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Fuel Economy and Exhaust Emissions of a Methanol-Fueled Chevette

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Abstract

This report presents the results of a series of tests conducted over a period of several months on a 1979 Chevrolet Chevette powered by anhydrous methanol. Baseline tests with gasoline were also conducted about three months before the methanol test series began. The car is part of an alcohol evaluation program run by the Bonneville Power Administration. These tests were conducted for EPA in Portland, Oregon by a test contractor, Hamilton Test Systems.

The exhaust emissions from this car were greatly affected by air-fuel ratio and state of tune. Driveability was not good during most tests when CO met Federal standards. The best optimized adjustments gave a 10 percent better energy efficiency on pure methanol than on gasoline with approximately similar exhaust emission levels.

Background

In 1979, the Bonneville Power Administration (BPA) of the U.S. Department of Energy began a program of evaluating alcohols as motor vehicle fuels and gasoline extenders. BPA's activity reflected its interest in domestically produced alcohol for motor fuel and the need to develop user experience and information on the subject. With the enactment of the Energy Security Act of 1980, BPA's program became more significant.

To BPA personnel, methanol (CH_3OH) is particularly attractive as a motor fuel because it is cheaper than ethanol (C_2H_5OH), which is made from food crops such as corn, grain, or sugar beets. Methanol would be made from coal, municipal wastes, and forest wastes.

By the summer of 1980 BPA's program was far enough along that exhaust emissions tests were needed. Data from Federal exhaust emissions tests would reveal whether emission-control performance was degraded by the use of alcohol-gasoline blends or conversion to straight alcohol.

Following inquiries from BPA, the EPA Portland Study Project Office arranged for a series of tests to be conducted by its testing contractor, Hamilton Test Systems. In August and September 1980, baseline gasoline tests and a series of tests with alcohol-gasoline blends were conducted on a BPA owned Chevette. After the car was converted to run on straight methanol, a series of tests was conducted between November 1980 and February 1981.

Test Vehicle

The test vehicle was a 1979 Chevrolet Chevette with 98 cubic inch displacement engine and automatic transmission. Emission controls on this car include exhaust gas recirculation and oxidation catalyst.

Dynamometer loads for testing were 2500 lbs. inertia weight and 9.2 actual hp at 50 mph.

For the gasoline baseline tests, the car was in totally stock condition with all engine operating variables at manufacturer's specifications.

Converting the engine to run on methanol included these steps:

The idle mixture was adjusted and the main metering jet was enlarged. The carburetor float was coated with a methanol-resistant substance. A mixture heater below the carburetor and a fuel preheater, both making use of the heat in the engine coolant, were employed to aid in methanol vaporization. A cold start device was installed for providing a spray of gasoline into the carburetor during cold ambient cold starts. (This manually-operated device was not used in the emissions tests.)

The initial ignition timing was advanced about 8 degrees from manufacturer's specification. Original equipment spark plugs were replaced with ones of lower heat rating.

In its original form, the methanol conversion included the plugging of the vacuum line to the EGR valve. This had been done because of the erroneous assumption that fueling with methanol automatically resulted in low NOx emissions. After the first set of tests, the EGR vacuum line was unplugged.

Testing Program

The tests consisted of the cold start 1975 Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET) for measuring exhaust emissions and fuel economy. Engine diagnostic tests were conducted from time to time to check the engine's state of tune. Evaporative emissions were not measured.

Baseline conditions were established with Indolene HO Unleaded and commercial unleaded gasolines in tests in August and September 1980.

In November, shortly after the conversion to methanol was completed, a set of duplicate tests were conducted. These were followed by additional sets of duplicate tests after various repairs and adjustments from November 1980 through February 1981.

Results and Discussion

FTP composite mass emissions, FTP fuel economy, and HFET fuel economy are listed in Table 1. There are also comments on the car's performance on the FTP. Included are the "baseline" data using Indolene HO and commercial unleaded regular gasoline plus five different sets of duplicate tests using anhydrous methanol. (All fuels except Indolene were supplied by BPA.)

It is important to note that in the Federal Test Procedure, hydrocarbons are measured with a flame ionization detector. The response of this instrument to methanol is significantly less than unity. Therefore, the HC emissions listed are estimated to be only 75% of the actual levels of unburned fuel emitted.

On methanol, the car was plagued with driveability problems during the first three minutes of operation on the FTP. These problems were the result of methanol's high heat of vaporization and the resulting difficulty in vaporizing methanol in a cold engine. The need to go to wide-open throttle (WOT) in order to follow the FTP speed-time schedule reflects the lower energy content of methanol when compared to gasoline.

In the as-received condition after the conversion to methanol, the NOx emissions were almost three times as high as the baseline tests on gasoline. (See results for tests 6 and 7.) The party making the conversion had believed that because methanol "burned cooler" there was no need for NOx control and so plugged the EGR vacuum line.

The plug was removed for tests 8 and 9. This resulted in reduced NOx emissions but also severely degraded driveability. The high CO emissions on test 9 led to the discovery that the carburetor float had swollen in the presence of methanol and had stuck in a low position, thereby causing over-fueling. Replacement of that float resulted in tests 10 and 11.

The vehicle was in fleet service at BPA during most of December and January, during which time mixture adjustments were made to improve the cold-ambient driveability. The result of those adjustments are seen in tests 12 and 13, with the CO emissions at over two times the Federal standard, and almost three times the baseline levels.

The final adjustment made in this series of tests was to install different jets in the carburetor. Tests 14 and 15 showed that this action produced acceptable emissions and unimpaired driveability on the FTP.

The average results from the baseline on unleaded regular gasoline and the final "optimized" methanol version are as follows:

	Emissions			Fuel Economy	
	HC	CO	NOx	FTP	HFET
Gasoline	.56	13.0	1.13	24.7	30.5
Methanol	.75	15.4	1.20	13.3	16.0

The true HC emissions from methanol are probably about one gram per mile.

Fuel Economy can also be expressed according to the energy available in the fuel. The following values were taken from SAE paper number 800891:

Energy content, gasoline	115,400 Btu/gallon
Energy content, methanol	56,560 Btu/gallon

The FTP fuel economy ratings then become:

Gasoline: 2.14×10^{-4} mile per Btu
Methanol: 2.35×10^{-4} mile per Btu

It can be said that the energy in the methanol is being utilized about 10% more efficiently than that in the gasoline. This may be attributable to the advanced spark timing in the methanol configuration.

Conclusions

Tests 14 and 15 showed that a relatively simple conversion of a gasoline engine to methanol can result in acceptable levels of emissions and relatively unimpaired driveability. That statement is heavily qualified. Few people making such conversions will have the benefit of Federal exhaust emissions tests to use as a diagnostic tool. Few will also have a customer who is concerned with exhaust emissions.

Despite its reputation among its enthusiasts, methanol does not automatically "burn clean". All emission controls on a gasoline engine should remain in place and functioning when a methanol conversion is made. Particular care must be taken to ensure that there is no material incompatibility in the fuel system that could lead to overfueling the air-fuel charge.

Table 1
Emissions and Fuel Economy
1979 Chevette, 98 CID, A3

Test No.	Vehicle Condition Repairs, Adjustments	Fuel	FTP Emissions (gms/mi) HC*	CO	NOx	Fuel Economy (mi/gal) FTP	HFET	Comments
1	Stock	Indolene HO	.47	12.0	1.22	25.1	no test	Stumble at 165 sec. on FTP. WOT accel. at 170 sec.
2			.51	10.9	1.15	24.9	30.0	Same
3			.46	11.2	1.15	24.7	30.3	Same
4		Unleaded-	.60	12.4	1.12	24.6	30.7	Same
5		Regular	.51	13.5	1.14	24.7	30.3	Same
6	After conversion to methanol (EGR	Methanol	.58	10.0	3.18	13.6	16.1	Stall at 25 sec, Stumble at 45, 55, 165. WOT 168-173
7	vacuum line plugged, timing +8° from mfr. spec.)		.53	12.8	3.21	13.6	16.9	Same
8	Removed plug from	Methanol	.81	13.8	.99	13.8	16.6	Stall at 24 sec, Many stalls at 340. WOT 165-175, 190-200.
9	EGR vacuum line		.88	27.1	.96	13.1	16.8	Stall at 24 sec, WOT 190-200. False starts on FTP Bag 3.
10	Repaired sticking	Methanol	.90	12.7	1.06	13.6	17.0	Stall at 22 sec, Stumbled btwn. 40-165 WOT 170-175, 190-200
11	carburetor float		.71	9.5	1.17	13.7	17.0	Same
12	Adjusted A/F mixture	Methanol	.86	35.4	2.06	12.2	14.8	No stalls or stumbles
13	to improve cold-ambient operation.		.78	33.4	2.15	12.4	15.1	Stall at 23 sec.
14	Replaced carb jet	Methanol	.81	15.6	1.19	13.4	16.4	No stalls or stumbles
15			.68	15.2	1.20	13.1	15.6	Brief stumble at 190 sec.

NOTE: In the carbon balance fuel economy calculations, these values were used:
2421 gm C per gallon Indolene and Unleaded Regular
1153 gm C per gallon Methanol

*Due to the response characteristics of the FID instruments to methanol, the HC emissions listed are estimated to be only 75% of the actual levels of unburned fuel emitted.