ANALYSIS OF LIGHT-DUTY VEHICLE
FUEL SWITCHING IN THE NPD DATA BASE

EPA Prime Contract 68-01-6558

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EPA Prime Contract 68-01-6558
Subcontract 130.109
Work Assignment No. 30, Task 4
Work Assignment No. 30A, Task 2

Prepared for:

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This is the final report on misfueling work for EPA. Misfueling is defined as the use of leaded gasoline in vehicles certified for the use of unleaded gasoline. EPA is publishing the results to stimulate public discussion of the subject but the results do not represent EPA conclusions.

The work on this project was done under EPA Prime Contract 68-01-6558, Subcontract 130.109. This report combines the results from two work assignment/tasks:

Work Assignment 30, Task 4   "Misfueling of Light-Duty Vehicles in 1981: Interim Report"

Work Assignment 30A, Task 2   "Misfueling of Light-Duty Vehicles in 1982: Interim Report"

Each of these task reports is included as a section in this final report.

Part I of this report, "Misfueling of Light-Duty Vehicles in 1981: Interim Report," quantifies the rate of misfueling of light-duty vehicle (LDV) owners/operators in 1981. The report presents highlights of the misfueling trends observed in a time series data base of fuel purchasing behavior. Findings are presented without any attempt at interpretation.

Part II of this report, "Misfueling of Light-Duty Vehicles in 1982: Interim Report," repeats the work done for Part I using data for 1982.

1. THE NPD DATA BASE

The survey information in the NPD data base is derived from the NPD
Petroleum Marketing Index (PMI), a diary panel survey of over 5,000
households conducted by NPD Research, Inc. Panel members are chosen on
the basis of demographic characteristics and geographical location. The
panel does not include singles or non-family households.

In order to ensure that consistent demographic information is available
from all households, NPD requires an adult female be present in all
families selected for participation. The rest of Section 1 of this
preface discusses important characteristics of the NPD data base which
should be kept in mind when examining the results presented in this
report.

1.1 Selection of the Panel

Possible respondents for the PMI panel are selected from the American
Shoppers Panel (ASP). Each candidate is sent a letter asking about his
or her interest in participating in a vehicle use diary panel. Between
60 and 65 percent of those asked respond and return their initial
questionnaires. This percentage includes those people who own no
vehicle. The questionnaire requests information including the VIN and
other engine characteristics for a maximum of five separate vehicles per
family. Since the respondents are already in the ASP, no demographic
data needs to be collected. NPD selects a subset of these respondents
on a demographic basis in order to maintain a balanced sample for the
PMI survey. Those selected are sent a monthly diary, a visor holder,
and an introductory letter. There is a 75 to 80 percent response to the
first monthly diary. Respondents are guaranteed anonymity and at no
time are told who will be using the data, although they do know that

companies buy the data for gasoline brand market share studies. Respondents are given a hotline number to call if they have any questions, but the people who staff the phones do not know themselves who the clients are. Participants in the ASP are recruited from a variety of mailing lists. The response rate at this stage varies from 2 to 25 percent, depending upon the scope of a particular recruitment effort.

1.2 Coverage of Leased Vehicles

Survey respondents were asked to include "all leased cars whether leased by a company, a business, or privately by any family member."* Unfortunately, it is impossible to determine from the available data which vehicles are leased by a company or business.

1.3 Determination of Fuel Type Requirement

Although the respondent was asked if the vehicle required unleaded fuel, the answer to this question was not used in this report for classifying the vehicle fuel requirements. Rather, the fuel requirements were determined on the basis of make, model, model year, engine data provided by the respondent, and, when available, were confirmed with engine data obtained from the VIN.

1.4 Trucks in NPD

In any calendar year, nearly 2,000 light-duty trucks participate in the NPD survey. Due to difficulties in determining truck fuel requirements, only about 150 of these trucks may be positively identified as having catalysts. Because of the small sample size for trucks, only cars were

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*Statement from the letter mailed to each potential participant.

included in this analysis. The exclusion of trucks must be kept in mind when considering the results since the tampering rates for trucks have been reported to be substantially different from those for cars.*

1.5 Non-Catalyst Cars With Unleaded Fuel Requirements

Certain vehicles are required to use unleaded fuel even though they do not have a catalyst. Since it has been assumed that the ultimate use, if any, of this analysis will be for estimating the effect of misfueling on catalyst vehicles, a misfueling rate among catalyst vehicles is sufficient. While it can be assumed that the misfueling rates among non-catalyst unleaded cars are either the same or different, this issue is not relevant. Misfueling among non-catalyst unleaded cars does affect estimates of leaded gasoline consumption and lead emissions. However, the number of such vehicles and their contribution to leaded gasoline consumption and lead emissions is small and errors will be small if equal misfueling rates are assumed. Furthermore, the data base has few of these cars, so any separate estimates would have great uncertainty.

1.6 Confidence Intervals

Selected tables in this analysis include a statistic termed "Estimated Errors" to denote the reliability of reported misfueling rates. Inasmuch as the NPD data base is derived from a quota sample, it may be argued that no statistic can reflect the "error of estimate" as applied in the strict sense of a random sample. Nevertheless, it is important to realize that estimates derived from a quota sample are subject to variability and that the analyst must consider the variability of

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*"Motor Vehicle Tampering Survey - 1982," U.S. Environmental Protection Agency, Office of Enforcement and Legal Counsel, Publication No. EPA-330/1-83-001, April 1983, p. 20.

derived estimates in interpreting the findings. A more detailed explanation of the derivation of these estimates may be found in Appendix 1 of the analysis.

2. <u>VALIDITY OF THE DATA</u>

Since the NPD data is from a diary panel survey it is important to examine the make-up of the panel and to determine if observed trends in vehicle use behavior are consistent with results from other surveys.

Tables 1 and 2* present some of the demographic distributions observed in the NPD data base and compare them to distributions seen in the Residential Energy Consumption Survey (RECS) and in the National Family Opinion (NFO) gasoline diary survey. Table 3** presents a comparison of Household Income distribution as observed in NPD and as reported by the U.S. Bureau of the Census. Owing in large part to the exclusion of singles from NPD, the demographic profile is not strictly representative of the U.S. as a whole. This being the case, it is crucial to compare trends in driving behavior in NPD with those seen in other sources.

A comparison of monthly trends in household Vehicle Miles of Travel (VMT) is presented in Figure 1.[+] Notes on the pages following the figure describe the sampling and estimation techniques used in each of the studies. NPD is consistent with these other data sources with

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*Fuel Purchasing Patterns and Vehicle Use Trends From the NPD Research Gasoline Diary Data Base: Data Display, Energy and Environmental Analysis, Inc., prepared for the U.S. Department of Energy, September 1982.

**Ibid.

+Ibid.

TABLE 1

COMPOSITION AND LOCATION OF HOUSEHOLDS:
NPD VERSUS RECS AND NFO
(Percent)

			Family Size		
	One	Two	Three	Four	Five or More
RECS	15.8	36.6	18.1	16.1	13.4
NFO	17.1	38.5	16.8	16.2	11.4
NPD	00.0	42.7	20.5	23.3	13.5

			Number of Vehicles	
	One	Two	Three	Four or More
RECS	40.2	42.8	12.3	4.7
NFO	51.3	39.2	8.1	1.4
NPD	32.0	40.7	17.1	10.2

		Census Regions		
	Northeast	North Central	South	West
RECS	21.0	27.2	31.9	19.9
NFO	21.3	29.2	31.7	17.8
NPD	20.4	26.8	32.2	20.6

TABLE 2

AGE AND ECONOMIC STATUS OF HOUSEHOLDS:
NPD VERSUS RECS AND NFO
(Percent)

	Age of Head of Household			
	Under 30	30-39	40-49	50 and Over
RECS	16.9	20.5	17.7	44.9
NFO	3.2	19.5	18.0	59.3
NPD	7.8	22.8	16.8	52.6

	Own	Rent	Rent Free	Other
RECS	74.9	23.8	1.3	0.0
NFO	84.5	13.4	0.5	1.6
NPD	87.5	11.2	1.3	0.0

TABLE 3

HOUSEHOLD INCOME (1981$)
NPD VERSUS U.S. CENSUS
(Percent)

	Under 10,000	10,000 14,999	15,000 19,999	20,000 29,999	30,000 39,999	40,000 49,999	50,000 or More
Census*	25.4	14.4	12.3	21.1	13.1	6.6	7.1
NPD	17.2	18.2	16.2	27.2	13.1	4.7	3.3

*U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 134, "Money Income and Poverty Status of Families and Persons in the United States: 1981 (Advance Data from the March 1982 Current Population Survey)," U.S. Government Printing Office, Washington, D.C., 1982.

Note: NPD households include families only, while U.S. Census data uses a broader definition that includes singles.

FIGURE 1

MONTHLY TRENDS IN HOUSEHOLD VMT

MILES PER MONTH

EIA — Energy Information Administration Residential Energy Consumption Survey Transportation Panel
NPD — The Petroleum Marketing Index NPD Research, Inc
NFO — NFO Auto Facts Panel Survey Data
FHWA — Monthly Total Highway VMT in 10⁹ | U.S. DOT, Federal Highway Administration Traffic Volume Trends

EIA — ....
NPD — - - - - -
NFO — ————
FHWA — ————

1978   1979   1980   1981

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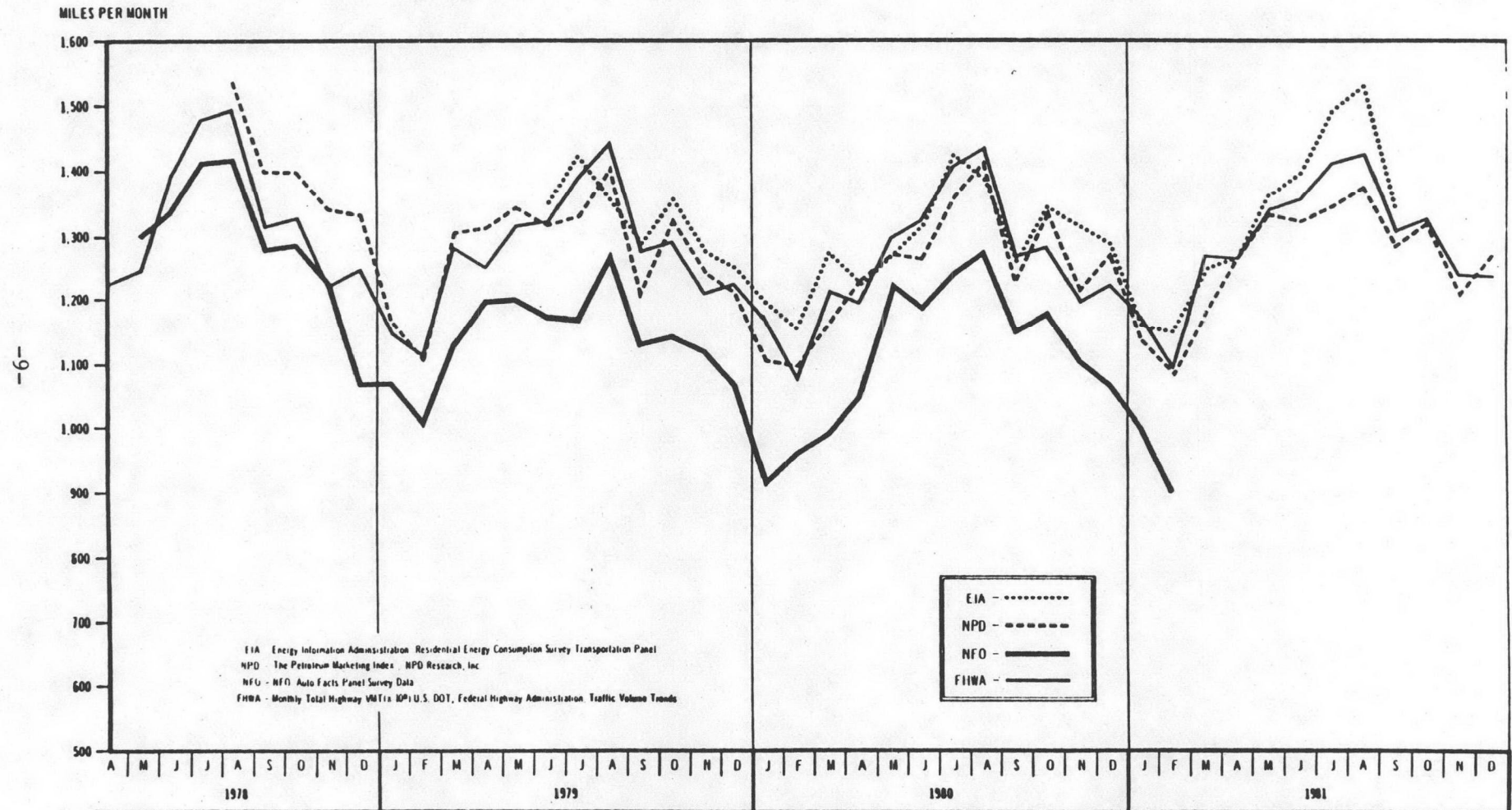
NOTES FOR FIGURE 1

COMPARABILITY OF HOUSEHOLD VMT SOURCES

● Data Sources

 - Energy Information Administration: Residential Energy Con-
   sumption Survey Household Transportation Panel (June 1979 to
   September 1981)

 - Federal Highway Administration (FHWA): Traffic Volume Trends
   (April 1978 to December 1981)

 - National Family Opinion Poll: NFO/Auto-Facts Gasoline Diary
   Panel (May 1978 to February 1981)

 - NPD Research, Inc.: Petroleum Marketing Index Diary Panel
   (August 1978 to December 1981)

● Sampling Techniques

 - RECS: Systematic random sample of households (includes single
   people and unrelated persons sharing a dwelling)

 - FHWA: Does not sample individual vehicles

 - NFO/Auto-Facts: Quota sample survey of households (includes
   single people and unrelated persons sharing a dwelling)

 - NPD Research: Quota sample survey of families (single people
   and unrelated persons sharing a dwelling are not included)

● Estimation Techniques

 - RECS: Odometer readings -- data weighted to national level on
   the basis of demographic characteristics of household

 - FHWA: City and highway traffic flow counts conducted by State
   highway departments -- estimate of total travel scaled down by
   factor of 10^8 for directional trend comparison to household
   estimates; Census data show approximately 68 million vehicle-
   operating households in the U.S.

 - NFO/Auto-Facts: Odometer readings -- data are sample-
   weighted.

 - NPD Research: Odometer readings -- data weighted to national
   level on the basis of demographic characteristics of household

● Coverage
 - RECS, NFO/Auto-Facts, NPD Research: Report on all vehicles
   driven (owned/operated) by a household

 - FHWA: Includes trucking and commercial travel

respect to monthly trends in household VMT. Further evidence of NPD's consistency may be found in comparisons of annual vehicle miles of travel by vehicle age.

Figures 2 and 3 plot the relationship between annual VMT (Vehicle Miles of Travel) and vehicle age for cars and light-duty trucks. The figures show the well-known trend in decreasing VMT with age as observed in NPD and three other surveys. The other surveys are the Nationwide Personal Transportation Study (NPTS) conducted by the U.S. Department of Transportation, Office of Highway Planning; the Residential Energy Consumption Survey (RECS) conducted by the Energy Information Administration; and the NFO/Auto-Facts (NFO) national panel diary survey conducted by Auto-Facts, Inc. As can be seen from the two plots, the vehicle-age dependent declines in VMT found in NPD are consistent with those reported by RECS and NFO. The NPTS survey, which consistently reports higher annual VMT than the other data sources, was collected several years earlier than the other studies. Furthermore, NPTS respondents were simply asked to recollect their prior year's mileage accumulation; no effort was made to corroborate the response with odometer records. The RECS survey, which did ask for odometer readings, is a systematic random sample of households, including single people and unrelated persons sharing a dwelling. Since the NPD results are not markedly different from those in RECS, it appears that NPD does not have a serious non-response bias vis-a-vis a random sample with respect to vehicle travel characteristics. In addition, the exclusion of singles seems to have little effect on observed aggregate vehicle use behavior.

The preponderance of evidence suggests that NPD is valid and appropriate for studies of vehicle use behavior in the U.S. Besides having proven itself to be reliable, NPD is also the only currently available source of extensive time series data for the U.S. personal transportation

FIGURE 2

ANNUAL VMT PER CAR BY AGE

LEGEND

%-----% = 1969 NPTS
&------& = 1980 NFO
$------$ = 1980 RECS
#-----# = 1981 RECS
"-----" = 1977 NPTS
+------+ = 1981 NPD
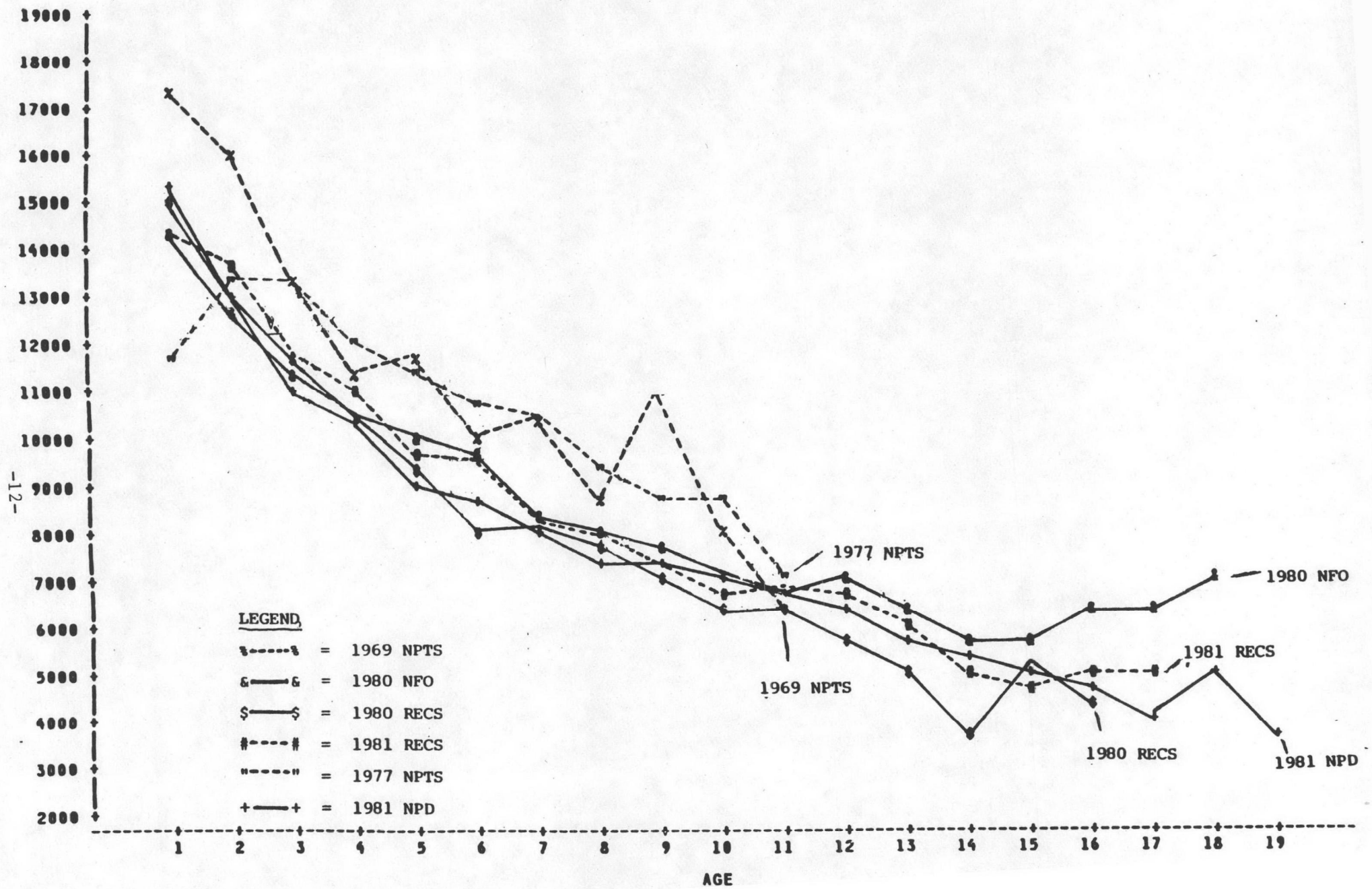
FIGURE 3

ANNUAL VMT PER LIGHT TRUCK BY AGE

LEGEND

&——& = 1980 NFO

#·····# = 1981 RECS

$——$ = 1980 RECS

+——+ = 1981 NPD

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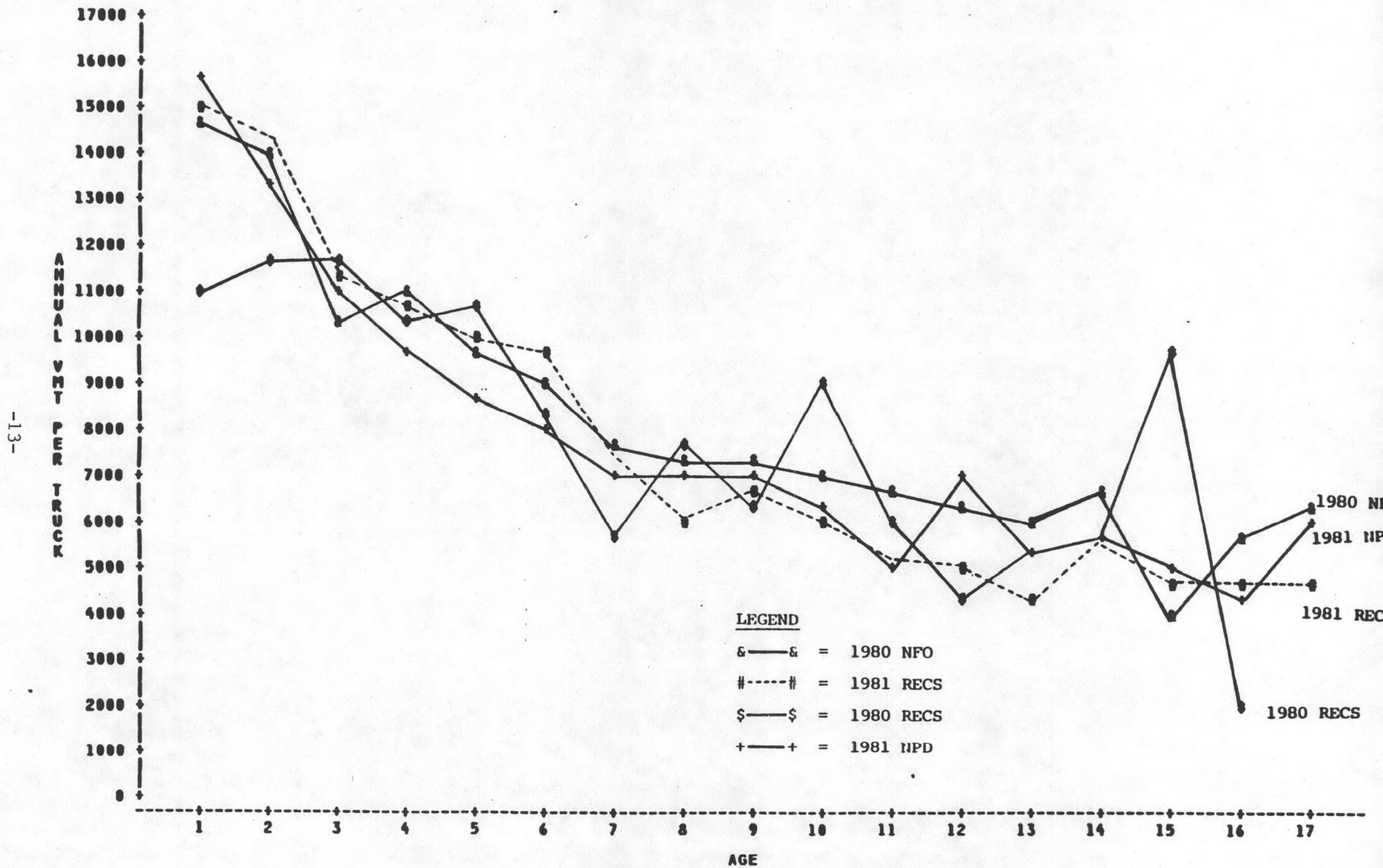
fleet. Vehicles typically stay in the panel for 10 to 12 months, thus making it possible to take a detailed look at the behavior of many individual vehicle owners over an extended period.

3. ASSUMPTIONS PERTAINING TO THIS ANALYSIS

In processing the NPD data for this analysis, assumptions have been made about unknown fuel type purchases and about reporting errors. These assumptions are discussed in this section.

3.1 Unknown Fuel Purchase Assumption

In approximately 1.6 percent of all purchases reported by the catalyst-equipped cars in NPD, the respondent failed to report whether the fuel purchase was leaded or unleaded. For purposes of assigning misfueling involvement categories the unknown fuel volume is divided between leaded and unleaded fuel on the basis of the ratio between known leaded volume and known unleaded volume for the vehicle making the unknown purchase. Assumptions that unknown is always unleaded or always leaded have also been examined to determine the sensitivity to this approach. The resulting involvement rates are displayed in both the 1981 and 1982 sections of this analysis.*

For purposes of determining the maximum number of successive leaded purchases, unknown purchases are treated as if they were unleaded. It is not practical to randomly assign individual purchases as either leaded or unleaded since on average a vehicle reports only 0.7 unknown purchases during a year. In order to provide bounds for the effect of

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*The results may be found in Table 4 "Comparison of Involvement Under Alternate Assumptions About Unknown Fuel Type." This table is included in both the 1981 and the 1982 sections.

this methodology two alternate cases have been tested. The first case assumes unknown purchases are unleaded; the second case assumes unknown purchases are leaded. Table 4 compares these two cases. Percentages on the diagonal represent vehicles not affected by the manner in which unknown fuel is classified. Percentages to the right of the diagonal represent vehicles that would move into a higher successive purchase category if unknown fuel were assumed to be leaded. When the maximum number of successive leaded purchases is at least three, assuming unknown fuel to be leaded has little effect on the distribution of vehicles.

In summary, the unknown fuel type volume is assigned to leaded or unleaded but no attempt is made to correct each individual purchase. If individual purchases were reassigned, the effect on the repeated misfueling statistics is not expected to be large.

3.2 Reporting Errors Assumption

In any large data collection effort there is a potential for recording or transcribing errors.* To avoid overstating the incidence of misfueling, only those vehicles recording at least three leaded purchases during the time they were in the sample are counted as misfuelers. If no more than two leaded purchases are reported, a data error is assumed and the fuel type designator is changed to unleaded.

The rationale for this screening criterion is based on the fact that even with a probability of reporting error as low as 1 percent, there is about one chance in three that one or two misfuelings would be reported

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*H.T. McAdams, Analysis Memorandum to R. Dulla (EEA), "Reporting Errors in Fuel Purchase Records," under Letter of Agreement No. 026003-1, Contract No. B-F6895-AZ, February 17 and 20, 1984.

TABLE 4

COMPARISON OF ALTERNATE ASSUMPTIONS ABOUT UNKOWN FUEL TYPE
PURCHASES USING 1982 NPD DATA
(Using Weighted Data)

Maximum Number of Successive Leaded Purchases Assuming That Unknown is Unleaded	Number of 1982 Vehicles So Classified	Classification Under Alternate Assumptions (Unknown = Leaded) (Percent of Vehicles)						
		0	1	2	3	4	5	6
0	3,050	74.6	11.0	7.6	2.4	1.3	0.8	2.2
1	10		90.4	9.6	0.0	0.0	0.0	0.0
2	34			81.5	4.4	4.3	0.0	9.7
3	106				87.7	3.3	3.0	6.0
4	100					98.4	1.3	0.4
5	55						97.6	2.4
6 or more	339							100.0

during the course of the survey, even though no leaded purchases were actually made. On the other hand, actual misfuelers who misfuel to a significant degree would seldom report as few as two misfuelings during the survey. Thus, the rule is structured to strike a compromise between the two types of errors to provide a refined estimate of the actual vehicle involvement rate in the context of the study.*

Table 5 displays the effect of this methodology on the vehicle involvement rate using data from 1982.** Using the criteria, the overall vehicle involvement rate is 18.0 percent. Without the criteria, taking all leaded designations at face value, the involvement rate is 30.0 percent. Table 6 displays the effect of the methodology on the amount of leaded fuel purchased by the catalyst car fleet. Using the criteria, 7.7 percent of the fuel purchased by the catalyst car fleet was leaded. Without that criteria, leaded fuel purchase volume rises to 8.1 percent of the fuel bought by the fleet. Thus, although the methodology reduces the apparent vehicle involvement in misfueling by 40 percent, the change in fuel volume is less than 5 percent.

The criteria results in a conservative lower bound estimate for vehicle involvement and has very little effect on the reported volume of misfueling. An 18 percent vehicle involvement rate, although a lower bound, is not insignificant. By comparison, the 1982 EPA tampering survey reports that 10.58 percent of vehicles sampled show at least one

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*H.T. McAdams, Analysis Memorandum to R. Dulla (EEA), "Vehicle Involvement Rate and Its Dependence on Sample Size," under Letter of Agreement No. 026003-1, Contract No. B-F6895-A-Z, March 30, 1984.

**A total of 445 cars meet the maximum-of-two leaded purchase criteria in 1982.

TABLE 5

COMPARISON OF VEHICLE INVOLVEMENT IN MISFUELING IN 1982
RESET MAXIMUM-OF-TWO LEADED PURCHASES TO UNLEADED VERSUS NO RESET

Model Year	Number of Vehicles	Vehicle Involvement Misfueling Rate			
		Reset		No Reset	
		Rate (% of Fleet)	Estimated Error	Rate (% of Fleet)	Estimated Error
1975	280	25.0	5.1	37.2	5.7
1976	465	22.4	3.8	32.1	4.2
1977	586	22.0	3.4	32.3	3.8
1978	632	17.1	2.9	29.1	3.5
1979	590	14.8	2.9	26.9	3.6
1980	450	16.0	3.4	26.3	4.1
1981	485	13.0	3.0	26.9	4.0
1982	185	16.6	5.4	39.6	7.1
1983	21	16.3	15.8	23.2	18.1
Overall	3,694	18.0	1.2	30.0	1.5

TABLE 6

COMPARISON OF VEHICLE INVOLVEMENT IN MISFUELING IN 1982
RESET MAXIMUM-OF-TWO LEADED TO UNLEADED VERSUS NO RESET

Model Year	Number of Vehicles	Leaded Fuel Purchased as Percent of Total	
		Reset	No Reset
		Percent Leaded	Percent Leaded
1975	280	15.3 (4.2)*	15.7 (4.3)
1976	465	11.0 (2.9)	11.3 (2.9)
1977	586	13.4 (2.8)	13.7 (2.8)
1978	632	7.4 (2.0)	7.8 (2.1)
1979	590	4.8 (1.7)	5.2 (1.8)
1980	450	4.2 (1.9)	4.5 (1.9)
1981	485	1.6 (1.1)	2.0 (1.3)
1982	185	2.2 (2.1)	3.0 (2.5)
1983	21	3.5 (7.8)	4.5 (8.9)
Overall	3,694	7.7 (0.9)	8.1 (0.9)

*Values in parentheses are estimated errors.

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positive indication of misfueling.* Since the EPA survey is a random
sample and does include trucks, this comparison to NPD is necessarily
approximate. However, since EPA reports a higher tampering rate for
trucks than for cars a combined sample might be expected to yield a
higher rate than for cars alone. A key to the results might be found in
the different manner in which the two surveys collected information.
The NPD data was collected over a long period of time from individuals
who thought they were simply providing marketing information. The EPA
data is a compilation of single observations on a random selection of
vehicles. One advantage to the EPA method is that classification of a
misfueler is based on a direct examination of each vehicle by the survey
team. The examination includes a Plumbtesmo test for lead in the
exhaust pipe, a check of the filler neck restrictor to see if it has
been tampered with, and chemical analysis of a gasoline sample to see if
lead in the gas tank is above a threshold of 0.05 grams per gallon.
There is very little chance that a regular misfueler could escape
detection. At the same time, there is some chance that an infrequent
misfueler might be overlooked. For example, an individual purchasing
leaded gasoline every five or six tankfuls, who uses a funnel to bypass
the filler neck restrictor, would show no obvious tampering and might
easily have less than 0.05 grams of lead per gallon of fuel in the tank
at the time of survey. Furthermore, as noted in the tampering survey, a
hastily field-administered Plumbtesmo tailpipe test is unreliable when
negative.** Thus, while a positive Plumbtesmo test is reliable evidence
of lead in the tailpipe, a negative test means only that lead was not
detected -- the possibility remains that a repeat test under more ideal

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*Motor Vehicle Tampering Survey - 1982, U.S. Environmental Protection
  Agency, Publication No. EPA-330/1-83-001, April 1983, p. 28.

**Ibid.

circumstances would yield a positive result. An additional negative bias is associated with the non-compulsory nature of the survey. Since the EPA survey is openly conducted for a government agency, misfuelers may be extremely hesitant to participate.

In conclusion, while it is difficult to make an exact comparison between NPD and EPA results, each has sources of downward bias and each has strong points. EPA uses a random sample and, through actual examination of the vehicles, has a high probability of identifying regular misfuelers. NPD samples a wider geographic range, including rural areas, and provides demographic information, as well as detailed time-series purchase data. Preference for one type of survey over another is ultimately dependent upon the analysis to be performed and it is the analyst's responsibility to judge the suitability of a particular data base to the task at hand.

PART I:

MISFUELING OF LIGHT DUTY VEHICLES
IN 1981:
INTERIM REPORT

EPA Prime Contract 68-01-6558
Subcontract 130.109
Work Assignment No. 30, Task 4

Prepared for:

ENVIRONMENTAL PROTECTION AGENCY
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September 1984

LIST OF TABLES

SUMMARY

The purpose of this task is to quantify the rate of misfueling by light-duty vehicle (LDV) owners/operators in 1981. At the direction of EPA, light-duty trucks are specifically excluded from the analysis. This report presents highlights of the misfueling trends observed in a time series data base of fuel purchasing behavior. The survey information is derived from the NPD Petroleum Marketing Index (NPD), a diary panel survey of over 5,000 households conducted by NPD Research Inc. The tables and accompanying descriptive notes in this paper present findings without any attempt at interpretation.

Misfueling may be measured in a variety of ways; the appropriate method depends upon the questions to be answered. In this study the misfueling rate is measured by fleet involvement, i.e., the proportion of all catalyst vehicles which are misfueled. Vehicles are categorized on the basis of whether or not they are ever misfueled, on the ratio of leaded fuel purchased to total fuel purchased, and on the maximum number of successive leaded purchases made during the survey period. Most of the tables presented here are aggregated across all model years. An appendix to this report contains a computer printout with more detailed results on specific model years.

This study is not intended to answer questions about why people misfuel. Rather, it quantifies the behavior observed in a representative sample of individuals during the course of a recent calendar year. Most previous studies of misfueling have sampled a cross-section of the vehicle population at one point in time. A major advantage of using a diary panel survey is that individuals may be followed through time.

Such a survey provides more complete information about the frequency of misfueling and could allow for detailed studies of the demographic characteristics of misfuelers or motivational factors.

The most common reservation about the use of diary surveys is that they depend upon consistent and truthful self-reporting. Despite concerns about respondents' potential unwillingness to incriminate themselves, the panel participants were quite open about their purchasing behavior and freely indicated the purchase of leaded fuel. The participants know their responses are being collected for gasoline brand market share studies and they are accustomed to reporting detailed information about what they have purchased. The participants do not know that government agencies purchase the raw survey data for studies such as this one. Furthermore, the participants are guaranteed anonymity by NPD Research, Inc. when they agree to participate.

DATA BASE PREPARATION

The NPD data base contains fuel purchase histories for over 12,000 privately operated vehicles. The data, collected during 1981, contain detailed information about fuel purchases, including date, gallons, type of fuel, and total cost. An example of the purchase logs filled in by respondents is shown in Appendix 2. There is body style/engine information as well as household demographic data associated with each vehicle purchase history. This data base has been used extensively by the U.S. Department of Energy (DOE) to examine trends in fuel consumption, on-road fuel economy, and vehicle miles of travel. During the course of this previous work the data were cleaned and established as a SAS data

set. As part of this work for DOE, the engine description information provided by the survey respondent was verified (and corrected when necessary using information extracted from the vehicle identification number (VIN).* Based on this engine information, each vehicle has bee classified as to whether or not it has a catalyst.

The only additional processing of the data in the current work was to re-examine and verify existing catalyst information. Identification o a catalyst equipped vehicle is made on the basis of the VIN-augmented data for make/model, model year, CID, number of cylinders, fuel system and type of transmission.

As noted previously, this task is based on a study of the 3353 catalyst equipped LDVs from NPD. A small number of LDVs manufactured during the late seventies required unleaded fuel but were not actually equipped with a catalyst. We have assumed that the ultimate use, if any, of thi analysis will be for estimating the effect of misfueling on catalyst vehicles. For this purpose, a misfueling rate among catalyst vehicles is sufficient. Therefore, those vehicles not having a catalyst but requiring unleaded were not included in the study. Another group of LDVs excluded from the study were those participating for less than two nonths. For the most part, respondents with only one month of partici-)ation have very poor record-keeping practices and incomplete purchase listories. Frequently only one or two purchases are reported and :ypically consist mostly of missing information. A total of 127 vehi- :les were deleted from the survey for participating less than two ionths. An additional three vehicles were deleted because none of thei urchases were identified as either leaded or unleaded.

The VIN is reported by the owner, along with the engine description information, when a vehicle first enters the survey.

In any large data collection effort there is a potential for recording or transcribing errors. To avoid over-reporting the incidence of misfueling, only those vehicles recording at least three leaded purchases during the year are counted as misfuelers. If no more than two leaded purchases are reported, a data error is assumed and the fuel type designation is changed to unleaded. A total of 524 vehicles meet this maximum-of-two leaded purchases criteria. A total of 1,110 "purchases" showing 0.0 gallons of fuel bought were deleted. In general, these records are null entries representing months when a diary was returned but no fuel was purchased.

The tables in this report highlight misfueling behavior in the catalyst fleet. They also provide information pertaining to the manner in which the data are weighted and to the way in which unknown fuel type purchases are handled. Each table is prefaced with explanatory notes to assist the reader in interpreting the information presented.

Table 1 - Highlights of Misfueling Frequency Distributions

- Data in this table are weighted on the basis of the NPD projection factors. For information on the effect of alternative weighting methods, see Table 3.

- Total fuel purchased includes leaded, unleaded, and type unknown. For more detail on the treatment of purchases with unknown fuel type, and its effect on the findings, see Table 4.

- Leaded fuel as a percent of total fuel purchased by the catalyst fleet measures misfueling on a <u>gallons purchased</u> basis.

- The leaded fuel under 11 percent and 91-100 percent of total fuel purchased categories measure misfueling on a vehicle basis. Each vehicle's degree of involvement is judged on the basis of how much of their purchase volume is leaded. The vehicle is then assigned to an appropriate category. So, for example, 5.6 percent of the vehicles in the catalyst fleet were misfuelers whose leaded purchases amounted to less than 11 percent of the fuel they purchased during the year. By comparison, 3.5 percent of the vehicles in the catalyst fleet purchased 91 to 100 percent leaded fuel by volume.

- Catalyst fleet involvement in misfueling includes any catalyst vehicle that ever purchased leaded fuel, regardless of quantity or percentage of total fuel purchased over the year.

- There is a small number of vehicles (0.2 percent) of the catalyst fleet who purchased leaded fuel, but less than 10 gallons worth. These vehicles are included in the "Leaded Fuel Under 11% of Total" category regardless of actual percentage.

TABLE 1

HIGHLIGHTS OF MISFUELING FREQUENCY DISTRIBUTIONS

Number of Catalyst Equipped Vehicles	3353
Leaded Fuel as Percent of Total Fuel Purchased by the Catalyst Fleet	6.4 (0.8)*
Leaded Fuel Under 11% of Total Fuel Purchased by Vehicle (percent of catalyst fleet)	5.6 (0.8)
Leaded Fuel 91-100% of Total Fuel Purchased by Vehicle (percent of catalyst fleet)	3.5 (0.6)
Catalyst Fleet Involvement in Misfueling (percent of catalyst fleet)	14.3 (1.2)
Purchased at least 10 gallons of Leaded Fuel (percent of catalyst fleet)	14.5 (1.2)
Purchased leaded fuel at least 3 times from January to June 1981 and not at all from July to December 1981 (percent of catalyst fleet)	3.0 (0.6)
Purchased leaded fuel at least 3 times from January to June 1981 (percent of catalyst fleet)	10.0 (1.0)

*Values in parentheses are estimated errors in the percent of catalyst fleet.

Table 2 - Distribution of Misfueling by Degree of Involvement

- In the table, vehicle involvement in misfueling is measured by the ratio of leaded fuel to total fuel purchased. A vehicle purchasing a total of 400 gallons of fuel (all types) during 1981, of which 30 gallons are leaded, has a ratio of 30 to 400 or 7.5 percent. This vehicle is placed in the under 11 percent leaded category. Had the same vehicle purchased 350 gallons of leaded, out of 400 gallons total, the ratio would be 87.5 percent leaded and the vehicle would be placed in the 81-90 percent leaded category.

- 5.7 percent of the catalyst fleet, or 39.6 percent of the misfuelers, have leaded fuel purchases totaling less than 11 percent of their annual fuel purchases. By comparison, 3.5 percent of the fleet, or 24.3 percent of misfuelers, purchased 91-100 percent leaded fuel by volume.

TABLE 2

DISTRIBUTION OF MISFUELING
BY DEGREE OF INVOLVEMENT
Aggregated Across All Model Years

Leaded Fuel Purchased by Vehicle as Percent of Total Fuel Purchased	Percent of Catalyst Fleet In Category	Estimated Error	Percent of Misfueling Vehicles
Under 11	5.7	0.8	39.6
11-20	2.2	0.5	15.3
21-30	0.6	0.3	4.2
31-40	0.3	0.2	2.1
41-50	0.3	0.2	2.1
51-60	0.2	0.2	1.4
61-70	0.3	0.2	2.1
71-80	0.8	0.3	5.6
81-90	0.5	0.3	3.5
91-100	3.5	0.6	24.3

Table 3 - Comparison of Weighting Methods

- Each vehicle contributes one observation to the misfueling analysis. When calculating the overall misfueling rate it is helpful if an individual vehicle's contribution can be weighted to account for its importance relative to other vehicles in the fleet. This table compares three methods of weighting.

- Sample weighting, with each vehicle assigned a weight of one, does not distinguish among vehicles.

- The NPD projection factor weights are assigned to each household on a monthly basis by NPD Inc. The factors are designed to weight the sample, demographically, to the national level based on income, race, region, and the educational level and occupation of the female head of house. As respondents enter and leave the survey, each household projection factor is adjusted to maintain the national level weighting scheme. The weight used in this study is the sum of these factors over each month a vehicle participates in the survey.

- The Months in Survey method assigns a weight to each vehicle solely on the basis of the number of months a vehicle participates in the survey.

- Overall the three weighting methods produce similar results, although on a model year specific basis there are some differences. This is particularly true for model year 1982 where small sample size is a problem.

- Since the NPD projection factors were designed to weight the survey to a national level on the basis of household demographics, these factors are used in reporting all results except those in this table.

TABLE 3

COMPARISON OF WEIGHTING METHODS

| | Vehicle Count | | | Vehicle Involvement Misfueling Rate (percent) | | | |
| | | NPD | | | | NPD | |
Model Year	Sample Weight	Projection Factors	Months in Survey	Sample Weight	Estimated Error*	Projection Factors	Months in Survey
1975	266	366,200	2,664	21.1	4.9	20.7	21.4
1976	444	613,373	4,642	17.3	3.5	16.9	17.1
1977	598	835,144	6,056	16.4	3.0	17.1	16.5
1978	631	841,370	6,380	13.9	2.7	13.0	14.0
1979	520	714,709	5,246	12.7	2.9	12.6	13.0
1980	485	663,866	4,848	10.3	2.7	9.0	9.9
1981	387	402,127	2,649	12.9	3.3	12.7	14.4
1982	22	10,011	75	18.2	16.1	16.4	16.0
TOTAL	3,353	4,446,800	32,560	14.6	1.2	14.3	14.8

*Estimated errors would all be based on the unweighted vehicle count, hence they would be nearly identical across the weighting methods. In order to simplify comparisons of the fleet involvement percentages the error estimates have been included only for the sample weight calculation.

Table 4 - Comparison of Involvement Under Alternate Assumptions About
          Unknown Fuel Type

- This table compares three methods of treating unknown fuel
  types. An unknown fuel type purchase is one in which the
  respondent has failed to check either the leaded or the
  unleaded column on the monthly diary log.

- If unknown fuel type is assumed to be leaded fuel, the overall
  fleet involvement in misfueling is 42.0 percent of the cata-
  lyst fleet.

- If unknown fuel type is assumed to be unleaded fuel, the
  overall fleet involvement in misfueling is 14.3 percent of the
  catalyst fleet.

- If the unknown fuel for each vehicle is allocated between
  leaded and unleaded, based on the percentages of known leaded
  and known unleaded bought for that vehicle, the overall fleet
  involvement in misfueling is 14.3 percent of the catalyst
  fleet.

- On average, each vehicle in the survey made 1.3 purchases of
  unknown fuel type during 1981. This fuel, roughly 12.6
  gallons per vehicle, typically represents approximately 2.3
  percent of the year's total fuel purchases. Including all of
  these purchases in the leaded category increases fleet in-
  volvement in misfueling by 190 percent.

- The assumption that unknown fuel purchases actually represent
  leaded fuel is made to test the belief that consumers do not
  wish to implicate themselves in misfueling. While there may
  be a handful of respondents whose behavior fits this pattern,
  most individuals appear to be extremely forthcoming about
  their misfueling habits. Given the wide distribution of
  unknown fuel type purchases and people's willingness to report
  buying leaded fuel, it is likely that most, though not all,
  unknown fuel purchases are the result of recording error
  rather than of half-hearted deception.

- The assumption that unknown fuel is unleaded is the most
  conservative method of allocating unknown fuel. As may be
  seen in the table, the results are almost identical to those
  obtained by allocating the unknown fuel between leaded and
  unleaded.

- All of the tables in this report are based on the assumption
  that unknown fuel may reasonably be allocated between leaded
  and unleaded on the basis of the percentages of known leaded
  and known unleaded bought for an individual vehicle.

TABLE 4

COMPARISON OF INVOLVEMENT UNDER ALTERNATE
ASSUMPTIONS ABOUT UNKNOWN FUEL TYPE

		Vehicle Involvement Misfueling Rate					
		Unknown is Unleaded		Unknown is Leaded		Unknown Allocated	
Model Year	Number of Vehicles	Rate (% of fleet)	Estimated Error	Rate (% of fleet)	Estimated Error	Rate (% of fleet)	Estimated Error
1975	266	20.7	4.9	40.8	5.9	20.7	4.9
1976	444	16.9	3.5	39.1	4.5	16.9	3.5
1977	598	17.1	3.0	45.4	4.0	17.1	3.0
1978	631	13.0	2.6	45.7	3.9	13.0	2.6
1979	520	12.6	2.9	40.7	4.2	12.6	2.9
1980	485	9.0	2.5	42.5	4.4	9.0	2.6
1981	387	12.7	3.3	34.5	4.7	12.7	3.3
1982	22	16.4	15.5	45.3	20.8	16.4	15.5
OVERALL	3,353	14.3	1.2	42.0	1.7	14.3	1.2

Table 5 - Misfueling Fleet Involvement by Model Year

- Number of vehicles is a count of the actual, unweighted, number of LDVs in each model year.

- The categories reported here are identical to the third, fourth and fifth items in Table 1. For example, for model year 1975, of which there are 266 catalyst equipped LDVs in the survey, 5.1 percent were misfuelers whose leaded purchases amounted to less than 11 percent of the fuel they purchased during the year. At the same time, 9.0 percent of the model year vehicles purchased 91-100 percent leaded fuel by volume. Overall, 20.7 percent of the model year 1975 vehicles misfueled at least part of the time.

- In general it is assumed that misfueling will increase with vehicle age. With some slight deviations the data presented in Table 5 shows misfueling involvement remaining relatively flat for vehicles from model years 1978 through 1981. Vehicles from model year 1977 and earlier show misfueling increasing with age. Even for model years 1978 to 1981, the percentage of vehicles in the 91-100 percent leaded category increases with vehicle age. The involvement rate for model year 1982 is suspect due to relatively small sample size.

TABLE 5

VEHICLE INVOLVEMENT MISFUELING RATES BY MODEL YEAR

Model Year	Number of Vehicles	Fuel Under 11% Leaded (% of Fleet)	Fuel 91–100% Leaded (% of Fleet)	Overall Vehicle Involvement (% of Fleet)	Estimated Error in Involvement
1975	266	5.1	9.0	20.7	4.9
1976	444	4.9	4.5	16.9	3.5
1977	598	7.2	5.1	17.1	3.0
1978	631	5.0	3.6	13.0	2.6
1979	520	5.4	2.0	12.6	2.9
1980	485	4.7	0.7	9.0	2.5
1981	387	7.5	0.0	12.7	3.3
1982	22	0.0	10.8	16.4	15.5
Overall	3,353	5.6	3.5	14.3	1.2

Table 6 - Repeated Misfueling

- This table displays the incidence of successive misfueling for vehicles at each end of the age spectrum (model years 1975 and 1981), and for the catalyst fleet as a whole. Model year 1982 was excluded because of relatively small sample size. Vehicle involvement rates are percents of the model year fleets.

- Vehicles having made at least two leaded purchases in a row are assigned to one of five purchasing categories. The assignment is based on the longest string of leaded purchases made by that vehicle during 1981.

- Vehicles making only singleton purchases of leaded gasoline will not appear in this table. Thus, although 20.7 percent of the model year 1975 vehicles misfueled at least once (see Table 5), only 20.6 percent (the sum of the five purchasing categories for 1975 vehicles) of the fleet is represented in Table 6. The remaining 0.1 percent of the fleet that misfueled never purchased leaded twice in a row.

- Percent of leaded purchases is calculated on a model year specific basis. For example, 95.4 percent of the leaded purchases made by catalyst equipped model year 1975 vehicles were made by vehicles that have purchased leaded at least 6 times in a row.

- Category assignments are exclusive. A vehicle making two leaded purchases in a row on several occasions, and four leaded purchases in a row on one occasion will be assigned only to the category for vehicles having made four successive leaded purchases.

TABLE 6

REPEATED MISFUELING

Maximum Number of Successive Leaded Purchases During the Year	Percent of Model Year Catalyst Fleet Vehicles Involved	Estimated Error	Percent of Leaded Purchases By Fleet
	MY 75 Fleet		
2	0.8	1.0	0.8
3	0.7	1.0	0.5
4	2.2	1.8	2.7
5	0.4	0.7	0.4
6 or more	16.5	4.5	95.4
	MY 81 Fleet		
2	0.3	0.5	1.1
3	5.2	2.2	24.7
4	3.2	1.8	22.4
5	0.7	0.8	4.5
6 or more	3.4	1.8	47.4
	Overall Fleet		
2	1.0	0.3	1.2
3	2.5	0.5	2.5
4	1.7	0.4	3.2
5	1.0	0.3	2.1
6 or more	7.8	0.9	90.4

Table 7 - Length of Survey Participation

- In order to be included in this misfueling study a vehicle must have provided data for at least two months. Vehicles reporting for only one month generally provide purchase records with much missing or inconsistent information. In order to reduce the effect of missing data, the minimum reporting requirement was adopted. A total of 127 vehicles were eliminated as a result of this requirement.

- The majority of vehicles contributed a full 12 months of data.

TABLE 7

LENGTH OF SURVEY PARTICIPATION

Number of Months In Survey During 1982	Number of Vehicles	Percent of Catalyst Fleet
2	92	0.6
3	102	1.0
4	109	1.3
5	317	6.0
6	73	1.3
7	114	2.2
8	86	2.2
9	100	2.8
10	92	2.7
11	161	5.8
12	2,107	74.2

Table 8 - The Distribution of Successive Misfueling Purchases
          Cross-Tabulated with The Distribution of Misfueling by Degree
          of Involvement

- This table shows the degree of misfueling involvement,
  measured on a volume basis as in Table 6, for the vehicles in
  each of the successive misfuel purchasing categories shown in
  Table 5.

- PBMAX identifies the maximum number of successive leaded
  purchases: 0 (includes single isolated purchases), 2-5, and 6
  or more.

- PBCAT identifies categories of leaded fuel as a percent of
  total fuel purchased by a vehicle during 1981.

- FREQUENCY is the NPD projection factor weighted vehicle count.

- PERCENT is the percentage of the catalyst fleet.

- Cumulative values are reported for both FREQUENCY and PERCENT.

- Since only non-zero percentages are reported, some values of
  PBCAT are not printed for some values of PBMAX.

- Due to the labeling limitations of the SAS statistical package
  the work "LEADED" is usally truncated to "LEA" in this table.
  In a final indignity the word is further reduced to the letter
  "L" for the under 11 percent category.

TABLE 8

THE DISTRIBUTION OF SUCCESSIVE MISFUELING PURCHASES
CROSS-TABULATED WITH
THE DISTRIBUTION OF MISFUELING BY DEGREE OF INVOLVEMENT

PBMAX	PBCAT	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
0	NO LEADED	3812663	3812663	85.739	85.739
1	FUEL UNDER 11% L	25085	3837748	0.564	86.304
1	FUEL 11- 20% LEA	1007	3838755	0.023	86.326
2	FUEL UNDER 11% L	35199	3873954	0.792	87.118
2	FUEL 11- 20% LEA	8223	3882177	0.185	87.303
2	FUEL 21- 30% LEA	765	3882942	0.017	87.320
2	FUEL 31- 40% LEA	798	3883740	0.018	87.338
3	FUEL UNDER 11% L	79856	3963596	1.796	89.134
3	FUEL 11- 20% LEA	16183	3979779	0.364	89.498
3	FUEL 21- 30% LEA	749	3980528	0.017	89.514
3	FUEL 31- 40% LEA	1106	3981634	0.025	89.539
3	FUEL 41- 50% LEA	180	3981814	0.004	89.543
3	FUEL 71- 80% LEA	234	3982048	0.005	89.549
3	FUEL 81- 90% LEA	1259	3983307	0.028	89.577
3	FUEL 91-100% LEA	1533	3984840	0.034	89.611
4	FUEL UNDER 11% L	49901	4034741	1.122	90.734
4	FUEL 11- 20% LEA	20905	4055646	0.470	91.204
4	FUEL 21- 30% LEA	6578	4062224	0.148	91.352
4	FUEL 31- 40% LEA	2640	4064864	0.059	91.411
4	FUEL 41- 50% LEA	1112	4065976	0.025	91.436
4	FUEL 51- 60% LEA	385	4066361	0.009	91.445
4	FUEL 61- 70% LEA	606	4066967	0.014	91.458
5	FUEL UNDER 11% L	21903	4088870	0.493	91.951
5	FUEL 11- 20% LEA	14463	4103333	0.325	92.276
5	FUEL 21- 30% LEA	2068	4105401	0.047	92.323
5	FUEL 41- 50% LEA	566	4105967	0.013	92.335
5	FUEL 51- 60% LEA	3662	4109629	0.082	92.418
6	FUEL UNDER 11% L	38369	4147998	0.863	93.280
6	FUEL 11- 20% LEA	35115	4183113	0.790	94.070
6	FUEL 21- 30% LEA	14669	4197782	0.330	94.400
6.	FUEL 31- 40% LEA	10025	4207807	0.225	94.625
6	FUEL 41- 50% LEA	9521	4217328	0.214	94.840
6	FUEL 51- 60% LEA	6964	4224292	0.157	94.996
6	FUEL 61- 70% LEA	12030	4236322	0.271	95.267
6	FUEL 71- 80% LEA	35243	4271565	0.793	96.059
6	FUEL 81- 90% LEA	22776	4294341	0.512	96.571
6	FUEL 91-100% LEA	152459	4446800	3.429	100.000

APPENDIX 1
ESTIMATED ERRORS

Selected tables within the body of this report have included a statistic termed "estimated error" to denote the reliability of key misfueling rates. The purpose of this appendix is to discuss briefly the calculation of this quantity and the considerations that led to its use.

Inasmuch as the NPD data base is derived from a quota sample, it may be justifiably argued that no statistic can reflect the "error of estimate" as applied on the strict sense of a random sample. Nevertheless, it is important to realize that estimates derived from a quota sample are subject to variability and that, as a matter of pragmatism, the issues of bias and variability should be decoupled. The analyst must exercise due caution in selecting a quota sample, considering the purposes of the study, comparison of sample composition and observables (estimates of known quantities) with independent reference sources, and the availability of alternatives to the quota sample's use.

Given that the quota sample is accepted for the purposes at hand, the analyst must consider the variability of derived estimates in interpreting the findings. The estimated error statistic is used in this report to reflect the variability of estimates in the sense described above. This calculation follows that of a standard error of estimate derived from a random sample. For sufficiently large samples of size N, the 95 percent confidence limit of an observed proportion p is given by:*

$$CI_{95} = \pm 1.96 \sqrt{p(1-p)/N}$$

In this study, the proportions p are calculated as ratios of vehicles falling within a defined misfueling category to the total number of catalyst vehicles in the survey. Where noted, the proportions are weighted by the NPD projection factors (thereby incorporating both survey participation and control of the sample's demographic balance). In all instances, the sample size is taken to be the (un-weighted) number of catalyst vehicles in the sample.

The resulting estimated error is an approximation to the variability that is present in sample estimates. A more exacting calculation would need to consider the time-series nature of the data (i.e., extended observations of vehicles across many purchases) and the implications of weighting factors for determining the "effective" sample size. These extended considerations are not germane, however, to the use of the estimated errors as an order-of-magnitude guideline to estimate variability.

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*Engineering Statistics (Second Edition) by Albert H. Bowker and Gerald Lieberman, Prentice-Hall Inc., 1972, pp. 466-467

APPENDIX 2

This appendix contains an example of the purchase logs filled in by NPD panel participants.

AMERICAN SHOPPERS PANEL
P.O. BOX 5401, NEW HYDE PARK, NY 11040

INSTRUCTIONS

1. Slip this diary in the visor holder you attach to the sun visor.
2. Write in ODOMETER (Speedometer) READING when you receive this diary (but no sooner than the date indicated) and again before you return it. There is space for these readings above. NOTE: If you replace this vehicle, be sure to write in Odometer readings for BOTH vehicles.
3. Enter all GASOLINE/MOTOR FUEL PURCHASES on the reverse side of this diary.
4. Enter ALL OIL AND ANTIFREEZE PURCHASES on this side of the diary. Make sure purchases at services stations are included.
5. Be sure to tell me all the necessary details if another vehicle is added (see back of return envelope). Tell me about the change in this vehicle (sold, no longer used, disposed of, traded-in, etc.) to the right.
6. All your diaries are important, so please be sure to mail this diary even if no gasoline or oil was purchased this month.

Was the vehicle described on the ID label (top left) SOLD, RETIRED FROM USE, TRADED-IN or otherwise disposed of during the month? ☐ YES ☐ NO

If YES, and vehicle was TRADED-IN or OTHERWISE REPLACED, fill in below for new vehicle:
If NO, please do not fill in below.

MAKE...
(Chevrolet, Ford, Toyota, Dodge, etc.)

MODEL NAME/SERIES...
(Malibu, B 210, Cutlass, Rabbit, TR 7, etc.)

MODEL YEAR 19.............

BODY STYLE..
(2 dr. sedan, 4 dr. sedan, 2 dr. hardtop, hatchback, van, station wagon, pick up, convertible, camper, etc.)

DOES THIS VEHICLE
REQUIRE UNLEADED FUEL? (✓) One   Yes ☐   No ☐
REQUIRE DIESEL FUEL? (✓) One   Yes ☐   No ☐
HAVE AIR-CONDITIONING? (✓) One   Yes ☐   No ☐

VEHICLE IDENTIFICATION NUMBER (Serial Number.)

ENGINE DISPLACEMENT (See owner's manual Ex 160 Cubic Inches, 1.8 Liters.)

.... OR ....
Number of Cubic Inches   Numbers of Liters

WHAT TRANSMISSION DOES IT HAVE? (✓) One

☐ 3 Speed Manual   ☐ Four Speed Manual   ☐ 5 Speed Manual
☐ Automatic   ☐ Automatic w/ Overdrive

NUMBER OF CYLINDERS (✓) One
☐ Four   ☐ Five   ☐ Six   ☐ Eight   ☐ Rotary

IS IT? (✓) One
☐ Turbocharged
☐ Fuel Injected
☐ Regulator Carburetor

VEHICLE MAINTENANCE--DOES FAMILY MEMBER....

CHANGE THE OIL? (✓) One   Yes ☐   No ☐
TUNE-UP THE CAR? (✓) One   Yes ☐   No ☐

PRINCIPAL DRIVER:
YEAR OF BIRTH: 19............   SEX: M ☐   F ☐

WHICH CREDIT CARDS DOES THIS DRIVER CARRY?

....
....
....

GAS

			COPY THIS INFORMATION DIRECTLY FROM GAS PUMP							METHOD OF PAYMENT				DID STATION HAVE..... (✓) all that apply				DID YOU USE.. (✓) all that apply				DID YOU FILL UP THE TANK?	SPECIAL OFFER			WAS PURCHASE WITHIN 100 MILES OF YOUR HOME?
	BUYER		NAME OF BRAND	NAME OF GRADE	IS THIS GAS..... (✓) one		NUMBER OF GALLONS/ LITERS PURCHASED		(✓) one		TOTAL AMOUNT PAID (gasoline purchase only)		(✓) one		If credit card was used — NAME OF CREDIT CARD									Was there a special offer? (✓) one	IF YES, describe offer such as: Price-Off, Free Gift (describe Gift), Discount for Cash, etc.	
DATE	Year of birth 19__	Sex	Such as: Shell, Texaco, Exxon, etc.	Such as: Regular, Premium, Super, Diesel, Gasohol, etc.	LEADED	UNLEADED	Gal/Lt.	10ths	GALLONS	LITERS	$	¢	CASH/CHECK	CREDIT CARD	STATION CHARGE	FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	YES NO	YES NO	write in	YES NO

GAS

			COPY THIS INFORMATION DIRECTLY FROM GAS PUMP							METHOD OF PAYMENT				DID STATION HAVE..... (✓) all that apply				DID YOU USE.. (✓) all that apply				DID YOU FILL UP THE TANK?	SPECIAL OFFER			WAS PURCHASE WITHIN 100 MILES OF YOUR HOME?
	BUYER		NAME OF BRAND	NAME OF GRADE	IS THIS GAS..... (✓) one		NUMBER OF GALLONS/ LITERS PURCHASED		(✓) one		TOTAL AMOUNT PAID (gasoline purchase only)		(✓) one		If credit card was used — NAME OF CREDIT CARD									Was there a special offer? (✓) one	IF YES, describe offer such as: Price-Off, Free Gift (describe Gift), Discount for Cash, etc.	
DATE	Year of birth 19__	Sex	Such as: Shell, Texaco, Exxon, etc.	Such as: Regular, Premium, Super, Diesel, Gasohol, etc.	LEADED	UNLEADED	Gal/Lt.	10ths	GALLONS	LITERS	$	¢	CASH/CHECK	CREDIT CARD	STATION CHARGE	FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	YES NO	YES NO	write in	YES NO

PART II:

MISFUELING OF LIGHT DUTY VEHICLES
IN 1982:
INTERIM REPORT

EPA Prime Contract 68-01-6558
Subcontract 130.109
Work Assignment No. 30A, Task 2

Prepared for:

ENVIRONMENTAL PROTECTION AGENCY
Motor Vehicle Emissions Laboratory
Ann Arbor, Michigan

Prepared by:

ENERGY AND ENVIRONMENTAL ANALYSIS, INC.
1655 North Fort Myer Drive
Arlington, Virginia 22209

September 1984

LIST OF TABLES

SUMMARY

The purpose of this task is to quantify the rate of misfueling by light-
duty vehicle (LDV) owners/operators in 1982. At the direction of EPA,
light-duty trucks are specifically excluded from the analysis. This
report presents highlights of the misfueling trends observed in a time
series data base of fuel purchasing behavior. The survey information is
derived from the NPD Petroleum Marketing Index (NPD), a diary panel
survey of over 5,000 households conducted by NPD Research Inc. The
tables and accompanying descriptive notes in this paper present findings
without any attempt at interpretation.

Misfueling may be measured in a variety of ways; the appropriate method
depends upon the questions to be answered. In this study the misfueling
rate is measured by fleet involvement, i.e., the proportion of all
catalyst vehicles which are misfueled. Vehicles are categorized on the
basis of whether or not they are ever misfueled, on the ratio of leaded
fuel purchased to total fuel purchased, and on the maximum number of
successive leaded purchases made during the survey period. Most of the
tables presented here are aggregated across all model years. An appen-
dix to this report contains a computer printout with more detailed
results on specific model years.

This study is not intended to answer questions about why people misfuel.
Rather, it quantifies the behavior observed in a representative sample
of individuals during the course of a recent calendar year. Most
previous studies of misfueling have sampled a cross-section of the
vehicle population at one point in time. A major advantage of using a
diary panel survey is that individuals may be followed through time.

Such a survey provides more complete information about the frequency of misfueling and could allow for detailed studies of the demographic characteristics of misfuelers or motivational factors.

The most common reservation about the use of diary surveys is that they depend upon consistent and truthful self-reporting. Despite concerns about respondents' potential unwillingness to incriminate themselves, the panel participants were quite open about their purchasing behavior and freely indicated the purchase of leaded fuel. The participants know their responses are being collected for gasoline brand market share studies and they are accustomed to reporting detailed information about what they have purchased. The participants do not know that government agencies purchase the raw survey data for studies such as this one. Furthermore, the participants are guaranteed anomymity by NPD Research, Inc. when they agree to participate.

DATA BASE PREPARATION

The NPD data base contains fuel purchase histories for over 12,000 privately operated vehicles. The data, collected during 1982, contain detailed information about fuel purchases, including date, gallons, type of fuel, and total cost. An example of the purchase logs filled in by respondents is shown in Appendix 2. There is body style/engine informa- tion as well as household demographic data associated with each vehicle purchase history. This data base has been used extensively by the U.S. Department of Energy (DOE) to examine trends in fuel consumption, on-road fuel economy, and vehicle miles of travel. During the course of this previous work the data were cleaned and established as a SAS data

set. As part of this work for DOE, the engine description information provided by the survey respondent was verified (and corrected when necessary using information extracted from the vehicle identification number (VIN).* Based on this engine information, each vehicle has been classified as to whether or not it has a catalyst.

The only additional processing of the data in the current work was to re-examine and verify existing catalyst information. Identification of a catalyst equipped vehicle is made on the basis of the VIN-augmented data for make/model, model year, CID, number of cylinders, fuel system, and type of transmission.

As noted previously, this task is based on a study of the 3694 catalyst equipped LDVs from NPD. A small number of LDVs manufactured during the late seventies required unleaded fuel but were not actually equipped with a catalyst. We have assumed that the ultimate use, if any, of this analysis will be for estimating the effect of misfueling on catalyst vehicles. For this purpose, a misfueling rate among catalyst vehicles is sufficient. Therefore, those vehicles not having a catalyst but requiring unleaded were not included in the study. Another group of LDVs excluded from the study were those participating for less than two months. For the most part, respondents with only one month of partici-pation have very poor record-keeping practices and incomplete purchase histories. Frequently only one or two purchases are reported and typically consist mostly of missing information. A total of 148 vehi-cles were deleted from the survey for participating less than two months.

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* The VIN is reported by the owner, along with the engine description information, when a vehicle first enters the survey.

In any large data collection effort there is a potential for recording or transcribing errors. To avoid over-reporting the incidence of misfueling, only those vehicles recording at least three leaded purchases during the year are counted as misfuelers. If no more than two leaded purchases are reported, a data error is assumed and the fuel type designation is changed to unleaded. A total of 445 vehicles meet this maximum-of-two leaded purchases criteria. A total of 1439 "purchases" showing 0.0 gallons of fuel bought were deleted. In general, these records are null entries representing months when a diary was returned but no fuel was purchased.

The tables in this report highlight misfueling behavior in the catalyst fleet. They also provide information pertaining to the manner in which the data are weighted and to the way in which unknown fuel type purchases are handled. Each table is prefaced with explanatory notes to assist the reader in interpreting the information presented.

Table 1 - Highlights of Misfueling Frequency Distributions

- Data in this table are weighted on the basis of the NPD projection factors. For information on the effect of alternative weighting methods, see Table 3.

- Total fuel purchased includes leaded, unleaded, and type unknown. For more detail on the treatment of purchases with unknown fuel type, and its effect on the findings, see Table 4.

- Leaded fuel as a percent of total fuel purchased by the catalyst fleet measures misfueling on a <u>gallons purchased</u> basis.

- The leaded fuel under 11 percent and 91-100 percent of total fuel purchased categories measure misfueling on a vehicle basis. Each vehicle's degree of involvement is judged on the basis of how much of their purchase volume is leaded. The vehicle is then assigned to an appropriate category. So, for example, 7.0 percent of the vehicles in the catalyst fleet were misfuelers whose leaded purchases amounted to less than 11 percent of the fuel they purchased during the year. By comparison, 4.3 percent of the vehicles in the catalyst fleet purchased 91-100 percent leaded fuel by volume.

- Catalyst fleet involvement in misfueling includes any catalyst vehicle that ever purchased leaded fuel, regardless of quantity or percentage of total fuel purchased over the year.

- There is a small number of vehicles (0.1 percent) of the catalyst fleet who purchased leaded fuel, but less than 10 gallons worth. These vehicles are included in the "Leaded Fuel Under 11% of Total" category regardless of actual percentage.

TABLE 1

HIGHLIGHTS OF MISFUELING FREQUENCY DISTRIBUTIONS

Number of Catalyst Equipped Vehicles	3694
Leaded Fuel as Percent of Total Fuel Purchased by the Catalyst Fleet	7.7 (0.9)*
Leaded Fuel Under 11% of Total Fuel Purchased by Vehicle (percent of catalyst fleet)	7.0 (0.8)
Leaded Fuel 91-100% of Total Fuel Purchased by Vehicle (percent of catalyst fleet)	4.3 (0.6)
Catalyst Fleet Involvement in Misfueling (percent of catalyst fleet)	18.0 (1.2)
Purchased at least 10 gallons of Leaded Fuel (percent of catalyst fleet)	17.9 (1.2)
Purchased leaded fuel at least 3 times from January to June 1982 and not at all from July to December 1982 (percent of catalyst fleet)	2.0 (0.5)
Purchased leaded fuel at least 3 times from January to June 1981 (percent of catalyst fleet)	8.0 (0.9)

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*Values in parentheses are estimated errors in the percent of catalyst fleet.

Table 2 - Distribution of Misfueling by Degree of Involvement

- In the table, vehicle involvement in misfueling is measured by the ratio of leaded fuel to total fuel purchased. A vehicle purchasing a total of 400 gallons of fuel (all types) during 1982, of which 30 gallons are leaded, has a ratio of 30 to 400 or 7.5 percent. This vehicle is placed in the under 11 percent leaded category. Had the same vehicle purchased 350 gallons of leaded, out of 400 gallons total, the ratio would be 87.5 percent leaded and the vehicle would be placed in the 81-90 percent leaded category.

- 7.0 percent of the catalyst fleet, or 38.7 percent of the misfuelers, have leaded fuel purchases totaling less than 11 percent of their annual fuel purchases. By comparison, 4.3 percent of the fleet, or 23.8 percent of misfuelers, purchased 91-100 percent leaded fuel by volume.

TABLE 2

DISTRIBUTION OF MISFUELING
BY DEGREE OF INVOLVEMENT
Aggregated Across All Model Years

Leaded Fuel Purchased by Vehicle as Percent of Total Fuel Purchased	Percent of Catalyst Fleet In Category	Estimated Error	Percent of Misfueling Vehicles
Under 11	7.0	0.8	38.7
11-20	3.4	0.6	18.8
21-30	0.8	0.3	4.4
31-40	0.4	0.2	2.2
41-50	0.4	0.2	2.2
51-60	0.4	0.2	2.2
61-70	0.1	0.1	0.5
71-80	0.4	0.2	2.2
81-90	0.9	0.3	5.0
91-100	4.3	0.7	23.8

Table 3 - Comparison of Weighting Methods

- Each vehicle contributes one observation to the misfueling analysis. When calculating the overall misfueling rate it is helpful if an individual vehicle's contribution can be weighted to account for its importance relative to other vehicles in the fleet. This table compares three methods of weighting.

- Sample weighting, with each vehicle assigned a weight of one, does not distinguish among vehicles.

- The NPD projection factor weights are assigned to each household on a monthly basis by NPD Inc. The factors are designed to weight the sample, demographically, to the national level based on income, race, region, and the educational level and occupation of the female head of house. As respondents enter and leave the survey, each household projection factor is adjusted to maintain the national level weighting scheme. The weight used in this study is the sum of these factors over each month a vehicle participates in the survey.

- The Months in Survey method assigns a weight to each vehicle solely on the basis of the number of months a vehicle participates in the survey.

- Overall the three weighting methods produce similar results, although on a model year specific basis there are some differences. This is particularly true for model year 1983 where small sample size is a problem.

- Since the NPD projection factors were designed to weight the survey to a national level on the basis of household demographics, these factors are used in reporting all results except those in this table.

TABLE 3

COMPARISON OF WEIGHTING METHODS

Model Year	Vehicle Count			Vehicle Involvement Misfueling Rate (percent)			
		NPD				NPD	
	Sample Weight	Projection Factors	Months in Survey	Sample Weight	Estimated Error*	Projection Factors	Months in Survey
1975	280	374,844	2,646	25.4	5.1	25.0	24.5
1976	465	631,075	4,602	21.7	3.8	22.4	21.7
1977	586	813,714	5,785	20.8	3.3	22.0	21.5
1978	632	875,895	6,275	17.6	3.0	17.1	18.2
1979	590	801,696	5,821	14.8	2.9	14.8	14.7
1980	450	622,582	4,276	13.8	3.2	16.0	15.0
1981	485	718,297	4,760	12.4	2.9	13.0	13.0
1982	185	194,821	1,280	14.1	5.0	16.6	15.2
1983	21	8,002	59	19.1	16.8	16.3	18.6
TOTAL	3,694	5,040,926	35,510	17.4	1.2	18.0	17.9

*Estimated errors would all be based on the unweighted vehicle count, hence they would be nearly identical across the weighting methods. In order to simplify comparisons of the fleet involvement percentages the error estimates have been included only for the sample weight calculation.

Table 4 - Comparison of Involvement Under Alternate Assumptions About
         Unknown Fuel Type

- This table compares three methods of treating unknown fuel
  types. An unknown fuel type purchase is one in which the
  respondent has failed to check either the leaded or the
  unleaded column on the monthly diary log.

- If unknown fuel type is assumed to be leaded fuel, the overall
  fleet involvement in misfueling is 35.9 percent of the cata-
  lyst fleet.

- If unknown fuel type is assumed to be unleaded fuel, the
  overall fleet involvement in misfueling is 18.0 percent of the
  catalyst fleet.

- If the unknown fuel for each vehicle is allocated between
  leaded and unleaded, based on the percentages of known leaded
  and known unleaded bought for that vehicle, the overall fleet
  involvement in misfueling is 18.0 percent of the catalyst
  fleet.

- On average, each vehicle in the survey made one purchase of
  unknown fuel type during 1982. This purchase, of roughly 7.0
  gallons, typically represents less than 1.6 percent of the
  year's total fuel purchases. Including all of these purchases
  in the leaded category increases fleet involvement in misfuel-
  ing by 100 percent.

- The assumption that unknown fuel purchases actually represent
  leaded fuel is made to test the belief that consumers do not
  wish to implicate themselves in misfueling. While there may
  be a handful of respondents whose behavior fits this pattern,
  most individuals appear to be extremely forthcoming about
  their misfueling habits. Given the wide distribution of
  unknown fuel type purchases and people's willingness to report
  buying leaded fuel, it is likely that most, though not all,
  unknown fuel purchases are the result of recording error
  rather than of half-hearted deception.

- The assumption that unknown fuel is unleaded is the most
  conservative method of allocating unknown fuel. As may be
  seen in the table, the results are almost identical to those
  obtained by allocating the unknown fuel between leaded and
  unleaded.

- All of the tables in this report are based on the assumption
  that unknown fuel may reasonably be allocated between leaded
  and unleaded on the basis of the percentages of known leaded
  and known unleaded bought for an individual vehicles.

TABLE 4

COMPARISON OF INVOLVEMENT UNDER ALTERNATE ASSUMPTIONS
ABOUT UNKNOWN FUEL TYPE

		Vehicle Involvement Misfueling Rate					
		Unknown is Unleaded		Unknown is Leaded		Unknown Allocated	
Model Year	Number of Vehicles	Rate (% of fleet)	Estimated Error	Rate (% of fleet)	Estimated Error	Rate (% of fleet)	Estimated Error
1975	280	25.0	5.1	37.5	5.7	25.0	5.1
1976	465	22.4	3.8	39.6	4.5	22.4	3.8
1977	586	22.0	3.4	37.8	3.9	22.0	3.4
1978	632	17.1	2.9	38.0	3.8	17.1	2.9
1979	590	14.8	2.9	33.7	3.8	14.8	2.9
1980	450	16.0	3.4	33.6	4.4	16.0	3.4
1981	485	13.0	3.0	32.6	4.2	13.0	3.0
1982	185	16.6	5.4	32.5	6.8	16.6	5.4
1983	21	16.3	15.8	18.2	16.5	16.3	15.8
OVERALL	3,694	18.0	1.2	35.9	1.6	18.0	1.2

Table 5 - Misfueling Fleet Involvement by Model Year

- Number of vehicles is a count of the actual, unweighted, number of LDVs in each model year.

- The categories reported here are identical to the third, fourth and fifth items in Table 1. For example, for model year 1975, of which there are 280 catalyst equipped LDVs in the survey, 4.5 percent were misfuelers whose leaded purchases amounted to less than 11 percent of the fuel they purchased during the year. At the same time, 9.2 percent of the model year vehicles purchased 91-100 percent leaded fuel by volume. Overall, 25.0 percent of the model year 1975 vehicles misfueled at least part of the time.

- In general it is assumed that misfueling will increase with vehicle age. With some slight deviations the data presented in Table 5 shows misfueling involvement remaining relatively flat for vehicles from model years 1979 through 1982. Vehicles from model year 1978 and earlier show misfueling increasing with age. Even for model years 1979 to 1982 the percentage of vehicles in the 91-100 percent leaded category increases with vehicle age. The invovlement rate for model year 1983 is suspect due to relatively small sample size.

TABLE 5

VEHICLE INVOLVEMENT MISFUELING RATES BY MODEL YEAR

Model Year	Number of Vehicles	Fuel Under 11% Leaded (% of Fleet)	Fuel 91-100% Leaded (% of Fleet)	Overall Vehicle Involvement (% of Fleet)	Estimated Error in Involvement
1975	280	4.5	9.2	25.0	5.1
1976	465	6.3	7.3	22.4	3.8
1977	586	6.8	8.8	22.0	3.4
1978	632	6.5	4.2	17.1	2.9
1979	590	6.6	1.6	14.8	2.9
1980	450	9.7	1.4	16.0	3.4
1981	485	7.7	0.3	13.0	3.0
1982	185	7.8	0.6	16.6	5.4
1983	21	0.0	0.0	16.3	15.8
Overall	3,694	7.0	4.3	18.0	1.2

Table 6 - Repeated Misfueling

- This table displays the incidence of successive misfueling for vehicles at each end of the age spectrum (model years 1975 and 1982), and for the catalyst fleet as a whole. Model year 1983 was excluded because of relatively small sample size. Vehicle involvement rates are percents of the model year fleets.

- Vehicles having made at least two leaded purchases in a row are assigned to one of five purchasing categories. The assignment is based on the longest string of leaded purchases made by that vehicle during 1982.

- Vehicles making only singleton purchases of leaded gasoline will not appear in this table. Thus, although 25.0 percent of the model year 1975 vehicles misfueled at least once (see Table 5), only 24.3 percent (the sum of the five purchasing categories for 1975 vehicles) of the fleet is represented in Table 6. The remaining 0.7 percent of the fleet that misfueled never purchased leaded twice in a row.

- Percent of leaded purchases is calculated on a model year specific basis. For example, 95.2 percent of the leaded purchases made by catalyst equipped model year 1975 vehicles were made by vehicles that have purchased leaded at least 6 times in a row.

- Category assignments are exclusive. A vehicle making two leaded purchases in a row on several occasions, and four leaded purchases in a row on one occasion will be assigned only to the category for vehicles having made four successive leaded purchases.

TABLE 6

REPEATED MISFUELING

Maximum Number of Successive Leaded Purchases During the Year	Percent of Model Year Catalyst Fleet Vehicles Involved	Estimated Error	Percent of Leaded Purchases By Fleet
MY 75 Fleet			
2	0.9	1.1	0.5
3	1.0	1.2	0.6
4	3.3	2.1	2.5
5	1.0	1.2	0.9
6 or more	18.1	4.5	95.2
MY 82 Fleet			
2	2.3	2.2	11.9
3	5.1	3.2	20.9
4	2.1	2.0	9.7
5	0.8	1.3	4.0
6 or more	6.4	3.5	53.4
Overall Fleet			
2	0.9	0.3	1.0
3	3.4	0.6	4.0
4	3.1	0.6	4.4
5	1.5	0.4	2.7
6 or more	8.9	0.9	87.6

Table 7 - Length of Survey Participation

- In order to be included in this misfueling study a vehicle
  must have provided data for at least two months. Vehicles
  reporting for only one month generally provide purchase
  records with much missing or inconsistent information. In
  order to reduce the effect of missing data, the minimum
  reporting requirement was adopted. A total of 148 vehicles
  were eliminated as a result of this requirement.

- The majority of vehicles contributed a full 12 months of data.

TABLE 7

LENGTH OF SURVEY PARTICIPATION

Number of Months In Survey During 1982	Number of Vehicles	Percent of Catalyst Fleet
2	128	0.8
3	117	1.1
4	125	1.6
5	278	5.2
6	96	1.5
7	154	3.1
8	199	5.0
9	111	2.8
10	115	3.0
11	159	4.8
12	2,212	71.3

Table 8 - The Distribution of Successive Misfueling Purchases
           Cross-Tabulated with The Distribution of Misfueling by Degree
           of Involvement

- This table shows the degree of misfueling involvement,
  measured on a volume basis as in Table 6, for the vehicles in
  each of the successive misfuel purchasing categories shown in
  Table 5.

- PBMAX identifies the maximum number of successive leaded
  purchases: 0 (includes single isolated purchases), 2-5, and 6
  or more.

- PBCAT identifies categories of leaded fuel as a percent of
  total fuel purchased by a vehicle during 1982.

- FREQUENCY is the NPD projection factor weighted vehicle count.

- PERCENT is the percentage of the catalyst fleet.

- Cumulative values are reported for both FREQUENCY and PERCENT.

- Since only non-zero percentages are reported, some values of
  PBCAT are not printed for some values of PBMAX.

- Due to the labeling limitations of the SAS statistical package
  the work "LEADED" is usally truncated to "LEA" in this table.
  In a final indignity the word is further reduced to the letter
  "L" for the under 11 percent category.

THE DISTRIBUTION OF SUCCESSIVE MISFUELING PURCHASES
CROSS-TABULATED WITH
THE DISTRIBUTION OF MISFUELING BY DEGREE OF INVOLVEMENT

PBMAX	PBCAT	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
0	NO LEADED	4132638	4132638	81.982	81.982
1	FUEL UNDER 11% L	9387	4142025	0.186	82.168
1	FUEL 11- 20% LEA	1081	4143106	0.021	82.189
1	FUEL 21- 30% LEA	737	4143843	0.015	82.204
2	FUEL UNDER 11% L	32282	4176125	0.640	82.844
2	FUEL 11- 20% LEA	13400	4189525	0.266	83.110
3	FUEL UNDER 11% L	119312	4308837	2.367	85.477
3	FUEL 11- 20% LEA	35829	4344666	0.711	86.188
3	FUEL 21- 30% LEA	3314	4347980	0.066	86.254
3	FUEL 31- 40% LEA	1724	4349704	0.034	86.288
3	FUEL 41- 50% LEA	497	4350201	0.010	86.298
3	FUEL 91-100% LEA	9292	4359493	0.184	86.482
4	FUEL UNDER 11% L	110498	4469991	2.192	88.674
4	FUEL 11- 20% LEA	32437	4502428	0.643	89.317
4	FUEL 21- 30% LEA	9484	4511912	0.188	89.506
4	FUEL 31- 40% LEA	252	4512164	0.005	89.511
4	FUEL 41- 50% LEA	1552	4513716	0.031	89.541
4	FUEL 51- 60% LEA	130	4513846	0.003	89.544
4	FUEL 91-100% LEA	2146	4515992	0.043	89.587
5	FUEL UNDER 11% L	40754	4556746	0.808	90.395
5	FUEL 11- 20% LEA	30347	4587093	0.602	90.997
5	FUEL 21- 30% LEA	1176	4588269	0.023	91.020
5	FUEL 41- 50% LEA	188	4588457	0.004	91.024
5	FUEL 51- 60% LEA	2860	4591317	0.057	91.081
5	FUEL 61- 70% LEA	942	4592259	0.019	91.099
5	FUEL 91-100% LEA	323	4592582	0.006	91.106
6	FUEL UNDER 11% L	40593	4633175	0.805	91.911
6	FUEL 11- 20% LEA	57707	4690882	1.145	93.056
6	FUEL 21- 30% LEA	28025	4718907	0.556	93.612
6	FUEL 31- 40% LEA	17780	4736687	0.353	93.965
6	FUEL 41- 50% LEA	17335	4754022	0.344	94.308
6	FUEL 51- 60% LEA	17136	4771158	0.340	94.648
6	FUEL 61- 70% LEA	6188	4777346	0.123	94.771
6	FUEL 71- 80% LEA	17984	4795330	0.357	95.128
6	FUEL 81- 90% LEA	43220	4838550	0.857	95.985
6	FUEL 91-100% LEA	202376	5040926	4.015	100.000

APPENDIX 1
ESTIMATED ERRORS

Selected tables within the body of this report have included a statistic termed "estimated error" to denote the reliability of key misfueling rates. The purpose of this appendix is to discuss briefly the calculation of this quantity and the considerations that led to its use.

Inasmuch as the NPD data base is derived from a quota sample, it may be justifiably argued that no statistic can reflect the "error of estimate" as applied on the strict sense of a random sample. Nevertheless, it is important to realize that estimates derived from a quota sample are subject to variability and that, as a matter of pragmatism, the issues of bias and variability should be decoupled. The analyst must exercise due caution in selecting a quota sample, considering the purposes of the study, comparison of sample composition and observables (estimates of known quantities) with independent reference sources, and the availability of alternatives to the quota sample's use.

Given that the quota sample is accepted for the purposes at hand, the analyst must consider the variability of derived estimates in interpreting the findings. The estimated error statistic is used in this report to reflect the variability of estimates in the sense described above. This calculation follows that of a standard error of estimate derived from a random sample. For sufficiently large samples of size N, the 95 percent confidence limit of an observed proportion p is given by:*

$$CI_{95} = \pm 1.96 \sqrt{p(1-p)/N}$$

In this study, the proportions p are calculated as ratios of vehicles falling within a defined misfueling category to the total number of catalyst vehicles in the survey. Where noted, the proportions are weighted by the NPD projection factors (thereby incorporating both survey participation and control of the sample's demographic balance). In all instances, the sample size is taken to be the (un-weighted) number of catalyst vehicles in the sample.

The resulting estimated error is an approximation to the variability that is present in sample estimates. A more exacting calculation would need to consider the time-series nature of the data (i.e., extended observations of vehicles across many purchases) and the implications of weighting factors for determining the "effective" sample size. These extended considerations are not germane, however, to the use of the estimated errors as an order-of-magnitude guideline to estimate variability.

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*Engineering Statistics (Second Edition) by Albert H. Bowker and Gerald Lieberman, Prentice-Hall Inc., 1972, pp. 466-467

APPENDIX 2

This appendix contains an example of the purchase logs filled in by NPD panel participants.

AMERICAN SHOPPERS PANEL
P.O. BOX 5401, NEW HYDE PARK, NY 11040

INSTRUCTIONS

1. Slip this diary in the visor holder you attach to the sun visor.
2. Write in ODOMETER (Speedometer) READING when you receive this diary (but no sooner than the date indicated) and again before you return it. There is space for these readings above. NOTE: If you replace this vehicle, be sure to write in Odometer readings for BOTH vehicles.
3. Enter all GASOLINE/MOTOR FUEL PURCHASES on the reverse side of this diary.
4. Enter ALL OIL AND ANTIFREEZE PURCHASES on this side of the diary. Make sure purchases at services stations are included.
5. Be sure to tell me all the necessary details if another vehicle is added (see back of return envelope). Tell me about the change in this vehicle (sold, no longer used, disposed of, traded-in, etc.) to the right.
6. All your diaries are important, so please be sure to mail this diary even if no gasoline or oil was purchased this month.

Was the vehicle described on the ID label (top left) SOLD, RETIRED FROM USE, TRADED-IN or otherwise disposed of during the month? ☐ YES ☐ NO

If YES, and vehicle was TRADED-IN or OTHERWISE REPLACED, fill in below for new vehicle:
If NO, please do not fill in below.

MAKE...
(Chevrolet, Ford, Toyota, Dodge, etc.)

MODEL NAME/SERIES...
(Malibu, B 210, Cutlass, Rabbit, TR 7, etc.)

MODEL YEAR 19...........

BODY STYLE..
(2 dr. sedan, 4 dr. sedan, 2 dr hardtop, hatchback, van, station wagon, pick-up, convertible, camper, etc)

DOES THIS VEHICLE
REQUIRE UNLEADED FUEL? (✓ One   Yes ☐   No ☐
REQUIRE DIESEL FUEL? (✓ One   Yes ☐   No ☐
HAVE AIR-CONDITIONING? (✓ One   Yes ☐   No ☐

VEHICLE IDENTIFICATION NUMBER (Serial Number.)

ENGINE DISPLACEMENT (See owner's manual. Ex. 180 Cubic Inches, 1.8 Liters.)

.... OR ....
Number of Cubic Inches   Numbers of Liters

WHAT TRANSMISSION DOES IT HAVE? (✓ One

☐ 3 Speed Manual   ☐ Four Speed Manual   ☐ 5 Speed Manual
☐ Automatic   ☐ Automatic w/ Overdrive

NUMBER OF CYLINDERS (✓ One
☐ Four   ☐ Five   ☐ Six   ☐ Eight   ☐ Rotary

IS IT? (✓ One
☐ Turbocharged
☐ Fuel Injected
☐ Regulator Carburetor

VEHICLE MAINTENANCE—DOES FAMILY MEMBER....

CHANGE THE OIL? (✓ One   Yes ☐   No ☐
TUNE-UP THE CAR? (✓ One   Yes ☐   No ☐

PRINCIPAL DRIVER:
YEAR OF BIRTH: 19...........   SEX: M ☐   F ☐

WHICH CREDIT CARDS DOES THIS DRIVER CARRY?

....
....
....

GAS

COPY THIS INFORMATION DIRECTLY FROM GAS PUMP

DATE	BUYER Year of birth 19__	Sex	NAME OF BRAND Such as: Shell, Texaco, Exxon, etc.	NAME OF GRADE Such as: Regular, Premium, Super, Diesel, Gasohol, etc.	IS THIS GAS..... (✓) one LEADED	UNLEADED	NUMBER OF GALLONS/ LITERS PURCHASED Gal/Lt.	10ths	(✓) one GALLONS	LITERS	TOTAL AMOUNT PAID (gasoline purchase only) $	¢	METHOD OF PAYMENT (✓) one CASH/CHECK	CREDIT CARD	STATION CHARGE	If credit card was used — NAME OF CREDIT CARD	DID STATION HAVE..... (✓) all that apply FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	DID YOU USE.. (✓) all that apply FULL SERVICE PUMPS	SELF-SERVICE PUMPS	CAR WASH	GROCERY/DAIRY DEPARTMENT	DID YOU FILL UP THE TANK? (✓) one YES	NO	SPECIAL OFFER Was there a special offer? (✓) one YES	NO	IF YES, describe offer such as: Price-Off, Free Gift (describe Gift), Discount for Cash, etc. write in	WAS PURCHASE WITHIN 100 MILES OF YOUR HOME? (✓) one YES	NO