Remote Sensing:

A New Tool For Automobile Inspection & Maintenance

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Executive Summary

Federally-mandated emissions testing of automobiles in Colorado has decreased emissions, albeit much less than predicted. Recent breakthroughs in manufacturing low-emitting vehicles and in remote sensing of a moving car's exhaust could enable Colorado to phase out or drastically increase the efficiency of treadmill-style testing centers.

Remote sensing technology now allows a piece of equipment small enough to fit in a van to assess the mass of pollutants per gallon of fuel emitted by a passing car. Once an emissions scofflaw is identified, a number of options exist:

- immediate pullover and ticketing by a police officer;
- a "smart sign" simply informing each vehicle's driver of how compliant or non-compliant their car is;
- a letter mailed to the driver's home mandating a treadmill-style test within 30 days.

Under the current emissions testing protocol, every automobile that's older than four years but not a "classic" must be tested every year or two, most at a cost to the owner of $24.25. Cars in good repair pass the tests without repairs or retesting. But the worst of the worst cars — the ones the tests are designed to catch — are only a small minority of the cars that pass through EnviroTest's dynanometer stations. A large number of people are inconvenienced to catch one person who is non-compliant.

Remote sensing technology has become so sophisticated that individual cars in heavy traffic can be measured, thus reducing emissions testing costs and inconvenience to vehicle owners. The latest analytical software can tell a car that has just been started from one that is warmed up and still polluting.

Drivers who maintain relatively new cars in good shape would never have to be tested again, unless they passed a remote sensing site that noticed something wrong with their emissions. Only the drivers driving the illegally polluting cars would be notified or stopped regarding their emissions.

Specific recommendations include: introduction of a flat fee, no more than $7[1] per year, charged to all owners of vehicles in the testing area; "smart sign" public emissions information sites; continuous on-road emissions evaluations administered by the Air Quality Control Commission (AQCC); annual reports on the benefits of emissions testing to the Colorado General Assembly; either a gross emitter pullover program or a Clean Screen program coupled with a more efficient, faster, centralized testing program with the goal of developing into a gross polluter identification program.

Remote Sensing: A New Tool For Automobile Inspection & Maintenance

By Dr. Donald H. Stedman, DU Professor of Chemistry

I. Introduction

If I were governor of Colorado, what would I do about vehicle inspection/maintenance (I/M) emission testing? Do we need the testing at all in view of the fact that we are in compliance with federal air quality standards? I believe we do because there remain gross emitters on the road, and many of them are in violation of state law.

Unfortunately, emissions testing has come to be regarded as a cost of vehicle ownership in which optimization of testing efficiency may be less important to testers and pollution control agencies than the fees they collect. If testing is going to continue, it should become much more efficient, less centralized, and less inconvenient and expensive for individual vehicle owners.

A. Considering All the Factors

There are several considerations, not all of which are compatible:

1) The State Implementation Plan (SIP), filed with the Environmental Protection Agency (EPA) as the state's promise to control air pollution, commits the state to some level of inspection and maintenance; however, if the state came up with an innovative alternative program, the EPA would probably accept it if the emissions reduction claims were reasonable. The National Highway Systems Designation Act allows states considerable flexibility in program benefit claims as long as they are documentable.[2]

2) EnviroTest, which has the current contract for $24.25 biennial emissions testing, retains all the best lobbyists and has an exclusive license to patents for the remote sensing system invented in Colorado at the University of Denver. There are, however, competitive remote sensing systems.[3]

3) The current Colorado program costs consumers about $40 million per year. This is bad news for Front Range inhabitants, but good news for EnviroTest. Testing costs are not currently regarded legally as a tax.

4) Under the TABOR restrictions in the state constitution, the state cannot increase taxes without a vote of the people.

5) The National Research Council (NRC) in a recent report ("Evaluating Vehicle Emissions Inspection and Maintenance Programs," National Research Council, July 2001) suggests decreased emphasis on testing of low-emitting vehicles. The current Colorado program, with a $24.25 cost and six percent failure rate, is costing us $400 cumulatively just to identify one failing vehicle. The NRC report correctly points out that gross emitters are more probable among older cars. Also, the probability of gross emissions increases for cars which have had multiple owners and whose current owners may not readily afford necessary repairs. Thus, increased emphasis on gross emitters might increasingly impact poor people. However, the current Colorado treadmill program already has this presumably unfair impact, arising from the four-year exemption for new cars and the fact that, even with more relaxed cut points, most failures are in the oldest model years. Figure 1 shows the reported failure rate in the Colorado I/M program by model year.[4] The oldest cars fail the most.

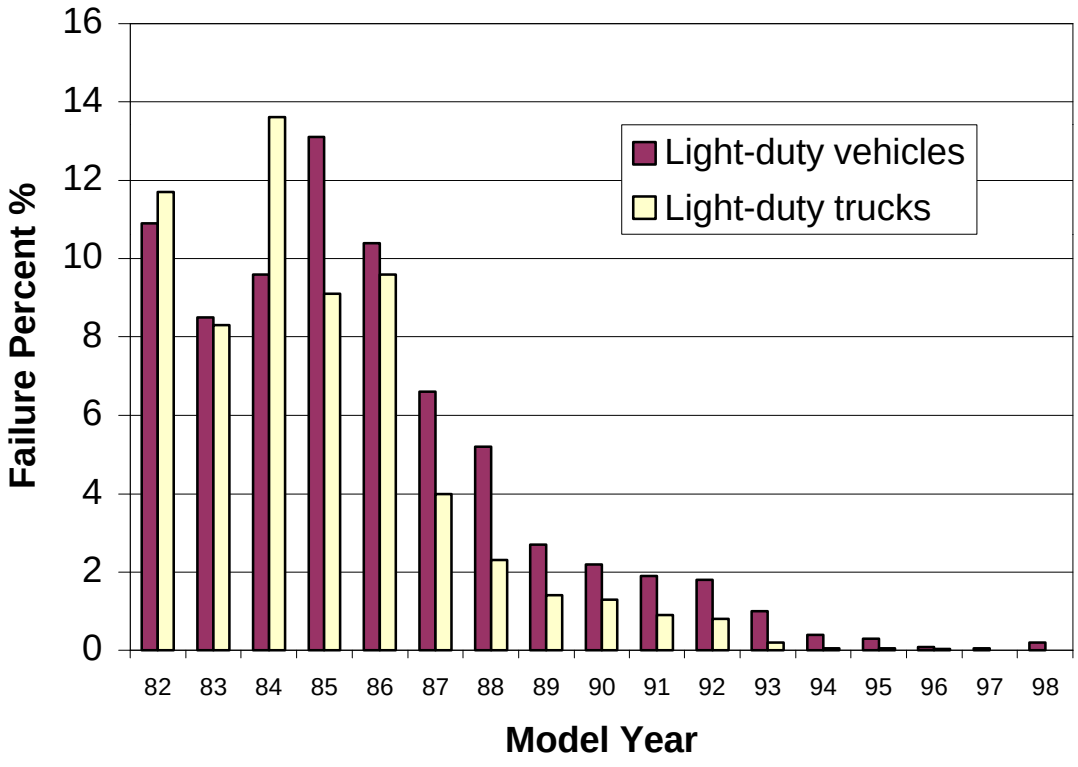


Figure 1. Emissions (CO, HC and NOx) Failure Rate in the Colorado I/M240 program during 1997. Data are from CDPHE 1998 report[4].

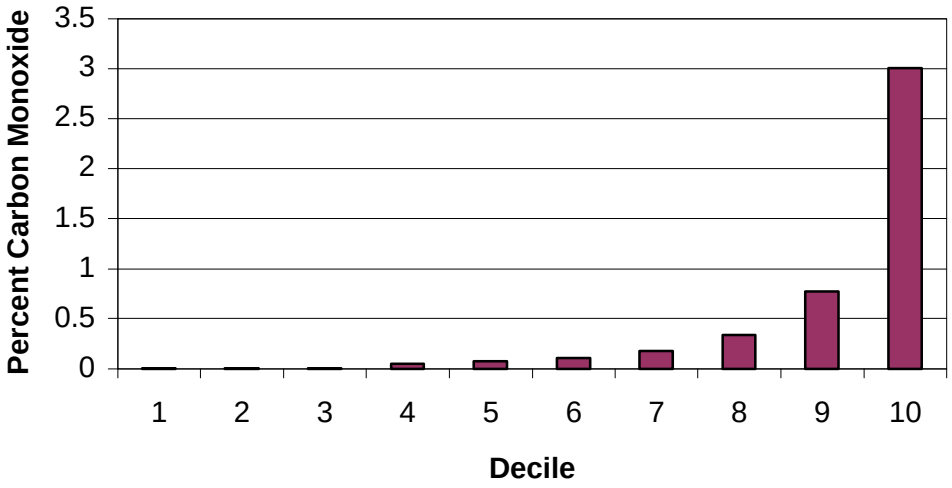
6) Approximately 25% of vehicles identified as failures by the IM240 treadmill-style dynamometers do not come back and pass the test, although legally required to do so. Several of these vehicles are still found by on-road remote sensing as gross emitters driving in the Denver area.

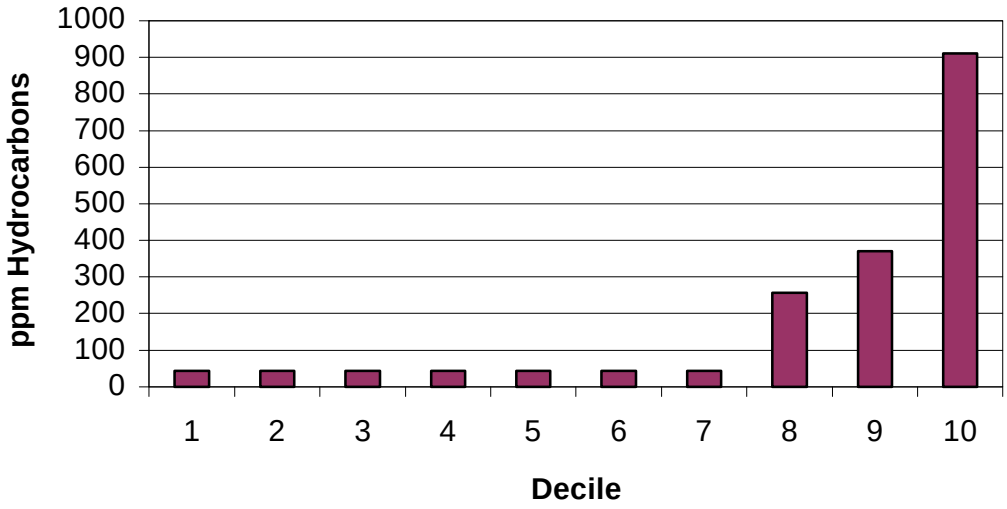
7) More than 80% of the failed vehicles which later pass do not provide valid repair information, and about one-third pass within a few hours of their test failure.

8) So-called "classic" cars more than 25 years of age are effectively exempt from emission testing regardless of their annual mileage accumulation and actual emissions.

9) The current registration-based, biennial test (or the required annual idle test outside the main metro areas) take no account of the fact that some service vehicles, such as taxis and delivery vans, drive 30,000 to 70,000 miles per year and are thus more likely to deteriorate and begin emitting gross emissions before their exemption is up. These vehicles experience a disproportionate number of emissions equipment failures by reason of their high annual mileage. High-mileage vehicles are more likely to be identified by on-road sensing.

10) Modern automobiles are low emitting when new and generally remain that way for many years with minimal maintenance. As a result, overall on-road emissions are diminishing even as miles traveled increase. As a further result, the relatively few gross emitters emit an ever-larger fraction of the diminished emissions. When we initiated on-road remote sensing in Denver,[5] one car in ten emitted more than the total of the remaining nine. Since 1999, we now note that one in 20 (5%) emits more than the sum total of the remaining 19 (see Denver emissions reports provided for the Coordinating Research Council, available at http://www.feat.biochem.du.edu/). Figure 2 shows as bars the emissions of carbon monoxide (CO), hydrocarbons (HC) and nitric oxide (NO) from a fleet of ten vehicles designed to match the current Denver measurements. Figure 3 shows the same data as cumulative curves. Notice how low emitting are most vehicles and how few are in the gross emitter category.





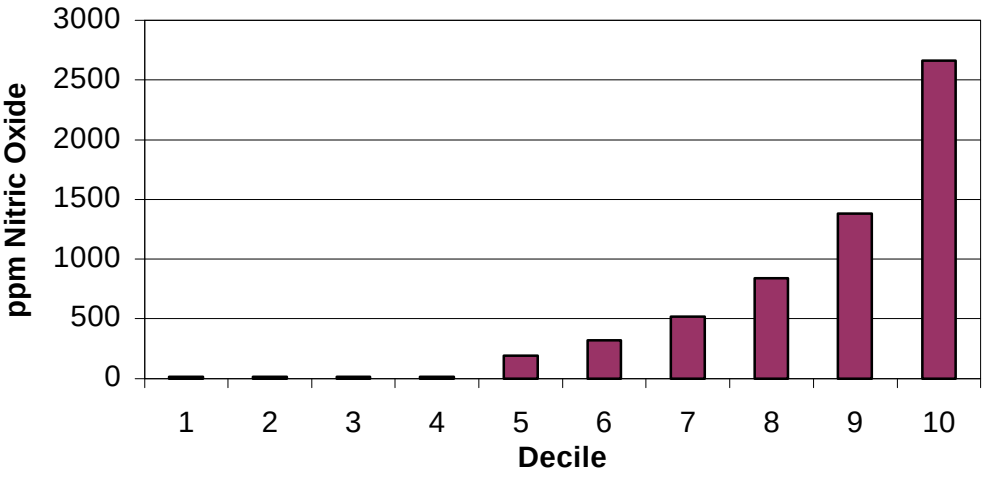


Figure 2. Emissions of a statistically representative fleet of ten vehicles in the Denver 1998/9 remote sensing data set. For each pollutant, the worst 10% of cars cause about as much pollution as the other 90% of cars combined.

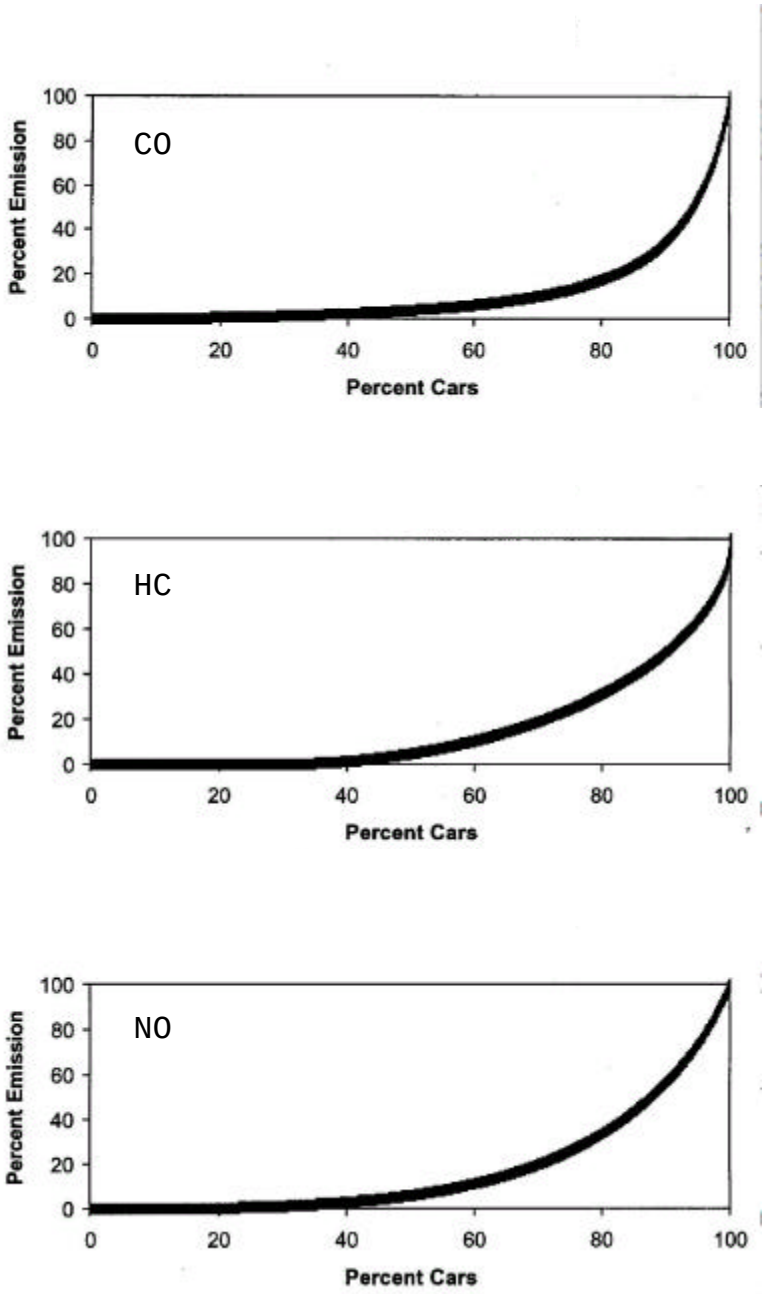


Figure 3. Cumulative curves of three pollutants measured by remote sensing in Denver in 1998/99. Note that 50% of the fleet is essentially eligible for enforcement action.

11) The EPA has required manufacturers of 1996 and newer model year cars to add sensors, actuators and computers cumulatively called OBDII. They are designed to illuminate the "check engine" light if a problem is diagnosed with the vehicle (or with the sensors and actuators!) which might, in the future, lead to emissions only 50% more than the miniscule federal

certification standards. This OBDII system is supposed to encourage early preventive maintenance, which at the time will negligibly affect emissions but is predicted (by the EPA) to lower future deterioration. Their new computer model (Mobile 6), which will be used in the next SIP, gives large future emissions credits for an I/M program which biennially inspects only the "check engine" light and associated computer. The test technician has to get you out of the car and grope around, usually under your dashboard, to perform this test. With much fanfare, this is heralded as a better, cheaper and more convenient I/M system. There are many critics (including the National Research Council report cited earlier) who believe an OBDII stand-alone I/M system will be even less effective (and for the poorer citizens, a lot more expensive) than our current biennial IM240 treadmill inspections. The Regional Air Quality Council in 2000 recommended to the governor that OBDII failure be advisory and the IM240 (a real emission test) result should prevail as the Pass/Fail decision. Other critics include Richard Joy (of Sierra Research in California)[6] and this author.[7] (This article is available at http://www.feat.biochem.du.edu/). OBDII is not useless — it is certainly a useful tool to assist mechanics in deciding which component of a gross-emitting 1996 or new vehicle might be in need of repair or replacement.

12) The Colorado Department of Public Health and Environment and EnviroTest are gradually implementing a "Clean Screen" program in Colorado. This is an astute political move. Recognizing that most vehicles on the road are well-maintained low emitters, on-road remote sensing is used to identify these vehicles (two on-road measurements per vehicle, one within 120 days of registration). Under various plans being discussed, these owners are exempted from testing. Independence Institute Research Associate Mike Krause, in the I.I. Issue Paper "The Expanding Surveillance State," (http://www.i2i.org/Publications/IP/PersonalFreedom/FaceRecognition.htm)[8] makes the case that there are significant negative aspects to the state knowing whose car is being driven where and when. The current Missouri "Clean Screen" program is operational. It makes about six million tests per year with six remote sensing vans. By contrast, note that EnviroTest's 72 IM240 treadmills do not achieve even one million total tests per year in Colorado.

13) It is said to be a fundamental tenet of environmental law that the polluter pays. This may be the ideal legal concept, but in practice centralized motor vehicle emission testing means everyone pays $24.25 because a few cars are broken. I/M is a negative incentive program in the sense that you are assumed guilty till proven innocent. This is probably one of the reasons for consumer resentment.

14) Vehicle emissions testing by any technique does nothing by itself to improve our air quality. The air only benefits when a failed vehicle is repaired, scrapped or removed from the area to pollute elsewhere. On-road remote sensing studies have shown that I/M programs motivate pre-test repair/maintenance but it has never been demonstrated whether this action

has been motivated by the test, or would have taken place in any case but actually has been delayed for a year until the test is due.

15) Assessment of the benefits motorists are getting from the dollars spent is a critical consideration. The current Colorado treadmill program is assessed every two years; these assessments are managed by the state auditor's office and usually are carried out by an out-of-state contractor in cooperation with the state health department. The results have never been peer reviewed. The AQCC has made its primary recommendation to the state legislature to evaluate the federally-mandated program's effectiveness by means of on-road remote sensing. The State of Georgia assesses $0.25 per test for an ongoing assessment of the program's benefits conducted by Georgia Technical University. Colorado should immediately begin a similar program at the University of Denver, which has carried out previous I/M program evaluations and subjected them to rigorous peer review. This could be managed through the state auditor's office or perhaps better by the AQCC, which has in its membership experts in I/M evaluation (Dr. Douglas Lawson was a member of the prestigious NRC Committee on I/M Evaluation).

B. The Current I/M Program and Its Alternatives

The current program tests, inconveniences and charges all vehicle owners to find the few dirty ones (guilty unless proven innocent). The EPA's OBDII program has the same shortcomings. It will be hard to resist EPA pressure to use OBDII, even though the data from Wisconsin indicate that the failure rate (for model year 1996 or newer vehicles) is seven times greater than the IM240 failure rate. Immediate addition of a Fast Screen pilot program, and then full program, at the EnviroTest stations would provide an even more convenient test for all motorists. As the vehicle arrives at the test station, it stops, drives through an unmanned remote sensor, stops again and the machine delivers a printout with immediate results. Fifty (50) percent of the vehicles receive:

"Congratulations, your vehicle meets the strict Colorado Fast Screen low emission requirements. You may proceed directly to the cashier who will enter your plate and VIN and provide you with the 'Pass Test' paperwork."

Fifty (50) percent receive: "Your vehicle did not meet the very strict Fast Screen low emission requirements, perhaps because it was not fully warmed up. Go to the next available dynamometer lane where your vehicle will be prepared for the normal Colorado IM240 test to ensure that it does meet our State's emission requirements."

The reason for using a pilot program first is that more than 50% of the arriving vehicles can be exempted by Fast Screen without compromising the current failure rates, and without the driver ever needing to exit his or her automobile. All remote sensing tests are a loaded-mode, test-only, mass emission test (per gallon of fuel) in strict compliance with the 1990 Clean Air Act and EPA rule making.

The on-road Clean Screen concept is an even greater improvement in motorist convenience, but it still emphasizes identifying and extracting money from the many low emitters while devoting no extra attention to the few high emitters. Clean Screen also suffers from the surveillance problem mentioned earlier.

According to the recent NRC report: “I/M programs should focus primarily on identification, diagnosis and repair of the highest emitting vehicles along with verification of those repairs.” A program using on-road remote sensing to identify these few vehicles is the obvious way to achieve the identification goal at low cost with minimal inconvenience to owners of the vast majority of low-emitting vehicles. There is no consensus on what steps should be taken once an on-road high emitter has been identified by remote sensing.

Studies have shown that immediate police pullovers of gross emitters and emissions testing by treadmill-style dynamometers or other techniques lead to about a 95% failure rate. Immediate police pullovers are, however, not popular with legislators.

The majority of the vehicles pulled over in California studies showed evidence of illegal emissions system tampering. In Arizona the (now canceled) on-road gross emitter identification program was sending identified vehicle owners a letter requiring them to take the treadmill test within the next month. Only about 50% of the owners “required” to do so actually showed up. Even then, while allowing for repairs to be carried out in the interim, 50% of those so identified, failed. Contrast this to about a 10% failure rate for the scheduled Arizona testing program. Arizona’s analysis, as reported by the NRC, states that this program was costing them about $300 per identified IM240 failure. The current Colorado program is cumulatively costing owners of low-emitting vehicles $400 per identified failure.[9,10]

Each one of Colorado’s 72 IM240 treadmills identifies only about two IM240 failures per day. A single remote sensor makes about 5,000 measurements per day. With a failure rate as low as the top one percent of really gross polluters, which are responsible for about 20% of all emissions, a single system identifies 50 gross emitters each day of operation. The vehicles identified by the remote sensor are actually on the road polluting the air in the Denver metropolitan area. It is well known that some of these are registered outside the emission testing area, even though they regularly drive in Denver. There is a law against this, but enforcement is essentially non-existent.

II. Improving Our I/M Program

How can we evolve from a program which costs a lot of money for little return and achieve a program which identifies and motivates only the gross polluters? This is a political question. The most efficient and effective method is certainly a well-publicized and -enforced (even if very small scale) on-road gross polluter pullover program with law breakers ticketed but high emitters just warned to get their car fixed. This program would send a very strong signal. It would send a signal both to the lawbreakers (illegal tampering with emissions controls and/or driving with registration not the same as home

address to avoid emission testing) and to the owners of gross emitters. They might not be motivated to repair the vehicles but might be motivated to drive them less, which in itself has an air quality benefit.

A. Cost-Effective Solutions

Strategies could include penalties to the owners of gross emitters only, even if they are poor people. California has adopted an income-based subsidy program to assist low-income owners of high polluting vehicles in getting their vehicles repaired. The solution for Colorado should motivate owners of gross emitters to repair their cars while costing the owners of low emitters little or nothing.

In Illinois all taxpayers, regardless of county, pay for the testing in Chicago's I/M program. It seems fairer to offer a free test to all vehicle owners in the testing area regardless of vehicle age. This would entitle the owner to a free Clean Screen, a free treadmill test if indicated, and a single free retest after repairing the car. It more tests are needed before passing, the owner will pay for these. This brings in at least some of the "polluter pays" concept. Vehicle owners who commute into the area (as presently) would be screened by on-road sensors, and could be ticketed if caught polluting. Commuters from outside the testing area who drive low emitters would not be identified, but gross emitters would be, and would also be required to pay full costs for all tests.

There is no doubt that the most cost-effective program would move towards on-road gross emitter identification as an I/M component. To make progress towards this goal, Colorado should place a few permanent "smart signs" around the metropolitan area, which would inform owners, as they drive by, of the emissions status of their vehicles without penalty. The world's first of these was placed at the Speer/I-25 exit ramp from 1996 to 1997 and removed because of roadway reconstruction. Funds have been requested from the Colorado Department of Public Health and Environment to replace it. Operating costs are less than $0.01 per test. Drivers average about 11 tests per year.

Independent evaluation indicates that these signs do cause voluntary repairs to be carried out.[11,12] They also get the public accustomed to remote sensing of their emissions and educate them about how few gross emitters there really are. If remote sensing which identifies gross emitters is coming in the future, then providing the citizens a way to find out beforehand if they are going to have a problem is a wise move for any government to take. However, the signs cost about $250,000 each to install. Who should pay for low-cost emissions testing since it is free to the passing drivers? Colorado should investigate what Front Range drivers are willing to pay in order to never be treadmill tested again.

B. Remote Sensing is a Different Kind of I/M Program

On-road remote sensing with gross emitter identification is potentially a very different kind of inspection than a scheduled I/M test. Scheduled I/M is based on registration and is considered "fair" if every registered vehicle is subjected to the test. As practiced, it is quite unfair. New vehicles are exempted for several years and "classic" vehicles are also exempt based only on model year, regardless of condition or annual miles driven. Remote sensing measures vehicles when and where they are driven, regardless of registration or model year. It is driving which pollutes the air, not registration; so, in many respects remote sensing is fairer than traditional I/M.

An IM240 dynamometer makes about 50 tests per day, and costs about $200,000 with associated real estate and several operators. A single remote sensing van, for about the same capital and operating costs, makes about 5,000 tests per day. Even greater "productivity" has been achieved from unmanned (bunkered) remote sensing units. Bunkered units are, however, relatively immobile.

C. Remote Sensing Cut Points

Cut points (a scoring method assigning Pass/Fail values to each pollution factor for different model years) for testing failure are set politically with the goals of not irritating too many voters but also of failing the most egregiously polluting vehicles. Cut points are set tightly for relatively new vehicles. Even then, very few fail (1-2%). Older vehicles are given looser cut points; however, a much larger fraction of those in the oldest eligible categories (10-15%) typically fail (see Figure 1). In 1995, the average treadmill test failure rate was 9.4% in Phoenix. Failing a treadmill test is supposed to be followed by successful repair of the automobile and subsequent passage of the test. In actuality, the vehicle owner is only required to pass a subsequent test. Even so, a very significant fraction of vehicles which failed treadmill inspections in Phoenix in 1995 did neither. Sixty-seven percent of the initially failed vehicles ultimately passed in 1995. Thirteen percent never returned to the test centers, and 20% did return but never passed the tests.[9]

D. Political Considerations

Arizona's on-road remote sensing program was hobbled legislatively in several ways. The vans were forbidden from operating in the low-income neighborhoods where the largest number of gross emitters were found and the threat of registration denial was never actually carried out. Thus, less than 50% of the worst polluters actually showed up for treadmill testing. Those that did had a 50% failure rate (far above the 8-10% for the general public). Furthermore, it is known only from personal communication that several owners repaired their vehicles in the warning period, passed the required emissions test, then complained to their legislator about the "unfair" remote sensing. This analysis shows that the remote sensor gross polluter identification, even as carried out in Arizona, is more efficient than regularly scheduled testing. However, the funding source was state tax funds, not fees paid by individual drivers.

III. Identifying the Grossest Emitters

These experiences suggest that a totally different concept for setting remote sensing cut points might be both fairer and ultimately more productive. The *entire* Colorado Front Range IM240 program fails about six percent of the vehicles tested, i.e. about 120 vehicles per day. A *single* remote sensor at a productive, 10,000-car-per-day site with a six percent failure rate would fail 600 vehicles per day: this alone would overwhelm the available repair industry. The suggestion presented herein is not to fix particular cut points (unless necessary politically); but rather, fix the remote sensing failure rate at one percent (the grossest of the gross). If fixed cut points must be set then they should be set very strictly and the message disseminated that the enforcement will only be for the worst of the worst. This concept is analogous to residential speed limit enforcement wherein a 30 m.p.h. limit is rarely enforced unless vehicles are traveling over 40 m.p.h. and very rigorously enforced for vehicles over 70 m.p.h.

A. Remote Sensing Avoids Socio-Economic Bias

A typical 5,000-car-per-day remote sensing van would fail 50 cars per day under this concept. The highest emitting vehicle in 100 is certainly broken, regardless of whether in a low-rent district where many cars are older and higher emitting, or in an upscale neighborhood where most vehicles have undetectable emissions by any test.

The top one percent gross emitters are responsible for about 20% of the on-road emissions. How to select one percent from among the highest hydrocarbon (HC), CO and NO emitters is a matter of state choice. In Colorado, nitric oxide (NO) is thought to be unimportant. I would advocate an algorithm that would choose one highest hydrocarbon and four highest carbon monoxide (CO) vehicles until the one percent total is achieved. Remote sensing studies in California combined with the federal test procedure (FTP)[13] indicate that a fail ratio of 1:4 HC:CO very efficiently reduces both hydrocarbon and carbon monoxide emissions after proper repairs. If NO is a concern, one could include one or two highest NO but leave the majority triggered by CO because high CO is an excellent indicator of a broken emissions systems and because proper repair also reduces HC and NO.[14]

B. Starting Off With “Smart Signs”

For necessary background information, see http://www.feat.biochem.du.edu/ for pictures, data and a published, peer-reviewed report. If I were to implement such a system, I would start with an on-road emissions monitor coupled to a variable message sign (billboard). The “smart sign” alerts passing drivers to their emissions status (good, fair or poor) and shows most of them that they repeatedly obtain “good” readings. The sign would be set so “poor” was the reading provided to about the top one percent. The “smart sign” and accompanying PR, media events, etc., would emphasize that this information is purely a voluntary government service (no video camera). The public information would also

emphasize that, several months in the future, people whose vehicles get "poor" readings when they pass a remote sensing van will be inconvenienced.

C. How to Motivate Repairs

Having identified an on-road gross emitter, we need to motivate and verify proper repair. Motorists could go to an unscheduled I/M test that would simulate real-life driving conditions (loaded mode as opposed to idle mode). If they do, there must be considerable advance publicity about the fact that high emitters often have highly variable emissions (even while broken); thus, they may fail one test and pass the next whatever the nature of the test: remote sensing, IM240 or even the Federal Test Procedure. This emission variability has been extensively studied but is little publicized since it is a source of potential embarrassment to federal and state agencies involved in emissions testing.[15,16,17] Since we know from pullover studies that the on-road gross emitters are broken, they could be sent directly to repair with any other confirmatory emissions testing. However, the treadmill tests are very useful emissions tests, particularly for verifying that gross emitters have been properly repaired; and, when a vehicle fails the test, the second-by-second data are useful to the repair mechanic to assist diagnosis of which components might have failed.

One needs also to consider what to do about the scofflaws. The remote sensor will identify gross polluters who have registered their vehicles fraudulently (claiming their son has it at an out-of-state college; registering outside the testing area; not bothering to register at all; fixing their car for the one day only when it takes the treadmill test, etc.). I know of no way to deal with these "worst of the worst" unless the political will exists to have a police officer pull them over on the spot and enforce any laws which they are found to be breaking. In normally law-abiding Edinburgh, Scotland, four out of 15 on-road gross polluters pulled over by the police turned out to have no driver's license, or insurance, and one out of 15 was stolen.

Studies in the early 1990's in California have shown that pulling over on-road gross polluters and on-the-spot testing achieves a 95% higher failure rate compared to regular treadmill testing. Furthermore, 50% of the vehicles appeared upon under-hood inspection to have broken or tampered-with emissions control equipment. Tampering with emission controls is against the law, but that law is almost never enforced. Drivers whose cars are pulled over and which show no evidence of illegal activity can be given a brochure explaining how their high emissions are costing them money in reduced fuel economy. They can also be told that the inconvenience they suffered from being pulled over, or being sent a "gross polluter" letter, can be avoided with proper repairs.

D. Clean Screen Is More Intrusive

An added advantage of identifying only the top one percent is: very few vehicle license plates need to be read, identified, stored or matched to DMV records. This contrasts to the expensive and extensive "surveillance" infrastructure needed for a Clean Screen Remote Sensing Device (RSD) program. Site-to-site vehicle load differences and

summer-winter fuel differences become irrelevant. Even calibration becomes relatively unimportant. One obtains one day's data and sorts for the highest one percent depending on the pre-set criteria (for instance, one HC and four CO out of each five in Colorado; perhaps one HC, two NO, and four CO out of each seven in Virginia, depending on how much emphasis is to be placed on NO).

If the state decides to move slowly into a remote sensing program by carrying out a Clean Screen program, let it be the most efficient and beneficial anywhere in the U.S.A. This can be done if the state has secured the necessary funding and allows, even encourages EnviroTest (or some other contractor) to construct fixed, unmanned and well-publicized Clean Screen sites. The state should also run a Fast Screen pilot program at the centralized testing stations.

E. Three Caveats

There are three caveats to "the dirtiest one percent" as a cut point definition. If high NO emissions are to be identified, then diesel-powered vehicles will be disproportionately represented. They are high NO emitters, so the representation is correct, but they are not suffering from a repairable fault (see later discussion on remote sensing of fuel status). The solution to this problem is to notify the owners of vehicles which DMV records indicated are diesel-powered only for smoke (also detectable by remote sensing), not NO emissions.

The second caveat is "steam" plumes. When the ambient temperature is below about 40° F and the humidity is high, many small cars never fully warm up their exhaust systems if the driving load is light. Honda Civic sized vehicles driving in suburban areas are a typical example. They show a small, white, so-called "steam" plume from their exhaust. This plume is composed of liquid water droplets. The University of Denver's Fuel Efficiency Automobile Tests (FEAT) units and EnviroTest's Environmental Systems Products (ESP) units up to the 3000 series read this water as gross HC. We are told that this error will be corrected in the EnviroTest 4000 units, but they are not yet in use. MD Laser does not have this problem. SPX, Inc. remains an unknown since its equipment has yet to be seen on-road.

The third caveat is that vehicles at very high loads enter a power enrichment/off-cycle emissions driving mode. Measurement of vehicle speed and acceleration is now commonplace with on-road remote sensing and formulae are available to eliminate these (correctly identified as gross emitting, but only temporarily so) vehicles from notification.

There is no doubt that a "top one percent" gross emitter identification program will mostly identify 15- to 20-year-old vehicles. Current treadmill-style programs do the same thing but at a cost to all drivers; any state screening for the top one percent should have the political will to admit, up front, that any program targeting the worst on-road emitters will inevitably target older (and some newer, very high-mileage taxi and delivery) vehicles.

About 75 seconds after a cold start, even Honda Civics on cold days have warmed up their sensors and controlled emissions output. However, all vehicles less than 75 seconds from a cold start have higher emissions because the emissions control system has not become activated. These vehicles are correctly identified as on-road gross emitters; however, they do not have a repairable fault. For this reason, it is useful for a gross polluter identification program to be able to determine if a motor vehicle is in this "cold start" condition.

IV. Distinguishing Cold Start Vehicles

As discussed earlier, vehicles in a cold-start mode are correctly identified by on-road remote sensing as gross emitters. However, they have no repairable fault. Thus, it is desirable to be able either to avoid this occurrence, or to flag the vehicles which are identified as gross emitters but might be in a cold-start mode. Operation of remote sensors at centralized test stations, freeway exits or interchanges eliminates cold-start vehicles from the tested fleet. Operations closer to locations where vehicles could have only recently started could use a cold-start identification method.

A. Reflective Infrared Detection

Researchers at DU looking into automobile emissions have considered this problem for some time. A patent (U.S. 5489777) has been established for a device which uses glancing reflection of infrared (IR) radiation off the road surface to see otherwise invisible hot exhaust system components underneath motor vehicles. A prototype was constructed and demonstrated in Virginia by Envirotest.[18] IR cameras which see the whole car and the roadway reflection have lately become much more reasonable in price. If gross polluter identification is the goal, and a "top one percent" cut point is used, and we wish not to notify cold cars, then human visual inspection of an IR image is straightforward. There will only be about 50 IR photographs from a single day's work to make sure that all the cars show hot parts, hot tires or hot reflections, and that the cameras have not been confused by sun glint. It is also relatively easy to arrange that only the IR photos of the potentially gross emitters are saved. To protect driver privacy, the license plate video files can be purged of the 99% low emitter pictures, or even triggered so the pictures are not saved unless high emitters are in the field of view.

B. Remote Detection of Fuel Type

The assignment to remotely detect fuel types is, in general, impossible. Compressed natural gas, liquid petroleum gas, diesel- and gasoline-fueled vehicles all emit CO_2, CO, HC and NO. There are, however, some special cases. Diesel-powered vehicles in our experience have never been seen to emit CO greater than three percent (or a CO/CO_2 ratio greater than about 0.3). LPG-fueled vehicles, if not properly controlled, will generally be read high on HC emissions because the Non-Dispersive Infrared (NDIR) sensors (used in several but not all on-road remote sensors) are calibrated for, and particularly sensitive to, propane. Hydrogen-fueled and battery/electric vehicles will generate "invalid" readings

because no CO or CO_2 is present at the rear of the passing vehicle. Evidence from Canada and elsewhere demonstrates that CNG and LPG conversions, although touted as "cleaner burning fuels," with *realistic* maintenance have much higher CO emissions than gasoline-powered vehicles of the same model year.[19]

V. Conclusion

There are many political decisions to be made by the elected and appointed officials who are entrusted with the Colorado environment. One proposal is to craft an "emissions testing" surcharge for metro area drivers which would avoid the need for everyone to be tested but which would motivate the owners of gross emitters to repair their vehicles, saving everyone money and achieving cleaner air.

Ideally, a few "smart signs" and a well-publicized (but actually quite small scale) gross emitter, on-the-spot pullover program would have optimum cost effectiveness, with independent on-road emissions measurements, administered by the AQCC, to continuously verify and evaluate the program. If Colorado decides to move more slowly through the Clean Screen and Fast Screen options the, nevertheless, the same ongoing, on-road evaluation through the AQCC should be carried out with the requirement to report the results annually to the Colorado General Assembly.

Technology, such as remote sensing and new automobiles which pollute much less, will help Colorado achieve better air quality while assisting vehicle owners by inconveniencing them less.

Recommendations:

- The flexibility offered under the National Highway System Designation Act should be exercised to phase out current federally-mandated emissions testing.
- As quickly as possible over the next three to five years, the current emissions testing program should be replaced with a "Clean Screen," or gross emitter detection, remote sensing program.
- A state-supervised trust fund should be established to receive and administer the program's funds.
- A flat fee of no more than $7 per year[1] should be assessed to all vehicles in the testing area and collected as part of the automobile licensing fee collection process.
- The program should pay for itself and all funds raised by the testing program should remain within the program; the program should never take in more than it expends.
- Monies should be set aside from the testing program's fund to pay for independent on-road emissions evaluations and program reviews by the AQCC, the results of which will be provided to the Colorado General Assembly.
- As Colorado moves closer to full air quality compliance, the General Assembly should periodically reconsider the testing program with the goals of reducing its

expense to the transportation consumer, making it conform to actual air quality needs and, ultimately, phasing it out completely. ■

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ADDITIONAL RESOURCES on this subject can be found at:
http://independenceinstitute.org/ResearchAreas/Environment/index.htm or
http://www.feat.biochem.du.edu/

NOTHING WRITTEN here is to be construed as necessarily representing the views of the Independence Institute or as an attempt to influence any election or legislative action.

Footnotes

1. "Expanded Clean Screen Program," House Bills 2001-1091 and 2001-1402 by State Sen. Mark Paschall. The first bill was killed in Senate Appropriations Committee on April 23, 2001; the second bill was approved by the General Assembly and vetoed by Gov. Owens.

2. National Highway Systems Designation Act, 1995.

3. MD Lasertech Ltd., 2024 W. McMillan St., Tuscon, AZ 85705 (http://www.md-lasertech.com/), SPX Corporation, 2550 N. Drogoon St., Suite 100, Tucson, AZ 85745 and Air Instruments and Measurements, Inc., 13300 Brooks Dr., Suite A, Baldwin Park, CA 91706.

4. "Report to the Colorado General Assembly on the Vehicle Emissions Inspection and Maintenance Program," Air Quality Control Commission, Colorado Department of Public Health and Environment, Denver, CO, 1998.

5. "IR Long-Path Photometry, A Remote Sensing Tool For Automobile Emissions," G.A.Bishop, J.R. Starkey, A. Ihlenfeldt, W.J. Williams and D.H. Stedman, *Anal. Chem.*, **61**: 671A-677A, 1989.

6. "Apples versus Oranges: Comparing I/M data to OBDII data," 17th annual Mobile Sources Clean Air Conference, Estes Park., Colorado, Sept. 2001.

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13. The Federal Test Procedure is the test used for new vehicle model certification. It costs about $2,000 and requires the vehicle to be at the dynamometer laboratory for 24 hours.

14. “Michigan Roadside Study: Emissions Intercomparison and Repair Effectiveness,” R.D. Stephens, M.T. Giles, P.J. Groblicki, R.A. Gorse, Jr., K.J. Mc Alinden, D.B. Hoffman, R. James, S. Smith. SAE 940582, International Congress, Detroit, MI, Feb. 28-March 3, 1994.

15. “Some Issues in the Statistical Analysis of Vehicle Emissions,” T. Wenzel, B.C. Singer and R. Slott, *J. Transportation Statistics*, 3: 1-14, 2000.

16. “Motor Vehicle Emissions Variability,” G.A. Bishop, D.H. Stedman and L. Ashbaugh, *J Air Waste Management Assoc.*, 46: 667-675, 1996.

17. “Fuel Effects on Auto-Oil High Emitting Vehicles,” J.C. Knepper, W.J. Koehl, J.D. Benson, V.R. Burns, R.A. Gorse Jr., R.M. Hochhauser, W.R. Leppard, L.A. Rapp and R.M Reuter, SAE Technical Paper Series 930137, Society of Automotive Engineers, 1993.

18. “Preliminary Results from Cold Start Sensor Testing,” C.S. Rendahl, J. Didomenico, J. Johnson, and J. Webster, Proceedings of the 7th CRC On-Road Vehicle Emissions Workshop, San Diego, CA, April, 1997.

19. “British Columbia AirCare I/M Program,” S. Stewart – AirCare, Proceedings of the 11th CRC On-Road vehicle Emissions Workshop, San Diego, CA, April, 2001.

Appendix

Definitions of Acronyms Used

AQCC	Air Quality Control Commission
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DMV	Department of Motor Vehicles
DU	University of Denver
EPA	Environmental Protection Agency
ESP	Environmental Systems Products
FEAT	Fuel Efficiency Automobile Test
FTP	Federal Test Procedure
HC	Hydrocarbons
I/M	Emissions Inspection and Maintenance
IM 240	The model of testing used by EnviroTest
IR	Infrared Radiation
NRC	National Research Council
NRDC	Natural Resources Defense Council
NO	Nitric Oxide
OBDII	Sensors, actuators and computers required by the EPA on all 1996 and newer model year automobiles
PPM	Parts per million
PR	Public relations
RSD	Remote sensing device
SIP	State Implementation Plan
TABOR	The Taxpayers Bill of Rights – Article X, Section 20 of the Colorado Constitution