Exhaust Emissions from 10 GSA Rebels and 10 GSA Falcons Equipped with LPG Conversion Kits

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Vehicles Tested

The exhaust emission characteristics of ten Falcons and ten Rebels were measured before and after installation of liquefied gas (LPG) kits. The gaseous systems used were the Impco, Model J regulator and carburetor, installed by Petrolane Incorporated. The cost of this installation is approximately $300. In addition to the gaseous fuel kit, the distributor vacuum advance was disconnected. The cars were tuned to TDC ignition timing and 600 rpm in drive. The 1970 Falcons have a 250 CID engine with automatic transmission and original manufacturer's specifications of six degrees BTDC and 550 rpm in drive. The 1970 Rebels have a 232 CID engine with automotic transmission and original manufacturer's specifications of three degrees BTDC and 550 rpm in drive. The Falcons were further modified by the installation of hardened valve seats.

Two vehicles were evaluated more extensively than the other 18 and will be discussed separately in this report.

Tests Conducted

Baseline Tests:

All vehicles were tested prior to installation of LPG conversion kits using the constant volume sampling technique with the LA 4-S3 driving schedule as specified for 1972 and later testing.

LPG Conversion Tests:

The following tests were performed on the converted vehicles. All of the cars were not available to receive all of the tests.

1. Standard 1970 Federal test procedure for exhaust emissions (FTP).

2. Closed, constant volume sampling technique using nine repeats of the Federal emission 7-mode test cycle (9 CVS).

3. Closed, constant volume sampling technique using the LA 4-S3 driving schedule as specified for 1972 and later testing.

Closed cycle data were taken using a constant volume sampling technique. Bag samples were analyzed using non-dispersive infrared analysis for carbon monoxide with hydrocarbons measured using a flame ionization detector. The Whittaker "NO_X Box", an electro-chemical device, was used for determination of oxides of nitrogen in the CVS sample.

In addition to the standard emission tests, performance data was obtained for some of the vehicles. The acceleration tests consisted of wide open throttle acceleration (WOT) from 0-60 mph, 20-50 mph, 50-80 mph.

Emission Results

Rebels:

Table I shows the test results for nine Rebels tested. The average baseline values (gasoline operation) for these cars obtained using the 1972 Federal emissions test procedure are 2.67 grams per mile (gpm) hydrocarbons, 22.13 gpm carbon monoxide, and 6.85 gpm oxides of nitrogen. The 1973 Federal emissions standards of 3.4 gpm hydrocarbons, 39 gpm carbon monoxide, and 3.0 gpm oxides of nitrogen were not met by any vehicle while seven of the nine gasoline powered vehicles reported met the 1972 Federal emission standards (no NO_x requirement). The range of hydrocarbon values was 4.23 gpm to 1.60 gpm, carbon monoxide from 55.38 gpm to 9.09 gpm, oxides of nitrogen from 8.28 gpm to 3.59 gpm. After installation of the LPG conversion kits the average 1972 Federal emissions test results were lowered to 0.51 gpm hydrocarbons, 3.89 gpm carbon monoxide and 3.13 gpm oxides of nitrogen. Five vehicles met the 1973 Federal emissions standards. Three met the 1975 standards of 0.46 gpm hydrocarbon, 4.7 gpm carbon monoxide, and 3.0 gpm oxides of nitrogen (as NO_2). None of the Rebels could meet 1976 Federal emissions standards because of the very low NO_x requirement. The range of results was hydrocarbons from 1.28 gpm to 0.14 gpm, carbon monoxide from 27.50 gpm to 1.24 gpm, and oxides of nitrogen from 3.93 gpm to 2.39 gpm. The 9 CVS procedure was used on only four of the Rebels giving average values of 0.98 gpm hydrocarbons, 3.37 gpm carbon monoxide, and 3.48 gpm oxides of nitrogen. In general this procedure appears to result in slightly higher emission values for these cars. The average values of emissions obtained using the 1970 FTP were 0.91 gpm hydrocarbons and 2.42 gpm carbon monoxide. The range of results was 1.50 gpm to 0.54 gpm hydrocarbon and 3.26 gpm to 1.09 gpm carbon monoxide. The 1970-1971 Federal emission standards are 2.2 gpm hydrocarbon and 23 gpm carbon monoxide.

Comparing the baseline results to the gaseous fuel results (1972 FTP), reductions of 81 percent in hydrocarbons, 82 percent in carbon monoxide and 54 percent in oxides of nitrogen were realized with the LPG conversion for the nine Rebels reported.

Falcons:

Table II shows the test results for nine Falcons tested. The average baseline values (gasoline operation) for these cars obtained using the 1972 FTP are 3.70 gpm hydrocarbons, 15.99 gpm carbon monoxide, and 9.43 gpm oxides of nitrogen. None of the gasoline powered Falcons met the 1973 Federal emissions standards and three met the 1972 standards. The range of values was 4.34 gpm to 2.81 gpm hydrocarbons, 24.62 gpm to 11.01 gpm carbon monoxide and 12.18 gpm to 7.85 gpm oxides of nitrogen. After installation of the LPG conversion kit the average 1972 FTP results were 0.69 gpm hydrocarbons, 1.76 gpm carbon monoxide, 2.59 gpm oxides of nitrogen. Seven vehicles met the 1973 Federal emission standards; none met the 1975 standards. The range of emissions values was 1.15 gpm to 0.20 gpm hydrocarbons, 2.42 gpm to 1.33 gpm carbon monoxide and 3.89 gpm to 1.26 gpm oxides of nitrogen. The 9 CVS procedure was used on eight of the vehicles giving average values of 0.69 gpm hydrocarbon, 1.74 gpm carbon monoxide and 3.21 gpm oxides of nitrogen. Again this procedure tends to give somewhat higher emission values than the 1972 FTP. The range of values for the 9 CVS was 1.03 gpm to 0.50 gpm hydrocarbons, 3.47 gpm to 1.19 gpm carbon monoxide and 4.92 gpm to 1.63 gpm oxides of nitrogen. The average values of emissions obtained using the 1970 FTP were 0.57 gpm hydrocarbons and 1.88 gpm carbon monoxide. The range of values obtained for the 1970 FTP was 0.90 gpm to 0.33 gpm hydrocarbons and 2.61 gpm to 0.87 gpm carbon monoxide.

Comparing the baseline results to the gaseous fuel results (1972 FTP) reductions of 81 percent in hydrocarbons, 89 percent in carbon monoxide, and 73 percent in oxides of nitrogen were realized with the LPG conversion for the nine Falcons reported.

Performance Tests

Acceleration tests were conducted on four Rebels and four Falcons after installation of LPG conversion kits. The tests were run with a passenger load of 350 pounds. Table III shows the actual test results for three accelerations 20-50 mph, 0-60 mph, and 50-80 mph. The Rebels averaged an elapsed time of 11.4 seconds for the 20-50 mph acceleration, 20.0 seconds for the 0-60 mph and 31.0 seconds for the 50-80 acceleration. The range of times were respectively 12.0 to 10.8 seconds, 25.8 to 17.2 seconds, and 52.0 to 21.2 seconds.

A 1969, gasoline-powered, Ambassador (a heavier vehicle than the Rebel) with a 232 CID engine was tested for comparative purposes. The car had accumulated 31,000 miles and had an ignition problem causing it to break-down during the 50-80 mph acceleration. The Ambassador averaged 9.6 seconds for the 20-50 mph acceleration and 17.9 seconds for the 0-60 mph. Thus even in poor mechanical condition it displayed better acceleration performance than the 1970 low-mileage Rebels.

The Falcons averaged an elapsed time of 11.4 seconds for the 20-50 mph acceleration, 20.1 seconds for the 0-60 mph acceleration and 31.6 seconds for the 50-80 mph acceleration. The range of times were respectively: 15.2 to 8.0 seconds, 25.2 to 15.5 seconds, 43.6 to 21.8 seconds. Although no tests were run on the gasoline equipped vehicles it was obvious to test personnel that performance had been appreciably sacrificed. The LPG equipped cars had serious tip-in problems and demonstrated stretchiness on acceleration.

One Rebel was tested with the ignition timing advanced to 3° before TDC as well as at the gaseous fuel specification of TDC. The following table indicates the comparison of these two configurations:

Acceleration	TDC Seconds	3° BTDC Seconds
20-50 mph	12.0	8.9
0-60 mph	19.0	17.0
50-80 mph	24.5	22.9

The percentage improvement by advancing the timing in this way was 26 percent for the 20-50 mph acceleration, 11 percent for the 0-60 mph acceleration, and 7 percent for the 50-80 mph acceleration.

Extended Vehicle Evaluation

One Rebel and one Falcon were placed in the Test and Evaluation Branch's vehicle fleet. Mileage accumulation, periodic emission testing, fuel consumption, comparative performance testing, and general observations were made on these vehicles.

Table IV indicates the emission test results obtained with these vehicles. The average Rebel emissions utilizing the 1972 FTP were 0.38 gpm hydrocarbons, 1.86 gpm carbon monoxide, and 2.47 gpm oxides of nitrogen. This represents reductions over baseline of 86 percent in hydrocarbons, 84 percent in carbon monoxide, and 70 percent in oxides of nitrogen. The average Falcon 1972 FTP emissions were 0.85 gpm hydrocarbons,

1.61 gpm carbon monoxide, and 3.05 gpm oxides of nitrogen. This represents reductions over baseline of 69 percent in hydrocarbons, 92 percent in carbon monoxide, and 61 percent in oxides of nitrogen.

The Rebel was driven about 700 miles under ordinary driving conditions. As Table I indicates no appreciable change in the emissions levels was reported.

Because of the performance problem apparent with the conversion to LPG it was desired to measure the effect of advancing the timing to 6° before TDC on the Falcon. This helped the overall performance of the car, but as Table I indicates resulted in an increase in all three pollutants. Hydrocarbons increased by 22 percent over the optimized LPG configuration; carbon monoxide increased 13 percent; and as expected oxides of nitrogen rose 35 percent above the retarded level.

Fuel consumption data was collected during the mileage accumulation phase of the evaluation of the vehicles. As indicated the Rebel consumed 63.4 gallons in 559 miles for an average fuel consumption rate of 8.8 miles per gallon. The Falcon used 12.4 gallons when driven 139.0 miles (with timing advanced to 6° before TDC) for an average consumption rate of 11.2 miles per gallon.

One technical problem which occurred during winter driving deserves comment. On days below 32° F the small regulators installed with the LPG conversion would freeze. This resulted in the necessity of thawing with hot water before the car could be driven away. This problem was remedied by the installation of large capacity regulators.

Conclusions

1. The LPG conversion adopted on these cars resulted in overall average emission levels according to the 1972 FTP of 0.60 grams per mile hydrocarbons, 2.83 grams per mile carbon monoxide, and 2.86 grams per mile oxides of nitrogen. Twelve vehicles tested surpassed the 1973 Federal standards, but only three met the proposed 1975 Federal standards (0.46 gpm hydrocarbons, 4.7 gpm carbon monoxide, and 3.0 gpm oxides of nitrogen). None of the 20 vehicles tested could meet the stringent NO_x standard proposed for 1976 model year vehicles. With proper adjustments the hydrocarbon levels could be brought below the 0.47 gpm level. The control of carbon monoxide is well below any standards yet established. It does appear,

however, that a specific control for the oxides of nitrogen is necessary to bring the cars consistently to the 1976 level.

One other consideration, not previously mentioned, is that the vehicles running on LPG do generate a distinctive odor. This seems objectionable and should be curbed.

2. A penalty caused by the installation of the LPG conversion kit is performance. The driveability of the vehicles was appreciably damaged. Some of the vehicles showed such sluggishness that high speed entrance to expressways could prove to be hazardous. To some extent this problem was lessened by advancing the timing with a resulting yet tolerable increase in emissions.

3. While data on fuel consumption of the gasoline powered vehicles was not available, it can be safely assumed that an average of 8.8 mpg and 11.2 mpg (with advanced timing) is well below the mileage attainable by these light weight small displacement vehicles when running on gasoline.

TABLE I

Emissions Results - Rebels

Car Number G 11	Baseline			LPG Equipped								
	1972 FTP grams/mile			1972 FTP grams/mile			1970 FTP grams/mile			9 CVS grams/mile		
	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*
44044	4.23	55.38	8.04	.14	2.24	3.89	----	----	----	----	----	----
				.16	2.49	3.82	----	----	----	----	----	----
54378	2.67	20.70	7.27	.40	1.52	2.39	----	----	----	----	----	----
				.33	1.24	2.67	----	----	----	----	----	----
54368	2.24	13.78	6.04	.56	1.59	2.88	.76	1.52	2.47	.77	1.58	3.20
				.52	1.67	2.47	.77	1.09	3.20	.83	1.09	2.82
54369	3.62	28.98	7.59	1.28	27.56	3.88	1.50	3.26	6.12	1.79	9.83	4.08
				1.14	11.59	3.66	1.28	3.91	6.47	1.42	3.87	4.66
54380	1.60	19.52	3.59	.38	1.51	2.96	----	----	----	----	----	----
				.36	1.86	2.74	----	----	----	----	----	----
54373	2.34	9.09	8.28	.41	1.49	3.71	----	----	----	----	----	----
				.43	1.70	3.34	----	----	----	----	----	----
54360	1.89	9.95	6.19	.35	2.81	3.92	----	----	----	----	----	----
				.39	2.14	3.11	----	----	----	----	----	----
54364	2.18	18.48	6.85	.47	2.38	2.27	.54	3.04	2.28	.65	4.67	2.30
				.32	1.95	2.84	.57	1.95	2.25	.55	2.50	2.73
54370	3.28	23.31	7.82	.71	2.34	2.96	.81	3.26	5.14	.90	1.55	3.94
				.74	1.94	3.30	1.12	1.30	5.83	.89	1.84	4.08
Average	2.67	22.13	6.85	.51	3.89	3.13	.91	2.42	4.22	.98	3.37	3.48

* presented as NO_2 not corrected for humidity

TABLE II

Emissions Results - Falcons

Car Number G 11	Baseline 1972 FTP grams/mile			LPG Equipped 1972 FTP grams/mile			1970 FTP grams/mile			9 CVS grams/mile		
	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*
54356	3.17	11.01	9.73	.97	1.63	2.79	.65	2.61	1.92	.81	1.59	2.82
				.85	1.46	2.94	.64	2.39	1.52	.78	1.59	3.04
46982	4.19	13.07	9.96	.54	1.67	2.76	.47	1.30	3.37	.60	2.11	4.19
				.56	2.42	2.67	.46	1.09	3.37	.59	2.43	3.80
49738	3.66	13.05	9.20	.47	1.33	3.89	.39	2.39	3.89	.51	1.19	4.92
				.52	1.37	3.71	.43	2.61	3.84	.53	1.29	4.92
54352	2.81	16.82	8.02	.48	1.74	2.99	.39	1.52	3.69	.50	1.24	4.08
				.50	1.58	3.48	.33	1.52	3.49	.47	1.57	4.15
				1.14	1.82	1.26	.86	1.52	1.32	1.01	1.69	1.67
49741	4.21	24.62	12.17	1.15	1.89	1.46	.90	2.61	1.21	1.03	1.85	1.81
				1.11	2.04	1.38	---	----	----	----	----	----
				.55	1.94	2.56	.54	.87	2.38	.65	1.80	3.27
46983	3.33	22.97	8.06	.70	1.46	2.68	.50	.87	2.85	.63	1.39	3.51
				.64	2.28	2.39	---	----	----	----	----	----
46988	4.34	13.67	10.49	.26	2.61	2.57	---	----	----	----	----	----
				.20	1.62	3.77	---	----	----	----	----	----
46985	3.56	15.77	9.31	1.06	1.53	1.81	.82	1.96	2.16	.95	1.43	2.90
				.94	1.54	2.02	.90	1.96	2.19	.93	1.51	2.52
49734	4.04	12.91	7.85	.56	1.62	1.89	.45	2.39	1.33	.56	3.47	1.62
				.61	1.58	1.70	.46	2.39	.72	.50	1.66	1.92
Average	3.70	15.99	9.43	.69	1.76	2.59	.57	1.88	2.45	.69	1.74	3.20

* presented as NO_2, not corrected for humidity

TABLE III

Performance Results - Rebels and Falcons

Rebels

Car Number G 11	Accelerations 20-50 mph	0-60 mph	50-80 mph
54368	12.0 seconds	19.0 seconds	24.5 seconds
54369	11.5 seconds	23.4 seconds	52.0 seconds
54364	11.1 seconds	19.7 seconds	26.0 seconds
54370	10.8 seconds	17.7 seconds	21.5 seconds

Falcons

Car Number G 11	Accelerations 20-50 mph	0-60 mph	50-80 mph
54356	10.9 seconds	18.5 seconds	22.7 seconds
46982	11.5 seconds	21.1 seconds	28.4 seconds
49741	15.1 seconds	25.2 seconds	43.6 seconds
46983	8.2 seconds	15.5 seconds	----------

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Emission Results - Extended Evaluation
(all results as grams per mile)

Rebel G 11 - 54372

Gasoline Baseline 1972 FTP				LPG Conversion Results								
				1972 FTP			9 CVS			1970 FTP		
HC	CO	NO_x*	Odometer	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*
2.67	11.49	8.11	3570 mi.	.33	2.29	2.10	.49	2.64	2.44	.47	2.33	----
				.35	1.66	2.21	.59	2.95	1.81	.46	1.23	2.56
			4070 mi.	.37	1.08	2.03	.54	1.39	3.15	.60	1.52	3.51
				.34	1.10	2.07	.54	1.54	3.45	----	----	----
			4200 mi.	.30	2.54	2.54	----	----	----	----	----	----
				.48	2.26	3.11	----	----	----	----	----	----
				.39	1.41	2.85	----	----	----	----	----	----
				.51	2.55	2.82	----	----	----	----	----	----
			Average	.38	1.86	2.47	.54	2.13	2.71	.51	1.69	3.03

Falcon G 11 - 46989

Gasoline Baseline 1972 FTP				LPG Conversion Results								
				1972 FTP			9 CVS			1970 FTP		
HC	CO	NO_x*	Odometer	HC	CO	NO_x*	HC	CO	NO_x*	HC	CO	NO_x*
2.74	20.69	7.80	2500 mi.	.94	1.98	3.52	1.01	1.79	4.13	1.04	1.07	4.26
				.75	1.24	2.58	.86	1.47	3.29	.84	1.24	5.04
			Average	.85	1.61	3.05	.94	1.63	3.71	.94	1.16	4.66
		NOTE:	2800 mi.	1.07	1.83	4.74	----	----	----	----	----	----
				1.22	1.72	4.54	----	----	----	----	----	----
				.88	1.67	4.83	----	----	----	----	----	----
				.98	2.12	4.77	----	----	----	----	----	----
			Average	1.04	1.84	4.72						

* presented as NO_2, corrected for humidity
NOTE: timing advanced 6° BTDC

TABLE V

GSA LPG Vehicles

Fuel Consumption

Rebel G 11 - 54372

Mileage Driven	Fuel Consumed	MPG
153.0 mi	17.0 gal	9.0 mpg
137.0 mi	15.0 gal	9.1 mpg
154.0 mi	18.0 gal	8.6 mpg
115.0 mi	13.4 gal	8.6 mpg
559.0 mi	63.4 gal	

Average fuel consumption
8.8 miles per gallon

Falcon G 11 - 46989

Mileage Driven	Fuel Consumed	MPG
139.0 mi	12.4 gal	11.2 mpg

Average fuel consumption
11.2 miles per gallon