AD-A271 775

CRC Report No. 585

ASSESSMENT AND CORRELATION OF CUSTOMER AND RATER RESPONSE TO COLD-START AND WARMUP DRIVEABILITY

DAAK-70-89-C-0022

August 1993

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 USA 30346
PHONE: (404) 396-3400
FAX: (404) 396-3404

ASSESSMENT AND CORRELATION OF CUSTOMER AND RATER RESPONSE TO COLD-START AND WARMUP DRIVEABILITY (CRC Project No. CM-118-91)

Prepared by the

CRC Volatility Group

August 1993

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc

TABLE OF CONTENTS

TABLES AND FIGURES

APPENDICES

ABSTRACT

A program was conducted from January 14 through March 8, 1991, at Southwest Research Institute (SwRI) in San Antonio, Texas, to establish a relationship between demerits observed in CRC Cold-Start and Warmup Driveability assessments to customer satisfaction levels, and to determine which of several performance deficiencies associated with low volatility gasolines are most troublesome to customers during normal vehicle warmup. Customers used their vehicles in daily service, and a subset of the test fleet was evaluated by trained raters using the established CRC test procedure. There were 7,206 driveability performance assessments by customers which were correlated with 661 trained-rater cold-start driveability evaluations. One hundred sixty-seven SwRI employees participated in the program. Hesitation was the most widely observed problem and was the primary cause of dissatisfaction. The gasoline-ethanol and hydrocarbon-only fuel sets had distinctly different malfunction patterns. Hesitation was strongly associated with gasoline-ethanol blends, while surge and stumble were strongly associated with hydrocarbon-only fuels. The current total weighted demerit (TWD) system was found to correlate poorly with customer satisfaction; however, customer observations of problems correlated no better with customer satisfaction. If TWD is to be an indicator of customer perception of driveability performance there should be uniform weighting of rater-observed malfunctions, and start-time should be assigned a greater weighting and a shorter grace period.

I. Introduction

In recent years, the Coordinating Research Council (CRC) has run several cold-start driveability programs [(1-4)] to determine the performance of late-model vehicles using a wide variety of fuel volatilities and fuel compositions. The results of these programs have demonstrated that driveability is related to fuel volatility and that the newer throttle-body-injected and port-injected vehicles perform better than the older carbureted vehicles in controlled testing by trained raters. It is not known, however, if customers can appreciate these differences. It is widely believed that customer satisfaction has improved, but data to verify this have been lacking. Customers could be more sensitive, and they might expect vehicles to perform better. The only customer data publicly available prior to this program were from a CRC program in San Antonio conducted in 1978 [(5)]. During that program, data were obtained from about 100 customers in 1973-1978 vehicles. The data are valid on those vehicles, but must be updated on newer vehicles. In addition, data are lacking on the customer acceptance of oxygenated fuels.

The CRC Volatility Group thus conducted a program from January 14 through March 8, 1991, at Southwest Research Institute (SwRI) in San Antonio, Texas. The objectives of the program were to establish a relationship between demerits observed in CRC Cold-Start and Warmup Driveability assessments to customer satisfaction levels, and to determine which of several performance deficiencies associated with low volatility gasolines are most troublesome to customers during normal vehicle warmup. Customers used their vehicles in daily service, and a subset of the test fleet was evaluated by trained raters using the established CRC test procedure. There were 7,206 driveability performance assessments by customers which were correlated with 661 trained-rater cold-start driveability evaluations. In addition, 166 cold-start driveability evaluations were performed by trained raters on the rental car fleet. Because the customers were informed of the driveability problems to evaluate, they were actually "informed drivers" rather than typical customers. For simplicity, however, the term customer will be used throughout this report.

Members of the Data Analysis Panel, program participants, and the program proposal are given in Appendices A, B, and C, respectively. Because of the enormous size of the data set, the data listing is not included in this report; however, the data set is available from the CRC office in SAS format and requires 9.5 megabytes of disk space.

II. Summary and Conclusions

- The current total weighted demerit (TWD) system correlates poorly with customer satisfaction; however, customer observations of problems correlate no better with customer satisfaction. With the exception of surge, and to a lesser extent start time and stumble, the current TWD system also correlates poorly with customer problems.

- The best correlation of customer satisfaction and rater-observed problems was achieved using a discriminant model rather than a traditional regression model, or any other statistical method evaluated.

- Hesitation, occurring in 15 percent of all trips, was the most widely observed problem.

- Stalls at idle, hard starting, and idle roughness occurred in 7 to 9 percent of trips.

- Hesitation was the primary cause of dissatisfaction (31%). Stall at idle and hard starting together accounted for 30 percent of dissatisfied trips.

- A good correlation was found between customer problems and rater-observed malfunctions using a non-routine statistical technique.

- The gasoline-ethanol and hydrocarbon-only fuel sets had distinctly different malfunction patterns. Hesitation was strongly associated with gasoline-ethanol blends; surge and stumble was strongly associated with hydrocarbon-only fuels.

- The breakpoint between customer satisfaction and dissatisfaction occurs primarily between a Driveability Index (DI) of 1140 to 1250 for gasoline-ethanol blends, and 1210 to 1290 for hydrocarbon-only fuels. Approximately 30 percent of the customer fleet was satisfied with all fuels tested. ($DI = 1.5T_{90} + 3T_{50} + T_{90}$)

- The only comparison between hydrocarbon-only fuels, gasoline-ethanol blends, and gasoline-MTBE blends that can be made is through Fuels 3, 8, and 11. Percent of customer satisfaction for these fuels as a function of the vehicle fuel-delivery system is shown below:

	Percent Satisfaction on Fuel		
Fuel	Carb	PFI	TBI
3 (HC only)	90	94	95
8 (EtOH blend)	64	86	85
11 (MTBE blend)	95	96	97

  Carbureted vehicles operating on gasoline-ethanol blends had the lowest percent satisfaction of any fuel delivery system vehicles operating on any fuel.

- If TWD in the current CRC Cold-Start and Warmup Driving Cycle is to be an indicator of customer perception of driveability performance, the following changes to the numerical scoring method should be made:

  Uniform weighting of rater-observed malfunctions.

  Start time should be assigned a greater weighting and a shorter grace period.

- The current CRC test procedure evaluates relative fuel performance in vehicles, but does not correlate well with customer satisfaction or perception, in part because customer perception varies widely with the performance of any given vehicle. In order to improve the correlation between raters and customers, modification of the demerit system, the driving cycle, or both should be considered.

III. Customer Base and Test Vehicles

One hundred sixty-seven SwRI employees participated in the program. An application form, shown in Appendix C, was circulated to all SwRI employees. Customers were selected based upon review of the application forms, subsequent telephone interviews, and physical evaluations of the applicant vehicles. All drove 1985-1991 vehicles daily, stopped several times in the first few miles to work, and were requested to park their vehicles outdoors overnight. A summary of the model year, fuel system, and number of cylinders of the customer test fleet is given in Table 1, and a detailed description of the customer test fleet is given in Appendix D.

Forty-eight rental vehicles were used to provide transportation for the customers when their personal vehicles were retained overnight for testing. These rental vehicles were also evaluated each week by the trained raters to develop rater correction factors. Partway through the program, it was necessary to replace sixteen of the rental vehicles because of rental agency constraints. A detailed list of the rental vehicles is shown in Appendix E.

Fuel systems in 152 customer vehicles were drained during fuel changeover through Schroeder valves in the vehicle fuel systems. In some cases, it was necessary to install tees equipped with Schroeder valves and caps. Fifteen of the customer vehicles were equipped with fuel systems which were unable to be drained. All customer vehicles which were evaluated by trained raters were able to be drained. The rental vehicles were drained and fueled with test fuel at the start of the program. They were fueled with the same test fuel throughout the program; thus, they were not drained during the program.

IV. Fuels

The test fuel set contained hydrocarbon-only fuels, 10 volume percent gasoline-ethanol blends, and a 15 volume percent gasoline-MTBE blend.

The hydrocarbon-only fuel set was targeted as follows:

	Fuel 1	Fuel 2	Fuel 3	Fuel 4	Fuel 5
RVP, psi	7.5	75% of Fuel 1 plus 25% of Fuel 5	50% of Fuel 1 plus 50% of Fuel 5	25% of Fuel 1 plus 75% of Fuel 5	11.0
T_{10},°F, % Evap	138				100
T_{50},°F, % Evap	240				200
T_{90},°F, % Evap	355				300

Fuel 1 was a hydrocarbon-only fuel close to the minimum volatility specifications for ASTM Class C fuels. Fuel 5 had higher volatility than Fuel 1, and provided parallel distillation curves in the blended fuels. Fuel 5 was near the 60th percentile of volatility for fuels sold in ASTM Class C areas.

The gasoline-ethanol fuel set was targeted as follows:

Fuel 6	Fuel 7	Fuel 8	Fuel 9	Fuel 10
10 EtOH splashed in Fuel 1	75% of Fuel 6 plus 25% of Fuel 10	50% of Fuel 6 plus 50% of Fuel 10	25% of Fuel 6 plus 75% of Fuel 10	10% EtOH splashed in Fuel 5

In addition, there was an MTBE fuel (Fuel 11). This was a 15 volume percent gasoline-MTBE blend splash-blended into Fuel 3.

All fuels were targeted to have 92-93 (R+M)/2 octane number, with a commercial fuel detergency additive package, including a corrosion inhibitor and antioxidant.

Samples of each fuel were sent to eight laboratories for analysis. The major average fuel properties are shown in Table 2; detailed average fuel properties as well as individual laboratory analyses are given in Appendix F.

Test fuels were dispensed to customers from underground storage tanks at SwRI. Fuels 1 through 5 were dispensed through one blend pump; Fuels 6 through 10 were dispensed through a separate blend pump; Fuel 11 was dispensed through a single dispenser.

V. Test Facilities

The program was conducted at Southwest Research Institute (SwRI) in San Antonio, Texas. SwRI met a variety of criteria necessary to conduct the program, including a population of drivers commuting to a central location, a mix of suburban and freeway driving, appropriate weather conditions, low altitude, on-site fueling facilities, and an on-site test track. SwRI was also able to provide various miscellaneous support activities to ensure smooth operation during the program.

The test track for trained-rater evaluations was a half-mile paved track sufficiently wide for two vehicles to pass abreast with turnarounds at each end. Test vehicles were parked overnight at the west end of the track. A schematic of the test track is presented in Figure 1.

VI. Test Conditions

Soak and test temperatures were taken at SwRI during the trained-rater evaluations. Customers experienced a range of soak and start-up temperatures depending upon their location; thus, no data are available regarding the precise weather conditions under which the customer vehicles were operated by the customers. All customers lived within a reasonable commuting distance of SwRI; however, it is expected that those living in the Hill Country located north and west of the city encountered lower temperatures than those recorded at SwRI, and those living south of San Antonio may have encountered higher temperatures.

The range of overnight soak temperatures recorded at the SwRI test track is 37°F to 63°F, with a mean soak temperature of 50°F, and a standard deviation from the mean of 6.4°F. The range of test temperatures is 40°F to 68°F, with a mean test temperature of 53°F, and a standard deviation from the mean of 6.2°F. A summary of temperatures recorded at SwRI is presented in Appendix G.

There were no test days lost due to poor weather.

VII. Test Design

The program encompassed 167 customers (SwRI employees) who were requested to come in to the SwRI fueling facility each week for refueling. Of this overall fleet, 96 vehicles were selected based upon logistical evaluations for CRC trained-rater evaluations. Each customer was assigned a fixed day each week for refueling. Of the 96 vehicles in the trained-rater-evaluated subset, 24 vehicles were retained overnight each Monday through Thursday night for overnight soak and rater evaluation the following morning. The customers were given a rental car to use for their personal transportation while their vehicle was being rated. All customer vehicles were returned to the customers by Friday so that the customers were able to use their own vehicles over the weekend. Since all the rental cars were back in the possession of CRC over the weekend, the rental cars were tested by the trained raters each Monday morning. Since there were two rater teams each testing twelve vehicles per day, it was necessary to alternate rental cars each week.

All 167 customers completed a questionnaire each day evaluating the performance of their vehicles, along with a weekly questionnaire reporting their overall satisfaction with their vehicles' performance over the entire week. Customers were asked to list observed problems. If they were dissatisfied, they were asked to circle the primary cause of their dissatisfaction. Blank questionnaires are included in Appendix C. These questionnaires were collected and reviewed when the vehicle was brought in for the assigned weekly refueling, and the selection of the new fuel was based on the customer's report for that test period. The customer's vehicle was then drained and refueled with the new test fuel. Those vehicles not being evaluated by the trained raters were then available for the customers to retrieve at their convenience during the day. Those vehicles in the trained-rater-evaluation subset were then taken to the test track and parked overnight to test the following morning. Following testing, the vehicles were returned to the fueling area for customer retrieval.

Special precautions were taken to ensure that vehicle owners were not subjected to potentially dangerous fuel-related malfunctions. Accordingly, vehicles in the trained-rater-evaluation subset were tested by trained raters prior to returning them to their owners. If the rater considered the vehicle's performance potentially dangerous on the road, the vehicle was given a brief mechanical check and refueled if necessary with a more volatile fuel. The vehicle was then retained another night and tested by the trained rater with the new fuel. Similarly, customer vehicles which were not evaluated by trained raters were never given Fuels 1 or 6, the blends with lowest volatility.

Customers were allowed to bring their vehicles to the fueling facility for filling their fuel tanks with their assigned test fuel at any time during the week. Refueling was always handled by CRC personnel. The customers were never told which test fuels were in their vehicles. Fuel codes were added to the rating sheets after they were collected by CRC personnel using the master fuel assignment list. A small percentage of the customers were observed to complete more than one daily questionnaire at the time the questionnaires were collected. This is a source of error for which no correction can be made, and is to be expected in programs of this type.

VIII. Test Procedure

The test procedure used during the trained-rater evaluations was the CRC Cold-Start and Warmup Driveability Procedure, presented in Appendix C. The driving technique for manual transmission vehicles was modified to minimize demerits associated with clutch operation and gear changes. Shift speeds, gear selection, and throttle were chosen to give smooth warmed-up operation while meeting test requirements for acceleration and speed. The technique used for manual transmission vehicles is also described in Appendix C.

IX. Assignment of Vehicles to Fleets

Potential customers who had previously indicated a willingness to participate in the program were assigned to one of three subsets. The subsets were:

Hydrocarbon-Only TWD Fleet	-	48 Vehicles Required
Ethanol Blends TWD Fleet	-	48 Vehicles Required
Survey Fleet	-	Unlimited Vehicles (71)

In making assignments of vehicles to groups, the priority was to complete the two TWD fleets first. Only customers that were willing to leave their vehicles overnight at SwRI for TWD testing the following day could be accepted into this group. It was required that fuel be drained from the vehicle for weekly fuel changeover; therefore, participants unwilling to leave their vehicle overnight or those whose vehicle could not be drained were assigned to the survey fleet. After the 96-vehicle TWD fleet requirements were completed, additional participants were assigned to the survey fleet.

The assignment of test vehicles to the hydrocarbon-only or ethanol blend fleets was strictly on a random basis. No attempt was made to balance these two fleets with regard to make, fuel delivery system, model year, odometer, etc.

X. Relationship of Fuel System Performance to Fuel Type

Fuels 3, 8, and 11 are the only fuels tested by all vehicles within the hydrocarbon-only TWD fleet, the ethanol-blend TWD fleet, and the survey fleet, respectively. Fuels 3, 8, and 11 are all 50/50 blends of the highest and lowest volatility parent fuels, with Fuels 8 and 11 being splash-blended with ethanol and MTBE, respectively. The data from these three fuels thus provide the least biased estimate regarding the effects of oxygenates on customer perception of driveability. It should be noted that the MTBE fleet contained more vehicles equipped with manual transmissions. The results are presented below. There is a certain amount of bias since all vehicles did not test all fuels. This will be handled in Section XI.

Percent of Customers Satisfied

Fuel Volatility	Vehicle Subset	Carburetor	PFI	TBI
Hydrocarbon-only Fuels				
Low (Fuels 1 & 2)	Low	87* (1211)**	78 (1627)	89 (1013)
Median (Fuel 3)	All	90 (404)	94 (626)	95 (390)
High (Fuels 4 & 5)	High	85 (97)	93 (105)	95 (42)
Ethanol Blends				
Low (Fuels 6 & 7)	Low	79 (265)	75 (878)	89 (459)
Median (Fuel 8)	All	64 (132)	86 (372)	85 (162)
High (Fuels 9 & 10)	High	64 (95)	48 (64)	96 (24)
MTBE Blend				
Median (Fuel 11)	Non-Rater	95 (282)	96 (485)	97 (274)

* Customer Daily Data Set - Overall Percent Satisfaction of Vehicle Testing the Fuel Category Listed

** Numbers in parentheses = number of tests

Vehicle Subset - Based upon vehicle customer sensitivity to fuel volatility

For the hydrocarbon-only fuel (Fuel 3), customer satisfaction was 90, 94, and 95 percent for carbureted, TBI, and PFI vehicles, respectively; whereas for the ethanol blend (Fuel 8), satisfaction was 64, 86, and 85 percent for the three fuel-system types, respectively. The MTBE blend (Fuel 11) gave excellent satisfaction (approximately 96 percent) for all fuel systems; however, no low-volatility MTBE blends were tested, so direct comparision with low-volatility hydrocarbon-only fuels and ethanol blends is not possible. The debit in driveability associated with ethanol blends which has been shown in prior trained-rater programs is substantiated in this program with customer data. The effect is especially prominent for carbureted vehicles.

XI. Satisfaction Curves - TWD Fleet

There are fundamental limits on a customer program. For example, the customer may not be given a fuel that might cause a dangerous stall; therefore, the customers were only dispensed fuels that might be legally sold, and were found to be safe in their vehicle during the trained-rater testing. Further, if a customer was dissatisfied with a fuel, they were not given a worse fuel. These restrictions cause sensitive vehicles or customers to use only the more volatile fuels, while less sensitive vehicles or customers use only the less volatile fuels. Each fuel is, therefore, tested by a different subpopulation of vehicles/customers, so comparisons cannot be made among the percent of customers satisfied with each fuel.

An approximation of that number can be obtained, however, by defining a "satisfaction breakpoint." This number is defined as the mean of the highest volatility fuel with which a given customer was dissatisfied and the lowest volatility fuel with which the customer was satisfied. It is effectively the line between satisfaction and dissatisfaction for that customer. Given this definition, the data generated by the customer/rater fleet can be analyzed to find the percent of customers who found their breakpoint at or above a given Driveability Index (DI) (Figure 2). This approximates the percent satisfied as a function of DI. Taking the satisfaction breakpoint as a measure of customer satisfaction, at the same volatility, more customers are satisfied with hydrocarbon-only fuel, than with fuel containing 10 percent splash-blended ethanol. The slopes of the two curves are roughly parallel, however, except for a long "tail" on the ethanol blend curve. This seems to indicate that, with the exception of a few vehicles that are very sensitive to the addition of ethanol, the same number of customers can be satisfied if the DI is lowered by 50 when 10 percent ethanol is splashed into hydrocarbon-only fuel. Much of this decrease typically occurs automatically, because adding ethanol to fuel lowers the T_{50} and, in some cases, lowers the T_{10} as well.

Approximately 10 percent of the modern fleet would still be dissatisfied, however, represented by the vehicles in the "tail" of the ethanol curve. The characteristics of those vehicles were studied to see if similarities could be found. The vehicles were found to be carbureted and PFI trucks, vans, and a large passenger car. With the exception of one truck, they all had engines with 5.0-liter displacement or more. Because this population is also well-represented in the hydrocarbon-only fleet, it is likely that the effect is real and not a manifestation of bias between the fleets. Approximately 15 percent of the vehicles are extremely sensitive to the ethanol-blended fuels and may account for the difference between the ethanol blends and hydrocarbon-only fuels seen in previous studies. The other 85 percent of the vehicles in this program showed a similar trend of percent satisfied with the ethanol blends as they did with the hydrocarbon-only fuels.

The rater demerits associated with each customer weekly rating can be analyzed in a parallel fashion. For each customer, the mean number of demerits found on the lowest volatility fuel with which they were satisfied and the highest volatility fuel with which they were dissatisfied can be averaged to obtain a measure of the mean demerits at the breakpoint. These values can be averaged for all customers with their breakpoint at a given DI level. The mean demerits at the breakpoint are not a function of volatility; the variation in mean demerits at the breakpoint varies randomly along the breakpoint curve. Further, the means for ethanol-containing and hydrocarbon-only fuels are not statistically significantly different. Overall, the mean is 83 demerits at the breakpoint, including rater correction for Rater C.

XII. Satisfaction Versus Fuel Volatility Level - TWD Vehicles

The rules for fuel selection for each individual vehicle were:

1. Initially, fuel with average volatility level (Fuel 3 for hydrocarbon-only fleet, and Fuel 8 for ethanol-blend fleet) was dispensed.

2. If the customer reported satisfaction on Fuel 3 or 8, he was given the next lowest volatility fuel (Fuel 2 or 7) for the next week. If the customer indicated dissatisfaction on Fuel 3 or 8, he was given the next most volatile fuel (Fuel 4 or 9) for the following week.

3. This selection process continued each week, with each vehicle treated individually throughout the program.

Initial operating weeks are not useful in computing a satisfaction curve, because it took several weeks for each customer and vehicle to reach their threshold fuel. By the very nature of the schedule, all vehicles operated on Fuel 3 or 8 in Week 1. During Week 2, all vehicles operating on hydrocarbon-only fuels received either Fuel 2 or 4, while all vehicles operating on the ethanol blends received either Fuel 7 or 9. Fuel 1 or 6 was not dispensed until the third week of the program. By Week 4, vehicles were operating on a distribution of fuels.

Weekly evaluations of customer satisfaction levels for each fuel were calculated using a method which extracts information on performance with fuel/customer combinations that may not have actually been tested. To make these calculations, the letters in the following table were assigned to represent the number of customers either dissatisfied or satisfied on a given fuel:

	Fuel Number				
	1 or 6	2 or 7	3 or 8	4 or 9	5 or 10
Number Dissatisfied	A	B	C	D	E
Number Satisfied	a	b	c	d	e

For the hydrocarbon-only fuel set, "a" represents the number of customers satisfied with their vehicles's performance on Fuel 1 for a given week. The percent satisfied with Fuel 1 is "a" divided by the total number of reports submitted that week for all fuels, "A+a+B+b+C+c+D+d+E+e." Since, by Week 4, those running on Fuels 2 through 5 had already reported either dissatisfaction with Fuel 1 or a higher number fuel, they were assumed to be dissatisfied with Fuel 1.

By Week 4, the satisfaction of customers represented by "b" was ambiguous. Although they were now satisfied with Fuel 2, at one point during the first four weeks they were dissatisfied with Fuel 1, and it is unknown if they would have been satisfied with Fuel 1 during the current week. For the purposes of this calculation, it was assumed that customers remained either satisfied or dissatisfied with a given fuel until they retested it and stated otherwise.

The percent satisfied with Fuel 2 was "A+a+b" divided again by the total number of reports. Note that both satisfied and dissatisfied customers using Fuel 1 are assumed to be satisfied with Fuel 2. This same logic was used for all fuels except the single MTBE-gasoline blend, Fuel 11. In summary, the mathematical expressions used to calculate customer satisfaction levels were:

% satisfied Fuel 1 or 6 = (a/Total Reports)*100
where Total Reports = A+a+B+b+C+c+D+d+E+e

% satisfied Fuel 2 or 7 = ((A+a+b)/Total Reports)*100

% satisfied Fuel 3 or 8 = ((A+a+B+b+c)/Total Reports)*100

% satisfied Fuel 4 or 9 = ((A+a+B+b+C+c+d)/Total Reports)*100

% satisfied Fuel 5 or 10 = ((A+a+B+b+C+c+D+d+e)/Total Reports)*100

Because 10 percent of the customers did not start the program until the second week, those vehicles did not have the opportunity to reach their threshold fuel until Week 4; therefore, satisfaction levels were computed beginning with Week 4. The week-by-week levels for Weeks 4, 5, and 6 were very consistent. Week 7 satisfaction levels are somewhat higher, probably due to the warmer prevailing weather that week. The mean satisfaction levels for Weeks 4-6 are shown in Figure 3.

The results are generally parallel to those for the satisfaction breakpoint analysis described in Section XI. Satisfaction levels of 42 percent were found on Fuel 1 and 33 percent on Fuel 6. In each case, there is lower satisfaction with the ethanol blends in spite of their higher volatility as measured by the DI scale. Although the two curves represent two different fleets of 48 vehicles each, there is no reason to believe that one group of vehicles was more critical and/or sensitive to fuel volatility than the other. This result was expected. The ethanol fuels were included in the program to improve discrimination capabilities of the experiment and test the effect of oxygenates while maintaining fuels within ASTM specification limits.

XIII. Comparison of Customer and Rater Results

The Analysis Panel attempted to analyze the data in a way that would be equivalent to the data analysis for the 1978 program [5]. This could not be a straightforward imitation of the 1978 work, however, because of the differences in the studies. The 1978 study had a standard factorial design for vehicles and fuels, such that each vehicle saw each fuel the same number of times. The 1991 study had a deterministic design. Concern c... customer safety, along with economic and time constraints, precluded use of a factorial test design similar to that used in 1978. The intent of this study was to determine the relationship between fuel volatility and customer driveability satisfaction. In addition, there was the specific desire for the development of a revised TWD function which would be based on its ability to provide a consistent representation of how the customer would evaluate the fuel.

There were two types of customer information: malfunction indications, and weekly evaluations of the fuel, both for satisfaction and rating. It was attempted to define a customer demerit function that would provide weights for weekly customer averages for each malfunction type such that the customer demerit function would relate well to customer satisfaction and rating for the fuel. There did not appear to be any practically consistent set of weights for the average weekly malfunction results that would do a good job correctly classifying or rating the customer's weekly assessment. The one that was selected with statistical and engineering rationale did not correlate much better with TWD than the results for the 1978 study. This led to the need to develop a revised TWD.

Trained-rater results similarly had little classification ability for the customer satisfaction or rating. Data analysis did not indicate any improvement could be achieved by changing from the current 0-1-2-4 weighting system for None/Trace/Moderate/Heavy (N-T-M-H) evaluations, so there is no recommendation for a change. Canonical correlation analysis showed that a linear combination of the customer average weekly demerits could be found that correlated well with a linear combination of the trained-rater demerits. Averaging malfunctions over all cycles seemed to give the best correlation between customer and rater observations with the exception of moving stalls. Moving stalls are infrequent and random.

A. Rater Correction Factors

Rater correction factors are needed if one or more raters rate significantly differently from the rest. The correction factor corrects that raters data so that the rater's mean equals that of the other raters. In this program, the ratings of the rental vehicles were used to determine the rater correction factors. The rental vehicles were only rated on Fuel 1, so no fuel effects are possible. Initially, all the rater data on the rental vehicles were analyzed, including temperature correction to 55°F, using SAS proc GLM. This analysis showed that Rater C provided ratings that were significantly lower than the other three. There was no significant difference among the other three raters. Results can be seen in the following table of least squares means for LOG (TWD):

Rater	Mean
A	5.03
B	5.02
C	4.32
D	4.99

Simple offset of Rater C's ratings by 58 demerits would correct the means; however, it would also require that any vehicle rated by Rater C would have a minimum of 58 demerits. Since this program involved many vehicles that seldom exceeded 50 demerits, this is not a reasonable method to correct Rater C's data. Instead, a multiplicative factor was sought. The determination of the multiplicative factor is dominated by the low demerit data, leading to a factor slightly greater than two. This approach encounters difficulties when Rater C finds a large number of demerits, because these ratings become unrealistically high. Thus, an exponential factor of the form (X) (TWD)**Z was used where X and Z are constants determined from the temperature-corrected data using SAS proc REG, so that Rater C will have the same mean corrected TWD as all the other raters lumped together.

Using regression analysis, it was determined that the adjustment for Rater C should be:

$$\text{Adjusted TWD(C)} = 7.192 * \text{TWD(C)} ** 0.694$$

The equation was based on the sixteen vehicles evaluated by Rater C which were also evaluated by at least one of the other raters. This transform was applied to Rater C's data prior to further analysis.

B. Development of Customer Mean Weighted Demerit Calculation (CMWD)

In order to evaluate customer perception in a numerical fashion, a customer demerit system was developed. The demerit system reflects the demerit system for trained raters in that each possible malfunction is assigned a weight and that weight is multiplied by a severity factor to arrive at that malfunction's contribution to total demerits. The weights reflect the degree to which that malfunction can contribute to total dissatisfaction. This occurs in two ways: the problem can cause dissatisfaction by itself, or the malfunction can contribute to overall dissatisfaction. A measure of how likely a malfunction can cause dissatisfaction all by itself is the probability that customers circled the malfunction as the primary cause of dissatisfaction given that the malfunction occurred. Likewise, the probability that the customer was dissatisfied when the malfunction occurred is a measure of that malfunction's ability to contribute to dissatisfaction.

Weightings for malfunction severity were also evaluated to determine whether alternatives to the traditional 0-1-2-4 weightings for None, Trace, Moderate, and Heavy might better correlate customer data with customer satisfaction. The following eight weighting systems were compared for the trip that is indicated.

System	Trip	Stalls	Other Malfunctions	Y Score	N Score
1	1	0-7-7-7	0-1-3-7	9	25
2	1	0-1-3-7	0-1-3-7	7	28
3	1	0-1-2-4	0-1-2-4	8	23
4	1	0-0-1-2	0-0-1-2	6	29
5	2	0-4-4-4	0-1-2-4	7	25
6	1 and 2	0-4-4-4	0-1-2-4	9	22
7	1 Circles	0-7-7-7	0-1-3-7	0	5
8	1 and 2 Circles	0-4-4-4	0-1-2-4	0	5

Trip 1 is the first trip of the day, usually near dawn. Trip 2 is the second trip of the day which occurred at a variety of times during the day, after at least a six-hour soak period. Customers experienced few malfunctions and little dissatisfaction during these second trips, so fuel effects were not as clear. Analyses in this report are thus based upon Trip 1 data.

Comparisons of the weighting systems were made by discriminant analysis of customer satisfaction. For each trip, stalls and other malfunctions were separately weighted for the N-T-M-H problem severity indicated by the customer using the weights shown in the table above. Discriminant analysis evaluates the ability of the resulting malfunction variables to correctly identify Yes (Y) or No (N) for customer satisfaction. The Y score and N score columns indicate the number of incorrect identifications out of 661 observations using that weighting system.

After considerable discussion of the numerical results, as represented by both the discriminant analysis coefficients and by logistic regression coefficients, which result from fitting satisfaction directly as a scored response variable, the following system was designed to define a Customer Mean Weighted Demerit (CMWD) value. Each week, the average demerit score, using 0-1-2-4 for N-T-M-H, was calculated for each vehicle-driver combination for each malfunction. To obtain the CMWD, each malfunction score was multiplied by the weight shown below:

Problem	Weight
Idle Roughness	29
Hard Starting	40
Hesitation	44
Idle Stall	47
Stumble	51
Driving Stall	56
Surge	56

These weights are the mean of the probability that the customer circled the malfunction and the probability that the customer was dissatisfied when the malfunction occurred divided by 2. Using the mean captures both aspects of contribution to dissatisfaction; division of the mean by 2 yields a total weighted demerit number of the same magnitude as the current rater demerit totals. It does emphasize those times the malfunction caused dissatisfaction, in that those cases are included in both probabilities.

In Figure 4, CMWD is plotted versus TWD for the trained-rater evaluations during Week 1 of Fuels 3 and 8, the two fuels for which many data points were available over a short span of time. The plots show that when the CMWD was large, generally the TWD was large as well. The bulk of the data points, however, consist of pairs in which the CMWD is zero but TWD is not, including several of the large values of TWD. Similar results are found across all weeks and for all fuels, as shown in Figure 5. This shows that most customers are not very discriminating compared with raters, and there is a broad spectrum of customer sensitivity. Good correlation between customer and rater data will be difficult to achieve because there is a wide range in customer ability to detect malfunctions; there is a wide range in the level of customer dissatisfaction given that a malfunction occurs; customers give seven evaluations during a week, each of which can differ in the malfunctions observed and the level of satisfaction; raters only give one evaluation during the week, which must be correlated with all the customer data for that week; substantial temperature differences exist during the test period between customer and rater evaluations; and normal experimental error. Because of these sources of random error, use of advanced statistical tools was necessary.

Additional information was obtained in trying to determine an appropriate system of customer problem weights. Below are tabulated relative rankings for customer satisfaction, based on a problem severity with a N-T-M-H scaling using 0-1-3-7 values, and from data for only the circled problems, for which the rankings are based on coefficients from logistic regression of satisfaction versus the problem:

Problem	All Data	Circles
Idle Roughness	0.75	18.8
Idle Stall	1.29	25.1
Hesitation	1.54	22.9
Stumble	1.19	15.7
Surge	1.59	14.6
Driving Stall	0.70	17.1
Hard Starting	1.27	20.4

The larger coefficients represent more important malfunctions.

Different weighting systems, however, did not improve the correlation versus TWD. A final method of determining weights was derived from considering problem occurrences, instead of relationships of customer evaluations to customer satisfaction. Below are occurrences of the problem itself, occurrences of weekly dissatisfaction (N) when the problem was identified, and occurrences of circles when the problem was identified:

Problem	% not Satisfied	% circles	% occurrence	New TWD factor+
Surge	60.5	51.1	2.6	56
Driving Stall	59.6	52.6	1.9	56
Stumble	57.8	44.7	3.5	51
Idle Stall	53.5	41.7	8.8	47
Hesitation	49.8	37.9	14.7	44
Hard Starting	49.2	31.9	8.2	40
Idle Roughness	36.5	22.5	6.9	29

+ Average of percent not satisfied and percent circles
Based upon 7,206 tests

Use of these percentages as a scoring system was not technically appealing, either.

It was concluded that there was poor consistency between the customer evaluations and the customer satisfaction, because the customers simply are not trained as raters, and that the weights used to calculate CMWD were the best combination of engineering judgment and data analysis that could be found. Because none of these methods gave a good correlation with TWD, the next step was to investigate new ways of calculating TWD that would improve the correlation between customer and rater data.

C. Evaluation of Alternative TWD Systems

The preceding section involved an exhaustive development of a numerical index for problem-weighted demerits for the customers. It was noted that the correlation between the customer satisfaction and the customer problem identification was not good, so additional technical considerations were used to develop the weights for CMWD. CMWD did not correlate well with traditional TWD. The next step was thus to find the new weights for the CRC driveability maneuvers that could be used to make a revised TWD that would correlate with the CMWD.

Regression analysis was used to fit Log CMWD versus the score, N-T-M-H = 0-1-2-4, for 94 scored cycle and maneuver variables. Direct reduction and backward elimination reduced the number of variables to 15, listed below, which had no particular pattern relative to the CRC driveability test in being selected as important. In order to effectively identify cycle, maneuver, and malfunction simultaneously, the following code is used:

start	=	start time	SG	=	surge
IDN	=	idle neutral	SB	=	stumble
IDD	=	idle drive	AC	=	accel stall
CC1	=	cold cycle 1	DC	=	decel stall
CC2	=	cold cycle 2	RUF	=	idle roughness
CC3	=	cold cycle 3	STL	=	idle stall
CWD	=	crowd cycle	BF	=	backfire
M#	=	maneuver number within cycle	CLD	=	all cold cycles
HS	=	hesitation			

Problems	Score
Start	26
IDN - STL	3
IDD - STL	3
IDD - RUF	17
CC1M1 - HS	6
CC1M1 - SG	11
CC1M2 - SB	5
CC1M5 - SB	3
CC1M5 - DC	3
CC2M1 - SG	3
CC3M1 - SG	4
CC3M1 - SB	3
CWDM1 - RUF	5
CWDM3 - SB	12
CWDM3 - HS	4

The scores are F-statistics so larger numbers indicate greater importance, and in this case, 3 is borderline importance. Only a half-dozen or so are really important. Obviously important factors are included, and a number of doubtfully important factors are also included. Clearly, start time has the best correlation to customer dissatisfaction and should receive greater weighting than it is currently given. For the significant regression variables, the R-squared value was 0.21 for fitting the log of CMWD. The mean square error in logs, 0.97, indicates a large relative error in using the entire set of trained-rater results to predict CMWD.

Next, the use of CMWD to represent the customer perception was replaced by weekly fuel performance evaluations [Very Good (VG), Good (G), OK, Poor (P), Very Poor (VP)]. Here, Very Good and Good are dropped, since TWD represents demerits, not good performance. A scale of OK-P-VP = 1-2-4 was used to quantify the rating. Regression analysis was performed for all results and separately by fuel type (hydrocarbon-only and ethanol blends). Below are the three sets of variables and scores that result from variable elimination:

ALL		Hydrocarbon-Only Fuels		Ethanol Blends	
Variable	Score	Variable	Score	Variable	Score
IDD-STL	4	IDD-RUF	14	IDN-RUF	4
CC1M2-SB	9	IDD-STL	4	IDD-STL	4
CC1M2-SG	3	CC1M2-SB	3	CC1M1-HS	6
CC1M3-SG	5	CC1M3-BF	24	CC1M2-HS	4
CC1M3-DC	12	CC1M4-SG	17	CC1M2-SB	27
CC1M5-SG	3	CC2M2-SG	12	CC1M3-HS	5
CC2M2-SG	6	CC2M3-SG	3	CC1M3-DC	13
CC2M4-AC	7	CC2M4-SG	9	CC1M5-SB	5
CC3M3-SG	5	CC2M4-BF	7	CC2M1-AC	3
CC3M4-HS	9	CC2M5-SB	11	CC2M2-HS	3
CWDM1-SG	8	CC2M5-SG	8	CC2M3-SB	9
CWDM1-BF	10	CLD2-RUF	6	CC2M3-BF	7
CWDM3-SG	3	CC3M2-SG	18	CC2M5-HS	6
CWDI-RUF	6	CC3M3-AC	3	CC2M5-BF	4
		CC2M4-SG	4	CC3M1-SG	6
		CC3M4-AC	6	CC3M4-AC	12
		CWDM1-SB	6	CWDM4-HS	7
		CWDM2-SG	4	CWDM4-SG	11
		CWDM3-SG	4		
		CWDM4-HS	5		

Overall model summaries were:

			Standard
All	14	0.21	0.68
Hydrocarbon-Only Fuels	20	0.49	0.51
Ethanol Blends	18	0.39	0.68

Another methodology for determining important variables, discriminant analysis, was used for relating the trained-rater variables versus customer satisfaction (Y or N), and versus customer ratings (OK, P, VP). Each method produced a set of important variables. Among the six most important variables in each method, only two appear in both sets.

	Y or N Satisfaction	OK, P, or VP Rating
Number of Data	655	302
Variables in Model	20	15
Six Most Important	CC2M4-AC	CC1M3-DC
	CC3M1-SG	CC1M3-BF
	START	CWDM1-BF
	CWDM1-BF	CC2M2-SG
	CWDM2-SB	CC2M4-AC
	CC2M1-BF	CC1M2-SB

Overall, these various ways of selecting important trained-rater variables were inconsistent, chose some problems which occurred infrequently, and were generally uninformative in guiding a selection of new weights for a revised TWD calculation.

This information does show, however, that there is no compelling reason to change the driving cycle since maneuvers from each cycle contribute significantly to prediction of customer-observed malfunctions. In addition, variables that are less important, such as idle roughness and Maneuver 4 in the crowd cycle, precondition for subsequent maneuvers. Many believe that an initial light-throttle reverse maneuver would improve the correlation between customer-observed and trained-rater-observed malfunctions.

Start time is given a low weighting in the traditional TWD calculation system, but correlated strongly with customer satisfaction; therefore, some simple correlations were done using the total start time to predict CMWD. Similarly, total start time was used to predict the customer weekly average hard-start scores, when they were nonzero, using 1-2-4 = T-M-H daily. The correlation coefficient was 0.32 for average hard start and 0.27 for CMWD, showing that total start time, at least, had predictive value for customer evaluation.

The following scoring system defined for the revised Rater TWD (RTWD) was based again on a combination of engineering and statistical information:

Occurrence	Action	Number
Any Malfunction	Score	6
Any Stall	Score	16
Start Time	Multiply	4
Delay for Start	Subtract	1
CC1 and CWD	Multiply	2
All CLD Roughness	Eliminate	0
CWD Maneuver 4	Eliminate	0

Consistent with the 1978 report,[5] it was attempted to correlate the RTWD to CMWD, defined with the problem weights shown above. Correlations were also checked for CMWD (Customer Mean Weighted Demerits) versus TWD (traditional Total Weighted Demerits) and for CTWD (Customer Total Weighted Demerits calculated using the 1978-basis formula) versus TWD.

Rating system quartiles are:

	CMWD	RTWD	CTWD	TWD
Minimum	4	12	0	2
25%	29	74	0	25
Median	75	116	12	52
75%	139	192	60	96
Maximum	502	790	870	544

RTWD is numerically larger than TWD, while CMWD is larger than CTWD. Numerically, CMWD and RTWD are more consistent than CTWD and TWD.

Results for correlation are shown for all the data and also separately by fuel type:

	Correlation Coefficient
CMWD Versus RTWD	0.25
by hydrocarbon-only fuels	0.13
by ethanol blends	0.31
CMWD Versus TWD	0.21
by hydrocarbon-only fuels	0.11
by ethanol blends	0.29
CTWD Versus TWD	0.23
by hydrocarbon-only fuels	0.14
by ethanol blends	0.30

CMWD is marginally better-predicted by RTWD than TWD, and the CMWD-RTWD correlation developed in this study is marginally better than the CTWD-TWD correlation developed in 1978. Ethanol blends show better prediction of customer perception by trained raters. None of the correlations is very good; however, the CMWD and RTWD systems are an improvement over those used in the 1978 program, as shown by the correlations.

D. Canonical Correlation of Customer and Rater Data

Canonical correlation is another approach to investigating the relationship between customers and trained raters.

Two sets of variables are defined:

Customers = The weekly averages for each of the seven problems: idle roughness, hesitation, stumble, surge, hard starting, idle stall, and driving stall.

Trained Raters = The weekly evaluation of ninety-four rater variables for each customer's vehicle-fuel combination, in which all cycles and maneuvers that registered demerits for some rater-vehicle evaluation are used.

A canonical correlation between the Y or dependent variables (Customers) and the X predictor variables (Trained Raters) was developed. This created weights for the Y's and X's that maximized the correlations of the two linear combinations with each other. This correlation explains a portion of the variability between the X's and the Y's.

Results show the correlations between the resulting first canonical variables and the variability explained. Also shown are the standardized weights for the most heavily weighted variables. Since these are standardized weights, 1.0 represents perfect correlation.

	All Data	Hydrocarbon-Only Fuels	Ethanol Blends
Canonical Correlation	0.71	0.82	0.89
% Variability Explained	0.33	0.41	0.45
Largest Customer Variable	SB	SB	SB
	(0.94)	(0.77)	(0.98)
	SG	SG	SG
	(0.23)	(0.40)	(0.13)
Largest Rater Variable	CC1M2-SB	CWDM1-BF	CC1M2-SB
	(0.45)	(0.50)	(0.65)
	CWDM1-BF	START	CWDM4-SG
	(0.38)	(0.33)	(0.53)

Again, a correlation methodology has isolated generally obscure trained-rater variables. Surge and stumble rather clearly are the strongest contributors from the customer set to the correlation with the raters. The correlation coefficient for either fuel type by itself is much better than the correlation coefficient for all data. This reflects the fact that different malfunctions are predominantly associated with different fuel types.

The first canonical variables, C1X and C1Y, are linear combinations of the X's and the Y's. Creating the linear combinations, but adjusting for negative weights, the canonical CMWD (CCMWD) and RTWD (CRTWD) correlate as shown below:

	Correlation Coefficient	
	All Data	Drop Outliers
All Data	0.58	0.67
Hydrocarbon-Only	0.56	0.63
Ethanol Blends	0.60	0.68

Deletion of obvious outliers give the improved correlations in the second column. This demonstrates that a revised TWD for the CRC test can be found that correlates well with customer fuel evaluations.

E. Combining Rater Malfunctions Across Cycles and Maneuvers

Ninety-four rater variables have been used, and another thirty-six malfunctions were possible, but not used in this analysis since they never generated demerits. Clearly, a functional approach must be simple, so the following new rater variables approach is proposed.

Step 1: Raters record traditional CRC driveability test results.

Step 2: Using score for N-T-M-H = 0-1-2-4, total the scores for each of the ten malfunctions across all cycles and all maneuvers within cycles (all stalls were considered to be "Heavy").

Step 3: Divide the total scores by the number of times each malfunction can occur.

Canonical correlation for this simplification for the trained raters versus the seven customer variables gave the following results:

	Correlation Coefficient
All Data	0.47
Hydrocarbon-only	0.52
Ethanol Blends	0.60

Again, it is easier to correlate customers to raters for ethanol blends. Adjusting to make all positive weights, weights are found to be much more consistent with expectations and with the frequency of occurrence for the problem.

Weights for the customers:

Problem	All Data	Hydrocarbon-Only Fuels	Ethanol Blends
Idle Stall	0.84	0.37	0.92
Hard Starting	0.58	0.79	0.36
Hesitation	0.46	0.31	0.62
Stumble	0.28	0.66	0.12
Driving Stall	0.11	0.24	0.11
Surge	0.06	0.06	0.09
Idle Roughness	0.01	0.01	0.01

Note that idle stalls and hesitation correlate better for ethanol blends than for hydrocarbon-only fuels, while hard-starting and stumble are better correlated for hydrocarbon-only fuels than for ethanol blends. This is in agreement with the results using ninety-four variables.

Weights for trained raters:

Problem	All Data	Hydrocarbon-Only Fuels	Ethanol Blends
Start	0.86	1.20	0.51
Driving Stall	0.50	0.40	0.47
Idle Stall	0.45	0.46	0.34
Hesitation	0.41	0.60	0.51
Surge	0.36	0.28	0.26
Accel Stall	0.30	0.05	0.10
Decel Stall	0.21	0.27	0.10
Stumble	0.13	0.37	0.03
Idle Roughness	0.07	0.01	0.08
Backfire	0.01	0.08	0.01

The important problems show good weight agreement, except for start and stumble which are better correlated for hydrocarbon-only fuels than for ethanol blends.

F. Classification of Customer Satisfaction

The previous section showed that a weighted sum for trained-rater demerits could be devised that would correlate well with a weighted sum of average customer demerits. To answer the question about whether or not it would be better to develop the weights for the trained-rater demerits versus customer satisfaction or customer rating, discriminant analysis is used to show the classification ability for the ten trained-rater variables. Classification percentages are:

	All Data	Hydrocarbon-Only Fuels	Ethanol Blends
Satisfaction			
Y Correct	62	57	66
N Correct	46	69	34
Rating			
Very Good/Good	53	51	68
Very Good/Good/OK	67	74	81
Good/OK/Poor	57	61	55
OK/Poor/Very Poor	61	68	43
Poor/Very Poor	64	75	60

Fifty-percent classification is coin-toss capability. The trained rater variables predict OK, Poor (P), and Very Poor (VP) ratings and dissatisfaction better for hydrocarbon-only fuels, and Very Good (VG), and Good (G) ratings and satisfaction better for ethanol blends.

To understand why there are better correlations between the trained raters and the customer demerits than there are between the trained raters and satisfaction or rating by the customers, consider how well the customer's demerits classify the customer's own satisfaction and rating:

	All Data	Hydrocarbon-Only Fuels	Ethanol Blends
Satisfaction			
Y Correct	77	78	72
N Correct	30	26	38
Rating			
VG Within 1	71	70	36
G Within 1	72	74	81
OK Within 1	25	38	80
P Within 1	40	40	64
VP Within 1	35	38	44

When satisfaction or rating is low, customer demerits are even worse at classification than trained rater demerits. The problem is particularly acute for hydrocarbon-only fuels. An analysis variable which might have been useful but was not obtained is a parallel overall satisfaction rating assessment by the trained rater using the same grading system as the customer.

Weights for the discriminant analysis are:

Trained Rater Malfunction	Customer Satisfaction	Customer Rating
Idle Roughness	2.66	2.76
Start	0.27	0.28
Hesitation	0.38	0.52
Idle Stall	0.73	0.02
Stumble	0.74	0.23
Driving Stall	0.07	0.42
Surge	2.76	3.40
Accel Stall	-4.63	-5.07
Decel Stall	-1.54	-3.70
Backfire	-2.92	-1.92

These weights again show that qualitative customer assessments are not good guidance on weights for a revised TWD.

A final verification of customer satisfaction capabilities was made by logistic regression, which correctly assigns 63 percent of the Y's and N's. It similarly uses a number of negative malfunction weights.

Ambient temperature, which impacted CTWD and TWD, did not improve canonical correlation.

G. Defining Rater TWD Weights by Regression

It has been shown that a weighted combination of trained-rater demerits, defined by averaging across all occurrences for each malfunction, can be correlated to a weighted function of customer demerits, defined as weekly averages by malfunction type for these data. This is not equivalent to being able to separately predict each of the customer's malfunction levels from the corresponding trained-rater malfunction.

As a test, the customer hard-start results, which had a large weight among the customer variables, were regressed versus the trained-rater start results. The correlation was around 0.25. Similarly, use of all the trained-rater variables to predict all of the customer variables is not any more successful. Using partial least squares for the multivariate regression, the trained-rater functions explained less than 20 percent of the variability in the customer variables.

H. Attempts to Simplify Canonical Correlation

The initial canonical correlation showed that a function of all 94 trained-rater malfunctions by cycle and maneuver correlated at 0.71 with a function of the customer malfunctions. The 10 average malfunction variables correlated only at 0.47, so there was incentive to see if somewhat less combining of the 94 variables would provide an improved correlation. Several attempts were made, using earlier results concerning importance of variables in different cycles and maneuvers for guidance.

1. Cold Cycle Separations

Variables were assigned to each type of malfunction in Cycle 1 and also to the average of each malfunction over the subsequent two cycles. This resulted in 18 variables, instead of 10, for the trained-rater results; however, the correlation increase was negligible, from 0.47 to 0.48. Essentially, the same correlation increase was also found for the other two cycle isolations: after Cycle 2 and after Cycle 3. Using four different sets of variables across cycles, which meant averaging across maneuvers for all cycles, an additional 16 variables, still only increased the correlation to 0.49. Splits by cycles thus do not seem useful in correlating the rater malfunctions to the customer malfunctions.

2. Maneuver Separations

Similarly, averaging was done for all maneuvers of the three cold cycles except Maneuver 1 and separately for Maneuver 1, resulting in 15 variables, and a similar lack of improvement, the correlation again being 0.48. Another maneuver combination, the average of Maneuvers 2 and 3 and the average of Maneuvers 4 and 5, with Maneuver 1 separate, resulted in 25 variables, but still only increased the correlation to 0.51. It was concluded that there was no simple way to have more than 10 rater variables and less than 94 while moving the correlation from 0.47 for the 10 variables to the 0.71 that was found for the 94 variables. Equivalent weighting for all malfunctions is thus indicated to be as effective as any of the wide range of systems investigated, and because of its simplicity is recommended. This is further supported by the high correlation of surge, which had traditionally been given a lower weighting, observed by customers and trained raters.

REFERENCES

1. Coordinating Research Council, Inc., "1984 CRC Intermediate-Temperature Driveability Program Using Gasoline-Alcohol Blends," CRC Report No. 554, August 1987.

2. Coordinating Research Council, Inc., "CRC Low- and Intermediate-Temperature Driveability Program Using Gasoline-Alcohol Blends," CRC Report No. 568, February 1990.

3. Coordinating Research Council, Inc., "CRC Volatility Program on the Effect of Oxygenated Fuels and Altitude on Cold-Start Driveability at Low Ambient Temperatures," CRC Report No. 569, January 1990.

4. Coordinating Research Council, Inc., "Effect of Volatility and Oxygenates on Driveability at Intermediate Ambient Temperarures," CRC Report No. 578, March 1992.

5. Coordinating Research Council, Inc., "Customer Perception of Cold Start and Warmup Driveability," CRC Report No. 512, February 1980.

TABLES

AND

FIGURES

TABLE 1

Model year *

Customer satisfaction fleet

Year	N	%
1985	13	18
1986	10	14
1987	12	16
1988	12	16
1989	14	19
1990	9	12
1991	3	4

Consumer / Rater Fleet

Hydrocarbon fuel			Ethanol fuel		
Year	N	%	Year	N	%
1985	8	15	1985	8	16
1986	7	13	1986	9	18
1987	8	15	1987	8	16
1988	11	21	1988	11	22
1989	9	17	1989	8	16
1990	8	15	1990	5	10
1991	2	4	1991	0	0

Fuel system *

Customer satisfaction fleet

Fuel system	N	%
Carbureted	19	26
PFI	33	45
TBI	21	29

Consumer / Rater Fleet

Hydrocarbon fuel			Ethanol fuel		
Fuel system	N	%	Fuel system	N	%
Carbureted	18	33	Carbureted	10	21
PFI	30	39	PFI	26	54
TBI	16	28	TBI	12	25

*See explanatory notes on page 30.

TABLE 1 - Cont.

of Cylinders

Customer satisfaction fleet

Cylinders	N	%
4	35	49
5	1	1
6	24	33
8	12	17

Consumer / Rater Fleet

Hydrocarbon fuel			Ethanol fuel		
Cylinders	N	%	Cylinders	N	%
4	16	30	4	19	39
6	17	32	6	16	33
8	21	39	8	14	29

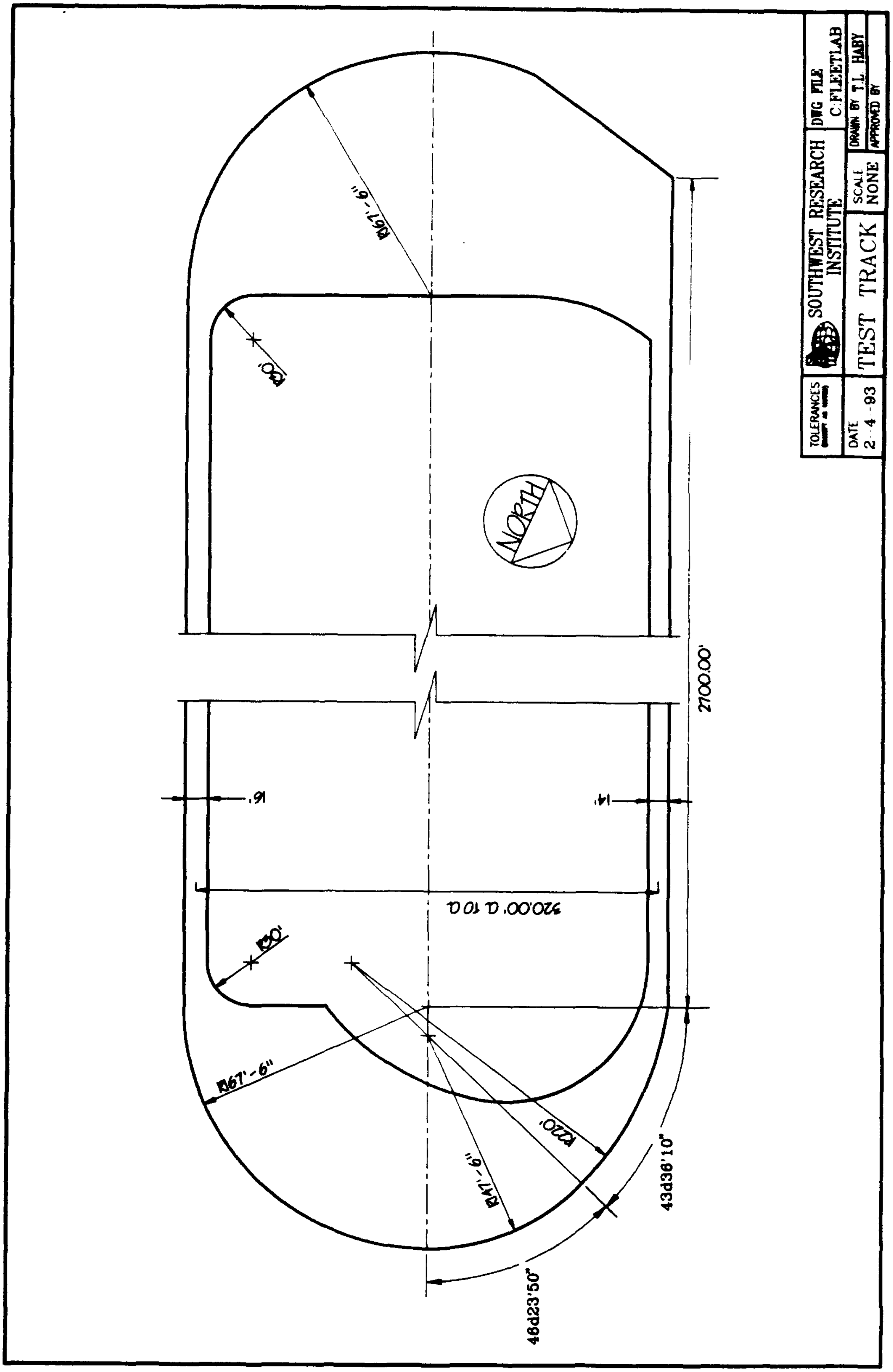
NOTES:
There is one missing value in each category summarized.
N is the number of vehicles.
% is the percentage in that subgroup, not of the overall fleet.
During the program, some vehicles were transferred between the customer fleet and one of the consumer/rater subfleets; these vehicles are included in both places in the tables above.

TABLE 2

AVERAGE FUEL PROPERTY DATA

Fuel	RVP, psi	% Evaporated T_{10}, °F	T_{50}, °F	T_{90}, °F	EtOH, vol %	MTBE vol %
1	7.4	142	242	355	0.0	0.0
2	8.1	129	240	344	0.0	0.0
3	8.8	118	238	326	0.0	0.0
4	9.8	110	233	311	0.0	0.0
5	10.7	104	204	296	0.0	0.0
6	8.6	133	234	351	9.5	0.2
7	9.3	126	230	338	9.9	0.2
8	10.1	118	216	323	9.7	0.1
9	10.8	111	174	308	9.7	0.1
10	11.7	106	157	296	9.4	0.0
11	8.8	119	206	320	0.0	14.0

Figure 1



SOUTHWEST RESEARCH INSTITUTE
DWG FILE C:FLEETLAB
DRAWN BY T.L. HABY
APPROVED BY
TOLERANCES
DATE 2-4-93
TEST TRACK
SCALE NONE
NORTH
R67'-6"
R30'
2700.00'
16'
14'
520.00' C TO C
R30'
R67'-6"
R220'
R47'-6"
43d36'10"
46d23'50"

Figure 2

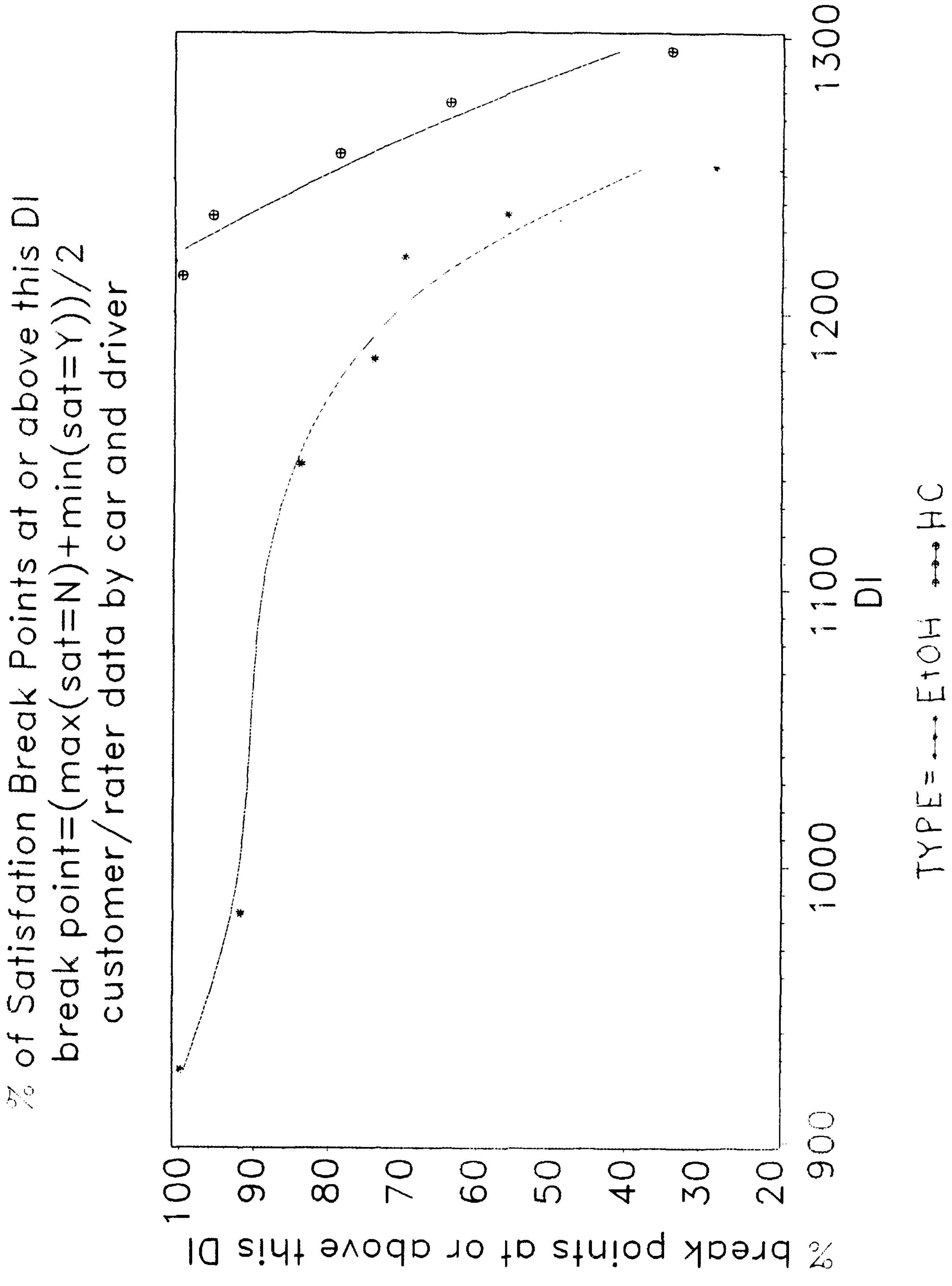

% of Satisfation Break Points at or above this DI
break point=(max(sat=N)+min(sat=Y))/2
customer/rater data by car and driver
% break points at or above this DI
100
90
80
70
60
50
40
30
20
900
1000
1100
1200
1300
DI
TYPE= EtOH HC

Figure 3

Percent Driveability Satisfaction

Weeks 4-6
by parent fuel

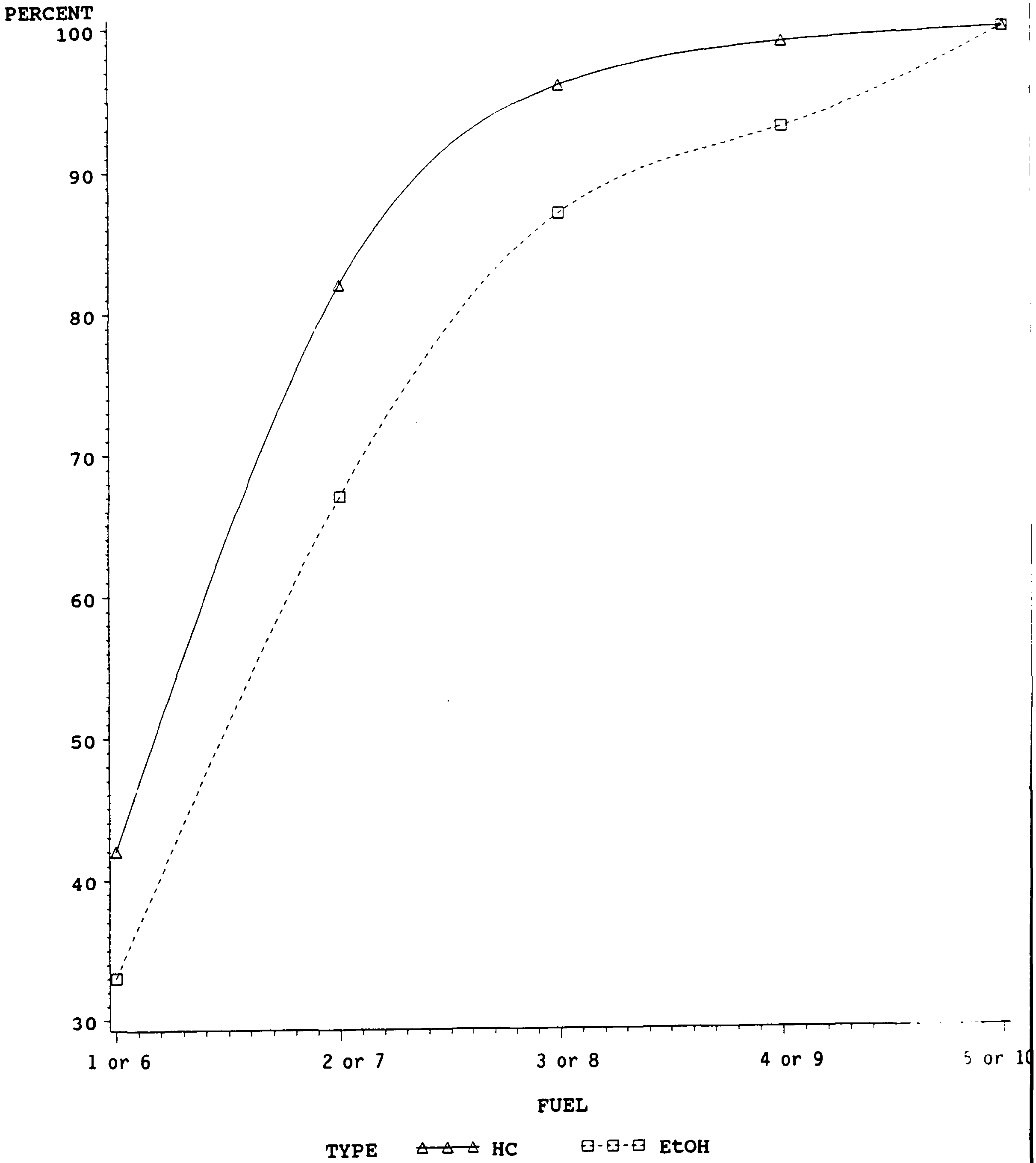
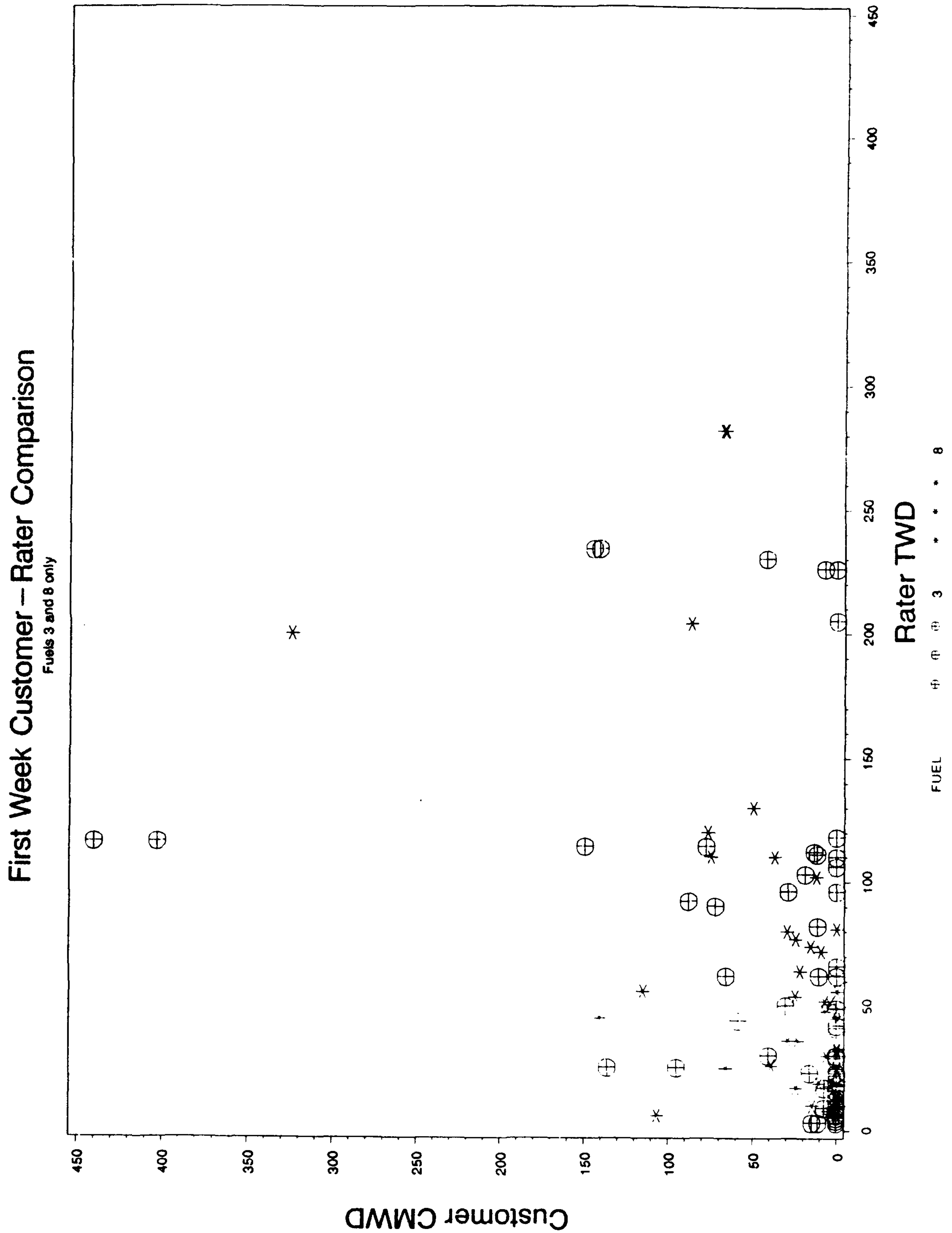
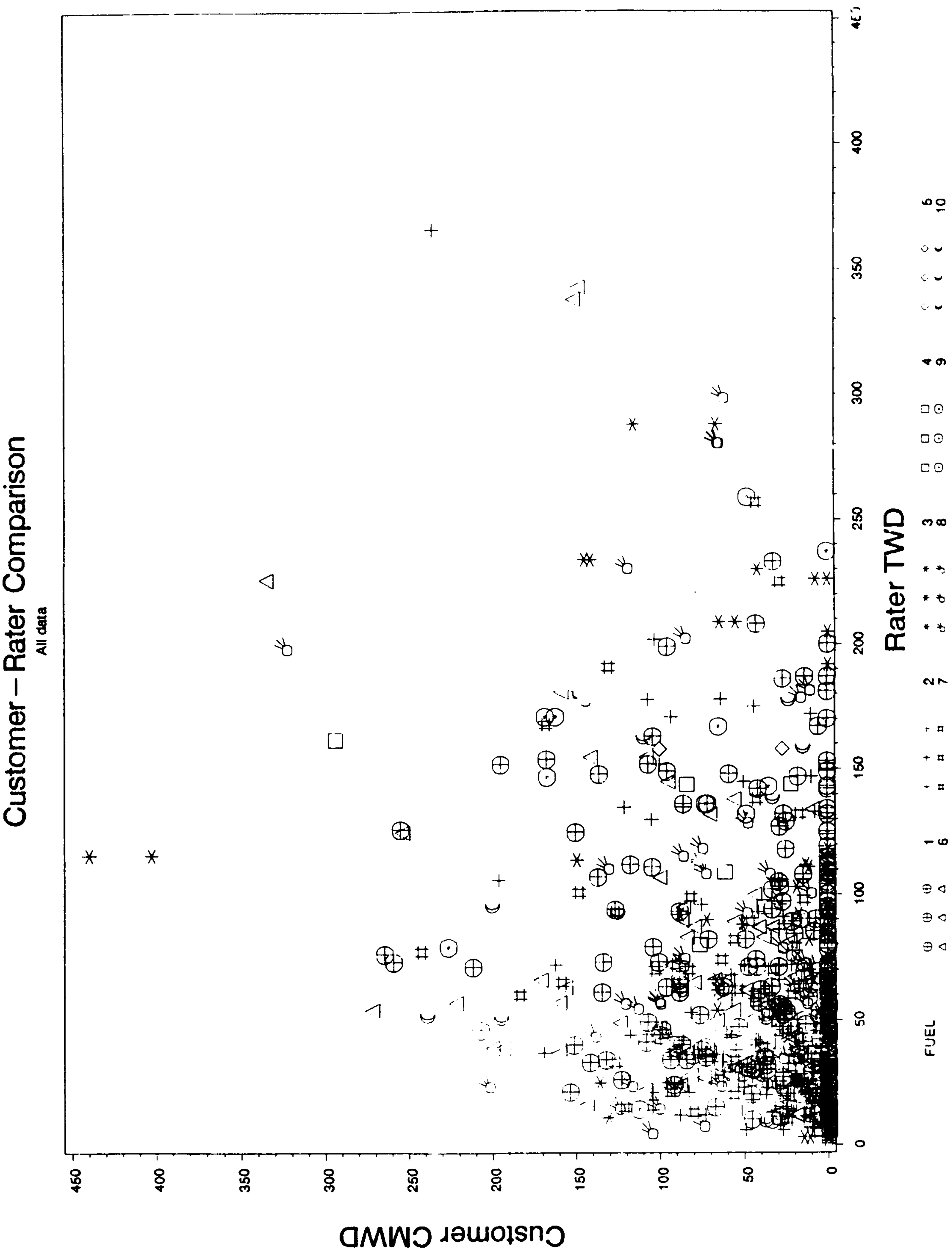


Figure 4



First Week Customer – Rater Comparison
Fuels 3 and 8 only
Customer CMWD
Rater TWD
0
50
100
150
200
250
300
350
400
450
FUEL
3
8

Figure 5


Customer – Rater Comparison
All data
Rater TWD
Customer CMWD
FUEL

APPENDIX A

MEMBERSHIP OF THE 1991 DATA ANALYSIS PANEL

APPENDIX A

MEMBERSHIP OF THE 1991 DATA ANALYSIS PANEL

Name	Company Affiliation
J. P. Graham, Leader	Chevron Research & Technology Co.
J. H. Baudino	AutoResearch Laboratories, Inc.
C. J. Bonés	Mobil Research & Development Corp.
*M. J. Hillyer	Chevron Research & Technology Co.
S. W. Jorgensen	General Motors Research
R. M. Reuter	Texaco Inc.
*M. A. Rozum	Shell Development Company
J. H. Steury	Amoco Oil Company
*E. R. Ziegel	Amoco Oil Company

*Statistician

APPENDIX B

PARTICIPANTS IN THE

1991 CUSTOMER/RATER DRIVEABILITY PROGRAM

PARTICIPANTS IN THE

1991 CUSTOMER/RATER DRIVEABILITY PROGRAM

NAME	AFFILIATION
Bob Reuter, Leader	Texaco Inc.
Harold "Archie" Archibald	BP Oil Company
Dave Barker	Shell Development Company
John Baudino	ALI
Carl Bonés	Mobil Research & Development Corporation
Robert Boom	Chevron Research & Technology Company
Mike Briggs	BP Oil Company
Tabb Buel	Phillips Petroleum Company
Raoul Caltenco	Texaco Inc.
Richard Campos	Toyota Technical Center
Ed Carhart	Texaco Inc.
Chris Dorsch	ALI
Jean Doyon	Shell Canada
Beth Evans	Coordinating Research Council, Inc.
John Graham	Chevron Research & Technology Company
Trude Helfrich	Toyota Technical Center
Bruce Henderson	Amoco Oil Company
Jack Hutchins	Shell Development Company
Scott Jorgensen	General Motors Research
Mark Matthews	BP Oil Company
Gus Mitsopoulos	General Motors Research
Brent Morrison	NIPER
Mike Patterson	NIPER
Mike Ragomo	Mobil Oil Company
Doug Rathe	Shell Development Company
Jim Reid	PetroCanada
Mike Rivenburgh	EG&G Automotive Research
Brenda Rountree	Amoco Oil Company
Brian Sanders	Chrysler Motors Corporation
Al Talbot	Sun Refining & Marketing Company
Chuck Valade	Chrysler Motors Corporation

APPENDIX C

PROGRAM PROPOSAL FOR

1991 CRC CUSTOMER/RATER VOLATILITY

PROGRAM TO ASSESS CUSTOMER RESPONSE

TO COLD-START AND WARMUP DRIVEABILITY

TABLE OF CONTENTS FOR APPENDIX C

1991 CRC CUSTOMER/RATER VOLATILITY PROGRAM TO ASSESS CUSTOMER RESPONSE TO COLD-START AND WARMUP DRIVEABILITY

Objective

The objective of this program is to:

- Establish a relationship between demerits observed in CRC warming-up assessments (or changes in such demerits) to customer satisfaction (or changes in satisfaction) levels; and

- Determine which of several performance deficiencies associated with low volatility gasolines during vehicle warmup are most troublesome to customers in normal consumer service.

Background

In recent years, CRC has run several cold-start driveability programs (1984, 1986/1987, 1988, 1989) to determine the performance of late-model vehicles. The results of these programs have demonstrated that the newer throttle-body-injected and port-injected vehicles perform better than the older carbureted vehicles in controlled testing by trained raters; however, data are lacking to determine whether customers can appreciate the performance improvements. It can be speculated that customer satisfaction has improved, but this is not certain. Customers could be more sensitive, and they might expect vehicles to perform better. The only customer data publicly available are from the CRC program in San Antonio that is over ten years old. During that program, data were obtained from about 100 customers in 1973-1978 vehicles. The data are valid on those vehicles, but it must be updated on newer vehicles. In addition, data are lacking on the customer acceptance of oxygenated fuels.

Test Site

The program will be conducted at Southwest Research Institute in San Antonio, Texas. This location meets the following criteria: acceptable morning temperatures, low altitude, low precipitation, a population of drivers commuting to a central location, a mix of suburban and freeway driving, a nearby test track, and fueling facilities.

Test Dates

The program will be conducted for eight weeks, beginning January 14, 1991.

Test Fuels

The test fuel set will contain hydrocarbon-only fuels, 10 volume percent ethanol-gasoline blends, and a 15 volume percent MtBE-gasoline blend.

The hydrocarbon-only fuel set is as follows:

	Fuel 1	Fuel 2	Fuel 3	Fuel 4	Fuel 5
RVP	7.5	75% of Fuel 1 plus 25% of Fuel 5	50% of Fuel 1 plus 50% of Fuel 5	25% of Fuel 1 plus 75% of Fuel 5	11.0
T_{10}	138				100
T_{50}	240				200
T_{90}	355				300

Fuel 1 is a hydrocarbon-only fuel that is close to the minimum volatility specifications for ASTM Class C fuels. Fuel 5 has higher volatility than Fuel 1, and will provide parallel distillation curves in the blended fuels. The volatility of Fuel 5 is near the 60th percentile of the fuels sold in ASTM Class C areas.

The ethanol-gasoline fuel set is as follows:

Fuel 6	Fuel 7	Fuel 8	Fuel 9	Fuel 10
10% EtOH splashed in Fuel 1	75% of Fuel 6 plus 25% of Fuel 10	50% of Fuel 6 plus 50% of Fuel 10	25% of Fuel 6 plus 75% of Fuel 10	10% EtOH splashed in Fuel 5

In addition, there will be an MtBE fuel (Fuel 11). This will be a 15 volume percent MtBE-gasoline blend splash-blended into Fuel 3.

All fuels will be 92-93 (R+M)/2 octane number, with a quality premium additive package.

Program Size

The program is targeted for 200 customer participants, and 24 rental vehicles.

Basic Requirement and General Program Conduct

Customer assessment of performance malfunctions and CRC trained driver assessments of performance on the same vehicles with the same fuels in the same time interval will be investigated.

(A) Ninety-six vehicles will be selected fro the 200-vehicle fleet for initial CRC trained-driver versus customer evaluations. During the first week of the program, 48 vehicles will be fueled with Fuel 3, and 48 vehicles will be fueled with Fuel 8. After fueling, these vehicles will be parked overnight at Southwest Research Institute for CRC driveability evaluations the next morning. Customers will be given rental vehicles to use for the time period their vehicle is being used for testing. Two test crews can evaluate 24 vehicles per day on this schedule. After the evaluation, the customer's vehicle will be returned to him, and he will be asked to complete questionnaires daily, reporting his cold-start and warmup driving experiences and his general satisfaction with the performance of the fuel.

Each day, for four days, 24 vehicles will be put on test: 12 on Fuel 3, and 12 on Fuel 8. Trained-rater evaluations will be made before returning the vehicles to the customers for their routine use. Each week, these customers will report back for fuel changeover (the same day of the week each week). Based upon their general satisfaction with the fuel performance as indicated by their questionnaires, the vehicles will be refueled with a fuel one step better or worse on the blending pump scale. Those that indicate no troubles will be given Fuel 2 or Fuel 7. After draining and refueling, these vehicles will be warmed-up on the new fuel and parked at the test track for trained-rater evaluations the following morning. This procedure will be followed each week until a borderline satisfaction-level fuel is determined for each of the fuel sets. If, during the trained-rater evaluations, the vehicle is deemed unacceptable for routine use by a customer, it will not be returned to the customer until it has been drained and refueled with a fuel previously determined to be satisfactory.

After a fuel which is considered to be unsatisfactory by the customer has been determined, the customer will be given a better fuel, and then subsequently the poorer fuel again.

The basic data set will consist of the CRC trained-rater tests on each car for fuels considered to be satisfactory and unsatisfactory. For the same time period, there will be questionnaires completed by customers indicating the problems they have noticed during warmup each day, their satisfaction, and, if dissatisfied, the problem which caused their dissatisfaction.

(B) The other 104 vehicles will initially be fueled with Fuel 3 the first week, Fuel 11 the second week, and Fuel 2 the third week. These defuelings and refuelings will be accomplished on prescribed days of the week as above, 26 vehicles per day. These customers will also complete daily questionnaires reporting their cold-start and warmup driving experiences. These data will provide a comparison of satisfaction and driving problem experiences between gasoline and octane-compensated 15 volume percent MtBE, as well as sensitivity of these vehicles to gasoline volatility.

(C) It is anticipated that after three weeks, it will be determined from the 96-vehicle fleet that 60 percent of the vehicles are able to operate on the lowest volatility fuel available in the series (either Fuel 1 or Fuel 6) without any indicated dissatisfaction. Of these, 50 percent will probably not even indicate any noticed performance deficiency. It is the intent to delete these vehicles from the 96-vehicle fleet and replace them with vehicles from the 104-vehicle fleet that have indicated some driveability problems or dissatisfaction. In this way, it is possible to maximize the number of customer vehicles that can contribute most to the major objective of comparison of CRC trained-rater evaluations with customer problem observances and customer judgments of the relative importance of driveability malfunctions.

All vehicles will be given fuel for the full eight weeks of the program.

Equipment Requirements

The following equipment will be necessary to conduct the program:

Twenty-four rental vehicles

Two rental vans

Two five-position Wayne blending pumps: one to dispense hydrocarbon-only fuels 1-5, and one to dispense 10 volume percent ethanol-gasoline blends 6-10

Four 4,000-gallon tanks to supply these blending pump dispensers

One 4,000-gallon tank and dispenser for Fuel 11

One 4,000-gallon tank and dispenser for Fuel 3 to relieve fueling requirements for Fuel 3, particularly during the early weeks when 150 vehicles will be supplied with this fuel

Fuel drain-out pumps

Telephone access and room for data storage

Miscellaneous fuel line fittings and connectors

Manifold vacuum gauges and tubing

Drum pumps for transfer of slop fuel

Manpower Requirements

A minimum of ten participants will be required on-site at all times. The first week of operation will require two additional people due to anticipated start-up problems associated with installation of manifold vacuum taps and fuel drain-out procedures.

To minimize the potential differences in trained drivers, it is recommended that driver/raters be assigned to the program for at least four weeks. This means that four driver/raters will be required.

In addition, it is anticipated that Mondays will be a difficult workday, due to outside fuel purchases. Replacement personnel should thus not be scheduled to begin work on Mondays.

Fuel Requirements

Required fuel supplies are estimated to be:

Fuel 1 (includes 5,000 gallons for rental vehicles)	22,000 gallons
Fuel 5	12,000 gallons
Fuel 6	6,000 gallons
Fuel 10	4,000 gallons
Fuel 11	3,000 gallons

CRC COLD START AND WARMUP DRIVEABILITY PROCEDURE AUTOMATIC TRANSMISSION VEHICLES

TEST PROCEDURE AND DATA RECORDING

A. Record all necessary test information at the top of the data sheet.

B. Start engine per Owner's Manual Procedure. Record start time.

C. If engine fails to start in 15 seconds of cranking, stop cranking and follow Owner's Manual Starting Procedure and crank for an additional 15 seconds. If the engine still fails to start mark the data sheet no start and start the vehicle by any means possible.

D. Record idle quality in "Neutral" or "Park" immediatly after start; foot should removed from the accelerator pedal.

E. If the engine stalls, repeat steps B and C. Record the number of stalls and the restart time. If the vehicle was a no start on the first start no times are required on restarts but number of stalls is required.

F. Allow engine to idle 15 seconds. Apply brake with right foot, shift to normal drive range and record idle quality. If the engine stalls, restart immediatly. Don't record start times, just the number of stalls. Idle 5 seconds in "Drive".

G. After 5 seconds in "Drive" (step F), make a light throttle (Lt.Th) acceleration from 0-25 mph for .1 mile at a constant throttle opening beginning at the predetermined manifold vacuum. Cruise at 25 mph for .1 mile. At the .2 mile marker open the throttle to the detent position and accelerate from 25 to 35 mph at a constant throttle opening. Stop at the .3 mile marker and make a 0 to 35 WOT acceleration. At the .4 mile marker decelerate to 10 mph and then accelerate at light throttle from 10 to 25 mph.

NOTE: Definitions of light throttle, detent, WOT accelerations and manifold vacuum settings are attached.

H. At the .5 mile marker, brake moderately to a stop on the right side of the track. Idle for 30 seconds in drive. Record idle quality and number of stalls. Don't record restart times.

I. Perform steps G and H three times for a total of 1.5 miles. The mile marker for the beginning of each maneuver is indicated on the data sheet.

J. At mile marker 1.5, after completing the 30 second idle, make a crowd acceleration (constant predetermined vacuum) from 0 to 45 mph. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 mph to 25 mph at the 1.9 mile marker, and open the throttle to the detent position and accelerate from 25 to 35 mph. At the 2.0 mile marker stop and accelerate at WOT from 0 to 35 mph. At the 2.1 mile marker decelerate to 10 mph and perform a light throttle acceleration from 10 to 25 mph. Stop at the 2.2 mile marker and idle in drive for 30 seconds.

K. Perform step J three times. Appropriate mile markers for the start of each maneuver are shown on the data sheet.

L. During the above maneuvers, observe and record the severity of any of the following malfunctions (see attached definitions):
   1. Hesitation
   2. Stumble
   3. Surge
   4. Accel Stall
   5. Decel Stall
   6. Backfire

   Record maneuvering stalls on the data sheet in the appropriate column: Ac Stall is acceleration stalls and Dc Stall is deceleration stalls. The Dc Stall should be recorded at the end of the maneuver. For example, after the 25 to 35mph detent acceleration you have to decelerate to a stop to perform the 0 to 35 WOT maneuver. If the vehicle stalls on the decel the stall would be recorded with the 25 to 35 detent maneuver.

CRC COLD START AND WARMUP DRIVEABILITY PROCEDURE
MANUAL TRANSMISSION VEHICLES

TEST PROCEDURE AND DATA RECORDING

A. Record all necessary test information at the top of the data sheet.

B. Start engine per Owner's Manual Procedure. Record start time.

C. If engine fails to start in 15 seconds of cranking, stop cranking and follow Owner's Manual Starting Procedure and crank for an additional 15 seconds. If the engine still fails to start mark the data sheet no start and start the vehicle by any means possible.

D. Record idle quality in "Neutral" with the clutch out immediately after start; foot should be removed from the accelerator pedal.

E. If the engine stalls, repeat steps B and C. Record the number of stalls and the restart time. If the vehicle was a no start on the first start no times are required on restarts but number of stalls is required.

F. Allow engine to idle 15 seconds. Push in the clutch and shift to first gear and record idle quality. If the engine stalls, restart immediately.Don't record start times, just the number of stalls. Idle 5 seconds in "First".

G. After 5 seconds in "First" (step F), make a light throttle (Lt.Th) acceleration from 0-25 mph for .1 mile at a constant throttle opening beginning at the predetermined manifold vacuum with the transmission in "Second Gear". Shift to "High" (1:1) Gear and cruise at 25 mph for .1 mile. At the .2 mile marker open the throttle to the detent position and accelerate from 25 to 35 mph at a constant throttle opening. Stop at the .3 mile marker and make a 0 to 35 WOT acceleration. At the .4 mile marker decelerate to 10 mph and then accelerate at light throttle from 10 to 25 mph the transmission should be in "Second Gear" for this maneuver.

NOTE: Definitions of light throttle, detent, WOT accelerations and manifold vacuum settings are attached.

H. At the .5 mile marker, brake moderately to a stop on the right side of the track. Idle for 30 seconds in first. Record idle quality and number of stalls. Don't record restart times.

I. Perform steps G and H three times for a total of 1.5 miles. The mile marker for the beginning of each maneuver is indicated on the data sheet.

J. At mile marker 1.5, after completing the 30 second idle, make a crowd acceleration (constant predetermined vacuum) from 15 to 45 mph in third gear. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 mph to 25 mph at the 1.9 mile marker, and open the throttle to the detent position and accelerate from 25 to 35 mph in high gear(1:1). At the 2.0 mile marker stop and accelerate at WOT from 10 to 35 mph. At the 2.1 mile marker decelerate to 10 mph and perform a light throttle acceleration from 10 to 25 mph. Stop at the 2.2 mile marker and idle for 30 seconds.

K. Perform step J three times. Appropriate mile markers for the start of each maneuver are shown on the data sheet.

L. During the above maneuvers, observe and record the severity of any of the following malfunctions (see attached definitions):

1. Hesitation
2. Stumble
3. Surge
4. Accel Stall
5. Decel Stall
6. Backfire

Record maneuvering stalls on the data sheet in the appropriate column: Ac Stall is acceleration stalls and Dc Stall is deceleration stalls. The Dc Stall should be recorded at the end of the maneuver. For example, after the 25 to 35mph detent acceleration you have to decelerate to a stop to perform the 10 to 35 WOT maneuver. If the vehicle stalls on the decel the stall would be recorded with the 25 to 35 detent maneuver.

DEFINITIONS AND EXPLANATIONS

TEST RUN

Operation of a vehicle throughout the prescribed sequence of operating conditions and/or maneuvers for a single test fuel.

MANEUVER

A specified single vehicle operation or change of operating conditions (such as idle,acceleration or cruise) that constitutes one segment of the driveability driving schedule. Each maneuver will be given a start mile marker position and an allotted distance to perform the evaluation. Some maneuvers may not require the total allotted distance to evaluate but the next maneuver should not be attempted until reaching the prescribed mile marker.

CRUISE

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

STALL

Any occasion during a test when the engine stops with the ignition on. The types of stalls are:

> IDLE STALL- This is any stall that is experienced when the vehicle is not in motion, or when a maneuver is not being attempted.
>
> ACCELERATION STALL-This is any stall that is experienced during a prescribed maneuver or an attempted maneuver where the throttle is at any position other than the idle position.
>
> DECELERATION STALL-This is any stall that is experienced while the vehicle is moving but the throttle is at the idle position. Heavy braking can induce a stall, that is not part of this drive procedure, for this reason all braking to get ready for the next maneuver should be light to moderate.

IDLE ROUGHNESS
An evaluation of the idle quality or degree of smoothness while the engine is idling. In all the idle maneuvers, the 5,15 and 30 second, the number of idle stalls is to be recorded but after the allotted time is reached or 4 stalls are recorded continue to the next maneuver.

BACKFIRE
An explosion in the induction or exhaust system. This should be rated not counted.

HESITATION
A temporary lack of vehicle response to the opening of the throttle.

STUMBLE
A short, sharp reduction in the acceleration after the vehicle is in motion.

SURGE
A cyclic power fluctuation occurring during acceleration or cruise.

NO-START
When the vehicle fails to fire and run after two starting attempts of 15 sec. each.

FALSE-START
When the rater inadvertently stops cranking before the vehicle has actually started. If this happens the time for this False-start should be added to the next full start.

MALFUNCTION SEVERITY RATINGS

The number of stalls encountered during any maneuver are to be listed in the appropriate data sheet column including any decel stalls at the end of the maneuver getting ready for the next maneuver. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings.

TRACE (T)- A level of malfunction severity that is just discernible to a trained rater but generally not to most drivers.

MODERATE (M)- A level of malfunction severity that is probably noticeable to the average driver.

HEAVY (H)- A level of malfunction severity that is pronounced and obvious to any driver.

Enter the T,M, or H in the appropriate data block to indicate both the occurrence of the malfunction and its severity. More than one type of malfunction may be recorded on each line. If no malfunctions occurs, enter a dash (-) to indicate that the maneuver was performed and the operation was satisfactory during the maneuver.

EXPLANATIONS OF MANEUVERS
AUTOMATIC VEHICLES

WIDE OPEN THROTTLE (WOT) ACCELERATION

"Floorboard" acceleration from 0 to 35 mph through the gears. The rate at which the throttle is to be depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

PART-THROTTLE (PT) ACCELERATIONS

An acceleration made at any defined throttle position, or consistent change in throttle position, less than wot. Several part throttle accelerations are used. They are:

LIGHT THROTTLE (LT TH) - All light throttle accelerations are begun by opening the throttle to an initial manifold vacuum and maintaining constant throttle position throughout the remainder of the acceleration. The 0-25 maneuver must be completed in .1 mile in 9 seconds. The selected vacuum is posted in each vehicle.

CROWD - An acceleration made at a constant manifold vacuum. To maintain constant vacuum, the throttle opening must be continuously increased with increasing engine RPM.

DETENT - All detent accelerations are begun by opening the throttle to a point just before the transmission would downshift and holding that throttle position throughout the acceleration up to 35 mph. The manifold vacuum corresponding to this point at 25 mph is posted in the vehicle.

EXPLANATIONS OF MANEUVERS
MANUAL VEHICLES

WIDE OPEN THROTTLE (WOT) ACCELERATION

"Floorboard" acceleration from 10 to 35 mph. The test procedure is to take off light throttle in first gear and accelerate up to 15 mph. At 15 shift to second gear, then with the clutch out and the throttle closed decelerate to 10 mph and floor the accelerator. Run the vehicle in second gear up to 35 mph. If 35 mph is too high an rpm in second then run the test to 30 mph.

PART-THROTTLE (PT) ACCELERATIONS

An acceleration made at any defined throttle position, or consistent change in throttle position, less then wot. Several part throttle accelerations are used. They are:

LIGHT THROTTLE (LT TH) 0 to 25 MPH - Take off very light throttle and accelerate to between 8 - 10 mph. Shift to second gear. Then with the clutch out decelerate to 5 mph with the throttle closed. At 5 mph accelerate at the light throttle vacuum setting up to 25 mph. All light throttle accelerations are performed by opening the throttle to an initial manifold vacuum setting then maintaining constant throttle position throughout the remainder of the maneuver.

LIGHT THROTTLE 10 TO 25 MPH - These are performed after the 0 - 35 WOT maneuver so the transmission is in second gear. Decelerate with the clutch out in second and the throttle closed to 10 mph then accelerate at the light throttle vacuum up to 25 mph.

CROWD - An acceleration made at a constant manifold vacuum. To maintain constant vacuum, the throttle opening must be continuously increased with increasing engine RPM. The maneuver is performed by first taking off very light throttle and accelerating up and shifting the transmission until the vehicle is in third gear. Then decelerate with the clutch out and the throttle closed to 15 mph. At 15 mph accelerate at the posted vacuum up to 45 mph.

DETENT - All detent accelerations are performed after the 25 mph cruise and the transmission should be in high gear (1:1). The throttle should be opened to approximately 3/4 throttle and held constant until the vehicle reaches 35 mph. The initial manifold vacuum for 3/4 throttle at 25 mph will be posted in the vehicle.

METHOD FOR CALCULATING TOTAL WEIGHTED DEMERITS (TWD)

Demerits for Poor Starting:

Demerits = Total Starting Time - 2

Demerits for Stalls:

DEmerits = (No. of Idle Stalls) x 8 + (No. of Maneuvering Stalls) x 32

Demerits for Malfunctions Rated Subjectively are:

Demerits for Subjective Ratings are:

Trace = 1

Moderate = 2

Heavy = 4

Weighting Factors for Each Malfunction are:

Idle Roughness = 1

Surge = 4

Hesitation = 6

Stumble = 6

Backfire = 6

Weighted Demerits = Demerits x Weighting Factor

Total Weighted Demerits is:

TWD = Weighted Demerits + Demerits for Stalls + Starting Demerits

NOTE: When more than one malfunction occurs in a driving maneuver, only the malfunction giving the highest weighted demerits is counted.

CRC Driveability Data Sheet

Run no.	Car	Fuel	Rater	Date	Time	Temperatures: Soak	Run	Fuel tank	X1	X2

Starting time, sec.: Initial	Restart 1	Restart 2	Restart 3	Idle N.: Ruf. stalls	Idle Dr.: Ruf. stalls

0.0 0-25 Lt. Th.	0.1 25 Cruise	0.2 25-35 Detent	0.3 0-35 WOT	0.4 10-25 Lt. Th.	0.5 Idle	Temperatures		
Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Ruf. stalls	Fuel tank	X1	X2
0.5	0.6	0.7	0.8	0.9	1.0			
1.0	1.1	1.2	1.3	1.4	1.5			

1.5 0-45 Crowd	1.9 25-35 Detent	2.0 0-35 WOT	2.1 10-25 Lt. Th.	2.2 Idle	Temperatures		
Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Stalls: Hes. Stm. Srg. Bkf. Ac Dc	Ruf. stalls	Fuel tank	X1	X2

Comments: ____________________

CRC Driveability Data Sheet - Manual Transmissions

Run no.	Car	Fuel	Rater	Date	Time	Temperatures: Soak	Run	Fuel tank	X1	X2

Starting time, sec.: Initial	Restart 1	Restart 2	Restart 3	Idle N. Ruf. stalls	Idle Dr. Ruf. stalls

0.0 0-25 Lt. Th. (5-25 2nd)	0.1 25 Cruise (25 4th)	0.2 25-35 Detent (Detent 4th)	0.3 0-35 WOT (10-35 WOT 2nd)	0.4 10-25 Lt. Th. (10-25 2nd)	0.5 Idle (Idle in 1st)			
Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Ruf. stalls	Temperatures: Fuel tank	X1	X2
0.5	0.6	0.7	0.8	0.9	1.0			
1.0	1.1	1.2	1.3	1.4	1.5			

1.5 0-45 Crowd (15-45 3rd)	1.9 25-35 Detent (Detent 4th)	2.0 0-35 WOT (10-35 WOT 2nd)	2.1 10-25 Lt. Th. (10-25 2nd)	2.2 Idle (Idle in 1st)			
Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Hes. Stm. Srg. Bkf. Ac Dc Stalls	Ruf. stalls	Temperatures: Fuel tank	X1	X2

Comments: ______

COORDINATING RESEARCH COUNCIL
INCORPORATED
219 PERIMETER CENTER PARKWAY
ATLANTA, GEORGIA 30346
(404) 396-3400

TO: Southwest Research Institute Employees

***** WANT FREE GASOLINE? *****

The Coordinating Research Council (CRC) plans to conduct a test program here at SwRI from January 14 to March 7, 1991. The purpose of the program is to evaluate car and gasoline performance during the cold-start and warm-up phase of driving. Participants will receive free unleaded premium gasoline in exchange for information about how you feel your car performed.

If you would like to participate, are 21 years of age or older, and own a 1985 or newer vehicle, please complete the attached form and **return it to Rona Maldonado, Fleet Lab Annex, Trailer 9, by October 1, 1990.** If you wish to submit more than one vehicle for consideration, please make a copy of the form and submit one form for each vehicle. Because the vehicle should be driven to work each day, only one vehicle per employee will be selected. Details of the program are shown on the attached page.

Thank you.

CRC is an organization supported by the Society of Automotive Engineers (SAE), the American Petroleum Institute (API), and others to draw upon engineers from the industry to work together on problems of mutual interest.

CRC PROGRAM

The selection of about 200 participants will be based on their normal driving patterns, vehicle make - model - year - engine size, and a mechanical check of the car. The mechanical check will be brief and will only ascertain that the car starts, idles, and runs satisfactorily. No repairs will be made. Those employees completing the attached questionnaire will be interviewed during the first week of December 1990, to determine their willingness to participate in the program and to allow prospective participants to ask questions. Vehicles selected for the test will be supplied with free gasoline throughout the program. These will be premium fuels and will not damage your vehicle. If you make long trips with your car which require you to purchase non-test fuel, this will not interfere with our program as long as you give us your evaluation of the fuel we dispensed to you before the purchase. Also, when you return, please let us know if any fuel was added so that we can drain your tank and refuel it with test gasoline.

Participants will supply information about performance by filling out a questionnaire each time the vehicle is used after being parked for at least 6 hours. The questionnaire must be completed faithfully so the desired information is obtained. Participants will use their cars normally for the duration of the program. Participants will be asked to park their car at the fueling area once a week for fuel changeover. About half of the participants will be asked to leave their car that night for performance tests by experienced raters the next day. This performance check is a brief, low speed (maximum 45 mph) driving cycle which is 2.2 miles long. Participants' cars will not be taken off SwRI property and will be returned to the participant the following day. A 1990-1991 rental car will be provided to participants for their use while their car is being evaluated.

For identification of test cars, a small decal will be placed on the windshield. This will be removed at the end of the test.

APPLICATION TO PARTICIPATE IN CRC TEST PROGRAM

Make copies and complete a separate form for each vehicle to be considered.

1. **Driver Information** (Circle One)

Name:________________________________ Sex: M F

21 or Older: Yes No

Department:______________ Bldg. No.__________ SwRI Phone:_______________

Do you work any shift except 8 AM to 4:30 PM?_______________________________

Vacation or expected travel on Company business from __________ (date) to __________ (date)

2. **Vehicle Information**

Make:_________________________________ Model______________________________

Year:______________ Engine Size:__________ No. of Cylinders:____________

*VIN #:____

Transmission Type: Automatic Manual Odometer Reading:____________

When was this vehicle last tuned up? ________ (month) ________ (year) ________________ (odometer reading)

Do you plan to have any repairs made in the next 3 months? ________________

If "yes" -- what?____

3. **Vehicle Use**

Distance to Work:______________________

Primary type of driving enroute to work: |___| City |___| Suburban |___| Highway

Approximate number of stops made in first four miles coming to work?__________

Approximate number of miles you drive each week?_____________________________

Are you willing to always park this vehicle outside?__________________________

Do you plan to keep this vehicle until April 1991?___________________________

---

* VIN No. is Vehicle Identification Number located on your registration and on the the dashboard, driver's side viewable through the windshield.

4. **Vehicle Problems**

Have you experienced any of the following problems?	No	Yes	What do you feel caused this problem? Poor Quality Gasoline	Mechanical Car Deficiency	Both Gasoline and Car	Not Sure	Other
Poor mileage							
Vehicle hard to start							
Stalling							
Engine knock or ping							
Engine continues running after ignition shutoff							
Contaminated gasoline (water, dirt, etc.)							
Hesitation of car during acceleration							
Exhaust odor							
Slow acceleration							
Rough idling							

Other ____________________

What repairs, adjustments or other engine modifications have been made to try to solve the problem(s)? ____________________

Do you still have the problem(s)? ____________________

Who normally performs your repair service? ☐ Dealer ☐ Service Station ☐ Self

CRC GASOLINE TEST

TO: Participants

The Coordinating Research Council, Inc. (CRC) will be conducting a gasoline test here at SwRI for an eight-week test period beginning the week of January 14, 1991. The objective of the program is to determine which performance deficiencies which may occur during the warm-up period are most important to you, as a consumer.

Our base of operations here at SwRI will be the new Fleet Lab fueling facility across the street from Emissions Research on Tom Slick Avenue. A paved parking area is available and a temporary trailer has been set up as an office. A drawing of the area is attached. Our Extension number is 5659, 5670 or 5687 at the trailer should you need to contact us.

Car Number

Each participant has been assigned a unique three-digit car number. Your number is shown on the front of the enclosed questionnaire booklet. Also clipped to the front of the questionnaire booklet is a glue-on sticker with the assigned number of your car. Please remove the paper backing from the sticker and place the sticker on the outside of the windshield in the top corner of the driver's side for easy identification of your car.

The first digit in the car number shows your assigned fuel changeover day. Cars assigned 100 and 600 numbers should report for fueling on Monday, January 14, 1991, and each subsequent Monday for eight weeks. Those with 200 and 700 numbers will report for fuel changeover on Tuesdays beginning on January 15th, etc., as shown in the following table.

Car Numbers	Fuel Changeover Day	First Fueling Day
100, 600	Mondays	Jan 14
200, 700	Tuesdays	Jan 15
300, 800	Wednesdays	Jan 16
400, 900	Thursdays	Jan 17

Fuel Changeovers

On your assigned fuel changeover day, please drive to, and park, at the fueling area. Park on rows A-D. Leave the keys in the ignition. DO NOT LOCK THE CAR.

If the last two digits of your serial number are 50-70, your car will be ready for your pick-up in the fueling area by 4:00 pm that day. During the day, we will have drained the fuel tank and refilled your car with the test gasoline we have assigned for the next week. For your convenience, we will have cars and drivers available to transport you to your place of work in the morning. These cars will have a "CRC" sign on the front doors. Please tell the driver if it will be necessary for us to pick you up at quitting time to return you to the fueling area in the evening.

If the last two digits of your car number are 1-20, we will be keeping your car overnight. We will defuel and refuel your car with test gasoline that day. The following morning we will conduct a short cold-start and warm-up test on your car. Your car will be ready for your pick-up and routine use the following day at 4:00 pm. Therefore, when you park your car at the fueling area in the morning on fuel changeover day we will give you a rental car for your use. The following day, at 4:00 pm or later, drive the rental car to the fueling area and pick up your own car.

Additional Fuel

At fuel changeover, we will fill your fuel tank. If you need additional fuel during the week, please report to the fueling area. The attendant will dispense any additional test fuel you request. Please limit your request to that fuel which you think you might need to get to your next scheduled changeover day. Our problem is that draining excess fuel quantities is time-consuming, but we want you to avoid purchases of outside non-test gasoline as much as possible.

If it is necessary to purchase gasoline, please note it on the questionnaire for that date and report to the fueling area at your earliest convenience. We will drain and refill the car with test gasoline.

Attendants will be available at the fueling area from 7:00 am to 5:30 pm, Monday through Friday.

Questionnaires

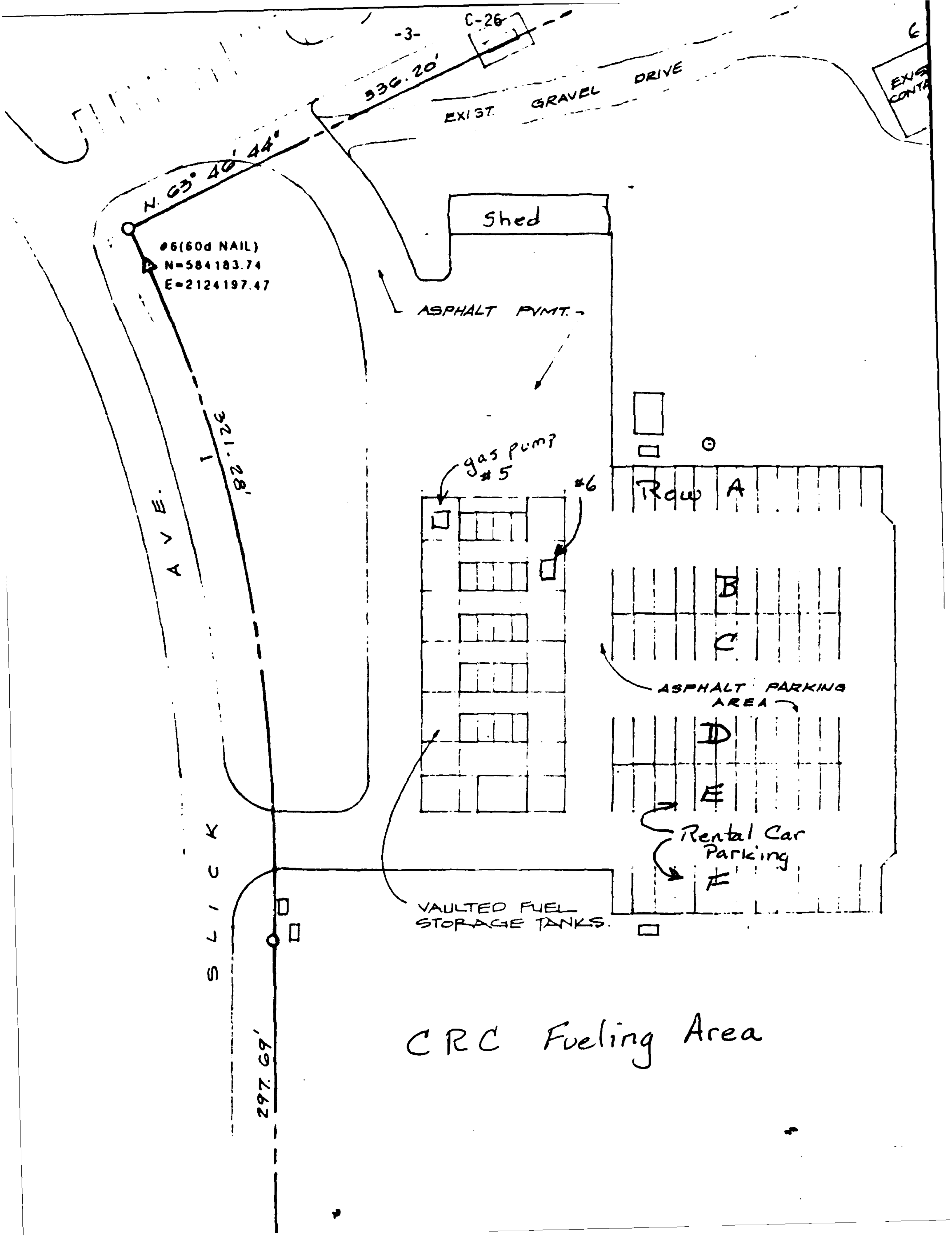
A booklet of questionnaires has been provided in this handout, as well as a separate questionnaire instruction sheet.

If you are driving a rental car, you will find a questionnaire booklet similar to your own on the front seat. Please complete a questionnaire regarding the performance of the rental car in the same manner as you would have completed the form for your own car.

Fueling Area

At least one CRC representative will be at the fueling area between 7:00 am and 5:30 pm, Monday through Friday. If you have any questions, problems, etc., please call us on Extensions 5659, 5670, 5687.

We thank you very much for your cooperation and assistance. Your opinions of vehicle performance are very important to us.



CRC Fueling Area

PERFORMANCE QUESTIONNAIRE INSTRUCTIONS

This questionnaire is designed to obtain information about the performance of your car during cold start and warming-up operation.

Each person doing any driving in the car should complete this questionnaire. They should be filled out as soon as possible after a trip is completed. Do not depend on memory. For this reason it is suggested that the questionnaires be kept on the seat of your car as a reminder and for your convenience.

Completed, up-to-date questionnaires will be collected at the time of your next refueling. Fuel will not be dispensed unless completed questionnaires are turned in.

(1) Car No.: A unique number has been assigned to your car. This number has been preprinted on your questionnaires.

(2) Date: The date has been preprinted on your questionnaire. Please be sure to use the appropriate form for the appropriate date. The forms are dated consecutively beginning with the first day after your first fuel changeover and continuing for the duration of the program.

(3) Name of Driver: The name of the driver completing the questionnaire must be entered.

(4) The questionnaire solicits information regarding warming-up performance. We consider warming-up performance to be the first five miles of driving after the car has been parked for six hours (the engine has cooled off to ambient temperature and would be cool to the touch). Space has been provided for two such trips on any day. It is highly unlikely that you will experience more than two such cold starts/day. On most days, if the car is driven to and from work, there will be a cold start trip at 7:00 am and another at 4:00 - 5:00 pm. If the car was driven at noontime, the 4:00 pm trip home would not be a cold start since it was not parked for 6 hours.

Time

Approximate time to the nearest hour of the day, such as 7:00 am, 3:00 pm, should be recorded.

Problem

Please record any problems you notice. We have included appropriate descriptive words that should cover most problems; however, feel free to use any words you like. Once you decide on the words to describe any problems, please be consistent. We are looking for changes in your car's performance due to the different fuels and weather conditions.

Most importantly, if the car is driven and no problems occur, record the trip time and write "none" under the problem heading.

Hard Starting -	Difficult starting or longer than normal cranking time before the engine would start.
Idle roughness -	An evaluation of the degree of smoothness while the engine is idling.
Hesitation -	A lack of, or deficiency in, immediate engine response to movement of the gas pedal.
Stumble -	A sharp, momentary, unexpected change in engine power. A misfire, with single or multiple.
Surge -	A continued condition of fluctuations in power. This has been described by some as a feeling like "gusts of wind hitting the front of the car."
Backfire -	An explosion in the exhaust system or a "cough" in the carburetor or intake system.
Knock -	A pinging, rattling sound from the engine, usually during acceleration or high speed driving.

The above malfunctions, if they are noticed, should be rated as to severity. Enter a T (trace), M (moderate), or H (heavy) to denote both the occurrence and the intensity. The following definitions should be used:

Trace (T)	Light, barely noticeable
Moderate (M)	Medium, easily noticed, distinct
Heavy (H)	Obvious, something no one could help but notice
Stalls at Idle	The engine stalls when the car is first started, when idling at a traffic light or stop sign or coming to a stop sign.
Stalls, Driving	The engine stalls during an attempted driving maneuver such as an acceleration, turn, or starting off from a stop.

Stalls, if they occur, should be recorded and the number of times it happened should be listed.

If the car is not driven on any particular day draw a big X across the entire data sheet to indicate that the car was not driven; not that you just forgot to fill out the questionnaire.

(5) Were You Satisfied With Performance? If you were satisfied with the fuel performance, mark "Yes". This would indicate that the fuel was of sufficient quality that you would purchase it. In your experience, this is an acceptable fuel. If you were not satisfied, mark "No". This would indicate that the fuel was of insufficient quality and you would not purchase it. In your experience, this is an unacceptable fuel.

(6) If you marked "No" to the performance satisfaction question, please circle the problem(s) in Part 4 that caused your dissatisfaction.

(7) Comments If you have additional explanations for any problems you noticed, write them in the comment section. If you had any outside fuel purchases, write the amount purchased in this section also, and report to the fueling area as soon as possible so that we may drain your fuel tank of non-test gasoline.

Weekly Questionnaire

In each questionnaire booklet, there is a weekly questionnaire. Please complete this form when you leave your car for fuel changeover. This form should be self-explanatory: Considering the entire week, how did the fuel perform?

Turning in Questionnaires

Please leave your questionnaire booklet on the front seat of your car. At fuel changeover, the attendant will remove the completed questionnaire.

CUSTOMER GASOLINE PROGRAM
DAILY QUESTIONNAIRE

Office Use Only

Fuel________

Type________

Class________

1) Car No. 101 2) Date 01/15/91 Tuescay

3) Name of Driver________________________

4) Warming-up Performance (First 5 miles of driving after being parked for more than 6 hours)

Time	Problem*	Severity or Number	Time	Problem*	Severity or Number

5) Were you satisfied with performance?

Yes______ No______

Were you satisfied with performance?

Yes______ No______

6) If "No" circle the performance problem(s) that caused your dissatisfaction.

7) Comments:______________________________________

* Suggested words for problems: knock, hard starting, idle roughness, hesitation, Stumble, stall at idle, stall driving, backfire, surge. If no problems, write "none".

CUSTOMER GASOLINE PROGRAM
WEEKLY QUESTIONNAIRE

Office Use Only

Fuel________
Type________
Class________

<u>Complete this form on fuel changeover day.</u>

1) Car No.__101__ 2) Date__01/21/91 Monday__

3) Name of Driver______________________________

4) Please rate the performance of this fuel.
(Circle one)

Very Poor

Poor

OK

Good

Very Good

5) Overall, were you satisfied with the performance of your car with this fuel this week?

Yes______ No______

Thank you.

SAMPLE

APPENDIX D

CUSTOMER TEST FLEET

Customer Test Vehicles

MODEL	MAKE	MODEL YR	CYLINDER	TRANS	DISP	FUEL SYS
VOYAGER	PLYMOUTH	.	6	A	3.0	PFI
98	OLDSMOBILE	85	6	A	.	
NOVA	CHEVROLET	85	4	M	1.5	CARB
GL WAGON	SUBARU	85	4	M	1.8	CARB
LYNX	MERCURY	85	4	M	1.9	CARB
ACCORD	HONDA	85	4	A	2.0	CARB
PRELUDE	HONDA	85	4	A	2.0	CARB
COLT VISTA	DODGE	85	4	M	2.0	CARB
VOYAGER	PLYMOUTH	85	4	A	2.6	CARB
BLAZER S1	CHEVROLET	85	6	A	2.8	CARB
S10	CHEVROLET	85	6	A	2.8	CARB
WAGONEER	JEEP	85	6	A	2.8	CARB
CJ7	JEEP	85	6	M	4.2	CARB
F150	FORD	85	6	M	4.9	CARB
PICKUP	CHEVROLET	85	8	A	5.0	CARB
VAN	FORD	85	8	A	5.0	CARB
FIREBIRD	PONTIAC	85	8	A	5.0	CARB
TRANS AM	PONTIAC	85	8	A	5.0	CARB
RAMCHARGE	DODGE	85	8	A	5.2	CARB
VAN	DODGE	85	8	A	5.2	CARB
SUBURBAN	CHEVROLET	85	8	A	5.7	CARB
SUBURBAN	CHEVROLET	85	8	A	5.7	CARB
VAN	FORD	85	8	A	5.8	CARB
RX7	MAZDA	85	.	M	1.3	PFI
QUANTUM	VOLKSWAGEN	85	5	A	2.2	PFI
MAXIMA	NISSAN	85	6	M	3.0	PFI
CIMARRON	CADILLAC	85	4	A	2.0	TBI
TEMPO	FORD	85	4	A	2.3	TBI
MARQUIS	MERCURY	85	6	A	3.8	TBI
FLEETWOOD	CADILLAC	85	8	A	4.1	TBI
COLT	DODGE	86	4	A	2.0	CARB
VOYAGER	PLYMOUTH	86	4	A	2.6	CARB
TROOPER I	ISUZU	86	4	M	2.6	CARB
CHEROKEE	JEEP	86	6	A	2.8	CARB
SUBURBAN	CHEVROLET	86	8	A	.	CARB
CAPRICE	CHEVROLET	86	8	A	5.0	CARB
VAN	DODGE	86	8	A	5.2	CARB
K-20	CHEVROLET	86	8	A	5.7	CARB
TRUCK	DODGE	86	8	A	5.9	CARB
323	MAZDA	86	4	M	1.5	PFI
JETTA	VOLKSWAGEN	86	4	M	1.8	PFI
200SX	NISSAN	86	4	A	2.0	PFI
CELICA	TOYOTA	86	4	A	2.0	PFI
CALAIS	OLDSMOBILE	86	6	A	2.8	PFI
6000	PONTIAC	86	6	A	2.8	PFI
AEROSTAR	FORD	86	6	A	3.0	PFI
CROWN VIC	FORD	86	8	A	5.0	PFI
F150 PU	FORD	86	8	A	5.0	PFI
MARQUIS	MERCURY	86	8	A	5.0	PFI
TEMPO	FORD	86	4	A	2.3	TBI
PICKUP	NISSAN	86	4	M	2.4	TBI
CAPRICE	CHEVROLET	86	6	A	4.3	TBI
MONTE CARL	CHEVROLET	86	6	A	4.3	TBI
DEVILLE	CADILLAC	86	8	A	4.1	TBI
SAMURAI	SUZUKI	87	4	M	1.3	CARB

Customer Test Vehicles

MODEL	MAKE	MODEL YR	CYLINDER	TRANS	DISP	FUEL SYS
EXCEL	HYUNDAI	87	4	M	1.5	CARB
CORROLA	TOYOTA	87	4	A	1.6	CARB
GLS	HYUNDAI	87	4	M	1.6	CARB
SENTRA	NISSAN	87	4	M	1.6	CARB
FIREBIRD	PONTIAC	87	8	A	5.0	CARB
FIFTH AVE	CHRYSLER	87	8	A	5.2	CARB
VAN	DODGE	87	8	A	5.2	CARB
IVORY COA	CHEVROLET	87	8	A	5.7	CARB
626	MAZDA	87	4	M	2.0	PFI
626 GT	MAZDA	87	4	M	2.0	PFI
STANZA	NISSAN	87	4	M	2.0	PFI
RANGER	FORD	87	4	A	2.3	PFI
LEGEND	ACURA	87	6	A	2.5	PFI
CENTURY	BUICK	87	6	A	2.8	PFI
BRONCO	FORD	87	6	A	2.9	PFI
RANGER	FORD	87	6	A	2.9	PFI
RANGER	FORDY	87	6	M	2.9	PFI
CARAVAN	DODGE	87	6	A	3.0	PFI
CHEROKEE	JEEP	87	6	A	4.0	PFI
CHEROKEE	JEEP	87	6	M	4.0	PFI
F150	FORD	87	6	M	4.9	PFI
F-150	FORD	87	8	A	5.0	PFI
GRAND MAR	MERCURY	87	8	A	5.0	PFI
KING CAB	NISSAN	87	4	M	2.4	TBI
LANCER	CHRYSLER	87	4	A	2.5	TBI
LANCER	DODGE	87	4	A	2.5	TBI
FIFTH AVE	CHRYSLER	87	8	A	5.2	TBI
SPECTRUM	CHEVROLET	88	4	A	1.5	CARB
B2200	MAZDA	88	4	M	2.2	CARB
GL	HYNDAI	88	8	M	1.5	CARB
CRUISER S	OLDSMOBILE	88	8	A	5.0	CARB
MX-6	MAZDA	88	4	A	2.2	PFI
CALAIS	OLDSMOBILE	88	4	A	2.3	PFI
CUTLASS	OLDSMOBILE	88	4	A	2.3	PFI
TROOPER	ISUZU	88	4	M	2.6	PFI
CELEBRITY	CHEVROLET	88	6	A	2.8	PFI
GRAND PRI	PONTIAC	88	6	A	2.8	PFI
BRONCO II	FORD	88	6	A	2.9	PFI
300-ZX	NISSAN	88	6	A	3.0	PFI
AEROSTAR	FORD	88	6	M	3.0	PFI
CENTURY	BUICK	88	6	A	3.8	PFI
BRONCO II	FORD	88	8	A	2.9	PFI
TOWN CAR	LINCOLN	88	8	A	5.0	PFI
COUGAR	MERCURY	88	8	A	5.0	PFI
MARQUIS	MERCURY	88	8	A	5.0	PFI
BRONCO	FORD	88	8	A	5.8	PFI
GL WAGON	SUBARU	88	4	M	1.8	TBI
SHADOW	DODGE	88	4	A	2.2	TBI
RELIANT	PLYMOUTH	88	4	A	2.2	TBI
RELIANT K	PLYMOUTH	88	4	A	2.2	TBI
SHADOW	DODGE	88	4	M	2.2	TBI
CELEBRITY	CHEVROLET	88	4	A	2.5	TBI
GRAND AM	PONTIAC	88	4	A	2.5	TBI
VOYAGER	PLYMOUTH	88	4	M	2.5	TBI
ASTRO VAN	CHEVROLET	88	6	A	4.3	TBI

Customer Test Vehicles

MODEL	MAKE	MODEL YR	CYLINDER	TRANS	DISP	FUEL SYS
DEVILLE	CADILLAC	89	8	A	4.5	TBI
DIPLOMAT	DODGE	89	8	A	5.2	TBI
SILVERADO	CHEVROLET	89	8	A	5.7	TBI
SUBURBAN	CHEVROLET	89	8	A	5.7	TBI
EXCEL GS	HYUNDAI	89	4	A	1.5	CARB
TERCEL	TOYOTA	89	4	A	1.5	CARB
CAMARY	TOYOTA	89	4	A	2.0	PFI
PROBE	FORD	89	4	A	2.2	PFI
PROBE	FORD	89	4	M	2.2	PFI
TEMPO	FORD	89	4	A	2.3	PFI
TOPAZ	MERCURY	89	4	A	2.3	PFI
SONATA	HYUNDAI	89	4	A	2.4	PFI
FIREBIRD	PONTIAC	89	6	A	2.8	PFI
BRONCO II	FORD	89	6	A	2.9	PFI
DYNASTY	DODGE	89	6	A	3.0	PFI
AEROSTAR	FORD	89	6	A	3.0	PFI
TAURUS GL	FORD	89	6	A	3.0	PFI
TAURUS GL	FORD	89	6	A	3.0	PFI
TAURUS	FORD	89	6	M	3.0	PFI
LESABRE	BUICK	89	6	A	3.8	PFI
CHEROKEE	JEEP	89	6	A	4.0	PFI
F-150	FORD	89	6	M	4.9	PFI
F150	FORD	89	6	M	4.9	PFI
CIVIC	HONDA	89	4	A	1.5	TBI
SENTRA	NISSAN	89	4	A	1.6	TBI
CAVALIER	CHEVROLET	89	4	M	2.0	TBI
CORSICA	CHEVROLET	89	4	M	2.0	TBI
GRAND AM	PONTIAC	89	4	A	2.5	TBI
GRAND AM	PONTIAC	89	4	M	2.5	TBI
JIMMY	GMC	89	6	M	2.8	TBI
TRUCK	DODGE	89	6	A	3.9	TBI
CAPRICE	CHEVROLET	89	8	A	5.0	TBI
CAMARO	CHEVROLET	89	8	M	5.0	TBI
TRUCK	CHEVROLET	89	8	M	5.7	TBI
MPV VAN	MAZDA	90	4	A	2.6	CARB
FESTIVA	FORD	90	4	M	1.3	PFI
PROTEGE	MAZDA	90	4	M	1.8	PFI
ECLIPSE	MITSUBISHI	90	4	M	2.0	PFI
ACCORD	HONDA	90	4	A	2.2	PFI
VOYAGER	PLYMOUTH	90	4	A	3.0	PFI
BRONCO II	FORD	90	6	M	2.9	PFI
RANGER	FORD	90	6	M	2.9	PFI
CAMARO	CHEVROLET	90	6	A	3.1	PFI
LUMINA	CHEVROLET	90	6	A	3.1	PFI
CUTLASS	OLDSMOBILE	90	6	A	3.1	PFI
CENTURY	BUICK	90	6	A	3.3	PFI
LARIAT	FORD	90	8	A	5.0	PFI
TOWN CAR	LINCOLN	90	8	A	5.0	PFI
SENTRA	NISSAN	90	4	M	1.6	TBI
SUNBIRD	PONTIAC	90	4	M	2.0	TBI
CORSICA	CHEVROLET	90	4	M	2.2	TBI
SILVERADO	CHEVROLET	90	6	A	4.3	TBI
SPORTSIDE	CHEVROLET	90	8	A	5.7	TBI
MR2	TOYOTA	91	4	M	2.2	PFI
EXPLORER	FORD	91	6	A	4.0	PFI

Customer Test Vehicles

MODEL	MAKE	MODEL YR	CYLINDER	TRANS	DISP	FUEL SYS
EXPLORER	FORD	91	6	M	4.0	PFI
S-10	CHEVROLET	91	6	M	2.8	TBI

APPENDIX E

RENTAL CAR FLEET

RENTAL CAR FLEET

Year	Make	Model	Number of Cars at Start of Program	Number of Cars at End of Program
1991	Pontiac	Grand Am	34	23
1991	Mercury	Cougar	8	10
1991	Toyota	Corolla	5	10
1991	Chevrolet	Corsica	0	3
1991	Toyota	Camry	0	2

NOTE: Midway through the program, it was necessary to return sixteen vehicles to the rental agency. These vehicles were replaced; however, the replacements were not necessarily identical makes and models.

APPENDIX F

INDIVIDUAL LABORATORY FUEL

PROPERTY DATA

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Fuel	Lab	RVP, psi	T_{10}, °F	T_{50}, °F	T_{90}, °F	EtOH, vol %	MTBE vol %
1	A	7.4	140	242	352	0.1	<0.1
1	B	7.3	144	236	346	<0.1	<0.1
1	C	7.5	144	244	357	-	-
1	D	-	-	-	-	-	-
1	E	7.5	138	241	358	0.0	0.0
1	F	7.6	142	245	359	0.0	0.0
1	G	7.2	146	245	361	-	-
1	H	7.3	143	242	353	-	-
2	A	7.8	128	240	341	<0.1	<0.1
2	B	8.0	128	230	339	0.1	<0.1
2	C	8.2	133	244	346	-	-
2	D	7.9	130	242	343	0.0	0.2
2	E	-	-	-	-	-	-
2	F	8.3	128	244	346	-	-
2	G	8.2	128	241	349	-	-
2	H	-	-	-	-	-	-
3	A	9.1	116	237	324	<0.1	<0.1
3	B	8.8	116	235	324	<0.1	<0.1
3	C	8.4	118	239	327	-	-
3	D	8.6	119	238	326	0.2	0.1
3	E	-	-	-	-	-	-
3	F	9.2	118	241	330	-	-
3	G	9.0	118	237	327	-	-
3	H	-	-	-	-	-	-
4	A	9.9	112	230	309	<0.1	<0.1
4	B	9.6	110	229	308	0.0	<0.1
4	C	10.0	114	234	313	-	-
4	D	9.4	113	233	311	0.1	0.2
4	E	-	-	-	-	-	-
4	F	10.0	102	238	314	-	-
4	G	10.0	111	233	311	-	-
4	H	-	-	-	-	-	-
5	A	10.4	104	202	294	<0.1	<0.1
5	B	10.8	102	194	288	0.0	<0.1
5	C	10.2	107	209	298	-	-
5	D	-	-	-	-	-	-
5	E	11.1	103	201	298	0.0	0.0
5	F	11.1	106	214	300	0.0	0.0
5	G	10.6	105	208	300	-	-
5	H	10.6	104	200	297	-	-

INDIVIDUAL LABORATORY FUEL PROPERTY DATA

Fuel	Lab	RVP, psi	T_{10}, °F	T_{50}, °F	T_{90}, °F	EtOH, vol %	MTBE vol %
6	A	8.6	131	231	344	9.5	0.3
6	B	8.5	131	230	346	8.2	<0.1
6	C	8.7	136	237	354	10.1	-
6	D	8.3	134	237	352	9.5	0.4
6	E	8.7	135	235	354	9.9	0.0
6	F	8.8	132	236	354	9.6	-
6	G	8.7	132	232	353	10.0	0.2
6	H	8.5	135	235	351	9.1	-
7	A	9.4	122	226	335	9.7	0.2
7	B	9.0	125	224	334	9.3	<0.1
7	C	9.3	126	231	336	10.6	-
7	D	9.3	128	235	339	9.2	0.3
7	E	-	-	-	-	-	-
7	F	9.4	128	236	342	-	-
7	G	9.3	124	227	342	10.6	0.2
7	H	-	-	-	-	-	-
8	A	10.2	116	205	320	9.6	0.1
8	B	9.8	118	208	320	9.2	<0.1
8	C	10.2	119	212	324	10.1	-
8	D	9.9	121	225	319	9.2	0.3
8	E	-	-	-	-	-	-
8	F	10.2	118	230	329	-	-
8	G	10.3	115	214	325	10.4	0.1
8	H	-	-	-	-	-	-
9	A	11.1	110	167	307	9.3	<0.1
9	B	10.7	111	163	305	9.3	<0.1
9	C	11.0	112	170	309	9.8	-
9	D	10.8	112	199	309	-	0.1
9	E	-	-	-	-	-	-
9	F	11.2	110	168	308	-	-
9	G	10.5	113	178	312	10.3	0.2
9	H	-	-	-	-	-	-
10	A	11.8	103	155	295	9.1	<0.1
10	B	11.6	106	154	295	8.9	<0.1
10	C	11.8	108	159	298	10.5	-
10	D	11.5	107	161	298	-	0.2
10	E	11.9	107	155	295	9.5	0.0
10	F	11.9	104	158	298	8.3	-
10	G	11.8	106	159	295	10.8	-
10	H	11.6	107	156	295	8.9	0.0
11	A	8.4	117	202	318	<0.1	14.1
11	B	8.7	118	204	316	0.0	14.5
11	C	8.7	121	209	322	-	14.7
11	D	-	-	-	-	-	-
11	E	9.3	119	203	318	0.0	14.7
11	F	8.9	118	212	326	-	12.4
11	G	-	-	-	-	-	-
11	H	8.8	119	206	318	-	13.7

APPENDIX G

TEMPERATURE SUMMARY

Temp Summary For 1991 CRC Rater/Customer Driveability Study

OBS	DATE	MIN TMP	TEST TMP
1	01/14/91	53	54
2	01/15/91	52	53
3	01/16/91	47	51
4	01/17/91	54	55
5	01/18/91	50	53
6	01/19/91	.	.
7	01/20/91	42	49
8	01/21/91	.	.
9	01/22/91	37	43
10	01/23/91	47	49
11	01/24/91	47	48
12	01/25/91	41	43
13	01/26/91	44	46
14	01/27/91	53	53
15	01/28/91	50	50
16	01/29/91	49	52
17	01/30/91	40	40
18	01/31/91	37	41
19	02/01/91	43	46
20	02/02/91	44	51
21	02/03/91	55	56
22	02/04/91	62	62
23	02/05/91	53	57
24	02/06/91	55	57
25	02/07/91	49	53
26	02/08/91	46	51
27	02/09/91	47	52
28	02/10/91	51	57
29	02/11/91	62	62
30	02/12/91	60	60
31	02/13/91	59	59
32	02/14/91	59	63
33	02/15/91	49	53
34	02/16/91	46	47
35	02/17/91	56	59
36	02/18/91	63	68
37	02/19/91	55	56
38	02/20/91	46	46
39	02/21/91	50	51
40	02/22/91	46	51
41	02/23/91	48	50
42	02/24/91	53	55
43	02/25/91	49	52
44	02/26/91	44	46
45	02/27/91	50	52
46	02/28/91	55	55
47	03/01/91	57	60
48	03/02/91	55	59
49	03/03/91	51	53
50	03/04/91	52	58
51	03/05/91	62	65