

Technical Report

Interim Report On the Evaluation of a
Methanol-Fueled LTD Crown Victoria

By

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March 1987

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR, MICHIGAN 48105

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Exemption From Peer and Administrative Review

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

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

The attached report entitled "Interim Report on the Evaluation of a Methanol-Fueled LTD Crown Victoria," (EPA-AA-CTAB-87-03) describes a project involving testing a M85 fueled cycles LTD Crown Victoria at MVEL on the FTP, HWY, New York City, and evaporative tests and includes a comparison to similar data taken at three other labs (Ford, Engines and Control Systems, Inc., and the City of New York). The vehicle tested is intended for taxicab fleet service in New York City.

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.

Approved: *Charles L. Gray, Jr.*
Charles L. Gray, Jr., Dir., ECTD

Date: *3/26/87*

Attachment

Background

The New York City Department of Environmental Protection is considering sponsoring a methanol-fueled taxi cab fleet of vehicles for operation in New York City. Celanese Corporation has sponsored the build of a prototype vehicle for this project, and that vehicle is the subject of this report.

Taxi permits (medallions) are required for operating a cab in New York City. Extra medallions could be used as an incentive to taxi cab companies willing to incorporate methanol-fueled taxis into their fleets.

EPA is interested in this program to assess the potential of methanol vehicles to reduce urban pollution levels.

Test Vehicle/Fuel

The vehicle tested in this program, a 1986 Ford LTD Crown Victoria (see Table 1), is powered by a 5-liter fuel-injected engine, equipped for operation on methanol/gasoline fuel. Approximately 3,500 miles had been accumulated on the vehicle when it was made available to EPA. The stock catalyst had been replaced at 1,500 miles, however, so only 2,000 miles had been accumulated on the replacement catalyst.

The vehicle was designed and built for use with M85 fuel (calibrated to run approximately stoichiometric, A/F = 7.6:1, for most speed/load combinations). A replacement electronic control unit to allow operation with M100 was not available, so no testing with M100 was possible.

The vehicle has a total fuel capacity of 33 gallons, using an 18-gallon main tank supplemented by a 15-gallon auxiliary tank in the trunk. The two tanks are connected in sequence to function as one source of fuel filled through one filler neck. The auxiliary tank is permanently connected to the main tank, rather than as an optional tank that can be connected and/or disconnected at will.

The vehicle was delivered with a tank of M85 fuel from an unknown source (assumed to be Celanese); additional M85 fuel needed to complete the test program was procured by EPA from Howell Hydrocarbons, San Antonio, Texas.

Tests Run in New York City

The car was tested five times by New York City's Department of Environmental Protection on the FTP and New York City cycles at 4,000 lbs inertia weight. As shown in Table 2, test number 4190 run on April 29, 1986 is the only valid New York test on the same catalyst tested in Ann Arbor. Tests 4176 and 4182 were made using M85 after the car had been misfueled with unleaded gasoline (see test 4172.) Test 4192 was a void test. Tables 3 and 4 give the results of the tests run in New York. At the time the car was tested in New York, the auxiliary fuel tank had not as yet been installed.

Table 2

FTP and New York City Cycle Tests Performed
On the 1986 Crown Victoria in New York City

<u>Date</u>	<u>Test Number</u>	<u>Odometer Reading</u>	<u>Comments</u>
03/14/86	4172	1449	Tested as delivered from Celanese; car was misfueled with unleaded gasoline. The NYC lab used Bag 3 data twice to get composite results.
03/19/86	4176	1469	Test with proper fuel (M85)
03/25/86	4182	1636	Test with proper fuel (M85)
04/29/86	4190	2500	After catalyst replaced
04/30/86	4192	2500	Void test; vehicle chains were not tight for the start of Bag 1; consequently a rocking motion of the vehicle affected throttle response and emissions.

Table 3

FTP Results Obtained in New York City
on the LTD Crown Victoria

Date	Test Number	Exhaust Emissions					MPG
		HC (g/mi)	CO (g/mi)	CO ₂ (g/mi)	NOx (g/mi)	HCHO (mg/mi)	
03/14/86	4172	Bag 1*	5.22	98.05	394	0.51	
		Bag 2	10.07	169.8	N/A	0.29	
		Bag 3	5.22	98.05	N/A	0.51	
		Composite	7.74	135.3	394	0.39	N/A
03/19/86	4176	Bag 1	0.80	2.92	N/A	1.26	
		Bag 2	0.16	0.11	N/A	0.72	
		Bag 3	0.18	0.31	N/A	1.05	
		Composite	0.30	0.74	481	0.92	N/A
03/25/86	4182	Bag 1	0.83	1.99	N/A	1.19	
		Bag 2	0.08	0.07	N/A	0.67	
		Bag 3	0.15	0.35	N/A	0.97	
		Composite	0.26	0.54	482	0.86	N/A
04/29/86	4190	Bag 1	0.35	0.96	N/A	1.13	
		Bag 2	0.04	0.05	N/A	0.61	
		Bag 3	0.12	0.19	N/A	1.00	
		Composite	0.13	0.28	497	0.82	N/A
04/30/86	4192	Bag 1	0.60	2.04	N/A	1.16	
		Bag 2	0.05	0.06	N/A	0.63	
		Bag 3	0.13	0.22	N/A	0.95	
		Composite	0.19	0.51	492	0.83	N/A

* The NYC lab used Bag 3 in lieu of Bag 1 to calculate composite emissions values.

Table 4

New York City Cycle Results
Obtained in New York City

Date	Test Number	Exhaust Emissions				HCHO (mg/mi)	MPG
		HC (g/mi)	CO (g/mi)	CO ₂ (g/mi)	NOx (g/mi)		
03/14/86	4172	22.21	337.2	726	0.58	N/A	3.6
03/19/86	4176	0.32	0.27	926	1.40	N/A	5.2
03/25/86	4182	0.30	0.74	943	1.45	N/A	5.1
04/29/86	4190	0.17	0.12	919	1.21	N/A	5.2
04/30/86	4192	0.18	0.26	919	1.17	N/A	5.2

Tests Run at MVEL

A total of 17 tests were run on the LTD Crown Victoria at MVEL. As shown in Table 5, seven of these were FTPs, four were HWY tests, three were EVAP/FTP tests, and three were NYC cycle tests. Fuel supplied by Celanese was used for the tests run through October 28, 1986; fuel supplied by Howell Hydrocarbons was used for the remaining tests.

For the evaporative test, 13.2 gallons was considered to be the equivalent of a 40 percent fill. For this test, the top mounted (auxiliary) tank was drained in the usual fashion by dropping a drain line into the main tank, venting it and pumping out the fuel. Due to the curved line from the auxiliary tank to the main tank, it was not possible to drain the main tank in the same manner as the auxiliary. The main was instead drained by hot wiring the fuel pump with a 12-volt battery and drawing the fuel off through a tap on the injector supply rail.

The car was then filled with 13.2 gallons of fuel through the filler neck. Because the drain pipe from the auxiliary to the main is tapped into the auxiliary tank almost two inches above the bottom of the auxiliary, approximately 10 of the 13.2 gallons flowed into the main tank. The other 3.2 gallons of fuel were trapped in the bottom of the auxiliary tank.

Table 5

Tests Run on M85 Fueled MY86 LTD Crown Victoria at MVEL

<u>Test Number</u>	<u>Date</u>	<u>Odometer Reading</u>	<u>Test Type</u>	<u>Fuel Source</u>
870379	10/23/86	3399.9	FTP	Celanese
870380	10/23/86	3410.6	HWY	Celanese
870381	10/24/86	3437.5	FTP	Celanese
870382	10/24/86	3447.2	HWY	Celanese
870383	10/28/86	3474.0	FTP	Celanese
870384	10/28/86	3485.7	HWY	Celanese
870555	11/06/86	3514.0	Evap/FTP*	Howell
870611	11/13/86	3532.0	FTP	Howell
870612	11/13/86	3552.2	HWY	Howell
870639	11/14/86	3569.0	FTP	Howell
870659	11/14/86	3580.9	NYC	Howell
871164	12/16/86	3589.0	Evap/FTP	Howell
871165	12/17/86	3607.0	Evap/FTP	Howell
871200	12/18/86	3625.4	FTP	Howell
871201	12/19/86	3631.2	NYC	Howell
871202	12/19/86	3644.5	FTP	Howell
871199	12/19/86	3655.2	NYC	Howell

* Results suspect.

For the diurnal heat build phase of the evaporative test, the metal tiedowns that hold the auxiliary tank in place were taken apart and both tanks wrapped with heat blankets. It was impossible to place thermocouples in both tanks. Instead, the temperature sensors that control the diurnal heat build up were epoxy cemented to the sanded skin of both tanks. Evaporative emissions results were as follows:

<u>Test Number</u>	<u>Diurnal Loss (grams)</u>	<u>Hot Soak Loss (grams)</u>	<u>Total Mass Loss (grams)</u>
870555	0.36	0.79	1.15
871164	7.56	0.71	8.27
<u>871165</u>	<u>3.48</u>	<u>0.70</u>	<u>4.18</u>
Average	3.80	0.73	4.53

The higher than normal evaporative emissions levels may have been caused by the car's evaporative emissions system being designed for only the main fuel tank, and not the additional tank.

Tables 6, 7, and 8 give the FTP and HWY test results from the test runs at MVEL on the car. The engine is calibrated to run slightly lean at idle making stalls likely at the beginning of a cold FTP, and causing poor driveability consistently during the first two minutes of FTP operation. The response was so poor that a conscious effort had to be made by the driver during this time period to keep the car from stalling, as noted on the driver's record for tests 870381 and 870383.

The calculations for the data presented in these tables were based on the new proposed test procedures for methanol fueled vehicles.*[1] These calculation procedures differ considerably from those used in the past and are discussed briefly in Appendix B.[2]

The data for test 870555 is suspect and in fact was excluded from the calculation of the averages in Table 6. The HC and CO results for this test were roughly twice as high as the other FTP tests at MVEL. This FTP test was run immediately after an evaporative emissions test. The high HC and CO emissions may have been caused by the evap canister becoming saturated during the heat build phase of the evap test and not being purged until the FTP was started.

* Numbers in brackets denote references listed at the end of this report.

Table 6

Emissions Data Obtained in FTP Tests
Of LTD Crown Victoria at MVEL

Test Number	Exhaust Emissions				MPG	Comments
	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)		
870379	.039	.30	.66	29.14	9.1	Celanese fuel
870381	.050	.54	.63	36.29	9.1	Celanese fuel
870383	.046	.29	.70	29.46	9.2	Celanese fuel
Average	.045	.38	.66	31.63	9.1	Celanese fuel
870555*	.082	.49	.69	17.42	9.1	Howell fuel
870611	.045	.24	.67	44.93	9.2	Howell fuel
870639	.046	.23	.71	32.38	9.2	Howell fuel
871164	.049	.34	.72	25.53	9.3	Howell fuel
871165	.071	.41	.68	30.38	9.2	Howell fuel
871200	.042	.28	.71	26.58	9.3	Howell fuel
871202	.044	.29	.68	26.16	9.3	Howell fuel
Average*	.050	.30	.70	31.00	9.2	Howell fuel
Average	.048	.32	.68	31.21	9.2	All but test 870555

* Suspect test not used in calculating any of the averages.

Table 7

FTP Aldehyde Emissions (mg/mi)
of LTD Crown Victoria at MVEL

<u>Test Number</u>	<u>Bag 1</u>	<u>Bag 2</u>	<u>Bag 3</u>	<u>Total</u>	<u>Fuel</u>
870379	104.51	3.41	21.56	29.14	Celanese
870381	120.53	10.28	22.43	36.29	Celanese
870383	101.14	4.08	23.83	29.46	Celanese
Average	108.73	5.92	22.60	31.63	Celanese
870555*	18.01	4.37	42.24	17.42	Howell
870611	153.73	11.00	27.74	44.93	Howell
870639	115.55	6.46	19.22	32.38	Howell
871164	89.72	5.54	15.65	25.53	Howell
871165	109.47	5.57	17.89	30.38	Howell
871200	90.29	5.27	20.54	26.58	Howell
871202	85.90	5.57	20.22	26.16	Howell
Average	107.44	6.57	20.21	31.00	Howell
Average all runs	107.87	6.35	21.01	31.21	All but test 870555

* Suspect test not used in calculating any of the averages.

Table 8

Emissions Data Obtained in HWY Tests
Of LTD Crown Victoria at MVEL

Test Number	Exhaust Emissions				MPG	Comments
	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)		
870380	.006	0.0	.54	0.00	15.2	Celanese fuel
870382	.007	0.0	.53	2.48	15.2	Celanese fuel
870384	.006	0.0	.53	4.10	15.2	Celanese fuel
Average	.006	0.0	.53	2.19	15.2	Celanese fuel
870612	.005	0.0	.71	5.09	15.4	Howell fuel
Average	.006	0.0	.58	2.92	15.2	All four tests

Table 9

Comparison of FTP Emissions From An M85
Fueled LTD Crown Victoria by Laboratory

Lab	Exhaust Emissions				MPG	Comments
	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)		
MVEL*	.05	.32	.68	30	9.2	Nine tests
NYC	.13	.22	.82	N/A	9.7	Test #4190**
Ford	.24	.22	.69	N/A	9.6***	
ECS	.20	.37	.65	N/A	9.1***	

* Calculations made in accordance with Reference 1. HC calculated using the same methods as those assumed to be used at the other labs gives 0.19 g/mi. FTP CH₃OH emissions from the MVEL tests were 0.24 g/mile.

** The only valid NYC test with the same catalyst as in the MVEL tests.

*** Personal communication, R. Nichols, Ford.

As mentioned earlier, two different sources of M85 fuel were used. Differences in the chemical content of the two fuels may account for some of the variation of the data in Tables 6, 7, and 8, but the consistency of the HC test results for the two fuel types on both the FTP and HWY tests makes this unlikely. Table 7 gives bag-by-bag FTP aldehyde emissions.

Table 9 compares the FTP results obtained at MVEL, New York, Ford, and Engine and Control Systems, Inc (ECS). The New York City NOx and MPG results are different than those obtained at the other labs. Possible causes of variation in the data include the fuel used, age of the catalyst, and unavoidable driver variance due to the tendency of the car to stall. In addition, the car was tested at 4,000 lbs inertia weight in New York vs. 4,500 lbs at MVEL which could explain the difference in fuel economy results.

These lab-to-lab differences also occur for the New York City cycles shown in Table 10.

Table 10

Comparison of NYC Cycle Emissions From An M85
Fueled LDT Crown Victoria by Laboratory

Lab	Exhaust Emissions				MPG	Comments
	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)		
MVEL*	.041	0.000	1.091	24.76	4.5	870659
MVEL	.033	0.000	1.065	19.73	4.6	871201
MVEL	.040	0.084	1.099	48.64	4.5	871199
MVEL	.038	0.028	1.085	31.04	4.5	Average
NYC	.17	.12	1.21	N/A	N/A	Test #4190**

* Calculations made in accordance with Reference 1.

** The only valid NYC test with the same catalyst as in the MVEL tests.

Summary

When tested at EPA's Motor Vehicle Emissions Laboratory, the methanol-fueled LTD Crown Victoria produced the emissions listed below. The evap results are grams per test.

<u>Test</u>	<u>HC</u> <u>(g/mi)</u>	<u>CO</u> <u>(g/mi)</u>	<u>NOx</u> <u>(g/mi)</u>	<u>HCHO</u> <u>(mg/mi)</u>	<u>MPG</u>
FTP	.05	.32	.68	31	9.2
HWY	.01	.00	.58	3	15.2
NYC	.04	.03	1.09	31	4.5
Evap	4.53	--	--	--	--

The composite fuel economy for the vehicle tested is 11.2 miles per gallon of M85. Using a gasoline equivalent conversion factor range of 1.75 to 1.82, this is equivalent to a range of 19.5 to 20.4 MPG. According to Ford Motor Company, the comparable gasoline-fueled model year 1986 LTD Crown Victoria car got 21.9 MPG on gasoline. Other MPG values for other Ford cars similar to the vehicle tested are shown in Appendix A.

* HC emissions were obtained with the FID calibrated with propane for the tests run at MVEL.

References

1. "Proposed Emission Standards and Test Procedures For Methanol-Fueled Vehicles, Draft Regulation," U.S. Environmental Protection Agency, Summer 1986.

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

APPENDIX A

1986 Certification Test Car List Data
 Ford 302-CID Fuel-Injected Engines With
4-Speed Lockup Transmissions

ETW	Thunderbird 3875 lbs	Mark VII 4000 lbs	Grand Marquis Wagon 4250 lbs	Grand Marquis Wagon 4250 lbs	Thunderbird 3750 lbs
Compression ratio	8.9	8.9	8.9	8.9	8.9
Axle ratio	2.73	2.73	3.27	3.27	2.73
<u>City Data:</u>					
HC (g/mi)	.140	.126	.144	.158	.226
CO (g/mi)	.24	.16	.40	.40	.54
NOx (g/mi)	.45	.35	.46	.41	.39
MPG	19.8	18.1	17.6	17.7	19.4
<u>Highway Data:</u>					
HC (g/mi)	0.043	0.039	0.061	0.069	0.139
CO (g/mi)	0.0	0.0	0.0	0.03	0.01
NOx (g/mi)	0.56	0.32	0.20	0.17	0.18
MPG	33.3	30.7	26.7	27.3	33.0
Composite MPG	24.2	22.2	20.8	21.0	23.8
Evap (grams)	N/A	0.84	0.65	N/A	N/A

APPENDIX B

Calculation of HC, Methanol and HCHO

As proposed, the regulations in reference 1 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.