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Mobile Source
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Technical Support Branch
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EPA

Motor Vehicle Tampering Survey (1978)

1978

MOTOR VEHICLE

TAMPERING SURVEY

U.S. Environmental Protection Agency
Mobile Source Enforcement Division
Technical Support Branch

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T A B L E O F C O N T E N T S

Executive Summary

The Technical Support Branch of EPA's Mobile Source Enforcement Division has completed a survey which 1) assesses the rate of vehicle emission tampering on a nationwide basis, 2) assesses the types of tampering most prevalent, and 3) quantifies the relationship between tampering and idle test emission scores. During the period May to August, 1978; 1,953 vehicles comprising model years 1973 through 1978 were inspected at six sites. These sites, Delaware, Maine, Virginia, Washington, Tennessee, and Texas, were chosen to represent various national geographic categories. Vehicles were observed while participating in a non-voluntary program such as a mandatory state safety inspection. The sites were selected such that the sample reasonably represents vehicles not currently subject to an emission oriented inspection-maintenance program.

Employees of the Technical Support Branch working with an expert consultant and NEIC personnel conducted the inspections. The same consultant was used at each site to assure a consistent application of the inspection criteria.

At each site 200 to 400 vehicles were inspected for tampering of 15 emission related components. In general, each inspection was no longer than five minutes. In addition to component inspection,

idle hydrocarbon and carbon monoxide emissions were measured and recorded. Fuel samples were taken from vehicles which required unleaded gasoline.

The results of the survey classified each car into one of four mutually exclusive groups: tampered (at least one case of obvious tampering), arguably tampered (potential, but not clear cut tampering), malfunctioning (some component not properly functioning), or "O.K." (all components properly functioning). The results show an overall tampering rate of 19% of the 1973 through 1978 vehicles in the nation. An additional 48% showed at least one item in the arguably tampered category (e.g., limiter cap removal).

These results are shown in Table 1, which displays the degree of tampered, arguably tampered, malfunctioning, and "O.K." cars by model year.

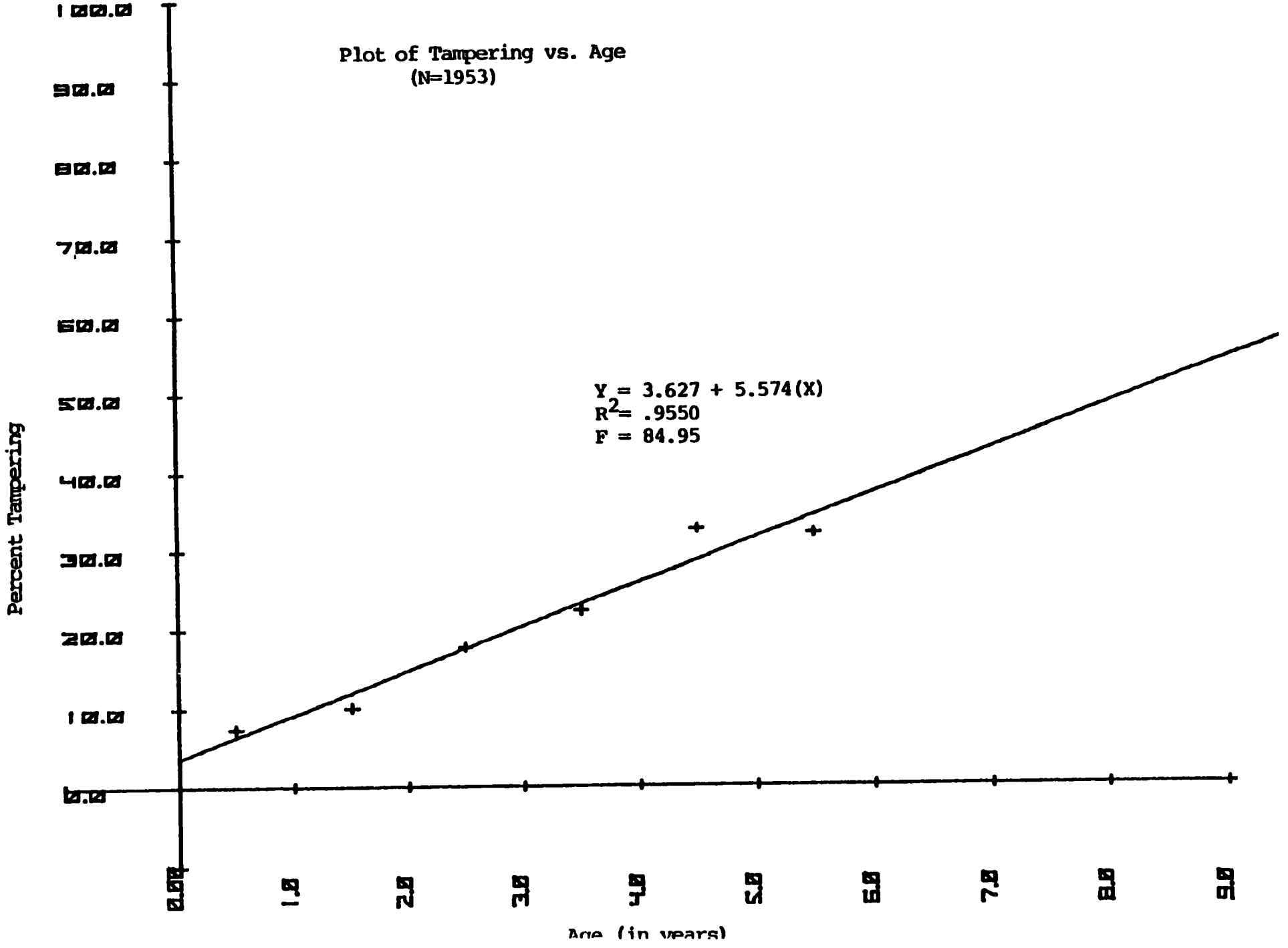
Table 1 - Tampering Summary

Age	Model Year	Tampered	Arguably Tampered	Malfunctioning	O.K.
0-1	78	7%	31%	4%	58%
1-2	77	10%	44%	1%	45%
2-3	76	18%	53%	1%	28%
3-4	75	22%	53%	2%	22%
4-5	74	33%	57%	1%	9%
5-6	73	32%	56%	3%	9%
Total		19%	48%	2%	31%

There is a direct relationship between the tampering rate and the age of the vehicle as shown in Figure 1. The projected rate of tampering increases to approximately 50% as the fleet approaches 100,000 miles. The rates of tampering at different sites were all within 5% of the 19% national average.

The rate of tampering correlates well with increased idle emissions scores. For each model year under consideration, idle emissions were significantly higher for tampered cars than for "O.K." cars. EGR tampering and vacuum spark retard tampering were the most prevalent forms of tampering. High idle carbon monoxide levels were found to be indicative of NO_x related EGR tampering. This is a secondary effect, however, indicating that a person who tampers with the NO_x control system also tampers with the idle settings. A relationship was also found between limiter cap removal and higher idle carbon monoxide readings. Significantly, 72.5% of cars with limiter caps in place were below a 1% idle CO level, while among vehicles with missing caps only 39.1% were below 1% CO. The positive relationship between idle scores and tampering demonstrates the ability of an idle test to detect tampered vehicles, and a corresponding benefit of an inspection-maintenance program.

Figure 1


Plot of Tampering vs. Age
(N=1953)
Y = 3.627 + 5.574(X)
R2= .9550
F = 84.95
Percent Tampering
Age (in years)

From the subset of vehicles inspected which required unleaded gas, an overall fuel switching rate of approximately 5% can be estimated. This is the percentage of vehicles with leaded fuel in the tanks (as determined by sample analysis) and/or tampered filler neck restrictors. Somewhat surprisingly, 75% of the cars with evidence of leaded gas in their tanks did not have tampered fillernecks, indicating either alternate methods of filling a car with leaded gas (e.g. funnels, slow fill), or nozzle violations at the gas pump. Conversely, 62% of the vehicles with tampered filler neck restrictors did not have leaded gas. Presumably, this indicated only sporadic use of leaded gas, or some other rationale such as second ownership of the vehicle. In either case, whatever motivated the removal of the filler neck did not apparently motivate continued switching. The 6% fuel switching rate differs from the estimate of 10% found in an MSED gas station observation survey. Differences in the vehicle mix observed in each survey may explain some of the discrepency . In order to assess the reasons for these differences further sampling will be instituted concentrating on 1977 and 1978 model year vehicles. It takes a minimum of three unleaded fills on top of a new empty tank (1 gallon left) to lower the tank lead level to less than .05g/gal lead after one fill of leaded @ 2.0g/gal. of lead .

The emission effect of an overall tampering rate of 19% is significant. Approximate calculations indicate that by the

time a vehicle reaches 50,000 miles, the average hydrocarbon and carbon monoxide emissions will be nearly four times that of a vehicle with no tampering or malmaintenance.

I. Introduction

The Mobile Source Enforcement Division of the U.S. EPA is responsible for enforcement of the mobile source provisions of the Clean Air Act, as amended August, 1977. Sections 203(a)(3)(A) and 203(a)(3)(B) of the Act prohibit the removal or rendering inoperative of emission controls by dealers and the service industry, and are generally referred to as the "tampering" provisions of the Act.

Prior to 1978, the Division had collected evidence indicating that tampering was occurring. However, these data were very difficult to quantitatively assess because of the variability among inspection procedures and inspectors. In conjunction with this variability was the absence of a specific method by which a non-voluntary vehicle sample could be inspected. The qualitative data that was available originated mostly from I/M areas and a voluntary sample, and was assumed to reflect less tampering than would be expected in non-I/M areas and with a non-voluntary sample. A summary of these data is presented in Table 1.1.

In early 1978, the Technical Support Branch undertook a systematic national tampering survey of non-I/M areas in

Table 1.1

III. Mobile Source In-Use Compliance Data

Year	Site/Study	Vehicle MY's	Gross Tampering	Limiter Cap Removal	Fuel Switching	Compliance w/ emission Stds
1977-78	New Jersey[1]	1975-78	14%	51%	--	--
1977-78	Fuel Switching (Nationwide)	1975-1978	--	--	10%	--
1977-78	VW Field Fix Survey	1975-76[2]	100%	--	--	--
1977-78	Ford Recall Data	1977	20%[3]	--	--	--
1977	Portland, Oregon	1975-77	8%[4]	--	--	--
1976-77	CARB	1975-1976	15%	--	--	47%
1976-77	MSAPC Restor. Maint.	1975-76	~30%*	45%	--	42%
1976	Chrysler Recall Data	1975	24%[5]	--	--	--
1975	MSAPC Emission Factors Program	1972-76	--	--	--	23%[6]
1975	New Jersey	1970-1976	6%	57%	--	--
1974	New Jersey	1970-1974	11%	53%	--	--
1974	D. C.	1970-74	15%	33%	--	--
1973	EPA Rpt. Auto. Exh. Emission Surv. (1973)	1968-71	--	--	--	37%[7]

1 Preliminary results
2 Rabbits and Sciroccos, 19 of 19 randomly selected vehicles
3 3 of 15 randomly selected vehicles
4 Checked only for catalyst, unleaded labels, fuel inlet restriction
5 7 of 29 randomly selected vehicles
6 By city: Denver-7% Los Angeles-33% Chc. Houston, St. Louis, Phoenix, D.C.-31%
By model year: 1976-47%, 1975-28%, 1974-13%, 1973-13%, 1972-17%
7 HC and CO only; By city: Denver 6%, By model year: 1969-70%, 1970-81%, 1971-62%.
* Unconfirmed data

order to obtain data sufficient to (1) quantitatively project the incidence of tampering on a national level with high confidence, (2) to determine the most prevelant types of tampering, (3) and to determine the relationship between tampering and idle emissions.

The original strategy was to "tag-on" to mandatory state/city safety inspection programs where a representative, non-voluntary vehicle sample would be expected. This strategy was subsequently modified to include "tagging along" on state police license/safety roadside checks for the same reason. The strategy called for one expert to supervise the inspection teams throughout the survey, in order to minimize variability.

II. Design of the Survey

The major elements of design were as follows:

1. A minimum of six (6) sites in areas with mandatory safety inspections would be required for projection to a national level.

2. 300 to 500 vehicles per site would yield the 1800 to 3000 vehicles necessary for a confident national projection. Survey dates were to be chosen for peak flow such as at the end of the month when inspection stickers expire.

3. 1973 and newer light duty vehicles and light duty trucks would be the target population. 1973 was the first model year that these vehicle classes possessed significant emission controls.

4. The sample would be completely random. No attempt would be made to approximate the national vehicle mix according to manufacturer, model, or model year. The main goal was to survey as many vehicles as possible, and not skip any because they were rare or too many of one type had already been inspected.

5. Representative geographic diversity would be essential and sites would be chosen from major geographic areas of the country.

6. The inspection must be thorough and check all visible emission control systems, record basic

data, obtain a fuel sample, and require less than four to five minutes. It was felt that this speed would be necessary if the cooperation of the safety agencies was to be maintained. A detailed description of the inspection is given later in this report.

7. At least two inspectors would be required, and in the busiest cases, three or four.

8. Idle HC and CO emissions would be measured with portable analyzers.

9. A single expert should perform the inspection of the major emission control devices throughout the survey in order to maintain consistency. This person must have a thorough knowledge of the emission control systems used by the major domestic and foreign manufacturers.

10. The inspection would objectively record the condition of the emission controls. A method would be developed for determining which conditions constituted tampering.

11. The survey should be completed by September, 1978.

An "expert" in emission controls was recruited from the private sector to conduct the summary. Jack Gockel, a recognized emission expert, was under contract to MSED and agreed to perform the survey.

In arranging survey sites, the agencies responsible for the vehicle safety inspections in the following areas were contacted:

New York State
Georgia
Delaware
Nebraska
Chattanooga, Tenn.
Memphis, Tenn.
Washington, D.C.
Virginia
Florida
Texas

Not all non-I/M areas with mandatory safety inspections were contacted. The above were judged to be the most desirable from which to select a geographically diverse sample. Contact

was initially made by phone. Letters requesting permission to conduct the survey were sent to each along with a list of the items to be inspected in each car. It was emphasized that this was an informational survey and that no enforcement action would be taken.

It should be noted that the term "tampering" was avoided in oral and written communication with the agencies. The survey was described as a "check of the emission control equipment."

All agreed to participate except Memphis and Florida. Memphis has a high volume 5 minute safety check where a vehicle stops for one minute at each of 4 positions along the safety lane. Memphis was concerned that the tampering inspection would be too disruptive to the flow. Florida declined because of current controversy in the state legislature over the state safety inspection. The Florida state police did not want the safety inspection to become involved in any activity that could result in adverse publicity.

Delaware, Tennessee (Chattanooga), Texas, and Virginia were chosen as survey sites because they represented a

reasonable geographic diversity. However, it was judged that at least two additional sites in other areas of the country were necessary. Thus, additional states were contacted concerning the possibility of "tagging along" on state police roadside license and safety checks. Using this approach, roadside surveys in Maine and Seattle, Washington were arranged.

In principle, participation in the tampering survey was voluntary. That is, the driver was given a choice before his car was inspected. However, by virtue of the safety inspection or roadside check by police, the audience was "captive" or non-voluntary and thus most people were encouraged and inclined to participate.

III. The Tampering Inspection and Tampering Rationale

The circumstances under which the sample was obtained in each area will be described in a later section. The following is a description of the inspection procedure, and the rationale used to determine tampering. The forms used to record data (figures 3.1 and 3.2) were essentially identical to forms used by the New Jersey Department of Environmental

FIGURE 3.1

EPA Vehicle Tampering Study

Date: _____

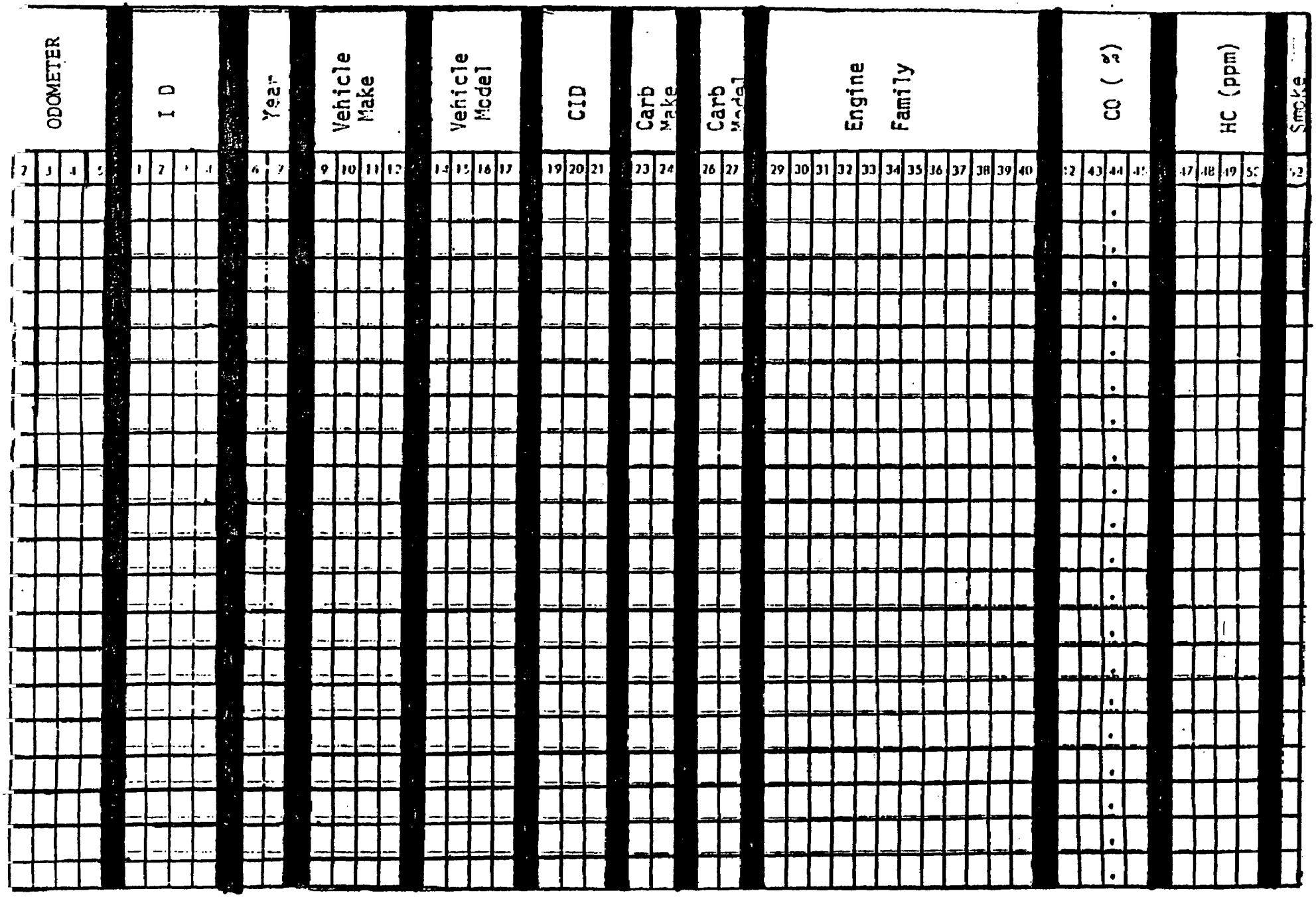
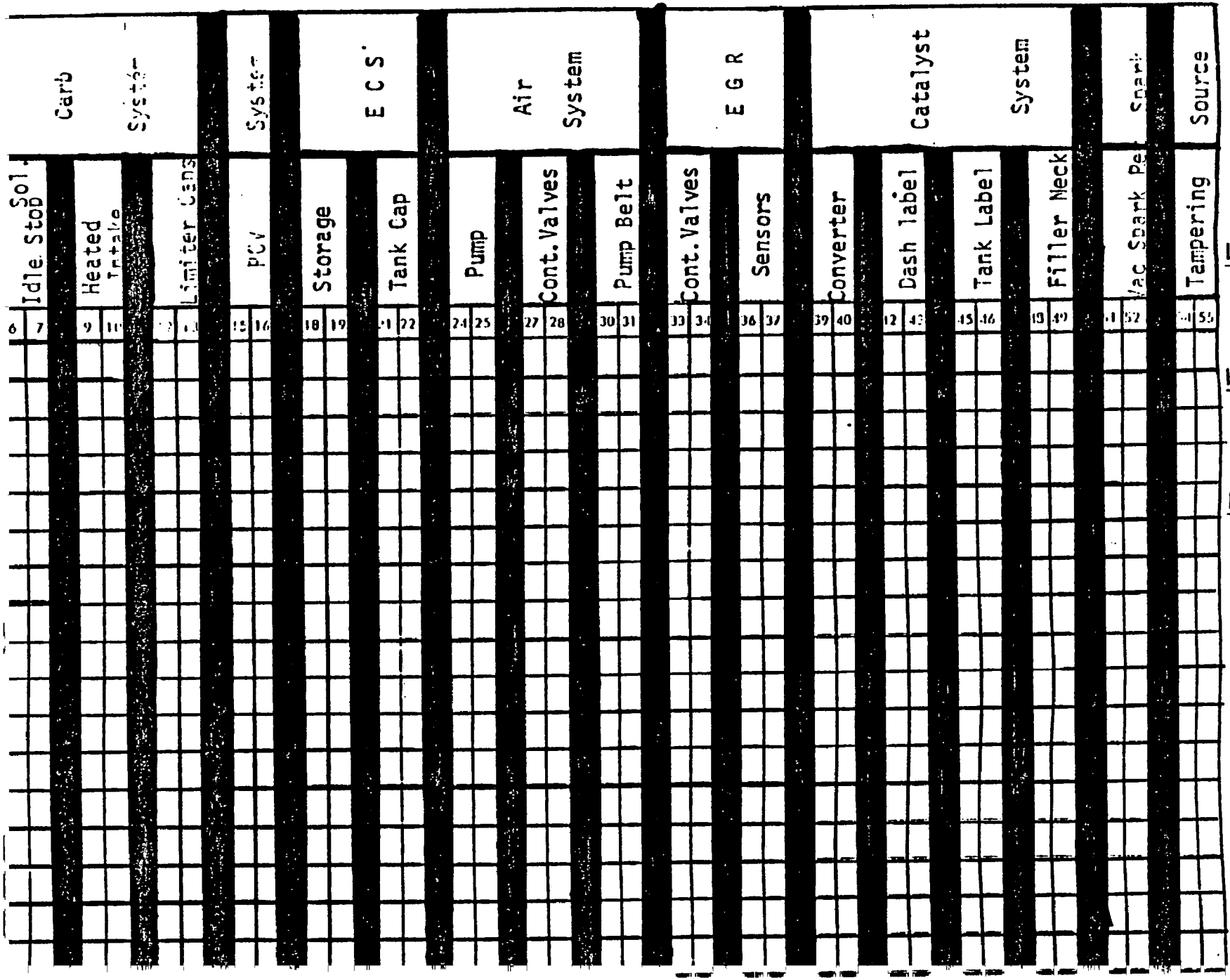


FIGURE 3.2

EPA Vehicle Tampering Study

Date: _____



Codes:

Disconnected Unit
- Electrical - 1
- Vacuum - 2
- Mechanical - 3

Hoses
- Incorrect Rt - 4
- Rev. Operation - 5
- Bypass - 6

Parts
- Missing - 7
- Misadjusted - 8
- Malfunction - 9

Functioning Properly - 0

Non-Stock Equip. - 99

Protection in performance of a prior tampering survey for MSED. These forms covered all the items to be checked in the tampering inspection, and did not need modification except for the addition of space to record odometer readings. The functional check of emission components was performed mostly by Jack Gockel.

Arrangements were made with the Region III lab in Wheeling, West Virginia to analyze the fuel samples for lead content.

A. Equipment

The following equipment was used:

1. Leaded nozzle to check the fuel filler inlet for penetration.

2. Hand fuel pump with a 3 ounce sample bottle and approximately three feet of hose.

3. Flashlight.

4. Hand held mirror.

5. Hand vacuum pump and gauge for use in the EGR functional check, including hose and adapting nipples.

6. Fender covers.

7. Screwdriver and pliers for disconnecting and reconnecting vacuum hoses.

8. Two Horiba Mexa 300 A emission analyzers

9. Power converters to run the analyzers off the car batteries when out in the field.

10. Gasoline can for replacement fuel and fuel to flush the fuel line after each sample.

11. Spare fuel line.

12. Extension cords.

13. 200-300 sample bottles per site. (1973 and 1974 vehicles did not require fuel samples.)

14. Boxes and tape for packing fuel samples.

15. Labels for fuel sample bottles.

16. Shipping labels to Wheeling, W.Va. fuel analysis lab.

17. Flammable liquid labels for fuel shipment.

18. Clip boards.

19. Spare data forms.

20. Spare parts for the fuel pump.

21. Spare fuel pump.

22. Spare leaded nozzle.

23. Pens for recording data (black ink, not blue).

24. Cloth gloves.

B. Data for Vehicle Identification

The following data were recorded on the form presented in figure 3.1.

1. Date
2. Vehicle identifying survey number - vehicles were numbered sequentially as they were inspected, and this number was followed by a site identifying letter. For example, "S" was used for the Seattle area.
3. Make - determined by observation.
4. Model - determined by observation.
5. Model year - obtained from driver and verified by underhood emission label.
6. Odometer mileage
7. Engine family/CID as recorded from the underhood vehicle emission control information label.
8. HC in ppm and CO in % for idle and high rev (approximately 2500 rpm).
9. The presence of smoke.
10. Carburetor - if the carburetor was original equipment a "P" was used to indicate that it was a production unit. If fuel injection was used then "FI" was recorded. If the carburetor had been replaced with a non-stock unit, then a "99" was used. Jack Gockel's experience was relied upon to determine if a carburetor appeared to be a non-stock unit. The number of barrels was easy to determine by the size and shape of the carburetor

body. A one barrel carburetor had a one "jug" body and one idle mixture screw. Two and four barrel carburetors had two idle mixture screws and two and four "jugs" respectively. The number of barrels was recorded under "carb model".

C. Emission Control Checks, Data Recording, and Tampering

The form presented in Figure 3.2 was used to record the inspection of the emission control devices. The following codes, as shown on the form, were used.

Code

0 - item is functioning properly

1 - electrical disconnect

2 - vacuum disconnect

3 - mechanical disconnect

4 - incorrectly routed hose

5 - hoses connected so that an item operates in a reverse manner (special case of incorrectly routed hoses, mostly applicable to vacuum delay valves).

6 - hoses routed such that an item is bypassed (another special case of incorrectly routed hoses).

7 - missing item

8 - misadjusted item

9 - malfunctioning item

99 - non-stock equipment

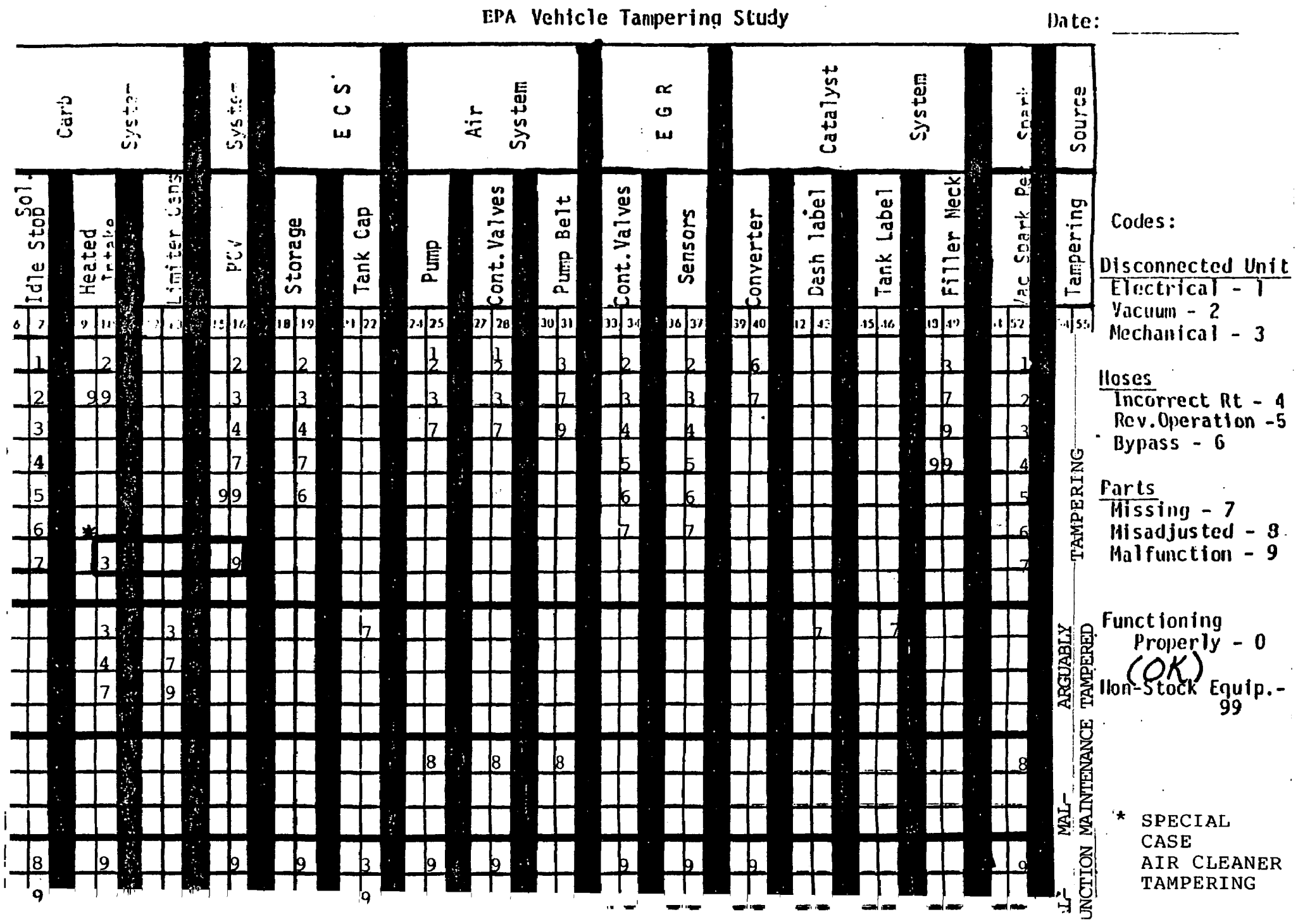
The codes are designed so that the inspector can objectively record the condition of a device, and he does not have to make an "on the spot" judgement with respect to tampering.

The observations were broken down into five categories: tampered, arguably (or questionably) tampered, malmaintenance, malfunctioning, and "O.K." Most of the items considered tampering are obvious. However, some are not so obvious and the rationale for placing them in the tampering category is presented. Figure 3.3 shows how the codes were categorized for each item. Note that not every code applies to each item.

No malmaintenance, defined by figure 3.3 as a misadjusted air injection system or vacuum spark retard, was found. Thus, the results discussed in Section V, Major Results, will consist of only four categories, "O.K.", tampered, arguably tampered, and malfunctioning.

The tampering rationale is based on the following sections of the Clean Air Act: Section 203(a). The following

FIGURE 3.3


EPA Vehicle Tampering Study
Date:
Carb
System
System
E C S
Air System
E G R
Catalyst System
Spark
Source
Idle Stop Sol.
Heated Intake
Limiter Cap
PCV
Storage
Tank Cap
Pump
Cont. Valves
Pump Belt
Cont. Valves
Sensors
Converter
Dash label
Tank Label
Filler Neck
Vac Spark Pc
Tampering
6 7 9 11 13 15 16 18 19 21 22 24 25 27 28 30 31 33 34 36 37 39 40 42 43 45 46 48 49 51 52 54 55
TAMPERING
ARGUABLY MAL-FUNCTION MAINTENANCE TAMPERED
Codes:
Disconnected Unit
Electrical - 1
Vacuum - 2
Mechanical - 3
Hoses
Incorrect Rt - 4
Rev. Operation -5
Bypass - 6
Parts
Missing - 7
Misadjusted - 8
Malfunction - 9
Functioning Properly - 0
(OK)
Non-Stock Equip.- 99
* SPECIAL CASE AIR CLEANER TAMPERING

acts and the causing thereof are prohibited --

(3)(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.

The "knowingly" element does not imply intent to tamper, but rather knowledge that an act occurred. For example, some people have inverted the top of the carburetor air cleaner under the assumption that it will improve engine

performance. This renders inoperative the positive crankcase ventilation system, the evaporative control system in most cases, and the heated air intake system, and while it may not be done to tamper per se, it is none the less a prohibited act.

The following items were inspected. (See figures 3.2 and 3.3). The applicable codes and inspection criteria are noted, and tampering is discussed.

1. Idle stop solenoid - This solenoid provides an idle stop for maintaining idle speeds to the higher speeds needed to minimize CO emissions. On some vehicles, it is used to close the throttle and thus prevent run-on when the engine ignition is turned off. On vehicles with air conditioning, it is used for increasing engine idle speed to compensate for a decrease in idle speed when the air conditioner is engaged.

   (a) The electrical connection was checked.
   If it was disconnected or broken - code 1.
   A disconnected connection is considered obvious tampering. A broken connection,

could have been deliberate or accidental. Both cases were considered tampering because it is unlikely they could have occurred except by a deliberate act.

(b) With the air conditioner on, (or in non-air conditioned vehicles) the solenoid should activate and contact the throttle linkage. With the air conditioning turned off there would be a small gap between the solenoid stop and the throttle linkage. If the appropriate condition was not observed, the solenoid was recorded as malfunctioning - code 9. Time did not permit a check to see if the solenoid was defective or just mis-adjusted.

(c) Only codes 0, 1, 8, and 9 were observed. (Only one code 8 was observed, and it was grouped with code 9.)

2. Heated air intake - provides warm air to carburetor during cold engine operation.

(a) If the vacuum line to the vacuum override motor (top of air cleaner horn) was disconnected or missing, then code 2. It normally requires a deliberate act by a mechanic or owner to disconnect this line, and thus, it is considered tampering even though failure to reconnect might be due to negligence.

(b) If the "stovepipe" (the flimsy black paper/foil connection between the exhaust manifold shroud and the air cleaner horn) was missing - code 7. If it was present but not properly connected, (hanging from one connection, for example) it was considered disconnected - code 3. If it was torn or deteriorated, it was also considered disconnected - code 3. About half of the vehicles had metal stovepipes that were not as susceptible to these problems.

(c) If any problems were evident with the butterfly plate in the air cleaner horn which appeared to restrict its movement, it was considered to be malfunctioning - code 9.

(d) If the air cleaner top had been inverted, or holes were punched in the air cleaner, the heated air intake was considered disconnected - code 3. This is considered tampering because the heated intake is deliberately defeated and it also causes the PCV system and some evaporative control systems to malfunction. Malfunctions are registered through the code 9's on the PCV and on some storage canisters which purged with a line connected to the air cleaner.

(e) The question of tampering for a mechanically disconnected or missing stovepipe (codes 3 and 7) is controversial. Certainly an improperly connected, missing, or torn stovepipe renders the heated intake inoperative. However, no one who understands engines would expect any improvement in performance or fuel economy due to its removal or disconnection. These problems are the result of fragile design and careless replacement of the air cleaner, not of any attempt to tamper. Many times the foil just fits over the sharp edge of the exhaust shroud, and if it is not pushed on carefully, it easily tears. The

incidence of codes 3 and 7 is so high that it was determined that it would be misleading to place them in a tampering category. Thus, codes 3 and 7 are labeled as arguably tampered. If code 3 is coupled with code 9 on the PCV, this indicates the altered air cleaner, and is tampering.

(f) Problems with the butterfly plate in the air cleaner horn are considered defects, and are labeled as malfunctions.

(g) If a non-stock (code 99) air cleaner filter was installed and this element was wider than the production design, a gap was created in the air cleaner chamber. In this case, a 9 was recorded for the PCV system, a 9 for some storage canisters, and a code 3, mechanical disconnect, for the heated intake. This is considered tampering for the same reason as the inverted air cleaner top.

3. Limiter caps - plastic caps on idle mixture screws designed to limit carburetor adjustments.

(a) The inspector checked for the presence of the caps. In most cases they were missing - code 7.

(b) If caps appeared in good shape - code 0.

(c) If the caps appeared damaged, they were checked to see if they could be rotated past the stops. Caps with broken or bent tabs (allowing rotation past the stops) were given a 3. In some cases, the data recorder designated a 9. In this case, the code 3 and code 9 designate the same condition, a mechanically disconnected and ineffective limiter cap.

(d) Limiter cap removal is prevalent. To place it in the tampering category would obscure the rest of the data. However, it has defeated an element of emission control design and is done knowingly. Thus, missing or disconnected limiter caps are considered arguably tampered. This misadjustment usually causes a significant increase in CO emissions. Mechanics remove limiter caps to enrichen the idle mixture for smoother engine operation. Enrichments producing greater than about 1% CO in the exhaust, do not provide enough oxygen for the correct oxidizing function of the catalyst. As a

result, the vehicle usually exceeds EPA standards. These misadjustments are actions which render catalysts inoperative and represent the greatest single cause of maintenance related air pollution from post-1974 vehicles.

4. Positive crankcase ventilation system - A typical configuration for a V-8 engine consists of the PCV valve connected to a valve cover and then connected to the carburetor by a vacuum line. The other part of the system has a "fresh air tube" running from the air cleaner to the other valve cover.

(a) If the line between the PCV valve and the carburetor was disconnected then code 2 designates a vacuum disconnect. If the "fresh air tube" was disconnected, code 3 was recorded. Some code 4's, incorrect routing, were also recorded for this condition.

(b) Missing valve and hoses - code 7.

(c) A code 9, malfunction, was recorded if the air cleaner top was inverted, if holes had been punched in the air cleaner, a too thick

air filter was used, or if there were any holes or tears in the PCV lines.

(d) For add-on devices a non-stock equipment "99" was recorded.

(e) The PCV system is difficult to categorize for tampering. A good mechanic would not defeat it because it is common knowledge that it improves engine life by purging the crankcase of blow-by gases. In many cases, it becomes disconnected when the air cleaner is removed and it is inadvertently left that way when the air cleaner is replaced. However, it is also the target for many "gasoline savings" devices that install in the vacuum hose leading to the carburetor base. The PCV system is an important control that a) prevents crankcase emissions, b) is clearly visible, and c) is easily maintained. Thus, codes 2,3,4,7, and 99 are considered to be tampering. Code 9 is considered tampering only when it results from a tampered air cleaner.

5. Evaporative control system - Controls vapors from the fuel tank and carburetor. Some systems have two lines, one from the fuel tank to the canister, and one from the canister to the carburetor or air cleaner to air purge the canister. Other systems have a third line which is usually connected to the carburetor.

(a) The lines were checked for proper routing and connections. If any were missing or disconnected, code 2 was recorded for vacuum lines and code 3 was recorded for others. Both cases are clearly tampering.

(b) If the canister was missing, code 7 was recorded. This is clearly tampering.

(c) As discussed under the PCV system, if there were problems with the air cleaner, then code 9 was recorded if one of the canister lines was connected to the air cleaner.

6. Tank cap

(a) The cap was checked for a good gasket that sealed properly. If it did not seal properly,

code 9 was recorded. If the cap was missing, code 7 was recorded. (One code 3 was found, and it was grouped with code 9.)

(b) The gas cap is also a controversial tampering item. Its absence defeats the evaporative control system. Yet, it is highly unlikely that it would be left off on purpose. It was decided that there is no excuse for the cap to be missing, and that it should be considered as arguably tampered. A bad gasket is considered a malfunction.

7. Air injection system - Consists of an air pump driven by a crankshaft pulley which pumps air through a control valve and lines connected to the exhaust manifold.

(a) The pump, belt, lines, and control valve were checked visually. The most common problem was a missing drive belt which was usually recorded as code 7 for "missing". Occasionally, the data recorder improperly designated a code 3 for mechanical disconnect. Both codes designate the same condition. Removal of the drive belt renders the pump and the control valve inoper-

ative. Therefore, a code 9 for "malfunctioning" pumps and control valves was recorded in most cases.

The second most common air system problem was the removal of the air pump. This was denoted by a code 7 for both the pump and the valve. In many cases, the control valve is an integral part of the pump - thus, a 7 for the control valve. In a few cases, the recorder used 3 for mechanical disconnection for designating this same condition.

Other more minor problems were the disconnection of hoses and lines. If the vacuum line was disconnected to the control valve a code 2 was used. If the inlet or outlet hoses to the pump were disconnected a code 3 was used.

(b) Codes 2,3, and 7 were considered blatant tampering. While there were inconsistencies in recording the codes for the individual components, an accurate percentage of total system tampering may be determined if the system is analyzed as a whole.

8. Exhaust gas recirculation system - The standard configuration consists of a vacuum line from the carburetor to a sensor (used to detect temperature to activate the EGR valve), and another vacuum line from the sensor to the EGR valve. Some systems have multiple sensors and thus additional vacuum lines. The system directs a portion of the exhaust gases back into the cylinders for the control of oxides of nitrogen. This is one system where a functional check was performed. EGR valves are found in sealed and non-sealed units, and require different functional checks.

Non-sealed EGR valve functional check

(a) The system was visually inspected to see if the valve, sensor(s) and hoses were in place. If any hoses were disconnected, code 2 was recorded for the associated valve or sensor. Missing parts received code 7.

(b) The engine was revved and EGR valve stem movement was checked visually or by touch. If stem movement was detected, code 0 was entered for both the valve and the sensor, and the system passed the check.

(c) If no stem movement was detected, the vacuum line to the valve was pulled off and checked for blockage. If it was blocked, code 2 was recorded for the valve. If it was not blocked, a hand vacuum pump was then connected to the sensor outlet and the engine revved. If a vacuum was obtained, the sensor was good and the valve was given a 9 for a malfunction. If no vacuum was obtained, then the line to the sensor from the carburetor was checked for vacuum while revving the engine. If this line was blocked, then code 2 was recorded for the sensor and code 9 for the valve, if the valve did not already have a code. If this line to the sensor had vacuum, then the sensor was bad and code 9 was recorded for both the sensor and the valve.

(d) Some lines had a vacuum delay valve in them that was positioned backwards. A reverse operation, code 5, was recorded.

(e) On some systems with multiple sensors and multiple nipples, some code 4, mis-routings, were found.

(f) A crushed nipple on the EGR valve or sensor resulted in a code 3 for that component.

(g) For systems with multiple sensors, each sensor and hose was checked as above if no stem movement was detected.

Sealed EGR valve functional check

(a) The system was visually inspected.

(b) The vacuum hose to the EGR valve was disconnected. The hand vacuum pump was connected to the valve and vacuum applied with the engine running. If idle speed dropped with the application of vacuum, the valve was good. The vacuum pump was then inserted into the line leading to the valve's vacuum source. The engine was revved to determine if vacuum was available. If vacuum was available, the sensors were checked using the same procedure described for the non-sealed unit.

(c) Obviously, all codes except 9 are tampering (no code 6's were observed). Note, if a sensor

was bad, for what ever reason, the EGR valve was coded 9 automatically and not usually checked. Thus, the number of malfunctioning EGR valves is the total of the EGR valves that failed the functional check and the EGR valves assumed to have malfunctioned due to a bad or tampered sensor. The main reason for not checking each EGR valve after finding a bad sensor was time. However, EGR valves tend to freeze with dis-use and it would be impossible to determine which were defective and which froze from dis-use.

9. Catalytic converter

(a) The converter was visually inspected for its presence and high temperature discoloration. The only applicable code was "missing" - code 7. This is obvious tampering. If there was any uncertainty as to whether or not a vehicle was supposed to have a catalyst, the underhood vehicle emission control information label was checked. On most vehicles, the emission control systems are listed on this label. Chrysler is a notable exception.

(b) It is possible to remove the catalyst material from all General Motors' catalysts through a plug in the body of the canister. Our experience indicates that some catalyst material removal can be expected. However, an inspection for this was not performed in this survey.

10. Dash labels and tank labels

(a) The only applicable code is 7. Removal of the labels, which are an element of emission control design, is considered arguably tampered.

11. Filler Neck - Unleaded vehicles only.

(a) The filler neck inlet restrictor was checked with a leaded nozzle. If it fit (whether or not alteration was visible) a code 3 was recorded. If the restrictor was missing - code 7.

(b) It was difficult to determine which cars require unleaded fuel. Catalyst cars definitely required unleaded fuel. However, now several manufacturers produce non-catalyst cars that

require unleaded fuel. The easiest method to clarify any doubts was to check the dashboard since that label is rarely missing.

(c) Both acts are considered tampering. (Code 3 and 7.)

(d) One unleaded pick-up truck had an auxillary fuel tank installed with a leaded inlet. This was recorded as a non-stock 99, and was considered tampering.

12. Vacuum Spark retard system.

(a) Visually checked for proper connections.

(b) Codes 2 or 3 - disconnected - tampering.

(c) Missing - 7 - tampering.

(d) Only codes 0, 2, 3, and 7 were observed.

13. Tampering Source - with time permitting, some drivers with tampered cars were asked if they knew the origin of the tampering. Little value is given to these observations.

O - Owner

D - Dealer

OD - Other than dealer

DK - Don't know

D. Inspection Scenario

A typical inspection required a four-man crew and proceeded as follows:

The driver was approached and greeted with:

"Good morning, we are with the U.S. Environmental Protection Agency and we are performing a survey to check the condition of emission control equipment. If you have a few minutes, we would like to look under your hood and see if everything is in good shape, and also take a 3 ounce fuel sample to check for lead content."

The general answer was "yes" or "How long will it take?"

Those who questioned the time were told "three or four minutes." Most who were apprehensive at first were placated by the short time required. If the driver asked directly if

he was required to participate, he was informed that he wasn't, but that it was an important survey and it would be greatly appreciated if he would. Some people pleaded a case of being late and left. It is estimated that less than 5% skipped the tampering inspection. One reason for not participating used several times was that the driver was not the owner of the car and that he didn't want anything done to the car without the owner's permission.

Once the driver agreed, the car was brought to the inspection area and the hood was raised. On unleaded cars, one team member would check the dash unleaded fuel label, the unleaded label at the filler inlet, the size of the inlet with the leaded fuel nozzle, to see if it would fit and push open the flap, and visually inspect the inlet, tank cap, and tank cap gasket. He would then draw out a fuel sample.

The sample bottle was then tightly capped, marked with the survey identifying number, and placed in a container for shipment to the analysis laboratory. When requested by the owner, approximately 3 ounces of unleaded fuel was poured into his tank to replace the sample. A small amount of new fuel was then poured through the hand pump line to flush any leaded fuel residue that might have remained.

Some problems were encountered with locking gas caps. If the driver had to shut off his engine to get the key to open the cap and several vehicles were waiting, the locking gas caps on leaded cars were not checked.

When a damaged or missing gas cap gasket, a tampered filler inlet, or missing labels were found, it was recorded on the forms.

As soon as a car arrived at the inspection point, one team member would place the analyzer probe in the tailpipe and begin to fill out the vehicle data form. When all the vehicle data and inspection information except for the emission values had been obtained, he would read and record the analyzer at idle, then at a high rev. He would then remove the probe.

Meanwhile, the consultant, using a flashlight and mirror, would call out his underhood observations to another team member who recorded them on the appropriate form. When the observations were complete and Jack had revved the engine to complete the emission measurements the car was sent on its way. Time permitting, we would discuss any tampering we had found with the driver. Most drivers were very nice, cooperative, and interested. The few that were very adamant were sent on their way without an inspection.

IV. Site Data

A. Maine - Roadside Check.

Dates - May 16 through May 19, 1978.

Participants - Maine State Police
Jack Gockel (Expert Consultant)
Mel Petroccia - EPA Region I
Randy Rice - EPA Region I
Robert Knowles - EPA Region I

Samples - 338 vehicles

Fuel samples - Maine refused to allow fuel sampling for reasons of safety.

Sites - Tuesday - highway in Bangor suburbs.
Wednesday - under an overpass in downtown Bangor.
Thursday - weigh station on highway between Gay and Springfield.
Friday - same as Thursday.

The State Police conducted roadside registration and safety checks and passed the vehicles along to the survey team. The drivers were made aware of the tampering survey by the police and encouraged to participate. The police were very helpful and interested in the tampering survey. The tampering survey was rained out on Tuesday afternoon and a sheltered site was arranged for Wednesday, and it rained most of the day. Thursday was cloudy and Friday was sunny. Temperatures were in the 60's° F.

B. Virginia I - Private garage safety inspection.

Dates - May 30 through June 2, 1978.
June 19 through June 21, 1978.

Participants - Jack Gockel
Paul Gesalman - EPA/MSED
Jim Caldwell - EPA/MSED
Steve Albrink - EPA/MSED
Truman Wilson - NEIC

Samples - 98 vehicles (May 30-June 2)
13 vehicles (June 19-June 21)
111 Total

Fuel Samples - 39 analyzed

9 destroyed in shipment via UPS.

Sites - Fairfax Exxon, 10480 Lee Highway, Fairfax, Va. (May 30-June 2). Exxon at Seven Corners, Arlington, Va. (June 19-21).

Weather - Hot, sunny, 80's° F.

Virginia has a semi-annual private garage safety inspection. Flow is very low compared to a roadside check. However, the State Police initially refused to allow us to tag-on to a roadside check and that left only the garage sites. The peak inspection flow period is the final week of the month since the inspection stickers run out the first of the next month. Jack Gockel and Paul Gesalman worked the May 30-June 2 period and averaged about 25 vehicles a day, with the station inspecting around 40 to 50 vehicles per day, including pre-73 models. The low flow rate in this type of inspection requires only two inspectors. Because of extremely low flow rates, the inspection was discontinued after the third day of the second week and the State Police were contacted regarding a roadside check. A roadside check was arranged.

C. Virginia II - roadside check.

Dates - Monday, July 24-July 28, 1978.

Participants - Virginia State Police
Jim Caldwell - EAP/MSED
Paul Gesalman - EPA/MSED
Larry Walz - NEIC
Ron Snyder - NEIC
Steve Sinkez - EPA/MSED

Samples - 313 vehicles

Fuel samples - 189 obtained and analyzed.
Paul Gesalman drove the samples to Wheeling.

Sites - Monday - Parking lot of a dance hall on rural but busy State Route 17 south of Warrenton. Afternoon sampling was rained out.
Tuesday - weigh station on U.S. Route 1 in Woodbridge - very busy road.
Wednesday - State route 234, five miles south of Manassas.

Thursday - Route 1, five miles south of Alexandria, in high school parking lot.

Friday - same as Thursday.

Weather - Hot, mostly sunny, 80°F.

One trooper was assigned to perform the check each day. He was asked to send us only 1973 and later vehicles with Virginia plates. A few out of state cars were inspected. The trooper's inspection was very quick and there was generally one car waiting for the tampering inspection at all times.

D. Wilmington, Delaware - State run safety lanes.

Dates - June 12-16, 1978.

Participants - Jack Gockel
John Fahrenback - EPA/MSED
John Davis - EPA/MSED
Janet Littlejohn - EPA/MSED
Charles Case - EPA/MSED
Paul Gesalman - EPA/MSED
Jim Caldwell - EPA/MSED

Samples - 360 vehicles.

Fuel samples - 56 analyzed
83 are questionable because they were returned by UPS in poor condition and upon analysis, gave very atypical results.
37 destroyed by UPS.
176 Total

Site - Wilmington suburb, near airport.

Weather - Hot, sunny, 80°F, moderate humidity.

Delaware has an annual safety inspection performed at four state operated sites. The site chosen for an inspection was the largest and had four lanes, only two of which were being used. The team used a vacant lane outside the inspection building and cars were chosen by the team randomly from those waiting in the other lanes. The safety inspection personnel were very accomodating. In most cases, the vehicles we took out of the safety inspection waiting line were let back in behind the car originally in front of them. The flow was very heavy at times and overall just as good as the roadside check.

E. Chattanooga, Tennessee - City run safety lanes.

Dates -	June 26-30, 1978.
Participants -	Jack Gockel Paul Gesalman - EPA/MSED Tom Newman - NEIC John Dion - NEIC
Samples -	325 vehicles.
Fuel samples -	23 analyzed 98 lost by UPS.
Weather -	Hot, sunny, humid, 90°F, high air pollutant levels.

Chattanooga has a city-wide annual safety inspection at one four-lane site. Approximately 500 vehicles are checked per day in a four minute inspection. The tampering inspection was performed in front of an active lane and appropriate vehicles were directed to that lane by safety inspection personnel. The tampering survey received local TV and press coverage.

F. Seattle, Washington - Roadside check.

Dates - Monday, July 10-July 14, 1978.

Participants - Washington State Police
Jack Gockel
Bob Bernstein - EPA/MSED
Larry Walz - NEIC
Ron Snyder - NEIC
Jim Caldwell - EPA/MSED

Samples - 323 vehicles.

Fuel samples - 161 were taken and analyzed.

Sites - Monday - Rural highway in Seattle suburbs.
Tuesday - busy roadway in industrial area.
Wednesday - intersection of two interstate highways near Seattle.
Thursday - exit ramp of an interstate highway in Seattle suburbs.
Friday - local park in Seattle suburbs.

Weather - Hot, sunny, 80°F, low humidity.

A roadside check was conducted by the Washington State Police. The police performed a license/safety check and sent the vehicles to the tampering inspection team. There were generally two or three troopers present. The assistance from the troopers was excellent. Region X was very interested in the survey, sent several observers including a local politician, and arranged local TV and press coverage.

G. Houston, Texas - Private garage safety inspection.

Dates - Monday, August 28 - Saturday, September 2, 1978

Participants - Jack Gockel
Paul Gesalman - EPA/MSED
Herbert Vaughan - EPA/MSED
Ron Snyder - NEIC
Larry Walz - NEIC

Samples - 218 vehicles.

Fuel samples - 89 obtained and analyzed.

Sites - Team 1 - Monday - Mobile Station in a depressed neighborhood of downtown Houston. There were many old vehicles.

Tuesday - Exxon station on highway in a Houston suburb.

Wednesday - Texaco station in affluent suburbs.

Thursday - Service station in downtown Houston.

Friday, Saturday - same as Thursday.

Team 2 - Monday - same service station team 1 surveyed on Thursday.

Tuesday - Saturday - Shell station in suburbs.

Weather - Hot, sunny, humid, 90°F.

An attempt was made to conduct a roadside survey in Texas. However, the Texas Department of Public Safety did not feel it would be appropriate to delay traffic beyond the roadside license/safety check. In order to increase the sample size obtainable at private garages, two tampering inspection teams were formed. The State police took the teams to the stations and stayed until the tampering inspections got under way.

Jack Gockel lead team 2. Paul Gesalman lead team 1 and was replaced by Larry Walz for Thursday - Saturday.

V. Major Results

This section presents the basic aggregate results of the survey. Total tampering by site, model year, and type of tampering are discussed. As the data for each vehicle were processed, the vehicle was classified into one of four categories: "O.K.", tampered, arguably tampered, and malfunctioning. Since each vehicle inspected has various components, each of which could be tampered, the vehicle itself is classified by the worst state of any component in the vehicle. The hierarchy is in the order: tampered, arguably tampered, malfunctioning, not equipped, properly functioning. Thus, if any one component is tampered, the entire vehicle is considered tampered. If one component is "arguably tampered" and all the others are functioning properly, the entire vehicle is considered "arguably tampered". Thus an "O.K." vehicle must have all components functioning properly.

An "O.K." vehicle is one with no observable gross tampering, arguable tampering, malfunctioning, or missing equipment. The term, "O.K.", does not mean that the vehicle is necessarily operating properly. For example, a spark plug or coil may not be performing satisfactorily resulting in a poorly operating and excessively polluting vehicle. This situation would still be classified "O.K." for purposes of this tampering report.

A. Aggregate Results

The results for all vehicles tested are presented in Appendix V-I and summarized in Table 5.1

Table 5.1 - Aggregate Results

	Percent	Number
O.K. cars	30.7%	599
Tampered Cars	18.9%	370
Arguably Tampered	48.4%	945
Malfunctioning cars	2.0%	39
	100.0%	1,953

These results span several model years and the totals here represent a snapshot of vehicles at a specific point in time (Summer 1978). As such, the numbers must be viewed with caution. For instance, it would be incorrect to conclude that a mere 2.0% of the vehicles had malfunctioning components. This number appears low because of the hierarchy explained above. Many cars had components malfunctioning but if at least one other component were tampered or arguably tampered, the vehicle, as a whole, would have been classified in the tampered or arguably tampered state. Thus as soon as an item like a missing limiter cap (arguably tampered) is noted, the car cannot be classified as malfunctioning, no matter how many other components malfunction.

A major concern is the degree of confidence that exists in the 18.9% tampering estimate. Because of the large size of our sample, we are 95% confident that the true proportion of tampered cars is between 17.1% and 20.7%.

B. Tampering by Vehicle Age

Appendix V-1 also presents a breakout of tampering categories by model year of the vehicle. It is notable that the rate of tampering increases with the age of the vehicle, and correspondingly, the percentage of "O.K." cars decreases with the age of the vehicle as shown in Table 5.2.

Table 5.2 - Tampering by Vehicle Age

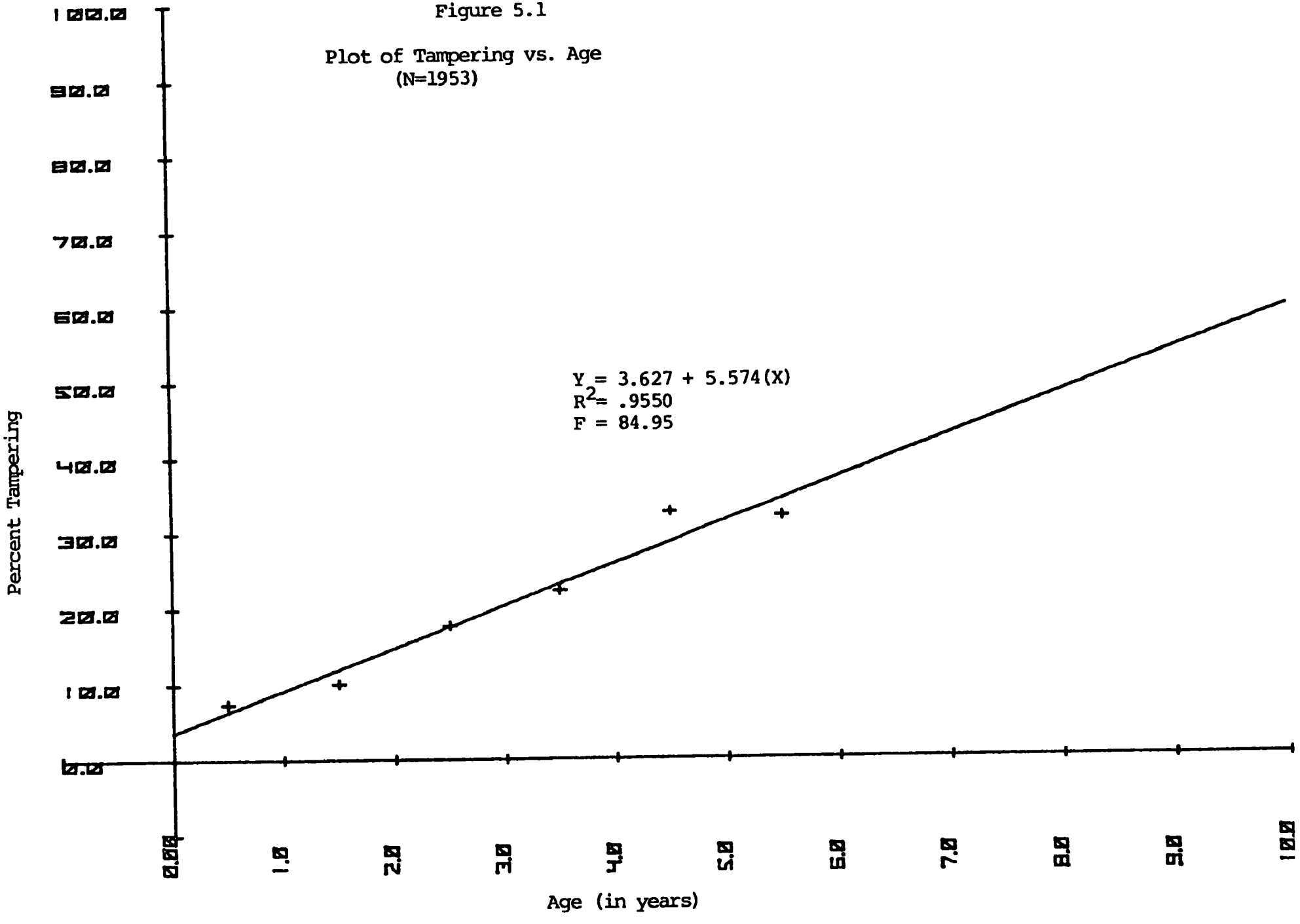
Age	Tampered	O.K.
0-1	7.4%	58.1%
1-2	10.1%	44.6%
2-3	17.7%	28.4%
3-4	22.3%	22.3%
4-5	32.6%	9.4%
5-6	32.0%	9.1%

Figure 5.1 demonstrates the virtually linear nature of the increase in tampering rate over the life of the vehicle.

This tampering increase with age is significant. The 19% tampering rate represents an average tampering rate in calendar year 1978. The data trend shows that by the end of six years in the life of a model, 37% of the cars will be tampered with. After eight years of driving (approximately 100,000 miles) about 48% of the fleet will be in the tampered classification. This means that almost half the cars will be in the tampered group, not just malmaintained or arguably tampered.

Figure 5.1

Plot of Tampering vs. Age
(N=1953)



C. Tampering by Site

Appendix V-2 breaks out tampering by site. It can be summarized in Table 5.3

Table 5.3 - Tampering by Site

Site	Total cars	Tampered	Arguably Tampered	Malfunctioning	O.K.
Washington	306	15.7%	41.8%	2.0%	40.5%
Virginia	416	14.2%	49.8%	2.6%	33.4%
Texas	216	22.2%	59.7%	1.4%	16.7%
Tennessee	324	20.4%	44.4%	.9%	34.3%
Maine	335	20.9%	46.3%	2.1%	30.7%
Delaware	356	22.8%	51.1%	2.5%	24.2%
Total	1953	18.9%	48.4%	2.0%	30.7%

It can be seen that there is some variation from the 18.9% nationwide average in the different sites. In an effort to ascertain if these departures from 18.9% are significant or if they are the result of random fluctuations, a Chi-Square test at the 5% level of significance was run. The results proved just significant, meaning random chance could have resulted in these fluctuations only 5% of the time.

Interestingly, when the same test was run on the percentage of "O.K." cars; the results proved very significantly different. There are less than 5 chances in 1000 that such a wide discrepancy occurs due to random chance. The factor that appears responsible for this is the low number of "O.K." cars in Texas.

D. Tampering by Type of Vehicle

In order to ascertain if any vehicle make exhibited more tampering than others, a breakout by make was run and is shown as Appendix V-3. This has been summarized by manufacturer in Table 5.4:

Table 5.4 - Tampering by Manufacturer

Manufacturer	Total cars	Tampering
GM	882	20.1%
Ford	491	20.2%
Chrysler	242	20.1%
AMC	64	31.3%
Foreign	272	8.5%

A Chi-Square Test was also run on these numbers. The results were significant at a 5% level. This indicates a distinct difference in tampering level amongst manufacturers. This difference is probably due to the low level of tampering among foreign vehicles.

E. Summary

To summarize, the national rate of tampering in 1978 is 18.9%. Tampering increases with age, and as many as 50% of the vehicles which are 8 years old can be expected to have been tampered with. The tampering rate appears higher for domestic makes than for foreign makes, and tends to be affected by geographic location.

VI. Further Results and Analysis

The previous section dealt with the major aggregate tampering results by age, site, and manufacturer. In this section some further insight is provided by examining specific individual forms of tampering, as well as certain "groups" of tampering such as fuel related tampering, (fillerneck restrictor tampering, gas cap tampering, and/or excess lead levels) or EGR system tampering (EGR control valve or EGR sensor tampering). Further, the relationship between idle emission levels and tampered vehicles is discussed.

A. Individual Types of Tampering

The rates of tampering by type are given in Table 6.1 Categories marked with an asterisk (*) were not considered as tampering.

Table 6.1 - Individual Rates of Tampering

Idle Stop Solenoid	0.74%
Heated Intake	0.84%
Limiter Cap Removal	*
PCV Valve	3.27%
ECS Storage	2.63%
ECS Tank Cap	*
Airpump	3.17%
Air Control Valve	2.90%
Air Pump Belt	5.74%
EGR Control Valve	11.87%
EGR Sensor	5.32%
Catalytic Converter	1.21%
Dashboard Label	*
Fuel tank label	*

Filler Neck Removal	3.37%
Vacuum Spark Retard	10.50%
Air Cleaner	0.87%

From these figures, it is apparent that EGR control and vacuum spark retard tampering are the two major sources of tampering. It should also be noted that while limiter cap removal was not included as definite tampering, this removal occurred in 65% of the vehicles observed. Assuming that a removed limiter cap allowed the idle to be set rich, the effect on emissions of such an action could be huge.

Given the high rate of limiter cap removal, an investigation was made on the effect of this on idle emission scores. Appendixes VI-1 and VI-2 demonstrate the mean HC and CO idle scores by model year for cars with and without limiter caps. The summary is shown in Table 6.2.

Table 6.2 - Limiter Cap vs. Idle Scores

Model Year	Mean Idle HC (ppm)		Mean Idle CO (%)	
	O.K.	Missing	O.K.	Missing
73	182	297	2.36	3.41
74	180	297	2.21	3.35
75	122	188	.99	2.19
76	145	259	1.35	2.52
77	128	188	.81	2.07
78	54	101	.52	1.40

It is quite clear that idle scores for both HC and CO with limiter caps removed are considerably above those with limiter caps in place for all model years. Further, of the 1844 cars that had limiter caps required as equipment, a test was made to see if their idle CO would have exceeded 1%. The results were that 72.5% of the vehicles with limiter caps in place would have passed a CO test with a 1% CO idle cutpoint. Conversely, 60.9% of those who removed the limiter cap would have failed such a test.

Since EGR tampering was the highest single item of tampering, it was desired to observe the idle test's ability to identify this form of tampering. Since EGR tampering affects NO_x, one might expect little relationship between idle HC and CO scores and EGR tampering. The results showed differently however. As demonstrated by Appendixes VI-3 and VI-4 average HC and CO idle scores increased as the EGR system was tampered with. A summary is provided in Table 6.3

Table 6.3 EGR Tampering vs. idle scores

Model Year	Idle HC (ppm)		Idle CO (%)	
	O.K.	Tampered	O.K.	Tampered
73	247	348	3.04	4.28
74	295	321	3.07	3.68
75	164	206	1.73	2.17
76	235	236	2.19	3.00
77	152	205	1.40	1.75
78	67	51	.71	1.21

Since, for physical reasons one would not expect an HC or CO effect from NO_x tampering, it appears that vehicles with NO_x system tampering also exhibit tampering with other systems or with limiter caps and thus degrade their HC and CO controls as well as their NO_x controls.

To assess the degree of this collateral effect, the data were examined for the amount of NO_x tampering that coincides with limiter cap removal, and the amount of NO_x tampering that occurs with at least one other form of tampering or arguable tampering.

The results showed that in at least 80% of the cases of NO_x tampering, limiter cap removal also occurred; and in 86% of the 223 cases of NO_x tampering, at least one other form of tampering or arguable tampering was present. This result tends to support the hypothesis that a vehicle exhibiting NO_x tampering also exhibits other tampering. In fact, the EPA Restorative maintenance study has demonstrated that even if EGR disablement is the only form of tampering, resultant HC and CO emissions will increase as well as the anticipated increase in NO_x.

B. Relationship of Tampering and Idle Emissions

Idle tests are the predominant test made associated

with inspection and maintenance programs. To the extent that idle test scores are capable of discriminating between tampered and non-tampered cars, the more useful the scores become in an inspection maintenance application. A few examples have been brought to EPA's attention in which extreme amounts of tampering including catalyst removal, have not affected a vehicle's ability to pass an idle test. These samples have shown the ability to circumvent an idle test if other settings were modified accordingly. This survey provided a unique opportunity to assess the ability of the idle test to detect tampering on a large in-use sample in non I/M states. Thus the results would not be based on a handful of specially prepared cars, but rather on a typical cross-section of in-use vehicles.

In order to assess this ability of the idle test, low and high CO and HC idle scores were measured on each vehicle. The following analyses have considered only the low idle in assessing idle scores and tampering.

Mean idle scores have been calculated for each of the four categories of cars (O.K., tampered, arguably tampered, and malfunctioning) for each model year in the survey. Appendixes VI-5 and VI-6 show the results. "O.K." cars have

generally lower idle scores on both HC and CO than either the tampered or arguably tampered cars for every model year, For malfunctioning equipment, the idle scores are comparable for some post-1975 models.

The most important results are reproduced below in Table 6.4

Table 6.4 - Relationship of tampering and mean idle scores

Model Year	Mean Idle HC(ppm)		Mean Idle CO(%)	
	O.K.	Tampered	O.K.	Tampered
73	124	328	1.95	3.95
74	230	313	2.63	3.43
75	115	211	1.07	2.49
76	151	254	1.43	2.66
77	109	221	0.687	1.77
78	56	51	0.483	0.591

In an analysis of variance test, idle scores proved to be very highly significantly correlated to tampered vehicles.

C. Fuel Related Tampering

Previous information indicated that a proportion of the population of vehicles requiring unleaded gas was being fueled with leaded gas. To evaluate the extent of this phenomenon, fuel samples were taken from vehicles requiring unleaded gas. Due to some difficulties in transporting the gas samples to laboratories, only 481 valid samples could be

considered for the study. From this smaller sample an attempt was made to relate filler neck inlet tampering to the evidence of leaded fuel (in excess of 0.05 grams per gallon) in the tank. The results appear in Appendix VI-7. Only 20 vehicles requiring unleaded gas (4.2%) had leaded gas in the tank. Among these 20, only 5 had tampered filler neck restrictors. This appears to indicate the use of some alternate means of filling the vehicle with leaded gas such as funnels or a slow fill procedure.

The percentage of the 481 vehicles with leaded fuel samples and/or tampered filler neck retrictors was 5.8%. The 95% confidence interval for this overall fuel switching potential rate, based upon a sample of size 481 is from 3.6% to 8.0%.

Since this estimate differs from another MSED study showing approximately 10% fuel switching, further analysis is being undertaken to examine any differences in vehicle populations observed that might account for this discrepancy. Further, more data will be obtained in order to attempt reconciliation of the observed differences. The additional sampling will concentrate on 1977 and later model year vehicles.

VII. Tampering and Inspection Maintenance Programs

In previous sections, the relationship between idle scores and the extent of tampering has been discussed. The basic results were that tampered cars had appreciably higher mean idle CO levels and but for one model year had higher idle HC levels than O.K. cars. Further, idle HC and CO scores were also found higher for tampered NO_x related control devices such as the EGR system. The probable reason for this is the concurrent tampering of the EGR system with at least one other component affecting CO or HC, such as limiter cap removal. Additionally, a very high correlation was found between limiter cap removal and the inability to pass an idle test with a cutpoint of 1% CO.

The next analysis was to simulate these vehicles undergoing a New Jersey inspection - maintenance program. New Jersey modified phase II cutpoints of 500ppm HC and 5.0% CO for model years 73 and 74; and 300ppm HC and 3.0% CO for model years 75 and later were used. The results are summarized in table 7.1

Table 7.1 - Relationship between Tampering and New Jersey Program

	Pass	Fail
O.K.	86%	14%
Tampered	65%	35%
Arguably Tampered	68%	32%
Malfunctioning	80%	20%

As can be seen, 35% of the tampered cars failed the New Jersey test, while only 14% of the "O.K." cars failed. Thus there appears to be a higher probablity of failing such a test with a tampered vehicle. It should be noted that the 65% of tampered vehicles which pass New Jersey standards do not necessarily mean that the idle test is incapable of identifying tampering, but rather that the general New Jersey standards can be considered somewhat lenient, in that most cars, tampered or non-tampered, appear to pass.

To summarize, of the O.K. vehicles 86% pass New Jersey standards, while vehicles in one of the other three groups have only a 67% chance of passing. The difference between the 86% and 67%, based on the sample size of this survey, is statistically very significant, demonstrating a marked inverse relationship between the rate of tampering and the ability to pass the New Jersey program.

It is important to remember that these relationships are derived from studying a set of vehicles not currently subject to an emissions inspection maintenance program. Any secondary effect such as the mere presence of such an I/M program dissuading tampering actions would not be reflected in these analyses.

VIII. Emission Effects of Tampering

The 19% overall tampering rate, along with projections for increased tampering by age for each vehicle model year have a considerable effect on resultant emissions. To try to quantify these effects, an emissions model which considers each component with its tampered condition effect on emissions, and the time phasing of different types of tampering is required.

While such a complete model does not now exist, an approximation may be made using an emission model as described in "Emissions from Catalyst Cars Beyond 50,000 Miles and the Implications for the Federal Motor Vehicle Control Program", (SAE paper 780027). This model considers vehicles to be classified in one of three states: properly functioning, poorly maintained, or disabled catalyst. For purposes of comparison, we have considered limiter cap removal as an indicator of poor maintenance. Further, not all the tampering observed in this study is of the extreme nature as catalyst disablement. Thus, the limiter cap removal rate, which increased by 10% of the vehicles per year was used as the rate of malmaintenance. The tampering rate which increases at 4% per year in a model's life was reduced to 3% to account for tampering incidents less egregious than catalyst disablement.

If these estimates are used in the approximation model, the results show a four fold increase in the average carbon monoxide and hydrocarbon emissions in the fourth year of the model's life. This means that by the time a fleet reaches 50,000 miles, the average emissions from this fleet will be four times the average emissions of the same fleet having no malmaintenance and no tampering. This estimate is a fairly gross approximation and is, of course, dependent on the assumptions made in the model. However, it does provide a good "ball park" assessment of the effects of tampering on vehicle emissions and should serve to underscore the severity of the problem.

The effect of EGR tampering on emissions has not been studied extensively, but some data is available. In a Restorative Maintenance Program conducted by EPA thirty-seven 1975 and 1976 automobiles were tested with their EGR systems deliberately plugged. Emissions increased from the non-plugged condition by an average of 21%, 71%, and 123% for HC, CO, and NO_x respectively.

IX Future Plans

The rates of tampering discussed in this paper were found in the period May - August, 1978. The results represent a rather large sample and reflect the condition of vehicles in this time period. While specific future plans for tampering assessment are still being designed, it is felt that the current survey has adequately assessed the tampering situation at the present time.

Thus, the thrust of future plans will be to observe the change in tampering rates observed as programs and resources are implemented to curb this problem. The specific recommendations are:

1. A survey in New Jersey of the same type performed in the other six sites, utilizing the same personnel, equipment, and definitions. In this way a consistent comparison can be made between tampering rates and the implementation of an inspection maintenance program.

2. Future controlled surveys, probably using contractor assistance, of sites in two EPA regions per calendar quarter. This will serve as a monitor of the trend of future tampering. For regions earmarked for concentrated tampering enforcement, or which have

on-going inspection maintenance programs, this will enable a measurement of the effects of these programs. To provide for a consistent check of tampering levels, it is suggested that the EPA consultant currently supervising the surveys be utilized to train MSED, contractor, and regional employees in the methods of tampering and the categorization of vehicles.

3. Additional investigation in order to understand the differences between the fuel switching rate observed in this study and other studies.

X Conclusions

A tampering study of 1,953 vehicles estimates the tampering rate at 19% gross tampering in areas not currently subject to emission inspection maintenance programs. Since the vast majority of the nation is comprised of non - I/M areas*, this rate is considered to be a reliable nationwide estimate. The tampering rate increases with the age of the vehicle from about 5% for new vehicles to close to 50% for 100,000 mile old vehicles. The most prevalent forms of gross tampering were the EGR system (13%) and the vacuum spark retard (11%). In addition, very high rates (65%) of limiter cap removal were observed. Vehicles with limiter caps removed had idle CO in excess of 1% most of the time (61%). The tampering observed has a very pronounced emission effect. Fuel switching as assessed by this survey is occuring in about 6% of the vehicles requiring unleaded gas.

Idle test scores detect tampered cars. In fact, idle test scores even catch EGR tampering which is NO_x related, due to the high level of concurrent presence of EGR tampering and at least one other form of tampering. This tends to strengthen the usefulness of inspection maintenance programs due to their ability to discourage vehicle tampering.

* Current mandatory I/M areas are: New Jersey, Cincinnati, Portland (Oregon), Arizona (two counties), Nevada, and Rhode Island. Approximately 6% of the nation's vehicles are included in such a program.

The surveillance should continue with emphasis on comparing these results with those in areas having an on-going inspection maintenance program, and in investigating future trends in tampering rates. The reasons for the difference between fuel switching observed in this study and other studies should be established.

Appendix V-I

FILE NONAME (CREATION DATE = 09/25/78)

* * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
MYR BY STATUS VEHICLE TAMPER STATUS
* PAGE 1 OF 1

MYR	STATUS: COUNT / ROW PCT / COL PCT / TOT PCT	OK 0.	TAMPERED 30.	ARGUABLE 31.	MALFNCTND 33.	ROW TOTAL
73.	COUNT	23	81	141	8	253
	ROW PCT	9.1	32.0	55.7	3.2	13.0
	COL PCT	3.8	21.9	14.9	20.5	
	TOT PCT	1.2	4.1	7.2	0.4	
74.	COUNT	26	90	156	4	276
	ROW PCT	9.4	32.6	56.5	1.4	14.1
	COL PCT	4.3	24.3	16.5	10.3	
	TOT PCT	1.3	4.6	8.0	0.2	
75.	COUNT	61	61	146	6	274
	ROW PCT	22.3	22.3	53.3	2.2	14.0
	COL PCT	10.2	16.5	15.4	15.4	
	TOT PCT	3.1	3.1	7.5	0.3	
76.	COUNT	112	70	209	4	395
	ROW PCT	28.4	17.7	52.9	1.0	20.2
	COL PCT	18.7	18.9	22.1	10.3	
	TOT PCT	5.7	3.6	10.7	0.2	
77.	COUNT	204	46	201	6	457
	ROW PCT	44.6	10.1	44.0	1.3	23.4
	COL PCT	34.1	12.4	21.3	15.4	
	TOT PCT	10.4	2.4	10.3	0.3	
78.	COUNT	173	22	92	11	298
	ROW PCT	58.1	7.4	30.9	3.7	15.3
	COL PCT	28.9	5.9	9.7	28.2	
	TOT PCT	8.9	1.1	4.7	0.6	
COLUMN TOTAL		599	370	945	39	1953
		30.7	18.9	48.4	2.0	100.0

CHI SQUARE = 319.75342 WITH 15 DEGREES OF FREEDOM SIGNIFICANCE = 0.0000

Appendix V-2

FILE NONAME (CREATION DATE = 09/25/78)

* CROSSTABULATION OF *
STATE BY STATUS VEHICLE TAMPER STATUS
* PAGE 1 OF 1

STATE	STATUS	0. OK	30. TAMPERED	31. ARGUABLE	33. MALFNCTN D	ROW TOTAL
WA	COUNT	124	48	128	6	306
	ROW PCT	40.5	15.7	41.8	2.0	15.7
	COL PCT	20.7	13.0	13.5	15.4	
	TOT PCT	6.3	2.5	6.6	0.3	
VA	COUNT	139	59	207	11	416
	ROW PCT	33.4	14.2	49.8	2.6	21.3
	COL PCT	23.2	15.9	21.9	28.2	
	TOT PCT	7.1	3.0	10.6	0.6	
TX	COUNT	36	48	129	3	216
	ROW PCT	16.7	22.2	59.7	1.4	11.1
	COL PCT	6.0	13.0	13.7	7.7	
	TOT PCT	1.8	2.5	6.6	0.2	
TN	COUNT	111	66	144	3	324
	ROW PCT	34.3	20.4	44.4	0.9	16.6
	COL PCT	18.5	17.8	15.2	7.7	
	TOT PCT	5.7	3.4	7.4	0.2	
ME	COUNT	103	70	155	7	335
	ROW PCT	30.7	20.9	46.3	2.1	17.2
	COL PCT	17.2	18.9	16.4	17.9	
	TOT PCT	5.3	3.6	7.9	0.4	
DE	COUNT	86	79	182	9	356
	ROW PCT	24.2	22.2	51.1	2.5	18.2
	COL PCT	14.4	21.4	19.3	23.1	
	TOT PCT	4.4	4.0	9.3	0.5	
COLUMN TOTAL		599 30.7	370 18.9	945 48.4	39 2.0	1953 100.0

CHI SQUARE = 55.89305 WITH 15 DEGREES OF FREEDOM SIGNIFICANCE = 0.0000

Appendix V-3

FILE NONAME (CREATION DATE = 09/25/78)

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * * *
MAKE BY STATUS VEHICLE TAMPER STATUS
* PAGE 1 OF 6

MAKE	COUNT / ROW PCT / COL PCT / TOT PCT	STATUS: OK 0.	TAMPERED 30.	ARGUABLE 31.	MALFNCTND 33.	ROW TOTAL
VW	COUNT	13	3	18	3	37
	ROW PCT	35.1	8.1	48.6	8.1	1.9
	COL PCT	2.2	0.8	1.9	7.7	
	TOT PCT	0.7	0.2	0.9	0.2	
VOLV	COUNT	10	1	0	0	11
	ROW PCT	90.9	9.1	0.0	0.0	0.6
	COL PCT	1.7	0.3	0.0	0.0	
	TOT PCT	0.5	0.1	0.0	0.0	
TRIU	COUNT	0	0	3	0	3
	ROW PCT	0.0	0.0	100.0	0.0	0.2
	COL PCT	0.0	0.0	0.3	0.0	
	TOT PCT	0.0	0.0	0.2	0.0	
TOYO	COUNT	9	4	72	0	85
	ROW PCT	10.6	4.7	84.7	0.0	4.4
	COL PCT	1.5	1.1	7.6	0.0	
	TOT PCT	0.5	0.2	3.7	0.0	
SUBA	COUNT	0	0	8	0	8
	ROW PCT	0.0	0.0	100.0	0.0	0.4
	COL PCT	0.0	0.0	0.8	0.0	
	TOT PCT	0.0	0.0	0.4	0.0	
SAAB	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
RENA	COUNT	0	0	1	0	1
	ROW PCT	0.0	0.0	100.0	0.0	0.1
	COL PCT	0.0	0.0	0.1	0.0	
	TOT PCT	0.0	0.0	0.1	0.0	
	COLUMN TOTAL	599	370	945	39	1953
		30.7	18.9	48.4	2.0	100.0

(CONTINUED)

FILE NONAME (CREATION DATE = 09/25/78)

* CROSSTABULATION OF *
MAKE BY STATUS VEHICLE TAMPER STATUS
* PAGE 2 OF 6

MAKE	STATUS	0. OK	30. TAMPERED	31. ARGUABLE	33. MALFNCTN D	ROW TOTAL
PONS	COUNT	1	1	0	0	2
	ROW PCT	50.0	50.0	0.0	0.0	0.1
	COL PCT	0.2	0.3	0.0	0.0	
	TOT PCT	0.1	0.1	0.0	0.0	
PONT	COUNT	47	31	53	2	133
	ROW PCT	35.3	23.3	39.8	1.5	6.8
	COL PCT	7.8	8.4	5.6	5.1	
	TOT PCT	2.4	1.6	2.7	0.1	
PLYM	COUNT	26	27	51	2	106
	ROW PCT	24.5	25.5	48.1	1.9	5.4
	COL PCT	4.3	7.3	5.4	5.1	
	TOT PCT	1.3	1.4	2.6	0.1	
PEUG	COUNT	0	0	3	0	3
	ROW PCT	0.0	0.0	100.0	0.0	0.2
	COL PCT	0.0	0.0	0.3	0.0	
	TOT PCT	0.0	0.0	0.2	0.0	
OPEL	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
OLDS	COUNT	52	21	66	2	141
	ROW PCT	36.9	14.9	46.8	1.4	7.2
	COL PCT	8.7	5.7	7.0	5.1	
	TOT PCT	2.7	1.1	3.4	0.1	
MG	COUNT	0	2	4	0	6
	ROW PCT	0.0	33.3	66.7	0.0	0.3
	COL PCT	0.0	0.5	0.4	0.0	
	TOT PCT	0.0	0.1	0.2	0.0	
COLUMN TOTAL		599 30.7	370 18.9	945 48.4	39 2.0	1953 100.0

(CONTINUED)

CROSSTABULATION OF MAKE BY STATUS VEHICLE TAMPER STATUS

MAKE	STATUS	OK (0)	TAMPERED (30)	ARGUABLE (31)	MALFNCTN D (33)	ROW TOTAL
MERS	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
MERC	COUNT	20	21	34	2	77
	ROW PCT	26.0	27.3	44.2	2.6	3.9
	COL PCT	3.3	5.7	3.6	5.1	
	TOT PCT	1.0	1.1	1.7	0.1	
MCDS	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
MAZD	COUNT	3	0	8	0	11
	ROW PCT	27.3	0.0	72.7	0.0	0.6
	COL PCT	0.5	0.0	0.8	0.0	
	TOT PCT	0.2	0.0	0.4	0.0	
MAZA	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
LINC	COUNT	8	3	9	1	21
	ROW PCT	38.1	14.3	42.9	4.8	1.1
	COL PCT	1.3	0.8	1.0	2.6	
	TOT PCT	0.4	0.2	0.5	0.1	
LANC	COUNT	1	0	0	0	1
	ROW PCT	100.0	0.0	0.0	0.0	0.1
	COL PCT	0.2	0.0	0.0	0.0	
	TOT PCT	0.1	0.0	0.0	0.0	
COLUMN TOTAL		599	370	945	39	1953
		30.7	18.9	48.4	2.0	100.0

(CONTINUED)

FILE NONAME (CREATION DATE = 09/25/78)

* * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
MAKE BY STATUS VEHICLE TAMPER STATUS
* PAGE 4 OF 6

MAKE	STATUS: COUNT / ROW PCT / COL PCT / TOT PCT	OK 0.	TAMPERED 30.	ARGUABLE 31.	MALFNCTND 33.	ROW TOTAL
JEEP	COUNT	2	0	2	0	4
	ROW PCT	50.0	0.0	50.0	0.0	0.2
	COL PCT	0.3	0.0	0.2	0.0	
	TOT PCT	0.1	0.0	0.1	0.0	
INTE	COUNT	0	1	1	0	2
	ROW PCT	0.0	50.0	50.0	0.0	0.1
	COL PCT	0.0	0.3	0.1	0.0	
	TOT PCT	0.0	0.1	0.1	0.0	
HOND	COUNT	11	2	15	0	28
	ROW PCT	39.3	7.1	53.6	0.0	1.4
	COL PCT	1.8	0.5	1.6	0.0	
	TOT PCT	0.6	0.1	0.8	0.0	
GMC	COUNT	2	3	6	0	11
	ROW PCT	18.2	27.3	54.5	0.0	0.6
	COL PCT	0.3	0.8	0.6	0.0	
	TOT PCT	0.1	0.2	0.3	0.0	
FORD	COUNT	90	75	222	6	393
	ROW PCT	22.9	19.1	56.5	1.5	20.1
	COL PCT	15.0	20.3	23.5	15.4	
	TOT PCT	4.6	3.8	11.4	0.3	
FIAT	COUNT	0	3	1	0	4
	ROW PCT	0.0	75.0	25.0	0.0	0.2
	COL PCT	0.0	0.8	0.1	0.0	
	TOT PCT	0.0	0.2	0.1	0.0	
DODG	COUNT	25	14	48	1	88
	ROW PCT	28.4	15.9	54.5	1.1	4.5
	COL PCT	4.2	3.8	5.1	2.6	
	TOT PCT	1.3	0.7	2.5	0.1	
COLUMN TOTAL		599	370	945	39	1953
		30.7	18.9	48.4	2.0	100.0

(CONTINUED)

FILE NONAME (CREATION DATE = 09/25/78)

* * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
MAKE BY STATUS VEHICLE TAMPER STATUS
* PAGE 5 OF 6

MAKE	STATUS: COUNT / ROW PCT / COL PCT / TOT PCT	OK 0.	TAMPERED 30.	ARGUABLE 31.	MALFNCTN D 33.	ROW TOTAL
DATS	COUNT	35	6	14	2	57
	ROW PCT	61.4	10.5	24.6	3.5	2.9
	COL PCT	5.8	1.6	1.5	5.1	
	TOT PCT	1.8	0.3	0.7	0.1	
CHRY	COUNT	15	9	23	1	48
	ROW PCT	31.3	18.8	47.9	2.1	2.5
	COL PCT	2.5	2.4	2.4	2.6	
	TOT PCT	0.8	0.5	1.2	0.1	
CHEV	COUNT	144	88	203	13	448
	ROW PCT	32.1	19.6	45.3	2.9	22.9
	COL PCT	24.0	23.8	21.5	33.3	
	TOT PCT	7.4	4.5	10.4	0.7	
CADI	COUNT	27	5	16	1	49
	ROW PCT	55.1	10.2	32.7	2.0	2.5
	COL PCT	4.5	1.4	1.7	2.6	
	TOT PCT	1.4	0.3	0.8	0.1	
BUIC	COUNT	41	29	29	1	100
	ROW PCT	41.0	29.0	29.0	1.0	5.1
	COL PCT	6.8	7.8	3.1	2.6	
	TOT PCT	2.1	1.5	1.5	0.1	
BMW	COUNT	3	0	0	0	3
	ROW PCT	100.0	0.0	0.0	0.0	0.2
	COL PCT	0.5	0.0	0.0	0.0	
	TOT PCT	0.2	0.0	0.0	0.0	
AUDI	COUNT	1	1	3	2	7
	ROW PCT	14.3	14.3	42.9	28.6	0.4
	COL PCT	0.2	0.3	0.3	5.1	
	TOT PCT	0.1	0.1	0.2	0.1	
COLUMN TOTAL		599	370	945	39	1953
		30.7	18.9	48.4	2.0	100.0

(CONTINUED)

FILE NONAME (CREATION DATE = 09/25/78)

* CROSSTABULATION OF *
MAKE BY STATUS VEHICLE TAMPER STATUS
* PAGE 6 OF 6

MAKE	STATUS COUNT / ROW PCT / COL PCT / TOT PCT	OK 0.	TAMPERED 30.	ARGUABLE 31.	MALFNCTN D 33.	ROW TOTAL
AMC		8	20	32	0	60
		13.3	33.3	53.3	0.0	3.1
		1.3	5.4	3.4	0.0	
		0.4	1.0	1.6	0.0	
COLUMN TOTAL		599 30.7	370 18.9	945 48.4	39 2.0	1953 100.0

CHI SQUARE = 267.76416 WITH 105 DEGREES OF FREEDOM SIGNIFICANCE = 0.0000

Appendix VI-1

FILE NONAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE IMC IDLE MC
BROKEN DOWN BY LIMCAP LIMITER CAPS
BY MYR

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			295109.0000	196.0857	259.4655	67322.3218	(1505)
LIMCAP	0.	FUNCT PROPERLY	56391.0000	116.5103	163.7625	26818.1510	(484)
MYR	73.		5645.0000	182.0968	243.2652	59177.9570	(31)
MYR	74.		4511.0000	180.4400	211.9735	44932.7567	(25)
MYR	75.		5840.0000	121.6667	195.1931	38100.3546	(48)
MYR	76.		12485.0000	145.1744	160.2800	25689.6751	(86)
MYR	77.		20805.0000	127.6380	161.6020	26115.2200	(163)
MYR	78.		7105.0000	54.2366	90.2464	8144.4128	(131)
LIMCAP	12.	ARGUABLE TAMPERING	227108.0000	239.8184	290.3218	84286.7429	(947)
MYR	73.		51695.0000	297.0977	342.6844	117432.5973	(174)
MYR	74.		54038.0000	296.9121	360.5927	130027.1193	(182)
MYR	75.		28166.0000	187.7733	225.2486	50736.9281	(150)
MYR	76.		55959.0000	259.0694	275.4513	75873.4324	(216)
MYR	77.		31280.0000	188.4337	212.9524	45348.7441	(166)
MYR	78.		5970.0000	101.1864	150.0956	22528.7405	(59)
LIMCAP	98.	NOT EQUIPPED	11610.0000	156.8919	221.2878	48968.2895	(74)
MYR	73.		1190.0000	238.0000	171.0848	29270.0000	(5)
MYR	74.		3745.0000	312.0833	380.1403	144506.6288	(12)
MYR	75.		1850.0000	142.3077	207.2098	42935.8974	(13)
MYR	76.		2600.0000	216.6667	209.2990	43806.0606	(12)
MYR	77.		1615.0000	76.9048	99.1019	9621.1905	(21)
MYR	78.		610.0000	55.4545	77.0861	5942.2727	(11)

TOTAL CASES = 1953
MISSING CASES = 448 OR 22.9 PCT.

CRITERION VARIABLE IHC

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
LIMCAP	0.	FUNCT PROPERLY	56391.0000	116.5103	163.7625	12953166.9483	(484)
LIMCAP	12.	ARGUABLE TAMPERING	227108.0000	239.8184	290.3218	79735258.7603	(947)
LIMCAP	98.	NOT EQUIPPED	11610.0000	156.8919	221.2878	3574685.1351	(74)
	WITHIN GROUPS TOTAL		295109.0000	196.0857	253.1599	96263110.8438	(1505)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	4989661.099	2	**********	38.927	0.0000
WITHIN GROUPS	96263110.844	1502	64089.954		

ETA = 0.2220 ETA SQUARED = 0.0493

Appendix VI-2

FILE NUNAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE ICU IDLE CU
BROKEN DOWN BY LIMCAP LIMITER CAPS
BY MYR

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			3945.3997	2.0243	2.4761	6.1310	(1949)
LIMCAP	0.	FUNCT PROPERLY	633.8999	0.9920	1.7758	3.1536	(639)
MYR	73.		87.2000	2.3568	2.3781	5.6553	(37)
MYR	74.		70.8000	2.2125	2.5494	6.4992	(32)
MYR	75.		57.3000	0.9879	1.5871	2.5190	(58)
MYR	76.		147.2000	1.3505	1.9850	3.9401	(109)
MYR	77.		173.4000	0.8065	1.5411	2.3750	(215)
MYR	78.		98.0000	0.5213	1.3679	1.8711	(188)
LIMCAP	12.	ARGUABLE TAMPERING	3136.6998	2.6117	2.6355	6.9461	(1201)
MYR	73.		712.0000	3.4067	2.7361	7.4861	(209)
MYR	74.		764.8999	3.3548	2.7872	7.7685	(228)
MYR	75.		420.0000	2.1875	2.5997	6.7583	(192)
MYR	76.		665.0999	2.5193	2.5294	6.3979	(264)
MYR	77.		444.1000	2.0656	2.3386	5.4691	(215)
MYR	78.		130.6000	1.4043	2.0227	4.0913	(93)
LIMCAP	98.	NOT EQUIPPED	174.8000	1.6037	2.1110	4.4563	(109)
MYR	73.		25.0000	4.1667	3.4679	12.0267	(6)
MYR	74.		36.7000	2.4467	2.4694	6.1970	(15)
MYR	75.		25.6000	1.0667	1.6972	2.8806	(24)
MYR	76.		46.3000	2.2048	2.4822	6.1615	(21)
MYR	77.		28.4000	1.0519	1.1630	1.3526	(27)
MYR	78.		12.8000	0.8000	1.3317	1.7733	(16)

TOTAL CASES = 1953
MISSING CASES = 4 OR 0.2 PCT.

CRITERION VARIABLE ICU

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
LIMCAP	0.	FUNCT PROPERLY	633.8999	0.9920	1.7758	2011.9691	(639)
LIMCAP	12.	ARGUABLE TAMPERING	3136.6998	2.6117	2.6355	8335.5259	(1201)
LIMCAP	98.	NOT EQUIPPED	174.8000	1.6037	2.1110	481.2765	(109)
	WITHIN GROUPS TOTAL		3945.3997	2.0243	2.3589	10828.5714	(1949)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	1114.655	2	557.327	100.157	0.0000
WITHIN GROUPS	10828.571	1946	5.565		

ETA = 0.3055 ETA SQUARED = 0.0933

Appendix VI-3

FILE NONAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE IHC IDLE HC
BROKEN DOWN BY EGRSTAT EGR SYSTEM STATUS
MYR

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			295109.0000	196.0857	259.4655	67322.5218	(1505)
EGRSTAT	0.	OK	191546.0000	181.5602	242.5808	58845.4269	(1055)
MYR	73.		21517.0000	247.3218	296.5500	87941.8952	(87)
MYR	74.		33382.0000	295.4159	351.6840	123681.6380	(113)
MYR	75.		24220.0000	163.6486	212.4025	45114.8281	(148)
MYR	76.		56962.0000	235.3802	264.0120	69702.3362	(242)
MYR	77.		43615.0000	151.9686	183.9353	33832.2123	(287)
MYR	78.		11850.0000	66.5730	114.1713	13035.0822	(178)
EGRSTAT	30.	TAMPERED	49880.0000	266.7380	329.7787	108753.9794	(187)
MYR	73.		14951.0000	347.6977	390.6443	152602.9302	(43)
MYR	74.		14772.0000	321.1304	421.2063	177414.7382	(46)
MYR	75.		6591.0000	205.9688	226.1573	51147.1260	(32)
MYR	76.		8276.0000	236.4571	231.8092	53735.4908	(35)
MYR	77.		4930.0000	205.4167	249.4686	62234.6014	(24)
MYR	78.		360.0000	51.4286	37.2731	1389.2857	(7)
EGRSTAT	33.	MALFNCTND	19256.0000	200.5833	195.1446	38081.4035	(96)
MYR	73.		9980.0000	249.5000	232.0665	53854.8718	(40)
MYR	74.		4735.0000	189.4000	153.5573	23579.6533	(25)
MYR	75.		1255.0000	139.4444	161.1374	25965.2778	(9)
MYR	76.		2811.0000	200.7857	180.4551	32564.0275	(14)
MYR	77.		460.0000	92.0000	59.3296	3520.0000	(5)
MYR	78.		15.0000	5.0000	8.6603	75.0000	(3)
EGRSTAT	98.	NOT EQUIPPED	32051.0000	194.2485	258.2238	66679.5293	(165)
MYR	73.		9706.0000	255.4211	292.7691	85713.7659	(38)
MYR	74.		9405.0000	268.7143	334.2603	111729.9160	(35)
MYR	75.		3790.0000	172.2727	272.0457	74008.8745	(22)
MYR	76.		2995.0000	130.2174	148.2817	21987.4506	(23)
MYR	77.		4695.0000	138.0882	185.0963	34260.6263	(34)
MYR	78.		1460.0000	112.3077	115.8234	13415.0641	(13)
EGRSTAT	99.	NON STOCK EQUIP	2376.0000	1188.0000	1149.7556	1321938.0000	(2)
MYR	73.		2376.0000	1188.0000	1149.7556	1321938.0000	(2)

TOTAL CASES = 1953
MISSING CASES = 448 OR 22.9 PCT.

CRITERION VARIABLE IMC

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
EGRSTAT	0.	OK	191546.0000	181.5602	242.5808	62023079.9280	(1055)
EGRSTAT	30.	TAMPERED	49880.0000	266.7380	329.7787	20228240.1604	(187)
EGRSTAT	33.	MALFNCTND	19256.0000	200.5833	195.1446	3617733.3333	(96)
EGRSTAT	98.	NOT EQUIPPED	32051.0000	194.2485	258.2238	10935442.8121	(165)
EGRSTAT	99.	NON STOCK EQUIP	2376.0000	1188.0000	1149.7556	1321938.0000	(2)
		WITHIN GROUPS TOTAL	295109.0000	196.0857	255.7687	98126434.2338	(1505)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	3126337.709	4	781584.427	11.948	0.0000
WITHIN GROUPS	98126434.234	1500	65417.623		

ETA = 0.1757 ETA SQUARED = 0.0309

Appendix VI-4

FILE NONAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE ICU IDLE CU
BROKEN DOWN BY EGRSTAT EGR SYSTEM STATUS
BY MYR

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			3945.3997	2.0243	2.4761	6.1310	(1949)
EGRSTAT	0.	OK	2462.7998	1.7885	2.3885	5.7047	(1377)
MYR	73.		334.7000	3.0427	2.6848	7.2080	(110)
MYR	74.		441.6000	3.0667	2.8237	7.9734	(144)
MYR	75.		314.4000	1.7275	2.4506	5.9077	(182)
MYR	76.		655.5999	2.1926	2.4608	6.0557	(299)
MYR	77.		529.5000	1.3971	2.0704	4.2867	(379)
MYR	78.		187.0000	0.7110	1.5238	2.3220	(263)
EGRSTAT	30.	TAMPERED	686.0000	3.0901	2.7842	7.7518	(222)
MYR	73.		218.4000	4.2824	3.0067	9.0403	(51)
MYR	74.		202.2000	3.6764	2.7913	7.7915	(55)
MYR	75.		82.4000	2.1684	2.2248	4.9498	(38)
MYR	76.		123.2000	3.0049	2.7655	7.6480	(41)
MYR	77.		48.9000	1.7464	2.2006	4.8426	(28)
MYR	78.		10.9000	1.2111	1.3555	1.7856	(9)
EGRSTAT	33.	MALFNCTND	377.6000	2.8179	2.6729	7.1446	(134)
MYR	73.		155.1000	3.3717	2.6510	6.9221	(46)
MYR	74.		106.6000	2.9611	2.5314	6.4082	(36)
MYR	75.		51.2000	2.5600	3.3343	11.1173	(20)
MYR	76.		34.9000	1.8368	2.2254	4.9536	(19)
MYR	77.		13.6000	1.9429	1.9848	3.9395	(7)
MYR	78.		16.2000	2.7000	3.1643	10.1400	(6)
EGRSTAT	98.	NOT EQUIPPED	406.4000	1.8991	2.1416	4.5865	(214)
MYR	73.		103.4000	2.4047	2.1935	4.8114	(43)
MYR	74.		122.0000	3.0500	2.7459	7.5292	(40)
MYR	75.		54.9000	1.6147	1.7245	2.9740	(34)
MYR	76.		44.9000	1.2829	1.5240	2.3226	(35)
MYR	77.		53.9000	1.2535	1.5956	2.5459	(43)
MYR	78.		27.3000	1.4368	2.2993	5.2869	(19)
EGRSTAT	99.	NON STOCK EQUIP	12.6000	6.3000	0.4243	0.1800	(2)
MYR	73.		12.6000	6.3000	0.4243	0.1800	(2)

TOTAL CASES = 1953
MISSING CASES = 4 OR 0.2 PCT.

CRITERION VARIABLE ICU

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
EGRSTAT	0.	OK	2462.7998	1.7885	2.3885	7849.7180	(1377)
EGRSTAT	30.	TAMPERED	686.0000	3.0901	2.7842	1713.1361	(222)
EGRSTAT	33.	MALFNCTNO	377.6000	2.8179	2.6729	950.2369	(134)
EGRSTAT	98.	NOT EQUIPPED	406.4000	1.8991	2.1416	976.9197	(214)
EGRSTAT	99.	NON STOCK EQUIP	12.6000	6.3000	0.4243	0.1800	(2)
	WITHIN GROUPS TOTAL		3945.3997	2.0243	2.4312	11490.1928	(1949)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	453.033	4	113.258	19.162	0.0000
WITHIN GROUPS	11490.193	1944	5.911		

ETA = 0.1948 ETA SQUARED = 0.0379

Appendix VI-5

FILE NUNAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE BROKEN DOWN BY: IHC STATUS BY MYR; IDLE HC VEHICLE TAMPER STATUS

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			295109.0000	196.0857	259.4655	67322.5218	(1505)
STATUS	0.	OK	47266.0000	109.1594	155.9874	24332.0602	(433)
MYR	73.		2350.0000	123.6842	123.1738	15171.7856	(19)
MYR	74.		4606.0000	230.3000	295.1506	87113.9053	(20)
MYR	75.		5080.0000	115.4545	180.2770	32499.7886	(44)
MYR	76.		12385.0000	151.0366	166.1078	27591.8135	(82)
MYR	77.		16200.0000	108.7248	145.8551	21273.7008	(149)
MYR	78.		6645.0000	55.8403	93.0129	8651.4065	(119)
STATUS	30.	TAMPERED	79569.0000	261.7401	311.3740	96953.7771	(304)
MYR	73.		22657.0000	328.0725	368.4803	150916.9211	(69)
MYR	74.		22532.0000	312.9444	382.4806	146291.3772	(72)
MYR	75.		10116.0000	210.7500	204.8237	41952.7447	(48)
MYR	76.		14744.0000	254.2069	221.9911	49280.0617	(58)
MYR	77.		8620.0000	221.0256	252.2691	63639.7099	(39)
MYR	78.		920.0000	51.1111	51.5796	2660.4575	(18)
STATUS	31.	ARGUABLE	163359.0000	222.2571	272.9193	74484.9188	(735)
MYR	73.		32723.0000	282.0948	312.6801	97768.8170	(116)
MYR	74.		33126.0000	269.3171	333.9081	111494.6241	(123)
MYR	75.		20520.0000	180.0000	236.8011	56074.7788	(114)
MYR	76.		42865.0000	252.1471	287.5100	82662.0197	(170)
MYR	77.		28530.0000	182.8846	198.3798	39354.5285	(156)
MYR	78.		5595.0000	99.9107	153.5415	23574.9919	(56)
STATUS	33.	MALFNCTND	4915.0000	148.9394	218.9027	47918.3712	(33)
MYR	73.		820.0000	136.6667	88.0152	7746.6667	(6)
MYR	74.		2030.0000	507.5000	417.2429	174091.6667	(4)
MYR	75.		140.0000	28.0000	40.8656	1670.0000	(5)
MYR	76.		1050.0000	262.5000	212.1910	45025.0000	(4)
MYR	77.		350.0000	58.3333	49.1596	2416.6667	(6)
MYR	78.		525.0000	65.6250	102.7284	10553.1250	(8)

TOTAL CASES = 1953
MISSING CASES = 448 OR 22.9 PCT.

CRITERION VARIABLE IHC

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ	N
STATUS	0.	OK	47266.0000	109.1594	155.9874	10511450.0046	(433)
STATUS	30.	TAMPERED	79569.0000	261.7401	311.3740	29576994.4704	(304)
STATUS	31.	ARGUABLE	163359.0000	222.2571	272.9193	54671930.4000	(735)
STATUS	33.	MALFNCTND	4915.0000	148.9394	218.9027	1553387.8788	(33)
	WITHIN GROUPS TOTAL		295109.0000	196.0857	253.0214	96093762.7538	(1505)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	5159009.189	3	**********	26.862	0.0000
WITHIN GROUPS	96093762.754	1501	64019.829		

ETA = 0.2257 ETA SQUARED = 0.0510

Appendix VI-6

FILE NONAME (CREATION DATE = 09/26/78)

DESCRIPTION OF SUBPOPULATIONS

CRITERION VARIABLE ICU IDLE CO
BROKEN DOWN BY STATUS VEHICLE TAMPER STATUS
BY MYR

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			3945.3997	2.0243	2.4761	6.1310	(1949)
STATUS	0.	OK	562.3999	0.9405	1.6939	2.8694	(598)
MYR	73.		44.8000	1.9478	2.2078	4.8744	(23)
MYR	74.		68.4000	2.6308	2.7727	7.6878	(26)
MYR	75.		65.5000	1.0738	1.5467	2.3923	(61)
MYR	76.		160.5000	1.4330	2.0439	4.1777	(112)
MYR	77.		140.2000	0.6873	1.3565	1.8401	(204)
MYR	78.		83.0000	0.4826	1.2278	1.5075	(172)
STATUS	30.	TAMPERED	1057.5999	2.8661	2.7055	7.3197	(369)
MYR	73.		315.9000	3.9487	2.9465	8.6818	(80)
MYR	74.		308.9000	3.4322	2.6931	7.2525	(90)
MYR	75.		151.8000	2.4885	2.6204	6.8667	(61)
MYR	76.		186.5000	2.6643	2.5079	6.2896	(70)
MYR	77.		81.5000	1.7717	2.0555	4.2252	(46)
MYR	78.		13.0000	0.5909	1.0479	1.0980	(22)
STATUS	31.	ARGUABLE	2259.8998	2.3965	2.5726	6.6185	(943)
MYR	73.		443.7000	3.1468	2.6111	6.8179	(141)
MYR	74.		482.0000	3.1097	2.7975	7.8262	(155)
MYR	75.		284.5000	1.9486	2.5519	6.5124	(146)
MYR	76.		503.5000	2.4207	2.5435	6.4693	(208)
MYR	77.		421.2000	2.0955	2.3550	5.5458	(201)
MYR	78.		125.0000	1.3587	2.0363	4.1464	(92)
STATUS	33.	MALFNCTND	65.5000	1.6795	2.3095	5.3338	(39)
MYR	73.		19.8000	2.4750	2.0197	4.0793	(8)
MYR	74.		15.1000	3.2750	3.6234	13.1292	(4)
MYR	75.		1.1000	0.1833	0.4021	0.1617	(6)
MYR	76.		8.1000	2.0250	1.7251	2.9758	(4)
MYR	77.		3.0000	0.5000	0.7899	0.6240	(6)
MYR	78.		20.4000	1.8545	2.8991	8.4047	(11)

TOTAL CASES = 1953
MISSING CASES = 4 OR 0.2 PCT.

CRITERION VARIABLE ICO

ANALYSIS OF VARIANCE

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	SUM OF SQ		N
STATUS	0.	OK	562.3999	0.9405	1.6939	1713.0605	(	598)
STATUS	30.	TAMPERED	1057.5999	2.8661	2.7055	2693.6463	(	369)
STATUS	31.	ARGUABLE	2259.8998	2.3965	2.5726	6234.5980	(	943)
STATUS	33.	MALFNCTND	65.5000	1.6795	2.3095	202.6836	(	39)
	WITHIN GROUPS TOTAL		3945.3997	2.0243	2.3612	10843.9884	(	1949)

ANALYSIS OF VARIANCE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	1099.238	3	366.413	65.721	0.0000
WITHIN GROUPS	10843.988	1945	5.575		

ETA = 0.3034 ETA SQUARED = 0.0920

Appendix VI-7

FILE NONAME (CREATION DATE = 10/26/78)

* CROSSTABULATION OF *
PBSTAT LEAD CONC STATUS BY FILSTAT FILLER NECK STATUS
* PAGE 1 OF 1

		FILSTAT		
	COUNT / ROW PCT / COL PCT / TOT PCT	PASS 0.	FAIL 1.	ROW TOTAL
PBSTAT				
	0.	455	8	461
PASS		98.3	1.7	95.8
		96.8	61.5	
		94.2	1.7	
	1.	15	5	20
FAIL		75.0	25.0	4.2
		3.2	38.5	
		3.1	1.0	
	COLUMN TOTAL	468 97.3	13 2.7	481 100.0

CORRECTED CHI SQUARE = 31.10187 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0000