87	34	17																						
				08-May-87	21	15																						
				11-May-87	19	13																						
				12-May-87	22	13																						

LAB 12

Table G-XII
CRC PORT FUEL INJECTOR DEPOSIT ROUND ROBIN PROGRAM
TEMPERATURE DATA

Run	Lab	Car	Fuel	Code	Date	Ambient Max C	Ambient Min C	INJECTOR	1	2	3	4	5	6	7	8	Max	Inlet Air C	Coolant C	Oil C	Fuel Tank C	Fuel Rail Pressure kPa	Ambient Max F	Ambient Min F	Inj Max F	Inlet Air F	Coolant F	Oil F	Fuel Tank F	Fuel Rail Pressure psi
(39)	12	D	A	120-A	06-Feb-87	8	-3																47	27						
					20-Feb-87	6	-3																42	26						
					03-Mar-87	8	0																46	32						
					09-Mar-87	16	-4																61	25						
					16-Mar-87	8	-1																47	31						
					24-Mar-87	21	3																70	38						
(40)	12	D	C	120-C	24-Mar-87	21	3																70	38						
					30-Mar-87	17	8																62	46						
					03-Apr-87	14	6																58	43						
					09-Apr-87	17	8																62	46						
					15-Apr-87	16	7																60	45						
					21-Apr-87	26	13																79	56						
					24-Apr-87	17	7																62	45						
(41)	12	S	A	125-A	07-Feb-87	11	-1																51	31						
					23-Feb-87	6	0																43	32						
					27-Feb-87	7	-2																44	29						
					05-Mar-87	6	-3																43	27						
					10-Mar-87	-1	-9																30	16						
					13-Mar-87	6	0																42	32						
					20-Mar-87	9	1																48	34						
(42)	12	S	C	125-C	26-Mar-87	19	8																67	47						
					03-Apr-87	14	6																58	43						
					09-Apr-87	17	8																62	46						
					15-Apr-87	16	7																60	45						
					30-Apr-87	16	9																60	49						
					05-May-87	11	7																51	44						
					07-May-87	27	8																80	46						

APPENDIX H

**STATISTICAL ANALYSIS
OF
FUEL INJECTOR FLOW DATA**

APPENDIX H

STATISTICAL ANALYSIS OF CRC
PORT FUEL INJECTOR PLUGGING DATALOUIS J. PAINTER
STATISTICS PLUS

26 February 1988

SUMMARY

The fuel injector plugging data were analyzed with two different models:

1. Exponential drop of percent of original flow to a lower limit (which could be zero flow) with miles on test.
2. A simple linear fit of percent flow reduction to miles on test, through the origin (without an intercept).

The parameters of these two models were then analyzed for fuel and engine type effects and subjected to an analysis of precision for repeated tests in a given car and for car-to-car variability. The exponential model is completely equivalent to looking at percent flow reduction starting at zero at zero test miles and rising at an exponentially decreasing rate to a fitted upper limit of percent flow reduction. The analyses for fuel and engine type effects were finally done in terms of the fitted flow reductions at 3K, 6K, and 10K miles for the exponential model, and slope for the simpler linear model.

Statistical analyses of all four measures of fuel and engine effects showed the same patterns, with all effects significant at at least the 95% level:

	Low	>	>	>	>	>	>	>	>	High	Plugging
Fuel	B					C				A	
Engine	L					GD				F	

Engine types G and D are not significantly different from each other. A detailed tabulation of these results is given in Table H-I, which shows the fitted relationships, the significance levels for the effects, and the fitted mean values for each fuel and engine type.

The test variability, both between repeated tests in the same vehicle and between different cars of the same engine type, is very high. For example, the difference of two single run slopes from a single car has to exceed 1.17 times the average of the two before the pair can be considered suspect. Similarly, the difference of the slopes from two different cars with the same engine type has to exceed 1.36 times the average before the results can be considered suspect. The precision relations are shown in Figures H-1, H-2, and H-3, showing the 95% confidence limits for the difference between two results as a function of their average. Thus, in standard ASTM D02 terminology, the difference between two results should not exceed the charted values more than one time in twenty, in the normal course of running the test as specified.

ANALYSIS DETAILS

The exponential model fits the data quite well, picking up readily those runs which showed a definite nonlinear pattern. For the runs where the plugging rate was high and there was no decided nonlinear pattern, the fitted lower limit on flow rate was close to zero.

Statistically, there is not much difference between the several measures of injector plugging performance. All four show highly significant differences between the fuels and engine types. If anything, the simple linear fitting shows slightly greater significance, but this is due mainly, I believe, to the fact that the lower plugging fuels and engines show a more decided tailing-off of plugging with test miles while the linear model tends to ignore the data close to the origin and fits more closely the high mileage points. This effect, sketched in Figure H-4, increases slightly the magnitude of the differences between the "good" and the "bad" fuels and engines, at least at 3000 miles.

The results of the fuel and engine type effects analyses are summarized in Table H-I, which shows I: the fitted relationships, II: the null hypothesis probabilities (small values indicate highly significant effects), and III: the least squares fitted mean values for each fuel and engine type. Using the 3K miles results as an example, let's look at what each section of Table H-I means.

I. FITTED MODEL COEFFICIENTS:

The numbers given here represent the coefficients in an equation for estimating the flow reduction at 3K miles (% δ = percentage plugged, 100-% δ = percentage clean or not plugged):

Thus $\ln(\% \delta / (100 - \% \delta)) = -4.046$
 +0.774 for Fuel A, or
 -1.301 for Fuel B, or
 +0.0 for Fuel C

 +1.292 for Engine D, or
 +2.064 for Engine F, or
 +1.003 for Engine G, or
 +0.0 for Engine L.

We see from this that the intercept is the estimated value of $\ln(\% \delta / (100 - \% \delta))$ for Fuel C and Engine L. Fuel C and Engine L were chosen as the "reference" fuel and engine simply because C and L are farther down the alphabet than the other codes. To use the equation for estimating a value for Fuel B in Engine F, we take $-4.046 - 1.301 + 2.064 = -3.283$. Working backwards through the log function, we find

$$\% \delta = 100 / (1 + \exp(-(-3.283))) = 3.62\%.$$

II. TAIL PROBABILITIES

These values estimate the probability that we would obtain a value for a model coefficient at least as big as was fitted when the true value of the coefficient is really zero. All fuel effects are relative to Fuel C and all engine effects are relative to engine type L. As the probabilities are all low, we have high confidence that the observed fuel and engine effects are real.

III. FITTED LEAST SQUARE MEANS:

These are estimates of what the averages for each fuel and engine type would have been if the experimental layout had been perfectly balanced, with all cars having been run on all fuels.

So, for Engine D, $-4.046 + (0.774 - 1.301 + 0)/3 + 1.292$
 $= -4.222 + 1.292 = -2.930$

$$\% \delta = 100 / (1 + \exp(2.930)) = 5.07.$$

What was done here was to take the intercept, add the average of the three fuel effects, then add the specific engine effect and then "defunctionalize."

For the Fuel B mean, $-4.046 + \text{average of the 4 engine effects} + \text{the B coefficient}$, or

$$\begin{aligned} & -4.046 + (1.292 + 2.064 + 1.003 + 0)/4 - 1.301 \\ & -4.046 + 1.0898 - 1.301 = -4.257 \end{aligned}$$

$$\% \delta = 100 / (1 + \exp(4.257)) = 1.40.$$

As expected, Fuel A shows greater plugging tendencies than Fuel C, while Fuel B is better than C. This implies that Fuel A is also significantly worse than Fuel C. The situation is somewhat different for engine types: each of the types D, F, and G has significantly greater plugging tendencies than Engine Type L, and F is significantly worse than either D or G, but D and G are not significantly different from each other.

The differences between repeated runs in the same car were analyzed to estimate a Repeatability value, while the differences among cars of a given engine type on each of the fuels were used to estimate Reproducibility (here actually car-to-car variability). The resultant precision estimates are not very well defined since they are based on relatively few degrees of freedom (only nine for Repeatability, and 19 for car-to-car variation).

The 3K and 6K Car-to-Car (same engine type) variations were not distinguishable and so were pooled for final presentation. The repeat (same car) variation was substantially the same for all three mileages

and was therefore pooled. The individual relationships are shown in Figure H-5, with the pooled 3K/6K being shown in Figure H-1, and the 10K precision in Figure H-2. The flow reduction functions used for the precision analysis are the same as shown in Table H-I, namely: $\ln \{ \% / (100 - \%) \}$ for the 3K, 6K and 10K results and $\ln \{ \text{slope} \}$ for the simple linear model. The standard deviations for the precision functions are as follows:

Flow Reduction @	Standard Deviations	
	within car pooled	car-to-car (same engine type) pooled
3K miles	0.504	0.667 } 0.644 } 0.753 } 0.656
6K miles	0.475	
10K miles	0.511	
Linear Slope	0.472	0.588

The transformation used for % plugging at 3K, 6K, and 10K miles results in a complicated precision expression, the results of which are shown in Figures H-1 and H-2 using the pooled values from the table above. Figure H-5 shows all the individual precisions simply to indicate how close are the several values that were pooled.

The logarithmic function for slope allows the slope precisions to be expressed simply as multiples of the average of the two measured slopes, to wit:

$$\begin{aligned} \text{Car-to-car (Reproducibility)} &= 1.36 * \text{Mean Slope} \\ \text{Same car (Repeatability)} &= 1.17 * \text{Mean Slope} \end{aligned}$$

These relationships are graphed in Figure H-3.

A detailed examination for statistical outliers was made for all fuel-engine type combinations in which five or more tests were run. No results could be declared outliers at the 99% significance level. And those few that were borderline at the 95% level were not the tests that were considered suspect by the originating labs. Thus no deletions have been made from the data for any of the analyses. The car-to-car variability also includes any lab-to-lab effects. There simply were not enough cars run at each of the labs to attempt to isolate any separate lab effects.

An analysis for the effects of various external conditions (soak temperatures, whether tests were run indoors or out, etc.), was not made because it was considered highly unlikely that anything useful would come from the effort. The basic reasoning here is that it is difficult enough to find minor effects in a well designed test program, but with the temperatures, modes of operation, etc. coming about in a totally unplanned way, it would be impossible to trust any of the statistical analysis results. No printed significant or insignificant results could be believed.

ACKNOWLEDGEMENTS

I would like to thank Mr. Brian Y. Taniguchi for his assistance in providing interpretation of the data and the Chevron Research Company for the use of the Chevron computing system in making the statistical analyses.

TABLE H-I

FUEL AND ENGINE TYPE EFFECTS: SUMMARY

I. FITTED MODEL COEFFICIENTS

	Analyzing Flow Reductions @			Linear
	<u>3K Miles</u>	<u>6K Miles</u>	<u>10K Miles</u>	<u>Slope</u>
Intercept	-4.046	-3.718	-3.616	-0.755
Fuel: A	+0.774	+0.908	+1.048	+0.774
B	-1.301	-1.518	-1.676	-1.402
C	0	0	0	0
Eng.: D	+1.292	+1.481	+1.708	+1.337
F	+2.064	+2.360	+2.721	+2.053
G	+1.003	+1.177	+1.362	+1.081
L	0	0	0	0

II. TAIL PROBABILITIES

	Analyzing Flow Reductions @			Linear
	<u>3K Miles</u>	<u>6K Miles</u>	<u>10K Miles</u>	<u>Slope</u>
Fuel: A	.0017	.0005	.0004	.0008
B	.0025	.0008	.0011	.0006
C	.	.	.	.
Eng.: D	.0090	.0043	.0039	.0038
F	.0002	.0001	.0001	.0001
G	.0482	.0265	.0243	.0224
L	.	.	.	.

III. FITTED LEAST SQUARE MEAN VALUES

	Analyzing Flow Reductions @			Linear
	<u>3K Miles</u>	<u>6K Miles</u>	<u>10K Miles</u>	<u>Slope</u>
Fuel: A	10.14	17.44	24.60	3.11
B	1.40	1.83	2.10	0.35
C	4.94	7.85	10.26	1.44
Eng.: D	5.07	8.02	10.74	1.45
F	10.36	17.36	24.90	2.97
G	3.85	6.05	7.85	1.12
L	1.45	1.94	2.14	0.38

Flow Reductions analyzed as $\ln \{ \% / (100 - \%) \}$
 Slope analyzed as $\ln \{ \text{slope} \}$

FIGURE H-1
PRECISION POOLED
% FLOW REDUCTION AT 3K AND 6K MILES
CRC-PFI Study - Exponential Model
95% Confidence Limits for Difference of Two Results

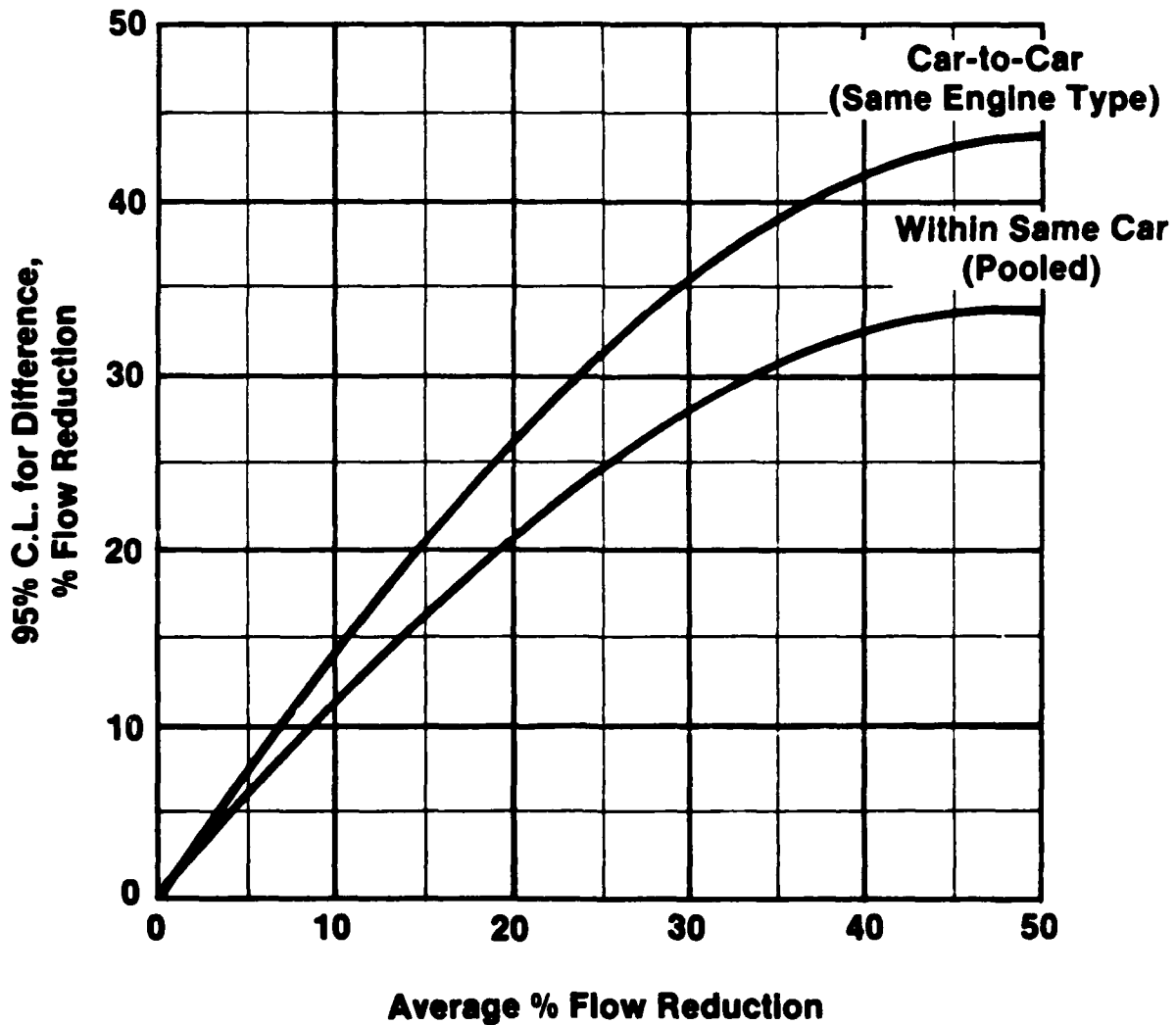


FIGURE H-2
PRECISION % FLOW REDUCTION AT 10K MILES
CRC-PFI Study - Exponential Model
95% Confidence Limits for Difference of Two Results

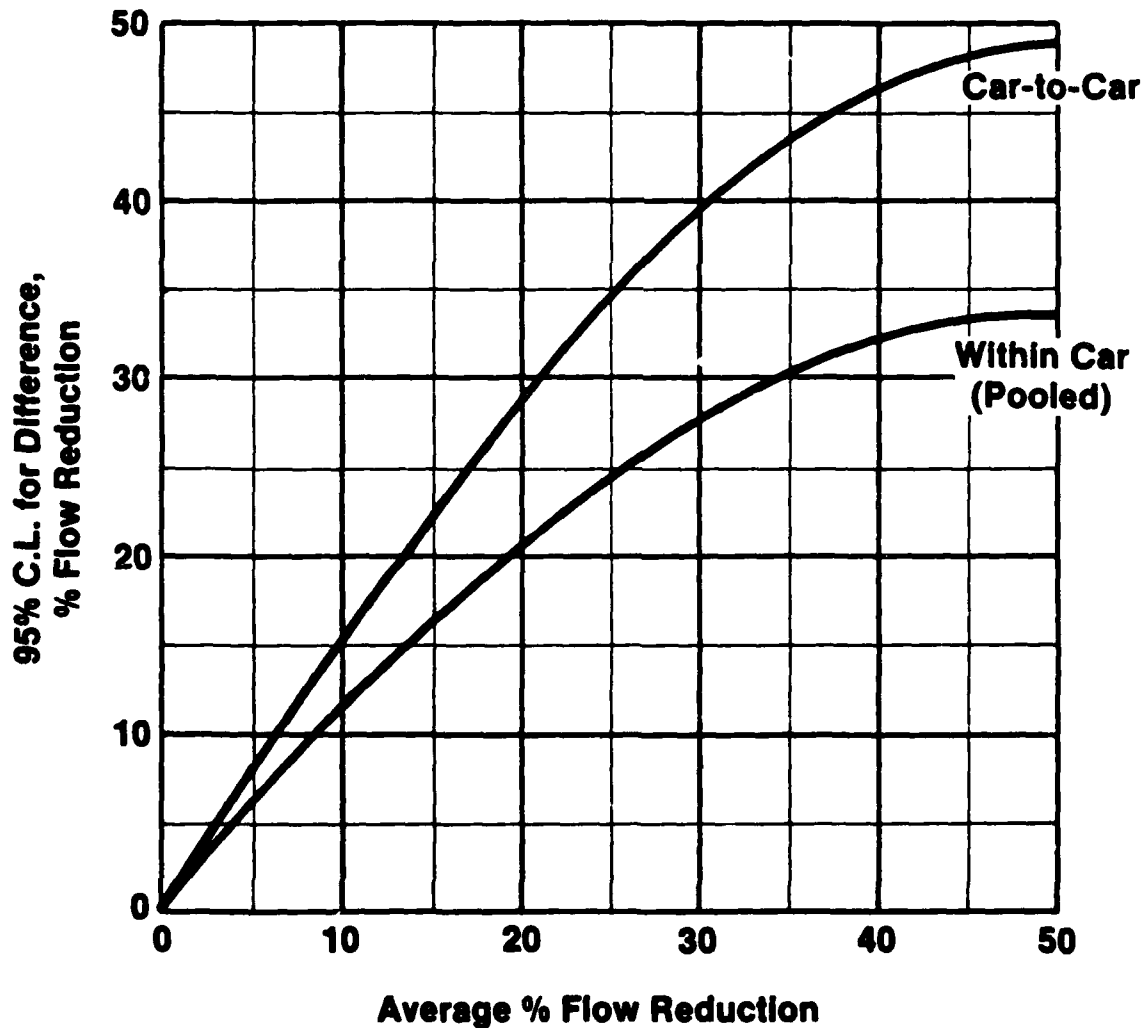


FIGURE H-3**PRECISION LINEAR SLOPE
% FLOW REDUCTION/1000 MILES**

**CRC-PFI Study - Linear Model
95% Confidence Limits for Difference of Two Results**

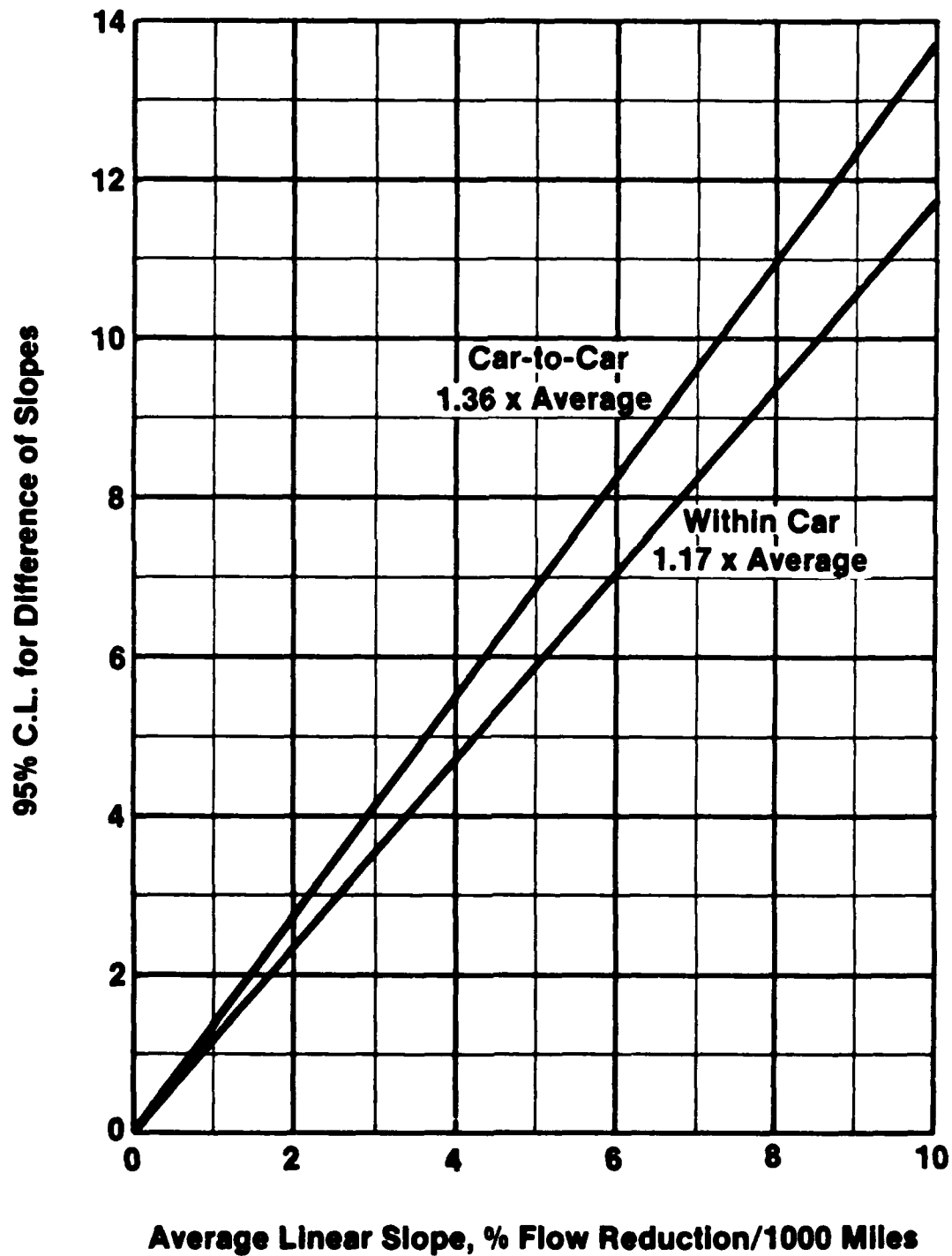


FIGURE H-4
SCHEMATIC PICTURE OF DIFFERENCES IN
FITTING EXPONENTIAL MODEL VERSUS
SIMPLE LINEAR REGRESSION

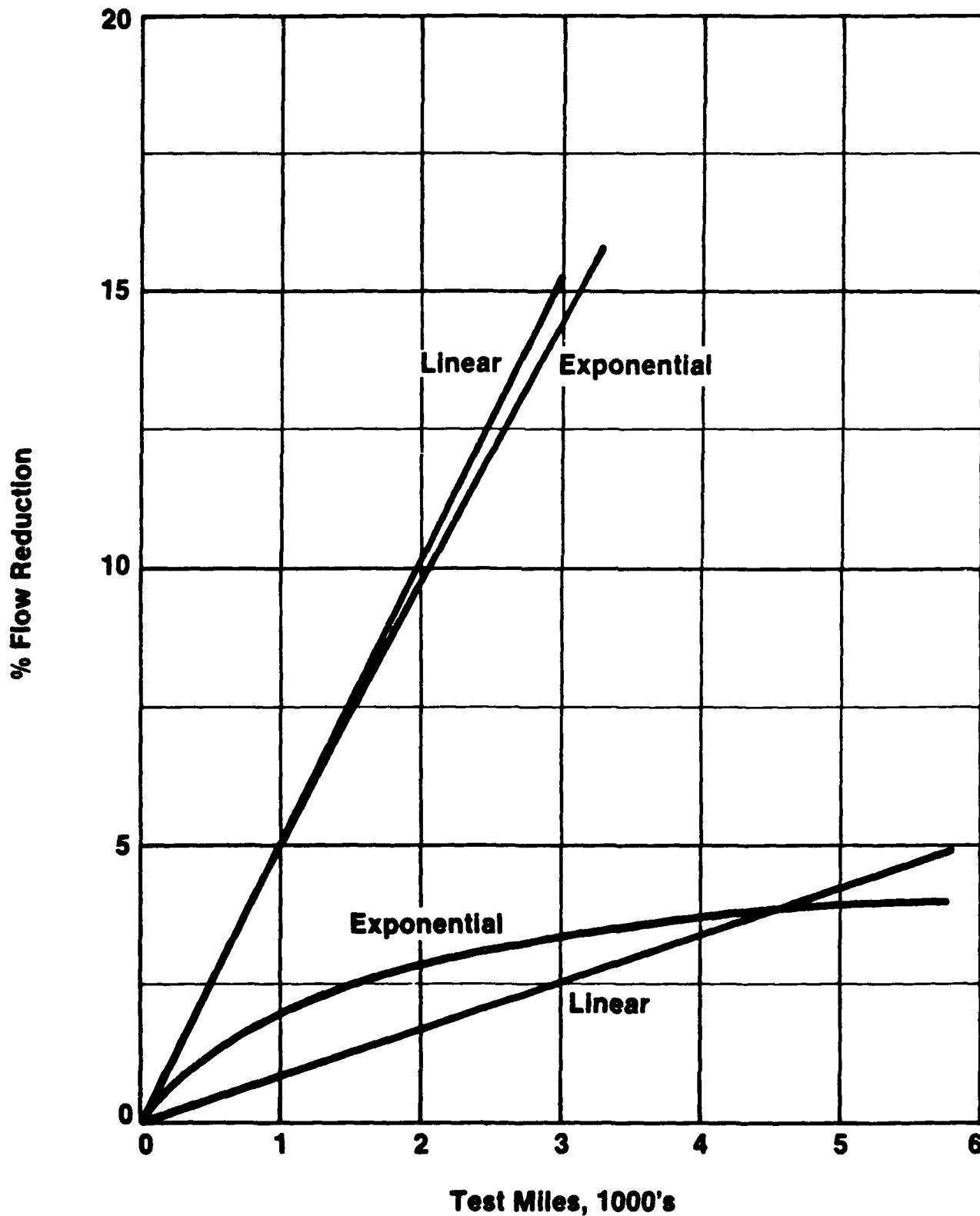


FIGURE H-5
PRECISION % FLOW REDUCTION AT 3K, 6K, 10K MILES
EXPONENTIAL MODEL

95% Confidence Limits for Difference of Two Results

