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I/M Network Type: Effects On Emission Reductions, Cost, and Convenience

Technical Information Document

By

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I/M Network Type: Effects On Emission Reductions, Cost, and Convenience

EXECUTIVE SUMMARY

The Clean Air Act Amendments (CAAA) of 1990 require that EPA revise and republish Inspection and Maintenance (I/M) guidance in the Federal Register addressing a variety of issues including network type, i.e., whether the program is centralized or decentralized.

Nearly every State that must operate an I/M program will need to obtain legislative authority to meet revised guidelines. This need provides an opportunity to reassess the effectiveness of current I/M program designs and make changes that will lead to improved air quality over the next decade. Network type is the most obvious and influential factor at work in an I/M program. This report attempts to analyze how emission reduction effectiveness, cost, and convenience vary by network type.

Major factors that influence the emission reductions in an I/M program are test procedures, analyzer accuracy, quality control, inspector competence and honesty, and quality assurance. One of the fundamental features that distinguishes centralized programs from decentralized is the number of analyzers, stations, and inspectors. Decentralized programs range from hundreds to thousands of stations, analyzers and inspectors. By contrast, large centralized programs have 10-20 stations in a given urban area with 3-5 testing lanes each. Consequently, maintaining a high level of quality assurance and quality control over analyzers and inspectors is very difficult and costly in decentralized programs while readily available and easily implemented in a centralized system. The results of a wide array of program audits, studies, and other analyses by EPA and local governments show that decentralized programs suffer from improper testing by inspectors, less accurate analyzers, and from more variation in test procedure performance. The magnitude of the differences is difficult to accurately quantify, but evidence indicates that decentralized programs may be 20-40% less effective than centralized.

Obtaining additional emission reductions from in-use motor vehicles is essential to meeting the goals for enhanced I/M programs in the CAAA of 1990. To achieve this, I/M programs need to adopt more sophisticated procedures and equipment to better identify high emitting vehicles. This would result in higher costs, which may make it difficult to justify low volume decentralized stations, and longer test times, implying the need for more lanes and stations in a centralized system. Further, alternatives such as loaded transient testing may not be practical in decentralized programs. Thus, centralized programs, which are already more effective, may also have greater potential for improving effectiveness.

The cost of I/M programs is also important Two components of cost are addressed in this report: the cost to the motorist and the cost of program oversight. There is a distinct difference in cost between centralized and decentralized programs; centralized programs are substantially cheaper, and the gap is widening. In most cases centralized programs have had decreasing or stable costs while decentralized programs have gotten more expensive due to improved equipment and the demands by inspectors for higher compensation. This trend is likely to continue given the additional inspection requirements imposed by the CAAA of 1990.

Convenience is named as the major advantage of decentralized programs. There are many more inspection locations, and waiting lines are generally non-existent. Vehicles which are identified as high emitters can be repaired by the testing facility, which is also authorized to issue a compliance or waiver certificate after retest. Centralized testing facilities, on the other hand, can be visited without appointment, but the motorist may encounter waiting lines during peak usage periods. Vehicles which fail the inspection must be taken elsewhere for repair and returned to a testing facility afterwards.

This report discusses the results of a consumer survey on decentralized program experiences and also discusses inspection facility siting and reported waiting time in centralized programs. Individual's experiences in decentralized programs vary, depending on whether they seek an inspection without an appointment, and whether the nearest licensed facility is also capable of completing complex engine repairs. So do the experiences in centralized networks; most vehicles will not need repair and one well-timed inspection visit will suffice. On the other hand, inadequately sized networks can produce serious problems for consumers.

In summary, the majority of centralized programs have been found to be more effective at reducing emissions at a lower cost than decentralized programs. Improvements to decentralized programs are needed to assure that objective, accurate inspections are performed. These improvements are likely to be costly, and desired levels of sophistication may be beyond the capabilities of most private garages. Consumer convenience continues to be an important factor in network design and public acceptance.

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

At any point in time, a certain percentage of vehicles on the road are emitting pollutants in excess of their design standards due to repairable causes. Motor vehicle emissions inspection and maintenance (I/M) programs employ a short screening test to identify high emitters and a retest after repairs to confirm their effectiveness in reducing emissions. It is the mandatory initial screening test and the retest after repairs that differentiate I/M from a public information campaign about motor vehicle maintenance or a program to train automotive mechanics.

Where and how those tests are conducted has been one of the fundamental choices in designing an I/M program. This choice is generally made by the elected officials who establish the necessary authorizing legislation. Two basic types of I/M systems exist: 1) inspection and retest at high volume, test-only lanes (a centralized network), and 2) inspection and retest at privately-owned, licensed facilities (a decentralized network). A combination of centralized and decentralized inspections is also found, the latter usually being for retests only.

This report discusses how the choice of network design can affect the quality, cost, and convenience of I/M inspections. This report examines operating results from inspection programs across the United States to compare the effects of network design. Each section will present available information and attempt to come to a conclusion regarding the relative merits of each network option.

The discussion of network choice is particularly important in light of the Clean Air Act (CAAA) Amendments of 1990, which include significant changes for I/M programs. The CAAA amendments require centralized testing in enhanced areas, unless the State can demonstrate that decentralized testing is equally effective. The phrasing of this requirement implies a desire on the part of Congress for getting the most out of I/M, while not wishing to close out the decentralized option altogether. This report lays the groundwork for discussing what may be necessary to make decentralized as effective as centralized testing.

2.0 BACKGROUND

The first emission I/M program was established in the State of New Jersey with mandatory inspection and voluntary repair in 1972. In 1974, repairs became mandatory for vehicles which failed the inspection test. New Jersey added the emission inspection to its existing, centralized safety inspection network. The States of Oregon and Arizona followed suit by establishing centralized inspection programs in 1975 and 1976. Oregon, like New Jersey, established a State-operated network, while Arizona was the first State to implement a contractor-operated network.

Following passage of the Clean Air Act Amendments of 1977, which mandated I/M for areas with long term air quality problems, other State and local governments established inspection programs. Table 2-1 illustrates the choices which have been made regarding network design in the United States as of January, 1991.

Table 2-1

Currently Operating or Scheduled I/M Programs

Centralized Contractor Operated	Centralized State/Local Operated	Decentralized Computerized Analyzers	Decentralized Manual Analyzers	Decentralized Parameter Inspection
Cleveland [1]	D.C.	Anchorage	Davis Co, UT [2]	Houston [1]
Connecticut	Delaware	California	Idaho	Louisiana
Arizona	Indiana	Colorado	N.Carolina [2]	N.Kentucky
Illinois	Memphis	Dallas/El Paso [3]	Rhode Island	Ohio
Florida [3]	New Jersey	Fairbanks	Provo, UT	Oklahoma
Louisville	Oregon	Georgia	Salt Lake City	
Maryland		Massachusetts		
Minnesota [3]		Michigan		
Nashville		Missouri		
Washington		Nevada		
Wisconsin		New Hampshire		
		New Mexico		
		New York		
		Pennsylvania		
		Virginia		
(11)	(6)	(15)	(6)	(3)

1 Texas and Ohio are counted as one program each but are listed in 2 columns.
2 Committed to switching to decentralized computerized analyzers.
3 Scheduled to begin in 1991.

Decentralized networks are more abundant due to a variety of factors. In seventeen areas, the emission inspection requirement was simply added to a pre-existing decentralized safety inspection network. Another ten areas implemented decentralized systems because they were perceived to be less costly and more convenient to the vehicle owner.

Those areas choosing to implement centralized systems cited improved quality control and avoidance of conflict of interest as the main reasons. Eleven areas selected to have private contractors own and operate the inspection network so as to avoid the initial capital investment as well as the ongoing responsibility for staffing and maintenance. Following New Jersey and Oregon's lead, four States chose to use State-owned centralized facilities and government employees to operate the test system.

The U.S. Environmental Protection Agency (EPA) did not attempt to specify network choice when it first established I/M policy in 1978. EPA assumed that decentralized programs could be as effective as centralized programs, if well designed and operated. At the time that the policy was developed, there were no decentralized I/M programs to observe. EPA did, however, anticipate the increased need for oversight in a decentralized network, and the 1978 policy required additional quality assurance activities for such systems.

In 1984, EPA initiated I/M program audits as a part of the National Air Audit System. The audit procedures were developed jointly by EPA, the State and Territorial Air Pollution Program Administrators (STAPPA), and the Association of Local Air Pollution Control Officials (ALAPCO). Since the audit program's inception, EPA has fielded audit teams on 96 different occasions totaling 320 days of on-site visits to assess program adequacy. Audit teams are composed of trained EPA staff specializing in I/M program evaluation. Every currently operating I/M program has been audited at least once and many have been audited several times. The major elements of I/M audits include:

1) overt visits to test stations to check for measurement instrument accuracy, to observe testing, to assess quality control and quality assurance procedures instituted by the program, and to review records kept in the station;

2) covert visits to test stations to obtain objective data on inspector performance;

3) a review of records kept by the program, including the history of station and inspector performance (e.g., failure rates and waiver rates), enforcement actions taken against stations and inspectors found to be violating regulations, and similar documents;

4) analysis of program operating statistics, including enforcement rates, failure rates, waiver rates, and similar information; and,

5) entrance and exit interviews with I/M program officials and a written report describing the audit findings and EPA recommendations on correcting any problems found.

Further detail on audit procedures can be found in the National Air Audit System Guidance.[1]

EPA has pursued several other means of monitoring I/M program performance. Roadside emission and tampering surveys[2] are conducted in I/M areas throughout the country each year. These surveys provide information on how well programs are correcting tampering and bringing about tailpipe emission reductions. EPA requests certain I/M programs to submit raw test data for in-depth analysis. These data are analyzed in a variety of ways to determine whether programs are operating adequately.[3] Studies conducted by individual States and other organizations also provide information on program effectiveness.[4,5,6] In preparing this report, all of these sources were considered in the discussion of network design impacts.

3.0 EMISSION REDUCTIONS FROM I/M PROGRAMS

From an environmental perspective, the most critical aspect in evaluating an I/M program is the emission reduction benefit it achieves. There are three major factors related to network type that must be considered in making such an assessment: the prescribed test procedures, instrumentation and quality control, and actual test performance (including the issuance of waivers).

3.1 Formal Test Procedures

In order to assure that air quality benefits are achieved, it is necessary to assure that high emitters are identified by the emission test and are properly repaired. The Federal Test Procedure (FTP), which is used to certify that new vehicle designs meet emission standards, is not practical for use in the field, because it is very expensive and time consuming. Short emission tests were developed for I/M programs to allow rapid screening of in-use vehicles for emission performance. It is desirable, however, that an I/M test be able to predict about the same pass/fail outcome that the FTP would, and especially that it not fail a vehicle which could not benefit from repair.

Generically, there are three short tests currently in use in I/M programs: idle, two-speed and loaded/idle. Which programs use which test is shown in Table 3-1. There are some variations between how programs define and carry out these tests, but the basic approach is the same for each test. There is no direct relationship between network type and test type, although loaded testing is currently only done in centralized programs.

The use of preconditioning, or preparation of the vehicle for testing, is another test-related variable illustrated in Table 3-1. Preconditioning is performed to assure that the vehicle is at normal operating temperature, and that any adverse effect of extended idling is eliminated. Some I/M programs utilize a period of high speed operation (2500 rpm for up to 30 seconds) to precondition vehicles; some operate the vehicle on a chassis dynamometer prior to conducting the idle test; others do no preconditioning. Most decentralized programs, especially those employing computerized analyzers, conduct high speed preconditioning. To reduce costs and test time, many centralized programs did not adopt preconditioning. As with loaded testing, only centralized programs are doing loaded preconditioning.

The importance of properly preconditioning a vehicle for the short test has become increasingly apparent to EPA during the last few years due to concerns about false failures of newer model vehicles. As a result, the merits of high speed preconditioning and loaded preconditioning have been studied to assess their effectiveness. Two recent EPA studies[7] gathered data related to this issue, one which recruited vehicles which failed the short test in Maryland's centralized I/M program, and one which recruited vehicles from Michigan's decentralized I/M program. In both

Table 3-1

Test Procedures Currently Used in I/M Programs

Program	Network Type[1]	Test Type[2]	Preconditioning
D.C.	CG/D	Idle	None
Delaware	CG	Idle	None
Indiana	CG	Two Speed	High Speed
Memphis	CG	Idle	None
New Jersey	CG	Idle	None
Oregon	CG	Two Speed	High Speed
Arizona	CC	Loaded/Idle	Loaded
Connecticut	CC	Idle	Loaded
Florida	CC	Idle	Loaded
Illinois	CC	Two Speed	High Speed
Louisville	CC	Idle	High Speed
Maryland	CC	Idle	High Speed
Minnesota	CC	Idle	Loaded
Nashville	CC	Idle	None
Washington	CC	Two Speed	High Speed
Wisconsin	CC	Idle	Loaded
Alaska	D	Two Speed	High Speed
California	D	Two Speed	High Speed
Colorado	D	Two Speed	High Speed
Dallas	D	Idle	High Speed
El Paso	D	Idle	High Speed
Georgia	D	Idle	High Speed
Idaho	D	Idle	None
Massachusetts	D	Idle	High Speed
Michigan	D	Idle	High Speed
Missouri	D	Idle	High Speed
Nevada	D	Two Speed	High Speed
New Hampshire	D	Idle	High Speed
North Carolina	D	Idle	High Speed
New Jersey	D	Idle	High Speed
New Mexico	D	Idle	High Speed
New York	D	Idle	High Speed
Pennsylvania	D	Idle	High Speed
Rhode Island	D	Idle	None
Utah	D	Two Speed	High Speed
Virginia	D	Idle	High Speed

1 CG = Centralized government, CC = Centralized contractor, D= Decentralized
2 Idle = pass/fail determined only from idle emission readings
Two Speed = pass/fail determined from both idle and 2500 rpm readings
Loaded/Idle = pass/fail determined from loaded and idle readings.

studies, vehicles that had failed their regularly scheduled I/M test were tested on the full FTP and carefully examined for anything that needed repair. Both studies revealed the existence of errors of commission (i.e., failed vehicles which had low FTP emissions and no apparent defects but nevertheless failed the I/M short test) in these programs which utilize 15-30 seconds of high speed preconditioning. The results are shown in Table 3-2. Since owners of incorrectly failed vehicles are subjected to unnecessary inconvenience and repair expense, the elimination of incorrect failures is a priority. To address the need for improved test procedures, EPA issued a technical report detailing recommended alternative short test procedures in December, 1990.[8] The procedures include three variations of the idle test, two variations of the two speed idle test, and a loaded test procedure. In all but the loaded test procedure and the idle test procedure with loaded preconditioning, a second-chance test which includes three minutes of high speed preconditioning is recommended upon failure of the initial test.

Table 3-2

Error of Commission Rates Using High Speed Preconditioning*

Program	Total Number Vehicles Recruited	Incorrect Failures	Incorrect Failure Rate
Michigan	237	70	30%
Maryland	178	55	33%

* The Michigan study used FTPs to verify whether each I/M failure was correct. The Maryland study gave vehicles a second short test and counted as incorrect failures the vehicles that passed. No FTPs were conducted on these vehicles, but they were assumed to be passes.

Twenty-four of the thirty-five programs currently operating use high speed preconditioning. Seven programs do no formal preconditioning. Three centralized programs utilize loaded preconditioning and Florida and Minnesota will soon begin such testing.

EPA has not done a definitive study of loaded preconditioning or no preconditioning programs but there is some revealing evidence in the data from the programs that use loaded preconditioning. In these programs, the idle test is repeated on initially failed vehicles after 30 or more seconds of loaded operation. The change in pass/fail status is shown in the Table 3-3. Although these data are not accompanied by FTP results, the in-depth studies in Maryland and Michigan indicate that vehicles which pass I/M cutpoints after loaded operation are more likely to be low emitters. The seven programs that use no formal preconditioning may be experiencing failure patterns similar to those on the first idle of the loaded preconditioning programs, i.e., they may have a large number of incorrect failures.

Table 3-3

Change in Failure Rates From First Idle to Second Idle

Model Years	Failed First Idle Test	Failed Both Tests	Delta*
Pre-1981	46%	21%	-54%
Post 1980	52%	39%	-25%

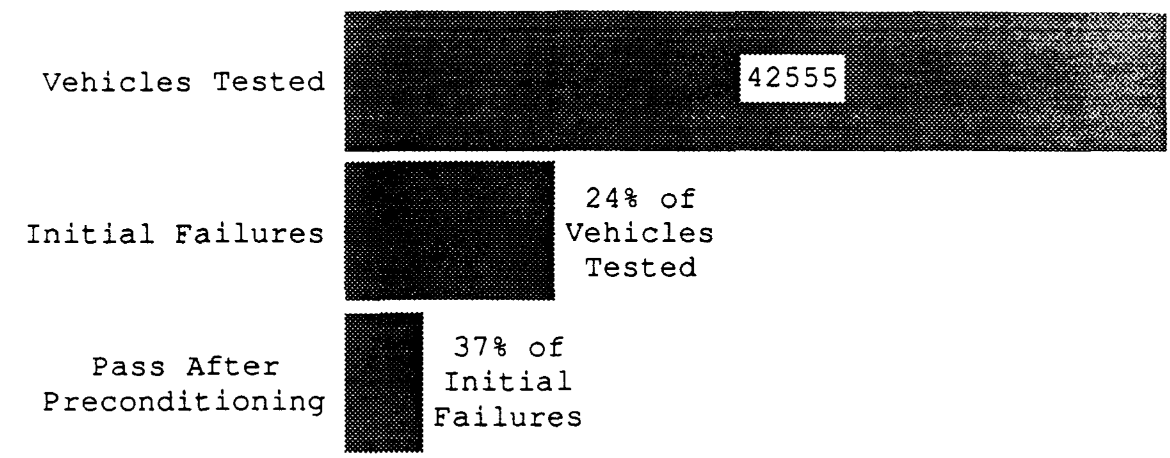
* Delta is the percent of unpreconditioned failures eliminated by loaded preconditioning.

Fifteen to thirty seconds of 2500 rpm operation does not seem adequate to precondition all vehicles. No preconditioning at all is probably worse. Thirty to ninety seconds of loaded operation seems to work well but may only be feasible in a centralized network because the purchase and installation of a chassis dynamometer is considered to be beyond the financial capability of most private garages. The Motor Vehicle Manufacturers Association has endorsed three minutes of 2500 rpm operation as adequate to precondition recent model year vehicles, and EPA's analysis shows that extended unloaded preconditioning reduces incorrect failures. This type of preconditioning is feasible in a decentralized network, and several programs that have recently switched to BAR 90 type analyzers are currently pursuing this approach. Figure 3-1 shows the results of second chance testing on 42,555 vehicles covering 1968 and newer model years in California using 3 minutes of 2500 rpm preconditioning on vehicles that fail the initial test. The data show that 37% of the vehicles that fail the initial test pass after extended preconditioning.

Based on this evidence, improving preconditioning is a high priority. The relative cost of loaded preconditioning and extended high speed preconditioning is an important question. Loaded preconditioning requires the installation of dynamometers. In centralized programs, that cost can be spread over tens of thousands tests. The typical decentralized station inspects about 1000 vehicles per year. Loaded preconditioning seems to accomplish the task of readying the vehicle for testing in much less time than high speed preconditioning, i.e., 30 seconds vs. 180 seconds. In a decentralized station, the time factor is important in terms of wage labor. In centralized programs, minimizing test time is essential to keeping throughput high and test costs low.

Figure 3-1

Vehicles Passing California I/M After Extended Preconditioning



Loaded mode operation is definitely necessary if an I/M jurisdiction wishes to test for emissions of oxides of nitrogen (NOx). There has been little attention focused on NOx in recent years. Only Los Angeles, California experiences violations of the ambient air quality standard for nitrogen dioxide, and emission control planners elsewhere have historically concentrated on hydrocarbon-only control strategies for reducing ozone levels. There has been growing interest lately, however, in a strategy which combines HC and NOx controls to reduce the potential for ozone formation. As discussed above, loaded mode testing may be practical from a cost standpoint only in centralized networks. Tampering checks may also provide NOx emission reductions. Section 3.4 addresses such tampering checks.

Transient loaded mode operation may also be essential for implementing tests that better identify vehicles that should get repairs. The steady-state idle, two speed and loaded tests currently used in I/M programs identify only 30-50% of the vehicles that need repair. EPA has developed a prototype short transient test that identifies essentially all vehicles that need repair. This procedure is being evaluated in the centralized I/M program in Indiana. Results thus far show that the test accurately identifies vehicles that need repair, while minimizing the number of falsely failed vehicles.

A transient loaded test is a more complicated, expensive and time consuming test. It involves the use of a more sophisticated dynamometer than those in use in most loaded testing programs.

More sophisticated sampling and measurement equipment is also involved. The test has many advantages, however, over the current tests. First, by accurately predicting FTP results it identifies more vehicles for repair, which should lead to greater emission reductions from the program and better cost effectiveness. It also allows for NOx testing and a functional test of the evaporative control system. Evaporative emissions represent a very large portion of the total hydrocarbon emissions from motor vehicles. Having an effective functional test to identify vehicles that need evaporative system repair is essential to reducing in-use emissions. Transient testing may also allow the elimination of other tampering checks frequently performed in I/M programs. It is accurate enough to not require this "double check."

Anti-tampering inspections are another part of the formal test procedure in I/M programs. As Table 2-1 shows, some programs only inspect for the presence and proper connection of emission control devices (parameter inspection), while others do both emission tests and tampering checks. Table 3-4 shows the current tampering test requirements in I/M programs. Centralized programs typically do no anti-tampering checks or fewer than decentralized programs. Again, the concern for rapid throughput in centralized lanes has been an important factor in this choice. Recently, centralized programs have been adding anti-tampering checks to their emission only programs. Maryland, Arizona, and New Jersey are examples of this. Their experiences show that anti-tampering inspections can be done quickly if limited to the items that are not in the engine compartment: the presence of a catalyst, the integrity of the fuel inlet restrictor, and a test for leaded fuel deposits in the tailpipe. Inspection of underhood components is possible in both centralized and decentralized networks, but only two centralized programs have so far adopted such inspections. Decentralized programs, in which throughput is less of a consideration, have more readily included underhood checks in their regulations.

To conclude, the choice of network type affects the relative costs of improvements in preconditioning and test procedures. Decentralized programs spread the equipment cost across as few as 3 or 4 tests per day. Centralized programs have shied away from preconditioning and anti-tampering checks in the past because of lack of clear need (at the time of original program adoption) and the impact on throughput, not because of the hardware cost. Anti-tampering checks are currently more prevalent in decentralized programs (the effectiveness of decentralized anti-tampering checks is an important factor which will be discussed in a later section.) Centralized networks are probably the best choice for loaded mode emission testing for NOx control and for improved identification of vehicles needing repair. An alternative that has not yet been tried but might be practical from a cost perspective would be a limited-participation decentralized network, in which a small number of stations would be licensed to insure a high volume of business at each.

Table 3-4

Model Year Coverage of Anti-Tampering Inspections
(oldest model year checked is listed)

Program	Network Type[1]	Catalytic Converter	Fuel Inlet	Lead Test	Air Pump	PCV	Evap Canister
Arizona	C	75	75	75	67		
Connecticut	C						
D.C.	C						
Delaware	C						
Florida[2]	C	75	75				
Illinois	C						
Indiana	C						
Louisville	C						
Maryland	C	77	77				
Memphis	C						
Minnesota[2]	C	76	76				
Nashville	C						
New Jersey	C	75	75				
Oregon	C	75	75		80	80	80
Washington	C						
Wisconsin	C	75	75				
Anchorage	D	75	75	75	75	75	
Fairbanks	D	75		75	75	75	
California	D	75	75		67	67	70
Colorado	D	75	75		75		
Dallas/El Paso	D	80	80	80	68	68	68
Georgia	D	78	78		78		
Idaho	D	84	84		84		
Massachusetts	D						
Michigan	D						
Missouri	D	81	81		71	71	71
Nevada	D	81	81		81		
New Hampshire	D	85	85				
New Mexico	D	75	75	75	75		
New York	D	84	84		84	64	84
North Carolina	D	77	77		77	77	
Pennsylvania	D						
Rhode Island	D						
Davis Co., UT	D	84	84		84	84	84
Provo	D	77	77	77	77		
Salt Lake City	D	84	84		84		
Virginia	D	75	75		73	73	73
Louisiana	A	80	80	80	80	80	80
N. Kentucky	A	80	80	80	80	80	80
Ohio	A	80	80	80	80	80	80
Oklahoma	A	79	79	79	79	79	79
Houston	A	80	80	80	68	68	68

1 C = Centralized, D= Decentralized, A = Anti-tampering only
2 Not currently operating

3.2 Emission Analyzer Accuracy and Quality Control

I/M tests are conducted with non-dispersive infrared analyzers which can measure hydrocarbons (HC) (as hexane), carbon monoxide (CO), and carbon dioxide (CO_2), although not all equipment includes the latter capability. The concentration of pollutants in vehicle exhaust is measured by placing a steel probe, attached to the analyzer by a sample hose, in the exhaust pipe and drawing a sample of exhaust into the instrument. The concentration in the exhaust stream is compared to the I/M program's pass/fail cutpoints (1.2% CO and 220 ppm HC for the majority of the fleet).

Accurate measurement capability is essential for several reasons. First, although cutpoints are high enough that small errors do not critically affect emission reductions, any significant error affects equity and public confidence in the testing process. Naturally, public support of the program is critical to the ultimate success of the effort. Second, leaks in the analyzer dilute the emission sample and could lead to false passes of high emitting vehicles. Leaks can quickly and easily become large enough to cause large amounts of dilution. This results in a loss in emission reduction benefits to the program. Finally, bad data obscure what is happening in the program. Tracking the performance of vehicles in the fleet over time is one indicator of the success of an I/M program. Inaccurate readings could mislead planners and decision makers.

The accuracy of the reading depends on periodic calibration checks and adjustments, regular maintenance of filters and water traps, and detection and repair of leaks in the sampling system. Each I/M program has requirements for maintaining the analyzers and also has an independent audit program in which analyzers are checked on a periodic basis. EPA recommends that program administrators use a +5%/-7% tolerance when auditing inspection equipment. That is, if an analyzer reads a known concentration of gas more than 5 percent too high or 7 percent too low during an audit, then it should be taken out of service until it can be adjusted or repaired.

EPA audits of operating I/M programs also include independent instrument checks with a gas bottle that EPA names and ships to the site from its Motor Vehicle Emission Laboratory in Ann Arbor, Michigan. Table 3-5 presents the findings from EPA audits regarding the accuracy of different programs' instrumentation.

The findings show mixed results depending upon program type. Centralized contractor-run programs show very strong quality control. Centralized government-run programs and decentralized programs are comparatively weak.

Table 3-5

Gas Audit Failure of Emission Analyzers By Program

Program	Network Type[1]	Number of Analyzers Tested	Rate of HC Failures	Rate of CO Failures
D.C.	CG	13	23 %	15 %
Delaware	CG	9	67 %	22 %
Indiana	CG	24	29 %	8 %
Medford	CG	4	50 %	0 %
Memphis	CG	9	44 %	33 %
Subtotal	CG	59	37 %	15 %
Connecticut	CC	32	0 %	0 %
Illinois	CC	47	0 %	0 %
Louisville	CC	6	0 %	0 %
Maryland	CC	11	0 %	0 %
Washington	CC	12	25 %	8 %
Wisconsin	CC	11	18 %	9 %
Subtotal	CC	119	4 %	2 %
California	D	22	9 %	14 %
Colorado	D	21	29 %	14 %
Georgia	D	21	14 %	10 %
New Hampshire	D	14	29 %	21 %
North Carolina	D	17	35 %	65 %
Pennsylvania	D	11	27 %	18 %
Subtotal	D	106	23 %	23 %

1 CG = Centralized government, CC = Centralized contractor, D= Decentralized

Minimum quality control requirements are specified in the Emission Performance Warranty Regulations promulgated pursuant to Section 207(b) of the Clean Air Act Amendments of 1977. Among other things, these regulations require weekly gas span and leak checks. Centralized programs go far beyond these minimum requirements, typically conducting these checks two or more times per day. The best centralized programs, in terms of quality control results, conduct leak checks and recalibrate equipment on an hourly basis. Frequent multi-point calibrations, daily preventative maintenance, and careful monitoring of equipment performance also characterize these quality control programs. While such activities are possible in a centralized program with a limited number of analyzers and the economies of scale in purchasing large quantities of high pressure calibration gas, decentralized stations simply could not afford this level of control. Also, the low average test volume in decentralized stations limits the number of vehicles affected by an equipment error. As a result, decentralized programs all require stations to conduct these checks only weekly. Some quality control practices, such as monthly multi-point calibrations, are never done in decentralized programs.

Centralized government-run programs tend to have problems with calibration gas quality. In fact, most of the quality control failures in these programs can be traced to gas problems. This is also true of the two centralized contractor-run programs that had quality control problems. Finally, limited operating budgets in centralized government-run programs usually result in less frequent quality control checks and less technical expertise available to maintain test equipment, when compared with centralized contractor-run programs.

Decentralized inspection facilities suffer from both problems to one degree or another. Each individual station usually is allowed to purchase gas on the open market and has no way of knowing if the gas is accurately labeled unless the State operates a gas naming program. The program manager also purchases gas for auditing station analyzers. These audits serve as the only tool for ensuring gas accuracy in decentralized programs. However, with a few exceptions, quality assurance audits occur only two to four times per year, which limits their effectiveness. Computerized analyzers used in decentralized programs are programmed to lock out from testing if the weekly calibration check and leak check by the station owner are not conducted and passed. In theory, this ensures a nominal level of instrument accuracy. Before computerization, these quality control checks depended upon the operator to remember to do them and do them correctly. However, EPA auditors frequently report finding computerized analyzers with leaking sample systems, even though the analyzer has recently passed a leak check conducted by the owner. The leak check mechanism is easily defeated (thus saving repair costs and analyzer down time) by temporarily removing the probe or the entire sample line and tightly sealing the system to pass the check. A simpler approach is to kink the sample line to accomplish the same objective: excluding the most susceptible portions of the sample system from the leak check. EPA auditors have observed this happening during overt station audits. At this point, no one has devised a solution to this problem that could not be defeated.

To conclude, quality control in centralized programs can more easily meet the highest standards achievable given current technology since economies of scale allow the use of better practices. Decentralized programs may always have to settle for lower quality control and the associated burden of extensive quality assurance, and less emission reduction benefit due to the number of stations and inspectors involved.

3.3 Emission Testing Objectivity and Accuracy

3.3.1 Background

Apart from the design considerations related to test procedure choice and instrument quality control, two crucial factors in the effectiveness of the inspection process are whether the test is actually conducted and whether it is done correctly. Even the best design is defeated by failure to address these factors. Obviously, simple error or inspector incompetence is a problem, but more significantly, malfeasance is a problem, as well. Thus, the term "improper testing" will be used in this report to refer to a deliberate failure by inspectors to "fail" vehicles that exceed idle emission cutpoints or which violate anti-tampering rules, either at initial test or at retest. The degree of machine control of the testing process and the level of human supervision of the inspector influence the degree to which improper testing is possible. Obviously, decentralized programs do not allow for the same level of human supervision of the testing process as centralized programs. Overt quality assurance visits occur, at most, once per month and rarely involve the observation of the testing process. Even if testing were observed during these visits, only the most inept inspectors would deliberately perform the test incorrectly while being observed by the State auditor.

In the early 1980's, almost all decentralized I/M programs employed manual emission analyzers, and the inspector/mechanic was responsible for every step of the process: selecting the proper cutpoints based on a vehicle's model year and type, recording the results from an analog (needle on dial) display onto a test form, and making the pass/fail decision. In short there was no machine control of the inspection process, so the inspector's proficiency and honesty were key to objective and accurate tests.

Across the board, decentralized manual analyzer programs were reporting operating statistics which did not agree with those reported by either centralized programs or decentralized programs using computerized analyzers, or with the available information about in-use emission performance. In most cases, the reported failure rate was only 20 to 40 percent of what would be expected. Table 3-6 shows failure rates from all programs reporting data from the early 1980's.

Table 3-6 might be hurriedly interpreted to mean that the manual programs were bad and the computerized and centralized programs were good. The reported failure rate, however, is only one indicator of I/M program performance. It would be rash to conclude that a program is succeeding or failing based only on that statistic. There are several reasons why this statistic is not a completely reliable indicator. The failure rate in a program is defined as the number of vehicles that fail an initial test. In order to accurately calculate this statistic, it must be possible to distinguish initial tests from retests. The computerized analyzers used in decentralized programs include a prompt that asks whether the test is initial or a retest. In some cases, inspectors are not aware that a vehicle has been inspected before at another station and code a retest as an initial test. Another more common problem is that the inspector simply chooses initial test (the default prompt) for any test. This confuses actual failure rates. Some centralized programs have the same kind of prompt but require the owner to present a document (e.g., vehicle registration or test form) which is marked when a test is performed. This reduces the problem but EPA audits have found instances where coding is not accurate. Many centralized systems use a computerized record call up system, based on the license plate or VIN, that automatically accesses the pre-existing vehicle record in the database. Thus, it is nearly always clear which is the initial test and which is the retest. It is possible to sort out the miscoding problem in any database that includes reliable vehicle identification information but this dramatically complicates data analysis, and I/M programs have not systematically pursued this. Another reason why reported initial tests failure rates are not reliable indicators is the problem of false failures discussed previously. The quality of preconditioning and the sophistication of the test procedures vary from program to program. Inadequate preconditioning or less sophisticated test procedures may result in exaggerated failure rates. Most importantly, even if the reported failure rate on the initial inspections were entirely accurate, there could still be problems with retests. In a manual program, the quickest approach to completing any test is to make up a passing reading, so it is not surprising that few failures were ever reported. In a computerized program the analyzer must at least at some point be turned on, vehicle identification data entered, and the test cycle allowed to run its course or no compliance document will be printed. Since most cars will pass their first test with no special tricks, the least-time approach for a dishonest inspector may be to do a reasonably normal first inspection on all vehicles, producing a respectably high failure rate report, and devote special attention only to the retest of the failed vehicles. So, failure rates were useful in identifying the severe problems that existed in manual I/M programs, but they are not useful in drawing finer distinctions between better run programs.

EPA examined in more depth six possible causes of the low failure rates in the manual programs [see EPA-AA-TSS-IM-87-1]. This study analyzed and discussed roadside idle survey data, reported I/M program data, and data collected during I/M program audits. EPA concluded that five of the explanations - quality control practices, fleet maintenance, fleet mix, differing emission standards, anticipatory maintenance, and pre-inspection repair - did not sufficiently explain low reported failure rates. By process of elimination, EPA concluded that the major problem contributing to low reported failure rates in decentralized, manual I/M programs was improper inspections by test station personnel. Anecdotes and observations reinforced this explanation.

Table 3-6

Early Emission Test Failure Rates in I/M Programs[1]

	Reported %	Expected[2] %	Ratio[3]
Centralized			
Arizona	20.2	36.8	.55
Connecticut	17.2	33.0	.52
Delaware	13.7	7.7	1.00
Louisville	15.7	16.2	.97
Maryland	14.6	14.0	1.00
Memphis, TN	8.1	3.7	1.00
Nashville, TN	24.5	25.4	.97
New Jersey	26.1	27.8	.94
Oregon	24.0	38.3	.63
Washington, D.C.	18.4	13.4	1.00
Washington	19.0	28.1	.68
Wisconsin	15.3	19.3	.79
Average			.85
Decentralized Computerized Analyzers			
Fairbanks, Alaska	19.4	22.7	.85
Anchorage, Alaska	15.7	24.7	.63
California	27.7	28.7	.96
Michigan	15.8	12.9	1.00
New York[4]	5.1	33.4	.15
Pennsylvania	17.6	19.5	.90
Average			.75
Decentralized Manual Analyzers			
Georgia	6.6	25.0	.26
Idaho	9.8	16.9	.58
Missouri	6.7	20.5	.33
North Carolina	5.6	21.1	.27
Clark Co., Nevada	9.5	29.4	.32
Washoe Co., Nevada	11.0	29.4	.37
Davis Co., Utah	8.7	21.3	.41
Salt Lake Co., Utah	10.0	21.3	.47
Virginia	2.3	15.6	.15
Average			.35

1 1983-1985 data, for all model years, including light-duty trucks.
2 Expected rates are based on data from the Louisville I/M program for 1988. They vary by area due mainly to differences in cutpoints.
3 Values greater than 1.00 are reported as 1.00.
4 New York's analyzers are only partially computerized.

In part because of the poor experience of the manual programs that had started earlier and because of encouragement from EPA, the next round of six decentralized programs that started in the mid-1980s chose to require computerized analyzers. By the beginning of 1989, four of the previously manual programs had required inspection stations to purchase and use new computerized analyzers to reduce improper testing. Two more programs are scheduled to switch in the near future. Thus, most decentralized programs now utilize computerized analyzers to control the testing process. The timely question is whether decentralized programs using computerized analyzers in fact get as much emission reduction as a comparable centralized program, as Table 3-6 might suggest could be the case. The next section examines the evidence that is available, including that from the newer computerized centralized programs. The remainder of this section discusses hypothetical problems as a useful preliminary to an examination of the evidence with some comparison to centralized programs.

The new computerized analyzers reduce many of the errors likely with the use of manual equipment by reducing the number and difficulty of the decisions an inspector has to make. The inspector enters vehicle identification information (make, model year, vehicle type, etc.), and based on this, the computer automatically selects appropriate emission standards, performs the test, makes the pass/fail decision, prints the compliance document, and stores the results on magnetic recording media. However, much of the process still relies on the inspector to correctly conduct the manual steps of the process: determine vehicle information, key in information correctly, properly precondition the vehicle, properly insert the probe in the tailpipe for the duration of the test, maintain idle speed at normal levels, etc. Thus, improper testing is still possible, and is not limited to cases of simple human error.

There are a variety of motivations that can lead an inspector to intentionally perform an improper test. First and foremost, some inspectors may not be interested in deriving revenue from the repair of vehicles but are primarily in the business to profit from testing. In many cases, I/M tests are performed by service stations or other outlets that have test analyzers but do not stock a full range of emission parts and do not employ fully qualified engine mechanics. The service such an outlet offers may be to provide as many customers with a certificate of compliance with as little hassle as possible. In addition to improper testing on the initial test, improper testing on the retest of a failed vehicle also occurs. One example of the motivation for this is when a mechanic attempts a repair but fails to resolve the excess emission problem. It puts the mechanic in a difficult position to tell a customer that the vehicle still failed after the agreed upon repairs were performed. To save face, the mechanic falsifies the results and the vehicle owner believes the problem was corrected. Finally, some inspectors may not hold the I/M program in high regard or may doubt its technical effectiveness, and may want to help out customers by passing them since they perceive no harm in doing so.

The mid-1980s experience in manual decentralized programs amply demonstrated that many licensed inspectors were willing to report test results they had not actually obtained, for the reasons given in the previous paragraph or others. To determine whether this willingness still exists and the degree to which it is affecting computerized programs, it is useful to enumerate the ways in which it is possible to conduct a computerized inspection improperly. This will suggest the type of evidence one might expect to be able to see. The most basic form of deliberate improper testing is no test at all, i.e. the inspector provides the customer with a compliance document without inspecting the vehicle. The accounting systems in most programs require that the inspector somehow produce an electronic record of an inspection for each certificate or sticker issued. This electronic record can be produced by testing a "clean" vehicle to achieve a passing score but entering the required identification information as if it were the subject vehicle.

Another approach is to intentionally enter erroneous vehicle identification information to make it easier for a vehicle to pass. All I/M programs have looser emission standards for older technology vehicles and most have looser standards for trucks compared with cars. Model year input to the computerized analyzer governs automatic selection of emission standards used by the system to decide pass/fail outcome. Thus, by entering an older model year or truck designation into the computer, the system automatically selects looser standards. The compliance document will then show the improper model year, but may never be examined closely enough to be questioned.

The decentralized computerized analyzer requires a minimum amount of CO_2 in the sample stream in order to consider a test valid. Most programs use cutpoints of 4-6%, well below the 10-14% CO_2 found in most vehicles' exhaust. One way to improperly test is to partially remove the probe from the tailpipe such that the sample is diluted enough to pass the HC and CO standards but not enough to fail the CO_2 check.

Similarly, computerized analyzers allow engine speed during the idle test to range between 300-1600 RPM. Improper testing may be accomplished by raising the engine speed above normal during the idle test. This usually lowers apparent emission levels leading to a passing result. To EPA's knowledge, no I/M agency tries to detect such actions on a routine basis.

Another technique is to make temporary vehicle alterations, e.g., introduce vacuum leaks or adjust idle, to get the vehicle to pass and then readjust the vehicle after the test. This type of improper testing is nearly impossible to detect.

Finally, vehicle owners can obtain inspection documents on the black market in some programs. A major element of quality assurance in a decentralized program is to determine whether all stickers or compliance certificates can be accounted for during the periodic audits of stations. A routine problem is the loss or theft of certificates or stickers, despite regulatory requirements that such documents be kept secure. Recently, Texas, New York, and other I/M programs have experienced problems with counterfeit I/M stickers.

As with the comparison of decentralized and centralized programs, the failure rates in Table 3-6 should not be taken to be reliable indications of which centralized programs were working the best. The low failure rate programs may have been doing a better job at getting cars fixed one year so they do not appear as failures the next, and in recording only one test on each vehicle as the initial test. A closer look at hypothetical possibilities and at the supporting evidence is necessary.

Improper testing is also possible in centralized networks, with some reason to suspect that such problems could be more common in government-run systems than in contractor-run systems. The lane capacity in some government-run programs was not designed or upgraded over time to handle the growing volume of vehicles demanding inspection. Also, the test equipment used is essentially identical to the equipment used in decentralized computerized programs. (This has been a cost-based decision, not one inherent to government-run stations.) Thus, all of the pitfalls associated with the use of those analyzers are possible. Finally, because enough aspects of government-run programs continue to be manual operations, they are subject to both error and malfeasance, making close personal supervision essential. As a result of these problems, vehicles have, at times, been waved through without emission testing in government-run lanes as a result of routine problems like equipment breakdown, and sloppy testing practices have been observed. Through the audit process, EPA and the State and local jurisdictions have made some progress in resolving these problems. It should be noted here that intentional violation of program policy or regulations by individual inspectors (i.e., deliberate improper testing) is not evident in these programs. Shortcuts have been observed on visual inspections, but infrequently. On occasion inspectors have been caught stealing or selling certificates or accepting payments but the supervision typical of centralized programs generally prevents this.

Centralized contractor-run programs can be expected to suffer few if any problems with improper testing for several reasons. The level of machine control in these programs is such that the inspector has almost no influence over the test outcome. In fully automated systems, the inspector only enters a license plate number to call up a pre-existing record that contains the other vehicle identification information used to make the pass/fail decision. Individual inspectors are held accountable for certificates of compliance just as a cashier is held responsible for a balanced cash drawer. The actual test process is completely computerized. In addition to machine control of the inspection process, the level of supervision in centralized programs is very high. The contractor is under pressure and scrutiny from both the public and the government agencies responsible for oversight. This pressure has led to high levels of quality control and quality assurance in every aspect of the inspection system.

Two other problems that may affect emission benefits of a program regardless of network type are readjustment after repair and test shopping. Readjustment after getting a "repair" and passing the test probably happens to some extent in all programs. A survey[9] of mechanics in Arizona showed a significant percent admitting to have made such readjustments. This problem stems from the fact that poor quality repairs may sacrifice driveability in order to reduce emissions to pass the test. Readjustment occurs after obtaining a passing reading to improve driveability. The improvement may be real or imagined. Some owners still have a 1970s mind set when it comes to emission controls and will not believe that a readjustment is not necessary. This problem is somewhat limited to older technology vehicles since computerized vehicles are not adjustable, per se.

Test shopping occurs when an individual fails an emission test at one I/M test station (either centralized or decentralized) and goes to another station to get another initial test. EPA auditors hear complaints from inspectors in decentralized programs that sometimes they fail a vehicle but the owner refuses repair and finds another station to get a passing result. In some cases these complaints have been verified by follow-up investigations conducted by program officials. Test shopping can result in a small number of dishonest garages "inspecting" a disproportionately large number of cars that should be failed and repaired. However, detecting or preventing this type of problem has only been systematically pursued in one decentralized program. In a centralized program, the main effect of test shopping is that cars with variable emission levels sometimes pass on a second or third test.

3.3.2 Supporting Evidence

The foregoing background discussion described what can go wrong with testing in each program type, and why it is reasonable to suppose a special problem may exist in decentralized programs. However, the closest possible scrutiny is appropriate given the stakes involved: air quality benefits and basic network choice. Ideally, an in-depth field study of the issue would be useful to quantify the extent of each of these problems and measure their impact on the emission reduction benefits of the program. However, such a study would require years of investigation and cost millions of dollars. Further, the results may not be clear cut because of the difficulty of observing I/M program operations without affecting the normal behavior of those observed and the difficulty obtaining a vehicle or station sample that is not biased by the non-participation of owners and mechanics who know they have evaded program requirements.

Short of doing such a study, there are a variety of sources of information that shed light on the extent of improper testing in I/M programs. One major source is the audit program EPA initiated in 1984. Another source is the auditing conducted by programs themselves. Data analysis by both programs and EPA have also provided information. Complaints and anecdotal information from consumers and others involved in test programs are also useful. Finally, EPA has conducted some in-depth studies of testing programs that contribute additional data on improper testing.

3.3.2.1 Failure Rate Data

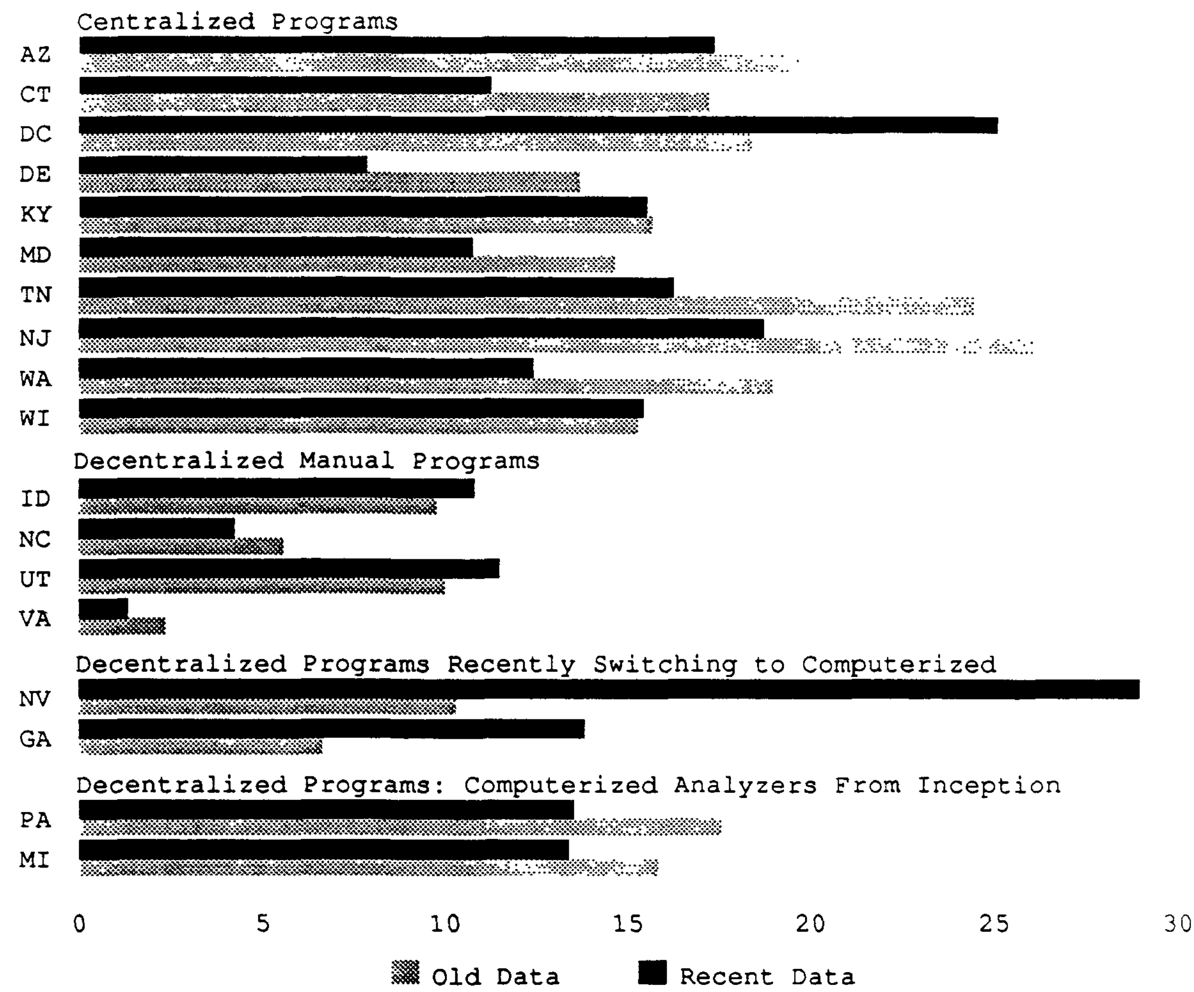
It was expected that switching from manual analyzers to computerized analyzers would solve the problem of low reported failure rates on the initial test, and that appears to have been the case. Figure 3-2 shows failure rate data from I/M programs in the 1987-1988 time frame.

Figure 3-2 also compares failures rates from the 1986 time frame and failure rates from the 1988 time frame. The data indicate that centralized program failure rates have decreased in most cases. This is expected as more new technology vehicles, which fail less often, enter the fleet and as the program effectively repairs existing vehicles in the fleet. Some centralized programs, Wisconsin and Louisville, for example, do not show this trend because they regularly increase the stringency of their cutpoints to maintain high levels of emission reduction benefits. The decentralized manual analyzer programs show little change or small increases in failure rates in this time period. The increases may result from increased pressure on these programs to perform. It is clear that the failure rates in these programs remain lower than expected.

A good example of this is the New Hampshire program which, at the time, used manual analyzers in about 20% of the stations and computerized analyzers in the rest. Figure 3-3 shows the failure rate data from each segment of the program, with the manual analyzer stations reporting a failure rate approximately 25% that of the computerized stations.

Figure 3-2

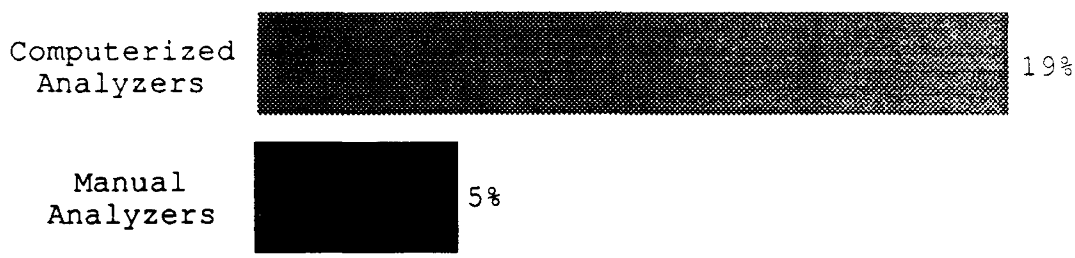
Old and New Emission Test Failure Rates in I/M Programs*



* The recent data is from 1987 - 1988 and the old data is from 1985 - 1986.

Figure 3-3

Failure Rates in Manual and Computerized Stations in New Hampshire*



* About 20% of the stations in the New Hampshire program used manual analyzers while the rest used computerized equipment.

The decentralized computerized programs now report high failure rates, in the range of what would be expected based on the emission standards and vehicle coverage of these programs. Thus, the operating data from decentralized computerized programs would suggest that more initial inspections are being performed properly than was the case using manual analyzers. As discussed previously, there are problems with relying solely on failure rate as an indicator. Increased failure rates are certainly a precondition to successful emission reductions, but not sufficient. The central factor is whether the final test on each vehicle is performed objectively.

3.3.2.2 Overt Audit Data

Quality assurance efforts in decentralized I/M programs always include overt audits of licensed inspection stations, typically on a quarterly basis or more often in systems using manual analyzers. Overt audits generally consist of collecting data from recent tests (either magnetic media or manually completed test forms), checking analyzer accuracy, and observing inspections in progress. These audits serve to maintain a presence of program management and control in the station. With computerized analyzers, software prompts inspectors through each step of the procedure, so overt audits of the test stations rarely find problems with inspectors not knowing how to correctly perform an emission test. Of course, overt audits still find problems unrelated to the emission analyzer: missing stickers, certificate security problems, disarray in record-keeping, and similar administrative details that could lead to a finding of improper testing. Overt audits of decentralized I/M programs by EPA generally involve observations at only a small fraction of the licensed test stations and no attempt is made to obtain a statistically accurate sample. As a result, the following discussion will speak in general terms about overt audit findings without citing specific rates. Nevertheless, EPA believes that the findings from these station visits are fairly representative.

Manual operations observed during overt audits of decentralized programs are done incorrectly so often that this is almost always identified as a major problem. This is true of both anti-tampering checks, discussed in more detail in Section 3.4, and emission tests. Inspectors fail to conduct the emission test properly by eliminating important steps, such as preconditioning or engine restart, or by not strictly following criteria, such as when to take the sample and at what speed to precondition. The properly conducted test is the exception rather than the rule when it comes to manual operations. For example, the most recent audit of a manual program by EPA included overtly observing 10 different inspectors test vehicles. Only two inspectors followed procedures completely. Computerized analyzers prevent some but not all of these problems. Sloppiness is also observed in steps such as properly warming up the vehicle, avoiding excessive idle, and properly inserting the probe in the tailpipe.

Overt audits find evidence of improper testing based on review of paperwork and test records. Auditors find that stickers or certificates have been issued or are missing but no test record is available to document proper issuance. Inspectors doing improper inspections issue the certificate or sticker and then at a convenient time enter the data into the computer and probe a passing vehicle to create both the magnetic and paper test record. In programs in which stations are required to keep detailed repair records, suspicious information has been found. For example, a station might charge the same exact amount of money for repairing and retesting most vehicles that come to it. This is an extremely unlikely occurrence. Another example is where the station supposedly documents the same repair on different vehicles again and again. The chances that any one repair is the one actually needed in so many cases makes the records dubious.

Centralized programs tend to vary considerably with regard to manual operations. In some cases, the only manual operations are verification of vehicle identification, probe insertion, and pressing a button. In other cases, especially where anti-tampering checks are conducted, manual operations can be significant. In these cases, more variation has been observed in the consistency of testing. This is especially a problem in programs that do uncontrolled high speed preconditioning. Subjective judgment must be used by the inspector in instructing the motorist to raise engine speed without the use of a tachometer. Centralized inspectors can also get sloppy with probe insertion, although the carbon dioxide check prevents excessive dilution of the sample.

The evidence from EPA and State overt audits indicates that some degree of improper testing occurs in every decentralized program, whether manual or computerized. The findings in centralized programs indicate that high levels of quality control are usually achieved, especially in the contractor-run systems.

3.3.2.3 Covert Audit Data

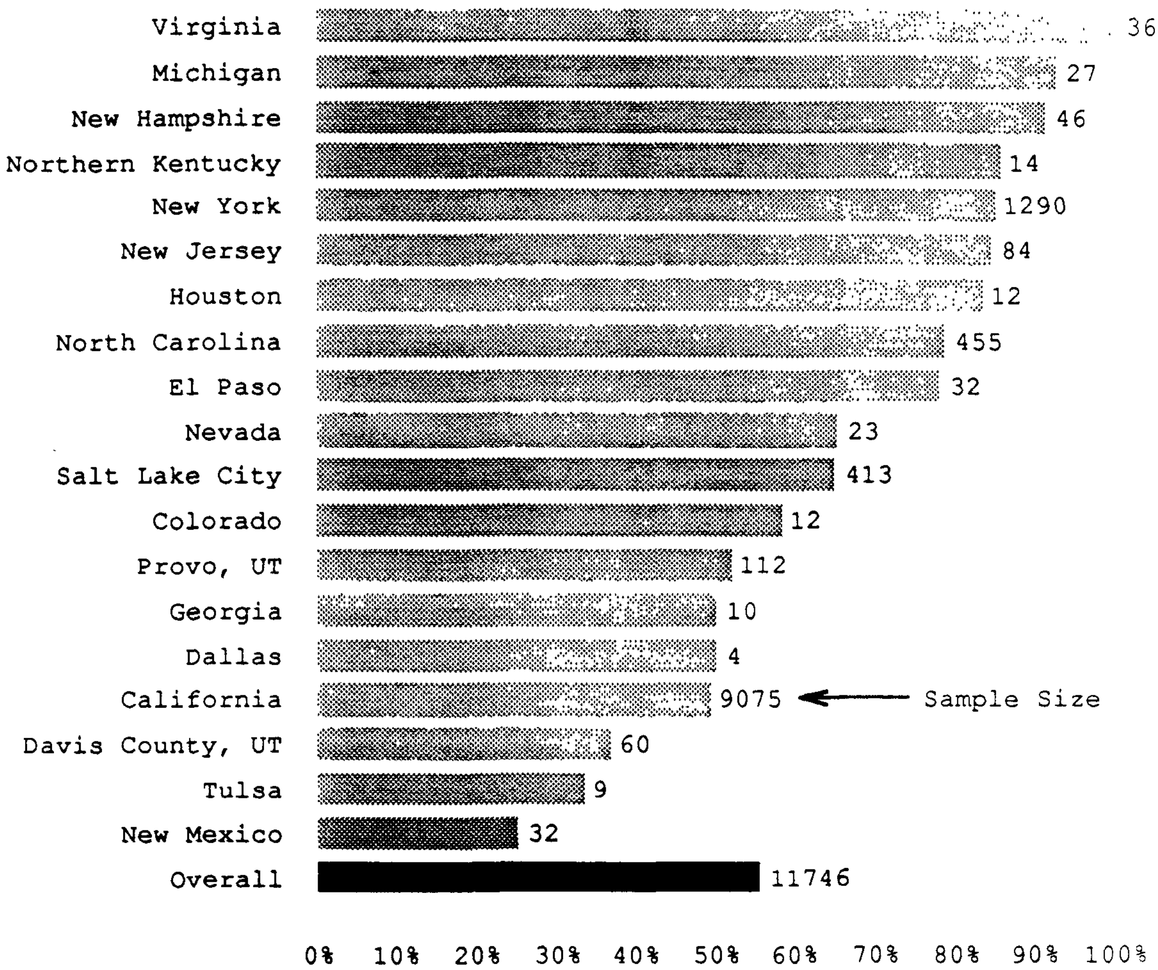
In addition to overt audits, many programs and EPA's audit program have initiated covert audits. These audits involve sending an auditor to a station with an unmarked vehicle, usually set to fail the emission test or the anti-tampering check. The auditor requests an inspection of the vehicle without revealing his or her true identity. Similarly, some programs have initiated remote observation of suspect inspection stations. Auditors use binoculars to watch inspectors working and look for improper practices. If problems are found in either of these approaches, enforcement actions are taken against stations. These audits serve to objectively assess the honesty and competence of licensed inspectors.

The findings from covert audits in 19 decentralized programs are shown in Figure 3-4. Note that the sample sizes vary considerably. The small samples represent covert audits conducted during an EPA audit. I/M program quality assurance staff and EPA auditors formed teams to conduct the audits. The large samples represent data on covert audits conducted by local I/M program staff. The stations visited are randomly selected, but the small samples may not be statistically significant (no attempt was made to obtain a statistically valid sample). Nevertheless, the samples reported by California, North Carolina, New York, and Utah represent large fractions of the station population and are likely to be representative. In any case, the results indicate a consistent pattern: that improper testing is found during covert audits in which the inspector does not know that his or her performance is being evaluated by an auditor. Improper testing has always been found to one degree or another whenever EPA audits have included covert efforts. The problems discussed in Section 3.3.1 are those encountered during these audits. As a result of the ability of covert audits to identify problems in I/M programs, covert auditing is being given a higher priority during EPA audits and EPA is encouraging programs to conduct such audits on a routine basis. It should be clear, however, that these are covert audits on the initial test. EPA is concerned that there does not appear to be a practical means by which covert audits can be done on retests. Covert audits have other limitations, as well. Covert vehicles and auditors must be changed frequently to avoid recognition. Experience indicates that inspectors are getting wise to covert audits and perform perfect inspections for strangers. Thus, the effectiveness of covert audits as a long-term quality assurance tool is questionable.

Covert audits have not typically been done in centralized programs. EPA included covert audits of the centralized and decentralized stations in the hybrid New Jersey program because overt audits showed problems with quality control. In 2 out of 8 State-run stations covertly audited in 1989, the vehicle was not failed for not having a catalyst, as it should have been. The same vehicle was used for covert audits of the licensed decentralized stations in New Jersey and 6 out of 8 stations did not fail the vehicle for a missing catalyst.

Figure 3-4

Fraction of Covert Audits Finding Improper Tests*
in Decentralized Programs



* Improper tests includes the full range of problems, including failure to conduct the test and use of improper procedures

3.3.2.4 Anecdotal Evidence

Anecdotal evidence and complaints derived from decentralized program managers and auditors, consumers, inspectors, and others are also primary sources. Reports of improper testing cover the full range of possibilities. Common anecdotes include failure to test the vehicle, probing another vehicle, raising the engine speed and not fully inserting probes into tailpipes. EPA and I/M program management are often alerted to improper testing at a particular I/M station by a concerned citizen. Another source of complaints and anecdotes is inspectors themselves. Inspectors complain about people who are test shopping, a practice which hurts the honest inspector. Inspectors have explained to covert auditors how they can get around the test program requirements. Forthcoming inspectors also tell of customers who try to bribe them or convince them to falsify results. When the inspector refuses, the customer simply announces that another station will surely comply with such a request. Sometimes, sharp inspectors have noticed vehicles they recently failed showing a current sticker but which are still in violation.

EPA has not been privy to similar anecdotal evidence in centralized programs. It is not clear whether that is because it does not exist or that because of the tighter control, EPA auditors are simply not given that information.

3.3.2.5 Waiver Rate Data

Most I/M programs issue waivers to vehicles that fail a retest but have met certain minimum requirements. Programs vary widely in what they require motorists to do before qualifying for a waiver, but the most common requirement is to spend a minimum amount of money on emission-related repairs. Table 3-7 shows the percentage of failed vehicles that get waived in programs that allow waivers and the minimum cost expenditure required.

A waiver represents lost emission reductions to the I/M program, so high waiver rates mean substantial numbers of vehicles that are high emitters are not getting adequate repair. Conversely, a truly low waiver rate indicates that maximum emission reduction benefits are being obtained. However, improper testing is, in a sense, a form of unofficial waiver that may be an alternative to the legitimate waiver system employed by programs. A low reported waiver rate by itself is therefore ambiguous with respect to program success.

Waiver rates tend to vary by program type to some degree. Centralized programs typically have higher rates and manual analyzer decentralized programs typically have lower rates. The centralized programs in Arizona, Delaware, Illinois, Indiana, and Wisconsin probably represent reasonable waiver rates. This is not to say that these limits are acceptable but all of these programs have good to excellent enforcement. Enforcement is important because there is no need to apply for a waiver if there is no threat from driving without an I/M sticker. These programs have established substantial procedural requirements for receiving a waiver,and try hard to limit waivers to only those vehicles that have met the requirements, in most cases. Given this, the waiver rates seen in these programs might be what one should expect from other programs.

Table 3-7

Waiver Rates in I/M Programs in 1989
(percent of initially failed vehicles)

Program	Pre-1981 Vehicles Waiver Rate[1]	Pre-1981 Vehicles Cost Limit[2,3]	Post-1980 Vehicles Waiver Rate[1]	Post-1980 Vehicles Cost Limit[2,3]
Decentralized Manual				
Davis Co., UT	13%	$60	7%	$150
Idaho	7%	$15	26%	$30
North Carolina	0%	$50	0%	$50
Provo, UT	3%	$15	4%	$100
Salt Lake City, UT	4%	$15	2%	$100
Decentralized Computerized				
Alaska	1%	$150	1%	$150
California	29%	$50	9%	$175-$300
Colorado	2%	$50	1%	$200
Dallas/El Paso, TX	na	$250	na	$250
Georgia	14%	$50	12%	$50
Massachusetts	na	$100	na	$100
Michigan	10%	$74	9%	$74
Missouri	11%	L	14%	L
Nevada	4%	$200	2%	$200
New Hampshire	na	$50	1%	$50
New York	na	L	na	L
Pennsylvania	2%	$50	1%	$50
Virginia	8%	$60-$175	3%	$200
Centralized Government				
Delaware	3%	$75	1%	$200
Indiana	10%	$100	13%	$100
Memphis	1%	$50	2%	$50
Centralized Contractor				
Arizona	12%	$200	12%	$300
Connecticut	5%	$40	4%	$40
Illinois	11%	L	11%	L
Louisville	17%	$35	12%	$30-$200
Maryland	20%	$75	19%	$75
Seattle, WA	21%	$50	22%	$150
Spokane, WA	9%	$50	9%	$150
Wisconsin	12%	$55	9%	$55

1 na = data not available
2 Some programs vary cost limits by model years and by pollutant failure; thus, some of the limits listed here are only typical of the model year group. Some programs do not have a set cost limit but required specific repairs, indicated by the letter L.
3 Except in Alaska and Utah, cost waivers are not given for tampering.

In decentralized programs, low waiver rates occur when it is inconvenient for either the motorist to obtain or the inspector to issue a waiver. In Colorado, an appointment must be made with a State representative to visit the station when the vehicle is present to issue the waiver. In North Carolina, the motorist must go to a State office to get the waiver. Alternative ways of avoiding an objective test become very attractive when this level of inconvenience is involved. Similarly, if the mechanic has to do extra paperwork, e.g., in Pennsylvania, the improper testing alternative is again more attractive. Effective January 1, 1990, California switched to a centralized waiver processing system. The data shown in Table 3-7 represent the combination of easy to get waivers and the aggressive enforcement against stations in California lead to waiver rates that would be considered typical given the cost limits.

Centralized programs are able to control the issuance of waivers to a high degree, but end up with higher waiver rates than are found in decentralized programs. This paradox results from the fact that it is usually very difficult to escape the test requirement in centralized programs. Lower rates are sometimes found when the enforcement system is not adequate and motorists faced with tough requirements simply choose to operate in a non-complying mode, e.g., Connecticut. Another factor that may be operative in some centralized programs (e.g., Seattle and Spokane, Washington) is that the program's geographic coverage is so constrained that it is relatively easy for an otherwise subject motorist to provide an address, for the purpose of vehicle registration, that places it outside the I/M area.

Thus, the potential for waiver control is very high in centralized programs that have high quality enforcement programs and adequate geographic coverage. High costs limits and other rigorously enforced qualification requirements are needed to keep waiver rates below 10% of failed vehicles. Waiver control in decentralized programs may not accomplish much since the alternative of avoiding an objective test is readily available.

3.3.2.6 Test Record Data

In an ongoing effort to identify techniques for finding and correcting operating problems, EPA has begun analyzing computerized test records from a variety of decentralized programs. The analyses involve looking at test histories of vehicles, especially comparing initial tests and retests. At this point, the analysis is still underway and the results discussed in this section represent a small part of the complete project. It is often difficult to calculate similar statistics because programs do not all record and store the same data. Thus, some of the analyses that follow were done on some programs but could not be done on others.

Three programs were analyzed to assess the rate of switches in model year between the initial test and a retest. An incorrect model year entry could mean that the wrong cutpoints are selected for a vehicle, since the computer automatically selects cutpoints based on model year. In decentralized programs, audits have found cases where the model year entry on an initial test was changed to an older year, yielding a less stringent cutpoint, and resulting in a test pass decision. Table 3-8 shows that a small amount of model year switching between initial and retest occurred in all three programs.

Naturally, some level of error is to be expected in any program. However, higher rates of switching were found in the two decentralized programs as compared with the centralized program.

There is no reason an inspector must wait for a retest to input an incorrect model year, so Table 3-8 may not reflect the true problem. The incidence of incorrect model year entries on first tests was therefore also analyzed for Pennsylvania by comparing the vehicle identification number with the model year entry. Only 1981 and later vehicles were analyzed because these are easily distinguished by the standardized 17 character VIN that went into effect for that model year. The data revealed that 6.4% of the 1981 and later vehicle records had model year entries that were pre-1981. This means that looser emission standards were being applied for these tests.

Table 3-8

Model Year Switching Between Initial and Retests

Program	Network Type	Sample Size	Number Switched	Percent Switched
Connecticut	C	1949	20	1.0
New Hampshire	D	3632	67	1.8
Pennsylvania	D	4958	156	3.1

Another data element analyzed was the $CO+CO_2$ scores from initial test failures and retest passes on the same vehicles. Test histories of vehicles failing the initial test were constructed and the dilution levels were compared between initial and retest in New Hampshire and Wisconsin. (Pennsylvania was not included because test time is not recorded, making it difficult to determine the actual final test). These I/M programs accept as valid any $CO+CO_2$ measurement above 6%. A vehicle with no exhaust leaks and no air injection system has a $CO+CO_2$ level of about 14%. Table 3-9 shows the fraction of vehicles in the sample that were below 8% $CO+CO_2$ on the initial test and the retest. On the initial test about 12% of the vehicles in Wisconsin and about 10% of the vehicles in New Hampshire scored below 8%. On the retest, the number of vehicles scoring below 8% nearly doubled in New Hampshire to 19% of the vehicles, while the number was essentially unchanged in Wisconsin. This analysis, while in no way conclusive, is consistent with what audits and anecdotes are telling us about intentional sample dilution in decentralized programs.

The time that elapses between an initial test on a vehicle and a retest is another aspect that EPA is investigating. An analysis of New Hampshire data indicates that about half of all failed vehicles get retests within ten minutes of the initial test. The overall average time between initial and retests is only 11 minutes. Presumably, if an inspector fails a vehicle, and then does diagnosis and repair on that vehicle, one might expect a longer amount of time to have elapsed. Covert audit experience indicates that inspectors in decentralized stations have performed multiple tests on a vehicle that initially fails in an attempt to get a passing score without any diagnosis or repair.

Table 3-9

Vehicles With Dilution Levels Below 8%

Program	Sample Size	Initial Test Failures Below 8%	Retest Passes Below 8%
New Hampshire	390	10%	19%
Wisconsin	503	12%	11%

3.3.3 Conclusions

The available evidence shows that objectivity and quality of testing and the accuracy of instrumentation differ by program type. It was previously found that decentralized programs using manual analyzers suffered from severe quality control problems both in testing and instrumentation. At this point, only one manual program has not committed to switching to computerized analyzers.

Decentralized programs using computerized analyzers represent a substantial improvement over manual systems. Analyzer quality control is better, but EPA audits still fail about 20-25% of the analyzers checked. The gross level of errors made by inspectors and the influence of incompetent inspectors are far less because software controls some aspects of the test and determines some of the major decisions about the outcome.

Computerized decentralized programs seem to have substantial failure rates, much closer than before to what we would expect based on the emission standards being used and the vehicle mix being tested. Nevertheless, we observe improper testing during audits, and program records describe in detail cases discovered by program auditors. Improper retests are certainly problematic since these are vehicles that have already been found to need repair. Thus, improper testing of these vehicles directly impacts the emission benefit of the program.

At this point, the information available on improper testing in decentralized programs is sufficient to conclude that a problem definitely exists. Where waivers are cheap and convenient, the waiver rate is typically about 10-20% in both centralized and decentralized programs. Improper testing is a cheap and convenient alternative in the decentralized programs where waivers are not readily available, and for some vehicles easier than a true repair. It may be optimistic to think that more than 60-80% of high emitting vehicles are actually repaired in any decentralized computerized analyzer program. The actual percentage may be more or less, but it is difficult or maybe impossible to accurately determine. Detecting improper testing is extremely difficult because of the ways in which it occurs. It is relatively easy to catch the gross violators using covert vehicles set to fail the test, as EPA and State experience shows. But, some stations simply will not test vehicles for other than regular customers. Cautious inspectors may not do an improper initial test for strangers. Doing covert audits at new car dealerships presents formidable problems; usually, only regular customers who purchased a vehicle from the dealer would get tested at the dealership. Conducting an evaluation of improper retesting would require purchase of repairs and subsequent retesting, driving the cost of quality assurance higher. Given these problems, it may be too difficult for most State programs to adequately quantify the incidence of improper testing.

The question arises about what can be done to deal with the vulnerability of decentralized computerized programs to improper testing. It is unlikely that test equipment can be developed that will completely prevent improper testing, at least not at a reasonable cost. Improvements are being made in the form of the "BAR-90" equipment and software, but programs that have adopted the updated equipment have experienced costs about 2-3 times the price of "BAR-84" equipment of about $6000 - $7000. Nevertheless, even these improvements will not prevent improper testing in decentralized computerized programs.

Another way to address the problem is through more aggressive quality assurance and enforcement. More intensive covert and overt auditing and more sophisticated data analysis will enhance identification of problem stations and inspectors. Obtaining funding for additional auditors, covert vehicles, computers, programmers, analysts, judges, etc. will have to be given a priority even in the face of tight government budgets.

Streamlined administrative procedures and broader legal authority for suspending or revoking station licenses and imposing fines will also help rid programs of problem stations and inspectors. Most decentralized programs face major obstacles in trying to get rid of problem stations once they have identified them. Administrative procedures requirements saddle program managers with difficult and expensive barriers. Convincing judges to impose significant penalties or to suspend stations for a substantial amount of time are considerable problems. Furthermore, permanently barring specific individuals from a program is more difficult. Decentralized programs will have to put more financial and good will resources into this aspect of quality assurance.

Some, but not all, centralized government-run programs have suffered from improper testing although for different reasons than decentralized programs. Unlike the situation in decentralized programs, it has been easier to gather sufficient evidence to quantify the emission reduction loss from poorly run programs. Ultimately, the problems found in these programs can be resolved and high quality results can be obtained. The solution is better management and equipment, more computer controls and expanded test capacity. EPA is working with the remaining problem government-run programs to upgrade their systems to achieve better results.

Contractor-run centralized I/M programs do not seem to suffer from serious improper testing problems as far as we can tell. The efficient management and thorough computer control of these programs eliminate nearly all opportunities for improper testing.

Even with all the possible improvements, decentralized programs will have a more uncertain measure of their own effectiveness than centralized programs, due to the greater possibility of continuing but invisible test irregularities.

3.4 Visual and Functional Inspections of Emission Controls

3.4.1 Background

EPA provides State Implementation Plan emission reduction credits for the inspection of certain emission control components. The inspection involves determining whether the emission control device is present and properly connected. The components for which credit is available are the catalytic converter, air injection system, PCV valve, evaporative canister, EGR valve and gas cap. Additional credit is given for misfueling checks: requiring catalyst replacement if the fuel inlet restrictor is tampered or if there is evidence of lead deposits in the tailpipe.

Implementation of anti-tampering inspections has varied widely among I/M programs, as can be seen in Table 3-4. Of course, anti-tampering inspections are a completely manual operation. They depend upon the skill and the persistence of the inspector to find components and make the determination that they are properly connected. While this is fairly easy for the catalyst and misfueling checks, finding underhood components can be difficult. The configuration of components varies from make to make and even among models from the same manufacturer. Thus, inspector training is an essential component of an anti-tampering program.

With the cooperation of State and local governments, EPA has conducted roadside tampering surveys of motor vehicles in cities throughout the country each year for the past 10 years. These surveys provide information about national tampering rates and trends in tampering behavior. The surveys also provide EPA with the basic information needed to estimate the emission reduction potential of a program. In addition, they provide information on local tampering rates.

There are two components to the emission benefit attributed to I/M programs that relate to tampering. Anti-tampering inspections are supposed to identify and correct existing tampering when the program starts. Also, tampering programs are supposed to deter new intentional tampering both on existing vehicles as well as new vehicles entering the fleet. As it turns out, emission testing programs have the latter effect as well. Because of the difficulty in determining whether a vehicle actually exhibits tampering, the emission reduction benefit includes an assumption that not all tampering will be identified and corrected. In the past, this concept applied equally to centralized and decentralized programs.

Until 1984, when California and Houston, Texas began comprehensive anti-tampering programs, Oregon was the only program that inspected the complete range of emission control components (see Table 3-4 for details). A few other decentralized programs were doing comprehensive emission control checks, but only as part of pre-existing safety inspection program and no emission reduction credit was being claimed. Texas and California were formal programs and the emission reduction credit assigned to these systems was based on the experience in Oregon.

Improper anti-tampering testing is as much if not more of a problem in I/M programs than improper emission testing, since the process is completely manual. The same opportunity exists for irregularities as with tailpipe testing, with no greater ability by the program to detect them. Decentralized inspectors have many of the same motives for improperly inspecting a vehicle for tampering as they do for omitting or improperly conducting an emission test.

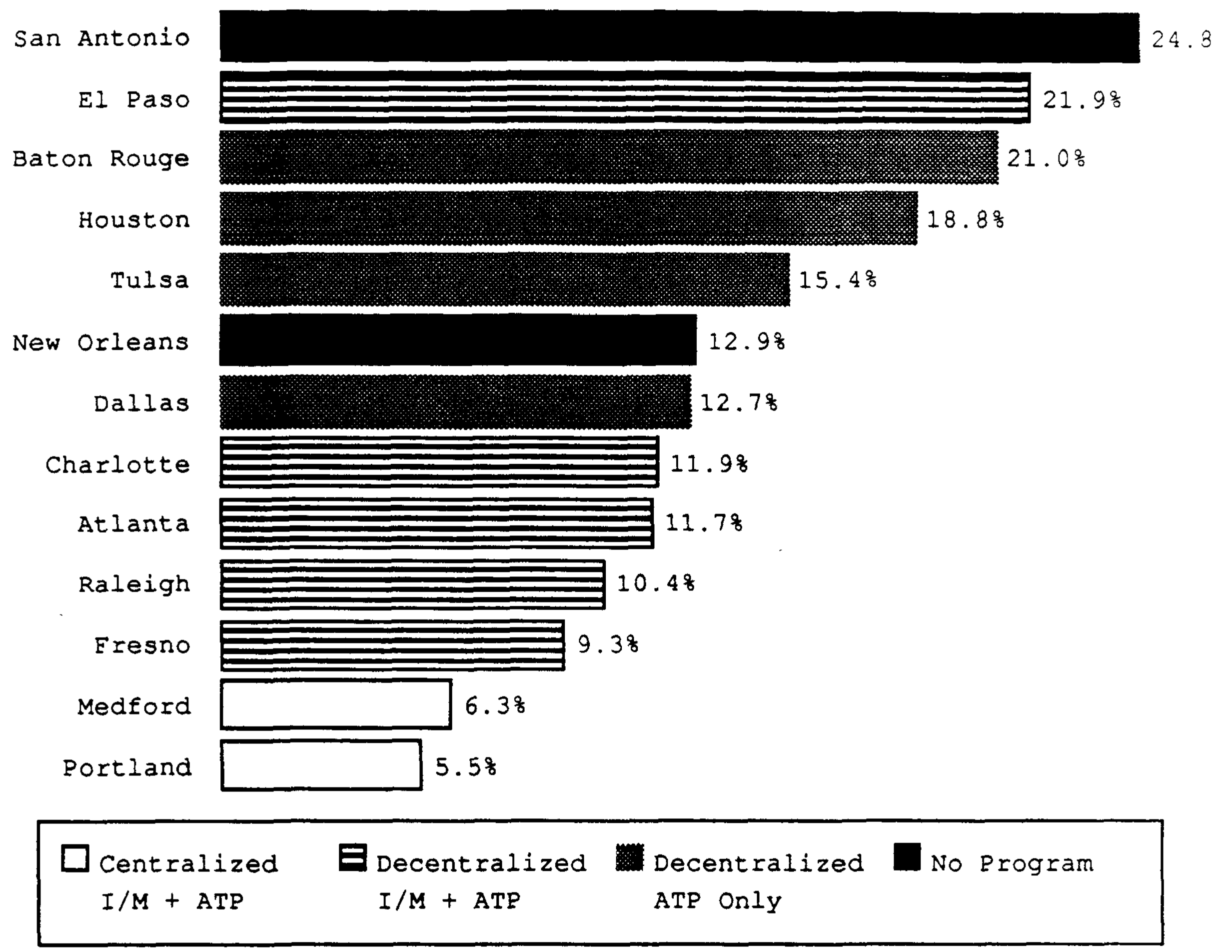
Centralized programs are also subject to improper anti-tampering checks. Unlike emission tests, the tampering check is completely manual and relies on the honesty, attention to detail, and competency of the inspector to be performed correctly. Centralized programs may benefit from the presence of on-site supervision, the importance to the contractor or agency of maintaining a public image of being accurate and impartial, and by the opportunity for inspectors to become more familiar with underhood geometries due to their constant exposure. At this point, Oregon is the only centralized program that has been conducting comprehensive tampering checks long enough to be fairly evaluated, in terms of fleet-wide tampering rates. Nevertheless, observations of tampering checks in the centralized lanes in Arizona and New Jersey provide additional information about potential effectiveness and will be discussed where appropriate.

3.4.2 Supporting Evidence

Tampering surveys conducted by EPA are the main source of tampering rate information. Comparing programs is difficult since the model year and emission control component coverage varies widely among programs. Even a perfect program would not eliminate all tampering since inspections are spread over one or two years (in biennial programs) and the fleet is constantly changing. Immigration of vehicles from outside the program area is one source of "new" tampering. Also, as vehicles age the likelihood of either passive or intentional tampering increases. Thus, an ongoing program is needed to control these problems, and we expect to see at least low levels of tampering whenever a survey is conducted.

Figure 3-5

Overall Tampering Rates in Select I/M Programs*



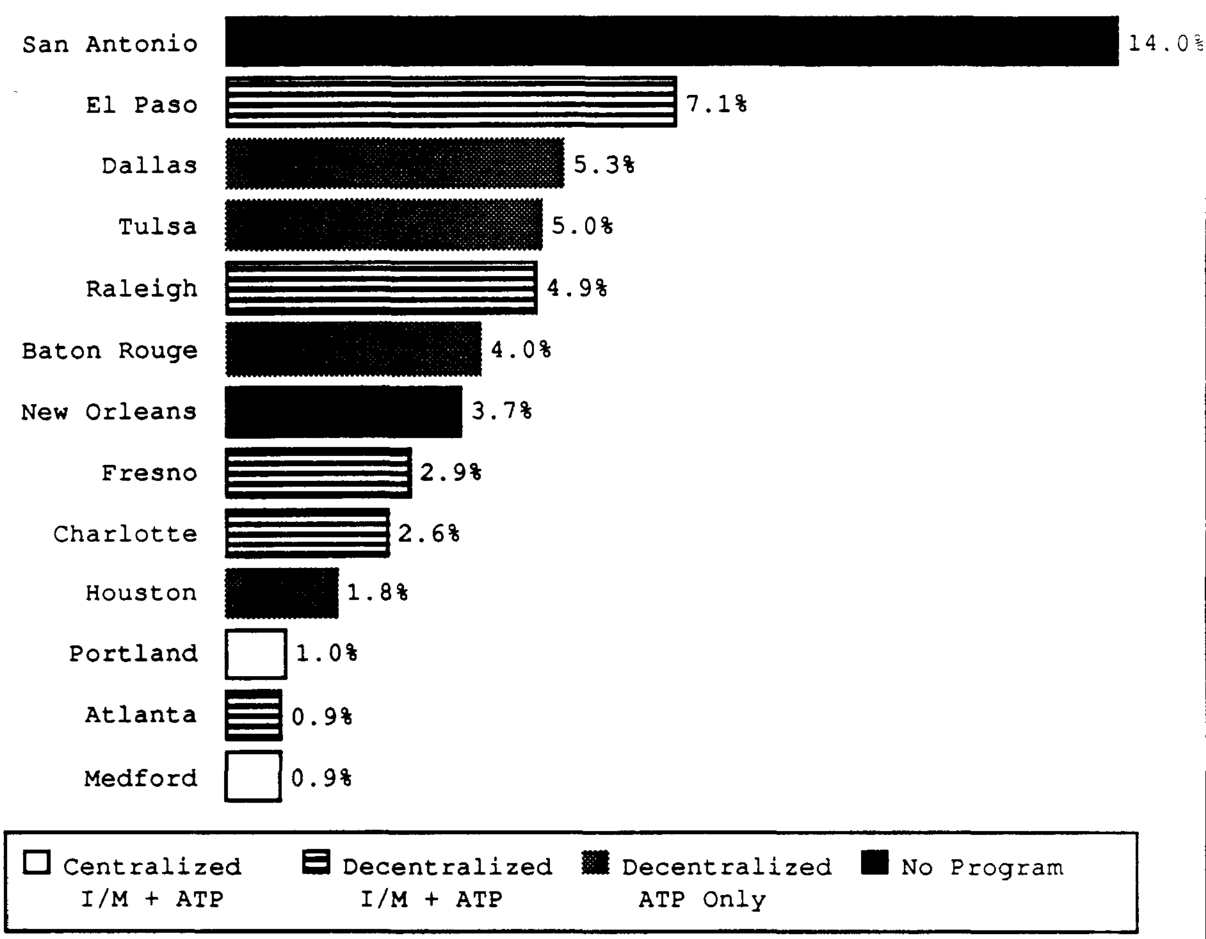
* The rates shown here are for catalyst, inlet, air, PCV and evaporative system on 1980 - 1984 vehicles. Programs listed inspect and have been doing so for at least two years at the time of the survey.

Figure 3-5 lists all programs that were operating for at least two years at the time of the survey and inspecting at least the 1980 - 1984 model years for catalyst, inlet, air injection system, PCV and evaporative canister. The analysis was limited to these model years and components to establish a fair basis for comparing results. Two no-program areas are included for reference and the rates are all from 1987 and 1988 surveys. Decentralized anti-tampering-only programs still show high overall tampering rates and appear to be at most about 65% effective (Dallas) compared to the extremes of San Antonio and the Oregon sites. Decentralized I/M + anti-tampering programs have lower tampering rates (except for El Paso) but not as low as in the Oregon cities.

Given the model years and survey years involved, it may be that the I/M tailpipe test requirement has played a role in deterring tampering in the combined programs, rather than the tampering check being successful in getting tampering fixed once it has occurred. At this point, the Oregon program is the only one that serves to represent centralized I/M anti-tampering effectiveness. The low rate in Portland may also reflect deterrence more than detection but that cannot be said of Medford since the program there started much later, in 1986. When the analysis is limited to catalyst and inlet tampering, decentralized programs appear to be more effective at finding and fixing this tampering, as shown in Figure 3-6. This may reflect the lower skill and effort required to detect these types of tampering, or the higher cost and therefore profit associated with repair.

Figure 3-6

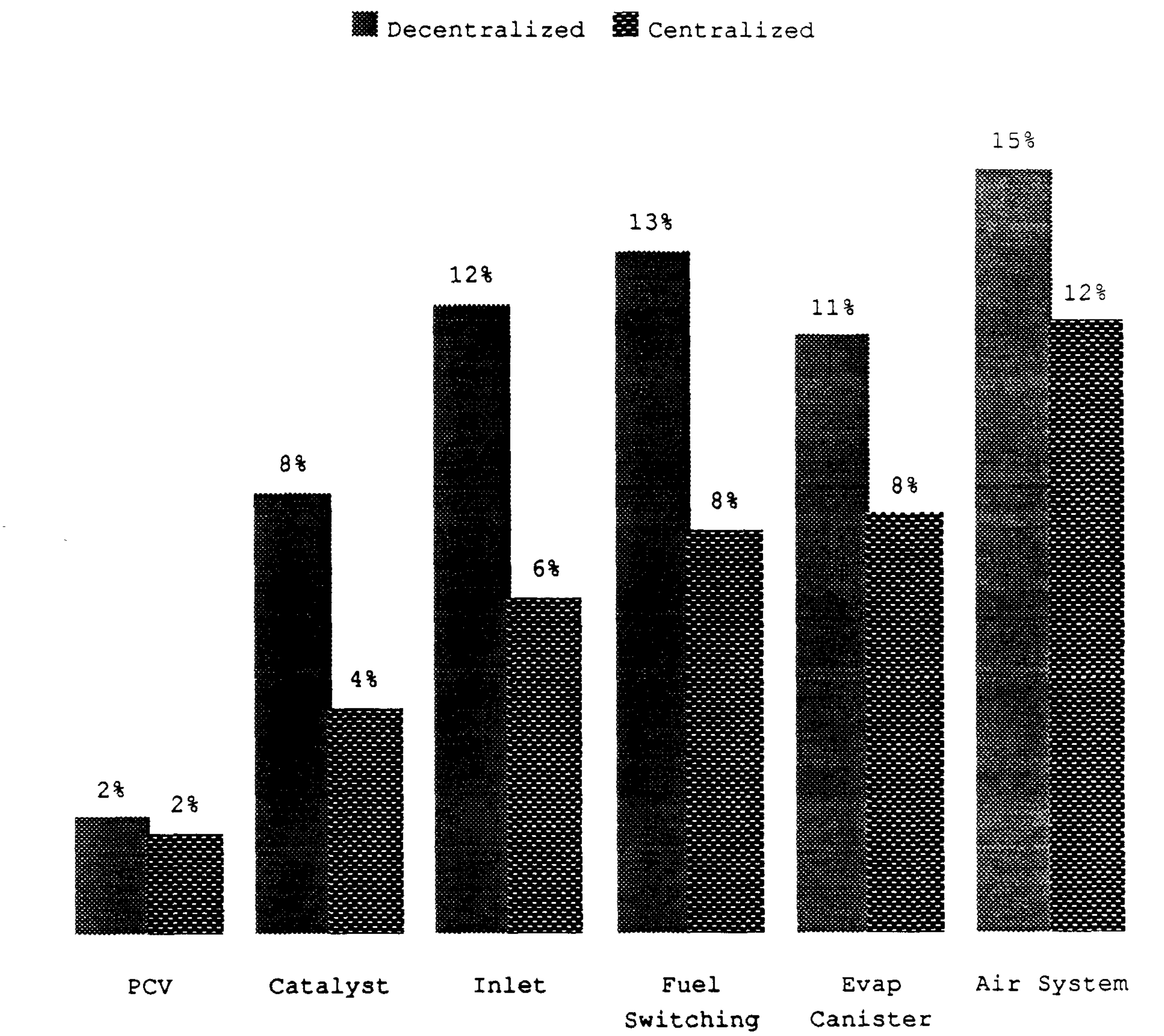
Catalyst and Inlet Tampering Rates in Select I/M Programs*



* The rates shown here are for catalyst and inlet tampering 1980 - 1984 model year vehicles only.

Figure 3-7

Tampering Rates in Decentralized and Centralized Programs*

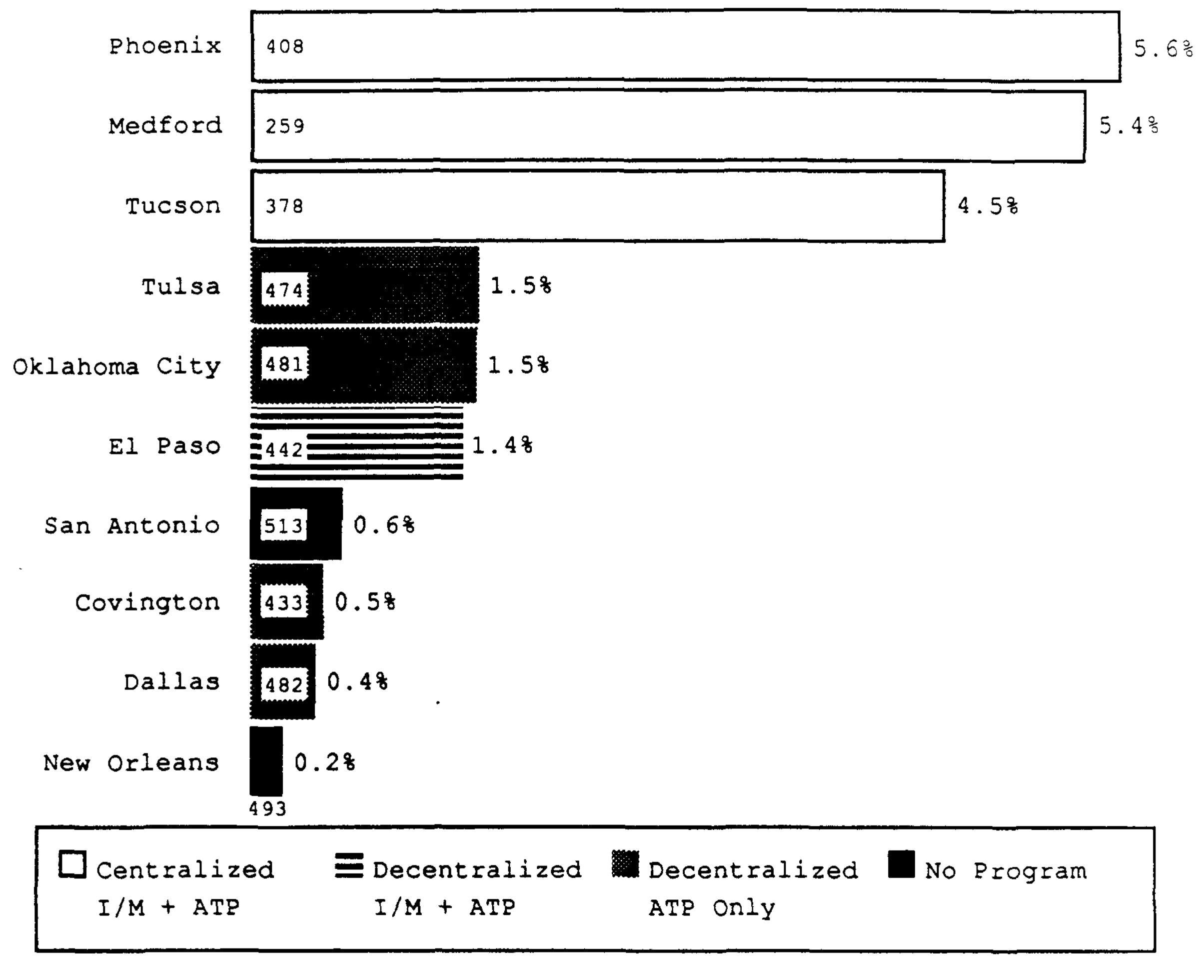


* The rates shown here are for 1975 - 1983 model year vehicles only in the 1987, 1988 and 1989 tampering surveys..

Tampering rates may be an indicator of the effectiveness of emission testing, with or without tampering checks. Figure 3-7 shows the combined tampering rates by component from the surveys in 1987-1989 for model years 1975-1983. The tampering rates are lower in the centralized I/M programs for catalyst, inlet and fuel switching. Underhood tampering shows a less dramatic difference but is still lower in centralized programs, despite the fact that only two of the seven centralized programs represented in the survey do underhood tampering checks. Only one decentralized program represented here does no tampering checks at all.

Figure 3-8

Aftermarket Catalyst Usage in Anti-Tampering Programs*

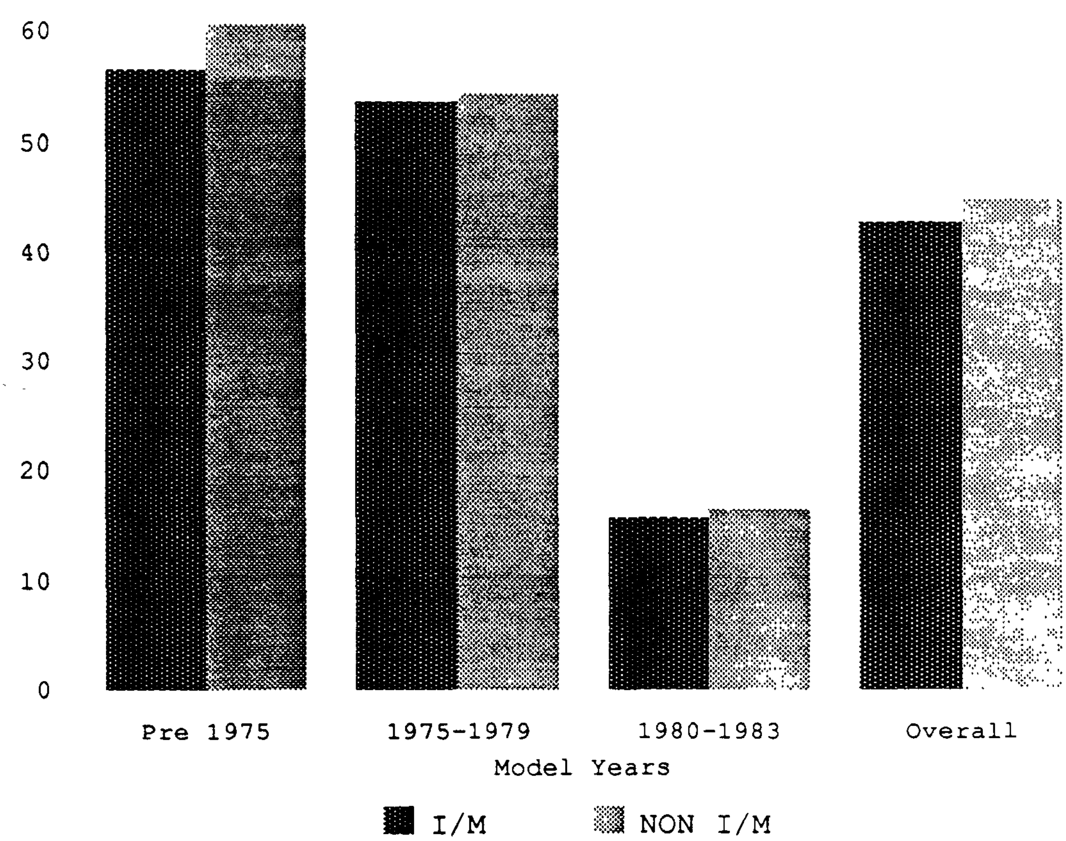


* All of the operating programs listed here started in January 1986 except Phoenix, Tucson, and Oklahoma City which started in January 1987. The sample size is the number listed inside the bar.

Another indicator of the effectiveness of anti-tampering programs is the frequency with which aftermarket catalysts are found during tampering surveys, i.e., evidence of actual replacement of catalysts. Since aftermarket catalysts are much cheaper than original equipment manufacturer parts, one would expect them to be the replacement of choice in all programs. Figure 3-8 shows the findings for aftermarket catalysts from areas with catalyst inspections that started operation after 1984. Programs that started earlier mostly have been causing owners not to remove their original catalysts, not making them replace ones already removed. Also, prior to 1985, anyone wanting to replace a catalyst would not have been able to buy an aftermarket catalyst. The three centralized programs show relatively high rates of aftermarket catalyst installation. On the other hand, the decentralized programs show relatively low rates of aftermarket catalyst usage, in some cases no different than non-I/M areas.

Figure 3-9

Tampering Rates in I/M and Non-I/M Areas in California

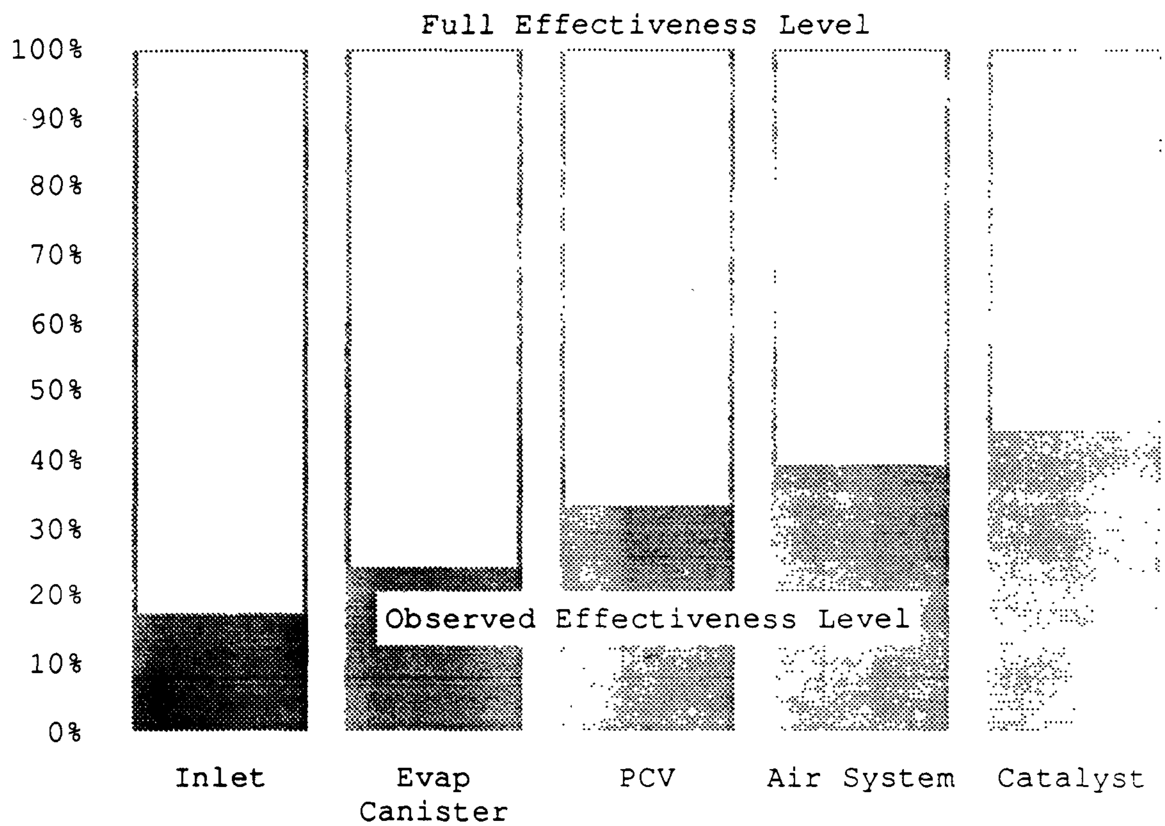


A variety of sources of data on decentralized anti-tampering programs are available. California has done extensive review and evaluation[10] of its decentralized biennial program, which started in the major urban areas around the State in 1984. The study used a variety of techniques including roadside tampering surveys. One of the many important findings of this study was that roadside tampering rates for the items checked in the I/M test did not differ substantially between the vehicles that had already been subject to I/M and those that had not. It should be noted that California uses a broader definition of the term "tampering" for both its survey and I/M checklist than that used by EPA; thus, the overall rates are not comparable to EPA's national survey rates. These results are illustrated in Figure 3-9.

In addition to the survey data, audits of decentralized anti-tampering programs find improper inspections. Covert investigations continually find that inspectors fail to check for components, fail to fail tampered vehicles, and sometimes fail to do the inspection at all. California's covert auditing work indicates that licensed inspectors neglect to fail tampered vehicles in the majority of cases. Figure 3-10 shows the results by component. During EPA overt audits in decentralized programs, inspectors have been asked by auditors to demonstrate an inspection, and are frequently unable to do the check correctly, either neglecting to check for one or more components or improperly identifying components.

Figure 3-10

Frequency of Proper Tampering Tests
in California's Covert Audit Program



In contrast to the apparent ineffectiveness of decentralized tampering programs, the success of the centralized Oregon program can be seen during audits of the program. The inspection system is well run and the inspectors, employees of the Department of Environmental Quality, are highly trained and perform the inspections diligently. By contrast, EPA's observations of the centralized lanes in New Jersey have found that inspectors sometimes neglect to check for the presence of catalysts, the only component they are supposed to check. Management oversight and motivation of inspectors is not adequate in that program. New Jersey has historically low tampering rates, so roadside surveys are of only limited use in evaluating program effectiveness there. Arizona, Wisconsin, and Maryland also recently started anti-tampering inspections, the first contractor-run systems to do so.

3.4.3 Conclusions

Based on the evidence that decentralized anti-tampering inspections were not resulting in tampered emission controls getting repaired to the degree expected, EPA reduced the emission reduction benefit (in MOBILE4, for purposes of approving post-1987 SIPs) associated with them by 50%, unless a specific program demonstrates better performance. Centralized tampering programs, except in New Jersey, seem to be working about as well as expected, but additional survey work needs to be done in centralized programs that have recently started anti-tampering inspections.

The potential for effective anti-tampering checks in centralized and decentralized programs is influenced by basic constraints. In the decentralized systems, there is less concern about throughput, but inspection quality seems inherently limited by the difficulties of imposing high levels of quality control. In centralized systems the time it takes to conduct the inspection is a major constraint leading most programs that have started anti-tampering checks to do only the catalyst, inlet and sometimes the air system. It should be noted that these three checks obtain 58% of the potential HC and 85% of the potential CO benefit of visual anti-tampering checks. Furthermore, the remaining available checks are all for underhood components which require considerable expertise and care in inspection. Given this, limited but effective centralized checks may result in greater emission reduction benefits than the comprehensive but largely ineffective decentralized checks. It is not known if decentralized program performance could be significantly improved by limiting the tampering check to the easily found items and focusing enforcement and educational resources on those items.

The magnitude of training differs sharply between centralized and decentralized programs. Depending on the size of the system, the number of licensed inspectors in a decentralized program can range from a few hundred to over 10,000. Centralized programs range from a few dozen to a couple of hundred inspectors. So, just the physical magnitude of the training requirements for anti-tampering inspections can be daunting in a decentralized system, which partly explains why EPA audit findings show that inspector proficiency is an ongoing problem in decentralized programs.

4.0 PROGRAM COSTS

4.1 Inspection Costs

Just as there is a wide range of I/M program designs, there is also a wide range of program costs. In every case, there are expenditures related to establishing inspection sites, purchasing equipment, labor associated with conducting the inspection, and program oversight. But the actual level of expenditure seems to be most related to the age of the inspection network, and to the centralized/decentralized choice.

To compare the full cost of different I/M designs, EPA collected and analyzed data from as many I/M programs as could provide four basic pieces of information for calendar year 1989: I/M program agency budget, number of initial tests, the fee for each test, and the portion of the test fee returned to the State or local government. Using these parameters, EPA calculated an estimated cost per vehicle in 33 I/M programs currently operating around the country. The results are displayed in Figure 4-1.

Decentralized computerized programs have the highest costs, averaging about $17.70 per vehicle, as shown in Figure 4-2. Removing the two highest cost areas (Alaska and California) reduces the average to $13.41. These two programs are much more expensive due to larger fees retained by the two States for aggressive program enforcement, higher labor and material costs, in Alaska especially, and a more involved and complicated test in California. Decentralized programs with manual inspections incur lower costs at an average of $11.60. Most decentralized programs cap the test fee, which may not represent the full cost to the station or, eventually, the public. Centralized contractor-run programs average $8.42 per vehicle, and centralized government-run programs claim the lowest costs at $7.46 per vehicle (the latter figure is somewhat uncertain because detailed budget information is not often available).

Figure 4-1

Cost Per Vehicle of I/M Programs

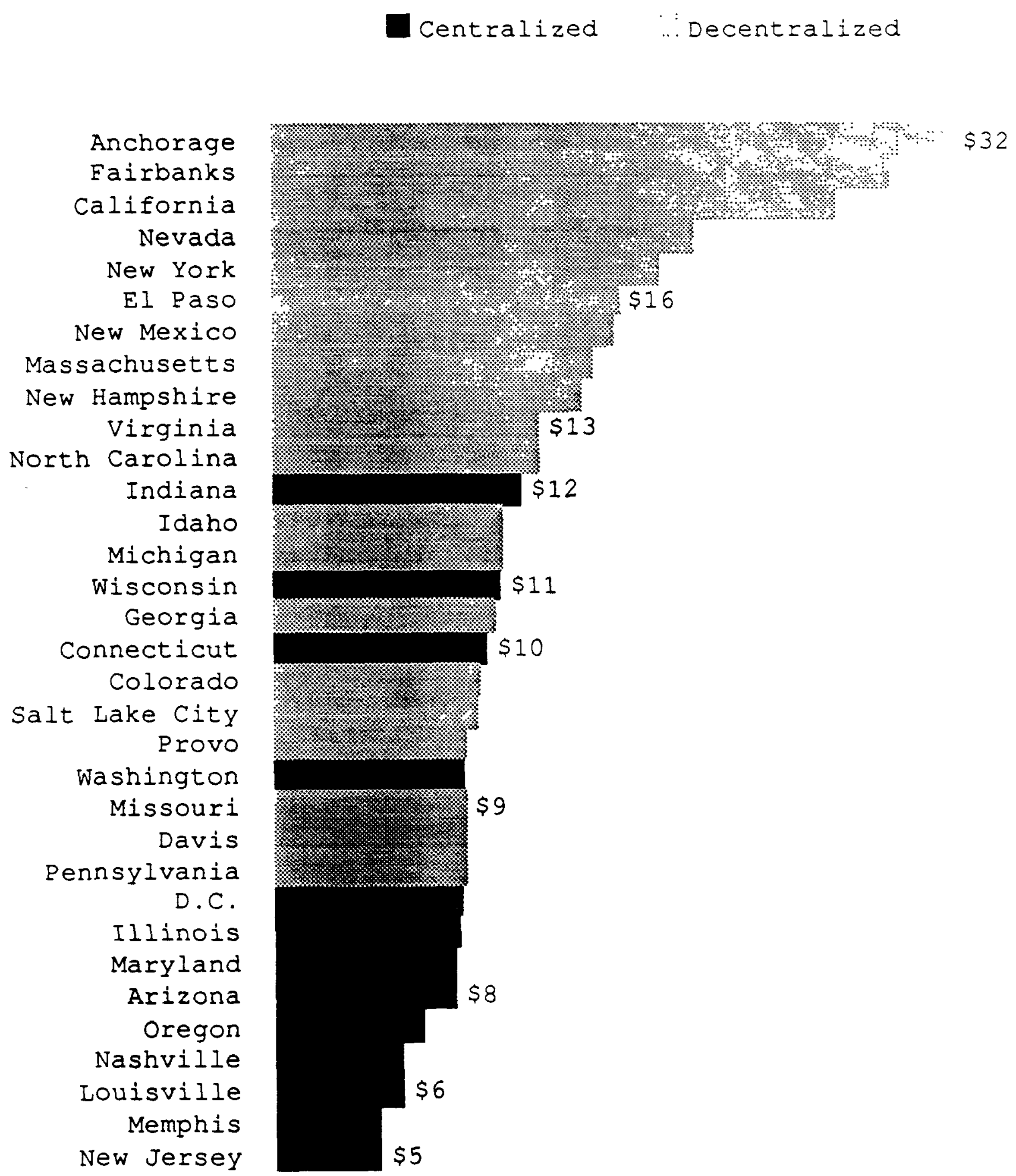
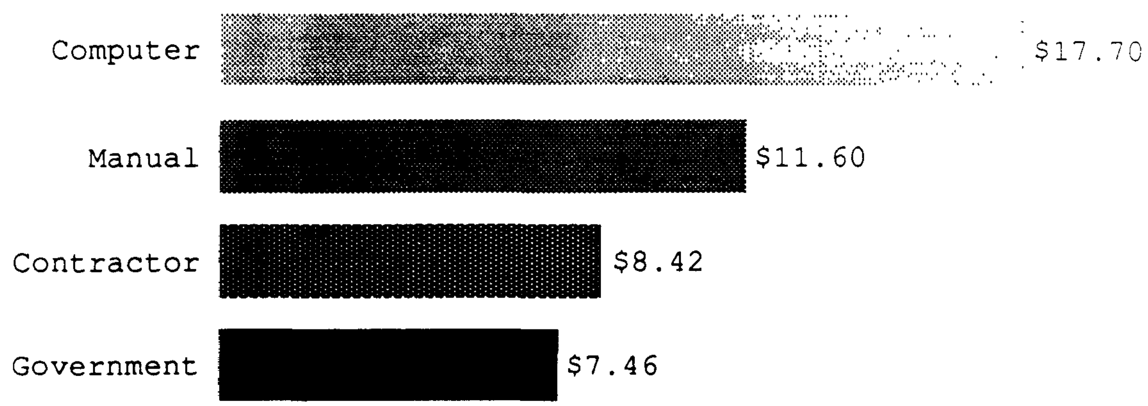


Figure 4-2

Cost Per Vehicle By Network Type



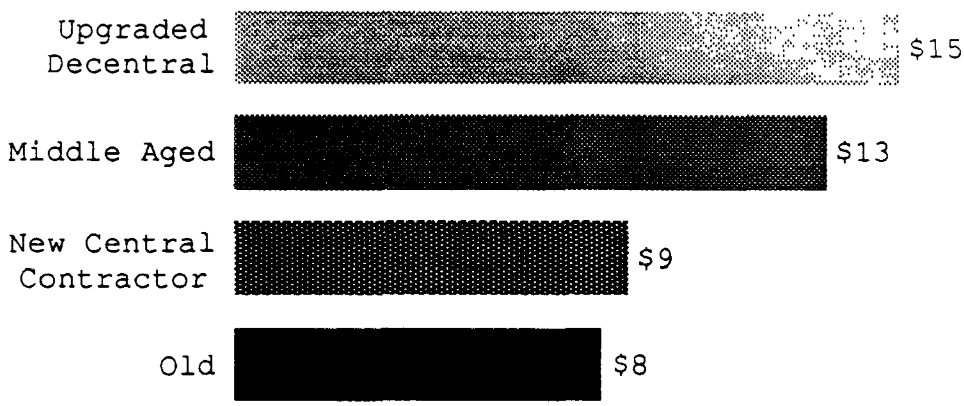
There is also a relationship between the age of a program and its inspection fees. Older programs that added I/M to existing safety systems have amortized the infrastructure costs and tend to utilize old technology in the inspection process. These programs come out cheapest, but at a price. They have neither the capacity nor equipment capability that matches the demand created by a growing population of vehicles.

The middle aged programs generally came on line after computerization was in full swing and tend to be more sophisticated. In this category, centralized and decentralized systems tend to experience similar costs - around ten dollars.

In the newest programs, and in those where a transition is occurring from manual to computerized analyzers, a divergence appears. The increasing sophistication and growing expertise in operating centralized testing networks, along with growing competition among centralized contractors, has tended to keep costs stable, or even decreasing in some cases. At the same time, the increase in mechanic labor costs and the requirement that garages purchase new, more sophisticated testing equipment has caused the fees in upgraded decentralized programs to rise significantly. A comparison of the average fees for programs of different ages is shown in Figure 4-3.

Figure 4-3

Cost By Program Age

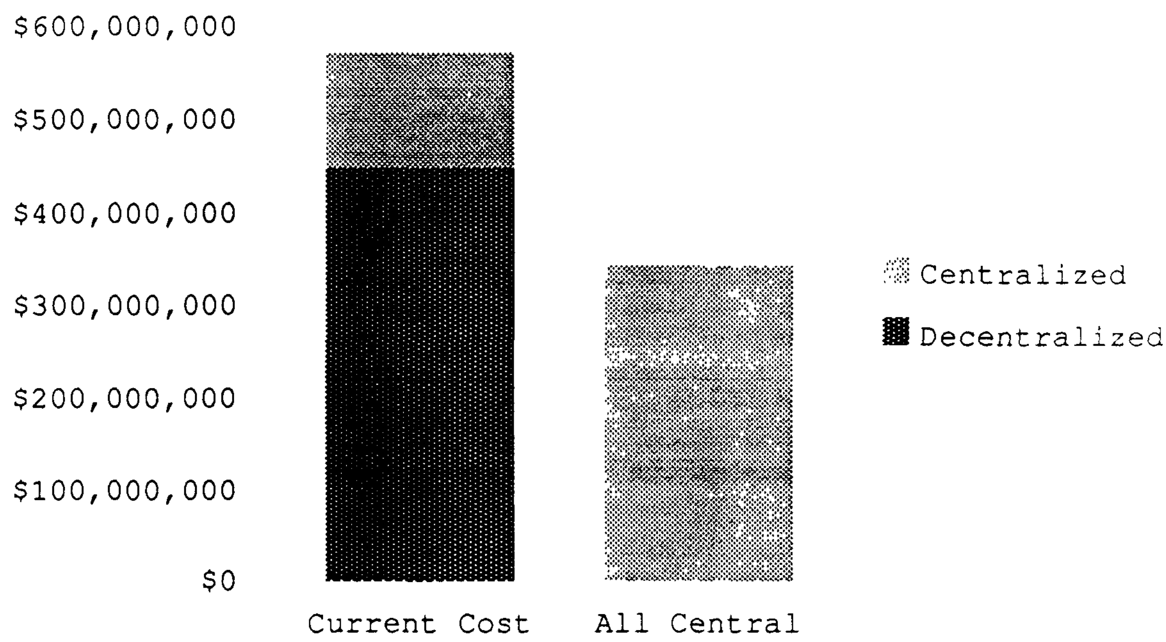


The ability of "new" centralized programs to provide inspections at a lower cost is well illustrated by the following example. The cost of inspections in Arizona's centralized, contractor-run program recently dropped from $7.50 to $5.40. The decrease resulted from the competitive bidding process that ensued when Arizona issued a new RFP for the program. The decrease occurred despite substantial improvements in the quality, quantity, and range of equipment and services called for in the new contract. The changes include all new test stations and test equipment. Expansion of the network to include an additional station and 14 additional lanes. Test station hours are expanded on Saturdays. There are three lanes for testing heavy duty vehicles rather than two. Finally, the contractor built and staffed a new referee station, and all of the other State referee stations were upgraded with new equipment. The open market process associated with contractor operated systems has forced suppliers to innovate technically, allowing these reductions in cost.

If we assume that all I/M programs in the country were centralized and that the inspection and oversight costs would be the same as the average of current centralized programs, the national cost of I/M would be about $230 million less than the cost in 1989. Figure 4-4 shows the total current cost of I/M to be about $570 million. If all programs were central, at today's average cost per vehicle in centralized programs, the national cost of I/M would be $340 million. It may be the case that the per vehicle cost in some decentralized programs, such as the one in California, would be higher than the current national average if it switched to centralized testing. Thus, the potential savings may not be as high as $230 but likely would be substantial.

Figure 4-4

Nationwide Inspection and Oversight Cost of I/M
Currently and if All Programs Were Centralized



4.2 Repair Costs

Repair expenditures are also a legitimate cost of I/M. But, regardless of the inspection network, the repairs will be performed in the same way - either by the vehicle owner or by a professional mechanic. Any difference in the cost of similar repairs should be attributable to the relative efficiency of different mechanics or to differences in shop labor rates, rather than where the initial test was conducted.

Repair cost information is collected only sporadically in decentralized I/M programs, and is unreliable. Generally, programs do not require cost data to be entered into the record unless the vehicle is to get a waiver. Only a few centralized programs collect cost data. These programs generally require motorists coming in for a retest to provide cost information. Thus, while some reliable repair cost data exists for centralized programs, an analysis of the difference between centralized and decentralized repair costs is not possible.

It may be that total repair costs are higher in centralized programs, since improper testing in decentralized programs allows some vehicles owners to avoid needed repairs. One should bear in mind, however, that decentralized programs put more vehicle owners in a situation in which they may be persuaded to obtain repairs and maintenance services they do not need or would otherwise have purchased elsewhere. In a 1987 public opinion survey[14], sixteen percent of motorists living in four decentralized program areas reported that while their vehicle was being tested, service technicians recommended or suggested other services such as tune-ups, brakes, or tires. Forty-three percent of the motorists who had services recommended believed that they were not really needed.

4.2 Conclusions

Inspection and oversight costs of I/M programs differ widely among programs. Decentralized programs are more expensive than centralized programs, in nearly all cases. The average cost of decentralized computerized analyzer programs is about double the cost of centralized contractor systems. The national cost of I/M could be substantially lower, on the order of $200 million less, if all programs were centralized.

5.0 CONVENIENCE

The relative convenience of decentralized vs. centralized I/M is an issue that should concern policy makers because inconvenience and lost time can be the most negative impact of an I/M program on the public, and it is important that the program be accepted by the public. The factors influencing the convenience or inconvenience of an I/M program are station location, hours of operation, required number of visits, waiting time, and certainty of service.

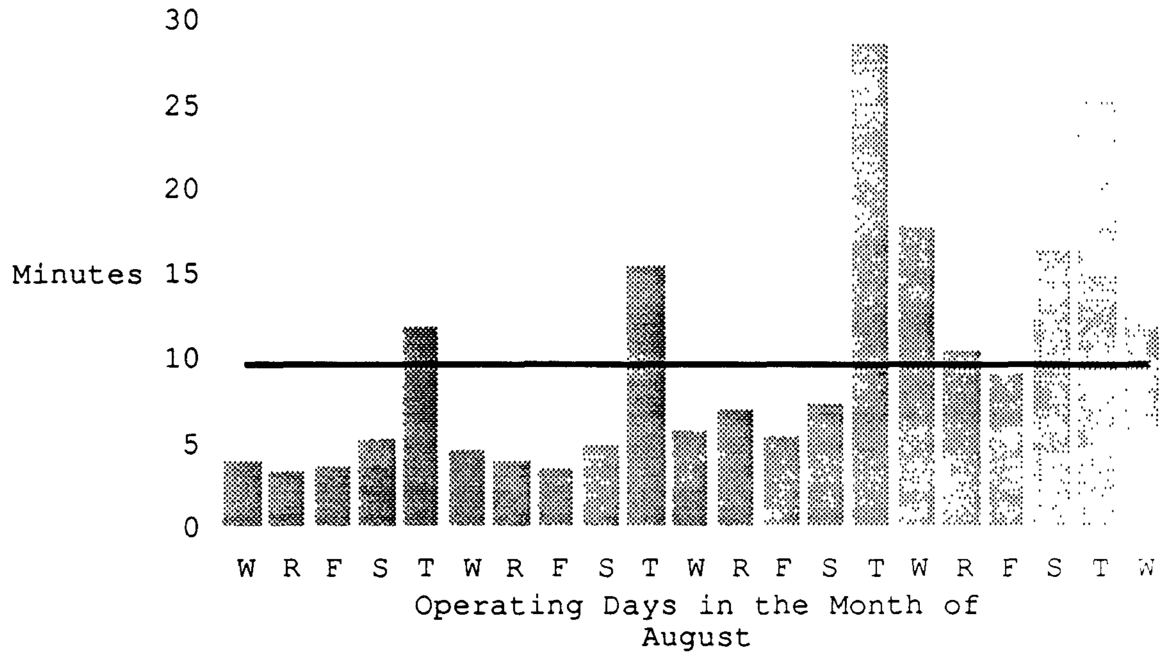
Decentralized programs typically offer numerous test stations scattered throughout the program area and are open to the public during the week and on weekends. These features form the basis for providing a convenient inspection network. Theoretically, I/M tests can be combined with other planned vehicle services, or a vehicle owner can simply drop into the corner garage for a quick test. In practice, the situation is not as simple. According to survey work done in decentralized programs[11], the majority of the public experience one or more "inconveniences" in getting their vehicles tested. About 60 percent of the vehicle owners surveyed reported waiting anywhere from 25 to 50 minutes to be tested. Thirty four percent had left their vehicles at a station as long as a day for testing. Some of these may have chosen to do so in order to have other services performed, however. About 20 percent of vehicle owners surveyed were turned away by the first decentralized station they visited for a test. Also 20 percent reported being told to make an appointment and return at a later date. (The responses total more than 100 percent, because some motorists surveyed had had multiple experiences with I/M inspections.)

In a decentralized program, all vehicles must get service at a licensed station, not just those which will need repair. Decentralized I/M does not guarantee that a vehicle owner will be able to get a quick emission test on demand at the first station visited.

Centralized test networks appear less convenient because there are a limited number of test stations operating during fewer hours than at a typical service station. Further, centralized test stations are not as conveniently located as service stations. Nevertheless, centralized testing has been shown to be reasonably convenient when the network is well designed. A good example is the Milwaukee, Wisconsin system which imposes an average travel distance of 5-6 miles on vehicle owners and a maximum of 10-15 miles. The Wisconsin program is also a good example of providing rapid service. About 98 percent of all vehicle owners wait less than 15 minutes for a test. In the busiest month in Wisconsin, only 4 percent of the vehicle owners have to wait more than 15 minutes and maximum waiting time is 30 minutes. In other centralized programs, average waiting times are generally comparable to the Wisconsin experience. Maximum waiting times vary, however, due to the rush at the end of the month for those who wait till the last minute to get tested. Figure 5-1 shows the daily and overall average waiting times in Illinois. Towards the end of the month, the deadline for compliance, waiting times increase, but overall Illinois achieves an average waiting time of under ten minutes. So, good network design means short waiting times and short driving distances for vehicle owners.

Figure 5-1

Average Daily Waiting Times in Illinois' I/M Program



Some centralized I/M programs have experienced problems with waiting times. In one instance, the problem related to enforcement of the program which was very uneven. On occasion the police would suddenly start to enforce the testing requirement and long queues would develop of people who neglected to get tested when they were scheduled. This has happened in a decentralized program, too. In another case, population growth was not matched by expansion of testing facilities. As the area grew, the program administration failed to install new lanes and test facilities and eventually a crisis developed. It is obvious that good management and adequate funding of the program are needed to avoid these kinds of problems. For the majority of centralized I/M areas where that is the case, however, waiting times are not a problem.

For some motorists whose vehicles fail the initial inspection, a centralized program may, in fact, be considerably less convenient than a decentralized program, because they will need to return to an inspection facility for a retest following repairs. But this inconvenience will be limited to the portion of the population that fails the initial inspection. At present, this portion is about to 20 percent. In the survey mentioned previously, a much greater percentage of the respondents in decentralized programs needed to make two trips just to accomplish an initial inspection. This is in part because the type of automotive service facility that can provide on-demand inspections most readily (retail gasoline stations) in a decentralized program is also most likely to lack the repair expertise and parts inventory to repair many vehicles. This will become more likely in the 1990s and as a result, the "extra" trip for a repair in a centralized program would often occur in a decentralized program anyway.

The biggest potential convenience problem in a centralized program is where owners are "ping-ponged" between failing tests and ineffective repairs. On-site State advisors and steps to improve repair industry performance can help. Well run centralized programs do these types of things. For example, Wisconsin monitors repair facility performance and visits shops that are having trouble repairing vehicles to pass. The visits include providing assistance to the mechanic in proper retest procedures, providing calibration of the test equipment the shop might own, and referrals on where additional training can be obtained.

6.0 FUTURE CONSIDERATIONS AFFECTING THE COMPARISON OF NETWORK TYPES

A number of future developments may affect the relative performance and cost of different network types. For the most part these developments cannot, at this time, be subject to the kinds of evidential examination produced above. What follows is a discussion of the potential outcomes based on known constraints.

Biennial inspections are becoming an increasingly attractive alternative to annual inspections. The largest portion of the cost of I/M is in the inspection process. Thus, reducing inspection frequency will cut the overall cost of I/M, although it may increase the per test cost. EPA has found that the loss in emission reduction benefits is less than the savings. Thus, in a typical switch, about 10% of the benefits will be lost but a minimum 20% of the dollar cost will be averted. Owner inconvenience will be reduced by essentially 50%, since a test is required only half as often.

As a result of switching to biennial inspections, some existing centralized networks will have extra capacity that can be used to absorb growth, provide shorter lines in peak periods, or to allow a longer inspection process. However, in the short run, there could be an increase in the per test cost in some networks unless excess existing inspection facilities or lanes are closed. Biennial inspections in decentralized programs mean fewer tests per year per station and analyzer. This means that overhead costs (training, staff, equipment, etc.) must be spread over fewer tests, unless sufficient numbers of stations drop out. In order to maintain profitability, an increase in the test fee will likely be required.

The CAAA of 1990 require EPA to establish a performance standard for enhanced I/M programs using an annual program as a model. This means that testing on a biennial basis will require programs to make up for the associated emission reduction loss. Given the reduced effectiveness of decentralized programs, achieving enough reductions will be more difficult, if not impossible.

Another option being considered by some and pursued by at least two programs is exempting new vehicles until they reach three or four years of age. The most recent three model years represent about 22% of the vehicle fleet. However, because they have had little time to develop problems, inspecting them produces very little emission reduction. Exempting these vehicles would have effects similar to that of biennial testing, reducing test volume and revenue. The same kinds of impacts in terms of each network type would follow as well. However, it should be noted that exempting new vehicles can cause owners to miss the opportunity to exercise the 2 year/24,000 mile emission performance warranty provided under Section 207 of the Clean Air Act.

Another major change needed in all I/M programs in the next few years will be adoption of advanced test procedures, improved preconditioning methods, better emission sampling algorithms, more sophisticated computer systems, and more extensive data recording. All of these improvements are needed as a result of refinements in our understanding of existing vehicle technology and what we expect in terms of future technology. The need for preconditioning was discussed in detail in section 3.1. The adaptability of I/M programs to changing conditions becomes a major issue in light of these needs.

Most centralized programs use mainframe or mini computers to operate the analyzers and record data. These systems can easily be reprogrammed whenever a change in the inspection process is desirable. Such a change can be debugged and implemented quickly with a minimum of expense and difficulty. The existing computerized emission analyzers in decentralized I/M programs are for the most part hardware programmed or closed-architecture systems, with computer chips rather than software governing operation of the analyzer. Thus, making changes to these analyzers requires installation of new computer chips, a more costly proposition than a simple software update.

The latest developments in decentralized analyzers call for the use of an open-architecture system that will allow reprogramming; however, these analyzers cost $12,000-$15,000 for the basic machine as compared to $6,000-$8,000 for the existing technology. This additional expense will further the demand for increased test fees in decentralized programs. The existing analyzers in most programs are aging, although still good for repair work if properly maintained and calibrated regularly. Many decentralized programs will be faced with the choice of replacing computerized analyzers to meet new testing requirements, or making a switch to centralized testing.

On the newest fuel injected vehicles, current short tests leave room for improvement. As time passes, the fuel injected portion of the fleet will grow more and more important, making it more important to improve testing of these vehicles. However, improved test procedures may require the use of steady-state or transient dynamometers. At this point, the use of either type of dynamometer is most feasible in centralized programs where the cost can be spread over many tests. Use in a decentralized program would likely result in fewer test locations.

Another testing frontier relates to the use of "on-board diagnostics" or OBD. Starting in 1981, some motor vehicles were manufactured with computers that monitor engine performance during vehicle operation, detect any malfunctions in the system, and store diagnostic information in the computer memory. Usually, the motorist is alerted through the use of a malfunction indicator light on the dashboard of the vehicle. OBD is currently required for all new vehicles in California, and EPA is developing regulations to standardize the systems at the federal level, as required by the CAAA of 1990. I/M programs will be required to perform OBD checks once these vehicles are in use. OBD has great potential to enhance repair effectiveness and provide an alternative or an add-on to emission testing. In the near term, decentralized I/M programs may suffer from improper testing of OBD since checking for the malfunction light, while simple, is essentially a manual process. Even in the long term when the vehicle computer will "talk" directly with the analyzer computer, there will be ways to defeat a decentralized test, for example, by connecting the analyzer to a known "clean" vehicle instead of the subject vehicle, as is done currently with the emission test.

7.0 PREDICTED EMISSION REDUCTIONS FROM MOBILE4 AND AN ADDITIONAL ASSUMPTION REGARDING WAIVERS

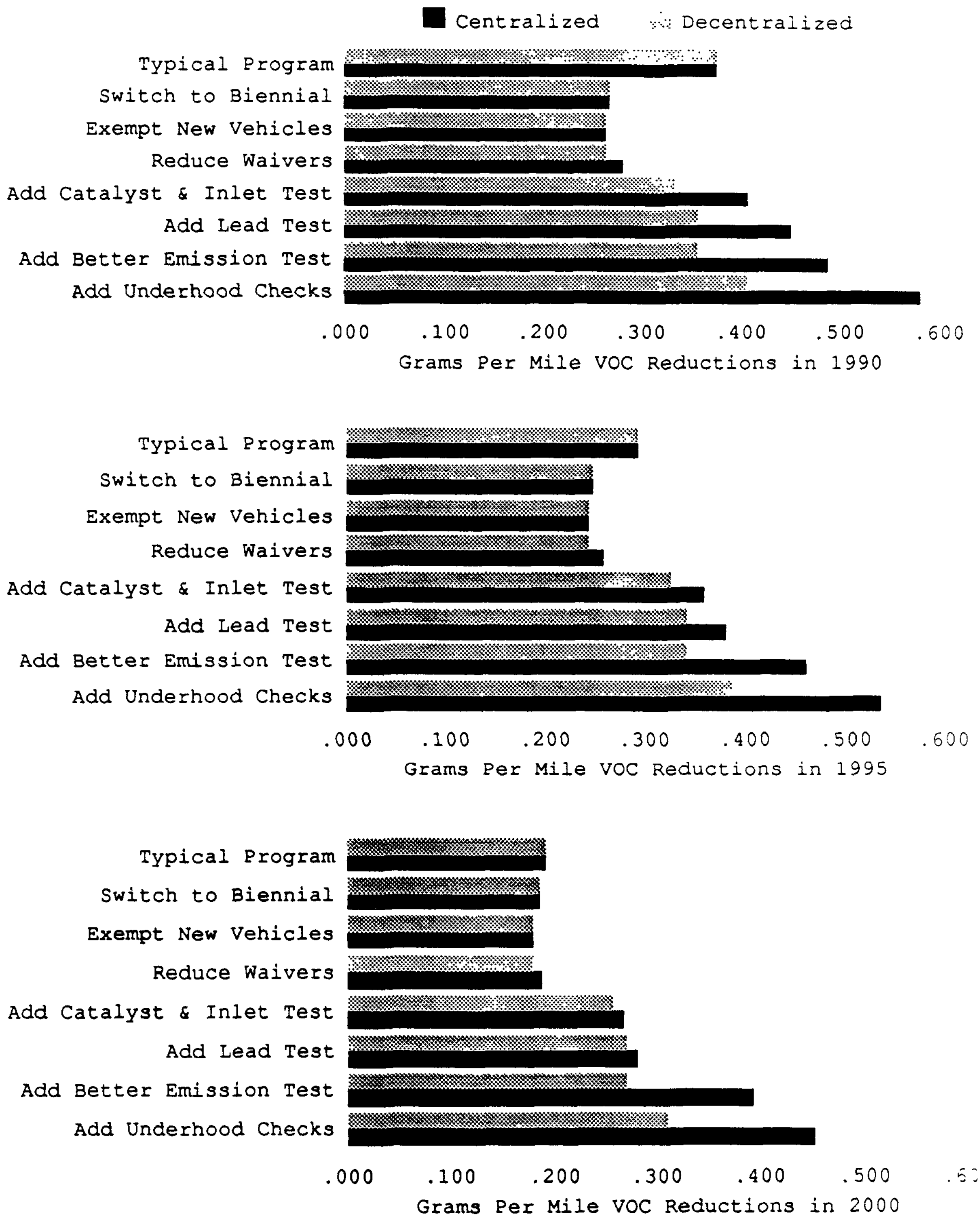
The emission reduction impacts of various potential changes to I/M programs were analyzed for their relative effects and to assess the difference between centralized and decentralized networks. The most recent version of EPA's mobile source emission model, MOBILE4, was used for the mechanics of the calculation. MOBILE4 assumes that anti-tampering inspections in decentralized are only half as effective as centralized programs; it assumes emission testing is equally effective in either program type. For the purpose of this analysis, an additional "what if" assumption regarding the outcomes of a higher waiver limit was made, as explained below.

Figure 7-1 serves mainly to put the known and possible differences between centralized and decentralized programs into perspective with the emission reduction effects that are possible via other program changes. The first bar in each of the charts in Figure 7-1 shows the VOC emission reduction benefit from a typical emission test-only I/M program. While no two programs are exactly alike, a typical program was taken to be one which covered all model years, all light duty vehicles and light duty trucks, failed 20% of the pre-1981 vehicles, used an idle test, and annual inspections. The waiver rate is assumed to be 15%.

The next bar shows the level of benefit this program design would achieve if it switched to biennial inspections. The third bar shows the benefit from a typical program with biennial inspections that exempts vehicles up to four years old. The next bar shows the impact of reducing waivers to 5% of failed vehicles by increasing the cost limits and tightening procedures. For the purposes of this bar, decentralized programs are assumed to achieve no additional benefit on the theory that improper testing would be substituted when waivers are constrained. Other judgmental estimates can be interpolated visually. The next two bars show the benefit from adding catalyst and misfueling checks. The differential impact is based on the assumptions built into MOBILE4. The assumptions for decentralized programs are that detection is 50% of centralized, but deterrence is assumed to be equal that of a centralized program. The addition of an improved emission test (i.e., a transient test) would not be feasible in a decentralized program, so no additional benefit is credited there. Finally, underhood checks are added and the differential impact is once again based on the assumptions built into MOBILE4. The figure shows the benefit in 1990, 1995 and 2000. These scenarios do not take into consideration any loss in benefit associated with improper emission testing in decentralized programs (except as noted in the reduced waiver scenario). MOBILE4.1, which will be used to construct base inventories required by the CAAA of 1990, will do so. Benefits for carbon monoxide reductions are not shown but are similar except that tampering checks are not as important.

Figure 7-1

Benefits From Various Potential Changes to I/M Programs*



8.0 CONCLUSIONS

The first I/M programs, established voluntarily by three States in the 1970s, were set up as centralized networks. Decentralized networks appeared in response to the requirements of the 1977 Clean Air Act Amendments and currently comprise the majority of I/M programs in the United States. The early thinking was that decentralized inspection would be less costly and more convenient to the vehicle owner. It was acknowledged that more quality assurance would be required to ensure equivalent emission reductions, but it was also assumed, at least officially, that success could be achieved with a reasonable level of resources.

This report discusses the relative effects of centralized and decentralized I/M programs. It focuses on three key issues: emission reduction effectiveness, cost, and convenience. It presents information derived from EPA testing programs, EPA and State audits of I/M programs, and analyses of I/M operating data.

Recent studies have found that vehicles require adequate preconditioning before a test to assure that they are at normal operating temperature, and that any adverse effect of extended idling is eliminated. A period of loaded operation on a chassis dynamometer has been found to be most effective. Most decentralized programs, especially those requiring the use of computerized analyzers do unloaded, high-speed preconditioning. This can work if I/M programs extend the length of the preconditioning, as EPA has recommended. A chassis dynamometer would allow a shorter period but the purchase and installation of a chassis dynamometer is considered beyond the financial capability of most private repair facilities. Some centralized programs have avoided pre-conditioning because it was not thought essential and to keep costs and test time as low as possible. The trend now, however, is to provide loaded preconditioning and a second chance test to vehicles which fail an initial idle test.

Centralized programs typically do few or no anti-tampering inspections. Decentralized programs typically require comprehensive checks on at least some portion of the vehicle population. The effectiveness of decentralized tampering inspections is highly suspect, however. As with preconditioning, centralized programs are starting to add anti-tampering checks to the normal test routine.

EPA audit findings show that centralized contractor-run programs have very high levels of instrument quality control. Centralized government-run systems and computerized decentralized programs are comparatively weak. The quality of calibration gas that is purchased, the frequency with which checks are performed, the easy opportunity to defeat the checks, and the less sophisticated instrument technology are to blame. Manual decentralized programs have, with a few exceptions, had unacceptable levels of quality control. This has led to most manual programs changing over to computerized analyzers.

The available evidence shows that objectivity and quality of testing - the keys to emission reduction effectiveness - differ greatly by program type. It was previously found that decentralized programs using manual analyzers had a very high rate of inspectors conducting tests improperly, either intentionally or inadvertently. For the most part, inspectors were passing vehicles which should have failed and been repaired. The use of computerized analyzers in decentralized programs has reduced the level of inadvertent improper testing. Correspondingly, the initial test failure rates have risen substantially in programs that have computerized. Audits have found, however, that improper testing, both on the initial test and the retest, sometimes occurs despite the use of computers.

Current inspection costs per vehicle were determined for a number of operating programs. The earliest decentralized programs did, in fact, charge lower inspection fees, because State legislatures imposed fee caps to protect vehicle owners. The trend has reversed, however, since requirements for computerized analyzers have been imposed. Sophisticated, high through-put centralized systems are now "outbidding" the local garage, much as franchise muffler and tune-up shops have overtaken their respective aspects of the repair business. The trend occurring in programs which are new, revised, or reauthorizing is for increasing fees in decentralized programs and decreasing fees among competing contractors. Decentralized computerized programs now have the highest costs, averaging $17.70 per vehicle. Centralized contractor-run programs average $8.42 per vehicle. Centralized government-run systems claim the lowest cost at $7.46 per vehicle, on average.

The factors influencing the convenience or inconvenience of an I/M program include station location, hours of operation, waiting time, required number of visits, and certainty of service. Decentralized programs offer stations located conveniently to most motorists. However, a significant number of respondents to a recent survey reported being turned away without an inspection, or having to wait 25-50 minutes for an inspection. Because there is a growing scarcity of qualified mechanics in the automotive aftermarket, and since many gas stations have converted repair bays into convenience stores, it has become increasingly difficult to obtain "on demand" automotive services. Centralized programs have a limited number of facilities, and may experience long lines if the system is not well designed. Most new programs, however, have taken steps to minimize the travel distance and the waiting time, such that centralized programs are just as convenient or more convenient than decentralized systems.

The overall conclusion is that centralized I/M will usually offer greater emission reduction benefits than decentralized I/M, unless the decentralized program makes special efforts that may border on the unreasonable. It has been shown that this greater benefit can be achieved at a lower cost and with limited inconvenience to the motorist. These advantages also dovetail with trends in I/M technology, which all point in the direction of increased sophistication, leading to higher cost unless economies of scale can be achieved. There is a growing need to assure that all of the emission reduction potential of I/M programs is achieved in actual operation. Quality is a must, if I/M is to play its part in achieving the ambient air quality standards.

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