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FIELD EVALUATION OF MILES-PER-GALLON METERS

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. Abstract

One hundred forty fleet automobiles based in Los Angeles were sed to determine the influence of miles-per-gallon meters on fuel conomy. Seventy cars were instrumented with the meters, and 70 ere used without meters for control purposes. Fuel use and mileage ecords were collected over a 12-week period. The cars were used rimarily for commuting in a mixture of highway, urban, and suburban riving. Drivers in both groups were paid every three weeks for the mount of fuel they saved as compared with pre-test fuel-use records. nalysis of variance of the resulting miles-per-gallon averages evealed no significant difference in fuel economy between the two roups.

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PREFACE

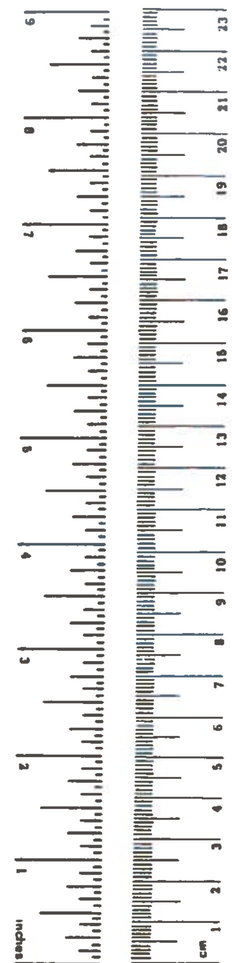
An objective of the Transportation Energy Efficiency Program (TEEP) of the U.S. Department of Transportation, Transportation Systems Center, is to determine the effectiveness of driver aids in improving automobile fuel economy. A device to measure and present instantaneous, real-time miles-per-gallon (mpg) information is one such aid which the Center felt should be evaluated under conditions representative of normal, average American driving.

The Automobile Club of Southern California (ACSC) was selected to conduct the tests, because its membership provided an automobile fleet with known historical performance data on each vehicle, and a group of drivers who daily operate their automobiles under driving conditions approximating the Environmental Protection Agency (EPA) highway and urban-suburban drive cycles.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

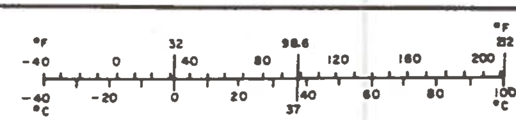


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

This report presents results of tests conducted by the Automobile Club of Southern California (ACSC) on miles-per-gallon meters. The intent was to determine if a device which presents the driver with an instantaneous, real-time indication of miles-per-gallon engine performance would help the driver achieve improved fuel economy in vehicle operation. Data was collected over a twelve week period, from March 1976 to June 1976.

The ACSC membership provided a group of cooperative drivers with cars having documented, baseline information, pertinent to the tests, with the Club records.

2. METHOD

2.1 TEST VEHICLES

The vehicles used in the study were selected from ACSC's 200-plus vehicles according to the following criteria:

a. Each of the vehicles was to be a 1974 or 1975 model,

b. Each of the vehicles was to have a stable and reasonable fuel-economy history as indicated by the Club's fleet records,

c. The vehicles were to be stationed as close as possible to the Club's main office located in central Los Angeles,

d. Each vehicle was dedicated to a single driver throughout its history of ownership by the Club, and

e. Those cars receiving the miles-per-gallon equipment had to be origninally manufactured with a vapor return line to the gas tank.

Table 2-1 shows the initial vehicle selection. The final number (70) analyzed in each group was somewhat less than the initial number selected because of car failures and logistic difficulties of collecting data from certain drivers.

2.2 TEST PLAN

One half of the cars (i.e., the experimental group) were equipped with miles-per-gallon meters before the start of the test, and the other half were not so equipped; the latter provided a baseline comparison group. The two groups of cars were matched so that average historical miles driven per month by each car were approximately the same. The historical data were obtained from ACSC's computerized fuel consumption-and-mileage records.

Every vehicle selected was given a motor tuneup just prior to starting the test. All drivers were informed of economical driving practices by giving each driver a copy of the driving tips included in this report as Appendix A.

None of the drivers received training either in how to attain fuel economy or how to use the miles-per-gallon meters. Fuel use and mileage records were collected over a 12-week period. The cars were used primarily for commuting in a mixture of highway, urban, and suburban driving. Drivers in both groups were paid every third week for the amount of the fuel they saved as compared with pre-test fuel-use records. Drivers were "penalized" for a decrease in fuel economy by informing them of the total fuel lost nationally if all drivers performed in a like manner. Data collected by the ACSC included fuel-purchase receipts and fuel-consumption information from the totalizers on the meter-equipped cars.

TABLE 2-1. VEHICLES SELECTED

Model Year	Manufacturer	Model	Experimental	Control
1975	AMC	Matador	--	2
1975	Buick	Century	9	4
1975	Buick	Skylark	19	18
1975	Chevy	Chevelle	13	5
1975	Dodge	Dart	--	6
1975	Dodge	Coronet	--	4
1975	Ford	Torino	--	6
1975	Olds	Cutlass	--	8
1975	Olds	Omega	9	4
1975	Pontiac	Ventura	11	5
1975	Pontiac	LeMans	1	--
1975	Plymouth	Fury	--	4
1975	Plymouth	Valiant	--	2
1975	Chevy	Nova	1	--
			Subtotal 63	68
1974	Buick	Century	1	3
1974	Buick	Skylark	2	3
1974	Chevy	Chevelle	1	1
1974	Dodge	Dart	--	3
1974	Ford	Torino	--	1
1974	Plymouth	Valiant	--	1
1974	Pontiac	LeMans	--	1
1974	Olds	Cutlass	2	--
1974	Olds	Omega	3	1
			Subtotal 9	14
			Total 72	82

3. SYSTEM OPERATION AND INSTALLATION

3.1 GENERAL

All of the vehicles used in the evaluation were prepared prior to the test. Each vehicle was tuned up, and the miles-per-gallon meters were installed on the experimental vehicles. Figure 3-1 shows the miles-per-gallon meter display mounted on the automobile steering wheel and a detail of the meter face.

FIGURE 3-1. MILES-PER-GALLON METER DISPLAY AT DRIVER'S SEAT

3.2 PREPARATION OF VEHICLES

Prior to participating in the study, each vehicle was given a motor tuneup consisting of changing the spark plugs, changing the ignition points and condenser (if so equipped), changing the fuel filter, changing the air filter, and adjusting the ignition timing and idle rpm to manufacturer's specifications.

3.3 MILES-PER-GALLON METER INSTALLATION

The miles-per-gallon meters used were manufactured by the Flo-Scan Instrument Company of Seattle, Washington, and were provided to the ACSC, together with related equipment, by the Transportation Systems Center. The major components of the system are:

1. Model 255PB-15 fuel flow transducer made up of a turbine fuel flow transducer, a pulsation damper and a vapor separator;
2. Electronic module;
3. Totalizer (resettable electro-mechanical counter);
4. Speed sensor; and
5. Model 10A mpg meter display.

The FloScan device was selected as the means for evaluating the mpg mix concept because, at the time of testing, it was the most sophisticated device of its type on the market. It had features designed to correct for fuel vaporization and surge which tend to cause spuriously high fuel consumption readings. These elements, except for the electronic module, are shown in Figure 3-2. Fuel consumption is measured by the fuel flow transducer which sends an

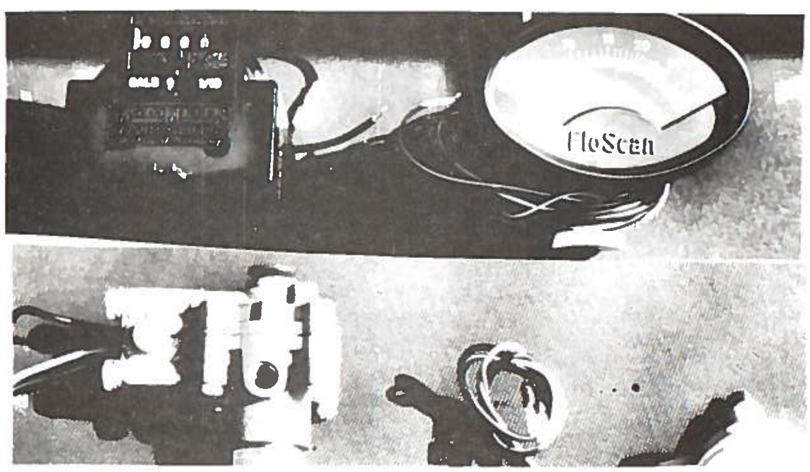


FIGURE 3-2. MILES-PER-GALLON METER SYSTEM COMPONENTS (ELECTRONIC MODULE NOT SHOWN)

electrical signal proportional to the flow to the electronic module. The electronic module also receives a signal from the speed sensor which it combines with the flow signal to produce the mpg signal for the mpg meter. It also sends an impulse to the totalizer for each 0.1 gallon of fuel consumed.

No sensor installation problems were encountered using the instructions provided by FloScan. Following these recommendations, the fuel flow transducer was mounted as close to the carburetor as physically possible. The connection between the transducer and the carburetor was made with copper fuel line. The fuel line from the fuel pump to the transducer was neoprene. FloScan recommends this type of transducer plumbing for two reasons:

1. The rigid copper fuel line between the carburetor and the flow transducer helps to minimize the backflow through the transducer that could result from using a hose which is subject to expansion due to the fuel pump pulses. This backflow would introduce errors in the transducer measurement.
2. The neoprene fuel line before the transducer, by virtue of its nonrigid characteristics, helps to dampen the fuel pump pulsations. Backflow occurring before the flow transducer is of no consequence since it does not affect the transducer measurement.

A by-pass line from the vapor separation was "teed" into the tank before being measured by the transducer. See Figure 3-3 for installation block diagram.

The electronic module was mounted under the hood on the left front inner panel. Attached to the electronic module was the totalizer counter. The miles-per-gallon meters were installed on the steering columns of the vehicles with a large hose clamp. The speed sensor was mounted in the speedometer cable at the lower portion of the firewall.

Views of the various elements installed are shown in Figures 3-4, 3-5, 3-6, and 3-7.

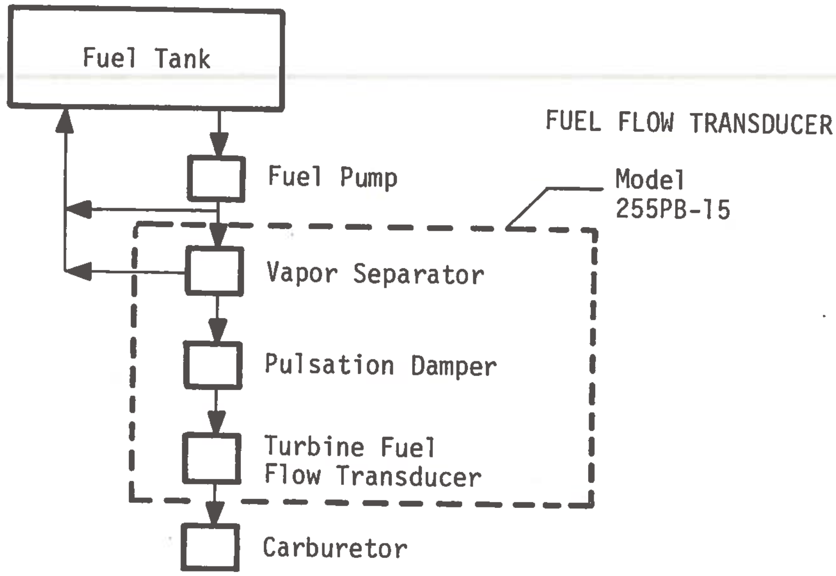


FIGURE 3-3. INSTALLATION BLOCK DIAGRAM

The time required for installation of the equipment varied from about 16 man-hours for the first installation to about 4 man-hours for later installations after considerable experience had been gained. This decrease in man-hours required is partly attributable to the fact that all vehicles fell within two model years and to that extent were similar. In most instances, the plumbing and wiring could be prefabricated before the vehicles actually arrived for the installation. If the mechanic were familiar with the car and the installation of the device but could not prepare for the individual cars before they arrived or use an assembly-line-like installation strategy, it is estimated that the average installation would take about eight hours. Irrespective of the total time spent on an installation, about 40 percent of the time was spent installing the fuel flow transducer and fuel lines; 25 percent of the time was spent installing the electronic module totalizer and wiring the system; and about 35 percent of the time was spent installing the speed sensor in the speedometer cable and installing the meter on the steering column of the vehicle.

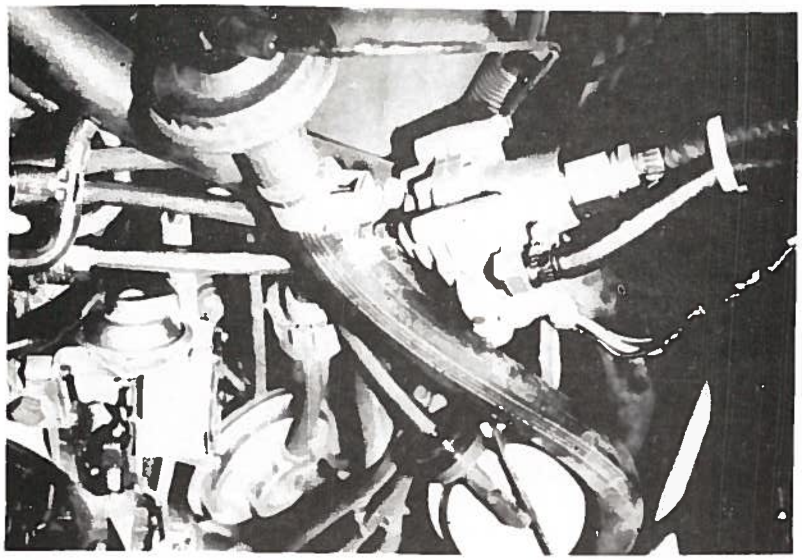


FIGURE 3-4. MPG METER FUEL FLOW TRANSDUCER INSTALLED

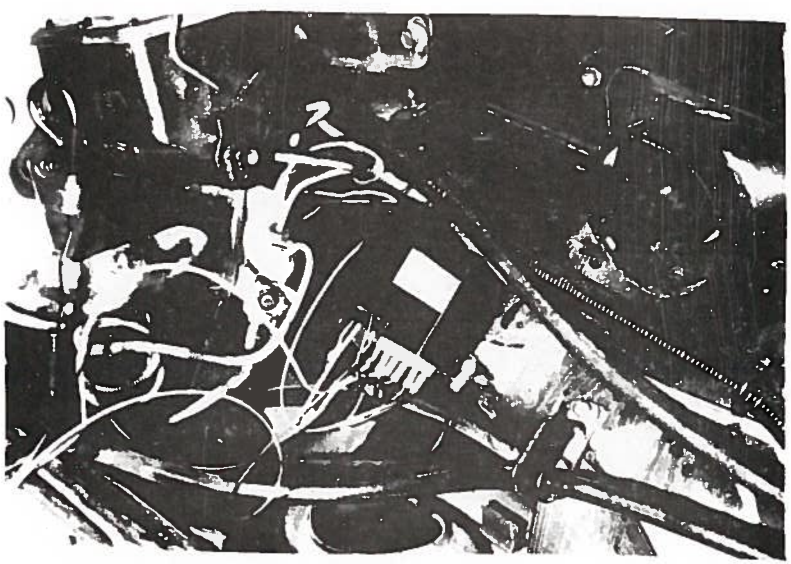


FIGURE 3-5. MPG METER ELECTRONIC MODULE INSTALLED

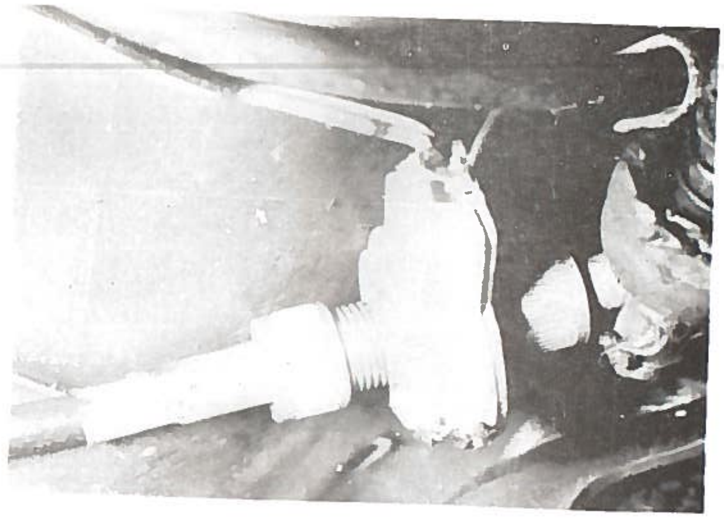


FIGURE 3-6. MPG METER SPEED SENSOR INSTALLED

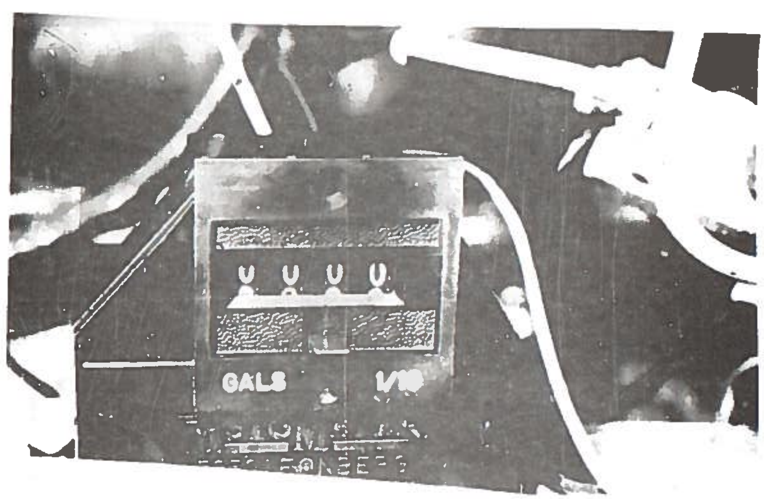


FIGURE 3-7. MPG METER TOTALIZER INSTALLED

4. DATA COLLECTION PROCEDURE

4.1 GENERAL

The test fleet was divided into approximate thirds to facilitate gas receipt collection. Each third was given a color code--red, blue, or green. Stickers of the proper color were placed on the windshield side of the inside rear-view mirror, left-front door jamb, and near the fuel-tank filler neck. Each week the receipts were collected from a different color coded group. An envelope was placed on the dash of the car to aid the drivers in saving their fuel purchase receipts. The full envelope was exchanged at the time of collection for an empty one marked with the date of the next collection week. Collections were made every three weeks.

At the time of data collection, the fuel tank was topped off by ACSC personnel. The topping consisted of filling the tank until no more fuel could be added by repeated squeezes of the nozzle handle. The cars were filled at ACSC's gas pumps.

To facilitate the collection of the mileage data, the drivers noted the odometer reading on the fuel receipt at the time of each fill-up.

4.2 DRIVER PERFORMANCE RECORDS

A fuel-use record was given each driver after each three-week data collection period. This record included the historical fuel economy of the driver's car from the ACSC's fleet records, the fuel economy from the just-completed three-week period, the difference in fuel economy between these two values, and the number of barrels of fuel which would be saved, or lost, annually if all of the drivers in the United States were to increase their fuel economy by a similar amount.

The record also showed the dollar equivalent of the fuel saved, or lost, during the last reporting period based on the number of miles driven and a standard price per gallon of gasoline of 62 cents. The fuel-use record form is shown in Figure 4-1.

FUEL-USE RECORD

DRIVER__________________________________ CAR NO:________

OBSERVATION PERIOD:________________________

Avg. Pre-1976 Gas Mileage	________
Observation Period Gas Mileage	_____.__
Percent Change	______%
Dollar Equivalent of Fuel Savings (losses)	$_______
Equivalent Annual, National Fuel Savings (losses)	__bbls._

FIGURE 4-1. FUEL-USE RECORD

All of the drivers used ACSC's credit cards for their fuel purchases. Therefore, to simulate the dollar savings of driving more economically, those control and experimental drivers increasing their fuel economy over the historical fuel economy were "rewarded" by a check in the amount of the savings. This check was included with the fuel-use record. Drivers were "punished" for a decrease in fuel economy by being informed of the size of the decrease and the impact on the national fuel economy if all American drivers had performed similarly.

5. RESULTS

The fuel economy data were analyzed using 2 x 4 analysis of variance with repeated measures on one factor.[1] This type of analysis allows the experimenter to determine the statistical significance of the fuel economy differences between the two groups of subjects (control and experimental), the differences among the data collection periods, and possible interactions between data collection periods and the groups.

Prior to the analysis, the number of subjects in the control and experimental groups was equalized. This was done by:

1. Eliminating any subjects with missing data (control cars and experimental cars were dropped for this reason), and
2. Eliminating the excess number of subjects from the larger group randomly by the use of a table of random numbers.

This process reduced the number of subjects to 70 per group. A summary of the subjects and their data is included as Appendix B.

Prior to performing the analysis of variance on the data collected during the four evaluation periods, a t test was performed to evaluate the significance of the samll difference in the historical mpg fuel economy averages between the two groups. The results of the t test showed no significant differences between the groups ($t = 0.147$; $p > 0.05$). Accordingly, the groups were considered comparable for the purposes of this evaluation.

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[1] Winer, B.J., Statistical Principles in Experimental Design, McGraw-Hill, New York, NY, 1962, pp. 298-318.

Table 5-1 shows a summary of the test data. The mpg scores for four collection periods are the averages (means) of mpg performance scores of the 70 cars in each group. Each of the 70 performance scores was determined by dividing the number of miles the car traveled during the preceding three-week data collection period by the number of gallons the car used to cover this distance. The scores in the average column are the means of the values of the four collection periods. The historical figures are the means of the 70 individual performance scores calculated from the pre-evaluation fuel use and mileage data stored in ACSC's data system over the life of the car. The standard deviations represent the variance among the 70 scores associated with the corresponding mean mpg values. Figure 5-1 is a graphic representation of these data. In averaging the fuel economy of all 70 subjects in each group for all four collection periods, the fuel economy of the experimental group (13.89 mpg) was found to be 2.8 percent higher than that of the control group (13.51 mpg).

The results of the analysis of variance conducted on the miles-per-gallon performance scores of the 140 cars are summarized in Table 5-2. The analysis revealed that:

1. The difference between the miles-per-gallon averages of the two groups of cars was not statistically significant ($F_{1,138} = 3.01$; $p>0.05$);

2. The differences in the miles-per-gallon averages among the four collection periods was not significant ($F_{3,414} = 1.94$; $p>0.05$); and

3. The differences among the miles-per-gallon averages in the four collection periods of the control group were not significantly different than for the experimental group ($F_{3,414} = 0.77$; $p> 0.05$).

TABLE 5-1. DATA SUMMARY

	History	Average	Collection Period 1	Collection Period 2	Collection Period 3	Collection Period 4
Control (70 cars)						
MPG	13.62	13.51	13.52	13.55	13.43	13.55
Std. Dev.	1.73	1.47	1.59	1.36	1.49	1.42
Experimental (70 cars)						
MPG	13.59	13.89	13.88	14.10	13.76	13.83
Std. Dev.	1.44	1.48	1.42	1.48	1.58	1.45

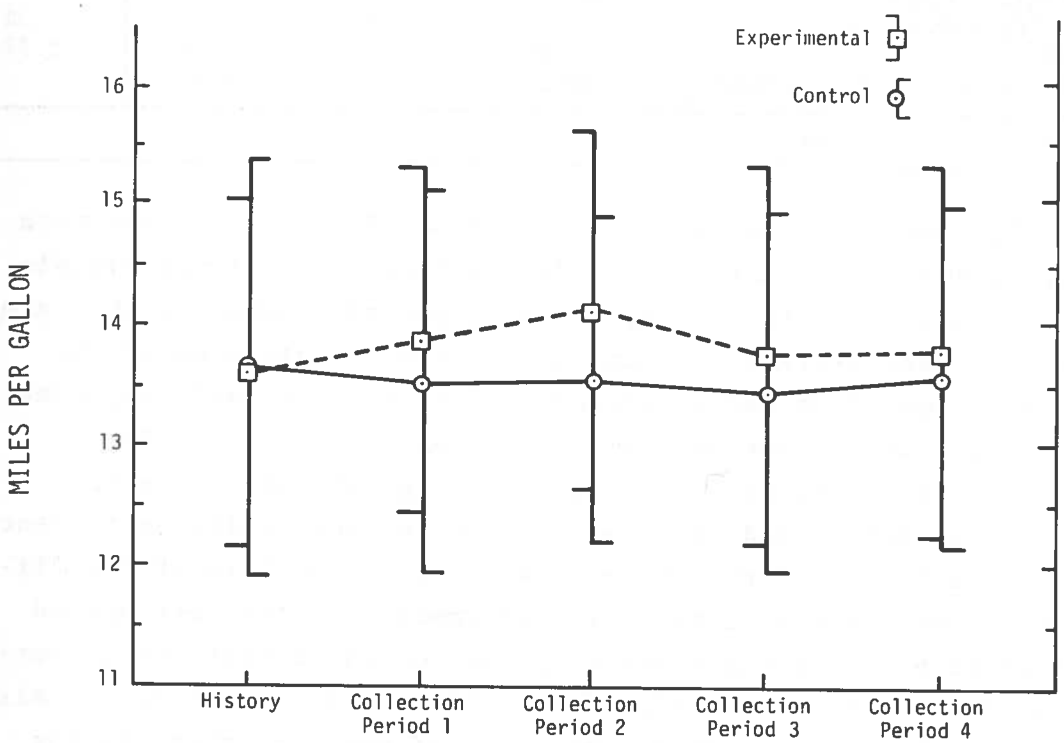

FIGURE 5-1. MEAN PLUS ONE STANDARD DEVIATION OF MPG PERFORMANCE OF EXPERIMENTAL AND CONTROL CARS AS A FUNCTION OF DATA COLLECTION PERIOD

Thus, the miles-per-gallon performance achieved by drivers who drove cars equipped with miles-per-gallon meters was not reliably different from that of drivers who drove cars without the meters with both groups having the same booklet on fuel-economy tips.

The lack of significant differences among the collection periods indicated that time-associated effects such as learning or changes in motivation which should be considered in the interpretation of the results, if they occurred, did not, in fact, take place.

TABLE 5-2. SUMMARY OF VARIANCE ANALYSIS

Sources of Variation	SS	df	MS	F
Between Subjects	952.31	139		
A (Groups)	20.33	1	20.33	3.01*
Subjects within groups	931.98	138	6.75	
Within Subjects	263.42	420		
B (Periods)	3.64	3	1.21	1.94*
AB	1.45	3	0.48	0.77*
Bx subjects within groups	258.33	414	0.62	

* Not Significant

Because of the different time frames during which the data were collected, the historical data are not strictly comparable to the data collected during the test period. However, they are the only data available which can be used to determine if the driving tips alone had an effect on fuel economy, and, so, some tentative comparisons were made. It can be seen in Table 5-1 that mileage performance of the control group during the test period did not exceed the historical miles-per-gallon performance Also, a t test performed to evaluate the reliability of the difference between the historical performance and the test-period performance of the experimental group indicated that the difference found here was not significant ($t = -1.85$; $p > 0.05$). This supports the findings of the analysis of variance that driving tips in combination with miles-per-gallon meters do not increase fuel economy.

6. CONCLUSIONS AND COMMENTS

6.1 FUEL-ECONOMY BENEFITS

The 70 drivers with miles-per-gallon meters in their cars averaged 13.89 miles per gallon over the 12-week test period, compared with an average 13.51 miles per gallon of the group of drivers without meters. However, an analysis of variance of the miles-per-gallon data revealed that this 2.8 percent was not statistically significant. In the absence of a reliable difference in fuel economy between the two groups of drivers, it must be concluded that within the conditions investigated in this study, miles-per-gallon meters were not shown to improve the fuel economy of automobiles.

6.2 COMMENTS ON INSTALLATION

To install a miles-per-gallon meter, the mechanic must be familiar with the electrical and the fuel systems of the car, or he must have enough experience with these systems to find the appropriate connections required for the device. Even with such an experienced mechanic, the installation in a car would require, conservatively, eight man-hours. If unforeseen problems occurred, the time required could conceivably be 16 man-hours. However, if the unit were factory-installed, this added time would be eliminated.

If each of the passenger vehicles in the United States were required to have a miles-per-gallon meter installed as an after-market device, the following could be expected to happen:

1. A wide range of installation procedures, special fabrication of brackets, and individually selected fittings would be required because of the variety of vehicles on the road;
2. Some modification or disfigurement of the dashboard would occur;

3. Metal fuel-return lines to the fuel tank would have to be added;

4. The speed-sensing unit would require complete removal and reinstallation of the speedometer cable;

5. Those vehicles having fuel injection or some other unconventional carburetion system would be impossible to equip with the fuel flow transducer;

6. Foreign cars with metric fasteners and fittings would cause interfacing problems with miles-per-gallon meter connections which are standard in American cars; and

7. Older cars with their less-crowded engine compartments would be easier to adapt than newer, more-cramped models.

APPENDIX A
TIPS FOR IMPROVING YOUR DRIVING SKILLS[1]

The most important element in determining the fuel economy of a particular car is the driving technique of the individual behind the wheel. One authority declares that a careful driver should be able to get at least 30 percent better mileage than an average driver, and 50 percent better mileage than a poor one. Here's our advice:

1. Start slowly. Accelerate gently except when entering high-speed traffic lanes or when passing. Hot rod driving and jerky acceleration can increase fuel consumption by 2 miles per gallon in city traffic.

2. Avoid unnecessary braking. And try to anticipate the traffic ahead. When the traffic light far ahead turns red, take your foot off the accelerator immediately. The light may turn green again by the time you reach the intersection. If not, there's still a fuel saving. In coasting, the car's kinetic energy maintains propulsion rather than the burning of additional fuel. There is less energy to be dissipated in braking. Don't tailgate. This necessitates additional braking too.

3. Drive at moderate speeds. As your speed increases, so does your car's wind resistance--a big factor in gasoline mileage. Most automobiles get about 28 percent more miles per gallon on the highway at 50 miles per hour than at 70, and about 21 percent more at 55 than at 70.

4. Drive at steady speeds. Hold a steady foot on the accelerator as long as traffic conditions permit. On the highway, "see-sawing" or repeatedly varying the speed by 5 miles per hour can reduce gas mileage by as much as 1.3 miles per gallon.

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[1] "Tips for the Motorist, Don't be Fuelish," Office of Energy Conservation and Environment, Federal Energy Administration.

5. Save gas when changing gears. If you drive a car with a manual transmission, run through the lower gears gently and quickly for minimum gasoline consumption, then build up speed in high gear. If you drive a car with an automatic transmission, apply enough gas pedal pressure to get the car rolling, then let up slightly on the pedal to ease the automatic transmission into high range as quickly as possible. More gas is consumed in the lower gears.

6. Avoid unnecessary use of air conditioning equipment. When in use, it reduces fuel economy by as much as 2.5 miles per gallon.

7. Avoid excessive idling. The average American car consumes a cup of gasoline every six minutes when idling. When you stop the car, don't idle the engine for more than a minute. If you are waiting for someone, turn off the engine. It takes less gasoline to restart the car than it does to idle it.

8. Break gas-wasting habits. For instance, don't pump the accelerator or race the engine when your car isn't in motion. It wastes gasoline. And use the brake pedal rather than the accelerator to hold your car in place on a hill."

APPENDIX B

SUBJECT DATA SUMMARY

TABLE B-1. CONTROL GROUP 1

CONTROL NUMBER	YEAR	MAKE	MODEL	HISTORY	1ST COLLECTION	2ND COLLECTION	3RD COLLECTION	4TH COLLECTION
2420	1975	Ford	Torino	12.3	12.1	12.5	12.1	12.5
2470	1975	Pontiac	Ventura	12.3	11.9	12.0	12.1	12.3
2291	1975	Ford	Torino	11.7	12.4	12.8	11.5	12.2
2467	1975	Olds	Cutlass	14.0	14.1	14.7	13.9	14.1
2360	1975	Olds	Cutlass	12.8	12.8	12.8	12.6	12.0
2019	1974	Buick	Apollo	11.9	12.7	13.6	13.7	13.9
2462*	1975	Buick	Skylark	12.7	13.6	14.0	14.6	---
2305	1975	Dodge	Dart	14.2	14.0	12.9	12.9	11.6
2358*	1975	Olds	Omega	14.3	13.1	12.8	13.3	11.5
2460	1975	Pontiac	Ventura	12.0	8.9	13.1	10.8	14.3
2334	1975	Pontiac	Ventura	11.3	12.0	12.1	11.3	12.9
2265*	1975	Buick	Apollo	15.9	16.9	16.6	15.9	15.5
2201*	1975	Buick	Skylark	15.9	15.1	16.0	13.8	14.7
2317	1975	Buick	Century	15.5	14.4	16.7	14.4	14.5
2213	1975	Olds	Omega	14.5	14.1	15.2	13.7	13.6
2193	1975	Buick	Skylark	13.9	14.8	13.4	14.3	14.6
2137	1975	Plymouth	Fury	12.2	12.3	12.6	12.5	13.0
2101	1974	Dodge	Dart	11.8	15.1	13.5	14.0	13.4
2454	1975	Chevy	Chevelle	12.2	12.7	12.2	13.3	12.1
2119	1975	Plymouth	Valiant	14.1	13.6	14.5	13.2	13.0
2165	1975	Buick	Skylark	13.1	12.4	12.8	12.8	13.0
2129	1975	Dodge	Coronet	14.7	13.5	14.1	12.8	12.2
2109	1974	Ford	Torino	11.3	13.7	13.3	14.1	15.2
2388*	1975	Pontiac	Ventura	14.9	17.2	17.1	17.4	17.4
2429*	1975	Dodge	Dart	---	---	---	---	---
2282	1975	Buick	Skylark	12.7	13.0	13.1	10.8	10.8
2406	1975	Buick	Skylark	15.6	14.6	14.5	14.6	14.4
2254	1975	Buick	Apollo	14.6	15.0	15.6	14.5	14.9
2367	1975	Buick	Apollo	13.5	15.7	14.4	14.1	14.6
2025	1974	Buick	Century	11.9	12.6	10.4	10.9	10.7
2331	1975	Buick	Apollo	14.4	13.3	13.3	13.1	13.2
2446	1975	Buick	Apollo	15.9	15.8	15.6	15.1	15.6
2312	1975	Olds	Omega	13.6	13.7	13.3	12.6	13.2
2314	1975	Buick	Apollo	15.0	13.1	16.5	16.2	16.2
2251	1975	Buick	Apollo	13.5	12.6	12.0	12.3	12.6
2348	1975	Buick	Apollo	18.0	17.1	16.4	16.2	16.8
2306	1975	Chevy	Malibu	14.9	14.2	14.1	14.1	14.0
2148	1975	AMC	Matador	12.6	11.4	12.6	12.1	14.2
2085	1974	Buick	Century	8.3	12.3	13.6	12.7	10.6
2380*	1975	Buick	Apollo	12.7	12.3	11.4	11.8	10.6
2359	1975	AMC	Matador	13.5	10.0	12.2	12.2	13.1

* Cars not in analysis.

TABLE B-2. CONTROL GROUP 2

CONTROL NUMBER	YEAR	MAKE	MODEL	HISTORY	1ST COLLECTION	2ND COLLECTION	3RD COLLECTION	4TH COLLECTION
2100	1974	Buick	Apollo	11.3	15.5	13.9	13.3	13.3
2034	1974	Olds	Omega	11.9	11.6	11.2	13.6	13.1
2046	1974	Buick	Century	12.1	12.1	12.5	12.4	12.0
2278	1975	Dodge	Coronet	12.6	10.9	11.8	11.5	12.4
2361	1975	Plymouth	Fury	13.3	13.0	13.4	12.6	12.5
2304	1975	Dodge	Dart	13.6	14.4	14.0	15.4	15.8
2464*	1975	Dodge	Dart	15.0	16.6	17.8	---	---
2074	1974	Plymouth	Valiant	13.9	15.2	14.7	14.2	15.3
2138	1975	Buick	Century	14.8	13.6	13.6	13.6	13.6
2126	1975	Buick	Century	13.9	13.7	14.2	13.1	13.3
2323	1975	Buick	Century	14.2	14.6	14.4	13.9	12.4
2219	1975	Olds	Cutlass	15.0	13.1	13.7	14.0	13.5
2131	1975	Dodge	Coronet	13.8	12.9	13.1	12.9	12.6
2160	1975	Plymouth	Fury	20.3	16.9	15.4	14.9	14.9
2363	1975	Plymouth	Fury	13.5	15.0	14.0	14.8	13.2
2300	1975	Dodge	Coronet	14.0	13.5	12.4	15.1	13.3
2106*	1974	Dodge	Dart	13.3	17.2	16.4	15.6	16.3
2122	1975	Chevy	Malibu	13.6	12.1	12.6	13.8	13.9
2144	1975	Olds	Cutlass	14.7	13.8	14.0	13.7	15.4
2158	1975	Ford	Torino	13.3	13.5	13.4	12.6	13.0
2384	1975	Olds	Cutlass	13.6	13.5	12.4	13.8	13.2
2329	1975	Plymouth	Valiant	16.2	16.7	14.7	15.3	15.0
2385	1975	Chevy	Chevelle	13.1	12.5	12.1	12.9	13.0
2295	1975	Dodge	Dart	16.7	16.6	17.1	17.9	17.5
2225	1975	Olds	Omega	13.5	11.8	12.4	11.7	13.2
2290	1975	Olds	Cutlass	13.9	13.9	13.9	15.3	13.9
2125*	1975	Olds	Cutlass	14.2	13.6	14.5	13.8	11.8
2063	1974	Buick	Skylark	11.9	12.7	12.8	12.2	13.9
2359*	1975	AMC	Matador	13.5	10.0	12.2	12.2	13.1
2127	1975	Olds	Cutlass	15.4	14.7	15.0	15.3	12.6
2440	1975	Buick	Skylark	15.4	15.8	15.9	15.3	15.2
2095	1974	Dodge	Dart	14.1	15.1	15.1	15.8	15.9
2307	1975	Buick	Apollo	13.4	12.6	13.0	11.4	11.0
2372	1975	Pontiac	Centura	12.7	12.5	12.7	13.5	13.6
2374	1975	Buick	Apollo	13.4	14.8	14.1	13.1	14.1
2218	1975	Dodge	Dart	16.3	13.9	13.8	14.3	14.6
2145	1975	Dodge	Dart	12.9	14.0	13.2	12.9	12.2
2116	1975	Ford	Torino	14.0	10.8	11.7	10.9	12.6
2159*	1975	Ford	Torino	12.2	11.2	12.0	---	---
1979	1974	Pontiac	LeMans	9.7	12.1	12.3	11.7	12.6
[illegible]	1975	Ford	Torino	13.5	14.8	11.4	13.6	15.8

TABLE B-3. EXPERIMENTAL GROUP 1

CONTROL NUMBER	YEAR	MAKE	MODEL	HISTORY	1ST COLLECTION	2ND COLLECTION	3RD COLLECTION	4TH COLLECTION
2275*	1975	Olds	Omega	14.2	16.4	---	---	15.3
2143	1975	Olds	Omega	14.7	14.7	12.9	12.9	11.8
2437	1975	Olds	Omega	16.5	16.0	16.3	15.8	16.0
2017	1974	Olds	Cutlass	12.2	13.8	14.1	14.5	13.9
2455	1975	Chevy	Chevelle	12.9	11.8	12.2	9.0	10.6
2191	1975	Pontiac	Ventura	11.2	11.3	12.8	12.1	12.1
2479	1975	Buick	Century	13.2	11.6	11.7	11.4	10.2
2350	1975	Chevy	Malibu	13.2	12.8	13.6	13.9	13.3
2250	1975	Buick	Skylark	16.2	16.7	16.0	16.9	14.5
2274	1975	Buick	Skylark	13.0	14.7	14.2	13.7	14.6
2480	1975	Chevy	Chevelle	12.3	12.9	13.6	12.7	13.0
1981	1974	Buick	Century	10.7	14.3	12.8	13.2	13.3
2413	1975	Buick	Apollo	12.8	14.5	16.2	14.6	14.5
2061	1974	Buick	Skylark	12.2	13.8	14.8	13.9	14.2
2169	1975	Chevy	Chevellle	12.9	13.8	13.9	14.2	14.0
2149	1975	Olds	Omega	14.1	14.6	15.3	14.2	14.8
2083	1974	Olds	Omega	11.9	14.6	14.7	15.1	15.9
2239	1975	Pontiac	Ventura	14.4	14.4	14.7	13.0	12.5
2237	1975	Pontiac	Ventura	14.0	13.8	15.3	14.1	13.4
2249	1975	Buick	Apollo	13.9	14.4	15.3	14.4	14.4
2465	1975	Chevy	Malibu	15.6	12.8	14.4	14.3	15.7
2117	1975	Pontiac	LeMans	14.9	16.0	16.2	16.0	15.7
2472	1975	Pontiac	Ventura	13.8	13.8	13.5	14.6	13.3
2375	1975	Buick	Skylark	14.7	13.2	15.2	13.3	13.6
2338	1975	Chevy	Malibu	12.8	12.5	12.5	12.5	12.6
2086	1974	Buick	Apollo	13.3	14.9	13.1	12.9	14.4
2475	1975	Buick	Apollo	14.1	12.9	13.9	13.1	12.4
2216	1975	Chevy	Chevelle	13.4	14.0	13.5	14.0	14.1
2287	1975	Buick	Apollo	15.1	15.0	13.5	10.1	14.7
2400	1975	Buick	Apollo	13.3	14.2	14.3	13.9	14.3
2405	1975	Chevy	Chevelle	14.1	13.3	13.4	13.1	13.4
2483	1975	Chevy	Chevelle	11.9	12.1	11.9	12.6	12.4

*Cars not in analysis.

TABLE B-4. EXPERIMENTAL GROUP 2

CONTROL NUMBER	YEAR	MAKE	MODEL	HISTORY	1ST COLLECTION	2ND COLLECTION	3RD COLLECTION	4TH COLLECTION
2322	1975	Buick	Century	12.9	11.6	12.9	12.0	12.5
2417	1975	Buick	Century	12.7	12.2	12.9	11.9	13.4
2399	1975	Buick	Skylark	13.4	13.5	14.7	14.8	13.0
2252	1975	Buick	Skylark	14.1	13.5	14.7	12.9	12.4
2189	1975	Buick	Skylark	15.0	17.1	17.0	18.0	16.8
2362	1975	Buick	Century	13.5	15.6	16.7	14.6	14.6
2461	1975	Buick	Skylark	13.9	13.9	13.9	12.6	13.3
2316	1975	Buick	Century	12.5	11.7	11.7	11.6	12.5
2262	1975	Buick	Skylark	12.3	12.5	11.9	12.3	13.5
2298	1975	Buick	Skylark	13.8	15.0	15.2	14.7	14.1
2152	1975	Buick	Century	15.4	12.8	12.4	12.4	13.5
2477	1975	Pontiac	Ventura	13.9	14.4	15.7	15.2	15.3
2425	1975	Pontiac	Ventura	12.0	12.1	11.6	11.6	11.9
2221	1975	Chevy	Chevelle	13.4	15.2	13.7	14.6	14.9
2368	1975	Pontiac	Ventura	14.2	15.3	14.7	14.3	14.8
2450	1975	Pontiac	Ventura	14.8	13.5	17.9	16.1	15.9
2187	1975	Buick	Apollo	14.1	15.4	14.9	15.1	13.7
2068	1974	Olds	Omega	12.2	14.3	14.6	15.1	15.0
2273	1975	Pontiac	Ventura	12.2	10.4	9.8	10.4	11.1
2211*	1975	Buick	Century	13.7	12.7	---	---	10.8
2245	1975	Olds	Omega	16.9	15.8	15.4	15.4	15.3
2452	1975	Chevy	Chevelle	11.4	11.5	13.1	11.4	11.9
2315	1975	Buick	Skylark	13.5	12.5	13.3	14.0	13.7
2223	1975	Buick	Skylark	11.0	12.3	12.4	14.0	12.2
2009	1974	Chevy	Malibu	13.7	12.9	12.9	13.3	13.2
2256	1975	Buick	Century	14.6	12.1	15.6	15.3	14.9
2294	1975	Olds	Omega	13.7	15.2	15.1	15.2	15.1
2244	1975	Olds	Omega	11.6	14.7	12.2	12.1	9.5
2408	1975	Olds	Omega	14.7	13.0	13.5	13.0	13.3
2474	1975	Chevy	Chevelle	13.1	13.7	13.5	13.3	13.2
2297	1975	Pontiac	Ventura	16.8	14.4	15.8	15.4	15.4
2296	1975	Buick	Skylark	15.6	15.9	15.3	15.1	14.8
1990	1974	Olds	Cutlass	13.2	15.2	13.7	13.7	15.1
2208	1975	Chevy	Chevelle	12.9	12.9	13.2	13.3	13.5
2381	1975	Buick	Skylark	14.2	14.2	14.2	14.3	14.5
2327	1975	Olds	Century	15.3	15.0	15.1	15.3	15.2
2018	1974	Olds	Omega	11.2	14.7	14.2	15.5	16.1
2321	1975	Chevy	Nova	11.4	16.0	14.6	14.3	14.9
2299	1975	Pontiac	Ventura	14.8	14.8	15.7	14.2	14.9
2288	1975	Olds	Omega	14.7	15.5	15.2	15.1	15.0

APPENDIX C
FUEL TOTALIZER ACCURACY AND EQUIPMENT FAILURES

C.1 FUEL TOTALIZER ACCURACY

A minor objective of this field study experiment was to determine the accuracy of the fuel flow totalizer included with the miles-per-gallon meter equipment. The amount of fuel consumed by the vehicle as indicated by the totalizer was compared with the amount of fuel purchased as shown in the fuel purchase receipts. The totalizers, on the average, indicated 5.5 percent more fuel consumed than shown by the purchase receipts. Table C-1 shows a summary of the data collected over the four collection periods.

TABLE C-1. TOTALIZER VERSUS FUEL RECEIPTS

Variable	Collection Period 1	Collection Period 2	Collection Period 3	Collection Period 4
% Error	+5.68	+4.04	+6.30	+6.07
Standard Deviation (%)	15.32	18.57	17.48	24.88
Number of Cars *	65	63	58	61

*Because data were not collected from every car during each collection period, the number of cars providing data is less than 70%.

Prompted by some very large discrepancies between the gallons consumed as measured by the fuel totalizer and the fuel purchase receipts during the first data collection period, a representative of FloScan checked a sample of the vehicles in question. His findings were as follows:

a. Cars with totalizer errors which are negative over 15 percent positive should have the input wiring checked. Two cars with large totalizer errors were found to have the installation incorrectly wired.

b. Cars with totalizer errors between zero and +15 percent were probably installed correctly according to FloScan instructions. Their errors come from heat expansion and pulsation effects. Heat can cause an error by expanding the gasoline before it goes through the flow transducer. The pulsation problem occurs during idling when the engine gets quite hot. It is an error which does not affect the mpg reading because it only occurs when the car is not moving. This error can be minimized by blocking off the return line from the fuel pump and returning fuel only from the flow transducer. The amount of this error in any totalizer reading depends on how much idling a driver does and how hot his engine gets. See Appendix D

At the request of FloScan, a slight modification was made to the fuel system of one of the vehicles, Control Number 2417, in an attempt to improve the accuracy of the totalizer. The modification consisted of blocking off the fuel return line from the fuel pump thus forcing all of the fuel through to the flow transducer. The bypass from the transducer was left connected to allow a portion of the fuel and the vapor bubbles to return to the fuel tank. Prior to the modification, which occurred eight days into the fourth collection period, the totalizer accuracy was for Collection Period 1, +10.5 percent; Collection Period 2, +21.6 percent; and Collection Period 3, +8.2 percent. After the modifica tion, the accuracy for collection period was +2.4 percent. Howeve a supplementary collection period held for this vehicle alone produced an error of +5.5 percent indicating the possiblity of further error increases with time.

A table showing totalizer accuracy for each of the vehicles over all four collection periods is given in Appendix D.

C.2 EQUIPMENT FAILURES

Two basic types of equipment failures were encountered. Whil the vehicle was moving, the mpg meter display indicated 80 miles per gallon (full scale) or the meter went to zero miles per gallon and remained. The more common failure was the meter going to full scale. This type of failure can be caused by either electronic module or fuel flow transducer malfunctions.

When a vehicle was encountered with the meter reading full scale with the vehicle in motion, the wiring was checked and the electronic module replaced. If that did not correct the problem, the fuel flow transducer was replaced.

During the very early portion of the program, two electronic module failures were experienced, both occurring within two days of installation. Also, five fuel flow transducers failed. Each of these operated satisfactorily when installed but failed under normal operating conditions within two days.

APPENDIX D

TOTALIZER ACCURACY

TABLE D-1. TOTALIZER ACCURACY (PERCENT)

CONTROL NUMBER	COLLECTION PERIOD 1	COLLECTION PERIOD 2	COLLECTION PERIOD 3	COLLECTION PERIOD 4
2189	+24.7	+29.8	-----	+127.5
2399	-----	+ 5.6	+ 5.9	+ 7.6
2362	-----	+14.0	-91.1	-----
2322	-28.6	+31.8	+11.3	+ 5.0
2417	+10.5	+21.6	+ 8.2	+ 2.4
2252	+ 4.5	+ 3.1	+ 4.6	-----
2221	-----	+ 4.7	-----	+ 7.5
2009	+ 2.2	+ 3.2	- 9.6	+ 2.4
2297	-20.3	+18.1	+ 8.6	+ 5.7
2245	+ 7.6	+ 4.2	+11.3	+19.1
2425	+ 5.4	+ 5.5	+ 5.6	+ 5.5
2298	+ 3.6	+ 1.6	- .6	-21.3
2316	-64.8	- 5.8	+23.7	+15.2
2152	+ 5.2	+ 4.0	+ 6.9	-18.4
2474	+10.5	+ 4.0	+ 3.9	-----
1990	+18.1	+ 4.4	+ 3.7	+ 2.9
2208	+ 7.6	-----	-27.8	+ 3.9
2479	+52.7	+ 5.0	+ 7.9	+10.8
2327	+ 4.7	-28.2	+ 4.7	+ 6.5
2469	+18.8	+ 4.6	+50.1	+56.6
1981	+13.1	+ 8.6	+ 6.0	+ 9.3
2018	+ 7.2	+ 2.8	-----	+ 5.8
2413	+ 7.3	+21.2	+ 9.5	+ 6.3
2408	+ 9.4	+10.2	+ 8.9	+ 9.0
2477	+ 3.5	+ 8.6	+ 3.5	+ 4.7
2256	+ 5.0	+ 4.6	+ 4.9	+ 3.9
2211	-----	-----	-----	+58.6
2461	+10.2	+ 9.2	+ 9.6	+16.4
2068	-26.8	-67.7	+63.7	-60.0
2187	- 7.2	+ 6.0	+ 5.5	- 1.0
2223	+ 7.9	+ 6.2	+ 5.4	+ 5.8
2375	+ 8.4	+14.3	+ 7.4	+ 9.2
2083	+15.0	+10.0	+ 8.6	-----
2321	+22.8	+ 6.3	+ 7.1	+ 4.9
2149	+ 9.6	+13.8	+12.4	+10.0
2017	+ 6.3	-----	+ 5.3	+ 6.5

\+ Totalizer gallons greater than fuel receipts gallons.
\- Totalizer gallons less than fuel receipts gallons.

TABLE D-1. TOTALIZER ACCURACY (PERCENT)(CONTINUED)

CONTROL NUMBER	COLLECTION PERIOD 1	COLLECTION PERIOD 2	COLLECTION PERIOD 3	COLLECTION PERIOD 4
2417	+49.2	+37.0	+ 4.7	+ 1.4
2298	+ 5.4	+ 4.5	+ 6.7	-----
2472	-10.3	+10.4	-----	+ 8.7
2437	+ 4.8	-22.4	+ 8.3	-----
2143	+ 8.5	+ 4.2	+ 3.7	+ 1.9
2450	+ 9.0	+20.8	+ 7.6	+ 6.9
2239	+ 9.4	+ 8.2	+10.2	-65.8
2274	+ 5.5	+ 5.9	+ 6.2	+ 5.3
2237	-----	+ 6.2	- .7	- 3.6
2086	+ 8.8	- 3.6	-----	+ .3
2249	+ 6.7	+ 7.2	+ 6.9	+ 9.8
2350	+10.1	+ 8.8	+ 7.8	+ 7.5
2338	+ 7.9	+ 9.2	-----	+49.2
2273	+ 9.0	- 9.4	+ 4.5	+ 6.5
2262	+ 7.3	+ 7.4	+ 9.0	+ 8.7
2465	+ 5.3	+ 3.9	-----	-30.7
2480	-14.3	+ 3.4	+ 3.4	+ 3.9
2368	-----	-----	+ 1.3	-----
2244	+17.0	+ 7.3	-----	+ 5.1
2216	- 1.6	- 1.6	- 1.0	- 3.1
2287	-17.4	+ 6.4	+ 6.7	+ 9.2
2452	+ 7.4	+21.6	+27.0	-----
2400	+ 3.8	+ 3.8	+ 5.8	+ 4.2
2296	+ 7.6	-----	-----	+ 5.4
2315	+ 5.9	+ 4.7	+ 2.6	-----
2455	+ .3	+ 4.8	+ 4.1	+ 6.1
2299	+ 6.3	+ 6.5	+13.5	+ 7.0
2475	+ 5.7	+16.3	-----	+ 5.6
2250	+10.1	-----	+ 7.9	+ 8.6
2483	+ 5.0	-67.4	+ 5.9	+ 6.2
2405	+ 3.5	-60.1	+ 4.3	+ 3.7
2191	-----	-----	-----	-----
2275	+ 9.8	-----	-----	+ 4.7
2288	+13.3	-----	+16.2	-40.4
2381	+ 7.6	+ 7.5	-----	+ 7.9
2061	+ 8.7	+17.3	+ 7.8	-----
Number of Cars	65	63	58	61
Error	+ 5.68	+ 4.04	+ 6.30	+ 6.07
Standard Deviation	15.32	18.57	17.48	24.88

APPENDIX E

REPORT OF INVENTIONS

Although, as expected, the field evaluation of driver aids did not result in any inventions, additional important knowledge was gained on the effect which miles-per-gallon meters have on increasing automobile fuel economy. Briefly, after extensive field testing of 140 fleet vehicles, analysis of the resulting miles-per gallon averages reveals no significant difference in fuel economy between those drivers who used a miles-per-gallon meter and those who did not.

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