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National Energy Efficient Driving System (NEEDS) Volume III–

A. J. McKnight
M. Goldsmith
D. Shinar

National Public Services Research Institute
123 North Pitt Street
Alexandria, Virginia 22314

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16. Abstract Eight vehicles were instrumented to permit travel distance and fuel consumption to be measured. Following the collection of baseline measures, three different systems were provided to feed back distance and fuel information to drivers: manual, a weekly trip log filled out by drivers; instrumented, an in-car device displaying the information; and mediated, a system in which information was summarized and discussed with drivers.

Results disclosed that approximately 70% of trips involved one-way distances of three miles or less. This greatly exceeds estimates of short trip travel obtained from drivers elsewhere. The introduction of feedback did not cause a reduction in either the number or proportion of short trips, nor was there any improvement in average mpg. Failure to achieve an effect is attributed to the drivers' failure to perceive a need for further increases in fuel efficiency, given the ready availability of fuel at the time the study was conducted.

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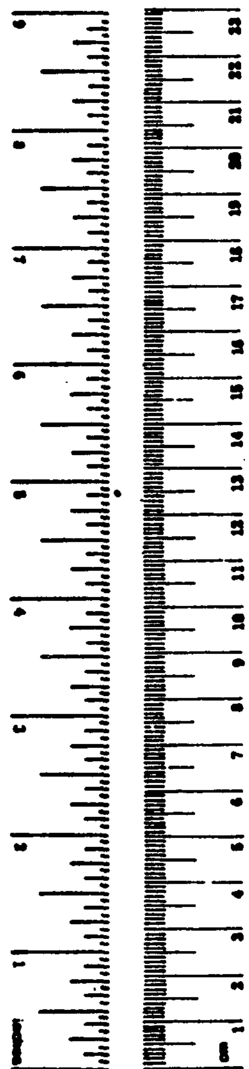
METRIC CONVERSION FACTORS

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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
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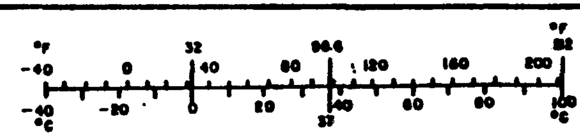
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		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



PREFACE

This volume describes the nature and results of a Home Vehicle Use Study undertaken to determine the effectiveness of various information feedback systems fostering more efficient use of family vehicles. The study was conducted by the National Public Services Research Institute (NPSRI) under contract to the National Highway Traffic Safety Administration (Contract No. DOT-HS-7-01775) and with the assistance of the Texas A & M University.

The study was part of a broad investigation of voluntary fuel consumption that constituted the National Energy Efficient Driving System (NEEDS) project. The following additional volumes describe other activities undertaken as a part of the NEEDS effort:

National Energy Efficient Driving System, Volume I: System Requirements. This report describes a broad range of energy-efficient driving behaviors, the information needed to influence those behaviors, the target audiences to be addressed, the materials needed to reach the target audiences, and the delivery systems capable of disseminating materials.

National Energy Efficient Driving System, Volume II: Driver Education Program. This report describes the development and evaluation of a broad program in fuel-efficient driving intended for students in driver education programs.

Dr. A. James McKnight served as the NPSRI Principal Investigator during the phase of the activity reported upon in this volume. Mr. Morris Goldsmith served as Project Administrator, supervising the preparation of materials and analysis of data. Dr. R. Don Williams, Texas Transportation Institute, served as Principal Investigator of the Texas A & M University subcontract and supervised the study activities described.

The authors are indebted to:

Dr. John Eberhard, NHTSA, Contract Technical Manager, for his advice and support throughout the NEEDS project.

Dr. David Shinar, Ben Gurion University of the Negev, for his assistance in preparing an initial draft of this report.

Mr. Michael Sadof, NPSRI Data Processing Manager, for carrying out the statistical analyses contained in this report.

Dr. N. R. Strader, Texas A & M University, for design of the equipment used to measure distance and fuel consumption.

The Prince Corporation for furnishing the in-car instruments used to provide fuel and distance feedback.

Ms. Ruth Freitas, Ms. Patricia Goll, and Mr. Eugene Fasnacht for preparing the report manuscript.

The eight families who permitted their vehicles to be instrumented and their trip characteristics to be measured.

INTRODUCTION

Home Vehicle Use

Transportation statistics indicate that over three-quarters of the automobile mileage is devoted to domestic travel--social, recreational, shopping, etc. Because that kind of travel generally involves short trips, the engine is cold during much of the drive. Consequently, these trips consume a disproportionate share of the fuel. Therefore, a reduction in the number of domestic trips through either consolidation or a combination of trips can lead to substantial fuel savings for the family and the nation. Trip consolidation involves combining several trips to the same place into one trip. Trip combination involves going to several places in succession rather than traveling to each one independently. The first approach leads to a reduction in number of trips and the number of miles, while the second approach reduces the number of trips, the number of miles, and the proportion of each trip driven with a cold engine.

Magnitude of Short-Trip Problem

While transportation statistics reveal the relative number of short trips for which family vehicles are used, they do not provide a good basis for estimating the amount of energy consumed on those trips. Most of the estimates of the relationship between trip length and fuel consumption are based upon analytic or laboratory studies. Based primarily upon vehicle characteristics, such studies do not take full account of the traffic conditions that characterize short trips.

In order to obtain some estimate of the magnitude of the problem created by short trips, a brief exploratory effort was undertaken prior to the study described in this report.

The travel patterns of three widely different cars used primarily for private personal transportation were studied. The vehicles were a 1977 Ford pickup, a 1972 Toyota, and a 1976 Ford Granada. All cars had automatic transmissions. Electronic sensors and recording equipment were installed in each car so that for each trip taken the total number of miles and the total amount of fuel consumed were recorded. The observation period lasted one week, during which 97 trips were made.

Although the absolute mpg levels varied widely among the three vehicles, the relationships between distance and mpg were similar for all vehicles. The results can be summarized as follows:

- o The distance-mpg curve appears to be a negatively accelerating one rising sharply from a very low point for trips under two miles and gradually leveling out for trips over ten miles.
- o Despite the obvious curvilinear relationship, the linear correlation between distance and mpg is quite high ($0.57 < r < .71$).

- The average trip length was quite low with median distances of 1.6 to 2.9 miles. Thus, defining short trips as trips less or equal to three miles is a convenient cutoff point, since it includes more than a half of all the trips.

- Fuel consumption for the very short distances (less than two miles) averaged about a half of maximum vehicle mpg. This probably reflects the effect of "cold starts" and driving in urban traffic.

- Fuel consumption over the mid-distance trip (2-9 miles) averaged about two-thirds of maximum vehicle mpg. This probably resulted from the stop-and-go nature of driving that characterizes most short trips, even though the engine may have warmed up somewhat after the first couple of miles.

- Fuel consumption rate for the long-distance trips (over 10 miles) was 90% of the maximum mpg and probably results from the use of limited access highways for substantial portions of the trip.

Reducing Short Trips

It is difficult to predict the potential savings to be obtained through trip consolidation and combination since there is no way of knowing how many short trips are unnecessary. However, eliminating those trips that are truly unnecessary and combining those that are necessary requires no sacrifice of travel objectives--only the time and effort it takes to plan ahead. Given the high cost of fuel, the benefit/cost ratio would seem to be incentive enough to make more efficient vehicle use a promising route to reduced fuel consumption.

Research of the literature has failed to reveal any program that has succeeded in getting families to use their cars more energy-efficiently. However, there have been many studies of home energy conservation showing that, under the right conditions, people can be motivated to reduce their consumption of energy.

One element of programs that have been successful in fostering long-term energy conservation has been a system of providing informational feedback to family members concerning the amount and source of their current energy consumption, ways in which they can reduce it, and how much they would be saving when they do succeed in reducing their consumption. Thus, the critical element appears to be one of feedback that relates the investment in either money or effort to the payoff in savings or fuel costs.

The research reviewed in Volume I demonstrated that drivers trained to conserve fuel can do so. What needed to be demonstrated was whether or not feedback is a sufficient incentive to motivate them to change their driving habits accordingly.

Previous attempts to provide an incentive to fuel saving in driving by giving drivers feedback on their fuel consumption have not been very successful. This may have been due in part to the need for drivers to keep "trip logs." The writing involved has proven to be too bothersome for drivers to keep them for more than a short time without some extrinsic incentive (e.g., money).

PURPOSE OF STUDY

The Home Vehicle Use Study described in this volume was undertaken to determine whether drivers could be induced to make more fuel-efficient use of their family vehicles if they were provided with informational feedback on the nature of their trips and the fuel consumed. The specific feedback to be provided was information that would show them the poor mileage realized in short trips and its effect upon their total fuel consumption.

The specific behavior change sought was a reduction in the number of short trips by consolidating trips to the same destination and combining different destinations into a single trip. In addition to pursuing this objective, an estimate of the need for informational feedback would be sought through a comparison of drivers' perceptions of their vehicle use with a measure of their actual use.

METHODOLOGY

The study methods involved measuring the mileage and fuel consumption of a sample of vehicles prior to and following the introduction of an informational feedback system. Measures collected prior to introduction of feedback would provide a picture of current trip characteristics, while a before-and-after comparison would show the effect of feedback. The measured trip characteristics, when compared with driver perceptions of vehicle use, would help provide an estimate of the public's need for informational feedback.

This discussion of experimental methodology will describe the vehicles whose mileage and fuel was measured, the equipment used for measurement, the informational feedback systems employed, and the procedures under which the experiment was conducted.

The Home Vehicle Use Study was conducted with the assistance of the Texas Transportation Institute, whose staff participated in the actual experimentation.

Vehicles

The fuel consumption of eight vehicles belonging to six families in College Station, Texas, was analyzed. Four of the vehicles came from two-car families, while the other four were from single-car families. This mixture was designed to allow the results of the study to reflect differences between vehicles that fulfill all family transportation functions and vehicles that primarily serve a single function, either commuting or family business. The characteristics of the vehicles are summarized in Table 1 below.

TABLE 1
CHARACTERISTICS OF VEHICLES USED IN THE STUDY

Veh. No.	Veh. Make	Veh. Model	Model Year	GVW	Trans.	Vehs./ Family
1	Ford	Pickup	1970	4200	Std.	1
2	Toyota	Wagon	1978	2300	Std.	1
3	Plymouth	Horizon	1980	2100	Auto.	1
4	Toyota	Corolla	1978	2100	Auto.	1
5	Ford	Esquire	1972	4200	Auto.	2
6	Chev.	Malibu	1978	3400	Auto.	2
7	Ford	Pinto	1974	2100	Std.	2
8	Mercury	Montego	1971	3800	Auto.	2

All vehicles were owned by members of the staff of Texas A & M University. Participation in the study involved some sacrifice of vehicle use while measurement equipment was installed. The University's involvement in the study provided a reason for participation by University staff and an incentive that could not be matched in an attempt to solicit vehicles from the general driving public.

The sample of families from which vehicles were obtained is certainly not representative of the driving public or any large identifiable segment of it. Under no circumstances could a sample of six families from any one location ever be considered "representative." However, there is no reason to believe that they are markedly different from other families in their patterns of vehicle use or with respect to factors that would determine responsiveness to an information feedback system.

It was important that drivers of the vehicles in the study not be aware of the study's objectives during the baseline data collection period, that is, the period prior to the introduction of feedback. If they had been, they might have altered their travel behavior. This would have prevented the baseline data from providing an accurate picture of their day-to-day travel. Moreover, any premature behavior change that produced a reduction in trips would make it difficult for feedback to show any effect.

The families were informed that the vehicles would be instrumented to permit a study of vehicle characteristics. They were not told that the vehicle information would be used as a way of studying their own travel characteristics. Each participant was paid $100 for the inconvenience the study entailed. They were told that the results of the measurements would be discussed with them after the data had been collected.

Measuring Equipment

In order to measure the effect of feedback upon trip characteristics, it was necessary to instrument all vehicles with a device that would record the distance and fuel consumption of individual trips.

Requirements

Any device used had to be capable of installation in the vehicle in a way that would prevent drivers from determining what was being measured. It also had to be small enough to occupy some area of the vehicle to which drivers did not require day-to-day access in order to avoid inconvenience to the drivers and prevent the device from being damaged.

The device most often employed to record distance and fuel consumption is a multichannel recorder in which different types of information are recorded on different strips of a magnetic tape. The cost of such equipment and the space it would require made it unsuitable for the proposed application. The most appropriate device was deemed to be a microprocessor in which information could be stored over a period of time and read out at periodic intervals.

Device Design

A device was designed by Dr. N. R. Strader of Texas A & M University and fabricated by the staff of the Texas Transportation Institute. Its design is described in detail in Appendix A.

The device, referred to below as the "Fuel Distance Trip Monitor" or simply "monitor," records distance and fuel consumption for up to 48 separate trips. The device is activated when the engine is started and records pulses from fuel and distance in a pair of counters until the ignition is turned off. The device automatically advances to the next pair of counters each time the ignition is turned on, unless the vehicle fails to move (i.e., a false start).

The fuel sensor is a turbine-type fuel meter installed in the fuel line. It is calibrated so that each pulse equals 1/1000th of a gallon. The distance sensor consists of two permanent magnets mounted on opposite sides of the drive shaft near the transmission end. Each rotation of the drive shaft sends a pulse to the monitor. Since the vehicle travel distance corresponding to the rotations of the drive shaft differs from one vehicle to another, the device must be calibrated over a known distance. The monitor is stored under the hood in a case that protects it from oil, water splash, etc.

Use of Device

The stored information is read out periodically by a research assistant. Three displays present the trip number, function (fuel or distance) and number of pulses. A manual advance allows the assistant to move from one trip and function to the next. The data are manually transcribed. Once all counters have been read out, a manual reset button clears all counters and prepares the monitor to receive data for the next series of trips.

Information Feedback Systems

Three approaches to information feedback were attempted, each representing a different point on a continuum of cost and potential effectiveness. The three types of feedback have been labeled, respectively, Manual, Instrumented, and Mediated feedback.

Manual

The simplest system was a printed form on which drivers manually recorded their fuel and distance at each fill-up. The form helped them to calculate their weekly fuel consumption as well as their mpg. The form was part of a booklet entitled "Are You Being Penalized By Short Trips?" that described how to save fuel by combining and consolidating trips. A copy of the booklet is provided in Appendix B.

Instrumented

The system that represented the midpoint of the continuum was an Instrumented system using a microprocessor that measured distance and fuel flow and displayed accumulated trip distance, fuel consumption, and mpg, as well as instantaneous mpg. The driver could select among these displays through a selector switch.

Mediated

The most expensive system was one in which feedback was mediated. Data obtained from the monitors were analyzed and used by the TTI staff to prepare "Weekly Trip Profiles" that totaled the number of trips, the amount of gas consumed, number of miles traveled, and miles per gallon, separately by trip length. A reproduction of the form appears on the following page.

This Mediated feedback provided a goal for the following week's travel. As such, it resembles strongly the type of feedback provided in most of the successful efforts to reduce home energy consumption. Research has shown goal setting to be an effective means of enhancing behavior change. Because of the expense of feedback systems mediated by outside agents, this form of feedback was not introduced until Manual and Instrumented feedback had been evaluated and proven ineffective.

FIGURE 1
WEEKLY TRIP PROFILE

Trips made by Vehicle Toyota (#2) for the week beginning January 28 and ending February 5

Data	Trip Length Comparison 0-3 miles	10 miles +	Total Trips
Number of trips made	24 (77%)	1 (3.2%)	31
Amount of gas consumed (gals.)	2.78 (53%)	.57 (11%)	5.25 gal
Number of miles traveled	32.7 (42%)	12.5 (42%)	77 miles
Miles per gallon	11.78	21.38	14.72 mpg

This week's number of short trips (0-3 miles)	24 trips
Target reduction	4%
Next week's short trip goal	20 trips

Experimental Procedure

Once the six families agreed to participate in the program, the monitors were installed on the eight vehicles. Baseline fuel and distance data were collected over a two-week period prior to introducing feedback.

First Feedback Phase

Following the collection of baseline data, the first feedback phase, lasting four weeks, was instituted. Half of the families received Manual feedback, while the cther half received Instrumented feedback. Each of these treatment groups consisted of two single-car families, and one two-car family.

For all families, the feedback system was introduced as something that "selected" members of the University staff were being asked to try out. The experimental families were told they had been selected because of their present participation in a vehicle-related study. The feedback devices were disassociated from the measuring equipment in order to avoid giving the impression the subjects' fuel consumption was being monitored. Such an impression might have created an incentive to conserve beyond that created by feedback alone.

During the first feedback phase, the only feedback available to the Instrumented feedback group was fuel consumption. This element of feedback involved far less installation cost than that involving mileage information. It was hypothesized that merely seeing the amount of fuel consumed in short trips could provide sufficient feedback to motivate a change in behavior. If this were true, there would be no point in going to the added expense of providing distance and mpg feedback.

During the four weeks following introduction of feedback, fuel and distance data were recorded and weekly fuel consumption compared with that over the baseline period. Unfortunately, as will be seen, the comparisons showed no marked reduction in the number of short trips or weekly fuel consumption, nor was there an increase in mpg.

Second Feedback Phase

When the first feedback phase proved unsuccessful, the second feedback phase began with the introduction of Mediated feedback. At the beginning of this phase, project staff met with each of the families individually and the fuel consumption records from the first feedback phase were reviewed. Fuel consumption for the previous week was plotted on the Weekly Trip Profile. The meetings in which fuel consumption records were received and discussed were, with the participant's permission, tape recorded for analysis.

Following the meeting, drivers were provided trip profiles once a week for the next four weeks. In addition, the distance sensor was connected to the in-car feedback devices to allow the Instrumented feedback group to receive all of the data the devices were capable of displaying.

Survey of Perceptions

As a means of determining how worthwhile it would be to provide feedback to the general public, a survey of driver perceptions of their own travel behavior and fuel consumption was undertaken. Because of restrictions on surveys performed under federally funded projects, the survey was conducted by NPSRI with its own resources.

To obtain a reasonably representative picture of driver perceptions, drivers seeking renewal of their driver's license were sampled. On any given day, drivers appearing at a licensing station to renew their licenses are a fairly representative cross section of drivers in general. The sample consisted of 113 renewal applicants seeking to renew their licenses at a large licensing station outside of Baltimore, Maryland. Because of its location, the station drew from urban, suburban, and rural areas.

On the day of the survey, renewal applicants were asked by the clerk processing their applications if they would be willing to take a moment to complete a short survey while paperwork was being completed. The clerks reported no refusals. The survey consisted of three questions concerning actual vehicle use, four knowledge questions, and four questions asking for driver opinion. The questions will be provided later in the discussion of results. A copy of the survey questionnaire appears in Appendix C.

RESULTS

The discussion of Home Vehicle Use Study results will include the trip characteristics of the subject population, the survey of driver perceptions, and the effects of the feedback systems. The subjective reports of the drivers participating in the study will also be discussed.

TRIP CHARACTERISTICS

Over the period in which travel and fuel consumption were monitored, the vehicles were used for approximately 3,000 trips totaling approximately 10,000 miles and consuming slightly over 500 gallons of gasoline. The division of trips, miles, and gasoline consumption by length of trip is presented in Table 2 below.

TABLE 2
TRIP CHARACTERISTICS OF EIGHT FAMILY VEHICLES OVER FOUR MONTHS

Trip Length	Trips		Distance		Fuel		Avg MPG
	N	%	N	%	N	%	
<1 mile	790	26.6	348	3.5	43	6.7	7.9
1-2 miles	833	28.0	1249	12.6	114	17.6	11.0
2-3 miles	453	15.2	1147	11.5	103	15.9	11.1
3-5 miles	505	17.0	1926	19.4	131	20.2	14.7
5-10 miles	225	7.5	1488	15.0	76	11.7	19.6
>10 miles	163	5.4	3753	37.8	179	27.6	20.9

Trip Length (Miles)		Trip Fuel (Gals.)		Miles Per Gallon	
Mean	3.33	Mean	.218	Mean	13.88
Median	1.83	Median	.147	Median	12.67
25th Percentile	.93	25th Percentile	.074	25th Percentile	8.53
75th Percentile	3.29	75th Percentile	.261	75th Percentile	18.07

Results from baseline and feedback phases have been combined in the table to maximize the reliability of the estimates. Since no consistent differences were ultimately observed across phases, the data may be legitimately merged to provide overall estimates.

As can be seen from the table, most trips are short trips and most of the gas is spent on those short trips. Median trip length for the sample of eight vehicles was 1.83 miles, the median amount of gas used on each trip was .147 gallons, and the median mpg was 12.67.

What is of particular interest is the effect of trip length upon average mpg. It is apparent that average mpg increases with the length of the trip. Trips under one mile average (7.93 ÷ 20.93 =) 38% of maximum mpg. At the median trip length of 1.83 miles, vehicles are achieving only (12.68 ÷ 20.93 =) 60% of maximum mpg. This means in about half their trips, drivers were realizing only 60% of the mpg their vehicles were capable of providing.

To determine the general relationship between trip length and fuel consumption, trip distance was plotted for each vehicle as a function of mpg. "Best fit" regression line appears in Figure 2. In all cases, the logarithmic relationship provided a close fit to the data, Pearson r correlations ranging from 0.6 to 0.9 between mpg and log miles.

Scatterplots for each vehicle are provided in Appendix D. It appears from the plots that the differences in fuel efficiency among the vehicles are manifested only for trips that are greater than one mile (log miles = 0). For shorter distances, all vehicles are equally fuel inefficient. The slope of the regression functions seems to be somewhat related to vehicle weight, the heavier vehicles having a lower slope and reaching a lower level of maximum fuel efficiency at the longer trips than the lighter vehicles.

SURVEY OF DRIVER PERCEPTIONS

It is advantageous at this point to review, for comparison purposes, the results obtained from the survey of renewal applicants. As explained earlier, this survey called upon drivers to describe their trip characteristics, as well as their knowledge of and opinions concerning fuel conservation.

Trip Characteristics

The drivers' estimates of the percentage of trips made, miles compiled, and fuel consumed in trips of varying distances appear in Table 3 below.

TABLE 3
DRIVER ESTIMATES OF TRIPS, DISTANCE, AND FUEL BY TRIP LENGTH

Trip Length	Trips	Distance	Fuel
< 1 mile	3.3%	4.8%	2.8%
1-2 miles	9.1%	8.2%	8.9%
2-3 miles	9.0%	9.1%	8.5%
3-5 miles	12.9%	11.3%	13.9%
5-10 miles	26.7%	23.8%	22.9%
> 10 miles	39.0%	42.8%	43.0%
	100.0%	100.0%	100.0%

Because the drivers were not always careful to see that their estimated percentages of trips added to 100%, it was necessary to make an adjustment to the total percentages so that they did equal 100%. The adjusted percentages appear in the table.

Internal Inconsistencies

A casual observation of the three columns of percentages would suggest very strongly that drivers were not able to distinguish clearly among the three questions. This is particularly striking when a comparison is made between the "trips" and "distance" columns. If people were consistent in their judgments, then the percentages under "distance" should equal the percentages under "trips" multiplied by the mean trip length. In fact, the "distance" percentages make it appear as if the number of miles driven on each long trip is the same as the number of miles driven on each short trip.

The relationship between the "trips" and "fuel" percentages is similarly inconsistent. Since it is obvious that long trips consume more gas than short trips, again one would have expected proportionately greater fuel to be expended on long trips. This, however, was not the case, and the "fuel" percentages are similar to "trips," implying that the amount of gas consumed is the same regardless of the trip length.

Comparison of Estimates with Measures

In addition to being internally inconsistent, drivers' estimates of their trip characteristics are at some variance with measurements of trip characteristics. Their estimates for the number of trips undertaken at various distances show much higher proportions of longer trips than do the measurements of trip length reported in Table 2.

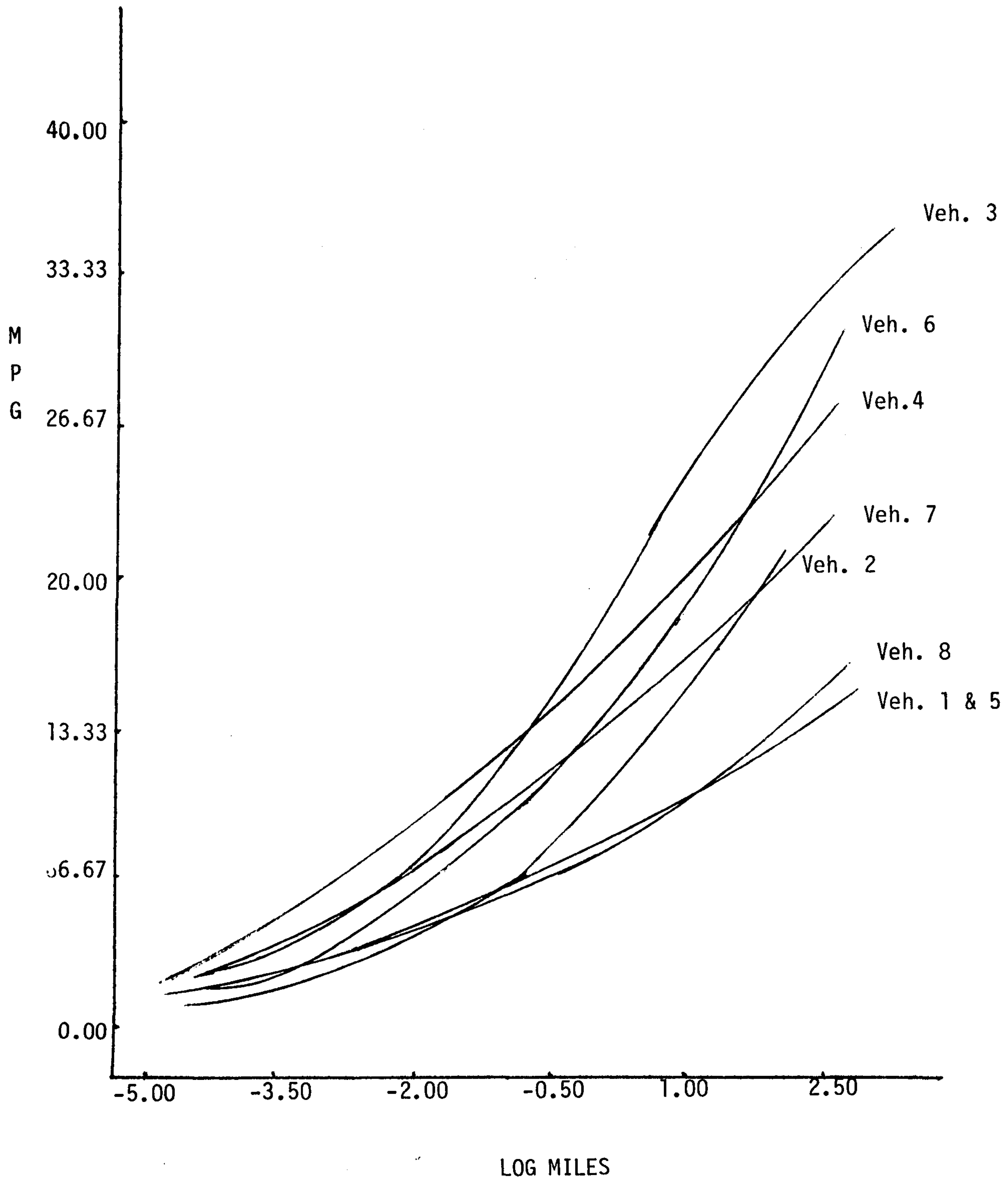
In part, the differences between Tables 2 and 3 may be attributable to what the renewal applicants considered a "trip." In making their estimates, they may have used round trips rather than one-way distance. For example, a trip to a shopping center two miles away may have been considered a single four-mile trip, whereas the monitor employed in the measurement of the trip characteristic would have recorded it as two trips of two miles. Yet, even allowing for such a difference of interpretation, the number of short trips is still underestimated. For example, renewal applicants estimated that 39% of their trips were over 10 miles long. Even if they really meant two trips of 5 miles in length, it exceeds the percentage of trips exceeding 5 miles in Table 2, which is only 13%. That is a threefold difference.

Because of their failure to recognize that long trips involve more miles and more fuel consumption than short trips, the renewal applicants inadvertently came up with reasonably accurate estimates of the percent of miles and the percent of gas consumed in trips of various lengths. If the simple arithmetic involved in estimating distance and fuel consumption had been accurately carried out, it is likely they would have also greatly underestimated the amount of distance and fuel involved in the shorter trips.

The estimates of trip length obtained from the survey and the measurements of trip length obtained from the sample of eight vehicles differed substantially. It is possible that some of this difference reflects true differences in the characteristics in the samples; the drivers surveyed may actually have had a lower percentage of short trips than the drivers whose trip characteristics were measured. However, it is difficult to attribute the difference entirely to differences in sample characteristics. It is likely that the renewal applicants underestimated the amount of their own driving taken up by short trips.

FIGURE 2

THE RELATIONSHIP BETWEEN MPG AND LOG MILES
FOR EIGHT VEHICLES



Knowledge of Fuel Consumption

Driver responses to the four knowledge questions are shown in Table 4 below.

TABLE 4
RESULTS FROM KNOWLEDGE QUESTIONS

1. Your car generally gets the best mileage on trips which are:

(2.7%) a. Under 5 miles long

(2.7%) b. 5-10 miles long

*(88.5%)c. Over 10 miles long

2. The trip pattern that would generally offer the best fuel economy would be:

*(84.1%)a. One 30-mile trip

(7.2%) b. A 15-mile trip in the morning and a 15-mile trip in late afternoon

(3.5%) c. Three 10-mile trips spread over the day

3. A vehicle which goes 10 miles on a gallon of gas when the engine is warm will go how far on a gallon when it is cold?

(18.6%)a. Over 9 miles

*(39.8%)b. About 8 miles

(34.5%)c. Under 7 miles

4. In cold weather, how far do you generally have to drive to reach maximum mpg:

*(37.2%)a. 15 miles

(31.9%)b. 6 miles

(23.9%)c. 2 miles

While it is not possible to infer a great deal from the responses to four questions, it seems reasonable to conclude that drivers:

- Know that short trips are less fuel-efficient than long trips (Questions 1 and 2).
- Do not know how much less fuel-efficient short trips are (Questions 2 and 3).

Opinions Concerning Fuel Consumption

Results obtained from the four opinion questions appear in Table 5 below.

TABLE 5
RESULTS FROM OPINION QUESTIONS

5. When deciding whether or not to drive somewhere, the cost of gas should influence you:

(38.9%)	a.	A lot
(36.6%)	b.	Some
(21.2%)	c.	A little

6. Of the trips people make in their cars every day, how many are really necessary?

(12.4%)	a.	Most
(20.4%)	b.	Many
(63.7%)	c.	Few

7. By planning their daily trips better, people could save:

(80.5%)	a.	A lot of gas
(13.3%)	b.	Some gas
(2.7%)	c.	A little gas

8. People should drive their cars:

(38.1%)	a.	Only when absolutely necessary
(42.5%)	b.	As little as possible
(15.0%)	c.	Whenever it's convenient

It would appear that the drivers, as a group, were favorably disposed toward fuel conservation. The great majority believed that:

- The cost of gas should influence the driving decision at least some.
- Only a few of the trips people take are really necessary.
- Better planning could save a lot of gas.
- People should minimize the amount of driving they do.

Summary

Drivers in general are favorably disposed toward fuel efficiency in general and better travel planning in particular. They are aware that short trips are fuel inefficient. However, they do not seem to realize how inefficient short trips are or how much of their driving is consumed by them.

EFFECTS OF FEEDBACK SYSTEMS

The effects of the Instrumented and Manual feedback systems were studied by comparing changes in trip characteristics from the baseline to first feedback phase within each of the two feedback groups. The effect of the Mediated feedback program was measured by comparing the changes from first to second feedback phases within each group.

The trip characteristics studied were fuel consumption, number of trips, and mileage (mpg).

Fuel Consumption

The weekly fuel consumption of the eight vehicles in the baseline and two feedback phases is summarized in Table 6 below.

TABLE 6
CONSUMPTION OF FUEL BY FEEDBACK SYSTEM AND PHASE

	PHASE			
FEEDBACK	Baseline	Feedback-1	Feedback-2	Total
Manual	8.6	5.3	5.6	6.5
Instrumented	5.9	5.3	5.2	5.5
Total	7.3	5.3	5.4	6.0

An analysis of variance performed upon the data in the table fails to show a significant effect for feedback system or phase or for the interaction between the two. However, the major comparison of interest is that between the baseline phase and the two feedback phases. A test of contrasts shows this difference to be significant ($p = .02$).*

To determine whether or not the reduction in fuel consumption was due to the feedback systems, the changes in trip characteristics over the three phases were examined. The next two sections examine the number of trips and vehicle miles per gallon.

---

* Analysis of variance tables for all comparisons discussed in determining the effects of feedback appear in Appendix E.

Number of Trips

If the feedback systems were successful in encouraging trip consolidation, one would expect a reduction in the number of trips the families took per week. The effect would, presumably, be greatest for short trips, that is, those under three miles in length. Table 7 below shows the total trips and the number of short trips per week, as well as the proportion of trips that were short trips.

TABLE 7
NUMBER OF WEEKLY TRIPS BY FEEDBACK SYSTEM AND PHASE

	Instrumented			Manual		
Trips	Baseline	FB-1	FB-2	Baseline	FB-1	FB-2
Total	31.9	28.3	31.7	26.5	22.3	24.1
Short	22.7	19.4	22.4	13.8	16.1	19.0
Proportion	.711	.686	.710	.520	.722	.788

There appears to be a slight reduction in total number of weekly trips between the baseline and first feedback phase, with a falling back during the second feedback phase. However, neither the overall differences among phases, nor the difference between the baseline and combined feedback phases was statistically significant.

Short trips, like total trips, evidenced no significant differences across phases or between baseline and feedback phases. Curiously, the Manual feedback group seems to show an increase in the number of short trips over the three phases. However, the absence of a significant interaction between feedback system and phase suggests that the trend is not statistically significant. Nor is there any rational explanation for it.

Failing to find a reduction in the absolute number of short trips, one might expect a decrease in the proportion of short trips to total trips. It is apparent from the table above that no such decrease exists. In fact, the proportion actually seems to rise among families in the Manual feedback group.

Among the differences shown in the table, the only ones that are statistically significant are those between types of feedback, those receiving the Manual feedback having significantly fewer weekly trips, both total trips and short trips. Since these differences prevail across the three phases, they cannot be attributed to any characteristic of the feedback systems themselves but must be related to characteristics of the families driving the vehicles.

From the analysis of the trips, it does not appear that the decrease in total fuel consumption noted in Table 6 can be attributed to a reduction in either the number of total trips or the number of trips under 3 miles in distance.

Vehicle Miles Per Gallon

If the reduction in fuel consumption over the three phases is not due to changes in the number of trips, or the distance traveled, it must be due at least in part to the way the vehicles are driven. Such changes might be expected to show up in vehicle miles per gallon. An analysis of mpg for the total number of trips and those under three miles appears in Table 8 below.

TABLE 8
MPG BY FEEDBACK SYSTEM AND PHASE

	Instrumented			Manual		
Trips	Baseline	FB-1	FB-2	Baseline	FB-1	FB-2
Total	17.6	16.9	19.2	16.6	12.2	11.4
Short	13.4	13.0	14.2	12.7	9.4	9.7

The most noteworthy finding in the table is the difference between the Manual and Instrumented feedback groups. The Manual feedback group experienced a decrease in mpg between the baseline and feedback phases. This may be attributed, at least in part, to the previously noted increase in the number of short trips. The Instrumented feedback group experienced an increase in mpg between the first and second feedback phases. This may be due to the fact that the ability of the Instrumented feedback to display mpg was not utilized until the second feedback phase.

The significance of the separate trends for tne two feedback groups was not tested. It would not have been legitimate to apply significance tests to differences that emerged from the data in the first place. However, the interaction between phase and feedback system was significant for all trips ($p = .03$) and almost significant for short trips ($p = .06$).

As in the case of trips, mpg showed significant differences between two feedback groups, this time favoring groups that received the Instrumented feedback. However, since they appeared in the baseline as well as feedback phases, they cannot be attributed to the type of feedback system.

DRIVER REPORTS

Because of the small sample size and large variations in driving habits and vehicle characteristics, the drivers' observations concerning their travel habits and the usefulness of feedback may be considered as important as the quantitative data obtained from their vehicles. The following comments made by the drivers were taken from the tape recordings made during the meetings at the beginning of the second feedback phase.

1. All drivers said they were already trying to save fuel one way or another.

2. To a greater or lesser extent, all claimed they were familiar with the information presented in the pamphlet.

3. Three of the four drivers who received the Instrumented feedback said it was "useful" or that they "used it" but did not specify how it was useful or how they used it. One thought it was a "nuisance."

4. One couple stated they always kept a log of fuel purchases and odometer readings so that they were constantly aware of their fuel consumption.

5. Although not all drivers planned all their trips in advance, all said that they already combined trips.

6. Individual comments on fuel saving techniques they had already been using included the following:

    a. One man bicycled as much as possible.

    b. In one two-car family, there was a tendency to use the more efficient car whenever possible.

    c. One woman pooled all her shopping and child-related trips with a friend.

    d. One woman stated she plans all her trips in the beginning of the week so she can combine them to the maximum extent possible.

    e. A woman stated that whenever she stops the car to talk, she does not leave the motor idling.

    f. One man stopped using his own car for work-related trips and now uses only the University car for that purpose.

When confronted with a weekly log of all their trips, 7 out of the 8 drivers expressed surprise at the large number of trips that they took and said they had "no idea" what all these trips were or where they came from. Although, at the end of the interviews, drivers typically agreed to set a new goal of fewer short trips, they rarely succeeded in reaching their goal.

DISCUSSION

There are obvious limitations to the generality of results obtained from a sample of only six families. However, if the drivers who were surveyed and those whose fuel consumption was measured resemble the public at large, the following can be said of drivers in general and their home vehicle use:

- They recognize the importance of reducing fuel consumption and the amount of fuel wasted on unnecessary trips.
- They recognize that short trips are less fuel efficient than long trips, but do not realize how much less.
- They underestimate the number of short trips they take and, therefore, the amount of fuel consumed on them.
- When confronted with the number of short trips they take, they recognize the need for more efficient home vehicle use, but do not make the changes needed to achieve it.

The results do not make the prospects of achieving more efficient use of home vehicles very promising. If a Mediated feedback system involving measured fuel consumption and mileage along with a personalized profile of weekly fuel consumption doesn't succeed in changing behaviors, it is hard to imagine what will succeed.

Obstacles to Efficient Home Vehicle Use

Probably one of the greatest obstacles to more efficient home vehicle use is the need for planning. To consolidate or combine trips, the driver must think ahead. Other routes to fuel savings can be effected at the moment the driver realizes the need for them. A driver who recognizes he is overaccelerating can come off the accelerator. A driver who is fed up with footing the bill for a gas guzzler can go out and buy another vehicle. However, the driver who suddenly realizes he needs a loaf of bread, a package of fuses, or another pound of hamburger has already missed the opportunity to combine the trip with an earlier one.

Doubtless, drivers could reduce the number of short trips if they felt they had to. They could make the effort needed to plan ahead or, having failed to do so, could postpone fulfillment of their immediate travel objectives until a later trip. Right now, it would appear that most families are unwilling to make this effort.

A few of the drivers interviewed were quite candid in acknowledging their disinclination to alter travel habits. One who had recently purchased a highly fuel-efficient vehicle claimed he had done so specifically to avoid the need to change his travel habits. Others, while not so outspoken, probably shared similar feelings--if not when they were being interviewed, at least at the time their travel decisions were being made.

Potential Fuel Savings

It is difficult to estimate the amount of fuel that could be saved by a reduction in short trips. The data collected during the study do not permit any determination of how many of the short trips taken could have been combined or consolidated. Trip logs were eschewed as a data-gathering device because of the danger that the act of keeping them might alter the very behavior they were to measure. Besides, merely knowing the nature and purpose of trips would not have enabled one to determine which ones were necessary and which ones were not.

Deciding whether any one trip is truly necessary involves a purely subjective trade-off between the urgency of travel objectives and the urgency of fuel consumption. The only way to accurately estimate how much fuel could be saved through a reduction in the number of short trips is to provide an incentive to trip reduction equivalent to that prevailing under short fuel supplies and see how individual drivers resolve the competition.

In the sample of drivers studied, approximately 40% of fuel was consumed in trips under 3 miles. If one-half of these trips could be eliminated through consolidation and combining of trips, the overall reduction in fuel consumption would be 20%. A reduction of this size does not approach that attainable through the purchase of more fuel-efficient vehicles. However, as a fuel conservation measure, it offers the following combination of virtues:

> Immediacy--Short trip reduction can be effected immediately in response to fuel shortage. Vehicle downsizing, on the other hand, is an evolutionary process, requiring time both for fuel-efficient vehicles to enter the fleet and for fuel-inefficient vehicles to leave the fleet.
>
> Scope--Almost every family can take advantage of short trip reduction. Many other measures, such as use of mass transit, are available to only a segment of the driving population.
>
> Certainty--Fuel saved by trips not taken is fuel that is not consumed. The savings resulting from many other fuel conservation measures end up being consumed elsewhere. For example, much of the fuel saved in carpooling is consumed in picking up and dropping off passengers and by making other use of the vehicles that are freed by the carpool.
>
> Magnitude--While perhaps small in relation to the benefits of vehicle downsizing, the fuel savings through short trip reduction exceed the savings possible through, for example, improved operating techniques, tune-ups or improved maintenance.

Prospects of More Efficient Vehicle Use

What are the long-range prospects for achieving more efficient use of family vehicles?

Effects of Fuel Shortages

From the results of research surveyed in Volume I, it appears that there have been two periods during which drivers were motivated to economize in fuel--in 1974 and in 1978, when fuel was in short supply and long lines appeared at the gas pumps. During these crises, drivers forsook the use of their personal automobiles in favor of carpooling, mass transit, and simply not traveling. Once the crises had passed, there was a drift back to normal travel patterns. Fortunately, the two crises and the steep rise in fuel costs following each stimulated the purchase of smaller vehicles. This, in combination with general downsizing of the vehicle fleet, has produced a continuing reduction in fuel consumption.

As long as fuel is readily available, cost alone does not appear to be sufficient to alter travel habits. Nor should it really be expected to. At the time this report is written, cost of fuel--approximately $1.30 a gallon--is still modest. When inflation is taken into account, it is no more expensive than it was approximately 30 years ago.

Future Prospects

When fuel supplies are again curtailed, and long lines return to the service stations, drivers will be again motivated to conserve in order to lengthen the period of time between fill-ups. A permanent curtailment may give rise to some form of rationing, which will motivate voluntary changes in travel behavior just as it did in World War II. The question is whether drivers will include a reduction in short trips among their conservation efforts.

Based upon the information gathered in this study, the likelihood that drivers will seek to improve fuel economy through a reduction in short trips does not appear to be great unless a strong effort is undertaken to encourage it. This speculation is based upon the drivers' underestimates of both the number of short trips they take and the fuel penalty these trips entail.

There is also the experience of the two previous fuel crises, during which conservation was achieved primarily by reduction in the number of long trips (e.g., summer vacations). Obviously, part of the reduction in long trips had to do with the uncertainty of fuel availability. However, even where drivers could reach a distant location and return on a tankful of gas, it seems likely that they were more mindful of the fuel expended in such long trips than they were of that consumed in their numerous short trips.

Before drivers can be expected to include a reduction in short trips among their fuel conservation measures, they will need to know much more about the magnitude of short trip fuel penalties than they do now. The need for such information must be addressed by those governmental and private sector organizations that have traditionally undertaken to educate the public with regard to fuel conservation.

Measuring Device

One other finding of the study that warrants mention is the effectiveness of the Fuel Distance Trip Monitor in providing reliable measures of distance and fuel consumption. The success of the monitors in this regard represents one of the few positive "findings" of the study. The following characteristics all contributed to its success:

> Unobtrusiveness--Because its small size allowed it to be tucked away under the hood, the device did not influence the driver whose behavior was being measured.
>
> Reliability--None of the devices failed from internal malfunctions or the effect of heat, cold, or vibration.
>
> Cost--Because they were made from off-the-shelf components, the devices were quite inexpensive to build. Cost of labor and materials was in the neighborhood of $300 per unit.

The major limitation of the device was the need to manually transcribe accumulated data on a periodic basis. The need to keep the device small and inexpensive precluded the use of magnetic or paper tape readouts. The need for manual transcription could be overcome by modifying the device to permit data to be read onto magnetic tape. If the devices were to be used in long-term data gathering for either research or operational purposes, such a modification would be desirable.

The monitors would probably have their most valuable use in fostering efficient use of fleet vehicles. While travel patterns in many fleets are determined by prescribed routes or by dispatchers, in many other fleets the travel pattern is left primarily to drivers, e.g., sales and delivery personnel. In such situations, the installation of monitors on vehicles would allow fleet managers to study the trip characteristics of drivers for both research and operational purposes. Unless they were told, drivers would not know the devices had been installed. If they did become aware of the devices, they could not tamper with the data. In most fleets, it would not be difficult to bring vehicles to one location on a daily or weekly basis so that data could be read out of the monitors.

Efforts at the present time to seek more efficient vehicle use may prove more effective among commercial fleets than among individual families for the following reasons:

- The savings realized through more efficient vehicle use become highly significant when extended over a large number of vehicles.
- Because commercial fleets are part of a business enterprise, fleet managers are likely to be more responsive to cost considerations than are individual families.
- Fleet managers are in a better position to maintain the records needed to assess the effects of short-trip reduction efforts than are families.
- Fleet managers control financial incentives for modifying behavior that are missing in most families.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the Home Vehicle Use Study, the following conclusions are offered:

- Somewhere between 50% and 70% of travel by family vehicles involves trips having a one-way distance of three miles or less.
- Drivers underestimate the amount of their travel devoted to short trips.
- While aware that short trips are fuel-inefficient, drivers are not aware of the extent of the inefficiency.
- The provision of feedback on fuel, distance, and mpg does not reduce the amount of proportion of travel involved in short trips.

No specific action is recommended at the present time. However, at such time as the fuel available for personal transportation becomes curtailed, the following action at the federal level is recommended:

- Information and education materials describing the magnitude of the short-trip penalty, as well as the techniques of trip consolidation and combination, should be prepared and disseminated to seek reduction in the number of short trips taken by the driving public.
- Research should be initiated to assess the cost-effectiveness of various ways of providing individualized feedback on short trips and their relation to fuel consumption.

APPENDIX A

FUEL DISTANCE TRIP MONITOR
INSTRUCTION MANUAL

prepared under contract to
NATIONAL PUBLIC SERVICES RESEARCH INSTITUTE

by
Dr. N.R. Strader II, P.E.
Consultant

TABLE OF CONTENTS

1.0 OPERATION

Operation of the Fuel/Distance Trip Monitor includes some automatic and some manual functions. The fuel and distance measuring and storage functions are performed automatically. Display of previously stored trip data and clearing the trip data file are the only operations requiring user interaction. Two pushbutton controls, RESET and ADV (advance) are provided to control display and storage of trip data. See Figure 1.

1.1 RESET The RESET pushbutton clears the display and resets the internal trip pointer to the first trip. Depressing and releasing the button performs this function. This button will normally be used at the beginning of a read-out sequence.

In addition, the RESET button is used in conjunction with the ADV (advance) button to clear the trip history file. The RESET button must be held down while the ADV button is pressed and released. The simultaneous two button operation is required to minimize the possibility of accidentally clearing the trip history file. Either button, by itself, will not clear the file.

1.2 ADV The ADV (advance) pushbutton is used to sequence through the stored data for previous trips. The stored data includes trip number (1 to 32), fuel usage, and distance traveled. The first time the ADV button is pushed after RESET has been pushed, the number 01 will be displayed indicating trip number one. The second push of ADV causes the fuel for trip number one to be displayed. A small LED indicator labeled FUEL also lights to indicate the fuel display. The third push of ADV causes the distance traveled to be displayed and the LED labeled DIST to light.

Subsequent pushes of the ADV button cause data for other trips to be displayed. The sequence of trip number, fuel usage, and distance traveled is repeated. After the distance traveled for the most recent trip is displayed, the sequence starts over with the number 01 displayed again. The sequence can be restarted with trip number one at any time by pushing the RESET button once to reset the internal trip display pointer.

1.3 OVERFLOW Two kinds of overflow are possible. First, more than 32 trips could be made before the trip history file is cleared. Since no memory is available to store data after the 32nd trip, any additional fuel

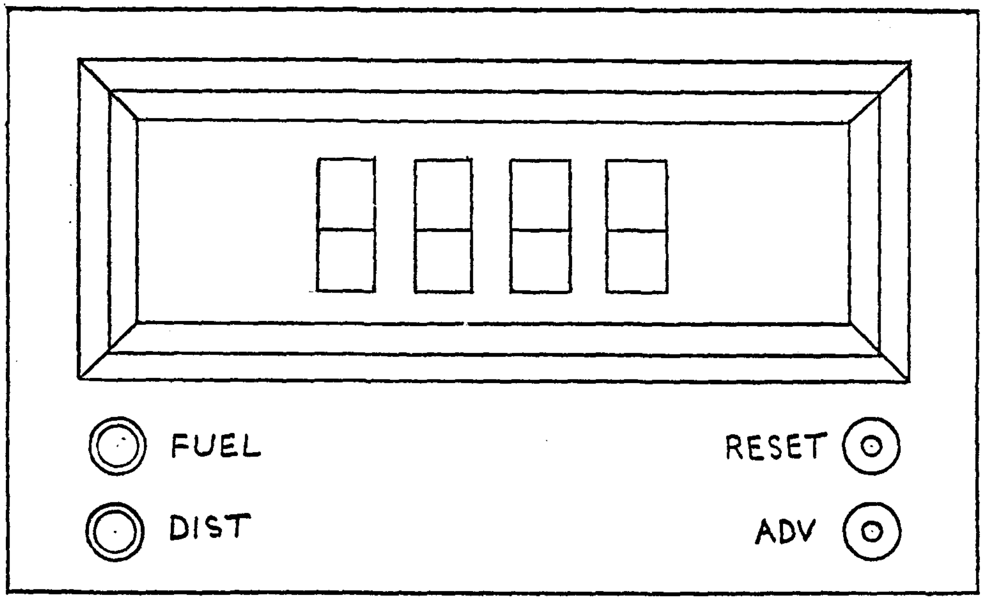


Figure 1 - Front Panel Display and Controls

and distance results are lost. The data stored for the first 32 trips remains valid. Normal operation should include recording trip data and clearing the data file prior to the 33rd trip.

Secondly, it is possible to overflow the fuel and/or distance displays. It is highly unlikely that the fuel display range (approximately 99.99 gallons) will be exceeded. The distance display range of 99.99 miles is more likely to be exceeded. However, the internal distance counter has a range of over 650 miles. If a trip of more than 99.99 miles (for example, 142.62 miles) were made, the display would drop the most significant digit and display the last four digits (42.62 miles in this example). No overt indication of an overflow condition would be given. However, the correspondingly large fuel usage and the odometer reading should allow a determination and correction of the overflow data.

2.0 DESIGN DESCRIPTION

The Fuel/Distance Trip Monitor is an instrument designed to measure and remember the fuel usage and trip length for a sequence of automobile trips. The instrument consists of a fuel transducer, a rotational transducer, an ignition ON/OFF sensing connection, and an electronics package. A four digit decimal display device and control pushbuttons are also included.

2.1 FUEL TRANSDUCER The fuel transducer is an impeller type flow meter manufactured by Zemco. The transducer is mounted in series with the fuel line between the fuel pump and carburetor. The transducer is applicable to gasoline powered cars except those with fuel injection.

Fuel flow causes an impeller to turn at a rate proportional to fuel flow. This impeller drives a second impeller which interrupts a light beam between an incandescent light source and a photo diode. Each time an impeller blade passes between the light source and the photo diode, a corresponding change of current through the photo diode is sensed by the electronics package.

2.2 DISTANCE TRANSDUCER The distance transducer consists of a sensing device and a set of small permanent magnets. The two permanent magnets are attached to opposite sides of the drive shaft near the transmission. The sensing device is mounted to the car chassis near the permanent magnets on the drive shaft. The sensing device is positioned beside the drive shaft near the path of the permanent magnets.

As the car moves and the drive shaft turns, the permanent magnets move past the sensing device. A small current is induced in the sensing device each time a permanent magnet passes. This current is sensed by the electronics package and converted to distance.

2.3 IGNITION ON/OFF The ignition ON/OFF sensing connection is used to control the trip fuel and distance memory. A source of 12 volts which is switched ON and OFF by the ignition switch is required for this sensing function. While the instrument is powered, the fuel and distance sensors are active. Each time the ignition switch is turned OFF, the current fuel and distance counts are stored in the trip memory and the fuel and distance count accumulators are set to zero. The storage function is conditional on a non-zero fuel value. This prevents a false trip if the ignition is cycled.

2.4 ELECTRONICS PACKAGE The electronics package consists of wave shaping electronics, counting circuitry, memory devices, display electronics, display devices, and pushbutton inputs. The package is continuously powered from the automobile's 12 volt electrical system. Almost all active components of the electronics package are of the CMOS type to minimize the current drain on the automobile battery. When the display is OFF, the total drain is about 50 milliamperes or approximately one-tenth that of a car radio.

The wave shaping electronics consists of RC filters and CMOS inverters connected as amplifiers. These devices minimize extraneous noise and convert the input signals to levels compatible with digital electronic components. These input signals arrive from three external sources including 1) the fuel sensing transducer, 2) the distance transducer, and 3) the ignition sensing connection. In addition, the RESET pushbutton and the ADV pushbutton are sensed as inputs.

The counting circuitry, memory devices, and display electronics are provided by a simple microprocessor system. This system is comprised of a microprocessor, a permanent memory device, a read/write memory device, digital inputs, and digital outputs. The microprocessor, guided by a firmware instruction sequence stored in the permanent memory device, controls the other components to perform the fuel/distance trip monitoring function. The read/write memory device is used to store the fuel usage and distance traveled for up to 32 separate trips. The digital inputs sense the information from the various transducers and pushbuttons, while the digital outputs are used to drive the decimal and indicating LED displays.

The display devices consist of a four digit decimal display and two function indicating LED's. The decimal display can show fuel usage in the form XX.XX gallons, distance traveled in the form XX.XX miles, and trip number in the form b̸b̸XX (b̸ indicates a blank display digit). The fuel and distance quantities are set for an "average" car. The exact values depend somewhat on the average fuel flow rate and particularly the tire size and differential gear ratio. A scale factor can be developed (see Calibration Section) to convert the displayed quantities to correct fuel and distance. The two indicating LED's are used to show whether the four digit display is fuel or distance.

The pushbutton inputs are used to control the display of fuel and distance data for each trip. The RESET pushbutton always clears the display and resets the trip pointer to the first trip. The ADV (advance) pushbutton is used to step through the stored trips in the sequence of trip number, fuel used, and distance traveled. If the ADV pushbutton is pushed while the RESET button is held down, the entire trip memory is cleared.

3.0 INSTALLATION

There are three main subassemblies for the Fuel/Distance Trip Monitor. Installation of each subassembly and subsequent system interconnection are described in the following paragraphs and in Figure 2.

3.1 FUEL METER The fuel meter is to be installed in the fuel line between the fuel pump and the carburetor. The fuel meter should be installed in an upright position away from engine heat for proper operation. Flexible gasoline hose can be used to connect the fuel meter.

A suitable metal bracket should be fabricated to mount the fuel meter. This bracket can be connected to the fuel meter using one of the small bolts holding the two halves of the fuel meter together. Do not remove more of these small bolts than necessary to prevent breaking the seal of the internal fuel meter gasket. The other end of the bracket should be connected to the car body or the engine block at a convenient place. The fuel meter should be positioned away from engine heat in an upright, level position with the hard white plastic cylinder with the two spade lug connectors toward the top. The fuel meter will be less accurate if mounted in a nonvertical position. Intense engine heat may cause premature failure of the fuel meter. Do not mount the fuel meter above the engine block where it will receive stagnant engine heat after the engine is shut off.

On many cars, a metal fuel line connects the fuel pump and the carburetor. A convenient method of connecting the fuel meter requires that a section be cut from the fuel line. The fuel line should be removed from the car during the cutting operation and cleaned afterwards to prevent a potentially harmful residue of metal filings from remaining in the fuel line. With a section of the fuel line removed, gasoline hose can be placed over the fuel pump side of the cut line and run to the underside of the fuel meter. A second section of gasoline hose can be run from the top of the fuel meter to the carburetor side of the cut line. All four connections should be clamped with a hose clamp of the proper size.

3.2 DISTANCE TRANSDUCER The distance transducer consists of a sensing device and two permanent magnets. The two permanent magnets are to be mounted on opposite sides of the drive shaft near the transmission end of the drive shaft. The magnets must be positioned on opposite sides of the drive shaft

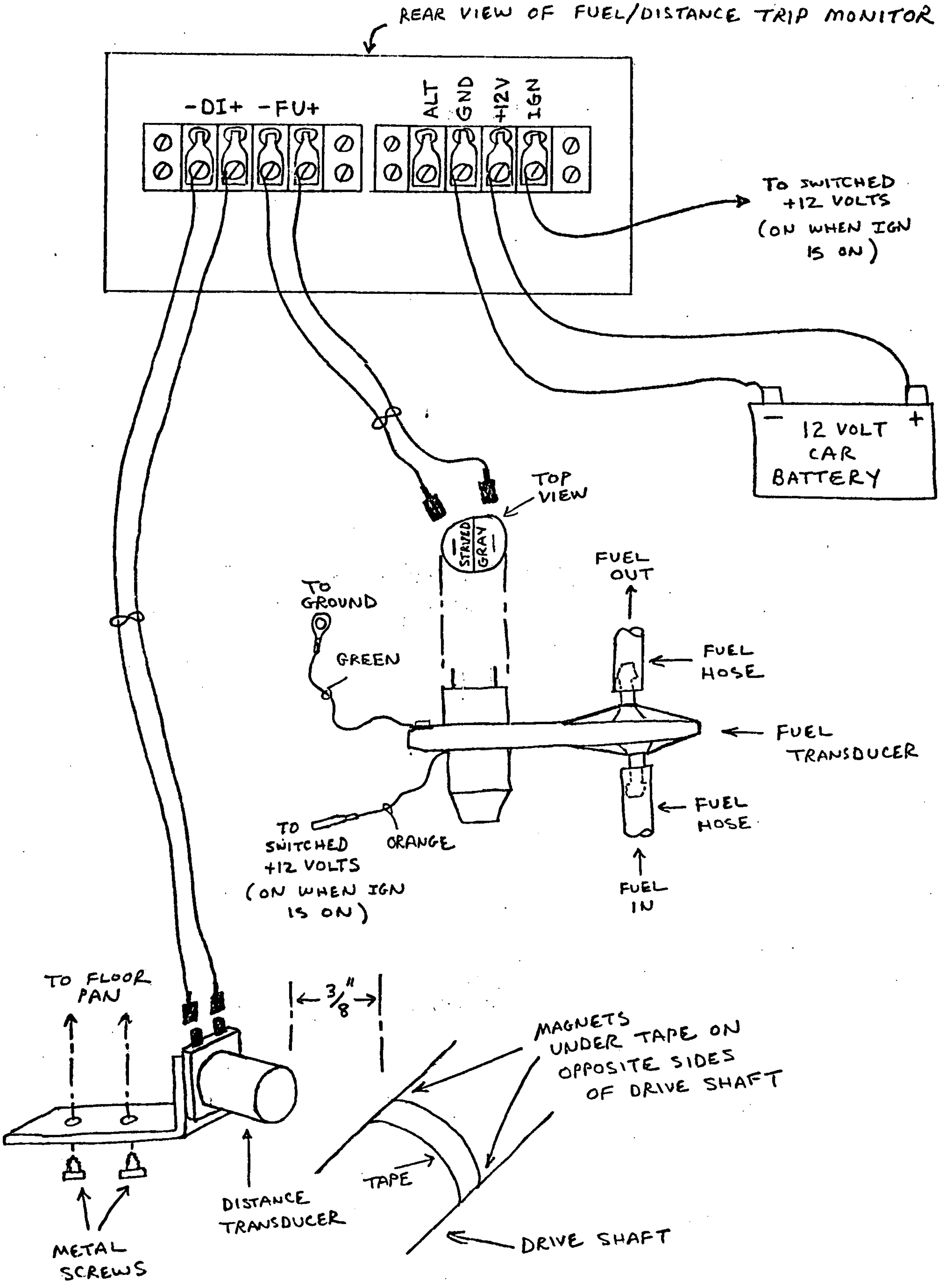


Figure 2. System Interconnection

to minimize any unbalance of the drive shaft. A section of strong fiber tape can be used to cover and hold the magnets in place on the drive shaft. The tape should be wound around the drive shaft in the direction opposite to the normal rotation of the drive shaft. A spot of glue should be used to cover the end of the tape to prevent fraying.

The sensing device should be mounted to the car body at the side of the drive shaft in line with the path of the permanent magnets. The metal mounting strap should be attached to the floor pan of the car so that the sensing device can be positioned between one-fourth and three-eighths of an inch from the permanent magnets. The sensing device is to be mounted beside, rather than above or below, the drive shaft to minimize the effects of vertical drive shaft motion. Prior to operation of the car, verify that adequate clearance exists between the sensing device and the permanent magnets as the drive shaft is turned through a complete revolution.

3.3 ELECTRONICS PACKAGE The electronics package can be placed in the trunk of the car or at a convenient point inside the car. Engine compartment mounting is discouraged. The package is not sealed against water and must not be placed where road splash or rain can penetrate the cover. Although the electronics package can be attached to the car, it is probably more convenient to leave the package free so that it can be repositioned when data readings are taken.

If the electronics package is to be mounted to the car, the six cover retaining screws should be removed and the cover lifted off. Obtain two small "L" brackets, drill mounting holes in each side of the cover, and bolt the "L" brackets to the cover. Attach the cover to the electronics package and then bolt the entire assembly to the car using the "L" brackets.

3.4 SYSTEM ELECTRICAL CONNECTION After the fuel meter and the distance transducer are in place and a position has been chosen for the electronics package, the three devices must be interconnected. The connection of each device is described in the following paragraphs. When running interconnecting wires, be sure to keep the wires away from moving parts or high heat points. See Figure 2 for pictorial details.

The fuel transducer requires connection to the car's electrical system and to the electronics package. The connection to the car's electrical system provides power for the fuel transducer light source. The green wire from the fuel meter should be attached to a ground connection. Almost any metal in the engine compartment will suffice. The orange wire should be connected to a switched 12 volt source which is at 12 volts only when the ignition switch is ON. The "hot" or "+" side of the ignition coil is a possible connection point.

The two spade lug connection points on top of the fuel transducer are to be connected to the rear of the electronics package. A twisted-pair, shielded cable of 18 to 22 gage wire is sufficient. The fuel transducer spade lug marked "GRAY" should be connected to the electronics package terminal screw marked "FU+". The other spade lug marked "STRIPED" should be connected to the terminal screw marked "-FU".

The distance transducer only requires a connection to the electronics package. Use a twisted-pair, shielded cable of 18 to 22 gage wire to make the connection. Connect one spade lug (either one) of the distance transducer to the terminal screw marked "-DI". Connect the remaining spade lug to the terminal screw marked "DI+". Be sure that the cable is routed away from the drive shaft and exhaust systems.

Power for the electronics package must be provided from an unswitched source of +12 volts. This could come from the battery or possibly from the car's lighting system. Connect this wire to the terminal screw marked "+12" and run a corresponding wire from a ground point (car frame) to the terminal screw marked "GND". This connection will power-up the electronics package. The current drain on the battery is small and will not significantly discharge the battery under normal circumstances. Use 18 gage wire for this run.

The remaining connection is to provide the ignition ON/OFF sensing function. An 18 to 22 gage wire should be connected to a point which is powered only when the car ignition switch is ON. The other end of this wire should be connected to the terminal screw marked "IGN".

3.5 PRELIMINARY TEST After the connections in Section 3.4, the electronics package should be operational. Test the unit by pressing RESET followed by ADV. At this point, the number 01 should be displayed on the LED display. If there is no display, check the power connections and insure that +12 volts and ground are present. If these connections are good, momentarily disconnect and reconnect the wire at the +12 volt terminal screw. Use the RESET and the ADV buttons to bring up the 01 display.

3.6 ALTERNATE BATTERY SOURCE On some automobiles, turning the ignition switch to START and activating the starting motor solenoid creates a virtual short circuit condition across the car's battery. Where this is the case, the battery voltage may drop below about 5 to 7 volts momentarily due to this "short circuit". Although this is a temporary condition, a voltage of less than five volts may cause the Fuel/Distance Trip Monitor to forget the stored trip values and require a reset.

An alternate external battery can be connected with the positive battery terminal to the terminal screw marked "ALT" and the negative battery terminal to the terminal screw marked "GND". This will prevent loss of trip data in the Fuel/Distance Trip Monitor due to a momentary low voltage from the car's electrical system. A 9 volt transistor battery is sufficient for this purpose. The current drain on the 9 volt battery is insignificant since it supplies current (about 50 milliamperes) for only a fraction of a second each time the car is started. The main limitation on the lifetime of the 9 volt battery will be from environmental causes. The 9 volt battery should be replaced every three to six months.

4.0 CALIBRATION

The Fuel/Distance Trip Monitor needs to be calibrated for each installation on a different model car. Both fuel calibration and distance calibration should be performed. The fuel calibration will remain fairly stable from car to car. The distance calibration will depend significantly on tire size and differential gear ratio. Suggested calibration techniques are given in the next two sections. Note that valid trip data can be accumulated during the calibration trips.

4.1 FUEL TRANSDUCER CALIBRATION The fuel transducer calibration will vary slightly with different fuel flow rates, different transducers, and different mounting positions. The fuel transducer output drives an electronics package which provides a 4 digit readout in hundredths of a gallon for an "average" car. This readout and actual fuel intake can be used to provide a calibration factor.

This calibration factor can be obtained in much the same way that an individual would determine gas mileage. The necessary steps are to:

1) Install the Fuel/Distance Trip Monitor.
2) Fill the car's gas tank completely with the car on level ground.
3) Drive the car normally, accumulating trip fuel and distance data for more than half a tank of gas (10 gallons).
4) Repeat step 2 and record the quantity of fuel required.
5) Total the accumulated fuel data over the trips between steps 2 and 4.
6) Determine the ratio of fill-up fuel quantity from step 4 to the accumulated fuel total from step 5. This ratio can then be multiplied by the fuel reading for any single trip to obtain the actual fuel used.

For example, assume that the gas tank was filled and 10 trips were made. The fuel readings for these 10 trips were 0.89, 0.50, 1.45, 3.20, 2.45, 0.68, 0.30, 0.88, 1.30, and 0.45 gallons for a total accumulated fuel usage of 12.10 gallons. Assume that 11.35 gallons were required to refill the gas tank. The ratio of 11.35 gallons to 12.10 gallons gives a calibration factor of 0.938. This factor should be multiplied by the single trip fuel readings to obtain the actual fuel used. In the first trip above, 0.89 gallons was the trip fuel reading. The actual fuel used was 0.89 x 0.938 = 0.83 gallons.

Since the car fill-up fuel may vary due to car position and air pockets in the gas tank, a more accurate calibration can be obtained by repeating the procedure above for more than one tank of gas.

4.2 DISTANCE TRANSDUCER CALIBRATION The distance transducer calibration will vary significantly with tire size and differential gear ratio. The distance transducer output drives an electronics package which provides a 4 digit readout which roughly corresponds to hundredths of a mile. This readout and odometer readings from the car can be used to provide a calibration factor.

This calibration factor can be obtained during the same trips used to obtain the fuel calibration factor. The necessary steps are to:

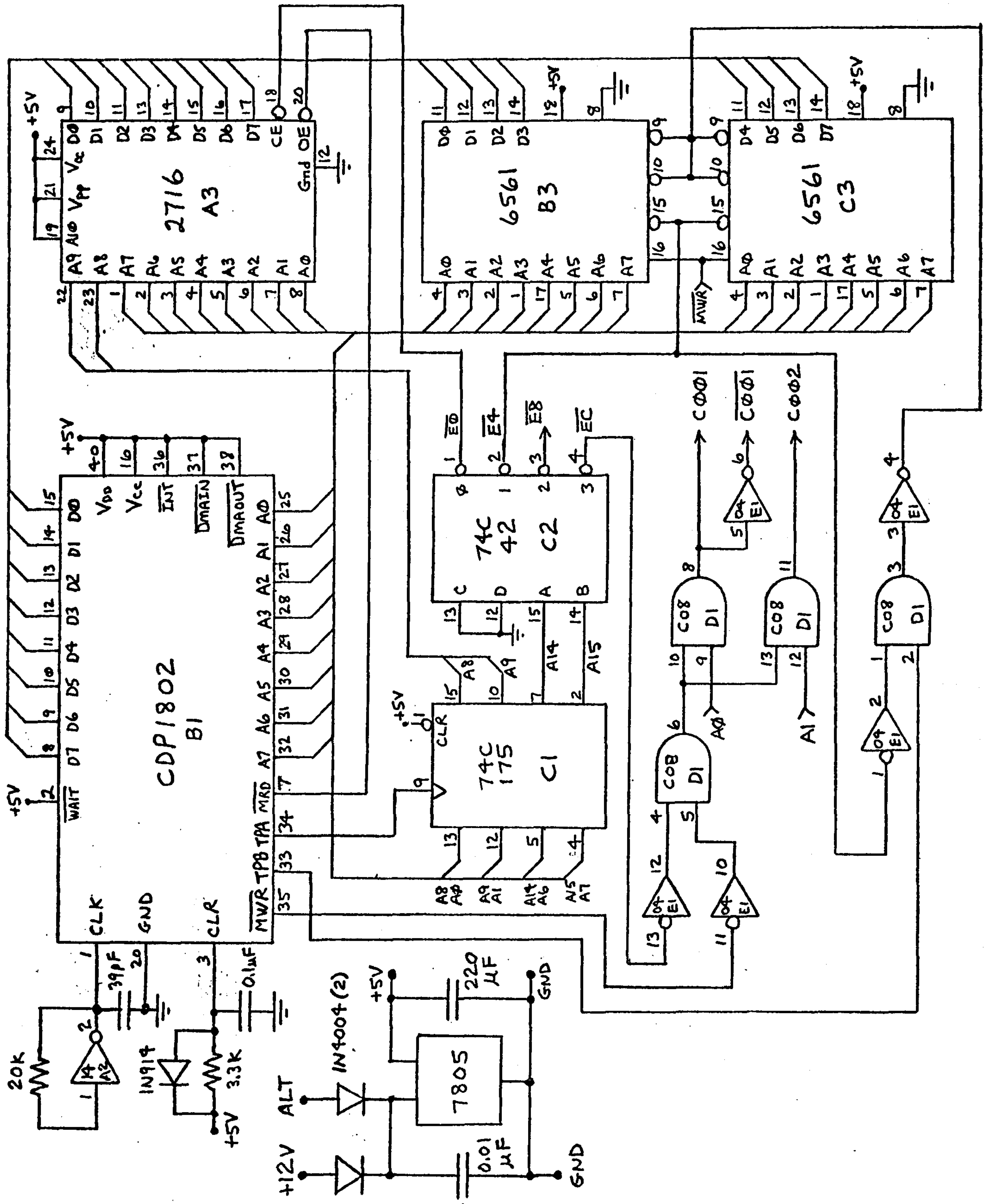
1) Install the Fuel/Distance Trip Monitor.
2) Read and record the car's odometer with the car on level ground.
3) Drive the car normally, accumulating trip fuel and distance data for several trips (preferably 100 miles or more).
4) Repeat step 2 and calculate the difference in odometer readings.
5) Total the accumulated distance data over the trips between steps 2 and 4.
6) Determine the ratio of odometer determined distance from step 4 to the accumulated distance total from step 5. This ratio can then be multiplied by the distance reading for any single trip to obtain the actual distance traveled for that trip.

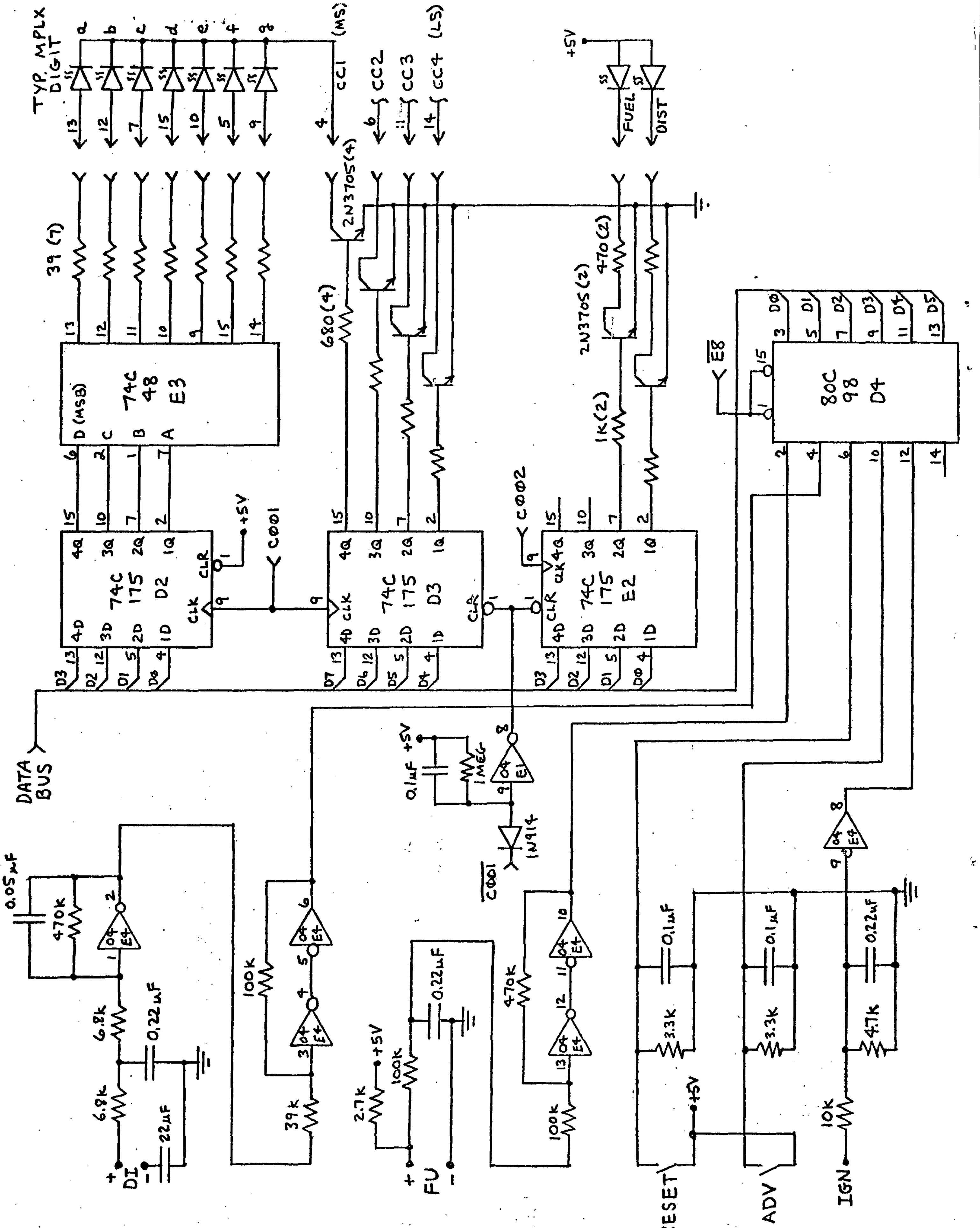
For example, assume that the odometer read 10384.6 in step 2 and that 6 trips were made. The distance readings for these trips were 5.30, 15.45, 25.66, 2.34, 54.34, and 18.45 miles for a total accumulated distance of 121.54 miles. Assume that the odometer reading in step 4 was 10545.1 for a traveled distance of 160.5 miles. The ratio of odometer distance (160.5) to accumulated trip distance (121.54) gives a calibration factor of 1.321. This factor should be multiplied by the single trip distance readings to obtain the actual distance traveled. In the first trip above, the trip reading was 5.30. The actual distance traveled was 1.321 x 5.30 = 7.00 miles.

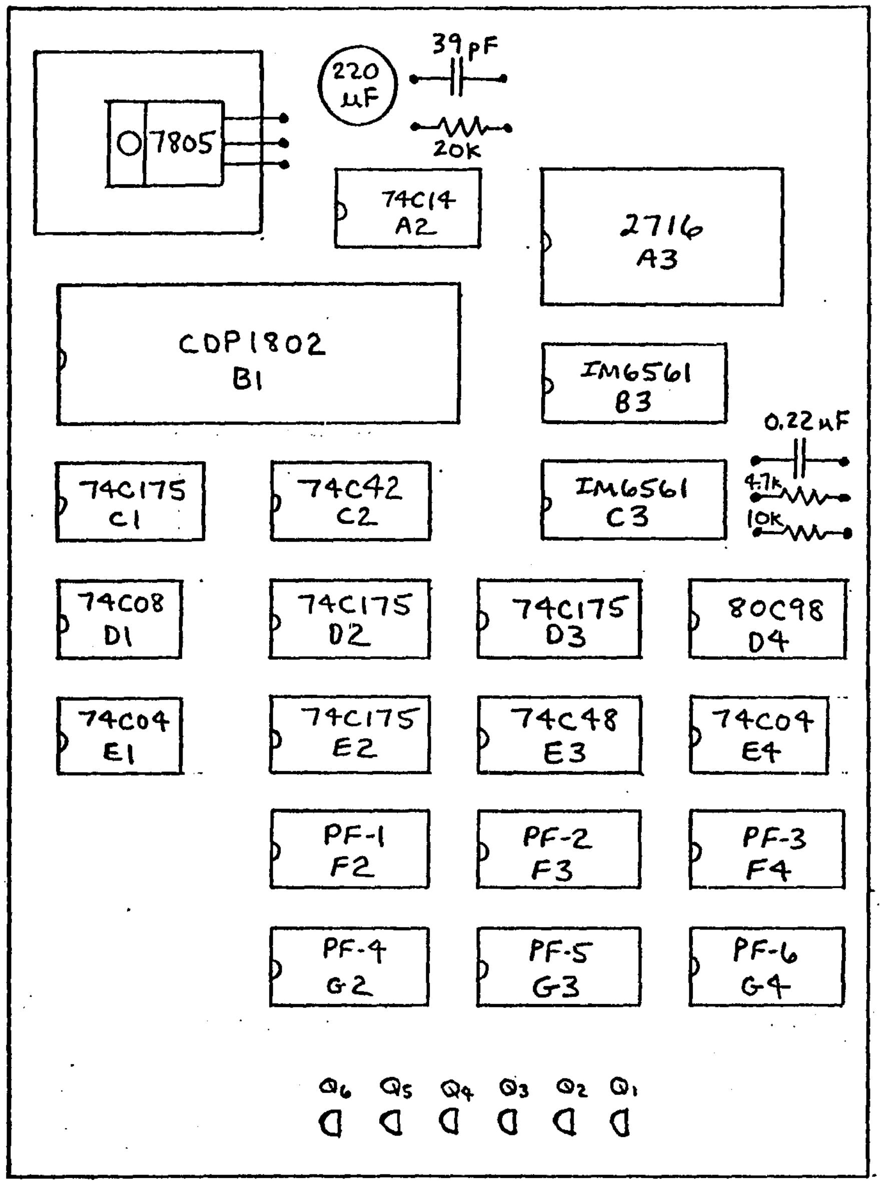
As with fuel calibration, a more accurate calibration can be obtained by repeating the procedure for several trips. It would be a good idea to read the car's odometer each time the accumulated trip totals were read and recorded.

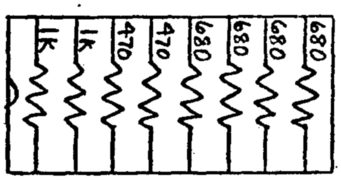
APPENDIX 1

LOGIC DIAGRAMS

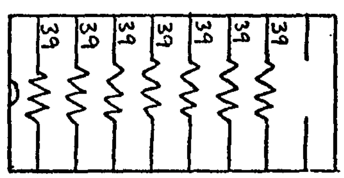

CDP1802
B1
2716
A3
6561
B3
6561
C3
74C
42
C2
74C
175
C1
C08
D1
04
E1
7805
+5V
+12V
ALT
GND
1N4004(2)
1N914
20K
3.3K
39pF
0.1µF
220 µF
0.01 µF
C0Φ1
C0Φ2
MWR
A0
A1
A8
A9
A14
A15


TYP. MPLX DIGIT
a b c d e f g
(MS)
CC1 CC2 CC3 CC4 (LS)
+5V
FUEL DIST
2N3705(4)
2N3705(2)
39 (7)
470(2)
680(4)
1K(2)
74C 48 E3
D (MSB) C B A
80C 98 D4
E8
D0 D1 D2 D3 D4 D5
74C 175 D2
74C 175 D3
74C 175 E2
C001
C002
CLK CLR
4Q 3Q 2Q 1Q
4D 3D 2D 1D
DATA BUS
0.1µF
1MEG
1N914
04 E1
04 E4
0.05µF
470k
6.8k
0.22µF
22µF
100k
39k
2.7k
3.3k
4.7k
10k
DI
FU
RESET
ADV
IGN

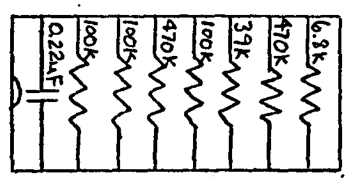




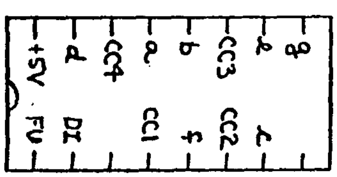
PF-1



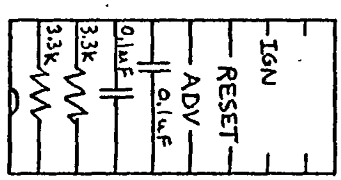
PF-2



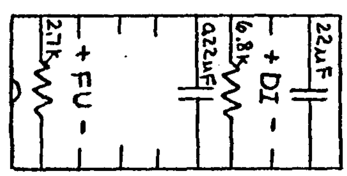
PF-3



PF-4



PF-5



PF-6

APPENDIX 2

CONTROLLER FIRMWARE

```
                    ***************************************************
                    **  REGISTER DEFINITION AND USAGE
                    **  R0 - MAIN PROGRAM COUNTER
                    **  R2 - BCD CONVERSION SUBROUTINE
                    **  R3 - BCD DIGIT CONVERSION SUBROUTINE
                    **  R4 - POINTS TO DISPLAY SUBROUTINE
                    **  R5 - R5.0 USED AS DISPLAY STATUS FLAG
                    **       - R5.1 SAVES RESIDUE ON INPUT PROCESSING
                    **  R6 - CONTAINS THE DISPLAY TIME-OUT COUNT
                    **  R7 - R7.0 USE AS TEMP DATA
                    **       - R7.1 USED TO SAVE CURRENT DATA IMAGE
                    **  R8 - STATUS INPUT POINTER
                    **  R9 - FUEL COUNT
                    **  RA - DISTANCE COUNT
                    **  RB - RB.0 DIVIDE COUNT FOR DISTANCE
                    **       - RB.1 DIVIDE COUNT FOR FUEL
                    **  RC - DISPLAY LATCH POINTER
                    **  RD - BCD DISPLAY FILE POINTER
                    **  RE - PASSES BINARY DATA TO BINDEC
                    **  RF - BINDEC USES TO POINT TO POWER OF TEN TABLE
                    *************************************************
                    ** INITIALIZATION PROGRAM **
           00B1 DECE EQU  $B1      BCD CONVERT SUBROUTINE
           00F0 DISE EQU  $F0      DISPLAY SUBROUTINE
           00CE DSTE EQU  $CE      BCD DIGIT CONVERT
0000                 ORG  INIS
0000       FFFF INIT FDB  SMI+$FF   DOUBLE NOP
0002       F8C0      FDB  LDI+$C0
0004       BC        FCB  PHI+C
0005       F840      FDB  LDI+$40
0007       BD        FCB  PHI+D
0008       FE        FCB  SHL       SET D TO $80
0009       B8        FCB  PHI+8
000A       FE        FCB  SHL       SET D TO ZERO
000B       A8        FCB  PLO+8     SET R8 TO $8000
000C       AC        FCB  PLO+C
000D       1C        FCB  INC+C     SET RC TO $C001
000E       BF        FCB  PHI+F     CLEAR RF HI BYTE
000F       B5        FCB  PHI+5
0010       A5        FCB  PLO+5     CLEAR R5
0011       B6        FCB  PHI+6
0012       A6        FCB  PLO+6     CLEAR R6
0013       B2        FCB  PHI+2
0014       B3        FCB  PHI+3
0015       B4        FCB  PHI+4
0016       F8B1      FDB  LDI+DECE
0018       A2        FCB  PLO+2     SET R2 TO BDC CONVERT SUBROUTINE
0019       F8CE      FDB  LDI+DSTE
001B       A3        FCB  PLO+3     SET R3 TO BCD DIGIT CONVERT
001C       F8F0      FDB  LDI+DISE
001E       A4        FCB  PLO+4     SET R4 TO DISPLAY ROUTINE
001F       F808      FDB  LDI+$08
0021       AD        FCB  PLO+D     SET ADR TO $4008
0022       F87F      FDB  LDI+$7F
0024       5D        FCB  STR+D     SET HIST FILE 'OUT' POINTER
0025       1D        FCB  INC+D     NEXT ADR
0026       F880      FDB  LDI+$80
0028       5D        FCB  STR+D     SET HIST FILE 'IN' POINTER
0029       92        FCB  GHI+2     GET ZERO
002A       AD        FCB  PLO+D     SET TO BCD DISPLAY FILE
002B       08        FCB  LDN+8     GET SWITCH STATUS DATA
002C       B7        FCB  PHI+7     SAVE LAST DATA
002D       3030      FDB  BR+PROG   MAIN PROG ADR
```

```
               ***************************************************************
          0030 PROG EQU  $30
          0300 PAG3 EQU  $0300
          0030 FUSC EQU  48       FUEL SCALE COUNT
          0018 FUS2 EQU  24       1/2 FUEL SCALE CNT
          0032 DISC EQU  50      DISTANCE SCALE CNT
          0019 DIS2 EQU  25      1/2 DIST SCALE CNT
               ** MAIN PROGRAM LOOP *******************************
0030                ORG  PROG
0030      92   SUSL FCB  GHI+2     GET ZERO
0031      B5        FCB  PHI+5     CLEAR RESIDUE HOLD
0032      16        FCB  INC+6     COUNT TIME DELAY
0033      96        FCB  GHI+6     LOOK AT DELAY
0034      32A1      FDB  BZ+CLRD   TIME TO TURN DISPLAY OFF
0036      D4        FCB  SEP+4     CALL DISPLAY
0037      E8   SKPD FCB  SEX+8     INDEX TO INPUT STATUS
0038      97        FCB  GHI+7     GET LAST DATA
0039      F3        FCB  XOR
003A      FA1F      FDB  ANI+$1F   SELECT ACTIVE BITS
003C      3230      FDB  BZ+SUBL
003E      B5        FCB  PHI+5     SAVE CHANGES
003F      F0        FCB  LDX       GET NEW DATA
0040      B7        FCB  PHI+7     SAVE AS CURRENT DATA
0041      95        FCB  GHI+5     GET CHANGES
0042      F2        FCB  AND       PICK OFF ZERO TO ONE TRANSITIONS
0043      3230      FDB  BZ+SUBL   NONE THERE
               ** PROCESS BIT 0 - FUEL COUNTER
0045      F6   BIT0 FCB  SHR
0046      3B63      FDB  BNF+BIT1 BIT 0 NOT SET
0048      B5        FCB  PHI+5     SAVE RESIDUE
0049      08        FCB  LDN+8     GET INPUT STATUS
004A      FA01      FDB  ANI+$01
004C      3262      FDB  BZ+BAT0   GO AWAY IF NOT THERE
004E      9B        FCB  GHI+B
004F      FC01      FDB  ADI+1     INCREMENT DIVIDE CNT
0051      BB        FCB  PHI+B
0052      FB30      FDB  XRI+FUSC IS IT MAX CNT?
0054      3A62      FDB  BNZ+BAT0 SKIP IF NOT THERE
0056      BB        FCB  PHI+B     SET CNT TO ZERO
0057      19        FCB  INC+9     INCREMENT FUEL
0058      85        FCB  GLO+5     GET DISPLAY STATUS
0059      FA01      FDB  ANI+1     TEST FOR BIT 0
005B      3262      FDB  BZ+BAT0   NOT ON DISPLAY
005D      89        FCB  GLO+9
005E      AE        FCB  PLO+E
005F      99        FCB  GHI+9
0060      BE        FCB  PHI+E
0061      D2        FCB  SEP+2     CALL CONVERT
0062      95   BAT0 FCB  GHI+5     GET RESIDUE BACK
               ** PROCESS BIT 1 - DISTANCE COUNTER
0063      F6   BIT1 FCB  SHR
0064      3B7F      FDB  BNF+BIT2 BIT 1 NOT SET
0066      B5        FCB  PHI+5     SAVE RESIDUE
0067      08        FCB  LDN+8     GET INPUT STATUS
0068      FA02      FDB  ANI+$02
006A      327E      FDB  BZ+BAT1   GO AWAY IF NOT THERE
006C      1B        FCB  INC+B     INCR DIV CNTR
006D      8B        FCB  GLO+B
006E      FB32      FDB  XRI+DISC IS IT MAX CNT?
0070      3A7E      FDB  BNZ+BAT1
```

```
0072     AB          FCB   PLO+B      RESET TO ZERO
0073     1A          FCB   INC+A      INCR DISTANCE
0074     85          FCB   GLO+5      GET DISPLAY STATUS
0075     FA02        FDB   ANI+2      TEST FOR BIT 1
0077     327E        FDB   BZ+BAT1    NOT ON DISPLAY
0079     8A          FCB   GLO+A
007A     AE          FCB   PLO+E
007B     9A          FCB   GHI+A
007C     BE          FCB   PHI+E
007D     D2          FCB   SEP+2      CALL CONVERT ROUTINE
007E     95    BAT1  FCB   GHI+5      GET RESIDUE BACK
               ** PROCESS BIT 2 - RESET BUTTON
007F     F6    BIT2  FCB   SHR
0080     3BA7        FDB   BNF+BIT3E  BIT 2 NOT SET
0082     B5          FCB   PHI+5      SAVE RESIDUE
0083     98          FCB   GHI+8      GET $80
0084     FF01  BBT2  FDB   SMI+1
0086     3A84        FDB   BNZ+BBT2   WAIT FOR CNT
0088     08          FCB   LDN+8      GET INPUT STATUS
0089     A7          FCB   PLO+7      TEMP SAVE
008A     FA04        FDB   ANI+$04
008C     32A6        FDB   BZ+BAT2E   EXIT IF NOT SET
008E     F808        FDB   LDI+$08    GET 'OUT' PNTR ADR
0090     AD          FCB   PLO+D
0091     F87F        FDB   LDI+$7F
0093     5D          FCB   STR+D      RESET HIST FILE 'OUT' PNTR
0094     85          FCB   GLO+5      GET DISPLAY STATUS
0095     FAFC        FDB   ANI+$FC    TURN OFF REAL TIME DISPLAY
0097     A5          FCB   PLO+5
0098     87          FCB   GLO+7      RESTORE
0099     FA08        FDB   ANI+$08    CHECK FOR ADV ALSO
009B     32A1        FDB   BZ+CLRD    BR IF NOT THERE
009D     85          FCB   GLO+5      GET DISPLAY STATUS
009E     F901        FDB   ORI+$01    SET TO FUEL CNTR
00A0     A5          FCB   PLO+5      SET DISPLAY STATUS
00A1     92    CLRD  FCB   GHI+2      GET ZERO FROM R2.1
00A2     AD          FCB   PLO+D      SET DISPLAY POINTER TO ZERO
00A3     C0          FCB   $C0
00A4     0300        FDB   PAG3
00A6     95    BAT2E FCB   GHI+5
00A7     C0    BIT3E FCB   $C0
00A8     030D        FDB   PAG3+BIT3
0000                 ORG   PAG3-$0300
0000     5D          FCB   STR+D
0001     1D          FCB   INC+D
0002     5D          FCB   STR+D
0003     1D          FCB   INC+D
0004     5D          FCB   STR+D
0005     1D          FCB   INC+D
0006     5D          FCB   STR+D      CLEAR BCD DISPLAY FILE
0007     1C          FCB   INC+C
0008     5C          FCB   STR+C      CLEAR LED INDICATORS
0009     2C          FCB   DEC+C      BACK TO 7 SEG LED
000A     8C          FCB   GLO+C      GET A $01
000B     B6          FCB   PHI+6      RENEW DISPLAY TIME OUT CNT
000C     95    BAT2  FCB   GHI+5      GET RESIDUE BACK
```

```
                          ** PROCESS BIT 3 - ADVANCE BUTTON
000D      F6     BIT3 FCB  SHR
000E      3BA6        FDB  BNF+BIT4 BIT 3 NOT SET
0010      B5          FCB  PHI+5    SAVE RESIDUE
0011      98          FCB  GHI+8    GET $80
0012      FF01   BBT3 FDB  SMI+1
0014      3A12        FDB  BNZ+BBT3 WAIT FOR CNT
0016      08          FCB  LDN+8    GET INPUT STATUS
0017      A7          FCB  PLO+7    SAVE INPUT STATUS
0018      FA08        FDB  ANI+$08
001A      32A5        FDB  BZ+BAT3  EXIT IF NOT SET
001C      8C          FCB  GLO+C    GET A $01
001D      B6          FCB  PHI+6    RENEW DELAY TIME OUT
001E      87          FCB  GLO+7    RESTORE
001F      FA04        FDB  ANI+$04  CHECK FOR RESET ALSO
0021      3242        FDB  BZ+BCT3  CONTINUE ADV PROCESSING
0023      F8FF        FDB  LDI+$FF  GET CLEAR DATA
0025      A7          FCB  PLO+7    SAVE FOR LOOP
0026      AD          FCB  PLO+D    SET PNTR TO END
0027      87     BLT3 FCB  GLO+7    GET CLEAR DATA
0028      5D          FCB  STR+D    STUFF IN HIST FILE
0029      2D          FCB  DEC+D    BACK UP
002A      8D          FCB  GLO+D    GET LOW ADR
002B      FB7F        FDB  XRI+$7F  AT BEGIN YET?
002D      3A27        FDB  BNZ+BLT3 GO SOME MORE
002F      F809        FDB  LDI+$09  GET 'IN' PNTR ADR
0031      AD          FCB  PLO+D
0032      98          FCB  GHI+8    GET $80
0033      5D          FCB  STR+D    RESET HIST 'IN' PNTR
0034      92     CCTR FCB  GHI+2    GET ZERO
0035      AD          FCB  PLO+D    RESET BCD DISPLAY FILE PNTR
0036      B9          FCB  PHI+9
0037      A9          FCB  PLO+9    CLEAR FUEL CNTR
0038      BA          FCB  PHI+A
0039      AA          FCB  PLO+A    CLEAR DIST CNTR
003A      F819        FDB  LDI+DIS2 GET HALF DIST SCALE CNT
003C      AB          FCB  PLO+B
003D      F818        FDB  LDI+FUS2 GET HALF FUEL SCALE CNT
003F      BB          FCB  PHI+B
0040      30A5        FDB  BR+BAT3  SKIP OTHER PROCESSING
0042      85     BCT3 FCB  GLO+5    GET DISPLAY STATUS
0043      FA03        FDB  ANI+$03  SEE IF REAL TIME DISPLAY ON
0045      325A        FDB  BZ+BRT3  BR IF NOT REAL TIME
0047      85          FCB  GLO+5    GET DISPLAY STATUS
0048      FB03        FDB  XRI+$03  ALTERNATE DISPLAYS
004A      A5          FCB  PLO+5    STORE STATUS
004B      F6          FCB  SHR
004C      3353        FDB  BDF+B9T3 BR IF ODD
004E      8A          FCB  GLO+A    COUNTER 2 TO CONVERT BUFFER
004F      AE          FCB  PLO+E
0050      9A          FCB  GHI+A
0051      3056        FDB  BR+BFT3  TO COMMON EXIT
0053      89     B9T3 FCB  GLO+9    COUNTER 1 TO CONVERT BUF
0054      AE          FCB  PLO+E
0055      99          FCB  GHI+9
0056      BE     BFT3 FCB  PHI+E
0057      D2     BST3 FCB  SEP+2    CALL CONVERT
0058      30A5        FDB  BR+BAT3  GO TO COMMON EXIT
005A      F808   BRT3 FDB  LDI+$08  GET 'OUT' PNTR ADR
005C      AD          FCB  PLO+D
```

```
005D    0D          FCB  LDN+D     GET HIST FILE 'OUT' PNTR
005E    F6          FCB  SHR       TEST FOR ODD
005F    337B        FDB  BDF+BDT3  BR IF ODD
0061    0D          FCB  LDN+D     GET HIST FILE 'OUT' PNTR
0062    AD          FCB  PLO+D     USE RAM PNTR
0063    4D          FCB  LDA+D     GET HIGH BYTE FROM FILE
0064    BE          FCB  PHI+E
0065    4D          FCB  LDA+D     GET LOW BYTE
0066    AE          FCB  PLO+E     STUFF IN CONVERT BUFFER
0067    8D          FCB  GLO+D     GET LOW BYTE OF PNTR
0068    FA03        FDB  ANI+$03   PICK OFF LOW TWO BITS
006A    3A6F        FDB  BNZ+BQT3  SKIP IF NOT MOD 4
006C    F901        FDB  ORI+$01   TURN ON BIT 0
006E    2D          FCB  DEC+D     BACK ONE
006F    1C    BQT3  FCB  INC+C     SET TO LED'S
0070    5C          FCB  STR+C     STUFF DATA
0071    2C          FCB  DEC+C     BACK TO 7 SEG LED
0072    8D          FCB  GLO+D     GET LOW BYTE OF PNTR
0073    A7          FCB  PLO+7     TEMP SAVE
0074    F808        FDB  LDI+$08   GET 'OUT' PNTR ADR
0076    AD          FCB  PLO+D
0077    87          FCB  GLO+7     RESTORE
0078    5D          FCB  STR+D     UPDATE HIST FILE 'OUT' PNTR
0079    3057        FDB  BR+BST3   TO COMMON EXIT
007B    0D    BDT3  FCB  LDN+D     GET HIST FILE 'OUT' PNTR
007C    FC01        FDB  ADI+$01   INCR
007E    5D          FCB  STR+D     UPDATE HIST FILE 'OUT' PNTR
007F    3292        FDB  BZ+BVT3   AT END OF DISPLAY FILE
0081    1D          FCB  INC+D     PNT TO 'IN' PNTR
0082    ED          FCB  SEX+D
0083    F7          FCB  SM        'OUT' MINUS 'IN'
0084    2D          FCB  DEC+D     BACK TO 'OUT' PNTR
0085    3A94        FDB  BNZ+BYT3
0087    0D          FCB  LDN+D     GET 'OUT' PNTR
0088    FB80        FDB  XRI+$80   SEE IF AT BEGINNING
008A    3A92        FDB  BNZ+BVT3
008C    F87F        FDB  LDI+$7F
008E    5D          FCB  STR+D     BACK TO TRIP 1
008F    98          FCB  GHI+8     GET $80
0090    3095        FDB  BR+BXT3   TO SHIFT
0092    98    BVT3  FCB  GHI+8     GET $80
0093    5D          FCB  STR+D     RESET HIST FILE 'OUT' PNTR
0094    0D    BYT3  FCB  LDN+D     GET 'OUT' PNTR
0095    F6    BXT3  FCB  SHR       DIV BY 2
0096    F6          FCB  SHR       THIS GET CNT/4
0097    FF1F        FDB  SMI+$1F   GET RID OF OFFSET LESS ONE
0099    AE          FCB  PLO+E     STUFF CNT IN CONVERT BUF
009A    92          FCB  GHI+2     GET ZERO
009B    BE          FCB  PHI+E
009C    D2          FCB  SEP+2     CALL CONVERT
009D    92          FCB  GHI+2     GET ZERO
009E    AD          FCB  PLO+D     POINT TO BCD DISP FILE
009F    5D          FCB  STR+D     BLANK HIGH DIGIT
00A0    1D          FCB  INC+D
00A1    5D          FCB  STR+D     BLANK NEXT DIGIT
00A2    1C          FCB  INC+C
00A3    5C          FCB  STR+C     BLANK LED'S
00A4    2C          FCB  DEC+C     BACK TO 7 SEG LED
00A5    95    BAT3  FCB  GHI+5     GET RESIDUE BACK
```

```
                 ** PROCESS BIT 4 - IGNITION OFF/ON INDICATOR
00A6   F6        BIT4 FCB  SHR
00A7   3BD6           FDB  BNF+BEND GO TO END
00A9   B5             FCB  PHI+5   SAVE RESIDUE
00AA   08             FCB  LDN+8    GET INPUT STATUS
00AB   FA10           FDB  ANI+$10
00AD   32D5           FDB  BZ+BAT4  SKIP IF NOT THERE
00AF   99             FCB  GHI+9    GET FUEL CNT HIGH
00B0   3AB5           FDB  BNZ+BCT4
00B2   89             FCB  GLO+9    GET FUEL CNT LOW
00B3   32D5           FDB  BZ+BAT4  SKIP OUT IF NONE
00B5   F809      BCT4 FDB  LDI+$09  GET 'IN' PNTR ADR
00B7   AD             FCB  PLO+D
00B8   0D             FCB  LDN+D    GET HIST FILE 'IN' PNTR
00B9   AD             FCB  PLO+D
00BA   32D0           FDB  BZ+BET4  SKIP STORE IF NO MORE ROOM
00BC   99             FCB  GHI+9    GET FUEL CNT
00BD   5D             FCB  STR+D
00BE   1D             FCB  INC+D
00BF   89             FCB  GLO+9
00C0   5D             FCB  STR+D
00C1   1D             FCB  INC+D
00C2   9A             FCB  GHI+A    GET DIST CNT
00C3   5D             FCB  STR+D
00C4   1D             FCB  INC+D
00C5   8A             FCB  GLO+A
00C6   5D             FCB  STR+D
00C7   8D             FCB  GLO+D
00C8   FC01           FDB  ADI+$01  INCR HIST FILE 'IN' PNTR
00CA   A7             FCB  PLO+7    TEMP SAVE
00CB   F809           FDB  LDI+$09  GET 'IN' PNTR ADR
00CD   AD             FCB  PLO+D
00CE   87             FCB  GLO+7    RESTORE DATA
00CF   5D             FCB  STR+D    UPDATE HIST FILE 'IN' PNTR
00D0   95        BET4 FCB  GHI+5   GET RESIDUE BACK
00D1   FE             FCB  SHL     BACK UP ONE
00D2   B5             FCB  PHI+5   SET FOR BAT3 RECALL
00D3   3034           FDB  BR+CCTR GO TO COMMON CLEAR PROCESSING
00D5   95        BAT4 FCB  GHI+5   GET RESIDUE BACK
                 ** END OF INPUT BIT PROCESSING
00D6             BEND RMB  0
00D6   C0             FCB  $C0     LONG BRANCH
00D7   0030           FDB  SUBL
                      END
```

```
                  ***************************************************
                  **     SUBROUTINE BINDEC - BINARY TO DECIMAL CONVERSIC
                  **  R2 IS THE PROGRAM COUNTER
                  **  R3 IS USED TO CALL A SUBROUTINE
                  **  RD POINTER TO BCD DISPLAY FILE
                  **  RE CONTAINS BINARY DATA ON ENTRY
                  **  RF POINTS TO THE POWER OF TEN TABLE
00B0                   ORG  $B0
00B0    D0        SRET FCB  SEP+0      RETURN TO MAIN PROGRAM
00B1    92        DECE FCB  GHI+2     GET ZERO
00B2    AD             FCB  PLO+D     SET BCD FILE POINTER TO ZERO
00B3    F8E7           FDB  LDI+PTAB  GET HIGH BYTE OF PTAB ADR
00B5    AF             FCB  PLO+F
00B6    EF             FCB  SEX+F     SET UP INDEX REGISTER
00B7    D3             FCB  SEP+3     CALL DECDIG 10K
00B8    D3             FCB  SEP+3     CALL DECDIG  1K
00B9    F980           FDB  ORI+$80
00BB    5D             FCB  STR+D
00BC    1D             FCB  INC+D
00BD    D3             FCB  SEP+3     CALL DECDIG 100
00BE    F940           FDB  ORI+$40
00C0    5D             FCB  STR+D
00C1    1D             FCB  INC+D
00C2    D3             FCB  SEP+3     CALL DECDIG  10
00C3    F920           FDB  ORI+$20
00C5    5D             FCB  STR+D
00C6    1D             FCB  INC+D
00C7    8E             FCB  GLO+E     GET UNITS DIGIT
00C8    F910           FDB  ORI+$10
00CA    5D             FCB  STR+D     THIS LEAVES BCD FILE POINTER AT 3
00CB    30B0           FDB  BR+SRET
                  ****************************************************
                  **     SUBROUTINE DECDIG - CONVERT A SINGLE DIGIT
                  **  R2 IS THE RETURN PC
                  **  R3 IS THE PROGRAM COUNTER
                  **  RE CONTAINS THE DATA
                  **  RF POINTS TO POWER OF TEN TABLE
                  **  R7 USED AS TEMP REGISTER
00CD    D2        DSTR FCB  SEP+2      RETURN TO R2 AS PC
00CE    92        DSTE FCB  GHI+2      GET ZERO
00CF    A7             FCB  PLO+7      CLEAR CNTR
00D0    8E        DLPA FCB  GLO+E      GET LOW DATA BYTE
00D1    F7             FCB  SM
00D2    AE             FCB  PLO+E      RETURN LOW BYTE
00D3    9E             FCB  GHI+E      GET HIGH DATA BYTE
00D4    1F             FCB  INC+F      MOVE TABLE PNTR
00D5    77             FCB  SMB
00D6    2F             FCB  DEC+F      RESTORE TABLE PNTR
00D7    BE             FCB  PHI+E      RETURN HIGH BYTE
00D8    17             FCB  INC+7      DIGIT CNTR
00D9    33D0           FDB  BDF+DLPA   BRANCH IF POSITIVE
00DB    8E             FCB  GLO+E
00DC    F4             FCB  ADD
00DD    AE             FCB  PLO+E      RESTORE
00DE    9E             FCB  GHI+E
00DF    1F             FCB  INC+F     MOVE TABLE PNTR
00E0    74             FCB  ADC
00E1    BE             FCB  PHI+E      RESTORE HIGH BYTE
00E2    1F             FCB  INC+F     MOVE TO NEXT PAIR
00E3    27             FCB  DEC+7      CORRECT DIGIT CNTR
00E4    87             FCB  GLO+7      GET THIS DEC DIGIT
00E5    30CD           FDB  BR+DSTR    RETURN
```

```
                    **********************************************************
                    **     POWER OF TEN TABLE
   00E7     1027 PTAB FDB  $1027
   00E9     E803      FDB  $E803
   00EB     6400      FDB  $6400
   00ED     0A00      FDB  $0A00
                    *********************************************************
                    **     SUBROUTINE DISPLAY - TO DISPLAY DECIMAL COUNT
   00EF     D0   DISP FCB  SEP      RETURN TO R0 FOR PC
   00F0     4D   DISE FCB  LDA+D    GET DATA + STROBE BIT
   00F1     5C        FCB  STR+C
   00F2     8D        FCB  GLO+D    GET LOW BYTE OF BCD FILE ADR
   00F3     FB04      FDB  XRI+4    IS IT LAST ADR?
   00F5     3AF8      FDB  BNZ+DND  TO END
   00F7     AD        FCB  PLO+D    STUFF ZERO AND START OVER
   00F8     30EF DND  FDB  BR+DISP  GO AWAY
                          END
```

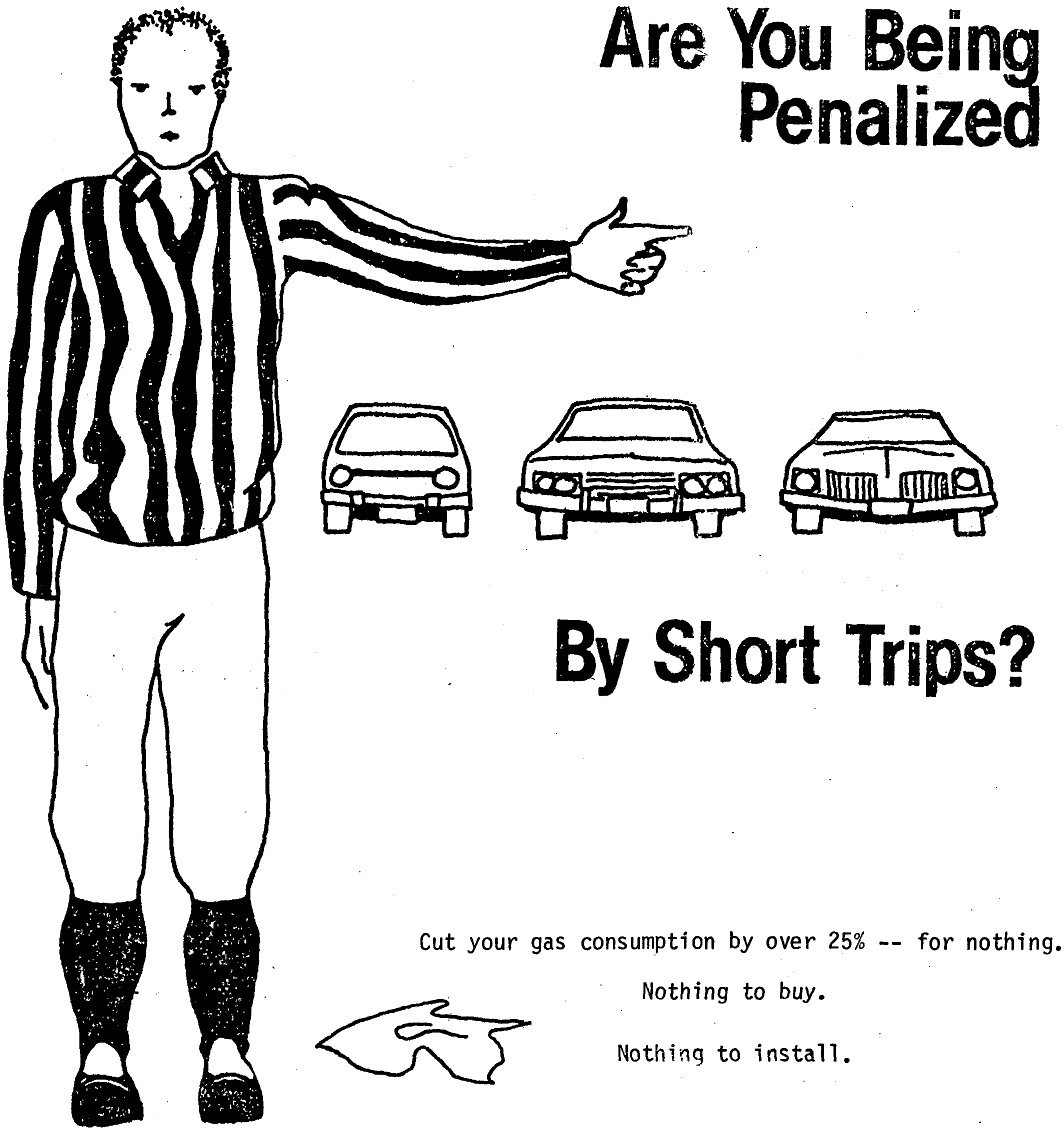
APPENDIX 3

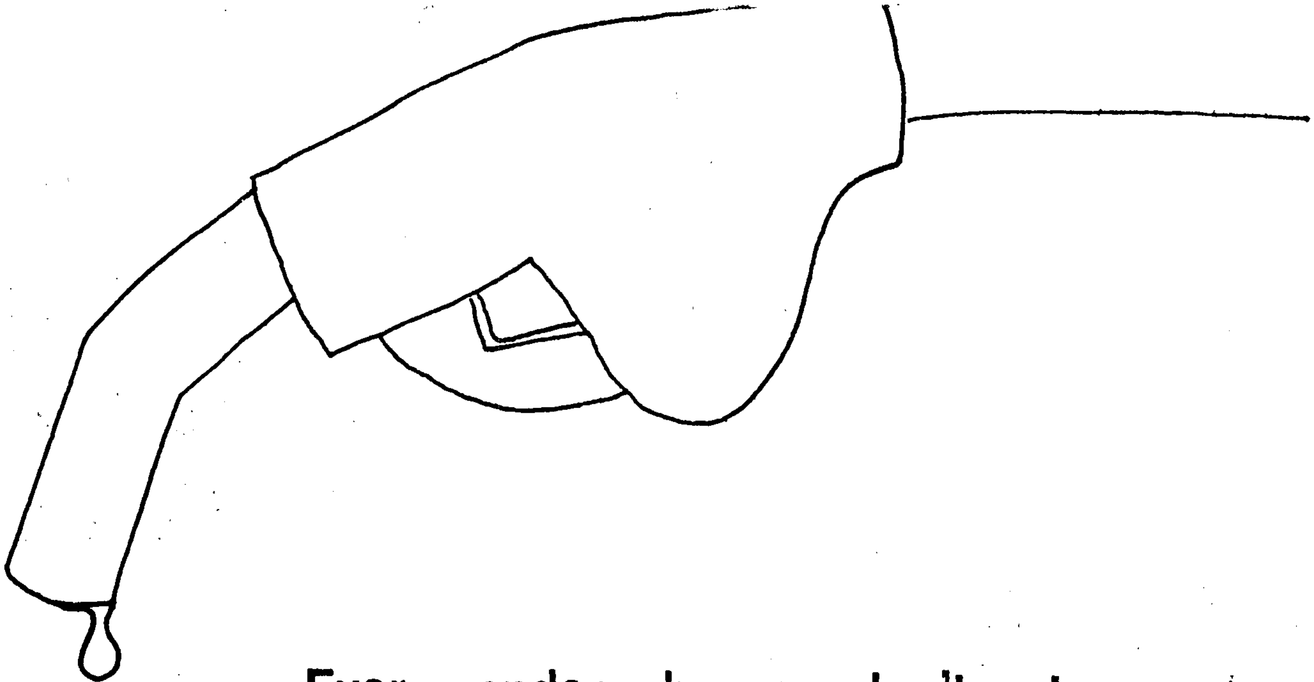
PARTS LIST

ITEM	NUMBER	DESCRIPTION	QTY
1	400	Digital display bezel	1
2	422	PC board nounting adapter	1
3	NSB7881	Multidigit LED series	1
4	-	Red LED with mtg hardware	2
5	-	SPST momentary pushbutton switches	2
6	1802	COSMAC microprocessor (RCA)	1
7	2716	Single 5 volt supply EPROM (Intel)	1
8	IM6561	256x4 RAM (Harris)	2
9	74C04	Hex inverter (National)	2
10	74C08	Quad 2 IN AND (National)	1
11	74C14	Hex Schmidt inverter (National)	1
12	74C42	BCD to decimal decoder (National)	1
13	74C48	BCD to 7 segment decoder (National)	1
14	74C175	Quad D flip-flop (National)	4
15	80C97	Hex tri-state buffer	1
16	UA7805	5 volt regulator	1
17	2N3705	Transistor	6
18	1N914	Signal diode	2
19	1N4004	Rectifying diode	2
20	C9114	14 pin WW socket	4
21	C9116	16 pin WW socket	13
22	C9118	18 pin WW socket	2
23	C9124	24 pin WW socket	1
24	C9140	40 pin WW socket	1
25	-	16 pin DIP header	6
26	220uF	Capacitor (25 volt)	1
27	22uF	"	1
28	0.22uF	Capacitor (15 volt)	3
29	0.10uF	"	5
30	0.05uF	"	1
31	39pF	"	1

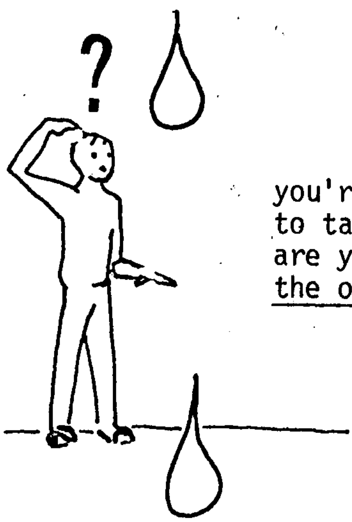
ITEM	NUMBER	DESCRIPTION	QTY
32	1Meg	Resistor (1/4 watt)	1
33	470k	"	2
34	100k	"	3
35	39k	"	1
36	20k	"	1
37	10k	"	1
38	6.8k	"	2
39	4.7k	"	1
40	3.3k	"	3
41	2.7k	"	1
42	1k	"	2
43	680	"	4
44	470	"	2
45	39	"	7
46	-	Enclosure	1
47	-	4 1/2 x 6 inch perfboard	1
48	-	Quad screw type terminal strips	2
49	-	Heat sink for TO220 package	1
50	-	6-32 x 1 inch stand-offs	2
51	-	Small "L" brackets	2
52	-	Miscellaneious mtg screws	1

APPENDIX B


Are You Being Penalized
By Short Trips?
Cut your gas consumption by over 25% -- for nothing.
Nothing to buy.
Nothing to install.

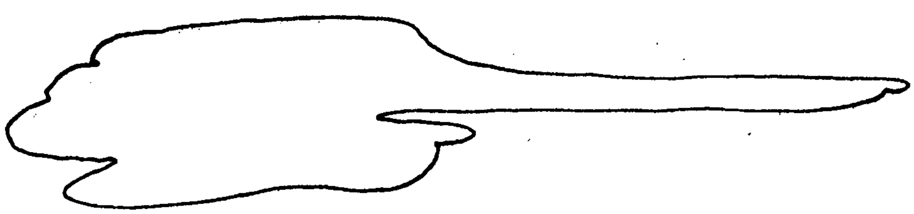


Ever wonder why you don't get your EPA estimated mileage?



If you check your mpg on a long trip, you probably find you're doing pretty well. But, if you check it from tankful to tankful during everyday driving around town, the chances are you'll find you're getting only half of what you get on the open road.

Why?



Statistics show that the majority of trips you make with the family car are short trips--under 5 miles each way. These short trips penalize you in two ways.

Cold Start--While the engine is warming up a rich fuel mixture and sluggish lubrication system will drive your mpg way down. For the first couple of miles, you're lucky to get even half of your rated mpg.

Stop-and-Go--Not many people have a freeway from their front door to the supermarket. Most short trips involve a lot of stop and go. Each time you stop for a traffic light, stop sign, or other traffic, it takes more gas to build back up to speed. Even with a warmed-up engine, you still lose about a third of your rated mpg.

Save money

Save time

Save wear

Defending against the short trip can save you a bundle. All you have to do to cut your total gas bill by 25% is follow the four C's.

- Consolidate your trips--get everything at one time.
- Combine--several places into a single trip.
- Call--let your fingers do the driving.
- Count the gallons you save.

Consolidate

Do you sometimes find yourself driving to the same store or shopping center two or three times in one week--or even in one day?

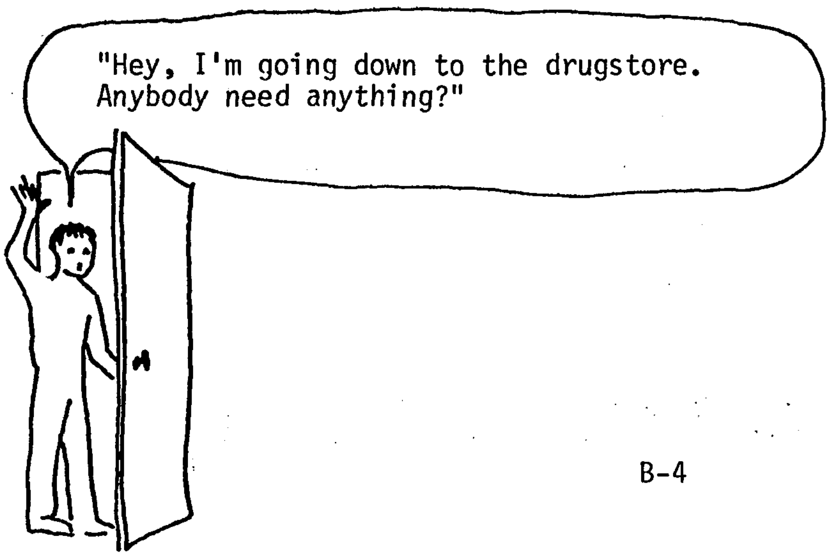
Is it possible that you could have handled everything in one trip?

Many people find that they can by following these simple rules:

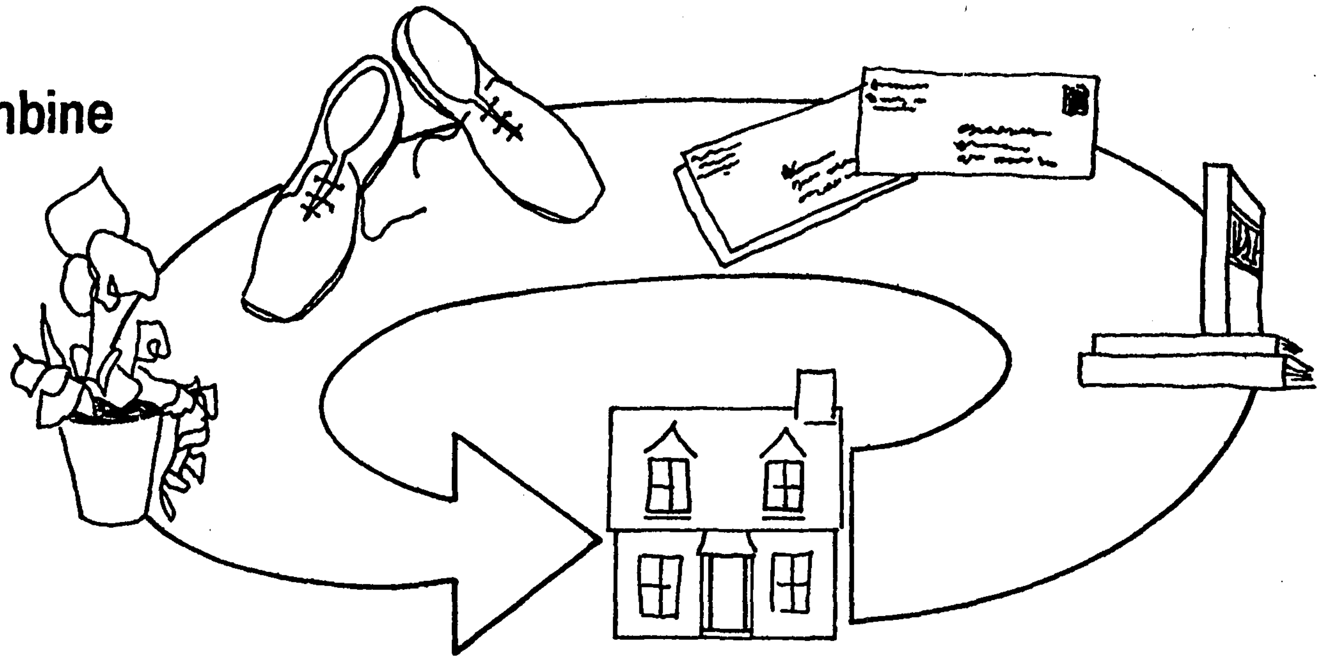
Procrastinate--Putting things off until later isn't always a bad idea--particularly if there are other things that are going to have to be done later. Before you hop in the car and go get something ask yourself (or whoever is sending you), "Do I really have to get it now?"

Keep Errand Lists--The best way to get everything in one trip is to know what "everything" is. Keep a family list of things you need from the supermarket, drugstore, hardware store, etc., and think ahead.

Ask Others--Whenever anyone is about to take off in a car, take a moment to think of what you need. It may be able to save you a trip. By the same token, when you are the one who's going out, see what you can pick up for others.



Combine



You can't always do everything you need to at one place. You can still save gas by combining places into one trip.

Look at what the Thompsons discovered about the way their family car was being used.

TUESDAY'S TRIPS

HOW IT WAS

Driver	Purpose	Miles
Sis	Take Tommy to school	4
Sis	Drive Home	4
Mom	To supermarket for week's shopping	4
Mom	Drive home	4
Sis	To Sally's to get books	3
Sis	Drive home	3
Mom	To school to pick up Tommy	4
Mom	Drive home	4
Dad	Drugstore for cigarettes	2
Dad	Drive home	2
Dad	To bowling alley (league night)	3
Dad	Drive home	3
Sis	To Sally's to return books	3
Sis	Drive home	3
		46

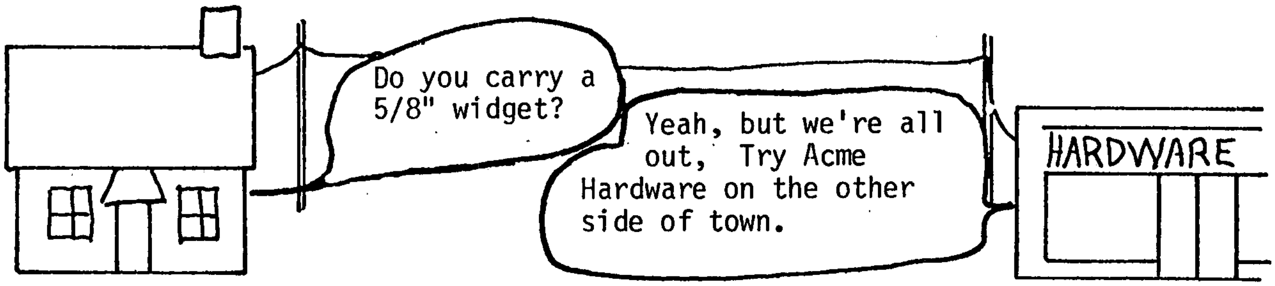
HOW IT COULD HAVE BEEN

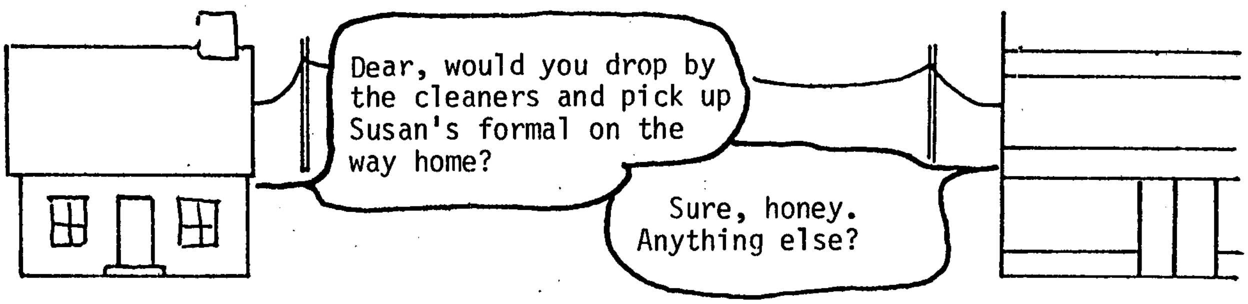
Driver	Purpose	Miles
Mom	Take Tommy to school	4
Mom	To supermarket for week's shopping	1
Mom	Drive home	4
Sis	To Sally's to get books	3
Sis	To school to pick up Tommy	2
Sis	Drive home	4
Dad	To drugstore for cigarettes	2
Dad	To Sally's to drop off Sis's books	2
Dad	To bowling alley	2
Dad	Drive home	3
		27

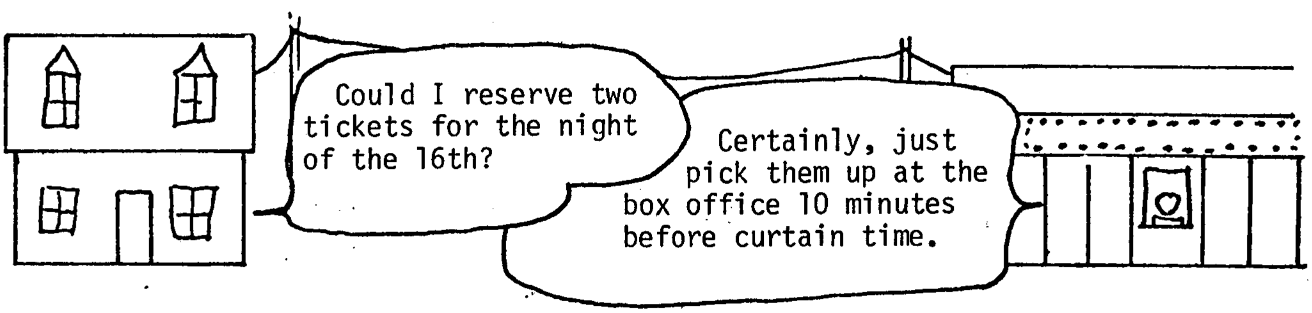
The Thompsons could have cut their driving almost in half, and their gas consumption even more (eliminating cold starts) without giving up anything! All they had to do was to get their act together early enough in the day to combine trips.

Call

The telephone can carry your words more cheaply than your car can carry the rest of you. Here are some words that can save money.







Count

Even though short trips don't add many miles to your odometer, they are expensive miles.

Cutting your short trips in half can reduce your overall gas consumption as much as 25%. That adds up to over $300 a year for the average family.

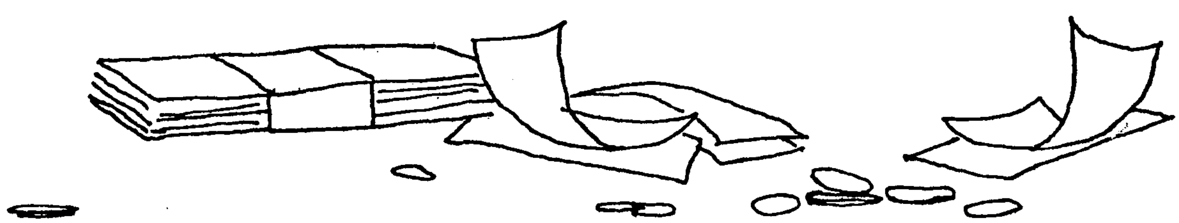
COUNT up your own savings using the simple "Four C's Savings Log" on the back page. This log will tell you how many gallons, miles, and dollars you are saving.

And remember, to get these savings you don't have to give up a thing!

In fact, you actually gain:

Time--Each short trip you eliminate means one less interruption of the day's activity to go wrestle with stop-and-go traffic.

Car Life--The miles devoted to short trips and cold starts are the hardest miles you can put on a car. Each trip you don't take adds a little to the life of a car.



Four C's Counting Guide

To see how much you can save through the Four C's program, you need only to be willing to fill your car's tank once a week, on the same day, for 15 weeks. (After the first couple of weeks, it should be fun to see how much you are saving.)

On the back of this booklet is the Four C's Saving Log. You can use this Log to help you count your savings. Here's how:

1. Start with a full tank.

2. Exactly one week later, fill it again. Write down how many gallons your tank took under "Gallons." (If someone else fills the tank, have them tell you the amount or give you the credit card receipt.) In the example below, the car took 19.2 gallons.

3. At the end of the second week, fill it again and enter the "gallons." In the example, the car took 20.4 gallons.

4. At this point, average the gas consumption for the first two weeks. The "average gallons" will become the basis for estimating what you save (two weeks are necessary to get a good basis for comparison). In the example, the average consumption was (19.2 + 20.4) ÷ 2 = 19.8 gallons.

5. Now start the Four C's program. Get the family together and go over the program with them. Tell them you're keeping a record of how much they are saving.

6. During the next 13 weeks, compare each week's gas consumption with the "average gallons" and write the difference under "saved." In the example, the car took 14.6 gallons (in Week 3) after the Four C's program was introduced. This was a savings of 19.8 - 14.6 = 5.2 gallons.

7. At the end of 13 weeks, add up the total gallons saved. In the example, it totaled 67.6 gallons.

8. To estimate the yearly savings, multiply the 13-week savings by 4. In the example, the estimated yearly savings in gasoline is 67.6 x 4 = 270.4 gallons. To figure out what this is worth, simply multiply that total by the prevailing cost of gasoline. In the example, the cost of gasoline was $1.30 per gallon. When this was miltiplied by 270.4 gallons, the total saved was $351.52.

Sample
4 C's Savings Log

	WEEK	GALLONS USED	GALLONS SAVED
START PROGRAM	1	19.2	
	2	20.4	
Average gallons		19.8	
START 4 C's	3	14.6	5.2
	4	13.7	6.1
	5	15.1	4.7
	15	14.4	5.4
TOTAL SAVINGS			67.6
GAS PER YEAR	67.6 x 4 =		270.4
DOLLARS PER YEAR	270.4 x $1.30 =		$351.52

Here are some additional suggestions to make the program work better.

- Decide in advance what you're going to do with the money you save (a week at the beach, a moped, etc.).
- Review the savings with your family on a weekly basis. Talk about ways of saving more.
- Try to set a goal. Experience shows people will save more if they have a particular goal in mind. After one goal is reached, set another one.
- Skip any week in which you take a really long trip (200 miles or more). Pick up again the next week.

Your 4 C's Saving Log

	WEEK	GALLONS USED	GALLONS SAVED
START PROGRAM	1		
	2		
average gallons			
START 4 C's	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
	13		
	14		
	15		
TOTAL SAVINGS			
GAS PER YEAR			
DOLLARS PER YEAR			

CODE #__________

AGE__________

SEX__________

OCCUPATION__________

APPENDIX C

HOME VEHICLE USE SURVEY I

1. Of the total number of trips you make each week, what percent are trips which are:

0-1 mile long?	____%
1-2 miles long?	____%
2-3 miles long?	____%
3-5 miles long?	____%
5-10 miles long?	____%
10+ miles long?	____%
TOTAL	100%

2. Of the total number of miles you drive each week, what percent are covered in trips which are:

0-1 mile long?	____%
1-2 miles long?	____%
2-3 miles long?	____%
3-5 miles long?	____%
5-10 miles long?	____%
10+ miles long:	____%
TOTAL	100%

3. Of the total amount of gas you use each week, what percent is consumed in trips which are:

0-1 mile long?	____%
1-2 miles long?	____%
2-3 miles long?	____%
3-5 miles long?	____%
5-10 miles long?	____%
10+ miles long?	____%
TOTAL	100%

CODE#____________

HOME VEHICLE USE SURVEY II

Circle the answer which is most correct.

1. A vehicle which goes 10 miles on a gallon of gas when the engine is warm, will go how far on a gallon when it is cold?

   a. Over 9 miles
   b. About 8 miles
   c. Under 7 miles

2. Your car generally gets the best mileage on trips which are:

   a. Under 5 miles long
   b. 5-10 miles long
   c. Over 10 miles long

3. The trip pattern that would generally offer the best fuel economy would be:

   a. One 30-mile trip
   b. A 15-mile trip in the morning and a 15-mile trip in late afternoon
   c. Three 10-mile trips spread over the day

4. In cold weather, how far do you generally have to drive to reach maximum mpg?

   a. 15 miles
   b. 6 miles
   c. 2 miles

Circle the answer which best represents your opinion.

5. When deciding whether or nor to drive somewhere, the cost of gas should influence you:

   a. A lot
   b. Some
   c. A little

6. Of the trips people make in their cars every day, how many are really necessary?

   a. Most
   b. Many
   c. Few

7. By planning their daily trips better, people could save:

   a. A lot of gas
   b. Some gas
   c. A little gas

8. People should drive their cars:

   a. Only when absolutely necessary
   b. As little as possible
   c. Whenever it's convenient

APPENDIX D

MPG-DISTANCE SCATTER PLOT

The following figures provide scatter plots of the relationship between trip length and trip mpg. Because of the curvilinear relationship between these two variables, trip distance is expressed in log miles. A separate scatter plot has been provided for each vehicle. The characteristics of each vehicle can be obtained from Table 1 in the text.

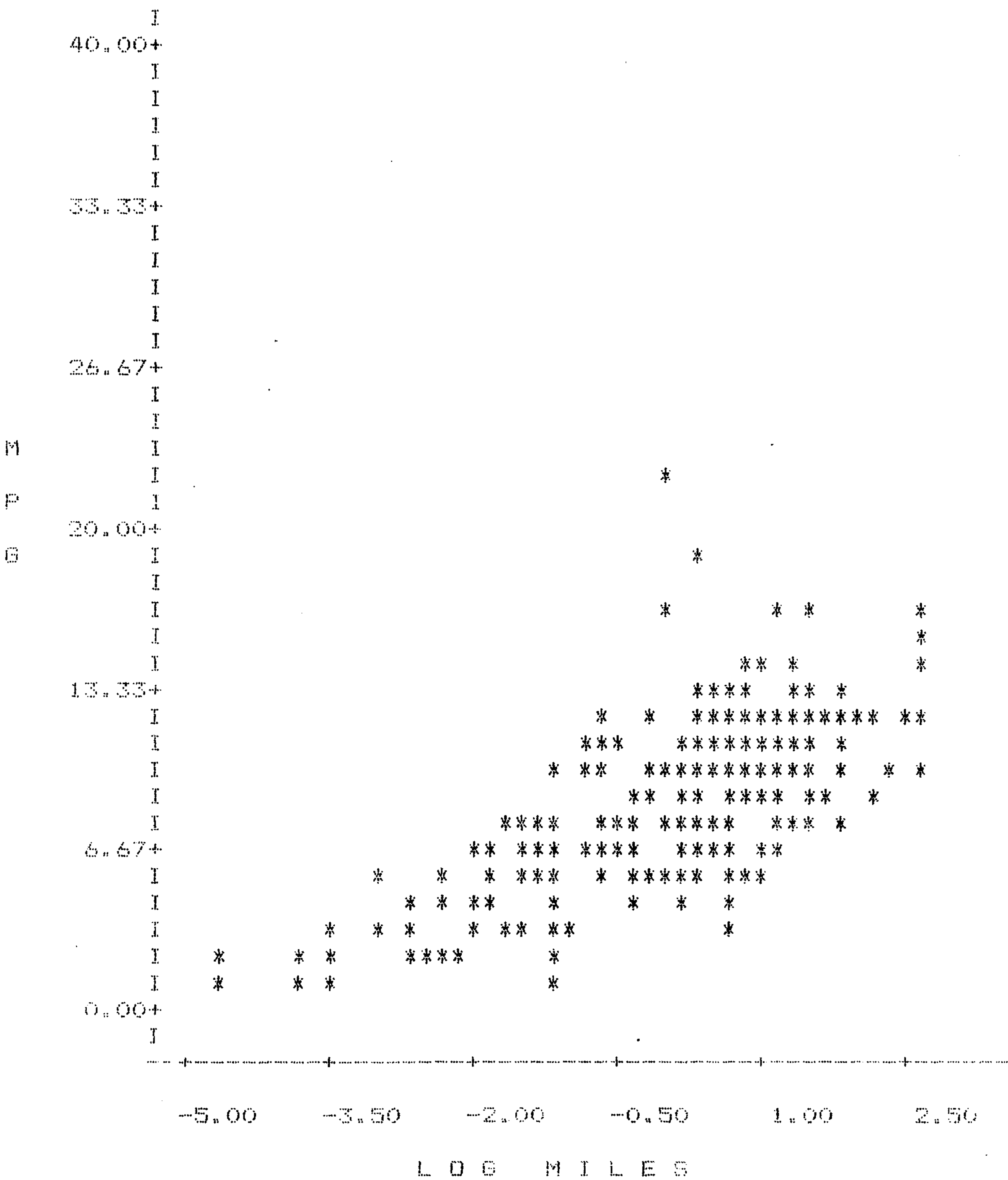
Each asterisk in the scatter plot represents one or more trips falling within the cell represented by the intervals of mpg and log miles indicated on the coordinates of the chart. More than one trip falling in the same cell appears as a single asterisk. For that reason, the number of trips exceeds the number of asterisks on the scatter plot. (The number of trips corresponds to "Number of Pairs" in the table above each scatter plot.)

HOME VEHICLE USE STUDY

VEHICLE 1 - 1970 Ford Pickup

VARIABLE X : LOG MILES		VARIABLE Y : MPG	
MEAN OF X	= -.0362806	MEAN OF Y	= 7.66802
S.D. OF X	= 1.55182	S.D. OF Y	= 3.57432

NUMBER OF PAIRS (N)	= 339
CORRELATION COEFFICIENT (R)	= .727
DEGREES OF FREEDOM (DF)	= 337
SLOPE OF REGRESSION LINE (M)	= 1.6743
Y INTERCEPT (B)	= 7.72876

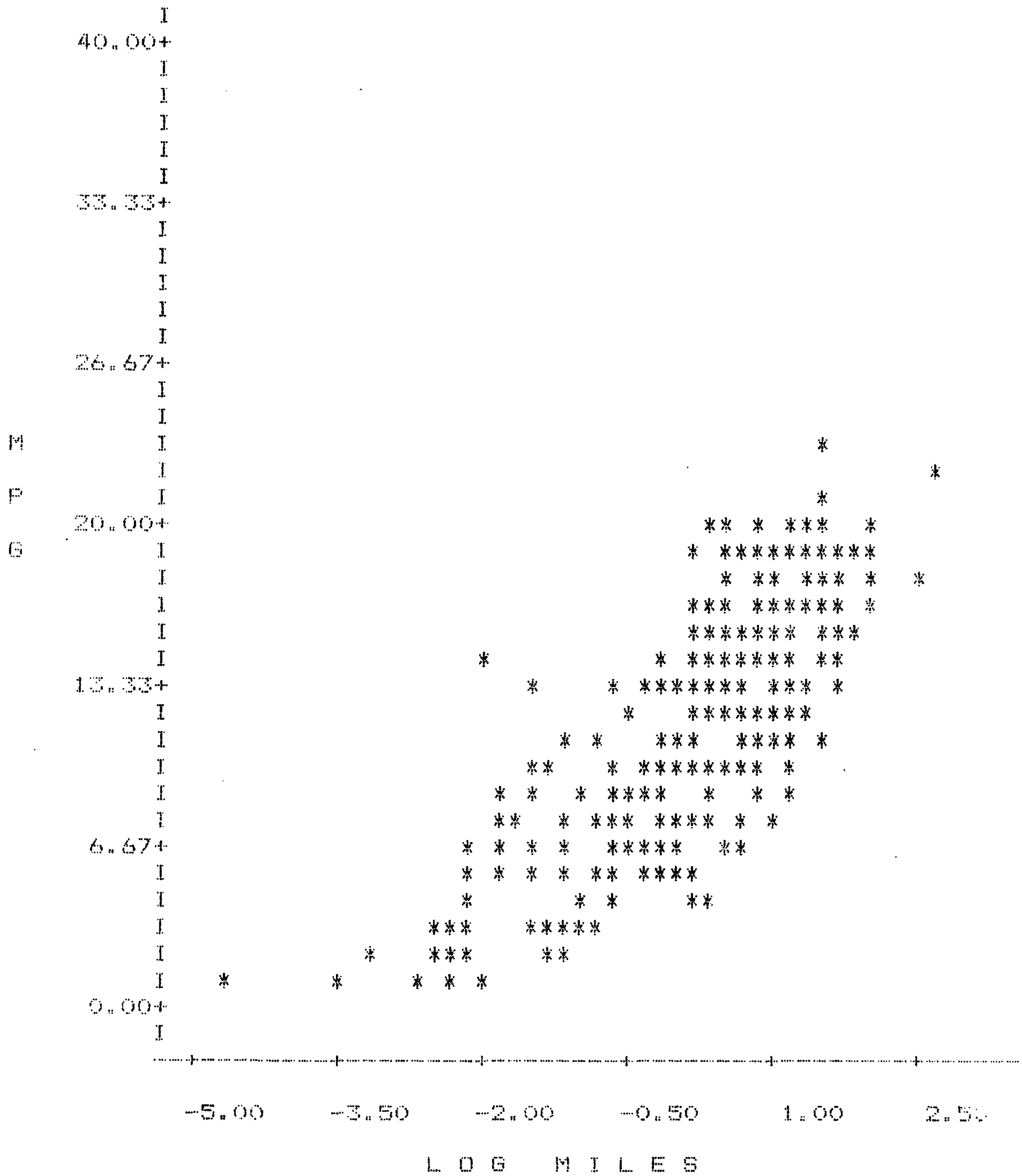


HOME VEHICLE USE STUDY

VEHICLE 2 - 1978 Toyota Wagon

VARIABLE X : LOG MILES	VARIABLE Y : MPG
MEAN OF X = .149185	MEAN OF Y = 11.2541
S.D. OF X = 1.28451	S.D. OF Y = 5.19343

NUMBER OF PAIRS (N)	=	302
CORRELATION COEFFICIENT (R)	=	.796
DEGREES OF FREEDOM (DF)	=	300
SLOPE OF REGRESSION LINE (M)	=	3.21671
Y INTERCEPT (B)	=	10.7742



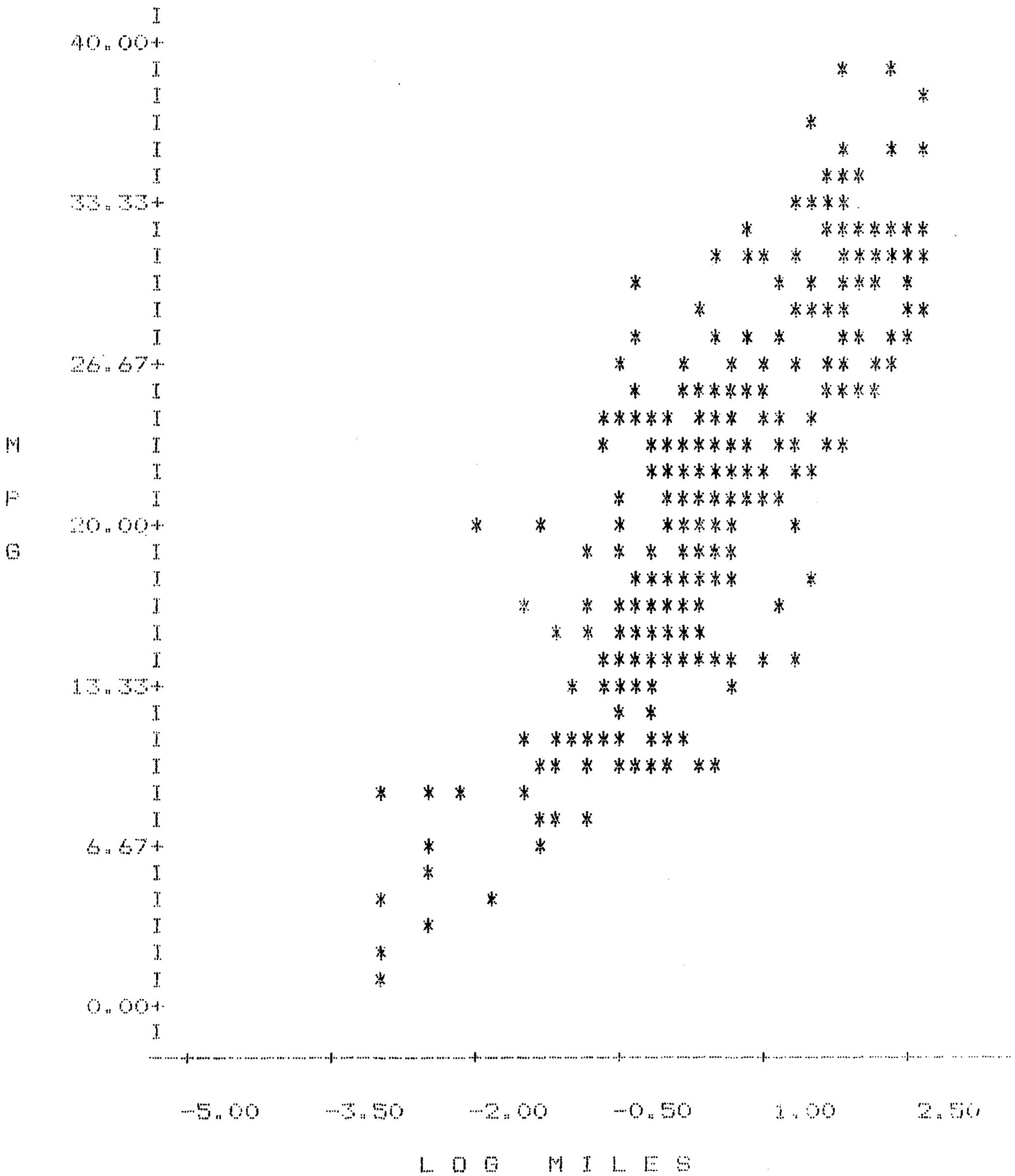
HOME VEHICLE USE STUDY

VEHICLE 3 - **1980 Plymouth Horizon**

VARIABLE X : LOG MILES
MEAN OF X = .56969
S.D. OF X = 1.20695

VARIABLE Y : MPG
MEAN OF Y = 21.3853
S.D. OF Y = 7.65074

NUMBER OF PAIRS (N) = 421
CORRELATION COEFFICIENT (R) = .838
DEGREES OF FREEDOM (DF) = 419
SLOPE OF REGRESSION LINE (M) = 5.31171
Y INTERCEPT (B) = 18.3593



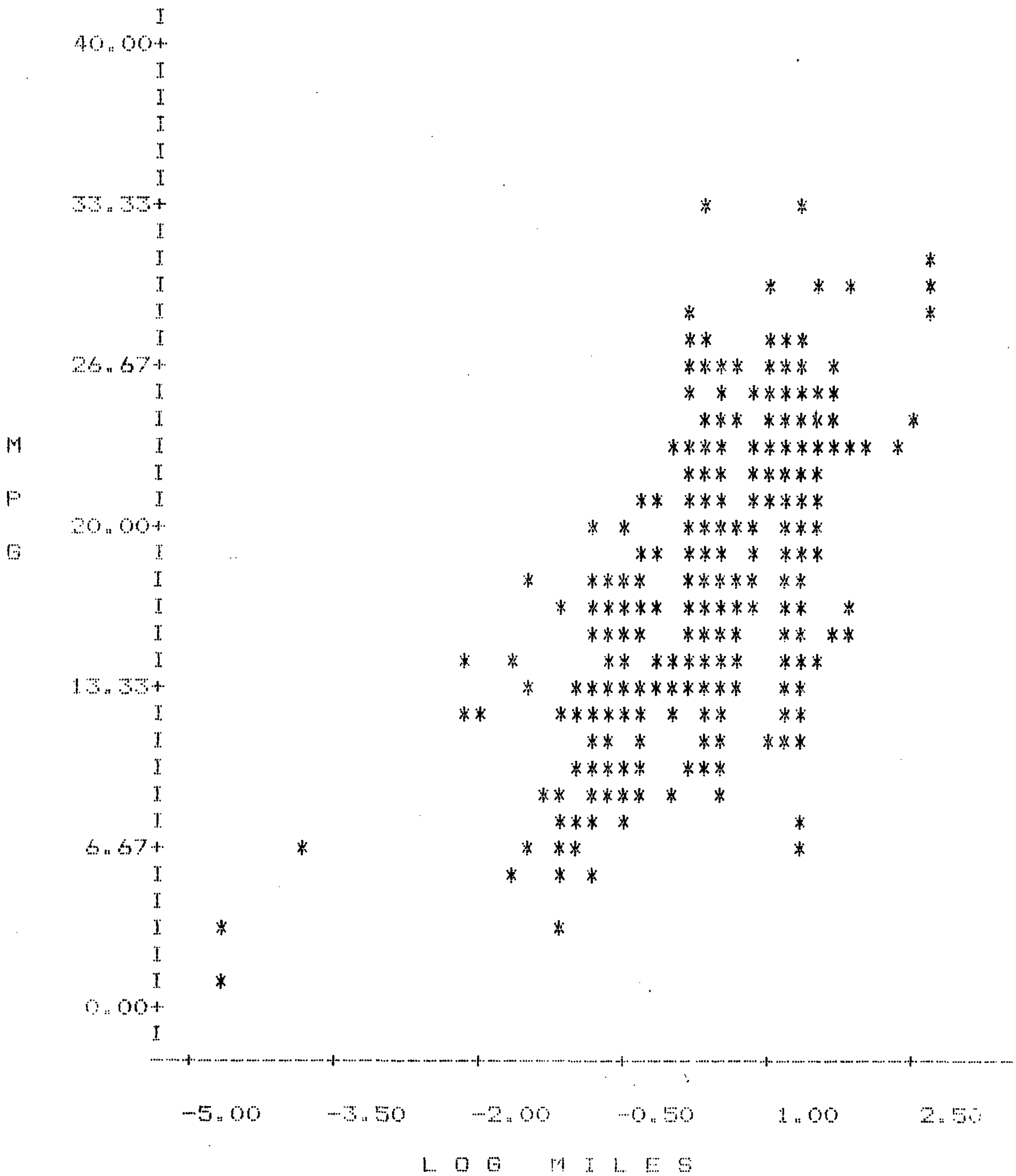
HOME VEHICLE USE STUDY

VEHICLE 4 - 1978 Toyota Corolla

VARIABLE X : LOG MILES
MEAN OF X = .423829
S.D. OF X = 1.01195

VARIABLE Y : MPG
MEAN OF Y = 17.2822
S.D. OF Y = 5.70845

NUMBER OF PAIRS (N) = 491
CORRELATION COEFFICIENT (R) = .648
DEGREES OF FREEDOM (DF) = 489
SLOPE OF REGRESSION LINE (M) = 3.65648
Y INTERCEPT (B) = 15.7325



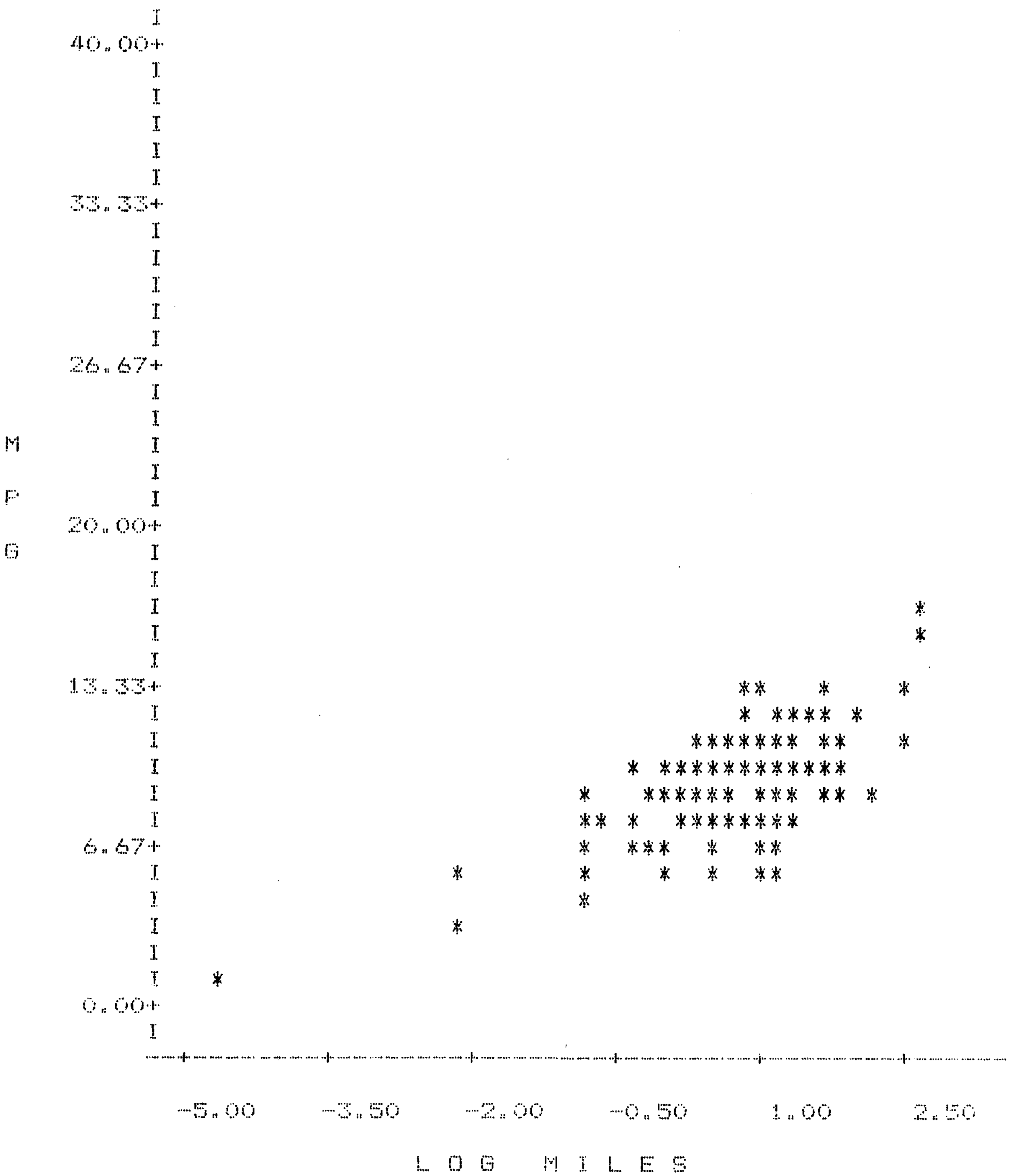
HOME VEHICLE USE STUDY

VEHICLE 5 - 1972 Ford Esquire

VARIABLE X : LOG MILES
MEAN OF X = .778748
S.D. OF X = .777746

VARIABLE Y : MPG
MEAN OF Y = 8.96377
S.D. OF Y = 2.10452

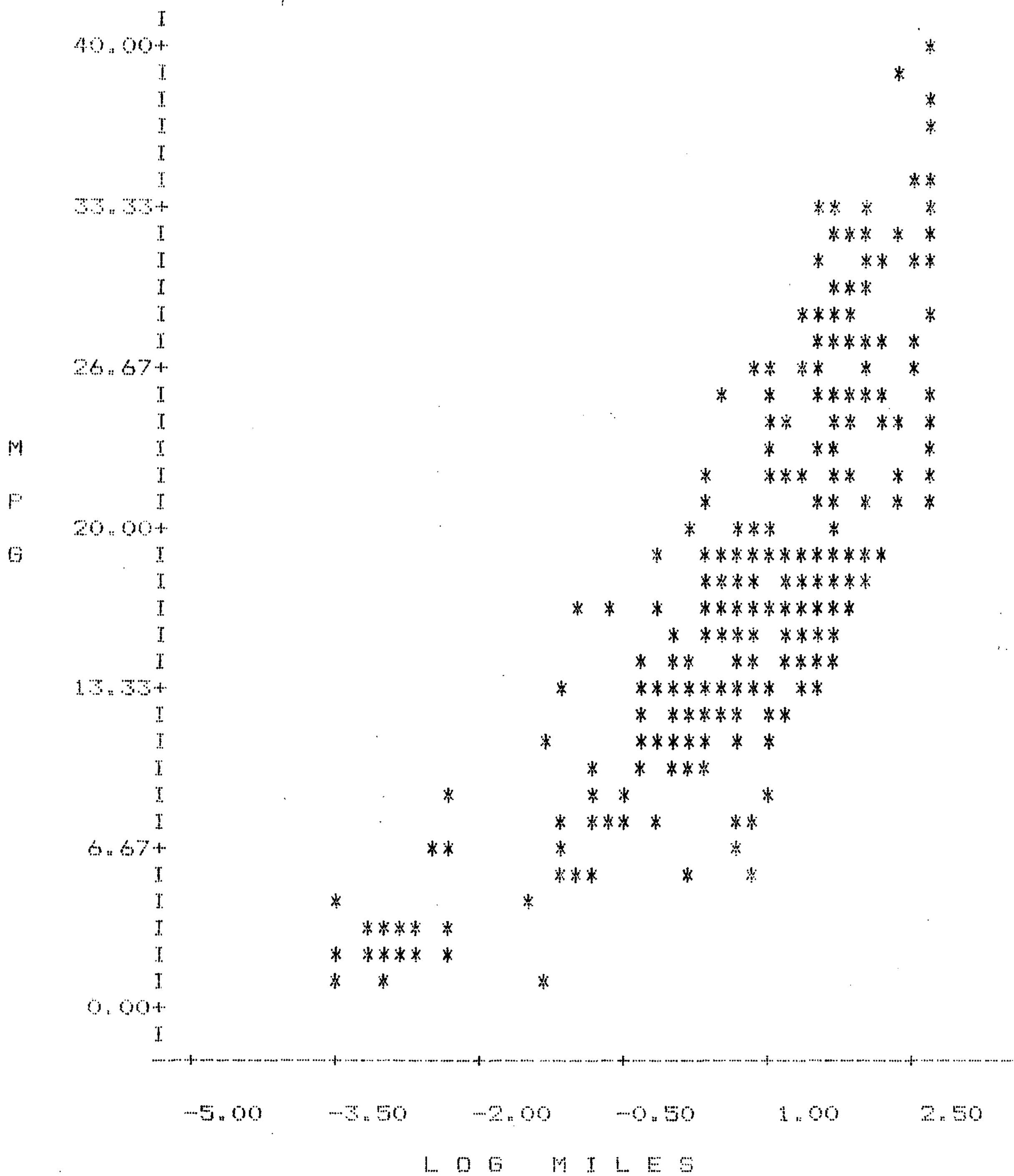
NUMBER OF PAIRS (N) = 224
CORRELATION COEFFICIENT (R) = .602
DEGREES OF FREEDOM (DF) = 222
SLOPE OF REGRESSION LINE (M) = 1.63028
Y INTERCEPT (B) = 7.69419



VEHICLE 6 - 1978 Chevrolet Malibu

VARIABLE X : LOG MILES	VARIABLE Y : MPG
MEAN OF X = .808123	MEAN OF Y = 16.7645
S.D. OF X = 1.35394	S.D. OF Y = 7.7167

NUMBER OF PAIRS (N)	=	400
CORRELATION COEFFICIENT (R)	=	.78
DEGREES OF FREEDOM (DF)	=	398
SLOPE OF REGRESSION LINE (M)	=	4.44568
Y INTERCEPT (B)	=	13.1719

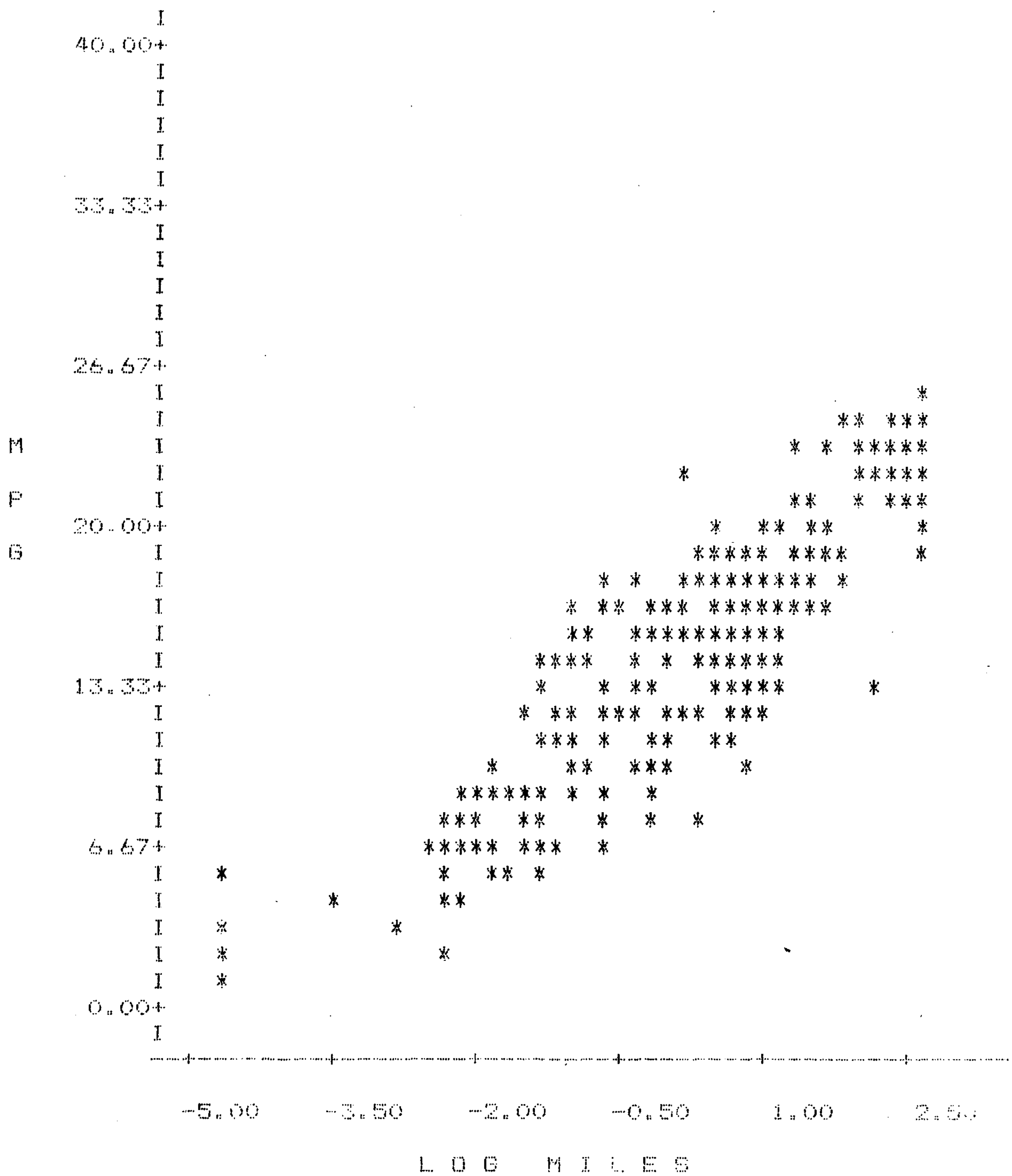


HOME VEHICLE USE STUDY

VEHICLE 7 - 1974 Ford Pinto

VARIABLE X : LOG MILES	VARIABLE Y : MPG
MEAN OF X = .378513	MEAN OF Y = 14.6501
S.D. OF X = 1.598	S.D. OF Y = 5.63016

NUMBER OF PAIRS (N)	=	362
CORRELATION COEFFICIENT (R)	=	.905
DEGREES OF FREEDOM (DF)	=	360
SLOPE OF REGRESSION LINE (M)	=	3.1899
Y INTERCEPT (B)	=	13.4427



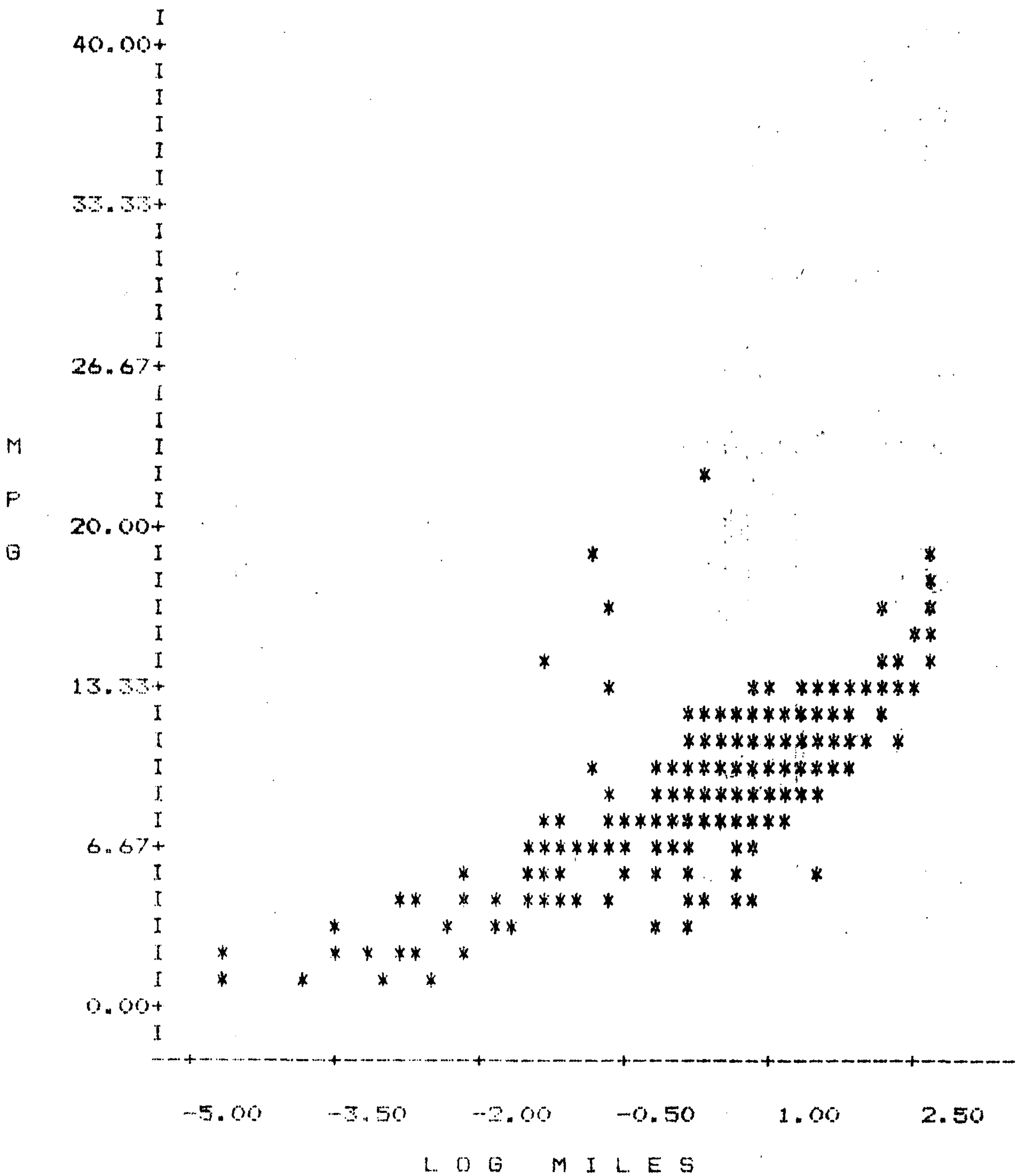
HOME VEHICLE USE STUDY

VEHICLE 8 - 1971 Mercury Montego

VARIABLE X : LOG MILES
MEAN OF X = .479147
S.D. OF X = 1.41588

VARIABLE Y : MPG
MEAN OF Y = 8.66618
S.D. OF Y = 3.23911

NUMBER OF PAIRS (N) = 430
CORRELATION COEFFICIENT (R) = .803
DEGREES OF FREEDOM (DF) = 428
SLOPE OF REGRESSION LINE (M) = 1.83601
Y INTERCEPT (B) = 7.78646



APPENDIX E

ANALYSIS OF VARIANCE TABLES

In the following tables:

Factor A = Feedback
Level 1 = Manual
Level 2 = Instrumented

Factor B = Phase
Level 1 = Baseline
Level 2 = FB-1
Level 3 = FB-2

FUEL CONSUMPTION

SOURCE	D.F.	SUM-SQR.	MEAN SQUARE	F-RATIO	PROB
A(18)	1	28.4031	28.4031	1.67656	.325
B(15)	2	78.9414	39.4707	2.32986	.300
AB	2	33.8825	16.9412	.926227	NS
ERROR	101	1847.35	18.2906	1	
ADJ. TOT.	106	1988.58	18.7602	0	

MODEL R-SQUARED: .0710191

TABLE OF TESTS ON CONTRASTS

CONTRAST VALUES	ESTIMATE	SUM-SQR.	F-RATIO	PROB
A1 -1 1	-.520435	28.4031	1.55288	.213
B1 -2 1 1	-.637184	78.928	4.31522	.016
B2 0 -1 1	.0125797	.0120102	6.56635E-04	NS
A1B1	.412617	33.0975	1.80954	.167
A1B2	-.101213	.777464	.0425062	NS

TABLE OF ADJUSTED MEANS FOR VARIABLE 2

	N	MEAN	SD
FACTOR A(18)			
LEVEL 1	55	6.50412	5.58541
LEVEL 2	52	5.46325	2.37761
FACTOR B(15)			
LEVEL 1	31	7.25805	6.69575
LEVEL 2	38	5.33392	2.83175
LEVEL 3	38	5.35908	2.66102
FACTOR AB...INTERACTION			
LEVEL A(1) B(1)	18	8.60372	8.48315
LEVEL A(1) B(2)	19	5.34053	3.34884
LEVEL A(1) B(3)	18	5.56811	2.8549
LEVEL A(2) B(1)	13	5.91239	2.3617
LEVEL A(2) B(2)	19	5.32732	2.29526
LEVEL A(2) B(3)	20	5.15005	2.53174

TOTAL TRIPS

SOURCE	D.F.	SUM-SQR.	MEAN SQUARE	F-RATIO	PROB
A(18)	1	1062.94	1062.94	90.0699	.008
B(15)	2	275.864	137.932	11.6878	.079
AB	2	23.6026	11.8013	.139106	NS
ERROR	101	8568.53	84.8369	1	
ADJ. TOT.	106	9930.93	93.6881	0	

MODEL R-SQUARED: .137188

TABLE OF TESTS ON CONTRASTS

CONTRAST VALUES	ESTIMATE	SUM-SQR.	F-RATIO	PROB
A1 -1 1	-3.18375	1062.94	12.5293	.001
B1 -2 1 1	-.871733	147.73	1.74134	.179
B2 0 -1 1	1.29832	127.93	1.50796	.225
A1B1	-.221148	9.50753	.112068	NS
A1B2	-.431213	14.1122	.166345	NS

TABLE OF ADJUSTED MEANS FOR VARIABLE 5

	N	MEAN	SD
FACTOR A(18)			
LEVEL 1	55	30.6433	8.92064
LEVEL 2	52	24.2758	9.45887
FACTOR B(15)			
LEVEL 1	31	29.203	9.45357
LEVEL 2	38	25.2895	11.4677
LEVEL 3	38	27.8861	7.60905
FACTOR AB...INTERACTION			
LEVEL A(1) B(1)	18	31.9444	9.01941
LEVEL A(1) B(2)	19	28.2632	10.3325
LEVEL A(1) B(3)	18	31.7222	7.00257
LEVEL A(2) B(1)	13	26.4615	9.44824
LEVEL A(2) B(2)	19	22.3158	12.0372
LEVEL A(2) B(3)	20	24.05	6.28679

NUMBER OF SHORT TRIPS

SOURCE	D.F.	SUM-SQR.	MEAN SQUARE	F-RATIO	PROB
A(18)	1	707.407	707.407	8.58292	.099
B(15)	2	188.322	94.1608	1.14245	.467
AB	2	164.841	82.4203	1.46198	.235
ERROR	101	5693.96	56.3758	1	
ADJ. TOT.	106	6754.53	63.722	0	

MODEL R-SQUARED: .157016

TABLE OF TESTS ON CONTRASTS

CONTRAST VALUES	ESTIMATE	SUM-SQR.	F-RATIO	PROB
A1 -1 1	-2.59728	707.407	12.548	.001
B1 -2 1 1	.315115	19.3036	.342409	NS
B2 0 -1 1	1.49269	169.103	2.99956	.053
A1B1	.920378	164.677	2.92106	.057
A1B2	-.0453216	.155891	2.76522E-03	NS

TABLE OF ADJUSTED MEANS FOR VARIABLE 9

	N	MEAN	SD
FACTOR A(18)			
LEVEL 1	55	21.5117	6.52305
LEVEL 2	52	16.3171	8.56781
FACTOR B(15)			
LEVEL 1	31	18.2842	8.5362
LEVEL 2	38	17.7368	9.19954
LEVEL 3	38	20.7222	5.65887
FACTOR AB...INTERACTION			
LEVEL A(1) B(1)	18	22.7222	6.85828
LEVEL A(1) B(2)	19	19.3684	7.44767
LEVEL A(1) B(3)	18	22.4444	4.66807
LEVEL A(2) B(1)	13	13.8462	8.12246
LEVEL A(2) B(2)	19	16.1053	10.6244
LEVEL A(2) B(3)	20	19	6.07844

MILES PER GALLON

SOURCE	D.F.	SUM-SQR.	MEAN SQUARE	F-RATIO	PROB
A(18)	1	527.407	527.407	5.48051	.145
B(15)	2	118.045	59.0224	.613326	NS
AB	2	192.467	96.2333	3.54905	.031
ERROR	101	2738.64	27.1153	1	
ADJ. TOT.	106	3576.56	33.7411	0	

MODEL R-SQUARED: .234281

TABLE OF TESTS ON CONTRASTS

CONTRAST VALUES				ESTIMATE	SUM-SQR.	F-RATIO	PROB
A1	-1	1		-2.24263	527.407	19.4506	.000
B1	-2	1	1	-.744501	107.753	3.97391	.021
B2	0	-1	1	.367356	10.242	.377721	NS
A1B1				-.869777	147.067	5.42379	.006
A1B2				-.774455	45.5201	1.67876	.190

TABLE OF ADJUSTED MEANS FOR VARIABLE 4

	N	MEAN	SD
FACTOR A(18)			
LEVEL 1	55	17.8911	5.59866
LEVEL 2	52	13.4058	5.1101
FACTOR B(15)			
LEVEL 1	31	17.1375	5.87132
LEVEL 2	38	14.5366	5.2463
LEVEL 3	38	15.2713	6.31161
FACTOR AB...INTERACTION			
LEVEL A(1) B(1)	18	17.6405	4.93774
LEVEL A(1) B(2)	19	16.8745	5.22649
LEVEL A(1) B(3)	18	19.1582	6.58347
LEVEL A(2) B(1)	13	16.6344	7.14171
LEVEL A(2) B(2)	19	12.1986	4.20961
LEVEL A(2) B(3)	20	11.3844	2.94361