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Evaluation of Gastell
A Device to Modify Driving Habits

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by

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Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction and/or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve fuel economy, or both. EPA invites developers of such systems to provide complete technical information on the system's principle of operation, together with available test data on the system. In those cases for which review by EPA technical staff suggests that the data available shows promise, confirmatory tests are run at the EPA Motor Vehicle Emission Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Test and Evaluation Reports, of which this report is one.

EPA received an application from Automotive Devices Inc. (ADI) to perform an evaluation of the Gastell Device. Section 511 of the Motor Vehicle Information and Cost Savings Act (15 USC 2011) requires EPA to evaluate fuel economy retrofit devices with regard to both emissions and fuel economy, and to publish the results in the Federal Register. Such an evaluation is based upon valid test data submitted by the manufacturer and, if required, EPA testing.

Gastell is a device that senses vehicle manifold vacuum. The device is preset to give audible and visual signals to the driver so that the driver can efficiently modify his driving habits. Data submitted by ADI showed fuel economy benefits for some drivers and some vehicles. Because of these apparent benefits, EPA decided to conduct confirmatory tests as part of the evaluation. This test program was conducted over an extended time period and consisted of three distinct test phases. This report details the results of this three phase confirmatory test program.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of a concept in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test cars used; however, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

Summary of Findings (test vehicles grouped together)

The Phase I testing consisted of FTP and HFET dynamometer tests of the Gastell Device. Overall, the use of the Gastell Device as a driving aid did not show a significant effect on the vehicles' fuel economy or emissions for either the FTP or HFET.

The Phase II testing consisted of modified LA-4's (FTP) and acceleration rate studies conducted on the vehicle chassis dynamometer without using the Gastell Device.

The more aggressive (greater acceleration rates) modifications of the LA-4 cycle developed showed little or no change in fuel economy when compared to the standard FTP (LA-4). Therefore, since the preceding tests with the Gastell Device did not show an improvement in the vehicles' fuel economy for either the FTP or HFET, the Gastell Device was not tested with these more aggressive driving cycles.

Evaluation of five vehicles on a test cycle consisting predominately of accelerations did show that there was an average 14.6% improvement in fuel economy between a very low acceleration rate (1 mph/sec.) and the highest acceleration rates used (up to 5 mph/sec.). There was an average 8.5% improvement in fuel economy between the moderate (2 mph/sec) and highest acceleration rates. This indicates that reduced vehicle acceleration rates can improve fuel economy for some vehicle operating conditions. However, when these acceleration fuel economy improvements are adjusted for the average portion of driving time actually devoted to acceleration, the maximum fuel economy savings would be 1.9%; but, in consideration of the constraints of actual driving conditions, a more realistic potential saving would be less than 1/2%. A similar analysis based on fuel consumed during acceleration modes yielded an average estimated improvement potential of 1.3%.

Having found no appreciable fuel economy effects in Phases I and II using the vehicle dynamometer, a road test program, Phase III, was undertaken with the Gastell Device. For the six combinations of vehicle and operator, in only one case did the use of the Gastell Device cause an improvement in vehicle fuel economy greater than 1%. The amount of the fuel economy improvement for this one case was 5%. It is interesting to note that even for this one case, the other less aggressive driver's fuel economy in this vehicle was the same with or without the device and 4% better than the driver who showed an improvement.

In general, the EPA testing of the Gastell Device did not show a positive benefit from its use. None of the Phase I chassis dynamometer tests with the device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in San Antonio (with from one to two drivers each) and only one vehicle/driver combination showed a fuel economy improvement (5%). It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this device and then only if: (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the device and (2) the driver consistently responded to the device signal and refrained from such aggressive driving.

Description of Device

Gastell is an add-on device developed and marketed by Automotive Devices, Inc. of Williamsport, Pennsylvania. The device senses vehicle manifold vacuum and emits an audible and visual signal when the manifold vacuum drops below a preset level. The driver responds by easing off the accelerator, thereby achieving a higher manifold vacuum which turns these signals off. The vehicle is thus operated at a higher manifold vacuum level which the manufacturer claims is more fuel efficient.

The manufacturer claims the following benefits for Gastell:

1. Fuel economy savings of up to 30%, depending on driving habits.

2. Indicates engine problems when the alarm and light are on more frequently than usual (i.e., functions as a vacuum gauge).

The unit is packaged in a 4 inch by 3 inch by 2 inch case that mounts to the vehicle dash panel. A picture of the unit and operating instructions are contained in the "Gastell Operator's Manual" in Appendix A.

The unit is easily installed. A vacuum line is attached to a source of manifold vacuum and the electrical connections are attached to the vehicle's 12 volt power. A copy of the manufacturer's installation instructions is given in Appendix A.

Test Vehicle Description

Phase I: FTP and HFET chassis dynamometer testing with the Gastell Device used the following three test vehicles:

A 1979 Buick Regal equipped with a 3.8 liter V-6 engine and an automatic transmission. This vehicle used EGR and an oxidation catalyst for emission control.

A 1979 Chevrolet Impala equipped with a 5.7 liter V-8 engine and an automatic transmission. This vehicle also used EGR and an oxidation catalyst for emission control.

A 1975 Dodge Dart equipped with a 225 cubic inch inline 6-cylinder engine and an automatic transmission. This vehicle was calibrated to meet the 1975 California emission standards. This vehicle used an air pump, EGR, and an oxidation catalyst for emission control.

A complete description of these vehicles is given in the test vehicle descriptions in Appendix A.

Phase II: Modified LA-4, modified FTP, and acceleration rate chassis dynamometer testing without the device:

A 1980 Chevrolet Citation and a 1975 Chevrolet Nova were used in the development of the more aggressive driving cycles. A more detailed description of these vehicles is given in Appendix B, "Development of a More Aggressive Driving Cycle."

A 1980 Chevrolet Citation, 1980 Dodge Aspen, 1979 Ford Pinto, 1979 Mercury Zephyr and a 1979 Oldsmobile Cutlass were used in the Acceleration Test Program. A more detailed description of these vehicles is given in Appendix C, "Fuel Economy vs. Acceleration Rate."

Phase III: Road testing with the Gastell Device:

A 1980 Chevrolet Citation, 1975 Chevrolet Nova, a 1980 Mercury Cougar XR-7, and a 1979 Mercury Marquis were used in the San Antonio road test program. A more detailed description of these vehicles is given in Appendix D, "Road Testing with the Gastell Device."

Test Procedures

Phase I: FTP and HFET dynamometer testing with the Gastell Device:

Exhaust emission tests were conducted according to the 1977 Federal Test Procedure (FTP) described in the Federal Register of June 28, 1977, and the EPA Highway Fuel Economy Test (HFET), described in the Federal Register of September 10, 1976. The vehicles were not tested for evaporative emissions. Additional tests were conducted as an evaluation tool. These tests consisted of hot start LA-4 cycles. This driving cycle is the basic cycle used in the FTP and the results of these tests are similar to bags 2 and 3 of the FTP.

Prior to initial testing, each vehicle was given a specification check and inspection. The ignition timing, idle speed, and fast idle speed were checked for agreement with the manufacturer's specifications given on the Vehicle Emission Control Information label affixed to the engine compartment. Each vehicle met its manufacturer's specifications and, therefore, no adjustments were required.

The vehicles were inspected for engine vacuum leaks, proper connection of vacuum hoses, functioning PCV valve, oil and water levels, and general condition of the engine compartment. Each test vehicle was in satisfactory condition.

The test program consisted of baseline tests and Gastell tests. The Gastell tests consisted of a standard test procedure (FTP or HFET) which was altered by having the operator back off the accelerator, as necessary, to silence the audible and visual Gastell vacuum alarms. At each test condition a minimum of two FTP and two HFET tests were conducted.

A second Gastell procedure, "modified" was also used. For this procedure the FTP (LA-4) driving cycle was modified by reducing the vehicle acceleration rate to a level just below that at which the device would signal. This smoothed the cycle and would be representative of a very experienced driver's use of the device.

A third Gastell procedure, "frozen accelerator" was also used. For this procedure the operator again backed off the accelerator to shut off the Gastell alarms. The operator then held his foot fixed in this position until the vehicle's speed matched the driving cycle.

Phase II: Modified LA-4, modified FTP, and acceleration rate chassis dynamometer testing without the Gastell Device:

After the conclusion of the Phase I Gastell test program, two additional dynamometer test programs were conducted to further evaluate the effect of acceleration rate on vehicle fuel economy. These test programs and a detailed description of the test procedures are contained in Appendices B and C of this report.

"Development of a More Aggressive Driving Cycle," Appendix B, was a short test program in which the basic FTP driving cycle, the LA-4 was modified. The LA-4 cycle was modified by increasing the acceleration rates at speeds below 25 mph. Two cycles were used - Mod. 1 which used slightly increased acceleration rates and Mod. 2 which used nearly wide-open-throttle (WOT) accelerations.

"Fuel Economy vs. Acceleration Rate," Appendix C, was a short test program which used a test cycle consisting of a series of accelerations. The vehicle was accelerated at a fixed rate to a cruise speed, cruised for a few seconds, and then decelerated at a fixed rate of 2 mph/sec. The cruise time was chosen so that all tests to a selected cruise speed would be of equal distance. This sequence was repeated 4 times (5 total cycles). This test sequence was done for each combination of acceleration rate and final cruise speed.

The complete test matrix used was:

	Acceleration Rate mph/sec				
Vehicle Speed change mph	1.0	2.0	3.3	4.0	5.0
0-35	x	x	x	x	x
0-45	x	x	x		
20-35	x	x	x	x	x
30-45	x	x	x		

The dynamometer rolls were coupled to minimize tire slippage. Fuel consumption was measured with a fuel flowmeter. No gaseous emission data was taken.

Phase III: Road Testing with the Gastell Device procedures:

"Road Testing with the Gastell Device," Appendix D, was a carefully controlled road test with the Gastell Device. The drivers drove the vehicles over a specified road route in San Antonio. Testing was done both with and without (baseline) the Gastell Device. Details of the test program and the San Antonio test route are given in Appendix D.

Discussion of Results

The FTP and HFET test results are summarized in Tables I and II below. The test results of individual tests are given in Tables A-I, A-II, and

A-III in Appendix A. Results of the tests using the more aggressive driving cycle are given in Table B-1 Appendix B. Results of the acceleration rate tests are given in Tables C-II thru C-V of Appendix C. Results of the road tests are given in Table III.

1. Federal Test Procedure Results - Phase I dynamometer testing with Gastell

The test results are summarized in Table I below:

Table I
Average Vehicle FTP Emissions
grams per mile

Test Condition	HC	CO	CO_2	NOx	MPG
Buick Regal-FTP					
Baseline Avg. (2 tests)	.72	7.89	459	1.24	18.8
Gastell Avg. (2 tests)	1.07	7.71	464	1.01	18.5
Chevrolet Impala-FTP					
Baseline Avg. (3 tests)	.63	4.80	565	1.27	15.5
Gastell Avg. (2 tests)	.56	4.72	563	1.34	15.5
Dodge Dart-FTP					
Baseline Avg. (2 tests)	.44	6.53	550	2.05	15.8
Gastell Avg. (2 tests)	.38	5.86	555	1.83	15.7
Gastell Frozen Accelerator Avg. (2 tests)	.53	6.76	569	1.82	15.3

Overall the Gastell Device did not show a significant positive or negative effect on vehicle FTP emissions or fuel economy.

The use of the Gastell Device as a driver's aid did not significantly affect the vehicle's HC emissions.

The vehicle's CO emissions were also not significantly affected by the use of the Gastell Device.

Gastell caused mixed effects on NOx emissions. The Buick's and Dart's FTP NOx emissions were significantly lowered. The Impala's NOx emissions were judged to be unchanged.

The amount the Gastell Device required the driving cycle to be modified varied appreciably between vehicles. The Gastell Device typically sounded 15 to 20 times during the standard FTP cycle for the Buick. However, the easing off of the accelerator only caused the driving cycle to be appreciably altered during the long hard acceleration occurring at 195 seconds in bags 1 and 3 of the FTP for the Buick. For the Impala, the device rarely sounded, and the device only caused the driving cycle to be appreciably modified at 195 seconds in bag 1 of the FTP. For the Dart, the device sounded 20 times during the FTP and appreciably altered the driving cycle most of the time.

2. Highway Fuel Economy Test Results - Phase I dynamometer testing with Gastell

The test results are summarized in Table II below:

Table II
Average Vehicle HFET Emissions
grams per mile

Test Condition	HC	CO	CO_2	NOx	MPG
Buick Regal-HFET					
Baseline Avg. (2 tests)	.07	.39	348	1.30	25.4
Gastell Avg. (2 tests)	.07	.48	351	1.44	25.2
Chevrolet Impala-HFET					
Baseline Avg. (4 tests)	.11	.59	410	1.51	21.6
Gastell Avg. (2 tests)	.09	.07	404	1.56	22.0
Dodge Dart-HFET					
Baseline Avg. (2 tests)	.05	.21	359	3.13	24.7
Gastell Avg. (2 tests)	.05	.16	359	2.20	24.7
Gastell Frozen Accelerator Avg. (2 tests)	.08	.12	363	2.84	24.7

Overall the use of the Gastell Device as a driver's aid did not show a significant positive or negative effect on vehicle HFET emissions or fuel economy.

The Gastell device did not significantly affect the vehicle's HC emissions. The HC emissions were at relatively low levels both with and without the usage of the device.

Although one vehicle's CO decreased, overall the average emissions were not significantly affected by the use of the Gastell Device. However, these changes were not significant. The change in the Impala's CO emissions was judged to be not caused by the use of Gastell.

Overall, the vehicle's NOx emissions were unaffected by using Gastell.

The amount the Gastell Device required the driving cycle to be modified varied appreciably between vehicles. The device typically signalled during the initial long acceleration and the acceleration midway through the cycle. The Buick's, Impala's and Dart's highway driving cycle were only slightly modified at these points.

3. Alternative Driving Cycles Results - Phase I dynamometer testing with Gastell

Because in the initial EPA tests Gastell had, in general, shown no effects on emissions or fuel economy, alternative tests were conducted in an effort to confirm the manufacturer's claimed benefits. Since the continual modulation of the throttle in response to the device could potentially adversely affect vehicle emissions and/or fuel economy, two alternative cycles were tried. These were the "modified" and "frozen accelerator" cycles.

The "modified" driving cycle was an FTP (LA-4) cycle in which the vehicle acceleration rate was reduced to a level just below the level at which the device would signal. This smoothed the cycle and would be representative of a very experienced driver's use of the device. A "modified" LA-4 cycle was conducted using the Buick Regal (see Table A-III). These "modified" LA-4 tests showed no improvement in emissions or fuel economy over the Gastell LA-4 tests.

The "frozen accelerator" cycle was an FTP or HFET in which the driver backed off the accelerator sufficiently to silence the Gastell Device. The driver then held the accelerator frozen at that setting until the vehicle speed matched the driving trace. Frozen accelerator tests were done for the FTP and HFET for the Dart. These tests (see Tables I and II) showed no significant improvement in emissions or fuel economy for either the FTP or HFET.

4. Post Test Gastell Checkout - Phase I

The Gastell units tested were provided by the manufacturer and therefore presumed to function properly. However, since no benefits were perceived in the test results, the units were checked at the conclusion of testing. The vacuum specifications for the devices and the results of these checks were:

Gastell Vacuum Checks
Inches Hg

	Gastell 6 Cyl. Vehicle Unit		Gastell 8 Cyl. Vehicle Unit	
	On	Off	On	Off
Mfg. Spec.	5	6	7	8
Test Unit 1	5.3	5.7	6.7	7.3
Test Unit 2	5.1	5.9	-	-

Therefore, all units were found to function properly.

5. Post Test Vehicle Inspection - Phase I

All vehicles were inspected at the conclusion of testing. The Impala and Dart were acceptable. However, the Buick Regal had a noticeable vacuum leak at the throttle shaft. The shaft had considerable lateral play. When the shaft was sprayed with a carburetor cleaner, the engine idle speed noticeably increased.

Since the effect of the leak would be lowered manifold vacuum, the leak would tend to trigger the Gastell device sooner. Therefore, on a Buick without the leak, Gastell would trigger less often and have an expected lesser effect. Thus, since there was a negligible Gastell effect on the test vehicle's emissions or fuel economy, it is reasonable to assume that the Gastell would show a lesser benefit on another similar vehicle. Therefore, the Buick data is included in this report.

6. Development of a More Aggressive Driving Cycle - Phase II modified LA-4 and modified FTP dynamometer testing without Gastell

The original test program for the Gastell Device was based on the use of the FTP and HFET cycles and the results showed no significant negative or positive effect on either emissions or fuel economy. Since an acceleration limiting device was expected to reduce fuel consumption, additional testing to investigate the effects of acceleration was undertaken.

Two altered LA-4 cycles were devised with greater acceleration rates at the lower vehicle speeds. A small test sequence was run to evaluate the suitability of these cycles for testing the Gastell Device. For this study several available EPA test vehicles underwent a variety of emission tests with modified cycles and emission tests using dynamometer coupled rolls. Results of these tests are given in Table B-I of Appendix B. The results are also summarized in Appendix B.

An analysis of the data from these tests indicated that the fuel economy with the more aggressive cycles was not measurably different from that on the standard FTP. Since the Gastell device had made no measurable fuel economy difference on the FTP, it was concluded that the same result would be found with the revised cycles and no tests were run with the device installed.

7. Fuel Economy vs. Acceleration Rate Tests - Phase II dynamometer acceleration testing without Gastell

Since the net result of the preceding studies was that, for the cycles used, there was no effect on fuel economy, a test cycle consisting predominantly of accelerations was developed to directly quantify the effect of fuel economy versus acceleration rate. For this study five available EPA test vehicles were used. Results of these tests are given in Tables C-II thru C-V of Appendix C and these results are plotted in Figures C-1 thru C-5 of Appendix C.

Vehicle manifold vacuum was measured during these acceleration tests. Based on the vacuum levels at which the Gastell device would function for 4, 6, and 8 cylinder engines - all five of these vehicles would have given signals at very low acceleration rates. The Citation would have signaled at acceleration rates slightly less than 2 mph/sec. The Aspen, Cougar, Zephyr, Pinto and Cutlass at rates near 1 mph/sec.

For this acceleration study, the average improvement in vehicle fuel economy between worst case (greatest acceleration rate) and the lowest acceleration rate (1 mph/sec.) was 14.6%. The improvements ranged from 6.0 to 28.9% (see Table C-III). The average improvement in vehicle fuel economy between worst case and 2 mph/sec. was 8.5%. This improvement ranged from 1.9% to 15.5% (see Table C-IV).

The above effects - no discernable improvement in transient (i.e. FTP) fuel economy even though the preceding acceleration study shows differences in fuel economy - is explained by considering available data on vehicle operating characteristics[1]. In these chase car studies, it was found that less than 13% of vehicle operating time is spent accelerating and only 34% of these accelerations occur at rates above 2.2 mph/sec. Even if the 14% improvement in fuel economy was applied to all the 13% of vehicle operation involving acceleration, the maximum possible fuel savings would be 1.9%. To achieve these savings would require that the driver always reduced acceleration to a level on the order of one mph/sec. when signalled by the device. More realistically the fuel economy improvement should only be applied to the accelerations above 2.2 mph/sec. since accelerations at rates as low as one mph/sec. would many times be unsafe. Combining the potential fuel economy improvement (8.5%), the percentage of time accelerating (13%) and the percentage of time at accelerations above 2.2 mph/sec. (34%), gives an overall anticipated improvement of .4%. Such a fuel economy increment is below the threshold of sensitivity for all but the most highly controlled tests.

A similar analysis can be applied to the fuel consumption data from the GM study. It was found in that study that 20.8% of total fuel used per trip is consumed during acceleration modes. Again, if the Gastell Device would reduce all acceleration rates down to the order of one mph/sec., the maximum potential savings would be 14.6% of 20.8% which is equal to 3%. If the Gastell device alerts the driver to only those accelerations above two mph/sec., then only the fuel consumption during accelerations at rates above two mph/sec. would be reduced. This yields a potential savings of 14.6% of (37.5% of 20.8%) equals 1.3%. Validation of this potential improvement would also require a large number of controlled tests.

8. Road Tests with the Gastell Device - Phase III

During the course of the various phases of the chassis dynamometer test program, the developer of the device, Mr. Ray Smith, was kept abreast of the results. As more and more of the testing continued to yield negative results, he became critical of the chassis dynamometer procedure and made a number of suggestions, primarily directed toward road testing of the device. In an effort to try every reasonable possibility in evaluating the device, his suggestion was pursued.

EPA first looked into the feasibility of a road test program in some type of fleet operation. The basic approach was for the selection of government owned vehicles which are operated by the same driver over essentially the same route every day. After investigating several options, the particular fleet considered was that of the United States Park Police which operates in the metropolitan Washington DC area. The Park Police

(1) "Measurement of Motor Vehicle Operation Pertinent to Fuel Economy" (GM Chase Car Study), SAE Paper 750003, February, 1975

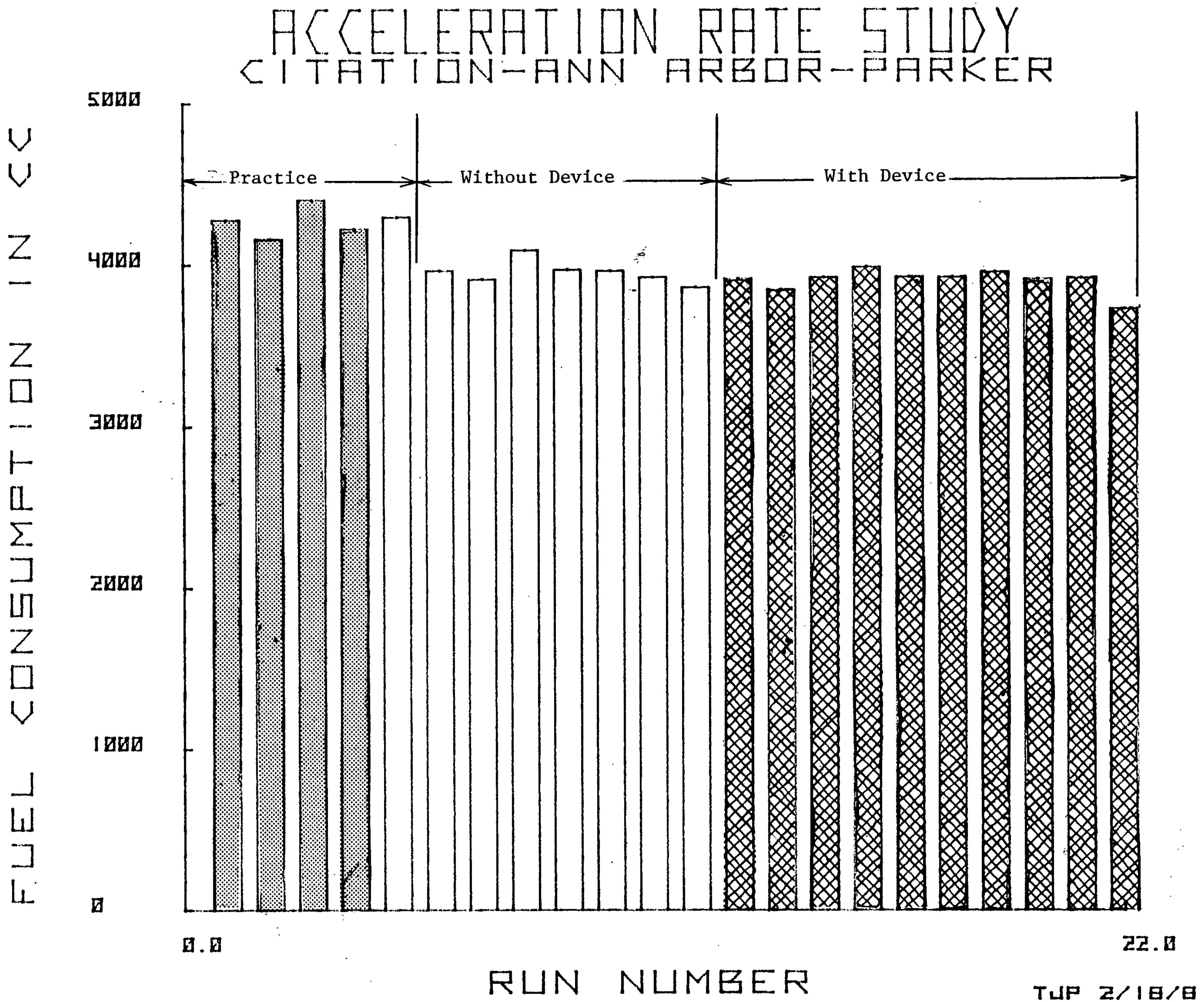
volunteered the availability of 20 of their vehicles, 10 of which could be used as test cars and 10 for control. After an appropriate interval, the control and test fleets could be reversed. It was recognized that the vehicle operation would not be representative of private owner usage and most importantly, that test variability involving fleet tests is generally very high. Estimates of the average effectiveness of the device documented in Section 7 above indicated that a more controlled road test might be necessary so the Park Police fleet test was deferred.

A pilot test program was run over a route in Ann Arbor which had previously been selected for durability testing. The route, which had been approved for the EPA durability driving schedule, is approximately 30 miles long with an average speed of 34 miles per hour. An available EPA test vehicle (a 1980 Citation - see vehicle description in Appendix D) was instrumented with a Fluidyne fuel flow meter and driven repeatedly over the route. Fuel flow was totaled over each circuit of the 29.5 mile route and the data with and without the device is plotted in Figure 1. Data variability was high and at least part of the variability was attributed to the late autumn weather conditions with frequent rain, variable winds, and wide temperature excursions. Because of this variability, it was decided that a road test program should be conducted in the southwestern United States where more temperate weather conditions are available.

San Antonio, Texas was selected as the test site for two major reasons. An urban road route had been defined there several years ago for use in an emission factors program which has traffic conditions known to be representative of most cities. Southwest Research Institute is also there and offered the use of their laboratory facilities for any work which needed to be done on test cars. Two EPA technicians drove the instrumented Citation to San Antonio and rented a late model full-sized car with a V-8 engine (1980 Cougar - see vehicle description in Appendix D) as a second test car. Each driver took turns driving the two cars with and without the Gastell Device installed over the San Antonio road route. Sufficient driving was done prior to the test to familiarize the drivers with the route and with the test vehicles. The Ann Arbor experience had suggested that such familiarization would enhance repeatability during a test. Further information on the driving route and the test procedures used are given in Appendix D.

Results of the tests are shown in Figures 2 through 5. These figures illustrate that only one of the four vehicle/driver combinations showed a significant positive result with the devices. One driver had better fuel economy on both cars without the driver's aid than the other driver had on either car with the driver's aid. The data suggest two things. One, that the effectiveness of the device is highly dependent on the driving technique or "agressiveness" of the driver and two, that effectiveness is also a function of characteristics associated with the vehicle.

At the conclusion of this test series the drivers returned to Ann Arbor and the data were analyzed. Table III provides the results of that analysis. Since the device had shown a positive effect on the Cougar and Mr. Smith had suggested that more effectiveness should be found on large cars than small cars like the Citation, a second road test program was


ACCELERATION RATE STUDY
CITATION-ANN ARBOR-PARKER
FUEL CONSUMPTION IN CC
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4000
3000
2000
1000
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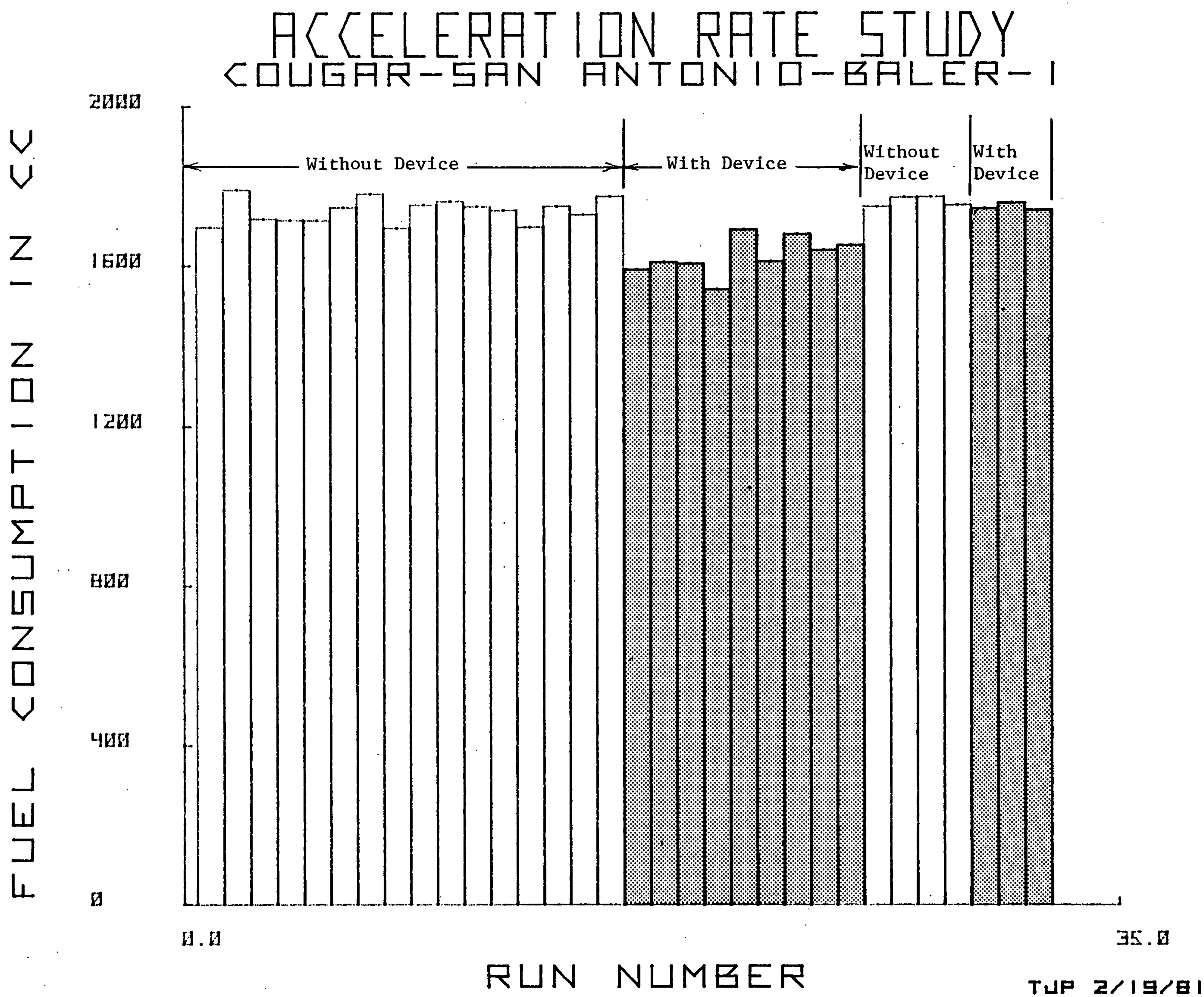
Practice
Without Device
With Device
0.0
22.0
RUN NUMBER
TJP 2/18/81

Figure #1



ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-BALER-1
FUEL CONSUMPTION IN CC
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1600
1200
800
400
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Without Device
With Device
Without Device
With Device
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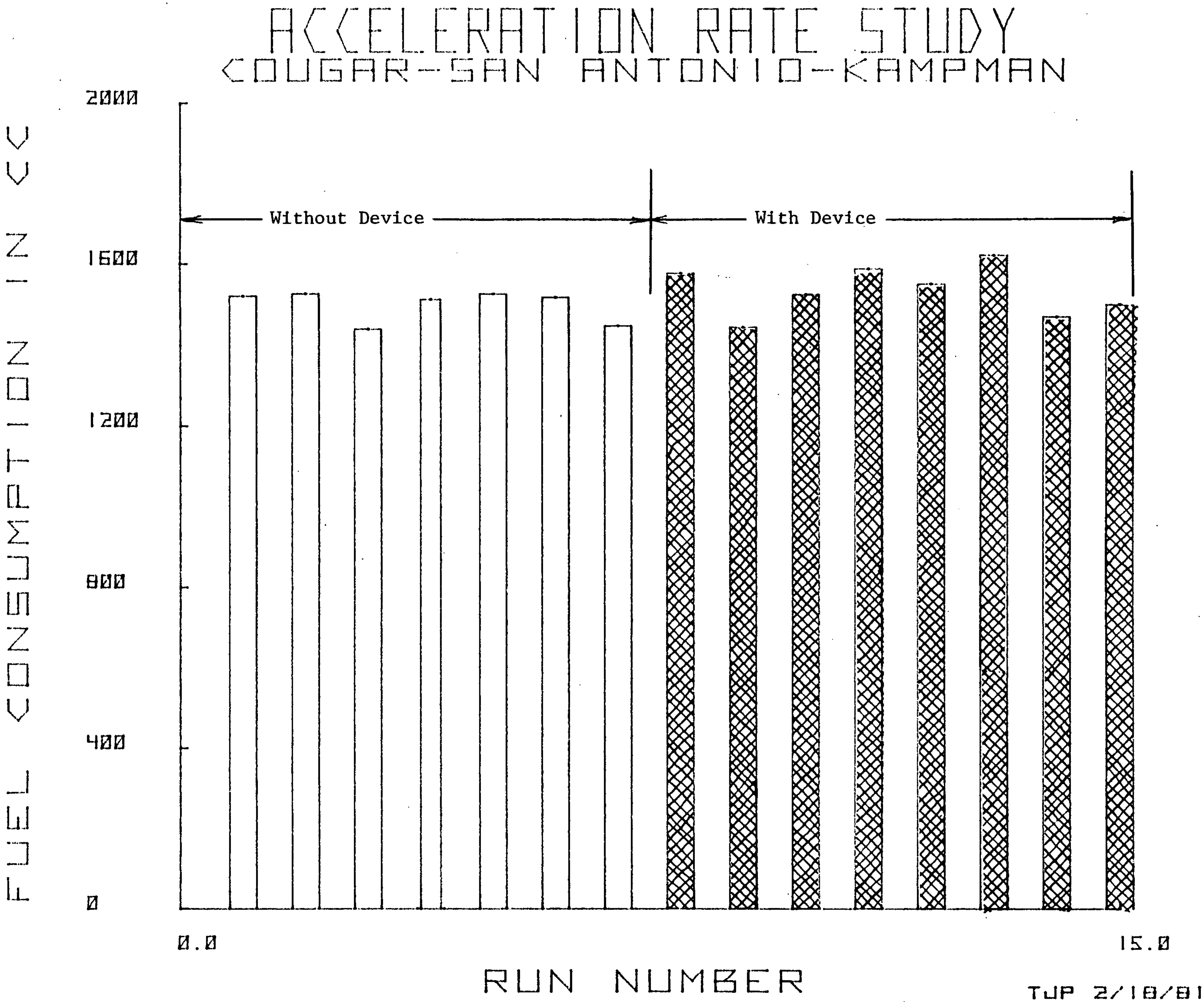
Figure #2


ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-KAMPMAN
FUEL CONSUMPTION IN CC
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1200
800
400
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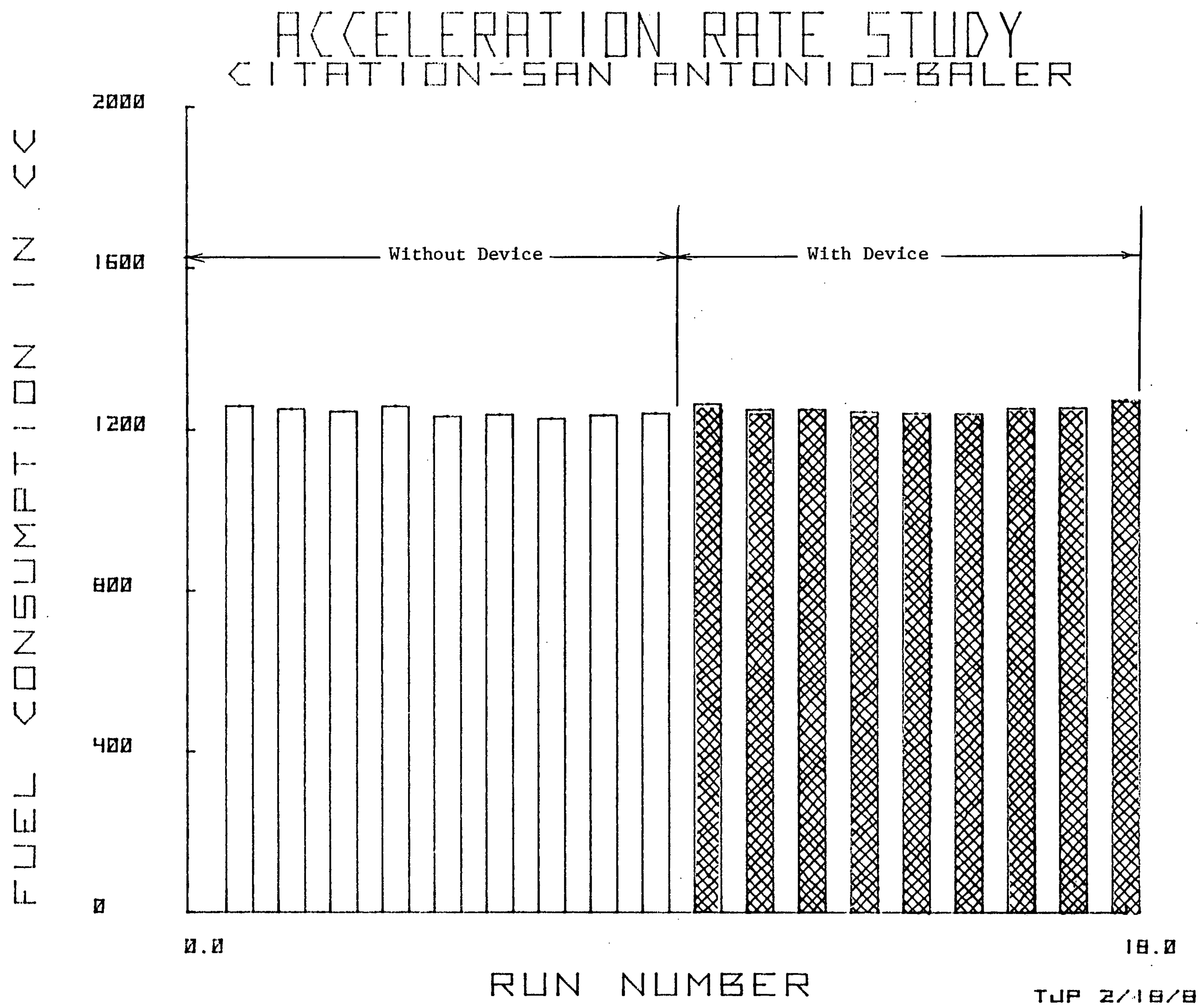
Without Device
With Device
0.0
15.0
RUN NUMBER
TJP 2/18/81

Figure #3


ACCELERATION RATE STUDY
CITATION-SAN ANTONIO-BALER
FUEL CONSUMPTION IN CC
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1200
800
400
0
Without Device
With Device
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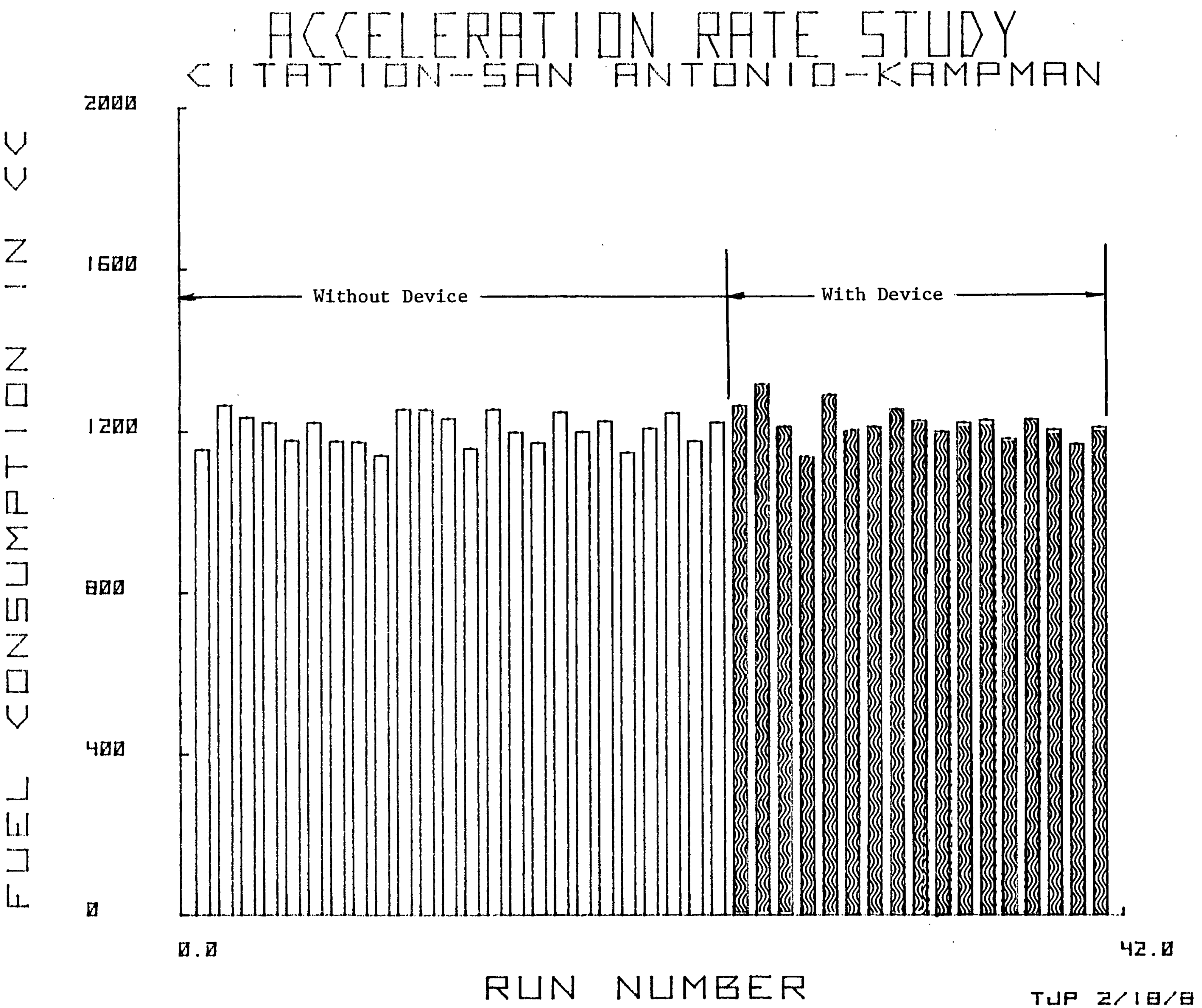
18.0
RUN NUMBER
TJP 2/18/81

Figure #4



ACCELERATION RATE STUDY
CITATION-SAN ANTONIO-KAMPMAN
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
0.0
42.0
RUN NUMBER
TJP 2/18/81

Figure #5

initiated. Carl Baler, the more aggressive driver, took another EPA test car, a 1975 Nova (see vehicle description in Appendix D) with a 350 engine, to San Antonio and ran the same test sequences run on the previous cars. The baseline was run with no problem and good repeatability, but with the Gastell Device installed it was found that the device never actuated under normal traffic conditions. After making several checks to make sure the device was properly calibrated and that the manifold vacuum tap was correctly installed, it was decided that a test would be run with the calibration changed to actuate on at 9" Hg, off at 10" Hg instead of on at 7" Hg, off at 8" Hg as specified by the manufacturer. This is a two inch change from the normal Gastell V-8 calibration. The tests were resumed and it was found that again the device did not actuate on the test route. Further adjustment was made until the device would actuate on a number of accelerations but the acceleration rates were so limited at these settings (on at 12.5" Hg, off at 13.5" Hg or on at 11.5" Hg, off at 12.5" Hg) that the vehicle could not be driven onto the freeway safely. No setting was found that seemed satisfactory on this high power to weight car.

Furthermore, these tests on the Nova demonstrated that the Gastell Device's calibration needs to be very carefully matched to the specific vehicle. At the manufacturer's calibration setting, the Gastell never signaled. At the calibration settings at which the Gastell signaled, the vehicles fuel economy was altered. The results of both tests were significant, however, at one setting there was a 2.49% fuel economy penalty while the other showed a .96% fuel economy improvement.

The Cougar driven in the earlier test program was rerun to confirm the data previously collected. The results of this retesting showed good agreement with the previous improvement in fuel economy. The results are given in Figure 6.

Another car was sought that would be more representative of high production power-to-weight ratio vehicles. A 1979 Mercury with a 351 CID engine (see vehicle description in Appendix D) was obtained. This has approximately the same power-to-weight as the other high production Ford and General Motors full sized cars. Figure 7 presents the data on the Mercury. The average improvement of .86% was statistically significant.

Tables III and IV present the statistical analysis of all of the road test data. A total of two hundred and thirty road tests were conducted using these vehicles. At the 90% confidence level ($\alpha = .1$) two vehicle/driver combinations showed statistically significant fuel economy improvements. However, at the 80% confidence level ($\alpha = .2$) 4 vehicle/driver combinations showed statistically significant fuel economy changes. Two showed a statistically significant fuel economy improvement and two showed statistically significant fuel economy penalties with the use of the Gastell Device.

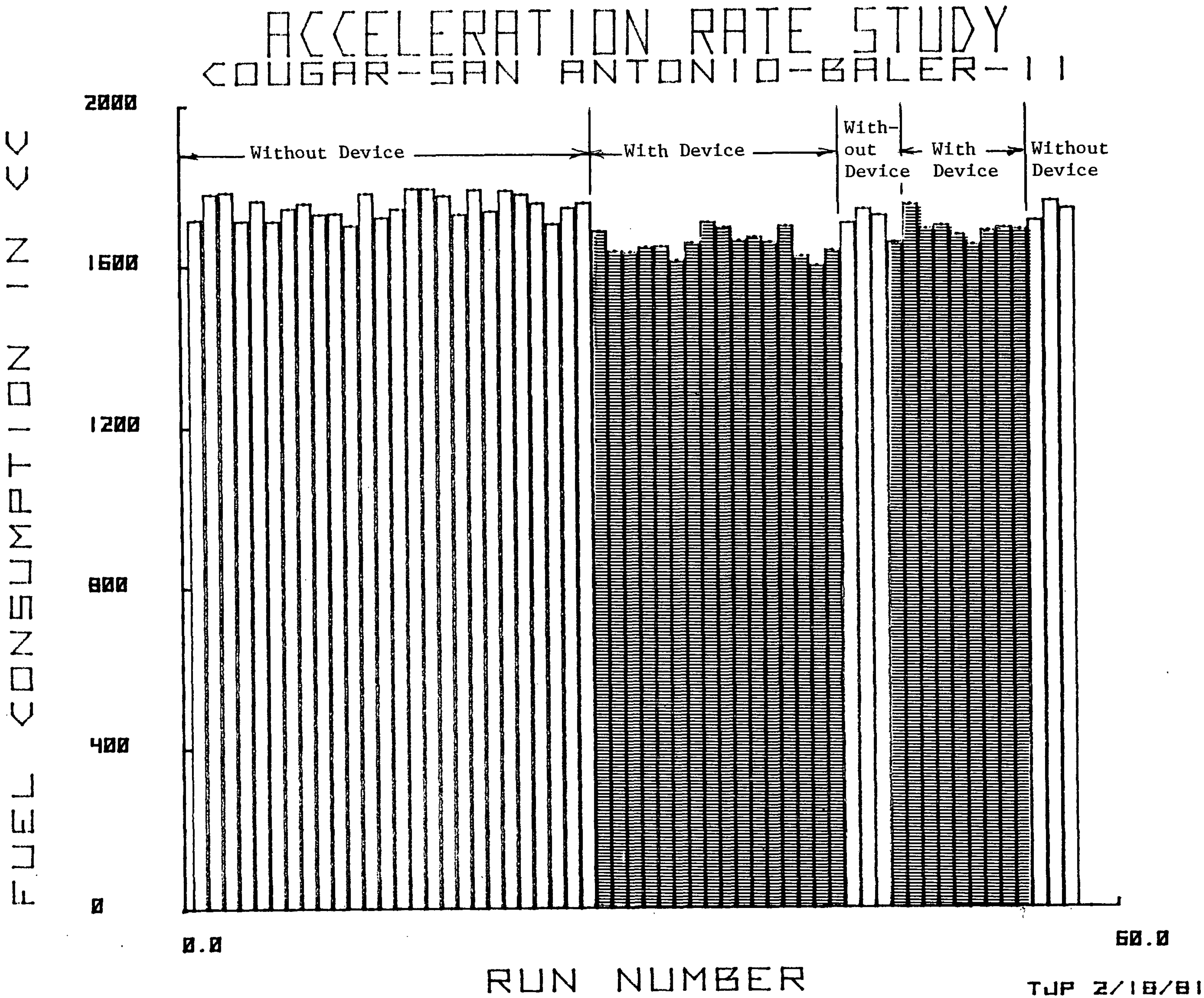
Conclusion

In general, the EPA testing of the Gastell Device did not show a positive benefit from its use. None of the Phase I chassis dynamometer tests with the device installed showed a positive fuel economy effect. Four vehicles of varying size and power-to-weight ratio were road tested in

San Antonio (with from one to two drivers each) and only one vehicle/driver combination showed an appreciable fuel economy improvement (5%) with the Gastell Device. It is concluded from the test data available that only drivers with aggressive driving behavior (or other driving habits that involve excessive throttle manipulation) could benefit from use of this device and then only if (1) their vehicle happened to have the fuel economy response characteristics that favorably matched the activation setting of the device and (2) the driver consistently responded to the device signal and refrained from such aggressive driving.

None of the Phase I chassis dynamometer tests with the device installed showed a positive or negative effect on emissions.

Intuitively, many people might expect the principles behind the Gastell device to produce an improvement in fuel economy. In fact, at the beginning of the program, EPA evaluation engineers involved in the evaluation expected the device to produce significant benefits and were surprised when the early data showed no effect on fuel economy. This evaluation has been more extensive than most such projects at EPA, but as a result, we are comfortable in supporting this evaluation.



ACCELERATION RATE STUDY
COUGAR-SAN ANTONIO-BALER-II
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
With-out Device
With Device
Without Device
0.0
60.0
RUN NUMBER
TJP 2/18/81

Figure #6

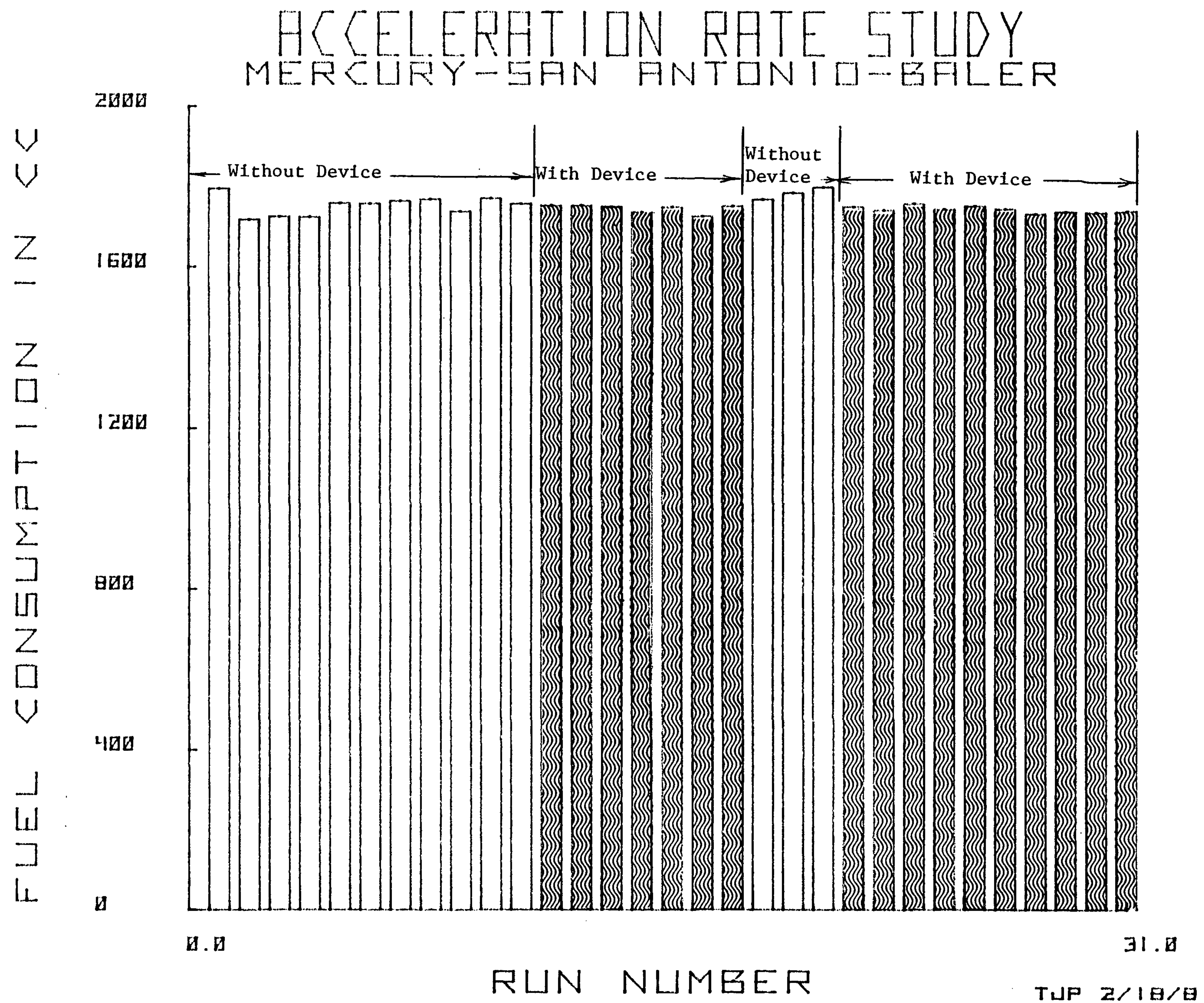

ACCELERATION RATE STUDY
MERCURY-SAN ANTONIO-BALER
FUEL CONSUMPTION IN CC
2000
1600
1200
800
400
0
Without Device
With Device
Without Device
With Device
0.0
31.0
RUN NUMBER
TJP 2/18/81

Figure #7

Table III
Results of San Antonio Road Route Testing

1. Vehicle	Cougar				Citation				Cougar		Mercury Marquis	
2. Driver	Baler		Kampman		Baler		Kampman		Baler (2nd time)		Baler	
3. With or without device	w/o	with	w/o	with	w/o	with	w/o	with	w/o	with	w/o	with
4. Number of tests	20	12	7	8	9	9	24	17	32	25	14	17
5. Average fuel consumption (cc)	1742.5	1655.3	1499.7	1534.7	1243.7	1252.2	1207.2	1221.4	1745.9	1663.8	1759.8	1744.7
6. Standard Deviation	29.07	67.85	38.08	60.65	11.08	11.25	37.75	43.16	29.85	33.63	25.28	8.74
7. Variance	845.05	4603.6	1450.4	3678.7	122.81	126.6	1425.06	1862.60	890.84	1131.16	639.21	73.38
8. Difference between with and w/o testing fuel consumption	(+)87.23 cc		(-)35.00 cc		(-)9.0 cc		(-)14.15 cc		(+)82.15 cc		(+)15.07 cc	
9. % difference fuel consumption	(+)5.13%		(-)2.31%		(-).72%		(-)1.17%		(+)4.82%		(+).86%	
10. Ave. number of signals per cycle	29.5		19.6		4.55		6.76		29.2		5.40	
11. Calculated T Statistic	4.23		1.36		1.71		1.09		9.61		2.13	
12. Calculated degrees of Freedom	14.0		14.0		12.0		33		50		16	
13. Tablulated T Statistics for α =.1	1.761		1.761		1.734		1.694		1.675		1.746	
for α =.2	1.345		1.345		1.330		1.308		1.299		1.337	
14. Significant? at α =.1	Yes		No		No		No		Yes		Yes	
at α =.2	Yes		Yes (marginal)		Yes		No		Yes		Yes	

Table IV
Results of San Antonio Road Route Testing on Chevrolet Nova

1. Vehicle	Nova	Nova	Nova	Nova	Nova
2. Driver	Baler	Baler	Baler	Baler	Baler
3. Calibration - On" Hg, Off" Hg	N/A	7"Hg, 8"Hg(1)	9"Hg, 10"Hg	12.5"Hg, 13.5"Hg(2)	11.5"Hg, 12.5"Hg(3)
4. With or without device	without	with	with	with	with
5. Number of tests	16	11	5	4	2
6. Average fuel consumption (cc)	1793.5	1790.7	1782.9	1838.7	1776.3
7. Standard Dev.	28.94	24.99	23.45	29.85	3.50
8. Variance	837.52	624.50	549.90	891.02	12.25
9. Difference between with and w/o testing fuel consumption	-	(+)2.80	(+)10.60	(-)45.20	(+)17.20
10. % difference fuel consumption		(+) .16%	(+) .59%	(-)2.49%	(+) .96%
11. Ave. number of signals per cycle		0.0	0.0	17.4	8.5
12. Calculated T Statistic		.268	.832	2.725	2.203
13. Calculated degrees of Freedom		26	10	6	18

14. Tablulated T Statistics				
for α =.1	1.706	1.812	1.943	1.734
for α =.2	1.315	1.372	1.440	1.330
15. Significant?				
at α =.1	No	No	Yes	Yes
at α =.2	No	No	Yes	Yes

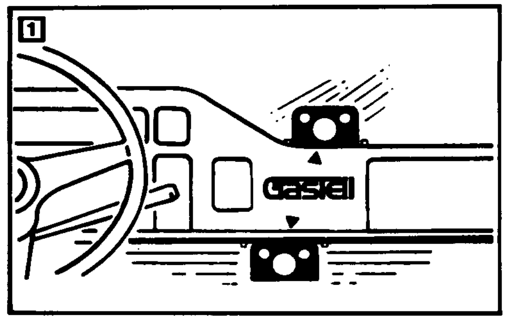
---

(1) Gastell Device manufacturer setting.
(2) When Gastell was recalibrated to this setting, vehicle could not safely be driven on to freeway.
(3) When Gastell was recalibrated to this setting, vehicle acceleration was marginal for entering the freeway.

Gastell T.M. INSTALLATION INSTRUCTIONS

AUTOMOTIVE DEVICES, INC.

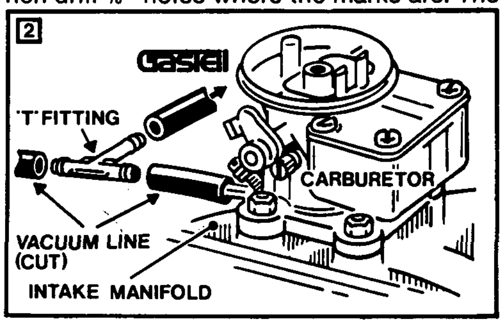
For Models 2004, 2005, 2006, 2008



- Your car or truck should be tuned before installation.
- Read ALL instructions before starting installation. All necessary hardware to install Gastell is included in hardware kit.

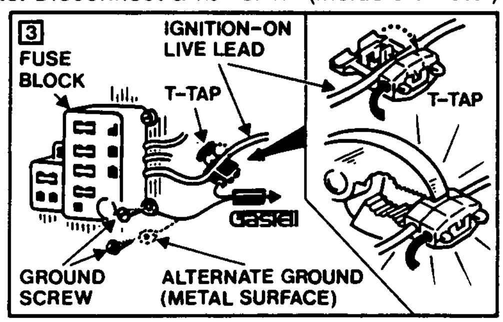
① Select location for Gastell, preferably centered under dash (fig. 1), but make sure that the chosen location will not interfere with the operation of your vehicle. Attach mounting brackets to Gastell. Note that the brackets are reversible for either under—or above—dash mounting (fig. 4). Use the two hex head sheet metal screws furnished with internal-tooth lock washers. DO NOT OVER TIGHTEN.

② Most American-made cars have ashtrays held by two sheet metal screws. Often the spacing of these screws is equal to that of the Gastell brackets. So before you drill, try to use the ashtray mounting screws. If you find that you must drill, position Gastell to dash and hold firmly. Use lead pencil to mark hole locations. Then drill ⅛" holes where the marks are. The hex head sheet metal screws furnished will work in plastic or metal. Use them to fasten the Gastell to the dash. Do not over tighten.



③ Choose desired routing for Gastell vacuum hose and electrical wiring. Do not make electrical or hose connection yet. The vacuum hose must go through the firewall without pinching or chaffing. Try to locate an existing hole that has a rubber grommet. On most vehicles, the emergency brake, speedometer, and gas pedal cables pass through a rubber grommet in the firewall. If you can, enlarge this grommet to accept vacuum line. If this cannot be done, drill ½" hole in a nearby location. Install furnished rubber grommet; then insert rubber hose from Gastell through firewall to engine compartment. Do not stretch or pull Gastell hose. The electrical wiring from Gastell may be connected to the fuse panel or ignition switch. The wires should be routed along the path of existing auto wiring. Use wire ties furnished. Be sure that wires and hose are clear of all sharp surfaces and clear of clutch, brake, accelerator, and other moving parts.

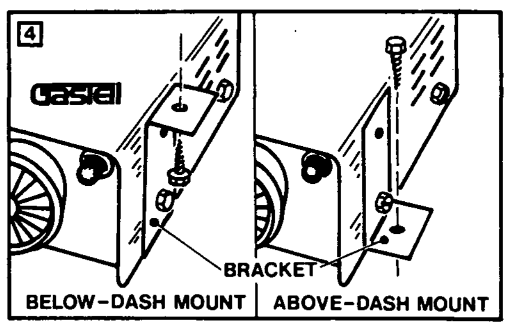
④ Attach Gastell vacuum line to engine intake manifold system. To locate the proper vacuum line on the intake manifold, start engine. Keep hands and loose clothing free of fan blade or moving parts. Disconnect a ³⁄₁₆" or ¼" (inside diameter) hose from the intake manifold while engine is running (see fig. 2). When the proper vacuum hose is removed, there will be a distinct change in idle speed. Once proper vacuum line is identified, turn off engine, and reconnect vacuum line to manifold. Then cut the vacuum line in an appropriate location, preferably 5" to 6" from a connection; insert "T" fitting furnished. Attach Gastell vacuum line securely to remaining branch of "T" (fig. 2). Be sure Gastell vacuum line is away from all moving parts. Using wire tie furnished, secure vacuum line to existing wiring on hoses.



⑤ Locate your vehicle's fuse panel and wiring, and identify a source of electricity that has current only when the key is in the "on" position: this may be a wire that runs to any accessory that is activated by turning on the key. To this wire, the red wire from Gastell (with Electro T-Tap splicer) is connected (fig. 3). Use standard pliers for installing T-Tap splicer. Wrap around a wire from 14 to 20 gauge. Apply pliers, and squeeze until T-Tap locks. Connect the remaining black wire with the eyelet to a suitable ground. If existing ground screw is not available, drill ⅛" hole in sheet metal near fuse panel. Use hex head sheet metal screw furnished with internal tooth lock washers. Do not over tighten. Wrap up any extra wire and secure to existing wiring with wire tie furnished. Do not shorten wiring or hoses: your next vehicle may require the extra length.

Now your Gastell is ready to operate. Start engine. When the key is turned on, red light and audible tone will operate. As soon as the engine starts, the light and tone will cease to operate, and the green light will go on. Keep your Gastell operating in the green for maximum mileage.

See operating manual for operation.



- **Warning:** When drilling holes anywhere in your vehicle, make sure your drill does not come in contact with wiring or hoses. Common sense and **caution** should be exercised in drilling. Electrical damage could result if you ignore this warning.

AUTOMOTIVE DEVICES, INC. 129 Susquehanna Street, P.O. Box 3513, Williamsport, PA 17701

Appendix A
Test Vehicle Description

Chassis model year/make-1979 Buick Regal
Vehicle ID 4J47A9H123351

Engine

type . . . . Otto Spark, V-6
bore x stroke. . . . . 3.8 x 3.4 in.
displacement . . . . 3.8 liter/231 CID
compression ratio. 8.0:1
maximum power @ rpm. . . . . . 115 hp/86 KW @ 4800 rpm
fuel metering. . . . . 2 Venturi carburetor
fuel requirement . . . . unleaded, tested with indolene HO unleaded

Drive Train

transmission type. . . . . . . 3 speed automatic
final drive ratio. 2.40

Chassis

type . . . . 2 Dr. Sedan
tire size. . . . . P 195/75 R 14
curb weight. . . . . 3312 lb/1502 kg.
passenger capacity 5

Emission Control System

basic type . . . . EGR
Oxidation Catalyst

Vehicle Odometer mileage at
start of program . . . . . . 14950 miles

Appendix A (cont.)
Test Vehicle Description
Chassis model year/make-1979 Chevrolet Impala
Vehicle I.D. 1L47L9S115799

Engine

type . . . . Otto Spark, V-8
bore x stroke. . . . . 4.00 x 3.48 in/101.6 x 88.4 mm
displacement . . . . 350 CID/5.7 liter
compression ratio. 8.3:1
maximum power @ rpm. . . . . 170 hp/126 kW
fuel metering. . . . . 4 venturi carburetor
fuel requirement . . . . . . Unleaded, tested with indolene HO unleaded

Drive Train

transmission type. . . . . . 3 speed automatic
final drive ratio 2.41

Chassis

type . . . . 2 door sedan
tire size. . . . . FR 78 x 15
curb weight. . . . . 3840 lb/1742 kg
inertia weight . . . . 4000 lb.
passenger capacity 6

Emission Control System

basic type . . . . EGR
Oxidation Catalyst

Vehicle mileage at start of
test program . . . . 12,700 miles

Appendix A (cont.)
Test Vehicle Description

Chassis model year/make-1975 Dodge Dart
Emission Control System-Air Pump, Catalyst, EGR
Vehicle I.D. LH41C5B290359

Engine

type	Inline 6, 4 cycle
bore x stroke	3.40 x 4.125 in.
displacement	225 CID/3687 cc
compression ratio	8.4:1 fuel metering
carburetor	1 Venturi
fuel requirement	unleaded, tested with Indolene HO unleaded

Drive Train

transmission type.	3 speed automatic
final drive ratio.	2.75

Chassis

type	4 door sedan
tire size	D78 x 14
inertia weight	3500 lbs.
passenger capacity	6

Emission Control System

basic type	air pump oxidation catalyst EGR calibrated to 1975 California standards

Vehicle Odometer mileage at start of test.	21,500 miles

Appendix A (cont.)

Table A-I

FTP Mass Emissions

grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
baseline	80-0453	.76	8.03	465	1.24	18.5
baseline	80-0567	.68	7.75	453	1.24	19.0
Gastell	80-0455	1.45	8.82	467	.90	18.3
Gastell	80-0569	.69	6.60	461	1.11	18.7
Chevrolet Impala						
Baseline	80-0573	.72	4.85	569	1.29	15.3
Baseline	80-0575	.59	4.54	565	1.29	15.5
Baseline	80-0446	.58	5.01	560	1.23	15.6
Gastell	80-0578	.59	5.59	561	1.43	15.5
Gastell	80-0576	.53	3.84	565	1.24	15.5
Dodge Dart						
Baseline	80-0246	.38	6.06	547	1.99	15.9
Baseline	80-0735	.50	7.00	553	2.11	15.7
Gastell	79-4788	.29	5.20	553	1.85	15.8
Gastell	80-0244	.47	6.51	557	1.81	15.6
Gastell (Frozen)	80-0579	.59	7.61	574	1.73	15.1
Gastell (Accelerator)	80-0581	.47	5.90	563	1.91	15.5

Appendix A (cont.)

Table A-II
Highway Fuel Economy Test Mass Emissions
grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
Baseline	80-0454	.06	.32	351	1.29	25.2
Baseline	80-0568	.07	.45	345	1.30	25.6
Gastell	80-0456	.07	.78	354	1.59	24.9
Gastell	80-0570	.06	.18	347	1.29	25.5
Chevrolet Impala						
Baseline	80-0438	.10	.54	402	1.55	22.0
Baseline	80-0445	.12	.72	410	1.51	21.6
Baseline	80-0574	.12	.69	415	1.52	21.3
Baseline	80-0886	.11	.08	414	1.55	21.9
Gastell	80-0831	.09	.05	403	1.56	22.0
Gastell	80-0577	.09	.08	404	1.55	21.9
Dodge Dart						
Baseline	80-0316	.03	.19	356	2.78	24.9
Baseline	80-0734	.06	.22	362	3.48	24.5
Gastell	79-4789	.05	.18	358	2.59	24.8
Gastell	80-0245	.05	.13	361	1.81	24.6
Gastell (Frozen)	79-0580	.05	.24	363	2.88	24.4
Gastell (Accelerator)	79-0582	.10	.00	362	2.79	24.4

Table A-III
LA-4 Mass Emissions
grams per mile

Test Condition	Test No.	HC	CO	CO_2	NOx	MPG
Buick Regal						
Baseline	80-0663	.44	1.75	432	.72	20.3
Gastell	80-0661	.19	1.04	433	1.01	20.4
Gastell	80-0662	.21	1.11	434	1.03	20.3
Gastell (modified)	80-0571	.23	1.12	428	.96	20.6
Gastell (modified)	80-0572	.23	1.07	426	.93	20.7
Dodge Dart						
Gastell	79-4790	.64	13.72	572	1.82	14.9

Appendix B
Development of A More Aggressive Driving Cycle

In order to evaluate the effects of more aggressive driving behavior on fuel economy, EPA modified the standard FTP (LA-4) cycle by increasing the acceleration rates at speeds below 25 mph. The Mod. 1 cycle had slightly greater acceleration rates than the LA-4. The Mod. 2 cycle had nearly WOT accelerations. The intention was to use these cycles as a new reference with which to evaluate the effects of driver habit modification prescribed by Gastell.

A small test sequence was undertaken to evaluate the suitability of these cycles for testing Gastell. For this study two available EPA test vehicles were used for emission tests with the standard and modified driving cycles. The results of these tests are tabularized in this Appendix and are summarized below:

1.) For the LA-4 cycle, a slightly <u>greater</u> acceleration rate (Mod #1) did not effect the Citation's HC emissions, NOx emissions or fuel economy. CO emissions increased 58%.

2.) For the LA-4 cycle a greater acceleration rate (Mod #2) the Citation's HC emissions were doubled, CO emissions were increased fivefold, NOx emissions were unchanged, and fuel economy was reduced 1%. The Nova's HC emissions doubled, CO emissions were increased tenfold, NOx emissions increased 11%, and fuel economy was reduced 3%*.

Because it was anticipated that there might be increased tire slippage (see note) at higher acceleration rates, a test sequence was conducted with coupled rolls. The results of these tests were similar to the preceding tests with uncoupled rolls (the standard test condition).

Note: Tire slippage means that the front roll (inertia and power absorbing unit roll) lags the rear roll (vehicle speed roll). This effect would tend to mask the loading effects of increased vehicle acceleration rates.

The overall analysis of this effort to evaluate more aggessive driving behavior was that the mod #1 cycle used appeared to have little or no effect on fuel economy. Since the mod #2 cycle used WOT accelerations for all accelerations and was, therefore, not a representative cycle and the mod #1 cycle showed minimal differences, it did not appear fruitful to try developing a test cycle to test the Gastell Device. Therefore, no Gastell testing was attempted with these cycles.

The test vehicles used for this testing, a 1980 Chevrolet Citation and a 1975 Chevrolet Nova were also used in the road testing and are described in more detail in Appendix D.

*Subsequent to these emission and fuel economy tests with the Nova, the vehicle was discovered to have a carburetor problem. This problem may have contributed in a large part to the emissions and fuel economy results of the mod #2 tests and, therefore, the findings of this vehicle are suspect.

Table B-I
Composite FTP and Hot Start LA-4 Emissions
grams per mile

Test Date	Test Number	Test Type	Accel. Type	Roll Configuration	HC	CO	CO2	NOx	MPG
1980 Citation with P 185/80 R 13 radial tire, 7.3 hp, 2750 lb. inertia weight									
2-7-80	80-1475	Hot LA-4	Mod #1	Standard	.08	.84	370	.34	23.9
2-7-80	80-1476	Hot LA-4	Stand.	Standard	.04	.58	370	.34	23.9
2-7-80	80-1477	Hot LA-4	Mod #1	Standard	.05	1.14	369	.37	23.9
2-7-80	80-1478	Hot LA-4	Stand.	Standard	.04	.67	368	.43	24.0
2-7-80	80-1480	Hot LA-4	Mod #2	Standard	.09	3.58	367	.33	23.8
2-22-80	80-1543	Hot LA-4	Stand.	Coupled	.07	1.63	385	.35	22.9
2-22-80	80-1544	Hot LA-4	Mod #2	Coupled	.18	10.51	376	.26	22.6
2-22-80	80-1545	Hot LA-4	Stand.	Coupled	.07	1.85	385	.35	22.8
2-22-80	80-1546	Hot LA-4	Mod #2	Coupled	.16	8.64	378	.25	22.6
1975 Nova with ER 78 x 14 radial tires, 12.0 hp, 4000 lb. inertia weight									
*2-22-80	80-1365	FTP	Baseline	Standard	.66	2.34	697	1.31	12.6
*2-26-80	80-1367	FTP	Baseline	Standard	.60	2.08	704	1.37	12.5
*3-01-80	80-1796	FTP	Mod #2	Coupled	1.43	23.44	721	1.49	11.6**

Note: Acceleration type standard is LA-4 cycle prescribed for the FTP. Mod. #1 modifies the LA-4 cycle by using slightly greater acceleration rates at speeds below 25 mph. Mod. #2 modifies the LA-4 cycle by using much greater acceleration rates at speeds below 25 mph.

*Results questionable see preceding text

**Because the baseline runs for the Nova were run with standard dynamometer rolls and the Mod #2 was run with coupled rolls, the data are not directly comparable. The coupled roll configuration causes a fuel economy penalty of approximately 5% which yields an actual fuel economy difference, attributable to the Mod #2 cycle, of about 3% for the Nova.

Appendix C
Acceleration Rate vs. Fuel Economy Test

Since the Gastell and modified cycle test programs (Appendix A and B) showed little effect on emissions or fuel economy, EPA undertook a small test program to further investigate the fuel economy effects of reduced acceleration.

A test program was devised consisting predominately of accelerations. The test cycles used a sequence of accelerations to a cruise speed, cruise for a few seconds, and then deceleration at a fixed, moderate rate. The cruise times were chosen so that all tests to a selected cruise speed would be of equal distance. This sequence was repeated 4 times (5 total cycles). The cycle was run for each combination of acceleration rate and final cruise speed.

A similar sequence between two vehicle speeds was performed to evaluate passing manuever fuel economy. As a control, vehicles were also tested several times for steady state fuel economy.

The testing was performed in randomized order to minimize any systematic test effects (see Acceleration Rate vs. Fuel Economy test sequence). A fuel flowmeter was used to measure fuel consumed (no gaseous emission data was taken). The dynamometer rolls were coupled together to minimize tire slippage.

The maximum and minimum acceleration rates were chosen to bracket the acceleration rates most current vehicles are capable of achieving.

The complete test matrix was:

MPH	Acceleration rate				
	1	2	3.3	4	5
0-35	x	x	x	x	x
0-45	x	x	x	@	@
20-35	x	x	x	x	x
30-45	x	x	x	@	@

@ Most vehicles unable to follow the driving traces at this acceleration rate/speed combination.

A 1980 Chevrolet Citation, 1980 Dodge Aspen, 1979 Ford Pinto, 1979 Mercury Zephyr, and a 1979 Oldsmobile Cutlass were used in this acceleration test program. A description of these vehicles is given in Table C-I. Each vehicle was checked for agreement with manufacturer's specifications and inspected. All vehicles were in satisfactory condition.

Tabel C-I
Phase 3 Acceleration Rate vs. Fuel Economy Testing
Test Vehicle Description

	1980 Chevrolet Citation	1980 Dodge Aspen	1979 Ford Pinto	1979 Mercury Zephyr	1979 Oldsmobile Cutlass
Vehicle ID	1X687AW119256	NE29CAB11858B	9T11Y186165	9E35F621630	3R47A9M523280
Engine					
Type	V-6	Inline 6	Inline 4	V-8	V-6
Displacement	2.8 Liter	225 CID	140 CID	302 CID	3.8 Liter
Carburetor	2 Venturi	1 Venturi	1 Venturi	1 Venturi	2 Venturi
Transmission	3 Speed Automatic	3 Speed Lockup Automatic	3 Speed Automatic	3 Speed Automatic	3 Speed Automatic
Test Weight	3000 lb	4000 lb	3000 lb	3500 lb	4000 lb
Dynamometer HP	10.3 hp	12.0 hp	10.3 hp	11.2	12.0
Tire Type	Radial	BIAS	BIAS	Radial	Radial
Tire Size	P185/80R13	D78x14	B78x13	CR78x14	P195R/75
Emission Control	EGR	EGR	EGR	EGR	EGR
	Air Pump	Pulsating Air	Pulsating Air	Air Pump	Air Pump
	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst	Oxidation Catalyst

Appendix C
Acceleration Rate vs. Fuel Economy Test Sequence

Fuel Economy Sample	Speed	Comments
	50 mph	initial vehicle warm up for 30 minutes
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	accelerations at 1 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	accelerations at 4 mph/sec.
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	acceleration @ 3.3 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-35 mph	acceleration @ 2 mph/sec.
	0 mph	idle (drive) for 30 second
X	0-35 mph	accelerations @ 5mph/sec.
	0 mph	idle (drive) for 30 seconds
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	0 mph	idle (drive) for 1 minute
X	0 mph	idle (drive) fuel consumption for 3 minutes
	45 mph	warm up for 2 minutes
X	45 mph	steady state fuel economy for 80 seconds
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 1 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 3.3 mph/sec.
	0 mph	idle (drive) for 30 seconds
X	0-45 mph	accelerations @ 2 mph/sec.
	0 mph	idle (drive) for 30 seconds
	45 mph	warm up for 2 minutes
X	45 mph	steady state fuel economy for 80 seconds
	0 mph	idle (drive) for 30 seconds
	20 mph	warm up for 2 minutes
X	20 mph	steady state fuel economy for 3 minutes
	35 mph	warm up for 2 minutes
X	35 mph	steady state fuel economy for 103 seconds
	20 mph	warm up for 2 minutes
X	20-35 mph	accelerations @ 1 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 4 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 3.3 mph/sec.
	20 mph	warm up for 30 seconds
X	20-35 mph	accelerations @ 2 mph/sec.
	20 mph	warm up for 30 seconds

X	20-35 mph	acceleration @ 5 mph/sec.
	20 mph	warm up for 2 minutes
X	20 mph	fuel economy for 3 minutes
	35 mph	warm up for 2 minutes
X	35 mph	fuel economy fo 103 seconds
	0 mph	idle (drive) for 1 minute
X	0 mph	idle (drive) fuel consumption for 3 minutes
	30 mph	warm up for 2 minutes
X	30 mph	fuel economy for 2 minutes
	45 mph	warm up for 2 minutes
X	45 mph	fuel economy for 80 seconds
	30 mph	warm up for 2 minutes
X	30-45 mph	accelerations @ 1 mph/sec.
	30 mph	warm up for 2 minutes
X	30-45 mph	accelerations @ 3.3 mph/sec.
	30 mph	warm up for 30 seconds
X	30-45 mph	accelerations @ 2 mph/sec.
	30 mph	warm up for 2 minutes
X	30 mph	fuel economy for 2 minutes
	45 mph	warm up for 2 minutes
X	45 mph	fuel economy for 80 seconds.

Table C-II
Acceleration Rate Fuel Economy
miles per gallon

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph					
1 mph/sec.	19.3	16.8	21.8	16.0	17.4
2 mph/sec.	19.7	16.0	21.4	15.8	17.5
3.3 mph/sec.	19.4	15.6	20.4	15.3	16.9
4 mph/sec.	18.6	14.1	19.3	15.0	16.2
5 mph/sec.	18.2	14.3	19.1	14.7	15.2
0-45 mph					
1 mph/sec.	20.7	17.9	22.1	17.3	18.6
2 mph/sec.	20.4	16.1	21.6	16.9	17.9
3.3 mph/sec.	19.5	15.8	20.6	16.1	16.3
20-35 mph					
1 mph/sec.	25.0	22.3	27.3	20.1	21.8
2 mph/sec.	23.2	19.7	24.9	18.9	20.2
3.3 mph/sec.	22.4	18.0	23.6	18.3	18.9
4 mph/sec.	22.0	17.4	22.4	18.2	18.2
5 mph/sec.	20.8	17.3	22.6	17.9	18.4
30-45 mph					
1 mph/sec.	25.6	22.6	26.8	21.5	23.0
2 mph/sec.	23.1	20.0	25.1	19.6	20.9
3.3 mph/sec.	20.9	19.4	24.1	18.7	18.1

Table C-III
Acceleration Rate: Fuel Economy
Percentage Improvement from Highest Acceleration
Rate to 1 mph/sec. Acceleration Rate

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph	6.0%	17.5%	14.1%	8.8%	14.4%
0-45 mph	6.1%	13.3%	7.3%	7.5%	14.1%
20-35 mph	20.1%	28.9%	20.8%	12.3%	18.5%
30-45 mph	22.5%	16.5%	11.2%	15.0%	27.1%

combined average for all vehicles is 14.6%

Table C-IV

Percentage Rate Fuel Economy
Percentage Improvement from Highest Acceleration
Rate to 2 mph/sec. Acceleration Rate

	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
0-35 mph	8.2%	11.8%	12.0%	7.5%	15.1%
0-45 mph	4.6%	1.9%	4.9%	5.0%	9.8%
20-35 mph	11.5%	13.9%	10.2%	5.6%	9.8%
30-45 mph	10.5%	3.1%	4.6%	4.8%	15.5%

combined average for all vehicles is 8.5%

Table C-V

Cruise Fuel Economy
miles per gallon

Cruise Speed-mph	Chevrolet Citation 2.8 liter	Dodge Aspen 225 CID	Ford Pinto 140 CID	Mercury Zephyr 302 CID	Oldsmobile Cutlass 3.8 liter
Idle (drive)*	.35	.56	.31	.76	.45
20	30.8	33.5	35.5	26.2	36.4
30	32.2	36.0	35.0	28.0	37.1
35	32.6	35.3	35.3	28.0	34.3
45	30.7	31.0	33.3	26.9	30.4

*Idle fuel consumption is expressed in gallons per hour

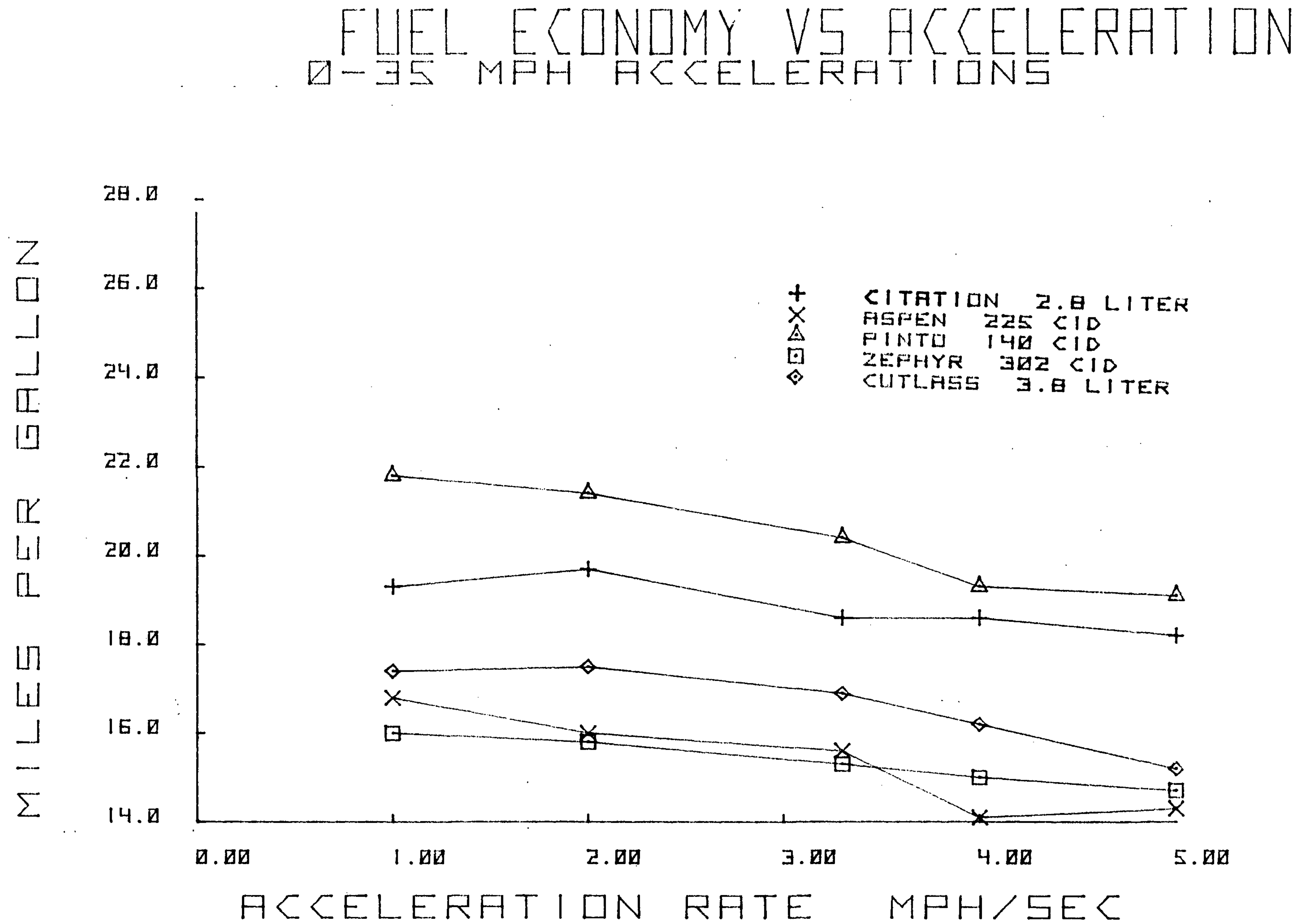

FUEL ECONOMY VS ACCELERATION
0-35 MPH ACCELERATIONS
MILES PER GALLON
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
0.00
1.00
2.00
3.00
4.00
5.00
ACCELERATION RATE MPH/SEC

Figure C-1

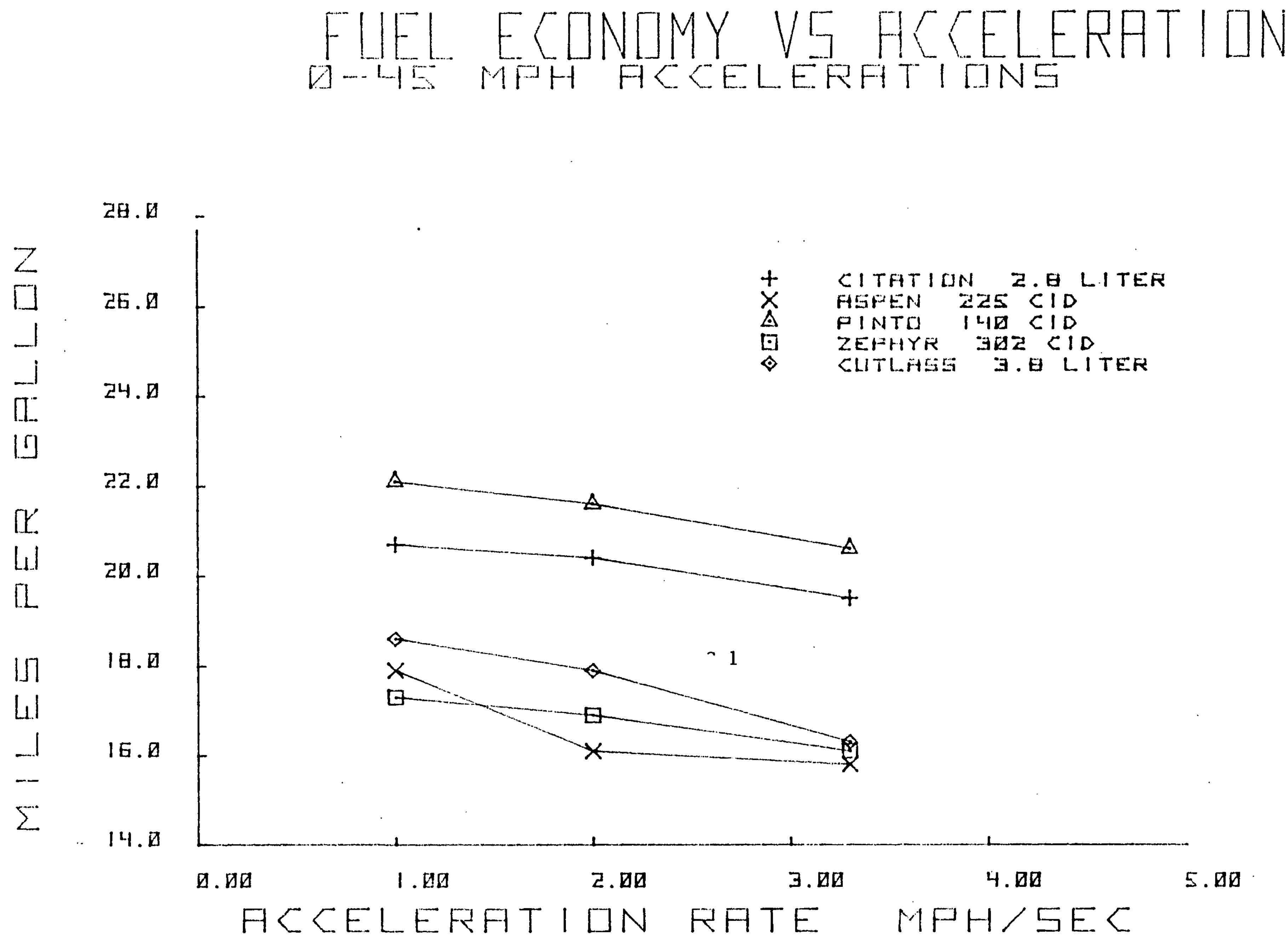

FUEL ECONOMY VS ACCELERATION
0-45 MPH ACCELERATIONS
MILES PER GALLON
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
0.00
1.00
2.00
3.00
4.00
5.00
ACCELERATION RATE MPH/SEC

Figure C-2

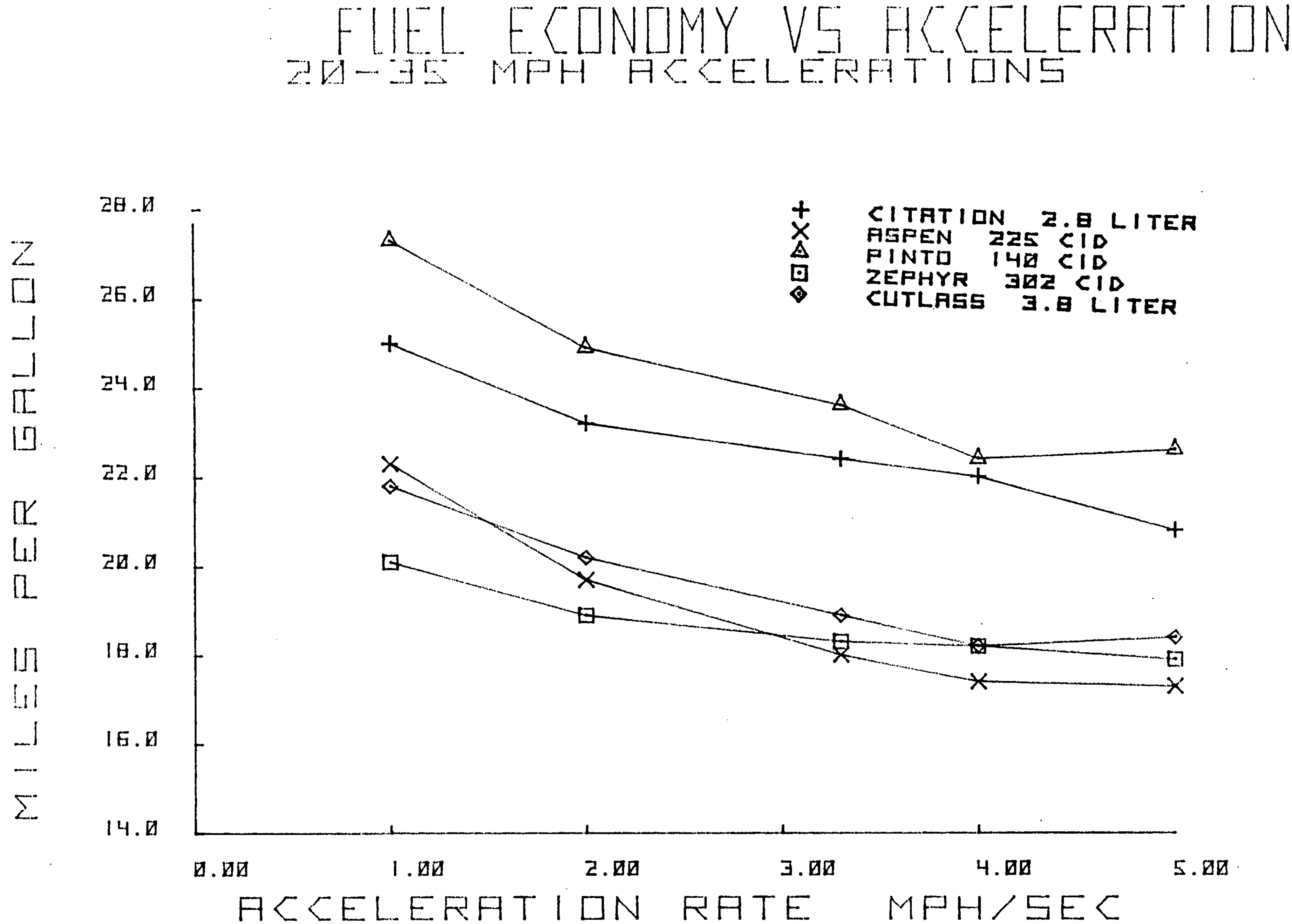

FUEL ECONOMY VS ACCELERATION
20-35 MPH ACCELERATIONS
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
MILES PER GALLON
0.00
1.00
2.00
3.00
4.00
5.00
ACCELERATION RATE MPH/SEC

Figure C-3

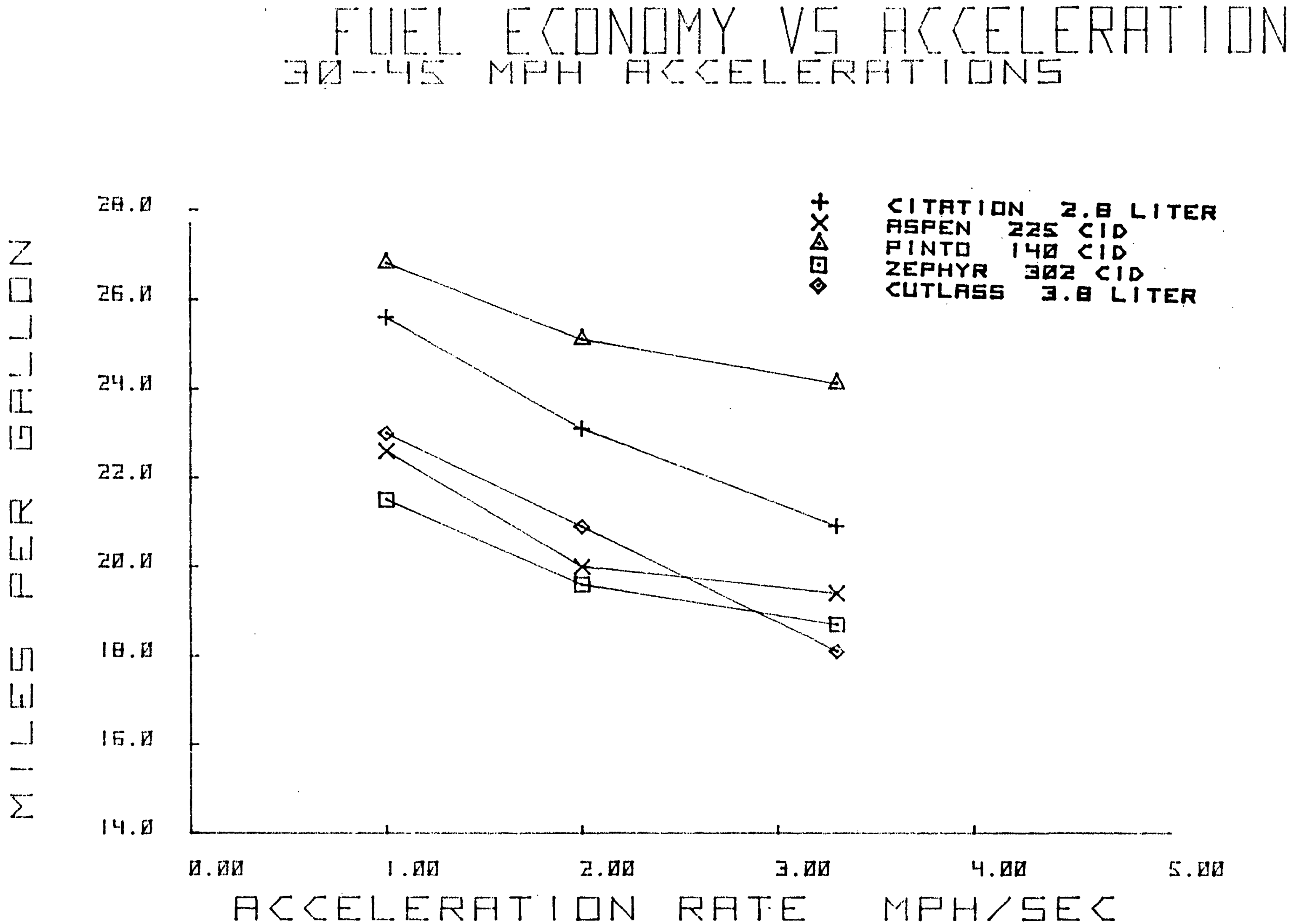

FUEL ECONOMY VS ACCELERATION
30-45 MPH ACCELERATIONS
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
MILES PER GALLON
0.00
1.00
2.00
3.00
4.00
5.00
ACCELERATION RATE MPH/SEC

Figure C-4

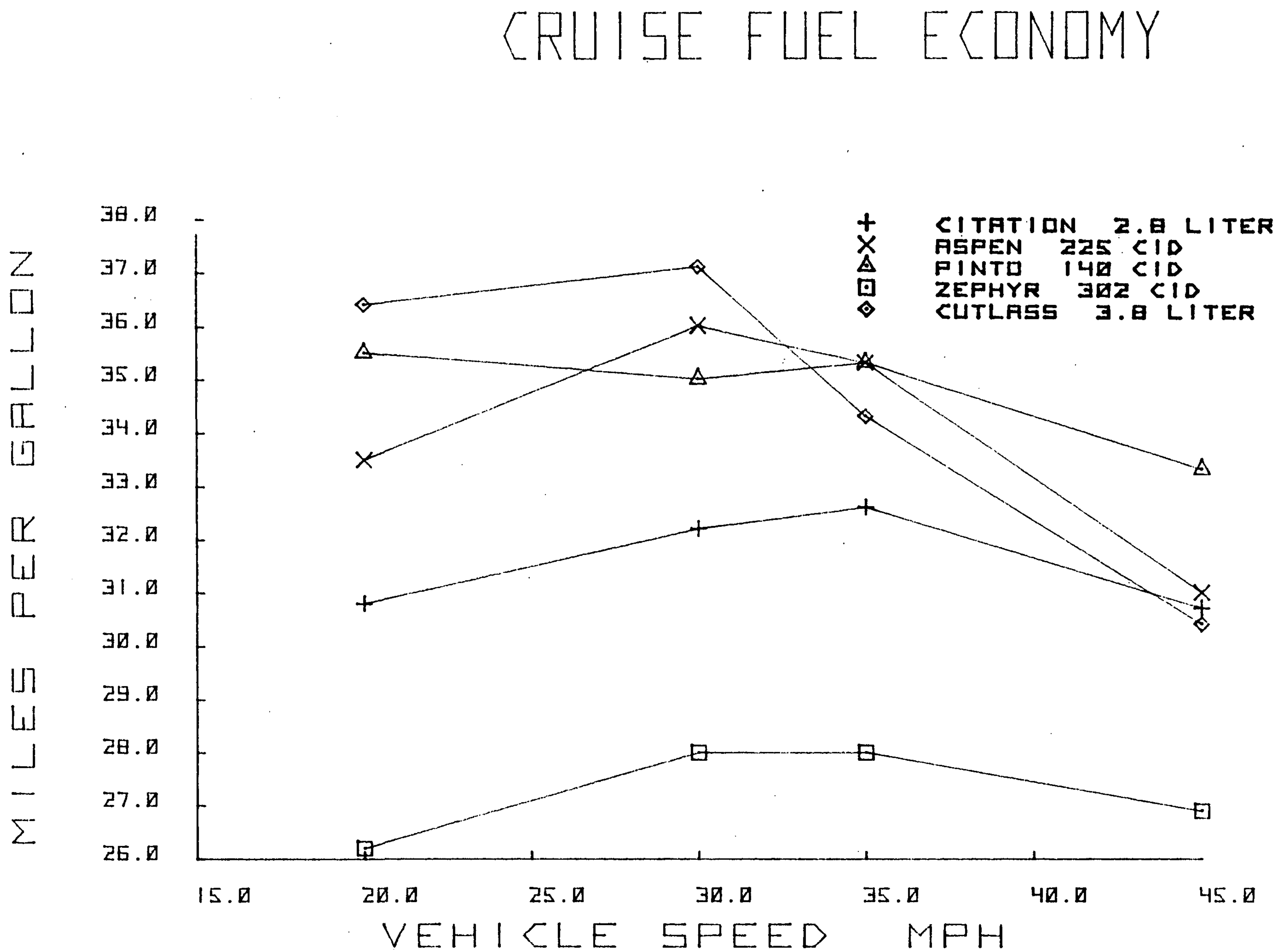

CRUISE FUEL ECONOMY
CITATION 2.8 LITER
ASPEN 225 CID
PINTO 140 CID
ZEPHYR 302 CID
CUTLASS 3.8 LITER
MILES PER GALLON
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
VEHICLE SPEED MPH

Figure C-5

Appendix D
Road Testing with the Gastell Device

SAN ANTONIO ROAD ROUTE TEST PROCEDURE

A. The general procedure is as follows:

1. Drive test vehicle from Southwest Research Institute to Layover Point.

2. Start Vehicle

3. Start Fluidyne Recorder, wait 60 seconds. Then drive road course. Use normal driving techniques.

4. Return to Layover Point, shift into park, idle for 60 seconds. At 60 secs, stop Fluidyne totalizer and hit print button. Record fuel and temperature readings on work sheet.

5. Shut engine off, zero and start Fluidyne timer.

6. At 500 seconds, start vehicle using hot start procedure.

7. At 560 seconds shift into drive and drive road course using normal driving technique. (Go to Step 4 - repeat as many times as possible before 3:00 p.m.).

Note: The Mercury Marquis was run with 60 second layovers instead of 500 seconds.

B. General Test Requirements

1. The first test run of each day was considered warm up and the data was not used in any subsequent calculations.

2. Only tests run between 9:00 a.m. and 3:00 p.m. were used due to San Antonio traffic considerations.

3. Only tests run on weekdays, Monday through Friday, were used due to San Antonio traffic considerations.

4. Temperature, humidity, barometer, wind speed and direction were taken at 9:00 a.m. and 3:00 p.m.

5. All test fuel was from a single batch of Gulfpride unleaded fuel provided by Southwest designated EM-356.

6. All test vehicle fuel tanks were drained prior to start of testing to avoid fuel mixing.

7. All vehicles were specification checked and examined for proper vacuum line routing and evidence of tampering.

8. The Chevrolet Citation and Nova were extensively checked out to manufacturers specifications at the EPA-MVEL prior to being driven to San Antonio.

9. Fuel Tanks on each vehicle were filled with EM-356 fuel each morning. Vehicles used about 1/4 tank each testing day.

10. Tire pressure of all test vehicle tires was checked and set to manufacturer's specifications each morning prior to leaving Southwest Research.

11. Test runs with abnormal time, fuel consumption, or circumstances were deleted from consideration. Examples of such circumstances were funeral processions (3 occurences) and could not exit highway due to traffic (1 time).

12. In all test days where the Gastell Device was to be used, the device calibration was checked prior to leaving Southwest using the following procedure.

    An 8" diameter pressure gauge that was previously checked versus a mercury manometer in Ann Arbor was attached to a hand vacuum pump which was then connected to the device. Ray Smith of Gastell had transmitted the following device specifications:

	ON	OFF
4 cylinder vehicles	3.5" Hg	4.5" Hg
6 cylinder vehicles	5.0" Hg	6" Hg
8 cylinder vehicles	7.0" Hg	8"Hg

    The devices did not need calibration until the setpoints were modified on the Nova. The calibration checks of the 8 cylinder devices were about on at 7.0" Hg. Since these devices were submitted by Ray Smith with the 511 Application for evaluation and the specifications given in the application only specified the <u>ON</u> set point, the devices were deemed acceptable.

13. Testing run when the pavement was wet was not used in the analysis. When pavement was damp the results were used if they appeared in-line with other measurements.

14. A minimum of 5 tests were run with most vehicles to familiarize the driver with the vehicle and route. Data was not collected during driver familarization.

15. The fuel totalizer display was located in the vehicle so that the driver could not see the display while driving.

16. The Fluidyne flowmeters were calibrated in July, 1980 and checked for calibration in December 1980.

Table D-I
Phase 4 Gastell Road Testing
Test Vehicle Description

	1980 Citation Citation	1975 Chevrolet Nova	1980 Mercury Cougar XR-7	1979 Mercury Marquis
Vehicle ID	1X685AW15057	1X27L5L115735	OH93D626537	9Z6ZH619190
Engine				
type	inline, 4 cylinder	V-8	V-8	V-8
Displacement	2.5 liters	350 CID	255 CID	351
Carburetor	2 venturi	4 venturi	2 venturi	2 venturi
Transmission	3 speed automatic	3 speed automatic	3 speed automatic	3 speed automatic
axle ratio	2.53	3.08	2.50	2.30
Tire Type	radial	radial	radial	radial
Tire Size	P185xR13	ER78x14	P195/75R14	GR78x14
Emission Control	EGR closed loop 3 way catalyst	air injection pump oxidation catalyst	EGR oxidation catalyst	air injection oxidation catalyst

San Antonio Road Route

Number of Stop Signs: 0

Number of Stop Lights: 28

Average Distance: 7.2 miles

Average Speed: 19.6 mph

Maximum Speed: 55 mph

Stops/Mile: 3.9

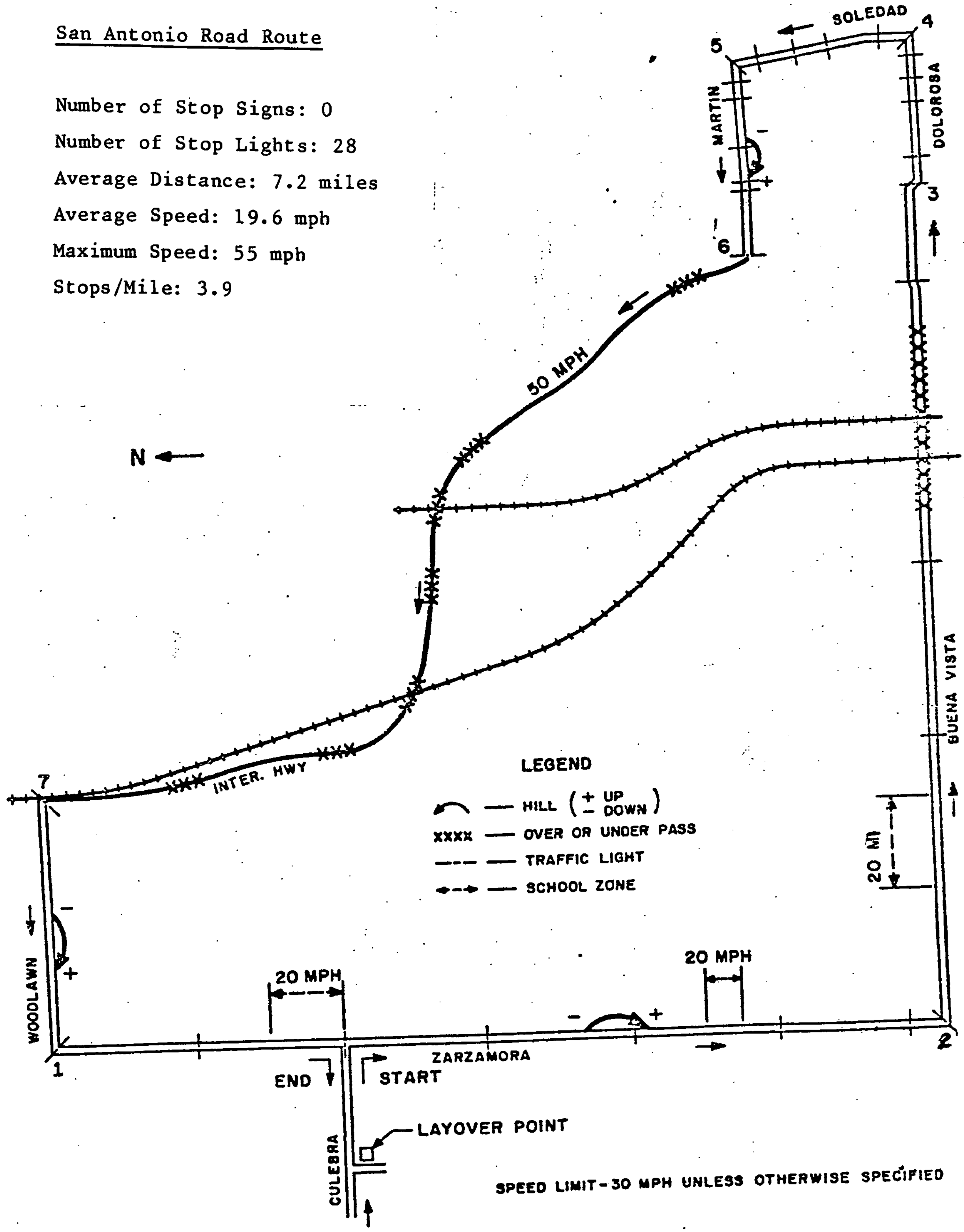


Figure D-1 San Antonio Road Route