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Technical Report

The Effect of Acceleration Rate on Automatic Transmission Shift-Speeds for Two 1979 Novas

By

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NOTICE

Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

I. Introduction

The Federal Test Procedure and the Highway Fuel Economy Test are currently used by EPA to measure emissions and fuel economy. The driving cycles used for these tests simulate the experience of a vehicle on an average urban excursion and during typical highway travel. However, during the development of the driving cycles the maximum acceleration rate was limited to 3.3 mph/sec, because of performance limitations of the twin roll dynamometers available at the time.1/

Variations in acceleration rates will result in variations in vehicle fuel economy. If typical vehicle acceleration rates are distributed in the same manner as the accelerations are distributed on the EPA test cycles, or if the vehicle operational characteristics do not significantly change with acceleration rate, then results from the EPA cycles should be representative of average vehicle use. However, if vehicle operational characteristcs change with changing acceleration rates, and if vehicle accelerations in consumer use are not distributed in the same manner as the accelerations of the EPA test cycle, then significant differences between EPA estimated fuel economy and actual vehicle fuel consumption may result. This effect would be most dramatic if the vehicle operational characteristics significantly change when acceleration rates exceed 3.3 mph/sec.

One important vehicle characteristic which often changes with acceleration rate is the transmission shift speed for vehicles with automatic transmissions. Consequently, to determine the effects of acceleration rates on transmission shift speeds and to determine if any anomalous change occurs in transmission shift speeds at acceleration rates near 3.3 mph/sec., EPA recently conducted a short test sequence on two vehicles with automatic transmissions. These tests determined the relation between vehicle acceleration rate and transmission shift speed for acceleration rates from 1 to 6 mph/sec. The vehicles, the test sequence, and the results are discussed in detail in the following sections of the report.

II. Discussion

A. Test Equipment and Test Site

The test vehicles were two 1979 Chevrolet Novas; similar in model, equipment, and accumulated mileage. Each vehicle was equipped with a three-speed automatic transmission. A detailed vehicle description is given in Appendix A.

To assure consistent operation of the vehicles, a "drivers aid" strip chart recorder was installed in each. This "drivers aid" was a feedback system which provided a continuous chart trace of vehicle speed. The speed was sensed by a fifth wheel mounted on the rear of the vehicle.

The tests were conducted at the Transportation Research Center of Ohio. The test site used for data collection was the straight, smooth, north-south section of high speed oval track.

B. Procedure

Prior to conducting the tests, speed time lines representing constant acceleration rates from 0 to 60 mph were drawn on the "drivers aid" strip chart. The acceleration rates of the speed time lines varied from one to six mph/sec. in increments of one mph/sec.

The vehicles were first driven over a warm-up cycle consisting of steady-speed operation at 55 mph for about 22.5 miles. The vehicles were operated at all times with a driver and observer on board.

In each test trial the driver matched, as accurately as possible, the vehicle speed, as indicated on the "driver's aid" system, to the constant acceleration speed-time lines previously drawn on the strip chart paper. Each trial began with the vehicle at rest and the transmission selector in the "drive" position. The observer noted on the strip chart trace the transmission gear shift points, judged by sound and sensed movement of the vehicle. Five trials were conducted in each direction at each rate of acceleration.

An example strip chart recording for two test trials of Vehicle B is given in Figure I. The speed time lines represent constant acceleration rates of 2 mph/sec. The vehicle speed trace follows each acceleration trace closly. The X's denote the 1st-2nd and 2nd-3rd gear transmission shift speeds of the vehicle.

The speed at each transmission shift point was later read from the strip chart for all test trials. All transmission shift speed data are tabulated in Appendix B.

C. Results

Each vehicle experienced an increase in 1st-2nd and 2nd-3rd gear shift speeds with an increase in acceleration rate. The average shift speed for each five-trial test sequence was computed and tabulated in Table I.

Graphical representations (Figures II and III) indicate that for each vehicle the relation between 1st-2nd gear transmission shift speed and acceleration rate was approximately linear in two distinct regions; acceleration rates from 1-3 mph/sec and acceleration rates from 4-6 mph/sec. A distinct change in slope of the linear relation occurred between acceleration rates of 3 mph/sec and 4 mph/sec. Vehicle A experienced a significantly greater delay

Table 1

Five Trial Average Vehicle Shift Speed for Each Acceleration Rate

Acceleration Rate	Direction of Test	Average Shift Speed 1st-2nd gear Vehicle B	1st-2nd gear Vehicle A	2nd-3rd gear Vehicle B	2nd-3rd gear Vehicle A
1 mph/sec	North	11.5	13.4	24.8	22.6
	South	11.6	13.0	19.0	23.8
2 mph/sec	North	19.8	18.6	45.0	50.0
	South	18.8	17.8	42.8	43.4
3 mph/sec	North	28.4	25.2	58.0	60 +
	South	25.6	24.0	58.4	60 +
4 mph/sec	North	33.4	40.4	--	--
	South	34.0	40.4	--	--
5 mph/sec	North	37.4	44.0	--	--
	South	37.0	43.8	--	--
6 mph/sec	North	40.6	43.8	--	--
	South	41.6	43.8	--	--

Figure I

Vehicle B Speed-Time Trace

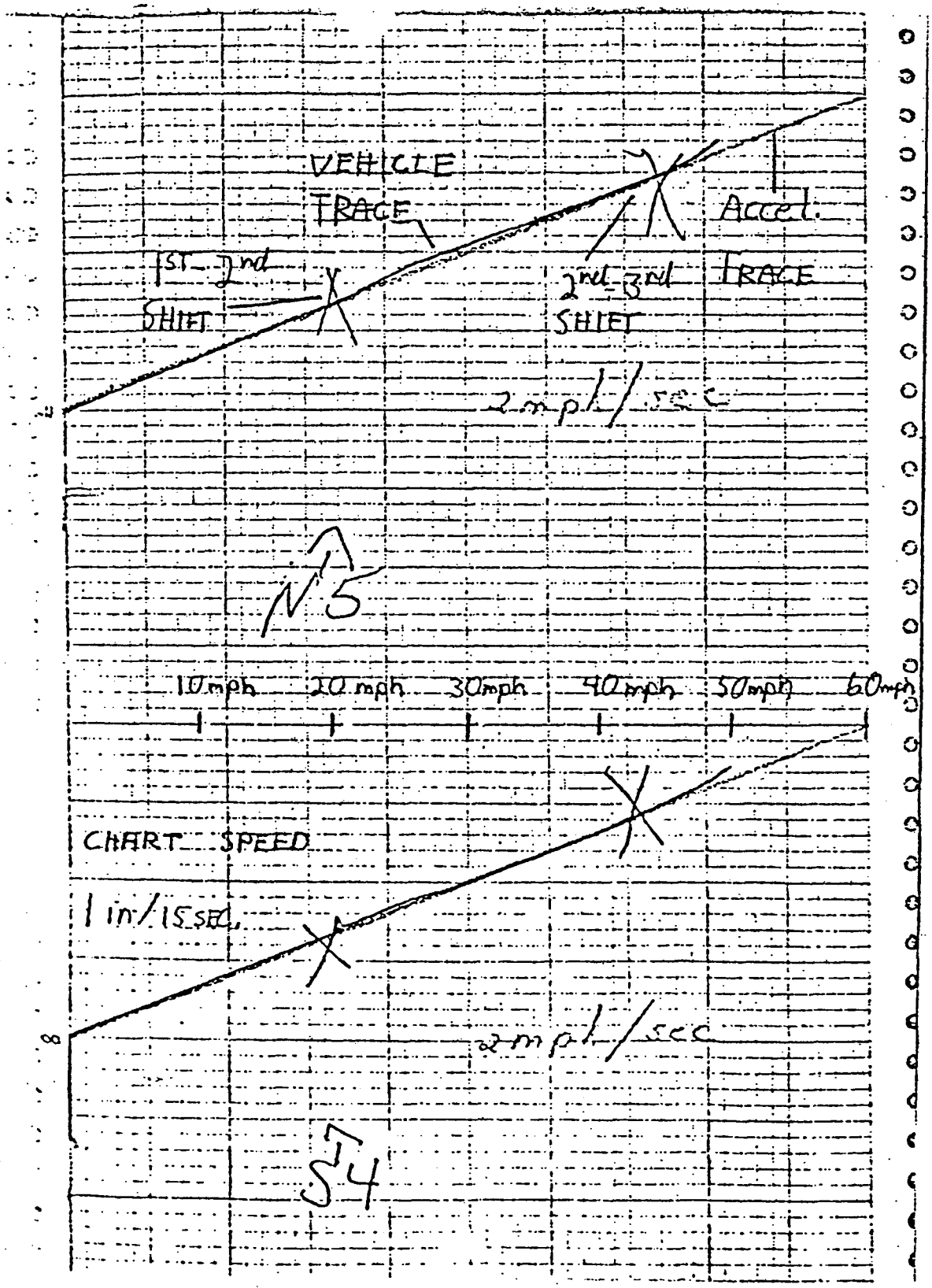


Figure II

Average Shift Speed vs.
Acceleration Rate - Vehicle A

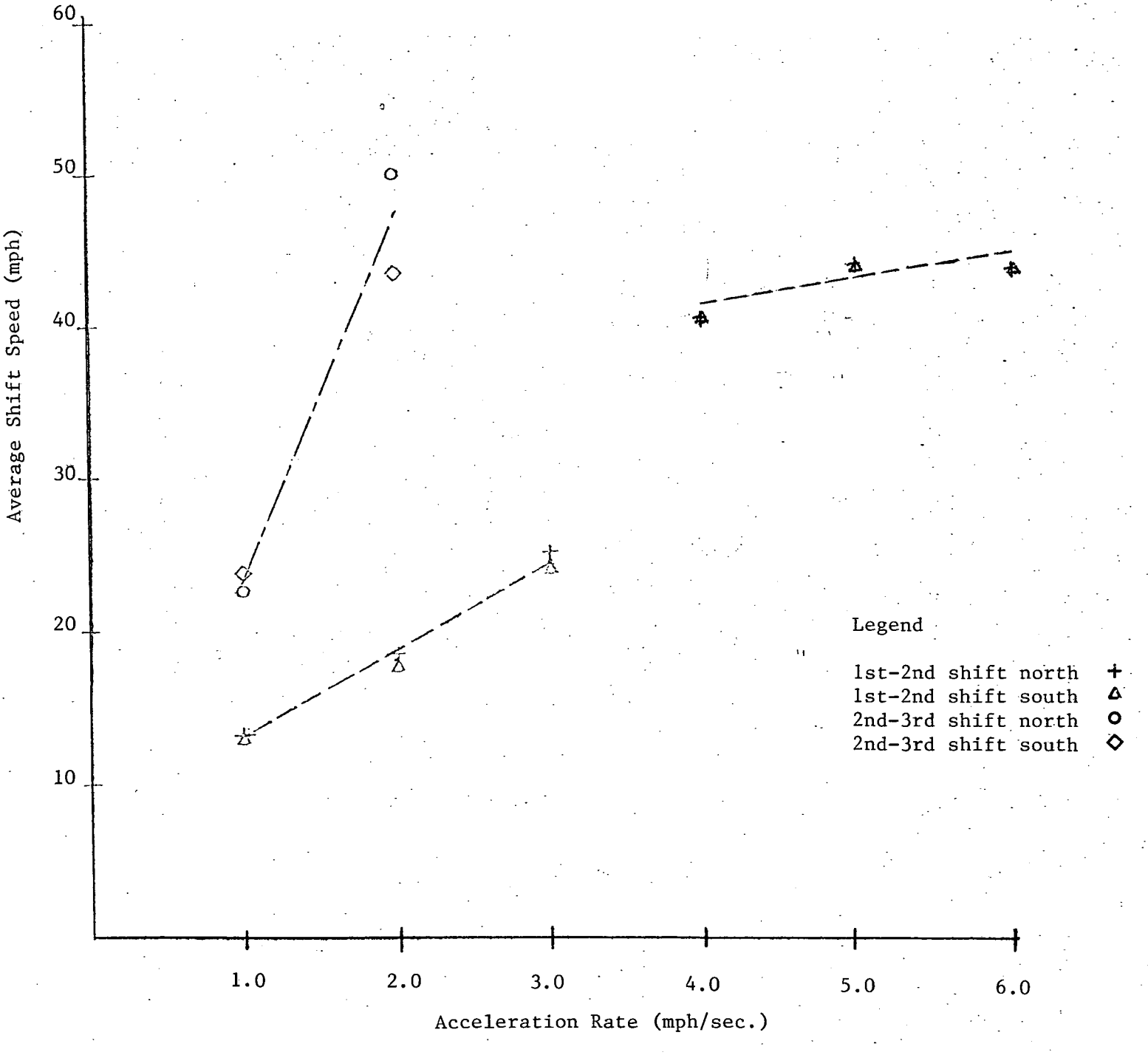
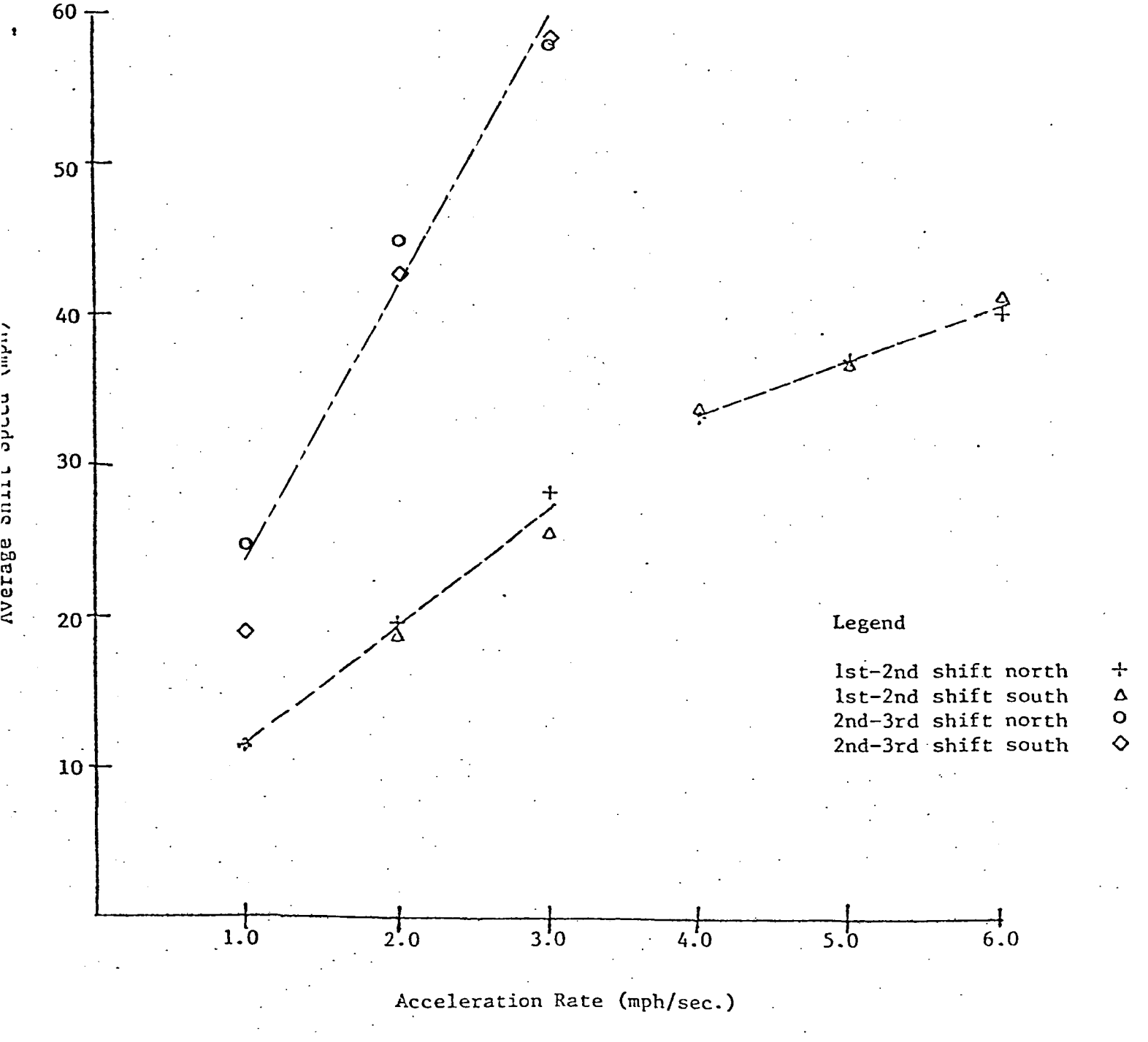


Figure III

Average Shift Speed vs.
Acceleration Rate - Vehicle B



in 1st-2nd gear shift speed at an acceleration rate of 4 mph/sec than anticipated from the shift points at the first three acceleration rates. Vehicle B experienced less of a dramatic change of 1st-2nd gear shift speed between the acceleration rates of 3 to 4 mph/sec.

The 2nd-3rd gear shift speed appeared to be approximately linear with acceleration rates for both vehicles up to accelerations of 3 mph/sec. However, the shift speed for Vehicle A when accelerating at 3 mph/sec. is not precisely known since it occured at speeds greater than 60 mph. At acceleration rates of 4 mph/sec. and above, the 2nd-3rd shift occurred above 60 mph on all test trials.

The differences between the shift speed characteristics of the two vehicles are surprising considering the similarity of the vehicles. Ambient conditions could not have caused the observed differences since the tests were run concurrently. Operator error was possible in all test trials since the transmission shifts were subjectively determined by sound and sensed movement of the vehicle. However, all tests indicated very repeatable results, indicating at least consistent operator behavior. No reason, other than actual vehicle differences could be identified to explain the variation in the shift speed characteristics of the vehicles.

Direction of travel appeared to have little effect on the test results. This would be expected since the force required to accelerate the vehicle would greatly exceed the forces resulting from the low winds and small track grade. Any effects wind and track grade might have had, were small.

D. Potential Effects on Vehicle Fuel Consumption

An EPA study has shown that delaying transmission shift points until higher vehicle speeds results in increased vehicle fuel consumption, even when the vehicle is accelerated at the same rate.2/ This effect of transmission shift points on vehicle fuel economy has also been reported by automotive manufacturers.3/

Data on typical vehicle use indicate that consumer vehicles are often operated at acceleration rates greater than 3.3 mph/sec., the maximum acceleration rate of the EPA test cycles.4/ Both vehicles used in this test program demonstrated a delay in the transmission shift points with increasing acceleration rate. Therefore, in consumer use the delay in transmission shift points would be expected to contribute to greater fuel consumption than that measured on the EPA test cycles. In addition, more rapid vehicle acceleration demands greater power from the vehicle, which also results in greater fuel consumption.

This shortfall between EPA measured fuel economy and consumer fuel economy would be most dramatic in the case of Vehicle A. For this vehicle an anomously large change in the speed of the 1st-2nd transmission gear shift, from 24.5 mph to 40.4 mph, occurred when the vehicle acceleration rate changed from 3 mph/sec to 4 mph/sec.

III. Conclusion

The two vehicles tested exhibited an increase in the vehicle speed at both the 1st to 2nd and 2nd to 3rd gear shift points with an increase in acceleration rate.

Vehicle A exhibited a significant anomalous change in the speed at which the transmisison 1st-2nd gear shift occurred when the vehicle acceleration rate exceeded the maximum acceleration rate which occurs during the EPA test cycle. Vehicle B also experienced a significant, but less dramatic, change in 1st-2nd gear shift characteristics once the vehicle exceeded the maximum acceleration rate on EPA test cycles. The difference in the behavior between the two vehicles was attributed to inherent vehicle-transmission differences.

The fuel consumption of both vehicles in consumer use would be expected to be greater than that measured on the EPA test cycles because the acceleration rates of vehicles in consumer use are often greater than those of the EPA test schedules and because of the occurrence of the characteristic delay in transmission shift speeds at the greater acceleration rates. This consumer-EPA shortfall would be most dramatic in the case of Vehicle A which experienced a large anomalous delay in the vehicle speed at which the transmission 1st-2nd gear shift occurred when the vehicle acceleration rate exceeded the maximum acceleration rate of the EPA test cycles.

References

1/ "Development of the Federal Urban Driving Schedule," Kruse, Ronald E., Huls, Thomas A., SAE Paper 730553, Society of Automotive Engineers, New York, 1973.

2/ Memo to John P. DeKany, EPA/ECTD, "Manual Transmission Shift Points on the FTP and HFET," Hutchins, F. Peter, EPA/ TAEB, May 4, 1977.

3/ "A Summary and Analysis of Comments Received in Response to the EPA/NHTSA Information Request Regarding the Effects of Test Procedure Changes on Fuel Economy," Hourihane, James, Thompson, Glenn D., LeBaron, Edward, EPA Technical Report, January 1980.

4/ Memo to Charles Gray, EPA/ECTD, Garbe, Robert J., January 17, 1980.

Appendix A

Test Equipment

Vehicle A - Silver 1979 Nova
250 CID engine/1bbl.
Model 350 turbo-hydromatic transmission
EPA combined city/highway : 20 mpg
OEM tires
Approximate test weight: 3750 lbs.

Vehicle B - Brown 1979 Nova
250 CID engine/1bbl.
Model 350 turbo-hydromatic transmission
EPA combined city/highway: 20 mpg
OEM tires
Approximate test weight: 3750 lbs.

Appendix B

Vehicle A
November 7, 1979

Acceleration Rate -	1 mph/sec		2 mph/sec		3 mph/sec		4 mph/sec	5 mph/sec	6 mph/sec
Shift Point -	1st-2nd	2nd-3rd	1st-2nd	2nd-3rd	1st-2nd	2nd-3rd	1st-2nd	1st-2nd	1st-2nd
Trial Direction									
1 North	14	23	18	--	24	60+	35	44	44
South	13	--	15	43	25	60+	35	44	44
2 North	14	22	20	48	23	60+	46	44	44
South	13	29	18	38	23	60+	41	44	44
3 North	13	23	19	--	27	60+	37	44	44
South	13	22	17	53	25	60+	44	43	44
4 North	13	22	17	50	27	60+	43	44	43
South	13	22	20	42	24	60+	40	44	44
5 North	13	23	19	52	25	--	41	44	44
South	13	22	19	41	23	--	42	44	43
Ambient Temperature:	35°		36°		36°		37°	37°	37°
Barometric Pressure:	29.06 "HG		29.06 "HG		29.06 "HG		29.05 "HG	29.05 "HG	29.05 "HG
Wind Speed:	7 mph		8 mph		5 mph		6 mph	6 mph	8 mph
Wind Direction:	270° S		270° S		270° S		270° S	270° S	270° S

Appendix B

Vehicle B
November 7, 1979

Acceleration Rate -	1 mph/sec		2 mph/sec		3 mph/sec		4 mph/sec	5 mph/sec	6 mph/sec
Shift Point -	1st-2nd	2nd-3rd	1st-2nd	2nd-3rd	1st-2nd	2nd-3rd	1st-2nd	1st-2nd	1st-2nd
Trial Direction									
1 North	--	28	23	38	23	53	30	35	35
South	13	--	19	43	26	59	37	36	41
2 North	11	22	20	42	27	57	29	36	42
South	10	19	18	42	24	53	30	38	42
3 North	10	25	18	53	34	60	36	39	42
South	12	--	20	44	28	60	31	36	41
4 North	12	23	18	48	28	60	36	38	42
South	12	--	19	42	24	60+	37	40	42
5 North	13	26	20	44	30	60	36	39	42
South	11	--	18	43	26	60	35	35	42
Ambient Temperature:	35°		--		36°		37°	37°	37°
Barometric Pressure:	29.06 "HG		--		29.06 "HG		29.06 "HG	29.05 "HG	29.05 "HG
Wind Speed:	6 mph		--		8 mph		6 mph	6 mph	6 mph
Wind Direction:	315° SE		--		270° S		225° SW	270° S	270° S

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: February 12, 1980

SUBJECT: Release of Report

FROM: Randy Jones
Standards Development and Support Branch

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

THRU: Glenn Thompson, Project Manager
Standards Development and Support Branch

The attached Technical Report has been prepared by SDSB and is now submitted for your approval for distribution.

Number and Title

SDSB_____ "The Effect of Acceleration Rate on Automatic Transmission Shift Speeds for Two 1979 Novas."

Subject Matter

The results of a recent track test to determine the relation between acceleration rate and the vehicle speed at the automatic transmission shift points for two similar 1979 Novas are discussed in this report.

Results

Each vehicle experienced an increase in the vehicle speed at both 1st-2nd gear and 2nd-3rd gear shift points when the vehicle acclleration rate increased. Also, each vehicle experienced a change in 1st-2nd gear shift speed characteristic when the vehicle acceleration rate changed from 3 to 4 mph/sec. For example in the case of Vehicle "A", an anomalous delay in the speed of the 1st-2nd gear shift point, from 24 to 40 mph, occurred when the accleration rate changed from 3 to 4 mph/sec.

Conclusion

Recent data indicates consumer vehicles are often operated at accleration rates exceeding the 3.3 mph/sec. maximum currently represented on EPA test cycles. Therefore, the report concludes

the characteristic delay in shift speed, particularly the dramatic delay observed in the case of Vehicle "A", could contribute to greater consumer fuel consumption than that measured on EPA test cycles.

Attachment

Approved:

Charles L. Gray, Director
Emission Control Technology Division

2-7-80
Date

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: Februray 25, 1980

SUBJECT: Distribution of Report

FROM: Randy Jones
Standards Development and Support Branch

TO: Distribution List Below

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

A copy of the EPA Technical Report, "The Effect of Acceleration Rate on Automatic Transmission Shift Speed for Two 1979 Novas" is attached for your information.

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