The Effects of Manual Transmission Shift Points on Emissions and Fuel Economy of a 1977 Chevrolet Chevette When Tested by the Hot LA-4 Procedure

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Background

The Environmental Protection Agency is presently conducting studies which are directed to identifying differences in fuel economy as measured on the FTP test and reported in the Mileage Guide compared to in-use vehicle measurement. One of these studies is directed to the identification of differences in the fuel economy performance of production vehicles relative to the counterpart certification vehicle. A brief study of the effects on emissions and fuel economy of variations in manual transmission shift points was conducted on one of these production vehicles.

The results of this transmission shift point study are contained in this report. The conclusions from these tests can be considered to be quantitatively valid only for the specific type of vehicle used in the study, although it is reasonable to extrapolate the results to other types of vehicles in a directional or qualitative manner.

Test Vehicle

The vehicle used in this study was a production, 1977 Chevrolet Chevette, equipped with the 1.6 litre engine, 4-speed manual transmission, standard rear axle and original equipment tires. A detailed description of the vehicle is given in the Appendix.

Test Program

Duplicate hot LA-4 tests were performed for each transmission shift point sequence which was under study. Every precaution was taken to minimize the effects of such testing variables as; 1) the driver 2) changes in barometric pressure, humidity, dynamometer performance and instrumentation, and 3) changes in the vehicle during the time of testing. Control of the first two types of variables was accomplished by performing all tests with the same driver, on the same dynamometer using the same analytical equipment during one day of testing. Changes, if any, in the vehicle were accounted for by performing the tests in the following sequence:

Test Number	Transmission Shift Sequence
1	General Motors shift point procedure (GM)
2	Previously standard EPA shift point procedure (EPA)
3	Torque peak bracketing shift point procedure (TPB)
4	General Motors shift point procedure (GM)
5	Previously standard EPA shift point procedure (EPA)
6	Torque peak bracketing shift point procedure (RPB)

The modal analyzer was used to facilitate a detailed evaluation of the effects on emissions and fuel economy of the three shift point procedures.

Transmission Shift Sequences Which Were Investigated

1. The General Motors procedure which appears to ensure that, at any given point on the driving cycle, the vehicle is always in the highest gear which, with the use of wide open throttle, permits the vehicle to just follow the driving trace. The result of this approach is that there is a random appearance to the shift points when compared to vehicle speed (Figure 1(a)). This procedure also results in the lowest engine rotational speeds in the lower transmission gears of the three procedures.

2. The previously standard EPA procedure specifies the following manual transmission shift points for all vehicles: 1st to 2nd @ 15 MPH; 2nd to 3rd @ 25 MPH and 3rd to 4th @ 40 MPH (Figure 1(b)).

3. The torque peak bracketing procedure is based on exercising the engine in such a fashion as to include the peak torque rpm within the operating range of each gear. The vehicle speed at which each gear change occurs is a function of both the overall gearing of the vehicle (N/V in highest gear), the gear ratios of the lower gears, the peak torque rpm of the engine and the idle rpm of the engine. The transmission shift points which were selected for the test vehicle using this procedure are as follows: 1st to 2nd @ 17.5 MPH; 2nd to 3rd @ 28 MPH and 3rd to 4th @ 40 MPH (Figure 1(c)). This procedure results in the highest engine rotational speeds in the lower transmission gears of the three procedures.

Test Results

Table 1 summarizes the vehicle exhaust emissions and fuel economy for the three transmission shift point procedures as determined by the hot LA-4 test. This table shows that, of the three manual transmission shift point procedures which were investigated on the hot LA-4 test, the General Motors shift point procedure produced the lowest HC and CO emissions, the highest fuel economy and the highest NOx emissions.

Table II shows the average acceleration mode emissions from each pair of tests for each cycle of the LA-4 as determined by the modal analyzer.

Table III is similar to Table II but shows the average cruise mode emissions.

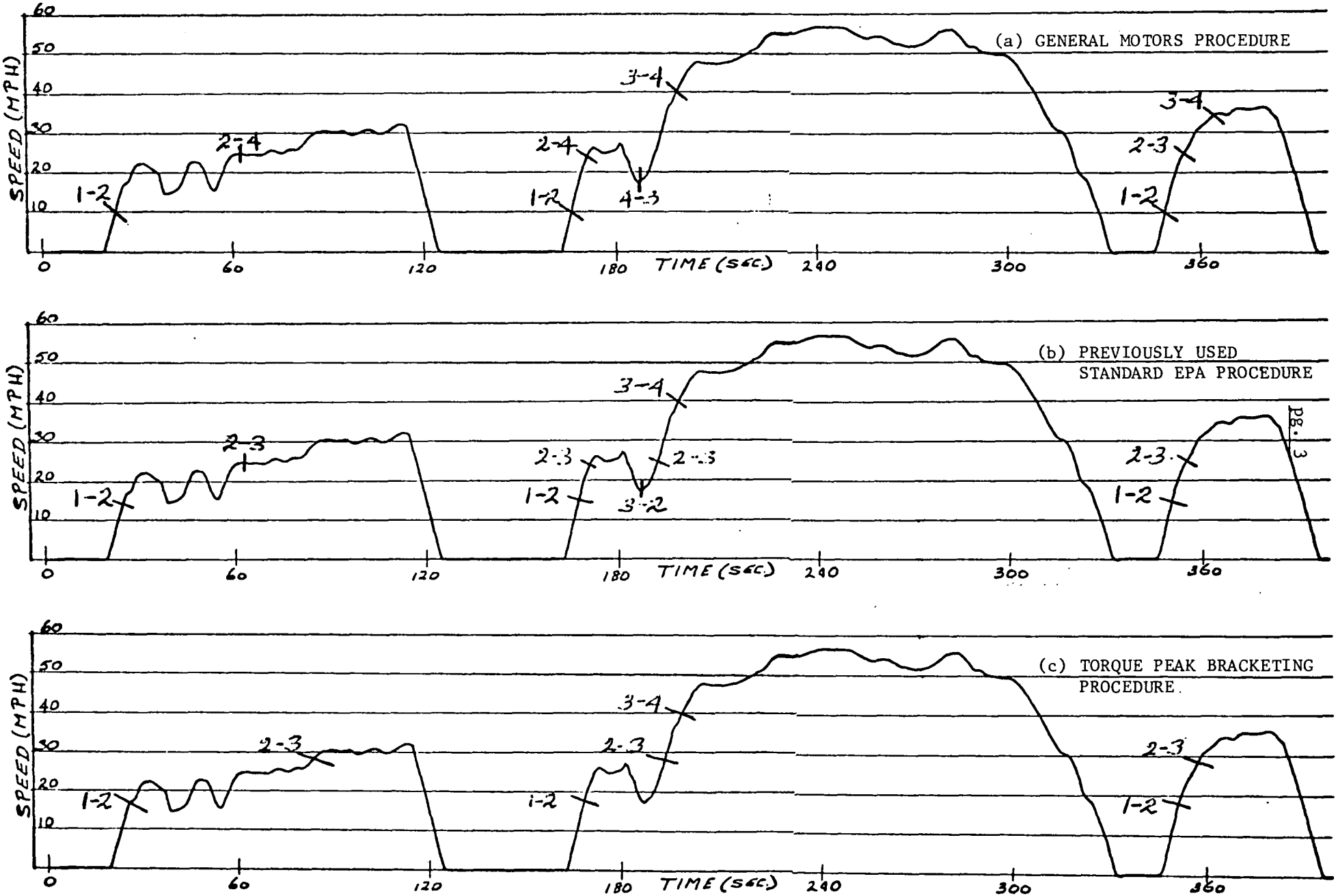
(a) GENERAL MOTORS PROCEDURE
(b) PREVIOUSLY USED STANDARD EPA PROCEDURE
(c) TORQUE PEAK BRACKETING PROCEDURE
SPEED (MPH)
TIME (SEC)
0
60
120
180
240
300
360
10
20
30
40
50
60
1-2
2-4
3-4
4-3
2-3
3-2

Figure 1

Both of these tables clearly show the modal superiority of the GM procedure in controlling HC and CO emissions while causing an increase in NOx emissions.

Table IV shows the average idle, acceleration, cruise and deceleration mode emissions for each pair of tests for the LA-4. Of note is the continued benefit in HC and CO emissions even at idle and during deceleration of the GM procedure.

Table 1
Hot LA-4 Mass Emissions in Grams/Mile
and Fuel Economy in Miles/Gallon

	Shift Point Procedure		
	General Motors	Previously Standard EPA	Torque Peak Bracketing
Hydrocarbon			
Test 1	0.20	0.28	0.36
Test 2	0.21	0.31	0.34
MEAN	0.21	0.30	0.35
Carbon Monoxide			
Test 1	2.54	3.87	4.80
Test 2	2.98	4.01	4.88
MEAN	2.76	3.94	4.84
Oxides of Nitrogen			
Test 1	1.47	1.34	1.28
Test 2	1.56	1.39	1.33
MEAN	1.52	1.37	1.31
Fuel Economy			
Test 1	29.65	26.81	25.07
Test 2	29.61	26.78	25.10
Mean	29.63	26.80	25.09

Table II

Acceleration Mode Mass Emissions in Grams/Mile by Cycle as a Function of Shift Point Procedure

Cycle #	HC Emissions Shift Point Procedure			CO Emissions Shift Point Procedure			NOx Emissions Shift Point Procedure		
	GM	EPA	TPB	GM	EPA	TPB	GM	EPA	TPB
1	.064	.087	.107	.738	1.116	1.453	.067	.088	.073
2	.211	.383	.385	2.563	4.560	4.404	.737	.626*	.535*
3	.068	.123	.141	1.355	2.077	2.048	.307	.291*	.287*
4	.055	.132	.101	1.428	2.061	1.514	.121	.188	.252
5	.079	.132	.197	1.761	1.829	2.570	.267	.280	.304
6	.012	.041	.042	.231	.687	.853	.166	.161*	.160*
7	.015	.006*	.007*	.502	.125*	.126*	.054	.052*	.033*
8	.020	.032	.095	.375	.697	1.287	.146	.147	.138*
9	.017	.024	.034	.395	.557	1.017	.195	.169*	.141*
10	.025	.046	.084	.566	1.108	1.592	.176	.195	.169*
11	.049	.063	.072	1.421	1.582	1.924	.112	.150	.150
12	.048	.055	.057	1.273	1.229	1.641	.098	.154	.193
13	.055	.054*	.113	1.190	1.136	2.072	.156	.207	.114*
14	.015	.042	.068	.216	.945	1.182	.200	.129*	.191*
15	.039	.052	.053	.836	.701*	1.115	.054	.066	.090
16	.019	.050	.049	.346	.913	1.036	.178	.136*	.156*
17	.036	.075	.073	.754	1.121	1.242	.149	.164	.194
18	.015	.024	.062	.233	.493	1.185	.139	.084*	.094*

*Cycle/pollutant where the previously standard EPA and/or Torque Peak Bracketing shift point procedures resulted in lower emissions than the GM procedure.

Table III
Cruise Mode Mass Emissions in Grams/Mile by Cycle
as a Function of Shift Point Procedure

Cycle #	HC Emissions Shift Point Procedure			CO Emissions Shift Point Procedure			NOx Emissions Shift Point Procedure		
	GM	EPA	TPB	GM	EPA	TPB	GM	EPA	TPB
1	.187	.235	.294	.999	1.334	2.843	.703	.663*	.540*
2	.148	.159	.123*	.563	1.038	.941	2.265	2.127*	2.032*
3	.008	.011	.012	.028	.015*	.136	.237	.190*	.161*
4	-	-	-	-	-	-	-	-	-
5	.015	.013*	.018	.207	.035*	.088*	.390	.281*	.299*
6	.004	.005	.007	.007	.022	.024	.161	.137*	.089*
7	.018	.015*	.012*	.195	.182*	.169*	.246	.260	.249
8	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-
11	.050	.085	.059	.191	1.049	.715	1.873	1.508*	1.479*
12	.025	.022*	.013*	.415	.350*	.203*	.378	.294*	.334*
13	-	-	-	-	-	-	-	-	-
14	.009	.009	.011	.063	.091	.063	.309	.230*	.128*
15	-	-	-	-	-	-	-	-	-
16	.007	.022	.035	.008	.145	.368	.096	.111	.118
17	.013	.027	.016	.046	.328	.094	.319	.177*	.133*
18	-	-	-	-	-	-	-	-	-

*Cycle/pollutant where the previously standard EPA and/or Torque Peak Bracketing shift point procedures resulted in lower emissions than the GM procedure.

Table IV
Total LA-4 Modal Emissions, in Grams

Mode	HC Emissions Shift Point Procedure			CO Emissions Shift Point Procedure			NOx Emissions Shift Point Procedure		
	GM	EPA	TPB	GM	EPA	TPB	GM	EPA	TPB
Idle	.107*	.113	.120	.125*	.729	.696	.251*	.298	.311
Accel	.840*	1.371	1.738	16.182*	22.980	28.250	3.321	3.298	3.274
Cruise	.485*	.602	.602	2.722*	4.589	5.643	6.978	5.977	5.561
Decel	.117*	.142	.170	1.154*	1.280	1.672	.845	.690	.680

*Modes/pollutants where the GM shift point procedure resulted in lower emissions than the other shift point procedures under study.

Comparative Summary of Results

1) The overall percentile change as measured by the Hot LA-4 test on exhaust emissions and fuel economy of the two alternative shift point procedures relative to the General Motors shift point procedure are summarized in Table V.

Table V
Percentage Change in Emissions and Fuel Economy Relative to the General Motors Manual Transmission Shift Point Procedure

Transmission Shift Point Procedure	Emissions HC	CO	NOx	Fuel Economy
Previously Standard EPA	42.9%	42.8%	-9.9%*	-9.6%*
Torque Peak Bracketing Procedure	66.7%	75.4%	-13.8%	-15.3%

*A negative result means a reduction in either emissions or fuel economy relative to the General Motors Shift Point Procedure.

2) The percentile change, by mode, as measured by the Hot LA-4 test on exhaust emissions of the two alternative shift point procedures relative to the General Motors shift point procedure are summarized in Table VI.

Table VI

Percentage Change in Modal Emissions Relative to the General Motors Manual Transmission Shift Point Procedure

Transmission Shift Point Procedure	Modes											
	Idle			Accel.			Cruise			Decel.		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
Previously Standard EPA	5.6%	483.2%	18.7%	68.2%	42.0%	-0.7%*	24.1%	68.6%	-14.4%*	21.4%	10.9%	-8.3%*
Torque Peak Bracketing	12.2%	456.8%	23.9%	106.9%	74.6%	-1.4%*	24.1%	107.3%	-20.3%*	45.3%	44.9%	-19.5%*

*A negative result means a reduction in emissions relative to the General Motors Shift Point Procedure.

Conclusions

1. The transmission shift points selected by General Motors resulted in significantly better fuel economy on the Hot LA-4 test than was obtained by the other shift point procedures.

2. The transmission shift points selected by General Motors and used in the certification process resulted in significantly lower hydrocarbon and carbon monoxide emissions when compared to the other shift point procedures. The General Motors shift points caused higher NOx emissions than the other two procedures.

3. The use of higher speed shift points by the public than those used by General Motors during the vehicle certification process can result in lower than expected fuel economy.

4. On the road Hydrocarbon and Carbon Monoxide emissions can be much higher than the certification values if other than the certification manual transmission shift points are used by the public.

Appendix

Test Vehicle Description

Model Year/Make - 1977 Chevrolet Chevette
VIN - 1B08E7Y155084
Emission Control System - EM/EGR/CAT

Engine

Type ..... 4 stroke, Otto Cycle, 4 cyl., ohc
Bore x stroke ..... 82 mm (3.23 in) x 75.7 mm (2.98 in)
Displacement ..... 1.6 litre (97.6 cu. in.)
Compression ratio 8.5:1
Maximum power @ rpm ... 63 HP 2 4800 RPM
Maximum torque @ rpm .. 82 ft lb. @ 3200 RPM
Fuel metering ..... Single, 1 barrel carburetor
Fuel requirement ..... Unleaded regular

Drive Train

Transmission type ..... 4 speed manual
Gear ratios ..... 1st - 3.75:1; 2nd - 2.16:1; 3rd - 1.36:1; 4th - 1.0:1
Final drive ratio 3.7:1

Chassis

Type ..... Unitized
Tire size ..... P 155/80 R 13
Curb weight ..... 2020 lb.
Inertia weight ..... 2250 lb.
Passenger capacity 4