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1989 CRC OCTANE NUMBER REQUIREMENT SURVEY

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219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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COORDINATING RESEARCH COUNCIL

INCORPORATED

219 PERIMETER CENTER PARKWAY

ATLANTA, GEORGIA 30346

(404) 396-3400

1989 CRC OCTANE NUMBER REQUIREMENT SURVEY
(CRC Project No. CM-123-89)

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Prepared by the

1989 Analysis Panel

of the

CRC Octane Number Requirement Survey Group

August 1990

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

ABSTRACT

An annual statistical survey of octane number requirements of current model vehicles is conducted by the Coordinating Research Council, Inc. Test data have been obtained by eighteen companies on 391 1989 vehicles including passenger cars and light-duty trucks and vans, of which 179 were equipped with knock sensors. Maximum octane number requirements were determined by testing at maximum-throttle conditions, as well as at part-throttle, with three unleaded fuel series of varying sensitivities. Requirements are expressed as the (R+M)/2 octane number, Research octane number, and Motor octane number of the reference fuel producing knock which was recurrent and repeatable at the lowest audible level. Estimated octane number requirements for the total vehicles are weighted in proportion to the 1989 vehicle model production and/or sales figures. The maximum octane number requirements of 1989 models with average sensitivity unleaded fuels were 85.1 (R+M)/2 octane numbers at the 50 percent satisfaction level, and 89.2 (R+M)/2 octane numbers at the 90 percent satisfaction level. Comparison with previous Surveys are made in this report.

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I. INTRODUCTION

This is the forty-third annual statistical survey of octane requirements of current model vehicles conducted by the Coordinating Research Council, Inc. This Survey studies distributions of vehicle octane requirements as a function of satisfaction levels and fuel sensitivity in a sample representative of 1989 model vehicles. Distributions of vehicle octane requirements are estimated from these data. The effect of fuel sensitivity, which is the difference between Research octane number (RON) and Motor octane number (MON), is investigated by using two full-boiling range fuel series and the primary reference fuel series. This is done because vehicles do not respond to RON and MON in the same way.

Knock sensors enable engines to adapt to fuels of varying octane numbers which can result in lowest audible knock occurring over a range of octane numbers. The high and low ends of this range are determined for each knock-sensor-equipped vehicle and the effect of these two octane requirements on the distribution is calculated.

The data in this Survey are obtained by trained raters under controlled conditions. For some vehicles, information on the owner's perception of vehicle knock and the owner's current choice of gasoline octane are available. A comparison between the trained rater's and customer's report of knock on tank fuel is presented, and trends are shown.

Eighteen companies participated in this Survey; they are listed in Appendix A. Members of the CRC Octane Number Requirement Survey Analysis Panel are identified in Appendix B.

II. SUMMARY

Octane number requirements were determined on 391 1989 model year vehicles, including 313 passenger cars and 78 light-duty trucks and vans. One hundred seventy-nine of the test vehicles were equipped with knock sensors. Estimated octane number requirements for the vehicle population are weighted in proportion to the 1989 vehicle model production and/or sales data. Maximum octane number requirements for the 1989 models and changes from 1988 for the four weighted vehicle population groups at the 50 percent and 90 percent levels using FBRU (full-boiling range unleaded) fuels are summarized below:

FBRU (R+M)/2 OCTANE NUMBER REQUIREMENTS AND 95% CONFIDENCE LEVELS

1989 AND CHANGES FROM 1988

<u>Weighted Population</u>	<u>KS-H**</u>	<u>▲ from 1988</u>	<u>KS-L***</u>	<u>▲ from 1988</u>
50% Satisfaction				
Total Vehicles (45.8%)*	85.1±0.3	0.4	84.9±0.3	0.9
Total Cars (42.8%)*	84.8±0.4	0.1	84.6±0.4	0.4
Total Trucks (57.7%)*	85.8±0.6	1.0	85.4±0.6	1.6
Total Knock-Sensor Vehicles	85.4±0.5	0.4	84.9±0.5	1.9
90% Satisfaction				
Total Vehicles	89.2±0.4	-0.1	88.7±0.4	0.1
Total Cars	89.2±0.5	0.0	88.8±0.5	0.1
Total Trucks	89.2±0.9	-0.4	88.7±0.8	0.1
Total Knock-Sensor Vehicles	89.7±0.7	-0.5	88.7±0.6	0.1

* Knock-sensor-equipped vehicles as percent of the associated population.

** KS-H = Population with knock sensor-equipped vehicles at maximum requirement.

*** KS-L = Population with knock-sensor-equipped vehicles at minimum-borderline requirement.

Maximum octane number requirements of the total 1989 vehicle population increased by $0.4 (R+M)/2$ at 50 percent satisfaction and decreased by $0.1 (R+M)/2$ at 90 percent satisfaction compared with 1988 on FBRU fuels. Maximum octane requirements of 1989 knock-sensor vehicles increased by $0.4 (R+M)/2$ at 50 percent and decreased by $0.5 (R+M)/2$ at 90 percent satisfaction compared with 1988.

The above data suggest the yearly difference in total vehicle satisfaction at the 50 percent level is significant and driven by changes in the total truck population. Changes in other distributions are not significant at the 95 percent confidence level.

Maximum and minimum-borderline octane number requirements were determined for knock-sensor-equipped vehicles. For the 1989 knock-sensor vehicle population, minimum-borderline octane number requirements were $0.5 (R+M)/2$ lower than the maximum requirements at the 50 percent satisfaction level and $1.0 (R+M)/2$ lower than the maximum requirements at the 90 percent level. Inclusion of the knock-sensor-equipped vehicles at their minimum-borderline requirement reduced the total vehicle population requirements by $0.2 (R+M)/2$ at the 50 percent level and $0.5 (R+M)/2$ at the 90 percent satisfaction levels relative to those calculated at their maximum requirements.

Part-throttle octane requirements were equal to or higher than the maximum-throttle octane requirements on 26 percent of all 1989 vehicles with FBRU fuels (97 of 379 vehicles). This compares with 31 percent of all 1988 vehicles with part-throttle requirement on FBRU fuels.

In the 1989 Survey, 30 percent of the vehicles tested knocked on tank fuel, which compares with 31 percent in the 1988 Survey.

The 1989 Survey included sufficient data for thirteen specific models to be analyzed separately as select models. All select models had automatic transmissions, and eight were equipped with knock sensors. Maximum octane requirements for the select models at the 50 percent and 90 percent satisfaction levels for FBRU fuels are summarized in the following table.

SELECT MODELS

MAXIMUM PFRU OCTANE NUMBER REQUIREMENTS

<u>Select Model</u>	<u>No. Tested</u>	<u>(R+M)/2</u>	
		<u>50% Sat.</u>	<u>90% Sat.</u>
C11BU2*P30A44 (Maximum)	10	86.5	89.5
C11BU2*P30A44 (Minimum-Borderline)	10	86.0	88.8
C21RC3*P22A4	11	82.7	86.8
C21D42*P38A4/C21S42*P38A4/C22S42* P38A4	23	86.9	89.7
C21PF2*P50A4/C22PF2*P50A4/C24PF2* P50A4	10	86.8	90.6
C31AR2*T25A3/C32AR2*T25A3/C33AR2* T25A3/C34AR2*T25A3/C34NR2*T25A3	11	86.2	89.9
C31AW2*P28A4/C32AW2*P28A4/C32WW2* P28A4/C33AW2*P28A4/C33WW2*P28A4/ C34WW2*P28A4 (Maximum)	23	86.9	90.8
C31AW2*P28A4/C32AW2*P28A4/C32WW2* P28A4/C33AW2*P28A4/C33WW2*P28A4/ C34WW2*P28A4 (Minimum-Borderline)	21	85.2	89.6
C31J12*T20A3/C31L12*T20A3	11	85.5	90.3
C32ND4*P23A3/C33ND4*P23A3/C34ND4* P23A3 (Maximum)	12	83.7	89.4
C32ND4*P23A3/C33ND4*P23A3/C34ND4* P23A3 (Minimum-Borderline)	11	82.2	86.8
C32WT2*P31A4/C33WT2*P31A4/C34WT2* P31A4 (Maximum)	11	85.5	90.3
C32WT2*P31A4/C33WT2*P31A4/C34WT2* P31A4 (Minimum-Borderline)	11	84.1	89.0
C33AN2*P33A4/C34AN2*P33A4 (Maximum)	12	87.6	92.2

SELECT MODELS - (Continued)

MAXIMUM FBRU OCTANE NUMBER REQUIREMENTS

<u>Select Model</u>	<u>No. Tested</u>	<u>(R+M)/2</u>	
		<u>50% Sat.</u>	<u>90% Sat.</u>
C33AN2*P33A4/C34AN2*P33A4 (Minimum-Borderline)	11	86.8	91.8
C32HC2*P38A4/C33EC2*P38A4/C33HC2* P38A4/C34HC2*P38A4/C34CC2*P38A4 (Maximum)	15	81.8	87.0
C32HC2*P38A4/C33EC2*P38A4/C33HC2* P38A4/C34HC2*P38A4/C34CC2*P38A4 (Minimum-Borderline)	14	80.5	85.5
S15XL2*P40A4 (Maximum)	10	85.1	91.2
S15XL2*P40A4 (Minimum-Borderline)	10	84.3	90.5
S36RK2*T57A4/V36GK2*T57A4/P36CK2* T57A4/S36UK2*T57A4/P36KK2*T57A4 (Maximum)	11	86.4	89.4
S36RK2*T57A4/V36GK2*T57A4/P36CK2* T57A4/S36UK2*T57A4/P36KK2*T57A4 (Minimum-Borderline)	10	85.6	88.4

III. TEST VEHICLES

This year's Survey tested a total of 391 1989 model vehicles, the same number as in the 1988 Survey. The analysis of the data included 313 passenger cars and 78 light-duty trucks and vans. Also included are 179 knock sensor-equipped vehicles (134 cars and 45 trucks).

Beginning with the 1987 Survey, test vehicles are divided into four main categories:

- (1) Total Vehicles, which includes all US and imported passenger cars and light-duty trucks and vans
- (2) Total Cars, which includes all US and imported passenger cars
- (3) Total Trucks, which includes all US and imported light-duty trucks and vans
- (4) Total Knock-Sensor Vehicles, which includes all knock-sensor-equipped US and imported passenger cars and light-duty trucks and vans.

In the 1989 Survey, 86 percent of the transmissions were automatic. Thirty-four percent of the automatics were three-speeds, and the rest four-speeds. The manual transmissions were divided into 5 percent four-speeds and 95 percent five-speeds. Ninety-seven percent of the surveyed vehicles were air-conditioned.

The select models shown in Table 1 include six additional models not included in the program proposal (Table D-1 of Appendix D). Although not appearing as select models in the program proposal, six of the models in Table 1 are included as select models because ten or more vehicles per model were tested.

Table 2 shows the distribution of odometer mileage for both the 1989 and 1988 Surveys. The 1989 distribution is shown as a bar chart in Figure 1. The average odometer mileage was 12,773. The average displacement of those vehicles tested in 1989 was 3.05 liters, compared with 3.01 in 1988. The average compression ratio of those vehicles tested in 1989 was 9.04 compared with 9.02 in 1988.

Trends in the sales-weighted average compression ratio, engine displacement, and knock-sensor penetration for the US vehicle population over the last five model years are shown below. Also included are the percent of vehicles tested in this Survey which have automatic transmissions and air conditioners.

1989 ONR SURVEY TEST VEHICLE DATA

Average Vehicle Parameters

<u>Model Year</u>	<u>Sales Weighted</u>			<u>Percent of Vehicles Tested</u>	
	<u>Displacement (liters)</u>	<u>Compression Ratio</u>	<u>% Knock Sensor</u>	<u>Automatic Transmissions</u>	<u>Air Conditioners</u>
1989	3.1	9.0	40.2	86	97
1988	3.0	9.0	39.6	82	92
1987	2.9	9.0	35.0	81	89
1986	3.0	9.0	35.5	84	94
1985	3.2	8.8	27.5	84	92

The basic spark timing was adjusted to the manufacturer's recommended setting (within $\pm 1^\circ$) prior to testing. A total of ten vehicles were adjusted; eight were two or more degrees off from the manufacturer's setting. The number of vehicles and their deviation in spark setting are shown in Table 3.

Participants were requested to rate specific vehicle models in a pattern which would minimize data bias due to differences among testing laboratories and vehicles. To accomplish this, the United States and Canada were divided into four geographical areas, and companies within each geographical area were requested to test specific vehicles.

IV. REFERENCE FUELS

Three series of reference fuels were used in the 1989 Survey:

- Primary Reference (PR) Fuels
- Average Sensitivity Full-Boiling Range Unleaded (FBRU) Reference Fuels with sensitivities similar to those of commercial gasoline
- High-Sensitivity Full-Boiling Range Unleaded (FBRSU) Reference Fuels with sensitivities about two octane numbers higher than the FBRU fuels.

A. PR Fuels

Isooctane and normal heptane, meeting ASTM specifications, were blended in two octane number increments from 76 to 82 octane numbers, and in one octane number increments from 82 to 100 octane numbers.

B. FBRU Reference Fuels

FBRU fuels were prepared from three base blends (RMFD-368-89/90, RMFD-369-89/90, and RMFD-370-89/90) in two octane number increments from 80 to 84 RON, and in one octane number increments from 84 to 104 RON. The base blends were prepared from normal refinery components. Inspection data furnished by the supplier are shown in Appendix C, Table C-1. The composition and average laboratory octane data for the 1989/1990 FBRU reference fuel series are presented in Appendix C, Table C-2.

C. FBRSU Reference Fuels

FBRSU fuels were prepared from three base blends (RMFD-371-89/90, RMFD-372-89/90, and RMFD-373-89/90) in two octane number increments from 80 to 84 RON, and in one octane number increments from 84 to 103.5 RON. The base blends were prepared from normal refinery components. Inspection data furnished by the supplier are shown in Appendix C, Table C-3. The laboratory blending octane data for the 1989/1990 FBRSU reference fuels are presented in Table C-4.

V. TEST TECHNIQUE

The test technique (CRC Designation E-15-89, Attachment 2 of Appendix D) specified that octane number requirements be determined at level road acceleration conditions. The order of fuel testing was tank fuel, FBRSU fuels, FBRU fuels, and PR fuels. Knocking tendencies were investigated using both maximum-throttle and part-throttle acceleration techniques.* Part-throttle was investigated in each vehicle to determine if the part-throttle requirement was higher or equal to the maximum-throttle requirement with all three fuel series. Part-throttle requirements were also determined with FBRU fuels down to four Research octane numbers below the maximum requirement at maximum-throttle.

The maximum octane number requirement of a vehicle is defined as the octane number of the highest octane test fuel producing borderline knock. This requirement is defined at either maximum- or part-throttle acceleration conditions. For vehicles equipped with knock sensors, the technique also identifies the lowest octane fuel that gives borderline knock (minimum-borderline requirement). Requirements are expressed as the (R+M)/2 octane number, Research octane number (RON), and Motor octane number (MON) of the reference fuel which produces knock that is recurrent and repeatable at the lowest audible level.

Of the eighteen laboratories participating in the 1989 Survey, three used level roads and fifteen used chassis dynamometers. Seventy-two percent of the vehicles were tested on chassis dynamometers.

Average test temperature was 69°F, with a barometric pressure average of 29.75 inches Hg and average humidity of 58 grains per pound. Test conditions for individual observations are reported in Appendix E.

The table below shows the average test conditions and the average odometer readings for the last five Surveys.

Average Ambient Test Conditions

<u>Year</u>	<u>Temperature, F°</u>	<u>Barometric Pressure, inches Hg</u>	<u>Humidity, grains per pound</u>	<u>Mileage</u>
1989	69	29.75	58	12772
1988	70	29.84	57	12407
1987	67	29.85	49	13720
1986	70	29.83	58	11849
1985	69	29.91	57	12343

* Maximum-throttle is either full-throttle for manual transmissions or widest throttle position (detent) that does not cause the transmission to downshift for automatic transmissions.

There is general agreement that ambient temperature, pressure, and humidity can influence the octane number requirement of a vehicle at any time. (1,2) Octane requirement increases as temperature and pressure increase, and as humidity decreases. The coefficients of these effects are difficult to determine and may be dependent upon the vehicle.

VI. DISCUSSION OF RESULTS

A. Distribution of Maximum Octane Number Requirements

The octane number requirement data were used to prepare satisfaction curves and tables for the following samples of 1989 model vehicles:

- (1) Total Vehicles,
- (2) Total Cars,
- (3) Total Trucks,
- (4) Total Knock-Sensor Vehicles.

Maximum $(R+M)/2$, RON, and MON requirements and 95 percent confidence limits for the four categories at 50 percent and 90 percent satisfaction are shown in Table 4. In preparing the curves and tables, the octane number requirement data were weighted in accordance with final 1989 model-year production and/or sales figures. Each curve and table, therefore, provides an estimate of the distribution of octane number requirements of the appropriate vehicle population on the road. The procedure for assigning weighting factors and for calculating the octane number requirement distributions is described in Appendix F.

Vehicles equipped with knock sensors were included in the 1989 models tested. All vehicles with knock sensors were tested for maximum octane number requirements, and 163 of the 179 vehicles were tested for minimum-borderline octane number requirements. Octane number requirement distributions were calculated for each group of vehicles using the requirements from those vehicles with knock sensors rated at maximum requirement and with their ratings at minimum-borderline requirement.

-
- (1) B. D. Keller, J. H. Steury, T. O. Wagner, SAE Paper 780668 (1978)
 - (2) H. A. Bigley, Jr., B. D. Keller and M. G. Kloppe, SAE Paper 710675 (1971).

Requirements are expressed as the $(R+M)/2$, Research, and Motor octane numbers of the reference fuel which produced knock that was recurrent and repeatable at the lowest audible level.

Round-off techniques were changed beginning with the 1988 Survey, and are described in Appendix F.

1. Total Vehicles

In the 1989 Survey, maximum octane number requirements were determined on 372 vehicles with PR fuels, and 391 vehicles with FBRU and FBRSU fuels. One hundred seventy-nine of the vehicles were equipped with knock sensors.

Maximum $(R+M)/2$ octane number requirements for all three reference fuels are shown in Figures 2, 3, and 4. Each plot compares two distributions of maximum octane requirements for total vehicles. One distribution includes knock-sensor vehicles at their maximum requirement; the other includes knock-sensor vehicles at their minimum-borderline requirement. The maximum $(R+M)/2$ octane number requirements for all three reference fuels are plotted in Figure 5. The octane number requirement distributions for FBRU and FBRSU fuels are similar. Maximum $(R+M)/2$, Research, and Motor octane number requirements are listed in Table 5. The 50 percent and 90 percent satisfaction level requirements are:

MAXIMUM OCTANE NUMBER REQUIREMENTS

(Total Vehicles)

<u>Fuel</u>	<u>50% Satisfied</u>			<u>90% Satisfied</u>		
	<u>$(R+M)/2$</u>	<u>RON</u>	<u>MON</u>	<u>$(R+M)/2$</u>	<u>RON</u>	<u>MON</u>
PR	87.8	87.8	87.8	92.7	92.7	92.7
FBRU	85.1	89.0	81.3	89.2	94.0	84.5
FBRSU	85.1	90.1	80.1	89.3	95.2	83.4

Differences between 1989 and 1988 Survey maximum $(R+M)/2$, Research, and Motor octane number requirements are also shown in Tables 5 and 6 for all three fuel series. Distributions of the 1989 and 1988 maximum $(R+M)/2$ requirements are shown in Figure 6 for FBRU fuels. The differences at the 50 percent and 90 percent satisfaction levels are:

**DIFFERENCES BETWEEN 1989 AND 1988 MAXIMUM
OCTANE NUMBER REQUIREMENTS**

(Total Vehicles)

<u>Fuel</u>	<u>50% Satisfied</u>			<u>90% Satisfied</u>		
	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>
PR	0.4	0.4	0.4	-0.2	-0.2	-0.2
FBRU	0.4	0.4	0.5	-0.1	-0.3	0.1
FBRSU	0.4	0.2	0.7	-0.5	-0.7	-0.3

Octane number requirements with knock-sensor-equipped vehicles tested at minimum-borderline level, along with differences between the 1989 and 1988 octane number requirements, are given in Table 6.

Confidence limits for maximum octane number requirement distributions are given in Appendix G, Table G-1. The 95 percent confidence limits for (R+M)/2 octane number requirements were ± 0.3 to ± 0.4 at the 50 percent satisfaction level, and ± 0.4 to ± 0.5 at the 90 percent satisfaction level. The yearly difference at the 50 percent satisfaction is significant at the 95 percent confidence level.

2. Total Cars

Maximum octane number requirements were determined on 298 cars with PR fuels, and 313 cars with FBRU and FBRSU fuels.

Maximum (R+M)/2, Research, and Motor octane number requirements on all three fuel series are given in Table 7. The maximum (R+M)/2 octane number requirement distributions for all three reference fuel series are plotted in Figure 7. Maximum octane number requirements at the 50 percent and 90 percent satisfaction levels are:

MAXIMUM OCTANE NUMBER REQUIREMENTS

(Total Cars)

<u>Fuel</u>	<u>50% Satisfied</u>			<u>90% Satisfied</u>		
	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>
PR	87.3	87.3	87.3	92.1	92.1	92.1
FBRU	84.8	88.5	81.0	89.2	94.0	84.5
FBRSU	84.8	89.7	79.8	89.5	95.4	83.6

Differences between the 1989 and 1988 Survey maximum $(R+M)/2$, Research and Motor octane number requirements are also shown in Table 7 for PR, FBRU, and FBRSU fuels. Distributions of the 1989 and 1988 maximum $(R+M)/2$ requirements are shown in Figure 8 for FBRU fuels. Differences between 1989 and 1988 data at the 50 percent and 90 percent satisfaction levels are:

DIFFERENCES BETWEEN 1989 AND 1988 MAXIMUM
OCTANE NUMBER REQUIREMENTS

(Total Cars)

Fuel	50% Satisfied			90% Satisfied		
	$(R+M)/2$	RON	MON	$(R+M)/2$	RON	MON
PR	0.2	0.2	0.2	-0.4	-0.4	-0.4
FBRU	0.1	-0.1	0.2	0.0	-0.2	0.2
FBRSU	0.3	0.0	0.5	-0.3	-0.5	-0.1

Octane number requirements with knock-sensor-equipped cars tested at minimum-borderline levels, along with differences between the 1989 and 1988 octane number requirements, are given in Table 8.

Confidence limits for maximum octane number requirement distributions of 1989 total cars are given in Appendix G, Table G-1. The 95 percent confidence limits for $(R+M)/2$ requirements were ± 0.4 at the 50 percent satisfaction level, and ± 0.5 at the 90 percent satisfaction level. The yearly changes for the total car population are not significant at the 95 percent confidence level.

3. Total Trucks

Maximum octane number requirements were determined on 74 light-duty trucks and vans with PR fuels, and 78 with FBRU and FBRSU fuels. Maximum $(R+M)/2$ octane number requirements for all three reference fuel series are plotted in Figure 9. Maximum $(R+M)/2$, Research, and Motor octane number requirements on all three fuel series are given in Table 9. The 50 percent and 90 percent satisfaction level maximum octane number requirements are:

MAXIMUM OCTANE NUMBER REQUIREMENTS

(Total Trucks)

Fuel	50% Satisfied			90% Satisfied		
	(R+M)/2	RON	MON	(R+M)/2	RON	MON
PR	89.0	89.0	89.0	93.5	93.5	93.5
FBRU	85.8	89.8	81.8	89.2	94.0	84.5
FBRSU	85.6	90.7	80.4	89.1	94.9	83.2

Differences between the maximum (R+M)/2, Research, and Motor octane number requirements of trucks in the 1989 and 1988 Surveys are also given in Table 9 for all three fuel series. The differences at the 50 percent and 90 percent satisfaction levels are:

DIFFERENCES BETWEEN 1989 AND 1988 MAXIMUM OCTANE NUMBER REQUIREMENTS

(Total Trucks)

Fuel	50% Satisfied			90% Satisfied		
	(R+M)/2	RON	MON	(R+M)/2	RON	MON
PR	1.0	1.0	1.0	-0.2	-0.2	-0.2
FBRU	1.0	1.1	0.9	-0.4	-0.6	-0.1
FBRSU	0.6	0.4	0.7	-0.7	-1.0	-0.5

Octane number requirements with knock-sensor-equipped trucks tested at minimum-borderline levels, along with the differences between the 1989 and 1988 octane number requirements, are given in Table 10. Distributions of the 1989 and 1988 maximum (R+M)/2 requirements are shown in Figure 10 for FBRU fuels.

Confidence limits for maximum octane number requirement distributions of 1989 trucks are tabulated in Appendix G, Table G-1. The 95 percent confidence limits for (R+M)/2 octane number requirements varied from +0.6 to +0.8 at the 50 percent satisfaction level, and from +0.9 to +1.1 at the 90 percent satisfaction level. The yearly difference at 50 percent satisfaction is significant at the 95 percent confidence level.

4. Total Knock-Sensor Vehicles

Maximum octane number requirements were determined on 171 vehicles containing knock sensors with PR fuels, and 179 vehicles with FBRU and FBRSU fuels. Minimum-borderline octane number requirements were determined on 107 vehicles, with PR fuels, 163 vehicles with FBRU fuels, and 114 vehicles with the FBRSU fuel series.

The distributions of maximum (R+M)/2 octane number requirements at the maximum and the minimum-borderline levels are shown in Figures 11 and 12, respectively, for the three fuel series. Maximum (R+M)/2, Research, and Motor octane number requirements for all three fuel series are given in Table 11. Maximum octane number requirements for the 50 percent and 90 percent satisfaction levels are:

MAXIMUM OCTANE NUMBER REQUIREMENTS

(Total Knock-Sensor Vehicles)

Fuel	50% Satisfied			90% Satisfied		
	(R+M)/2	RON	MON	(R+M)/2	RON	MON
PR	88.3	88.3	88.3	93.7	93.7	93.7
FBRU	85.4	89.3	81.5	89.7	94.5	84.9
FBRSU	85.4	90.5	80.3	89.7	95.6	83.7

Differences between 1989 and 1988 Survey maximum (R+M)/2, Research, and Motor octane number requirements are also shown in Table 11. Distributions of maximum (R+M)/2 octane number requirements are shown in Figure 13 for FBRU fuels. The differences at the 50 percent and 90 percent satisfaction levels are:

DIFFERENCES BETWEEN 1989 AND 1988 MAXIMUM
OCTANE NUMBER REQUIREMENTS

(Total Knock-Sensor Vehicles)

Fuel	50% Satisfied			90% Satisfied		
	(R+M)/2	RON	MON	(R+M)/2	RON	MON
PR	0.4	0.4	0.4	0.3	0.3	0.3
FBRU	0.4	0.3	0.4	-0.5	-0.8	-0.2
FBRSU	0.2	-0.1	0.4	-0.6	-0.9	-0.4

Octane number requirements with knock-sensor-equipped vehicles tested at minimum-borderline levels, along with the differences between the 1989 and 1988 octane number requirements, are given in Table 12.

The differences between the maximum octane number requirements of 179 vehicles tested, and the octane number requirements at minimum-borderline levels of 163 vehicles are:

**DIFFERENCES BETWEEN MAXIMUM AND MINIMUM
OCTANE NUMBER REQUIREMENTS**

(Total Knock-Sensor Vehicles)

<u>Fuel</u>	<u>50% Satisfied</u>			<u>90% Satisfied</u>		
	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>	<u>(R+M)/2</u>	<u>RON</u>	<u>MON</u>
PR	1.1	1.1	1.1	1.9	1.9	1.9
FBRU	0.5	0.6	0.4	1.0	1.2	0.8
FBRSU	1.0	1.2	0.8	1.6	1.8	1.2

Confidence limits for maximum octane number requirement distributions of 1989 knock-sensor vehicles are given in Appendix G, Table G-1. The 95 percent confidence limits for maximum (R+M)/2 octane number requirements varied between +0.5 and +0.7 at the 50 percent satisfaction level, and between +0.7 and +0.9 at the 90 percent satisfaction level.

The 95 percent confidence limits for minimum-borderline (R+M)/2 octane number requirements varied between +0.5 and +0.8 at the 50 percent satisfaction level, and between +0.6 and +1.0 at the 90 percent satisfaction level. The yearly changes for the total knock-sensor vehicle population are not significant at the 95 percent confidence level.

B. Maximum Octane Number Requirement Trends

Trends over the last five years in the sales-weighted maximum octane number requirements of the four vehicle categories analyzed in this report are given below.

FBRU (R+M)/2 MAXIMUM OCTANE NUMBER REQUIREMENTS

1985 TO 1989

<u>Weighted Population</u>	<u>1989</u>	<u>1988</u>	<u>1987</u>	<u>1986</u>	<u>1985</u>
50% Satisfaction					
Total Vehicles	85.1	84.7	85.7	85.3	86.4
Total Cars	84.8	84.7	85.4	85.0	86.2
Total Trucks	85.8	84.8	86.3	86.9*	--
Total Knock-Sensor Vehicles	85.4	85.0	86.6	85.4	86.7
90% Satisfaction					
Total Vehicles	89.2	89.3	90.5	89.8	90.1
Total Cars	89.2	89.2	90.4	89.5	90.0
Total Trucks	89.2	89.6	91.6	90.3*	--
Total Knock-Sensor Vehicles	89.7	90.2	91.9	90.2	91.5

*The total trucks octane number requirements for 1986 were estimated from the percent satisfaction distributions for total vehicles and total cars

C. Part-Throttle Requirements

Part-throttle octane requirements were equal to or higher than the maximum-throttle octane requirements on 26 percent of all 1989 vehicles with FBRU fuels (97 of 379 vehicles). This compares with 31 percent in 1988.

D. Select Models

Select models, representing thirteen engine-transmission-chassis combinations, were tested. The select models tested in this year's Survey included eight knock-sensor-equipped models. The specifications of the engine-chassis combinations of the select models are in Table 1.

Maximum octane number requirements for each select model at various satisfaction levels are listed in Tables 13 through 25. The maximum and minimum-borderline octane number requirements for the eight knock-sensor-equipped models are given in Tables 13, 18, and 20 through 25.

E. Tank Fuel

Tank fuel was tested for incidence of knock on all vehicles. Owners' questionnaires, however, were obtained only when the vehicle tested had a regular driver and the spark timing was not reset.

1. Owner/Rater Comparisons of Tank Fuel Knock

For 124 vehicles, both owner and rater data were reported, and no adjustments of spark timing were made. The trained raters reported that 31 percent of the vehicles knocked, while the owners reported that 7 percent knocked, an owner/rater knock ratio of 0.24. The 31 percent of vehicles found to be knocking by trained raters compared with 39 percent for the 1988 Survey. These owner/rater comparisons of tank fuel knock for 1989, along with previous Survey data back to 1982, are presented in Table 26.

Tank fuel Research and Motor octane number data were reported for a total of 101 vehicles with both owner/rater data and no adjustments of spark timing. Sixty-eight vehicles were reported to have tank fuel octane numbers less than $91.0 (R+M)/2$. Trained observers reported knock on 28 percent of these, compared with 4 percent for owners. Of the other 19 vehicles having tank fuels greater than or equal to $91.0 (R+M)/2$, 11 percent knocked according to trained raters, while no owners reported knock.

2. Objectionable Versus Non-Objectionable Knock

Of the owners reporting tank-fuel knock with vehicles which had no change in spark timing, 10 percent found the knock to be objectionable, as compared to 4 percent in the 1988 Survey. Comparisons of objectionable knock for the 1982 through 1989 Surveys are also given in Table 26.

3. Tank Fuel Knock Reported by Trained Raters

Tank fuel knock observations were reported for 265 of the 391 vehicles tested. The percentages of all 1989 vehicles knocking on tank fuel are shown in Table 27. Knock was observed on 30 percent of the 1989 vehicles tested, compared with 31 percent in the 1988 Survey.

The percentages of select models knocking on tank fuel, also shown in Table 27 varied from a low of 0 percent to a high of 67 percent.

F. Engine Speed for Maximum Octane Number Requirements

Engine speeds at which maximum octane number requirements occurred for each select model are shown in Table 28 for PR, FBRU, and FBRSU fuels. Weighted data for all 1989 vehicles are shown in Table 29.

G. Gear Position for Maximum Octane Number Requirements

The throttle/gear position for maximum octane number requirements on FBRU fuels is shown in Table 30. Of the 391 vehicles tested, 336 (86 percent) were equipped with automatic transmissions and 55 (14 percent) were equipped with manual transmissions.

Maximum requirements at maximum-throttle occurred in 76 percent of the automatic transmission vehicles (13 percent in fourth gear, 39 percent in third gear, and 24 percent in second gear). Maximum requirements at part-throttle occurred in 24 percent of the automatic transmission vehicles (11 percent in fourth gear, 11 percent in third gear, and 2 percent in second gear).

For manual transmission vehicles, 63 percent had maximum requirements at maximum-throttle (37 percent in fourth gear, 24 percent in third gear, and 2 percent in second gear). Maximum requirements at part-throttle occurred in 37 percent of manual transmission vehicles (26 percent in fourth gear, and 11 percent in third gear). Fifth gear for five-speed manual transmissions was not examined per program instructions.

T A B L E S
and
F I G U R E S

TABLE 1
1989 SELECT MODEL SPECIFICATIONS

<u>Model</u>	<u>Knock Sensor</u>	<u>Disp. (L)</u>	<u>Engine Type</u>	<u>Fuel System Type *</u>	<u>Comp. Ratio</u>	<u>Brake HP</u>	<u>Trans- mission</u>
C11BU2*P30A44	KS	3.0	V6	MFI	9.3	150	A4
C21RC3*P22A4		2.2	L4	MFI	8.6	110	A4
C21D42*P38A4/C21S42*P38A4/C22S42*P38A4		3.8	V6	MFI	9.0	140	A4
C21PF2*P50A4/C22PF2*P50A4/C24PF2*P50A4		5.0	V8	MFI	8.9	150	A4
C31AR2*T25A3/C32AR2*T25A3/ C33AR2*T25A3		2.5	L4	TBI	8.3	98	A3
C31AW2*P28A4/C32AW2*P28A4/ C32WW2*P28A4	KS	2.8	V6	MFI	8.9	125	A4
C31J12*T20A3/C31L12*T20A3		2.0	L4	TBI	9.0	90	A3
C32ND4*P23A3/C33ND4*P233A3/ C34ND4*P23A3	KS	2.3	L4	MFI	9.5	150	A3
C32WT2*P31A4/C33WT2*P31A4/ C34WT2*P31A4	KS	3.1	V6	MFI	8.8	140	A4
C33AN2*P33A4/C34AN2*P33A4	KS	3.3	V6	MFI	9.0	160	A4
C32HC2*P38A4/C33EC2*P38A4/ C33HC2*P38A4/C34HC2*P38A4/ C34CC2*P38A4	KS	3.8	V6	MFI	8.5	165	A4
S15XL2*P40A4	KS	4.0	L6	MFI	8.8	177	A4
S36RK2*T57A4/V36GK2*T57A4/ P36CK2*T57A4	KS	5.7	V8	TBI	9.1	210	A4

* TBI = Throttle Body Fuel Injection;
Individual manufacturers may use different abbreviations.

TABLE 2
DISTRIBUTION OF ODOMETER MILEAGE
FOR TESTED VEHICLES

<u>No. of Vehicles Within Mileage Increments</u>		
<u>Mileage</u>	<u>1989 Vehicles</u>	<u>1988 Vehicles</u>
0 - 1,999	0	0
2,000 - 3,999	0	0
4,000 - 5,999	0	4
6,000 - 7,999	85	80
8,000 - 9,999	72	79
10,000 - 11,999	51	73
12,000 - 13,999	35	35
14,000 - 15,999	47	30
16,000 - 17,999	39	29
18,000 - 19,999	20	24
20,000 - 24,999	29	27
25,000 - 29,999	11	4
30,000 +	2	6
No. of Vehicles	391	391
Average Mileage	12,773	12,407

TABLE 3

1989 BASIC SPARK TIMING ADJUSTMENTS

<u>Degrees From Manufacturer's Setting</u>	<u>No. of Vehicles</u>	
	<u>+</u>	<u>-</u>
1	0	2
2	1	3
3	1	1
4	0	0
5	1	0
6	0	0
7	1	0
8	0	0
9	0	0
10	0	0
11+	0	0
	4	6
Total vehicles adjusted		10
Total vehicles not adjusted		203
Total vehicles with timing not adjustable		178

TABLE 4

MAXIMUM OCTANE NUMBER REQUIREMENTS WITH 95% CONFIDENCE LIMITS

Fuel	No. Vehicles	(R+M)/2		Research Octane No.		Motor Octane No.	
		50% Sat.	90% Sat.	50% Sat.	90% Sat.	50% Sat.	90% Sat.
Total Vehicles							
PR	372	87.8±0.4	92.7±0.5	87.8±0.4	92.7±0.5	87.8±0.4	92.7±0.5
FBRU	391	85.1±0.3	89.2±0.4	89.0±0.4	94.0±0.5	81.3±0.3	84.5±0.3
FBRSU	391	85.1±0.3	89.3±0.5	90.1±0.4	95.2±0.5	80.1±0.3	83.4±0.4
Total Cars							
PR	298	87.3±0.4	92.1±0.5	87.3±0.4	92.1±0.5	87.3±0.4	92.1±0.5
FBRU	313	84.8±0.4	89.2±0.5	88.5±0.5	94.0±0.6	81.0±0.3	84.5±0.4
FBRSU	313	84.8±0.4	89.5±0.5	89.7±0.5	95.4±0.7	79.8±0.3	83.6±0.4
Total Trucks and Vans							
PR	74	89.0±0.8	93.5±1.1	89.0±0.8	93.5±1.1	89.0±0.8	93.5±1.1
FBRU	78	85.8±0.6	89.2±0.9	89.8±0.8	94.0±1.1	81.8±0.5	84.5±0.7
FBRSU	78	85.6±0.7	89.1±0.9	90.7±0.8	94.9±1.1	80.4±0.5	83.2±0.7
Total Knock-Sensor Vehicles							
PR	171	88.3±0.7	93.7±0.9	88.3±0.7	93.7±0.9	88.3±0.7	93.7±0.9
FBRU	179	85.4±0.5	89.7±0.7	89.3±0.6	94.5±0.9	81.5±0.4	84.9±0.5
FBRSU	179	85.4±0.5	89.7±0.7	90.5±0.6	95.6±0.8	80.3±0.4	83.7±0.5

TABLE 5

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL VEHICLES

[For Knock-Sensor Vehicles, Maximum Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels			FBRU Fuels						FBRSU Fuels											
	1989	Diff. 1988		(R+M)/2			RON			MON			(R+M)/2			RON			MON		
				1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988				
10	83.4	1.9		81.0	1.1		83.9	1.0		78.0	1.1		80.8	1.0		85.1	1.0		76.6	1.0	
20	84.8	0.9		82.5	0.7		85.7	0.6		79.2	0.7		82.2	0.7		86.7	0.5		77.7	0.9	
30	85.9	0.6		83.4	0.4		86.9	0.3		80.0	0.6		83.1	0.5		87.8	0.3		78.5	0.8	
40	86.9	0.5		84.3	0.4		87.9	0.2		80.6	0.4		84.0	0.3		88.8	0.1		79.2	0.6	
50	87.8	0.4		85.1	0.4		89.0	0.4		81.3	0.5		85.1	0.4		90.1	0.2		80.1	0.7	
60	88.8	0.4		85.9	0.2		90.0	0.2		81.9	0.3		85.9	0.3		91.2	0.2		80.7	0.5	
70	89.9	0.4		86.9	0.1		91.1	-0.1		82.7	0.3		86.8	0.1		92.2	-0.1		81.3	0.2	
80	90.9	-0.2		87.9	-0.1		92.3	-0.3		83.5	0.2		87.9	-0.1		93.6	-0.2		82.3	0.2	
90	92.7	-0.2		89.2	-0.1		94.0	-0.3		84.5	0.1		89.3	-0.5		95.2	-0.7		83.4	-0.3	
95	94.1	0.2		90.5	-0.1		95.4	-0.3		85.5	0.1		90.7	-0.3		96.8	-0.5		84.6	-0.2	
98	95.8	0.2		92.9	0.9		98.3	0.8		87.5	0.9		93.0	0.5		99.4	0.6		86.7	0.6	
99	97.1	0.5		93.8	0.9		99.3	0.8		88.3	1.0		93.9	-0.7		100.4	-0.7		87.5	-0.6	

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL VEHICLES

Percent Satisfied	PR Fuels			FBRU Fuels						FBRSU								
	1989	Diff. 1988	(R+M)/2	RON			MON			1989	Diff. 1988	(R+M)/2	RON			MON		
				1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988				1989	Diff. 1988	1989	Diff. 1988		
																	1989	Diff. 1988
10	82.8	1.9	80.1	0.6	82.9	0.5	77.3	0.8	80.2	0.9	84.4	0.9	76.1	1.0				
20	84.4	1.0	82.2	0.8	85.4	0.8	79.0	0.9	81.7	0.7	86.2	0.6	77.3	0.9				
30	85.5	0.9	83.2	0.8	86.7	0.8	79.8	0.8	82.8	0.8	87.4	0.6	78.2	0.9				
40	86.5	0.9	84.1	0.8	87.7	0.8	80.5	0.8	83.7	0.8	88.4	0.5	78.9	0.9				
50	87.4	0.7	84.9	0.9	88.7	0.9	81.1	0.8	84.6	0.8	89.5	0.6	79.7	1.0				
60	88.4	0.8	85.7	0.7	89.7	0.8	81.7	0.7	85.6	0.8	90.8	0.7	80.5	0.9				
70	89.6	0.9	86.5	0.5	90.7	0.5	82.4	0.6	86.4	0.5	91.8	0.4	81.1	0.7				
80	90.6	0.6	87.5	0.2	91.8	0.0	83.2	0.4	87.2	0.0	92.7	-0.2	81.7	0.3				
90	91.9	-0.3	88.7	0.1	93.3	-0.1	84.1	0.2	88.9	-0.3	94.7	-0.5	83.1	-0.1				
95	93.0	-0.5	90.0	0.1	94.9	0.0	85.1	0.3	90.1	-0.2	96.1	-0.4	84.1	-0.1				
98	94.8	-0.1	91.7	0.5	96.9	0.4	86.6	0.7	91.9	0.1	98.1	0.0	85.6	0.1				
99	96.2	-0.2	92.9	0.8	98.3	0.7	87.5	0.9	93.2	-0.3	99.6	-0.4	86.8	-0.3				

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL CARS

[For Knock-Sensor Vehicles, Maximum Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels		FBRU Fuels						FBRSU					
	1989	Diff. 1988	(R+M)/2		RON		MON		(R+M)/2		RON		MON	
			1989	1988	1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988		
10	83.1	2.2	80.3	0.9	83.2	0.9	77.5	1.0	80.4	1.0	84.6	0.9	76.3	1.1
20	84.5	1.1	82.2	0.8	85.4	0.7	79.0	0.8	82.0	0.9	86.5	0.8	77.5	1.0
30	85.6	0.8	83.1	0.3	86.5	0.1	79.7	0.4	82.9	0.5	87.5	0.3	78.3	0.8
40	86.5	0.6	84.0	0.2	87.5	0.0	80.4	0.3	83.7	0.2	88.5	-0.1	78.9	0.4
50	87.3	0.2	84.8	0.1	88.5	-0.1	81.0	0.2	84.8	0.3	89.7	0.0	79.8	0.5
60	88.2	0.1	85.6	0.0	89.6	-0.1	81.6	0.1	85.8	0.4	90.9	0.1	80.6	0.6
70	89.2	-0.1	86.5	-0.3	90.6	-0.6	82.3	-0.1	86.5	-0.3	91.9	-0.5	81.1	-0.1
80	90.3	-0.6	87.6	-0.4	92.0	-0.6	83.3	-0.1	87.6	-0.7	93.2	-1.0	82.0	-0.3
90	92.1	-0.4	89.2	0.0	94.0	-0.2	84.5	0.2	89.5	-0.3	95.4	-0.5	83.6	-0.1
95	93.7	0.3	91.1	0.9	96.1	0.8	86.0	0.9	91.4	0.6	97.7	0.7	85.2	0.7
98	95.6	1.0	93.2	1.6	98.7	1.7	87.8	1.5	93.4	1.0	99.9	1.1	87.0	1.0
99	96.8	0.6	94.0	0.2	99.5	0.1	88.4	0.2	94.2	-0.6	100.8	0.5	87.7	-0.6

TABLE 8

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL CARS

[For Knock-Sensor Vehicles, Minimum-Borderline Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels			FBRU Fuels						FBRSU Fuels						
	1989	Diff. 1988		(R+M)/2		RON		MON		(R+M)/2		RON		MON		
				1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988			
10	83.0	2.7		79.6	0.7	82.3	0.7	76.9	0.8		80.1	1.4	84.2	1.3	76.0	1.4
20	84.3	1.4		81.9	0.9	85.1	0.9	78.8	0.9		81.6	0.9	86.1	1.0	77.2	1.0
30	85.2	0.8		82.9	0.4	86.2	0.2	79.5	0.5		82.7	0.7	87.3	0.5	78.1	0.8
40	86.2	0.6		83.8	0.4	87.3	0.2	80.2	0.4		83.4	0.3	88.2	0.1	78.7	0.6
50	87.0	0.3		84.6	0.4	88.3	0.3	80.9	0.5		84.4	0.3	89.3	0.1	79.5	0.5
60	87.9	0.3		85.5	0.3	89.4	0.2	81.5	0.3		85.4	0.4	90.5	0.2	80.3	0.6
70	89.0	0.3		86.2	-0.1	90.3	-0.2	82.1	0.1		86.2	0.0	91.5	-0.3	80.9	0.2
80	90.1	0.0		87.2	-0.3	91.5	-0.5	82.9	0.0		87.2	-0.3	92.7	-0.6	81.7	0.0
90	91.4	-0.7		88.8	0.1	93.4	0.0	84.2	0.3		89.1	-0.3	95.0	-0.4	83.3	0.0
95	93.2	0.2		90.3	0.3	95.3	0.3	85.4	0.5		90.3	-0.1	96.3	-0.3	84.2	0.0
98	94.7	0.3		91.8	0.5	96.9	0.3	86.6	0.6		92.4	0.1	98.7	0.1	86.0	0.1
99	95.5	-0.2		93.0	0.0	98.4	-0.1	87.6	0.2		93.8	-0.9	100.3	-0.9	87.3	-0.8

TABLE 9

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL TRUCKS AND VANS

[For Knock-Sensor Vehicles, Maximum Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels			FBRU Fuels						FBRSU Fuels					
	1989	Diff. 1988		(R+M)/2		RON		MON		(R+M)/2		RON		MON	
				1989	1988	Diff. 1988	1989	1988	Diff. 1988	1989	1988	Diff. 1988	1989	1988	Diff. 1988
10	84.0	1.3		81.7	0.8	84.8	0.7	78.6	0.8	81.3	0.4	85.7	0.2	77.0	0.6
20	85.5	0.5		83.1	0.9	86.6	1.0	79.7	0.9	82.8	0.7	87.4	0.6	78.2	0.9
30	87.0	1.0		84.1	0.6	87.8	0.6	80.5	0.7	83.7	0.7	88.5	0.5	78.9	0.8
40	88.0	0.8		85.0	0.9	88.8	0.9	81.2	0.9	84.7	0.8	89.6	0.6	79.7	0.9
50	89.0	1.0		85.8	1.0	89.8	1.1	81.8	0.9	85.6	0.6	90.7	0.4	80.4	0.7
60	90.2	1.3		86.7	0.8	90.9	0.8	82.5	0.8	86.4	0.6	91.7	0.5	81.0	0.6
70	90.1	0.9		87.5	0.7	91.8	0.6	83.1	0.7	87.4	0.8	92.9	0.8	81.8	0.8
80	92.0	0.4		89.3	0.4	92.8	0.3	83.8	0.5	88.2	0.8	93.9	0.7	82.5	0.9
90	93.5	-0.2		89.2	-0.4	94.0	-0.6	84.5	-0.1	89.1	-0.7	94.9	-1.0	83.2	-0.5
95	94.5	-0.6		89.8	-1.6	94.6	-2.1	84.9	-1.2	90.0	-1.4	96.0	-1.7	84.0	-1.1
98	96.0	-0.3		91.4	-0.8	96.5	-1.2	86.3	-0.4	91.7	-1.4	98.0	-1.5	85.5	-1.2
99	****	****		93.1	****	98.5	****	87.7	****	92.9	-1.4	99.2	-1.6	86.5	-1.3

**** Insufficient data for numerical assignment

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL TRUCKS AND VANS

[For Knock-Sensor Vehicles, Minimum Borderline Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels			FBRU Fuels						FBRSU Fuels											
	1989	Diff. 1988		--- (R+M)/2 ---			--- RON ---			--- MON ---			--- (R+M)/2 ---			--- RON ---			--- MON ---		
				1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988		1989	Diff. 1988				
10	82.1	-0.1		81.4	0.6		84.4	0.5		78.4	0.8		80.4	-0.2		84.5	-0.6		76.2	0.1	
20	84.8	0.7		83.0	1.3		86.3	1.2		79.6	1.2		82.1	0.7		86.5	0.5		77.6	0.9	
30	86.4	1.5		84.0	1.6		87.6	1.8		80.4	1.5		83.3	1.3		88.0	1.2		78.6	1.3	
40	87.5	1.8		84.7	1.6		88.5	1.8		81.0	1.5		84.1	1.4		88.9	1.3		79.3	1.5	
50	88.5	1.8		85.4	1.6		89.3	1.8		81.5	1.5		85.2	1.8		90.2	1.8		80.1	1.7	
60	90.1	2.4		86.2	1.7		90.3	2.0		82.1	1.5		86.1	1.7		91.4	1.9		80.8	1.6	
70	90.8	2.1		87.1	1.7		91.4	1.9		82.8	1.4		86.7	1.3		92.1	1.4		81.3	1.3	
80	91.4	1.5		87.8	0.9		92.2	0.9		83.4	0.9		87.3	0.7		92.8	0.6		81.7	0.7	
90	92.2	-0.9		88.7	0.1		93.3	0.9		84.1	0.3		88.4	0.4		94.1	0.2		82.7	0.6	
95	92.8	-1.4		89.4	-0.4		94.2	-0.6		84.6	-0.1		89.7	-0.3		95.6	-0.5		83.7	-0.2	
98	96.0	0.2		90.8	-0.2		95.9	-0.9		85.8	0.0		91.2	-0.1		97.4	-0.2		85.0	0.0	
99	****	****		93.0	****		98.4	****		87.6	****		92.3	****		98.6	****		86.0	****	

*** Insufficient data for numerical assignment

TABLE 11

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL KNOCK-SENSOR VEHICLES[For Knock-Sensor Vehicles, Maximum Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels		FBRU Fuels				FBRU Fuels				FBRU Fuels			
	1989	Diff. 1988	(R+M)/2		RON	Diff. 1988	(R+M)/2		RON	Diff. 1988	(R+M)/2		RON	Diff. 1988
			1989	1988			1989	1988			1989	1988		
10	82.6	2.5	79.9	1.0	82.6	1.0	77.1	1.0	80.2	0.9	84.3	0.8	76.1	1.0
20	84.9	1.8	82.3	1.0	85.6	1.1	79.1	1.1	82.1	0.9	86.6	0.8	77.7	1.1
30	86.1	1.4	83.6	0.8	87.2	0.9	80.1	0.9	83.4	0.9	88.2	0.9	78.7	1.1
40	87.2	0.8	84.6	0.5	88.3	0.4	80.9	0.6	84.4	0.4	89.3	0.2	79.5	0.6
50	88.3	0.4	85.4	0.4	89.3	0.4	81.5	0.4	85.4	0.2	90.5	-0.1	80.3	0.4
60	89.4	0.3	86.3	0.0	90.5	0.0	82.2	0.2	86.3	0.1	91.6	-0.1	80.9	0.2
70	90.5	0.2	87.6	-0.1	91.9	-0.4	83.3	0.2	87.5	0.2	93.1	0.0	82.0	0.4
80	91.8	-0.4	88.5	-0.3	93.1	-0.6	84.0	0.0	88.4	-0.4	94.2	-0.6	82.7	-0.1
90	93.7	0.3	89.7	-0.5	94.5	-0.8	84.9	-0.2	89.7	-0.6	95.6	-0.9	83.7	-0.4
95	94.8	0.7	91.8	0.4	97.0	0.3	86.6	0.5	92.0	0.6	98.2	0.5	85.7	0.6
98	96.6	1.2	93.5	1.2	98.9	1.1	88.0	1.2	93.5	0.4	99.9	0.4	87.0	0.4
99	****	****	94.4	1.7	100.0	1.7	88.8	1.7	94.0	****	100.5	****	87.5	****

**** Insufficient data for numerical assignment

TABLE 12

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 TOTAL KNOCK-SENSOR VEHICLES

[For Knock-Sensor Vehicles, Minimum Borderline Octane Number Requirements Are Used]

Percent Satisfied	PR Fuels		FBRU Fuels				FBRSU Fuels			
	1989	Diff. 1988	(R+M)/2		RON		(R+M)/2		RON	
			1989	1988	1989	Diff. 1988	1989	Diff. 1988	1989	Diff. 1988
10	80.4	3.4	78.7	****	81.2	****	76.1	****	79.3	1.5
									83.2	1.5
									75.4	1.6
20	83.3	1.8	81.3	1.2	84.4	1.2	78.3	1.2	80.4	0.2
									84.6	0.1
									76.3	0.5
30	84.9	1.6	82.8	1.2	86.2	1.3	79.5	1.2	82.1	1.0
									86.6	0.9
									77.6	1.1
40	86.1	1.8	84.1	1.7	87.7	1.9	80.5	1.6	83.5	1.6
									88.2	1.6
									78.7	1.6
50	87.2	2.1	84.9	1.9	88.7	2.1	81.1	1.7	84.4	1.7
									89.3	1.7
									79.5	1.7
60	88.4	2.1	85.6	1.8	89.5	2.0	81.6	1.6	85.3	1.7
									90.4	1.8
									80.3	1.8
70	90.1	2.5	86.4	1.5	90.6	1.7	82.3	1.3	86.2	1.2
									91.5	1.2
									80.9	1.2
80	90.8	1.5	87.6	1.0	92.0	1.1	83.3	1.1	87.0	0.5
									92.5	0.4
									81.5	0.6
90	91.8	-0.4	88.7	0.1	93.3	-0.1	84.1	0.3	88.1	-0.4
									93.8	-0.6
									82.5	0.0
95	92.9	-0.3	90.2	0.1	95.1	0.0	85.3	0.3	90.1	0.5
									96.2	0.6
									84.1	0.6
98	94.6	0.6	91.4	0.5	96.5	0.4	86.3	0.7	91.3	0.4
									97.4	0.2
									85.1	0.5
99	95.8	****	92.4	0.9	97.6	0.8	87.1	1.0	92.3	0.4
									98.6	0.3
									86.0	0.4

**** Insufficient data for numerical assignment

TABLE 13

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
SELECT MODEL: C11BU2*P30A4

Percent Satisfied	PR C%	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	83.2	86.1	79.4	82.8	87.9	78.6	83.2
10	84.4	87.1	80.1	83.6	88.8	79.1	84.0
20	85.8	88.4	80.9	84.6	89.9	79.9	84.9
30	86.8	89.2	81.5	85.3	90.6	80.4	85.5
40	87.7	90.0	81.9	86.0	91.3	80.8	86.0
50	88.5	90.7	82.4	86.5	91.9	81.2	86.6
60	89.3	91.4	82.9	87.1	92.5	81.6	87.1
70	90.2	92.2	83.3	87.8	93.2	82.0	87.6
80	91.2	93.0	83.9	88.5	93.9	82.6	88.2
90	92.6	94.3	84.7	89.5	95.0	83.3	89.1
95	93.8	95.3	85.4	90.3	95.9	83.9	89.9
N	10	10	10	10	10	10	10
Mean	88.5	90.7	82.4	86.5	91.9	81.2	86.6
Estimated Std. Dev. of the Sample Population	3.2	2.8	1.8	2.3	2.4	1.5	2.0

TABLE 13 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum-Borderline
SELECT MODEL: C11BU2*P30A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	82.8	85.8	79.2	82.5	86.9	77.9	82.4
10	84.0	86.8	79.9	83.3	87.8	78.4	83.1
20	85.5	87.9	80.6	84.3	88.8	79.2	84.0
30	86.6	88.7	81.1	84.9	89.6	79.7	84.6
40	87.5	89.4	81.6	85.5	90.3	80.1	85.2
50	88.4	90.1	82.0	86.0	90.9	80.5	85.7
60	89.2	90.8	82.4	86.6	91.5	80.9	86.2
70	90.2	91.5	82.9	87.2	92.1	81.4	86.8
80	91.2	92.3	83.4	87.8	92.9	81.9	87.4
90	92.7	93.4	84.1	88.8	94.0	82.6	88.3
95	94.0	94.4	84.8	89.6	94.9	83.2	89.0
N	8	10	10	10	8	8	8
Mean	88.4	90.1	82.0	86.0	90.9	80.5	85.7
Estimated Std. Dev. of the Sample Population	3.4	2.6	1.7	2.1	2.4	1.6	2.0

TABLE 14

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

SELECT MODEL: C21RC3*P22A4

Percent Satisfied	PR ON	FERU			FERSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	80.5	79.7	75.2	77.5	80.6	73.7	77.1
10	81.6	81.1	76.1	78.6	82.0	74.6	78.3
20	82.9	82.8	77.2	80.0	83.6	75.7	79.7
30	83.9	84.0	78.0	81.0	84.8	76.5	80.7
40	84.7	85.1	78.7	81.9	85.9	77.2	81.5
50	85.4	86.0	79.4	82.7	86.8	77.8	82.3
60	86.2	87.0	80.0	83.5	87.8	78.4	83.1
70	87.0	88.1	80.7	84.4	88.8	79.1	83.9
80	88.0	89.3	81.5	85.4	90.0	79.9	84.9
90	89.3	91.0	82.6	86.8	91.7	81.0	86.3
95	90.4	92.4	83.5	87.9	93.0	81.9	87.5
N	10	11	11	11	11	11	11
Mean	85.4	86.0	79.4	82.7	86.8	77.8	82.3
Estimated Std. Dev. of the Sample Population	3.0	3.8	2.5	3.2	3.8	2.5	3.1

TABLE 15

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

SELECT MODEL: C21D42*P38A4/C21S42*P38A4/C22S42*P38A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	85.4	86.8	79.9	83.3	87.7	78.3	83.0
10	86.5	87.7	80.5	84.1	88.7	79.0	83.9
20	87.7	88.9	81.2	85.1	90.0	79.9	84.9
30	88.6	89.7	81.8	85.7	90.9	80.5	85.7
40	89.4	90.4	82.2	86.3	91.6	81.0	86.3
50	90.1	91.1	82.7	86.9	92.3	81.5	86.9
60	90.9	91.8	83.1	87.4	93.1	82.0	87.5
70	91.6	92.5	83.6	88.0	93.8	82.5	88.2
80	92.5	93.3	84.1	88.7	94.7	83.1	88.9
90	93.8	94.5	84.9	89.7	96.0	84.0	90.0
95	94.8	95.4	85.5	90.4	97.0	84.7	90.8
N	23	23	23	23	23	23	23
Mean	90.1	91.1	82.7	86.9	92.3	81.5	86.9
Estimated Std. Dev. of of the Sample Population	2.8	2.6	1.7	2.2	2.8	1.9	2.4

TABLE 16

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

SELECT MODEL: C21PF2*P50A4/C22PF2*P50A4/C24PF2*P50A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	85.2	85.1	78.7	81.9	85.1	76.5	80.8
10	86.2	86.4	79.6	83.0	86.5	77.5	82.0
20	87.5	88.0	80.6	84.3	88.2	78.7	83.4
30	88.4	89.1	81.4	85.3	89.4	79.5	84.4
40	89.1	90.1	82.0	86.1	90.4	80.2	85.3
50	89.8	91.0	82.6	86.8	91.3	80.9	86.1
60	90.6	91.9	83.2	87.6	92.3	81.5	86.9
70	91.3	92.9	83.9	88.4	93.3	82.3	87.8
80	92.2	94.0	84.6	89.3	94.5	83.1	88.8
90	93.5	95.6	85.6	90.6	96.2	84.3	90.2
95	94.5	96.9	86.5	91.7	97.6	85.2	91.4
N	10	10	10	10	10	10	10
Mean	89.8	91.0	82.6	86.8	91.3	80.9	86.1
Estimated Std. Dev. of of the Sample Population	2.8	3.6	2.4	3.0	3.8	2.6	3.2

TABLE 17

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

SELECT MODEL: C31AR2*T25A3/C32AR2*T25A3/C33AR2*T25A3/
C34AR2*T25A3/C34NR2*T25A3

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	81.5	84.6	78.4	81.5	86.0	77.2	81.6
10	82.4	85.9	79.3	82.6	87.3	78.1	82.7
20	83.5	87.4	80.3	83.8	88.9	79.2	84.1
30	84.3	88.5	81.0	84.7	90.1	80.0	85.0
40	85.0	89.4	81.6	85.5	91.1	80.7	85.9
50	85.6	90.3	82.2	86.2	92.0	81.3	86.6
60	86.2	91.2	82.7	87.0	92.9	81.9	87.4
70	86.9	92.1	83.4	87.7	93.9	82.6	88.3
80	87.7	93.2	84.1	88.7	95.1	83.4	89.2
90	88.8	94.8	85.1	89.9	96.7	84.5	90.6
95	89.7	96.0	85.9	91.0	98.0	85.4	91.7
N	11	11	11	11	11	11	11
Mean	85.6	90.3	82.2	86.2	92.0	81.3	86.6
Estimated Std. Dev. of the Sample Population	2.5	3.5	2.3	2.9	3.6	2.5	3.1

TABLE 18

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum

SELECT MODEL: C31AW2*P28A4/C32AW2*P28A4/C32WW2*P28A4/
C33AW2*P28A4/C33WW2*P28A4/C34WW2*P28A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	83.6	85.1	78.7	81.9	86.7	77.7	82.2
10	84.6	86.4	79.6	83.0	88.0	78.6	83.3
20	85.8	88.0	80.7	84.3	89.6	79.7	84.6
30	86.7	89.2	81.4	85.3	90.8	80.4	85.6
40	87.4	90.2	82.1	86.1	91.7	81.1	86.4
50	88.2	91.1	82.7	86.9	92.7	81.7	87.2
60	88.9	92.0	83.3	87.6	93.6	82.4	88.0
70	89.6	93.0	83.9	88.5	94.5	83.0	88.8
80	90.5	94.2	84.7	89.4	95.7	83.8	89.8
90	91.7	95.8	85.7	90.8	97.3	84.9	91.1
95	92.7	97.1	86.6	91.9	98.6	85.8	92.2
N	23	23	23	23	23	23	23
Mean	88.2	91.1	82.7	86.9	92.7	81.7	87.2
Estimated Std. Dev. of the Sample Population	2.8	3.7	2.4	3.0	3.6	2.5	3.0

TABLE 18 (Continued)
MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock-Sensor Select Model - Minimum Borderline

SELECT MODEL: C31AW2*P28A4/C32AW2*P28A4/C32WW2*P28A4/
C33AW2*P28A4/C33WW2*P28A4/C34WW2*P28A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	82.1	82.2	76.8	79.5	84.5	76.2	80.3
10	83.1	83.7	77.8	80.8	85.9	77.2	81.6
20	84.4	85.5	79.0	82.3	87.7	78.4	83.1
30	85.3	86.8	79.9	83.4	89.0	79.3	84.2
40	86.1	88.0	80.6	84.3	90.1	80.1	85.1
50	86.8	89.0	81.3	85.2	91.2	80.7	86.0
60	87.5	90.1	82.0	86.0	92.2	81.4	86.8
70	88.3	91.2	82.7	87.0	93.3	82.2	87.8
80	89.2	92.5	83.6	88.1	94.6	83.1	88.8
90	90.5	94.4	84.8	89.6	96.4	84.3	90.3
95	91.6	95.9	85.8	90.8	97.9	85.3	91.6
N	14	21	21	21	14	14	14
Mean	86.8	89.0	81.3	85.2	91.2	80.7	86.0
Estimated Std. Dev. of the Sample Population	2.9	4.2	2.7	3.4	4.1	2.7	3.4

TABLE 19

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

SELECT MODEL: C31J12*T20A3/C31L12*T20A3

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	80.3	81.8	76.6	79.2	82.7	74.9	78.8
10	81.7	83.5	77.7	80.6	84.5	76.1	80.3
20	83.5	85.5	79.0	82.3	86.7	77.7	82.2
30	84.8	87.0	80.0	83.5	88.3	78.8	83.6
40	85.9	88.2	80.8	84.5	89.7	79.7	84.7
50	86.9	89.4	81.5	85.5	91.0	80.6	85.8
60	88.0	90.5	82.3	86.4	92.2	81.5	86.9
70	89.1	91.8	83.1	87.4	93.6	82.5	88.0
80	90.4	93.2	84.1	88.6	95.2	83.6	89.4
90	92.2	95.2	85.4	90.3	97.4	85.1	91.2
95	93.6	96.9	86.5	91.7	99.2	86.4	92.8
N	10	11	11	11	11	11	11
Mean	86.9	89.4	81.5	85.5	91.0	80.6	85.8
Estimated Std. Dev. of the Sample Population	4.1	4.6	3.0	3.8	5.0	3.5	4.3

TABLE 20

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
SELECT MODEL: C32ND4*P23A3/C33ND4*P23A3/C34ND4*P23A3

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	75.2	78.6	74.3	76.5	78.6	72.2	75.4
10	77.4	80.5	75.6	78.1	80.9	73.7	77.3
20	80.1	82.9	77.2	80.0	83.6	75.6	79.6
30	82.0	84.6	78.3	81.4	85.5	76.9	81.2
40	83.7	86.0	79.3	82.6	87.2	78.0	82.6
50	85.2	87.3	80.2	83.7	88.7	79.1	83.9
60	86.8	88.7	81.1	84.9	90.3	80.1	85.2
70	88.5	90.1	82.0	86.1	92.0	81.3	86.6
80	90.4	91.8	83.2	87.5	93.9	82.6	88.3
90	93.1	94.1	84.7	89.4	96.6	84.4	90.5
95	95.3	96.1	86.0	91.0	98.9	86.0	92.4
N	12	12	12	12	12	12	12
Mean	85.2	87.3	80.2	83.7	88.7	79.1	83.9
Estimated Std. Dev. of the Sample Population	6.1	5.3	3.6	4.4	6.1	4.2	5.2

TABLE 20 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline
 SELECT MODEL: C32ND4*P23A3/C33ND4*P23A3/C34ND4*P23A3

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	75.3	78.5	74.2	76.4	79.1	72.6	75.8
10	77.2	80.1	75.3	77.7	80.9	73.8	77.3
20	79.5	81.9	76.5	79.2	83.0	75.2	79.1
30	81.2	83.3	77.5	80.4	84.6	76.2	80.4
40	82.6	84.4	78.2	81.3	85.9	77.1	81.5
50	83.9	85.5	79.0	82.2	87.1	78.0	82.5
60	85.3	86.6	79.7	83.1	88.3	78.8	83.6
70	86.7	87.7	80.5	84.1	89.7	79.7	84.7
80	88.4	89.1	81.4	85.2	91.2	80.7	86.0
90	90.7	90.9	82.6	86.8	93.3	82.2	87.8
95	92.6	92.5	83.7	88.1	95.1	83.4	89.2
N	9	11	11	11	9	9	9
Mean	83.9	85.5	79.0	82.2	87.1	78.0	82.5
Estimated Std. Dev. of the Sample Population	5.2	4.2	2.9	3.6	4.9	3.3	4.1

TABLE 21

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
SELECT MODEL: C32WT2*P31A4/C33WT2*P31A4/C34T2*P31A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	81.2	82.1	76.8	79.4	83.4	75.3	79.4
10	82.5	83.7	77.8	80.8	85.1	76.5	80.8
20	84.1	85.7	79.1	82.4	87.2	78.0	82.6
30	85.2	87.1	80.1	83.6	88.8	79.1	83.9
40	86.2	88.3	80.9	84.6	90.1	80.0	85.0
50	87.1	89.5	81.6	85.5	91.3	80.8	86.1
60	88.0	90.6	82.4	86.5	92.5	81.7	87.1
70	89.0	91.8	83.2	87.5	93.8	82.6	88.2
80	90.1	93.2	84.1	88.7	95.3	83.7	89.5
90	91.7	95.2	85.4	90.3	97.4	85.1	91.3
95	93.0	96.8	86.5	91.6	99.2	86.4	92.8
N	11	11	11	11	11	11	11
Mean	87.1	89.5	81.6	85.5	91.3	80.8	86.1
Estimated Std. Dev. of the Sample Population	3.6	4.5	2.9	3.7	4.8	3.4	4.1

TABLE 21 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline
 SELECT MODEL: C32WT2*P31A4/C33WT2*P31A4/C34WT2*P31A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	76.6	80.1	75.5	77.8	81.2	73.9	77.5
10	78.3	81.8	76.6	79.2	82.7	74.9	78.8
20	80.3	83.9	78.0	80.9	84.5	76.2	80.3
30	81.7	85.3	78.9	82.1	85.8	77.1	81.4
40	82.9	86.6	79.7	83.1	86.9	77.8	82.4
50	84.1	87.7	80.5	84.1	88.0	78.6	83.3
60	85.2	88.9	81.3	85.1	89.1	79.3	84.2
70	86.4	90.1	82.1	86.1	90.2	80.0	85.1
80	87.9	91.6	83.0	87.3	91.5	80.9	86.2
90	89.8	93.6	84.3	89.0	93.3	82.2	87.7
95	91.5	95.3	85.4	90.4	94.8	83.2	89.0
N	9	11	11	11	9	9	9
Mean	84.1	87.7	80.5	84.1	88.0	78.6	83.3
Estimated Std. Dev. of the Sample Population	4.5	4.6	3.0	3.8	4.2	2.8	3.5

TABLE 22

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
SELECT MODEL: C33AN2*P33A4/C34AN2*P33A4

Percent Satisfied	PR ON	FBRU			FERSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	85.1	84.7	78.5	81.6	85.0	76.5	80.7
10	86.3	86.3	79.6	82.9	86.7	77.7	82.2
20	87.8	88.2	80.8	84.5	88.8	79.1	84.0
30	88.8	89.6	81.7	85.7	90.3	80.2	85.2
40	89.7	90.8	82.5	86.7	91.6	81.0	86.3
50	90.6	91.9	83.2	87.6	92.8	81.9	87.4
60	91.4	93.0	84.0	88.5	94.0	82.7	88.4
70	92.3	94.2	84.7	89.5	95.3	83.6	89.5
80	93.4	95.6	85.6	90.6	96.8	84.7	90.7
90	94.9	97.5	86.9	92.2	98.9	86.1	92.5
95	96.1	99.1	88.0	93.5	100.7	87.3	94.0
N	11	12	12	12	12	12	12
Mean	90.6	91.9	83.2	87.6	92.8	81.9	87.4
Estimated Std. Dev. of the Sample Population	3.4	4.4	2.9	3.6	4.8	3.3	4.0

TABLE 22 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline
SELECT MODEL: C33AN2*P33A4/C34AN2*P33A4

Percent Satisfied	PR ON	FBRU			FBRSL		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	84.3	83.3	77.6	80.4	83.3	75.4	79.4
10	85.1	85.0	78.7	81.8	84.6	76.3	80.4
20	86.0	87.1	80.0	83.5	86.1	77.3	81.7
30	86.7	88.5	81.0	84.8	87.2	78.0	82.6
40	87.3	89.8	81.9	85.8	88.1	78.7	83.4
50	87.8	91.0	82.6	86.8	89.0	79.2	84.1
60	88.4	92.2	83.4	87.8	89.9	79.8	84.9
70	89.0	93.5	84.2	88.8	90.8	80.5	85.6
80	89.6	94.9	85.2	90.1	91.9	81.2	86.6
90	90.6	97.0	86.6	91.8	93.4	82.2	87.8
95	91.3	98.7	87.7	93.2	94.7	83.1	88.9
N	6	11	11	11	7	7	7
Mean	87.8	91.0	82.6	86.8	89.0	79.2	84.1
Estimated Std. Dev. of the Sample Population	2.1	4.7	3.1	3.9	3.5	2.3	2.9

TABLE 23

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
 SELECT MODEL: C32HC2*P38A4/C33EC2*P38A4/C33HC2*P38A4/
 C34HC2*P38A4/C34CC2*P38A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	72.6	76.9	73.2	75.0	76.5	70.8	73.6
10	74.5	78.7	74.4	76.5	78.6	72.2	75.4
20	76.9	80.8	75.8	78.3	81.2	74.0	77.6
30	78.5	82.4	76.9	79.6	83.1	75.2	79.2
40	80.0	83.7	77.8	80.7	84.7	76.3	80.5
50	81.3	85.0	78.6	81.8	86.2	77.3	81.7
60	82.7	86.2	79.4	82.8	87.7	78.3	83.0
70	84.1	87.5	80.3	83.9	89.3	79.4	84.3
80	85.8	89.1	81.4	85.2	91.1	80.7	85.9
90	88.2	91.2	82.8	87.0	93.7	82.4	88.1
95	90.1	93.0	84.0	88.5	95.9	83.9	89.9
N	15	15	15	15	15	15	15
Mean	81.3	85.0	78.6	81.8	86.2	77.3	81.7
Estimated Std. Dev. of the Sample Population	5.3	4.9	3.3	4.1	5.9	4.0	4.9

TABLE 23 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline

SELECT MODEL: C32HC2*P38A4/C33EC2*P38A4/C33HC2*P38A4/
C34HC2*P38A4/C34CC2*P38A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	72.0	75.8	72.4	74.1	74.9	69.7	72.3
10	73.8	77.5	73.6	75.5	77.0	71.1	74.0
20	75.9	79.6	74.9	77.2	79.5	72.8	76.1
30	77.4	81.0	75.9	78.5	81.3	74.0	77.7
40	78.7	82.3	76.8	79.5	82.9	75.1	79.0
50	79.9	83.5	77.6	80.5	84.3	76.1	80.2
60	81.1	84.6	78.4	81.5	85.8	77.1	81.4
70	82.4	85.9	79.2	82.6	87.3	78.1	82.7
80	83.9	87.4	80.2	83.8	89.2	79.3	84.3
90	86.0	89.4	81.6	85.5	91.7	81.1	86.4
95	87.7	91.1	82.7	86.9	93.8	82.5	88.1
N	9	14	14	14	9	9	9
Mean	79.9	83.5	77.6	80.5	84.3	76.1	80.2
Estimated Std. Dev. of the Sample Population	4.8	4.6	3.1	3.9	5.8	3.9	4.8

TABLE 24

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
SELECT MODEL: S15XL2*P40A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	77.2	79.5	74.9	77.2	81.7	74.2	77.9
10	79.4	81.6	76.3	79.0	83.6	75.5	79.5
20	82.0	84.1	78.0	81.1	85.9	77.1	81.5
30	83.9	85.9	79.3	82.6	87.5	78.3	82.9
40	85.5	87.4	80.3	83.9	89.0	79.3	84.1
50	87.0	88.8	81.3	85.1	90.3	80.2	85.3
60	88.5	90.3	82.2	86.3	91.6	81.1	86.4
70	90.1	91.8	83.3	87.6	93.1	82.1	87.6
80	92.0	93.6	84.5	89.1	94.7	83.3	89.0
90	94.6	96.1	86.2	91.2	97.0	84.9	91.0
95	96.8	98.2	87.6	92.9	98.9	86.2	92.6
N	9	10	10	10	10	10	10
Mean	87.0	88.8	81.3	85.1	90.3	80.2	85.3
Estimated Std. Dev. of the Sample Population	5.9	5.7	3.9	4.8	5.3	3.7	4.5

TABLE 24 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline
SELECT MODEL: S15XL2*P40A4

Percent Satisfied	PR ON	FBRU			FBRU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	76.0	78.4	74.2	76.3	80.2	73.3	76.8
10	78.2	80.5	75.7	78.1	81.7	74.3	78.0
20	80.9	83.0	77.4	80.2	83.4	75.5	79.4
30	82.8	84.9	78.6	81.8	84.7	76.3	80.5
40	84.5	86.5	79.7	83.1	85.7	77.0	81.4
50	86.0	87.9	80.7	84.3	86.7	77.7	82.2
60	87.5	89.4	81.7	85.5	87.8	78.4	83.1
70	89.2	91.0	82.7	86.9	88.8	79.1	84.0
80	91.1	92.9	84.0	88.4	90.1	80.0	85.0
90	93.8	95.4	85.7	90.5	91.8	81.2	86.5
95	96.0	97.5	87.1	92.3	93.3	82.1	87.7
N	8	10	10	10	8	8	8
Mean	86.0	87.9	80.7	84.3	86.7	77.7	82.2
Estimated Std. Dev. of the Sample Population	6.1	5.8	3.9	4.9	4.0	2.7	3.3

TABLE 25

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Maximum
 SELECT MODEL: S36RK2*T57A4/V36GK2*T57A4/P36CK2*T57A4/
 S36UK2*T57A4/P36KK2*T57A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	85.5	85.9	79.3	82.6	86.5	77.6	82.0
10	86.4	86.9	80.0	83.4	87.5	78.3	82.9
20	87.6	88.2	80.8	84.5	88.8	79.1	83.9
30	88.4	89.1	81.3	85.2	89.7	79.7	84.7
40	89.1	89.8	81.8	85.8	90.5	80.2	85.4
50	89.8	90.5	82.3	86.4	91.2	80.7	86.0
60	90.4	91.3	82.8	87.0	91.9	81.2	86.6
70	91.1	92.0	83.3	87.7	92.7	81.7	87.2
80	92.0	92.9	83.9	88.4	93.6	82.3	88.0
90	93.1	94.2	84.7	89.4	94.8	83.2	89.0
95	94.1	95.2	85.3	90.3	95.9	83.9	89.9
N	11	11	11	11	11	11	11
Mean	89.8	90.5	82.3	86.4	91.2	80.7	86.0
Estimated Std. Dev. of the Sample Population	2.6	2.8	1.8	2.3	2.9	1.9	2.4

TABLE 25 (Continued)

MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Knock Sensor Select Model - Minimum Borderline
SELECT MODEL: S36RK2*T57A4/V36GK2*T57A4/P36CK2*T57A4/
S36UK2*T57A4/P36KK2*T57A4

Percent Satisfied	PR ON	FBRU			FBRSU		
		RON	MON	(R+M)/2	RON	MON	(R+M)/2
5	84.4	85.2	78.8	82.0	85.9	77.2	81.6
10	85.5	86.1	79.4	82.8	86.9	77.8	82.4
20	86.9	87.3	80.2	83.7	88.0	78.6	83.3
30	87.9	88.2	80.7	84.4	88.8	79.1	84.0
40	88.7	88.9	81.2	85.0	89.5	79.6	84.6
50	89.5	89.5	81.7	85.6	90.2	80.0	85.1
60	90.3	90.2	82.1	86.2	90.9	80.5	85.7
70	91.1	90.9	82.6	86.8	91.6	80.9	86.2
80	92.1	91.8	83.1	87.5	92.4	81.5	86.9
90	93.5	93.0	83.9	88.4	93.5	82.2	87.9
95	94.6	93.9	84.5	89.2	94.5	82.9	88.7
N	3	10	10	10	5	5	5
Mean	89.5	89.5	81.7	85.6	90.2	80.0	85.1
Estimated Std. Dev. of the Sample Population	3.1	2.7	1.7	2.2	2.6	1.7	2.2

TABLE 26

OWNER/RATER COMPARISON OF TANK FUEL KNOCK

(1982-1989 CRC Octane Number Requirement Surveys)

Model Year:	1989	1988	1987	1986	1985	1984	1983	1982
Fuel:	Unleaded	Unleaded	Unleaded	Unleaded	Unleaded	Unleaded	Unleaded	Unleaded
Total Reports:	124	155	179	160	143	149	129	144
<u>Percent Knocking</u>								
Trained Rater	30.6	39.4	39.7	33.1	37.8	51.7	59.7	47.9
Owner	7.3	15.5	24.0	16.3	18.9	26.2	29.5	25.0
Owner/Rater Ratio	0.24	0.39	0.61	0.49	0.50	0.51	0.49	0.52

Percent Owners Objecting

Based on:

Total Reports	0.8	0.6	2.8	2.5	9.8	7.4	12.4	13.2
Owners Reporting Knock	11.1	4.2	11.6	15.4	51.9	28.2	42.1	52.8

TABLE 27

TANK-FUEL KNOCK REPORTED BY TRAINED OBSERVERS

I. Total Vehicles

<u>Model Year</u>	<u>No. Survey</u>	<u>Vehicles Tested on Tank Fuel</u>	
		<u>No. Tested</u>	<u>% Knocking (Wtg. Avg.)</u>
1989	391	265	30
1988	391	293	31
1987	389	322	35
1986	377	330	31
1985	374	327	37
1984	407	358	49
1983	383	314	45
1982	434	342	42

<u>II. 1989 Select Models</u>	<u>No. in Survey</u>	<u>No. Tested</u>	<u>% Knocking</u>
C11BU2*P30A44	10	3	33
C21RC3*P22A4	11	7	14
C21D42*P38A4/C21S42*P38A4/ C22S42*P38A4	23	14	50
C21PF2*P50A4/C22PF2*P50A4/ C24PF2*P50A4	10	8	38
C31AR2*T25A3/C32AR2*T25A3/ C33AR2*T25A3/ C34AR2*T25A3/C34NR2*T25A3	11	10	30
C31AW2*P28A4/C32AW2*P28A4/ C32WW2*P28A4/ C33AW2*P28A4/C33WW2*P28A4/ C34WW2*P28A4	23	14	43
C31J12*T20A3/C31L12*T20A3	11	6	0
C32ND4*P23A3/C33ND4*P23A3/ C34ND4*P23A3	12	7	14
C32WT2*P31A4/C33WT2*P31A4/ C34WT2*P31A4	11	8	37
C33AN2*P33A4/C34AN2*P33A4	12	9	44
C32HC2*P38A4/C33EC2*P38A4/ C33HC2*P38A4	15	9	11
S15XL2*P40A4	10	9	22
S36RK2*T57A4/V36GK2*T57A4/ P36CK2*T57A4/ S36UK2*T57A4/P36KK2*T57A4	11	3	67

* weighted average

TABLE 28

ENGINE SPEEDS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELSPercent of Vehicles Having Maximum Requirements Within Specified Speed (rpm) Ranges

SPEED RANGE	C11BU2*P30A44 (Maximum)				C11BU2*P30A44 (Minimum-Borderline)				C21RC3*P22A4			
	PR	FBRU	FBRSU		PR	FBRU	FBRSU		PR	FBRU	FBRSU	
Max Torque, RPM	3600				3600				3000			
Fuel:												
1599 and Lower	20	10	0		13	10	0		0	0	0	
1600 - 1999	50	30	20		61	30	13		10	0	0	
2000 - 2399	20	0	0		13	10	36		50	55	64	
2400 - 2799	10	20	0		13	10	13		30	45	36	
2800 - 3199	0	20	20		0	20	0		10	0	0	
3200 and Higher	0	20	60		0	10	38		0	0	0	
No. of Vehicles	10	10	10		8	8	10		10	11	11	

SPEED RANGE	C21D42*P38A4/ C21S42*P38A4/ C22S42*P38A4				C21PF2*P50A4/ C22PF2*P50A42*P50A4/ C24PF2*P50A4				C31AR2*T25A3/C32AR2*T25 C33AR2*T25A3/ C34AR2*T25A3/C34NR2*T25			
	PR	FBRU	FBRSU		PR	FBRU	FBRSU		PR	FBRU	FBRSU	
Max Torque, RPM	2200				2000				3200			
Fuel:												
1599 and Lower	31	27	17		80	80	80		20	37	9	
1600 - 1999	17	4	0		10	0	0		20	9	9	
2000 - 2399	22	13	4		10	0	0		30	18	18	
2400 - 2799	13	13	13		0	20	20		20	0	9	
2800 - 3199	13	17	17		0	0	0		0	9	9	
3200 and Higher	4	26	49		0	0	0		10	27	46	
No. of Vehicles	23	23	23		10	10	10		11	11	11	

TABLE 28 (Continued)

ENGINE SPEEDS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Percent of Vehicles Having Maximum Requirements Within Specified Speed (rpm) Ranges

SPEED RANGE	C31AW2*P28A4/C32AW2*P28A4/ C32WW2*P28A4/C33AW2*P28A4/ C33WW2*P28A4/C34WW2*P28A4 (Maximum)					C31J12*T20A3/ C31L12*T20A3 (Minimum-Borderline)					3200				
	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU
1599 and Lower	9	4	0	14	14	0	14	14	0	0	0	0	0	0	0
1600 - 1999	40	39	27	36	29	44	36	29	44	30	37	46	30	37	46
2000 - 2399	17	9	17	14	14	14	14	14	14	10	18	18	10	18	18
2400 - 2799	4	17	26	0	14	21	0	14	21	40	36	27	40	36	27
2800 - 3199	17	22	26	36	24	21	36	24	21	20	9	9	20	9	9
3200 and Higher	13	9	4	0	5	0	0	5	0	0	0	0	0	0	0
No. of Vehicles	23	23	23	14	21	14	14	21	14	10	11	11	10	11	11

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SPEED RANGE	C32ND4*P23A3/C33ND4*P23A3/ C34ND4*P23A3 (Maximum)					C32ND4*P23A3/C33ND4*P23A3/ C34ND4*P23A3 (Minimum-Borderline)					3600				
	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU
1599 and Lower	20	20	0	25	25	0	25	25	0	0	9	9	0	9	9
1600 - 1999	20	30	55	13	50	71	13	50	71	64	27	27	64	27	27
2000 - 2399	50	40	45	49	25	29	49	25	29	9	0	0	9	0	0
2400 - 2799	10	10	0	13	0	0	13	0	0	0	27	18	0	27	18
2800 - 3199	0	0	0	0	0	0	0	0	0	27	37	37	27	37	37
3200 and Higher	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of Vehicles	12	12	12	9	11	9	9	11	9	11	11	11	11	11	11

Knock Sensor, Maximum Model: C32ND4*P23A3/C33ND4*P23A3/
C34ND4*P23A3
(Maximum)

Max Torque, RPM 4000

Fuel:

TABLE 28 (Continued)

ENGINE SPEEDS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Percent of Vehicles Having Maximum Requirements Within Specified Speed (rpm) Ranges

Model: C32WT2*P31A4/C33WT2*P31A4/
C34WT2*P31A4
(Minimum Borderline) C33AN2*P33A4/C34AN2*P33A4
(Maximum) C33AN2*P33A4/C34AN2*P33A4
(Minimum Borderline)

Max Torque, RPM 3600 2000 2000

Fuel: PR FBRU FBRSU PR FBRU FBRSU PR FBRU FBRSU

SPEED RANGE

1599 and Lower
1600 - 1999
2000 - 2399
2400 - 2799
2800 - 3199
3200 and Higher

No. of Cars

-60-

Model: C32HC2*P38A4/C33EC2*P38A4/
C33HC2*P38A4/C34HC2*P38A4
(Maximum) S15XL2*P40A4
(Minimum Borderline) (Maximum)

Max Torque, RPM 2000 2000 2500

Fuel: PR FBRU FBRSU PR FBRU FBRSU PR FBRU FBRSU

SPEED RANGE

1599 and Lower
1600 - 1999
2000 - 2399
2400 - 2799
2800 - 3199
3200 and Higher

No. of Cars

TABLE 28 (Continued)

ENGINE SPEEDS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS - 1989 SELECT MODELS

Percent of Vehicles Having Maximum Requirements Within Specified Speed (rpm) Ranges

SPEED RANGE	1599 and Lower	8	10	8	Model: S15XL2*p40A4						S36RK2*T57A4/V36GK2*T57A4/V36GK2*T57A4					
					(Minimum-Borderline)						(Minimum-Borderline)					
					2500						2800					
					Max Torque, RPM						2800					
					Fuel:						Fuel:					
					PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU	PR	FBRU	FBRSU
					25	10	0	0	0	0	0	10	0	0	10	0
					13	20	13	18	36	18	36	30	18	67	30	40
					13	20	25	73	46	73	46	50	64	33	50	40
					36	0	13	0	9	0	9	10	9	0	10	20
2800 - 3199	2800 and Higher	13	0	0	0	50	49	9	0	0	0	0	0			
					0	0	0	9	0	0	0	0	0			
					0	0	0	9	0	0	0	0				
No. of Vehicles	5	3	10	11	11	11	11	11	3	10	5					

TABLE 29

ENGINE SPEEDS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS

Weighted % of Vehicles Having Requirements
in Indicated (rpm) Ranges

All 1989 Vehicles

<u>Maximum Requirements Engine Speed Range</u>	<u>PR Fuels</u>	<u>FBRU Fuels</u>	<u>FBRSU Fuels</u>
1599 and Lower	20	20	13
1600 - 1999	21	15	13
2000 - 2399	22	25	26
2400 - 2799	19	19	20
2800 - 3199	13	14	17
3200 - 3599	3	3	5
3600 and Higher	2	4	6

TABLE 30

THROTTLE/GEAR POSITION FOR 1989 MAXIMUM

FBRU OCTANE NUMBER REQUIREMENTS

Throttle Position	Transmission Type & Gear	No. of Vehicles*	% of Vehicles
-----Automatic Transmission-----			
Maximum	4-Speed: 4th	44	13.6
	3rd	72	22.2
	2nd	47	14.5
	3-Speed: 3rd	54	16.7
	2nd	30	9.3
Part	4-Speed: 4th	36	11.1
	3rd	13	4.0
	2nd	3	0.9
	3-Speed: 3rd	23	7.1
	2nd	2	0.6
		<u>324</u>	<u>100.0</u>
-----Manual Transmission-----			
Maximum	5-Speed: 4th	19	35.1
	3rd	13	24.1
	2nd	1	1.9
	4-Speed: 4th	1	1.9
Part	5-Speed: 4th	12	22.2
	3rd	6	11.1
	4-Speed: 4th	2	3.7
		<u>54</u>	<u>100.0</u>

* Twelve test vehicles not counted, because all FBRU fuels satisfied their octane number requirements. One missing value for gear position.

Figure 1
DISTRIBUTION OF ODOMETER MILEAGE FOR 1989 MODEL VEHICLES TESTED

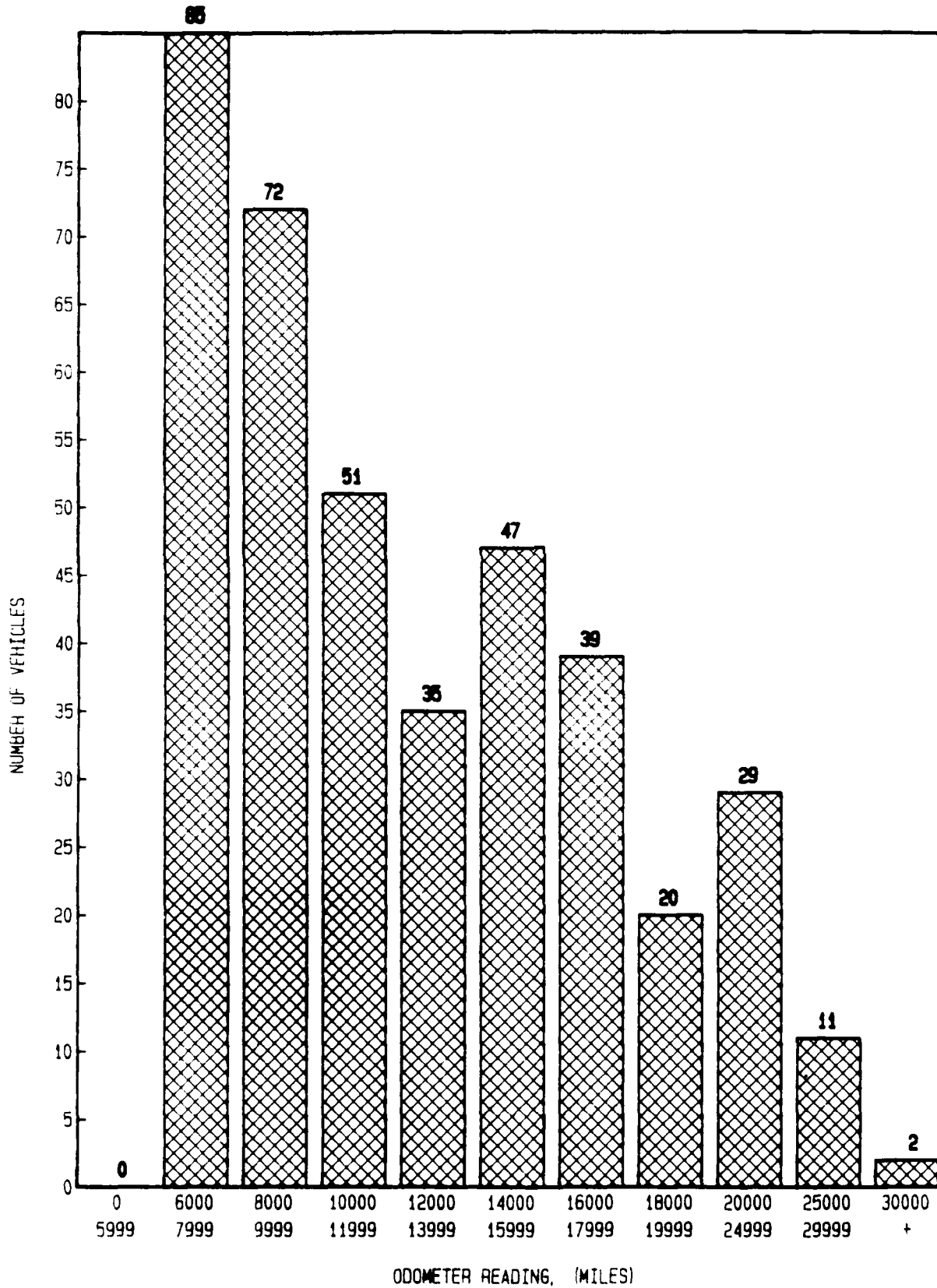


Figure 2
DISTRIBUTION OF MAXIMUM PR FUEL (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL VEHICLES

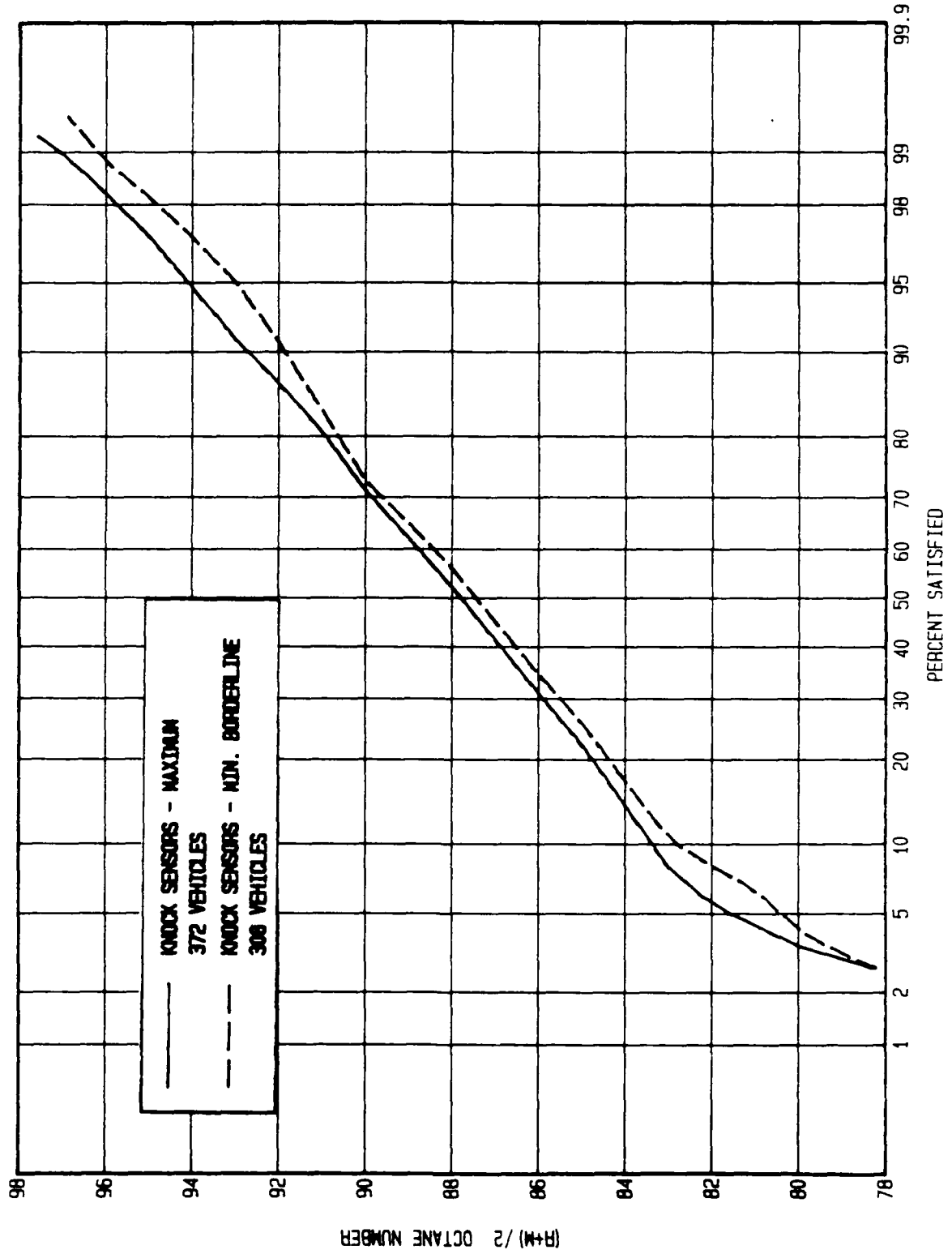


Figure 3
DISTRIBUTION OF MAXIMUM FBRU FUEL (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL VEHICLES

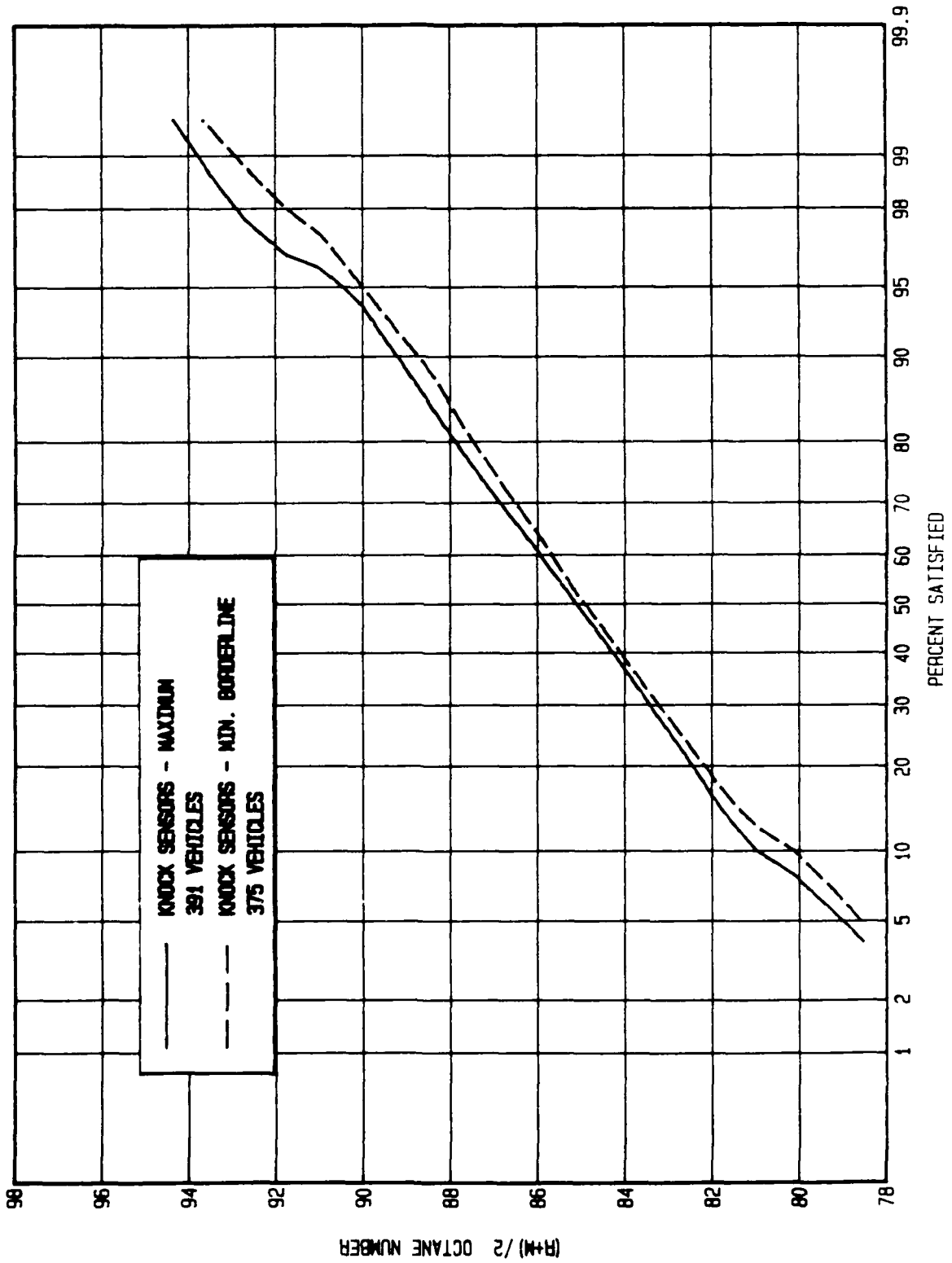


Figure 4
DISTRIBUTION OF MAXIMUM FBSU FUEL (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL VEHICLES

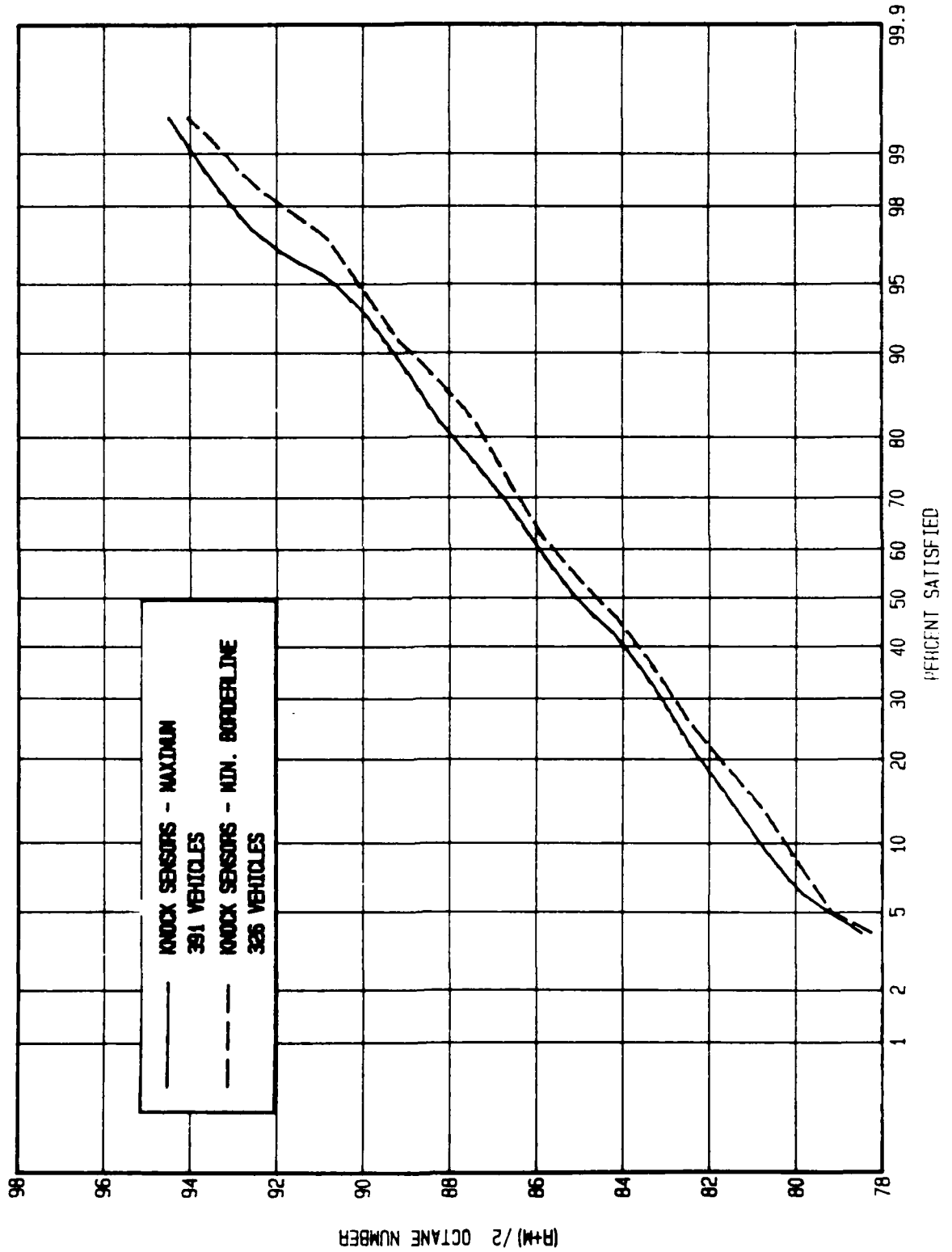


Figure 5
DISTRIBUTION OF MAXIMUM (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL VEHICLES

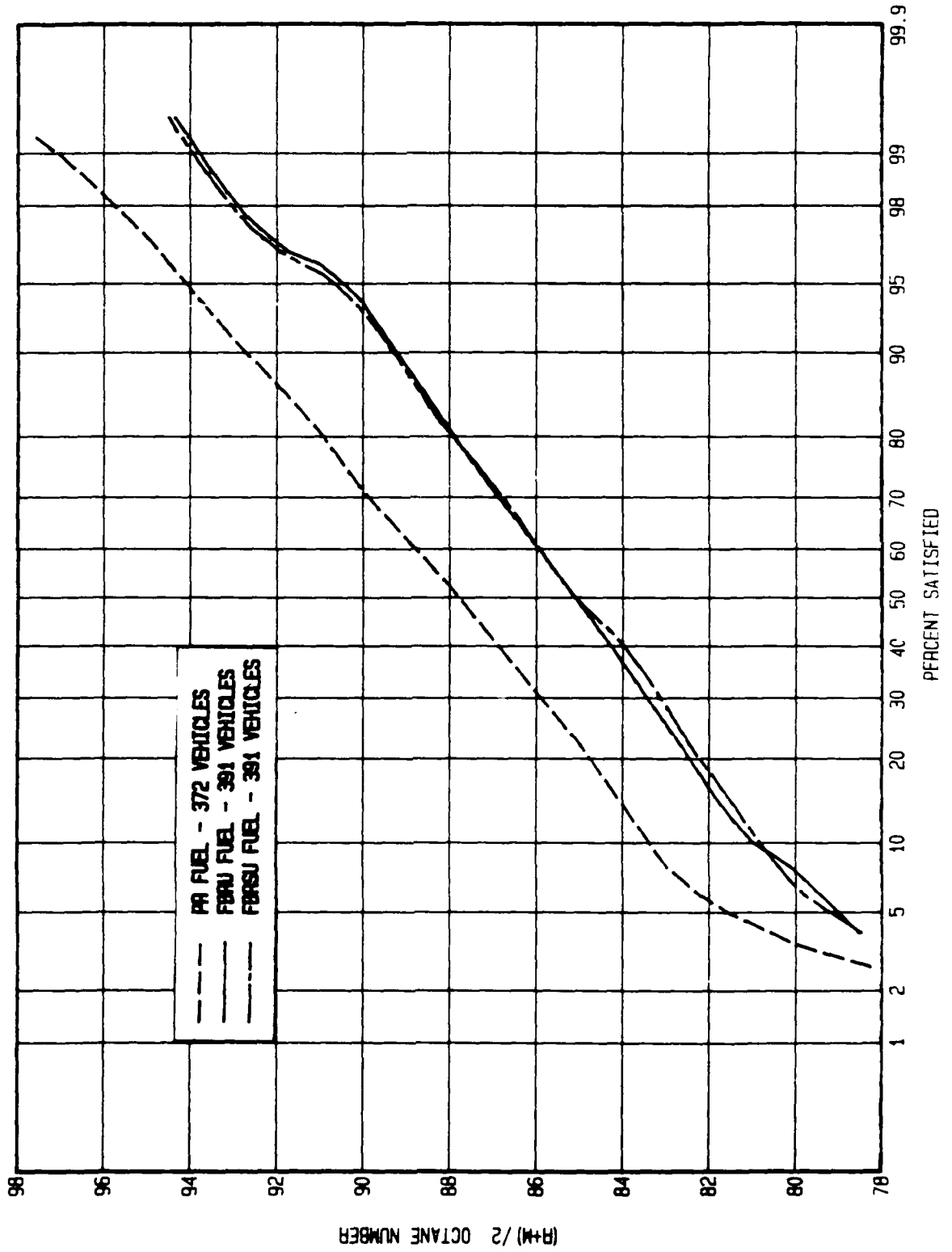


Figure 6
DISTRIBUTION OF MAXIMUM FBRU FUEL (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 AND 1988 TOTAL VEHICLES

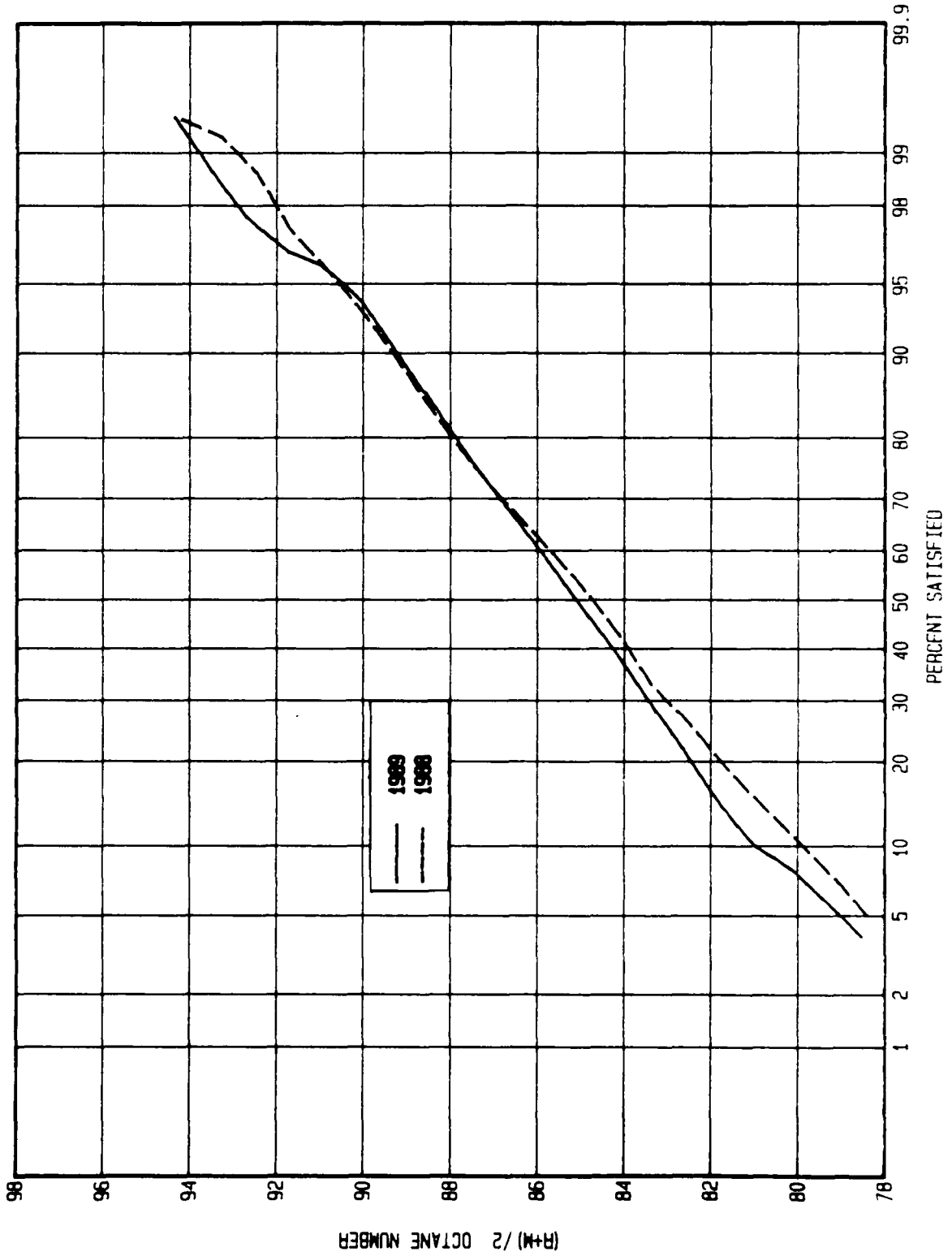


Figure 7
DISTRIBUTION OF MAXIMUM (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL CARS

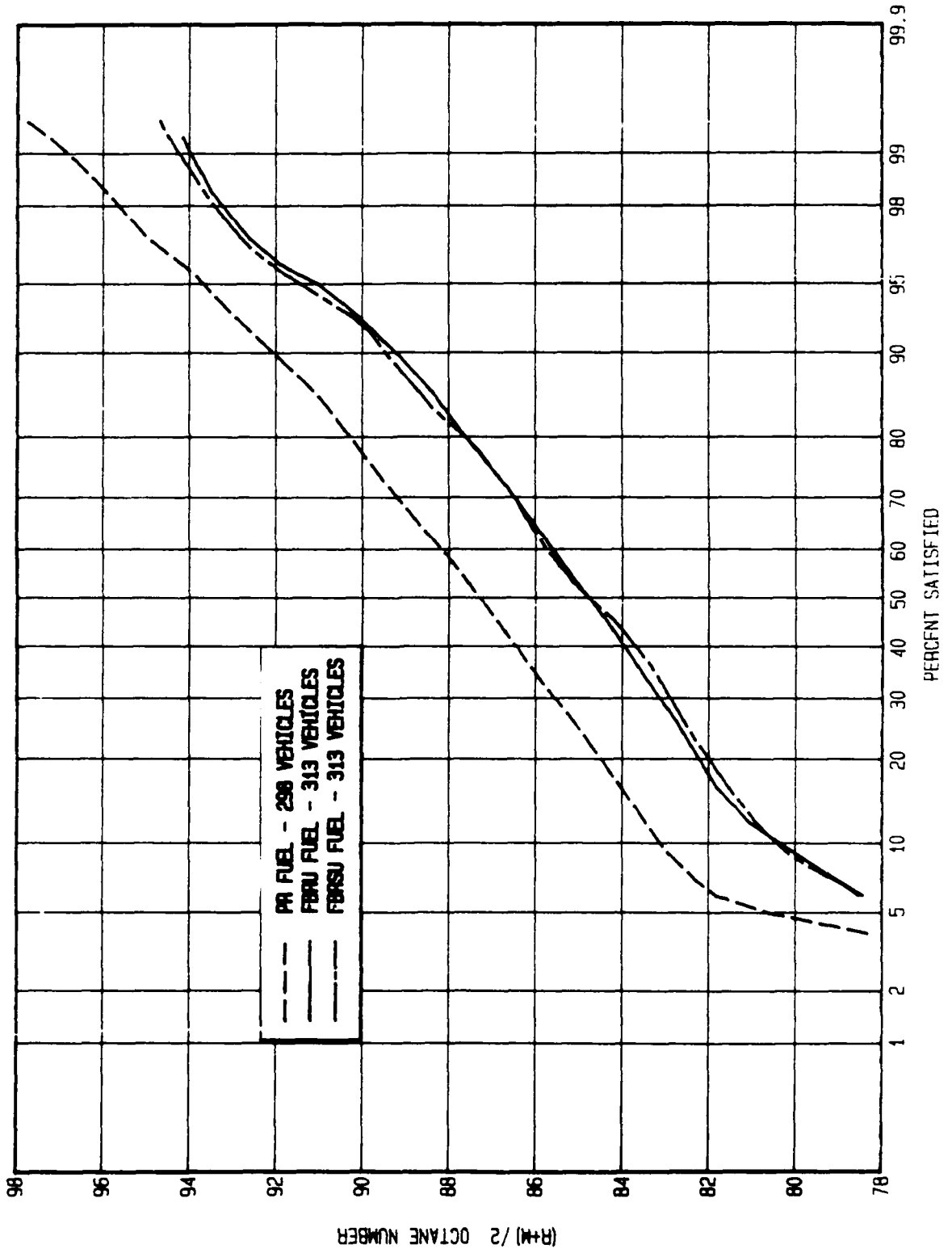


Figure 8
DISTRIBUTION OF MAXIMUM FBRU FUEL (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 AND 1988 TOTAL CARS

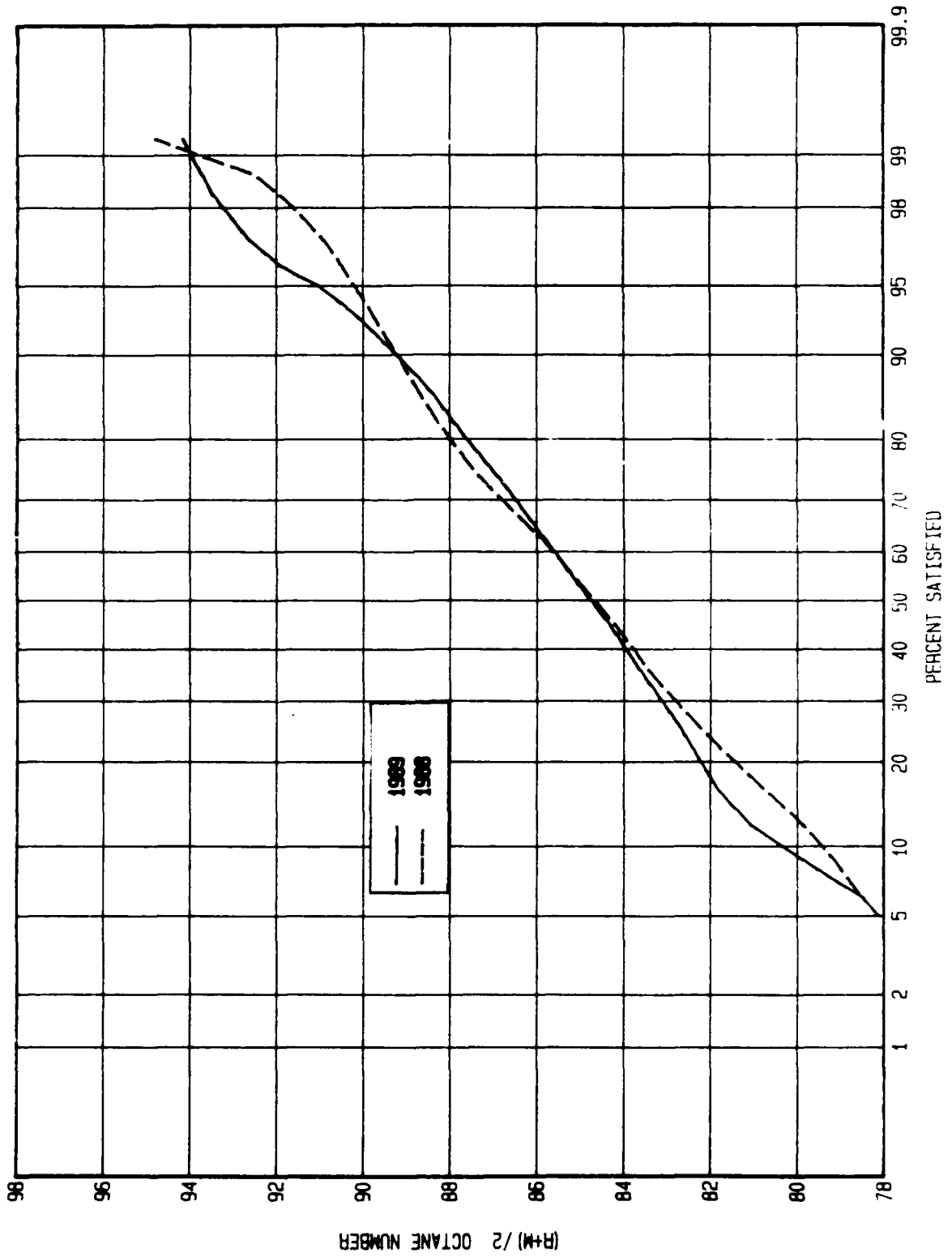


Figure 9
DISTRIBUTION OF MAXIMUM (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 TOTAL TRUCKS AND VANS

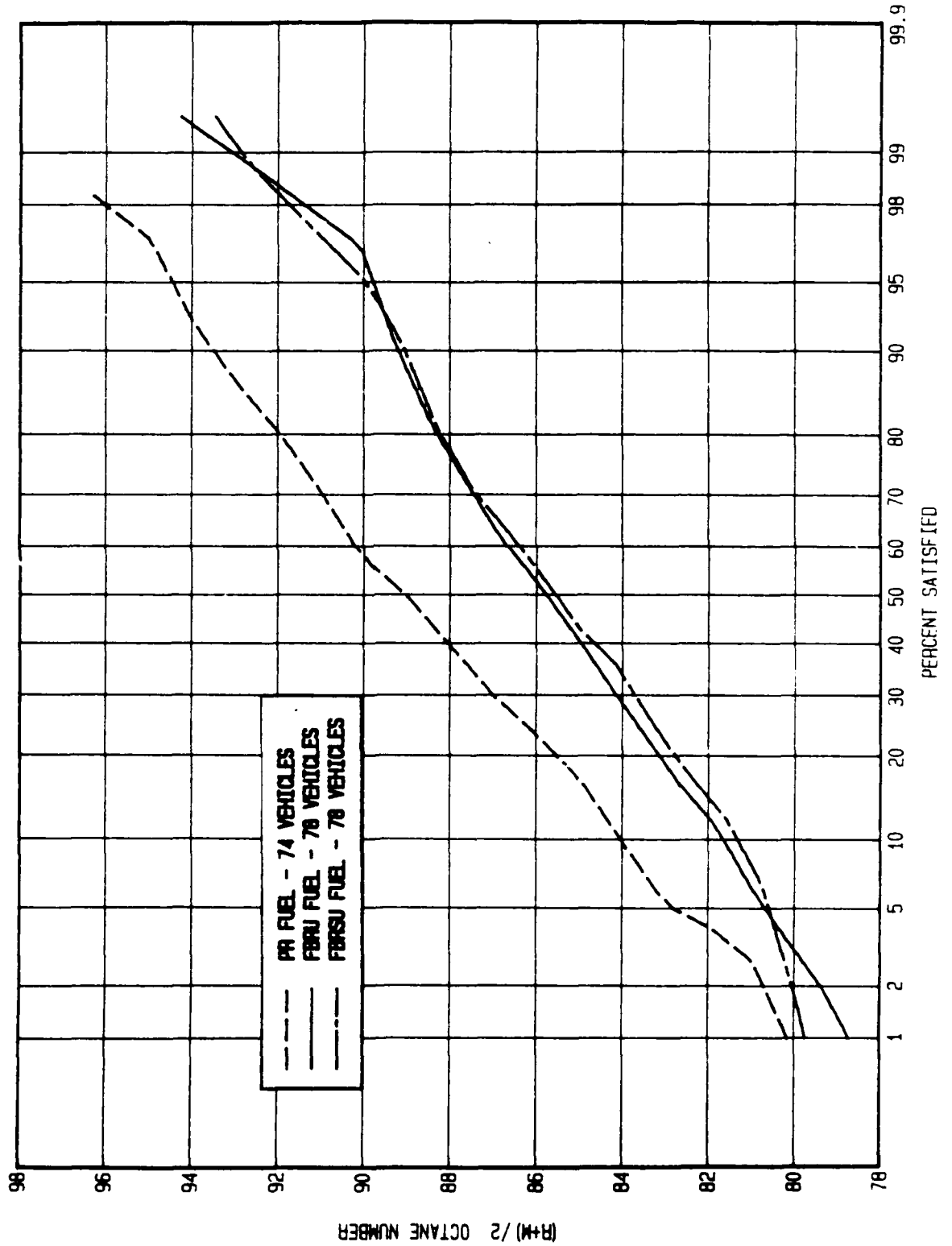


Figure 10
DISTRIBUTION OF MAXIMUM FBRU FUEL (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 AND 1988 TOTAL TRUCKS AND VANS

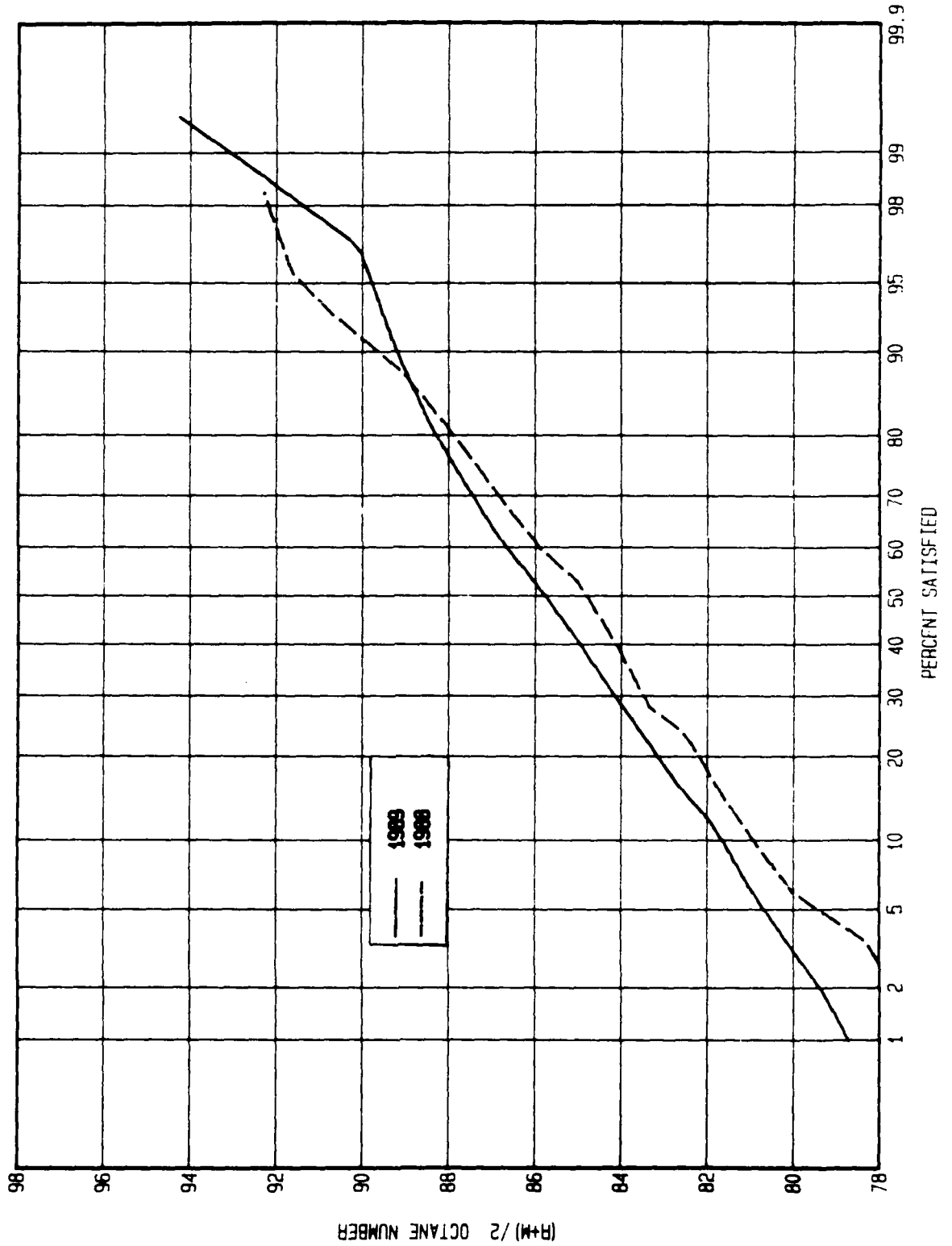


Figure 11
DISTRIBUTION OF MAXIMUM (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 KNOCK SENSOR VEHICLES

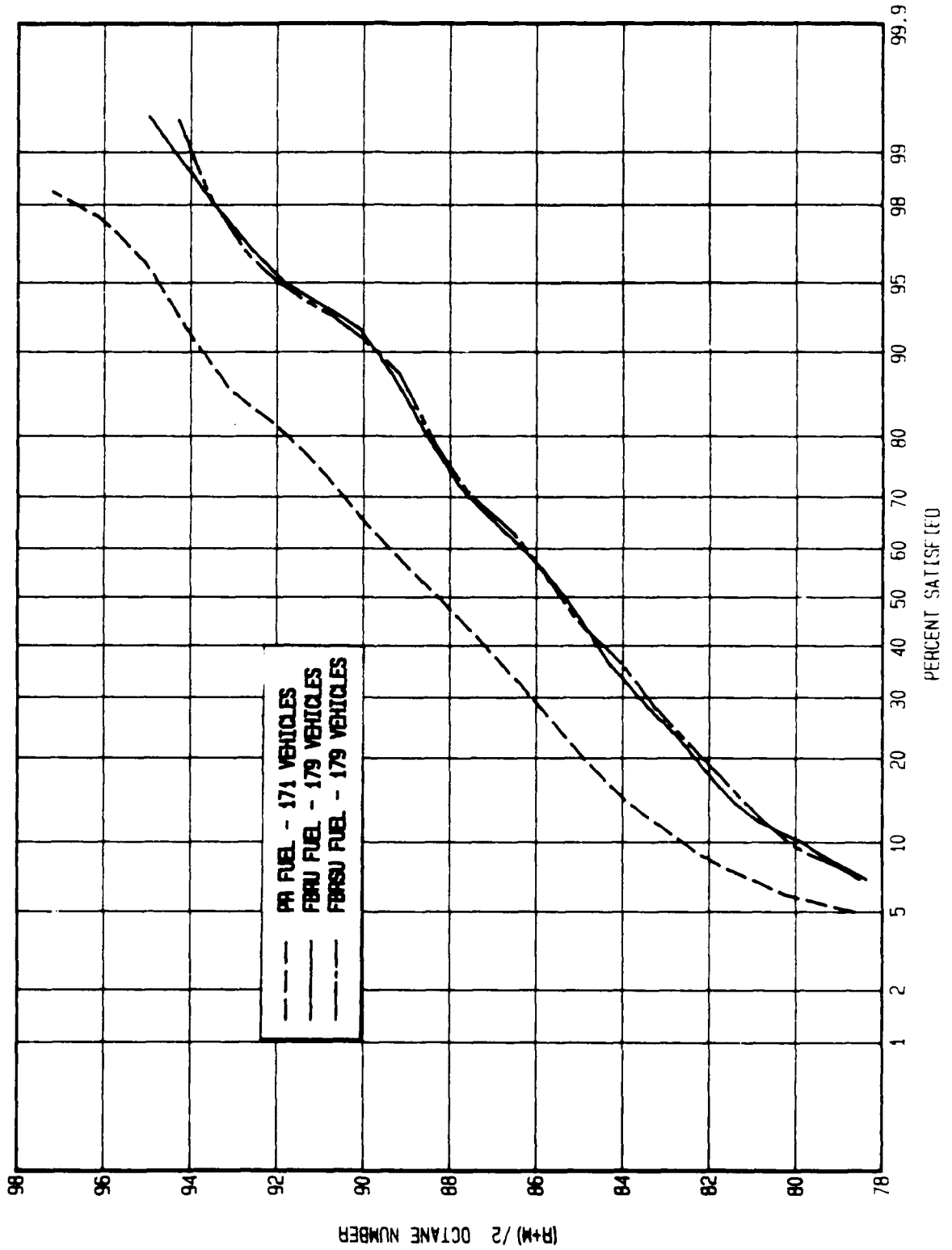


Figure 12
DISTRIBUTION OF MAXIMUM (R+M)/2 OCTANE NUMBER REQUIREMENTS
1989 KNOCK SENSOR VEHICLES - MINIMUM BORDERLINE

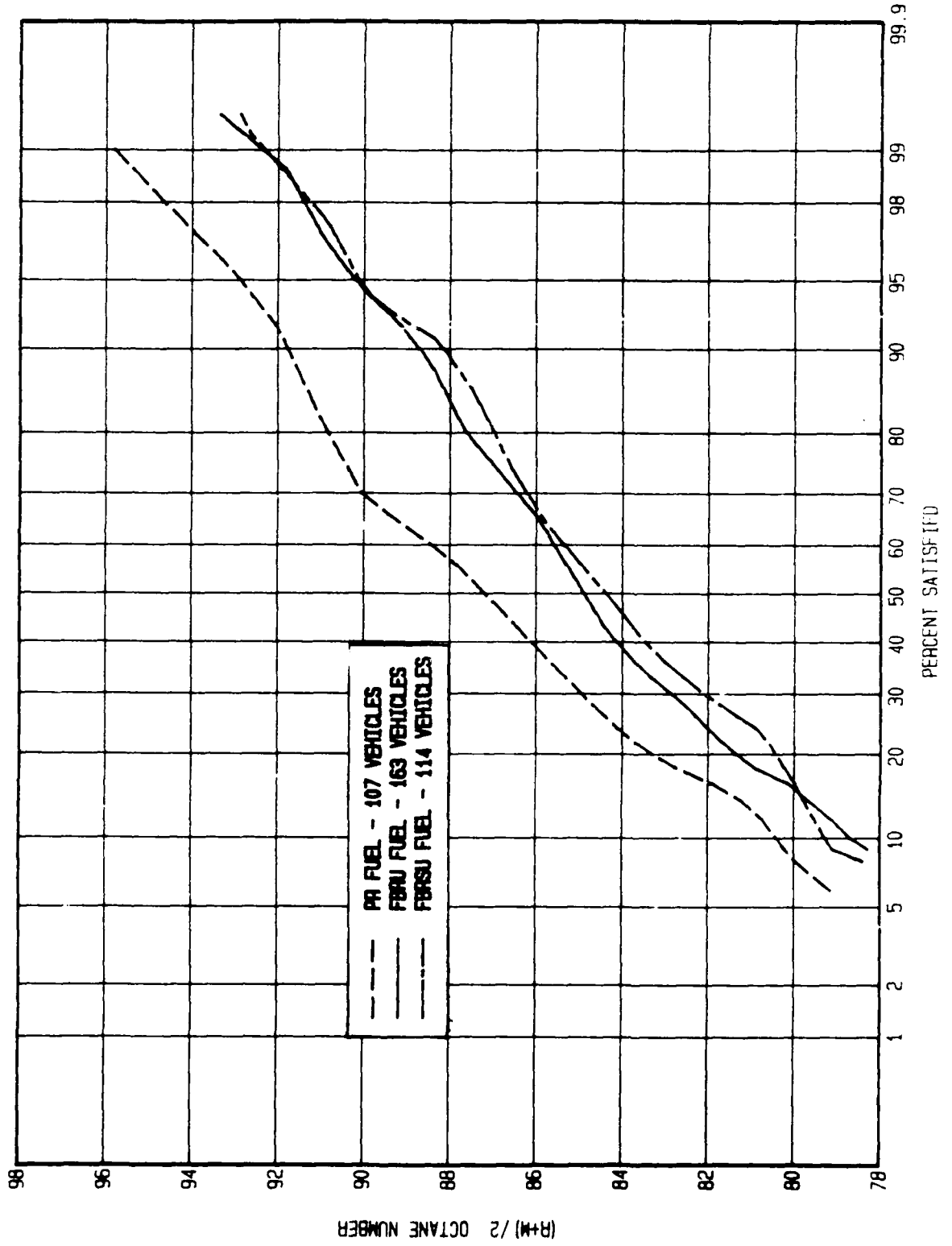
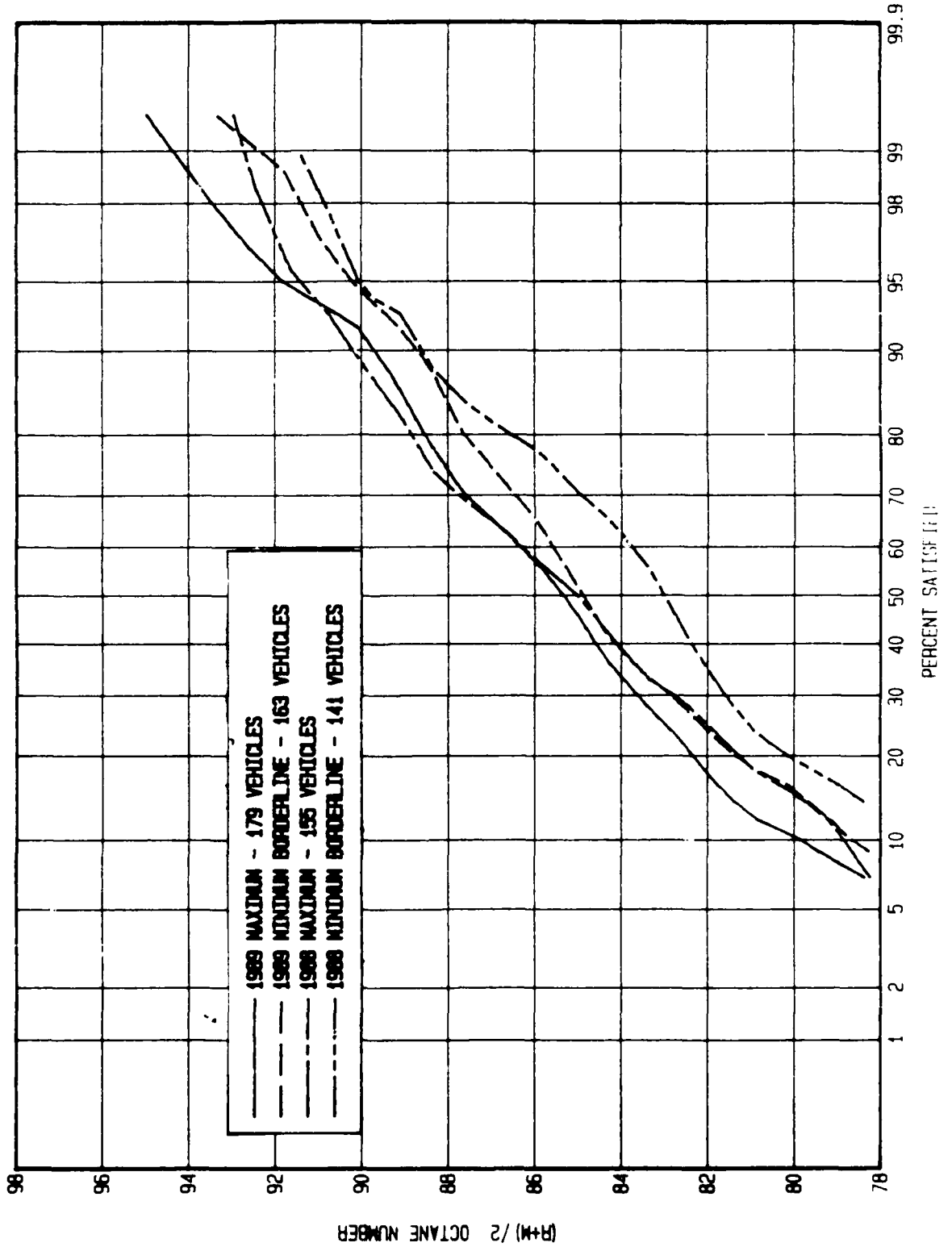


Figure 13
DISTRIBUTION OF MAXIMUM FBRU FUEL (R+M) / 2 OCTANE NUMBER REQUIREMENTS
1989 AND 1988 KNOCK SENSOR VEHICLES



PARTICIPATING LABORATORIES

<u>No. of Vehicles Tested</u>	<u>Eastern Area</u>	<u>East Central Area</u>	<u>No. of Vehicles Tested</u>
21	Exxon Res. & Engrg. Co. Linden, NJ	Ashland Oil Ashland, KY	6
31	Mobil Res. & Dev. Corp. Paulsboro, NJ	BP Oil Company Cleveland, OH	31
19	Sun Company Marcus Hook, PA	Ford Motor Company Dearborn, MI	18
30	Texaco Inc. Beacon, NY	General Motors Research Labs Warren, MI	30
		Nissan Res. & Dev. Ann Arbor, MI	7
		Petro-Canada Products Sheridan Park, Ontario	30
		Shell Canada Oakville, Ontario	7
		Toyota Motor Corp. Ann Arbor, MI	9
	<u>Western Area</u>	<u>West Central Area</u>	
30	Chevron Res. & Technology Co. Richmond, CA	Chrysler Corporation Detroit, MI	22
29	Unocal Corporation Brea, CA	Amoco Oil Company Naperville, IL	32
		Phillips Petroleum Co. Bartlesville, OK	16
		Shell Development Co. Houston, TX	23

A P P E N D I X B

MEMBERSHIP: 1989 ANALYSIS PANEL

1989 CRC OCTANE NUMBER REQUIREMENT SURVEY

1989 ANALYSIS PANEL

<u>Name</u>	<u>Company</u>
D. I. Hoel, Leader	Exxon Research and Engineering Company
W. F. Biller	Consultant
C. J. Bones	Sun Refining and Marketing Company
J. C. Callison	Amoco Oil Company
C. A. Carlson	Texaco, Inc.
J. P. Graham	Chevron Research and Technology Company
M. T. Noorman	Mobil Oil Corporation
M. G. Rogers	Mobil Research and Development Corporation
J. P. Uihlein	BP Oil Company (Sohio)
T. Wusz	Unocal Corporation

APPENDIX C

DATA ON 1989/1990

FULL-BOILING RANGE REFERENCE FUELS

TABLE C-1

SUPPLIERS' FUEL INSPECTIONS1989/1990 FBRU FUELS

	Low-Octane <u>Base Blend</u> RMFD 368-89/90	Intermediate- Octane <u>Base Blend</u> RMFD 369-89/90	High-Octane <u>Base Blend</u> RMFD 370-89/90
<u>Laboratory Inspection</u>			
Distillation, °F			
IBP	91	90	90
10% Evap.	136	118	127
30% Evap.	176	152	182
50% Evap.	209	196	218
70% Evap.	233	250	248
90% Evap.	325	334	286
End Point	426	425	357
RVP, psi	7.1	8.3	7.5
Lead, g/gal.	0.000	0.000	0.000
Oxidation Stab., min.	1440+	1440+	1440+
<u>Hydrocarbon Type, Vol. %</u>			
Aromatics	19.6	25.7	46.4
Olefins	10.0	15.0	3.2
Saturates	70.4	59.3	50.4
Research Octane Number	79.3	90.6	104.2
Motor Octane Number	74.5	82.2	92.7
Sensitivity	4.8	8.4	11.5

TABLE C-2

OCTANE NUMBERS AND COMPOSITIONS FOR 1989/1990 FBRU FUELS

Research Octane Number	Volume Percent			Motor Octane Number	Sensitivity
	RMFD 368-89/90	RMFD 369-89/90	RMFD 370-89/90		
80	91.5	8.5	---	75.2	4.8
82	75.0	25.0	---	76.7	5.3
84	59.0	41.0	---	78.1	5.9
85	51.0	49.0	---	78.7	6.3
86	42.5	57.5	---	79.4	6.6
87	34.0	66.0	---	80.0	7.0
88	25.0	75.0	---	80.7	7.3
89	15.5	84.5	---	81.3	7.7
90	5.0	95.0	---	81.9	8.1
91	---	96.5	3.5	82.6	8.4
92	---	90.0	10.0	83.3	8.7
93	---	83.5	16.5	83.9	9.1
94	---	76.5	23.5	84.5	9.5
95	---	69.5	30.5	85.2	9.8
96	---	62.5	37.5	85.9	10.1
97	---	55.0	45.0	86.6	10.4
98	---	48.0	52.0	87.3	10.7
99	---	40.5	59.5	88.0	11.0
100	---	32.5	67.5	88.8	11.2
101	---	24.0	76.0	89.6	11.4
102	---	16.0	84.0	90.4	11.6
103	---	8.0	92.0	91.4	11.6
104	---	0.0	100.0	92.6	11.4

TABLE C-3

SUPPLIERS' FUEL INSPECTIONS1989/1990 FBRSU FUELS

	Low-Octane Base Blend	Intermediate- Octane Base Blend	High-Octane Base Blend
	RMFD	RMFD	RMFD
	371-89/90	372-89/90	373-89/90
<u>Laboratory Inspection</u>			
Distillation, °F			
IBP	90	97	91
10% Evap.	135	127	137
30% Evap.	174	158	190
50% Evap.	207	206	232
70% Evap.	247	280	256
90% Evap.	365	369	312
End Point	431	430	402
RVP, psi	8.1	7.1	7.5
Lead, g/gal.	0.000	0.000	0.000
Oxidation Stab., min.	1440+	1440+	1440+
<u>Hydrocarbon Type, Vol. %</u>			
Aromatics	23.7	31.5	50.4
Olefins	29.9	21.5	3.8
Saturates	46.4	47.0	45.8
Research Octane Number	79.5	91.6	104.0
Motor Octane Number	72.9	81.2	90.5
Sensitivity	6.6	10.4	13.5

TABLE C-4

OCTANE NUMBERS AND COMPOSITIONS FOR 1989/1990 FBRU FUELS

Research Octane Number	Volume Percent			Motor Octane Number	Sensitivity
	RMFD 371-89/90	RMFD 372-89/90	RMFD 373-89/90		
80	96.5	3.5	---	73.1	6.9
82	80.5	19.5	---	74.6	7.4
84	65.5	34.5	---	75.9	8.1
85	58.0	42.0	---	76.5	8.5
86	49.5	50.5	---	77.2	8.8
87	41.0	59.0	---	77.9	9.1
88	32.5	67.5	---	78.6	9.4
89	24.5	75.5	---	78.3	9.7
90	15.5	84.5	---	80.0	10.0
91	6.5	93.5	---	80.6	10.4
92	---	98.0	2.0	81.2	10.8
93	---	90.5	9.5	81.9	11.1
94	---	83.5	16.5	82.6	11.4
95	---	75.5	24.5	83.3	11.7
96	---	67.5	32.5	84.0	12.0
97	---	59.5	40.5	84.7	12.3
98	---	51.0	49.0	85.5	12.5
99	---	42.5	57.5	86.3	12.7
100	---	34.0	66.0	87.1	12.9
101	---	25.0	75.0	87.9	13.1
102	---	15.5	84.5	88.8	13.2
103	---	5.0	95.0	89.8	13.2
103.5	---	0.0	100.0	90.3	13.2

A P P E N D I X D

PROGRAM

PROGRAM
for the
1989 CRC OCTANE NUMBER REQUIREMENT SURVEY

CRC Project No. CM-123-89

June 1989

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I. INTRODUCTION

The 1989 program of the CRC Light-Duty Octane Number Requirement Survey Group will consist of a survey of the octane number requirements of 1989 model domestic and imported vehicles. For the purposes of this program, the designation "passenger vehicles" will include passenger cars, light-duty (<8500 lb/3856 kg GVW) pickup trucks, and vans. Approximately 450 vehicles will be tested. Most of these vehicles will be sampled in proportion to their relative production or import volume, to provide data from which to estimate the distribution of octane number requirements for the 1989 model vehicle population in the United States. In addition, select models of special interest will be tested in sufficient numbers to estimate their requirement distributions.

Knocking characteristics will be investigated with three series of reference fuels. Tank fuel knock will also be evaluated. Maximum octane number requirements, whether at maximum-throttle or part-throttle, will be established for each vehicle using high sensitivity unleaded full-boiling range reference (FBRSU) fuels, average sensitivity unleaded full-boiling range reference (FBRU) fuels, and primary reference (PR) fuels. If the maximum requirement is at maximum-throttle, then part-throttle requirements are investigated with only FBRU fuels of up to, and including, four octane numbers lower than the maximum requirement. Also, minimum requirements are determined for knock-sensor equipped vehicles.

II. GEOGRAPHICAL AREAS

As in previous years, the 1989 Survey will be conducted on a nationwide basis for the US, and will include Canada. Four geographical areas have been established for test vehicle assignment purposes. Participants located in New York, New Jersey, and Pennsylvania are included in the Eastern Area; those located in Ohio, Michigan, and Kentucky comprise the East Central Area; those in Illinois, Texas, and Oklahoma comprise the West Central Area; and California participants make up the Western Area. Canadian participants are assigned to either the East or West Central Areas. Coordinators for each of the areas are as follows:

Eastern Area.....	D. I. Hoel
East Central Area.....	J. P. Uihlein
West Central Area.....	J. B. Baker
Western Area.....	T. Wusz

The area coordinators will contact their area participants periodically regarding the progress of the survey. To expedite this, it is suggested that participants send copies of all correspondence concerning the survey to the area coordinators. This program outlines the survey in broad terms. If more detailed information is desired, it is suggested that the participant contact his area coordinator.

III. VEHICLES

A total of approximately 450 vehicles will be tested in the 1989 Survey. Current experience indicates we can expect about 14 full participants and 5 partial participants. The 450 vehicle total will be divided into two groups: (1) the statistical group, sampled in proportion to US car model production or import volume, and (2) select models of special interest. Approximately 20 of each of these select models are assigned to be tested in order to provide an estimate of the octane requirement distribution of each model. Some of these 20 vehicles will be those already included in the statistical group, and the remainder will be additional vehicles added to the program.

The desired number of vehicles to be tested in each category is as follows:

Statistical Group	370
Additional Select Model Group	<u>80</u>
Total	450

A detailed breakdown of the specific models and the number of each model to be tested will be circulated to the participants in May 1989 after an estimate of vehicle model production has been obtained. Design specifications for select models to be tested in the 1989 Survey are shown in Table D-1. Selection of these vehicles has been based on new or modified design characteristics that might have a significant effect on octane number requirements and high sales volume which allows individual treatment without additional testing.

Wherever possible, specific vehicle assignments to individual participating laboratories will be made in a pattern which tends to minimize data bias. This will be accomplished by apportioning cars of a given model among the four geographical areas, and subsequently among the laboratories within each area, in order to minimize the effect of non-random factors on the results of the Survey.

IV. FUELS

A. Full-Boiling Range Reference Fuels

Two full-boiling range reference fuel series will be used to define the vehicle octane number requirements. The two series will be unleaded and of varying sensitivity. One series will be comparable to the average sensitivity of unleaded commercial fuels (FBRU); the other series (FBRSU) will be a minimum of two numbers higher in sensitivity than the FBRU fuels. The Research octane number (RON) range for both fuel series is 79 to 104.

These fuels will be blended in increments of two RON up to 84, and one RON above 84 from three base fuels for each series. The base fuels are compounded from normal refinery gasoline components. Limiting specifications for each base fuel for both series are shown in Table D-2. These specifications apply to both the 1989 and 1990 Surveys. Supplier inspection data will be shown in Table D-3.

Research and Motor ratings will be determined for incremental blends of each fuel series by participants to provide data for establishment of blending curves. The average ratings and blending curves will appear in Tables D-4 and D-5.

B. Primary Reference Fuels

Blends of ASTM-grade isooctane and normal heptane will be prepared in two octane number increments from 76 to 82, and one octane number increments from 82 to 100.

C. Tank Gasoline

Research and Motor octane ratings will be obtained only on gasoline samples from the tank of vehicles with owner questionnaire (Attachment 1). Owner's Questionnaire should be obtained if:

- a) vehicle has a regular driver; and
- b) the ignition timing is within $\pm 2^\circ$ of the manufacturer's specifications.

V. TEST TECHNIQUE

All tests are to be conducted using the technique entitled, "Technique for Determination of Octane Number Requirements of Light-Duty Vehicles" (CRC Designation E-15-89). A copy of this technique is included as Attachment 2 to this program. Octane number requirement investigations are to be conducted in all vehicles under level road conditions. Any vehicle obviously in poor mechanical condition or with malfunctioning emission control devices should not be considered for test work. The vehicles must have a minimum of 6000 deposit miles (9656 km), and preferably be privately owned and operated. Data with less than 6000 miles will not be analyzed. Vehicles previously used for fuel road octane rating must not be employed in this survey.

Data should be reported on each vehicle tested, even though knock was not encountered on any of the fuels.

The order in which the fuels are to be tested is as follows:

- | | |
|---------------|----------|
| 1) Tank fuel; | 3) FBRU; |
| 2) FBRSU; | 4) PR. |

VI. DATA FORMS

The test results on each vehicle will be reported on data forms DFMF-11-89 and DFMF-19-89. For knock sensor-equipped vehicles, data forms should be filled out completely for maximum requirements and include vehicle information with minimum requirements. Copies of these forms will be mailed to all participants from the CRC office with instructions for their use. Additional instructions are included in the E-15-89 technique.

VII. REPORTING RESULTS

The original data forms for each vehicle tested should be submitted to William F. Biller, 68 Yorktown Road, East Brunswick, New Jersey 08816, as soon as possible, but not later than October 31, 1989.

TABLE D-1

DESIGN SPECIFICATIONS FOR 1989 SELECT MODELS

<u>Make & Model</u>	<u>Engine Displ. Liters</u>	<u>Configuration & No. of Cylinders</u>	<u>Fuel System</u>	<u>Comp. Ratio</u>	<u>BHP</u>	<u>Knock- Sensor</u>	<u>VIN Engine Code</u>	<u>Trans. Type</u>
GM								
Pontiac Grandam/ Oldsmobile Calais/ Buick Skylark	2.3	L-4	PFI	-	-	Yes	D	A-3
Oldsmobile Ciera/ Oldsmobile Calais/ Buick Century/ Buick Skylark	3.3	V-6	PFI	-	-	Yes	N	A-3 only for Calais/Skylark; A-3 and A-4 for Ciera/Century
Chevrolet Celebrity/ Pontiac 6000/ Pontiac Grand Prix/ Oldsmobile Ciera/ Oldsmobile Cutlass Supreme/ Buick Century/ Buick Regal	2.8	V-6	PFI	-	-	Yes	W	A-4 only for Grand Prix/Cutlass Supreme/Regal; A-3 and A-4 for Celebrity/6000/ Ciera/Century
Ford								
Probe	2.2	L-4	PFI	8.6	110	Yes	C	A-4
Thunderbird/Cougar	3.8	V-6	PFI	9.0	144	No	4	A-4
Chrysler								
Eagle Premier	3.0	V-6	PFI	9.3	110	Yes	--	A-4
Jeep	4.0	L-6	PFI	9.2	113	Yes	--	A-3

TABLE D-2

LIMITING SPECIFICATIONS FOR 1989 AND 1990 FULL-BOILING RANGE REFERENCE FUELS*

Inspection Tests	Unleaded Average Sensitivity Reference Fuels (FBRU)		Unleaded High Sensitivity Reference Fuels (FBRU)	
	RMFD 368	RMFD 369	RMFD 371	RMFD 372
ASTM Distillation, °F(°C)				
IBP, Min.	90	90	90	90
10% Evap.	115-158 (46.1- 70.0)	115-158	115-158	115-158
30% Evap.	150-190 (65.6- 87.8)	150-190	150-190	150-190
50% Evap.	195-250 (90.6-121.1)	195-250	195-250	195-250
70% Evap.	230-300 (110.0-146.9)	230-300	230-300	230-300
90% Evap.	285-374 (140.6-190.0)	285-374	285-374	285-374
End Point, Max.	437 (225)	437	437	437
RVP, psi (kPa)	7-9 (48-62)	7-9	7-9	7-9
Lead, g/gal (g/l)	<0.03	<0.03	<0.03	<0.03
Oxidation Stability, Minutes, Min.	1440	1440	1440	1440
Hydrocarbon Type, Vol. %				
Aromatics, Max.**	20	35	35	45
Olefins, Max.	20	15	35	25
Saturates	Remainder	Remainder	Remainder	Remainder
Octane Number				
Research	79 ± 1	91 ± 1	79 ± 1	91 ± 1
Sensitivity***	4.5 ± .5	8.5 ± .5	6.5 ± .5	10.5 ± .5
Minimum of two units sensitivity difference between corresponding fuels of each series.				
Color	Bronze	Green	Yellow	Deep Purple
		Red		Light Blue

Note: All fuels to contain minimum 5 PTB of a 100% active antioxidant and 10 PTB of corrosion inhibitor.
No manganese added.
Confirmation of product quality of fuel blends to be approved by a six-laboratory CRC Fuel Acceptance Panel prior to drumming.

- * To be compounded from normal refinery components. Oxygenates are not to be used as fuel components.
- ** 1% maximum Benzene or legal.
- *** Sensitivities are shown for the mean Research octane number.

TABLE D-3

SUPPLIER INSPECTION DATA FOR 1989 AND 1990 FULL-BOILING RANGE REFERENCE FUELS*

Inspection Tests	Unleaded Average Sensitivity Reference Fuels (FBRU)			Unleaded High Sensitivity Reference Fuels (FBRSU)		
	RMFD 368	RMFD 369	RMFD 370	RMFD 371	RMFD 372	RMFD 373
ASTM Distillation, °F						
IBP	91	90	90	90	97	91
10% Evap.	136	118	127	135	127	137
30% Evap.	176	152	182	174	158	190
50% Evap.	209	196	218	207	206	232
70% Evap.	233	250	248	247	280	256
90% Evap.	325	334	286	365	369	312
Endpoint	426	425	357	431	430	407
RVP, psi	7.1	8.3	7.5	8.1	7.1	7.5
Lead, g/gal	0.000	0.000	0.000	0.000	0.000	0.000
Oxidation Stability, Minutes	1440+	1440+	1440+	1440+	1440+	1440+
Hydrocarbon Type, Vol. %						
Aromatics	19.6	25.7	46.4	23.7	31.5	50.4
Olefins	10.0	15.0	3.2	29.9	21.5	3.8
Saturates	70.4	59.3	50.4	46.4	47.0	45.8
Octane Number						
Research	79.3	90.6	104.2	79.5	91.6	104.0
Sensitivity	4.7	8.3	11.5	6.6	10.5	13.5
Color	Bronze	Green	Red	Yellow	Purple	Light Blue

TABLE D-4

COMPOSITIONS AND OCTANE NUMBERS
FOR CRC 1989-90 FBRU REFERENCE FUELS

Research Octane Number	Volume Percent			Motor Octane Number	Sensitivity
	RMFD 368-89	RMFD 369-89	RMFD 370-89		
80	91.5	8.5	--	75.2	4.8
82	75.0	25.0	--	76.7	5.3
84	59.0	41.0	--	78.1	5.9
85	51.0	49.0	--	78.7	6.3
86	42.5	57.5	--	79.4	6.6
87	34.0	66.0	--	80.0	7.0
88	25.0	75.0	--	80.7	7.3
89	15.5	84.5	--	81.3	7.7
90	5.0	95.0	--	81.9	8.1
91	--	96.5	3.5	82.6	8.4
92	--	90.0	10.0	83.3	8.7
93	--	83.5	16.5	83.9	9.1
94	--	76.5	23.5	84.5	9.5
95	--	69.5	30.5	85.2	9.8
96	--	62.5	37.5	85.9	10.1
97	--	55.0	45.0	86.6	10.4
98	--	48.0	52.0	87.3	10.7
99	--	40.5	59.5	88.0	11.0
100	--	32.5	67.5	88.8	11.2
101	--	24.0	76.0	89.6	11.4
102	--	16.0	84.0	90.4	11.6
103	--	8.0	92.0	91.4	11.6
104	--	0.0	100.0	92.6	11.4

TABLE D-5
COMPOSITIONS AND OCTANE NUMBERS
FOR CRC 1989-90 FERSU REFERENCE FUELS

Research Octane Number	Volume Percent			Motor Octane Number	Sensitivity
	RMFD 371-89	RMFD 372-89	RMFD 373-89		
80	96.5	3.5	--	73.1	6.9
82	80.5	19.5	--	74.6	7.4
84	65.5	34.5	--	75.9	8.1
85	58.0	42.0	--	76.5	8.5
86	49.5	50.5	--	77.2	8.8
87	41.0	59.0	--	77.9	9.1
88	32.5	67.5	--	78.6	9.4
89	24.5	75.5	--	79.3	9.7
90	15.5	84.5	--	80.0	10.0
91	6.5	93.5	--	80.6	10.4
92	--	98.0	2.0	81.2	10.8
93	--	90.5	9.5	81.9	11.1
94	--	83.5	16.5	82.6	11.4
95	--	75.5	24.5	83.3	11.7
96	--	67.5	32.5	84.0	12.0
97	--	59.5	40.5	84.7	12.3
98	--	51.0	49.0	85.5	12.5
99	--	42.5	57.5	86.3	12.7
100	--	34.0	66.0	87.1	12.9
101	--	25.0	75.0	87.9	13.1
102	--	15.5	84.5	88.8	13.2
103	--	5.0	95.0	89.8	13.2
103.5	--	0.0	100.0	90.3	13.2

CRC OCTANE NUMBER REQUIREMENT SURVEY

OWNER'S QUESTIONNAIRE

OWNER:

Your vehicle is being tested for fuel octane number requirements by a Coordinating Research Council activity. To help analyze the data, we would like the person who has recently been driving the vehicle to answer the following questions:

1. What grade of unleaded fuel was purchased the last two times?

☐

Regular

☐

Mid-Grade

☐

Premium

2. Has any engine knock (ping) been encountered with the fuel that is now in the tank?

☐

Yes

☐

No

3. Did you consider the knock (ping) objectionable?

☐

Yes

☐

No

Vehicle Make _____ License No. _____

Vehicle Identification No. _____

Company Testing Vehicle _____

**TECHNIQUE FOR DETERMINATION
OF OCTANE NUMBER REQUIREMENTS
OF LIGHT-DUTY VEHICLES**

(CRC Designation E-15-89)

June 1989

**TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS
OF LIGHT-DUTY VEHICLES**

(CRC Designation E-15-89 - Including Appendix A)

A. GENERAL

The technique provides for the determination of maximum octane number requirements (and minimum octane number requirements for vehicles equipped with knock sensors), whether at maximum-throttle or part-throttle, of a vehicle in terms of borderline spark knock on two series of full-boiling range reference fuels as well as on primary reference fuels. If the maximum requirement is at maximum-throttle, then part-throttle requirements are investigated with only FBRU fuels of up to, and including, four octane numbers lower than the maximum requirement.

Knock intensity on tank fuel will be measured.

B. DEFINITION OF TERMS

The following definitions of knock, approved by the CLR and CFR Committees on June 8, 1954, have been rephrased for clarification and adaptability to current technology by the Survey Steering Panel.

1. Spark Knock:

Spark knock is the noise associated with the autoignition* of a portion of the fuel-air mixture ahead of the advancing flame front. It is recurrent and repeatable in terms of audibility and fuel octane quality. This includes knock occurring when going from road load to other operating conditions (e.g., tip-in, etc.).

* Autoignition: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel-air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for autoignition.

a. Maximum-Throttle

The throttle is depressed and held at either full-throttle or the widest throttle position that does not cause the transmission to downshift (detent) throughout the acceleration in each of the required test gears listed in D.3.d.(1)(a). The detent manifold vacuum/pressure obtainable on a given model is determined by the transmission characteristics. For manual transmissions, the throttle is depressed fully throughout the acceleration.

b. Part-Throttle

The throttle is depressed and regulated throughout the acceleration to maintain a desired, constant critical manifold vacuum/pressure as defined in D.3.d.(1)(d).

C. VEHICLE PREPARATION

The following vehicle preparation steps should be completed before any octane tests are run. Detailed procedures for each adjustment can be found in the manufacturers' shop manuals.

1. Record vehicle identification number and emission control type, Federal, Altitude, California, or Fifty-State. Fill in headings on both sheets of data form DFMF-11-89. Ford emission calibration numbers are to be recorded.
2. Inspect all vacuum lines and air pump hoses for appropriate connections. Also, check to see if PCV valve, spark advance vacuum delay controls, EGR valve, knock sensors, and heated inlet air mechanism are functioning. Engine must be warmed up for these checks.
3. Check engine idle speed and observe anti-dieseling solenoid operation. Adjust to within manufacturers' recommended specifications as specified on the underhood decal.
4. Observe and record basic spark timing at recommended engine speed. Adjust to within manufacturers' recommended setting as specified on the underhood decal.
5. Crankcase oil, radiator coolant, automatic transmission fluid, and battery fluid levels shall be maintained as recommended by the manufacturer.

6. A calibrated tachometer graduated in 100 rpm (or smaller) increments shall be used.
7. One calibrated vacuum gage, graduated in one-half inch of mercury (or smaller) increments and capable of indicating vacuum from 0-24 inches of mercury (0-81 kPa) shall be connected to the intake manifold. For vehicles with turbochargers, a compound vacuum/pressure gage should be used; the pressure side of the gage should be capable of indicating pressures up to 15 psig (103 kPa).
8. An auxiliary fuel system shall be provided to supply test fuels to the engine. Caution shall be taken to avoid placing auxiliary fuel lines in locations which promote vapor lock. If vehicles with carbureted engines have tank return fuel lines, this return line should be blocked off. Disconnect fuel tank vent line at evaporation control system canister. Instructions for the auxiliary fuel system used with fuel injection are given in Appendix A.
9. For vehicles with owner questionnaire completed, a sample of the tank gasoline shall be withdrawn for determination of Research and Motor method octane number ratings. If insufficient fuel is available, omit this step and obtain tank fuel observations as described in Item D.3.d.(2).

D. TEST PROCEDURE

1. Engine Warm-Up

- a. To stabilize engine temperatures, a minimum of ten miles of warm-up is required. The test vehicle should be operated at 55-70 mph (88-113 kph) in top gear with a minimum of full-throttle operation.
- b. During the warm-up period, the general mechanical condition of the vehicle should be checked to insure satisfactory and safe operation during test work.

2. Fuel Changeover

To eliminate contamination of the new fuel with residual amounts of the previous fuel, fuel-injected systems should be flushed once with new fuel and carburetted systems should be flushed twice. Fuel handling

procedures for vehicles equipped with fuel injection systems are explained in Appendix A.

After fuel changeover, make one maximum-throttle acceleration before beginning Vehicle Rating Procedure.

3. Details of Observations

a. Operating Conditions

All octane number requirements will be determined under level road acceleration conditions.

Tests will be conducted on moderately dry days, preferably at ambient temperatures between 60°F (15.5°C) and 90°F (32.2°C). Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F (21°C) air temperature and 50 grains of water per pound (7.14 gm/kg) of dry air whenever possible.

Air-conditioned vehicles will be tested with air conditioner turned ON. (Normal setting, comfortable temperature, low fan. Air conditioner will be ON at all times.

b. Order of Fuel Testing

- | | |
|----------|------------|
| 1) Tank | 3) FBRU |
| 2) FBRSU | 4) Primary |

c. Determination of Knock Intensity

Maximum octane requirements will be established by evaluating the occurrence of knock in terms of knock intensity: "N" for none, "B" for borderline, and "A" for above borderline. Establishment of representative knock intensity for a given fuel will be accomplished with a maximum of three (3) rated accelerations. Coast-down time between the end of one acceleration and the beginning of the next should be approximately twenty (20) seconds. As defined below, the first two duplicating accelerations are sufficient with "N" and "B" intensity.

<u>Acceleration Number</u>			<u>Representative</u> <u>Rating</u>
<u>1</u>	<u>2</u>	<u>3</u>	
N	N	-	N
N	B	N	N
N	B	B	B
B	N	B	B
B	B	-	B
B	A	-	A
A	-	-	A

All accelerations will be discontinued when "A" knock intensity is experienced, and testing continued with a higher octane number fuel in that series. If "A" knock is experienced at initiation of acceleration, as limited by transmission characteristics, this speed will be considered the speed of maximum knock. Otherwise, the midpoint between knock-in and knock-out will be considered the speed of maximum knock. When establishing knock-in and knock-out, back off on the throttle between points to eliminate "A" knock.

Minimum octane number requirements for vehicles equipped with knock sensors will be established in a similar manner except that when "A" knock intensity is encountered, subsequent accelerations will be made with a given fuel until duplicate "A" ratings are obtained as measured above.

d. Determination of Octane Requirements

Tests should be run to 70 mph (113 kph). If required to terminate at lower speed, termination speed should be noted on data sheet.

(1) Vehicle Operating Procedure

Accelerations will be run up to 70 mph; however, engine speed should not exceed 4,000 rpm or 750 rpm over peak torque as defined in Automotive News, whichever is higher.

(a) Establishment of Automatic Transmission Characteristics

Determine the minimum obtainable road speed, and obtain the transmission downshift characteristics of engine rpm and manifold vacuum/pressure from minimum speed at 25, 35, 45, 55, and 65 mph (40, 56, 72, 88 and 104 kph) as applicable (as obtainable in each gear), by movement of the throttle through the detent, i.e., downshift, throttle position. These characteristics are to be determined for each of the gears specified in the table below. For transmissions with converter clutches, determine the minimum road speed for clutch application. At this initial speed and at 10 mph (16 kph), increments up to about 60 mph (97 kph) determine minimum vacuums (pressures) for application. Record all road speed/engine rpm/vacuum or pressure measurements from above on data sheet.

Do not use brakes, turn signals or hazard flashers during accelerations as these may affect electronic engine controls.

The selection of required test gears, and test gear/ converter clutch combinations (if applicable) for various types of transmissions are shown in Table T-I. Transmissions not explicitly described should be tested in a manner as similar as possible to those listed. Automatic transmission vehicles should be tested with the gear selector in the top forward gear, normally found to the right or below neutral; top gear should not be locked out. Transmissions equipped with electronic overdrive should be operated in overdrive. Transmissions equipped with power/normal selection should be operated in the normal position.

TABLE T-I

TRANSMISSION GEAR SELECTIONAUTOMATICS

Check for critical condition:

Place the selector in the top forward gear, normally found to the right or below neutral; top gear should not be locked out. Transmissions equipped with electronic overdrive should be operated in overdrive. Transmissions equipped with power/normal selection should be operated in the normal position.

<u>Type</u>	<u>Gears to be Tested</u>
GM 4-speed	4th gear, converter clutch engaged 3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
GM 3-speed/ Chrysler	3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged
3-speed with converter clutch	2nd gear, converter clutch disengaged
Ford Front-Wheel Drive:	
4-speed	4th gear, converter clutch engaged
overdrive	4th gear, converter clutch disengaged 3rd gear, converter clutch engaged, if applicable 3rd gear, converter clutch disengaged 2nd gear
Ford Rear-Wheel Drive:	
4-speed	4th gear, converter clutch engaged, if applicable
overdrive	4th gear, converter clutch disengaged 3rd gear, converter clutch engaged, if applicable 3rd gear, converter clutch disengaged 2nd gear
Other 3-speed	3rd gear 2nd gear

MANUALS

5-speed	4th and 3rd gears
4-speed	4th and 3rd gears
3-speed	3rd and 2nd gears

(b) Maximum-Throttle Accelerations - Automatic Transmissions

For maximum-throttle accelerations in each of the gears and gear/converter clutch combinations specified above, accelerate at the detent/application condition according to the speed versus vacuum/pressure profiles determined in (a) from the minimum obtainable speed to maximum test speed. If the transmission downshifts, abort and start the acceleration again. Start with the highest gear or gear/clutch combination and proceed in descending order.

(c) Maximum-Throttle Accelerations - Manual Transmissions

Select the highest gear as specified in the table above. Start at the lowest speed from which the vehicle will accelerate smoothly, but not less than 25 mph (40 kph) and depress the throttle fully throughout the acceleration up to maximum test speed.

Select the next lower gear specified in the table above and accelerate at full throttle from the minimum speed from which the vehicle will accelerate smoothly up to maximum test speed.

(d) Part-Throttle Accelerations for Both Automatic and Manual Transmissions

Select the highest gear as specified in Table T-I for manual transmissions. Select the two highest gears as specified in Table T-I for automatic transmissions. For example, on a four-speed automatic transmission, check both fourth locked and unlocked and third locked and unlocked; on a three-speed automatic transmission, check third locked and unlocked and second. For automatic transmissions with converter clutches use the highest gear up to the minimum vehicle speed at which the converter clutch will engage, and the highest gear/converter clutch combination above this minimum speed, to obtain the critical part-throttle vacuum or pressure. To obtain the critical part-throttle vacuum/pressure, first operate at constant speed road load, at 25, 35, 45, 55, and 65 mph (40, 56, 72, 88, and 105 kph) incremental speeds if obtainable in the specified gear. This is called "fanning". At each speed, move the throttle in approximately 3 seconds from the road-load vacuum to the positions described below for naturally aspirated and turbocharged engines:

1. for naturally aspirated vehicles, one inch Hg (3.34 kPa) above:
 - a. full-throttle vacuum for manual transmissions;
 - b. detent vacuum for automatic transmissions without converter clutches;
 - c. the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.
2. for turbocharged vehicles, one inch Hg or 0.5 psig (3.34 kPa) below:
 - a. full-throttle maximum boost for manual transmissions;
 - b. maximum boost at detent for automatic transmissions without converter clutches;
 - c. maximum boost or 0.5 psig (3.34 kPa) above the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

Use of vehicle brakes must be avoided.

If knocking occurs within any of the vacuum/pressure ranges, establish the manifold vacuum/pressure which gives maximum knock intensity on each fuel series. This is the critical vacuum/pressure to be used for all subsequent constant-vacuum/pressure part-throttle accelerations from the minimum obtainable speed in the test gear to 70 mph (113 kph), or until the vehicle ceases to accelerate. A critical vacuum/pressure should be determined for each reference fuel series.

If knock is encountered during the fanning procedure but during the constant-vacuum/pressure part-throttle accelerations, it should be recorded as tip-in.

(2) Tank Fuel Observations

Investigate for maximum-throttle and part-throttle knock as detailed in Item 3d(1), only if a customer questionnaire has been completed. Define maximum knock intensity as per Item 3c. Record maximum knock intensity, speed of maximum knock intensity, and manifold vacuum/pressure at each operating condition. Tank fuel rating should be terminated if a knock is encountered at any time.

(3) Vehicle Rating Procedure

All initial accelerations should be started from minimum obtainable gear/converter clutch combination at constant level road-load conditions. Knock rating should be performed while in a normal upright seated position with floor mats in place.

- Step 1 - After Tank Fuel Observations, use a fuel estimated to give borderline knock in a given fuel series and investigate for incidence of knock under conditions as described in D.3.d.(1)(b) above, and D.3.d.(1)(c) above, whichever is applicable.
- Step 2 - If no knock occurs, go to a lower octane number blend in that series and repeat Step 1.
- Step 3 - If knock occurs at one or more of the operating conditions in Step 1, continue investigation at the critical condition(s) with higher octane blends until highest octane fuel giving knock is determined within one octane number or one blend (the next higher fuel giving no knock). Record maximum knock intensity on all fuels. Record speed of maximum knock intensity and manifold vacuum/pressure on highest octane fuel that knocks.
- Step 4 - Using the highest octane blend that knocked in Step 3, investigate for incidence of part-throttle knock as described in D.3.d.(1)(d). If knock occurs, continue investigation at critical vacuum/pressure until requirement is defined. Record maximum knock intensity and critical manifold vacuum/pressure on all fuels, and speed of maximum knock intensity on highest octane fuel that knocks.
- Step 5 - With FBRU fuel only, if no knock occurs in Step 4, go to a lower octane number blend and repeat Step 4. Discontinue part-throttle investigation if knock is not observed with a fuel four octane numbers lower than the highest borderline knock determined in Step 3.
- Step 6 - With FBRU fuel only, for knock-sensor equipped vehicles after determination of maximum requirement, continue with lower octane blends until the lowest octane fuel giving borderline knock is determined (the next lowest fuel giving above borderline knock).

The rating procedure is given in arrow diagram form on page 26 for maximum requirement, and on page 27 for minimum requirement, for knock sensor-equipped cars.

E. INTERPRETATION OF DATA

The data will be recorded on data sheets DFMF-11-89 and DFMF-19-89. Data Form DFMF-11-89 has provisions for recording both the maximum and minimum requirements of knock-sensor equipped vehicles on the same sheet. Additional data sheets for recording run data may be appended to DFMF-11-89 as needed. Octane requirements for all reference fuels shall be determined as follows:

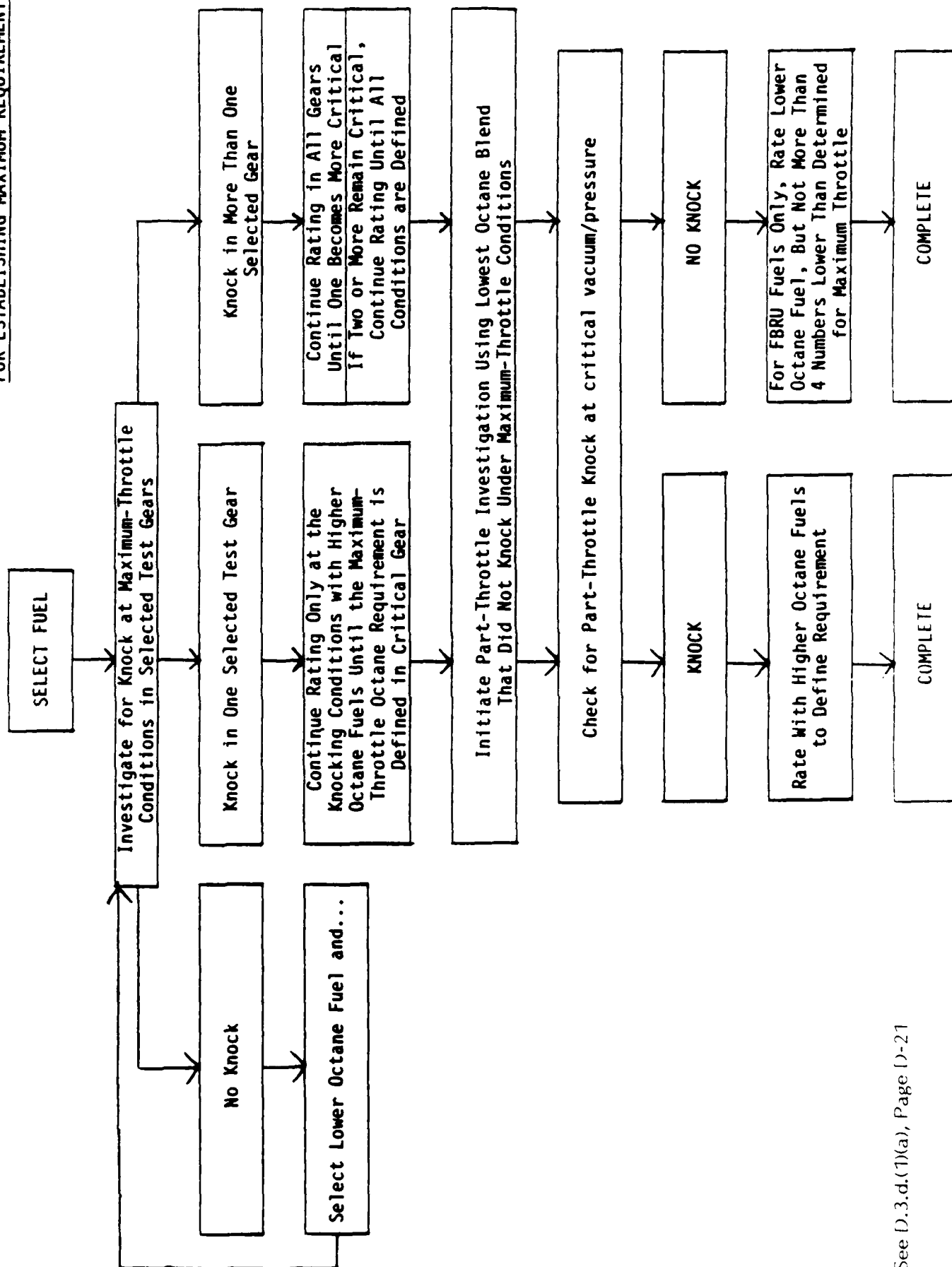
1. If the knock intensity of the highest reference fuel giving knock is borderline, the requirement shall be reported as the octane number of that fuel.
2. If the knock intensity of the highest fuel giving knock is above borderline, the requirement shall be reported as the mid-point between the octane number of the fuel giving knock and that of the next higher fuel.
3. If the octane requirement in high gear is equal to the requirement in a lower gear, report the highest gear data.
4. For part-throttle requirements, report the data from the critical manifold vacuum/pressure observations.
5. For knock-sensor equipped vehicles, report the highest and lowest fuel giving borderline knock. If the knock intensity with the lowest fuel giving knock is above borderline and the next highest fuel is no knock, then the minimum requirement is the mid-point between the two.

Record data on all fuels tested, even though knock was not encountered. The octane number requirement summary block on the first sheet of DFMF-11-89 provides space for both the maximum and the minimum requirements of knock-sensor equipped vehicles. When transferring data to the summary block, record maximum-throttle and part-throttle octane number requirements in the appropriate blocks. The higher of the two will be selected by the computer as the maximum octane number requirement. If both maximum-throttle and part-throttle requirements are equal, then the computer will select the part-throttle requirement as the maximum octane number requirement. Use proper letter designation (see footnotes on data sheet) to designate: (1) requirements outside of the reference fuel limits; (2) FBRU part-throttle requirement more than four numbers below maximum; and (3) all other cases for which the octane number requirement has not been determined. Note that in the case of a converter-clutch equipped vehicle, test gear numbers should indicate whether the converter clutch was locked or unlocked. Note also that in the case of turbo-equipped vehicles, a manifold pressure above atmospheric is indicated as a negative number in units of psig.

It is important that the vehicle identification number (VIN) of each vehicle tested be recorded on all data sheets to provide a means of cross-indexing.

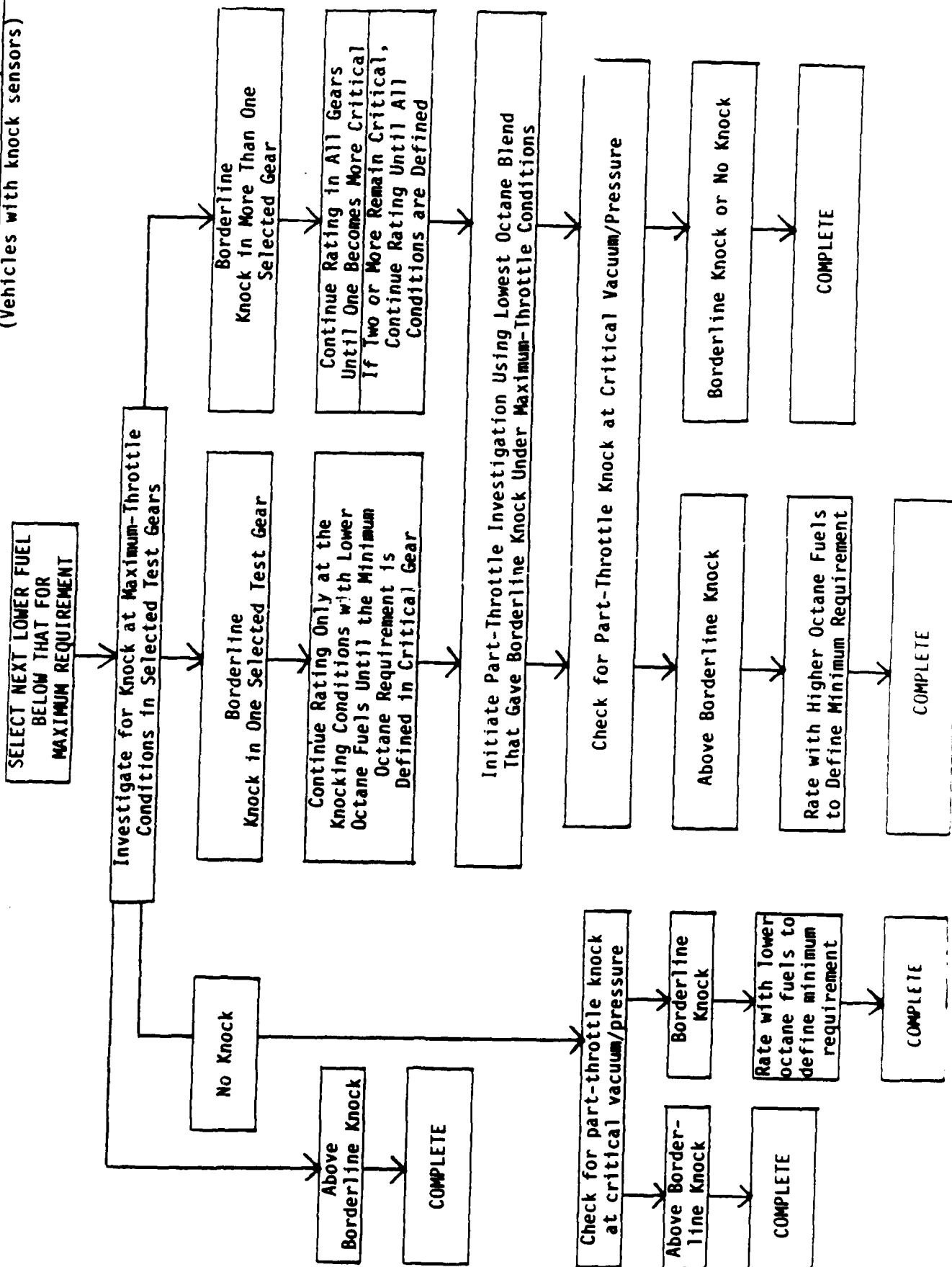
FOR ESTABLISHING MAXIMUM REQUIREMENTS

D-27



FOR ESTABLISHING MINIMUM REQUIREMENTS
(Vehicles with knock sensors)

FOR FBW FUELS ONLY:



APPENDIX A
to the
CRC E-15-89 TECHNIQUE

PROCEDURE FOR SETTING UP VEHICLES
WITH FUEL INJECTION

APPENDIX A

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE
FUELS: VEHICLES EQUIPPED WITH FUEL INJECTION

1. To run octane requirements on fuel-injected vehicles, it is necessary to install an external fuel supply line with auxiliary electric fuel pump from the reference fuel can to the vehicle fuel system and an external return line back to the reference fuel can.
2. There are two types of fuel injection systems: throttle-body injection, and multi-port injection. As a general description, the systems will contain the following parts:

Fuel Tank
 High- or Low-Pressure In-Tank Fuel Pump
 Fuel Supply Line(s)
 In-Line Filter(s)
 High-Pressure Chassis-Mounted Pump (not required for all vehicles)
 Fuel Rail (to supply multiple injectors on port fuel injection)
 Fuel-Pressure Regulator (integral on throttle-body, on fuel rail with multi-port injection; controls pressure at the injectors).

Depending upon the vehicle's specific fuel system and/or tester's preference, installation of the required auxiliary equipment can be accomplished in a variety of ways.

3. The auxiliary fuel supply line may be installed anywhere between the fuel tank and the inlet at the throttle-body or fuel rail. The auxiliary fuel return line may be installed anywhere between the fuel-pressure regulator outlet and the tank.
4. After connections have been broken, the fuel lines on the fuel tank side should be capped and the vehicle's pump(s) disconnected or disarmed. Alternately, an additional fuel line can be looped between the supply and return lines and the vehicle pump(s) allowed to circulate fuel directly back to the fuel tank. Caution should be exercised if this alternate technique is used. A high pressure will build up in the tank due to the large amount of vapors generated.

The auxiliary fuel supply system must be capable of supplying fuel at a pressure slightly higher than the maximum fuel pressure required (at wide-open-throttle on normally aspirated engines or at maximum manifold boost pressure on turbocharged or supercharged engines) by the particular vehicle being tested. This is to overcome any line losses and thus insure accurate results. This may be accomplished by using an adjustable high-pressure pump, or by using a low-pressure pump to supply fuel to the chassis-mounted high-pressure pump if the testing lab chooses to keep it in the system. A fuel filter may be required between the auxil

ary pump and the reference fuel can to protect the pump. The fuel return line should be connected to a tee at the auxiliary pump inlet. The reference fuel can should be vented to outside the vehicle.

It is possible to use three-way valves in the fuel line between the fuel pump and the fuel tank and between the return line and the fuel tank. When used, the operator must change the return line valve to the auxiliary fuel system while the engine is shut down, to avoid building up excessive pressure in the return line which could damage both the fuel-pressure regulator and injection pump.

5. When changing from one reference fuel can to another, the following steps should be followed:
 - a. Disconnect fuel inlet line from reference fuel can and run engine a short time; do not run out of fuel since this will introduce air into the fuel injection system and excessive cranking will be required to restart the engine.
 - b. With the engine shut off, disconnect the fuel return line from the auxiliary pump inlet and connect it to a sloop can. Connect the fuel supply line to the new reference fuel can and run the engine long enough to purge the old reference fuel from the system. The time required will be dependent upon length of added fuel lines, but it will be approximately 30-60 seconds; approximately 1-2 quarts of fuel will be discarded to sloop.
 - c. With the engine off, connect the fuel return line to the auxiliary pump inlet. The vehicle is then ready to be tested.
 - d. When changing to the next reference fuel, it is necessary to repeat Steps a, b, and c.

CAUTION

Fuel supply lines remain pressurized long after the engine is shut off; be sure to relieve the pressure before disconnecting fuel lines.

Use fuel lines designed for high pressure. They should be rated for at least 250 psi working pressure and for 1000 psi burst pressure.

-
- (1) It is critical to circulate an adequate amount of fuel to the sloop can to prevent reference fuel contamination.

CAUTION - (Continued)

The engine and auxiliary fuel pumps should be shut off while changing from auxiliary to tank fuels.

Purging procedures should be followed strictly to preclude reference fuel contamination or discarding more fuel than is required.

Vehicle pump(s) may be disarmed by use of the inertia switch if so equipped. The voltage supplied to the inertia switch may then be used to power the auxiliary pump. When making these electrical connections, do not "splice" into the wire; instead, connect the wire lead to the connector.

Do not disarm the vehicle fuel pump by removing the fuse, since other accessories may be connected to the same circuit; instead, disconnect the fuel pump electrical lead.

Auxiliary fuel return lines should be of a size large enough to prevent a build-up of back pressure which could prevent the proper operation of the pressure regulator.

Use of the "rolled edge" style hose clamps, such as those made by Chrysler, is recommended to prevent damage to fuel lines.

Note: Diagnostic scanners should not be used while knock testing.

A P P E N D I X E

1989 OCTANE NUMBER REQUIREMENT SURVEY DATA

G L O S S A R Y

(For Appendix E Only)

Emission Certification (EMCT):	A	Altitude
	C	California
	F	Federal
	E	Everything
Knock Sensor (KS):	H	Maximum Requirement
	L	Minimum-Borderline Requirement
	N	No
Air Conditioner (AIR):	Y	Yes
	N	No
Spark Advance:	+	Before Top Center
	-	After Top Center
Test Fuel:	1	Tank Fuel
	2	FBRSU
	3	FBRU
	4	PR
Octane Number Requirements: (expressed as Research ON)	L	Less than lowest available ON for FBRU and FBRSU fuels and less than 76 for PR fuels
	H	Higher than highest available ON for FBRU and FBRSU fuels and higher than 100 ON for PR fuels
	F	Part-throttle requirement greater than four numbers below maximum-throttle requirement
Throttle (THR):	M	Maximum
	P	Part
Gear:	1-5	Manual and Automatic
	U	Not tested in lockup (torque converter not engaged)
	L	Tested in lockup (torque converter engaged)
Manifold Vacuum (VAC):		Inches Hg, positive for vacuum, negative (-) for pressure
Owner-Reported Knock (OWKNK):	Y	Yes, Not Objectionable
	O	Objectionable
	N	No
Rater-Reported Noise Intensity (KNINT)	N	None
	B	Borderline
	A	Above Borderline

E-3

1994 ORO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PARTIAL-THROTTLE				RATES					
SPARK ADVANCE																									
E										E		E				E				O					
M										M		M				M				N					
S										S		S				S				N					
C										C		C				C				C					
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E-4

1992 OPG OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				DEPTH-THROTTLE				RATED					

E-5

1993 OPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION					
												MAXIMUM					PART-THROTTLE					DATED					

E-6

1989 OPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PART-THROTTLE				RATED					

E-7

1999 GPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION					
												MAXIMUM					PART-THROTTLE					PUMP					
SPARK ADVANCE																											
E																											
M																											
C																											
I																											
A																											
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E-8

1989 CPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					PART-THROTTLE					PUMP									

'333 CPC OCTAVE NUMBER REQUIREMENT' E.R.E.

[illegible]

E-10

1999 OPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION					
												MAXIMUM					PART-THROTTLE					RATED					
SPARK ADVANCE																											
E										F		G					H					I					
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1989 CPO CC#46 NUMBER REQUIREMENT 3,2,1.

[illegible]

THE CPC COMPANY LIMITED, HONG KONG

[illegible]

E-13

1992 GPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
										MAXIMUM				PART-THROTTLE				RATED							
SPARK ADVANCE																									

E-14

1999 GPO OCTANE NUMBER REQUIREMENT SUPPLY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					DEPTH-THROTTLE					FILTER									
SPARK ADVANCE																															
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E-15

389 390 OCTANE NUMBER REQUIREMENT SUR I

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MINIMUM					REPT-HATCHOLE					RATER									

E-16

1999 OPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					PART-THROTTLE					PUMP									
SPARK ADVANCE																															

E-17

1988 CPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER	OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
											MAXIMUM					PART-THROTTLE					RATED									

E-18

1999 GPC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION				WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
						MAXIMUM				PART-THROTTLE				RATED					
OBS. NO.	MODEL CODE	E M	C T	SPARK ADVANCE		O D	O C	O C	O C	O C	O C	O C	O C	O C	O C	O C	O C	O C	O C
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17-10	001LW2*P00A3	C	N	3.0	4	10000	70	29.55	50	3				39.0	3L	1650	5.0		
														101.0	3L	1700	5.0		
														32.0	3L	1600	5.0		
18-01	001LW2*P00A3	F	-	3.0	4	12570	70	29.55	45	3	32.0	3L	2800	1.5	39.0	3L	1250	4.5	B M 3L 1900 1.5
														1	34.0	3L	2600	1.5	
														4	39.0	3L	2250	1.5	
														3	39.0	3L	2300	1.5	
														1	31.0	3L	2650	1.5	
														4	35.0	3L	2400	1.5	
19-05	001LW2*P00A3	F	-	3.0	4	8075	70	29.55	50	3	39.0	3L	2500	1.4	P			N 30.4 31.7 B M 20 2450 1.4	
														2	31.0	3L	2350	1.4	
														4	35.0	3L	2400	1.4	
														3	37.0	3L	2500	1.4	
														1	30.0	3L	2400	1.4	
														4	35.0	3L	2350	1.4	
20-01	001LW2*P00A3	F	-	3.0	4	9767	67	29.55	50	3	31.0	3L	3000	1.4	30.0	3L	3000	2.0	
														1	35.0	3L	3000	1.4	
														4	30.0	3L	3100	1.4	
														3	31.0	3L	3000	1.4	
														2					
														4					
21-14	001LW2*P00A3	F	-	3.0	4	11412	69	29.75	53	3	38.0	3L	1600	1.0	39.0	3L	2050	2.0	N
														1	39.0	3L	2500	0.5	
														4	31.0	3L	1050	0.4	
														3	35.0	3L	2750	0.5	
														2	35.0	3L	1600	0.5	
														4	31.0	3L	1050	0.4	
24-10	001LW2*P00A3	F	-	3.0	4	6994	67	29.60	55	3	37.0	3L	1600	0.9	37.0	3L	1300	2.0	
														1	37.0	3L	1750	0.9	
														4	37.0	3L	1750	0.9	
														3	34.0	3L	1750	0.9	
														1	35.0	3L	1600	0.9	
														4	34.0	3L	1600	0.9	

1999 CFC OCTANE NUMBER REQUIREMENT S.P.E.

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1993 GRC OCTANE NUMBER REQUIREMENT GUIDE

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION							
												MAXIMUM				PART-THROTTLE				RATED							
SPARK ADVANCE																											
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THE CPC OCTANE NUMBER REQUIREMENT 3.2.3.

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E-22

1989 CRC OCTANE NUMBER REQUIREMENT SUPPLY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					PART-TANK POTENTIAL					PATER									

E-23

1993 GPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
										MAXIMUM					PART-THROTTLE					RATER											
SPARK ADVANCE																															
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1999 GFC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PART-THROTTLE				RATED					
SPARK ADVANCE																									
E										F		G				H				I					
M										N		O				P				Q					
A										B		C				D				E					
AS										AS		ODOM				AMB				OCT NO					
P										POD		TST				MILES				TMP					
C.P.										BAROM		HUM				L				NO					
P										R		PDM				140				NO					
P										P		PDM				140				P					
P										P		PDM				140				P					
P										P		PDM				140				P					
P										P		PDM				140				P					
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1999 CRO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION					
												MINIMUM					PART-FULL TANK					RATED					

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1993 GRC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER				OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
														MAXIMUM				PART-THROTTLE				DATE					
SPARK ADVANCE																											
E										F				G				G				C					
M										O				E				E				N					
A										O				A				A				N					
C										O				O				O				C					
N										O				O				O				N					
O										O				O				O				O					
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1988 CPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					BYPASS/THROTTLE														

[illegible]

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1989 CPO OCTANE NUMBER REQUIREMENT GUIDE

VEHICLE DESCRIPTION										WEATHER	OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
											MAXIMUM					OCTANE NUMBER					RATED									

333 GPO NOTICE NUMBER REQUIREMENT 2, P. 3.

[illegible]

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1993 CPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
										MAXIMUM				PART-THROTTLE				RATED							
SPARK ADVANCE										E				G				O							
E										E				E				K							
M										E				E				N							
C										E				E				K							
N										E				E				N							
C										E				E				K							
N										E				E				N							
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'333 CRC OCTAVE NUMBER REQUIREMENT SURVEY'

[illegible]

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1999 CPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PART-THROTTLE				RATED					

1384 CRC OCTANE NUMBER REQUIREMENT S.P. 1/E.

[illegible]

'999 CFC OCTANE NUMBER REQUIREMENT SURVEY'

[illegible]

1983 CFC OCTANE NUMBER REQUIREMENT SUPPLY

[illegible]

1999 CRC OCTANE NUMBER REQUIREMENT SURVEY

[illegible]

THE CPC OCTANE NUMBER REQUIREMENT IS:

[illegible]

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1999 CPO OCTANE NUMBER REQUIREMENT DISPLAY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PART-THROTTLE				RATED					

E-40

1988 ORO OCTANE NUMBER REQUIREMENT SUPPLY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION									
												MAXIMUM					PART-THROTTLE					RATED									

E-41

1983 OFC DO-14E NUMBER REQUIREMENT SUFF.

[illegible]

THE 2000-2001 FISCAL YEAR RECEIVED 2001

[illegible]

E-43

1999 ORO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION				WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION			
						MAXIMUM				PARTIAL-BOTTLE				RATED			

F-44

1980 080 007441 4-METHYL-2-PHENYL-2-PYRIDINE CARBONITRILE. S. R. J.

[illegible]

E-45

1988 CFC OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION							
												MAXIMUM				PART-THROTTLE				RATED							
SPARK ADVANCE																											
E										E		E				E				O							
M										M		M				M				W							
A										A		A				A				N							
I										I		I				I				S							
AS										AS		AS				AS				N							
AS										AS		AS				AS				S							
OCCV										OCCV		OCCV				OCCV				N							
AMB										AMB		AMB				AMB				S							
MILES										MILES		MILES				MILES				N							
TMP										TMP		TMP				TMP				S							
BAROM										BAROM		BAROM				BAROM				N							
HUM										HUM		HUM				HUM				S							
E										E		E				E				O							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
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P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
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HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
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RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
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RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
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OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							
RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
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RPM										RPM		RPM				RPM				S							
HAC										HAC		HAC				HAC				N							
OCT										OCT		OCT				OCT				W							
P										P		P				P				N							

E-46

1389 OPC OCTANE NUMBER REQUIREMENT SURVE

VEHICLE DESCRIPTION										WEATHER	OCTANE NUMBER REQUIREMENT DATA										TANK FUEL INFORMATION					
											MAXIMUM					PART-THROTTLE					RATED					

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

[illegible]

1949 CPC OCTAVE NUMBER REQUIREMENT SURVEY

[illegible]

E-49

1999 CPO OCTANE NUMBER REQUIREMENT SURVEY

VEHICLE DESCRIPTION										WEATHER		OCTANE NUMBER REQUIREMENT DATA								TANK FUEL INFORMATION					
												MAXIMUM				PART-THROTTLE				DATE					
SPARK ADVANCE																									
E										F		G				H				I					
W										U		V				W				X					
A										C		D				E				F					
N										O		P				Q				R					
N										O		P				Q				R					
N										O		P				Q				R					
N										O		P				Q				R					
N										O		P				Q				R					
N										O		P				Q				R					
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N										O															

443 CRC OCTANE NUMBER REQUIREMENT SURVEY

[illegible]

1989 CPO OCTAVE NUMBER REQUIREMENT S.C.13

[illegible]

A P P E N D I X F

**PROCEDURES FOR CALCULATING AND PLOTTING
OCTANE NUMBER REQUIREMENT DISTRIBUTION DATA**

WEIGHTED VEHICLE POPULATIONS

Weighting factors for each model tested were proportioned to the productions and/or sales volumes developed from information supplied by U.S. vehicle manufacturers and from published information (Ward's Automotive Reports) for imports. The weighting factors of each vehicle model were divided by the number of vehicles tested within the model to calculate the individual vehicle weighting factor. The octane requirement for each vehicle were then arranged in increasing order. The percent of vehicles at each octane level is the summation of all vehicle weighting factors with octane requirements lower than that level, plus one-half the sum of the weighting factors at that level. The individual vehicle weighting factors are adjusted so that the summation of all vehicle weighting factors within the population of interest equals 100. Vehicle weighting factors for vehicles with octane requirements lower (L) than the lowest available fuel are assigned to beginning of the distribution while weighting factors for vehicles with octane requirements higher (H) than the highest test fuel are assigned above the highest test fuel octane level. For L and H octane requirements no octane value is used in the computation of octane satisfaction.

Octane satisfaction at population distribution points of interest is interpolated from the above distributions based on numeric octane data and an assumption of normal distribution between the two interpolation points.

DATA ROUND-OFF

The octane number requirements were rounded by the computer to one decimal place. All computations leading to the final rounded values were carried out at the full precision of the computer. In previous surveys the computer rounded requirement data to two decimal places. In preparing report tables the Analysis Panel rounded the computer decimal requirements to one decimal place.

In order to provide consistent treatment comparing 1988 and 1987 survey data, the 1987 data were recomputed and rounded to one decimal place by the computer. This can result in occasional small differences (e.g. ± 0.1) if a comparison is made using the data in the 1987 survey report.

SELECT CAR MODELS

For individual models, the octane number requirement distribution curves were plotted by the "Z" method as described in "Statistical Estimation of the Gasoline Octane Number Requirement of New Model Automobiles," C. S. Brinegar and R. R. Miller, Technometrics, Vol. 2, No. 1, February 1960.

The procedure is as follows:

For any vehicles having octane requirements lower (L) than the lowest octane number fuel available within a given fuel level, a number 0.5 Research/0.4 Motor lower was assigned. Similarly, for individual vehicles having octane requirements higher (H) than the highest octane fuel available within a given fuel series, a number 0.5 Research/0.4 Motor higher was assigned.

Using all observed and estimated octane number values, calculate the mean ($\bar{X}$) and the standard deviation (s) from the data for each model.

$$s = \left[\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2 \right]^{1/2}$$

Where X_i = Octane number requirement of i^{th} car of a given model

n = Number of cars of that model.

Estimate octane number requirements at the percentiles of interest from octane number requirement distribution data by

$$\text{O.N.} = \bar{X} + ks$$

Where k is selected from normal distribution tables.

Values of k used to calculate percentiles in this report are:

<u>Percentile</u>	<u>k</u>
5	-1.645
10	-1.282
20	-0.842
30	-0.524
40	-0.253
50	0
60	+0.253
70	+0.524
80	+0.842
90	+1.282
95	+1.645

A P P E N D I X G

**CONFIDENCE LIMITS OF
OCTANE NUMBER REQUIREMENT DISTRIBUTIONS**

CONFIDENCE LIMITS OF OCTANE NUMBER REQUIREMENT DISTRIBUTIONS

Octane number requirements of vehicles presented in this Survey are determined at the levels that satisfy certain percentages of specific vehicle populations. In many cases, the recorded octane number requirement is followed by a plus and minus limit, referred to as the confidence interval. These limits are expected to bound the true requirement of the population represented by the test vehicles 95 percent of the time in replicate testing of the same number of test vehicles.

At the 50 percent satisfaction level, the 95 percent confidence interval is calculated as follows:

$$CI = \pm ts/(n)^{1/2}$$

where t = Students t at the proper number of degrees of freedom*

s = Standard deviation, calculated directly from the data or estimated as the difference between the 84.16th and 50th percentiles (assuming normal distribution)

n = Number of vehicles in population.

At other satisfaction levels:

$$CI = \pm ts \sqrt{1/n + k^2/[2(n-1)]}$$

At the 90 percent satisfaction level, $k = 1.2817$. For other satisfaction levels, appropriate values for k may be found in the standard statistical tables.

<u>Degrees of Freedom**</u>	<u>t</u>	<u>Degrees of Freedom**</u>	<u>t</u>
1	12.706	18	2.101
2	4.393	19	2.093
3	3.182	20	2.086
4	2.776	21	2.080
5	2.571	22	2.074
6	2.447	23	2.069
7	2.365	24	2.064
8	2.306	25	2.060
9	2.262	26	2.056
10	2.228	27	2.052
11	2.201	28	2.048
12	2.179	29	2.045
13	2.160	30	2.042
14	2.145	40	2.021
15	2.131	60	2.000
16	2.120	120	1.980
17	2.110	∞	1.960

* Distribution of t for probability = 0.05.

** Degrees of Freedom = (n-1).

TABLE G-1

95% CONFIDENCE LIMITS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS

1988 Weighted Population Groups

Population	Fuel	No. Veh.	t	Standard Dev.		95% Confidence Limits					
				(R+M)/2		RON		MON		(R+M)/2	
				RON	MON	50%	90%	50%	90%	50%	90%
Total Vehicles											
Includes Knock Sensor Maximum (High-Borderline) Requirements	PR	372	1.966	3.75	3.75	0.38	0.52	0.38	0.52	0.38	0.52
	FBRU	391	1.966	3.93	2.55	0.39	0.53	0.25	0.34	0.32	0.43
	FBRSU	391	1.966	4.06	2.66	0.40	0.55	0.26	0.36	0.33	0.45
Includes Knock Sensor Minimum (Low-Borderline) Requirements	PR	308	1.968	3.60	3.60	0.40	0.55	0.40	0.55	0.40	0.55
	FBRU	375	1.966	3.60	2.35	0.37	0.49	0.24	0.32	0.30	0.40
	FBRSU	326	1.967	3.80	2.46	0.41	0.56	0.27	0.36	0.34	0.46
Total Cars											
Includes Knock Sensor Maximum (High-Borderline) Requirements	PR	298	1.968	3.53	3.53	0.40	0.54	0.40	0.54	0.40	0.54
	FBRU	313	1.968	4.08	2.64	0.45	0.61	0.29	0.40	0.37	0.50
	FBRSU	313	1.968	4.39	2.88	0.49	0.66	0.32	0.43	0.40	0.54
Includes Knock Sensor Minimum (Low-Borderline) Requirements	PR	254	1.969	3.44	3.44	0.43	0.57	0.43	0.57	0.43	0.57
	FBRU	302	1.968	3.78	2.46	0.43	0.58	0.28	0.38	0.35	0.48
	FBRSU	267	1.969	4.22	2.76	0.51	0.69	0.33	0.45	0.42	0.57
Total Trucks											
Includes Knock Sensor Maximum (High-Borderline) Requirements	PR	74	1.992	3.51	3.51	0.81	1.10	0.81	1.10	0.81	1.10
	FBRU	78	1.990	3.43	2.25	0.77	1.05	0.51	0.69	0.64	0.87
	FBRSU	78	1.990	3.52	2.34	0.79	1.07	0.53	0.71	0.66	0.89
Includes Knock Sensor Minimum (Low-Borderline) Requirements	PR	54	2.004	3.16	3.16	0.86	1.17	0.86	1.17	0.86	1.17
	FBRU	73	1.992	3.22	2.13	0.75	1.02	0.50	0.67	0.63	0.84
	FBRSU	59	2.000	2.95	1.89	0.77	1.04	0.49	0.67	0.63	0.85

TABLE G-1
(Continued)

95% CONFIDENCE LIMITS FOR MAXIMUM OCTANE NUMBER REQUIREMENTS

1989 Weighted Population Groups

Population	Fuel	No. Veh.	t	Standard Dev.		95% Confidence Limits					
				RON	MON	RON		MON		(R+M)/2	
						50%	90%	50%	90%	50%	90%
Total Knock-Sensor Vehicles											
Includes Knock Sensor Maximum (High-Borderline) Requirements	PR	171	1.974	4.42	4.42	4.42	0.67	0.90	0.67	0.90	0.90
	FBRU	179	1.973	4.30	2.77	3.53	0.63	0.86	0.41	0.55	0.70
	FBRSU	179	1.973	3.98	2.64	3.31	0.59	0.79	0.39	0.53	0.66
Includes Knock Sensor Minimum (Low-Borderline) Requirements	PR	107	1.981	3.93	3.93	3.93	0.75	1.02	0.75	1.02	1.02
	FBRU	163	1.975	3.71	2.42	3.06	0.57	0.78	0.37	0.51	0.64
	FBRSU	114	1.980	3.55	2.29	2.92	0.66	0.89	0.42	0.57	0.73

TABLE G 2

95% CONFIDENCE LIMITS FOR MAXIMUM (R+M)/2, RON, AND MON REQUIREMENTS

1989 Select Models

Model	Fuel	n	t	95% Confidence Limits, (R+M)/2			Std. Dev. (s)			95% Confidence Limits, RON			Std. Dev. (s)			95% Confidence Limits, MON		
				50% Satis.	90% Satis.	50% Satis.	50% Satis.	90% Satis.	50% Satis.	50% Satis.	90% Satis.	50% Satis.	90% Satis.	50% Satis.	90% Satis.	50% Satis.	90% Satis.	50% Satis.
C11B02*P30A4 (High Borderline)	PR	10	2.26	2.3	3.2	3.2	3.2	3.2	3.2	2.3	3.2	3.2	3.2	3.2	3.2	2.3	3.2	3.2
	FBRU	10	2.26	1.6	2.3	2.3	2.3	2.3	2.3	2.0	2.8	2.8	1.8	1.8	1.8	1.3	1.8	1.8
	FBRSU	10	2.26	1.4	2.0	2.0	2.0	2.0	2.0	1.7	2.4	2.4	1.6	1.6	1.6	1.2	1.6	1.6
C11B02*P30A44 (Low Borderline)	PR	8	2.36	2.9	4.0	4.0	4.0	4.0	4.0	2.9	4.0	4.0	3.4	3.4	3.4	2.9	4.0	4.0
	FBRU	10	2.26	1.5	2.1	2.1	2.1	2.1	2.1	1.9	2.6	2.6	1.7	1.7	1.7	1.2	1.7	1.7
	FBRSU	8	2.36	1.7	2.4	2.4	2.4	2.4	2.4	2.0	2.8	2.8	1.6	1.6	1.6	1.4	1.9	1.9
C210C*P22A4	PR	10	2.26	2.2	3.0	3.0	3.0	3.0	3.0	2.2	3.0	3.0	3.0	3.0	3.0	2.2	3.0	3.0
	FBRU	11	2.23	2.1	2.9	2.9	2.9	2.9	2.9	2.6	3.8	3.8	2.5	2.5	2.5	1.7	2.3	2.3
	FBRSU	11	2.23	2.1	2.9	2.9	2.9	2.9	2.9	2.4	3.8	3.8	2.5	2.5	2.5	1.7	2.3	2.3
C210A2*P38A4/ C21S42*P38A4/ C22S42*P38A4	PR	23	2.07	1.2	1.7	1.7	1.7	1.7	1.7	1.2	1.7	1.7	2.8	2.8	2.8	1.2	1.7	1.7
	FBRU	23	2.07	0.9	1.3	1.3	1.3	1.3	1.3	1.1	1.5	1.5	1.7	1.7	1.7	0.7	1.0	1.0
	FBRSU	23	2.07	1.0	1.4	1.4	1.4	1.4	1.4	1.2	1.7	1.7	1.9	1.9	1.9	0.8	1.1	1.1
C21PF2*P50A4/C22PF2*P50A4/ C24PF2*P50A4	PR	10	2.26	2.0	2.8	2.8	2.8	2.8	2.8	2.0	2.8	2.8	2.8	2.8	2.8	2.0	2.8	2.8
	FBRU	10	2.26	2.1	2.9	2.9	2.9	2.9	2.9	2.6	3.5	3.5	2.4	2.4	2.4	1.7	2.3	2.3
	FBRSU	10	2.26	2.3	3.2	3.2	3.2	3.2	3.2	2.7	3.7	3.7	2.6	2.6	2.6	1.9	2.6	2.6
C31A42*P25A3/C32A42*P25A3/ C31A42*P25A3	PR	11	2.23	1.7	2.3	2.3	2.3	2.3	2.3	1.7	2.3	2.3	2.5	2.5	2.5	1.7	2.3	2.3
	FBRU	11	2.23	1.9	2.7	2.7	2.7	2.7	2.7	2.3	3.2	3.2	3.5	3.5	3.5	1.5	2.1	2.1
	FBRSU	11	2.23	2.1	2.8	2.8	2.8	2.8	2.8	2.4	3.4	3.4	3.6	3.6	3.6	1.7	2.3	2.3
C31A42*P34A4/C32A42*P34A4/ C31A42*P34A4/C33A42*P34A4/ C34A42*P34A4/C34A42*P34A4	PR	24	2.07	1.2	1.6	1.6	1.6	1.6	1.6	1.2	1.6	1.6	2.8	2.8	2.8	1.2	1.6	1.6
	FBRU	24	2.07	1.3	1.8	1.8	1.8	1.8	1.8	1.6	2.2	2.2	2.4	2.4	2.4	1.0	1.4	1.4
	FBRSU	24	2.07	1.3	1.8	1.8	1.8	1.8	1.8	1.6	2.2	2.2	2.4	2.4	2.4	1.1	1.5	1.5

TABLE G 2
(Continued)

95% CONFIDENCE LIMITS FOR MAXIMUM (R+M)/2, RON, AND MON REQUIREMENTS

1989 Select Models

Model	Fuel	n	t	95% Confidence Limits, (R+M)/2			Std. Dev. (s)	95% Confidence Limits, RON			Std. Dev. (s)	95% Confidence Limits, MON		
				50% Satis.	90% Satis.	90% Satis.		50% Satis.	90% Satis.	90% Satis.		50% Satis.	90% Satis.	90% Satis.
C31J12*120A3/C31L12*120A3	PR	10	2.26	4.1	2.9	4.0	4.1	2.9	4.1	4.1	4.1	2.9	4.1	4.1
	FBRU	11	2.23	3.8	2.5	3.5	4.6	3.1	4.2	3.0	3.0	2.0	2.8	2.8
	FBRSU	11	2.23	4.3	2.9	3.9	5.0	3.4	4.6	3.5	3.5	2.4	3.2	3.2
C32ND4*P2A3/C33ND4*P23A3/ C34ND*P23A3 (High Borderline)	PR	12	2.20	6.1	3.9	5.4	6.1	3.9	5.4	6.1	6.1	3.9	5.4	5.4
	FBRU	12	2.20	4.4	2.8	3.9	5.3	3.4	4.6	3.6	3.6	2.3	3.1	3.1
	FBRSU	12	2.20	5.2	3.3	4.5	6.1	3.9	5.4	4.2	4.2	2.7	3.7	3.7
C32ND4*P23A3/C33ND4*P23A3/ C34ND4*P23A3 (Low Borderline)	PR	9	2.31	5.2	4.0	5.6	5.2	4.0	5.6	5.2	5.2	4.0	5.6	5.6
	FBRU	11	2.23	3.6	2.4	3.3	4.2	2.9	3.9	2.9	2.9	1.9	2.7	2.7
	FBRSU	9	2.31	4.1	3.1	4.3	4.9	3.7	5.2	3.3	3.3	2.5	3.5	3.5
C32WT2*P31A4/C33WT2*P31A4/ C34WT2*P31A4 (High Borderline)	PR	11	2.23	3.6	2.4	3.3	3.6	2.4	3.3	3.6	3.6	2.4	3.3	3.3
	FBRU	11	2.23	3.7	2.5	3.4	4.5	3.0	4.2	2.9	2.9	2.0	2.7	2.7
	FBRSU	11	2.23	4.1	2.7	3.8	4.8	3.2	4.4	3.4	3.4	2.3	3.1	3.1
C32WT2*P31A4/C33WT2*P31A4/ C34WT2*P31A4 (Low Borderline)	PR	9	2.31	4.5	3.5	4.8	4.5	3.5	4.8	4.5	4.5	3.5	4.8	4.8
	FBRU	11	2.23	3.8	2.6	3.5	4.6	3.1	4.3	3.0	3.0	2.0	2.8	2.8
	FBRSU	9	2.31	3.5	2.7	3.7	4.2	3.2	4.4	2.8	2.8	2.2	3.0	3.0
C34AN2*P33A4/C34AN2*P33A4 (High Borderline)	PR	11	2.23	2.4	2.3	3.1	3.4	2.3	3.1	3.4	3.4	2.3	3.1	3.1
	FBRU	12	2.20	3.6	2.3	3.2	4.4	2.8	3.8	2.9	2.9	1.8	2.5	2.5
	FBRSU	12	2.20	4.0	2.6	3.5	4.8	3.0	4.2	3.3	3.3	2.1	2.9	2.9
C34AN2*P33A4/C34AN2*P33A4 (Low Borderline)	PR	6	2.57	2.1	2.2	3.2	2.1	2.2	3.2	2.1	2.1	2.2	3.2	3.2
	FBRU	11	2.23	3.9	2.6	3.6	4.7	3.2	4.3	3.1	3.1	2.1	2.8	2.8
	FBRSU	7	2.45	2.9	2.7	3.7	3.5	3.2	4.5	2.3	2.3	2.1	3.0	3.0
C34WT2*P3BAA/C34WT2*P3BAA/ C34WT2*P3BAA (Low Borderline)	PR	15	2.14	5.1	2.9	4.0	5.3	2.9	4.0	5.3	5.3	2.9	4.0	4.0
	FBRU	15	2.14	4.1	2.3	3.1	4.9	2.7	3.7	3.3	3.3	1.8	2.5	2.5
	FBRSU	15	2.14	4.7	2.7	3.6	5.4	3.4	4.5	4.0	4.0	1.7	2.5	2.5

TABLE G.2
(Continued)

95% CONFIDENCE LIMITS FOR MAXIMUM (R+M)/2, RON, AND MON REQUIREMENTS

1989 Select Models

Model	Fuel	n	t	95% Confidence Limits, (R+M)/2			Std.Dev. (s)			95% Confidence Limits, RON			Std.Dev. (s)			95% Confidence Limits, MON		
				50%	90%	Satis.	(R+M)/2	(s)	(R+M)/2	50%	90%	Satis.	(s)	(s)	MON	50%	90%	Satis.
SI5XL2*P40A4 (Low Borderline)	PR	8	2.36	5.1	7.1		6.1	6.1		5.1	7.1		6.1	6.1		5.1	7.1	
	FBRU	10	2.26	3.4	4.7		4.8	4.8		4.1	5.6		3.9	3.9		2.8	3.8	
	FBRSU	8	2.36	2.8	3.9		3.3	3.3		3.3	4.6		2.7	2.7		2.2	3.1	
S36RK2*TS7A4/V36GK2*TS7A4/ P36CK2*TS7A4 S36UK2*TS7A4/ P36KK2*TS7A4 (High Borderline)	PR	11	2.23	1.8	2.4		2.6	2.6		1.8	2.4		2.6	2.6		1.8	2.4	
	FBRU	11	2.23	1.6	2.2		2.3	2.3		1.9	2.6		1.8	1.8		1.2	1.7	
	FBRSU	11	2.23	1.6	2.2		2.4	2.4		1.9	2.6		1.9	1.9		1.3	1.8	
S36RK2*TS7A4/V36GK2*TS7A4/ P36CK2*TS7A4 S36UK2*TS7A4/ P36KK2*TS7A4 (Low Borderline)	PR	3	4.39	7.9	11.8		3.1	3.1		7.9	11.8		3.1	3.1		7.9	11.8	
	FBRU	10	2.26	1.6	2.2		2.2	2.2		1.9	2.6		1.7	1.7		1.2	1.7	
	FBRSU	5	2.78	2.7	3.8		2.2	2.2		3.2	4.6		1.7	1.7		2.1	3.0	
C31AW2*P28A4/C32AW2*P28A4/ C32MW2*P28A4 C33AW2*P28A4/ C34AW2*P28A4 (Low Borderline)	PR	14	2.16	1.7	2.3		2.9	2.9		1.7	2.3		2.9	2.9		1.7	2.3	
	FBRU	21	2.09	1.6	2.1		2.4	2.4		1.9	2.6		2.7	2.7		1.2	1.7	
	FBRSU	14	2.16	2.0	2.7		3.4	3.4		2.4	3.2		2.7	2.7		1.6	2.2	
C32HC2*P38A4/C33LC2*P38A4/ C34HC2*P38A4 C34MC2*P38A4/ C34CC2*P38A4 (Low Borderline)	PR	9	2.31	3.7	5.1		4.8	4.8		3.7	5.1		4.8	4.8		3.7	5.1	
	FBRU	14	2.16	2.2	3.1		3.9	3.9		2.7	3.7		3.1	3.1		1.8	2.5	
	FBRSU	9	2.31	3.7	5.1		4.8	4.8		4.4	6.1		3.9	3.9		3.0	4.1	
SI5XL2*P40A4 (High Borderline)	PR	8	2.31	4.6	6.3		5.9	5.9		4.6	6.3		5.9	5.9		4.6	6.3	
	FBRU	10	2.26	3.4	4.7		4.8	4.8		4.1	5.6		3.9	3.9		2.8	3.8	
	FBRSU	10	2.26	3.2	4.4		4.5	4.5		3.8	5.2		3.7	3.7		2.6	3.6	