Eastern Research Group, Inc.

Arizona Alternative Compliance and Testing Study (AZACTS) – Summary of Activities and Recommendations to Date

FINAL REPORT

Prepared for:

Arizona Department of Environmental Quality

January 31, 2006

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ARIZONA ALTERNATIVE COMPLIANCE AND TESTING STUDY (AZACTS) – SUMMARY OF ACTIVITIES AND RECOMMENDATIONS TO DATE

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Prepared for:

Air Quality Division
Arizona Department of Environmental Quality
3033 North Central Ave., Suite 1603B
Phoenix, AZ 85012-2809

Prepared by:

Eastern Research Group, Inc.
5608 Parkcrest Drive, Suite 100
Austin, TX 78731

January 31, 2006

5608 Parkcrest Drive, Suite 100, Austin, TX 78731-4947, Telephone: (512) 407-1820, Fax: (512) 419-0089
Arlington, VA • Austin, TX • Boston, MA • Chantilly, VA • Chicago, IL • Lexington, MA • Portland, ME • Morrisville, NC • Sacramento, CA

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1.0 Introduction

Under Task Assignment 8 of the Arizona Alternative Compliance and Testing Study (AZACTS – ADEQ Contract # EV01-0094), ERG was tasked with preparation of a Interim Report summarizing all work performed to date under the AZACTS, along with conclusions and recommendations regarding additional work which would contribute to attaining other AZACTS program goals. This report summarizes the analyses, conclusions and recommendations for each of the following Tasks Assignments conducted to date:

- Task Assignment 1 – Initial Planning and Implementation Steps for AZACTS
- Task Assignment 2 – Baseline Assessment and Evaluation of Alternative Testing Technologies for the AZACTS
- Task Assignment 3 – 2002 Bridging Activities
- Task Assignment 4 – Assessment of Compliance Behavior
- Task Assignment 5 – Methods for Improving Compliance with I/M Requirements
- Task Assignment 6 – Evaluation of Arizona I/M Program by Using 2002 Random Sample Data
- Task Assignment 7 – 2003 Bridging Activities
- Task Assignment 8 – 2004 Bridging Activities

2.0 Task Assignment 1 - Initial Planning and Implementation Steps for AZACTS

The purpose of this Task Assignment (TA) work was to finalize details of work to be done during the remainder of the project. The ERG Team also began negotiating with the companies who would perform the remote sensing data collection, and wrote a draft Task Assignment Work Order 2 (TASOW2) and the Task Assignment Offer 2 (TAO2).

ERG began this TA by organizing a Kickoff Meeting. The meeting was held on April 20, 2001 in Phoenix. The purpose of the meeting was to allow the ERG team to meet with ADEQ and its Contractor Oversight Committee to begin establishing the working relationship and to plan Contract Task 1 (CT1) and CT2. CT1 was referred to as the "Baseline Evaluations," and CT2 as the "Detailed Evaluation of Alternative Technology Options" in ERG's original proposal.

During the Kickoff Meeting, the ERG Team presented their proposal to ADEQ and the Contractor Oversight Committee. ERG also elaborated on some of the main points of their proposal and answered questions posed by ADEQ and the Contractor Oversight Committee. ERG assembled meeting minutes after the meeting, included in a deliverable submitted to ADEQ. ERG also prepared Task Assignment Offer #2 under this TA. In preparation for work under TA2, ERG prepared a draft version of a web site for the project. The web site provided another forum for communication between ERG, its subcontractors, ADEQ, and the Contractor Oversight Committee.

3.0 Task Assignment 2 - Baseline Assessment and Evaluation of Alternative Testing Technologies

The purpose of this TA was to conduct the Baseline Analyses and Evaluation of Alternative Control Technology tasks, including the following subtasks:

Subtask 1: Baseline Analysis (Contract Task #1) –ERG developed an estimate of the baseline levels of compliance and non-compliance, and the resulting impact on emission reductions. ERG also evaluated the emission reductions attributable to the current I/M program. Finally, we conducted an overview of the "State of the Science" in alternative control technologies and identified those technologies that would be the focus of Subtask #2.

Subtask 2: Alternative Technology Evaluation (Contract Task #2) – ERG evaluated selected alternative control technologies to determine their applicability and effectiveness in enhancing Arizona's I/M program.

Subtask 3: Logistical Support Activities – ERG performed logistical activities in support of Subtasks 1 and 2.

Subtask 4: Preparation of TAO #3 -- ERG prepared a draft TASOW, and a TAO in response for the next task of the project.

At the completion of the TA ERG prepared a summary Preliminary Progress Report.

3.1 Baseline Analysis of Historical Remote Sensing and I/M Emissions Data in Arizona

The following summarizes the ERG Team's analysis of over six years of I/M test results and remote sensing measurements. Two geographic regions were evaluated, termed Area A (Phoenix) and Area B (Tucson). Our findings are divided into three groups: characterization of the fleet of vehicles observed on-road in the Phoenix area and those reporting for I/M testing in the Phoenix and Tucson I/M areas; detailed analysis of the previous Smog Dog remote sensing measurements; and estimation of the effectiveness of the historical I/M program, using I/M test results. Our most important findings include:

- 25% of new vehicles are heavy light-duty trucks, and the use of these vehicles is increasing (see Figure 3-1). Because these vehicles are subject to less stringent emissions certification standards when new, and less stringent I/M cut points, their increased use may pose a problem for improving air quality in the state.

- Some of the historical Smog Dog remote sensing measurements are biased; this is shown in Figure 3-2 and 3-3, which compares emissions of the same vehicles measured by two instruments located only several feet apart, at two different sites. The historical measurements were not subject to consistent quality assurance procedures, which limited their accuracy in identifying suspected high emitters, and limits their usefulness in retrospective program analysis. For example, the roadway grade at the site of each measurement was not recorded, so the vehicle load at the time could not be estimated. We recommend that any new remote sensing measurements should be subject to strict quality assurance procedures. Any future analysis of the Smog Dog measurements should either attempt to correct for the biased measurements, or estimate the sensitivity of the results to using the measurements.

- The new IM147 test adopted in January 2000 results in lower emissions than the previous IM240 test. This can be seen in Figure 4, which compares the initial tests in the last year of IM240 testing (1999) with initial tests in the first year of IM147 testing (2000), by model year. Even though the vehicles given the IM147 test are one year older, most have lower IM147 emissions than vehicles given the IM240 test. The difference in IM147 and IM240 emissions could be due to real differences in the test procedures, or could be due to the separate methods used to convert fast-pass/-fail emissions in each test to full-IM240 equivalents. In any event, the emissions and failure rates under each test are not directly comparable.

- 14% to 18% of 1981 and newer vehicles that failed their initial test in Phoenix (Area A) never passed a retest; 12% to 13% of these vehicles in Tucson (Area B) never passed a retest (see Figure 3-5). Whether these vehicles represent an improvement in air quality depends on whether they have been permanently removed from the I/M areas or whether they continue to be driven in the I/M areas. Substantial number of remote sensing measurements, or unmanned license plate records, are needed to estimate what fraction of the no-final-pass vehicles continue to be driven in the I/M areas.

- 6% of vehicles in each area took more than two years to pass a retest. Because these vehicles eventually pass a retest, they likely were driven in the I/M areas without meeting program requirements. It is likely that program effectiveness and air quality could be improved by tightening motorist compliance with program requirements.

- Only 42% of 1981 and newer vehicles tested in Phoenix in 1995 were tested again in 1999; 55% of these vehicles in Tucson were tested again in 1999 (see Figure 3-6). (Note that 1999 represented the last full biennium of data available at the time of this analysis in 2002.) It is not clear whether these vehicles have been permanently removed from I/M areas, or continue to be driven in the areas without complying with program requirements. A substantial number of remote sensing measurements, or unmanned license plate records, is needed to estimate what fraction of these vehicles continue to be driven in the I/M areas.

- 65% of Phoenix vehicles that failed in 1995 failed again in at least one subsequent I/M cycle. In each cycle, over 30% of failed vehicles fail again in the next cycle. This finding suggests that program effectiveness is compromised by vehicles repeatedly failing their I/M test. Possible causes of repeat failures are: the previous repair was not sufficient or durable; the vehicle passed its last I/M test without any repair being made (taking advantage of intrinsic test-to-test emissions variability); or the repeat failure was due to a problem unrelated to the initial failure and repair. We recommend that ADEQ consider more frequent I/M testing of vehicles that failed their previous I/M test, in order to identify sooner, and hopefully permanently repair, vehicles with ineffective repairs.
- The emissions of vehicles tested in Arizona for the first time were used to estimate what emissions would have been if an I/M program were never adopted in the state. The difference in emissions between these "out-of-state" vehicles and "native" Arizona vehicles provides an estimate of the cumulative benefit of the Arizona I/M program over several years. The Arizona vehicles had HC, CO and NOx emissions 8%, 1% and 6% lower (respectively) than the out-of-state fleet in Phoenix in 1999 (see Figure 3-7). Because some of the out-of-state vehicles were subject to an I/M program in their previous state, this analysis represents the minimum cumulative benefit of the Arizona I/M program.
- Emissions of 1981 and newer vehicles in Phoenix were reduced 17%, 21%, and 10% for HC, CO and NOx (respectively) between their initial and final I/M test in the 1999 I/M cycle (see Figure 7). These reductions do not include any additional reductions from repairs performed prior to the initial I/M test, or any benefit from failing vehicles permanently removed from the I/M areas. On the other hand, these reductions are the maximum reductions as measured immediately after vehicles passed their last I/M test, and do not account for increases in emissions due to vehicles passing without being repaired, or vehicles receiving inadequate repairs.

Figure 3-1. Percent Heavy Light-Duty Trucks (LDT3-4) in each I/M Area and On-Road, by Model Year

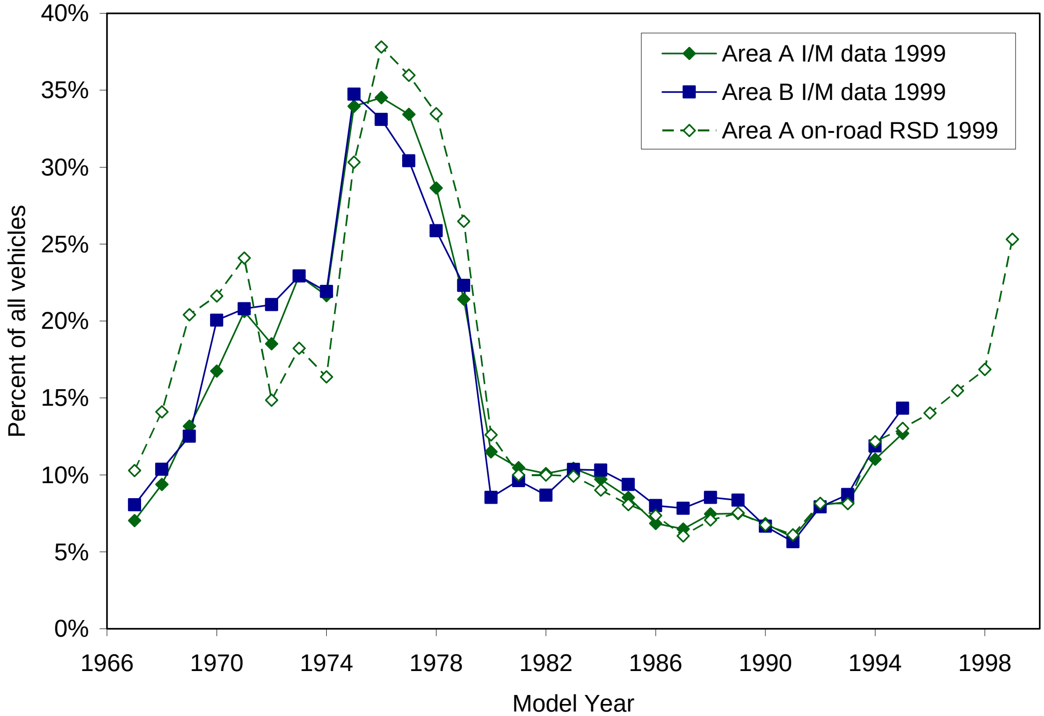
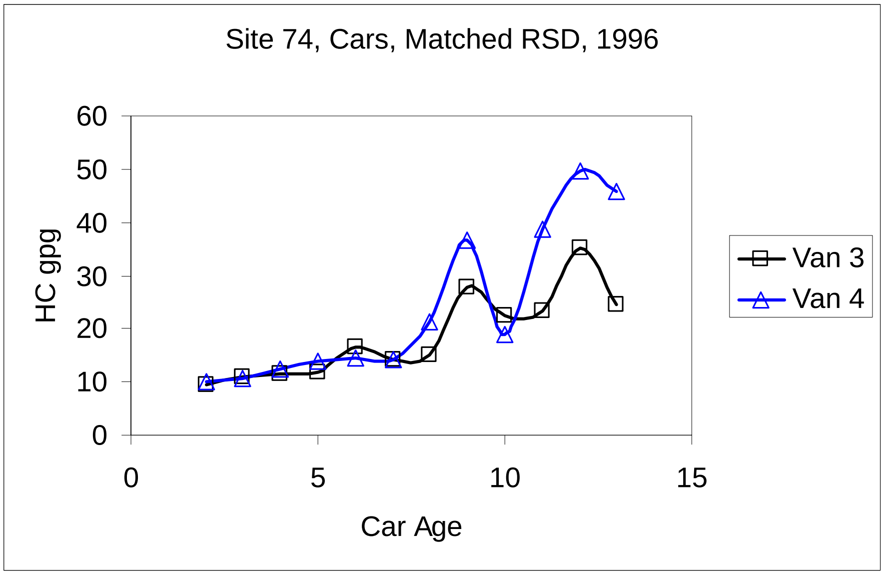


Figure 3-2. Example of Good Agreement in Matched Readings by Two Co-Located Remote Sensing Vans



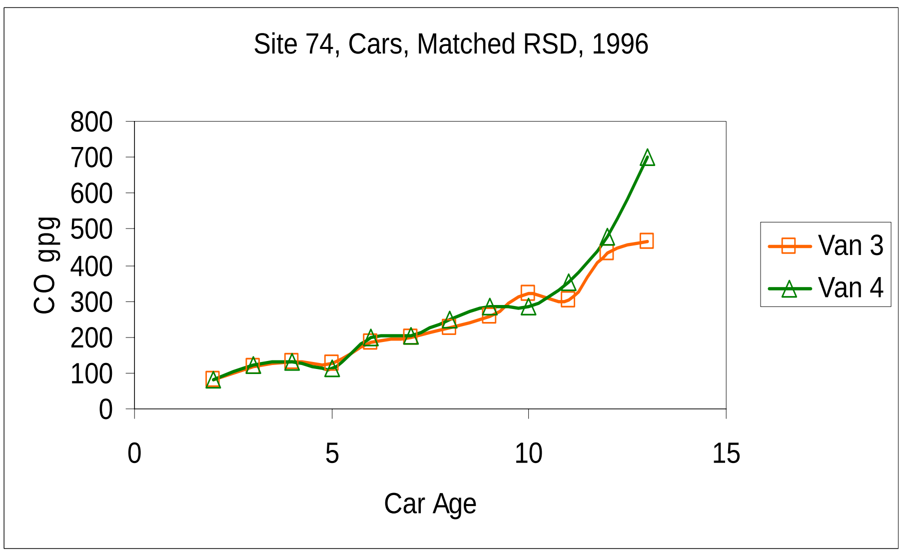
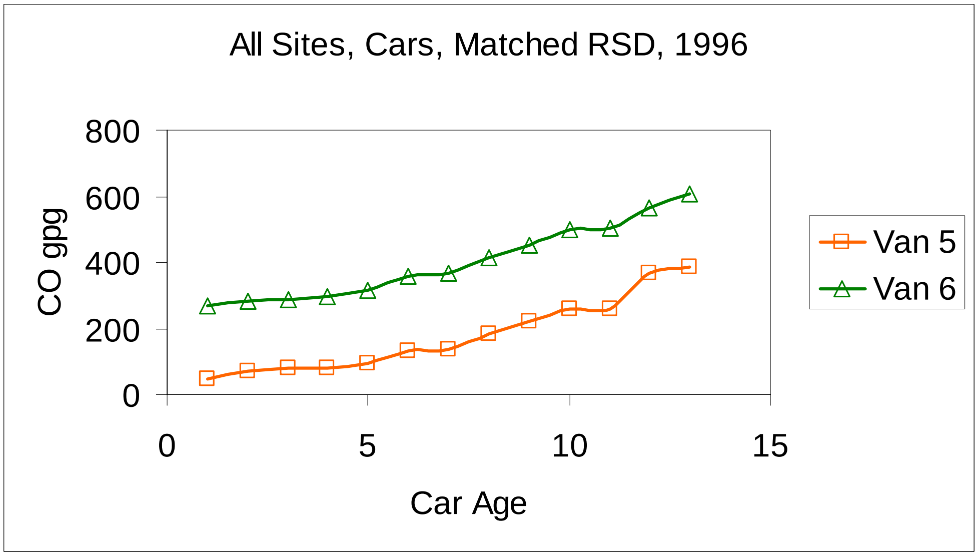


Figure 3-3. Example of Poor Agreement in Matched Readings by Two Co-Located Remote Sensing Vans



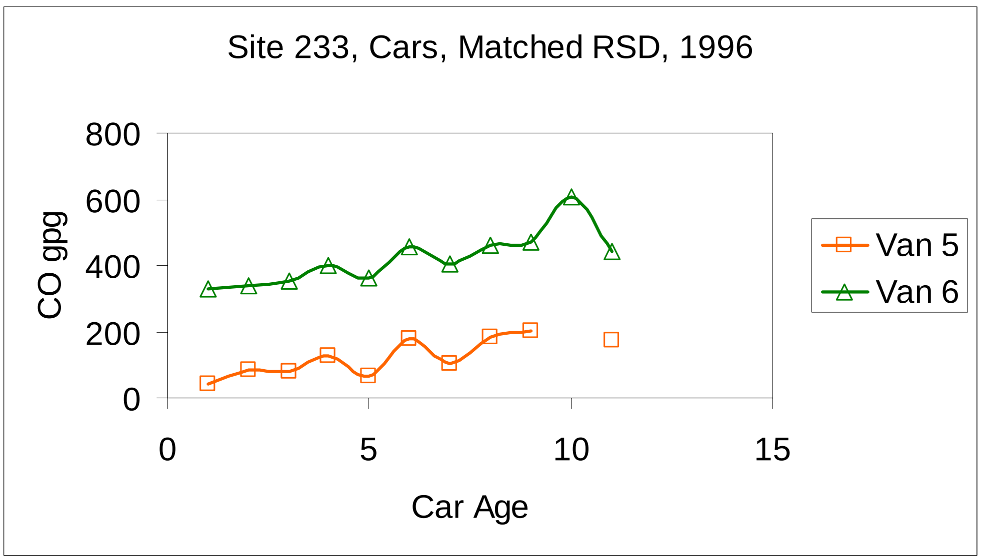


Figure 3-4. Average 1999 and 2000 Initial Emissions of Passenger Cars, by Pollutant, Model Year and Year

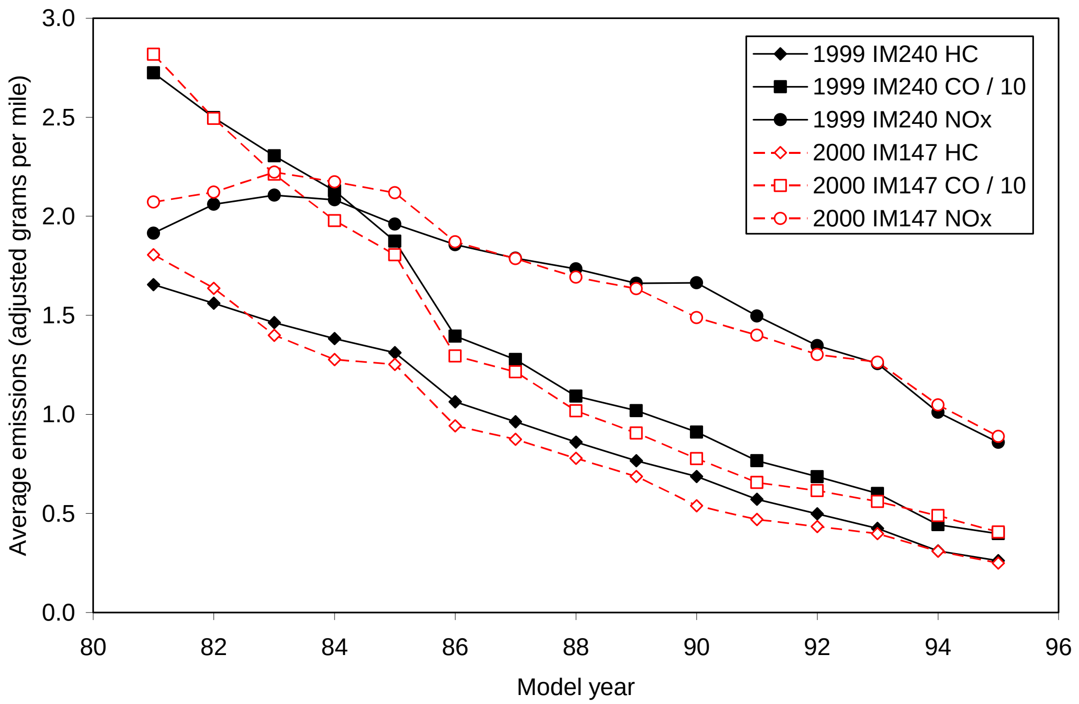


Figure 3-5. No-Final-Pass Rate of Light-Duty Vehicles, by I/M Area, Model Year and Year

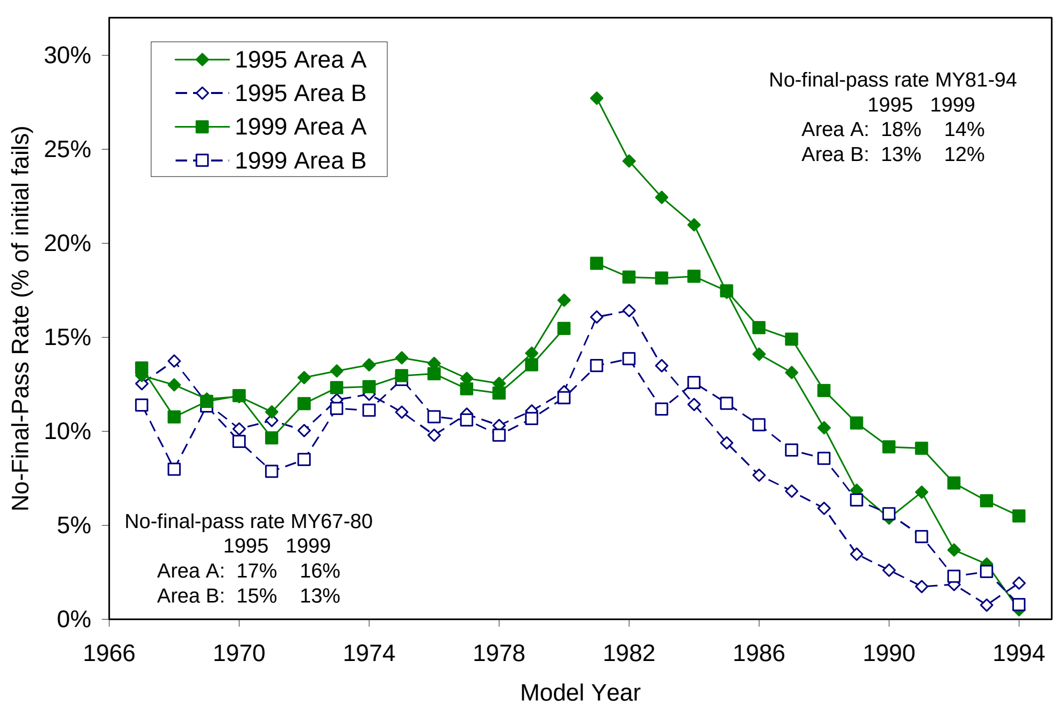
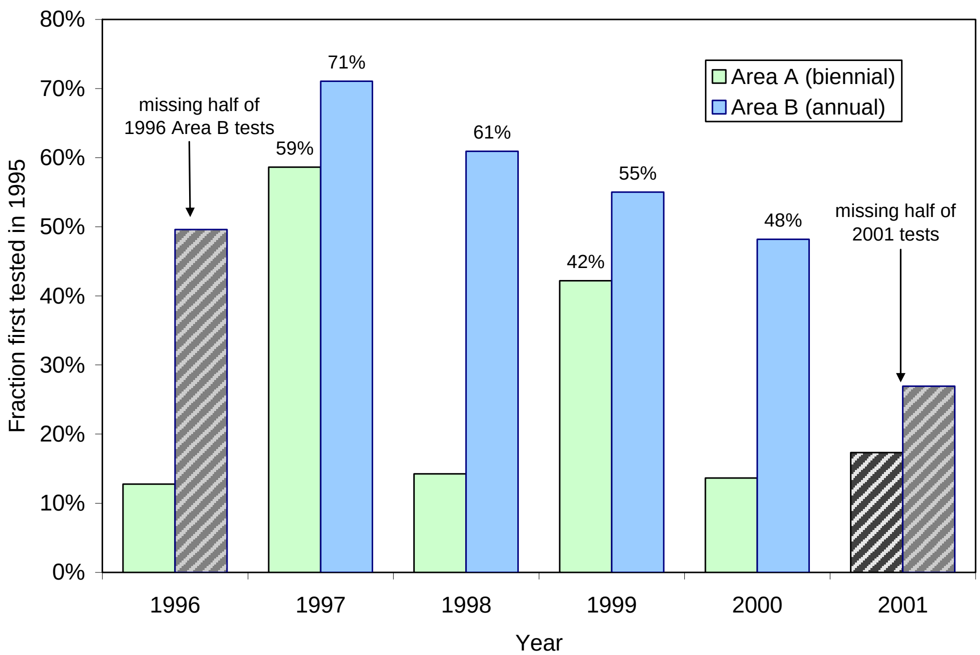
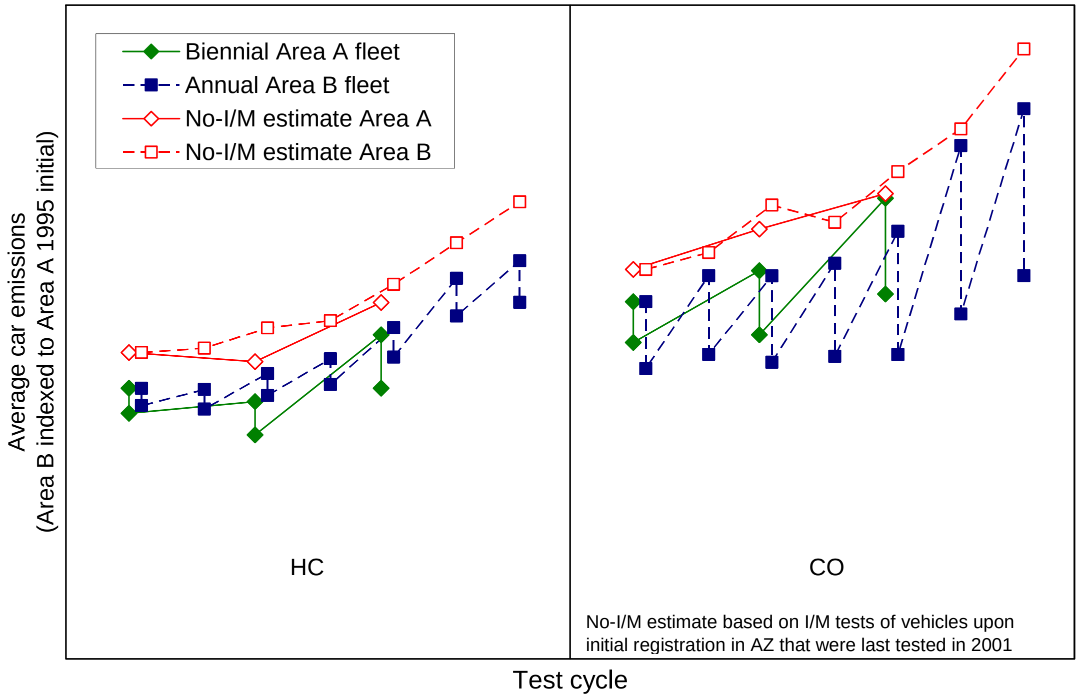


Figure 3-6. Fraction of 1981-94 Light-Duty Vehicles First Tested in 1995 that were Tested in Subsequent Years, by I/M Area



Note: At the time of this analysis idle test results were only available for half of the 1996 and 2001 calendar years in Area B.

Figure 3-7. Average HC and CO Emissions of 1981-94 Cars Tested over Multiple I/M Cycles, by I/M Area



3.2 Baseline Analysis of Compliance with I/M and Registration Requirements in Arizona

Using a combination of an extract of the registration database, I/M test records, and on-road measurements, the fraction of vehicles that were not complying with I/M testing or registration requirements was estimated. Because of discrepancies in the test and registration data (such as differences in vehicle type and year, and last passing I/M test date), as well as how non-compliance rates are expressed (statewide, or as a fraction of each I/M area), we presented a range of estimates of the non-compliance rate.

We estimated that 3% to 7% of I/M-eligible 1967 to 1996 gasoline light-duty vehicles in Arizona were non-compliant with I/M and/or registration requirements. The range is large because many vehicles that were last tested in an I/M area were later registered in a non-I/M area; the higher estimate assumes that all of these vehicles will continue to be regularly driven in I/M areas, non-compliant with program requirements. Nearly half of all vehicles in the registration extract had expired registrations; assuming that all of these vehicles were permanently relocated out of Arizona, then the estimate of the non-compliance rate rises to between 6% and 10% of the remaining vehicles. Some of these vehicles with expired registrations may have been renewed in subsequent months, after the registration data were extracted; accordingly, a second registration data extract would be needed to determine how many vehicles renew once their registration expires. If this is the case, then the non-compliance rates would be lower. On the other hand, some of these vehicles may continue to be driven in I/M areas, or elsewhere in the state, with expired registration; if so, the non-compliance rates would be even higher than the High Estimate.

The non-compliance rates listed above are statewide estimates; if we estimate what fraction of vehicles registered in I/M areas are non-compliant, the rates would be slightly higher (5% to 11% of all vehicles, 7% to 14% of currently registered vehicles only).

Historical remote sensing and I/M data were used to examine some aspects of the historical compliance rate in the Phoenix area. This analysis supports earlier findings that many vehicles that failed an initial I/M test and never passed a retest continued to be driven in I/M areas for several years after failing their initial test. However, an extensive analysis of the current degree of non-compliance requires large numbers of observations of vehicles on the road.[1]

The registration data were also used to estimate that about one-third of the light-duty vehicle fleet currently registered in I/M areas is exempted from I/M testing because of their age. Nearly all of these vehicles are exempted because they are within the first five model years.

3.3 Baseline Assessment of the State of the Science for Alternative Technology Options

Under TA2 the ERG team was directed to perform a baseline assessment of the "State of the Science" regarding alternative technologies and methods for controlling vehicle emissions. The main purpose of this report was to identify and recommend specific technologies or programmatic strategies worthy of future study and evaluation.

The current contract with the I/M testing provider in Arizona expires in 2009. Therefore, options selected for evaluation have a reasonable potential for incrementally improving the current program, or serving as an outright replacement for the program after 2009. While certain technology options may have the potential to completely replace the current program in the long-run (e.g., OBDII without tailpipe testing), the state of alternative testing technologies in 2009 is highly uncertain. Therefore, this report was limited to evaluating incremental program improvement options based on currently, or soon to be, available technologies rather than future options for replacement of the program in the long-run.

The technologies and strategies considered in this report included:

- Ways to increase emission reductions;
- Ways to improve cost-effectiveness;
- Strategies to improve the performance of On-Board Diagnostic Systems (OBDII);
- Methods to reduce fleet emissions outside of I/M and OBDII inspections; and,
- Strategies to improve program evaluation methods.

1 A subsequent evaluation using on road data was performed under TA5.

Strategies to improve compliance with current program requirements were investigated under Task Assignment #4 (Behavioral Assessment).

The State of the Science report served as one of the primary deliverables under Contract Task 1, as well as a key interim deliverable for the AZACTS as a whole. The findings from this report were used to guide the AZACTS project in developing potential enhancements to the current program.

Methodology

For this effort we used our team's industry and government contacts, readily available literature, and other sources to determine what strategies had been implemented or were under consideration in the U.S. and Canada. We then solicited expert opinions about the effectiveness, costs, public acceptance, and ability to verify both costs and benefits of each strategy. Our assessments focused on the *general benefits and drawbacks* rather than a detailed quantitative analysis of each option relative to the current I/M program. Finally, we used the judgment of our team members to recommend areas for further investigation under the AZACTS study.

Outputs of the Study

More than 20 specific technologies and program options were identified and analyzed in this report. While some data on costs and benefits of existing I/M programs in the aggregate were available, very little data were available on the marginal costs and benefits of incremental improvements to these programs. Therefore, many of the findings and recommendations presented in this report were qualitative in nature, based largely on anecdotal information from researchers and program administrators in other areas and on our own judgment. Nevertheless, the findings provided a reasonable basis for focusing subsequent data gathering and analysis efforts under the AZACTS.

In addition to specific recommendations for additional research under the AZACTS, this study provided Arizona with a comprehensive list of previous research conducted, contacts for ongoing programs, vendors of specific technologies, and service providers. ADEQ can use this information to further assess specific program options, implementation issues, or as the basis for developing RFPs.

Summary and Recommendations

This study identified 24 distinct options for improving the emission reductions, cost-effectiveness, and/or public acceptance of the current I/M program in Areas A (Phoenix) and B (Tucson). The report also provided recommendations for further evaluation of each of these options, considering available data, level of effort and other constraints. In addition, recommendations were provided for evaluating the OBDII and heavy diesel particulate matter (PM) testing components of the current program. OBDII and opacity test performance baselines will ultimately be necessary to estimate any incremental improvements to these programs.

Each strategy has a unique combination of advantages and disadvantages. Nevertheless, some general observations can be gleaned from this analysis. First, substantial (but as yet unquantified) emission reductions still appear to be possible for certain measures beyond the reductions resulting from the current program. However, most of these measures are also quite resource intensive (e.g., targeting high emitters for increased testing using remote sensing). Second, certain relatively small-scale strategies may be justified based on their low cost and positive public acceptance even though resulting benefits may be difficult to quantify (e.g., voluntary programs such as accelerated retrofit of diesel trucks with NO_x reduction kits).

Most importantly, there is considerable uncertainty associated with estimating the potential emission reductions, program costs, public acceptance, and other factors for many of these options. Therefore, most of these strategies need additional evaluation before reasonable assessments of effectiveness and other final evaluation criteria can be made.

In all, the ERG team identified over 50 different specific recommendations for further evaluation of these measures, an overview of which is provided below.

Conclusions

Comparative ranking of potential control options using the several evaluation criteria was outside the scope of this report. Nevertheless, based on our findings we grouped the strategies into six primary categories for prioritizing future data gathering and analysis efforts. These categories considered the potential costs, benefits, and uncertainties associated with each strategy, as well as the anticipated level of effort required for further analysis and quantification[2].

Each strategy is listed below, with the corresponding report section referenced.

Strategies Expected to Have High Costs, with Potentially Large but Uncertain Benefits

These strategies include:

- High emitter identification using Remote Sensing Devices (RSD) **-- §3.1.1**

In order to obtain reasonable fleet coverage, operation and administration costs for this measure are high. RSD technology has improved significantly since the previous Arizona "Smog Dog" program but additional analyses are needed to assess potential benefits. Given the potentially substantial benefits we believe this option merits continued investigation.

Strategies with Highly Uncertain Costs and Benefits

These strategies include:

- Identifying heavy diesel trucks with high NO_x emissions **-- §3.1.4**
- Heavy diesel truck loaded transient opacity testing **-- §3.1.5**

While remote sensing of heavy-duty diesel NO_x has been clearly demonstrated, the potential costs and benefits of diesel truck repairs remain highly uncertain at this time. (In addition, the screening accuracy of opacity measurements have yet to be demonstrated convincingly.) Similarly, the benefit of transient cycle testing and subsequent repair for opacity failures needs further evaluation[3]. Also, the additional data collection required for evaluating these strategies, especially repair effectiveness, could be somewhat daunting. Therefore, proof of concept demonstrations and quantification of emissions levels for these tests could be done, but the more involved process of determining SIP creditable reductions that could be derived from a full-scale heavy-duty

2 Please note that the assessments of available data for similar programs and the costs are primarily qualitative, based on the ERG team's past experience with similar programs.
3 Note that the incremental costs associated with actual transient opacity testing should be low, since I/M stations in both Areas A and B already have the required heavy-duty dynamometers in place.

diesel vehicles (HDDV) I/M program may need to be left to other agencies already investigating these options.

Low Cost Strategies with Uncertain Benefits

These include:

- Adopting a gross liquid leaker I/M check **-- §3.1.6**
- Identifying smoking vehicles using roadside video cameras **-- §3.1.5**
- Improving repair data collection **-- §3.2.1**
- Developing a repair quality index for repair stations **-- §3.2.2**
- Conducting "pattern failure" evaluations to improve repair effectiveness **-- §3.2.3**
- Developing separate I/M cutpoints for retests **-- §3.2.4**
- Performing dual OBDII/IM147 tests **-- §4.3**

For the most part these strategies should be able to utilize existing equipment and infrastructure, keeping incremental capital costs low.4 In addition, most of these strategies should have relatively low operating costs once they are up and running.[5] Therefore, the majority of the costs would be associated with up-front data collection, analysis, and program development. On the other hand, these strategies currently lack the data and analysis necessary to determine their likely impact on emission reductions or cost-effectiveness. However, given their relatively low evaluation and implementation costs, we believe further evaluation of these measures is a relatively low-risk undertaking.

Strategies Likely to be Cost-Effective, with Costs and Benefits Proportional to Program Scale

These strategies include:

- High emitter identification without RSD (using vehicle characteristics and/or I/M history) **– §3.1.1**

4 Capital costs could be somewhat significant for improved repair data collection efforts if electronic links to the centralized vehicle inspection database are established for participating repair stations.
5 Requiring dual OBDII/IM147 testing would increase I/M test times and motorist inconvenience somewhat. Therefore costs associated with decreased vehicle throughput and impacts on I/M lane capacity would have to be considered explicitly.

- Exempting clean vehicles from I/M requirements ("clean screening", with or without RSD) **-- §3.3.1**
- Performing functional exhaust gas recirculation (EGR) system tests in lieu of loaded tailpipe tests to identify high NO_x emitters in Area B or regions adjacent to I/M areas **– §3.1.2**
- Decentralized scanning of OBDII systems at repair stations or dealerships6 **-- §4.2**
- Adopting a scrappage program for high emitting gasoline vehicles **– §5.1**
- Expanding the current diesel retrofit program for PM control **– §5.2**

The ERG team believes these options are likely to be cost-effective on a per-vehicle basis, although total costs and emission reductions will vary depending on the number of vehicles involved. (Of course behavioral factors such as compliance, fraud and enforcement will need to be evaluated for these options as well to estimate total emission reduction potential, especially for decentralized OBDII and EGR testing.) Therefore, we believe further evaluation of these measures is merited to further quantify emission reduction potentials as well as to evaluate costs and benefits.

Low Cost, Low Benefit Measures Likely to be Cost-Effective

These measures include:

- Increased inspection frequency for high-mileage vehicles **– §3.1.1**
- Voluntary accelerated NO_x retrofits for heavy diesel trucks **-- §3.1.3**
- Improved use of the current Smoking Vehicle Hotline **– §3.1.5**
- Development of a web-based I/M history report for used car buyers **-- §5.3**
- Expanded use of the current gasoline vehicle catalyst retrofit program **– §5.2**
- Evaluation of limited code-specific exemptions from OBDII requirements **-- §4.3**

6 Although the cost-effectiveness of the baseline OBDII program has not been demonstrated at this time, especially for vehicles beyond their warranty period, we believe that offering a decentralized scanning option has the potential to improve the cost-effectiveness relative to the current program.

At the current time we view these as "niche" measures targeting a relatively small fraction of the fleet. Nevertheless, we expect these measures to be relatively cost-effective.

<u>Low Cost, Low Benefit Measures with Uncertain Cost-Effectiveness</u>

These strategies include:

- Development of a used car buyer's guide based on generic make/model data **-- §5.3**

While this measure may prove to be cost-effective, it is likely to impact a very small portion of the fleet. Therefore, we anticipate relatively small total emission reductions from this measure. In addition, although program operation costs should be low, quantification of benefits for this measure is likely to be difficult and costly.

3.4 Alternative Technology Evaluation

Additional analyses were performed for some of the more promising alternative control options. Specific Alternative Technology Evaluation reports were developed for remote sensing, OBDII, options for improving repair effectiveness, identifying high and low emitters via "profiling," and accelerated retirement of high emitting vehicles. These evaluations utilized historical and new data to assess technical feasibility, likely constraints, and potential emission reductions when possible.

Note that certain evaluations including the Retrofit, PM, and RSD analyses were actually completed under TA3, but are presented here for consistency.

3.4.1 Profiling Analysis

Vehicle profiling can be used to improve the cost-effectiveness of an I/M program. Profiling models can be built based on a vehicle's generic characteristics derived from decoded VIN information. Profiling models can also potentially benefit from the use of vehicle-specific information. This could include I/M program emissions and visual inspection results for the vehicle in the previous cycle, or from direct measurement of a specific vehicle's emissions using remote sensing. Improved cost-effectiveness can be realized using vehicle profiling because not all vehicles would necessarily need to receive a standard I/M program inspection test. For example, only a small fraction of relatively new vehicles will fail the IM147 test. Thus, these vehicles have a high probability of passing. Also, vehicles that have very high RSD emissions are highly likely to fail the IM147 test.

In ERG's Profiling and Prediction of Individual Vehicle IM147 Pass/Fail Results, prepared for the AZACTS under TA 2, we used a portion of the Arizona I/M program dataset from the calendar year 2001 and a dataset of matched RSD and I/M program emissions results to develop a set of models that could be used for "clean screening" or "dirty screening" the fleet. These models were not necessarily the final models that would be implemented in Arizona's I/M program. They may require further refinement and development. However, they serve as examples of the approaches that can be made towards vehicle profiling.

Applications of these models could include using RSD at the point where vehicles enter the I/M station, to provide clean screening of vehicles so they don't need to go through the IM147 lanes. On-road RSD may be beneficial for identifying high emitting vehicles for dirty screening purposes. These vehicles could be called in for inspection and repair in an attempt to lower excess emissions of the highest emitting vehicles immediately, rather than waiting for their next scheduled inspection. The cost-effectiveness of the I/M program can be improved through clean screening by reducing the number of vehicles that have a high probability of passing the test from receiving the IM147 test. Costs are saved on the I/M station side because the total number of vehicles inspected is smaller. In addition, costs are saved on the consumer side because vehicles that have a high likelihood of passing are not inconvenienced by requiring them to get an IM147 test. On the other hand, dirty screening vehicles may improve I/M program cost-effectiveness by preferentially targeting vehicles that have a higher probability of failing the IM147 test by getting them tested and repaired as soon as possible.

The best vehicle profiling models would be able to reduce I/M program costs substantially while making a low, but acceptable, number of incorrect vehicle pass/fail designations. In the study, five different types of vehicle profiling models were built and evaluated for their performance on the Arizona fleet.

Conclusions

a. Profiling models built with remote sensing information gathered at the entrance to I/M stations provided an incremental benefit for identifying vehicles that were likely to fail the IM147 emissions test, relative to models that used only generic vehicle information such as model year and other information (as decoded from the vehicle's vehicle identification number, or VIN). In addition, positive benefit was observed only when less than 30% of the vehicle fleet was screened. At higher screening percentages, subsequent vehicle selections are essentially no better than random, and therefore provide no incremental benefit over the base program.

b. The models developed in this study indicated that when used in a clean screening mode, the RSD information provided no incremental benefit over models that were built with generic vehicle information that could be obtained from the VIN.

c. Thus, this study indicates that if Arizona chooses to institute clean screen profiling of vehicles to exempt them from IM147 testing, RSD measurements taken at the entrance to I/M stations provide only marginal benefits. On the other hand, if Arizona institutes a dirty vehicle screening program, RSD testing of vehicles at the entrance of I/M stations provides an important incremental benefit that cannot be obtained by using generic vehicle characteristics alone. However, this RSD benefit disappears if fleet screening percentages of greater than 30% are desired.

These conclusions are based solely on the results of this study. However, they are consistent with our knowledge of RSD measurements and with our experience on profiling systems developed using other datasets. The models developed in this study are good indicators of potential performance, but they are not highly refined, and it is certainly possible that further refinement of the models could change the influence of RSD emissions and other information on predicting IM147 results. A number of opportunities for further development of the models and specifically for estimating the costs and benefits of using profiling in Arizona exist.

3.4.2 Improving Repair Effectiveness

As part of TA 2, one activity was to analyze historical repair data collected in the Arizona I/M program. The repair data was supplemented with emissions data from the program to evaluate the program and demonstrate its effectiveness. Arizona repair data for calendar years 1997 through 2001 was used to:

1. Make the association between the type of repairs and the apparent emissions reductions produced by the repairs. This included a discussion of the bias introduced in these apparent emission reductions by the I/M program procedures used to designate passing and failing vehicles, and to measure before-repair and after-repair emissions.

2. Determine if before-repair emissions data are associated with the type of repair that a vehicle eventually receives. These “emission fingerprints” could possibly be used to identify vehicles that require repairs even though emission levels are below I/M program cutpoints.

3. Evaluate the lifetime of repairs and discuss other measures of repair effectiveness. Repeat inspection failures were discussed in terms of “ping-ponging” and “shopping around.” Repair costs were examined in terms of the distribution of costs for different repair types.

Conclusions

- The Arizona repair dataset by itself and in conjunction with the emissions dataset useful in understanding the influence of repairs on emissions and the characteristics of repairs. Many trends were found in the Arizona repair data, indicating that the data are of high enough quality to resolve differences in effectiveness among the various types of repairs. The repair dataset does have some opportunities for improvement, however, which are described below, and discussed in detail in the report. Some of the analysis techniques described in the report are expected to yield additional insights if higher quality repair data were obtained.

- For each group of vehicles of the same technology type, the before-repair and after-repair emissions generally increased with vehicle age to levels substantially above the new-car certification standards.

- ERG’s previous analysis of average before-repair emission levels on British Columbia data indicated strong associations with the repair types performed; however, the analysis of Arizona individual vehicle emissions indicated weak associations with repair types performed. The variability in before-repair emissions measurements among individual vehicles was sufficiently large to cause emission fingerprints for different repair types to have substantial overlap. Nevertheless, the properties of the emissions fingerprints hinted that further analysis could lead to building models to predict the probability of specific emission control system failures based on emission fingerprints. If such models can be applied to the emissions of vehicles with emissions below the I/M program cutpoints, the models might be able to identify vehicles with specific malfunctioning emission control systems. The fingerprints that were most distinct from the emission patterns of vehicles as a whole were those for EGR system repairs, catalytic converter repairs, and dwell/timing repairs, which were also found to produce the largest reduction in NO_x emissions.

- An analysis of repair durability indicated that for most types of repairs, the duration of the effectiveness of the repair was relatively independent of the age of the repair. That is, the frequency at which a given repair type is made a second time is independent of the time between the first repair and the second repair. This leads to the conclusion that the quality of repairs in the program are relatively consistent, and that the need for subsequent repairs is most likely determined by component failures or other random events.

In the process of performing the analyses, we identified several possible improvements in the repair data collection system. Based on our analysis of the Arizona data and analyses of the repair data of other states, we recommended that Arizona undertake a two-phase program to upgrade the repair data collection system. In the first phase, the repair data collection procedures currently in use should be audited to identify the weak links in the collection of accurate repair data. Also in this first phase, the current repair data collection system should be patched with several improvements to rectify the weak links that are identified through the audit and through this report's analysis. In the second phase, we recommended that the current system be replaced with a new generation repair data collection system that would incentivize the collection of accurate, complete, and secure repair data from the I/M program. These system improvements would result in improved repair data that would allow for better estimates of the emissions benefit of the I/M program, and would provide a dataset from which improvements to the I/M program could be made.

Recommendations

- In several ways, the analysis of the repair data was more a demonstration of the types of analyses that can be performed, rather than an in-depth analysis of the repair database. Therefore, several of the analyses presented could be performed in more detail.
- The use of repair and emissions data to calculate emissions reductions is a common practice. Unfortunately, important and potentially large biases in the estimated emissions reductions are introduced in such an analysis because of the effect known as "regression toward the mean" [7]. Therefore, we recommended that the size of these biases be either estimated through simulation, or measured directly in the field so that the calculated emissions reductions produced by repairs may be adjusted accordingly.
- Further analysis should be done to investigate whether emissions fingerprints can be used to identify specific vehicles with specific emission control system malfunctions. Comparisons between measured before-repair emissions and expected emissions could lead to improved fingerprints. We believe that such models may be possible and could lead

[7] Regression toward the mean is a statistical phenomenon that applies to measured values that contain error. Specifically, when making 2 measurements of the same parameter, the second measurement will tend to be closer to the mean of the distribution than the first measurement. For example, if a "high-emitter" is identified based on an elevated RSD measurement, a subsequent RSD reading will likely be lower.

to the identification of vehicles with malfunctioning emission control systems (especially those malfunctioning systems that produce excess NO_x emissions) even though the emissions of the targeted vehicles may be below I/M program cutpoints. Since most vehicles have emissions below I/M program cutpoints, repair of these vehicles would result in a substantial reduction of NO_x emissions for the fleet as a whole.

- The engine family names of all inspected vehicles should be routinely recorded and entered into the VID. The engine family names of recent model year (1994 and newer) vehicles can be readily decoded to provide the most accurate information on the emissions control equipment installed and the applicable certification standard for each vehicle. This information can make the analysis of emissions and repair data more reliable and more useful.
- Finally, we recommend that Arizona take interim measures to improve the current repair data collection system, and make plans for a next generation repair data collection system to replace the current system.

3.4.3 Accelerated Vehicle Retirement Strategies

Voluntary scrap programs, also known as "early retirement programs," "accelerated retirement programs," or "scrappage programs" attempt to reduce emissions by removing high emitters from the vehicle fleet. Programs typically provide monetary incentives to vehicle owners to induce them to scrap their vehicles sooner than they otherwise would. Scrap programs have the potential to generate substantial emission reductions at relatively low cost. A voluntary scrap program can also be designed with great flexibility, acting as an adjunct to a traditional I/M program, as a stand-alone program, or both.

ERG and Mr. Joel Schwartz prepared a report under TA2 summarizing the history of vehicle scrap programs, highlighting design issues, estimating emission reductions, discussing potential sources of funding, and recommending next steps for potential design and implementation for Arizona. Note that no new data analysis was performed for this report. Future quantitative analyses of potential emission reductions, costs, cost-effectiveness, and public acceptance will require additional work.[8] The specific analyses needed are summarized below.

8 Specifically, IM147 and/or remote sensing tests on pre-1981 model year vehicles would be required to estimate potential benefits for the Arizona fleet.

Summary of Scrap Programs in North America

At least eight scrap programs are currently operating in the United States and Canada. The California Bureau of Automotive Repair (BAR) operates a statewide program as part of California's enhanced I/M program, while four California air pollution control districts (San Francisco Bay Area, South Coast, San Diego, and Santa Barbara) operate local programs based on guidelines established by the California Air Resources Board (CARB). Oregon has a pilot program that has been operational since September 2000. British Columbia and Ontario in Canada also operate scrap programs. In addition, Texas and Illinois have adopted rules for early retirement programs for local air pollution control districts to generate SIP credit, or for stationary sources to generate mobile source emission reduction credits.

Potential Emission Reductions

On-road emissions data strongly suggest that scrapping a small portion of the vehicle fleet could indeed generate a substantial amount of cost-effective emission reductions. For example, remote sensing (RSD) data collected in Phoenix in 1999 indicate that the worst 2 percent of hydrocarbon (HC) emitters accounted for several times the level of light-duty car and truck tailpipe HC emissions. Of these vehicles, 48 percent were more than 10 years old and 24 percent were more than 15 years old. Thus, a substantial percentage of on-road "super-emitters" are likely low-value vehicles, both because they are old, and because their very high emissions suggest they are in poor running condition.

These results suggest that a voluntary scrap program could, as a rough upper bound, generate up to a 10 percent to 15 percent reduction in current light-duty car and truck tailpipe HC emissions by inducing early retirement of a small fraction of the fleet.

Cost-Effectiveness Estimates

The cost-effectiveness of a scrap program will vary depending on how the program is structured. For example, if vehicles are eligible based solely on their age, then average emissions per scrapped vehicle might be lower than if vehicles' eligibility is based on failing an I/M test or a high on-road RSD reading. Cost-effectiveness also depends on the size of the cash incentive offered. Estimates of cost-effectiveness also include uncertainties due to the challenge of estimating emission reductions. Finally, because of the many differences between scrap programs and in the methods used to estimate emission reductions, additional analysis is necessary to place cost-effectiveness estimates for different programs on a comparable footing.

Reports on the Unocal Scrap II program in California, and the Delaware Vehicle Retirement Program estimated the cost-effectiveness of the programs to be about $5,000 per ton of HC. Both estimates included assumptions about the non-tailpipe HC emissions from the scrapped vehicles, the remaining life of the vehicles in absence of a scrap program, and the emissions from replacement transportation. The Scrap-It pilot program in British Columbia estimated a cost-effectiveness of $2,429 per ton of HC+NOx. Dixon and Garber (2001) predict that cost-effectiveness could range from $3,700 to $11,100 per ton (HC+NOx) for a cost of $500 per scrapped vehicle for the planned “M1 Program” in California, with cost-effectiveness increasing linearly with the cost per scrapped vehicle. The range of the cost-effectiveness estimate is due to uncertainty in the actual net emission reductions that the program would achieve.

Note that none of these programs solicited scrap candidates based on directly on emissions measurements. A program that focused only on the very highest emitters, based on I/M testing, on-road RSD, or some other method would likely have much better cost-effectiveness than the programs discussed above. Varying the size of the scrap payment based on the estimated value of each vehicle is another potential way to improve cost-effectiveness.

Identifying Scrap-Candidate Vehicles

A scrap program will be more effective to the extent that it can direct scrap offers to the vehicles with the highest overall emissions in terms of emissions rate, miles driven, and remaining useful life. Scrap candidates will generally be at least 10 years old, because only older vehicles have a low enough market value to make scrap a better option than repair. Older vehicles are also better scrap candidates because they have less sophisticated emission control technologies and are therefore inherently higher emitting.

There are several ways to identify scrap candidates, including:

- General vehicle characteristics, such as age, engine family, emission control technology, etc.
- High-emitter profiling
- High-emissions on an I/M test
- High on-road emissions

Based on our assessment, a combination of I/M test lane and on-road RSD appears to present the best scenario for maximizing the universe of scrap-candidate vehicles with very high emissions.

Funding Requirements

Additional analysis will be necessary before recommending an appropriate goal for the number of vehicles to be scrapped each year in a scrappage program. However, based on cost-effectiveness, likely budget constraints, and potential used vehicle market impacts, a reasonable goal for an aggressive scrap program could be to retire roughly 0.5 percent to 1 percent of the vehicle fleet per year. In Maricopa County, this would amount to scrapping roughly 5,000 to 10,000 vehicles per year, and 1,500 to 3,000 vehicles in Pima County. Using typical scrap costs from other programs, scrapping 0.5 percent of the fleet would require roughly $4 million to $7 million per year.[9]

Recommendations

We recommend that Arizona seriously consider adding a voluntary scrap program to its in-use emissions control strategy. A voluntary scrap program has great potential to deliver substantial and cost-effective pollution reductions. Additional study is necessary to make more definitive estimates of the likely costs and benefits of scrap in Arizona, and also whether and how such a program could be added onto Arizona's current I/M program. The following recommendations are offered (not in order of priority):

1. Begin detailed evaluation of program design and coordination issues, including:

- How to coordinate a scrap program with the current I/M program
- Methods of selecting candidate vehicles
- Feasibility of vehicle-specific scrap incentives
- Incentives needed to induce a given participation level.
- Requirements for contracting with auto dismantlers
- Plan for public outreach and pilot testing to ensure smooth rollout

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9 This estimate assumes the scrap incentive payment ranges from $500 to $1000 and adds assumed overhead costs of $100 per vehicle for solicitation and processing.

This assessment should include (1) in-depth interviews with staff from other scrap programs, (2) data collection from other scrap programs to estimate emission reductions and cost-effectiveness, (3) analysis of Arizona registration, I/M, and RSD data to understand the nature of the Arizona fleet, and (4) survey, focus group, and/or other market research with motorists to determine what factors would enhance or detract from motorist participation.

2. Identify funding sources for a scrap program. Depending on the scale of the program, a scrap effort could cost from a few hundred thousand to several million dollars per year. DEQ should begin identifying potential funding sources, such as an I/M "buyout" for newer vehicles, stationary source participation, federal funding, and/or other options.

3 Assess administrative and other resource requirements for operating a scrap program. This should include gathering of information on management costs for other scrap programs, as well as the specific needs for integrating a scrap-program administration in the Arizona DEQ.

4. Develop more sophisticated estimates of potential scrap emission reductions. Develop valid methods for assessing real-world emission reductions from scrap. Existing RSD, I/M and registration data present a wealth of information that could be harnessed to develop estimates. In addition, Arizona should also gather additional data on emissions of pre-1981 model year vehicles by sending a random sample for dynamometer tests. Arizona should also work with EPA to agree on methods for assessing actual emission reductions from scrap.

5. Develop Arizona-specific estimates of potential economic effects. Determine whether the RAND model for California can be easily adapted to assess potential economic effects of scrap in Arizona.

6. Assure appropriate SIP credit for scrap and other promising in-use programs. Determine whether current allocation of SIP credit discourages progress in reducing in-use vehicle emissions. If so, Arizona should seek flexibility from EPA to ensure that SIP requirements don't discourage implementation of effective and cost-effective real-world pollution reduction measures.

7. Determine the requirements for enacting the required "Enabling Legislation." According to recent SIPs, there is a lack of "Enabling Legislation" for certain types of scrappage programs.[10] If such legislation is ultimately required the impediments to writing and enacting it should be investigated.

3.4.4 On-Board Diagnostic (OBDII) Effectiveness Evaluation

Since January 2002, 1996 and newer vehicles have received OBDII inspections in the Phoenix and Tucson areas. This report provides a summary of analysis of that data (collected through March 2002), in comparison with I/M program data from Oregon, Illinois, and Wisconsin. Results of comparative analysis between OBDII and tailpipe tests from other programs are also provided, along with an overview of OBDII test issues such as possible sources of OBDII test fraud and fraud prevention, future changes expected for vehicle OBDII systems, and options for enhancements which could be made to OBDII test programs.

Analysis of OBDII Program Data

OBDII Fail Rate and Readiness Trends - A vehicle will fail the Arizona OBDII inspection if its malfunction indicator light (MIL) does not illuminate during the key on engine off (KOEO) check or if the MIL is commanded on by the vehicle's computer. A vehicle is rejected from testing if more than two monitors are not ready. In a comparison of OBDII inspection failure rates with Oregon, Wisconsin, and Illinois (Illinois is advisory only), Arizona was found to have a much higher MIL commanded on failure rate than Oregon and Wisconsin, and about the same as Illinois (Illinois' high rate is likely due to it's advisory-only policy). This trend was seen for both low and high-mileage vehicles. This high failure rate may indicate motorists are unfamiliar with Arizona's OBDII testing requirements. The Arizona dataset also had a low percentage of vehicles with more than two monitors "not ready", also implying motorists may not be repairing/resetting their vehicles prior to the OBDII inspection (again an indication of unfamiliarity with the OBDII test program).

Diagnostic Trouble Code (DTC) Trends - The average number of DTCs stored for vehicles that failed the OBDII test was similar between Arizona, Oregon, and Wisconsin (2/3 of the failing vehicles had only one DTC stored). The average number of DTCs per failed vehicle did not greatly increase with mileage in the Arizona fleet (most high mileage vehicles had only one DTC). By-mileage evaluation of the number of

10 Maricopa Association of Governments, "Serious Area Committed Particulate Control Measures for PM-10 for the Maricopa County Nonattainment Area and Support Technical Analysis," (Phoenix, December 1997).

DTCs was not performed for the other programs. DTC-specific analysis revealed common DTCs were seen among low and high-mileage vehicles (although catalyst failures increased in prevalence with mileage). Some of the most common DTCs were lean systems, low catalyst efficiency, Ford evaporative control valve failure, EGR flow insufficient, and O_2 sensors heater circuit malfunctions. These codes were also seen to be common for both low and high-mileage vehicles tested in Oregon, Wisconsin, and Illinois.

OBDII Test Issues - Of the four programs compared, Illinois and Arizona had the highest percentage of tests in which the inspector could not find the OBDII diagnostic link connector (DLC) (2.4% and 1.7%, respectively). This percentage is expected to drop as inspectors become more familiar with DLC locations in vehicles. Arizona and Wisconsin had OBDII communication failure rates just under 2%, Illinois and Oregon under 1%. These also are expected to drop in time as equipment improves and inspectors gain familiarity with test procedures. Over 14% of Arizona's OBDII retests were failed, 13% because of the MIL still being commanded on. As with the high initial OBDII failure rates seen in Arizona, this again indicates additional motorist education regarding OBDII test requirements may be needed.

Comparison of OBDII and Tailpipe Test Results

Tandem OBDII and tailpipe test data from Illinois and California was evaluated in order to evaluate the efficacy of OBDII in identifying high-emitting vehicles and to compare the relative benefits of each type of test. For both programs, the majority of vehicles passed both tests, and more vehicles failed the OBDII test than the tailpipe test. This higher OBDII failure rate is to be expected for several reasons

- OBDII continually monitors a vehicle's performance (not just a "snapshot" as with a tailpipe test)
- Unlike a tailpipe test, OBDII fails for evaporative system malfunctions, and
- OBDII often detects system malfunctions before an increase in tailpipe emissions occurs

However, a number of vehicles with high tailpipe emissions were "passed" by the OBDII system for both programs (only 35% of California's ASM "gross polluters" had an illuminated MIL, and 37% of Illinois' IM240 failures had an illuminated MIL). Several possible reasons for these tailpipe fail/OBDII pass vehicles exist:

- Allowing one or two “not ready” monitors may be masking system malfunctions that OBDII would otherwise detect (particularly a catalytic converter failure)
- The tailpipe test was used as the basis for evaluation for both studies. Doing so biases test results in favor of the tailpipe test
- Tailpipe test criteria differ from OBDII certification criteria
- Test inaccuracies (either tailpipe false failures or OBDII false passes)

To compare OBDII and tailpipe emissions benefits, vehicle emissions were calculated for various tailpipe/OBDII pass/fail combinations for both Illinois and California. This analysis revealed that, for both programs, vehicles that failed the OBDII test had higher emissions than those that passed, the lowest emissions were seen for vehicles that passed both tests, and the highest emissions were seen for vehicles that failed both tests. Also, for both programs, the average emissions of all vehicles that failed the tailpipe test were higher than the average emissions of all vehicles that failed the OBDII test.

Emission reductions were also calculated for various tailpipe/OBDII pass/fail combinations for both programs (based on initial failure emission levels using the in-program data and assuming 100% repair effectiveness). Overall (excluding the OBDII evaporative benefit results), tailpipe test repairs were projected to achieve higher HC and CO reductions than OBDII test repairs, but OBDII test repairs were projected to achieve higher NOx reductions. However, including the OBDII evaporative benefit as calculated by MOBILE6 yields a higher HC reduction benefit achieved by OBDII than the tailpipe test. For both programs, requiring vehicles to pass both the OBDII and tailpipe test would achieve the highest total emission reductions, while allowing vehicles to receive a “pass” if either test was passed would achieve the lowest total emission reductions.

Analyses of repair costs for tailpipe (ASM and BAR31) failures in comparison with OBDII failures was performed for both California and Oregon. Average repair costs were seen to be approximately $300 for vehicles in all three groups (ASM failures, BAR31 failures, and OBDII failures).

Other paired OBDII/tailpipe studies were also reviewed. EPA’s 200 Car Study, which compared IM240 and OBDII test results of vehicles that failed either OBDII or IM240 tests, found that OBDII identified 19 out of 21 true high-emitters (as measured by a full FTP test), as opposed to the IM240 test, which identified 13 of the 21 true FTP high emitters. OBDII also identified a number of vehicles with malfunctioning components but which had IM240 emissions below cutpoints, but no malfunctioning components could be identified on 29% of the OBDII failures. Another study, conducted by the University of California, Riverside, showed that 29 out of 77 vehicles with illuminated MILs had emissions over the certification standards. The remaining 48 vehicles had emissions lower than certification standards. Preliminary results from a third study currently being conducted by Colorado were also reviewed but did not yet reveal any clear trends.

Other OBDII Issues

Test Fraud **-** OBDII sensor simulators, clean scanning, electronic record manipulation, and code clearing are four primary sources of OBDII test fraud. OBDII sensor simulators, or cheater devices, send signals to the vehicle's computer to mask a malfunctioning or removed component. For example, oxygen sensor simulators may mask a removed oxygen sensor or a deficient catalytic converter from the OBDII monitoring algorithm by sending a false signal to the vehicle's computer. To identify this type of fraud, future versions of OBDII inspection software could incorporate logic to compare sensor outputs to specific operating conditions to verify response values. Two-way communication between the inspection system and the vehicle's computer could also be used to verify OBDII system responses to commands sent to the vehicle's computer (such as a "not-ready" status after a system reset command is sent).

Clean scanning (analogous to tailpipe clean piping) can generally be identified by evaluation of certain fields of the vehicle's downloaded test record, such as vehicle make, model, model year, parameter identification number (PID count), and powertrain control module (PCM) ID. Most I/M programs currently collect these parameters. In the future, additional parameters, such as the vehicle's VIN and PCM calibration verification number may also be used to further reduce clean scanning.

Electronic record manipulation can generally be prevented through record encryption.

Code clearing appears to be a potential loophole that allows vehicles with malfunctioning components to have their OBDII systems reset and be tested before the malfunctioning component is "ready" for testing (since I/M programs usually allow two "not ready" monitors).   Since the catalytic converter commonly fails and generally is one of the last monitors to reset, requiring this monitor to be "ready" upon reinspection (or requiring a tailpipe test upon reinspection) may prevent this type of false pass upon reinspection.

Future OBDII Changes - In order to improve the effectiveness of OBDII testing, the California ARB and USEPA are implementing new OBDII system requirements, beginning with 2004 model year vehicles. These changes include: Requiring a standardized DLC location; verification of OBDII communication with a generic scan tool during vehicle certification; inclusion of the Calibration ID, Calibration Verification Number, VIN, and "time since codes cleared" information in the OBDII download data stream; requiring manufacturers to provide drive cycle information necessary to enable OBDII monitoring (after repair resets); and requiring standardized monitor enabling criteria.

Decentralized Scanning **-** Decentralized scanning would involve having trained technicians or motorists perform scans of their own OBDII systems at repair garages, gas stations, or even at their homes. This could be beneficial as it may result in more timely repairs, reduced I/M program administration costs, and an increase in convenience for motorists. A study conducted in the Phoenix area indicated a majority of motorists were in favor of development of such a program (which would eliminate the need to take a vehicle to a centralized testing facility). However, such a program would also increase the possibility of fraud and abuse. A pilot test program could be performed in order to assess the viability of implementing a decentralized OBDII scanning program.

Conclusions and Recommendations

Overall, OBDII inspections are feasible in both centralized or decentralized inspection networks. However, analysis of paired tailpipe/OBDII inspection results indicates OBDII may not be identifying some high-emitting vehicles. Although this may in large part be due to inherent biases in the study design (tailpipe false failures and failures masked by readiness), additional analysis is warranted, especially as vehicles age and accumulate more miles. *This additional testing and analysis should include an assessment of whether the tailpipe test should be retained as a back up test in order to identify true high-emitters that OBDII misses or to verify OBDII performance in high-mileage vehicles.*

Results from Arizona's MIL illumination and readiness rates indicate additional motorist education of OBDII testing requirements may be needed. In addition, a focus group study investigating motorist responses to illuminated MILs (performed under TA6) may provide clues on how to improve motorist response rates to MIL illumination. Finally, investigation into implementing a decentralized testing network (at garages, gas stations, or even at motorist's homes) may be of benefit.

3.4.5 Gasoline and Diesel Vehicle Retrofit Strategies

As an alternative to scrappage programs, ERG developed an additional report providing an overview of the potential for vehicle retrofits to contribute additional emission reductions from older gasoline and diesel vehicles. Retrofit involves adding modern pollution controls to an existing older engine, or replacing an older engine with a new or rebuilt engine certified to more stringent emission standards (often referred to as "repower"). A retrofit program could speed the pace of air quality improvements by reducing emissions from some older vehicles and engines now, rather than waiting for them to be retired naturally.

Retrofit Options - Gasoline Vehicles

Although gasoline vehicles contribute substantially to VOC, NOx, and PM emissions, only 1975-80 model year vehicles are suitable for retrofit with a three-way catalyst. These cars originally had two-way catalytic converters and open-loop control systems, but can be retrofitted with an aftermarket three-way catalytic converter and a closed-loop control system. Neutronics, a San Diego-based company, is the only vendor of such systems.

Based on Maricopa County 1999 registration data, 1975-1980 vehicles made up 4.9% of the registered fleet in 2002. Based on remote sensing data collected in 2000 in Phoenix, these vehicles account for only about 1.2% of miles traveled, but 4.7% of tailpipe VOC emissions. Retrofitting gasoline vehicles could generate relatively cost effective emission reductions. Pre-1975 vehicles don't have catalytic converters, and could be retrofit with a two-way converter to reduce VOCs and CO. These vehicles make up a very small fraction of the fleet, and many are probably in too poor a condition to make retrofit a cost-effective option. Natural gas (NG) retrofits are another option for gasoline vehicles. However, because of their comparatively high cost ($2,000 to $3,000), scrappage and three-way catalytic converter retrofits are more cost effective for older vehicles.

Retrofit Options – Diesel Vehicles

Diesel emissions can be reduced by either retrofit or repower. In general, repowers reduce both PM and NOx. Costs vary with engine size, ranging from a few thousands dollars for smaller engines, up to $10,000 - $30,000 for large trucks and buses.

Among the current retrofit options for reducing PM emissions, the most important are diesel oxidation catalysts (DOCs) and diesel particulate filters (DPFs). DOCs reduce PM by between 25% and 50%, and can also reduce CO and HC emissions by more than 90%. DOCs have been installed on more than 250,000 vehicles (mainly in Europe) during the last 30 years and are a proven technology. DOCs range in cost from $425 to $1,750, depending on engine size, sales volume, and whether the retrofit includes muffler replacement. However, DOCs can increase fuel costs by up to two percent, but have little or no ongoing maintenance requirements.

Diesel Particulate Filters (DPF) combine a filter to trap PM with a catalyst that oxidizes the PM to carbon dioxide and water. DPFs are far more effective than DOCs, and can achieve PM reductions 80% to 90%. However, DOCs also require ULSD fuel[11] to be effective, while DOCs can work at substantially higher fuel-sulfur levels. DPFs increase fuel costs by between zero and four percent. In addition, ash must be removed from DPFs roughly every 60,000 or once per year. This maintenance requirement will likely become less important over time, as newer engines consume less lubricating oil (the source of the ash), and also because newer lubricating oils are being developed with lower ash content.

DPFs have been installed in off-road diesel vehicles since the 1980s, while on-road applications have increased substantially in the last few years. Tens of thousands of DPF-equipped diesel cars have been sold in Europe, and several thousand European buses have been retrofitted. DPF retrofits are also becoming more common in the U.S. DPFs typically cost about $5,000-$7,500.

Retrofits to reduce NOx emissions are mostly still in the developmental stage and are not yet widely used. These include Selective Catalytic Reduction (SCR), lean NOx catalysts, and Exhaust Gas Recirculation (EGR). EGR systems can reduce NOx by 40% and retrofit costs range from $13,000 to $15,000. Lean NOx catalyst systems can reduce NOx by 15% to 30%, while systems achieving 50% to 70% reductions are under

11 Current DPF retrofit programs include the use of either 15 ppm sulfur maximum, or in some cases 30 ppm sulfur maximum diesel fuel.

development. Lean NOx catalyst systems cost from $6,500 to $10,000. SCR systems can reduce NOx by 75% to 95%, and cost from $10,000 to $50,000. Because control technologies are advancing rapidly and sales volume is increasing, these effectiveness and cost estimates should only be considered rough estimates that will likely change with time.

There are also a number of combination options for reducing both NOx and PM. For instance, lean NOx catalyst systems are generally combined with a DPF. There are also so-called “reflash” systems combined with a DOC that reduce long-haul NOx emissions by about 25%, while also reducing PM by more than 25%. However, these systems are applicable only to those trucks (mainly the 1994-1998 model years) with built-in “defeat devices” that increase fuel economy, but also NOx emissions, during steady-state driving. An EPA consent decree requires that these be removed at the next rebuild.

Current Retrofit Programs

EPA, several states, and a number of other countries have implemented diesel retrofit programs for PM and NOx reductions, as well as programs to switch some vehicles to ULSD fuel. Because of the high costs of diesel NOx reduction technologies, these programs have typically focused on engine replacement for NOx reductions. The Retrofit report summarizes programs sponsored by the U.S.EPA as well as the states of California, Massachusetts, New York and Washington.

Emission Reductions and Cost Effectiveness

Information on emission reductions and cost effectiveness for retrofit programs is limited. This section provides a brief overview of current knowledge and information needs.

Gasoline Retrofits - A study of several vehicles retrofitted with the Neutronics three-way catalyst kit found that the system reduced emissions of all three pollutants by more than 60% immediately after installation. After 30,000 miles, emissions of HC and NOx were still 50% lower, while CO was 20% lower. The California Air Resources Board (CARB) has also certified the effectiveness of the Neutronics retrofit kit.

Maricopa County includes a retrofit option in its Voluntary Vehicle Repair and Retrofit Program. Between January 1999 and June 2002, the program installed retrofit kits in 158 vehicles at an average cost of $924 per vehicle. Additional information on the current program can be found in the section on Targeted Retrofits in the AZACTS State of the Science Report. It is not possible to directly estimate cost effectiveness of this program, because eligible vehicles receive only an idle test. However, based on reasonable assumptions regarding mass emission reductions, miles traveled, and useful life, the cost effectiveness is likely somewhere in the range of $3,500 to $9,000 per ton of HC+NOx+CO/60 eliminated. Although the cost-effectiveness of gasoline retrofit appears to be reasonably good, it might be possible to improve it significantly by using remote sensing to identify the highest-emitting eligible vehicles for retrofit.

Diesel Retrofits **-** As of March 2002, California's Carl Moyer program had repowered 3,867 engines with estimated annual emission reductions of 3,800 tons of NOx and 212 tons of PM. Roughly 30% of the NOx reductions were from vehicles, while the rest came mainly from repowering or replacing non-road engines. Cost effectiveness data exist mainly for repowers to reduce NOx emissions. Average cost effectiveness for the Carl Moyer program was between $4,000 and $5,000 per ton of NOx, but project-level cost and emissions data would be necessary to estimate cost effectiveness for land-vehicle repowers alone. Also, cost effectiveness is based only on the cost of the incentive grant, rather than the full cost of the project.

ERG was not able to locate cost effectiveness estimates for PM retrofits. Additional analysis will be necessary to determine the range of cost effectiveness levels for various vehicle classes and PM control technologies, and to then establish reasonable cost effectiveness goals for retrofit programs.

Some types of retrofits could also incur additional costs. For example, DPFs require low-sulfur fuel, which costs several cents more per gallon.[12] In addition, some retrofit technologies cause slight reductions in fuel economy, raising operating costs.

Based on 1998 Maricopa County registration data, about 23,000 heavy-duty diesel vehicles and 4,300 buses are registered in Maricopa County. There are also likely a large number of smaller diesel vehicles in the area. The Carl Moyer program experience in California suggests that Maricopa County could achieve substantial NOx and PM reductions through retrofit of some of these vehicles.

12 For on-road vehicles, this cost penalty will disappear in a relative sense when ULSD fuel is required nationwide in 2006.

Recommendations

We believe that Arizona should consider adding a diesel retrofit program to its in-use emissions control strategy. A retrofit program has great potential to deliver substantial and cost-effective pollution reductions. Additional study is necessary to make more definitive estimates of the likely costs and benefits of retrofit in Arizona. The following recommendations are offered:

1 ***Determine pollution reduction priorities.*** Because Maricopa County has been considered to be VOC limited, ADEQ should consider whether NOx reductions are a priority for a retrofit program, or whether the focus will be only on PM and VOC reductions.

2. ***Assess fuel sulfur issues.*** Assess the potential availability and costs of ULSD fuel. Near-term availability of ULSD fuel will determine the extent to which DPF retrofits are feasible. A lean NOx catalyst (LNC) combined with a DPF is a potential option for achieving 90% PM reductions without the need for ULSD.

3 ***Assess potential emission reductions, costs, and cost effectiveness.*** Data are available for generating preliminary estimates of emission reductions, costs, and cost effectiveness for a substantial retrofit program. ADEQ should make such estimates based on the current diesel fleet, data on typical emissions and duty cycles of various types of diesel equipment, and costs and performance of commercialized retrofit options.

4. ***Draw on experience of other states in designing a retrofit program.*** CARB and the California air districts that administer the Carl Moyer program now have multiple years of experience running a large-scale retrofit program. The program managers at each agency could provide detailed information on how to design a program and get it off the ground.

5. ***Identify funding sources.*** Incentive funding is crucial to a retrofit program, because of the program's voluntary nature. ADEQ should assess the availability of funding from federal, state and local sources, both public and private.

6. ***Assess potential SIP credit***. Given emission reduction estimates, EPA's SIP-credit framework can be used to assess potential SIP credit from retrofit.

7. ***Gasoline retrofit program***. Catalyst retrofit for gasoline vehicles appears to be reasonably cost effective. However, the cost effectiveness could be improved by identifying the highest-emitting candidate vehicles using on-road remote sensing.

3.4.6 Use of Remote Sensing Technologies

One goal of the AZACTS was to evaluate vehicle Remote Sensing Devices (RSD) for their applicability to strategies for reducing vehicle pollution. Although RSD has been used to measure emissions of vehicle fleets since the late 1980's, in many respects it is still evolving as a technology. Most of the technological changes have been aimed at expanding the capabilities of RSD. Other efforts have been aimed at understanding the applicability of RSD to measuring emissions of single vehicles.

RSD testing has previously been performed in Arizona. Arizona DEQ ran a remote sensing high emitter identification program from 1996 until April 2000. RSD has also been used in Arizona for several studies.

The following questions were addressed in this report.

- What systems are available for conducting large-scale RSD projects and what are their main similarities and differences?
- How good are these systems at capturing vehicle emissions data at various locations in Arizona?
- How stable and accurate are these RSD systems?
- How do the measurements produced by these systems compare to each other?
- During the course of collecting and analyzing the data required to answer the above questions, additional questions have emerged. Recommendations aimed at answering those questions are offered for consideration by Arizona.

Background

ERG subcontracted two companies that manufacture and operate competing on-road remote sensing technologies: MD LaserTech and Environmental Systems Products (ESP). ERG also contracted the University of Denver to co-locate its remote sensing unit with each of the commercial vendors, for at least part of the time each of the vendors were collecting data. This established a common baseline to which the vendors could be compared. It also provided data for each area from a single system.

We emphasize that the University of Denver unit is not considered “correct” or more accurate than the commercial units. It merely provided a datum, or common denominator, to which they could all be compared.

The two companies collected data in different areas of Arizona. MD LaserTech collected data in the Casa Grande area (between Tucson and Phoenix), which is outside the two I/M areas in Arizona. ESP collected data in the Phoenix I/M area. MD LaserTech also collected data in the Tucson I/M area as a partial replacement for a third vendor which dropped-out from the project.

Valid Data Capture Rate (Hit Rate)

For the purposes of this evaluation a "valid" data point was defined as one where all three pollutant measurements and the speed measurement were flagged as “valid” by the RSD system software, and the vehicle license plate was successfully transcribed. Remote sensing equipment typically is not expected to obtain 100 percent valid data; therefore, each vendor was expected to perform quality screening to sort the valid data from the invalid.

To obtain vehicle information, ERG matched the license plate of each remote sensing record to Arizona’s statewide registration database (with records for all vehicles that were currently registered on November 1, 2001) as well as to records collected in Arizona’s I/M program between January 1995 and June 2001.

The University of Denver’s data tended to have the highest percentage of valid measurements (64% to 79%) and the highest rate of successful matching to the registration database (49% to 63%). MD LaserTech’s data had a percentage of valid measurements and a rate of matching with the registration database of 65% and 40%, respectively. ESP had the lowest percentage of valid measurements and rate of matching with the registration database: 57% and 35%.

Whether a data point is valid or not is determined by the RSD system that took the measurement. It is in the best interest of the equipment manufacturer to only produce data that it considers defensible, but it is also in their interest to produce a high hit rate. Each vendor has set it's own criteria for meeting the conditions of defensibility.

It will be important for any RSD program to understand the criteria used by their vendors. It will also be important for the client of the vendor to specify any additional criteria that it feels are required to serve the goals of the RSD program.

Instrument Stability Issues

Drift and Calibration

All measurement instruments should be periodically have their readings compared and adjusted based on measurements from a known standard (i.e., calibrated). The difference between the expected and actual readings, referred to as drift, is corrected through a “calibration correction.”

Each RSD system used during this study was calibrated between three and nine times each day. Calibrations were not typically done at regular intervals. When calibrations were performed, correction values varied significantly. One likely cause of this is the difference in time lag between each calibration, since greater drift occurs over longer time periods between calibrations. Establishing a consistent calibration frequency helps reduce the incidence of extreme calibration corrections.

Low Measurement Noise

The noise in a measurement system is the variability of its readout when measuring a constant value. Every measurement system will exhibit noise. The noise of an RSD system may be estimated by auditing the system multiple times consecutively with a calibration gas. (Variations in the readouts for that constant, known value are an indication of the noise level in the system.) Another method, developed by the University of Denver, takes advantage of the fact that many vehicles have very low pollutant emissions. Only that method is discussed here. (Other methods are discussed later.) A summary of the noise of the systems calculated using the University of Denver method is shown in Table 3-1.

Table 3-1. Summary of “Noise Near Zero” Analysis for Each Measurement

Measurements	University of Denver (Casa Grande)	University of Denver (Phoenix)	University of Denver (Tucson)	MD LaserTech (Casa Grande)	MD LaserTech (Tucson)	ESP (Phoenix)
CO (%)	+/- 7.2	+/- 6.7	+/- 6.7	+/- 9.7	+/- 19.2	+/- 5.79
HC (ppm)	+/- 87	+/- 70	+/- 240	+/- 32	+/- 29	+/- 29
NO (ppm)	+/- 58	+/- 54	+/- 68	+/- 44	+/- 45	+/- 44

ERG observed from these analyses that noise for each system is not constant. Noise is important to quantify when analyzing the RSD data because it tells us the range of uncertainty in each measurement. Therefore, in future RSD data collection efforts it will be important to track how noise varies from day to day and from site to site. This can be accomplished in several ways. For example, frequent audits of the system using calibration gases would probably be sufficient to determine when noise levels change for a given system. Over time, it may be possible to determine why the noise levels change. That would probably allow the vendor to devise a solution to the problem, resulting in more consistent and better quality data in the future.

Remote sensing systems sometimes exhibit a bias in data for a given day or site. This bias is unexplained as of now, so its occurrence is not predictable. For example, the University of Denver has reported an occasional bias in their hydrocarbon (HC) measurement, which they refer to as "offset." They assess when offset occurs at a given site by looking at the average emissions for the cleanest category of vehicle in their data set (e.g., 2001 model year Toyota sedans). They assume that if the vehicles are warmed up and operating under a moderate load, their average emissions should be very low, and about the same, no matter the site or date of data collection.

When the University of Denver has determined there is an offset in their HC measurements, they correct for it by adjusting the HC readings for all vehicles. They simply add or subtract the same amount from each reading so that the average HC reading for the cleanest category of vehicle is set to zero. Although this adjustment in readings is probably not exactly accurate, it is reasonable. Many research projects have shown that the cleanest vehicles in the fleet have HC emission levels near zero.

In this report, the concept of offset is generalized to apply to all measured pollutants. However, since the offset is not treated the same here as by the University of Denver, we will only refer to it as bias.

The average emissions for the newest model-year vehicles observed by each instrument in each area are summarized in Table 3-2. This analysis was conducted using only measurements taken by both the vendor and the reference (University of Denver) system, so the fleets seen by both systems in a given area are nearly identical.

Table 3-2 Average Readings for Each Pollutant from Newest Model-Year Vehicles

Average Reading of Newest-2 Model-Years	Casa Grande		Tucson		Phoenix	
	Univ. of Denver	MD LaserTech	Univ. of Denver	MD LaserTech	Univ. of Denver	ESP
CO (g/gal)	10	68	46	160*	13	27
HC (g/gal)	5	3	28*	4	7	5
NO (g/gal)	4	2	8	5	3	2

* The lowest mean emission reading for HC by U. of Denver in Tucson was 15 gpg at vehicle age = 4 years. The lowest mean emission reading for CO by MDL in Tucson was 122 gpg at vehicle age = 1 year.

Significant bias is observed in at least two instances. The CO measurements made by MD LaserTech in Tucson appear unusually high, and the HC measurements made by the University of Denver in Tucson also appear unusually high. A third possible occurrence of bias is in the CO measurements made by MD LaserTech in Casa Grande. In general, the MD LaserTech system produced consistently higher readings for CO than the other systems.

As previously discussed, the reasons for bias are unknown, but can likely be corrected. The observation of an apparent bias in the CO readings from MD LaserTech's system is new. The data correction method developed by the University of Denver may be appropriate for application to MD LaserTech's CO data.

In future research, it would be helpful to develop a standardized method for determining when bias occurs. This will probably involve applying statistical tests of difference to the data set under question and a data set determined to be correct.

Agreement With Drive-By Audits

Drive-by audits were conducted for all these systems. These audits were performed using a truck which emits a simulated exhaust plume using calibration gases. The simulated exhaust plume is "dry," meaning that it does not have the water (approximately 15% by volume) found in vehicle exhaust plumes.

The differences between measured and true values during audits were often considerable, both in percentage and absolute units. Table 3-3 shows a summary of the mean and standard deviations of percent differences for non-zero bottle values and absolute differences in measurement unit for zero bottle values.

Table 3-3. Summary of Percentage Differences and Absolute Differences for Drive-By Audits

Pollutants	Vendor	City	Zero Bottle Values Absolute Differences (ppm or %)			Non-zero Bottle Values Percent Differences (% of point)		
			Mean	Std. Dev.	n	Mean	Std. Dev.	n
CO (%)	U. of Denver	Casa Grande	0.14	0.48	30	4.98	4.22	15
		Tucson	0.04	0.03	14	9.52	1.27	5
	MD Lasertech	Casa Grande	0.05	0.04	16	5.67	2.60	9
		Tucson	0.11	0.15	26	6.22	2.67	10
	ESP	Phoenix	0.03	0.05	7	35	9.33	4*
HC (ppm)	U. of Denver	Casa Grande	36.59	38.25	41	7.61	3.39	4
		Tucson	54.45	40.62	14	51.42	29.43	5
	MD Lasertech	Casa Grande	19.31	18.72	16	15.71	7.97	9
		Tucson	15.77	16.90	26	26.11	20.98	10
	ESP	Phoenix	27.29	24.83	7	30.46	11.26	4*
NO (ppm)	U. of Denver	Casa Grande	18.40	19.52	29	9.31	5.85	16
		Tucson	26.33	35.32	10	17.25	9.27	9
	MD Lasertech	Casa Grande	17.29	16.14	17	7.35	5.30	8
		Tucson	5.95	6.59	20	17.85	35.28	16
	ESP	Phoenix	6.75	4.86	4	25.62	19.27	7*

*ESP readings for non-zero bottle values were flagged by the vendor as "invalid."

The above audit results provide estimates of instrument noise and bias independent of the methods previously used. By comparing these audits to the previous results, certain conclusions can be drawn about the sources of instrument noise for the various systems.

Significant noise levels and bias were observed in the University of Denver's systems HC measurements in Tucson. Similarly high noise (the standard deviation of the difference between the audit gas value and the measurement result) and bias (the mean difference between the audit gas and measurement result) are observed in the University of Denver's data in Table 1-3. We conclude from this that the source of noise is in the equipment or operation of the equipment and not due to some characteristic of the vehicles being measured.

When audit results for MD LaserTech are compared to the previous noise and bias analyses for their data, one will observe that the two methods do not agree. The audit results do not have the previously high noise and bias in the CO readings (as are calculated in Sections 6.2 and 6.3 of the RSD Report). We conclude from this that the higher than expected CO readings are derived from some characteristic of the vehicles being measured. For example, it is possible that the MD LaserTech system gives high CO readings for certain vehicle driving modes, such as when the exhaust plume is too quickly diluted during the measurement.

Comparison of Co-located Measurements

Comparison of emission values measured on the same vehicle, seconds apart, is a good method for comparing RSD systems. It can be used to quickly determine any relationship (or lack thereof) between the results obtained by the systems. This method was used to compare the Reference and Vendor systems. The results of those comparisons for the emissions measurements tend to verify what has already been discussed here. (Please refer to Section 7-1 of the RSD Report for more information.) However, when co-located values for speed and acceleration were compared, new information was learned. The speed values correlated very well between the compared RSD systems, but the acceleration values did not compare well.

The lack of correlation between the accelerations calculated by the evaluated systems is unexplained as of yet. However, we speculate that the acceleration values are being overly influenced by the small noise in the speed measurements. Acceleration is calculated from 2 or more consecutive speed measurements. The difference between the consecutive speeds is almost always very small (as compared to the value of the speed), so even if the noise in the speed measurement is small compared to the speed value, it can greatly influence the acceleration calculation result.

If this is true, acceleration values cannot be usefully applied to individual vehicle measurements. In this case, they would only be useful in evaluating large sample sets of similar vehicles (i.e., the average acceleration of a given model year.) The implications of this possible problem are important. Acceleration is an important consideration when estimating a vehicle's engine load. Therefore, it will be more difficult to determine if an individual high emission reading is due to an inaccurate engine load determination or due to true high vehicle emissions.

Recommendations

Due to the various data quality criteria used by different RSD equipment vendors, ERG recommends Arizona consider establishing common goals for any future RSD program and use those goals to produce additional RSD data quality specifications (over and above those set by the vendors themselves). California has developed a set of specifications that were used in their OREMS II program that could serve as a good starting point for Arizona RSD specifications.

In order to minimize instrument drift, ERG recommends Arizona establish a system-specific calibration schedule to be used during testing. This schedule may be determined using audit results or by analyzing the previous performance of the system under consideration.

ERG also recommends future RSD data collection programs utilize frequent calibration gas audits to help track changes in noise levels during the course of regular data collection. Also, it would probably be instructive to conduct noise analyses in "real-time," as the data are collected. Doing so would facilitate early detection of excessive noise and allow corrective action to be taken in order to minimize the collection of invalid or unusable data. In addition to noise analysis, it would also be advisable to develop a standardized method for determining when bias occurs. The source of apparent bias in MD LaserTech’s CO readings should also be investigated in order to determine if the data correction method developed by the University of Denver is appropriate for application to MD LaserTech's CO data.

Finally, ERG recommends investigating the accuracy of acceleration estimates used to determine engine load by the various RSD test system. Such an investigation could involve auditing the acceleration results using a second, independent method, such as a "fifth wheel" attached to an audit vehicle.

3.4.7 Particulate Reduction Strategies

Maricopa County needs to reduce PM10 to attain the federal 24-hour and annual standards. Pima County is in attainment for PM10, but due to past exceedences has implemented a Natural Events Action Plan. Both areas experience periods of poor visibility, due in large part to particulate pollution. Both diesel and gasoline vehicles contribute significantly to ozone and PM levels in these areas. To fulfill requirements in the AZACTS to investigate alternative PM measurement and control techniques, ERG conducted the following.

1. Evaluate alternative technologies and strategies for PM reduction
2. Collect and analyze particulate data to estimate:
   - PM emissions from the on-road fleet in each I/M area (using the updated PART5-TX1 emission factor model instead of PART5), including raw inputs and outputs of the modeling exercises.

- The fraction of diesel vehicles (which are subject to I/M) in the fleets of each area with failing opacity levels, and the excess emissions due to those failing vehicles.
- The number of gasoline vehicles with visible smoke emissions reported to the Smoking Vehicle Hotline (some of the vehicles reported will be diesels), and the excess emissions due to those vehicles.

In the near future both diesel and gasoline vehicles will emit less and less particulate. Diesel vehicles especially will be subject to vastly more stringent standards, to be phased-in starting in 2004. PM emission reductions of over 90% are expected when comparing 2007 on-road diesels to pre-2004 diesels. By the year 2020 these new vehicle standards are expected to bring many areas of the United States into attainment for PM.

Analysis of Maricopa County's Smoking Vehicle Hotline Data

Maricopa County operates a Smoking Vehicle Hotline where motorists may call to report vehicles that are emitting excessive smoke. ERG analyzed data obtained from the Hotline to evaluate the extent of the problem of smoking vehicles in the area. The data were collected between January 1999 and April 2000. Only data for vehicles from Maricopa, Pinal, and Pima counties were considered. Of the three counties, only Maricopa had sufficient data to allow analyzing gasoline vehicles and diesel vehicles separately. Our method for evaluating the data consisted of:

1. Matching the Hotline database with the Arizona registration database.
2. Decoding information from valid VINs (vehicle identification numbers) using ERG's VIN Decoder software.
3. Comparing the registered fleet population (by model year) with the population of vehicles reported as smoking.

Table 3-4 summarizes where the reported vehicles were registered. During the period covered by the database, smoking vehicles were observed in most counties in the state.

Table 3-4. Summary Of Smoking Vehicle Database, By County Vehicle of Observation

County of Observed	Vehicle Reports	Percent of Reports
Unknown	661	8.04%
Apache	29	0.35%
Coconino	88	1.07%
Cochise	38	0.46%
Gila	76	0.93%
Graham	27	0.33%
Greenlee	3	0.04%
La Paz	9	0.11%
Maricopa	6,511	79.25%
Mohave	33	0.40%
Navajo	57	0.69%
Pima	143	1.74%
Pinal	302	3.68%
Santa	28	0.34%
Yavapai	168	2.05%
Yuma	43	0.52%
Total	*8,216*	*100%*

When the Hotline database was merged with the Arizona registration database, a total of 5,836 successful matches were generated (71% of the Smoking Vehicle database). ERG then decoded the VINs in the database to obtain specific information (e.g., make, model, model year, etc.) for the reported vehicles. Some vehicles were reported multiple times in the database. These vehicles are probably driven more, and probably emit more visible smoke than the average smoking vehicle (and therefore are more likely to elicit a call to the database). Table 3-5 shows the frequency distribution of vehicles reported multiple times.

Table 3-5. Number of Reports for Individual Vehicles

No. of Reports	Vehicles	Percent of Vehicles
1	6,951	92.45%
2	476	6.33%
3	75	1.00%
4	13	0.17%
5	1	0.01%
6	2	0.03%
12	1	0.01%
Total	*7,519*	*100%*

We expect that the smoking vehicles in the database are approximately representative of the smoking vehicles on the road.

***Maricopa County Registered Fleet* --** Table 3-6 compares the number of reported smoking vehicles to the number of similar vehicles in the Maricopa County registration database.

Table 3-6. Summary of Smoking Vehicles by Vehicle Type.

Vehicle Type	Smoking Vehicles	Registered Vehicles	Percentage of Vehicle Type
Heavy Duty Truck (HT)	150	201,839	0.07%
Light Duty Truck 1 (LT1)	427	344,644	0.12%
Light Duty Truck 2 (LT2)	658	472,782	0.14%
Other	4	437,007	0.00%
Passenger Car (P)	3,001	2,430,509	0.12%

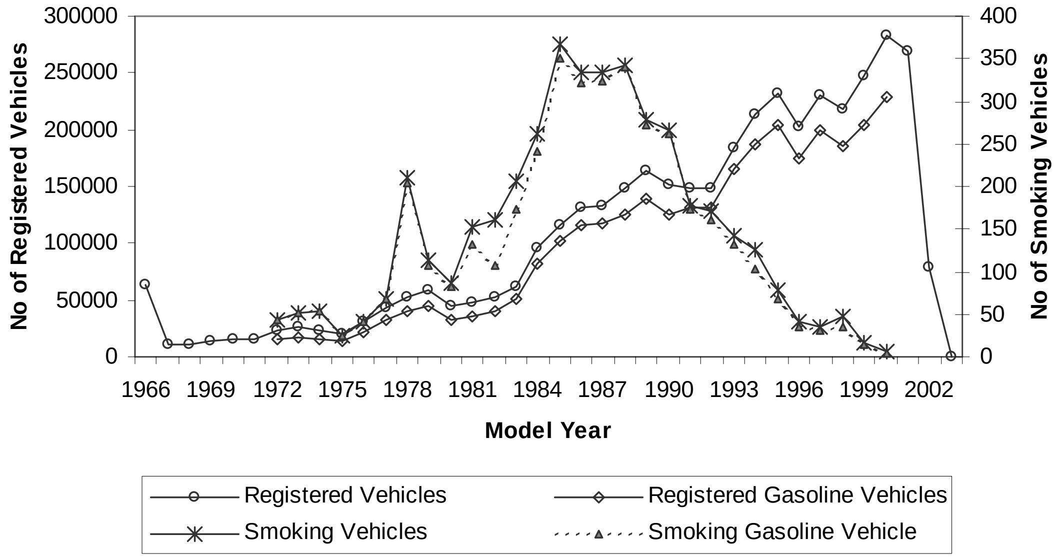
Table 3-7 summarizes the reported incidence of smoking vehicles according to the type of fuel.

Table 3-7. Summary of Smoking Vehicles by Fuel Type.

Fuel Type	Smoking Vehicles	Registered Vehicles	Percentage of Fuel Type
Compress Natural Gas (CNG)		184	-
Diesel (DSL)	279	61,401	0.45%
Ethanol (ETH)		8,138	-
Gasoline	3,958	3,007,390	0.13%
Liquid Petroleum Gas (LPG)	3	1,313	0.23%
Missing		932,866	-

ERG next investigated when vehicles start to smoke, and how quickly they are ultimately retired from the fleet by looking at the smoking vehicle reporting rate as a function of model year. Figure 3-8 shows this information for the overall fleet, and for gasoline vehicles only.

Figure 3-8. Maricopa County Registered and Smoking Vehicles by Model Year



A study conducted in 1999 in the South Coast Air Quality District of California found that approximately 1.5% of the on-road fleet emits visible smoke during normal driving conditions. If we assume that vehicles in southern California start smoking for the same reasons and at the same rate as the Arizona fleet, then we can use the distributions observed in the Maricopa County Smoking Vehicle Hotline to project the approximate number of smoking vehicles in the Maricopa fleet. An example calculation for model year 1986 vehicles is shown below.

Number of 1986 smoking gasoline vehicles in Maricopa Hotline Data =	322
Fractional increase between assumed incidence of smokers and incidence calculated from Maricopa Hotline data = 1.5/0.24 =	6.25
"Scaled-up" estimate of 1986 model year gasoline smokers registered in Maricopa County = 322*6.25 =	*2,000*

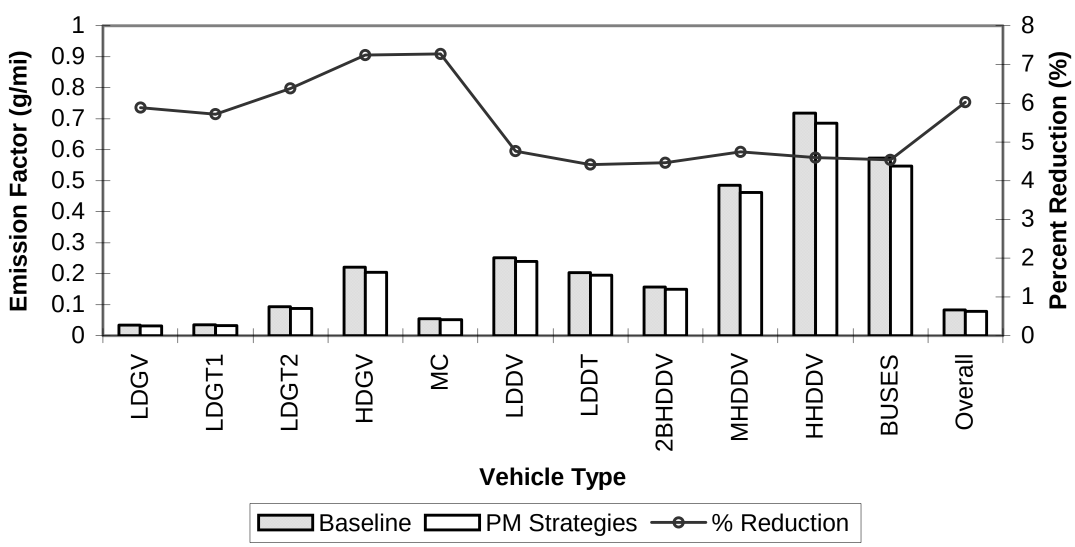
Estimating the Effects of Two Strategies: Smoking Vehicle Rejection at Time of I/M Test and Roadside Opacity Test of Diesel Vehicles

ERG used a modified version of the PART5 model to estimate the effects of two strategies for reducing on-road PM emissions. One strategy is not currently used in Arizona and would be a modification of the current I/M program, requiring vehicles that emit visible smoke be repaired to eliminate smoke emissions. The other strategy is a slightly modified version of the current opacity test for diesel vehicles. This strategy would call for a roadside opacity test that covers the heavy-duty diesel fleet.

ERG used Arizona vehicle registration distributions and vehicle miles traveled estimates to estimate the effects of the hypothetical PM reduction strategies. Two scenarios were modeled; one without the strategies (baseline), and the other with the smoking vehicle rejection and roadside opacity testing strategies in effect.

The roadside opacity test is targeted at diesel vehicles that do not already participate in the I/M program or that have developed high opacity emissions between I/M cycles. ERG modeled these strategies together since one addresses only gasoline vehicles and the other addresses only diesel vehicles. Results for the diesel vehicles include both the benefits of the current I/M opacity program and the benefits of the roadside pullover opacity test strategy. We assumed a compliance rate with both strategies of 97 percent. Comparison of PM emission factors from these two scenarios is presented in Figure 3-9.

Figure 3-9. Fleet Average Emission Factors as a Function of Vehicle Type and PM Reduction Strategy



Conclusions and Recommendations

As a result of the research and analysis that went into this report, ERG draws the following conclusions:

1. The Maricopa County Smoking Vehicle Hotline provides potentially valuable insight into the nature of the gross PM emitters in the local fleet;
2. Starting in 2004, as new vehicles enter the fleet, the rate of reduction in fleet-average exhaust particulate emissions will accelerate. This is due to much stricter new vehicle particulate standards that will be phased-in through 2007.
3. Current particulate reduction strategies for on-road vehicles can be marginally improved upon (i.e., about 6% greater reduction in on-road PM) by adding additional strategies, roadside opacity tests for diesel vehicles and required repair of smoking gasoline vehicles in the I/M program. This is in addition to other strategies that have been investigated, such as a scrappage and retrofit programs; and,
4. If such a particulate reduction is desirable and politically viable, then the cost effectiveness of these strategies should be investigated before proceeding.

3.4.8 Preliminary Progress Report

In 2002 the ERG Team prepared a Preliminary Progress Report summarizing the work performed during the first fiscal year of the AZACTS, and presented the study's major findings and recommendations to that time.

Conclusions

Baseline program performance—emission reductions: The analyses performed to this time indicated that the VEIP, Arizona's inspection and maintenance (I/M) program, produces real and quantifiable emission reductions. The ERG Team estimated I/M program effectiveness in two different areas:

- Area A: This encompassed the greater Phoenix area.
- Area B: This encompassed the greater Tucson area.

Two methods were chosen to estimate the VEIP benefits. One method estimated the benefits just before the fleet was tested in 1999 (a lower-bound estimate). The other method estimated benefits just after the failed vehicles passed their test in 1999 (an upper-bound estimate). Both estimates were made on a subset of vehicles that had been tested in each regular I/M cycle over the seven-year analysis period. The actual benefits of the program over the I/M cycle (the cycle-average benefits) are somewhere between the two estimates. Figures 3-10 and 3-11 depict these methods in graphic form.

Figure 3-10. Cumulative Benefits (A Lower-Bound Estimate)

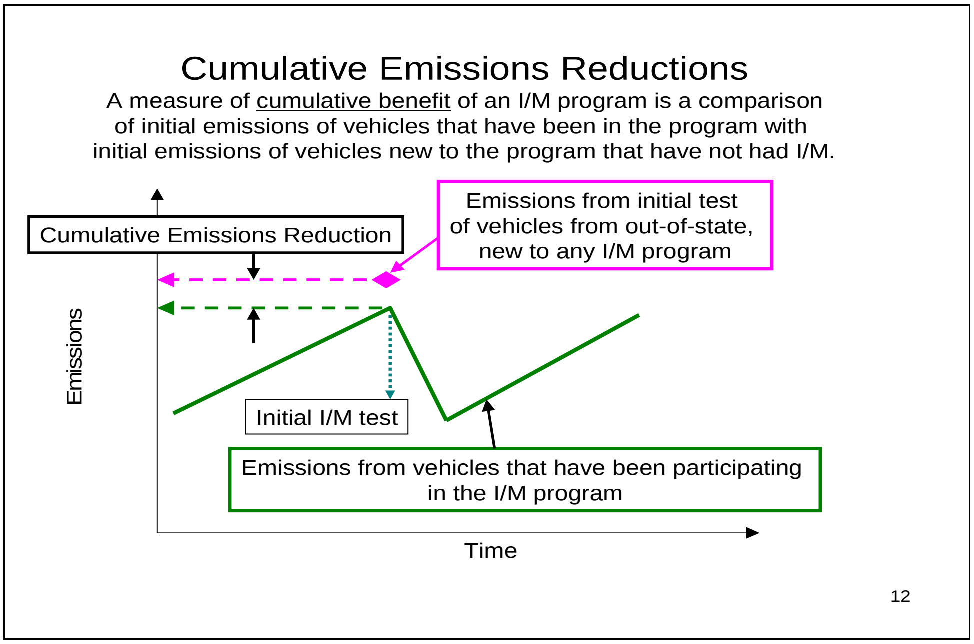


Figure 3-11. "One-Cycle" Benefits (An Upper-Bound Estimate)

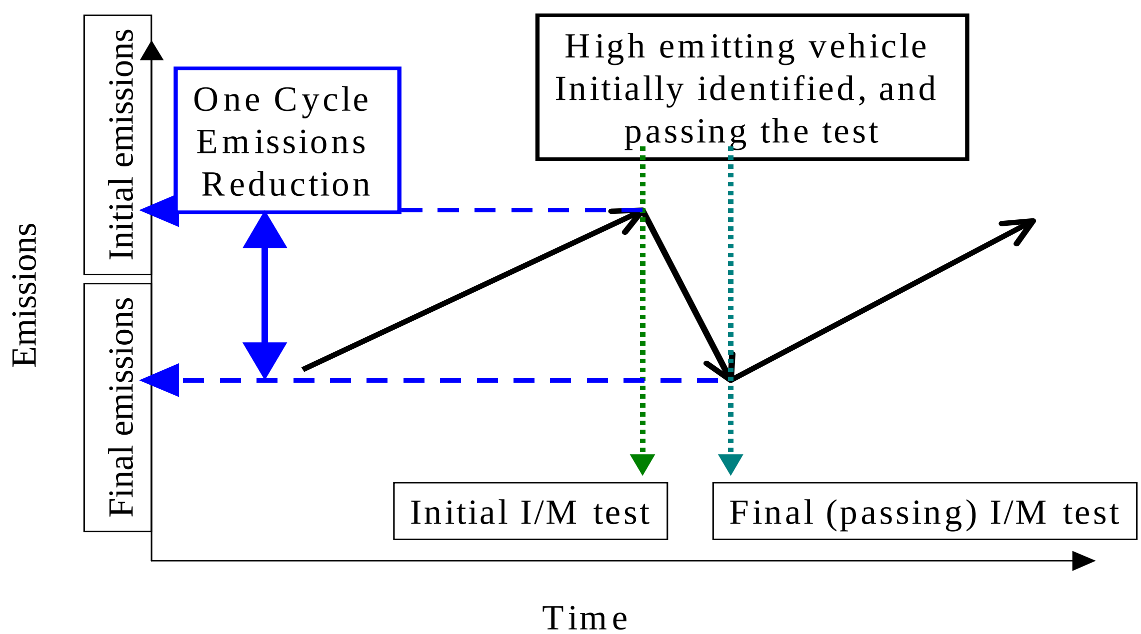


Figure 3-8 shows the “Cumulative Benefits Estimate” for the Area A and B programs. It estimates the benefit of the I/M program by comparing the initial (before repair) I/M test emissions of vehicles that have just moved to Arizona, with the initial tests of vehicles that have been in the I/M program for several years. Table 3-8 provides more detailed information about emissions reductions associated with specific pollutants. The Cumulative Benefits Estimate assumes that the emissions of the vehicles just arriving in Arizona are equivalent to the emissions rates if Arizona had never had an I/M program. This is a minimum estimate because some of the vehicles new to Arizona may have been participating in an I/M program in another state. Further improvement to this estimate can be made by identifying which of these vehicles have never been part of an I/M program.

Table 3-8. Fleet-Wide “Cumulative” Emissions Reductions

Area A (Biennial) Phoenix - Enhanced IM240			Area B (Annual) Tucson – 2-Speed Idle		
HC	CO	NO_x	HC	CO	NO_x
8%	1%	6%	14%	26%	Not measured

(A lower-bound estimate of VEIP benefit from comparing the initial I/M tests of out-of-state and vehicles participating in the VEIP for several cycles up to 1999)

Figure 3-9 and Table 3-9 present the “One-Cycle Benefits Estimate” for the Area A and B programs. These estimates are based on comparing the average initial and final test emission results. For passing vehicles these emissions are the same. For vehicles that fail initially, but eventually pass, final emissions will be lower than initial emissions. This estimate assumes that if the I/M program were before the 1999 cycle, emissions would have deteriorated at the same rate as they did after the 1999 cycle (parallel deterioration).

Table 3-9. Fleet-Wide “One-Cycle” Emissions Reductions

Area A (Biennial) 1981-newer, Enhanced IM240			Area B (Annual)		
HC	CO	NO_x	HC	CO	NO_x
24%	21%	15%	19%	45%	Not measured

(An upper-bound estimate of VEIP benefit from comparing initial and final I/M tests for 1999)

The estimates of program benefits were calculated based on a subset of vehicles tested in each I/M cycle over the seven-year period. This means that the estimates shown do not account for natural vehicle turnover (i.e. newer vehicles replacing older vehicles) or failing vehicles being permanently removed from the I/M areas. In addition, the estimates do not account for any additional emission reductions from vehicle maintenance or repairs that may have occurred prior to the initial 1999 I/M test.

Note that the benefit estimates for Area A should not be compared directly to the Area B estimates, as the Area B unloaded idle test is fundamentally different, and inherently less accurate, than the simulated on-road driving test administered in Area A. In addition, the new-to- Arizona vehicles entering the Tucson area may be quite different in terms of age, maintenance, and other factors compared to the vehicles newly registered in the Phoenix area. Finally, because the test used in Area B does not measure NOx the estimates for Area B are for HC and CO only. (NOx emissions in Area B may actually have been increased by the I/M program, as some repairs to reduce HC and CO can lead to increased NOx).

The reader should also keep in mind that the data used to calculate I/M benefits are subject to uncertain influences. For example, if a large percentage of vehicle owners perform pre-test repairs in anticipation of the I/M test, this would cause an underestimation of the emission reduction due to I/M testing. Other factors could lead to an overestimation of the emission reduction due to I/M testing. These factors include: test avoidance, statistical effects (e.g., “regression-to-the-mean”), rapid deterioration of repairs, and intermittent failures leading to vehicles passing without proper repair.

The uncertainty of the emissions reduction estimates could be reduced using independent emissions measurements and license plate readings of vehicles driving in I/M areas. As such, future analyses should be supplemented with independent data to improve the accuracy of the assessment. Such an analysis would incorporate the effect of pretest repairs, fleet turnover, non-complying vehicles, statistical effects, and inadequate repairs in the estimate of program benefits. The independent emissions measurements can be obtained either from a roadside vehicle pullover and testing program such as is done in California, or from remote sensing measurements.

Arizona has a large collection of historical remote sensing data, although these data have a number of weaknesses. Limited use of old remote sensing data, analysis of the new remote sensing data collected under the AZACTS beginning in 2001, additional license plate data, and a series of registration databases obtained over time, could provide the information necessary to more accurately estimate program benefits.

Baseline program performance—other issues: Evaluations of vehicles failing the I/M test multiple times seem to indicate that repair effectiveness could be improved. Roughly 30% of vehicles that fail and then pass in one I/M cycle tend to fail again in the next I/M cycle. The reasons for this high "re-fail" rate should be investigated to further improve program performance, as well as to reduce long-term repair costs to consumers.

The On-Board Diagnostic system check (OBDII, adopted in January of 2002) appears to be off to a good start in Arizona. As of mid-2002 test equipment effectively connected with 98% of the vehicles, and OBDII inspections took less time than traditional I/M tests. The system could be made even more effective if motorists were better educated about the OBDII malfunction indicator light (MIL). This would increase the likelihood of a vehicle being repaired as soon as the MIL goes on rather than waiting until the vehicle's next inspection date.

The characteristics of Arizona's vehicle fleet are changing. New vehicles have much lower emissions than older vehicles and are staying cleaner longer. Hence, fleet emissions are increasingly being reduced in Arizona as a result of fleet turnover. This trend actually makes I/M programs less efficient over the years as fewer high emitters are found among newer vehicles.

The fraction of the heavier light-duty trucks (6,000 to 8,500 lbs. gross vehicle weight) is increasing in Arizona. These vehicles may merit special attention in the future.

Baseline compliance assessment: One of the main purposes of the AZACTS was to improve motorist compliance with program requirements. Before methods to improve compliance can be developed, a better understanding of the number and types of vehicles out of compliance must be obtained.

Depending on the variables and assumptions used, the analysis found that anywhere from 2 to 14 percent of light-duty vehicles registered in either of the I/M areas are not in compliance with I/M and registration requirements. In addition, there is reason to believe that a substantial number of these vehicles have been inappropriately re-registered from inside to outside of I/M areas. About 7% of all currently registered vehicles moved into a non-I/M area between the date of their last I/M test and their most recent registration renewal. In contrast, only 1% of all registered vehicles moved into an I/M area. The high estimate of non-compliance assumes that all of the registered vehicles that switched from an I/M area to a non-I/M area continue to be driven regularly in a non-I/M area, without fulfilling I/M requirements.

The compliance analysis also accounted for vehicles that were not currently registered according to the MVD database. One-third to one-half of all previously registered vehicles in the Motor Vehicle Department (MVD) database had expired registrations. Since vehicles with expired registrations remain in the MVD database for about 5 years before their records are deleted (unless an owner returns the license plate by mail after removal from the state or scrappage), many of these vehicles may have been permanently retired or removed from the state. Alternatively, many of these vehicles may simply have been late in renewing their registration, or were avoiding registration requirements. In addition, the estimates of non-compliance assume that all of the expired vehicles were no longer operated in Arizona; if some of these expired vehicles were actually being driven in I/M areas on a regular basis, then the estimated non-compliance rates would be higher.

In addition, a historical analysis of vehicles inspected in 1995-1996 showed that many vehicles that failed and never passed the I/M test continued to be driven in the I/M area 5 years after inspection.

It is important to note that the emissions from a non-compliant vehicle may be higher than emissions from a compliant vehicle, based solely on the incentive for owners of high-emitting vehicles to avoid I/M tests. Therefore, these non-compliant vehicles may be producing a relatively large percent of the excess vehicle emissions in I/M areas.

Finally, this analysis (along with the baseline emission analysis described above) relied heavily upon registration and inspection data. However, some inconsistencies were found between the registration and inspection databases, such as the date of the last I/M test. (Some currently registered vehicles have no recent passing I/M test record.) Accordingly there may be opportunities for improved communication between ADEQ, MVD, the I/M contractor, and enforcement agencies, which in turn could lead to improved estimates of compliance.

Recommendations

A number of detailed recommendations were developed based on the findings of TA1 and TA2. The recommendations were of three types. First, strategies for immediate consideration were presented. These represent strategies that were expected to provide real and cost-effective emission reductions at low implementation and operations costs. These strategies were also expected to enjoy broad public support, and require no further analysis before implementation. Thus, these measures were considered “low-risk” in terms of investment and resources, and could be adopted as soon as practicable. Second, recommendations were provided specifically for policy makers and regulators regarding program implementation, agency activities, and the operation of current programs. Finally, detailed recommendations were made for further data collection and analysis.

Strategies for Immediate Consideration:

- Arizona should develop guidance and informational materials to help owners of failing vehicles obtain high-quality and cost-effective repairs. Other states with I/M programs provide information to motorists who have failed I/M tests and need to repair their vehicles. For example, these states provide information on how to locate quality repair facilities and technicians, what questions to ask technicians, and how to maintain vehicles between test cycles.
- Arizona should develop a Web site that provides used car buyers information on the I/M history of local vehicles, and should work with used car dealerships to publicize this service. Doing so could encourage chronically failing vehicles to move out of the I/M area or to be retired altogether.
- Arizona should develop and implement a voluntary program to retrofit heavy-duty diesel trucks with “NOx retrofit kits” ahead of the federally mandated schedule. Engine manufacturers provide funding for the kits and their installation so the cost to consumers will be very low. ADEQ could coordinate with the current I/M contractor, as well as with locally registered, centrally maintained diesel truck fleets to investigate the feasibility of offering on-site kit installation. This should minimize inconvenience for truck operators and encourage participation in the retrofit program.

Recommendations for Public Policy Makers and Regulators:

Policymakers and regulators would need to do the following to implement the measures listed above:

- Authorize, develop, pilot test, and publicize an I/M history Web site;
- Develop information packages and outreach/education strategies for owners of failing vehicles, and coordinate with the I/M contractor and repair facilities; and
- Work with diesel engine manufacturers to supply NOx retrofit kits, and coordinate training, kit installation, and recordkeeping requirements.

In addition, policymakers and regulators should do the following to enhance emissions reduction efforts in the state:

- Improve coordination between ADEQ, MVD, the I/M contractor, and local law enforcement officials. It appears that there are many ways to avoid I/M regulations while keeping vehicle registration intact. Such avoidance would be more difficult if government agencies, the I/M contractor, and local law enforcement officials joined efforts to ensure that vehicle owners were in compliance with I/M requirements. Specific contacts could be identified at MVD (regarding compliance with registration requirements) and the Department of Public Safety (for assorted enforcement issues), to work with ADEQ. This will help facilitate policy analysis and program implementation involving multiple agencies.
- Continue programs that complement the I/M program. In addition to the I/M program itself, several complimentary ongoing programs appear to be potentially cost-effective sources of emission reductions, and should be continued and possibly enhanced in the future. These programs include:
  - The current diesel PM opacity I/M tests;
  - The Maricopa County gasoline vehicle catalyst retrofit program; and
  - The recently adopted Maricopa County diesel PM retrofit program

<u>Recommendations for Additional Data Collection and Analysis:</u>

The following describes activities that should be undertaken to collect data on vehicle emissions and activities related to I/M program improvements:

- Additional emissions measurements and license plate readings from vehicles driving in the I/M area should be collected to more accurately assess I/M program compliance and effectiveness. Arizona has begun full IM147 testing on a random sample of the fleet. These data should continue to be collected and analyzed regularly to help evaluate the program. Additional opportunities for compliance analysis using license plate readers and for emissions characterizations using on-road measurements should be investigated.
- Behavior studies should be conducted. These studies can help policymakers gain an understanding of the public's attitudes toward the I/M program and how different strategies, such as imposing incentives and fines, might impact compliance and enforcement. (These studies were eventually conducted under TA4 – see Section 5).
- Arizona's current repair and data collection processes should be improved. Repair technicians and vehicle owners often provide inaccurate repair

data, or do not fill out required forms correctly. Near-term efforts should focus on improved reporting of information on repairs and the associated costs. Additionally, a number of inexpensive steps have been taken in other states that may improve the repair data collection process in the long run. These programs should be investigated for cost-effectiveness.

- Additional techniques should be developed to identify high-emitting vehicles. As newer vehicles become cleaner, more attention needs to focus on the subset of vehicles that contribute the most to excess emissions. Once identified, high-emitting vehicles can be targeted for more frequent testing and repair, or possibly removed from the I/M area through sale or early retirement. (Nevertheless, almost all vehicles emit some amount of on-road pollution and, with over 60 million miles driven per day in the Phoenix area, strategies addressing even the cleanest vehicles – such as transportation control measures – should also be pursued for congestion management, energy conservation, as well as for emission reductions.)
- Arizona should review studies that other states are conducting on OBDII technology, and investigate what these states are doing to improve motorist knowledge of OBDII systems. Several states have started evaluating OBDII technology. OBDII tests alone will not generate emission information. Remote sensing data may be used to evaluate the tailpipe emissions performance of OBDII vehicles. Evaluation of OBDII failure rates in other states as well as in Arizona will become more important as vehicles age, given the stringent performance standards in OBDII design.

4.0 Task Assignment 3 - 2002 Bridging Activities

ERG conducted several activities to "bridge" between TA2 and subsequent tasks under the AZACTS.

- ERG responded to questions and comments from stakeholders that arose from review of the public reports delivered under TA2. All public and other comments, and associated responses, were incorporated into the Draft Reports for TA2. After ADEQ had reviewed and commented upon the draft versions, ERG developed the Final TA2 Reports.
- ERG finalized the Retrofit Strategies reports begun under TA2. ERG also finalized the draft PM report begun under TA2.
- ERG performed certain on-going activities such as additional data gathering and preparation for upcoming analyses. These activities were:
    - ERG purchased the next 6-month update to the statewide vehicle registration database from the MVD. MVD was not able to fulfill the data purchase until early 2003.
    - ERG drafted a Standard Operating Procedure, arranged for the availability of equipment and operators, and began choosing data collection sites for future RSD data collection.

ADEQ's Project Manager also requested ERG to work with ADEQ to develop a set of planning documents to help ensure the goals of the AZACTS were being met as efficiently as possible during the next two fiscal years. A series draft documents were produced by ERG and reviewed by ADEQ. The result of this effort was a working paper that described the activities that were to be performed from September 2002 through June 2004, and how those activities relate to the original goals of the AZACTS.

Under this TA ERG also contacted researchers at the University of Kansas, who had been conducting behavioral assessments regarding the responses of private citizens to assorted control programs and public education efforts. ERG reviewed their work plans and discussed the research with University of Kansas researchers. Unfortunately, those researchers were not willing to collaborate in any meaningful way with the AZACTS without a contract. Therefore, it was decided not to pursue cooperative behavioral research with the University of Kansas.

ERG prepared a draft TAO for Task Assignment #4. The draft Task Assignment Offer focused on evaluating public opinions and behavioral responses regarding the current I/M program, as well as the proposed alternatives identified under TA2. The findings of previous behavioral research, and information learned during TA2, were used to shape the scope and focus of the draft TAO4 research.

Finally, ERG began assisting ADEQ in developing a plan for on-going analysis of the random sample data to be used in preparation of the Fleet Emission Reduction Report. Full IM147 test results were to be used to characterize the emission levels of vehicles that pass and vehicles that fail the I/M test. ERG submitted a draft list of analysis methods to be used to characterize the "mean emissions rates" and the "variability" of the emission rates. The ultimate report, completed under TA 7, may assist ADEQ in better understanding the actual fleet emission reduction attributable to the I/M program, and should meet EPA demonstration requirements.

5.0 Task Assignment 4 - Assessment of Compliance Behavior

One of the primary goals of the AZACTS was to identify ways to improve motorist compliance with the current I/M program (RFP Scope of Work §2.1.2.2), as well as ways to promote compliance with alternate control strategies (RFP §2.1.2.1). There are several factors that influence overall program compliance levels. These include:

- The level of awareness regarding program requirements and penalties for non-compliance;
- Perceptions regarding the costs and inconvenience of the program (test as well as repair components);
- Perceptions regarding the benefits (personal and public) of the program;
- Potential for non-compliance (due to loopholes, inconsistent enforcement, etc.).

Compliance levels are also dependent on the attitudes and behaviors of motorists, station owners and technicians, and enforcement personnel. Attitudes and behaviors of motorists and those involved in the test and repair process was investigated in this task assignment. Behavior of enforcement personnel should be evaluated as part of a future analysis of inter-agency coordination issues.

Under previous AZACTS tasks preliminary estimates of overall non-compliance rates were developed. However, additional information regarding the attitudes and behavior of motorists and other groups was needed in order to:

1. Identify the different ways in which people avoid program requirements, and the reasons for avoidance;
2. Estimate the frequency of the different methods of non-compliance; and,
3. Identify strategies for improving compliance.

In addition, previous analyses identified that a large number of vehicles continually fail I/M inspections. In order to develop strategies to make repairs more effective and durable, information is needed on why certain vehicles repeatedly fail I/M inspections over multiple cycles.

The purpose of this TA was to collect the information needed to improve the previous estimates and characterization of non-compliance, as well as to develop strategies to improve compliance and repair effectiveness. A combination of surveys and focus groups was used to investigate how perceptions and attitudes regarding the program influence overall behavior, and, in particular, motorist compliance with program requirements and repair shop owners/technicians attempts to repair vehicles.

The final ERG report covers behavioral analysis components from three different Task Assignments – TA4, TA6, and TA7. The results are presented here in order to provide a comprehensive overview of all findings related to compliance behavior in general.

5.1 Overview

The AZACTS behavioral analysis utilized iterative subtasks to obtain increasingly specific information on the attitudes and behaviors of motorists and station owners/technicians regarding air pollution and the I/M program in general, vehicle repair and compliance with program requirements, and about alternatives to the current program. The study asked respondents for general information about their household (address and/or zip code, number in household and ages, income, educational attainment, and possibly ethnicity and/or employment type and status), to describe the vehicles (model year, type, make, and, if possible, license plate number) used by the household, and which vehicle (if any) the respondent primarily drives.

The methods used to obtain this information depended on the type of questions asked and the prospective participants. There are several methods to obtain this type of information: written questionnaires with follow-up phone calls; computer-assisted telephone interviews (or CATI), where the interviewer guides the respondent through a questionnaire; web-based questionnaires or surveys that are accessible only to selected respondents; and small focus groups led by an experienced moderator that guides the conversation. Written or web-based questionnaires were not used in this project, as they tend to have a low response rate and the resulting sample is often subject to self-selection bias. CATI interviews were used to gather relatively straightforward information from large numbers of respondents (such as understanding of, and attitudes regarding, vehicle contributions to pollution problems). Detailed focus groups were used to gather in-depth understanding of behavior (such as specific instances of how and why motorists avoid complying with program requirements). All interviews and focus groups were conducted in either English or Spanish (or both), depending on which language the respondent was most comfortable with.

Recruitment of participants was targeted to more efficiently obtain responses to particular questions. Particular groups of motorists were identified using I/M test results and registration data. For instance, motorists whose vehicles' failed their previous I/M test were asked questions regarding their experience in having their vehicle repaired or otherwise passing a retest. And motorists who appeared to not be complying with program requirements (by, for instance, re-registering in a non-I/M area or failing and never passing a subsequent retest) were located and asked questions about how and why they avoid program requirements. Finally, random samples were drawn from each stratified group to insure that CATI and/or focus group participants were representative of their particular stratified subgroup.

This type of sampling required name and address information from MVD. ADEQ coordinated the procurement of the MVD data to obtain names and addresses of vehicle owners for sample recruitment for this analysis.

Protection of respondent anonymity was a challenge in this project, as we were particularly interested in obtaining self-reported information on potentially illegal or unethical behavior. Therefore ERG took steps to remove ourselves (and ADEQ) from the process of recruiting and collecting information from motorists. (Behavior Research Center – BRC – took the lead in this regard.) In addition, most focus group questions regarding sensitive activities asked about hypothetical actions or the actions of others, rather than about the specific behavior of the respondents themselves. (On the other hand, the telephone surveys, which are intended to characterize and estimate the types and relative frequencies of specific non-compliance behaviors, asked about specific personal activities, rather than describing hypothetical scenarios).

Finally, BRC staff instructed potential respondents that they would not be held responsible for past activities, in order to obtain truthful information about unethical or potentially illegal behavior. However, even with these precautions, respondents might still have been unwilling to share information about their own activities that may lead to the closure of loopholes they have taken advantage of in the past.

Throughout the project ERG and BRC worked closely with ADEQ to refine the protocols and procedures of the study, including sampling and recruitment plans, and the telephone interview and focus group questions.

5.2 Other Studies of Motorist Behavior

Under TA4 ERG attempted to identify existing behavioral studies to inform the development of the behavioral analysis work plan. The results of this effort are summarized below.

University of Kansas Car Care Study - The purpose of this study was to assess what effect voluntary measures have on reducing on-road vehicle emissions in the Kansas City area, an area that currently is not required to run an I/M program (but may in the near future). The criteria and methods used to develop these strata are proprietary. The ERG Team believes the study is an interesting attempt to target specific voluntary measures to specific sub-populations. The study is also interesting in that they propose to use a relatively large number of remote sensing measurements to estimate the effectiveness of individual measures. However, we are skeptical that a) voluntary measures alone will result in measurable reductions in on-road emissions; and b) that other factors that may account for reductions in on-road emissions can be controlled for. Unfortunately the project representative we spoke with indicated that they would not share their methods or approach unless it was under contract with the ADEQ. In addition, ERG was not been able to obtain any data, published or otherwise, regarding the status and findings of this analysis. ADEQ may wish to contact Kansas University at a later time to obtain its findings.

Evaluations in Other States - As part of this subtask ERG contacted other states to determine if there are any other relevant behavioral assessment or compliance improvement studies available for our review. ERG contacted 23 state-level I/M program administrators across the county requesting any information on prior or ongoing motorist and/or service provider behavior in their area. ERG received a response back from 15 administrators. Of these, 6 were not aware of any specific behavior-related studies. Of all the studies identified, the Ohio State University Center for Survey Research conducted the most comprehensive for the Ohio E-Check program (2001). A random sample of 1,250 motorists were surveyed. Most of the 50+ questions primarily focused on customer satisfaction, although several questions asked for information on pre-test repair behavior, and public perception with regard to cheating. A review of the data provided by Ohio EPA indicated that motorist attitudes were most strongly influenced by their vehicle test result (with vehicle failures having the most negative attitudes), and to a lesser extent, by the age of the respondent (older motorists being less receptive to the program). The ERG team adopted many of these questions for our own survey of general motorist attitudes and behavior.

ERG also reviewed Colorado State's National Center for Vehicle Emissions Control and Safety (NCVECS -- http://www.colostate.edu/depts/ncvecs/ncvecs1.html) website. The NCVECS has conducted preliminary attitudinal and behavior analysis for OBD systems (i.e., MIL illumination). The initial findings of these studies, conducted primarily in the late 1990s, found a broad lack of knowledge regarding the MIL and OBD system in general, but relatively high response rates (e.g., taking the vehicle to a mechanic quickly for diagnosis). However, these data may not be representative of current motorist response patterns, now that OBD 2 systems have been on the market for an extended period of time. Therefore ERG recommends evaluating the CRC study on MIL illumination response rates (CRC Project # E-72, "Consumer Response to MIL Illumination", due for release early 2005.)

5.3 Subtask 1 – Gather General Information on Motorist Attitudes and Behavior Regarding the Current I/M Program

The primary purpose of this subtask was to determine the attitudes and opinions of licensed drivers regarding the state's vehicle emission inspection program. The findings of this study provide information to help improve compliance with the current program. This study focused on the following key areas:

- Air pollution as a problem
- Effectiveness and fairness of Arizona's vehicle emissions test program
- Steps taken prior to last emissions inspection test
- Satisfaction with last emissions inspection test
- Outcome of last emissions inspection test
- Procedures followed if last emissions inspection test failed
- Recommended vehicle emissions test program improvements
- Prevalence of emission inspection test avoidance
- Used vehicle purchasing and emissions testing patterns
- Awareness of Malfunction Indicator Lamp (MIL)
- Awareness of On-Board Diagnostic (OBD) test requirement
- Routine vehicle maintenance pattern

Results - The information contained in this study is based on 803 in-depth telephone interviews conducted with metro Phoenix and Tucson area residents with responsibility for emissions testing of their household's motor vehicles. All of the drivers interviewed during this study had taken a vehicle in for testing at some point. A disproportionate, stratified sample was utilized in order to generate a sampling error of not more than +/ 5.0 percent at a 95 percent confidence level, within each of the study's two geographic regions.

Table 5-1 – Completed Interviews and Margin of Error by Region

GEOGRAPHIC SAMPLING AREA	NUMBER OF INTERVIEWS	+/- MARGIN OF ERROR AT 95% CONFIDENCE LEVEL
Metro Phoenix	401	5.0%
Metro Tucson	402	5.0%
TOTAL	*803*	*3.5%*

Household selection was accomplished via a computer-generated random telephone sample. A pre-identification screening process was also utilized, screening the sample to remove known business and commercial telephone prefixes.

The questionnaire used in this study was designed by BRC and ERG in conjunction with the ADEQ. Questions were selected to capture information on the bulleted topics listed above, as well as appropriate demographic data. After approval of the preliminary draft questionnaire, it was pre-tested with a randomly selected cross-section of 20 target area residents. The questionnaire was also translated into Spanish for use among Spanish-speaking residents who fell into the study sample.

Interviews were conducted during an approximately equal cross-section of daytime, evening and weekend hours. This procedure was followed to ensure that all households were equally represented, regardless of work schedules. All completed interviews were edited and those containing errors of administration were pulled, the respondent re-called, and the errors corrected. In addition, 15 percent of each interviewer's work was randomly selected for validation to ensure its authenticity and correctness. The final study data were weighted by the actual population in each geographic area to make the final study sample representative of the study universe.

Table 5-2 – Population Weightings

GEOGRAPHIC SAMPLING AREA	UNWEIGHTED	WEIGHTED BY RELATIVE POPULATION
Metro Phoenix	49.9%	77.6%
Metro Tucson	50.1%	22.4%
Total	*100.0%*	*100.0%*

An estimate of the sampling error range for this study is provided in the Table 5-3. Sampling error is the difference between the results obtained from a sample and those that would be obtained by surveying the entire population under consideration. The size of sampling error varies with the number of interviews completed and with the division of opinion on a particular question. As seen in the table, the overall sampling error for this study is approximately +/- 3.5 percent for the total sample (i.e., all 803 cases). However, when subsets of the total samples are studied, the amount of sampling error increases based on the sample size within the subset.

Table 5-3 – Sampling Error vs. Sample Size

SAMPLE SIZE	APPROXIMATE SAMPLING ERROR AT A 95% CONFIDENCE LEVEL (PLUS/MINUS PERCENTAGE OF SAMPLING TOLERANCE
800	3.5%
600	4.1%
400	5.0%
200	7.1%
100	10.0%

The above discussion and table applies when analyzing the results for any subset of the sample. When comparing two or more groups, however, Table 5-4 is more appropriate. For example, when a response difference between Phoenix and Tucson exceeds seven percent, it is "statistically significant", i.e., cannot be said to be an artifact of sampling.

Table 5-4 -- Sampling Error For Comparing Differences Between Two Groups

Smaller of the Two Sample Groups Compared	% Difference Needed For Significance At 95% Level
465 - 650	6%
345 – 465*	**7%**
270 - 345	8%
220 - 270	9%
185 - 220	10%
155 - 185	11%
130 - 155	12%
110 - 130	13%

* Relevant range for comparing Phoenix and Tucson samples.

A summary profile of the sample generated from the survey is presented in Table 5-5. We believe this sample is representative of telephone-owning households (estimated at 95 percent) in the metro Phoenix and Tucson area participating in the I/M program.

Key Study Findings

- Forty-one percent of drivers feel that air pollution is a major problem in their area, while 44 percent feel it is a minor problem and only 13 percent believe it is not a problem. Phoenix area drivers are significantly more likely to view air pollution as a "major problem" than Tucson area drivers (45% vs. 28%). Automobiles are viewed as the major source of air pollution at 72%, followed by buses and trucks (18%), and windblown dust (14%).
- Nearly two out of three drivers (65%) believe the vehicle emissions testing program has been effective in improving air quality in their area, with 20 percent believing it has been very effective and 45 percent somewhat effective. In comparison, 23 percent of drivers believe the program has not been effective (15% not very/8% not at all). The main reasons drivers give for believing the program is not effective are lack of improved air quality (41%) and limited testing coverage and requirements (36%).

Table 5-5 – Sample Profile

	NUMBER OF INTERVIEWS
TOTAL	803
REGION	
Phoenix	401
Tucson	402
GENDER	
Male	429
Female	374
AGE	
Under 35	147
35 to 54	343
55 and over	304
Refused	9
INCOME	
Under $25,000	111
$25,000 to $49,999	173
$50,000 to $74,999	149
$75,000 or over	158
Refused	212
YEARS OF RESIDENCE	
Under 6	133
6 to 10	155
Over 10	510
Refused	5
LAST VEHICLE TESTED[1]	
2000 to 2003	51
1996 to 1999	239
1990 to 1995	311
1967 to 1989	181
Refused/cannot recall	21

[1]Note: This study included 65 drivers who indicated the last vehicle they had tested was model year 1999 or newer. At the time of the survey these vehicles were exempt from emissions testing unless they were new area residents registering their vehicles in the Phoenix and Tucson for the first time. Review of the data reveals that only one of the 65 drivers in this group had lived in their area under one year. Other possible explanations for this seeming disparity are that drivers might have tested a vehicle prior to selling it, or that drivers might have mistakenly thought an I/M test was required prior to paying their annual vehicle registration fee.

- Nearly three out of four drivers (72%) believe the emissions testing program is fair to metro Phoenix and Tucson residents, while 18 percent believe it is not fair. The primary reasons drivers give for believing the program is not fair are: 1) the test is not statewide (28%); 2) an unqualified belief that the whole program is a "rip-off" (14%); 3) a belief that the test fees are too high (13%); 4) the fact that not all vehicles in the I/M areas are tested (12%).
- Nearly one-half of drivers (44%) took at least one of four specific steps before they went for their last emissions. The most common steps drivers took prior to testing were having a tune-up performed (37%) and checking to make sure the air pollution devices on their engine were hooked up and working (25%). While only 5% of all respondents indicated they actually performed some sort of pre-test repairs, these types of actions are not typically included in I/M program benefit estimates, though the impacts are real and potentially quantifiable.
- Drivers reveal generally high overall satisfaction with their last emissions test, with nearly eight out of ten drivers (78%) offering a rating of six or higher on a one-to-ten scale with ten being the highest degree of satisfaction. More specifically, drivers offer an overall mean rating of 7.5 with 39 percent offering a rating of six to eight and 38 percent offering a rating of nine or ten. When drivers who offer a rating of five or lower are asked to indicate the reasons behind their low rating, we find that the primary reason is dissatisfaction with the length of time the test took (37%). As expected, dissatisfaction had a strong correlation with vehicle failure during the last test.
- When drivers were asked to rate their last emissions test on six specific elements, four elements receive high ratings of 7.6 or more: 1) friendliness of the technicians (7.8); 2) technical ability of the technicians (7.8); 3) information provided on station locations (7.8); 4) convenience of the test station location (7.6) Receiving noticeably lower ratings are the length of time the test took (6.9) and, particularly, the emissions test fee (6.0). These two elements receive ratings of five or less from 30 percent and 44 percent of drivers, respectively.
- Ninety-three percent of drivers indicate they passed their last emissions test while seven percent failed. The failure rate is relatively consistent across subgroups (region, gender, age) except in the case of owners of pre-1990 vehicles who indicate a failure rate of 18 percent, and lower income drivers (under $25,000 annually) who indicate a failure rate of 15 percent. In 2002, the actual failure rate for all light-duty vehicles receiving an emissions inspection was 16 percent.
- Twenty-six percent of drivers who failed their last emissions indicate that test station personnel did not provide them with adequate information on what to do with their vehicle before returning for a retest.

- When drivers were asked to suggest improvements to Arizona's current I/M program, 61 percent offer at least one suggested improvement. The most frequently mentioned recommendations were to expand the coverage of the test (14%), to open more test stations (13%), and to speed up the time it takes for a test (11%).
- Nearly one out of five drivers (19%) believe that avoiding program requirements is a common practice in their area of Arizona, while 49 percent do not. The remaining 32 percent of drivers are not sure if avoidance is common or uncommon. The most common ways that drivers feel people avoid the emissions test are to register their vehicles outside of Maricopa or Pima counties (23%) or to make temporary adjustments on their vehicles in order to pass the emissions test (23%).

Seventy-eight percent of owners of 1996 or newer vehicles are aware of the Malfunction Indicator Lamp on their vehicles. [13] ·Approximately one out of three drivers (35%) who are aware of the MIL indicate their lamp has illuminated at some point. Fifty-one percent of these drivers took action regarding the light within one day, while an additional 28 percent took action within one week.

- Only about one in four drivers (28%) of 1996 or newer vehicles are aware of the new OBD test requirements for their vehicles. By a ratio of nearly seven-to-one, drivers aware of the OBD test believe it is better than the traditional tailpipe test – 41 percent vs. six percent. At the same time, 30 percent of drivers believe the two tests are about the same, while 23 percent are not sure.

5.4 Subtask 2 -- Gather Contact Information at I/M Test Lanes

In this subtask ERG/BRC asked motorists if they would be willing to participate in a phone interview or focus group, and to provide a phone number where they could be reached. Because the MVD registration data does not provide phone numbers of motorists, and nearly half of all Arizona residents have unlisted phone numbers, this was considered a cost-effective alternative for obtaining contact information for participation under Subtasks 3 and 4. Our solicitation efforts resulted in 177 positive responses. Of these, 175 provided local contact information including phone numbers. These respondents were subsequently cross-referenced with other data sources to determine subsequent I/M test result, and were included in the lists for Information collected included motorist name, phone number, and zip code of residence, willingness to

[13] As expected for a well-established I/M area, MIL awareness rates were much higher than found in the initial NCVECS study noted in Section 3.3.

participate in future data collection efforts, and basic vehicle information such as make, model, model year, and license plate number.

5.5 Subtask 3 -- Gather Information on Attitudes and Behavior Regarding Vehicle Repairs and Compliance with Program Requirements

In this subtask the ERG team obtained detailed information on the attitudes and behavior of motorists whose vehicles had recently failed an I/M test, station owners and/or technicians who are responsible for repairing those vehicles, as well as motorists suspected of avoiding program requirements. This effort provides information for improving compliance with the current program as well as for improving repair effectiveness. A series of focus groups was used to gather this information because they allow in-depth exploration of attitudes, and allow participants to describe in detail specific actions that have been taken, and why. BRC developed a comprehensive sampling plan to ensure that a random selection of qualified respondents was recruited for each targeted group.

BRC conducted a total of five focus groups in the Phoenix area -- 2 focus groups of Phoenix motorists who have recently failed an I/M test, 1 focus group of Phoenix station owners/technicians, and 2 focus groups on avoidance of program requirements.

The findings from the Focus Groups are not intended to be statistically representative of sample populations, and cannot be used to quantify specific behavior frequencies. However, the format allows us to explore certain key aspects of the existing program in great detail.

Station Owner/Technician Focus Group - A focus group composed of six professional automotive service technicians from throughout Maricopa County was conducted on June 18, 2003, at the Behavior Research Center focus group facility in Phoenix. The purpose of the group was to explore attitudes toward the Arizona Vehicle Inspection and Maintenance Program, as well as strengths, weaknesses and effectiveness of the program.

Eastern Research Group (ERG) worked with Mr. Mark Salem of the AZACTS Contractor Oversight Committee to develop an initial list of repair station owners and associated technicians in the Phoenix area for focus group recruitment. Attendees operated shops in Phoenix, Gilbert, and Youngtown.

Conclusions

ERG and its consultants reviewed the participant responses in detail and provide the following comments.

First, it was clear from the dialogue that there is a general adversarial tone between the repair industry and Gordon Darby. Some tension is understandable and even endemic to the given institutional arrangement, where the division between testing and repair responsibilities is absolute. (The frequent complaints regarding re-test failures serves as a case in point.) The I/M contractor's financial incentive to meet pre-defined failure rate targets compounds suspicions on the part of the repair industry. Under such an arrangement one would always expect some degree of "finger-pointing".

However, the participant discussions also point out areas where improvements could be made. Most importantly, there seems to be some misinformation among the repair industry on a few key points:

- One technician claimed that Gordon Darby fails for pending OBD codes – this is false; most likely there is some confusion between the treatment of pending and not-ready codes.
- There was general frustration with perceived "testing inconsistencies" on the part of Gordon Darby. Since these station owners operate their own testing equipment, they supposedly have an appreciation of the inherent test-to-test variability associated with emissions measurement, so the issue must be one of degree. On this point there is possibly a lack of appreciation of the extensive calibration, QA and auditing procedures required of Gordon Darby, both internal and external. Awareness of these requirements could also help alleviate suspicions regarding test manipulation to meet specific fail rate targets.
- Several participants were concerned with the perceived inequity of having uniform cutpoints for a given technology category, regardless of vehicle mileage. This opinion seemingly fails to understand the basis for the cutpoints, and the extended durability requirements for emissions components. Specifically, if a vehicle isn't meeting its cutpoints, there is most likely a repairable component that could be fixed, regardless of the vehicle's age/mileage.
- More than one participant claimed that MTBE and/or alcohol additives were causing wide-spread damage to fuel systems. Comments to this effect were anecdotal, but expressed with confidence. While this complaint was not targeted at Gordon Darby, it does reflect a concern over government-initiated, emissions related programs in general. Perhaps

these concerns would be dispelled by summarizing the extensive testing of such fuel additives from EPA, CRC, and other studies.

Recommendations

The focus group participants were in general agreement on the following recommendations for program improvement.

- Failed vehicles should automatically receive the trace graph for use by the repair shop personnel.
- Gordon Darby should be instructed to inform drivers of failed OBD II vehicles that they need to drive 55-60 miles after repairs are made so the vehicle's computer has a chance to reset itself.
- License renewal notices should be mailed 90 days in advance of the deadline date to give motorists more time to affect repairs when the vehicle fails.
- The 40th Street lab should be permitted to conduct courtesy tests for repair shops without the test results being entered into the computer system.
- Gordon Darby should be instructed to prohibit its employees from suggesting needed repairs to failed vehicles. It is not their job.

Motorist Focus Groups - In this subtask ERG and BRC collected information on the attitudes and behavior of motorists whose vehicles recently failed an I/M test, as well as motorists who were suspected of avoiding program requirements. This effort may provide information for improving compliance with the current program as well as for improving repair effectiveness.

Motorists with vehicles that recently failed an I/M test were identified using the database of I/M test results, and the results of the in-lane recruitment subtask described above. A combination of vehicle registration data and I/M test results were used to identify motorists suspected of not complying with program requirements. For instance, one method of avoiding the program is to re-register one's vehicle at an address in a non-I/M area, yet continue to drive it in an I/M area. Or motorists may simply drive their vehicle with expired registration. We identified vehicles suspected of such behavior by analyzing registration data. Another method is to simply not take one's vehicle in for a retest after failing an initial test -- we identified these "no-final-pass" vehicles in the I/M test result database.

ERG coordinated with ADEQ to obtain the necessary motorist contact information from the MVD. We provided the ADEQ with a list of 80,000 VINs of vehicles suspected of non-compliance, either through inappropriate re-registration outside the I/M area, or due to expired registration. ADEQ then provided MVD with this list. MVD in turn provided ADEQ with names and addresses for these vehicles.

BRC contacted potential focus group participants using this data set in combination with a reverse phone directory. Four focus groups were conducted by Behavior Research Center at BRC's focus group facility in Phoenix on June 22, and August 11, 2004. Participants in the groups were recruited from among Phoenix I/M area vehicle owners who either had failed an I/M test in December 2002, but not passed a retest as of March 4, 2004, or had failed an I/M test in March 2004. A total of 59 motorists agreed to participate in the groups, of which 36 showed up and actually participated.

ERG and its consultants reviewed the participant responses in detail and provide the following comments.

- Program inconvenience and test wait times were a consensus point of contention. Several possible measures were suggested which, depending on station configurations and contract terms, could be considered. These include expanded station hours, express lanes, and common queues.
- As in the station operator focus group, motorists re-iterated the lack of adequate guidance from inspectors regarding procedures upon vehicle failure.
- There was also a general consensus that expanding the program statewide would be equitable. Obviously, a detailed evaluation of the fraction of local VMT attributable to out-of-area vehicles would first be needed to assess the potential effectiveness of such an expansion. The evaluation should also include the potential benefits associated with undermining the "re-registration" problem discussed above.
- A strong perception continues among both motorists and station operators that cheating is prevalent, either due to re-registration outside the program area, driving with expired registration, and temporary engine adjustments. Given these persistent perceptions, more detailed assessment of these activities is warranted under subtask 4.
- As with the station operators, motorists uniformly agree that gas cap failures should not receive a full retest.

- Motorists consistently claimed poor public awareness regarding many key program features, including waiver provisions, the retrofit/repair program, and the smoking vehicle program.
- The perception that institutional enforcement is inconsistent and/or weak merits further investigation.

Finally, motorists, as well as the station operators, may be sending a mixed message to inspectors. On the one hand there is a consistent push for providing more diagnostic and process-related information for vehicle failures (e.g., providing each motorist of a failing vehicle with a copy of the drive trace for diagnostic purposes, vacuum system diagrams, etc.). On the other hand, the station operators uniformly criticized the inspectors for giving unqualified repair advice. One can imagine the inspectors often being pressured by motorists to provide more technical information than they are qualified to in the interest of customer service. Re-iteration of the guidelines regarding what information can and cannot be provided may help address this concern.

5.6 Subtask 4 – Targeted Surveys

In this subtask ERG and BRC developed and conducted targeted telephone surveys of different populations of motorists in order to quantify specific behaviors and fleet characteristics for further analysis. We used available MVD, RSD, I/M, and registration databases to identify specific sub-populations of interest. These include:

1. Motorists driving non-complying vehicles with expired registrations in an I/M area;
2. Motorists suspected of living in an I/M area but re-registering their vehicles in a non-I/M area to avoid program requirements.

The results of this subtask can help devise specific recommendations for improving overall compliance with the current program. Information on specific behavior by socio-economic and other strata can also help focus future enforcement efforts. The results may also be used as an independent verification of the compliance rate estimates previously developed under other AZACTS tasks.

Survey Overview - This subtask consisted of 809 in-depth telephone interviews conducted with 402 motorists who recently re-registered a vehicle from an I/M to a non-I/M area, and 407 motorists who were suspected of operating an unregistered vehicle in an I/M area.

Identifying motorists who are avoiding program requirements is difficult. The approach used was to look for motorists whose vehicles were seen driving in the Phoenix I/M area with expired plates (using unmanned plate readers), and motorists whose vehicles had been re-registered from Phoenix to a part of Arizona not subject to I/M requirements.

Motorist selection was accomplished using a suspected non-complier database of Arizona-registered vehicles. Three populations of vehicles were developed (expired, re-registered, and recently failed) from which to draw random samples of motorists to be contacted. For owners of re-registered vehicles we identified vehicles that were registered in a non-I/M zip code, but previously registered in I/M Area A (Phoenix area). We divided this group into three subgroups, in decreasing likelihood that the vehicle was not in compliance. The first subgroup (termed R1) contained vehicles currently registered outside the I/M area as of January 2002, but observed on-road in the Phoenix area in 2003 after their registration was renewed. The second subgroup (R2) included vehicles currently registered as of January 2002 and observed in the Phoenix area after their registration was renewed between 2000 and 2001. The third subgroup (R3) included vehicles currently registered as of January 2003 that were previously registered in Area A, and whose last pass in the MVD database was in 1999 or later; we had no on-road observations of the vehicles in the third subgroup.

We then identified vehicles with expired registrations for three other subgroups, using a combination of MVD registration data, on-road observations, and parking lot data from the Phoenix airport. The first subgroup (E1) included vehicles with expired registration as of January 2002, but observed on-road in the Phoenix area after their registration expired in 2003. The second subgroup (E2) included vehicles with expired registration as of January 2002, but observed after their registration had expired in the Phoenix area in late 2001. The third subgroup of expired vehicles (E3) consisted of vehicles in the January 2003 MVD extract whose registration had expired prior to October 2002; we had no on-road record of these vehicles in the Phoenix area for this third subgroup.

After the database was developed BRC conducted a telephone match to append telephone numbers to the available vehicle records. A total of 48.6 percent were successfully matched. This match rate is in line with the 45 to 52 percent match rate normally experienced on comparable projects. The fraction of vehicle owners that could be matched with listed phone numbers was slightly lower for re-registered (48%) and expired (49%) vehicles than for those that recently failed (52%). One would expect the phone match rate to be the lowest for the vehicles with expired registrations, as the majority of them should have been permanently removed from the state. Their comparable phone match rate to that of reregistered and recently failed vehicles suggests that many of the vehicles with expired registrations continue to be driven in the state, if not the Phoenix I/M area.

All of the interviewing on this project was conducted between June 7 and 28, 2004, at the BRC's central interviewing facility. The questionnaire used in this study was designed by BRC and ERG in conjunction with the ADEQ. After approval of the preliminary draft questionnaire, it was pre-tested and translated into Spanish.

Summary of Key Findings - A review of the outcomes of the survey calls and the status of the target vehicles reveals several key findings:

- 18,718 telephone numbers of owners of suspected non-complying vehicles were identified (7,571 re-registered and 11,147 expired). About half of these numbers were never reached, while 16 percent were disconnected. Contact was made with an additional six percent of the telephone numbers, but the respondents refused to be interviewed.
- Telephone contact was made for the remaining 29 percent of telephone numbers (5,403). The large fraction of unreachable telephone numbers suggests that the registration data used to identify current vehicle owners is not current; this is not unexpected, as the vehicle owner's name and address was obtained in June 2003, 12 months before the survey began.
- Of the 5,403 telephone numbers for which contact was established, 40 percent of the respondents claimed not to know the person listed as the owner of the vehicle in the registration database. Again, this may be because the registration information was a year old before the survey began. One percent of respondents knew the listed vehicle owner, but that person did not live at the number called -- these owners may be circumventing the I/M program by registering the vehicle at a residence where they do not live.
- The remaining 26 percent of respondents (809) were contacted and completed the survey. These respondents represent 15 percent of the residences contacted by phone, and only four percent of the total phone numbers called. The breakdown of responses for the owners of suspected re-registered and expired vehicles is similar in many regards.
- For re-registered vehicles, 71 percent of the owners contacted currently owned the targeted vehicle, while 16 percent claimed to have formerly owned the vehicle and have since sold it, and 11 percent claimed to have

never owned the targeted vehicle. One percent of respondents claimed they did not own the targeted vehicle, but refused to respond whether they had ever owned it or sold it, while another two percent of respondents refused to answer the question.

- Of the 284 owners who currently owned the targeted vehicle, 82 percent had the vehicle registered at their primary home address outside of the I/M area, and four percent had it registered at a second or vacation home. Three percent of owners refused to answer. Another two respondents stated that their vehicle was in fact registered in the I/M area. Therefore, of the vehicles that were re-registered to non-I/M areas, 16 percent were sold, while only three percent were registered to a second home outside of the I/M area.

- We assumed that up to 18 percent (73) of owners of re-registered vehicles may have illegally registered in a non-I/M area (i.e., reported they never owned the vehicle [43]; owned vehicle but refused to indicate registration location [12]; refused to indicate if they sold the vehicle if they previously owned it [11]; and refused to indicate if they owned vehicle at all [7]).

- Of the 407 owners of expired vehicles that were contacted, 32 percent responded that the targeted vehicle's registration now is current, 31 percent formerly owned the vehicle (with 104 registered when sold, and 23 unregistered when sold). 17 percent claimed never to have owned the targeted vehicle, and 11 percent admitted to owning the targeted vehicle but not renewing its registration. Another nine percent refused to respond whether the vehicle was currently registered.

- Therefore, of the vehicles with expired registrations that were suspected of avoiding registration requirements, 10 percent to 20 percent currently are not registered, and another six percent were unregistered at the time they were sold.

- We assume that up to 42 percent (171) of the respondents contacted had at one point owned a vehicle without having it registered (i.e., owned the vehicle but registrations was not current [43]; formerly owned the vehicle but was not registered [23]; refused to indicate whether vehicle was currently registered [35]; and reported they never owned the vehicle [70]).

- The percent of expired registration population interviewed who feel air pollution is a problem is very similar to the percent recorded in the General Population Survey conducted in 2003 (87% vs. 85%).

- Nearly two out of three of the expired population interviewed (63%) believe the I/M testing program has been effective in improving air quality in their area, while only four out of ten of the re-registered population interviewed (41%) hold a similar belief. In addition, 27 percent of the re-registered population interviewed were unsure of the program's effectiveness (compared to only 11 percent of expired population interviewed). The responses for the expired population interviewed are very similar to the readings from last year's General Public Survey.

- Motorists who believe the I/M program is not effective were asked to indicate why they felt this way. The main reasons given by motorists were: (1) limited testing coverage and requirements; (2) lack of improved air quality; (3) a belief that the whole program is an unqualified "ripoff", and; (4) the fact that they still see polluting vehicles on the road. The expired population interviewed were more likely to mention that the program is a "waste of time and money" (23% vs. 12% among the re-registered population interviewed).

- 31 percent of the expired population and 45 percent of the re-registered population were not able to offer any suggestions on how the I/M program could be improved. Additionally, 14 percent and 12 percent of each group's members, respectively, feel the program was fine as is. The most frequently made suggestions for improving the program were: (1) expand the coverage of the program; (2) eliminate it altogether; (3) lower the test fee, and; (4) enforce pollution/emissions laws.

- 25 percent of the expired population believe that I/M test avoidance is a common practice in their area, while 45 percent do not feel it is common, and 30 percent are not sure. 17 percent of the re-registered population believe test avoidance is a common practice, while 57 percent do not.

- The most common ways that the motorists believe people avoid the I/M test is to register their vehicles outside an I/M area, to make "temporary adjustments" to their vehicles in order to pass, or to simply not test their vehicles and drive illegally. These readings are similar to those received in last year's General Public Survey.

- Only one-half of motorists interviewed (50%) believe it is either extremely (5%), very (13%), or somewhat likely (32%) that motorists who do not comply with the I/M program will get caught and fined. These beliefs are consistent across the two sample groups.

- Motorists were asked to indicate what steps they believed could be taken by the State to encourage motorists to: 1) have their vehicles properly repaired after they fail an I/M test, and; 2) fully comply with the I/M program. Responses to these two questions were very similar. Two items lead the response to each question – stronger enforcement of existing laws with stiffer fines, and the reduction of costs and fees for complying with the program. Other responses included adjusting the test standards and providing more information to the public. Responses to these two areas of inquiry were very similar in each sample group.

- The motorists interviewed were asked to indicate how effective each of five measures might be in encouraging motorists to have their vehicles properly repaired after they failed an I/M test. 40 percent of motorists believed two methods would be "very effective": 1) suspend the driver's licenses for lapsed registrations (42%), and; 2) fine motorists who live in an I/M area $1,000 if they register in a non-I/M area to avoid compliance (40%). The readings among motorists in each sample group were relatively consistent.

- Awareness of the waiver option and the Voluntary Vehicle Retrofit & Repair Program, which are available to individuals who fail an I/M test, was very limited. For example, only one out of four (25%) of the re-registered population interviewed were either very (7%) or somewhat (18%) aware of the waiver option, while only 12 percent were aware of the VVR&R Program (4% very, 8% somewhat). Awareness of the waiver option is noticeably higher among expired population (54% total awareness), but only marginally higher for the VVR&R Program (25% total awareness).
- 26 percent of the expired population interviewed indicated that they had failed an I/M test in the past two years, while only two percent of the re-registered population interviewed indicate they had failed.
- Responses from motorists who failed a recent initial I/M test indicate:
- 92 percent of motorists who failed their first test returned for a retest (98 of 107), while eight percent did not (9 of 107), and either sold or quit driving the vehicle, or simply continued driving it illegally.
- 83 percent of motorists who returned for a retest passed the retest (81 of 98), while 17 percent did not (17 of 98).
- 59 percent of motorists who failed the second test returned for a second retest (10 of 17), while 41 percent did not (7 of 17).
- 80 percent of motorists interviewed who returned for a third test passed (8 of 10), while 20 percent did not pass.
- 17 percent of motorists who failed their first test never passed a subsequent retest (18 out of 107). This no-final-pass rate is comparable to 16 percent observed in the 2003 General Public Survey.

Conclusions - By their very nature, the motorists targeted in this survey are difficult to identify and obtain information from. These difficulties are reflected in the low overall contact and response rates observed (e.g., only 4% of all phone numbers attempted actually completed the survey). In addition, the responses themselves may not be completely reliable, since they require admission of illegal activity of one kind or another. In fact only a handful of respondents openly admitted to either inappropriate re-registration or expired registration. For these reasons the findings of this portion of the behavioral analysis should be viewed with caution.

Nevertheless, there are several indications that seem to corroborate the validity of our suspicions regarding the targeted motorists. First, while the overall failure rate in 2002 was 18%, 26% of motorists in the expired registration group had failed an inspection within the last two years, compared to only 2% of motorists in the re-registration group. The high failure rates among the expired group is expected, as an I/M failure may have led the owners of these vehicles to avoid future I/M testing. The very low fail rate among the re-registered group is suspicious, especially since their vehicles are somewhat older than the average failing vehicle. This seems to indicate that the re-registered vehicles are either cleaner than the average vehicle for some unexplained reason, or they have been registered in a non-I/M area long enough so that they have not received an I/M test in the last two years.

The model year distributions of the different survey groups are also consistent with our initial suspicions, with the expired group having the oldest vehicles on average, followed by vehicles in the re-registered group, and the general public having the newest vehicles on average (because they tend to be older vehicles, we expect the vehicles in the expired and re-registered groups to have higher failure rates than the general public). And as stated above, the phone match rates for both groups were comparable to that for recently failed vehicles in the General Public survey, indicating that many of the vehicles with expired registrations continue to be driven in the state.

For these reasons we believe the responses obtained from the survey to be fairly representative of the two target groups as a whole.

The above findings indicate that the non-compliance estimates previously developed for the re-registration category may be too high. Specifically, under other tasks we found that about 5.1% of registered vehicles had been re-registered from an I/M area to a non-I/M area, and that about half of the vehicles re-registered from Phoenix were still being driven in Phoenix (although not necessarily driven regularly). The current survey found up to 18%, not half, of owners of re-registered vehicles were likely avoiding program requirements (as opposed to relocating their vehicle because the household relocated or the vehicle was sold).

The previous analysis also estimated that 18% to 19% of the vehicles with expired Phoenix registration were still in use; that estimate is comparable with this latest estimate that 10% to 26% of survey respondents in the expired group were possibly avoiding registration requirements.

On the whole, motorists in the re-registered and expired groups expressed similar opinions to those in the General Public Survey regarding the problems and effectiveness of the I/M program and common methods of cheating. While no new insights were gained regarding the methods of, or reasons for, non-compliance, the survey did find a strong belief (>50%) that non-compliers are not likely to caught and fined. Accordingly, survey respondents clearly indicated that a credible punitive enforcement threat (such as suspending licenses for expired registrations, or $1,000 fines for illegal re-registration) would go a long way toward deterring non-compliance in the future. Expanded awareness of the existing waiver and VVRR program provisions (typically < 50%) could help improve compliance as well.

6.0 Task Assignment 5 - Revisions to Baseline Analysis of Compliance with I/M and Registration Requirements in Arizona

The purpose of Task Assignment 5 was to complete the assessment of ways to improve motorist compliance with the current I/M program (as described in Section 2.1.2 of the original AZACTS RFP). This included performing a definitive assessment of baseline compliance rates (improving upon the preliminary estimates developed under TA2), identifying strategies for improving compliance, and evaluating the potential costs and effectiveness of such strategies.

The TA5 report revises the previous estimate of non-compliance in the Arizona I/M programs (Baseline Analysis of Enhanced I/M Compliance, June 14, 2002). The original "high" estimate of non-compliance assumed that all vehicles that re-registered to a non-IM area from an I/M area were still regularly driven in an I/M area, and therefore were noncompliant. The original "low" estimate assumed that the last I/M test of any vehicle was properly recorded in the MVD registration extract, and that any discrepancy between the extract and the I/M test records was due to a missing test record, and not due to non-compliant no-final-pass vehicles (i.e. vehicles that failed an I/M test but were never repaired and passed). The original analysis used the previous Smog Dog dataset to estimate what fraction of non-compliant vehicles were being driven in I/M areas. This report reevaluated these assumptions, using a second extract of the MVD registration database and more recent (though much less extensive than the Smog Dog license plate data) on-road observations of vehicles. The study also used the I/M test result data to estimate how many vehicles with out-of-state license plates were brought into the I/M program, and presumably registered, as a result of the recent MVD crackdown. Finally, the earlier analysis of historical non-compliance was revised.

As a result of these new analyses it is estimated that about 230,000 light-duty 1967 to 1996 vehicles statewide, and 156,000 in the Phoenix area and 44,000 in the Tucson area, are not complying with either the I/M or state registration requirements. These vehicles represent 11% of currently registered vehicles statewide, and 13% and 16% in Phoenix and Tucson, respectively. Vehicles that had expired registrations in 2002, but renewed their registrations within the next year, account for one-third to one-half of these vehicles; most of the other noncompliant vehicles were re-registered to non-I/M areas from an I/M area, and appear to have been fraudulently renewed using paper emissions certificates.

Analysis of I/M test results suggests that the MVD's crackdown on vehicles with out-of-state license plates resulted in about 5,000 out-of-state vehicles reporting for an I/M inspection (and presumably becoming registered in Arizona). Additional I/M test results from 2003 are necessary to continue tracking this trend.

Conclusions and Recommendations

There are several limitations associated with the above estimates of non-compliance. First, there are many unexplained discrepancies between the registration database and the I/M test results; we have attributed some of these discrepancies, such as vehicles with different dates of their last passing I/M test, to non-compliant behavior, when in fact they may reflect poor record keeping. There also are unexplained inconsistencies between different fields in the registration database. We recommend that DEQ make an effort to better understand how the database is managed and updated. This should allow DEQ to assist MVD in improving their record keeping, and will enable DEQ to better understand the extent to which motorists avoid program requirements. One possibility mentioned in q meeting with MVD is for DEQ to hire an employee to work solely at MVD to work with their databases.

Databases including license plates of vehicles observed on-road can be extremely helpful in improving estimates of overall non-compliance, as well as identifying specific vehicles that are avoiding I/M and registration requirements. The extremely large database of historical Smog Dog remote sensing measurements was very useful in identifying vehicles that had been non-compliant; however, this large-scale remote sensing program ended in early 2000. The more recent remote sensing measurements and unmanned license plate observations, undertaken as part of the AZACTS, are not extensive enough to provide a definitive estimate of non-compliance. For technical reasons the license plate could not be determined for almost half of the latest readings from the unmanned system. We strongly urge any new contract to ensure that a higher portion of vehicle readings are useable in the future. Large numbers of remote sensing measurements as part of a “clean screen”, high emitter identification program, or other on-road license plate data collection program would be very valuable in assessing motorist compliance with I/M requirements.

Finally, a large number of vehicles are parked at the Phoenix Airport. The Airport parking lot data could be very helpful in identifying vehicles with expired registrations, or that have never been registered. We recommend that DEQ authorize the continual procurement of license plate data from the Airport to assist in the analysis of expired and unregistered vehicles.

7.0 Task Assignment 6 - Evaluation of the Arizona I/M Program Using Random Sample Data

One of the primary goals of the AZACTS was to evaluate methods to improve the monitoring of in-use emissions control systems. ADEQ and Gordon-Darby set up a random sample data collection system in 2002 to evaluate the I/M program on an on-going basis. Data from this sample is to be used by ADEQ to develop and deliver an I/M program effectiveness report to EPA on a regular basis. Under this task assignment, ERG assisted ADEQ to first evaluate the current program using the random sample data and then to develop a standard methodology and format for performing on-going I/M program effectiveness analysis.

Under Task Assignment 6 the I/M contractor, Gordon-Darby provided second-by-second emissions measurements of a stratified random sample of vehicles given three full IM147 tests between February 2002 and March 2004. Gordon-Darby was also asked to include 0.17% of all vehicles that passed their initial I/M test, 1% of all vehicles that failed their initial test, 0.83% of first retests, and 1.9% of subsequent retests, in the random sample.

Three months of second-by-second emissions data were obtained for all official tests (including fast-pass/-fail tests) in order to replicate the fast-pass/-fail algorithm currently used. When we applied our revised algorithm to the second-by-second official test data, we obtained the correct pass/fail result for 99% of the official tests. Although our algorithm results in nearly identical emissions for passing vehicles as the official tests, it results in 5% to 10% higher emissions for failing vehicles, and a slightly lower failure rate, than the official tests.

We then applied our revised fast-pass/-fail algorithm to the random sample of full IM147 tests, to assess the accuracy of the algorithm in identifying passing and failing vehicles. Only 2.5% of vehicles in the random sample would have been falsely fast-failed (5.3% of all fails), while 9.8% of the random sample would have been falsely fast-passed (18.4% of all passes). Since our revised algorithm incorrectly passed or failed less than 2% of the vehicles in the official tests, inaccuracies in our revised algorithm do not explain these rather high false pass and fail rates. The falsely fast-failed vehicles are evenly distributed among vehicle types and model years, while the false fast-passes are somewhat more concentrated in cars than in light-duty trucks. One-third of the false fails occur at the end of trace 1, while the false passes occur throughout the segments in both traces.

We then compared the full-test emissions of the random sample vehicles with the fast-pass/-fail emissions of the random sample vehicles. Fast-failed vehicles tended to have slightly higher fast-fail HC and NOx emissions (0% and 6% higher), but much lower fast-fail CO emissions (12% lower), than on a full IM147 test. Similarly, fast-pass vehicles had much higher fast-pass HC and NOx emissions (14% and 13% higher), and much lower fast-pass CO emissions (23% lower), than if they were given a full IM147 test. We used the subset of vehicles included in the random sample upon their initial I/M test to compare initial emission reductions based on full-test emissions with those based on fast-pass/-fail emissions. Percent emission reductions are 1% to 20% greater, depending on vehicle type and pollutant, when using the full test emissions rather than the fast-pass/-fail emissions for the random sample, while the percent emission reductions are 11% to 30% greater, than for the non-random sample that was fast-passed/failed (and 60% greater for LDT2 NOx). It is not clear why initial repair effectiveness is so much lower for the non-random sample of vehicles, as the non-random sample is similar in terms of vehicle type, age, and owner median household income as the random sample of vehicles.

Next we used a combination of official test results and remote sensing measurements to estimate the emission reduction benefits over a single I/M cycle, from post-failure repair of “fail-pass” vehicles, and removal and/or replacement of “no-final-pass” vehicles. Note that we did not have enough recent remote sensing measurements to estimate the program benefits from maintenance and repairs performed on vehicles in anticipation of their initial I/M test.

Emissions deterioration after repair was estimated using the measured emissions from the next initial I/M test, both for vehicles whose next test was roughly two years later, and a subset of vehicles that voluntarily reported for an “off-cycle” test less than two years later, usually prior to a change in ownership. 8% of all vehicles tested received an off-cycle test, with the percentage increasing for the newer model years. The emissions of vehicles receiving an off-cycle test deteriorate dramatically almost immediately after their previous I/M cycle, up to the level of vehicles not tested until roughly two years later. This suggests that, if the vehicles tested off-cycle are representative of the overall fleet, almost all of the emissions deterioration observed over two tests roughly two years apart actually occurs almost immediately after vehicles pass their previous I/M inspection. However, vehicles receiving an off-cycle test are not representative of the entire I/M fleet; they tend to have higher emissions on the initial test in their previous I/M cycle, and on the initial test in the current cycle, even though they have had less time for their emissions controls to deteriorate between tests than the majority of vehicles tested roughly two years apart. (Starting in 2002, 1996 and newer OBDII-equipped vehicles were tested based on their OBD system scans, rather than a tailpipe test; therefore, we had to estimate the increase in emissions between cycles for these vehicles.)

3% of all light-duty vehicles failed their initial I/M test in 2000 or 2001 and had not passed a retest through March 2004. These "no-final-pass" vehicles represent 14% of all vehicles that failed their initial I/M test. Cars had a higher no-final-pass rate (16%) than light trucks (12% for LDT1, 11% for LDT2). The no-final-pass rate decreases with newer vehicles. Not enough on-road observations were made in the AZACTS project to estimate the fraction of no-final-pass vehicles that continued to be driven in the Phoenix area as function of time. Instead, we used Smog Dog remote sensing measurements to identify 1998 or 1999 no-final-pass vehicles that continued to be driven in Phoenix through March 2000. On average, 15% of the no-final-pass vehicles are likely to be observed on-road in the two years after they failed their I/M test.

To estimate the emission benefits of the I/M program we made assumptions regarding how much emissions are reduced by repairs, how quickly they increase in the next two years, how many no-final-pass vehicles are removed by the program, as well as how high emissions would have been if there were no I/M program. For each of these assumptions we provide a best estimate, as well as a higher bound estimate and a lower bound estimate. Our best estimate is that the Phoenix I/M program reduces HC emissions by 6.2 tons per day, CO by 108 tons per day, and NOx by 5.7 tons per day; however, fuel use increases by 9,000 gallons per day. The I/M data suggest that fuel use increases after vehicles are repaired, and for 1996 and newer vehicles; we suspect this is an artifact of how fast-pass/-fail emissions are converted to full test emissions. About half of the emission benefits come from cars, and the other half from light trucks. About 80% of the benefit comes from repair of failed vehicles, with the remaining 20% from replacement of no-final-pass vehicles (the benefits from pre-inspection maintenance and repairs could not be estimated). The 24% oldest vehicles (1987 and older) account for about half of the HC and CO benefits, and 30% of the NOx reductions; similarly, the oldest half of vehicles (1991 and older) account for about 80% of the CO and HC benefits, and 60% of the NOx benefits. Program benefits per 100,000 vehicles tested are highest for late 1970s and early 1980s vehicles, and decline for the newer vehicles.

We also estimated what the I/M fleet emissions would have been without the I/M program, in order to estimate the percent reduction attributable to the I/M program. Our best estimate reduces the emissions of the I/M fleet 24% for HC, 27% for CO, and 10% for NOx, with essentially no change in fuel use. The percent reductions are largest for vehicles from the mid-1970s to the mid-1980s. We also estimated the total emissions from all vehicles on-road, including vehicles traveling through the Phoenix area and vehicles avoiding I/M requirements (but not including the newest vehicles exempt from the I/M program). Less than 5% of the 1985 to 1996 vehicles observed on road did not participate in the Phoenix I/M program; this percentage increases gradually to 10% for 1978 and older vehicles. Our best estimate reduces the emissions of the on-road, I/M-eligible fleet by about the same percentages as for the I/M fleet reporting for testing.

Recommended methodology to estimate program benefits in the future – ERG proposed a methodology for ADEQ to use in the future to estimate the benefits of the Arizona I/M program. The steps outlined here for the most part follow the method used for the benefits analysis described above.

Step 1 - Obtain several months (preferably two years) of official I/M test results

The purpose of tracking vehicles over two years (or until their next initial I/M test) is to determine how much their emissions deteriorate between I/M cycles. Tracking vehicles over two years also allows an analysis of the number of no-final-pass vehicles, and the number of vehicles that apparently migrate into or out of the I/M area. One problem with using only one or two months of initial tests is that failure rates and emissions vary by month, apparently as a function of ambient conditions and possibly fuel composition.

Step 2 - Include data from all test types

Vehicles tested in Maricopa County are included in each of the test result files provided by Gordon-Darby. For instance, in addition to vehicles that receive the IM147 test (testtype=6), 1980 and older vehicles are included in the loaded idle file (testtype=4), four- and all-wheel-drive vehicles are included in the two-speed idle file (testtype=0-4), vehicles rejected for testing are included in the reject file (testtype=5), and 1986 and newer OBDII-equipped vehicles are included in the OBD file (testtype=8). To analyze all of the vehicles tested in Maricopa County, the records from each of the different test files have to be merged. If one is analyzing only vehicles reporting for IM147 testing, one still needs to include vehicles in the reject file to get the complete test history of individual vehicles. The Vehicle Identification Number (VIN) can be used to identify unique vehicles; the license plate should not be used, as the license plate now does not remain with the vehicle when the vehicle is sold, and about 10% of license plates are coded as OS (out-of-state plate), PP (temporary paper plate), or NP (no plate).

A small number of vehicles are moved from Maricopa to Pima County, or vice versa, either within a test cycle or between test cycles. Therefore, data on Pima County (county=P) vehicles should be included to obtain the complete test history of individual vehicles.

IM147 cut points are based on vehicle type (LDT2, light-duty trucks between 6,001 and 8,500 lbs GVW=7; LDT1, light-duty trucks up to 6,000 lbs GVW=8; or passenger car=9), while idle and conditioned idle cut points are based on vehicle class (up to 6,000 lbs GVW with 4 cylinders=3; up to 6,000 lbs GVW with more than 4 cylinders=4; or between 6,001 and 8,500 lbs GVW=5). Although both variables are included in each of the test type databases, neither is consistently used for all vehicles (i.e. many vehicles given an IM147 test have a blank class variable, and many vehicles given an idle test have a blank type variable). One should use the class variable for vehicles given an OBDII test, since many OBDII vehicles have a blank type variable. There should be complete overlap between type=7 and class=5; however, class 3 and 4 vehicles cannot be readily converted to type 8 and 9 vehicles. This problem can be resolved in one of two ways: 1) analyze IM147 vehicles by type, and all other vehicles by class; or 2) use VIN decoding software to assign the correct vehicle type to vehicles given an idle or OBDII test.

Note that the class codes apply to gasoline vehicles only; diesel vehicles use the 3 class code for vehicles between 10,501 and 26,000 lbs GVW, and the 4 class code for vehicles more than 26,000 lbs GVW.

Step 3 - Sort vehicles by VIN, date, and time

Sort the data by VIN, test date and test time. This provides a database of the test history of individual vehicles.

Step 4 - Determine beginning and end of I/M cycles

Gordon-Darby includes a test variable that identifies initial tests (I) and retests (R), as well as special tests (S); however, any test more than five months since the previous test is coded as an initial test, even if the vehicle failed the previous test. If one were to use the Gordon-Darby variable, some vehicles would be coded as no-final-pass yet receive a subsequent test, and all initially failing vehicles would take less than five months to pass a retest. Therefore, one must determine the end of each I/M cycle, and the beginning of the next I/M cycle, based on the test results.

Two variables, certification code (certcode) and the overall test result (overall), are used: the I/M cycle ends only when certcode=C and overall=P. The next cycle begins with the next I/M test in the database. Add a numeric variable that denotes the cycle of each test (cycle), as well as the sequence of tests within a given I/M cycle (count).

Step 5 - Determine first and last test of each unique vehicle in database

Add flags that denote whether a given test is the first or last test of a given cycle (firstim=0 or 1, lastim=0 or 1), and flags that denote whether a given test is the first or last test overall (firstvin=0 or 1, lastvin=0 or 1).

Step 6 - Determine I/M cycle result

Sort the database by VIN and cycle, and compare the overall result for initial (ir) and final (fr) tests within a given I/M cycle, to classify vehicles into the following categories:

IP: initial pass;
FP: fail-pass;
FF: fail-fail;
F_: fail no second test;
PP: pass-pass, should be considered FP
PF: pass-fail, should be considered FF
X: intermediate tests that are neither the first nor last test of a cycle

Only a small number of vehicles are coded as PP or PF; all of these failed for gas cap (only) on their initial test and were coded as overall=P and certcode=T, but were required to be retested.

Assign the same cycle result to the first and last test of each I/M cycle.

Step 7 - Calculate the number of days to pass

Subtract the date of the initial test in a cycle (firstcyc=1) from the date of the final test in a cycle (lastcyc=1), to determine the number of days it takes a vehicle to pass. The days to pass should be 0 for IP and F_ vehicles, and 0 or greater for all other vehicles.

Step 8 - Calculate the number of days between cycles

Subtract the date of the final test of cycle n from the date of the next test (initial test of cycle n+1), to determine the number of days between I/M cycles.

Step 9 - Add emissions results

To limit computer processing time or requirements, perform steps 3 though 8 using data for all test types and from both Maricopa and Pima counties. Then merge with specific test emission data for the vehicles of choice (i.e. merge with IM147 data for vehicles receiving an IM147 test, and idle data for vehicles receiving an idle test). This minimizes the number of records with blank emissions test results (i.e. a blank NOx emissions field for vehicles given the idle test).

The Gordon-Darby lane software projects the full IM147 emissions of fast-pass/-fail vehicles; the reported IM147 emissions values in the database are these projected full IM147 emissions. Regression equations convert full IM147 to full IM240 emissions; however, this is an imperfect method as the regression coefficients were derived from IM147 and IM240 test on only a limited number of vehicles, and it is unlikely that this limited sample accurately reflects the distribution of low- and high-emitters, by emission profile (i.e., low-NOx/high-CO high emitters vs. low-CO/high-NOx high emitters).

The conditioned idle files first report the unconditioned idle test emissions, followed by the conditioned idle test emissions (if given). The loaded idle files first report the regular idle test emissions, followed by the loaded idle test emissions, although the loaded idle test is performed on the vehicle prior to the regular idle test.

Step 10 - Calculate initial emission reductions from vehicle repair

Calculate the number of fail-pass (result=FP) vehicles, and their initial (firstim) and final (lastim) emissions in a given cycle (cycle=n), by model year and type/class. Because of coding errors, a small number of vehicles “change” vehicle type/class or model year between their initial and final I/M test. For this reason the vehicle counts by type/class and/or model year may change between the initial and final test.

Step 11 - Estimate the total initial emission reduction from vehicle repair

Multiply the number of fail-pass vehicles by an estimate of annual miles traveled (such as MOBILE6 defaults) by vehicle type and age/model year, to determine the total number of miles by vehicle type/class and model year. Multiply the total miles by the average emissions on the initial and final I/M test, for each vehicle type/class and model year. Sum across vehicle types and model years to obtain total initial and final emissions, and convert grams to tons or tons per day.

Subtract the total final emissions from the total initial emissions. This is the initial benefit from the program from repairing vehicles that fail their initial test. This initial repair benefit can be compared with that of a random sample of vehicles given a full IM147 test, to determine whether the Sierra full-test adjustment method is accurate.

However, the estimated initial repair benefits do not last a full two years, as emissions deteriorate rather rapidly over time (see ERG analysis of vehicles receiving an off-cycle test). Other benefits of the I/M program include maintenance and repairs made immediately prior to the initial scheduled inspection (that can only be estimated using a large number of remote sensing measurements), and permanent removal of no-final-pass vehicles (that can only be estimated using a large number of either remote sensing measurements or on-road license plate observations).

8.0 Task Assignment 7 – 2003 Bridging Activities

The purpose of this Task Assignment was to conduct bridging activities and related tasks, as requested by ADEQ. Specifically, the following were completed under this Task Assignment (TA).

Subtask 1: Execution of TA4 Subtasks Not Started During the Previous Fiscal Year – ERG completed all subtasks not initiated under TA4 during the 2002 Fiscal Year. This included conducting Focus Groups with suspected I/M non-compliers as well as targeted phone surveys of suspected I/M non-compliers. The findings from these subtasks were combined with the findings from those subtasks previously completed under TA4, in an overall report providing conclusions and recommendations for improving program compliance in the future (see Section 5 for details).

Subtask 2: Collection of Minimal On-Road Remote Sensing Data – A requirement of the Arizona Alternative Compliance and Testing Study (AZACTS) is to collect Vehicle Remote Sensing Data (RSD) in a manner that conforms to 40 Code of Federal Regulations, Part 51, Section 51.371. To fulfill those requirements for the 2004 calendar year, ERG hired a subcontractor to collect at least 20,000 valid on-road RSD records in the Phoenix I/M area. The necessary data were collected during June 2004 and the results of that data collection were delivered in August 2004. In addition to providing a small increase to the RSD data collected under the AZACTS, these data also fulfill EPA's on-road testing requirement for Area A.

Subtask 3: Preparation of Six-Month Report – ERG prepared a Six-Month report as required in the AZACTS RFP. This subtask was ultimately moved to TA8.

Subtask 4: Preparation of a Interim Report summarizing all work performed to date under the AZACTS, along with conclusions and recommendations regarding additional work which would contribute to attaining other AZACTS program goals. This subtask was also moved to TA8.

9.0 2004 Bridging Activities

The purpose of this Task Assignment was to conduct additional bridging activities and related tasks, as requested by ADEQ. Specifically, ERG performed the following Subtasks under this TA.

Subtask 1: Preparation of Six-Month Report – ERG prepared a Six-Month report as required in the AZACTS RFP.

Subtask 2: Preparation of a Interim Report summarizing all work performed to date under the AZACTS, along with conclusions and recommendations regarding additional work which would contribute to attaining other AZACTS program goals. This document constitutes the deliverable under this Subtask.

Subtask 3: Recommend Methodology and Format for I/M Program Effectiveness Report. The results of this subtask were incorporated into the report titled, "Evaluation of the Arizona I/M Program Using Random Sample Data." In that report the ERG team discussed a step-by-step methodology that may be used by ADEQ or their I/M contractor to develop I/M program effectiveness reports on a regular basis. Algorithms and report formats were presented in a way that should allow the I/M contractor to reduce and input the data themselves. The results of this subtask were included with the results from TA6, and are summarized in Section 7 above.

Subtask 4: Replicate Fast-Pass/-Fail Algorithm Using Second-by-Second Official Test Data. The results of this subtask were also incorporated into the report titled, "Evaluation of the Arizona I/M Program Using Random Sample Data." In that report the ERG team discussed how we analyzed several months of second-by-second emissions from vehicles that were fast-passed/-failed, in order to replicate the Gordon-Darby fast-pass/-fail algorithm. The results using our version of the algorithm were compared with the official test results to determine the accuracy of our version of the algorithm. We applied our version of the algorithm to the random sample of vehicles given three full IM147 traces to determine the false fast-pass/-fail rates, and vehicle emissions, obtained using Gordon-Darby's algorithm. The results of this subtask were included with the results from TA6, and are summarized in Section 7 above.

10.0 Interim Conclusions and Recommendations

The following provides the Conclusions and Recommendations presented in the earlier sections of the Final Report.

10.1 Baseline Assessment of the State of the Science for Alternative Technology Options

10.1.1 Summary and Recommendations

This study identified 24 distinct options for improving the emission reductions, cost-effectiveness, and/or public acceptance of the current I/M program in Areas A (Phoenix) and B (Tucson). The report also provided recommendations for further evaluation of each of these options, considering available data, level of effort and other constraints. In addition, recommendations were provided for evaluating the OBDII and heavy diesel particulate matter (PM) testing components of the current program. OBDII and opacity test performance baselines will ultimately be necessary to estimate any incremental improvements to these programs.

Each strategy has a unique combination of advantages and disadvantages. Nevertheless, some general observations can be gleaned from this analysis. First, substantial (but as yet unquantified) emission reductions still appear to be possible for certain measures beyond the reductions resulting from the current program. However, most of these measures are also quite resource intensive (e.g., targeting high emitters for increased testing using remote sensing). Second, certain relatively small-scale strategies may be justified based on their low cost and positive public acceptance even though resulting benefits may be difficult to quantify (e.g., voluntary programs such as accelerated retrofit of diesel trucks with NO_x reduction kits).

Most importantly, there is considerable uncertainty associated with estimating the potential emission reductions, program costs, public acceptance, and other factors for many of these options. Therefore, most of these strategies need additional evaluation before reasonable assessments of effectiveness and other final evaluation criteria can be made.

In all, the ERG team identified over 50 different specific recommendations for further evaluation of these measures, an overview of which is provided below.

10.1.2 Conclusions

Comparative ranking of potential control options using the several evaluation criteria was outside the scope of this report. Nevertheless, based on our findings we grouped the strategies into six primary categories for prioritizing future data gathering and analysis efforts. These categories considered the potential costs, benefits, and uncertainties associated with each strategy, as well as the anticipated level of effort required for further analysis and quantification14.

Each strategy is listed below, with the corresponding report section referenced.

10.1.3 Strategies Expected to Have High Costs, with Potentially Large but Uncertain Benefits

These strategies include:

- High emitter identification using Remote Sensing Devices (RSD) **-- §3.1.1**

In order to obtain reasonable fleet coverage, operation and administration costs for this measure are high. RSD technology has improved significantly since the previous Arizona "Smog Dog" program but additional analyses are needed to assess potential benefits. Given the potentially substantial benefits we believe this option merits continued investigation.

10.1.4 Strategies with Highly Uncertain Costs and Benefits

These strategies include:

- Identifying heavy diesel trucks with high NO_x emissions **-- §3.1.4**
- Heavy diesel truck loaded transient opacity testing **-- §3.1.5**

While remote sensing of heavy-duty diesel NO_x has been clearly demonstrated, the potential costs and benefits of diesel truck <u>repairs</u> remain highly uncertain at this time. (In addition, the screening accuracy of opacity measurements have yet to be demonstrated convincingly.) Similarly, the benefit of transient cycle testing and

14 Please note that the assessments of available data for similar programs and the costs are primarily qualitative, based on the ERG team's past experience with similar programs.

subsequent repair for opacity failures needs further evaluation15. Also, the additional data collection required for evaluating these strategies, especially repair effectiveness, could be somewhat daunting, and a relatively risky use of state resources. Therefore, proof of concept demonstrations and quantification of emissions levels for these tests could be done, but the more involved process of determining SIP creditable reductions that could be derived from a full-scale heavy-duty diesel vehicles (HDDV) I/M program may need to be left to other agencies already investigating these options.

10.1.5 Low Cost Strategies with Uncertain Benefits

These include:

- Adopting a gross liquid leaker I/M check **-- §3.1.6**
- Identifying smoking vehicles using roadside video cameras **-- §3.1.5**
- Improving repair data collection **-- §3.2.1**
- Developing a repair quality index for repair stations **-- §3.2.2**
- Conducting “pattern failure” evaluations to improve repair effectiveness **-- §3.2.3**
- Developing separate I/M cutpoints for retests **-- §3.2.4**
- Performing dual OBDII/IM147 tests **-- §4.3**

For the most part these strategies should be able to utilize existing equipment and infrastructure, keeping incremental capital costs low.16 In addition, most of these strategies should have relatively low operating costs once they are up and running.17 Therefore, the majority of the costs would be associated with up-front data collection, analysis, and program development. On the other hand, these strategies currently lack the data and analysis necessary to determine their likely impact on emission reductions or cost-effectiveness. However, given their relatively low evaluation and implementation costs, we believe further evaluation of these measures is a relatively low-risk undertaking.

15 Note that the incremental costs associated with actual transient opacity testing should be low, since I/M stations in both Areas A and B already have the required heavy-duty dynamometers in place.
16 Capital costs could be somewhat significant for improved repair data collection efforts if electronic links to the centralized vehicle inspection database are established for participating repair stations.
17 Requiring dual OBDII/IM147 testing would increase I/M test times and motorist inconvenience somewhat. Therefore costs associated with decreased vehicle throughput and impacts on I/M lane capacity would have to be considered explicitly.

10.1.6 Strategies Likely to be Cost-Effective, with Costs and Benefits Proportional to Program Scale

These strategies include:

- High emitter identification without RSD (using vehicle characteristics and/or I/M history) **– §3.1.1**
- Exempting clean vehicles from I/M requirements ("clean screening", with or without RSD) **-- §3.3.1**
- Performing functional exhaust gas recirculation (EGR) system tests in lieu of loaded tailpipe tests to identify high NO_x emitters in Area B or regions adjacent to I/M areas **– §3.1.2**
- Decentralized scanning of OBDII systems at repair stations or dealerships18 **-- §4.2**
- Adopting a scrappage program for high emitting gasoline vehicles **– §5.1**
- Expanding the current diesel retrofit program for PM control **– §5.2**

The ERG team believes these options are likely to be cost-effective on a per-vehicle basis, although total costs and emission reductions will vary depending on the number of vehicles involved. (Of course behavioral factors such as compliance, fraud and enforcement will need to be evaluated for these options as well to estimate total emission reduction potential, especially for decentralized OBDII and EGR testing.) Therefore, we believe further evaluation of these measures is merited to further quantify emission reduction potentials as well as to evaluate costs and benefits.

10.1.7 Low Cost, Low Benefit Measures Likely to be Cost-Effective

These measures include:

- Increased inspection frequency for high-mileage vehicles **– §3.1.1**
- Voluntary accelerated NO_x retrofits for heavy diesel trucks **-- §3.1.3**
- Improved use of the current Smoking Vehicle Hotline **– §3.1.5**
- Development of a web-based I/M history report for used car buyers **-- §5.3**
- Expanded use of the current gasoline vehicle catalyst retrofit program **– §5.2**

18 Although the cost-effectiveness of the baseline OBDII program has not been demonstrated at this time, especially for vehicles beyond their warranty period, we believe that offering a decentralized scanning option has the potential to improve the cost-effectiveness relative to the current program.

- Evaluation of limited code-specific exemptions from OBDII requirements **-- §4.3**

At the current time we view these as "niche" measures targeting a relatively small fraction of the fleet. Nevertheless, we expect these measures to be relatively cost-effective.

10.1.8 Low Cost, Low Benefit Measures with Uncertain Cost-Effectiveness

These strategies include:

- Development of a used car buyer's guide based on generic make/model data **-- §5.3**

While this measure may prove to be cost-effective, it is likely to impact a very small portion of the fleet. Therefore, we anticipate relatively small total emission reductions from this measure. In addition, although program operation costs should be low, quantification of benefits for this measure is likely to be difficult and costly.

10.2 Alternative Technology Evaluation

10.2.1 Profiling Analysis

10.2.1.1 Conclusions

a. Profiling models built with remote sensing information gathered at the entrance to I/M stations provided an incremental benefit for identifying vehicles that were likely to fail the IM147 emissions test, relative to models that used only generic vehicle information such as model year and other information (as decoded from the vehicle's vehicle identification number, or VIN). In addition, positive benefit was observed only when less than 30% of the vehicle fleet was screened. At higher screening percentages, the use of RSD information provided no incremental benefit.

b. The models developed in this study indicated that when used in a clean screening mode, the RSD information provided no incremental benefit over models that were built with generic vehicle information that could be obtained from the VIN.

c. Thus, this study indicates that if Arizona chooses to institute clean screen profiling of vehicles to exempt them from IM147 testing, RSD measurements taken at the entrance to I/M stations provide only marginal benefits. On the other hand, if Arizona institutes a dirty vehicle screening program, RSD testing of vehicles at the entrance of I/M stations provides an important incremental benefit that cannot be obtained by using generic vehicle characteristics alone. However, this RSD benefit disappears if fleet screening percentages of greater than 30% are desired.

d. These conclusions are based solely on the results of this study. However, they are consistent with our knowledge of RSD measurements and with our experience on profiling systems developed using other datasets. The models developed in this study are good indicators of potential performance, but they are not highly refined, and it is certainly possible that further refinement of the models could change the influence of RSD emissions and other information on predicting IM147 results. A number of opportunities for further development of the models and specifically for estimating the costs and benefits of using profiling in Arizona exist.

10.3 Improving Repair Effectiveness

10.3.1 Conclusions

- The Arizona repair dataset by itself and in conjunction with the emissions dataset useful in understanding the influence of repairs on emissions and the characteristics of repairs. Many trends were found in the Arizona repair data, indicating that the data are of high enough quality to resolve differences in effectiveness among the various types of repairs. The repair dataset does have some opportunities for improvement, however, which are described below, and discussed in detail in the report. Some of the analysis techniques described in the report are expected to yield additional insights if higher quality repair data were obtained.
- For each group of vehicles of the same technology type, the before-repair and after-repair emissions generally increased with vehicle age to levels substantially above the new-car certification standards.
- ERG's previous analysis of <u>average</u> before-repair emission levels on British Columbia data indicated strong associations with the repair types performed; however, the analysis of Arizona <u>individual</u> vehicle emissions indicated weak associations with repair types performed. The variability in before-repair emissions measurements among individual vehicles was sufficiently large to cause emission fingerprints for different repair types to have substantial overlap. Nevertheless, the properties of the emissions fingerprints hinted that further analysis could lead to building models to predict the probability of specific emission control system failures based on emission fingerprints. If such models can be applied to the emissions of vehicles with emissions below the I/M program cutpoints, the models

might be able to identify vehicles with specific malfunctioning emission control systems. The fingerprints that were most distinct from the emission patterns of vehicles as a whole were those for EGR system repairs, catalytic converter repairs, and dwell/timing repairs, which were also found to produce the largest reduction in NO_x emissions.

- An analysis of repair durability indicated that for most types of repairs, the durability of the repair was relatively independent of the age of the repair. That is, the rate at which a given repair type is made a second time is independent of the time between the first repair and the second repair.
- An analysis of a repair costs indicated a wide range of costs for a given repair type. All costs in the analysis were only the cost of the repair paid by the motorist. No attempt was made to estimate motorist inconvenience, I/M program administration, or health impacts associated with emissions.

In the process of performing the analyses, we identified several possible improvements in the repair data collection system. Based on our analysis of the Arizona data and analyses of the repair data of other states, we recommended that Arizona undertake a two-phase program to upgrade the repair data collection system. In the first phase, the repair data collection procedures currently in use should be audited to identify the weak links in the collection of accurate repair data. Also in this first phase, the current repair data collection system should be patched with several improvements to rectify the weak links that are identified through the audit and through this report's analysis. In the second phase, we recommended that the current system be replaced with a new generation repair data collection system that would incentivize the collection of accurate, complete, and secure repair data from the I/M program. These system improvements would result in improved repair data that would allow for better estimates of the emissions benefit of the I/M program, and would provide a dataset from which improvements to the I/M program could be made.

10.3.2 Recommendations

- In several ways, the analysis of the repair data was more a demonstration of the types of analyses that can be performed, rather than an in-depth analysis of the repair database. Therefore, several of the analyses presented could be performed in more detail.
- The use of repair and emissions data to calculate emissions reductions is a common practice. Unfortunately, important and potentially large biases in the estimated emissions reductions are introduced in such an analysis because of the effect known as "regression toward the mean". Therefore, we recommended that the size of these biases be either estimated through

simulation, or measured directly in the field so that the calculated emissions reductions produced by repairs may be adjusted accordingly.

- Further analysis should be done to investigate whether emissions fingerprints can be used to identify specific vehicles with specific emission control system malfunctions. Comparisons between measured before-repair emissions and expected emissions could lead to improved fingerprints. We believe that such models may be possible and could lead to the identification of vehicles with malfunctioning emission control systems (especially those malfunctioning systems that produce excess NO_x emissions) even though the emissions of the targeted vehicles may be below I/M program cutpoints. Since most vehicles have emissions below I/M program cutpoints, repair of these vehicles would result in a substantial reduction of NO_x emissions for the fleet as a whole.
- The engine family names of all inspected vehicles should be routinely recorded and entered into the VID. The engine family names of recent model year (1994 and newer) vehicles can be readily decoded to provide the most accurate information on the emissions control equipment installed and the applicable certification standard for each vehicle. This information can make the analysis of emissions and repair data more reliable and more useful.
- Finally, we recommend that Arizona take interim measures to improve the current repair data collection system, and make plans for a next generation repair data collection system to replace the current system.

10.4 Accelerated Vehicle Retirement Strategies

10.4.1 Recommendations

We recommend that Arizona seriously consider adding a voluntary scrap program to its in-use emissions control strategy. A voluntary scrap program has great potential to deliver substantial and cost-effective pollution reductions. Additional study is necessary to make more definitive estimates of the likely costs and benefits of scrap in Arizona, and also whether and how such a program could be added onto Arizona's current I/M program. The following recommendations are offered (not in order of priority):

1. Begin detailed evaluation of program design and coordination issues, including:

- How to coordinate a scrap program with the current I/M program
- Methods of selecting candidate vehicles
- Feasibility of vehicle-specific scrap incentives
- Incentives needed to induce a given participation level.

- Requirements for contracting with auto dismantlers
- Plan for public outreach and pilot testing to ensure smooth rollout

This assessment should include (1) in-depth interviews with staff from other scrap programs, (2) data collection from other scrap programs to estimate emission reductions and cost-effectiveness, (3) analysis of Arizona registration, I/M, and RSD data to understand the nature of the Arizona fleet, and (4) survey, focus group, and/or other market research with motorists to determine what factors would enhance or detract from motorist participation.

2. Identify funding sources for a scrap program. Depending on the scale of the program, a scrap effort could cost from a few hundred thousand to several million dollars per year. DEQ should begin identifying potential funding sources, such as an I/M "buyout" for newer vehicles, stationary source participation, federal funding, and/or other options.

3 Assess administrative and other resource requirements for operating a scrap program. This should include gathering of information on management costs for other scrap programs, as well as the specific needs for integrating a scrap-program administration in the Arizona DEQ.

4. Develop more sophisticated estimates of potential scrap emission reductions. Develop valid methods for assessing real-world emission reductions from scrap. Existing RSD, I/M and registration data present a wealth of information that could be harnessed to develop estimates. In addition, Arizona should also gather additional data on emissions of pre-1981 model year vehicles by sending a random sample for dynamometer tests. Arizona should also work with EPA to agree on methods for assessing actual emission reductions from scrap.

5. Develop Arizona-specific estimates of potential economic effects. Determine whether the RAND model for California can be easily adapted to assess potential economic effects of scrap in Arizona.

6. Assure appropriate SIP credit for scrap and other promising in-use programs. Determine whether current allocation of SIP credit discourages progress in reducing in-use vehicle emissions. If so, Arizona should seek flexibility from EPA to ensure that SIP requirements don't discourage implementation of effective and cost-effective real-world pollution reduction measures.

7. Determine the requirements for enacting the required "Enabling Legislation." According to recent SIPs, there is a lack of "Enabling Legislation" for certain types of scrappage programs.19 If such legislation is ultimately required the impediments to writing and enacting it should be investigated.

10.5 On-Board Diagnostic (OBDII) Effectiveness Evaluation

10.5.1 Conclusions and Recommendations

Overall, OBDII inspections are feasible in both centralized or decentralized inspection networks. However, analysis of paired tailpipe/OBDII inspection results indicates OBDII may not be identifying some high-emitting vehicles. Although this may in large part be due to inherent biases in the study design (tailpipe false failures and failures masked by readiness), additional analysis is warranted, especially as vehicles age and accumulate more miles. *This additional testing and analysis should include an assessment of whether the tailpipe test should be retained as a back up test in order to identify true high-emitters that OBDII misses or to verify OBDII performance in high-mileage vehicles.*

Results from Arizona's MIL illumination and readiness rates indicate additional motorist education of OBDII testing requirements may be needed. In addition, a focus group study investigating motorist responses to illuminated MILs (performed under TA6) may provide clues on how to improve motorist response rates to MIL illumination. Finally, investigation into implementing a decentralized testing network (at garages, gas stations, or even at motorist's homes) may be of benefit.

10.6 Gasoline and Diesel Vehicle Retrofit Strategies

10.6.1 Recommendations

We believe that Arizona should consider adding a diesel retrofit program to its in-use emissions control strategy. A retrofit program has great potential to deliver substantial and cost-effective pollution reductions. Additional study is necessary to make more definitive estimates of the likely costs and benefits of retrofit in Arizona. The following recommendations are offered:

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19 Maricopa Association of Governments, "Serious Area Committed Particulate Control Measures for PM-10 for the Maricopa County Nonattainment Area and Support Technical Analysis," (Phoenix, December 1997).

1 ***Determine pollution reduction priorities.*** Because Maricopa County has been considered to be VOC limited, ADEQ should consider whether NOx reductions are a priority for a retrofit program, or whether the focus will be only on PM and VOC reductions.

2. ***Assess fuel sulfur issues.*** Assess the potential availability and costs of ULSD fuel. Near-term availability of ULSD fuel will determine the extent to which DPF retrofits are feasible. A lean NOx catalyst (LNC) combined with a DPF is a potential option for achieving 90% PM reductions without the need for ULSD.

3 ***Assess potential emission reductions, costs, and cost effectiveness.*** Data are available for generating preliminary estimates of emission reductions, costs, and cost effectiveness for a substantial retrofit program. ADEQ should make such estimates based on the current diesel fleet, data on typical emissions and duty cycles of various types of diesel equipment, and costs and performance of commercialized retrofit options.

3. ***Draw on experience of other states in designing a retrofit program.*** CARB and the California air districts that administer the Carl Moyer program now have multiple years of experience running a large-scale retrofit program. The program managers at each agency could provide detailed information on how to design a program and get it off the ground.

4. ***Identify funding sources.*** Incentive funding is crucial to a retrofit program, because of the program's voluntary nature. ADEQ should assess the availability of funding from federal, state and local sources, both public and private.

5. ***Assess potential SIP credit***. Given emission reduction estimates, EPA's SIP-credit framework can be used to assess potential SIP credit from retrofit.

6. ***Gasoline retrofit program***. Catalyst retrofit for gasoline vehicles appears to be reasonably cost effective. However, the cost effectiveness could be improved by identifying the highest-emitting candidate vehicles using on-road remote sensing. Furthermore, to maximize cost effectiveness across the suite of strategies for in-use vehicles, the retrofit program could be integrated with a scrap program.

10.6.2 Use of Remote Sensing Technologies

10.6.2.1 Recommendations

Due to the various data quality criteria used by different RSD equipment vendors, ERG recommends Arizona consider establishing common goals for any future RSD program and use those goals to produce additional RSD data quality specifications (over and above those set by the vendors themselves). California has developed a set of specifications that were used in their OREMS II program that could serve as a good starting point for Arizona RSD specifications.

In order to minimize instrument drift, ERG recommends Arizona establish a system-specific calibration schedule to be used during testing. This schedule may be determined using audit results or by analyzing the previous performance of the system under consideration.

ERG also recommends future RSD data collection programs utilize frequent calibration gas audits to help track changes in noise levels during the course of regular data collection. Also, it would probably be instructive to conduct noise analyses in "real-time," as the data are collected. Doing so would facilitate early detection of excessive noise and allow corrective action to be taken in order to minimize the collection of invalid or unusable data. In addition to noise analysis, it would also be advisable to develop a standardized method for determining when bias occurs. The source of apparent bias in MD LaserTech's CO readings should also be investigated in order to determine if the data correction method developed by the University of Denver is appropriate for application to MD LaserTech's CO data.

Finally, ERG recommends investigating the accuracy of acceleration estimates used to determine engine load by the various RSD test system. Such an investigation could involve auditing the acceleration results using a second, independent method, such as a "fifth wheel" attached to an audit vehicle.

10.7 Particulate Reduction Strategies

10.7.1 Conclusions and Recommendations

As a result of the research and analysis that went into this report, ERG draws the following conclusions:

5. The Maricopa County Smoking Vehicle Hotline provides potentially valuable insight into the nature of the gross PM emitters in the local fleet;
6. Starting in 2004, as new vehicles enter the fleet, the rate of reduction in fleet-average exhaust particulate emissions will accelerate. This is due to much stricter new vehicle particulate standards that will be phased-in through 2007.
7. Current particulate reduction strategies for on-road vehicles can be marginally improved upon (i.e., about 6% greater reduction in on-road PM) by adding additional strategies, roadside opacity tests for diesel vehicles and required

repair of smoking gasoline vehicles in the I/M program. This is in addition to other strategies that have been investigated, such as a scrappage and retrofit programs; and,

8. If such a particulate reduction is desirable and politically viable, then the cost effectiveness of these strategies should be investigated before proceeding.

10.8 Preliminary Progress Report

10.8.1 Conclusions

Baseline program performance—emission reductions: The analyses performed to this time indicated that the VEIP, Arizona's inspection and maintenance (I/M) program, produces real and quantifiable emission reductions. The ERG Team estimated I/M program effectiveness in two different areas:

- Area A: This encompassed the greater Phoenix area.
- Area B: This encompassed the greater Tucson area.

Two methods were chosen to estimate the VEIP benefits. One method estimated the benefits just before the fleet was tested in 1999 (a lower-bound estimate). The other method estimated benefits just after the failed vehicles passed their test in 1999 (an upper-bound estimate). Both estimates were made on a subset of vehicles that had been tested in each regular I/M cycle over the seven-year analysis period. The actual benefits of the program over the I/M cycle (the cycle-average benefits) are somewhere between the two estimates. Figures 10-1 and 10-2 depict these methods in graphic form.

Figure 10-1 shows the "Cumulative Benefits Estimate" for the Area A and B programs. It estimates the benefit of the I/M program by comparing the initial (before repair) I/M test emissions of vehicles that have just moved to Arizona, with the initial tests of vehicles that have been in the I/M program for several years. Table 10-1 provides more detailed information about emissions reductions associated with specific pollutants. The Cumulative Benefits Estimate assumes that the emissions of the vehicles just arriving in Arizona are equivalent to the emissions rates if Arizona had never had an I/M program. This is a minimum estimate because some of the vehicles new to Arizona may have been participating in an I/M program in another state. Further improvement to this estimate can be made by identifying which of these vehicles have never been part of an I/M program.

Figure 10-1. Cumulative Benefits (A Lower-Bound Estimate)

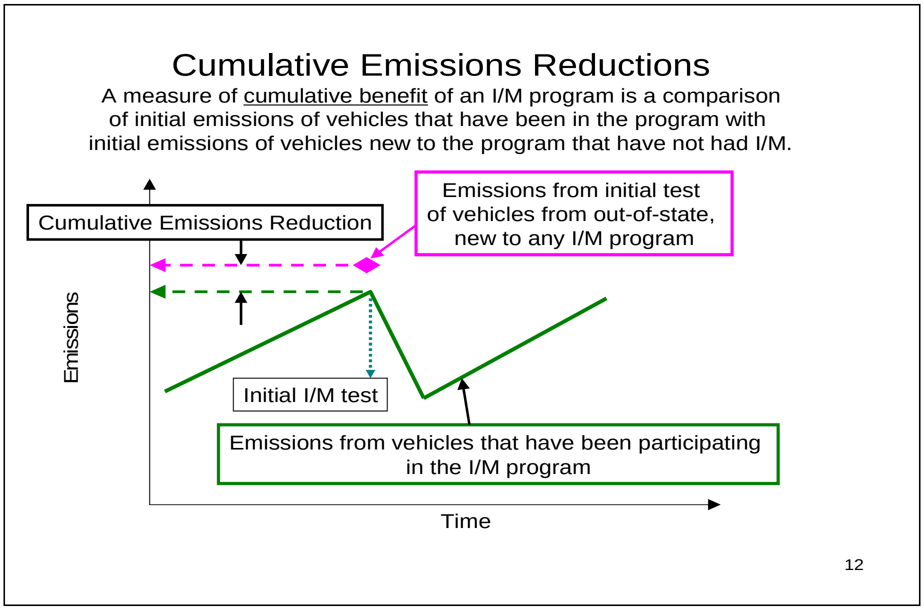

Figure 10-2. "One-Cycle" Benefits (An Upper-Bound Estimate)

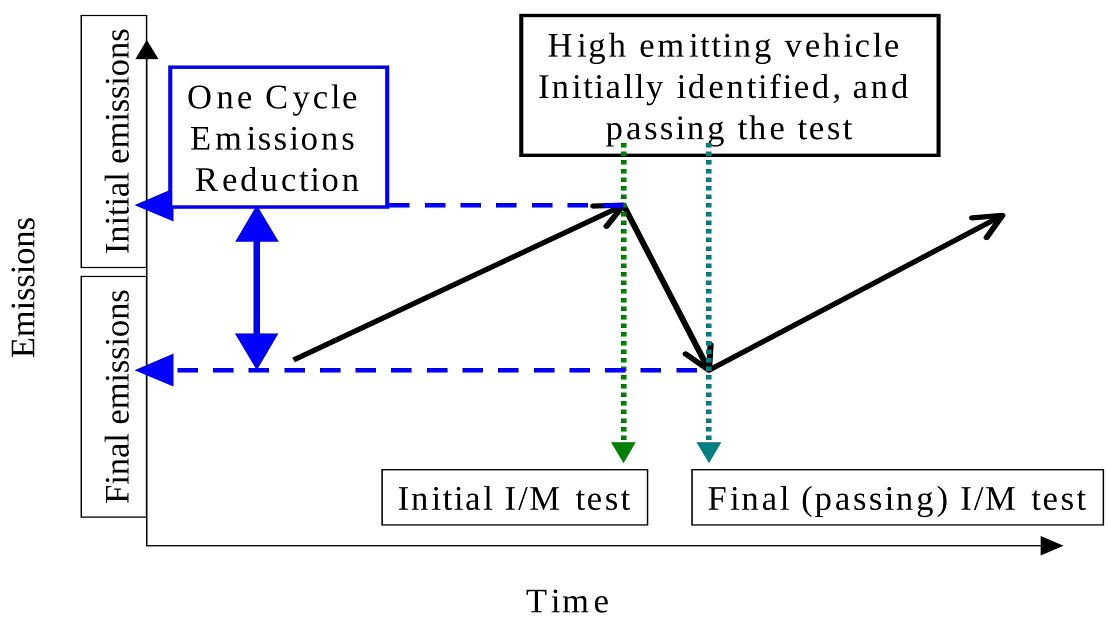

Table 10-1. Fleet-Wide "Cumulative" Emissions Reductions

Area A (Biennial) Phoenix - Enhanced IM240			Area B (Annual) Tucson – 2-Speed Idle		
HC	CO	NO_x	HC	CO	NO_x
8%	1%	6%	14%	26%	Not measured

(A lower-bound estimate of VEIP benefit from comparing the initial I/M tests of out-of-state and vehicles participating in the VEIP for several cycles up to 1999)

Figure 10-2 and Table 10-2 present the "One-Cycle Benefits Estimate" for the Area A and B programs. These estimates are based on comparing the average initial and final test emission results. For passing vehicles these emissions are the same. For vehicles that fail initially, but eventually pass, final emissions will be lower than initial emissions. This estimate assumes that if the I/M program were before the 1999 cycle, emissions would have deteriorated at the same rate as they did after the 1999 cycle (parallel deterioration).

Table 10-2. Fleet-Wide "One-Cycle" Emissions Reductions

Area A (Biennial) 1981-newer, Enhanced IM240			Area B (Annual)		
HC	CO	NO_x	HC	CO	NO_x
24%	21%	15%	19%	45%	Not measured

(An upper-bound estimate of VEIP benefit from comparing initial and final I/M tests for 1999)

The estimates of program benefits were calculated based on a subset of vehicles tested in each I/M cycle over the seven-year period. This means that the estimates shown do not account for natural vehicle turnover (i.e. newer vehicles replacing older vehicles) or failing vehicles being permanently removed from the I/M areas. In addition, the estimates do not account for any additional emission reductions from vehicle maintenance or repairs that may have occurred prior to the initial 1999 I/M test.

Note that the benefit estimates for Area A should not be compared directly to the Area B estimates, as the Area B unloaded idle test is fundamentally different, and inherently less accurate, than the simulated on-road driving test administered in Area A. In addition, the new-to- Arizona vehicles entering the Tucson area may be quite different in terms of age, maintenance, and other factors compared to the vehicles newly registered in the Phoenix area. Finally, because the test used in Area B does not measure NOx the estimates for Area B are for HC and CO only. (NOx emissions in Area B may actually have been increased by the I/M program, as some repairs to reduce HC and CO can lead to increased NOx).

The reader should also keep in mind that the data used to calculate I/M benefits are subject to uncertain influences. For example, if a large percentage of vehicle owners perform pre-test repairs in anticipation of the I/M test, this would cause an underestimation of the emission reduction due to I/M testing. Other factors could lead to an overestimation of the emission reduction due to I/M testing. These factors include: test avoidance, statistical effects (e.g., "regression-to-the-mean"), rapid deterioration of repairs, and intermittent failures leading to vehicles passing without proper repair.

The uncertainty of the emissions reduction estimates could be reduced using independent emissions measurements and license plate readings of vehicles driving in I/M areas. As such, future analyses should be supplemented with independent data to improve the accuracy of the assessment. Such an analysis would incorporate the effect of pretest repairs, fleet turnover, non-complying vehicles, statistical effects, and inadequate repairs in the estimate of program benefits. The independent emissions measurements can be obtained either from a roadside vehicle pullover and testing program such as is done in California, or from remote sensing measurements.

Arizona has a large collection of historical remote sensing data, although these data have a number of weaknesses. Limited use of old remote sensing data, analysis of the new remote sensing data collected under the AZACTS beginning in 2001, additional license plate data, and a series of registration databases obtained over time, could provide the information necessary to more accurately estimate program benefits.

Baseline program performance—other issues: Evaluations of vehicles failing the I/M test multiple times seem to indicate that repair effectiveness could be improved. Roughly 30% of vehicles that fail and then pass in one I/M cycle tend to fail again in the next I/M cycle. The reasons for this high "re-fail" rate should be investigated to further improve program performance, as well as to reduce long-term repair costs to consumers.

The On-Board Diagnostic system check (OBDII, adopted in January of 2002) appears to be off to a good start in Arizona. As of mid-2002 test equipment effectively connected with 98% of the vehicles, and OBDII inspections took less time than traditional I/M tests. The system could be made even more effective if motorists were better educated about the OBDII malfunction indicator light (MIL). This would increase the likelihood of a vehicle being repaired as soon as the MIL goes on rather than waiting until the vehicle's next inspection date.

The characteristics of Arizona's vehicle fleet are changing. New vehicles have much lower emissions than older vehicles and are staying cleaner longer. Hence, fleet emissions are increasingly being reduced in Arizona as a result of fleet turnover. This trend actually makes I/M programs less efficient over the years as fewer high emitters are found among newer vehicles.

The fraction of the heavier light-duty trucks (6,000 to 8,500 lbs. gross vehicle weight) is increasing in Arizona. These vehicles may merit special attention in the future.

Baseline compliance assessment: One of the main purposes of the AZACTS was to improve motorist compliance with program requirements. Before methods to improve compliance can be developed, a better understanding of the number and types of vehicles out of compliance must be obtained.

Depending on the variables and assumptions used, the analysis found that anywhere from 2 to 14 percent of light-duty vehicles registered in either of the I/M areas are not in compliance with I/M and registration requirements. In addition, there is reason to believe that a substantial number of these vehicles have been inappropriately re-registered from inside to outside of I/M areas. About 7% of all currently registered vehicles moved into a non-I/M area between the date of their last I/M test and their most recent registration renewal. In contrast, only 1% of all registered vehicles moved into an I/M area. The high estimate of non-compliance assumes that all of the registered vehicles that switched from an I/M area to a non-I/M area continue to be driven regularly in a non-I/M area, without fulfilling I/M requirements.

The compliance analysis also accounted for vehicles that were not currently registered according to the MVD database. One-third to one-half of all previously registered vehicles in the Motor Vehicle Department (MVD) database had expired registrations. Since vehicles with expired registrations remain in the MVD database for about 5 years before their records are deleted (unless an owner returns the license plate by mail after removal from the state or scrappage), many of these vehicles may have been permanently retired or removed from the state. Alternatively, many of these vehicles may simply have been late in renewing their registration, or were avoiding registration requirements. In addition, the estimates of non-compliance assume that all of the expired vehicles were no longer operated in Arizona; if some of these expired vehicles were actually being driven in I/M areas on a regular basis, then the estimated non-compliance rates would be higher.

In addition, a historical analysis of vehicles inspected in 1995-1996 showed that many vehicles that failed and never passed the I/M test continued to be driven in the I/M area 5 years after inspection.

It is important to note that the emissions from a non-compliant vehicle may be higher than emissions from a compliant vehicle, based solely on the incentive for owners of high-emitting vehicles to avoid I/M tests. Therefore, these non-compliant vehicles may be producing a relatively large percent of the excess vehicle emissions in I/M areas.

Finally, this analysis (along with the baseline emission analysis described above) relied heavily upon registration and inspection data. However, some inconsistencies were found between the registration and inspection databases, such as the date of the last I/M test. (Some currently registered vehicles have no recent passing I/M test record.) Accordingly there may be opportunities for improved communication between ADEQ, MVD, the I/M contractor, and enforcement agencies, which in turn could lead to improved estimates of compliance.

10.8.2 Recommendations

A number of detailed recommendations were developed based on the findings of TA1 and TA2. The recommendations were of three types. First, strategies for immediate consideration were presented. These represent strategies that were expected to provide real and cost-effective emission reductions at low implementation and operations costs. These strategies were also expected to enjoy broad public support, and require no further analysis before implementation. Thus, these measures were considered “low-risk” in terms of investment and resources, and could be adopted as soon as practicable. Second, recommendations were provided specifically for policy makers and regulators regarding program implementation, agency activities, and the operation of current programs. Finally, detailed recommendations were made for further data collection and analysis.

10.8.3 Strategies for Immediate Consideration

- Arizona should develop guidance and informational materials to help owners of failing vehicles obtain high-quality and cost-effective repairs. Other states with I/M programs provide information to motorists who have failed I/M tests and need to repair their vehicles. For example, these states provide information on how to locate quality repair facilities and technicians, what questions to ask technicians, and how to maintain vehicles between test cycles.

- Arizona should develop a Web site that provides used car buyers information on the I/M history of local vehicles, and should work with used car dealerships to publicize this service. Doing so could encourage chronically failing vehicles to move out of the I/M area or to be retired altogether.
- Arizona should develop and implement a voluntary program to retrofit heavy-duty diesel trucks with "NOx retrofit kits" ahead of the federally mandated schedule. Engine manufacturers provide funding for the kits and their installation so the cost to consumers will be very low. ADEQ could coordinate with the current I/M contractor, as well as with locally registered, centrally maintained diesel truck fleets to investigate the feasibility of offering on-site kit installation. This should minimize inconvenience for truck operators and encourage participation in the retrofit program.

10.8.4 Recommendations for Public Policy Makers and Regulators:

Policymakers and regulators would need to do the following to implement the measures listed above:

- Authorize, develop, pilot test, and publicize an I/M history Web site;
- Develop information packages and outreach/education strategies for owners of failing vehicles, and coordinate with the I/M contractor and repair facilities; and
- Work with diesel engine manufacturers to supply NOx retrofit kits, and coordinate training, kit installation, and recordkeeping requirements.

In addition, policymakers and regulators should do the following to enhance emissions reduction efforts in the state:

- Improve coordination between ADEQ, MVD, the I/M contractor, and local law enforcement officials. It appears that there are many ways to avoid I/M regulations while keeping vehicle registration intact. Such avoidance would be more difficult if government agencies, the I/M contractor, and local law enforcement officials joined efforts to ensure that vehicle owners were in compliance with I/M requirements. Specific contacts could be identified at MVD (regarding compliance with registration requirements) and the Department of Public Safety (for assorted enforcement issues), to work with ADEQ. This will help facilitate policy analysis and program implementation involving multiple agencies.

- Continue programs that complement the I/M program. In addition to the I/M program itself, several complimentary ongoing programs appear to be potentially cost-effective sources of emission reductions, and should be continued and possibly enhanced in the future. These programs include:
- The current diesel PM opacity I/M tests;
- The Maricopa County gasoline vehicle catalyst retrofit program;
- The recently adopted Maricopa County diesel PM retrofit program; and
- The ADEQ roadside PM opacity pilot program.

10.8.5 Recommendations for Additional Data Collection and Analysis:

The following describes activities that should be undertaken to collect data on vehicle emissions and activities related to I/M program improvements:

- Additional emissions measurements and license plate readings from vehicles driving in the I/M area should be collected to more accurately assess I/M program compliance and effectiveness. Arizona has begun full IM147 testing on a random sample of the fleet. These data should continue to be collected and analyzed regularly to help evaluate the program. Additional opportunities for compliance analysis using license plate readers and for emissions characterizations using on-road measurements should be investigated.
- Behavior studies should be conducted. These studies can help policymakers gain an understanding of the public's attitudes toward the I/M program and how different strategies, such as imposing incentives and fines, might impact compliance and enforcement. (These studies were eventually conducted under TA4 – see Section 5).
- Arizona's current repair and data collection processes should be improved. Repair technicians and vehicle owners often provide inaccurate repair data, or do not fill out required forms correctly. Near-term efforts should focus on improved reporting of information on repairs and the associated costs. Additionally, a number of inexpensive steps have been taken in other states that may improve the repair data collection process in the long run. These programs should be investigated for cost-effectiveness.
- Additional techniques should be developed to identify high-emitting vehicles. As newer vehicles become cleaner, more attention needs to focus on the subset of vehicles that contribute the most to excess emissions. Once identified, high-emitting vehicles can be targeted for more frequent testing and repair, or possibly removed from the I/M area through sale or early retirement. (Nevertheless, almost all vehicles emit some amount of on-road pollution and, with over 60 million miles driven per day in the

Phoenix area, strategies addressing even the cleanest vehicles – such as transportation control measures – should also be pursued for congestion management, energy conservation, as well as for emission reductions.)

- Arizona should review studies that other states are conducting on OBDII technology, and investigate what these states are doing to improve motorist knowledge of OBDII systems. Several states have started evaluating OBDII technology. OBDII tests alone will not generate emission information. Remote sensing data may be used to evaluate the tailpipe emissions performance of OBDII vehicles. Evaluation of OBDII failure rates in other states as well as in Arizona will become more important as vehicles age, given the stringent performance standards in OBDII design.

10.9 Subtask 3 -- Gather Information on Attitudes and Behavior Regarding Vehicle Repairs and Compliance with Program Requirements

10.9.1 Conclusions

ERG and its consultants reviewed the participant responses in detail and provide the following comments.

First, it was clear from the dialogue that there is a general adversarial tone between the repair industry and Gordon Darby. Some tension is understandable and even endemic to the given institutional arrangement, where the division between testing and repair responsibilities is absolute. (The frequent complaints regarding re-test failures serves as a case in point.) The I/M contractor's financial incentive to meet pre-defined failure rate targets compounds suspicions on the part of the repair industry. Under such an arrangement one would always expect some degree of "finger-pointing".

However, the participant discussions also point out areas where improvements could be made. Most importantly, there seems to be some misinformation among the repair industry on a few key points:

- One technician claimed that Gordon Darby fails for pending OBD codes – this is false; most likely there is some confusion between the treatment of pending and not-ready codes.
- There was general frustration with perceived "testing inconsistencies" on the part of Gordon Darby. Since these station owners operate their own testing equipment, they supposedly have an appreciation of the inherent test-to-test variability associated with emissions measurement, so the issue must be one of degree. On this point there is possibly a lack of appreciation of the extensive calibration, QA and auditing procedures

required of Gordon Darby, both internal and external. Awareness of these requirements could also help alleviate suspicions regarding test manipulation to meet specific fail rate targets.

- Several participants were concerned with the perceived inequity of having uniform cutpoints for a given technology category, regardless of vehicle mileage. This opinion seemingly fails to understand the basis for the cutpoints, and the extended durability requirements for emissions components. Specifically, if a vehicle isn't meeting its cutpoints, there is most likely a repairable component that could be fixed, regardless of the vehicle's age/mileage.
- More than one participant claimed that MTBE and/or alcohol additives were causing wide-spread damage to fuel systems. Comments to this effect were anecdotal, but expressed with confidence. While this complaint was not targeted at Gordon Darby, it does reflect a concern over government-initiated, emissions related programs in general. Perhaps these concerns would be dispelled by summarizing the extensive testing of such fuel additives from EPA, CRC, and other studies.

10.9.2 Recommendations

The focus group participants were in general agreement on the following recommendations for program improvement.

- Failed vehicles should automatically receive the trace graph for use by the repair shop personnel.
- Gordon Darby should be instructed to inform drivers of failed OBD II vehicles that they need to drive 55-60 miles after repairs are made so the vehicle's computer has a chance to reset itself.
- License renewal notices should be mailed 90 days in advance of the deadline date to give motorists more time to affect repairs when the vehicle fails.
- The 40th Street lab should be permitted to conduct courtesy tests for repair shops without the test results being entered into the computer system.
- Gordon Darby should be instructed to prohibit its employees from suggesting needed repairs to failed vehicles. It is not their job.

Motorist Focus Groups - In this subtask ERG and BRC collected information on the attitudes and behavior of motorists whose vehicles recently failed an I/M test, as well as motorists who were suspected of avoiding program requirements. This effort may provide information for improving compliance with the current program as well as for improving repair effectiveness.

Motorists with vehicles that recently failed an I/M test were identified using the database of I/M test results, and the results of the in-lane recruitment subtask described above. A combination of vehicle registration data and I/M test results were used to identify motorists suspected of not complying with program requirements. For instance, one method of avoiding the program is to re-register one's vehicle at an address in a non-I/M area, yet continue to drive it in an I/M area. Or motorists may simply drive their vehicle with expired registration. We identified vehicles suspected of such behavior by analyzing registration data. Another method is to simply not take one's vehicle in for a retest after failing an initial test -- we identified these "no-final-pass" vehicles in the I/M test result database.

ERG coordinated with ADEQ to obtain the necessary motorist contact information from the MVD. We provided the ADEQ with a list of 80,000 VINs of vehicles suspected of non-compliance, either through inappropriate re-registration outside the I/M area, or due to expired registration. ADEQ then provided MVD with this list. MVD in turn provided ADEQ with names and addresses for these vehicles.

BRC contacted potential focus group participants using this data set in combination with a reverse phone directory. Four focus groups were conducted by Behavior Research Center at BRC's focus group facility in Phoenix on June 22, and August 11, 2004. Participants in the groups were recruited from among Phoenix I/M area vehicle owners who either had failed an I/M test in December 2002, but not passed a retest as of March 4, 2004, or had failed an I/M test in March 2004. A total of 59 motorists agreed to participate in the groups, of which 36 showed up and actually participated.

ERG and its consultants reviewed the participant responses in detail and provide the following comments.

- Program inconvenience and test wait times were a consensus point of contention. Several possible measures were suggested which, depending on station configurations and contract terms, could be considered. These include expanded station hours, express lanes, and common queues.
- As in the station operator focus group, motorists re-iterated the lack of adequate guidance from inspectors regarding procedures upon vehicle failure.
- There was also a general consensus that expanding the program statewide would be equitable. Obviously, a detailed evaluation of the fraction of

local VMT attributable to out-of-area vehicles would first be needed to assess the potential effectiveness of such an expansion. The evaluation should also include the potential benefits associated with undermining the "re-registration" problem discussed above.

- A strong perception continues among both motorists and station operators that cheating is prevalent, either due to re-registration outside the program area, driving with expired registration, and temporary engine adjustments. Given these persistent perceptions, more detailed assessment of these activities is warranted under subtask 4.
- As with the station operators, motorists uniformly agree that gas cap failures should not receive a full retest.
- Motorists consistently claimed poor public awareness regarding many key program features, including waiver provisions, the retrofit/repair program, and the smoking vehicle program.
- The perception that institutional enforcement is inconsistent and/or weak merits further investigation.

Finally, motorists, as well as the station operators, may be sending a mixed message to inspectors. On the one hand there is a consistent push for providing more diagnostic and process-related information for vehicle failures (e.g., providing each motorist of a failing vehicle with a copy of the drive trace for diagnostic purposes, vacuum system diagrams, etc.). On the other hand, the station operators uniformly criticized the inspectors for giving unqualified repair advice. One can imagine the inspectors often being pressured by motorists to provide more technical information than they are qualified to in the interest of customer service. Re-iteration of the guidelines regarding what information can and cannot be provided may help address this concern.

10.10 Task Assignment 5 - Revisions to Baseline Analysis of Compliance with I/M and Registration Requirements in Arizona

10.10.1 Conclusions and Recommendations

There are several limitations associated with the above estimates of non-compliance. First, there are many unexplained discrepancies between the registration database and the I/M test results; we have attributed some of these discrepancies, such as vehicles with different dates of their last passing I/M test, to non-compliant behavior, when in fact they may reflect poor record keeping. There also are unexplained inconsistencies between different fields in the registration database. We recommend that DEQ make an effort to better understand how the database is managed and updated. This should allow DEQ to assist MVD in improving their record keeping, and will enable DEQ to better understand the extent to which motorists avoid program requirements. One possibility mentioned in q meeting with MVD is for DEQ to hire an employee to work solely at MVD to work with their databases.

Databases including license plates of vehicles observed on-road can be extremely helpful in improving estimates of overall non-compliance, as well as identifying specific vehicles that are avoiding I/M and registration requirements. The extremely large database of historical Smog Dog remote sensing measurements was very useful in identifying vehicles that had been non-compliant; however, this large-scale remote sensing program ended in early 2000. The more recent remote sensing measurements and unmanned license plate observations, undertaken as part of the AZACTS, are not extensive enough to provide a definitive estimate of non-compliance. For technical reasons the license plate could not be determined for almost half of the latest readings from the unmanned system. We strongly urge any new contract to ensure that a higher portion of vehicle readings are useable in the future. Large numbers of remote sensing measurements as part of a “clean screen”, high emitter identification program, or other on-road license plate data collection program would be very valuable in assessing motorist compliance with I/M requirements.

Finally, a large number of vehicles are parked at the Phoenix Airport. The Airport parking lot data could be very helpful in identifying vehicles with expired registrations, or that have never been registered. We recommend that DEQ authorize the continual procurement of license plate data from the Airport to assist in the analysis of expired and unregistered vehicles.