OCTANE REQUIREMENT INCREASE
OF 1964 MODEL VEHICLES

October 1986
OCTANE REQUIREMENT INCREASE OF 1984 MODEL VEHICLES
(CRC Project No. CM-124-84)

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Prepared by the
1984 Octane Requirement Increase Analysis Panel
of the
CRC-Automotive Octane Technology and Test Procedures Group

October 1986

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

- Octane requirement increase (ORI) was determined for sixty-two 1984 model cars and trucks operated on unleaded gasoline. The cars tested were not selected to represent the distribution of vehicles produced in the model year; rather the data base consists of information volunteered by participants. All ORI values were determined from the increase in maximum octane requirements irrespective of whether requirements were obtained at full- or part-throttle. Though the sample size is smaller than in previous years, it does not appear to have significantly affected the conclusions.

- At 15,000 miles, the mean ORI for all vehicles with full-boiling range unleaded (FBRU) fuels was 4.0 Research octane numbers, 2.6 Motor octane numbers, and 3.3 (R+M)/2 numbers.

- At 15,000 miles, the mean ORI with full-boiling range unleaded (FBRU) fuels for the fifty-six vehicle subset tested with all three reference fuels was 4.1 Research octane numbers, 2.6 Motor octane numbers, and 3.3 (R+M)/2 numbers.

- At 15,000 miles, the mean ORI for fifty-six vehicles with high-sensitivity full-boiling range unleaded (FERSU) fuels was 3.5 Research octane numbers, 2.7 Motor octane numbers, and 3.3 (R+M)/2 numbers.

- At 15,000 miles, the mean ORI for fifty-six vehicles with primary reference (PR) fuels was 4.0 octane numbers.

- Compared with 1983 models (seventy-nine), the mean ORI for all vehicles in the 1984 program with FBRU fuels decreased 0.4 RON, 0.3 MON, and 0.4 (R+M)/2.

- In general, the mean ORI (unweighted) with FBRU fuel exhibits a slight downward trend for the 1975 through 1984 model cars.

- ORI decreases about 0.3 to 0.4 octane number per octane number increase of initial octane requirements. This relationship is weak, but statistically significant.
II. INTRODUCTION

The need to study octane requirement increase (ORI) with unleaded fuel became evident in 1970 when manufacturers announced that future cars would use unleaded gasoline of at least 91 RON quality, and that they would require catalytic converters to meet emission standards in 1975 models. The Coordinating Research Council, Inc. (CRC) initiated a series of ORI programs in 1971 to study the effect of these changes. Since that time, manufacturers have made many engine and vehicle modifications to meet both exhaust emission and fuel economy standards. Because of continuing engineering changes and the now exclusive use of unleaded fuel, the ORI programs have been continued.

The ORI data from 1971 and 1973 through 1983 model cars have been reported previously. (1-11) This report will summarize ORI data for 1984 model vehicles.

III. EXPERIMENTAL

A. Vehicles Tested

In the 1984 program, forty-six US cars, four light-duty US trucks, and twelve imported cars were used to determine the ORI of 1984 model vehicles. Vehicles tested were not selected to represent the distribution of vehicles produced in that model year; rather the data base consists of information volunteered by participants. Participating laboratories are listed in Appendix A.

B. Mileage Accumulation

Mileage accumulation was conducted from the fall of 1983 through the summer of 1985. All test vehicles were operated in customer-type service using unleaded fuels typical of commercially available gasoline. No attempt was made to separate the data so that laboratory-to-laboratory effects could be determined.

C. Average Sensitivity Full-Boiling Range
   Unleaded Reference Fuel (FBRU)

In general, octane number requirements of 1984 model vehicles were defined initially with 1963 FBRU fuel. As mileage increased, the reference fuel was replaced with the 1984 FERU fuel. Laboratory X used a third FBRU reference fuel series for all octane requirements it submitted. Another laboratory initiated their tests with 1962 FBRU fuel, switching to later fuels as mileage increased. The RON-to-MCN conversions used in the data analysis for 1984 vehicles are shown in Appendix C, Table C-1.
D. High Sensitivity Full-Boiling Range Unleaded Reference Fuel (FBRSU)

Octane requirements of fifty-six vehicles were defined initially with 1982 or 1983 FBRSU fuels and later with 1986 and 1984 FLPSU fuels as well as with FBRSU. The RCN-to-MCN conversions used in data analysis are shown in Appendix C, Table C-II.

E. Primary Reference (PR) Fuel

Standard ASTM PR fuel was used in two octane number increments from 76 to 82, and in one octane number increments from 82 to 100, to cover the range of car requirements.

F. Test Technique

Octane number requirements were determined at incremental miles from zero to 15,000 miles by the CRC E-15-84 technique. Maximum octane number requirements were determined on sixty-two vehicles with FBRSU fuel and fifty-six with both FBRSU and PR fuels.

IV. DISCUSSION OF RESULTS

A. Data Analysis Technique

For this program, octane requirements were to be obtained at 0, 5,000, 10,000, and 15,000 miles; however, not all the data were obtained exactly at these mileage intervals. To compare the CRI of all vehicles at the same mileage, results were determined from best-fit curves of actual reported octane requirements. Research octane number requirements (RCN) reported by the participants were plotted at the mileages at which they were obtained. Requirements at 0, 5,000, 10,000, and 15,000 miles were then read from best-fit curves as shown in Figure 1. ORI at 5,000, 10,000, and 15,000 miles were determined from these best-fit curves.

CRI on a Motor octane number (MCN) basis was determined from best-fit curve RCN requirements that were translated into MCN requirements according to the RON-to-MCN conversions in Tables C-I and C-II. Similarly, ORI on an (R+M)/2 basis was determined from (R+M)/2 requirements that were calculated from best-fit curve RCN and corresponding MCN values. The appropriate RCN-to-MCN conversion was determined by the fuel series used to determine the actual reported requirement that was closest to the 0-, 5,000-, 10,000-, or 15,000-mile intervals. Requirements were determined initially with 1982 or 1983 fuels and with later series fuels as mileage increased. Laboratory X used a third FBRSU reference fuel series; all data reported by this laboratory were translated according to the Laboratory X RCN-to-MCN conversion in Table C-I.
Best-fit curve octane requirements at 0, 5,000, 10,000, and 15,000 miles are listed for each vehicle in Appendix D, Tables D-I, D-II, and D-III for FERU, FBRSU, and PR fuels, respectively. Copies of raw octane requirement data and best-fit curves are on file with CRC.

Distribution of initial RON, MON, and (R+M)/2 requirements, as well as ORI values for each mileage interval, are summarized in Tables I, II, and III for FERU, FBRSU, and PR fuels, respectively. The numbers in parenthesis in Table I are the average FERU values of the fifty-six vehicles for which data on all three reference fuels were reported. These tables also include a breakout by manufacturer and engine type where sufficient samples exist.

Distributions of initial RON requirements are plotted in Figure 2 for all three fuel series. Distributions of ORI at various mileages for RCH, RCR, and (R+M)/2 on FERU fuels are shown in Figures 3, 4, and 5, respectively, and on FBRSU fuels in Figures 6, 7, and 8. Similarly, distributions of GRI on PR fuels at various mileages are shown in Figure 9.

Because some laboratories tested cars on two different reference fuel series, the MON ORI may be different from that determined from a single reference fuel series. The difference in sensitivity (RON minus MON) ranges from 0.0 to 1.0 and 0.0 to 0.6 for the four FERU and three FBRSU fuel series, respectively. Although an estimate of the error cannot be made from these data, work by other researchers suggest it may be as much as 0.5 MON. (13)

Members of the Analysis Panel are listed in Appendix E.

B. Comparison of 1975 through 1984 ORI Studies

The mean GRI values for 1975 through 1984 model vehicles are:

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Accumulated Miles</th>
<th>Mean ORI FERU, RON</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>16,000</td>
<td>5.8</td>
<td>4.4</td>
</tr>
<tr>
<td>1976</td>
<td>15,000</td>
<td>5.4</td>
<td>3.6</td>
</tr>
<tr>
<td>1977</td>
<td>15,000</td>
<td>4.9</td>
<td>2.9</td>
</tr>
<tr>
<td>1978</td>
<td>15,000</td>
<td>6.0</td>
<td>4.2</td>
</tr>
<tr>
<td>1979</td>
<td>15,000</td>
<td>5.4</td>
<td>4.1</td>
</tr>
<tr>
<td>1980</td>
<td>15,000</td>
<td>5.1</td>
<td>2.9</td>
</tr>
<tr>
<td>1981</td>
<td>15,000</td>
<td>5.1</td>
<td>4.1</td>
</tr>
<tr>
<td>1982</td>
<td>15,000</td>
<td>4.9</td>
<td>4.0</td>
</tr>
<tr>
<td>1983</td>
<td>15,000</td>
<td>4.4</td>
<td>3.9</td>
</tr>
<tr>
<td>1984</td>
<td>15,000</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

1975-1984 Unweighted Average: 5.1 3.9
CRI with FBRU fuel continues a slight downward trend from 1975 and is illustrated on Figure 16. CRI with PR fuel is unchanged over this period.

C. ORI Versus Initial Octane Requirements

Initial RON requirements are plotted against ORI at 15,000 miles in Figures 11, 12, and 13 for FBRU, FBRSU, and PR fuels, respectively. The trend between initial requirements and ORI was determined by linear least squares regression analysis. The general form of the equation was:

\[ \text{ORI} = a + b \times (\text{Initial Octane Requirement}) \]

The best-fit lines are also shown in Figures 11, 12, and 13.

Equations for the three reference fuel series are:

<table>
<thead>
<tr>
<th>Reference Fuel Series</th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBRU</td>
<td>30.6</td>
<td>-0.30</td>
</tr>
<tr>
<td>FBRSU</td>
<td>28.5</td>
<td>-0.28</td>
</tr>
<tr>
<td>PR</td>
<td>37.1</td>
<td>-0.38</td>
</tr>
</tbody>
</table>

In general, ORI decreases about 0.3 to 0.4 units per unit increase of initial requirements. The equation only weakly fits the data as indicated by the small correlation coefficients \( R^2 \), but as in the past, the analysis has indicated that the estimates of the slope (ORI/Initial Requirement) are statistically significant.\(^{(8,9,10)}\) This relationship, however, was not statistically significant for the 1983 model vehicles.
REFERENCES
REFERENCES


TABLES

AND

FIGURES
| Group     | No. of Vehicles Tested | Initial Requirements Mean | 5,000 Mile OCT Mean | 10,000 Mile OCT Mean | 15,000 Mile OCT Mean | Initial Requirements Mean | 5,000 Mile OCT Mean | 10,000 Mile OCT Mean | 15,000 Mile OCT Mean | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD | Mean SD |
|-----------|------------------------|---------------------------|---------------------|---------------------|---------------------|------------------------|------------------------|---------------------|---------------------|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| All       | 56                     | 0.4 4.8                   | 2.1 2.1             | 3.5 2.5             | 3.9 2.6             | 19.6 3.3               | 1.9 1.6               | 2.5 1.7             | 2.7 1.7             | 84.4 4.1 | 2.3 1.8 | 3.0 1.9 | 3.3 1.2 |
| All Make A| 7                      | 0.3 5.2                   | 2.4 1.7             | 3.3 1.8             | 3.6 1.9             | 80.6 3.6               | 1.1 1.1               | 2.3 1.2             | 2.5 1.2             | 85.4 4.4 | 2.0 1.4 | 2.8 1.5 | 3.1 1.6 |
| All Make B| 14                     | 0.2 3.7                   | 2.6 2.4             | 3.3 2.6             | 3.7 2.9             | 19.6 2.5               | 2.8 1.6               | 2.2 1.8             | 2.5 1.9             | 84.7 3.1 | 2.2 1.9 | 2.8 1.5 | 3.1 1.8 |
| All Make C| 9                      | 0.4 4.5                   | 2.1 2.2             | 3.0 3.0             | 3.4 3.4             | 80.8 3.0               | 1.4 1.5               | 2.1 2.0             | 2.3 2.2             | 85.6 3.0 | 1.7 1.8 | 2.5 1.5 | 2.9 1.8 |
| All Others| 17                     | 0.8 3.5                   | 4.0 2.9             | 4.6 2.7             | 4.9 2.7             | 76.9 2.6               | 2.8 2.0               | 3.3 1.9             | 3.5 1.9             | 80.8 3.0 | 3.4 2.4 | 4.0 2.3 | 4.2 2.3 |

<p>| Engine A90 | 5                      | 0.2 0.8                   | 3.2 0.6             | 4.6 0.6             | 5.1 0.8             | 17.2 0.6               | 2.3 0.4               | 3.4 0.4             | 3.6 0.6             | 81.7 0.7 | 2.8 0.5 | 3.9 0.5 | 4.3 0.7 |
| Engine B98 | 5                      | 0.7 0.4                   | 1.7 2.0             | 2.7 2.1             | 2.9 3.0             | 114 0.3                | 1.1 1.3               | 1.6 1.7             | 1.9 2.0             | 86.3 0.4 | 1.4 1.1 | 2.0 1.2 | 2.4 1.5 |
| Engine C15 | 4                      | 0.3 4.9                   | 2.1 2.4             | 3.4 3.4             | 3.9 3.3             | 80.0 3.3               | 1.6 1.6               | 2.4 2.7             | 2.7 2.5             | 84.7 4.4 | 2.0 2.0 | 2.9 2.0 | 3.3 1.7 |
| Engine D17 | 5                      | 0.2 2.4                   | 3.4 1.7             | 4.3 2.1             | 4.7 2.7             | 10.7 1.7               | 2.4 1.2               | 3.0 1.4             | 3.3 1.5             | 82.9 2.0 | 2.9 1.5 | 3.1 1.8 | 4.0 1.6 |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>No of Vehicles</th>
<th>Initial Requirements</th>
<th>5,000-Mile</th>
<th>10,000-Mile</th>
<th>15,000-Mile</th>
<th>Initial Requirements</th>
<th>5,000-Mile</th>
<th>10,000-Mile</th>
<th>15,000-Mile</th>
<th>Initial Requirements</th>
<th>5,000-Mile</th>
<th>10,000-Mile</th>
<th>15,000-Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>62</td>
<td>8.7/6.8</td>
<td>2.0/2.3</td>
<td>3.7/2.6</td>
<td>4.0/2.8</td>
<td>0.7/1.1</td>
<td>1.3/1.0</td>
<td>1.6/1.0</td>
<td>1.4/1.0</td>
<td>2.4/1.4</td>
<td>1.8/1.4</td>
<td>1.2/1.0</td>
<td>1.8/1.4</td>
</tr>
<tr>
<td>Vehicles</td>
<td>56</td>
<td>9.6 (5.9)</td>
<td>2.8 (2.3)</td>
<td>3.7 (2.6)</td>
<td>4.1 (2.7)</td>
<td>0.7 (1.2)</td>
<td>1.1 (1.0)</td>
<td>1.6 (1.0)</td>
<td>1.4 (1.0)</td>
<td>2.4 (1.7)</td>
<td>1.8 (1.6)</td>
<td>1.2 (1.0)</td>
<td>1.8 (1.6)</td>
</tr>
<tr>
<td>All Make A</td>
<td>27</td>
<td>8.9 (5.2)</td>
<td>2.6 (2.0)</td>
<td>3.5 (2.3)</td>
<td>3.9 (2.4)</td>
<td>0.7 (1.4)</td>
<td>1.2 (1.2)</td>
<td>1.6 (1.2)</td>
<td>1.7 (1.3)</td>
<td>2.4 (1.6)</td>
<td>1.8 (1.7)</td>
<td>1.2 (1.3)</td>
<td>1.7 (1.7)</td>
</tr>
<tr>
<td>All Make B</td>
<td>14</td>
<td>8.7/3.5</td>
<td>2.7/2.4</td>
<td>3.7/3.0</td>
<td>4.0/3.5</td>
<td>0.7/1.1</td>
<td>1.1/1.0</td>
<td>1.6/1.0</td>
<td>1.4/1.0</td>
<td>2.4/1.6</td>
<td>1.8/1.6</td>
<td>1.2/1.3</td>
<td>1.7 (1.7)</td>
</tr>
<tr>
<td>All Make C</td>
<td>9</td>
<td>8.1/3.4</td>
<td>2.6/2.0</td>
<td>3.2/2.4</td>
<td>3.0/2.6</td>
<td>0.7/1.2</td>
<td>1.1/1.2</td>
<td>1.6/1.2</td>
<td>1.9/1.9</td>
<td>2.4/2.0</td>
<td>1.8/2.0</td>
<td>1.2/2.0</td>
<td>2.4/2.0</td>
</tr>
<tr>
<td>All Others</td>
<td>12</td>
<td>8.4/3.6</td>
<td>4.0/2.9</td>
<td>4.6/2.8</td>
<td>4.0/2.8</td>
<td>0.8/1.6</td>
<td>2.5/2.0</td>
<td>3.0/1.9</td>
<td>1.0/1.0</td>
<td>2.8/2.4</td>
<td>1.8/2.4</td>
<td>1.4/2.3</td>
<td>1.9/2.3</td>
</tr>
</tbody>
</table>

(1) Numbers in parentheses represent IHGU data on vehicles that were also tested on HMGH and PR fuels.
### TABLE III

**INITIAL OCTANE NUMBER REQUIREMENTS AND ORI AT VARIOUS MILEAGES -- PR FUEL**

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Vehicles Tested</th>
<th>Initial Requirements</th>
<th>5,000-Mile ORI</th>
<th>10,000-Mile ORI</th>
<th>15,000-Mile ORI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>All Vehicles</td>
<td>56</td>
<td>85.6</td>
<td>4.8</td>
<td>2.9</td>
<td>2.4</td>
</tr>
<tr>
<td>All Make A</td>
<td>21</td>
<td>87.0</td>
<td>4.9</td>
<td>2.4</td>
<td>1.7</td>
</tr>
<tr>
<td>All Make B</td>
<td>14</td>
<td>84.9</td>
<td>4.5</td>
<td>3.4</td>
<td>2.1</td>
</tr>
<tr>
<td>All Make C</td>
<td>9</td>
<td>86.1</td>
<td>4.1</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>All Others</td>
<td>12</td>
<td>83.2</td>
<td>4.4</td>
<td>4.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Engine All-1</td>
<td>5</td>
<td>82.4</td>
<td>0.6</td>
<td>3.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Engine R56</td>
<td>5</td>
<td>66.2</td>
<td>0.4</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Engine C125</td>
<td>6</td>
<td>86.5</td>
<td>3.9</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Engine D122</td>
<td>5</td>
<td>86.4</td>
<td>2.7</td>
<td>2.9</td>
<td>2.0</td>
</tr>
</tbody>
</table>
FIGURE 1
BEST-FIT CURVE ORI ANALYSIS

MILES : 1000

- 1983 Fuels
- 1984 Fuels

RONR @ 15 K Miles
RONR @ 10 K Miles
RONR @ 5 K Miles
FIGURE 2

DISTRIBUTION OF INITIAL RON REQUIREMENTS
FOR 1984 MODEL VEHICLES
FIGURE 3

DISTRIBUTION OF RON OI for 62 1984 MODEL VEHICLES AT VARIOUS MILEAGES ON FBRU FUEL
FIGURE 4

DISTRIBUTION OF MGN ORI FCR
62 1984 MODEL VEHICLES AT
VARIOUS MILEAGES ON FBRU FUEL

Octane Requirement Increase

15,000 Miles
10,000 Miles
5,000 Miles
FIGURE 5

DISTRIBUTION OF (R+M)/2 ORI FOR 62 1984 MODEL VEHICLES AT VARIOUS MILEAGES ON FBRU FUEL
FIGURE 6

DISTRIBUTION OF RON CRI FOR
56 1984 MODEL VEHICLES AT
VARIOUS MILEAGES ON F8SU FUEL
FIGURE 7

DISTRIBUTION OF MON ORI FOR 56 1984 MODEL VEHICLES AT VARIOUS MILEAGES ON FRSU FUEL
FIGURE 8

DISTRIBUTION OF \((R+M)/2\) ORI FOR
56 1984 MODEL VEHICLES AT
VARIOUS MILEAGES ON FBRSU FUEL
FIGURE 9

DISTRIBUTION OF CRI FCR
56 1984 MODEL VEHICLES AT
VARIOUS MILEAGES ON PR FUEL
Figure 10
Mean ORI of 1975 Through 1984 Model Years

Model Year

Mean ORI
FIGURE 11
EFFECT OF INITIAL OCTANE REQUIREMENT
on overall 15,000 miles of fuel performance.

Original Octane Requirement

11 10 9 8 7 6 5 4 3 2 1 0
110 90 80 70 60 50 40 30 20 10 0
FIGURE 13

EFFECT OF INITIAL OCTANE REQUIREMENT
ON ORI AT 15,000 MILES
FUEL=PR
APPENDIX A

LABORATORIES REPORTING OCTANE REQUIREMENT DATA AT VARIOUS MILEAGES
LABORATORIES REPORTING OCTANE REQUIREMENT DATA AT VARIOUS MILEAGES

Amoco Oil Company  
Naperville, Illinois

Exxon Research and Engineering Company  
Linden, New Jersey

General Motors Research Laboratories  
Warren, Michigan

Gulf Research and Development Company  
Pittsburgh, Pennsylvania

Shell Development Company  
Houston, Texas

Unocal Corporation  
Brea, California
APPENDIX B

MEMBERSHIP:

1984 OCTANE REQUIREMENT INCREASE
DATA ANALYSIS PANEL
# 1984 Octane Requirement Increase

## Data Analysis Panel

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APPENDIX C

REFERENCE FUEL DATA
### TABLE C-1

**AVERAGE SENSITIVITY FULL-BOILING RANGE**

**UNLEADED REFERENCE FUEL SERIES**

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APPENDIX D

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