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Technical Report

Road-Load Coastdown Testing of Selected 1981 thru 1984 Model Year Light-Duty Vehicles and Light-Duty Trucks

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I. Abstract

Twenty-four 1981 through 1984 model year light-duty vehicles and light-duty trucks were tested to determine the force required to overcome the sum of aerodynamic drag, tire rolling resistance and other frictional losses. The primary purpose of this testing was to compare the results from production vehicles with information submitted by the manufacturers for EPA's emission certification and fuel economy programs. Reevaluation of EPA's entire alternate road-load procedure was a secondary goal.

To the extent possible, test vehicles were obtained from private owners and rental fleets. Those vehicles supplied by the manufacturer had been used for general transportation and, from the records available, had not received any maintenance which would make them unrepresentative of production. Vehicles were tested under the procedure set forth in EPA's Office of Mobile Sources Advisory Circular No. 55B. At least 14 runs were made with the vehicle coasting (transmission in neutral) from 60 to 20 mph. Alternate runs were made in opposite directions; vehicle speed was recorded periodically. After mathematical processing, a final weather and mass corrected 55 to 45 mph "coastdown time" was calculated. (Coastdown time is a function of force and vehicle mass. Because of its usefulness in other testing, it is adopted as a convenient expression for force.)

Generally, production vehicles did not perform as well as specified in the manufacturer's application. While many of the differences were rather small, a few indicated that the manufacturer's application did not accurately describe the production vehicle. No explanation for these discrepancies is available. In addition, EPA's present procedure does not specifically address the testing of vehicles with retractable headlights.

II. Purpose

This test program had two main goals. First, and foremost, was the assessment of how well production vehicles compare to the information submitted by the manufacturers for the emission certification and fuel economy programs. In order to perform dynamometer testing for emissions and fuel economy, it is necessary that the actual road-load be known so that the dynamometer can be adjusted. Road-load is normally determined by manufacturer testing of prototype vehicles prior to production. Several years ago EPA discontinued the routine confirmatory coastdown testing of manufacturer prototype vehicles.

Instead, limited testing of production vehicles would be used to verify the representativeness of the manufacturers submitted information. This program was EPA's first such verification effort. The second purpose was to give EPA current, firsthand experience with the coastdown procedure. It has been several years since the coastdown procedure was developed; changes in vehicles and test equipment have occurred. A fresh examination, with an eye toward corrections and improvements, should be beneficial.

III. Road-Load Definition and Discussion

In this report the term "road-load" will be used to denote the sum total of aerodynamic, tire rolling resistance and drivetrain frictional losses. Road-load can be thought of as a force that the vehicle must overcome to maintain a constant velocity on a level road. The principle components are aerodynamic drag and tire rolling resistance; drivetrain frictional losses are much smaller. Road-load increases with vehicle speed. Although tire rolling resistance and drivetrain friction do not change significantly with speed, aerodynamic losses increase with the square of the speed. Therefore, at low speeds tire rolling resistance and friction are the most important while at high speeds aerodynamic drag predominates. While somewhat vehicle dependent, the crossover point is about 40 mph.

Since road-load is a force, the conventional units would be those of pounds-force (English) or Newtons (metric). Road-load force is not constant, therefore, a reference speed must be specified. However, instead of using force, road-load is typically expressed in terms of a 55 to 45 mph "coastdown time". The use of coastdown time as an expression for road-load developed as an outgrowth of EPA dynamometer testing. Dynamometer coastdown time is measured as a quick-check of the dynamometer adjustment. The dynamometer time must match the road time (with certain tolerances).

IV. Background

EPA's Office of Mobile Sources tests passenger cars and light trucks for exhaust emissions and fuel economy. These tests are conducted indoors on a chassis dynamometer with the vehicle held stationary. The chassis dynamometer allows the vehicle to be "driven" over a prescribed driving schedule while emissions and fuel economy are measured. The function of the dynamometer is to reproduce the engine load conditions that the vehicle would encounter on an actual street or highway.

The dynamometer must reproduce the mass and road-load that the vehicle encounters in real operation. The mass is very easy to simulate; a series of different size flywheels can be engaged or disengaged as necessary. The only information needed in making the flywheel selection is the vehicle's weight, easily measured on a scale.

Unfortunately, determining road-load is not as simple. Road-load is comprised of three major components: aerodynamic drag, tire rolling resistance and drivetrain frictional losses. These items are more difficult to measure (either singularly or combined) than vehicle weight, primarily because they only exist under actual operating conditions. Further, road-load is affected by wind and weather conditions. During the early days of emission and fuel economy testing, most manufacturers did not measure road-load.

EPA's original approach to dynamometer adjustment was to establish a general table of adjustment values. These values were a function of vehicle weight; a manufacturer only had to know the weight of a vehicle in order to establish its dynamometer adjustment. While not as sophisticated as the current procedure, the general table was adequate at that time. While not directly correlated with road-load, weight is an indirect predictor for many vehicles. Heavier vehicles tend to be larger with increased aerodynamic drag (tire and friction losses also increase). Vehicle manufacturers could elect to determine road-load for any vehicle in lieu of using these average adjustment factors. Whether due to the complexity and difficulty of measuring road-load or whether the average adjustment factors were generally adequate for existing vehicles, manufacturers rarely availed themselves of this opportunity.

Beginning with the oil embargo of 1973, the topic of dynamometer adjustment became much more important. EPA began publishing fuel economy results which were obtained as a by-product of emission testing. While dynamometer adjustment does affect emission results, fuel economy measurements are much more sensitive. This is especially true for "highway" fuel economy. The "city" (EPA Estimated MPG) number is derived from operation over a stop and go driving schedule. During the city cycle a large part of the engine output is used to overcome inertia; this energy is ultimately dissipated in the vehicle's brakes as heat. The highway driving sequence is much different as it is run at a higher and much more constant speed, both factors increasing the sensitivity to road-load.

In response to public demand for more fuel efficient vehicles, manufacturers began making various improvements to reduce road-load. They also sought credit for vehicles which were already more efficient than indicated by the general table. To obtain the appropriate fuel economy benefit for vehicle efficiency improvements, manufacturers began testing their vehicles for road-load.

Initially, the technique used to determine vehicle road-load was based on engine manifold vacuum. For gasoline engines, the amount of power produced is inversely related to the manifold-vacuum. Higher levels of power correspond to lower levels of vacuum. (As the engine throttle is opened to demand more power, the amount of pressure drop across the throttle plate decreases, therefore, decreasing the manifold vacuum.) In order to employ this principle, the vehicle was equipped with a vacuum gauge and then driven on a level road at 50 mph constant speed. The manifold vacuum reading was noted. The vehicle was then placed on a chassis dynamometer and operated at 50 mph. The dynamometer was adjusted until the same manifold vacuum reading was obtained. This technique was not as accurate as desired and was also effected by barometric pressure changes; with the advent of certain exhaust gas circulation systems it was difficult to use. (These systems were sensitive to engine manifold vacuum and, while in operation, would change the vaccum reading. Engine vacuum was not the reliable predictor of engine power that it had been.) Further, engine vacuum could not be used to determine the power output of diesel engines. (For diesels fuel flow can be measured, but this procedure has its own limitations.) An improved method was needed.

EPA developed a new general method to establish correct dynamometer adjustment. This method relies on frontal area, vehicle shape, tire type, weight and size of protuberances. The equation relating these factors was derived empirically; data was gathered using the coastdown test procedure described below. Most manufacturers do not use the general method for calculating road-load. It is to their advantage to establish specific road-load values for each vehicle. The coastdown technique is almost universally used.

V. Coastdown Test Procedure

The coastdown test has become the standard industry technique for determining vehicle road-load for purposes of EPA emissions and fuel economy testing. This procedure is set forth in EPA's Office of Mobile Sources Advisory Circular No. 55B. This technique is also set forth in the Society of Automotive Engineers (SAE) Recommended Practice J1263. The SAE practice has statistical screens for removing variable data (outliers). The reader is referred to those documents for a more detailed discussion; following is a brief outline.

The test vehicle is accelerated to a speed above 60 mph, the transmission is placed in neutral, and the vehicle is allowed to decelerate to a speed below 20 mph. This process is then repeated with the vehicle traveling in the opposite direction on the same test road. This road must be straight and quite level. Vehicle speed is obtained from a calibrated fifth wheel and is recorded periodically. Wind speed, wind direction, ambient temperature and barometric pressure are also recorded.

Results from each run are fit into a two term equation in which "acceleration" is predicted as a function of a constant and velocity squared term, $A = -(a_0 + a_2V^2)$. Various statistical tests performed, temperature, barometric pressure and wind corrections are made, and average coefficients are established. From these, a dynamometer coastdown time from 55 to 45 mph is calculated, appropriate corrections being made for the dynamometer inertia simulation actually used (as opposed to test vehicle mass) and the nonrotation of the two wheel assemblies not on the dynamometer. This 55 to 45 mph coastdown time is referred to as a "target" time and is used as a "quick-check" after vehicle dynamometer testing.

The reader is urged to consult Advisory Circular 55B and SAE recommended practice J1263 for further information.

VI. Vehicle Selection

Twenty-four test vehicles from the larger foreign and domestic manufacturers were selected for this program. Two criteria were employed in making the selections. First, an attempt was made to select the "best performing" vehicles, i.e. low road-load relative to their competition. To a lesser extent, a random cross section of vehicles was also selected. However, because of the importance of vehicle road-load in establishing fuel economy values, and because of the emphasis most manufacturers place on obtaining high fuel economy values, selections were biased toward smaller vehicles with high fuel economy.

Attempts were made to procure vehicles with approximately 4,000 miles from rental fleets or private owners. Occasionally, a particular vehicle would be difficult to obtain. In such case, the vehicle specification might be changed or the desired 4,000-mile odometer reading would be relaxed. In several instances, the manufacturer supplied vehicles from a "transportation fleet" or from a manufacturer employee. (Because the purpose of this program was to asess performance on production vehicles, an engineering or test vehicle might have received unrepresentative maintenance and would not be acceptable.)

A complete list of test vehicles and their specifications can be found in the Appendix.

VII. Test Program

Most of the testing in this program was performed (under EPA contract) by the Transportation Research Center (TRC) of East Liberty, Ohio. One test was performed by a manufacturer at its test facility. Several manufacturer correlation tests were also run. TRC's testing was done on a 1.9 mile straight segment of their 7 1/2 mile oval track. This straightaway is aligned approximately northwest and southeast with a 0.25 percent downgrade towards the southeast. Testing was conducted during the end of the summers of 1981, 1982, and 1983.

The following is a general outline of the procedure used for each vehicle tested at TRC:

A. Initial Inspection. The vehicle would be received and inspected to verify that it met the contract specifications. Safety and fluid level checks were also performed.

B. Instrumentation. A fifth wheel bracket was fabricated and installed. The necessary wiring from the fifth wheel to the passenger's compartment was put in place. Depending upon test scheduling, the instrumentation package was either installed at this point or immediately prior to vehicle weigh in.

C. Wheel Alignment. Wheel alignment adjustments were measured and, if necessary, the vehicle was adjusted to the manufacturer's recommended specifications. When recommended by the manufacturer, rear wheel alignment was also measured and adjusted. At the conclusion of the wheel alignment, brake drag was checked and adjusted, if necessary. The tires were inflated to five psi above manufacturer's recommended pressure, and the vehicle was placed outside.

D. Weight. After a minimum of four hours at ambient temperature, the tire pressures were reduced to the manufacturer's recommendation and the vehicle was weighed. Distance from the ground to the top of each fender opening was measured as an indication of vehicle height.

E. Warm-up. The vehicle was operated at 50 mph for a distance of approximately 26 miles in preparation for testing. Fifth wheel calibration was checked against a measured mile.

F. Coastdown Test. A total of fourteen 60 to 20 mph coastdowns were made, seven in each direction. (Occasionally, if the driver noticed or suspected a problem, additional runs were made.)

G. Weight. An after test weight with driver was obtained.

H. Data Processing. Test data was processed by computer in accordance with SAE Recommended Practice J1263 (without the cross-wind correction.)

Based on our experience during the 1981 testing season, manufacturers' representatives were invited to view the 1982 and 1983 testing. Also, for the 1983 testing, an attempt was made to perform the coastdown test with extremely low wind velocity, well below the maximum allowed in Advisory Circular No. 55B.

VIII. Results

Except for one vehicle, all test results yielded a shorter coastdown time than stated in the manufacturer's application for emission certification. Shorter coastdowns indicate a greater road-load force. A distribution of comparisons between vehicle tests and the manufacturer's application is shown in Figure 1. A summary of the test results is contained in the appendix.

Figure I

<u>Comparison of Results to Manufacturers Applications</u>

% Shortfall					
(1.0)	X				
0	X				
1.0	X				
2.0	X	X	X		
3.0	X	X			
4.0	X				
5.0	X	X	X	X	X
6.0					
7.0	X	X	X		
8.0					
9.0					
10.0					
11.0	X				
12.0	X				
13.0	X	X			
14.0	X				
15.0	X	X			

X= One Vehicle

In addition to the overall results, this test program yielded some additional information. The 1981 Toyota Celica was inadvertently tested with a very small door pillar vent open. After the first 10 runs, this error was noticed and the vent was closed. A full 14 run coastdown test was then performed. Results from the first 10 runs show a lower road-load, 16.00 vs. 14.20 seconds; such a large difference would not be expected. There is no present explanation, perhaps it can be partially attributed to tire cool down during the first 10 runs.

During testing of Vehicle Number 10, 1983 Ford Ranger, winds were within specification but higher than desirable, (5 to 8 mph with gusts from 7 to 12.) The wind direction was basically in line with the track. While the results did not pass the statistical screen in SAE Recommended Practice J1263, they did indicate a higher road-load than claimed by the manufacturer. Two tires were taken off this vehicle and were tested for rolling resistance coefficient on a 67 inch drum. Results were very low with rolling resistance coefficients of 0.0087 and 0.0091. A second 1983 Ford Ranger, Vehicle Number 12, was tested and agreed quite well with the manufacturer's submission. While testing Vehicle Number 22, a 1983 Ford Escort, the initial test sequence was aborted because of rain and gusty wind. The eight test runs (four pairs) with winds from 4.5 to 6 mph yielded a coastdown time only slightly shorter than the complete test with winds from 0.5 to 3.0 mph (14.28 versus 14.48 seconds).

The 1984 GM Fiero was the only vehicle in this program equipped with retractable headlights. The test procedure does not specifically discuss how such headlights are to be treated; the manufacturers application for certification was based on testing with the headlights off. EPA's testing was conducted at night with the headlights on. The manufacturer ran correlation tests before and after EPA's testing with headlights both on and off. (A total of four manufacturer tests were run.) The manufacturer tests indicated a 0.7 to 0.9 second decrease in coastdown time with the headlights operating. Had EPA tested the vehicle with the headlights off, a coastdown time in the vicinity of 16.4 would have been expected. This would be 10 percent less than the manufacturers application.

As an adjunct to this program, several manufacturer correlation tests were run. Agreement between TRC and the manufacturers tests was quite good with TRC indicating approximately one percent shorter coastdown times.

Vehicle	-Coastdown Time- Mfr. Before	TRC	Mfr. After
9 Cavalier	16.39s	15.99s	16.12s
14 Alliance		12.82	12.94
24 Fiero	15.74	15.57	15.81

Vehicles 9 and 24 were tested at the manufacturers test track a day or two before and after the TRC test. The manufacturer tested vehicle 14 immediately following the TRC test using its own driver and equipment.

IX. Acknowledgment

EPA would like to thank the manufacturers who participated in this program by sending representatives to view testing, providing test vehicles, and conducting correlation testing. The assistance provided was much appreciated.

American Motors
Chrysler
Ford
General Motors
Honda
Nissan
Toyota

Appendix I
Test Vehicles

No.	Year	Manufacturer	Model	Body Style	Odometer	Weight	Engine	Trans-mission	Tires			Pressure F/R
1	1981	Chrysler	Reliant	4-door	9587	2,510	2.2-L	A3	Good	Viva	P185/65R14	35/35
2	1981	Chrysler	TC3	2-door HBK	7817	2,510	2.2-L	A3	Fire	HPR	P195/60R14	35/35
3	1981	Ford	Granada	4-door	4608	2,940	3.3-L	A	UniR	Steel	P175/75R14	35/35
4	1982	Ford	LN7	2-door HBK	1056	2,290	1.6-L	M4	Mich	TRX	P165/70R365	30/30
5	1982	GM	Cavalier	4-door	397	2,520	1.8-L	M4	Fire	DCR	P175/80R13	35/35
6	1981	GM	Citation	2-door HBK	2406	2,695	2.8-L	A	Fire	DCR	P185/80R13	30/30
7	1981	Honda	Accord	2-door HBK	6033	2,200	1.8-L	M5	Bridg	RD108	165SR13	24/24
8	1981	Toyota	Celica GT	2-door HBK	14698	2,690	2.4-L	M5	Bridg	RD116	185/70SR14	24/24
9	1982	GM	Cavalier	2-door HBK	6419	2,630	1.8-L	M4	UniR	RSeal	P195/70R13	35/35
10	1983	Ford	Ranger	PU Truck	2285	2,705	2.3-L	A3	Fire	DCR	P185/75R14	35/35
11	1982	Nissan	Sentra	2-door	2979	1,950	1.5-L	M4	Yoko	GT	155/SR13	26/26
12	1983	Ford	Ranger	PU Truck	6886	2,620	2.3-L	M4	Good	Viva II	P185/75R13	35/35
13	1982	GM	Ciera	4-door	14233	2,780	2.5-L	A3	Fire	721	P185/80R13	35/35
14	1983	Renault	Alliance	4-door	5153	2,190	1.4-L	A3	Good	Corsa	P175/70R13	30/30
15	1983	GM	Cavalier	4-door	3942	2,560	2.0-L	A3	Good	Viva II	P175/80R13	35/35
16	1983	Ford	Ranger	PU Truck	8203	3,060	2.2-L	M4	Fire	721	P195/75R14	35/35
17	1983	Ford	LTD	4-door	17127	3,030	3.3-L	A3	Fire	721	P185/75R14	30/35
18	1983	Nissan	200SX	2-door	6392	2,660	2.2-L	M5	Bridg	RD113	185/70SR14	26/26
19	1983	Honda	Accord	4-door	2818	2,400	1.8-L	A4	Mich	X	P185/70R13	26/26
20	1983	Chrysler	Charger	2-door HBK	5396	2,260	1.6-L	M4	Good	Viva II	P175/70R13	35/35
21	1983	Ford	Ranger	PU Truck	21000		2.2-L	M4	Fire		P185/75R14	35/35
22	1983	Ford	Escort	4-door HBK	13463	2,270	1.6-L	A3	Good	Corsa	P165/80R13	35/35
23	1983	Toyota	Camry	4-door	5453	2,490	2.0-L	A4	Bridg	RD116	185/70SR13	30/30
24	1984	GM	Fiero	2-door	3905	2,560	2.5-L	M4	Fire	WR12	P185/80R13	35/35

Appendix II
Coastdown Testing Summary

	Vehicle	Model	Inertia Weight	Coastdown Time Vehicle	Coastdown Time Application	% Difference Application-Vehicle Application
1981 Testing						
1.	1981 Chrysler Reliant	4-dr	2875 lbs.	14.035	14.73	4.8%
2.	1981 Chrysler TC3 *1	2-dr HBK	2750	13.65	15.26	10.6
3.	1981 Ford Granada	4-dr	3500	14.74	15.08	2.3
4.	1981 Ford LN7	2-dr HBK	2625	14.57	15.69	7.1
5.	1982 GM Cavalier	4-dr	2875	14.67	16.91	13.2
6.	1981 GM Citation	2-dr HBK	3000	14.57	15.63	6.8
7.	1981 Honda Accord	2-dr HBK	2500	12.57	12.99	3.2
8.	1981 Toyota Celica GT	2-dr HBK	3000	14.20	16.49	13.9
1982 Testing						
9.	1982 GM Cavalier*2	2-dr HBK	2875	15.99	16.91	5.4
	(manufacturer pretest)			16.39		
	(manufacturer post-test)			16.12		
10.	1983 Ford Ranger (#1)	Truck	3000	11.64*3	13.45	13.5
11.	1982 Nissan Sentra	2-dr	2250	12.90	13.21	2.4
12.	1983 Ford Ranger (#2)	Truck	3000	13.24	13.45	1.6
13.	1982 GM Ciera	4-dr	3125	15.49	16.12	3.9
1983 Testing						
14.	1983 AMC/Renault Alliance	4-dr	2500	12.82	12.94	0.9
	(manufacturer test)			12.92		
15.	1983 GM Cavalier	4-dr	2875	15.23	17.86	14.7

	Vehicle	Model	Inertia Weight	Coastdown Time Vehicle	Coastdown Time Application	% Difference Application-Vehicle Application
16.	1983 Ford Ranger (#3)	Truck	3250	13.46*4	15.60	11.2
	Retest			13.28*5		12.4
17.	1983 Ford LTD	4-dr	3500	16.75	17.70	5.4
18.	1983 Nissan 200 SX	2-dr	3000	16.28	16.31	0.2
19.	1983 Honda Accord	4-dr	2625	13.14	14.08	6.7
20.	1983 Chrysler Charger	2-dr HBK	2750	16.38	16.91	3.1
21.	1983 Ford Ranger *2 (Manufacturer test)	Truck	3250		15.16	4.8
22.	1983 Ford Escort	4-dr HBK		14.48	15.28	5.2
23.	1983 Toyota Camry*2	4-dr	2750	14.24	14.10	(1.0)
24.	1984 GM Fiero*2	2-dr	2875		18.23	
	EPA Test			15.57*6		14.6
	Manufacturer pretest*7			15.74*6		
	Manufacturer pretest*7			16.61		
	Manufacturer post-test			15.81*6		
	Manufacturer post-test			16.53		

*1 New tires prior to test, not equipped with rear spoiler.

*2 Manufacturer supplied vehicle.

*3 Results are calculated from nine run pairs with RMS errors and standard deviations greater than permitted by SAE Recommended Practice J1263.

*4 Aftermarket step bumper and modified air dam.

*5 Production step bumper and air dam.

*6 Retractable headlights extended.

*7 Rear alignment possibly slightly misadjusted.