EPA/AA/CTAB/90-02

Technical Report

Recent Results From Prototype Vehicle Technology Evaluation Using M100 Neat Methanol Fuel

by

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Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

ANN ARBOR, MICHIGAN 48105

MAR 21 1990

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Exemption From Peer and Administrative Review

FROM: Karl H. Hellman, Chief
Control Technology and Applications Branch

TO: Charles L. Gray, Jr., Director
Emission Control Technology Division

The attached report entitled "Recent Results From Prototype Vehicle Technology Evaluation Using M100 Neat Methanol Fuel," (EPA/AA/CTAB/90-02) describes the evaluation of two prototype M100-fueled vehicles. Emissions and fuel economy test results from both vehicles are presented and compared here.

Since this report is concerned only with the presentation of data and its analysis and does not involve matters of policy or regulations, your concurrence is requested to waive administrative review according to the policy outlined in your directive of April 22, 1982.

Concurrence: ______________________ Date: 3-17-90
Charles L. Gray, Jr., Dir., ECTD

Nonconcurrence: ______________________ Date: ____________
Charles L. Gray, Jr., Dir., ECTD

cc: E. Burger, ECTD

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I. Summary

The Toyota Motor Corporation and the Nissan Motor Corporation recently supplied the U.S. Environmental Protection Agency (EPA) with advanced prototype vehicles which utilize M100 (neat methanol) fuel. These vehicles both make use of nominal lean burn calibrations controlled by an exhaust gas air/fuel sensor feedback control system and 4 valve per cylinder technology in 4-cylinder powerplants. Though these vehicles share these similar technological aspects, important differences between both engine/vehicle packages yet exist.

These two prototype vehicles have been evaluated by EPA for emissions and fuel economy. Nissan also supplied EPA with a gasoline-fueled vehicle for fuel economy and performance testing and comparison. The results from this preliminary round of testing are given here.

Both prototype vehicles achieved low emission levels over the Federal test procedure (FTP), at low mileage, of hydrocarbon, methanol, formaldehyde and organic material hydrocarbon equivalent emissions. Particularly noteworthy were the lower emissions of formaldehyde (9.0 milligrams per mile) and organic material hydrocarbon equivalents (0.12 grams per mile) over the FTP by the M100 lean burn Toyota Corolla. The M100 lean burn Nissan Sentra vehicle had very low emissions of carbon monoxide (0.45 grams per mile) over the FTP.

The gasoline equivalent fuel economy of the M100 Sentra was compared to that from a gasoline-fueled Nissan Pulsar equipped with a similar base engine. The M100 Sentra was evaluated at the same test weight, actual dynamometer horsepower and nominally equivalent N/V (rpm/MPH in top gear) ratio as the gasoline-fueled vehicle. The fuel economy of the M100 vehicle was also performance adjusted to eliminate the effects of this difference between the two fuels.

The methanol-fueled vehicle had a combined city/highway gasoline equivalent fuel economy approximately 47 percent greater than the gasoline-fueled comparison vehicle under these conditions.

II. Introduction

The U.S. Environmental Protection Agency (EPA) has been interested in methanol as an alternative motor vehicle fuel because of its environmental benefits over the continued use of gasoline. Methanol may be particularly attractive as an automotive fuel in areas of high ozone level occurrences because of its lower ozone-producing potential.[1] Methanol may also offer air quality benefits over gasoline with respect to a wide variety of organic air toxics.[2]

The Toyota Motor Corporation has provided substantial technical assistance to U.S. EPA efforts involving the use of methanol as a motor vehicle fuel. One part of this assistance was the consignment for technical evaluation to EPA of a Toyota Lean Combustion System-Methanol (T-LCS-M) Carina vehicle. Technical detail for this vehicle may be found in the literature.[3,4] This vehicle was initially evaluated for emissions and fuel economy and has been used in several emissions control technology evaluation efforts.[5,6,7,8,9]

A second-generation methanol-prototype vehicle has been produced by Toyota.[10] This prototype utilized both lean combustion, lean feedback air/fuel ratio control, and exhaust gas recirculation. The 4 valve per cylinder configuration results in a relatively compact combustion chamber for this engine. A significant goal of this research effort was to determine the feasibility of achieving 0.4 grams per mile NOx levels over the 1975 Federal test procedure (FTP) with this methanol-fueled lean burn engine.

EPA requested that Toyota provide a second generation methanol lean burn vehicle for evaluation and research assistance. Toyota provided EPA with a second-generation methanol lean burn system in a Corolla vehicle. This vehicle may operate on either M100 neat methanol or M85 blended methanol/gasoline fuel depending upon which of two provided calibrations is used.

The Nissan Motor Corporation has also provided substantial technical assistance to EPA with respect to alternative fuels research. Nissan technology has been used in several recent EPA efforts involving methanol-fueled vehicle technology.[11,12,13] Nissan also designed and produced a recent prototype methanol vehicle incorporating lean burn operation and 4-valve-per-cylinder technology. Upon request, Nissan provided EPA with a prototype methanol vehicle for evaluation and research. Nissan also lent a gasoline-fueled Pulsar vehicle to EPA to assist with an effort to compare gasoline equivalent fuel economy from a methanol-fueled vehicle to that from a comparable gasoline vehicle.

Preliminary emissions and fuel economy evaluations have been made of each of these vehicles on M100 fuel. Limited performance testing on each vehicle has also been conducted. The purpose of this report is to present and compare test data from each of these evaluations.

III. Test Vehicle Descriptions

A. Toyota Corolla Vehicle

The Toyota Corolla vehicle evaluated here was equipped with the second-generation Toyota methanol lean burn system as described in SAE Paper 892060.[10] The Corolla vehicle delivered to EPA was capable of operation on both M100 neat and M85 blended methanol fuels by changing calibrations. The data in this paper, however, is concerned only with operation on M100 neat methanol.

The base engine chosen by Toyota for the second-generation methanol lean burn system was the 1.6-liter 4A-FE, incorporating 4-valve/cylinder and compact combustion chamber technology.[14] The swirl control valve system, lean mixture sensor and sequential fuel injection, all essential components of the first lean burn system, were retained.[4] In addition, exhaust gas recirculation (EGR) was added in an attempt to further lower NOx emissions. A palladium underfloor catalyst was also incorporated in addition to the platinum:rhodium manifold close-coupled converter, in an attempt to lower formaldehyde emissions.

Detailed specifications are provided in Appendix A.

B. Nissan Sentra Vehicle

The Nissan test vehicle evaluated here is similar to the Toyota vehicle in that it utilizes a 4-valve/cylinder, 4-cylinder in-line base engine with a lean burn operating scheme. Electronic port fuel injection and swirl control valves are also incorporated, as in the Toyota vehicle.

While the general engine schemes are similar for the two test vehicles, many important differences also exist. For example, the Nissan engine is slightly larger in displacement at 1.8 liters and has a higher compression ratio (12.0:1) compared to 11.0:1 for the Toyota engine. The Sentra vehicle was tested at a lower test weight of 2,250 lbs as suggested by Nissan. A single underfloor Pt:Rh catalyst was used by Nissan instead of the two-catalyst system used by Toyota on the Corolla vehicle.

A detailed list of specifications for this vehicle is given in Appendix B.

IV. Test Facilities And Analytical Methods

Emissions testing at EPA was conducted on a Clayton Model ECE-50 double-roll chassis dynamometer using a direct-drive variable inertia flywheel unit and road load power control unit. The Philco Ford constant volume sampler used had a nominal capacity of 350 CFM. Exhaust HC emissions were measured with a Beckman Model 400 flame ionization detector (FID). CO was measured using a Bendix Model 8501-5CA infrared CO analyzer. NOx emissions were determined by a Beckman Model 951A chemiluminescent NOx analyzer.

Exhaust formaldehyde was measured using a dinitrophenylhydrazine (DNPH) technique.[15,16] Exhaust carbonyls including formaldehyde are reacted with DNPH solution forming hydrazine derivatives. These derivatives are separated from the DNPH solution by means of high performance liquid chromatography (HPLC), and quantization is accomplished by spectrophotometric analysis of the LC effluent stream.

The procedure developed for methanol sampling and presently in use employs water-filled impingers through which a sample of the dilute exhaust or evaporative emissions are pumped. The methanol in the sample gas dissolves in water. After the sampling period is complete, the solution in the impingers is analyzed using gas chromatographic (GC) analysis.[17]

Most of the emission results in this report are computed using the methods outlined in the "Final Rule for Methanol-Fueled Motor Vehicles and Motor Vehicle Engines," which was published in the Federal Register on Tuesday, April 11, 1989. Because these specialized procedures and calculation methods are not in widespread use, we have also included a hydrocarbon result, which is what would be obtained if the exhaust was treated as if the fuel were gasoline. This is done as a convenience for the readers and users of the report who may be more familiar with hydrocarbon results obtained this way.

V. Evaluation Process

The initial evaluation process reported on here consisted of emissions and fuel economy testing, followed by limited performance testing.

Both prototype vehicles were evaluated for emissions and fuel economy several times over the FTP and highway fuel economy test (HFET) cycles. Limited performance testing consisting of 5-60 miles per hour (MPH) acceleration tests on a chassis dynamometer were also conducted at several vehicle test weights and actual dynamometer horsepower settings. Wide open throttle (WOT) and 5,000 rpm shift points were used during this testing. The purpose of this testing was to assist in relating performance to fuel economy. The gasoline-fueled Pulsar provided by Nissan mentioned earlier was used here as a control vehicle.

VI. Discussion of Test Results

A. Vehicle Emissions

Upon arrival at the EPA Motor Vehicle Emission Laboratory (MVEL) both vehicles were tested approximately eight times over the FTP with M100 fuel. Average emission levels from this testing with both cars are presented in Table 1.

It is important to note that although both prototype vehicles referred to have significant basic technologies in common, e.g., lean operation, use of 4-valve/cylinder technology, etc., many fundamental differences between the two remain. These fundamental differences will significantly impact the emissions and fuel economy profiles of these two vehicles. No attempt is made in this report to quantify the effect of these differences on emissions and fuel economy. Instead, the data is presented in comparative fashion to provide an indication of what low mileage emissions and fuel economy levels might be expected from state-of-the-art M100-fueled vehicles equipped with premixed charge spark ignition engines.

The emissions levels from both vehicles may generally be described as being lower than the levels specified by exhaust emissions standards for light-duty methanol-fueled vehicles for the model year 1990.[18] Hydrocarbon (HC) emissions from both vehicles were approximately the same, at 0.02 grams per mile. Organic material hydrocarbon equivalents (OMHCE) were slightly higher, for example 0.20 grams per mile, from the Sentra vehicle. Both prototype vehicle OMHCE levels were substantially under the current 0.41 grams per mile standard, however.

Methanol emissions from the Corolla vehicle were very low over the FTP. The emissions of 0.22 grams per mile approach the levels of a stoichiometric air/fuel ratio M100-fueled vehicle equipped with a very effective resistively heated fast light-off catalyst.[19] CH_3OH emissions from the Sentra vehicle were higher, at an average 0.40 grams per mile.

Table 1

M100-Fueled Nissan/Toyota
Prototype Lean Burn Vehicles

Exhaust Emissions Over the FTP Cycle

Vehicle	HC* (g/mi)	HC** (g/mi)	NMHC (g/mi)	OMHCE (g/mi)	CH_3OH (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)
Toyota Corolla with 4A-FE lean burn engine	0.09	0.02	0.01	0.12	0.22	1.61	0.49	9.0
Nissan Sentra with CA18DE lean burn engine	0.15	0.02	0.02 ***	0.20	0.40	0.45	0.56	28.9

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* Measured as hydrocarbons with a propane-calibrated FID.

** Calculated per "Final Rule for Methanol-Fueled Motor Vehicles and Motor Vehicle Engines."

*** Less than 0.01 grams/mile CH_4 measured.

CO emission levels from the Corolla were substantially higher than those of the Sentra vehicle. The 0.45 grams per mile CO measured over the FTP with the M100 Sentra were low even when compared with CO levels from the stoichiometrically calibrated methanol vehicle referred to previously [19] and a gasoline-fueled vehicle, [20] both of which were equipped with resistively heated catalytic converters.

NOx emissions from both vehicles were similar, approximately one-half gram per mile over the FTP. These levels are significantly below the 0.75 grams per mile obtained with the first-generation Toyota lean combustion system (methanol) when tested at low mileage on M100 fuel at MVEL.[6] It is interesting to note that these lower NOx levels were attained without a perceptible degradation in driving performance from the high level of performance of the first-generation Toyota lean combustion system (methanol) noted at MVEL, based on a subjective evaluation of vehicle driveability.

Formaldehyde (HCHO) emissions from the Corolla vehicle were similar to those from the first-generation Toyota lean combustion system (methanol) at low mileage.[5,6] The Sentra had higher HCHO emissions levels of almost 29 milligrams per mile over the FTP.

The major portion of pollutant emissions from a catalyst-equipped methanol-fueled vehicle are generated during cold start and prior to light off of the catalytic converter.[21] These emissions are difficult to control because engine-out emissions are high and catalytic converters have low conversion efficiency during their warm-up phase of operation. Any effort to significantly reduce emission levels of unburned fuel, HCHO, and CO over the FTP will probably involve a lowering of these catalyst prelight-off emissions.

One quick way to roughly gauge the effect of these emissions over the FTP is to compare Bag 1 emission levels to those from Bag 3. The difference in emission levels might be attributed to this vehicle and catalyst warm-up phenomena. Table 2 is a comparison of Bag 1 versus Bag 3 emission levels from the Corolla and Sentra vehicles. The data from each emission category is presented in grams per bag except for HCHO which is given in milligrams per bag. Significant highlights from this data are then presented in graphical form.

Figure 1 presents OMHCE and methanol emissions over Bags 1 and 3, the cold start transient and hot start portions of the FTP. The graphic display of the data makes apparent the large difference in emissions of these pollutants attributable to

Table 2

M100-Fueled Toyota Corolla
Bag 1 versus Bag 3 Emissions, FTP Cycle

Test Segment	HC* (g)	HC** (g)	NMHC (g)	OMHCE (g)	CH_3OH (g)	CO (g)	NOx (g)	HCHO (mg)
Bag 1	1.30	0.21	0.17	1.72	3.37	15.34	2.32	105.8
Bag 3	0.11	0.05	0.03	0.13	0.18	4.25	2.34	14.8
Difference	1.19	0.16	0.14	1.59	3.19	11.09	(0.02)	91.0
Percent	92	76	82	92	95	72	--	86

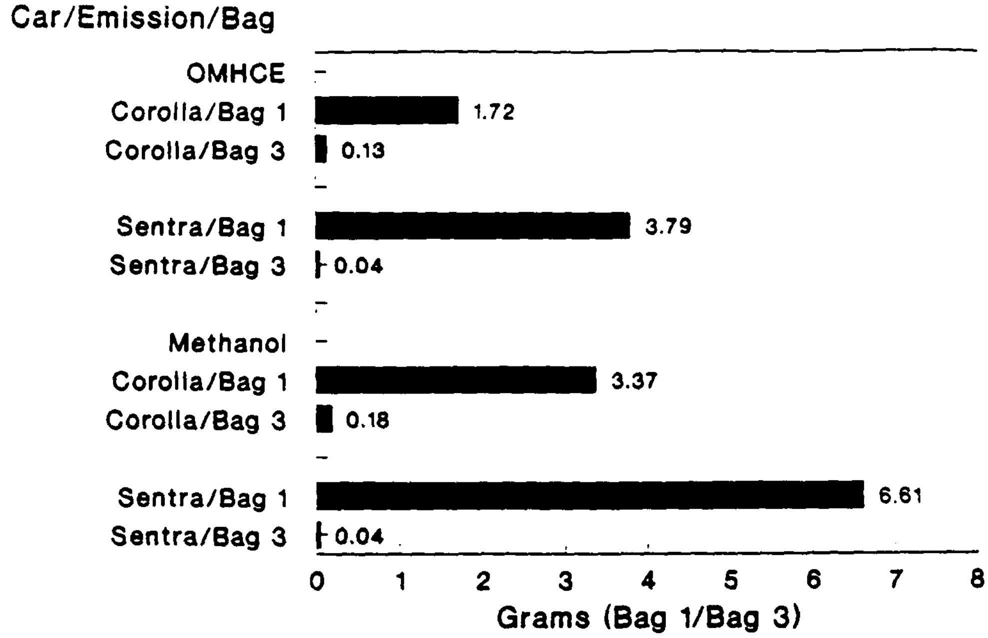
M100-Fueled Nissan Sentra
Bag 1 versus Bag 3 Emissions, FTP Cycle

Test Segment	HC* (g)	HC** (g)	NMHC (g)	OMHCE (g)	CH_3OH (g)	CO (g)	NOx (g)	HCHO (mg)
Bag 1	2.87	0.26	0.23	3.79	6.61	7.61	2.05	434.8
Bag 3	0.03	0.02	0.01	0.04	0.04	0.12	1.88	24.0
Difference	2.84	0.24	0.22	3.75	6.57	7.49	0.17	410.8
Percent	99	92	96	99	99	98	8	94

* Measured as hydrocarbons with a propane-calibrated FID.

** Calculated per "Final Rule for Methanol-Fueled Motor Vehicles and Motor Vehicle Engines."

Figure 1
Bag 1/Bag 3, CVS 75 (FTP)
OMHCE and Methanol Emissions



cold start. OMHCE levels from the Corolla during Bag 1 are roughly 13 times the level determined over Bag 3. This difference increases to almost a factor of 19 when methanol emissions from this vehicle are considered. The difference between Bags 1 and 3 levels of these emissions from the Sentra vehicle are even more pronounced. The influence of cold start on emissions of unburned fuel is clearly evident here.

This influence, as expected, extended to emissions of NMHC and formaldehyde (HCHO). Emissions of NMHC were at roughly the same level from both test vehicles; Figure 2 shows that Bag 1 NMHC emissions from the Sentra prototype were 23 times higher than Bag 1 emissions. HCHO emissions from both vehicles were affected by cold start to an even greater extent if the percent difference in emissions between the two phases is considered.

Emission levels of CO and NOx over Bags 1 and 3 are given in Figure 3. The effect of cold start on emissions of CO from the Sentra vehicle are especially pronounced. NOx emissions do not differ much between Bags 1 and 3.

Table 3 presents emission averages from both vehicles over the HFET cycle. Emissions from both vehicles are similar with the exception that a slightly greater amount of CO was emitted from the Corolla vehicle. These emission averages in grams per mile were uniformly low; they are presented here in Table 3, but not commented upon further.

For most emissions, further efforts at cleanup over the FTP cycle would appear to require emphasis on emissions related to cold start. This is true for emissions of methanol, HC, HCHO, OMHCE, and CO from both vehicles evaluated here.

B. Fuel Economy and Performance Testing

Fuel economy data from the two M100-fueled test vehicles is given in Table 4. The data is presented in two formats. First, miles per gallon (MPG) in terms of methanol fuel is presented, and then a gasoline equivalent fuel economy has been calculated. These computations have been explained in a previous paper;[6] the gasoline equivalent adjustment based on fuel energy content is 2.0105 times the calculated M100 methanol fuel economy.

Table 4 also contains fuel economy data from gasoline-fueled vehicles for comparison. The EPA 1990 Test Car List was reviewed for Toyota and Nissan vehicles configured in a similar manner to the M100-fueled prototypes. A Toyota Corolla wagon was chosen as a vehicle reasonably comparable to the M100-fueled Corolla. The gasoline-fueled vehicle also used

Figure 2
Bag 1/Bag 3, CVS 75 (FTP)
NMHC and HCHO Emissions

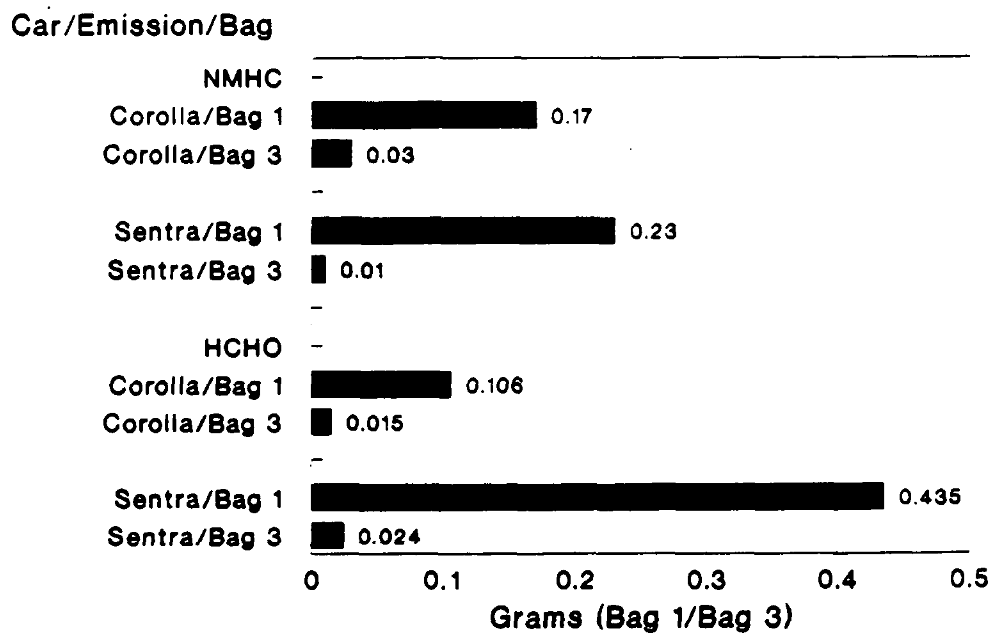


Figure 3
Bag 1/Bag 3, CVS 75 (FTP)
CO and NOx Emissions

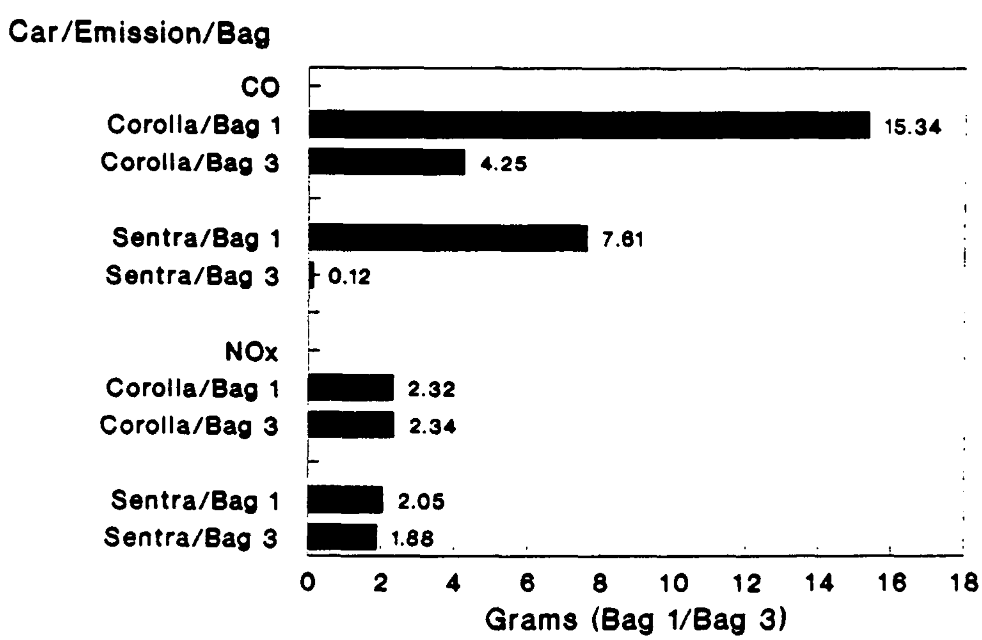


Table 3

M100-Fueled Nissan/Toyota
Prototype Lean Burn Vehicles

Exhaust Emissions Over the HFET Cycle

Vehicle	HC* (g/mi)	HC** (g/mi)	NMHC (g/mi)	OMHCE (g/mi)	CH_3OH (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)
Toyota Corolla with 4A-FE lean burn engine	0.005	0.002	0.001	0.007	0.010	0.13	0.45	2.4
Nissan Sentra with CA18DE lean burn engine	0.004	0.001	--***	0.007	0.012	0.01	0.48	2.2

* Measured as hydrocarbons with a propane-calibrated FID.

** Calculated per "Final Rule for Methanol-Fueled Motor Vehicles and Motor Vehicle Engines."

*** Calculated negative but assumed zero.

Table 4

Fuel Economy Comparison of Toyota and Nissan M100-Fueled Prototypes With "Equivalent" Toyota and Nissan Gasoline-Fueled Vehicles From the EPA 1990 Test Car List

A. Vehicle Specifications

Vehicle	Engine	Drive	N/V	Trans-mission	Dyno HP	Test Weight
M100 Corolla	97 CI, FI, 11.0 CR, EGR	FWD	46.4	M5	8.9	2750
Corolla Wagon (gasoline)	97 CI, FI	FWD	46.4	M5	8.6	2750
M100 Sentra	110 CI, FI, 12.0 CR	FWD	44.4	M5	7.3	2250
Gasoline Pulsar NX	110 CI, FI, EGR, 9.5 CR	FWD	53.6	M5	6.4	2875

B. Fuel Economy

Vehicle	Methanol Fuel Economy City	Hwy	Combined	Gasoline Equivalent MPG City	Hwy	Combined	Percent Diff.
M100 Corolla	16.9	23.1	19.2	33.9	46.4	38.6	+ 9%
Corolla Wagon (gasoline)	--	--	--	31.0	42.4	35.3	Base
M100 Sentra	18.2	25.9	21.0	36.6	52.1	42.2	+44%
Gasoline Pulsar NX	--	--	--	24.9	37.6	29.4	Base

the same final drive ratio (3.72) as the methanol-fueled vehicle. A 1990 Nissan Pulsar NX was selected for comparison to the M100-fueled Sentra. The Pulsar was equipped with the same CA18DE base engine as the methanol-fueled Sentra and also used a 5-speed manual transmission. The Pulsar referred to in Table 4, however, was tested at a higher weight of 2,875 lbs, and utilized a higher axle ratio (4.47).

The M100 Corolla had a combined city/highway gasoline equivalent MPG approximately 9 percent higher than that of the gasoline-fueled vehicle presented for comparison. The M100 Sentra had a combined city/highway fuel economy of 21.0 MPG of methanol fuel; this figure was approximately 9 percent higher than that from the Corolla. The gasoline equivalent fuel economy of the Sentra (42.2 MPG) was significantly higher than the gasoline-fueled Pulsar from the Test Car List. Overall, the calculated gasoline equivalent fuel economies of the M100 vehicle appeared to equal or exceed the fuel economies of roughly comparable gasoline-fueled vehicles. The differences between these vehicles should be kept in mind, however, when attempting a comparison between the fuels.

A further attempt to compare fuel economy from the M100-fueled Sentra with a gasoline vehicle was made when Nissan provided EPA with a 1988 gasoline-fueled Pulsar. This car was used as a comparison vehicle, and an attempt was made to eliminate differences in N/V ratio, test weight and road load horsepower between the M100-fueled car and the gasoline vehicle. The Pulsar utilized the base CA18DE powerplant. Performance was also accounted for in this fuel economy analysis.

Table 5 contains test data from the M100 Sentra and selected vehicles from EPA Test Car List. Case 1 compares the M100 Sentra with a 1990 Pulsar equipped with the same base engine. This case is the same as the data presented in Table 4; an efficiency of +44 percent from the gasoline vehicle's fuel economy is indicated. The Sentra was also compared to a Pulsar from the 1987 Test Car List; this gasoline-fueled Pulsar was tested at a higher actual horsepower, 7.1 hp. The percent improvement in gasoline-equivalent fuel economy with the methanol-fueled vehicle remained very close to that from comparison to the 1990 Pulsar, approximately 45 percent.

Case 3 compared the Sentra tested at 7:1 actual dynamometer horsepower and 2,875 lbs ETW to the gasoline 1987 Pulsar. The results are similar to the first two cases: a 47 percent increase in gasoline equivalent fuel economy of the M100 Sentra over the Pulsar is indicated. The N/V ratio (crankshaft speed in rpm over vehicle speed expressed in miles

Table 5

Comparison of Nissan M100-Fueled Sentra
With Gasoline-Fueled Nissan Pulsar Vehicles
From EPA Test Car Lists

Case	Vehicle	Engine CID	ETW	Dyno HP	Gasoline Equivalent MPG N/V	City	Hwy	Comb.	Percent Diff.
1	M100 Sentra	110	2250	7.3	44.4	36.6	52.1	42.2	+44%
1	1990 Pulsar	110	2875	6.4	53.6	24.9	37.6	29.4	--
2	M100 Sentra	110	2250	7.3	44.4	36.6	52.1	42.2	+45%
2	1987 Pulsar	110	2875	7.1	53.6	25.0	36.7	29.2	--
3	M100 Sentra	110	2875	7.1	44.4	36.8	53.8	42.9	+47%
3	1987 Pulsar	110	2875	7.1	53.6	25.0	36.7	29.2	--
4	M100 Sentra	110	2875	7.1	53.6*	35.3*	49.4*	40.5*	+39%
4	1987 Pulsar	110	2875	7.1	53.6	25.0	36.7	29.2	--

* Adjusted mathematically to infer results if tested at 53.6 N/V.

per hour) of the M100 Sentra was measured at EPA at 44.4; this is lower than the N/V ratio of 53.6 for the 1987 Pulsar given in the 1990 Test Car List. The MPG value of the Sentra was mathematically adjusted to account for this difference.[22] N/V sensitivities of 0.21 for city and 0.43 for highway MPG were used. The result, Case 4, lowers the increase in M100 Sentra fuel economy to 39 percent above the Pulsar, still a significant increase.

Table 6 compares fuel economy data from the M100 Sentra with a 1988 Pulsar equipped with a CA18DE engine provided by Nissan as a comparison vehicle. Case 1 compares both vehicles tested at 2,875 lbs and 7.1 actual dynamometer horsepower. The value of N/V for the Pulsar was 53.3, compared to the measured N/V of 44.4 of the M100 Sentra. The lower combined MPG of 28.3 for the 1988 Pulsar caused the percent difference between the M100 Sentra and gasoline Pulsar fuel economies to rise 52 percent above the level of the Pulsar.

EPA had the M100 Sentra modified to accept the same final drive of the Pulsar (a final drive gear ratio of 4.167:1); this caused the M100 Sentra N/V to rise to 54.0. The only N/V difference now between the two vehicles would be that introduced by the tire outside diameters, and this would be minimal.[22]

Case 2 in Table 6 compares the M100 Sentra modified in this manner to the gasoline-fueled Pulsar. The percent increase in gasoline equivalent fuel economy enjoyed by the methanol-fueled vehicle over the gasoline Pulsar decreased to 33 percent.

Finally, acceleration performance testing was conducted on both vehicles to assist in the adjustment of fuel economy for performance factors.[23] Both vehicles were tested using 5,000 rpm gear shift points and wide-open throttle (WOT) acceleration. The measure of performance was determined to be the time to accelerate at WOT from 5 to 60 MPH. Both cars were equipped with manual transmissions for the shift sequence.

The Sentra fueled with M100 was roughly 19 percent faster than the Pulsar fueled with gasoline. The average 5-60 MPH acceleration time for the M100 Sentra was approximately 8.3 seconds; the Pulsar fueled with gasoline averaged 10.2 seconds for 5-60 MPH acceleration. A sensitivity value of 0.454 [24] was used to account for this difference in performance measured by the difference in acceleration times, and the fuel economy of the M100 Sentra was adjusted accordingly. The comparison between this adjusted MPG for the M100 Sentra and the gasoline-fueled Pulsar is given as Case 3 in Table 6. The M100 Sentra performance-adjusted combined MPG is 41.6; this figure is 47 percent higher than the gasoline-fueled Pulsar.

Table 6

Comparison of Nissan M100-Fueled Sentra
With Gasoline-Fueled 1988 Nissan Pulsar

Case	Vehicle	Engine CID	ETW	Dyno HP	Gasoline Equivalent MPG N/V	City	Hwy	Comb.	Percent Diff.
1	M100 Sentra	110	2875	7.1	44.4	36.8	53.8	42.9	+52%
1	1988 Pulsar	110	2875	7.1	53.3	23.9	36.7	28.3	--
2	M100 Sentra	110	2875	7.1	54.4	32.6	46.7	37.7	+33%
2	1988 Pulsar	110	2875	7.1	53.3	23.9	36.7	28.3	--
3	M100 Sentra	110	2875	7.1	54.0	--	--	41.6*	+47%
3	1988 Pulsar	110	2875	7.1	53.3	--	--	28.3	--

* Adjusted to account for the difference in performance with a sensitivity value of 0.454.

Several comparisons of gasoline equivalent fuel economy between the M100 Sentra and comparable gasoline vehicles have been made here. It is difficult to do an exact comparison, because of fundamental differences in the properties of the fuels and the vehicles involved. The comparisons made here reflect a "best effort" attempt at resolving some of these differences.

The M100 Corolla as received from Toyota (46.4 N/V, 2750 lbs ETW, actual dynamometer horsepower 8.9 HP and final drive ratio 3.72) was tested for acceleration performance over 5-60 MPH under the same conditions as the Nissan vehicle testing previously described. The average acceleration time noted for this vehicle was 10.3 seconds. We also evaluated the 5-60 MPH acceleration performance of this vehicle at the same dynamometer horsepower (7.1) and test weight (2,875 lbs) as the Nissan vehicles; no changes to the drivetrain/transaxle were made however. Under these conditions, the 5-60 MPH acceleration time for the M100 Corolla increased to 10.8 seconds. We did not test a comparable Toyota gasoline vehicle under these conditions; no attempt is made here to adjust the gasoline equivalent fuel economy of the M100 Corolla for performance with respect to a specific gasoline fueled Toyota vehicle.

VII. Highlights from Testing

1. Calculated OMHCE emissions from both test vehicles at low mileage were well below the levels of the standard of 0.41 grams per vehicle mile established in the 1990 emissions standards for a light-duty methanol vehicle. The M100 Corolla vehicle had OMHCE emissions of only 0.12 grams per mile over the FTP.

2. Emissions of methanol, formaldehyde and HC over the FTP from the Corolla vehicle were also low. HCHO emissions from the Corolla were only 9.0 milligrams per mile; this level was as low as that from the first-generation methanol lean burn system at low mileage.[6]

3. NOx levels at low mileage from both vehicles were below the levels of the recently proposed NOx light-duty vehicle standard of 0.70 grams per mile over the FTP.

4. Bag 1 FTP emissions of HC, CH_3OH, OMHCE and HCHO attributable to cold start were much higher than those from Bag 3 for both vehicles. The greatest differences between cold and hot start related emissions with respect to the level of cold start emissions occurred with the M100 Sentra vehicle.

5. The combined city/highway gasoline equivalent fuel economy of the M100 Corolla exceeded the fuel economy of a comparable gasoline-fueled Corolla vehicle by approximately 9 percent.

6. Fuel economy test data from the M100 Sentra vehicle were compared to selected gasoline-fueled Nissan vehicles from recent EPA Test Car Lists. Fuel economy data from the M100 Sentra was also compared to test data from a gasoline-fueled Pulsar vehicle equipped with a similar CA18DE base engine.

The M100-fueled Sentra was evaluated at the test weight and actual dynamometer horsepower of a 1987 gasoline Pulsar vehicle from the EPA Test Car List. An adjustment was made to compensate for the lower measured N/V (44.4) of the M100 Sentra compared to the higher N/V (53.6) of the Pulsar. The combined city/highway gasoline equivalent MPG of the methanol fueled car exceeded that of the gasoline vehicle by 39 percent.

The gasoline equivalent fuel economy of the M100 Sentra was also compared to that of a 1988 CA18DE engine equipped Pulsar vehicle. The M100 Sentra was evaluated at the same test weight, actual dynamometer horsepower and nominally equivalent N/V ratio as the gasoline Pulsar. The M100 Sentra fuel economy was also adjusted to account for the difference in driving performance between the two fuels.

The methanol-fueled vehicle had a combined city/highway gasoline equivalent fuel economy approximately 47 percent higher than the gasoline fueled comparison vehicle under these conditions.

VIII. Future Efforts

The M100 Sentra prototype vehicle is receiving new pistons per instructions from Nissan Motor Corporation. Nissan has agreed to furnish a dummy catalyst for this vehicle to facilitate baseline testing. Toyota has supplied EPA with dummy catalysts for the two-catalyst system on the Corolla prototype. Baseline emissions testing, using M85 and M100 fuels, has been conducted on this vehicle. This data will be presented in a future technical report.

Advanced catalyst testing will also be conducted on both vehicles in the future. This testing will involve the use of both resistively heated and conventional substrate catalysts.

Preliminary evaporative emissions testing has also been conducted on the M100 Corolla. Additional testing on this vehicle and the M100 Sentra will be performed, and the results included in a later technical report.

IX. Acknowledgments

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APPENDIX A

DESCRIPTION OF SECOND-GENERATION TOYOTA LCS-M PROTOTYPE VEHICLE

Engine:

General	L4, 4A-FE engine, 1.6-liter, dual overhead cam design
Compression ratio	11.0:1
Fuel metering	D-Jetronic sequential port fuel injection
Ignition	W27ESR-U Nippondenso spark plugs
Combustion Chamber	Compact pent roof design
Bore x Stroke (mm)	81 x 77
Idle Speed	700 rpm, 10° BTDC ignition timing at idle
Spark Timing Control	Electronic spark advance
Fuel	M100 or M85 (Toyota provided different calibrations for each fuel)
Exhaust Gas Recirculation	EGR used

Vehicle:

Base vehicle	1988 Corolla sedan
Test weight	2,750 lbs
Test HP	8.9 hp
Transmission	5-speed manual transmission, shifting schedule 15-25-40-45 MPH
Gear ratio	1st 3.545 2nd 1.904 3rd 1.233 4th 0.885 5th 0.725

APPENDIX A (CONT'D)

DESCRIPTION OF SECOND-GENERATION TOYOTA LCS-M PROTOTYPE VEHICLE

Differential Ratio	3.722
Tire Size	155SR13
Catalytic Converter System	0.71-liter Pt:Rh (manifold close coupled) 0.51-liter Pd (underfloor)

Other Modifications Made:

Engine Oil	Multiweight oil specially formulated for use with methanol
Fuel Tank, Inlet, Delivery Pipes	Nickel/phosphorus plated
Intake Valves	Martensitic steel with stelliting
Exhaust Valves	Austenitic steel with stelliting
Fuel Injectors	Modified to accommodate greater flowrate of methanol
Fuel Lines	Nickel plated
Fuel Hose	NBR modified
Fuel Pump	In-tank fuel pump body nickel plated

APPENDIX B

DESCRIPTION OF M100-FUELED NISSAN SENTRA PROTOTYPE VEHICLE

Engine:

General	CA18DE base engine, 4-cylinder, in-line
Displacement	1.8 liters
Valvetrain	4 valves/cylinder, dual overhead camshafts
Bore x Stroke (mm)	83 x 83.6
Compression Ratio	12.0:1
Ignition	Direct ignition system
Air/Fuel Management	Ultra lean burn scheme under closed loop control
Idle Speed	650 rpm, 15° BTDC ignition timing at idle
Fuel Metering	Electronically controlled port fuel injection
Fuel Type	M100 fuel exclusively

Vehicle and Special Modifications:

Base Vehicle	B12 Nissan Sentra USA model
Test Weight	2,250 lbs suggested test weight
Test Horsepower	7.3 actual dynamometer horsepower
Transmission	5-speed manual transmission, shifting schedule 15-25-40-45 MPH
Engine Oil	Multiweight oil specially formulated for low friction and use with methanol
Catalyst System	1.7-liter volume Pt:Rh catalyst