

Clarification of Misconceptions Regarding the Sacramento RSD Pilot Program

California I/M Review Committee

prepared by

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March 31, 1995

Introduction

Recent analyses of the Sacramento Pilot study remote sensing (RSD) data may have created misconceptions regarding the following issues (see for example Austin, 1995; Austin and Heirigs, 1995):

- Can RSD detect cars with reducible emissions without improperly failing low emitters?
- What level of fleet coverage can be expected of remote sensing?
- Does a small percentage of cars account for the majority of on-road emissions?

We address these issues below.

Can Remote Sensors Detect Cars With Reducible Emissions Without Improperly Failing Low Emitters?

Summary: A recent study (Austin and Heirigs, 1995) compares RSD measurements with IM240 measurements for the same cars, both taken for the Sacramento pilot study. However, the IM240 measurements were taken about three months after the RSD measurements. Previous studies have shown that when any emissions test is performed more than once on the same cars, the correlation is not perfect between successive tests and the correlation decreases with time between tests. When cars are measured on the road with RSD and then given an IM240 at the roadside, RSD false failures are uncommon, and RSD captures the majority of excess emissions. This shows that an RSD measurement is a good indicator of whether a car will fail a dynamometer test. What we are seeing in the Sacramento data are intrinsic changes in the cars over a three month period, not inaccuracy of RSD.

Austin and Heirigs (1995) state the following: "...it is clear that [remote sensing] is incapable of detecting the most common forms of tampering, prone to a high rate of false failures, and unable to identify most of the excess emissions that exist in the fleet even using cutpoints that yield a relative [sic] high false failure rate." As we show below, these statements are mistaken.

Several studies have measured cars with RSD and then performed a dynamometer test on the cars soon after the RSD measurements. We review the results of these studies below:

- In 1991, Doug Lawson of the Desert Research Institute¹ tested 76 cars on IM240 that were above either 0.25% HC or 4% CO on two consecutive on-road RSD readings. Seventy-three of the cars failed the IM240 at EPA's IM240 cutpoints.²

¹ Thanks to Doug Lawson, Bob Stephens and Mark Carlock for supplying the data set we analyzed for this paper.

² Cutpoints are the following:

Model Year	HC	CO	NO _x
1983+	0.8	15.0	2.0
1981-1982	0.8	30.0	2.0
1980	0.8	30.0	4.0
1977-1979	3.0	65.0	4.0
pre-1977	3.0	65.0	6.0

- In 1992, Bob Stephens of GM pulled over 119 post-1980 vehicles measured by remote sensor and tested them on IM240. These cars included both low and high emitters, allowing a determination of errors of commission and excess emissions captured. The results were the following:

Table 1
Performance of RSD Relative to IM240 for
Vehicles Measured on the Road

Method: Using RSD readings, fail the following cars:

- highest 20% of CO emitters (RSD cutpoint of 5.5%)
- highest 15% of HC emitters (RSD cutpoint of 0.094%)

	HC	CO	NOx
Excess Emissions Captured	78%	71%	33%
Errors of Commission	4 out 119 cars, or 3.4%		

Another way to use remote sensing on the road is as a screen for cars that are low emitting. These cars could then be excused from periodic testing. Using the same data set as above, we analyzed what would happen if the cars that were in the lowest 25% of emissions for both HC and CO RSD were excused from their periodic test.

Table 2
Excess Emissions Lost if RSD Used On-Road to Excuse Cars in Lowest 25% for
Each of HC and CO from Periodic Testing

	HC	CO	NOx
Excess Emissions Lost	0.3%	0%	13%
Percent of Cars Excused from Periodic Test	16%		

- In 1993, the California Air Resources Board measured 556 cars on RSD three times for both HC and CO and then tested the same cars on the FTP. In this case, the cars were measured by RSD under controlled conditions. Thus, this test is analogous to what would happen if RSD were used as a pre-screen for cars at a centralized test station. We analyzed the data for the 405 post-1980 cars in the data set. We

compared the average of the three RSD readings to the FTP. The FTP cutpoints were set at twice the certification standard for each pollutant (CO: 14.0, HC: 0.82, NO_x: 1.4, all in grams per mile). RSD cutpoints were set so that cars that were in the lowest 50% of RSD emissions for each of HC and CO were excused from further testing. Note that errors of commission are not an issue here because we are assuming that all cars will have a scheduled dynamometer test. We are only asking whether RSD can be used as a fast pre-screen to allow some cars to avoid further testing. The results are presented below:

Table 3
Excess Emissions Captured with RSD as a Pre-Screen for Dynamometer Testing

	HC	CO	NO_x
Excess Emissions Captured	93%	96%	85%
Percent of Cars Excused from Further Testing	34%		

As all three of the above studies show, RSD is very effective in identifying cars with excess emissions without improperly identifying a substantial number of low emitting cars.³ Austin and Heirigs (1995) report results opposite to what we have presented above. The reason is that they analyzed data obtained when cars were measured with RSD at one point in time, and then measured by IM240 about three months later. Because the results above show that RSD does a good job identifying cars that fail a dynamometer test, we conclude that what we are seeing in the Sacramento data is actually intrinsic variability in the cars themselves during the three months between the two tests. If the same cars were given two IM240 tests separated by three months, we would also expect to see a poor correlation between the tests.

In fact USEPA IM240 data indicate that this is the case. In one study, when cars were given two IM240 tests in a row at EPA's laboratory, the coefficient of determination (r-squared) between the two HC tests was 0.73. When one IM240 was performed at a test lane, and the second one was performed at USEPA's lab within a few days afterwards, the correlation dropped to 0.62 (ARB, 1994). Similarly, Knepper, et al. (1993), performed multiple FTP tests on high emitting vehicles. They found that HC emissions varied between successive FTP tests by up to a factor of 12. In both of these studies the cars were given multiple dynamometer tests over a period of days and the cars were under the control of the researchers. In the Sacramento study, the period between tests was much longer, allowing not only for the cars to be driven, but also to receive maintenance, changes in ownership, changes in license plate, etc., all of which might result in

³ The data we analyzed come from Doug Lawson of Desert Research Institute, Bob Stephens of General Motors, and Mark Carlock of ARB. We would be pleased to have our results checked by any interested party.

differences between the IM240 and RSD emission measurements.⁴ In addition, we also know that during the remote sensing study, conducted in late Summer, Sacramento gasoline did not contain added oxygenates. When the IM240 tests were conducted in late fall, Sacramento gasoline was oxygenated. Since oxygenates reduce CO emissions by 10% to 15%, this effect alone might create a substantial number of apparent false failures by RSD when compared with IM240.

What Level of Fleet Coverage Can be Expected of Remote Sensing?

Austin and Heirigs (1995) state the following: "Using mobile vans equipped with remote sensing devices (RSDs), measurements could not be obtained on about 75% of pre-1980 model vehicles during 500 van-days of testing."

This statement is correct, but also misleading. In 488 instrument-days (several remote sensing units operating for about 2 months), 45% of the cars in Sacramento County were measured at least once by RSD. That means that a single RSD unit operating every day for a year would measure one-third (about 250,000 cars) of the Sacramento fleet. (By contrast, one IM240 unit, costing roughly the same as an RSD unit, could measure about 19,000 cars.⁵ Note also that a scheduled dynamometer test can be prepared for, while it is difficult to prepare for an on-road RSD test.) That "only" 45% of the fleet was measured during the pilot study is due to the fact that the program was stopped after 488 instrument-days. By the time the program was ended, fleet coverage was still increasing linearly as new measurements were taken, and three of every ten cars passing by an RSD had not been seen before (see Figure 5-18, below). We do not know what the potential level of coverage is for RSD, but the Sacramento study results indicate that the level of coverage might have been substantially increased if the program had continued for several more weeks.

A number of other factors are also worth noting:

- The cars measured by RSD are the ones that drive more. Thus, the RSD measurements sample the cars that account for the most vehicle miles.
- The Sacramento study focused on on- and off-ramps of freeways. Cars that are less likely to drive on freeways might be found operating RSD units on streets.
- A potential impact of RSD is deterrence. The potential for RSD identification may encourage motorists to take preemptive action to ensure that their cars are low emitting. This deterrent effect would likely not require 100% coverage, or even 50% coverage, of the on-road fleet.
- The Sacramento study is only the first step towards implementing an actual RSD program. Future experience might allow greater effectiveness at targeting a wider segment of the fleet.
- There might be ways to encourage motorists to drive by a remote sensor, for example, by excusing RSD low emitters from their periodic test.

⁴ For example, a secretary in my office was selected for an IM240 test and had also driven by the RSD on a number of occasions. She told me that she had had her car's engine rebuilt shortly before the IM240 test, but after the RSD program had ended. Although only anecdotal, and probably not typical in its degree of "engine variability" between tests, many sources of variability during a three month period are likely.

⁵ Assuming that an IM240 lane operates 60 hours per week, 52 weeks per year, at a continuous throughput of 6 cars per hour.

Does a Small Percentage of Cars Account for the Majority of On-Road Emissions?

Austin and Heirigs (1995) state the following: "As reported by the University of Denver, 'The basic finding... ..is that a small minority (8.2%) of the vehicles is responsible for fifty percent of the carbon monoxide emissions.' This conclusion was based on the assumption that the RSD measurements accurately compare the emissions of one vehicle to another..."

"...This is precisely the problem with many analyses of remote sensing data. The assumption is made that the instantaneous measurements represent the average emissions for each vehicle. As a result, analyses of remote sensing data that draw conclusions about the distribution of emissions in the vehicle fleet are nonsense."

We note that the results we presented in the first section show that a one-second RSD measurement is a good predictor of whether a given car will be a high (or low) emitter on a dynamometer test. Therefore, RSD measurements do indeed predict average vehicle emissions, at least well enough for the purposes of I/M.

The result that a small percentage of cars contributes the majority of emissions comes not only from on-road RSD measurements, but also from dynamometer testing. For example, Figure 1, shows the IM240 emissions distribution by decile for about 1200 cars solicited at random by USEPA as they arrived for their scheduled idle test inspection in Phoenix, Arizona. The cars were ranked separately for each pollutant from lowest to highest emissions, and then divided into deciles. As the figure shows, the emissions distribution is highly skewed, particularly for CO and HC.

Figure 1

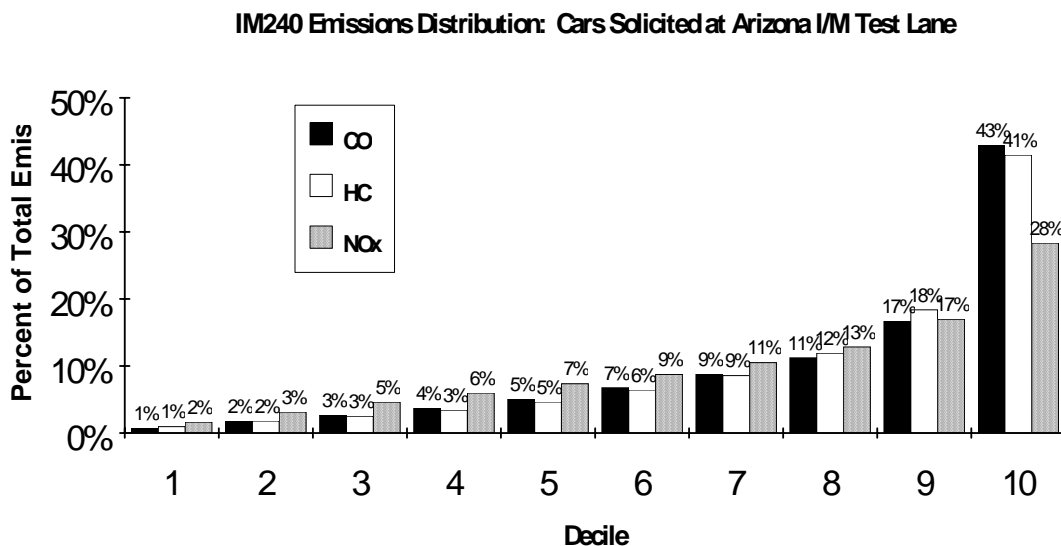
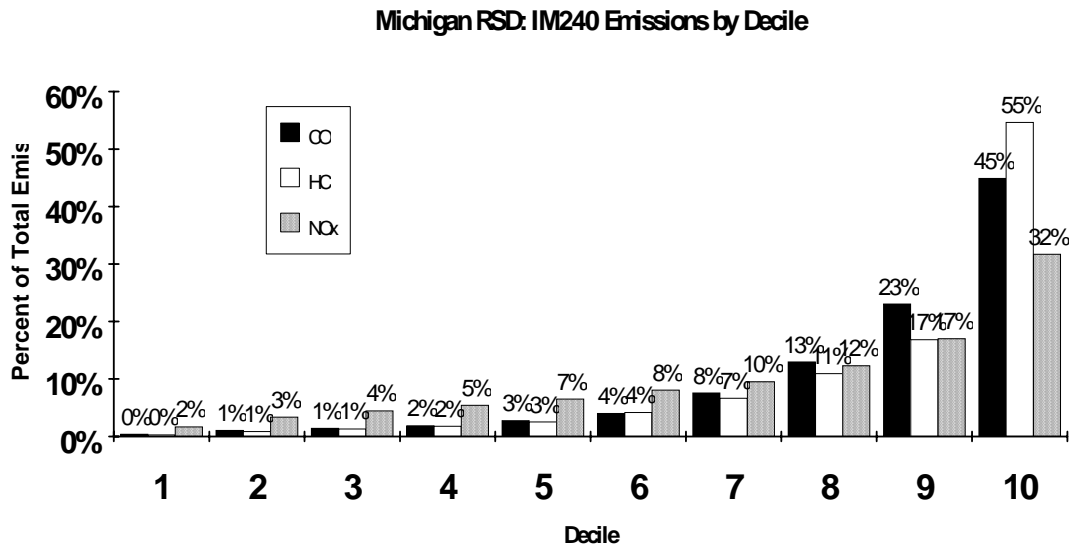


Figure 2 presents the IM240 emissions distribution for the 119 cars in Bob Stephens' study discussed above. Once again, a small percentage of cars accounts for most of the emissions.

Figure 2



A study done by Sierra Research for the previous California I/M Review Committee also showed a skewed emissions distribution (California I/M Review Committee, 1993). Of 681 vehicles, all of which failed Smog Check, the highest 20% of CO emitters accounted for 41% of the fleet CO emissions; the highest emitting 20% of HC emitters accounted for 47% of the fleet HC emissions (Lawson, 1995). Thus, even among only failing vehicles, emissions are still skewed towards the highest emitters.

ARB's EMFAC model is the vehicle emissions model used by California to predict on-road vehicle emissions.⁶ Sierra Research has used EMFAC in some of its studies for ARB and the previous I/M Review Committee. As shown by Pollack (1992), EMFAC7E predicts that 10 percent of the cars contribute 55% of CO emissions, and that 20% contribute 74% of CO emissions (see Figure 3). Note also that EMFAC7E is based on dynamometer test data of vehicles.

In summary, the general rule, from both dynamometer and RSD data is that a small percentage of the fleet contributes most of the emissions from the fleet. Furthermore, the fact that on-road comparisons of RSD and IM240 show that RSD properly detects high emitters shows that RSD measurements are predictive of dynamometer measurements.

Responses to Other Recent Statements Regarding Remote Sensing

⁶ A number of researchers have pointed out problems with the design and predictive capability of EMFAC and EPA's MOBILE model, but this is not important for the current discussion. We do note, however, that our discussion of EMFAC should not be taken as an endorsement of the model's validity.

- "The fundamental flaw in essentially all analyses favorable to the use of RSDs is that the emissions measured by RSD are representative of the average emissions for the particular vehicle being measured. Unfortunately, this is not the case." (Austin and Heirigs, 1995).

"Representative" is a vague term, and RSD does not need to measure the "average" emissions of a car to be effective. The specific issue for the use of RSD in an I/M program is the following: Can remote sensing measurements be used to capture the cars that account for most of the excess emissions, without improperly identifying cars that would not fail a dynamometer test? As we showed above, RSD performs this task effectively.

- "The problems introduced by vehicle emissions variability can be illustrated with a hypothetical example. If each vehicle on the road emitted 1 g/mi 90% of the time and 9 g/mi 10% of the time, and if the emissions mode at any instant was random, then, based on instantaneous measurements of a large sample of cars driving past a particular point it would appear that 10% of the vehicles were emitting 50% of the emissions. In fact, all of the vehicles would be contributing equally to the total emissions occurring in the area. Obviously, there are significant differences between the average emissions of vehicles in customer service. However, this hypothetical example illustrates why the distribution of emissions in the vehicle fleet cannot be accurately constructed from an analysis of data collected by remote sensors." (Austin and Heirigs, 1995)

The results presented above, which compare RSD and IM240 for cars measured on the road, show that this hypothetical example does not reflect reality. We showed that when real cars are measured by RSD, and then pulled over and given an IM240, cars that are high emitters on RSD are also high emitters on IM240. Furthermore, we also showed that whether measured by IM240, RSD, or other tests, a small percentage of cars do indeed dominate the emissions from the on-road fleet.

Conclusion

This document is not intended to indicate that remote sensing is a panacea for inspection and maintenance. There are many issues involved in using RSD in an operating I/M program. For example:

- Because cars do change with time, what are the implications for using RSD to cite high emitters by mail? Weeks may pass between the time of the RSD measurement, and the time that the car is brought into a repair shop.
- How should RSD cutpoints be determined? Should they be absolute, or site specific? Should they vary by engine size and vehicle age?
- Can RSD be sited so that many or most high emitters can be detected?
- Can RSD be sited so that it is not noticeable to motorists who might then try to avoid it?

These and many other issues must be resolved as we gain more experience with remote sensing technology. However, there are a number of other aspects of RSD that are no longer at issue. As we showed above:

- On-road remote sensing detects the majority of excess HC and CO emissions (as measured by IM240) without a high false failure rate.
- As a pre-screen for scheduled dynamometer testing, remote sensing can effectively screen out cars that are low emitters while still capturing the majority of excess emissions.
- As shown by the Sacramento study, a modest RSD effort (one instrument operating for a year) can measure one-third of the county fleet. The data suggest that a larger effort could capture a proportionally larger percentage of the fleet.
- On-road RSD measurements indicate that a small portion of the fleet accounts for the majority of fleet emissions. Dynamometer measurements have found similar results. A small fraction of the fleet is indeed responsible for the majority of fleet emissions.

Recent studies might have created misconceptions about what the Sacramento pilot study data can tell us, and about what RSD can or can not do. We hope that this document clarifies some of these issues.

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