EPA/AA/CTAB/88-03

Technical Report

Evaluation of a Methanol-Fueled (M85) Turbocharged Nissan Sentra

by

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May 1988

NOTICE

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.

U. S. Environmental Protection Agency
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF
AIR AND RADIATION

June 16, 1988

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 "Evaluation of Methanol-Fueled (M85) Turbocharged Nissan Sentra" (EPA/AA/CTAB/88-03), describes emissions testing conducted at the Motor Vehicle Emissions Laboratory on a turbocharged Sentra, which was designed by Nissan to use methanol fuel (M85).

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: Charles L. Gray, Jr. Date: 6-16-88
Charles L. Gray, Jr., Dir., ECTD

Nonconcurrence: _____ Date: _____
Charles L. Gray, Jr., Dir., ECTD

Attachment
cc: E. Burger, ECTD

Introduction

Section 211 of the Clean Air Act[1] requires that the United States Environmental Protection Agency (EPA) play a key role in the introduction of new motor vehicle fuels. The Emission Control Technology Division (ECTD), of the Office of Mobile Sources, EPA, assesses technology that could be used to reduce mobile source emissions, including evalution of alternate-fueled vehicles.

A turbocharged Nissan Sentra was emission tested at the U.S. EPA Motor Vehicle Emissions Laboratory located in Ann Arbor, Michigan. This vehicle was designed by Nissan to operate on M85 (85 percent methanol/15 percent gasoline) fuel. The vehicle's chassis is a late-1986 configuration while the engine is based on a 1983 1.3-liter design. Additional vehicle information is presented in Table 1.

Project Summary

The turbocharged Nissan Sentra was loaned to the EPA through a formal cooperative agreement between Nissan and the EPA dated July 6, 1987. Nissan supplied the EPA with the methanol-fueled Sentra for use in EPA's program to evaluate Nissan's and other manufacturer's methanol technology. The stated purpose of the EPA program is to evaluate the use of methanol as an alternative to gasoline for automotive uses to: 1) improve the ambient air quality, and 2) reduce U.S. dependence on imported petroleum.[2]

The Sentra arrived at the Motor Vehicle Emissions Laboratory (MVEL) in July of 1987 and was then baseline emission tested during late July and early August 1987. Nissan previously emissions tested this vehicle and a similar vehicle at their Japanese and Ann Arbor laboratories. These results are presented in the Appendix and show that Nissan's evaluation of the Sentra is close to the EPA evaluation of the Sentra. An updated Nissan vehicle is scheduled to arrive at MVEL at the end of September 1988. Both the Sentra and the upgraded vehicle are scheduled to be returned to Nissan by November 30, 1988.

Testing conducted from February 25, 1988 to March 24, 1988 is the basis of this report. These tests were all conducted after new fuel injectors were installed in the Sentra. Replacement was required due to a resistance rise of the injectors and a corresponding inability to deliver fuel, which caused vehicle driveability problems. Inspection of the injectors revealed what appeared to be corrosion on the fuel inlet side of the injector. Based on Nissan's investigation, the injector's solenoid metals and copper wires were corroded by methanol. This corrosion is caused by a seal's insufficient ability to close off the flow of methanol to the solenoid coil.

Table 1

Vehicle Description

Turbocharged Nissan Sentra

Vehicle Identification Number (VIN):

JN1PB15S6FU151356

Engine:*

Type	4-stroke Otto cycle, in-line 4-cylinder
Bore X stroke	76 x 70 mm
Displacement	1270 cc
Compression ratio	9.8 to 1
Fuel metering	Electronic Fuel Injection (EFI)
Maximum turbo boost pressure	7.3 psi
Maximum power	106 PS/5600 rpm (NET)
Maximum torque	15.0 kg x m/4000 rpm (NET)
Minimum BSFC**	180g/PSh @ 2800 rpm

Chassis and Drivetrain:

Type	Two-door Sedan
Model	B11-USA Model
Tires	P155/80R13 Bridgestone radials
Curb weight	1,965 weight
Test weight (ETW)	2,250 weight
Actual Dynamometer Horsepower	7.5
Transmission	5-speed manual

Table 1 (cont'd)

Vehicle Description

Turbocharged Nissan Sentra

Other:

Fuel	M85 (methanol 85 volume percent, gasoline 15 volume percent)
Engine Oil	15W-30 (modified for methanol-fueled engine use)
Fuel tank	13.2 gallons-plastic construction
Exhaust	Single left side
Feedback	Closed-loop A/F ratio control
Catalyst	Located downstream of turbocharger catalyst 10 to 1 Pt/Rh with 35 grams/cuft loading
Odometer reading on vehicle when delivered to EPA	16,552 miles
Odometer reading at the start of the testing reported	16,739 miles
Odometer reading at end of testing	17,218 miles
Catalyst mileage	A new catalyst was installed in this vehicle by Nissan at 16,017 miles

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* Data supplied by Nissan.

** Gasoline equivalent.

Testing Summary

The vehicle was LA-4 prepped, then driven over the Federal test procedure (FTP) and highway fuel economy test (HFET) cycles at standard test conditions. Steady-state (SS) testing at idle, 10 miles per hour (MPH), and 30 MPH was conducted after the HFET was completed. Emissions of HC, NOx, CO, CO_2, methane and formaldehyde were sampled and measured. Evaporative loss tests were conducted according to the Code of Federal Regulations (CFR) procedures. No HFET or steady-state tests were conducted after the completion of the hot soak evaporative testing.

Testing was conducted in two phases: "as received," the Sentra with the standard catalyst installed, and "engine-out," the Sentra with a dummy catalyst installed. Six FTP, three HFET, three idle, four 10 MPH SS and four 30 MPH SS repeatable tests were run in the "as received" configuration. Three FTP/HFET and two SS test sequences were run in the "engine-out" configuration. Three repeatable evaporative emission tests were also conducted on the Sentra in the "as-received" configuration. The average values are reported for the FTP, HFET and evaporative emission tests in the text, while individual FTP/HFET test results may be found in the Appendix. The results of the steady-state tests are presented in Tables A-5 and C-7.

Exhaust emission values in the text and in Appendix A are presented using the proposed methanol-fueled vehicle test procedures.[3] These calculation procedures differ considerably from the gasoline-fueled vehicle calculations. Modifications to the proposed methanol vehicle procedures were required since methanol emissions from the Sentra were not measured. These modifications are briefly discussed in Appendix B.[4] The data in Appendix C present the results of the testing using gasoline-fueled vehicle procedures. The Nissan-supplied data is presented in Appendix C using the gasoline-fueled vehicle procedures.

A problem with the evaporative emission and/or fuel system of the Sentra may exist as carbon monoxide (CO), organic material hydrocarbon equivalent (OMHCE) and oxides of nitrogen (NOx) tailpipe emissions were consistently higher over the FTP cycle when an evaporative loss test (diurnal heat build) was conducted prior to the start of the emissions testing. Results of the "as-received" FTP emission testing is thus presented in three parts: FTP testing conducted without evaporative testing (FTP/HFET), FTP testing conducted with evaporative testing (FTP/Evap), and an average of the above two phases (composite).

Discussion

The EPA proposed emission standards for throttled methanol engines over the FTP cycle are 1.0 grams per mile oxides of nitrogen (NOx), 3.4 grams per mile carbon monoxide (CO), and .41 grams per mile organic material hydrocarbon equivalent (OMHCE). The data presented in Table 2 indicate that the vehicle emission output would be unacceptable without a catalyst. The vehicle would fail the OMHCE and CO standards even with the catalyst installed if a diurnal heat build is conducted prior to the start of the FTP driving cycle. The vehicle meets all of the emission standards if a diurnal heat build is not conducted prior to the start of the FTP driving cycle.

The HFET data presented in Table 3 shows a very high catalyst efficiency for all regulated emissions except for NOx which has a conversion efficiency of only 17 percent. Analyzing the grams NOx per mile data shows that the vehicle only emits .55 g/mi NOx over the HFET without a catalyst.

Evaporative loss testing was done according to gasoline vehicle procedures. The flame ionization detector's (FID) response was not corrected for methanol and methanol evaporative loss was not measured. The reported values are grams of hydrocarbon (HC) and not grams of OMHCE. Calculation of OMHCE is required for evaporative loss tests with methanol-fueled vehicles according to the proposed rulemaking in reference 3.

The EPA evaluated evaporative emission testing is presented in Table 4 along with results for tests conducted at Nissan laboratories. The results show that the Sentra has evaporative emissions comparable to other methanol-fueled vehicles tested by the EPA. Nissan reported two test results: one with higher than EPA evaluated losses (first test), and one with lower than EPA evaluated losses (second test). The EPA evaporative emission evaluation resembles Nissan's first evaluation of the Sentra with 32 percent of the emission as diurnal losses and 68 percent of the emission as a hot soak loss. Nissan's second evaporative emission test does not correlate to either Nissan's first evaporative test or the EPA evaluation. The M85 fuel for the EPA and Nissan's Ann Arbor tests was supplied by Howell Hydrocarbons.

Fuel economy of the Sentra over the FTP and HFET cycles is presented in Table 5. The average EPA and individual Nissan evaluations are comparable. The gasoline energy equivalent MPG was 34.5 to 34.9 over the FTP and 51.3 to 51.6 over the HFET.

Table 2

FTP Emission Results*

Turbocharged M85-Fueled Nissan Sentra

	HC (g/mi)	HCHO (mg/mi)	CO (g/mi)	NOx (g/mi)	OMHCE (g/mi)	CH3OH (g/mi)	CO2 (g/mi)
Composite with cat.	.08	25	3.02	.57	.42	.76	235
FTP/HFET with cat.	.07	25	2.51	.56	.37	.67	235
FTP/Evap with cat.	.09	26	3.52	.59	.47	.85	235
Without cat.	.49	286	6.39	1.17	2.57	4.51	224
Composite cat. eff (percent)	83	91	83	51	84	83	--
FTP/HFET Cat. eff. (percent)	85	91	61	53	85	85	--
FTP/Evap Cat. eff. (percent)	81	91	45	49	82	81	--

* Calculated using proposed methanol procedures.

Table 3

HFET Emission Results*

Turbocharged M85-Fueled Nissan Sentra

	HC (g/mi)	HCHO (mg/mi)	CO (g/mi)	NOx (g/mi)	OMHCE (g/mi)	CH3OH (g/mi)	CO2 (g/mi)
With cat.	.01	4	.05	.45	.02	.04	164
Without cat.	.24	97	1.21	.55	1.23	2.18	158
Cat. eff. (percent)	98	96	96	17	98	98	--

* Calculated using proposed methanol procedures.

Table 4

Evaporative Emissions

Turbocharged M85-Fueled Nissan Sentra

Test Facility	Diurnal Loss (gram)	Hot Soak Loss (gram)	Total Loss (gram/test)
Ann Arbor 1*	.20	.42	.62
Ann Arbor 2*	.04	.22	.26
EPA	.16	.34	.50

* Test run at Nissan's Ann Arbor laboratory.

Table 5

Fuel Economy

Turbocharged M85-Fueled Nissan Sentra

Test Facility	Catalyst Installed	M85 Fuel Economy (mpg M85-FTP/HFET)	Energy Equivalent (mpg-FTP/HFET)
Japan*	Y	21.0/29.0	37.0/50.5
Ann Arbor**	Y	21.3/N/A	37.3/N/A
EPA	Y	20.0/29.4	34.5/51.3
EPA	N	20.0/29.5	34.9/51.6

* Test run at Nissan's Japanese laboratory.

** Test run at Nissan's Ann Arbor laboratory.

With the 13.2 gallon fuel tank and the actual fuel economy being 20.0 miles per gallon of M85 over the FTP and 29.5 miles per gallon of M85 over the HFET, the driving range of the Sentra would be approximately 264 miles in the city and 389 miles on the highway. These ranges do not include the reduction factors used to calculate Gas Mileage Guide fuel economy for gasoline-fueled vehicles.

Individual "as-received" FTP test results in Table A-1 of Appendix A indicate that the Sentra has a potential problem with the control of regulated pollutants after a diurnal heat build test. With the diurnal heat build, NOx is .03 grams per mile higher, CO is 1.40 grams per mile higher, and OMHCE is .10 grams per mile higher over the FTP driving cycle. "Engine-out" FTP test results presented in Table A-2 indicate that the Sentra also has a potential problem with the control of CO emissions. Bag 1 CO ranged from 43.28 grams to 61.75 grams, Bag 2 CO ranged from 16.87 grams to 19.22 grams, and Bag 3 CO ranged from 12.21 to 16.58 grams, while FTP CO emissions ranged from 5.69 grams per mile to 7.36 grams per mile. The tests with the higher CO emissions also tended to have increased OMHCE emissions. This could indicate that the engine was running richer or leaner than normal in some modes. However, reduction in NOx emissions was not apparent when CO/OMHCE emissions increased. HFET emission results show CO and HC to be very stable in both the "engine-out" and "as-received" configurations. This indicates that the CO/OMHCE inconsistency is probably caused at a low engine speed. This can be somewhat confirmed by the steady-state data presented in Table A-5. Ten MPH tests with the catalyst installed revealed highly variable CO (.09-6.02 gr/mi) and OMHCE (.034-.22 gr/mi). No abnormal vehicle behavior was apparent during any of the ten MPH testing.

Emission comparisons are made with Nissan's test results in Tables C-1 through C-3. Table C-1 shows that the EPA evaluated the Sentra's CO and HC emissions higher than Nissan, while the EPA measured formaldehyde (HCHO) emissions were lower than the Nissan value. NOx and CO_2 emission were evaluated to be almost equivalent by both Nissan and the EPA. The HFET comparison in Table C-2 reveals the same trends, higher CO and HC evaluated by EPA and equivalent NOx and CO_2. No HFET formaldehyde (HCHO) emission data was supplied by Nissan.

Air/fuel ratio testing conducted on the Sentra revealed that the engine operates at stoichiometric conditions (Lambda = 1.0) at idle and 10 MPH. The Sentra operated lean, at Lambda = 1.3 to Lambda = 1.4, during 30 MPH steady-state testing. This was expected since the Sentra's central processing unit (CPU) is calibrated to control the air/fuel ratio at stoichiometric at low speed, low torque conditions while in the first or second gear. However, if the vehicle is operated at low speed, low torque conditions in third, fourth or fifth gear, the calibration calls for lean operation. The 30 MPH steady state was run in third gear.

The average formaldehyde emissions over the FTP and HFET cycle, reported in Tables C-1 and C-3, are comparable to other methanol-fueled vehicles previously tested by the EPA. Over the FTP cycle, engine-out formaldehyde emission was 286 mg/mile. With the catalyst installed, this output dropped to 26 mg/mi which translates into a 91 percent catalyst efficiency for formaldehyde. HFET data show a 94 percent catalyst efficiency for formaldehyde. These efficiencies are slightly lower (approximately 5 percent) than other platinum/rhodium catalysts tested by the EPA.[6]

It should be noted that there were mechanical problems with the gas chromatagraph used to analyze the dilute samples which contained formaldehyde (HCHO) during part of the test program. These problems resulted in a ±15 percent uncertainty in the reported HCHO values. The OMHCE values, which rely partly on the HCHO level, will be variable to a much lesser extent. This uncertainty applied to the OMHCE would be at the most ±2 percent. The problems with the chromatagraph were not discovered until after the test program was completed, and it was not possible to reanalyze the formaldehyde samples from each test.

Even though this vehicle's catalyst is close coupled, it is located directly behind the turbocharger which cools the exhaust gas. One might expect catalyst efficiencies comparable with other methanol-fueled vehicles with underfloor catalysts for the Bag 1 testing of the FTP cycle. Table C-8, which was calculated using gasoline-fueled vehicle procedures, indicates that the Bag 1 catalyst efficiencies for tests conducted without evaporative loss tests were lower than expected: 61 percent for HC, 32 percent for CO, 43 percent for NOx, and 66 percent for HCHO. Table C-8 also shows that the Sentra's Bag 2 and Bag 3 catalyst efficiencies are comparable to a M100-fueled Volkswagen Rabbits, except for Bag 3 CO which was 32 percent less efficient for the Sentra. Overall, FTP catalyst efficiencies are comparable for both vehicles except for CO. FTP CO catalyst efficiency of the Sentra was observed to be much lower than the Volkswagen's catalyst efficiency. These low efficiencies could indicate a catalyst temperature problem with the Sentra.

Conclusions

Since the Sentra's fuel injectors had to be replaced after operating for 16,738 miles, work is shown to be needed in design of more methanol-tolerant fuel system components or possibly a fuel additive to improve injector life. Injector problems seem to be a common occurrence on methanol vehicles fueled with M100 or M85.

Other methanol-fueled vehicles tested by the EPA have shown variable CO and OMHCE emissions over the FTP driving cycle. Thus, the variable CO and OMHCE emissions recorded for the Sentra in the "engine-out" configuration over the FTP driving cycle may not signal a vehicle problem, but may actually be an expected occurrence.

Work may be needed on the Sentra's evaporative emissions system since FID measured HC and CO tailpipe emissions increased significantly over the FTP, especially during Bag 1 (11 percent HC, and 30 percent CO), when a diurnal heat build was conducted prior to the start of the FTP driving cycle. Canister purge rates may have to be adjusted to limit the amount of fuel vapor which can be delivered to the engine under cold operating and warm-up conditions and/or main injector delivery rates could be adjusted to compensate for the additional fuel being delivered from the evaporative emission system.

Nissan may want to develop a more effective catalyst system which would light-off quicker under cold starting conditions. The fundamental problem is one of trying to quickly heat a catalyst to light-off temperature with the cool methanol exhaust produced from a small 1.3-liter turbocharged engine. Work is thus needed in the area of optimum catalysts for small displacement methanol-fueled vehicles if such small displacement engines are to be used to replace larger gasoline engines due to methanol's efficiency/power advantages over gasoline.

Acknowledgements

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In addition, the author appreciates the efforts of Jennifer Criss and Marilyn Alff of the Control Technology Applications Branch, ECTD, who typed this manuscript.

References

1. The Clean Air Act as amended through July 1981, Section 211(C)(1).

2. Loan agreement between Nissan (Nagayuki Marumo) and the EPA (Charles Gray), July 6, 1988.

3. "Proposed Emission Standards and Tests Procedures for Methanol-Fueled Vehicles, Draft Regulation" U.S. EPA, Summer 1986.

4. "Calculation of Emissions and Fuel Economy When Using Alternate Fuels," EPA 460/3-83-009, Urban, Charles M., March 1983.

5. "Interim Report on the Evaluation of a Methanol-Fueled LTD Crown Victoria," EPA/AA/CTAB/87-03, Piotrowski, G. P., R. M. Heavenrich, R. I. Bruetsch, J. P. Cheng, March, 1987.

6. "Evaluation of Emissions From Low Mileage Catalysts On a Light-Duty Methanol-Fueled Vehicle," EPA/AA/CTAB/87-05; Piotrowski, G. K., April 1987.

APPENDIX A

INDIVIDUAL TEST RESULTS USING METHANOL VEHICLE PROCEDURES

Table A-1

Individual FTP Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions** HC	HCHO	CO	NOx	OMHCE	CH3OH	CO2
882091 (FTP/HFET):							
Bag 1 (g)	1.25	344	37.92	2.13	6.39	11.52	857
Bag 2 (g)	.02	20	.59	1.85	.13	.22	961
Bag 3 (g)	.06	33	3.48	2.28	.29	.51	740
Composite (g/mi)	.08	25	2.52	.54	.41	.73	234
882142 (FTP/HFET):							
Bag 1 (g)	1.11	369	32.23	2.18	5.74	10.29	861
Bag 2 (g)	.02	16	.32	2.00	.12	.21	964
Bag 3 (g)	.08	40	6.92	2.16	.44	.78	747
Composite (g/mi)	.07	26	2.43	.56	.38	.68	236
882169 (FTP/HFET):							
Bag 1 (g)	.98	313	35.48	2.39	5.04	9.04	834
Bag 2 (g)	.02	20	1.50	1.83	.13	.22	954
Bag 3 (g)	.06	37	4.13	2.30	.33	.58	727
Composite (g/mi)	.07	24	2.59	.56	.34	.60	234
882233 (FTP/Evap):							
Bag 1 (g)	1.38	370	47.90	2.29	7.06	12.72	873
Bag 2 (g)	.02	31	1.19	2.16	.11	.18	983
Bag 3 (g)	.08	55	8.77	2.20	.44	.77	757
Composite (g/mi)	.09	30	3.58	.59	.45	.81	239
882413 (FTP/Evap):							
Bag 1 (g)	1.38	297	49.04	2.38	7.03	12.73	844
Bag 2 (g)	.02	21	.67	2.02	.11	.19	962
Bag 3 (g)	.08	56	5.88	2.44	.42	.72	743
Composite (g/mi)	.09	24	3.33	.59	.45	.81	233

Table A-1 (cont'd)

Individual FTP Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions** HC	HCHO	CO	NOx	OMHCE	CH3OH	CO2
882411 (FTP/Evap):							
Bag 1 (g)	1.58	335	54.56	2.34	8.05	14.59	847
Bag 2 (g)	.03	18	1.11	2.05	.16	.27	961
Bag 3 (g)	.08	46	4.99	2.55	.42	.74	754
Composite (g/mi)	.10	25	3.65	.60	.51	.93	234

* Calculated using proposed methanol procedures.

** HCHO emission presented in mg or mg/mi.

Table A-2

Individual FTP Emission Results With No Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions** HC	HCHO	CO	NOx	OMHCE	CH3OH	CO2
882475:							
Bag 1 (g)	3.26	1110	61.75	3.89	16.82	30.13	833
Bag 2 (g)	1.68	1156	19.22	4.88	8.94	15.53	930
Bag 3 (g)	1.55	940	16.58	4.17	8.20	14.34	721
Composite (g/mi)	.53	289	7.36	1.19	2.78	4.88	226
882480:							
Bag 1 (g)	2.99	1017	50.26	3.84	15.42	27.62	821
Bag 2 (g)	1.63	1253	17.58	4.57	8.73	15.06	913
Bag 3 (g)	1.34	902	12.40	3.99	7.12	12.39	707
Composite (g/mi)	.49	293	6.14	1.13	2.58	4.52	222
882618:							
Bag 1 (g)	2.35	904	43.28	4.01	12.19	21.74	814
Bag 2 (g)	1.59	1092	16.87	4.78	8.46	14.70	909
Bag 3 (g)	1.29	1027	12.21	4.27	6.92	11.90	707
Composite (g/mi)	.45	277	5.69	1.20	2.36	4.13	223

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* Calculated using proposed methanol procedures.

** HCHO emission presented in mg or mg/mi.

Table A-3

Individual HFET Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	HC (g/mi)	HCHO (mg/mi)	CO (g/mi)	NOx (g/mi)	OMHCE (g/mi)	CH3OH (g/mi)	CO2 (g/mi)
882143	<.01	1	.05	.43	.02	.04	165
882170	<.01	5	.05	.49	.02	.04	162
882471	<.01	7	.04	.45	.03	.04	165

* Calculated using proposed methanol procedures.

Table A-4

Individual HFET Emission Results With No Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	HC (g/mi)	HCHO (mg/mi)	CO (g/mi)	NOx (g/mi)	OMHCE (g/mi)	CH3OH (g/mi)	CO2 (g/mi)
882476	.24	99	1.29	.59	1.24	2.21	161
882481	.23	96	1.22	.55	1.22	2.16	156
882619	.24	95	1.13	.50	1.22	2.17	157

* Calculated using proposed methanol procedures.

Table A-5

Steady-State Emission Results*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Cat Inst.	Speed (mph)	Exhaust Emissions** HC (g/mi)	HCHO (mg/mi)	CO (g/mi)	NOx (g/mi)	OMHCE (g/mi)	CH3OH (g/mi)	CO2 (g/mi)
882144	Y	Idle	.01	6	.01	.10	.03	.05	259
882171	Y	Idle	.01	6	.01	.11	.04	.06	266
882472	Y	Idle	.01	7	.01	.08	.03	.04	254
882145	Y	10	.01	1	.21	.03	.05	.08	327
882172	Y	10	.04	7	6.02	.03	.22	.40	319
882203	Y	10	.01	7	.09	.06	.03	.06	322
882473	Y	10	.04	8	5.34	.09	.20	.35	322
882146	Y	30	<.01	3	.01	.11	.01	.02	163
882173	Y	30	<.01	2	.01	.14	.02	.03	157
882204	Y	30	.01	3	.01	.09	.03	.06	162
882474	Y	30	<.01	4	<.01	.09	.02	.02	168
882482	N	Idle	.22	213	3.89	.18	1.19	2.01	250
882620	N	Idle	.20	190	2.58	.23	1.07	1.82	251
882483	N	10	.15	179	8.20	.44	.81	1.35	307
882621	N	10	.14	156	7.95	.44	.75	1.25	304
882479	N	30	.27	240	1.22	.14	1.44	2.45	160
882622	N	30	.25	219	1.20	.14	1.33	2.26	156

* Calculated using proposed methanol procedures.
** Grams per 10 minutes for idle tests except HCHO which is mg per 10 minutes for idle tests.

APPENDIX B

Calculation of HC, Methanol, and HCHO

As proposed, the regulations in reference 3 require the measurement of methanol (CH_3OH) and formaldehyde (HCHO). Methanol emissions are especially important since the dilution factor equation includes CH_3OH emissions. At the time the test results reported here were made, the EPA lab did not measure CH_3OH. Therefore, the results shown here were computed with a FID response factor of 0.75 and an assumed HC ppm to methanol ppm factor of xx/.85, where xx is the fraction of methanol in a methanol gasoline blend. HC results were then computed using the procedures specified in the draft regulations.[5]

APPENDIX C

INDIVIDUAL TEST RESULTS USING GASOLINE VEHICLE PROCEDURES

Table C-1

FTP Emission Results*

Turbocharged M85-Fueled Nissan Sentra

Test Facility	Catalyst (y/n)	HC (g/mi)	CO (g/mi)	CO2 (g/mi)	NOx (g/mi)	HCHO (mg/mi)
Japan**	Y	.20	2.04	N/A	.57	N/A
Japan***	Y	.23	1.82	223	.57	41
Ann Arbor****	Y	.28	2.45	222	.54	N/A
EPA (composite)	Y	.33	3.02	235	.57	26
EPA (FTP/HFET)	Y	.29	2.51	235	.55	26
EPA (FTP/Evap)	Y	.37	3.52	235	.59	26
EPA	N	1.96	6.40	224	1.17	286

* Calculated using current gasoline procedure.
** Average of three FTP/Evap tests run on a similar vehicle at Nissan's Japanese laboratory.
*** FTP/HFET test run at Nissan's Japanese laboratory.
**** FTP/Evap test run at Nissan's Ann Arbor laboratory.

Table C-2

HFET Emission Results*

Turbocharged M85-Fueled Nissan Sentra

Test Facility	Catalyst (y/n)	HC (g/mi)	CO (g/mi)	CO2 (g/mi)	NOx (g/mi)	HCHO (mg/mi)
Japan**	Y	.01	.01	168	.52	N/A
EPA	Y	.02	.05	164	.46	6
EPA	N	.94	1.21	158	.55	96

* Calculated using current gasoline procedure.
** Test run at Nissan's Japanese laboratory.

Table C-3

Individual FTP Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions**					Fuel Economy	
	HC	CO	CO2	NOx	HCHO	MPG***	EMPG****
Japan*****:							
Bag 1 (g)	3.60	28.7	863	2.13	414		
Bag 2 (g)	.05	.51	910	1.90	87		
Bag 3 (g)	.18	.18	733	2.52	66		
Composite (g/mi)	.23	1.82	223	.57	41	21.0	37.0
Ann Arbor******:							
Bag 1 (g)	4.40	39.67	801	1.86	N/A		
Bag 2 (g)	.14	.13	920	1.95	N/A		
Bag 3 (g)	.14	2.08	705	2.22	N/A		
Composite (g/mi)	.28	2.45	222	.54	N/A	21.3	37.3
882091 (FTP/HFET):							
Bag 1 (g)	4.99	37.92	857	2.13	344		
Bag 2 (g)	.10	.59	961	1.85	21		
Bag 3 (g)	.22	3.48	740	2.29	33		
Composite (g/mi)	.32	2.52	234	.54	25	20.2	35.3
882142 (FTP/HFET):							
Bag 1 (g)	4.46	32.23	861	2.18	369		
Bag 2 (g)	.09	.32	964	2.00	16		
Bag 3 (g)	.34	6.92	747	2.16	59		
Composite (g/mi)	.29	2.43	236	.56	28	20.1	35.0
882169 (FTP/HFET):							
Bag 1 (g)	3.91	35.48	834	2.39	313		
Bag 2 (g)	.09	1.50	954	1.83	21		
Bag 3 (g)	.25	4.13	727	2.30	38		
Composite (g/mi)	.26	2.59	234	.56	24	20.2	35.3

Table C-3 (cont'd)

Individual FTP Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions**					Fuel Economy	
	HC	CO	CO2	NOx	HCHO	MPG***	EMPG****
882233 (FTP/Evap):							
Bag 1 (g)	5.51	47.90	873	2.29	370		
Bag 2 (g)	.08	1.19	983	2.16	31		
Bag 3 (g)	.33	8.77	757	2.20	52		
Composite (g/mi)	.35	3.58	239	.59	30	19.6	34.2
882413 (FTP/Evap):							
Bag 1 (g)	5.51	49.04	844	2.38	297		
Bag 2 (g)	.08	.67	962	2.02	22		
Bag 3 (g)	.31	5.88	743	2.44	56		
Composite (g/mi)	.35	3.33	233	.59	24	20.2	35.2
882411 (FTP/Evap):							
Bag 1 (g)	6.32	54.56	847	2.34	335		
Bag 2 (g)	.12	1.11	961	2.05	19		
Bag 3 (g)	.32	4.99	754	2.55	46		
Composite (g/mi)	.40	3.65	234	.60	25	20.0	34.9

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* Calculated using current gasoline procedure.

** HCHO emission is presented in mg or mg/mi.

*** Methanol miles per gallon calculated using methanol-fueled vehicle procedures.

**** Gasoline energy equivalent miles per gallon.

***** FTP/HFET test run at Nissan's Japanese laboratory.

****** FTP/Evap test run at Nissan's Ann Arbor laboratory.

Table C-4

Individual FTP Emission Results With No Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Exhaust Emissions**					Fuel Economy	
	HC	CO	CO2	NOx	HCHO	MPG***	EMPG****
882475:							
Bag 1 (g)	13.05	61.75	833	3.89	1109		
Bag 2 (g)	6.72	19.22	930	4.88	1156		
Bag 3 (g)	6.21	16.58	721	4.17	939		
Composite	2.12	7.36	226	1.19	289	19.6	34.1
882480:							
Bag 1 (g)	11.96	50.26	821	3.84	1016		
Bag 2 (g)	6.52	17.58	913	4.57	1252		
Bag 3 (g)	5.36	12.40	707	3.99	902		
Composite (g/mi)	1.96	6.14	222	1.13	293	20.2	35.2
882618:							
Bag 1 (g)	9.41	43.28	814	4.01	904		
Bag 2 (g)	6.37	16.87	909	4.78	1092		
Bag 3 (g)	5.15	12.21	707	4.27	1027		
Composite (g/mi)	1.79	5.69	223	1.20	277	20.2	35.3

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* Calculated using current gasoline procedure.

** HCHO emission is presented in mg or mg/mi.

*** Methanol miles per gallon calculated using methanol-fueled vehicle procedures.

**** Gasoline energy equivalent miles per gallon.

Table C-5

Individual HFET Emission Results With Catalyst Installed*

Turbocharged M85-Fueled Nissan Sentra

	Exhaust Emissions					Fuel Economy	
Test Number	HC (g/mi)	CO (g/mi)	CO2 (g/mi)	NOx (g/mi)	HCHO (mg/mi)	MPG**	EMPG***
882143	.02	.05	165	.43	6	29.2	51.0
882170	.02	.05	162	.49	5	29.7	51.9
882471	.02	.04	165	.45	7	29.2	51.1

* Calculated using current gasoline procedure.

** Methanol miles per gallon calculated using methanol-fueled vehicle procedures.

*** Gasoline energy equivalent miles per gallon.

Table C-6

Individual HFET Emission Results With No Catalyst*

Turbocharged M85-Fueled Nissan Sentra

	Exhaust Emissions					Fuel Economy	
Test Number	HC (g/mi)	CO (g/mi)	CO2 (g/mi)	NOx (g/mi)	HCHO (mg/mi)	MPG**	EMPG***
882476	.96	1.29	160	.59	99	29.0	50.6
882481	.94	1.22	156	.55	96	29.9	52.2
882619	.94	1.13	157	.50	95	29.7	51.9

* Calculated using current gasoline procedure.

** Methanol miles per gallon calculated using methanol-fueled vehicle procedures.

*** Gasoline energy equivalent miles per gallon.

Table C-7

Steady-State Emission Results*

Turbocharged M85-Fueled Nissan Sentra

Test Number	Cat. Inst.	Speed (mph)	Exhaust Emissions**** HC (g/mi)	CO (g/mi)	CO2 (g/mi)	NOx (g/mi)	HCHO (mg/mi)	Fuel Economy***** MPG**	EMPG***
882144	Y	Idle	.02	.01	259	.10	7	.3	.2
882171	Y	Idle	.03	.01	266	.11	7	.3	.2
882472	Y	Idle	.02	.01	254	.08	8	.3	.2
882145	Y	10	.04	.21	327	.03	2	14.8	25.8
882172	Y	10	.18	6.02	319	.03	7	14.7	25.6
882203	Y	10	.03	.09	322	.06	7	14.9	26.1
882473	Y	10	.15	5.34	322	.08	9	14.6	25.5
882146	Y	30	.01	.01	163	.11	3	29.7	51.8
882173	Y	30	.01	.01	157	.14	2	30.7	53.6
882204	Y	30	.03	.01	162	.09	3	29.8	52.0
882474	Y	30	.01	<.01	168	.09	5	28.7	50.1
882482	N	Idle	.87	3.89	250	.18	214	.3	.2
882620	N	Idle	.79	2.58	251	.23	191	.3	.2
882483	N	10	.58	8.20	307	.44	179	15.0	26.1
882621	N	10	.54	7.95	304	.44	157	15.1	26.4
882479	N	30	1.06	1.22	160	.14	240	29.0	50.6
882622	N	30	.98	1.20	156	.14	219	29.7	51.9

* Calculated using current gasoline procedure.
** Methanol miles per gallon calculated using methanol-fueled vehicle procedures.
*** Gasoline energy equivalent miles per gallon.
**** Grams per 10 minutes for idle tests except HCHO which is mg per 10 minutes for idle tests.
***** Gallons per hour for idle tests.

Table C-8

Average FTP Catalyst Efficiencies*

	Exhaust Emissions**(Sentra/M100 VW***)			
	HC	CO	NOx	HCHO
Composite:				
Bag 1	55/72	17/77	42/51	67/81
Bag 2	99/98	95/98	58/44	98/96
Bag 3	95/89	59/97	44/52	95/95
FTP	83/86	53/90	51/49	91/92
FTP/HFET:				
Bag 1	61/72	32/77	43/51	66/81
Bag 2	99/98	96/98	60/44	98/96
Bag 3	95/89	65/97	46/52	96/95
FTP	85/86	61/90	53/49	91/92
FTP/Evap:				
Bag 1	50/72	2/77	40/51	67/81
Bag 2	99/98	94/98	56/44	98/96
Bag 3	94/89	52/97	42/52	95/95
FTP	81/86	45/90	50/49	91/92

* Calculated using current gasoline procedures.

** Values reported are catalyst efficiencies of the M85-fueled Sentra/catalyst efficiencies of an M100-fueled Volkswagen Rabbit with a 5 Pt to 1 Rh underfloor catalyst with 40 grams per cubic foot loading.

*** Volkswagen data is from a FTP driving cycle test done without evaporative emissions testing.