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# Results from the Third Year of Operation of the Federal Methanol Fleet at Lawrence Berkeley Laboratory

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OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/TM-11401

Engineering Technology Division

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Published Date - December 1989

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract DE-AC05-84OR21400

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## ACKNOWLEDGMENTS

The authors greatly appreciate the continuing help and support of the staff at Lawrence Berkeley Laboratory who have made this project a success. Special thanks are expressed to David Nielsen, Head of Business and Protective Services Department; Harry Moitoza, Motor Pool Supervisor; John Stamatelos, Chief Mechanic; and Vernice Arnett, Motor Pool Staff. Also, the Bank of America has continued to be very cooperative in providing technical advice to both ORNL and LBL staff. The authors also appreciate the helpful attitude and cooperation of the Northern California Emissions Laboratory, particularly Mr. Michael Spencer-Smith.

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ABSTRACT

Lawrence Berkeley Laboratory has completed three years of operation of ten vehicles for the Federal Methanol Fleet Project; five of the vehicles are fueled with methanol. Nearly 74,000 miles were accumulated on the ten vehicles during the third year, bringing the total for three years to over 280,000 miles. The five gasoline cars in the project at Berkeley have been retired from service by the General Services Administration, but the five methanol cars will continue to be monitored. Recent emissions tests of the methanol cars revealed higher emissions than when the cars were originally tested in 1985, and evidence suggests that there has been some deterioration of emissions control by the catalytic converters. Rates of accumulation of wear metals in the lubricating oil of the methanol engines improved during the third year; only iron remains appreciably elevated in the oil when compared to that of the gasoline engines. Drivers continued to express a high degree of satisfaction with the performance of the methanol cars as compared to that of the gasoline cars.

## 1. INTRODUCTION

Lawrence Berkeley Laboratory (LBL) has operated ten cars for a period of three years for the Department of Energy's Federal Methanol Fleet Project; five of the cars are methanol-powered and five are comparable gasoline vehicles. The Oak Ridge National Laboratory (ORNL) has project management responsibility for the entire Methanol Fleet Project including activities at LBL and, as such, collects and disseminates data and information related to the operation of the project. Previous ORNL reports (1, 2)* detailed the results of the first two years of operation at LBL; this report deals with the third year's operation. Because much of the background of the project has been described in previous reports (1,2,3,4,5), it will not be discussed

*Numbers in parentheses refer to references at the end of the report.

again at any length in this report. The reader is encouraged to refer to the previous reports for those details. This report will deal primarily with the results and data from the third year of operation and the comparison of those data with the similar results from the first two years.

Ten 1984 model Chevrolet Citations have been involved in the project at LBL; five were modified to operate on methanol by the Bank of America in the San Francisco, California area. The five gasoline vehicles were retired from service by the General Services Administration in October, 1988 after nearly three years in the project and will no longer be part of the demonstration. They are included in all of the comparisons in this report since they were part of the demonstration for nearly all of the third year.

The gasoline cars had been in service for nearly a year before they were pressed into duty as control vehicles for this project, whereas the methanol vehicles were basically new cars when they were converted to methanol and placed in service. As a result, the gasoline cars were at later points in their serviceable lives than the methanol cars during the entire three years of this project. Therefore, the reader should be cautious when comparing the data between methanol and gasoline vehicles, especially those related to maintenance. At the time of their retirement the gasoline cars had an average of 58,300 miles on their odometers, while the comparable average for the methanol cars was only 24,300 miles.

The methanol fuel mixture used at LBL contains a portion of regular unleaded gasoline to aid in cold-starting, but the mixture is not the more common "M85" (85% methanol, 15% gasoline, used in the rest of the Federal Methanol Fleet). Instead, the fuel supplier provides a mixture that is nominally 88% methanol and 12% gasoline; this ratio is varied throughout the year as needed for cold startability. An above-ground tank and associated dispensing pump are used on-site at LBL for dispensing fuel into the five methanol-powered Citations.

All ten vehicles are operated by LBL at their central motor pool and serve some of the general transportation needs of LBL personnel. They generally are used for transportation in and around the LBL site, for trips to Lawrence Livermore National Laboratory, and for trips to the Stanford Linear Accelerator Center. Occasionally a car is taken on longer, overnight trips, and usually one of the five gasoline vehicles has been assigned to that duty.

A small amount of data including the drivers' ratings of the cars' ease of starting and driveability is recorded for each trip. Fueling and maintenance data are kept by the motor pool personnel. The lubricating oil is sampled in each car every 1000 miles and sent to a laboratory where it is analyzed for wear metal content, base number, viscosity, etc. All data from the methanol fleet project at LBL are forwarded to the ORNL project management office where the Federal Methanol Fleet database is maintained.

## 2. SUMMARY

The Federal Methanol Fleet operating at Lawrence Berkeley Laboratory completed a satisfactory third year of operation with the accumulation of nearly 74,000 miles (118,000 kilometers) on the ten vehicles, bringing the total for three years to over 280,000 miles (448,000 kilometers). The five gasoline cars were retired from service near the end of the third year by the General Services Administration, but the five methanol cars will continue in service at LBL as long as practical. Fuel economy for the gasoline cars declined during the third year, most likely as a result of differences in assignments as compared to previous years. The gasoline cars were used in the third year for more driving around the hilly LBL site in short trips, much like the methanol cars have been used for the entire project.

Emissions tests of the methanol vehicles revealed general increases in carbon monoxide and oxides of nitrogen, while hydrocarbon emissions decreased when compared to emissions tests just after the cars had been converted to methanol. Replacing the catalytic converters on two cars and further testing suggest that the increases in oxides of nitrogen were due to catalyst degradation.

Rates of accumulation of metals in the lubricating oil decreased in the third year, just as for the previous year. Only the iron accumulation rate in methanol cars remains elevated to suspicious levels. Nevertheless, its rate appears stable now and at a level that may be tolerable.

The methanol cars continued to require more maintenance than their gasoline counterparts, much of the difference being identified as fuel related or having been occasioned by elements of the methanol conversion. There remained an apparent tendency on the part of users to request maintenance or service for the methanol cars more frequently than for the gasoline cars.

Drivers continued to express general acceptance of the methanol vehicles in their ratings of ease of starting and driveability for each trip. Their ratings do not appear to reflect any sizeable degradation over previous years. Additionally, the drivers indicated in a separate survey near the end of the third year that they are generally favorably impressed with the methanol vehicles and the prospects for methanol as a viable alternative fuel.

# 3. RESULTS

## 3.1 Fleet Utilization and Fuel Consumption

Table 1 summarizes the fleet utilization (mileage accumulation) and fuel consumption results from the LBL fleet for the third year of operation. Shown are data for total miles driven, average miles per trip, and average fuel economy for each of the ten cars as well as aggregate totals for the five cars of each type - methanol or gasoline. Table 2 summarizes the same parameters for the entire three years of operation. Tables 3 and 4 (summaries from first and second years of fleet, respectively) are repeated from previous annual reports for the purposes of comparison.

Over 284,000 miles (454,000 kilometers) have been accumulated on the ten cars in the three years of operation, with approximately 73,000 miles (117,000 kilometers) being accumulated in the third year. The five gasoline cars were retired from service at LBL by the General Services Administration at the end of September, 1988 at which time data collection for them also ended. Therefore, this is the last report of LBL fleet activities that will include recent operating data from the gasoline cars. The methanol cars will continue to be operated as long as they contribute to the project's findings.

During the third year the gasoline cars were used in shorter trips than at any time before. As a result, the average trip lengths were equalized between methanol and gasoline cars. Also, the gasoline cars were more confined to driving around the hilly LBL site than in previous years and experienced more idle engine operation. (Previously, the gasoline cars were used for more of the longer trips involving freeway driving.) Some of the gasoline cars were loaned for periods of time to the LBL security department for use as backup patrol cars, as well. All of these factors together resulted in lower fuel economy than previously attained by the gasoline cars. Their use, as a group, was much more similar to the usage patterns for the methanol vehicles than at any time in the past, and the energy efficiencies for the two groups reflect this by being nearly the same.

## 3.2 Results of Emissions Tests

The methanol Citations were originally tested for emissions shortly after they had been converted to methanol. These tests were conducted by Santa Clara University in 1985 when the vehicles had approximately 2,000 miles of gasoline service and almost no service on methanol.

A second round of emissions tests was arranged after the vehicles had accumulated about 20,000 miles on methanol. The testing was conducted by Northern California Emissions Laboratory in Berkeley, California. Prior to testing, each vehicle was tuned up at the LBL

Table 1. LBL Fleet Utilization and Fuel Consumption Data.
Third Year – November 1, 1987 to October 31, 1988

| Vehicle ID (License No.) | Total miles | Average miles/trip | Fuel Economy | |
|---|---|---|---|---|
| | | | mpg | km/Gj[a] |
| *Methanol vehicles* | | | | |
| E-753 | 4,601 | 32 | 10.6 | 254 |
| E-754 | 6,600 | 38 | 11.0 | 264 |
| E-755 | 7,111 | 50 | 10.2 | 247 |
| E-756 | 6,038 | 25 | 11.4 | 273 |
| E-757 | 6,090 | 59 | 11.2 | 269 |
| TOTAL | 30,440 | 38[b] | 10.9[b] | 260[b] |
| *Gasoline vehicles* | | | | |
| G-563 | 10,082 | 25 | 20.5 | 271 |
| G-580 | 8,572 | 44 | 20.8 | 275 |
| G-611 | 4,584 | 21 | 20.4 | 270 |
| G-709 | 8,994 | 55 | 22.3 | 295 |
| G-771 | 10,825 | 78 | 23.2 | 307 |
| TOTAL | 43,057 | 38[b] | 21.5[b] | 284[b] |

[a]Based on methanol heating value of 56,560 Btu/gal and gasoline heating value of 115,400 Btu/gal; hence, M88 heating value equals 63,620 Btu/gal.

[b]Based on total quantities, not an average of individual averages.

Table 2. LBL Fleet Utilization and Fuel Consumption Data.
Three Years – Through October 31, 1988

| Vehicle ID (License No.) | Total miles | Average miles/trip | Fuel Economy | |
|---|---|---|---|---|
| | | | mpg | km/Gj[a] |
| *Methanol vehicles* | | | | |
| E-753 | 19,749 | 38 | 11.3 | 271 |
| E-754 | 23,707 | 44 | 11.9 | 285 |
| E-755 | 19,750 | 33 | 10.5 | 252 |
| E-756 | 20,449 | 31 | 11.5 | 276 |
| E-757 | 19,607 | 43 | 11.3 | 271 |
| TOTAL | 103,262 | 37[b] | 11.3[b] | 271[b] |
| *Gasoline vehicles* | | | | |
| G-563 | 36,370 | 40 | 23.9 | 316 |
| G-580 | 40,296 | 56 | 23.4 | 309 |
| G-611 | 33,556 | 45 | 23.8 | 315 |
| G-709 | 37,466 | 69 | 24.3 | 321 |
| G-771 | 33,510 | 38 | 22.8 | 301 |
| TOTAL | 181,198 | 48[b] | 23.6[b] | 312[b] |

[a]Based on methanol heating value of 56,560 Btu/gal and gasoline heating value of 115,400 Btu/gal; hence, M88 heating value equals 63,620 Btu/gal.

[b]Based on total quantities, not an average of individual averages.

Table 3. LBL Fleet Utilization and Fuel Consumption Data. First Year - Through October 31, 1986

| Vehicle ID (License No.) | Total miles | Average miles/trip | Fuel Economy | |
|---|---|---|---|---|
| | | | mpg | km/Gj[a] |
| *Methanol vehicles* | | | | |
| E-753 | 8,361 | 42 | 11.2 | 269 |
| E-754 | 8,320 | 46 | 11.8 | 283 |
| E-755 | 6,855 | 34 | 11.7 | 281 |
| E-756 | 6,969 | 32 | 11.9 | 285 |
| E-757 | 6,359 | 28 | 11.0 | 264 |
| TOTAL | 36,864 | 36[b] | 11.4[b] | 274[b] |
| *Gasoline vehicles* | | | | |
| G-563 | 16,067 | 69 | 25.1 | 332 |
| G-580 | 17,082 | 55 | 23.3 | 308 |
| G-611 | 13,609 | 43 | 22.6 | 299 |
| G-709 | 14,741 | 109 | 26.0 | 343 |
| G-771 | 12,830 | 41 | 23.8 | 315 |
| TOTAL | 74,329 | 57[b] | 24.1[b] | 318[b] |

[a]Based on methanol heating value of 56,560 Btu/gal and gasoline heating value of 115,400 Btu/gal; hence, M88 heating value equals 63,620 Btu/gal.

[b]Based on total quantities, not an average of individual averages.

Table 4. LBL Fleet Utilization and Fuel Consumption Data. Second Year - November 1, 1986 to October 31, 1987

| Vehicle ID (License No.) | Total miles | Average miles/trip | Fuel Economy | |
|---|---|---|---|---|
| | | | mpg | km/Gj[a] |
| *Methanol vehicles* | | | | |
| E-753 | 6,787 | 39 | 12.2 | 293 |
| E-754 | 8,787 | 46 | 12.8 | 307 |
| E-755 | 5,784 | 22 | 9.8 | 235 |
| E-756 | 7,442 | 39 | 11.6 | 278 |
| E-757 | 7,158 | 59 | 11.8 | 283 |
| TOTAL | 35,958 | 38[b] | 11.7[b] | 281[b] |
| *Gasoline vehicles* | | | | |
| G-563 | 10,221 | 38 | 27.1 | 358 |
| G-580 | 14,642 | 65 | 25.5 | 337 |
| G-611 | 15,363 | 73 | 26.3 | 347 |
| G-709 | 13,731 | 56 | 24.1 | 318 |
| G-771 | 9,855 | 23 | 21.4 | 282 |
| TOTAL | 63,812[b] | 46[b] | 24.9[b] | 329[b] |

[a]Based on methanol heating value of 56,560 Btu/gal and gasoline heating value of 115,400 Btu/gal; hence, M88 heating value equals 63,620 Btu/gal.

[b]Based on total quantities, not an average of individual averages.

fleet garage and subjected to a California Air Resources Board idle and fast idle tailpipe "sniff" emissions check, and as a result, further repairs were made to the vehicles, some possibly unnecessary (such as spark plugs, spark plug wires, and EGR valve replacements).

The results from both sets of emissions tests, original and recent, are summarized in Table 5. The relatively poor $NO_x$ performance of four of the vehicles in Round 2 of the emissions tests was of concern, so the two cars with highest $NO_x$ measurements (753 and 754), were returned to the Bank of America (BofA, who originally performed the conversion to methanol) to ensure that the engines were in compliance with their specifications. Subsequent additional emissions tests on these two vehicles showed some small reductions in all three measured emission constituents, but the levels were still higher than expected. Two consecutive tests were also conducted on vehicle 754 to gain some insight regarding the repeatability of the testing procedures at the emissions laboratory (see Table 6).

Finally, the catalytic converters on both vehicles were replaced, and the cars were tested for emissions again. Table 6 summarizes the results of the entire sequence of emissions tests for vehicles 753 and 754. Note that the cars met the Federal standards for $NO_x$ after

Table 5. Results of Emissions Tests
Round 1 = Original Tests (1985)
Round 2 = Recent Tests (1988)

| Vehicle No. | Emissions (grams/mile) | | | | | |
|---|---|---|---|---|---|---|
| | CO | | HC[a] | | $NO_x$ | |
| | Round 1 | Round 2 | Round 1 | Round 2 | Round 1 | Round 2 |
| 753 | 1.87 | 2.50 | 0.98[b] | 0.30 | 0.66 | 1.30[b] |
| 754 | 2.38 | 4.03[b] | 0.59[b] | 0.29 | 1.06b | 1.22[b] |
| 755 | 2.27 | 3.53[b] | 0.75[b] | 0.51[b] | 0.80 | 0.95 |
| 756 | 3.28 | 2.85 | 1.27 | 0.31 | 0.53 | 1.20[b] |
| 757 | 1.55 | 2.97 | 0.74[b] | 0.33 | 0.29 | 1.06[b] |

[a]The data reduction protocol used in Round 1 corrected the HC values for the mass of oxygen present in unburned methanol contained in the exhaust. In Round 2 the HC values are reported as Organic Material Hydrocarbon Equivalents (OMHCE). In both cases, aldehydes were not measured and methanol values were inferred from the Flame Ionization Detector measurements.

[b]Denotes a value that exceeds the certification level (U. S. EPA standards of 3.4 grams/mile CO, 0.41 grams/mile HC, 1.0 grams/mile $NO_x$).

Table 6. Emissions Results for Repeatability Tests and After Catalyst Replacement

| | | Emissions (grams/mile) | | | |
|---|---|---|---|---|---|
| | | CO | OMHCE[a] | $NO_x$ | $CO_2$ |
| **Vehicle No. 753** | | | | | |
| Condition, date, (odometer) | | | | | |
| Round 1, 1/85 | (1,475) | 1.87 | 0.98[b] | 0.66 | n/a |
| Round 2, 10/88 | (22,305) | 2.50 | 0.30 | 1.30[b] | 400 |
| After BofA Work 2/89 | (23,344) | 1.88 | 0.24 | 1.06[b] | 416 |
| After Cat. Repl. 3/89 | (24,152) | 0.84 | 0.16 | 0.81 | 403 |
| **Vehicle No. 754** | | | | | |
| Condition, date, (odometer) | | | | | |
| Round 1, 1/85 | (1,669) | 2.38 | 0.59[b] | 1.06[b] | n/a |
| Round 2, 12/88 | (26,845) | 4.03[b] | 0.29 | 1.22[b] | 401 |
| After BofA Work 3/89 | (28,110) | 2.88 | 0.27 | 1.16[b] | 395 |
| Repeatability 4/89 | (28,623) | 1.71 | 0.23 | 1.16[b] | 393 |
| Repeatability 4/89 | (28,642) | 2.38 | 0.23 | 1.13[b] | 387 |
| After Cat. Repl. 5/89 | (28,858) | 1.39 | 0.12 | 1.00 | 384 |

[a]The data reduction protocol used in Round 1 corrected the HC values for the mass of oxygen present in unburned methanol contained in the exhaust. In Round 2 the HC values are reported as Organic Material Hydrocarbon Equivalents (OMHCE). In both cases, aldehydes were not measured and methanol values were inferred from the Flame Ionization Detector measurements.

[b]Denotes a value that exceeds the certification level (U. S. EPA standards of 3.4 grams/mile CO, 0.41 grams/mile HC, 1.0 grams/mile $NO_x$).

catalyst replacement. The results exhibit considerable scatter in the carbon monoxide values, with poor repeatability shown on consecutive tests run with vehicle 754, although the repeatability of the OMHCE and $NO_x$ is much better. These data suggest that catalyst degradation was responsible for the high $NO_x$ (over Federal standards) experienced during the Round 2 testing. Catalyst replacement also resulted in dramatic reductions of OMHCE and CO, however they were below the standards even before catalyst replacement. These results are consistent with results reported by the California Air Resources Board in long-term emissions tests of methanol-fueled vehicles (6).

## 3.3 Comparison of Maintenance and Service — Methanol and Gasoline Vehicles

Statistics illustrating the comparison of maintenance and service of the methanol and gasoline vehicles are presented in Tables 7 through 10. Included in this comparison are data on numbers of occasions of maintenance, frequency of maintenance (occasions per 1000 miles), numbers of labor hours required for maintenance, and labor intensity (labor hours per 1000 miles). Statistics for the third year as well as summaries for the entire three years are presented. In the tables "All Maintenance" includes all occasions of maintenance for which a service work order was written. This would include all occasions of routine maintenance such as oil changes and tire maintenance as well as all occasions of unusual maintenance, i.e. those occasions that are prompted by complaints or malfunctions. The occasions that have been designated as "Fuel Related" are those which have been identified as being intimately related to the nature of the fuel and/or fuel delivery systems. In the case of the methanol cars, many of the fuel related occasions of maintenance result from situations that have been caused by the fuel or the systems incorporated in the conversion to methanol. Similar occasions for the gasoline cars have also been designated as fuel related. These designations are used only in an attempt to determine how much of the difference in maintenance between the two car types can be traced to the methanol fuel or its systems.

The methanol cars continued to require more frequent maintenance and more labor than their gasoline counterparts, but frequency of maintenance for the third year was very similar to the first two years for both car types. Fuel-related maintenance for the methanol cars does not appear to account for all of their greater frequency of maintenance. This suggests that users are sensitive to mechanical problems and, perhaps, request maintenance for the methanol cars on occasions that they would overlook in the gasoline cars.

Labor intensity for the methanol cars continued a slight upward trend in the third year for all maintenance, but the increase does not appear to be a result of fuel-related maintenance. The cause of this is unknown, but a similar increase is evident also in the gasoline cars.

The most common complaint about the methanol cars continued to be stalling, both on starting and in warmed-up conditions, which is usually remedied by carburetor adjustment. The carburetors on the stock Citations were originally tamper-proof, however access plugs to the mixture adjusting screws were ground off as part of the methanol conversion, allowing for future carburetor adjustments. Of the 15 fuel related occasions of maintenance during the third year for the methanol cars, six of them included carburetor adjustments. Another five of the occasions involved failed fuel level sending units, and three involved the heater grid below the carburetor used for enhancing cold-start performance.

Table 7. Frequency of Maintenance — Third Year Compared with All Years

| | Maintenance | | | |
|---|---|---|---|---|
| | 3rd year | | All 3 years | |
| | Occasions (No.) | Frequency (No./1000 mi.) | Occasions (No.) | Frequency (No./1000 mi.) |
| | *Five-car Totals* | | | |
| <u>All Maintenance</u> | | | | |
| Methanol | 47 | 1.5 | 171 | 1.7 |
| Gasoline | 33 | 0.8 | 131 | 0.7 |
| <u>Fuel-Related Maintenance</u> | | | | |
| Methanol | 15 | 0.5 | 53 | 0.5 |
| Gasoline | 1 | 0.02 | 3 | 0.02 |

Table 8. Frequency of Maintenance — Summary of Three Years

| | Frequency (Occasions/1000 miles) | | |
|---|---|---|---|
| | 3rd Year | 2nd Year | 1st Year |
| | *Five-car Averages* | | |
| <u>All Maintenance</u> | | | |
| Methanol | 1.5 | 1.7 | 1.7 |
| Gasoline | 0.8 | 0.7 | 0.7 |
| <u>Fuel-Related Maintenance</u> | | | |
| Methanol | 0.5 | 0.4 | 0.6 |
| Gasoline | 0.02 | 0 | 0.03 |

Table 9. Maintenance Labor Hours and Intensity — Third Year Compared With All Three Years

| | Maintenance Labor Hours and Intensity (h/1000 miles) | | | |
|---|---|---|---|---|
| | 3rd Year | | All 3 Years | |
| | Hours | Intensity | Hours | Intensity |
| | | *Five-car Totals* | | |
| All Maintenance | | | | |
| Methanol | 85 | 2.8 | 223 | 2.2 |
| Gasoline | 43 | 1.0 | 119 | 0.7 |
| Fuel-Related Maintenance | | | | |
| Methanol | 29 | 1.0 | 97 | 0.9 |
| Gasoline | 4 | 0.1 | 6 | 0.03 |

Table 10. Maintenance Labor Hours and Intensity — Summary of Three Years

| | Labor Intensity (h/1000 miles) | | |
|---|---|---|---|
| | 3rd Year | 2nd Year | 1st Year |
| | | *Five-car Averages* | |
| All Maintenance | | | |
| Methanol | 2.8 | 2.1 | 1.7 |
| Gasoline | 1.0 | 0.6 | 0.5 |
| Fuel-Related Maintenance | | | |
| Methanol | 1.0 | 0.9 | 0.9 |
| Gasoline | 0.1 | 0 | 0.03 |

### 3.4 Oil Sample Analyses

Samples of the lubricating oil are drawn from the crankcase of each of the ten vehicles at approximately 1000 mile intervals. These samples are analyzed for total base number, kinematic viscosity, and concentrations of iron, lead, copper, aluminum, chromium, sodium, and silicon. Generally, a fleet operator uses information from oil sample analyses as a diagnostic tool for implementing necessary preventive or corrective maintenance. In this project, however, the information is not generally used to intervene in the natural processes that are progressing in the engines under study. Only in rare circumstances, such as the revealed need for an air filter change, has the information been used to implement any vehicle service that would not have ordinarily occurred at a given point in time.

No significant abnormal trends have been observed in either the total base number or the kinematic viscosity of the oil of any of the cars for the period of this project. For the LBL vehicles, aluminum, chromium, and sodium do not accumulate in the lubricating oil in any amounts that would warrant further attention here. Silicon enters the oil usually by contamination from dirt in the environment, and data regarding its concentration are not as enlightening as that of other contaminants *vis-à-vis* engine wear. Iron is usually the largest contributor to lubricating oil contamination in both the methanol vehicles and the gasoline vehicles.

Results are presented in Table 11 for accumulation rates of wear metals (iron, lead, and copper) in the lubricating oil. Accumulation rates are found by (1) fitting linear regressions (least squares curve-fits) to data of wear metals concentration as a function of distance since oil change, and (2) determining the slopes (accumulation rates) of the regressions.

Table 11. Wear Metals Accumulation Rates

Average wear metals accumulated in lubricating oil in parts per million per 1000 miles of operation

| Wear metal | 3rd Year | 2nd Year | 1st Year | All 3 Years |
|---|---|---|---|---|
| | | *Methanol Vehicles* | | |
| Iron | 31 | 33 | 43 | 33 |
| Lead | 7 | 7 | 59 | 12 |
| Copper | 1 | 3 | 8 | 3 |
| | | *Gasoline Vehicles* | | |
| Iron | 1 | 4 | 8 | 3 |
| Lead | 1 | 2 | 7 | 2 |
| Copper | 2 | Nil | 1 | 1 |

The table includes results for the three years individually as well as a composite for all three years. In the third year, metals accumulation rates again generally declined for both methanol and gasoline vehicles. The average iron accumulation rate in the methanol vehicles appears to be stabilizing at a value around 30 ppm/1000 miles; a value which, while measurably higher than for gasoline cars, is not cause for great alarm. Lead and copper accumulation rates are low and stable for both methanol and gasoline vehicles.

## 3.5 Drivers' Perceptions of Vehicle Performance

Drivers at LBL are asked to evaluate the car's ease of starting and driveability at the end of each trip by making a check mark under either "Good", "Average", or "Poor" on the trip log for both "Ease of Starting" and "Driveability". This simple process yields a profile of the drivers' general impressions of the cars' performance and how their impressions may change over time.

During the third year 1926 trip log entries were recorded; 805 for the methanol vehicles and 1121 for the gasoline vehicles (for the entire three years, 2773 trips for methanol vehicles and 3806 trips for gasoline vehicles for a total of 6579 entries). Over 500 persons at LBL have driven the cars in the project over the three years.

Results from the third year are shown in Table 12 both in numbers of responses to questions and in percentages. The drivers rated the ease of starting of the methanol vehicles very nearly the same as that of the gasoline vehicles, but the driveability of the methanol vehicles suffered in the drivers ratings. This is probably the result of the drivers' experiencing stalling of the methanol vehicles in traffic - a complaint that has persisted for the entire three years. The frequency of the "Good" rating of driveability for the methanol vehicles declined again in the third year as illustrated in Figure 1, while the frequency of the "Good" rating of ease of starting of the methanol vehicles recovered from its losses in the second year. Results of drivers' ratings for the entire three years are shown in Table 13. Overall, the drivers have rated both the methanol and gasoline cars very highly, but the gasoline cars maintain an edge over the methanol cars in both categories of ratings.

## 3.6 Results of Driver Survey

Late in the third year drivers were surveyed in order to elicit from them more in-depth evaluations of the cars and their experiences and perceptions. Over 200 survey forms were mailed to LBL drivers; only 77 were returned by mail to ORNL. The survey results are summarized in Appendix A; included are all of the written remarks and comments that the drivers provided on their forms. Results from the survey indicate a generally favorable impression by LBL drivers of the methanol vehicle technology in the cars.

Table 12. Responses from Daily Trip Logs for Ease of Starting and Driveability
Third Year - November 1, 1987 to October 31, 1988
(To September 30, 1988 for gasoline cars)

| | Responses | | | |
|---|---|---|---|---|
| | Good | Average | Poor | No Response |
| Ease of Starting | | | | |
| | *Number of Responses* | | | |
| Methanol | 593 | 81 | 14 | 117 |
| Gasoline | 858 | 85 | 24 | 154 |
| | *Percent of Total* | | | |
| Methanol | 74 | 10 | 2 | 14 |
| Gasoline | 76 | 8 | 2 | 14 |
| Driveability | | | | |
| | *Number of Responses* | | | |
| Methanol | 409 | 243 | 23 | 130 |
| Gasoline | 749 | 143 | 52 | 177 |
| | *Percent of Total* | | | |
| Methanol | 51 | 30 | 3 | 16 |
| Gasoline | 67 | 13 | 4 | 16 |

Table 13. Responses from Daily Trip Logs for Ease of Starting and Driveability
Three Years - through October 31, 1988
(September 30, 1988 for gasoline cars)

| | Responses | | | |
|---|---|---|---|---|
| | Good | Average | Poor | No Response |
| Ease of Starting | | | | |
| | *Number of Responses* | | | |
| Methanol | 1916 | 466 | 98 | 293 |
| Gasoline | 2916 | 495 | 48 | 347 |
| | *Percent of Total* | | | |
| Methanol | 69 | 17 | 3 | 11 |
| Gasoline | 77 | 13 | 1 | 9 |
| Driveability | | | | |
| | *Number of Responses* | | | |
| Methanol | 1634 | 681 | 119 | 339 |
| Gasoline | 2547 | 808 | 72 | 379 |
| | *Percent of Total* | | | |
| Methanol | 59 | 25 | 4 | 12 |
| Gasoline | 67 | 21 | 2 | 10 |

## 4. REFERENCES


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4. R. N. McGill, J. L. Wantland, and S. L. Hillis, *First Year Results from the Federal Methanol Fleet at the Lawrence Berkeley Laboratory,* SAE paper 872042, Society of Automotive Engineers, Warrendale, Pennsylvania, November, 1987.

5. R. N. McGill and S. L. Hillis, *The Department of Energy's Federal Methanol Fleet — A Progress Report,* SAE paper 881629, Society of Automotive Engineers, Warrendale, Pennsylvania, October, 1988.

6. *Alcohol Fueled Fleet Test Program Eighth Interim Report,* ARB/MS-88-05, Mobile Source Division, State of California Air Resources Board, El Monte, June, 1988.

## APPENDIX A - RESULTS OF LBL DRIVER SURVEY

Results from the survey of LBL drivers are presented below in two sections; in the first, each survey question is listed along with the possible answers (all were multiple choice). The percentage of those responding to each possible answer is shown next to the answer. The only exception to this was the first question for which a profile of responses has been indicated. Additionally, in the second section all written comments and remarks from the survey respondents are listed under the question for which the comment was offered.

Many of the comments and complaints concerned stalling of the methanol cars. This is the problem (discussed in Section 3.3) that is usually corrected by properly adjusting the carburetor settings and is the most common "methanol-related" problem with the cars at LBL. Other comments reflect rather serious misperceptions about fuel economy of methanol vehicles, perhaps indicating that drivers expect fuel economy (mpg) in methanol vehicles similar to that which they experience in gasoline vehicles. This appears to represent a challenge for public relations personnel in any future marketing of methanol vehicles; it suggests that education is needed regarding the relationship between fuel economy and energy density of the fuel.

RESULTS OF 1988 DRIVER SURVEY AT LAWRENCE BERKELEY LABORATORY

FEDERAL METHANOL FLEET

**1. For the two types of Chevrolet Citations in the Motor Pool that you may have had the opportunity to drive, please indicate your best estimate of the percent of time that you drove each type.**

| Composite of responses | Frequency of response (%) |
|---|---|
| Methanol cars driven more | 34 |
| Both driven equally | 27 |
| Gasoline cars driven more | 39 |

**2. How long have you been driving either the 'METHANOL' or the 'GASOLINE' Citations in the motor pool? Remember, the cars were placed in service November of 1985.**

| | |
|---|---|
| Less than 1 year | 18 |
| 1 to 2 years | 25 |
| 2 to 3 years | 57 |

**3. How do the Citations (methanol or gasoline) in the Laboratory motor pool perform relative to other cars of their types that you have previously driven?**

| | |
|---|---|
| Better | 4 |
| Equal | 70 |
| Worse | 12 |
| No comparable experience | 14 |

**4. When you drove the Citations, which type of driving did you experience the most? (Please indicate 1 answer for EACH group).**

**METHANOL**

| | |
|---|---|
| Highway | 48 |
| In town | 5 |
| Both equally | 2 |
| No experience in these cars | 45 |

**GASOLINE**

| | |
|---|---|
| Highway | 42 |
| In town | 5 |
| Both equally | 2 |
| No experience in these cars | 51 |

5. **Did you have difficulty in STARTING the engines? (Please indicate 1 answer for EACH group.)**

**METHANOL**

| | |
|---|---|
| Yes | 6 |
| No | 72 |
| Do not remember | 22 |

**GASOLINE**

| | |
|---|---|
| Yes | 3 |
| No | 91 |
| Do not remember | 6 |

6. **Given your experience, how would you compare the EASE OF STARTING of the Citations?**

| | |
|---|---|
| Methanol much better | 0 |
| Methanol slightly better | 9 |
| About the same | 65 |
| Gasoline slightly better | 15 |
| Gasoline much better | 11 |

7. **How would you compare the performance of the vehicle during the WARM-UP period?**

| | |
|---|---|
| Methanol much better | 1 |
| Methanol slightly better | 6 |
| About the same | 57 |
| Gasoline slightly better | 20 |
| Gasoline much better | 16 |

**8. How would you compare the performance of the vehicles when FULLY WARMED-UP?**

| | |
|---|---|
| Methanol much better | 0 |
| Methanol slightly better | 7 |
| About the same | 66 |
| Gasoline slightly better | 20 |
| Gasoline much better | 7 |

**9. Comparing the methanol vehicles to their gasoline counterparts, which type of vehicle do you feel was better in OVERALL performance?**

| | |
|---|---|
| Methanol was best | 4 |
| About the same | 49 |
| Gasoline was best | 33 |
| Cannot say | 14 |

**10. How would you compare the DRIVEABILITY of the Citations?**

| | |
|---|---|
| Methanol much better | 1 |
| Methanol slightly better | 3 |
| About the same | 76 |
| Gasoline slightly better | 19 |
| Gasoline much better | 1 |

**11. Do you feel SAFE driving the Fleet vehicles?**

**METHANOL**

| | |
|---|---|
| Yes | 69 |
| No | 10 |
| Did not consider it | 21 |

**GASOLINE**

| | |
|---|---|
| Yes | 78 |
| No | 0 |
| Did not consider it | 22 |

**12. Given your experience, how would you rate the DRIVING RANGE of the methanol Citations as compared to the gasoline Citations?**

| | |
|---|---|
| Much better | 0 |
| Slightly better | 3 |
| About the same | 60 |
| Slightly worse | 24 |
| Much worse | 11 |
| Do not know | 2 |

**13. If methanol fuel were available at nearly every fueling station, would you be willing to use a methanol Citation for longer business trips?**

| | |
|---|---|
| Yes | 79 |
| No | 20 |
| Undecided | 1 |

**14. If the costs of running a vehicle on gasoline or methanol were roughly equal, which fuel would you prefer?**

| | |
|---|---|
| Prefer methanol by far | 16 |
| Prefer methanol slightly | 4 |
| Would make no difference | 58 |
| Prefer gasoline slightly | 8 |
| Prefer gasoline by far | 14 |

**15. Given your experience, would you consider buying a methanol powered vehicle?**

| | |
|---|---|
| Would definitely buy one | 6 |
| Might consider buying one | 47 |
| Probably would not buy one | 31 |
| Would definitely not buy one | 16 |

**16. Do you feel that the use of methanol fuel in vehicles is a possible solution to our nation's dependence on imported oil?**

| | |
|---|---|
| Yes | 60 |
| No | 3 |
| Do not know | 37 |

**17. In your experience, how frequently do people mistake methanol (wood alcohol) for ethanol (grain alcohol)?**

| | |
|---|---|
| Most are confused | 27 |
| Slightly more are confused | 8 |
| 50 - 50 | 11 |
| Slightly more are not confused | 0 |
| Most are not confused | 12 |
| Do not know | 42 |

**18. From what you've heard, which of the vehicles requires more service or repair, methanol or gasoline?**

| | |
|---|---|
| Methanol by far | 7 |
| Methanol slightly more | 28 |
| Both about the same | 36 |
| Gasoline slightly more | 6 |
| Gasoline by far | 1 |
| Do not know | 22 |

**19. Do you have any trouble with fuel (methanol) dispensing pumps at your refueling station? If so, what type of problems do you encounter?**

| | |
|---|---|
| Yes | 5 |
| No | 56 |
| No experience | 39 |

**20. To the best of your knowledge, does your refueling station have any problems in storing and dispensing the methanol fuel?**

| | |
|---|---|
| Yes | 1 |
| No | 99 |

**21. Which type of driving do you experience the most when you drive your personal vehicle.**

| | |
|---|---|
| Highway | 56 |
| In town | 37 |
| Both driven equally | 7 |

**22. Age**

| | |
|---|---|
| 18-35 | 13 |
| 36-49 | 57 |
| 50-UP | 30 |

**23. Sex**

| | |
|---|---|
| F | 13 |
| M | 87 |

RESULTS OF 1988 DRIVER SURVEY
LAWRENCE BERKELEY LABORATORY
RESPONDENTS COMMENTS

**QUESTION 8: How would you compare the performance of the vehicles when FULLY WARMED-UP?**

- "Methanol maybe slightly sluggish." [Answer to Q = gasoline slightly better]

**QUESTION 12. Given your experience, how would you rate the DRIVING RANGE of the methanol Citations as compared to the gasoline Citations?**

- "Almost ran out several times!" [Answer to Q = much worse]
- "Fuel availability restricts driving range." [Answer to Q = about the same]
- "In town about the same - availability on highway is a problem." Answer to Q = much worse highway but about the same in town]

**QUESTION 13. If methanol fuel were available at nearly every fueling station, would you be willing to use a methanol Citation for longer business trips?**

- "May reconsider if both cars were optimally tuned for their respective fuels." [Answer to Q = no]
- "Would prefer methanol if they produced less contaminants- in the emissions." [Answer to Q = yes]
- "Also if we could get a fuel gauge that works." [Answer to Q = yes]
- "Service for methanol type cars will have to be available." [Answer to Q = no]
- "I have absolutely no problems with methanol." [Answer to Q = yes] "But stalling problem would need looking into." [Answer to Q = yes)
- "Not if it continues to stall, especially in hill climbs." [Answer to Q = no]
- "Poor starting - engine dies when cold - less performance." [Answer to Q = no]
- "I do not feel that I can depend upon the methanol citations for longer trips. They may stall!" [Answer to Q = no]
- "Only if the methanol powered car was equal to the gasoline powered one." Answer to Q = yes]
- "The miles per gallon is much, much worse. I wouldn't want to be stranded because I couldn't make it to the next methanol station." [Answer to Q = no)
- "I would have no problem with that." Answer to Q = yes]
- "Have found they have a tendency to stall - also, gas gauges do not work, so it is unknown what fuel status is." [Answer to Q = no]

- "The only problem with methanol for all trips is availability of methanol." [Answer to Q = yes]
- "Performance of methanol car is adequate for business travel." [Answer to Q = yes]
- "Yes, dispensing is the same or better (less smell) as gasoline, price should be less than gas too." [Answer to Q = yes]
- "No reason not to." [Answer to Q = yes]
- "Especially for driving in bay area, methanol cars lack power to accelerate, otherwise okay for cruising or highway driving." [Answer to Q = no]
- "Other than some difficulties in start up, performance/ driveability is essentially the same." [Answer to Q = yes]
- "Only disadvantages in our moderate climate are shorter range per tank • slight inconvenience to fill up more often." ("Could be a safety plus • forced stops!)" [Answer to Q = yes]
- "Sluggish." [Answer to Q = no]

**QUESTION 14. If the costs of running a vehicle on gasoline or methanol were roughly equal, which fuel would you prefer?**

- "The methanol cars are poor performers and have low mpg!" [Answer to Q = prefer gasoline by far]
- "May reconsider if auto is designed only to use methanol • present performance of methanol Citations is poor • frequent stalls, lugging, & ignition failures • poor on hills!" [Answer to Q = prefer gasoline by far]
- "Availability of methanol fuel 1st consideration." [Answer to Q = would make no difference]
- "Methanol renewable, but perhaps greater pollution problem (greenhouse effect)." [Answer to Q = would make no difference]
- "Less national dependence on foreign oil." [Answer to Q = prefer methanol by far]
- "I would pick the one that cost less." [Answer to Q = would make no difference]
- "Help - with oil dependency." [Answer to Q = prefer methanol slightly]
- "With cost being equal, I'm sure that mechanics will be more knowledgeable with methanol cars." [Answer to Q = would make no difference]
- "Which ever fuel does not deplete natural resources would be my choice." [Answer to Q = respondent did not answer the question]
- "Methanol is renewable, less toxic, not carcinogenic, not imported. Its widespread use would help U.S. Farmers and U.S. Industry." [Answer to Q = would make no difference]
- "Methanol is terribly corrosive, very toxic, has lower heat content, also might tax natural resources." [Answer to Q = prefer gasoline slightly]
- "Gasoline engines faster response in quick acceleration." [Answer to Q = prefer gasoline slightly]
- "Engine does not keep stalling like the methanol." [Answer to Q = prefer gasoline by far]

- "Because I feel that the engine runs much more smoothly with gasoline." [Answer to Q = prefer gasoline by far]
- "I believe methanol can be manufactured and is cleaner." [Answer to Q = prefer methanol by far]
- "If the performance of the methanol car was better I would use methanol." [Answer to Q = would make no difference]
- "Better performance, better "gas" mileage." [Answer to Q = prefer gasoline by far]
- "The performance seems to be the same. Perhaps less pollution?" [Answer to Q = would make no difference]
- "Performance of methanol car is adequate for business travel." [Answer to Q = would make no difference]
- "Environmental concerns." [Answer to Q = prefer methanol slightly]
- "Reduce the use of a limited oil supply." [Answer to Q = would make no difference]
- "Better performance; higher mileage." [Answer to Q = prefer gasoline by far]
- "Renewable resource – ecologically better!" [Answer to Q = prefer methanol by far]
- "More power to gas than methanol; better starting on gas than methanol." [Answer to Q = prefer gasoline slightly]
- "Reduces our dependence on foreign oil." [Answer to Q = prefer methanol slightly]

**QUESTION 15. Given your experience, would you consider buying a methanol powered vehicle?**

- "If fuel was readily available everywhere." [Answer to Q = might consider buying one]
- "At present there appears to be only a very limited number of mechanics who know how to work on the methanol cars." [Answer to Q = probably would not buy one]
- "Reconsider if new technology improved performance." [Answer to Q = would definitely not buy one]
- "I would have to know more about maintenance of a methanol powered vehicle." [Answer to Q = might consider buying one]
- "Would like to see more studies with methanol through the USA." [Answer to Q = might consider buying one]
- "I have not had enough experience with the methanol to make a comparison. I would certainly be willing if it would benefit our atmosphere, etc." [Answer to Q = might consider buying one]
- "If methanol fuel is cheaper than gasoline." [Answer to Q = might consider buying one]
- "Would depend on fuel cost per mile. If equal would definitely buy one." [Answer to Q = might consider buying one]
- "If costs were about equal, at least as safe and supply roughly as convenient as gasoline." [Answer to Q = would definitely buy one]
- "If fuel was readily available." [Answer to Q = might consider buying one]
- "Until there is a lot more fuel available - would not consider it." [Answer to Q = probably would not buy one]

- "The methanol type cars need at least a 15 year track record. I keep my cars for approximately 12 years." [Answer to Q = would definitely not buy one]
- "If performance and cost of operation would be equal or better. I understand that use of methanol is better for the environment - that would be a definite factor in its favor." [Answer to Q = might consider buying one]
- "If methanol were as widely available as gasoline." [Answer to Q = might consider buying one]
- "Until fuel was more readily available - if so , ok - would consider it." [Answer to Q = would definitely not buy one]
- "Tough to start. Keeps stalling. At least vehicles at LBL." [Answer to Q = would definitely not buy one]
- "I have no information about the availability of methanol fuel - this is the prime motivation for my response." [Answer to Q = probably would not buy one]
- "Based upon my limited experience I believe that methanol powered vehicles are still on the learning curve. My belief is based on perhaps the more predictability of a gasoline powered vehicle." [Answer to Q = would definitely not buy one]
- "Only if (1) methanol were generally available, (2) would not cost more." [Answer to Q = might consider buying one]
- "Low power efficiency with methanol." [Answer to Q = probably would not buy one]
- "At this time I do not know enough about it." [Answer to Q = might consider buying one]
- "Because of comments in #12 (availability of fuel on trips), also methanol is not widely obtainable (which is also why I'm not keen on diesels, either)." [Answer to Q = would definitely not buy one]
- "All things being equal, I would prefer a gasoline car. However, in the future methanol may be more available than gasoline, making it a suitable alternative." [Answer to Q = probably would not buy one]
- "Performance for personal use would be less than I would prefer to have." [Answer to Q = probably would not buy one]
- "Cost is subsidized." [Answer to Q = probably would not buy one]
- "If methanol was as available as gasoline I would probably buy a methanol powered car." [Answer to Q = might consider buying one]
- "Albeit "cleaner" burning, methanol cars have few advantages over performance of gasoline powered cars." [Answer to Q = might consider buying one]
- "The car is still "special" in it's fuel and technical support requirements. If these issues were equalized, I'd give further consideration to a methanol powered vehicle." [Answer to Q = probably would not buy one]
- "If methanol fuel were universally available and engine life were proven comparable or guaranteed. Also oil additives would have to be inexpensive. [Answer to Q = would definitely buy one]
- "Availability of fuel is worse. Also I would anticipate service problems." [Answer to Q = would definitely not buy one]

- "Not enough sources of consumer supply, presently too expensive in relation to the cost of gas; less power than gas." [Answer to Q = probably would not buy one]
- "Availability of methanol would be the controlling factor." [Answer to Q = probably would not buy one]

**QUESTION 16. Do you feel that the use of methanol fuel in vehicles is a possible solution to our nation's dependence on imported oil?**

- "Turbine." [Answer to Q = no]
- "Maybe. This is only part of the solution." [Answer to Q = maybe]

**QUESTION 17. In your experience, how frequently do people mistake methanol (wood alcohol) for ethanol (grain alcohol)?**

- "Provided you call it wood alcohol." [Answer to Q = most are not confused]

**QUESTION 18. From what you have heard, which of the vehicles require more service or repair, methanol or gasoline?**

- "Methanol requires more frequent 'tune-ups' especially in 'cold' (50°F) weather." [Answer to Q = methanol slightly more]

**QUESTION 19. Do you have any trouble with fuel (methanol) dispensing pumps at your refueling station? If so, what type of problems do you encounter?**

- "Forgot to reset meter. Fortunately I had noticed starting number." [Answer to Q = yes]
- "I have had problems with some of methanol cars just quitting when pulling up to a stop after the engine is hot. They were then hard to start again. I was also put off with lack of fuel service when I ran out of fuel while the highway."

**QUESTION 20. Do you have any trouble with fuel (methanol) dispensing pumps at your refueling station? If so, what type of problems do you encounter?**

- "Sometimes I am unsure if the vehicle is filled with fuel." [Answer to Q = yes]

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