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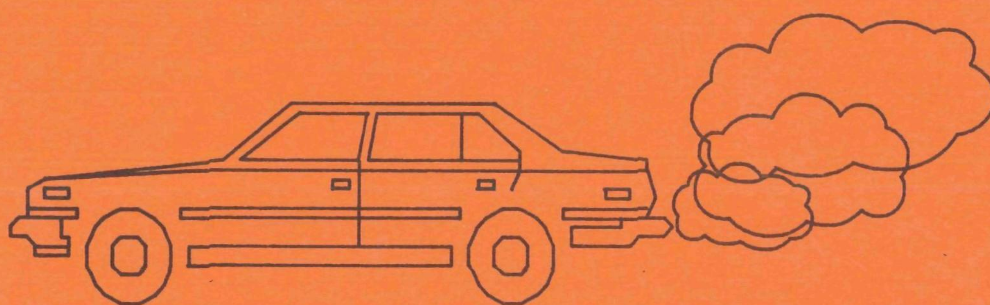
Air

EPA

Motor Vehicle Tampering Survey - 1986



United States Environmental Protection Agency

Office of Air and Radiation

MOTOR VEHICLE TAMPERING SURVEY - 1986

September 1987

FIELD OPERATIONS AND SUPPORT DIVISION
OFFICE OF MOBILE SOURCES
Washington, D.C.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OCT - 5 1987

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: 1986 Motor Vehicle Tampering Survey Report

FROM: Al Mannato, Chief
Regional/State/Local Coordination Section

TO: Regional Librarians

Two copies of the Field Operations and Support Division 1986 Tampering Survey are enclosed for inclusion to your library's periodical section. A limited supply of these reports are available, so please retain these as permanent copies and direct any specific inquiries to your Region's Air Management division, or have them write to:

U.S. EPA
Office of Air And Radiation (EN-397F)
Regional/State/Local Coordination Section
401 M Street S.W.
Washington, D.C. 20460

Verbal inquiries can be directed to Paul Argyropoulos at 202-475-8839 those areas within Regions I, III, V and IX, by Deanna hughes at 202-475-8837 for those areas within Regions II, IV, VI, and X, and by Dean Ross at 202-382-2947 for those areas within Regions VII and VIII.

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EXECUTIVE SUMMARY

INTRODUCTION

Under the direction of the Field Operations and Support Division (FOSD) of the Environmental Protection Agency (EPA), contract personnel from Colorado State University (CSU) conducted a survey of light-duty motor vehicle tampering in 15 cities between April and September, 1986. The areas surveyed and the total number of vehicles inspected are listed below.

St. Louis, MO	413	Hartford, CT	428
East St. Louis, IL	551	Camden, NJ	498
Jacksonville, FL	477	Covington, KY	500
Orlando, FL	575	Seattle, WA	504
Houston, TX	507	Los Angeles, CA	505
Memphis, TN	580	Tucson, AZ	499
Pittsburgh, PA	504	Baton Rouge, LA	500
Richmond, VA	500		
		TOTAL	7,541 vehicles

The objectives of this survey were:

1. To make local measurements of the types and extent of tampering and fuel switching.
2. To extend and update the knowledge gained from earlier surveys on:
   a. The rates of overall and component-specific tampering and fuel switching.
   b. The distribution of tampering by vehicle age, type, manufacturer, and other variables of interest.
   c. The relationship between tampering and vehicle idle emissions.
   d. The effect of vehicle inspection and maintenance (I/M) programs and antitampering programs (ATPs) on tampering and fuel switching.

To achieve these objectives, the inspection teams visually examined emission control devices and measured the idle hydrocarbon (HC) and carbon monoxide (CO) emissions of each vehicle. To provide information on fuel switching, the inspectors sampled gasoline from the tanks of vehicles (for later laboratory lead analysis), tested for lead deposits in tailpipes using Plumbtesmo® test paper, and checked the integrity of the fuel filler inlet restrictors. Four categories were used to summarize the condition of the inspected vehicles:

1. Tampered - at least one control device removed or rendered inoperative

2. Arguably Tampered - possible but not clear-cut tampering (i.e., may have resulted from either tampering or malmaintenance)

3. Malfunctioning

4. Okay - all control devices present and apparently operating properly

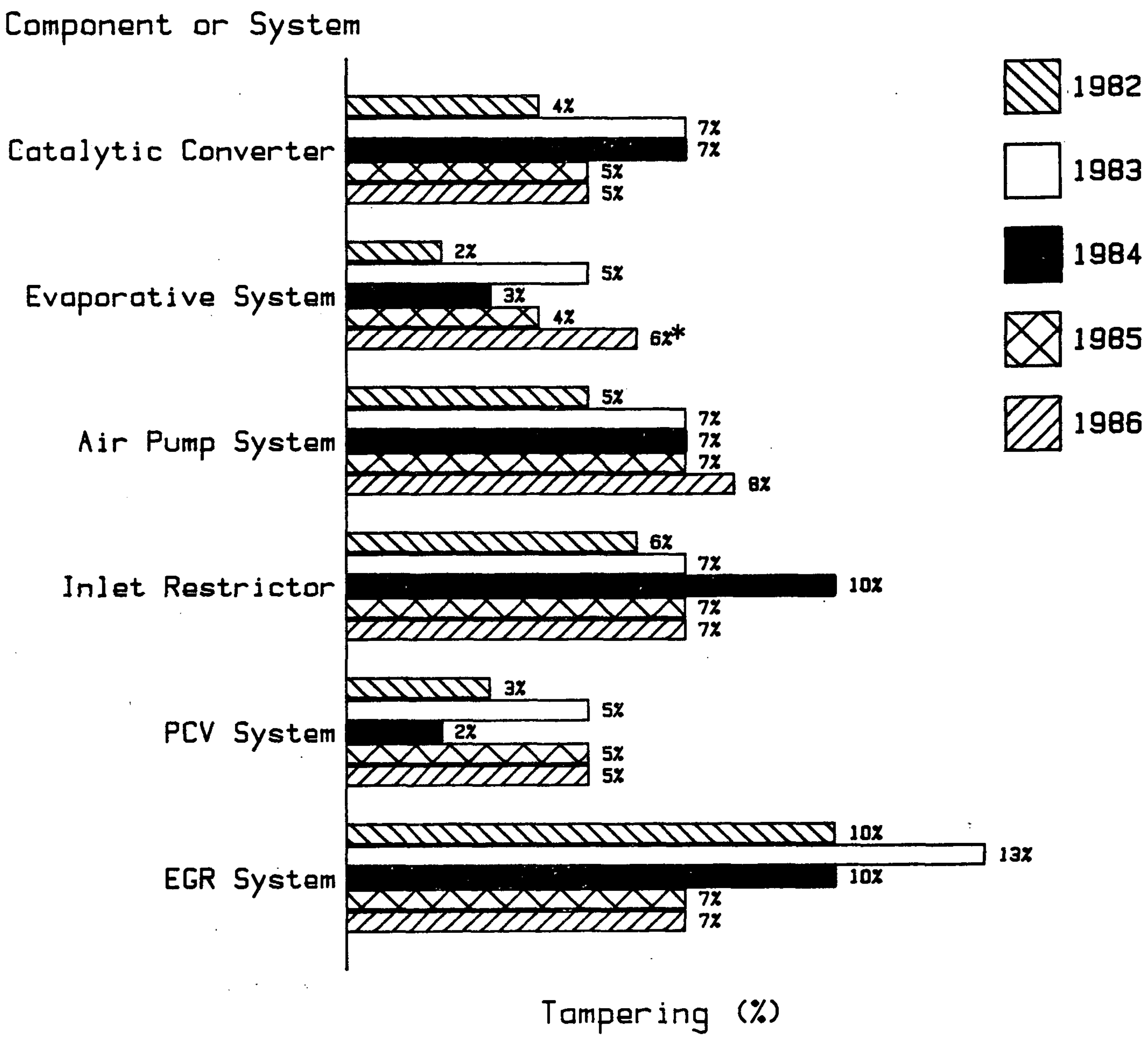
These brief but thorough inspections were performed with the consent of the vehicle owners in a variety of settings more fully detailed elsewhere in this report.

While the data from a survey such as this seem to invite inferences regarding program effectiveness, trends, etc., this approach can easily lead to incorrect conclusions. The sample size is reasonably adequate for evaluating tampering prevalence in any particular site, but the sampling of sites is neither large nor random. Simple comparisons of tampering by site across control program categories, for example, can overlook a variety of confounding factors. These may include geographical variability, fleet age structure and vehicle mix, variations in program maturity, coverage, history, and management, and the interactions among these factors. Straightforward experimental control of these variables, difficult to achieve under the best of circumstances, becomes impossible in a situation where site selection is driven by programmatic considerations unrelated to the experimental questions.

CONCLUSIONS

In this study the vehicles surveyed were classified as follows: tampered - 20%; arguably tampered - 25%; malfunctioning - 1%; okay - 54% (overall survey averages). This gross classification, while useful for some comparisons, is less informative concerning the emissions impact of tampering than an examination of component-specific rates. The percentage of tampered vehicles (20%) is the same as was found in the 1985 survey.

Component-specific tampering for selected critical components is shown in Figure 1. The results shown have not been weighted to compensate for I/M program representation; these rates probably underestimate the actual nationwide rates.



*Change in classification of evaporative system tampering. Tampering rate would have been 4% using prior classification method.

Figure 1. Component-specific tampering: 1982 - 1986 surveys.

Tampering with evaporative and air pump systems has increased since 1985, while the rates for other components have remained unchanged. The increase in evaporative system tampering, however, is the result of a change in the classification methodology in the 1986 survey, as will be discussed later in the report. Evaporative system tampering would have been 4% using the methodology from earlier surveys.

The catalytic converter removal rate for the 1986 survey was 5% overall. Catalytic converter removal increases HC and CO emissions by an average of 475% and 425%, respectively.[1] For vehicles equipped with three-way converters, substantial increases in NO_x emissions would also be expected to occur.

The air pump system was the most frequently tampered system (8%). This is the first survey is which air pump tampering was the most prevalent form of tampering.

Fuel Switching

Fuel switching, defined as the presence of any of the three indicators[2], was found in 9% of the unleaded vehicles in the 1986 survey. The pattern of overlap among the three misfueling

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1 The emissions increases mentioned in this report are from a study of three-way catalyst vehicles presented in Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions from Motor Vehicles, EPA-AA-TTS-83-10, December 31, 1983.

2 The three fuel switching indicators are: a tampered fuel filler inlet restrictor, a positive Plumbtesmo® tailpipe test, or a gasoline lead concentration of more than 0.05 gram per gallon.

indicators is discussed in detail later in this report. While the emissions impact of fuel switching depends upon its duration and certain vehicle characteristics, emission increases of 475% for HC and 425% for CO can easily occur.

Age of Vehicle

The probability that a vehicle has been tampered with is clearly related to its age, as has been shown in previous surveys. This is evident in Figure 2, which shows the rates by model year for both overall tampering and catalyst removal. These age-specific rates are investigated more thoroughly later in this report.

Vehicle Types

The tampering rates for light-duty trucks were equal to or higher than for automobiles in every tampering category, as shown in Table 1. Overall tampering with trucks was the same as for automobiles (20%), marking the first time overall truck tampering has not exceeded overall automobile tampering. This trend is discussed in greater detail later in this report. Converter tampering on trucks remained much greater than on automobiles (9% vs 5%) and fuel switching among trucks was greater as well (11% vs 8%).

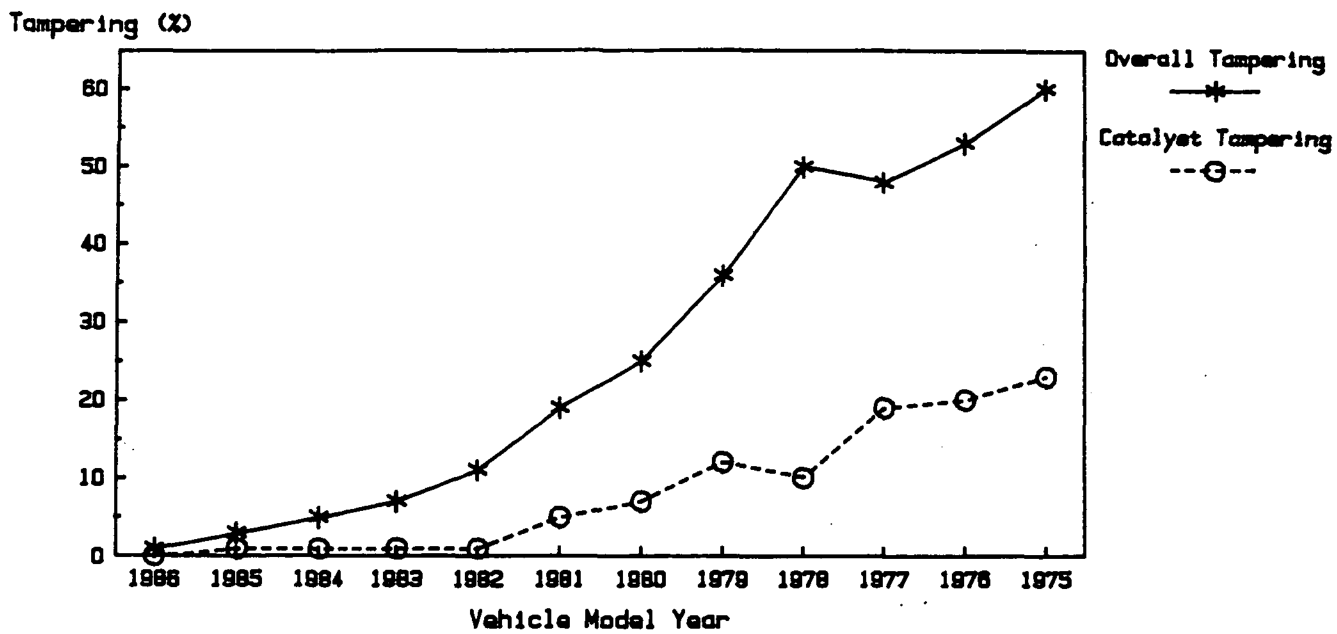

Figure 2. Overall and catalyst tampering by vehicle model year - 1986 survey.

TABLE 1

Tampering Prevalence by Vehicle Type for Critical Control Components

Component/System	Tampering Rate (%) Trucks	Cars	Overall
Catalytic Converter	9	5	5
Filler Neck Restrictor	8	7	7
Air Pump System	10	8	8
PCV System	5	5	5
Evaporative Control System	8	5	6
EGR System	7	7	7
OVERALL	20	20	20
Fuel Switching	11	8	9

I/M Programs and Tampering

Tampering in non-I/M sites surveyed was 24%, while tampering in ATP-only, I/M-only, and I/M + ATP sites were 20%, 18%, and 17%, respectively. Fuel switching was likewise greater in non-I/M areas (12%) than in ATP-only, I/M-only, and I/M + ATP areas (8%, 8%, 6%, respectively). Such comparisons across program categories should be made very carefully, since the number of sites per program category is small enough that site-specific factors other than program type may greatly influence tampering prevalence. In addition, the classification of sites into program categories is necessarily somewhat rough. The antitampering program in Baton Rouge, for example, only covers 1980 and newer vehicles. New Jersey's antitampering program, which was being phased in over a 16 month period, only covered 1982 and newer vehicles at the time of the survey. Because of restricted program coverage aimed at newer vehicles (those less likely to be tampered with because of warranty status and age) the impact of newly implemented programs may not be observable for several years. The effectiveness of control programs in deterring tampering among components and model years covered by each specific program will be investigated later in this report.

BACKGROUND

Motor vehicle emissions in urban areas account for nearly 90% of the total carbon monoxide (CO) and airborne lead, over 30% of the hydrocarbons (HC), and nearly 40% of the oxides of nitrogen (NO_x) emitted into the atmosphere. As a result, a major focus of the nation's efforts to achieve compliance with clean air standards has been the control of emissions from mobile sources. The first pollution control devices were installed on vehicles in 1962, and most light-duty vehicles manufactured since 1968 have been equipped with a variety of emission control devices to meet required emissions standards.

The 1977 amendments to the Clean Air Act (sections 203(a)(3)(A) and (B), found in Appendix A) make it illegal for automobile dealers, repair and service facilities, and fleet operators to disconnect or render inoperative emission control devices or elements of design. Regulations issued under section 211(c) of the Act (40 CFR Part 80) prohibit retailers and wholesale purchaser-consumers from introducing or allowing the introduction of leaded gasoline into vehicles labeled "unleaded gasoline only". The EPA's Field Operations and Support Division (FOSD), formerly the Mobile Source Enforcement Division (MSED), is responsible for enforcing the tampering and misfueling provisions of the Act.

Before 1978, the EPA had data suggesting that tampering with emission control devices and misfueling of "unleaded only" vehicles with leaded gasoline was occurring. Variability in the inspection procedures, however, prevented an accurate assessment of the nature and extent of the tampering. As a result, the Agency began conducting nationwide tampering surveys of light-duty motor vehicles in 1978 to determine the rates and types of tampering and fuel switching. These annual surveys have been conducted either by FOSD directly or by EPA's National Enforcement Investigations Center (NEIC) under the direction of FOSD. Consistent inspection procedures were used throughout these surveys to permit comparisons and identification of trends.

The uses for the tampering surveys have evolved since the first survey was conducted in 1978. Since 1983, the tampering survey results for some locations have been used to calculate credits for State Implementation Plans (SIPs), the measures taken by State and local governments to achieve ambient air quality standards by reducing mobile source emissions. Data from the surveys is also used in the default database for the Agency's mobile source computer model (MOBILE3) to estimate both the emissions loading impact and the reductions that may be achieved by various control programs. Sites for the surveys are chosen in light of the need for data on specific areas either currently operating or considering programs, as well as the continuing need to monitor the types and extent of tampering and fuel switching nationwide.

SURVEY METHODS

The 1986 tampering survey was conducted for FOSD by the National Center for Vehicle Emissions Control and Safety at Colorado State University (CSU). Approximately 400 to 600 vehicles were inspected in each of 15 cities between April and September, 1986, and the entire survey includes 7,541 vehicles. The mix of vehicles inspected was assumed to be a self-weighting sample, and no attempt was made to approximate the national vehicle mix.

Each inspection team consisted of at least four members: three CSU personnel, one or two EPA representatives, and frequently a state or local agency representative. The CSU personnel, assisted by the state or local person, performed the actual inspections, while the EPA representative(s) supervised the survey. Each vehicle inspection included the following:

1. basic vehicle identification data recorded (year, make, model)
2. all emission control systems checked
3. idle HC and CO emissions measured
4. fuel sample collected from unleaded-only vehicles for lead analysis
5. tailpipe tested for lead deposits using Plumbtesmo®[1] test paper
6. integrity of fuel inlet restrictor checked

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[1] Plumbtesmo® is a registered trademark, and appears hereafter without the ®. It is manufactured by Machery-Nagel, Duren, W. Germany, and marketed by Gallard-Schlesinger Chemical Corp., Carle Place, New York.

The inspection procedures used were consistent with those of previous surveys, except for one change made in the classification methodology for evaporative system tampering. In prior surveys a vehicle with a unsealed air cleaner was coded as malfunctioning for the evaporative system. In 1986 an unsealed air cleaner was recoded as tampering to reflect the deliberate nature of this condition. As a result, evaporative system tampering in 1986 was significantly higher than it would have been if the coding system from earlier surveys was used. The inspection and recording procedures are detailed in Appendix B.

The survey database has been reviewed by CSU and EPA to ensure its accuracy, and has been offered to the major automotive manufacturers to review the classification and reporting of their respective vehicles.

The tampering survey included only 1975 and newer light-duty cars and trucks fueled with gasoline. For the purposes of the tampering surveys, a vehicle is considered to be "unleaded" if a dash label, tank label, or filler inlet restrictor is observed at the time of the inspection, or if the emission control label indicates an unleaded fuel requirement (i.e., catalyst-equipped). A vehicle's designation as "unleaded" or "leaded" may be changed upon subsequent review of the data. Fuel switching rates are thus based only on the population of unleaded vehicles surveyed. Similarly, tampering rates for specific components are based only on the vehicles originally equipped with the component.

The inspections were performed with the consent of the vehicle owners at either roadside pullovers or inspection stations. The survey was designed to minimize the refusal rate of potential survey participants. A high refusal rate increases the uncertainty in the data gathered, since individuals who have tampered with or misfueled their vehicles are less likely to allow their vehicles to be surveyed. The overall refusal rate was very low (4%), however, and no survey sites had a refusal rate over 10%. A brief description of each survey site follows. Unless otherwise noted, the survey sites within a given city were changed daily.

<u>St. Louis, Missouri - I/M + ATP</u>

Dates:	April 14 - 18, 1986
Vehicles Surveyed:	413
Fuel Samples:	338
Refusal Rate:	10%

The St. Louis Police Department provided officers to stop potential survey participants, and the inspectors solicited permission to conduct the inspections. The decentralized I/M program includes a catalytic converter inspection on 1981 and later vehicles, and air pump, PCV, and EGR inspections on all vehicles.

East St. Louis, Illinois - non-I/M

Dates:	April 21 - 25, 1986
Vehicles Surveyed:	551
Fuel Samples:	392
Refusal Rate:	5%

Roadside pullovers were conducted with the help of the Illinois State Police. Inspection locations included East St. Louis (two days), Washington Park (2 days), and Alorton.

Jacksonville, Florida - non-I/M

Dates:	May 5 - 9, 1986
Vehicles Surveyed:	477
Fuel Samples:	426
Refusal Rate:	3%

Orlando, Florida - non-I/M

Dates:	May 12 - 16, 1986
Vehicles Surveyed:	575
Fuel Samples:	475
Refusal Rate:	4%

Roadside pullovers were conducted with the assistance of the Florida State Police in both Jacksonville and Orlando.

Houston, Texas - ATP-Only

Dates:	May 19 - 23, 1986
Vehicles Surveyed:	507
Fuel Samples:	422
Refusal Rate:	7%

The Texas Department of Public Safety provided officers to assist with the roadside pullovers. Inspection locations included Houston (three days), La Porte, and South Houston. The decentralized antitampering program includes Plumbtesmo testing and inspection of the catalytic converters and inlet restrictors on 1980 and newer vehicles, and inspection of the PCV, air pump, EGR, and evaporative systems on 1968 and later vehicles.

Memphis, Tennessee - I/M-only

Dates:	June 2 - 6, 1986
Vehicles Surveyed:	580
Fuel Samples:	464
Refusal Rate:	1%

The survey was conducted each day at the downtown centralized inspection station in Memphis. The inspection team set up and conducted the survey while vehicles were undergoing the emissions and safety inspection. The I/M program in Memphis covers all model years of light duty vehicles.

Pittsburgh, Pennsylvania - I/M-only

Dates:	June 16 - 20, 1986
Vehicles Surveyed:	504
Fuel Samples:	401
Refusal Rate:	4%

The Pittsburgh survey was conducted using roadside pullovers in the townships of Penn Hills, Moon, Ross, Shaler, and Robinson with the help of the local law enforcement officers in these municipalities. Pittsburgh's decentralized I/M program covers 1968 and newer vehicles.

Richmond, Virginia - ATP-only

Dates:	June 23 - 27, 1986
Vehicles Surveyed:	500
Fuel Samples:	395
Refusal Rate:	4%

The Richmond survey was conducted using roadside pullovers with the assistance of the Virginia State Police. Richmond has an antitampering inspection incorporated into its annual safety inspection program.

Hartford, Connecticut - I/M-only

Dates:	July 7 - 11, 1986
Vehicles Surveyed:	428
Fuel Samples:	341
Refusal Rate:	7%

The Hartford Police Department assisted with the roadside pullovers. Hartford's centralized I/M program covers 1968 and newer vehicles.

Camden, New Jersey - I/M + ATP

Dates:	July 14 - 18, 1986
Vehicles Surveyed:	498
Fuel Samples:	394
Refusal Rate:	8%

The New Jersey Police Department assisted with the roadside pullovers. New Jersey's I/M program dates back to 1974, and the antitampering inspection is being phased in to cover 1975 and newer vehicles by May 1987. At the time of the survey the ATP included a catalytic converter and inlet restrictor check on 1982 and newer vehicles.

Covington, Kentucky - non-I/M

Dates:	July 21 - 25, 1986
Vehicles Surveyed:	500
Fuel Samples:	403
Refusal Rate:	4%

The Covington survey was conducted in Boone County (two days), Campbell County, and Kenton County (two days). The respective County Police Departments assisted with the roadside pullovers. Covington was a non-I/M area at the time of the survey, but implemented a decentralized ATP-only in September 1986.

Seattle, Washington - I/M-only

Dates:	August 12 -16, 1986
Vehicles Surveyed:	504
Fuel Samples:	311
Refusal Rate:	3%

The survey was conducted at five centralized I/M stations in the metropolitan Seattle area. Seattle's I/M program covers all vehicles in the most recent 13 model years.

Los Angeles, California - I/M + ATP

Dates:	August 25 - 29, 1986
Vehicles Surveyed:	505
Fuel Samples:	373
Refusal Rate:	3%

The California Highway Patrol provided officers to assist with the roadside pullovers. The decentralized I/M + ATP includes inspection of the catalytic converter, air pump, PCV, EGR, and evaporative systems on all vehicles.

Tucson, Arizona - I/M-only

Dates:	September 8 - 12, 1986
Vehicles Surveyed:	499
Fuel Samples:	382
Refusal Rate:	1%

The Tucson survey was conducted at three centralized I/M stations. Tucson was an I/M-only area at the time of the survey, but added an ATP covering 1975 and newer vehicles in January 1987.

Baton Rouge, Louisiana - ATP-only

Dates:	September 15 - 19, 1986
Vehicles Surveyed:	500
Fuel Samples:	451
Refusal Rate:	4%

The Baton Rouge survey was conducted using roadside pullovers with the assistance of the Louisiana State Police. Survey locations were the same as in the 1985 survey. The decentralized ATP was implemented in September 1985, and includes a check of the converter, inlet restrictor, and Plumbtesmo test on 1980 and newer model year vehicles.

RESULTS

A. VEHICLE TAMPERING

1. Site and Aggregate Totals

The vehicles surveyed have been classified into four categories established by previous surveys: tampered, arguably tampered, malfunctioning, and okay. Each vehicle was classified by the worst state of any component in the vehicle. For example, a vehicle would be classified as "tampered" if any one component had been tampered, even if all other components were functioning properly. A vehicle classified as "okay" must have all observed components functioning properly[1]. The criteria used for component classification are presented in Appendix B. This overall tampering rate is useful only as a rough indicator of the emissions impact of a tampering problem, since the different components making up the rate may have widely varying emissions implications.

The proportion of inspected vehicles with at least one tampered component was 20%. Nearly half of the vehicles surveyed (46%) displayed some form of malfunction, arguable tampering, or clear tampering of emission control components. The specific distribution of surveyed vehicles among these categories is depicted in Figure 3.

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1 An "okay" vehicle, however, may still be classified as fuel switched (see section B.1., Fuel Switching Indicators and Overlap of this report).

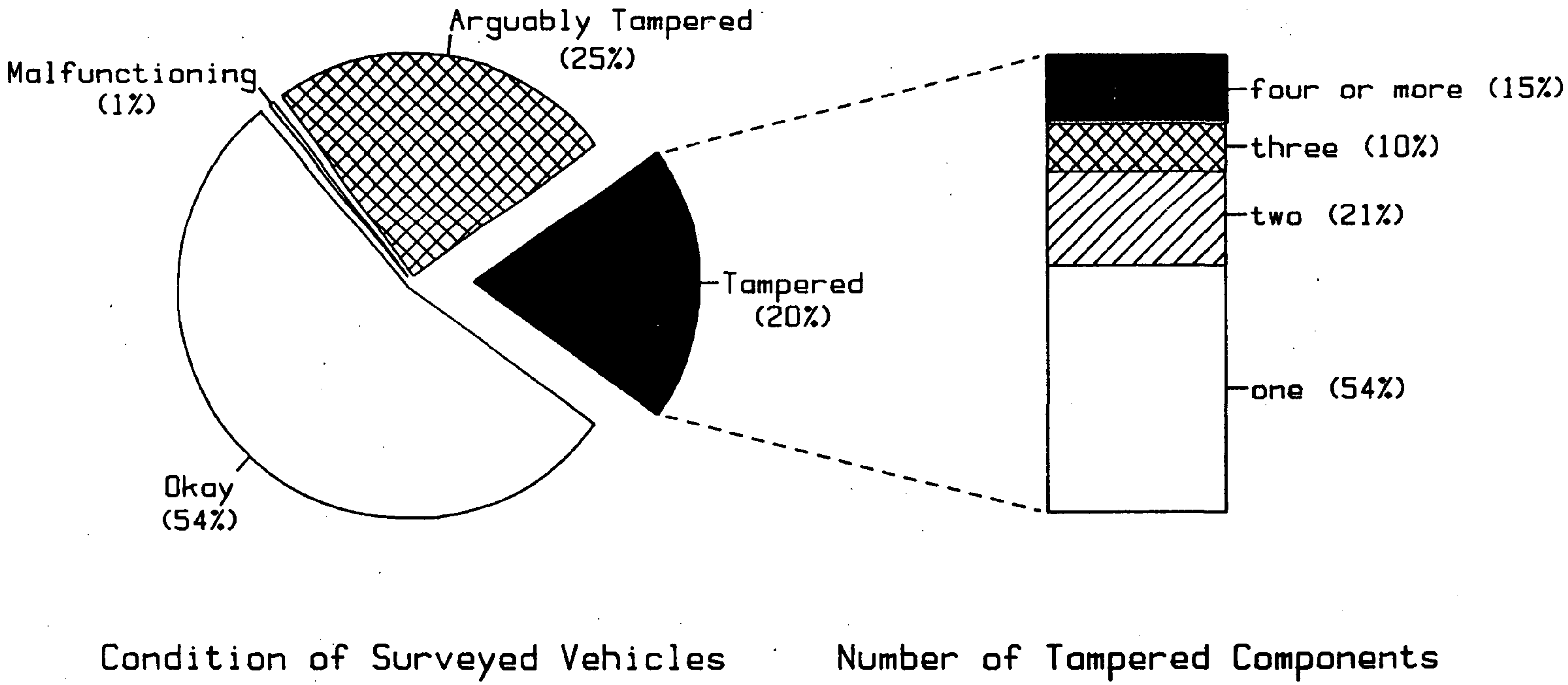


Figure 3. Breakdown of surveyed vehicles by condition and extent of tampering.

The frequency distribution of tampering instances for those vehicles classified as "tampered" is also shown in Figure 3. Forty-six percent of the tampered vehicles had multiple components tampered, and 15% had four or more instances of tampering.

Table 2 summarizes the 1986 survey data by site. As in previous surveys, the overall tampering in 1986 varies considerably from site to site. This can be attributed to the variety of program configurations among the cities surveyed and to geographic differences.

Table 2 also contains the refusal rate at each survey site. The overall refusal rate for the survey was very low (4%), and only one survey site (St. Louis) had a refusal rate equal to or exceeding 10%. The actual tampering rate in St. Louis may thus be higher than is reported here, since individuals who tamper with or misfuel their vehicles are less likely to allow their vehicles to be surveyed.

2. Tampering Trends 1978-1986

Table 3 shows the overall rates found in each of the eight tampering surveys. Overall tampering and arguable tampering generally appear to be decreasing, and the percent of properly maintained vehicles has been steadily increasing. The decrease in overall tampering can be examined more carefully by separating NO_x-related tampering (EGR system

TABLE 2

1986 Tampering Survey Summary

Survey Location	Number of Vehicles	Tampering Rate (%)	Misfueling Rate (%)	Survey Type*	Refusal Rate (%)
St. Louis, MO	413	15	4	R	10
East St. Louis, MO	551	23	8	R	5
Jacksonville, FL	477	21	9	R	3
Orlando, FL	575	26	15	R	4
Houston, TX	507	24	9	R	7
Memphis, TN	580	21	14	C	1
Pittsburgh, PA	504	12	4	R	4
Richmond, VA	500	14	5	R	4
Hartford, CT	428	13	5	R	7
Camden, NJ	498	19	6	R	8
Covington, KY	500	24	15	R	4
Seattle, WA	504	18	4	C	3
Los Angeles, CA	505	15	6	R	3
Tucson, AZ	499	25	10	C	1
Baton Rouge, LA	500	23	10	R	4
OVERALL	7,541	20	9	-	4

*R = roadside pullovers, C = centralized I/M stations

TABLE 3

Trends in Vehicle Condition Classification

Survey Year	Tampered (%)	Arguably Tampered(%)	Malfunctioning (%)	Okay (%)
1978	19	48	2	31
1979	18	47	2	33
1981*	14	45	3	38
1982	17	38	1	44
1983	25	30	3	42
1984	22	29	4	46
1985	20	27	1	52
1986	20	25	1	54

*Because the 1981 survey involved only two sites and a very limited sample size, these results may exhibit more variance than the other larger surveys.

tampering) from HC- and CO-related tampering. Table 4 shows that HC- and CO-related tampering have in fact remained relatively constant since 1983. EGR tampering, however, has declined markedly since 1983.

Direct comparisons between survey years should be made carefully, since they do not take into account differences among surveys in site selection, vehicle age, and car/truck distributions. More importantly, because of the 1986 survey's specific goals, it greatly overrepresents the portion of the national vehicle fleet under local control programs (see Table 5). Areas with control programs comprised 72% of the survey sample, while only approximately 41% of the national vehicle fleet were under such programs.

This discrepancy can be corrected to some degree by applying a weighting factor to the tampering rates found under each program type. The 1986 tampering rate weighted for program representation is 21%. The 1986 weighted tampering rate can be compared to the weighted rates from the 1985, 1984, 1983, and 1982 surveys (21%, 26%, 28% and 19%, respectively.) Applying weighting factors to the 1981 and earlier surveys would be difficult, since some surveys contained no I/M areas. The use of weighting factors here also does not account for differences in program coverage between sites. For the sake of clarity, only the actual, unweighted rates found during the surveys will be reported.

TABLE 4

Comparison of EGR System Tampering to Overall Tampering in the 1982-1986 Surveys

Tampering Category	Tampering (%) by Survey Year				
	1982	1983	1984	1985	1986
Overall Tampering	17%	25%	22%	20%	20%
Overall Tampering (excluding EGR System Tampering)	10*	19*	16*	17	17
EGR System Tampering	10	13	10	7	7
EGR System-only Tampering**	7	6	4	3	3

* Tampering with idle stop solenoid and vacuum spark retard were also excluded since these components were not inspected in 1985 and later surveys.

** Vehicles with EGR system tampering and no other tampering.

TABLE 5

Comparison of 1986 Survey Sample to Actual Nationwide Vehicle Fleet

Program Type	Percentage within Survey Sample (%)	Approx. Percentage of Nationwide Fleet (%)*
non-I/M	28	59
I/M-only	33	14
I/M + ATP	19	21
ATP-only	20	6

*Based on 1986 population data gathered from EPA Regional and State contacts.

3. Types of Tampering

The tampering rates for specific emission control components and systems for the surveys conducted since 1982 are presented in Table 6. The component-specific tampering rates for the 1986 survey are presented by survey site in Table 7. Only those vehicles originally equipped with a particular component are considered when computing the tampering rate for that component.

Table 6 shows that tampering with the major emission control components has generally remained unchanged from the 1985 survey. Air pump system tampering has been gradually increasing since 1982, and EGR system and catalytic converter tampering have been decreasing since 1983.

Table 7 shows the wide variation in tampering from site to site for any given component. Catalytic converter removal, for example, ranged from 1% in Los Angeles and Hartford to 11% in Covington and Orlando. This range is partly due to the effectiveness of I/M and antitampering programs (as will be discussed later in this report), geographic location, and socioeconomic background.

4. Vehicle Characteristics and Tampering

The next section of this report investigates the impact on tampering of three vehicle characteristics: manufacturer, vehicle type (car or truck), and age.

TABLE 6

Prevalence of Tampering by Component and Survey Year

Component/System	Survey Year 1982	1983	1984	1985	1986
Catalytic Converter	4%	7%	7%	5%	5%
Filler Neck Restrictor	6	7	10	7	
Air Pump System	5	7	7	7	8
Air Pump Belt	5	7	7	4	7
Air Pump/Valve	4	3	4	6	5
Aspirator*	1	1	1	2	2
PCV System	3	5	2	5	5
Evaporative Control System	2	5	3	4	6***
EGR System	10	13	10	7	7
EGR Control Valve	7	9	7	6	6
EGR Sensor	7	12	6	4	5
Heated Air Intake	1	1	1	1	2
Vacuum Spark Retard	0	1	5	**	**
Idle Stop Solenoid	0	1	1	**	**
Oxygen Sensor	**	0	0	0	1

*Vehicles with aspirated air systems are not equipped with other listed air-injection components, nor do conventional systems include aspirators.

**Component not checked during survey.

***Change in tampering classification system in 1986. Evaporative system tampering would have been 4% using the prior classification method.

TABLE 7

Component-Specific Tampering Rates (Percent) by Survey Location - 1986 Survey

Survey Location	Emission Control Component or System						
	Catalytic Converter	Inlet Restrictor	Air Pump System	PCV System	EGR System	Evaporative System	Any Component
St. Louis, MO	2	3	3	4	4	4	15
East St. Louis, IL	6	7	10	5	9	7	23
Jacksonville, FL	8	7	10	4	6	6	21
Orlando, FL	11	14	14	4	13	7	26
Houston, TX	6	7	8	7	9	8	24
Memphis, TN	8	12	8	4	5	4	21
Pittsburgh, PA	3	2	4	3	3	3	12
Richmond, VA	2	4	7	4	5	5	14
Hartford, CT	1	3	7	3	3	2	13
Camden, NJ	4	6	10	6	8	4	19
Covington, KY	11	12	11	3	10	7	24
Seattle, WA	3	4	8	3	9	5	18
Los Angeles, CA	1	5	6	3	5	5	15
Tucson, AZ	3	6	10	11	9	8	25
Baton Rouge, LA	8	9	9	6	11	8	23
OVERALL	5	7	8	5	7	6	20

Manufacturer. Figure 4 presents the 1986 tampering rates for each major manufacturer. Separate tampering rates are listed for each manufacturer with more than 100 vehicles in the survey. The remaining foreign manufacturers have been combined into two groups, Other European and Other Asian. With the exception of Volkswagen, vehicle tampering was higher among vehicles of domestic manufacture than among those of foreign manufacture. Overall, tampering with domestically manufactured vehicles was twice that found for the foreign manufactured vehicles (22% vs. 11%).

A number of factors might explain the discrepancy in tampering among manufacturers. Differences in design may make some vehicles more tamper-prone than others. Changing market share history results in different age distributions for vehicles of different makes, and vehicle age is clearly related to tampering prevalence. Tampering rates probably vary with geographic location and socioeconomic background, so the owner demographics for different makes may affect the likelihood of tampering.

Vehicle Type. The overall tampering prevalence for light-duty trucks (LDTs) was the same as for automobiles (LDVs), as was mentioned previously (Table 1). While the tampering rate for each emissions component on trucks was equal to or greater than on passenger cars (as in previous surveys) the 1986 survey is the first in which overall

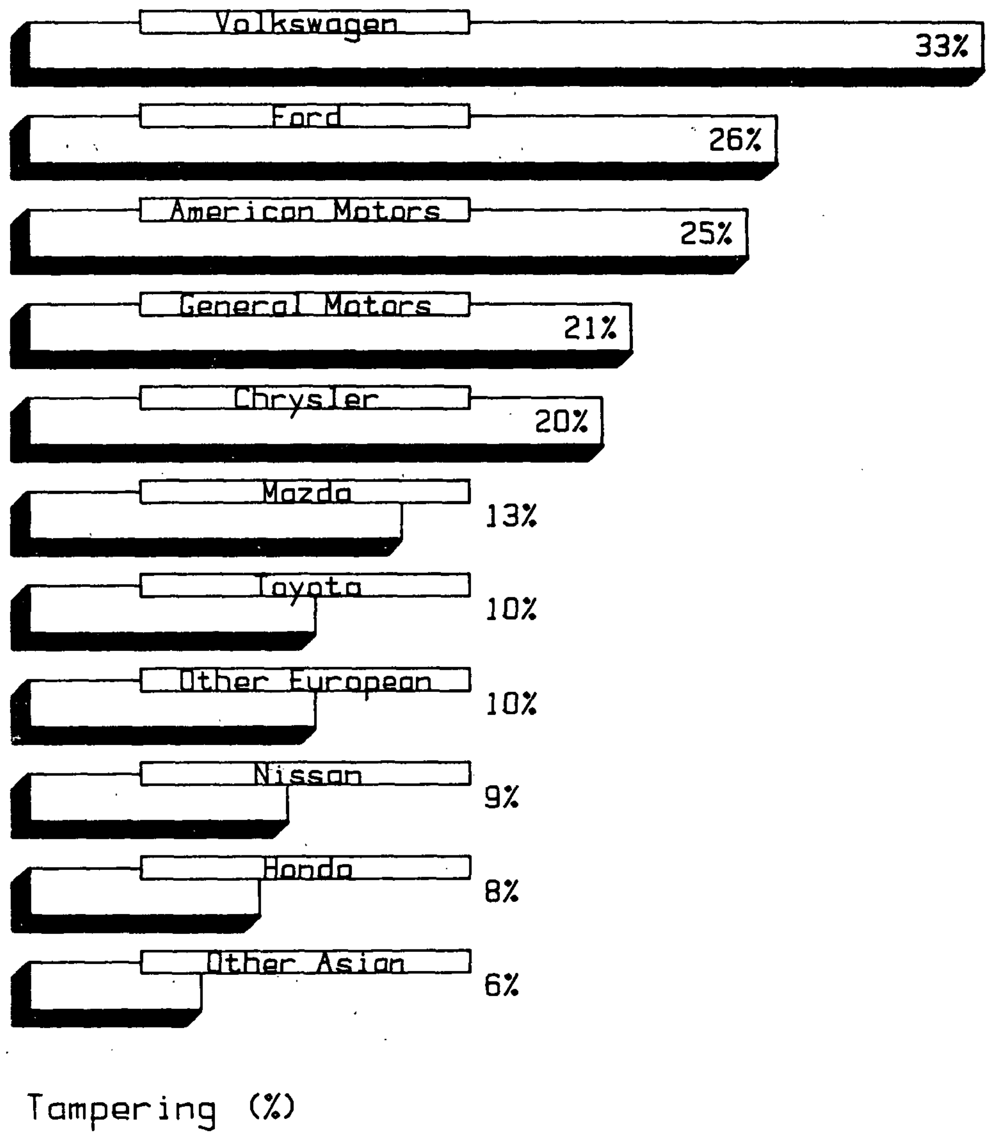


Figure 4. Tampering by Manufacturer: 1986 Survey.

tampering with trucks and cars was the same. Figure 5 shows that the discrepancy between car and truck tampering has been decreasing for the past five years.

One factor that may be contributing to the convergence in car and truck tampering is the increasing sales of imported trucks. Between 1982 and 1986 the proportion of imported trucks within the total truck population surveyed has increased from 10% to 15%. Since imported vehicles are tampered with much less frequently than domestic vehicles, the increase in imported trucks within the truck population surveyed may be contributing to the lower truck tampering prevalence. Another contributing factor may be the delayed impact of closed loop technology on truck tampering relative to car tampering. Closed loop technology first became widespread on trucks in 1983, while it had been widely used on cars since 1981. Any tampering deterrence from closed loop technology should thus be evident on cars first, and then later on trucks.

Vehicle Age. Table 8 relates vehicle age and model year with tampering prevalence for the 1978-1986 surveys. Catalytic converter removal rates are similarly related to vehicle age and model year in Table 9. The results from any given survey are entered diagonally in each table.

The results in Tables 8 and 9 indicate that vehicle tampering increases directly with vehicle age. Examining Table 8 diagonally (by survey) shows that tampering increases

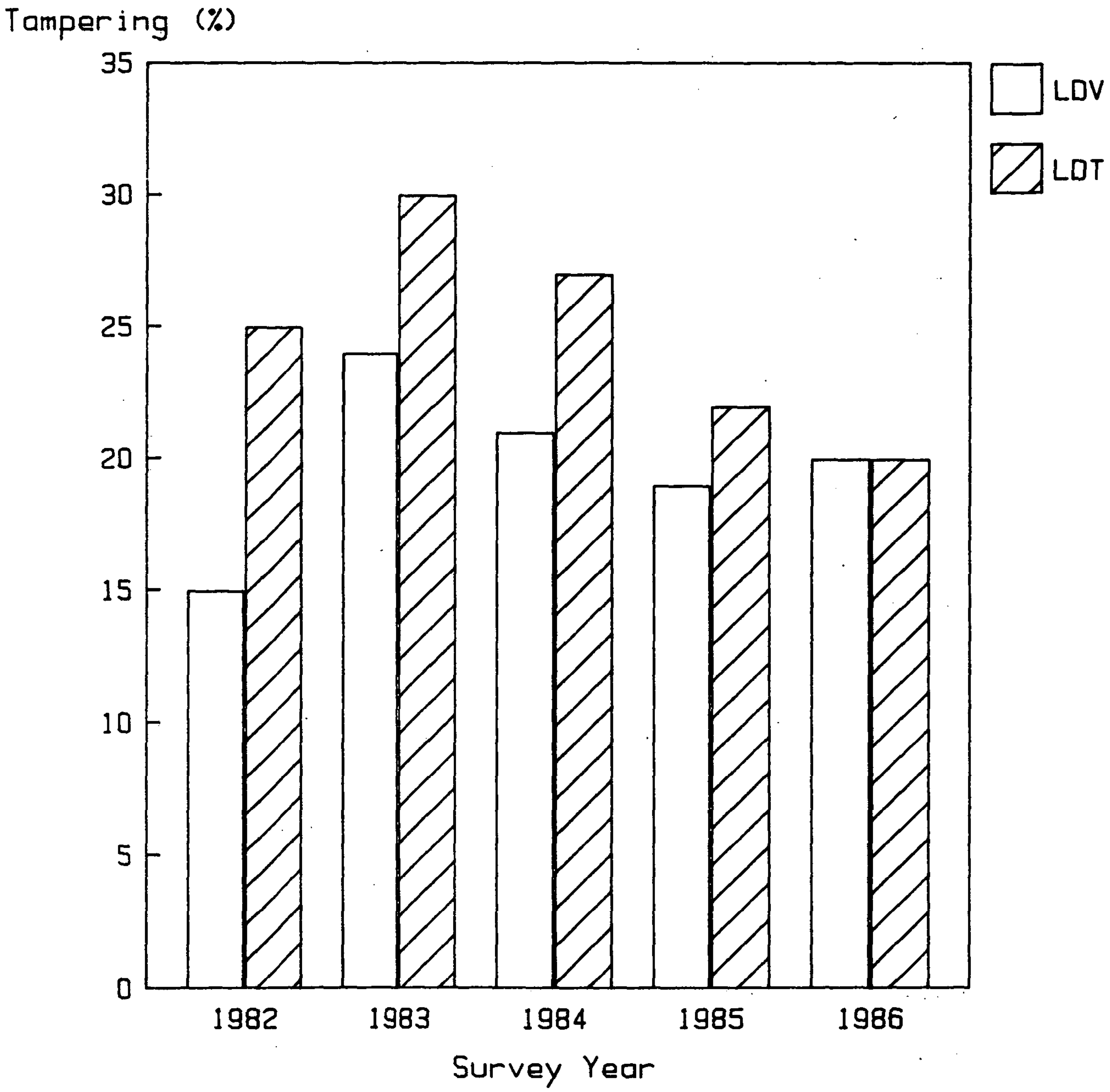


Figure 5. Comparison of LDV and LDT tampering in the 1982 - 1986 surveys.

TABLE 8

Tampering Percentage (and Sample Size) by Model Year and Vehicle Age at Time of Survey

	Year of Vehicle Life											
Model Year	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	Twelfth
1986	1(757)											
1985	2(816)	3(1130)										
1984	1(462)	2(1001)	5(1018)									
1983	7(182)	4(471)	6(710)	7(706)								
1982	1(250)	4(226)	7(466)	9(621)	11(574)							
1981	2(57)	7(448)	13(206)	15(458)	11(607)	19(560)						
1980		5(63)	9(454)	15(211)	18(516)	25(564)	25(556)					
1979	6(371)		9(59)	18(477)	31(288)	28(503)	37(673)	36(699)				
1978	7(298)	14(502)		15(79)	21(430)	39(238)	34(559)	37(562)	50(548)			
1977		10(457)	15(476)		21(66)	26(316)	44(190)	41(408)	48(452)	48(465)		
1976			18(395)	19(374)		29(52)	26(317)	40(171)	39(385)	49(369)	53(318)	
1975				22(274)	22(271)		32(22)	37(183)	55(89)	46(197)	54(194)	60(198)
1974					33(276)	27(242)						
1973						32(253)	36(251)					

TABLE 9

Percentage of Catalyst Removal (and Sample Size)
among Catalyst-equipped Vehicles by Model Year and Vehicle Age at Time of Survey

	Year of Vehicle Life											
Model Year	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	Twelfth
1986	0(757)*											
1985	0(808)	1(1128)										
1984	0(462)	0(978)	1(1018)									
1983	1(179)	2(471)	0(686)	1(706)								
1982	0(250)	1(225)	2(465)	2(597)	1(574)							
1981	0(57)	2(441)	5(204)	6(457)	3(567)	5(552)						
1980		2(61)	2(428)	3(200)	6(487)	6(522)	7(528)					
1979	0(326)		4(55)	6(429)	12(252)	10(455)	12(572)	12(638)				
1978	0(291)	0(445)		0(71)	4(362)	8(213)	8(486)	10(472)	10(466)			
1977		1(417)	1(417)		2(59)	2(271)	11(166)	14(357)	17(379)	19(409)		
1976			2(377)	2(305)		10(48)	6(257)	12(139)	12(314)	15(291)	20(276)	
1975				2(242)	2(204)		26(19)	12(139)	23(75)	16(174)	21(130)	23(167)

*Tampering rates have been rounded to the nearest whole percent. A zero does not necessarily indicate a total absence of tampering, but rather a level of tampering that rounded to zero.

consistently with vehicle age in each survey conducted. In the 1986 survey, for example, the tampering rate increases from 1% for first year (1986) vehicles to 60% among the 1975 model year vehicles surveyed. Table 9 shows a similar, though less pronounced, increase in catalyst removal. Examining these tables in this manner has the advantage of comparing data collected during one survey in one set of locations, but ignores the possible effects of model year differences (i.e., technology) on tampering.

Two additional ways of analyzing Tables 8 and 9 address the impact of model year on tampering rates. Analyzing the tables horizontally (holding the model year constant) provides a look at the tampering rates over time for the vehicles of a particular model year. This approach shows the same distinct increase in tampering with vehicle age for all model years since 1975. (The 1974 and 1973 data sets are too small to permit any conclusions.) For example, the tampering incidence for 1978 vehicles increased from 7% in their first year to 50% by the ninth year of use. The degree of overall tampering among very old vehicles (ninth through twelfth years of usage) appears to remain fairly constant at approximately 50% of the vehicles surveyed. A similar examination of Table 9 suggests that converter removal continues to increase among these very old vehicles. More data from future surveys may be necessary to discern any trend in tampering among these older vehicles.

Analyzing Tables 8 and 9 horizontally combines observations made from different survey sites at different times and should be undertaken cautiously.

The influence of vehicle age on tampering can be more clearly seen when the data in Tables 8 and 9 is presented graphically. Figures 6 and 7 plot overall and catalyst tampering, respectively, as a function of vehicle age for the 1982-1986 surveys. This is equivalent to the diagonal method of analysis used for Tables 8 and 9 that was outlined previously. Figure 6 demonstrates that the relationship between tampering rate and vehicle age is not only linear, but has remained nearly constant over the five most recent surveys. The strong correlation is obvious despite the different sizes, vehicle compositions, and locations of the surveys. In Figure 7 the catalyst tampering rate remains negligible for the first two to three years of a vehicle's life, and then increases thereafter. This delay in catalyst tampering is understandable, since the emission control components on all new vehicles are warranted for 5 years/50,000 miles by the manufacturer, providing an incentive to maintain the catalysts on vehicles still under warranty. A similar delay in overall tampering would also be expected, but is not readily apparent in Figure 6.

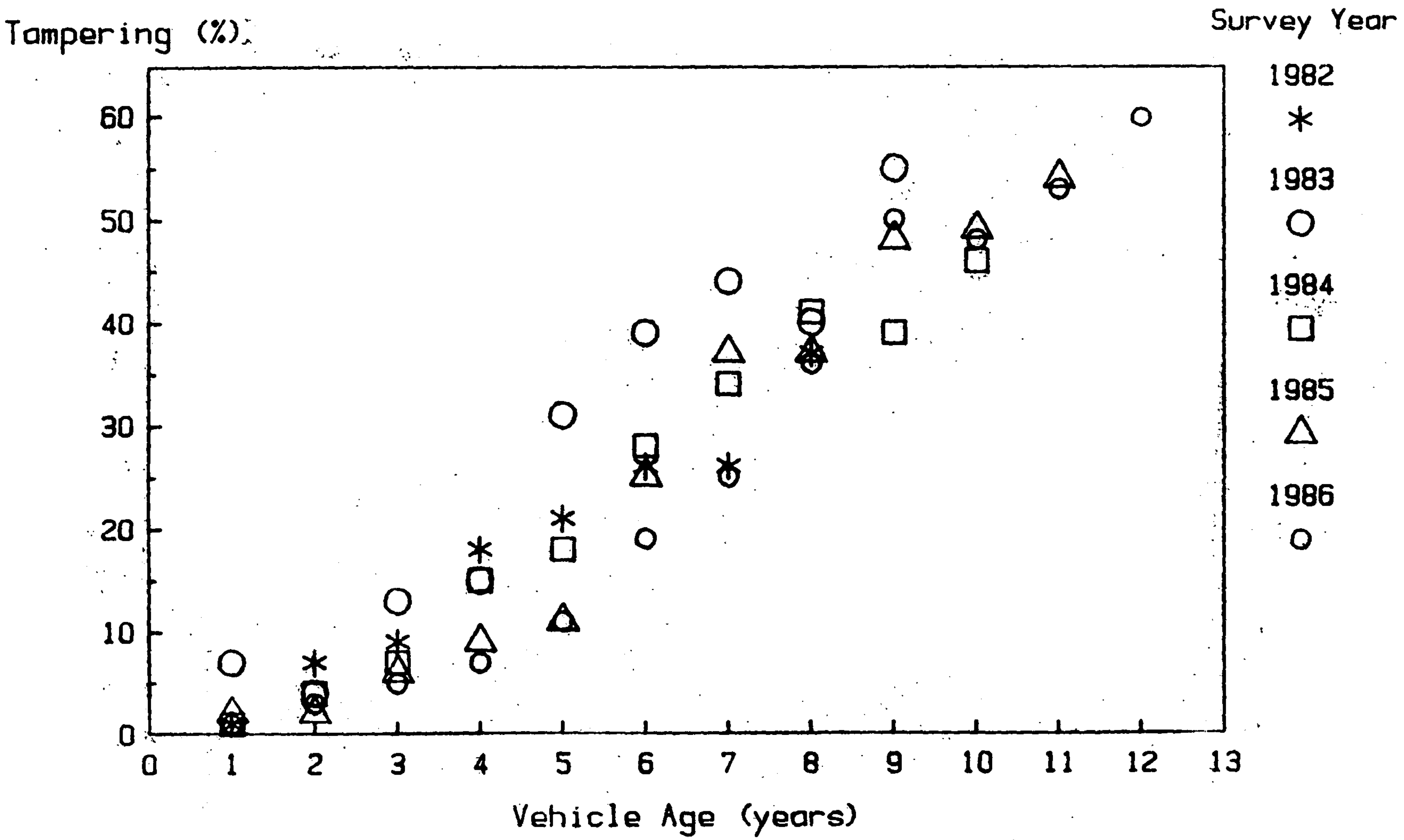


Figure 6. Cumulative tampering prevalence as a function of vehicle age for the 1982 - 1986 surveys.

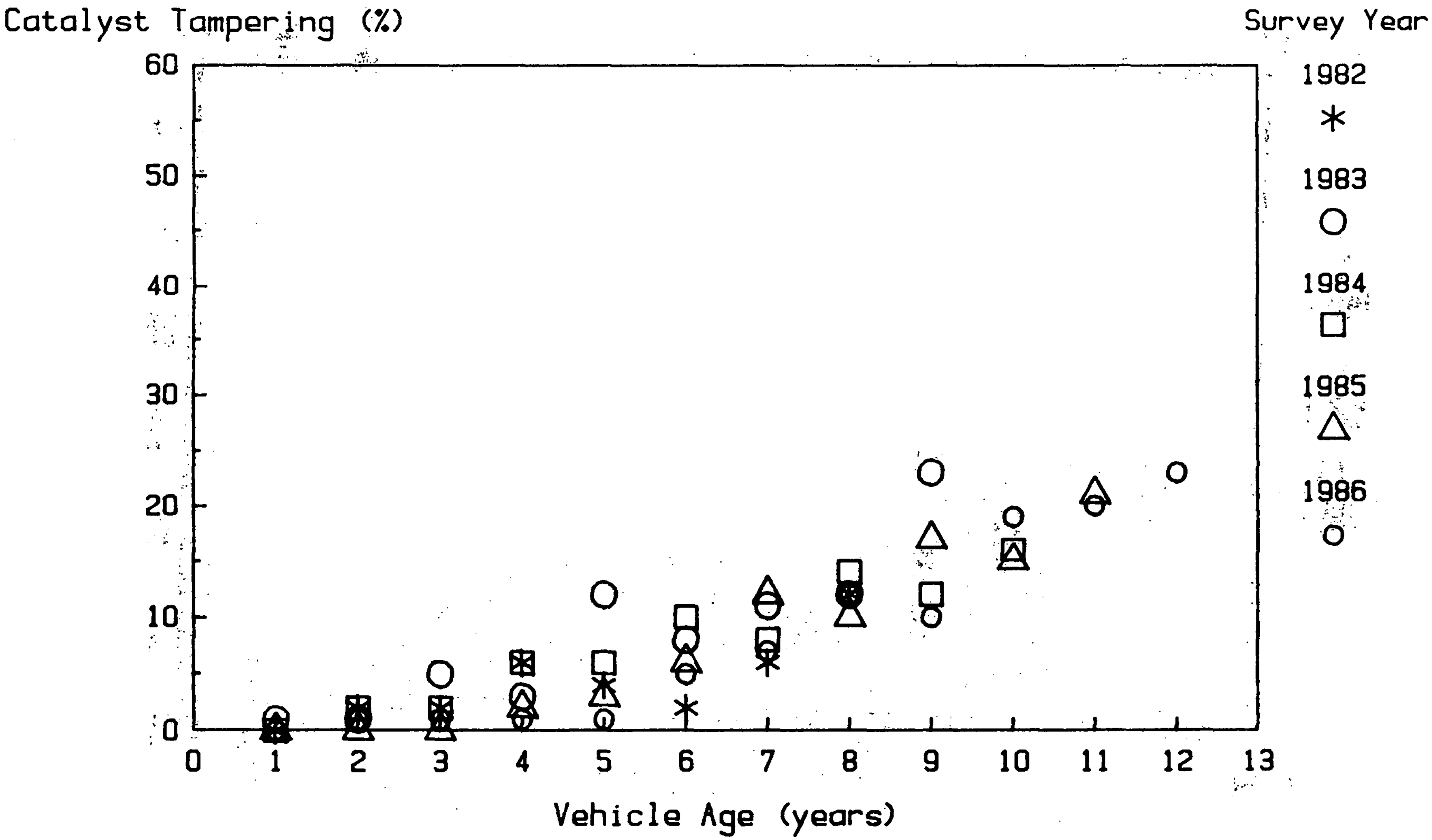


Figure 7. Cumulative catalyst tampering as a function of vehicle age for the 1982 - 1986 surveys.

Tables 8 and 9 can also be analyzed vertically (holding vehicle age constant), which provides a look at the tampering rates for different model year vehicles of the same age. This approach suggests that improvements in automotive technology, such as closed loop emission control systems, may affect overall tampering rates. For example, vehicle tampering among 1977 model year vehicles surveyed in their third year of usage was at 18%. By contrast, only 5% of the 1984 model year vehicles in their third year of usage were tampered. A similar vertical analysis of Table 8, however, fails to show a clear pattern or trend in age-specific catalyst tampering. Vertical analysis of Tables 8 and 9 introduces the same variability as the horizontal analysis.

5. Impact of I/M and Antitampering Programs

Inspection and maintenance (I/M) programs require vehicles to meet specific idle emission standards. Vehicles registered in areas with these programs are required to be periodically tested to assure that they comply with the specific idle emission cutpoints established by these jurisdictions. In addition to reducing emission levels by stimulating better owner maintenance, I/M programs may deter some tampering with emission control components. Data from previous surveys has tended to support this proposition, since tampering in I/M areas has historically been lower than in non-I/M areas.

Some I/M areas have also instituted antitampering programs (ATPs), which involve periodic vehicle inspections to check the integrity of specific emission control components. Antitampering programs vary greatly in the components inspected and the vehicle model years covered, so that a vehicle or component which would be inspected in one program area might not be inspected in a different program area. Successful antitampering programs should reduce existing tampering and deter future tampering with the components and model years covered by the program.

The sites surveyed in 1986 can be classified very generally as four non-I/M areas, five I/M-only areas, three I/M + ATP areas, and three ATP-only areas. Such classification is based solely on the presence or absence of a control program at the time the area was surveyed, and does not take into consideration variations in program coverage or effectiveness. Any comparisons between program types (i.e., I/M-only vs. non-I/M) should thus be made carefully.

6. Tampering Trends for Selected Sites

The impact of I/M and antitampering programs in specific locations can be examined by comparing the 1986 survey data with that from earlier surveys. Comparisons made between surveys widely spaced in time, however, must take into consideration the differences in average vehicle age in each survey. The average miles traveled per vehicle surveyed in 1986, for example, is one third greater than it was in 1983. Since vehicle age is directly related to tampering prevalence, a significant increase in tampering might be expected to have occurred between 1983 and 1986, if all other factors remained constant (car/truck distribution, owner demographics, etc.). Inferences regarding program effects should thus be made with this in mind.

Table 10 presents tampering data for three sites - Camden, Houston, and Baton Rouge. The comparisons made in this table have been limited to the specific components and vehicle model years covered by each antitampering program as of the 1986 survey. The tampering data listed in Table 10 were compiled only for surveyed vehicles included within the local program jurisdiction. The Houston tampering data, for example, are for Harris County vehicles only. Any non-Harris County vehicles surveyed were excluded from this analysis.

It is difficult to determine from Table 10 whether or not New Jersey's recently implemented antitampering program has had any impact on converter and inlet restrictor tampering found on 1982 and newer vehicles, since the incidence of tampering on these vehicles was already negligible. As of May 1, 1987, New Jersey's antitampering program expanded to 1975 and newer vehicles, and future surveys will examine the program's effectiveness against older vehicles having a higher tampering prevalence.

TABLE 10

Tampering Prevalence among Vehicles and Components Covered by Three Antitampering Programs for the 1983-1986 Tampering Surveys

Survey Location	Component and Model Years Covered		Tampering Prevalence (%) by Survey Year 1983	1984	1985	1986
Camden, NJ	Catalytic Converter	82+	-	1%	-	0%*
	Inlet Restrictor	82+	-	1	-	0*
Houston, TX	Catalytic Converter	80+	6	-	1*	3*
	Inlet Restrictor	80+	1	-	0*	2*
	Positive Plumbtesmo	80+	7	-	2*	2*
	PCV System	75+	9	-	4*	7*
	Evaporative System	75+**	8	-	4*	7*
	Air Pump System	75+	9	-	6*	8*
Baton Rouge, LA	Catalytic Converter	80+	-	-	4	3*
	Inlet Restrictor	80+	-	-	3	1*
	PCV System	80+	-	-	2	3*
	Evaporative System	80+**	-	-	3	3*
	EGR System	80+	-	-	4	4*
	Air Pump System	80+	-	-	6	4*

* survey was conducted after ATP had been implemented.

**classification of evaporative system tampering changed in 1986 survey. Evaporative system tampering in Houston and Baton Rouge would have been 5% and 2%, respectively, using the prior coding method.

TABLE 11

Comparison of Tampering among Missouri Vehicles (I/M + ATP) and Illinois Vehicles (non-I/M) Surveyed in St. Louis, MO and East St. Louis, IL in 1986

Component and Model Years Covered		Tampering (%) by State of Vehicle Registration: Missouri	Illinois
Catalytic Converter	81+	0%	2%
Air Pump System	75+	4	10
EGR System	75+	4	9
PCV System	75+	4	6

The tampering data for vehicles covered by Houston's ATP-only suggest that this program was less effective in its second year of operation than in its first. Catalyst and fuel-related tampering decreased sharply in 1985, after one year of program operation, and underhood components covered by the program had moderately reduced rates. Tampering seemed to have rebounded in 1986, however, particularly for the underhood components. Baton Rouge's ATP-only has been partially effective in its first year of operation, since tampering with 3 of the 6 components covered showed weak declines between the 1985 survey (before program implementation) and the 1986 survey (one year after program implementation). The other three components either did not change or actually showed higher tampering.

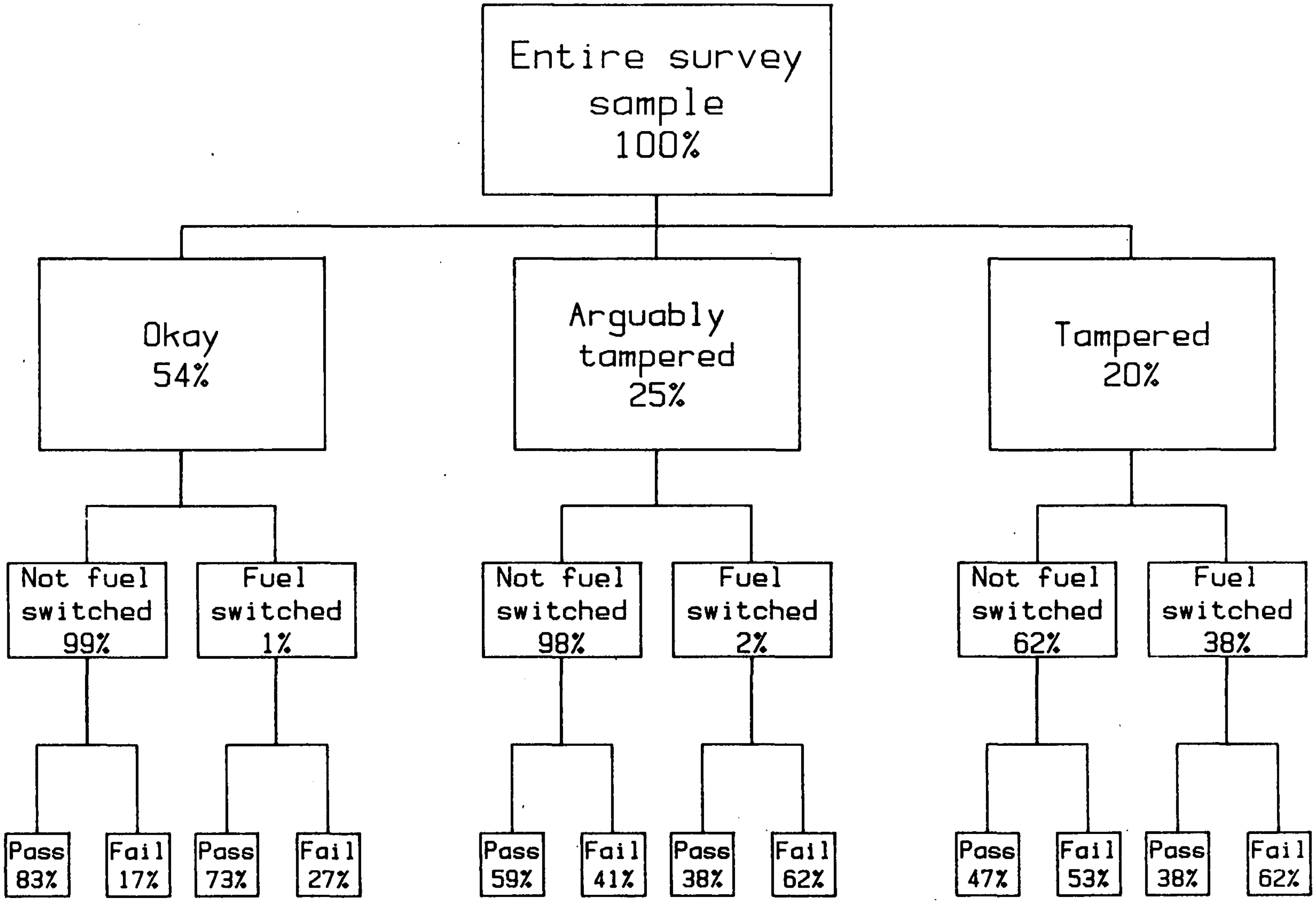
Table 11 examines the difference in tampering found in St. Louis, MO and East St. Louis, IL. In Table 11 the vehicles surveyed at these two sites have been classified by state of registration rather than location surveyed, since a number of Missouri vehicles were surveyed in Illinois and vice versa. Also the tampering rates were determined for the model year and components covered by Missouri's I/M + ATP to examine the Missouri program's effectiveness. Table 11 shows a dramatic difference in tampering among vehicles in close geographic proximity but under different control programs. Part of this difference is probably due to the different socioeconomic makeup of the two cities surveyed, but the presence of an I/M + ATP in Missouri is no doubt a contributing factor to the lower tampering rates.

7. Correlation between Tampering and Idle Emissions

As was mentioned previously, vehicles which are subject to an I/M program must meet specific idle emissions cutpoints. To assess the relationship between tampering and fuel switching and idle failure rates, the idle emissions from vehicles have been tested against the cutpoints established by the I/M program where they were sampled. Vehicles in non-I/M areas were tested against the cutpoints specified by the New Jersey I/M program. The cutpoints for each I/M area are listed in Appendix C.

The results of the idle tests are presented in Figure 8 for vehicles in the various tampering and fuel switching categories. Only 17% of the surveyed vehicles that were free of tampering and fuel switching failed an idle test, while 62% of the tampered and fuel switched vehicles failed that test. These results indicate that a substantially larger proportion of tampered and fuel switched vehicles than of okay vehicles fail an idle test at typical I/M cutpoints. This is partly due to the tendency for tampered vehicles to have misadjusted carburetors, since 77% of the tampered vehicles with conventional carburetors also had missing

Figure 8
Distribution of Survey Sample Among Tampering*, Fuel Switching, and Idle Test Categories



*excludes malfunctioning vehicles (1% of total) sealed plugs or limiter caps. It should be noted from Figure 9, however, that 38% of the tampered and fuel switched vehicles were still able to pass the idle test.

Table 12 shows the percentage of vehicles that failed the idle emissions test for each vehicle condition. The failure rates are listed for the entire survey, as well as in two model year groupings representing "old" technology (1975-1980) and "new" technology (1981+) vehicles. "New" technology signifies closed loop emissions control, which came into widespread usage in 1981 model year vehicles.

The overall percentage of tampered vehicles exceeding I/M cutpoints for HC emissions was nearly three times greater than for okay vehicles (41% vs 14%). Over five times as many tampered vehicles exceeded CO cutpoints as did okay vehicles (44% vs 9%). The majority (60%) of the vehicles that either had been fuel switched or had their catalysts removed also exceeded HC or CO limits. Conversely, 40% of the vehicles with missing catalysts or classified as fuel switched were still able to pass an idle emissions test. As in previous surveys, a significant number of arguably tampered vehicles also produced excess idle emissions. Since the majority of arguable tampering involves idle speed limiter caps and sealed plugs, the high failure rate demonstrates the adverse idle emissions impact of improperly adjusted carburetors.

TABLE 12

Idle Test Failure Rates (Percent) by Pollutant and Vehicle Condition

Vehicle Condition	Failure Rate (%) by Pollutant for Model Years listed: 1975-80 HC	1975-80 CO	1981+ HC	1981+ CO	Overall HC	Overall CO	Overall HC or CO
Okay	22	14	13	8	14	9	17
Arguably Tampered	34	37	20	21	29	31	42
Tampered	44	49	29	27	41	44	57
Cat. Removed or Misfueled	44	48	38	40	43	47	60

TABLE 13

Mean Idle Emissions by Vehicle Condition

Prgram Type	HC emissions(ppm) Tampered	HC emissions(ppm) Okay	CO emissions(%) Tampered	CO emissions(%) Okay
non-I/M	402.6	51.4	3.5	0.4
I/M*	280.2	51.5	2.4	0.3
ATP-only	328.9	45.2	2.8	0.4
OVERALL	346.1	50.6	2.9	0.3

* category includes any program where idle emissions are checked, including I/M + ATP areas.

The effectiveness of idle emissions testing on "new" technology vehicles can also be seen in Table 12. The data in Table 12 actually minimizes the impact of "new" technology because "old" technology trucks manufactured after 1980 have been included in the "new" technology category due to the model year split. As was found in the 1985 survey, idle emissions testing is more effective in identifying tampering on 1980 and older vehicles than on 1981 and newer vehicles. For example, 49% of the tampered "old" technology vehicles exceeded CO cutpoints compared to 27% of the tampered "new" technology vehicles. This suggests that idle emissions testing may not be an effective strategy for identifying tampering and fuel switching among "new" technology vehicles, since many vehicles with closed loop systems are able to produce low idle emissions even with tampered emission control devices.

The mean idle emissions for tampered and okay vehicles are presented in Table 13 by program type. Vehicles from Baton Rouge are considered to be ATP-only for model years 1980 and newer, while vehicles from model years 1975-1979 are classified as non-I/M (following the program coverage in the area). The vehicles surveyed in Memphis are classified as I/M for CO emissions but as non-I/M for HC emissions because the I/M program effectively has no cutpoints for HC (see Appendix C). Also areas with I/M or I/M + ATP have been combined in Table 13.

The mean idle emissions from tampered vehicles were considerably greater than from properly maintained vehicles (Table 13). Overall, HC emissions from tampered vehicles were nearly seven times greater on average than from okay vehicles, while CO emissions were nearly 10 times greater. Tampered vehicles from areas with I/M programs had the lowest average HC and CO emissions, while tampered vehicles from areas with ATP-only had slightly higher average emissions. The slightly higher idle emissions from vehicles in ATP-only areas is not surprising, since these vehicles have not been tuned to pass I/M cutpoints.

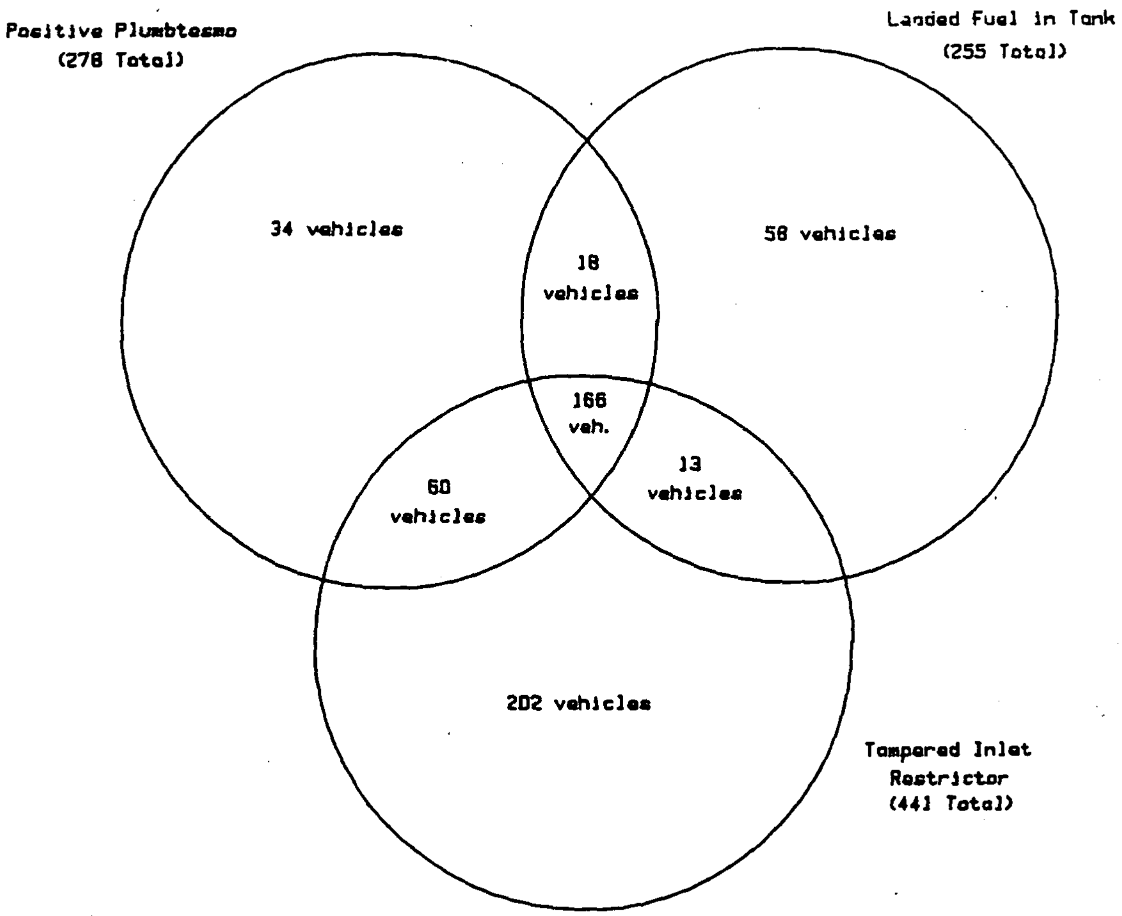
B. FUEL SWITCHING

1. Fuel Switching Indicators and Overlap

Fuel switching is more easily defined than measured, since no single indicator can accurately determine its prevalence. Since 1981 the surveys have used a combination of three indicators to measure fuel switching more accurately: a tampered fuel filler inlet restrictor, a positive Plumbtesmo test for lead deposits in the tailpipe, and a gasoline lead concentration of more than 0.05 gram per gallon (gpg). Of these three indicators, only a tampered inlet restrictor is also considered tampering, and as such is used to calculate both tampering and fuel switching rates. Since false positive indications should be extremely rare for these measures, the percentage of vehicles with at least one positive indicator is a reasonable minimum estimate of fuel switching.

The presence of any of these three indicators suggests that a given vehicle has been misfueled; their absence, however, does not rule it out. For example, fuel samples could only be obtained from 81% of the unleaded vehicles surveyed, limiting the scope of this variable. A vehicle misfueled repeatedly with leaded gasoline may also have little detectable lead in its fuel tank due to subsequent proper fueling. Similarly, a vehicle with an untampered fuel filler inlet restrictor may have been fueled at a leaded pump equipped with a smaller nozzle, or by using a funnel or similar device. The tailpipe lead test, due to the difficulties of field administration, may also fail to identify misfueling, and older vehicles may have had their tailpipes replaced since last operated on leaded fuel. As the lead phasedown program is lowering lead levels in leaded gasoline, the incidence of false negative Plumbtesmo results may be increasing. The uncertainty in these measures, then, is always toward underestimating the number of vehicles misfueled.

The limitations of the fuel switching indicators can be seen in their incomplete overlap. The results from these indicators would be expected to overlap significantly, since they are three indicators of the same phenomenon. This has not held true, however, in the 1986 survey or in previous surveys. The Venn diagram (Figure 9) illustrates the degree of overlap in the misfueling indicators for all unleaded



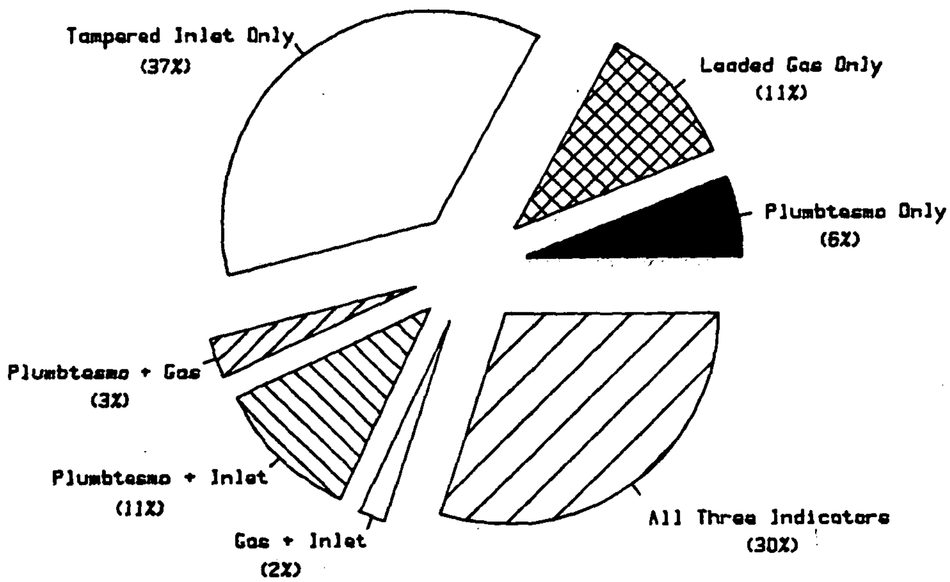


Figure 9. Overlap of fuel switching indicators among unleaded vehicles - 1986 survey.

vehicles surveyed in 1986 in which data for all three indicators were recorded. For example, only 72% of the vehicles having leaded fuel in their tank also registered a positive Plumbtesmo test. Additionally, only 41% of the vehicles with tampered inlet restrictors actually had leaded gasoline in their tanks at the time of the survey. The incomplete overlap reflects the limitations of each indicator as well as the different aspects of fuel switching each indicator identifies.

Figure 9 also shows that 80% of the fuel switched vehicles had a tampered inlet restrictor, making it the most frequently observed indicator of fuel switching. A positive Plumbtesmo result was observed on 50% of the fuel switched vehicles, while leaded fuel was found in the tanks of 46% of the fuel switched vehicles sampled. An antitampering program consisting of an inlet restrictor inspection and a Plumbtesmo test would have detected fuel switching in 89% of the fuel switched vehicles surveyed in 1986.

2. Fuel Switching Trends

Of the vehicles requiring unleaded fuel, 9% were identified as misfueled by at least one of the indicators discussed above. The fuel switching incidence by survey site is listed in Table 14. Table 15 compares the prevalence of each fuel switching indicator in the 1986 survey with previous surveys. The data in Table 15 suggest a general pattern of

TABLE 14

Fuel Switching Rates Among Unleaded Vehicles By
Site and Indicator - 1986 Survey

Survey Location	Leaded Fuel in Tank (%)	Tampered Inlet Restrictor (%)	Positive Plumbtesmo (%)	Overall Fuel Switching (%)
		Non-I/M Areas		
East St. Louis, IL	5	7	4	8
Jacksonville, FL	5	7	5	9
Orlando, FL	8	14	8	15
Covington, KY	9	12	10	15
		I/M-only Areas		
Memphis, TN	7	12	7	14
Pittsburgh, PA	3	2	2	4
Hartford, CT	3	4	1	5
Seattle, WA	2	4	2	4
Tucson, AZ	3	6	6	10
		I/M + ATP Areas		
St. Louis, MO	2	3	1	4
Camden, NJ	2	6	2	6
Los Angeles, CA	1	5	1	6
		ATP-Only Areas		
Houston, TX	6	7	5	9
Richmond, VA	2	4	3	5
Baton Rouge, LA	6	9	7	10
ALL SITES	5	7	4	9

TABLE 15

Fuel Switching Rates Among Unleaded Vehicles
by Indicator and Survey Year

Survey Year	Leaded Fuel in Tank(%)	Tampered Inlet Restrictor(%)	Positive Plumbtesmo(%)	Overall Fuel Switching (%)
1978	4	3	*	4
1979	10	4	*	10
1981	7	6	8	16
1982	6	6	7	11
1983	7	7	10	14
1984	8	10	9	14
1985	5	7	5	9
1986	5	7	4	9

*Plumbtesmo test not used.

decline in fuel switching. Since such a pattern could result from the selection of sites surveyed this year, strong conclusions must await the data from subsequent surveys.

Table 16 presents the combined tampering and fuel switching rates for the 1986 survey. The percentage of unleaded vehicles that were tampered or fuel switched was 20%, and the percentage of unleaded vehicles with missing or damaged converters was 10%. Table 16 thus suggests that half of all tampering and fuel switching is composed of vehicles in the catalyst removed or fuel switched category. Since these conditions have the largest emissions impact, this indicates the very serious nature of most tampering.

3. <u>Fuel Switching by Vehicle Type</u>

The prevalence of each fuel switching indicator by vehicle type is presented in Table 17. Overall fuel switching among trucks was higher than for passenger cars (11% vs. 8%) and the prevalence of each indicator was also greater among trucks.

4. <u>Fuel Switching and Catalyst Tampering</u>

Consumers and mechanics remove catalytic converters for a number of reasons, but much of their motivation is related to fuel switching. The vehicle owner may remove the catalytic converter either prior to misfueling, or after some misfueling

TABLE 16

Combined Tampering and Fuel Switching - 1986 Survey

Survey Location	Catalyst-equipped vehicles with catalysts removed or that were fuel switched (%)	Unleaded Vehicles either tampered or fuel switched (%)
	Non-I/M Areas	
East St. Louis, IL	10	23
Jacksonville, FL	12	22
Orlando, FL	19	27
Covington, KY	18	25
	I/M-only Areas	
Memphis, TN	16	22
Pittsburgh, PA	6	13
Hartford, CT	6	14
Seattle, WA	6	16
Tucson, AZ	11	26
	I/M + ATP Areas	
St. Louis, MO	5	16
Camdem, NJ	9	19
Los Angeles, CA	7	16
	ATP-only Areas	
Houston, TX	11	25
Richmond, VA	6	15
Baton Rouge, LA	13	25
TOTAL	10%	21%

Table 17

Prevalence of Fuel Switching Indicators by Vehicle Type

Fuel Switching Indicator	Percent Fuel Switching by Vehicle Type LDV	LDT
Tampered Inlet Restrictor	7	8
Positive Plumbtesmo	4	8
Leaded Fuel in Tank	4	7
Overall Fuel Switching	8	11

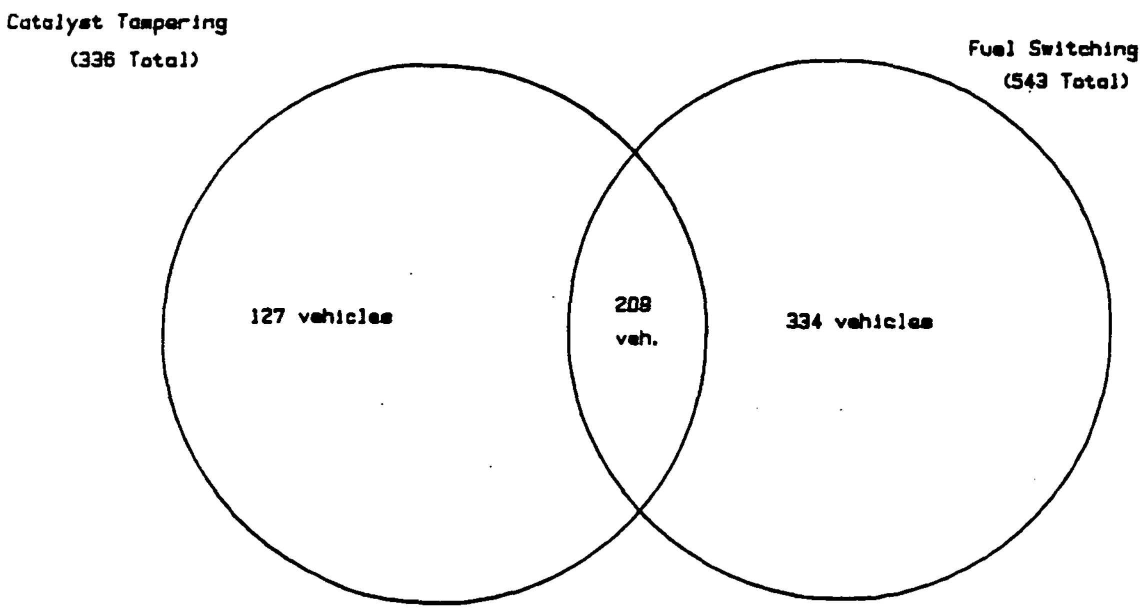
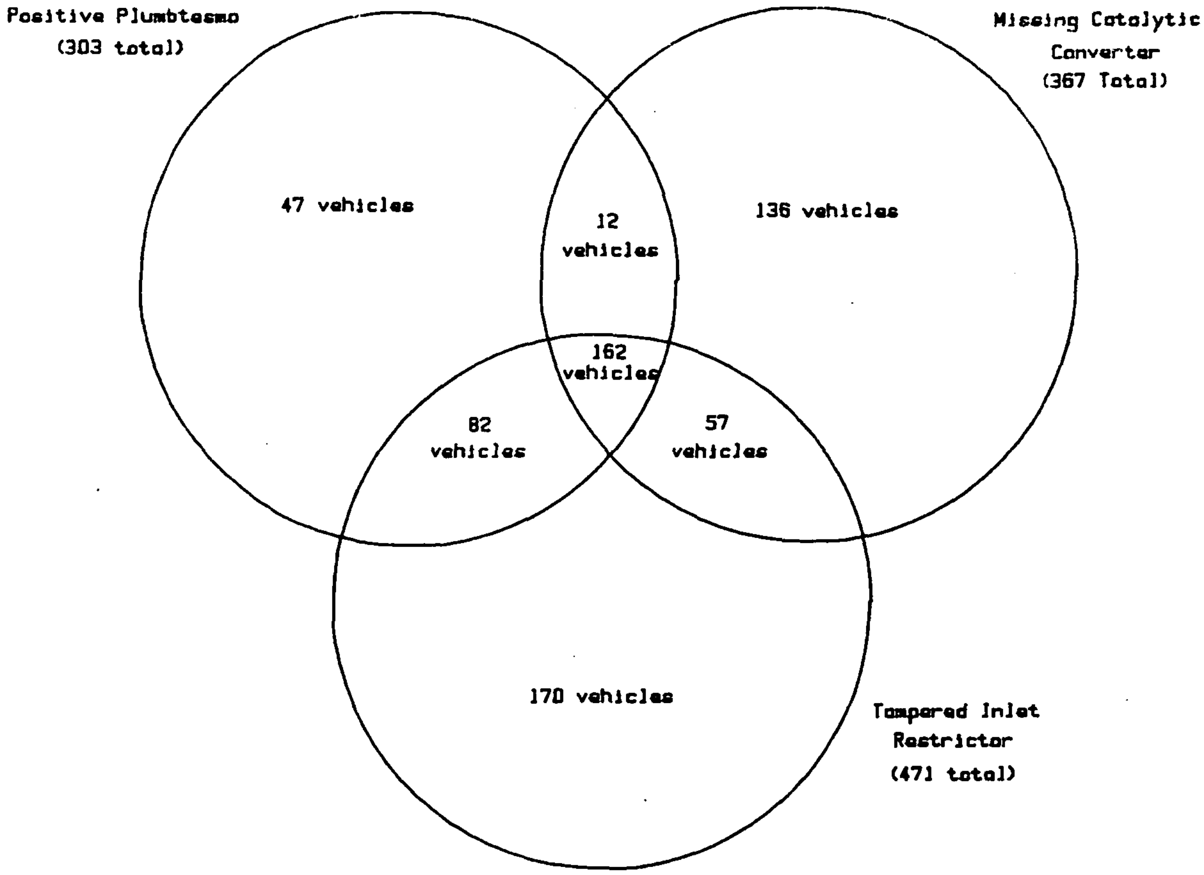


Figure 10. Overlap of catalyst tampering and fuel switching among catalyst-equipped vehicles - 1986 survey.

if the vehicle's driveability has been adversely affected by a catalyst damaged from the repeated misfueling. The data from this survey cannot be used to distinguish between these two situations, but can be used to examine the extent to which these types of abuse occur in conjunction.

Figure 10 depicts the degree of overlap between catalyst removal and fuel switching. Vehicles with catalyst tampering exclusive of fuel switching were relatively uncommon -- only 38% of the catalyst tampered vehicles were not fuel switched. Fuel switching, however, is not always accompanied by catalyst removal, since 62% of the fuel switched vehicles still had their catalysts.

Figure 11 examines the relationship between converter tampering and two of the three misfueling indicators (positive Plumbtesmo and tampered inlet restrictor). Only vehicles in which all three of these parameters were inspected are included in Figure 11. These three criteria have been incorporated into a number of antitampering programs, such as in Houston and Baton Rouge, to determine if a converter is missing or damaged. A vehicle failing the Plumbtesmo test or inlet restrictor inspection in these programs would have to have its converter replaced.



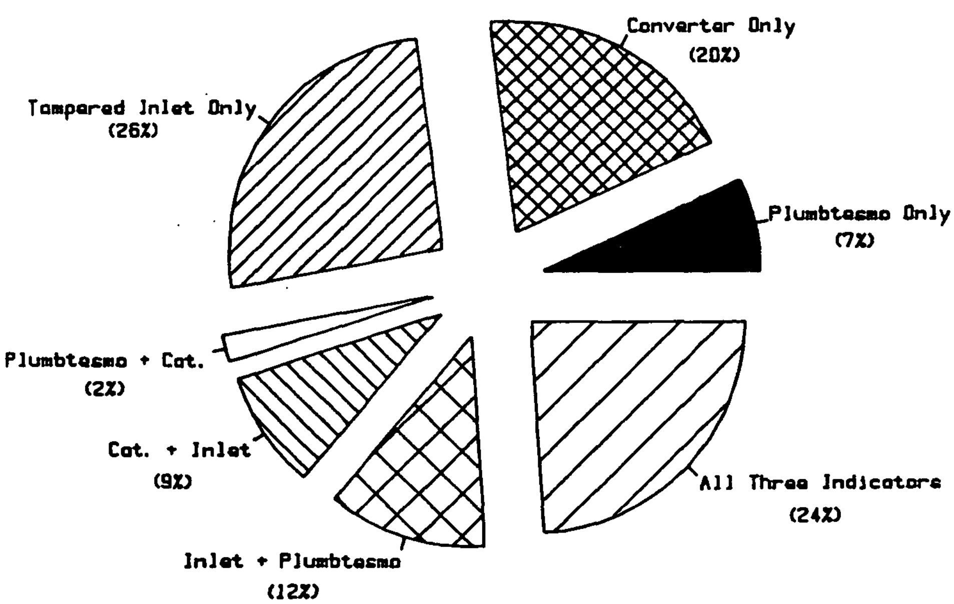


Figure 11. Overlap of indicators used by ATPs to detect missing/damaged catalysts - 1986 survey.

Figure 11 shows the value of these programmatic criteria in detecting missing or damaged converters. A simple inspection of the converter for example, would only catch 55% of the vehicles with missing or damaged converters. Inspecting both the converter and inlet restrictor, however, would detect 93% of these vehicles. The usefulness of Plumbtesmo as an indicator may be declining with the advent of lead phasedown, since only 7% of the vehicles in Figure 11 failed for Plumbtesmo only. In 1984, prior to lead phasedown, 17% of the vehicles failing one of these programmatic criteria failed for Plumbtesmo only.

5. Gasoline Lead Concentrations

Of the vehicles identified as misfueled by any of the three misfueling indicators, 52% had only trace amounts of lead (less than 0.05 gpg) in their gasoline when inspected. These vehicles, then, were identified as fuel switched by a tampered filler restrictor and/or a positive Plumbtesmo test. Figure 12 presents the distribution of lead concentrations of 0.05 gpg or more in misfueled vehicles. The impact of lead phasedown can be dramatically seen when Figure 12 is compared to similar data from the 1984 and 1985 surveys. In the 1984 survey 39% of the misfueled vehicles had a gasoline lead concentration in excess of 1.0 gpg, compared to 1% in 1985 and 1986. The distribution of lead concentrations in 1986 is centered on the 0.2-0.4 gpg range, compared to 0.4-0.6 gpg in 1985 and 1.0+ gpg in 1984.

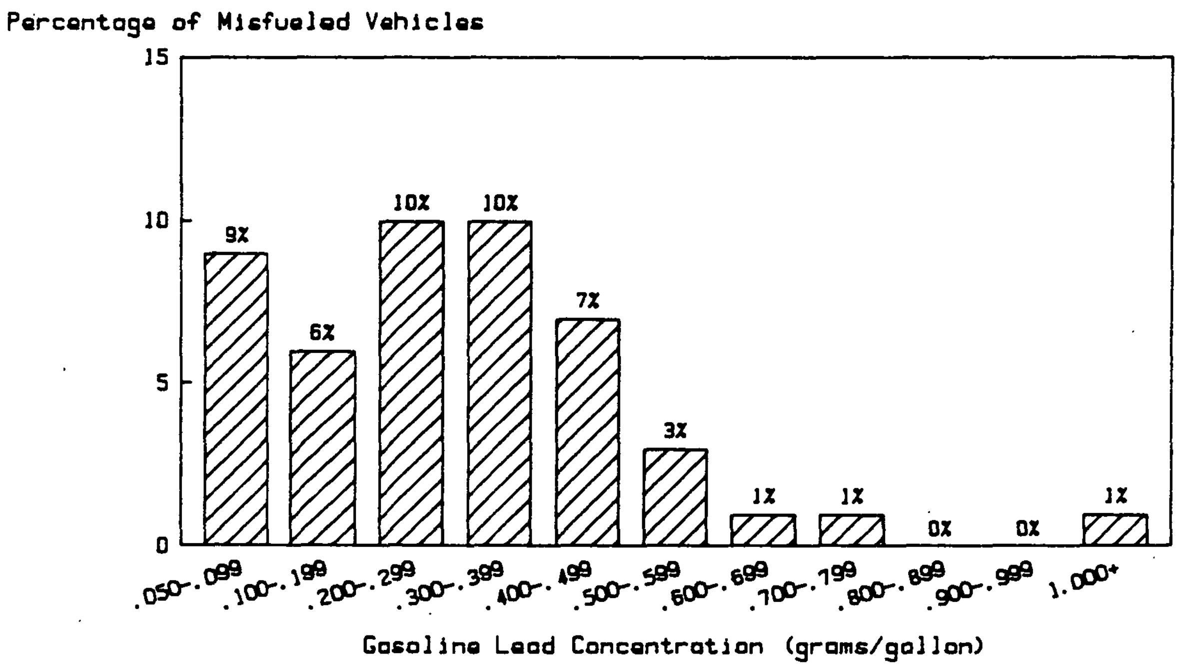


Figure 12. Lead concentrations in leaded fuel sampled from misfueled vehicles.

APPENDIX A

RELEVANT PORTIONS OF THE CLEAN AIR ACT

Section 203(a)(3): The following acts and the causing thereof are prohibited --

(A) for any person to remove or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this title prior to its sale and delivery to the ultimate purchaser, or for any manufacturer or dealer knowingly to remove or render inoperative any such device or element of design after such sale and delivery to the ultimate purchaser; or

(B) for any person engaged in the business of repairing, servicing, selling, leasing, or trading motor vehicles or motor vehicle engines, or who operates a fleet of motor vehicles, knowingly to remove or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this title following its sale and delivery to the ultimate purchaser.

APPENDIX B

SURVEY AND DATA RECORDING PROCEDURES

1. Explanation of Survey Forms

The forms on the following pages were used for recording the survey data in the field. The forms were forced choice to ensure coding consistency, and were designed to facilitate direct data entry. The following codes were used to record data for the major system components on the data sheets:

0 - Not originally equipped	8 - Misadjusted item
1 - Functioning properly	9 - Malfunctioning
2 - Electrical disconnect	A - Stock equipment
3 - Vacuum disconnect	B - Non-stock
4 - Mechanical disconnect	D - Add on equipment
5 - Incorrectly routed hose	Y - Yes
6 - Disconnect/Modification	Z - No
7 - Missing item	

Additional codes were used for those components which could not be classified into the above categories. If a determination could not be made about a given component's condition, the variable was left blank. A brief description of each data entry follows.

1986 TAMPERING SURVEY - PART A (UNDERHOOD)

1 [ ][ ][ ][ ] 4 ID NUMBER

5 M O Y R [ ][ ][ ][ ] 8 I/M STICKER (dates of last inspection)

9 [ ][ ][ ].[ ] 12 DISPLACEMENT (cubic inches or liters)

13 [ ][ ] 14 MODEL YEAR

**NOTE: if engine fam. is missing or illegible, copy all but the last 6 digits of the VIN. <u>DO NOT COPY SERIAL NUMBER PORTION OF VIN</u>.

15 ENGINE FAMILY [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 25

26 VIN (if engine family not available) [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 36

37 ORIGINALLY CATALYST EQUIPPED?

<u>FROM STICKER UNDER HOOD OR DRIVER'S DOOR POST</u>

[ ]
- Y- Yes
- Z- No
- X- Can't tell (no sticker, not readable, or not mentioned)

38 AIR CLEANER

[ ]
- A- Stock
- B- Non-Stock
- 7- Missing item

39 HEATED AIR INTAKE

[ ]
- 0- Not orig. equipped
- 1- Funct. properly
- 3- Vacuum disconnect
- 4- Mech. disconnect
- 7- Missing item (stovepipe hose)
- 9- Malfunct. item (vac. override)
- B- Non-stock (custom air cleaner)

40 PCV SYSTEM

[ ]
- 1-Funct. properly
- 3-Vacuum disconnect
- 4-Mech. disconnect (fresh air hose)
- 7-Missing item
- 9-Malfunct. item (collapsed hose)
- B-Non-stock (Inc. fuel economy devices)

41 TURBOCHARGER

[ ]
- 0- Not orig. equipped
- A- Stock
- B- Non-stock
- D- Add-on

42 EVAP. CONTROL SYSTEM

[ ]
- 1-Funct. properly
- 3-Vacuum discon. (carb. line)
- 4-Mech. discon. (tank line)
- 5-Incorr. routed hose
- 6-Disconnect/Modification (air cleaner unsealed)
- 7-Missing item
- 9-Malfunct. item (or cannister cracked)

43 ASPIRATED AIR INJECTION SYSTEM

[ ]
- 0- Not orig. equipped (if conventional system or none)
- 1- Funct. properly
- 4- Mech. disconnect
- 7- Missing item
- 9- Malfunctioning

44 AIR PUMP BELT (if Aspir., code "0")

[ ]
- 0- Not orig. equip.
- 1- Funct. properly
- 7- Missing item
- 8- Misadjusted item (loose)

45 AIR PUMP SYSTEM (incl. valve)

[ ]
- 0- Not orig. equipped (if aspirated or none)
- 1- Funct. properly
- 4- Mech. disc. (other than belt removal)
- 7- Missing item
- 9- Malfunctioning (frozen)

46 EXHAUST MANIFOLD

[ ]
- A- Stock
- B- Non-stock

47 OXYGEN SENSOR

[ ]
- 0- Not orig. equipped
- 1- Functioning properly
- 2- Electrical disconnect
- 4- Mech. disc. (unscrewed)
- 7- Missing item

48 CARBURATOR TYPE

[ ]
- S- Sealed
- F- Fuel Injection
- A- Stock
- B- Non-stock

49 LIMITER CAPS

[ ]
- 0- Not orig. equipped (fuel injection)
- 1- Funct. properly
- 4- Mech. disconnect (tabs broken or bent)
- 7- Missing item
- 8- Misadjusted (sealed plugs removed)

50 EGR CONTROL VALVE

[ ]
- 0-Not orig. equipped
- 1-Funct. properly
- 3-Vacuun disconnect
- 4-Mech. disconnect
- 7-Missing item
- 9-Malfunct. item(explain)

51 EGR SENSOR (coolant, back-pressure, etc.)

[ ]
- 0- Not orig. equipped
- 1- Funct. properly
- 3- Vacuum disconnect
- 5- Incorr. routed hose
- 7- Missing item

52 COMPUTER SYSTEM & RELATED SENSORS

[ ]
- 0- Not orig. equipped
- 1- Funct. properly
- 6- Disconnect/Modification (explain)

1986 TAMPERING SURVEY - PART B (REAR)

1 ID NUMBER (4)

5 MAKE (write out) (8)

9 MODEL (write out) (12)

13 VEHICLE TYPE
- C- Car
- T- Truck (includes vans)

14 LICENSE PLATE (State) (15)

16 IDLE HC (PPM) (19)

20 IDLE CO (%) (22)

23 ODOMETER (Thou.) (25)

26 DASH LABEL
- 0- Not orig. equipped
- 1- Funct. properly (present)
- 7- Missing item

27 CATALYTIC CONVERTER
- 0- Not orig. equipped
- 1- Funct. properly (present)
- 7- Missing item

28 EXHAUST SYSTEM
- A- Stock
- B- Non-Stock

29 EXHAUST SYSTEM INTEGRITY
- 1- Funct. properly (no obvious leaks)
- 9- Malfunctioning (leaks evident)

30 TANK CAP
- 1- Funct. properly
- 7- Missing item
- 9- Malfunctioning (loose or unsealed)

31 TANK LABEL
- 0- Not orig. equipped
- 1- Funct. properly (present)
- 7- Missing item

32 FILLER NECK RESTRICTOR
- 0- Not orig. equipped
- 1- Funct. properly
- 4- Mech. disc. (widened)
- 7- Missing item

33 PLUMBTESMO
- P- Positive
- N- Negative

34 FUEL SAMPLE
- Y- Yes
- Z- No

---

leave blank

35 FUEL DATA (38)

Form A - Underhood

1-4 ID Number - Vehicles are numbered sequentially as they are inspected. This number is preceded by a site identifying letter.

5-8 Month and year of last I/M inspection (left blank if vehicle is licensed in non-I/M area).

9-12 Displacement - as recorded on the underhood emission label.

13-14 Vehicle Model year

15-25 Engine Family - as recorded on the underhood emission label.

26-36 Non-serial number portion of VIN - as recorded on the driver's side of the dash under the windshield or the driver's door post. The VIN is recorded only if the engine family can not be determined.

37 Originally Catalyst Equipped - as recorded on the underhood emission label or the driver's door post.

38 Air Cleaner - is coded 'A', 'B', or '7'.

39 Heated Air Intake - provides warm air to the carburetor during cold engine operation. The heated air intake is coded '0', '1', '3', '4', '7' (stovepipe hose), '9' (vacuum override), or 'B' (custom air cleaner).

40 Positive Crankcase Ventilation (PCV) system - prevents crankcase emissions by purging the crankcase of blow-by gases which leak between the piston rings and the cylinder wall in the combustion chamber under high pressures. The PCV system is coded '1', '3', '4' (fresh air hose), '7', '9', or 'B' (includes fuel economy devices).

41 Turbocharger - coded '0', 'A', 'B', or 'D'.

42 Evaporative Control System (ECS) - controls vapors from the fuel tank and carburetor. Some systems have two lines: from the fuel tank to the canister, and from the canister to the carburetor or air cleaner (for purging the canister). Other systems have a third line connected to the carburetor. The ECS is coded '1', '3' (carburetor line), '4' (tank line), '5', '6' (air cleaner unsealed), '7', or '9' (cracked hose or canister).

Air Injection System - extends the combustion process into the engine's exhaust system by injecting fresh air into the exhaust ports, lowering exhaust emissions while still maintaining proper vehicle performance.

Two types of air injection systems are currently used. One type uses a belt-driven air pump to direct air through a control valve and into the exhaust manifold. The other type is a Pulse Air Injection Reaction (PAIR) system, which uses an aspirator commonly located in the air cleaner to supply air to the exhaust manifold.

43 PAIR - coded '0' (if air pump system or none), '1', '4', '7', or '9'.

44 Air Pump Belt - is coded '0' (if PAIR or none), '1', '7', or '8' (loose belt).

45 Air Pump System - for the purposes of this variable, consists of the air pump and control valve and is coded '0' (if a PAIR or none), '1', '4' (other than belt removal), '7', or '9'(frozen pump).

46 Exhaust Manifold - coded 'A' or 'B'.

47 Oxygen Sensor - Controls the air-fuel mixture going into the engine of vehicles equipped with three-way catalytic converters. The sensor is coded '0', '1', '2', '4' (unscrewed), or '7'.

48 Carburetor Type - is coded 'S' (sealed plugs covering mixture adjustment), 'F' (fuel injection), 'A', or 'B'.

49 Limiter Caps - plastic caps on the idle mixture screws to limit carburetor adjustments. The limiter caps are coded '0', '1', '4' (tabs broken or bent), '7', or '8' (sealed plugs removed).

Exhaust Gas Recirculation (EGR) System - directs a portion of the exhaust gases back into the cylinders to reduce NO_x emissions in the exhaust gas. The standard EGR configuration consists of a vacuum line from the carburetor to a sensor (used to detect engine operating temperature to activate the EGR valve), and another vacuum line from the sensor to the EGR valve.

50 EGR Control Valve - coded '0', '1', '3', '4', '7', or '9'.

51 EGR Sensor - coded '0', '1', '3', '5', '7'.

52 Computer Systems and Related Sensors - computerized engine and emissions control system which receives input from various sensors for engine condition information, and constantly adjusts the air/fuel ratio, distributor, and emissions devices for optimum economy, driveability, and emissions. The system

is coded '0', '1', or '6'. This variable includes the entire computer system except for the oxygen sensor, which is coded separately (see variable #47, Form A).

<u>Form B - Rear</u>

1-4 ID Number - Same as on Form A.

5-8 Make

9-12 Model

13 Vehicle Type - coded as follows: C = car, T = truck

14-15 License Plate - State abbreviation

16-19 Exhaust gas HC concentration (in ppm) at curb idle.

20-22 Exhaust gas CO concentration (in percent) at curb idle.

23-25 Odometer - mileage in thousands

26 Dash Label - displays the fuel required and is coded '0'(for leaded vehicles), '1', or '7'.

27 Catalytic Converter - oxidizes the HC and CO to water and CO_2 in the exhaust gas. Later model catalysts also reduce oxides of nitrogen. The converter is coded '0', '1', or '7' (entire catalyst canister removed).

28 Exhaust System - if as originally equipped an 'A' is coded. If non-stock a "B' is coded.

29 Exhaust System Integrity - the condition of the exhaust system is coded '1' (no obvious leaks) or '9' (leaks evident).

30 Tank Cap - seals the fuel tank during normal operating conditions and is coded '1', '7', or '9' (loose cap).

31 Tank Label - displays required fuel and is coded '0' (for leaded vehicles), '1', or '7'.

32 Filler Neck Inlet Restrictor - The restrictor is designed to prevent the introduction of leaded fuel into a vehicle requiring unleaded fuel. It is coded '0' (for leaded vehicles), '1', '4' (widened), or '7'.

33 Plumbtesmo - Plumbtesmo paper is used to check for the presence of lead in vehicle exhaust pipes. A positive indication is coded as 'P' and a negative as 'N'.

34 Fuel Sample - indicates if inspector was able to obtain fuel sample for later lead analysis ('Y' or 'Z').

2. Classification Of Component Conditions

The table below was used to classify the various system components as tampered (T), arguably tampered (A), or malfunctioning (M). Only those codes which are applicable to a given component are listed. Codes for 'not originally equipped' and 'functioning properly' are not included in this table. Refer to Appendix B, Part 1 for an explanation of the codes.

	Codes from forms A and B								
Component/system	2	3	4	5	6	7	8	9	B
Dash Label						A			
Tank Cap						A		M	
Tank Label						A			
Filler Neck Restrictor			T			T			
Catalytic Converter						T			
Oxygen Sensor	T		T			T			
PCV System		T	T			T		M	T
Heated Air Intake		T	A			A		M	T
Evaporative Control System		T	T	T	T	T		M	
Aspirated Air Injection System			T			T		M	
Air Pump Belt						T	M		

T = tampered
A = arguably tampered
M = malfunctioning

Component/system	Codes from forms A and B								
	2	3	4	5	6	7	8	9	B
Air Pump System			T			T		M	
EGR Control Valve		T	T			T		M	
EGR Sensor		T		T		T			

3. Fuel Sample Collection and Labeling Procedures

A fuel sample was taken from each vehicle requiring unleaded fuel. These samples were collected in two-ounce bottles with a hand-operated fuel pump. Once the sample was drawn, the fuel was replaced with an equivalent amount of unleaded fuel if the driver requested, and the pump was flushed with unleaded fuel.

Each bottle was identified with an adhesive label that had the vehicle identifying survey number on it. The vehicle identifying number was the first entry on the data forms described in Part 1 of Appendix B. The bottles were packed, labeled, and shipped to EPA's Motor Vehicle Emissions Laboratory in Ann Arbor according to the shipper's requirements.

4. Plumbtesmo Application

1) Clean a portion of the inside of the tailpipe large enough for the test paper by wiping it out with a paper towel or cloth. This may be necessary to remove soot deposits which might mask the color change.

2) Moisten the Plumbtesmo paper with distilled water and immediately* press firmly against the surface to be tested for approximately thirty seconds. If the tailpipe is hot you may wish to clamp the test paper in the tailpipe using a clean clamp.

*Note: The Plumbtesmo paper must be applied during the time that the paper is yellow for the reaction to take place. After approximately 15 seconds the yellow color disappears and the paper is no longer effective. Excess water also interferes with the reaction.

Care must be taken to avoid contamination of the test paper. If a person has recently handled a test paper with a positive reaction, some lead or reactive chemical may have been transferred to their fingers. Subsequently handling a clean test paper may cause contamination.

3) After removing the test paper, determine whether a color change has occurred. Red or pink coloration indicates the presence of lead.

5. Field Quality Control/Assurance

Reference and calibration gases were used to ensure the accuracy of the emissions analyzer. Horiba gases certified by RTP were used as reference gases. Two cylinders of reference gas were used to validate the accuracy of the calibration gases before they were taken to the field on each survey.

Three calibration gases (Horiba) were used. These gases were a mixture of CO and HC in nitrogen and were used to check the instrument at least three times daily. These calibration gases were certified by the manufacturer and the RTP reference gases. Their approximate compositions were:

8% CO
1560 ppm HC (Hexane equivalent)

4% CO
827 ppm HC (Hexane equivalent)

1.6% CO
320 ppm HC (Hexane equivalent)

APPENDIX C

EMISSION CUTPOINTS FOR I/M AREAS

The table below lists the emission cutpoints used in 1986 by the I/M areas covered in the 1986 tampering survey. The cutpoints for pre-1975 vehicles are not included, since these vehicles were not surveyed.

Survey Site	Model Year	Emissions Cutpoints CO (%)	HC (ppm)
St. Louis, MO	1975-79	6.0	600
	1980	3.0	300
	1981+	1.2	220
Memphis, TN	1975-79	8.5	1990
	1980+	6.5	1990
	1981+	3.0	1990
Pittsburgh, PA	1975-79	4.0	400
	1980	3.0	300
	1981+	1.2	220
Hartford, CT	1976-79	3.0	300
	1980	2.5	275
	1981+	1.2	220
Camden, NJ	1975-80	3.0	300
	1981+	1.2	220
Seattle, WA	1975-78	3.0	800
	1979+(no CC)	3.0	600
	1979+(CC, 4 cyl.)	2.0	300
	1979+(CC, 6-8 cyl.)	1.5	300

KEY: CC = catalytic converter (all types), CYL. = cylinder, OC = oxidation catalytic converter, AI = air injection, TWC = three way catalytic converter.

Survey Site	Model Year	Emissions Cutpoints CO (%)	HC (ppm)
Los Angeles, CA	1975-79(no CC)	3.5	200
	1975-79(OC, no AI)	4.5	250
	1975-79(OC, AI)	1.5	150
	1975-79(TWC)	1.5	100
	1980+(no CC)	2.5	150
	1980+(OC, no AI)	2.5	150
	1980+(OC, AI)	1.2	150
	1980+(TWC)	1.0	100
Tucson, AZ	1975-78(4 cyl.)	2.2	250
	1975-78(6-8 cyl.)	2.0	250
	1979 (4 cyl.)	2.2	220
	1979 (6-8 cyl.)	2.0	220
	1980+	1.2	220

KEY: CC = catalytic converter (all types), CYL. = cylinder, OC = oxidation catalytic converter, AI = air injection, TWC = three way catalytic converter.