Infrared Remote Sensing Of On-Road Motor Vehicle Emissions In Washington State

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Executive Summary

The Department of Ecology conducted a pilot study to evaluate the usefulness of remote sensing, a technology intended to measure emissions from motor vehicles as they travel along the road, rather than by visiting a test station.

A contractor took more than 200,000 readings at freeway ramps in King, Pierce and Snohomish counties. These were compared with test station records on the same vehicles over the previous two years. One third of the readings came from vehicles that had been inspected within that period. Of these previously inspected vehicles, only seven percent, were "viewed" three or more times during the six week pilot program. Remote sensing programs typically require three readings on individual vehicles.

Data from the pilot study correlated with test station measurements at a rate less than chance, even when vehicles had more than three "hits." The range of data for each vehicle averaged 70% of the total range of readings.

To view the 800,000 vehicles now inspected annually at test stations in the Puget Sound region, more than 35 million readings would be required. During the study, the remote sensing unit collected an average of 7,753 readings per day per location. At this rate, 4,583 days of data collection would have to be conducted each year. This would require several mobile test units and a very large number of suitable on-road testing sites to view the fleet currently tested at the test stations.

The cost per vehicle to obtain a set of three or more hits was more than $11. Ecology currently pays approximately $8.50 to the test station contractor for each inspection.

The low rate of data correlation and high data range indicate that on-road vehicle operating factors significantly affect emissions at any time. Careful remote sensing site selection can offset only some of these factors. Test station inspections provide far superior control over engine load and speed, while ensuring that all vehicles are subject to an equitable number of inspections. This helps to ensure that inspections are conducted in a fair manner.

Remote sensing would provide no practical benefit to Washington's Emission Check program as a means to evaluate individual vehicle emissions. Ecology's past and planned efforts to reduce the frequency of test station inspections have promoted customer convenience without compromising the integrity of the inspections. A limited remote sensing program could track the at-large emissions trends of the subset of a geographic region's vehicle fleet that does not receive regular test station inspections as a group over a multi-year period.

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Background

Washington's Emission Check program tests the tailpipe exhaust of gasoline and diesel-powered vehicles to identify those with excessive air pollutant emissions so they can be repaired to pollute less. The program covers urban areas of Clark, King, Pierce, Snohomish and Spokane counties. It includes 1968 and newer vehicles. Motorists bring their vehicles to Emission Check stations for testing. Generally, tests are required every two years and when vehicles are purchased from private parties.

Ecology has studied on-road emission testing, a newly available technology, to evaluate whether it could be a useful part of Emission Check. Ecology's study is part of an overall evaluation of the Emission Check program.

What is Remote Sensing?

On-road testing uses remote sensing technology to check vehicle emissions. Unlike equipment now used at Emission Check stations and repair shops, remote sensing devices do not need a physical connection to the vehicle. A vehicle travelling along a road past a remote sensing station crosses a beam that detects emissions. Depending on the manufacturer and design, remote sensing systems use infrared, ultraviolet or laser beams.[1] Ecology has evaluated infrared remote sensing, the most commonly used on-road emission testing technology.[2]

Other equipment at the remote sensing station detects the vehicle's operating mode, that is, its speed and rate of acceleration. These factors can significantly affect a vehicle's instantaneous emissions level. An on-road emission-testing program may require a specific operating mode for a valid or meaningful reading.[3]

A freeze-frame video camera records a digitized image of the license plate number. Information on monitored vehicles can then be stored on a computer.

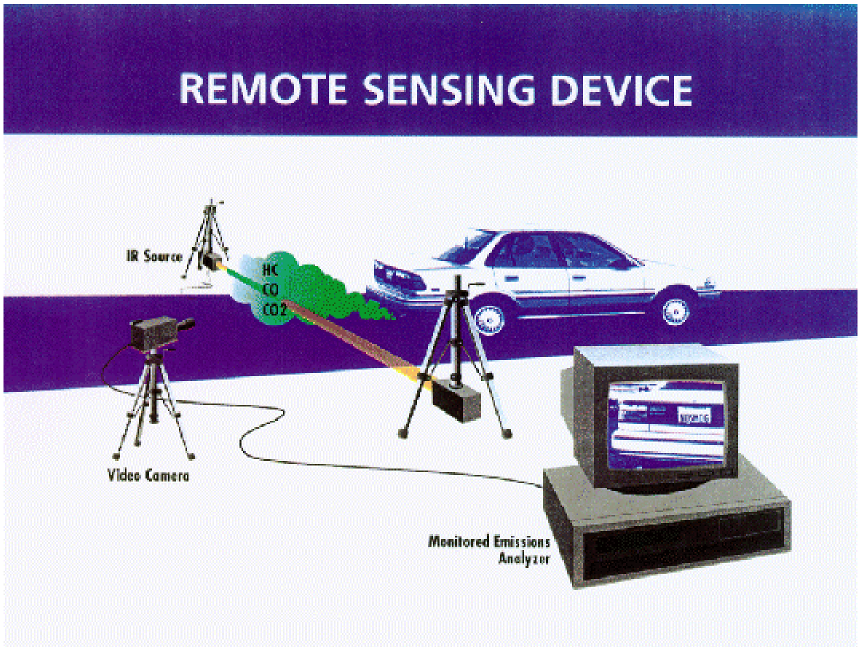
How does an infrared Remote Sensing Device work?

- An "emitter" beams a narrow ray of infrared (IR) light across a lane of traffic to an infrared photoelectric detector. Alternatively, the emitter may direct the IR beam across the traffic lane to a mirror, then back across the lane to the detector. This detector converts the infrared energy to an electric signal. The greater the infrared energy detected, the higher the electric signal and the lower the emission reading. Dirtier exhaust plumes absorb more of the signal.

- The Remote Sensing Device (RSD) detects hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and carbon dioxide (CO2). Each absorbs infrared energy at different wavelengths. For example, the more CO in the exhaust gas, the more infrared energy at the CO wavelength that gets absorbed and the less energy at this wavelength that reaches the detector. Therefore, the electric signal is inversely proportional to the gas concentration.

What equipment is required for infrared remote sensing?

- The RSD uses an Infrared Source/Detector pair. An IR source emits a beam of IR energy, which crosses the traffic lane to an IR detector. The beam is placed at the proper height to intersect the exhaust plume of most vehicles. The source and detector can be placed on the same side of the road, with the beam bounced off a mirror placed on the other side.
- A high-resolution, high-speed video or digital camera takes a still photograph of the rear of the vehicle, including its license plate, while the other equipment measures the exhaust gases. A video monitor displays the license plate and emissions readings for the station operator to observe.



- The camera image is digitized and decoded using an optical character recognition system designed to automatically identify, read, and merge the license plate number with the exhaust emissions readings of the vehicle into a database.
- The system uses a known blend of calibration gases at frequent intervals to calibrate the sensor to maintain its accuracy.
- The system uses devices that detect some aspects of the vehicle's mode of operation, such as speed and acceleration/deceleration, at the time of the exhaust emissions measurement.
- The system uses a vehicle counter device to keep track of the total traffic flow.
- A computer controls the entire process and records all the data collected.

Factors that limit the effectiveness of RSD

Remote sensing technology accurately measures the pollutants detected within the sensing beam,[4] but several variable and difficult-to-control conditions compromise the value of these readings. These include the vehicle's speed, acceleration, operating temperature and load.[5]

Careful testing site selection can help regularize speed, acceleration, and the operating temperature of the engine and catalyst,[6] but no way has been developed to remotely measure and control on-road vehicle loads, such as passengers, cargo and tire inflation. RSD programs attempt to overcome these weaknesses by obtaining multiple readings on individual vehicles.[7] A limited number of suitable sensing locations may be available, restricting the ability to view all of the fleet. Wet weather conditions, such as those in Western Washington, can make infrared remote sensing unavailable for use much of the year.[8] Finally, RSD cannot measure non-tailpipe evaporative emissions[9]—which are a significant concern in western Washington's ground-level ozone problem areas —which can occur even when the vehicle is not in use.[10] Washington may need to introduce or expand evaporative emission control system inspections in some Emission Check program areas in the future.

Locating the remote sensing device

Several factors combine to limit the number of effective, safe and economical places to use RSD. To view the entire fleet that is currently inspected a very large number of sites would have to be located throughout the Emission Check program area. (*See* "Limited on-road RSD sites are available." *on page 10.*)

RSD cannot measure more than a single lane of traffic. Without an array of costly special equipment, current RSD technology can only measure emissions of vehicles driving in a single traffic lane.[11] Restricting multiple lanes to a single lane for RSD measurement may not be practical in many cases, particularly during heavy traffic periods. Some studies have successfully used RSD monitors along multiple lane roadways without restricting traffic to a single lane.[12] This involved placing pylons between lanes to protect some of the RSD equipment.

Consistent vehicle operating conditions are a necessity for using RSD. This is important for two reasons. First, the vehicle's operating speed and rate of acceleration can significantly affect its instantaneous emission level.[13] Second, similar speeds and acceleration rates ensure that vehicles are tested under similar operating conditions for fair comparisons of emission rates.[14]

- Low speeds typically cause many vehicles to produce unfairly low emissions. At low speeds, vehicles operate under low or no load.
- A decelerating vehicle tends to have higher hydrocarbon and lower carbon monoxide emissions.[15]
- An excessive rate of acceleration commonly increases a vehicle's carbon monoxide emissions.[16]

Properly selected terrain yields more consistent testing conditions. One-lane roadways with a slight incline and a sweeping bend provide very good testing conditions because they tend to regulate the speed and acceleration rate of traffic.[17] Freeway interchange ramps and on-ramps provide the best opportunities to combine needed site characteristics: single lane, proper slope and curve, proper degrees and relative uniformity of speed and acceleration, economical traffic volumes, and safety for crews and equipment. RSD testing during peak traffic periods would probably be necessary to avoid missing high-emitting cars that could be parked during business hours.[18] Nevertheless, many vehicles would never pass along a freeway RSD test site;[19] many vehicles never travel on the freeway.

The cold-start phase should be avoided. A vehicle is in the "cold-start" phase during the time between starting a cold engine and when the catalytic converter reaches proper operating temperature. (This is not the same as the temperature displayed on the instrument panel, which indicates engine coolant temperature. The catalyst may need more time than the engine coolant to "warm up.") Below that temperature, the catalyst does not function. Vehicles tested in the cold-start condition will have high emissions.[20] Several minutes or more of travel at freeway speed are needed to properly warm the catalyst. RSD sites must be located in ways that minimize the likelihood that vehicles passing by will be in the cold-start phase.[21] On-ramps can pose a problem because some or most vehicles entering a freeway from surface streets may be in the cold-start phase. Catalysts also can cool below proper temperature during long waits at traffic signals, so RSD units must be located far enough from signals to allow vehicles to run long enough for catalysts to re-warm. Many freeway interchange ramps address these concerns well, but many vehicles do not travel on freeways or freeway interchange ramps.

In view of these concerns, RSD sites should meet these criteria:[22]

- The operator and equipment are safe throughout set-up, operation, and tear-down.
- The operation does not present a safety hazard to the driving public.
- Coning should be minimized as much as possible to prevent the alteration of motorists' driving patterns and to enable an unobtrusive placement of the RSD unit.
- There are no nearby traffic devices (stop lights, stop signs, etc.) to alter driving conditions, i.e., a forced acceleration or deceleration, or traffic backing up into the monitoring site.
- The road climbs gradually into the monitoring site in a sweeping bend. This tends to keep a driver maintaining a constant speed.
- An ideal site would have a low likelihood of cold start situations. All vehicles passing through the site should be likely to be fully warmed up.

Loads

Emissions increase with engine load:

> Under heavy load conditions, vehicle engines may enter enrichment modes in which an engine's process controls order a richer air/fuel ratio that can lead to high CO emissions. Heavy load conditions may also increase HC and NOx.[23]

An RSD program has no control over the variety of factors that affect the load placed on the engine, such as a vehicle's cargo, number of passengers, tire pressure and accessory use.

Payload weight: Test station dynamometers place identical weight loads on each vehicle size class. This is not possible in on-road testing. Increasing the load by only a few hundred pounds—two or three passengers—can skew emissions upward.[24]

Tire pressure: Under-inflated tires have a higher surface area in contact with the road, which increases friction—and therefore load—and can significantly increase carbon monoxide emissions.[25]

Accessories: Equipment such as headlights, air conditioners, blowers and defoggers place additional demand on the alternator, which requires more work from the engine to maintain an electrical current.[26] Headlights, air conditioners and defoggers place especially high loads on the engine. All accessories are turned off for test station inspections. Remote sensing cannot determine how much extra load a vehicle's accessories may be placing on its engine.

RSD cannot recognize these load factors. Therefore, even if a site promotes uniformity in speed and acceleration, we cannot know what load each vehicle bears.

Need for multiple readings

To overcome on-road variations in load, speed and acceleration, most RSD programs obtain multiple readings, or "hits," from individual vehicles.[27] No statistical advantage has been documented for obtaining more than three readings.[28] A large number of readings must be gathered in order to collect triple readings on vehicles as the rate of obtaining multiple hits is very low;[29] some RSD programs have adjusted their hit requirements from three to two.[30] The number of triple-hits can be increased by operating more RSD units, so more test sites can be covered more of the time, but these additional sites would add to the cost of the program. *(See* "RSD produced a low yield of useable 'hits.'" *on page 10.*)

Moisture, wind and darkness

Infrared RSD cannot be used during times of moisture, high wind, or darkness. Infrared sensors are very sensitive to moisture. Fog, rain or tire spray from wet pavement obscure the signal to the analyzer.[31] Precipitation occurred in Seattle on 207 days during 1996,[32] as shown month-by-month below:

Jan.	28	Feb.	19	Mar.	21	Apr.	23
May	19	Jun.	5	Jul.	5	Aug.	5
Sep.	12	Oct.	19	Nov.	24	Dec.	27

Excessive wind or other air movement caused by traffic flow may disperse the vehicle exhaust plume. This would dilute the emissions sample.

Darkness prevents the capture of license plate images, unless area lighting is used.

Evaporative emissions

Preventing evaporative emissions of gasoline vapors from motor vehicles can play a major role in controlling volatile organic compound (VOC) pollution in areas with ground-level ozone problems, such as Puget Sound and the Vancouver-Portland area. (Ground-level ozone results from the mixing of VOC vapors—such as gasoline and other hydrocarbons–with oxides of nitrogen on hot, sunny days. This is a separate issue from the depletion of the ozone "layer" in the upper atmosphere.)

At present, Emission Check has a limited program to test evaporative emission control systems—a gas cap seal inspection in Clark County. In the same airshed, Oregon's vehicle inspection program requires Portland area vehicles to receive a gas cap check plus a test of other vapor control systems that involves connecting test equipment to vapor return hoses under the hood. Puget Sound has no evaporative emissions inspection, but Ecology is considering the introduction of one. (In Spokane, the Emission Check program focuses primarily on carbon monoxide, a tailpipe-only pollutant.)

Some of these emissions come from the tailpipe, but other parts of the vehicle can vent gasoline fumes, even when the engine is not running.[33] Fuel evaporation is an important source of VOC pollution that can exceed tailpipe VOC emissions on hot days.[34] Non-tailpipe evaporative emission control is an element of vehicle emission control strategies in many of North America's ozone problem areas.[35]

Non-tailpipe emissions are highest in hot weather.[36] RSD targets only tailpipe emissions from running vehicles and cannot measure non-tailpipe and non-running evaporative emissions at all.[37] Only direct checks of vehicle evaporative emission control systems can detect leaks or other equipment failures that cause excessive evaporation of fuel.[38] The potential need to detect and repair non-tailpipe gasoline vapor emissions calls into question the use of RSD in Washington's ozone control areas.

The problem with instantaneous measurement

Remote sensing measures a less-than-a-second "snapshot" of a vehicle's emissions. Austin and Heirigs[39] assert that this brief measurement cannot reflect the average emissions of a measured vehicle. They challenge findings that remote sensing can identify a minority of vehicles responsible for the majority of emissions.[40]

> This conclusion was based on the assumption that the RSD measurements accurately compare the emissions of one vehicle to another. In fact, 10% of the operation of any vehicle is responsible for a disproportionately large fraction of the total emissions from that vehicle…[41]

Tailpipe emissions measured from a single vehicle, using an on-board emissions measurement system that sampled tailpipe emissions second-by-second, revealed that 10% of the readings produced 83% of the total emissions.[42]

Vehicles undergoing test station inspections undergo procedures to ensure that the engine is operating under optimal conditions. The inspection procedure quickly passes a vehicle that shows 30 seconds of consistent low average emissions. Vehicles with high emissions at the outset undergo additional sampling to ensure proper engine operating conditions. On-road measurements provide a single split-second reading of the trailing exhaust plume.

Washington's pilot RSD study

The Washington State Department of Ecology conducted a pilot study to help determine whether a role exists for RSD as part of the state's Emission Check program. A contractor took on-road emissions readings during August and September of 1996. The tests took place at locations in King, Pierce and Snohomish counties.

Ecology sought answers to the following questions:

- How will RSD data from cars recently inspected at test stations compare with test station data for those cars?
- How much will RSD data vary when individual vehicles receive multiple tests?

- How many suitable on-road RSD locations are available?
- How much of the data collected is useful?

To answer these questions, Ecology contracted with Hughes Aircraft Company's Santa Barbara Research Center subsidiary to obtain valid RSD readings, or "hits," on

- 50,000 vehicles that had received test center inspections in the last two years
- 5,000 of these to receive three or more RSD "hits"

Each valid reading included all of the following:

- Carbon monoxide
- Hydrocarbons
- Nitrogen oxides
- Carbon dioxide
- Speed range 20 to 50 mph
- Acceleration range between 1 and 2 delta, a measure of speed change
- License plate number reading

For the purpose of comparison in the study, vehicles had to have had an Emission Check station inspection in the last two years.

Ecology set the following test site criteria for on-road testing:

- Single traffic lane
- Light grade
- Traffic moving 25-35 miles per hour
- Vehicles accelerating slightly, 1 to 2 delta
- Relatively similar test site conditions

The Department of Transportation and State Patrol assisted Ecology by allowing testing on state highway system access and interchange ramps on the condition that traffic could not be impeded.

Data collection at six freeway ramps took place during August and September 1996. The contractor operated an RSD site on 26 weekdays, covering a six-week period. Rain or wet roads prevented data collection for most of one day and parts of others.

This information was collected for study purposes and to meet federal audit requirements.

Findings

Limited on-road RSD sites are available. Ecology obtained design and traffic flow data on all state highway system on-ramp and interchange roadways in the three counties. Of 62 possible sites, only 20 were suitable. Of these, 14 were too close to the Emission Check program boundaries and would have yielded much test data not useful to the study, which primarily sought vehicles inspected at test centers in the previous two years. That left six available RSD sites in the three-county area. [43]

RSD produced a low yield of useable 'hits.' A large share of the data collected for the study could not be used.[44] To produce triple-hit readings on 4,500 vehicles required 200,000 readings.

- 201,581 total readings taken
- 137,523 (68% of the total) of these readings were valid. A reading was invalid if it lacked any of the following:
  - License plate number.
  - Any of the pollutants measured.
  - Speed or acceleration within the specified range
- 64,028 (32% of the total) of the readings met the study's requirement that the measured vehicle appear on record as having had an Emission Check inspection within the previous two years.
- 4,539 vehicles had three or more valid readings. The ratio between readings taken and vehicles with at least three valid readings was:
  - Two percent of all readings taken.
  - Three percent of the valid readings.
  - Seven percent of the readings that met the study requirements.

RSD produced no meaningful emissions data. RSD readings correlated poorly with test station readings. RSD Readings on vehicles with three or more "hits" that had been inspected at a test station within 90 days had a correlation factor of 0.36 for both hydrocarbons and carbon monoxide.[45] A 0.50 correlation is chance, equivalent to a coin toss. Increasing the number of readings per vehicle did not substantially improve the correlation, which ranged from 0.30 for vehicles with three readings to 0.46 for vehicles with eight readings.[46] In addition, the range of readings for each vehicle was high, so that the same-vehicle range averaged more than 70% of the total range of readings.[47]

Cost of an RSD unit

In Ecology's pilot study, the cost per reading was as follows:

All readings..$0.248
Valid reading..0.364
Readings that met pilot study criteria ...0.781

The cost per measurement goes up as the share of usable readings decreases.

The cost per vehicle to obtain a set of three or more hits was $11.016. In the pilot study, only vehicles with valid tests that had undergone a test station inspection within the past two years were counted for triple hits. Seven percent of these vehicles had three or more hits. If the seven percent triple hit yield were applied to all vehicles with valid hits, then the cost per vehicle would have been $5.129. Ecology currently pays approximately $8.50 to the test station contractor for each inspection.

A competitive market environment does not presently exist for infrared RSD. Envirotest Systems, Inc., Washington's test station contractor, is the dominant vehicle emission testing company in North America. It has acquired nearly all of the companies that operate emissions testing stations and now possesses the commercial rights to all available infrared RSD systems on the market.[48] Texas has hired another firm to operate a laser RSD system to detect gross polluters.[49] Other entrepreneurs are attempting to develop competitive laser RSD products, as well.

Envirotest, since purchasing the last independent infrared RSD provider, has not sold or leased RSD systems, but has operated them under contract.[50] When a purchase option was available, the pricing for a single RSD unit would have been similar to the following:[51]

Equipment.. $150,000.00
License plate recognition $40,000.00
License plate recognition software......... $20,000.00 (One time purchase)
Vehicle... $50,000.00

A typical leasing plan for a single unit would have averaged about $1,500 to $2,000 a day. This charge would be for equipment and operator. The cost of operation can vary by location. A price of 15 cents per reading was a typical unit cost.[52] (This is the cost for all readings whether valid or not; as noted above, the cost per usable reading is higher.) As an example, if 15,000 readings were taken during a test day, the cost would be $2,250.00. The lease period could be for as little as three months, to an ongoing continual program.

Cost burdens

In addition to RSD equipment and operators, other costs would accrue to the state. The Departments of Licensing and Ecology and law enforcement agencies would be called upon to provide the following support functions for an RSD program:

Ecology

- Oversight of RSD operation.
- Issuing notices of violation to gross emitters.
- Issuing notices of compliance to clean vehicles.
- Notifying Licensing of each vehicle's compliance status.
- Notifying vehicle owners of test requirements.

Licensing

- Clean screening would require tracking of registration periods with RSD data.
- The implementation of an across the board I/M – RSD surcharge at the time of registration.
- Revoking, suspending or denying of registrations by gross polluter identification.

Law enforcement

- Enforcing registrations and tab requirements.

Possible RSD applications

RSD has been attempted or considered for the following purposes, discussed here in light of the pilot study findings:

Out of area vehicle registration

Some states[53] use the license plate reading function to track out-of-area vehicle registration. This makes it possible to identify vehicles traveling on a regular basis inside an emission test area that are registered outside of that area. By identifying these vehicles, it may be determined that a test area may need to be increased in size or these vehicles may be targeted for testing. The digital camera and license plate reading software -- without the emissions sensing equipment -- can be used to collect this information.

Pass-through vehicles

RSD could be used to measure the emissions of vehicles that pass through an Emission Check program area. The cost of conducting remote sensing aimed solely at this group of vehicles may prove excessive, either because the bulk of vehicles are not in this category, or because a highly intensive monitoring program would be required to obtain meaningful screening data on this relatively small vehicle group.

Traffic tracking

Vehicle identification data from RSD sites could be used to study vehicle travel patterns. The digital camera and plate reading software can accomplish this function alone, without emissions sensing, under a sufficiently intensive monitoring program.

Clean Screening

A "clean screen" program identifies low-emission vehicles with RSD so they do not need to be driven to testing centers. This assumes that RSD can accurately predict which vehicles are clean. Ecology's data showed such a low correlation between RSD and test station results (See "RSD produced no meaningful emissions data." *on page 11*.) that a dirty vehicle has the same chance of scoring a low RSD reading as a clean vehicle. RSD does not assure confidence that a "clean screen" program does not falsely pass dirty vehicles, nor fail clean ones.

Gross Polluter Identification

RSD correlates with recent test station results at a less-than-50-percent rate, which is less predictive than the toss of a coin. (See "RSD produced no meaningful emissions data." *on page 11*.) This does not assure confidence that RSD can be used as a fair means to identify individual vehicles that require a closer emissions inspection.

Each gross polluter would be expensive to identify. The pilot study's seven percent three-hit rate applied to the number of valid hits and combined with a 15 percent failure rate would yield a cost of $34.63 for each gross polluter. To avoid falsely identifying clean vehicles as high emitters, most gross polluter programs set a higher emissions threshold. This reduces the yield of high polluter vehicles and drives the cost higher. For example, a gross polluter program with a 10 percent failure rate would cost $51.92 for each vehicle identified.

These cost estimates do not account for the low correlation rate. If RSD correlated 50 percent with test station inspections, the cost per correctly identified vehicle would be doubled to $69.26 to $103.84.

On-road fleet evaluation

An aggregation of RSD data could provide data on emission trends of a region's on-road vehicle fleet or a subset of the fleet, such as vehicles not subject to regular inspections. Over time, a consistently conducted RSD program could track changes in a vehicle group's tailpipe emission rates. This data would be useful only to evaluate changes in the emissions performance of a large group of vehicles, but not for individual vehicles.

Tailpipe Emission Prediction

Data from the study show that RSD did not provide an accurate prediction of individual vehicle tailpipe emissions. (See '**RSD produced no meaningful emissions data.**" *on page 11*.)

Conclusion

The RSD data have little practical use in identifying individual dirty or clean vehicles.

Remote sensing predicts vehicle emissions at a rate less than chance. It measures emissions with unacceptably wide variation. While the technical components all appear to provide accurate data, the wide variability in vehicle operating modes cannot be resolved in on-road situations, even when highly selective siting criteria are applied. Until a quality assurance method is developed, the data cannot be used with confidence. Direct tests allow consistent speed and engine load conditions under which a vehicle's emissions performance can be fairly compared with itself and other vehicles.

RSD can view only part of the fleet.

Siting limitations, including a limited number of suitable on-road testing locations, make it likely that a significant share of vehicles would not be viewed by a remote sensing program. In Ecology's six-week pilot study, only seven percent of the vehicles that yielded valid readings had three or more "hits."

Currently, approximately 800,000 vehicles visit a test station each year in the Puget Sound region. Each visit results in a valid inspection. To obtain the same information on the same vehicles by completely replacing drive-in inspections with on-road sensing would require an astonishing number of remote sensing hits. In Ecology's pilot study, 44 readings were required for each vehicle with three valid "hits." Assuming that on-road sensors could be set up in enough places to "see" all registered vehicles enough times, a remote sensing program would need to gather 35.5 million readings per year to return triple hits on 800,000 vehicles. During the study the remote sensing unit collected an average of 7,753 readings per day per location. At this rate, 4,583 days of data collection would have to be conducted each year. This would require several mobile test units and a very large number of suitable on-road testing sites to view the fleet currently tested at the test stations. However, on-road tests correlated with test station inspections less than half the time, suggesting that twice or more than 35.5 million readings would be needed to evaluate each vehicle with the reliability provided by today's drive-in program.

In addition, Western Washington's weather would make infrared RSD unusable for more than half the year. This would contribute to the inability to fully and fairly view the fleet with infrared RSD.

RSD has uses other than screening individual vehicles.

A consistently operated RSD program that obtained a statistically valid number of readings could track the tailpipe performance of a large group of vehicles in a region from year to year. Washington may find RSD useful in assessing some informational gaps:

- Washington's exclusion of vehicle under five and over 25 years old from test station inspections, will leave this major group of vehicles -- 25 percent of the fleet -- unprofiled for emissions performance.
- Ecology's RSD pilot study revealed significant numbers of vehicles operating in the Emission Check program area that were not registered in the area. RSD camera surveillance could help improve our understanding of where vehicle trips in area originate. Full RSD surveillance could profile emission trends of registered-out-of-area vehicles as a group. This information could help support decisions on adjusting Emission Check program area boundaries.

RSD may produce meaningful trend information on large groups of vehicles, even though it cannot do so for individual vehicles. While data from test station inspections supports the profiling of much of the fleet -- no additional cost -- special RSD projects could provide information on new vehicles under five years old and other uninspected vehicles that routinely operate in the program area. Given the shortcomings of remote sensing such projects would not yield definitive data, but could serve as screening studies to guide further evaluation of vehicle fleet segments.

License plate surveillance could support efforts to track compliance with vehicle registration requirements. Vehicles based in the program area, but registered illegally outside of it, not only compromise the Emission Check program, they divert transportation funds away from the motorist's home county.

Other program changes promote customer convenience without a loss of integrity.

The primary push behind establishing RSD programs is to promote the convenience of vehicle owners by reducing visits to test stations. Ecology has already taken steps and is planning and considering more to reduce the inconvenience of making visits to test stations:

- In 1990 annual testing ended and every-other-year testing began, reducing test station visits by half.
- Legislation adopted in 1998 will exempt vehicles newer than five years and older than 25 years from the program, removing about 25 percent of the fleet from test station inspections.

Emission Check, which once required inspections each year for all vehicles in program areas, will soon inspect only three eighths of the vehicles each year. In other words, five eighths of the vehicles already are excused from testing in any given year.

In addition to reducing test station visits, Ecology has reduced Emission Check fees in current and real dollar terms since the program began.

Washington should not inspect individual vehicles with remote sensing at this time.

Remote sensing—in its present state of the art—would compromise the fair and effective detection of excessively polluting vehicles if employed in attempt to measure emissions from individual vehicles. Vehicles that do not routinely travel routes suitable for sensing sites would be virtually exempt from detection. RSD readings on detected vehicles are unreliable, even on vehicles with three or more "hits." On-road testing may appear appealing as a more convenient replacement for test station visits, but Ecology is addressing convenience issues other ways: Test station visits have been reduced by half. A quarter of the fleet will be exempted from inspections altogether. These efforts promote customer convenience without significantly reducing air quality benefits from the inspections.

Remote sensing may provide useful data on emission trends -- but not actual emission levels -- of a large population of vehicles in a region over a multi-year period.

Notes

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[4] Smith, loc. cit.
Rendahl and McClintock, op. cit., p. 1.

[5] Smith, loc. cit.
Klausmeier and McClintock, op. cit., p. 14.

[6] Klausmeier and McClintock, loc. cit.

[7] Smith, op. cit., p. 570.
Klausmeier and McClintock, op.cit., p. 40.

[8] P.A. Walsh and A.W. Gertler, *Texas 1996 Remote Sensing Feasibility Study, Final Report.* (Prepared for the Texas Natural Resource Conservation Commission, Austin TX.) Desert Research Institute, Energy and Environmental Engineer Center, Reno NV, 1997, p. 3-9.
Klausmeier and McClintock, op. cit., pp. 25, 54.

[9] "Remote Sensing: A Supplemental Tool for Vehicle emission Control," EPA 400-F-92-017, Environmental Protection Agency. Fact Sheet OMS-15.
Roland J. Hwang, Transportation Program Director, Union of Concerned Scientists. Letter to Joseph Somers, U.S. EPA Assessment and Modeling Division, August 4, 1998, p. 1. "…remote sensing devices cannot measure evaporative hydrocarbon emissions at all."

[10] Hwang, loc. cit.

[11] "Remote Sensing: A Supplemental Tool for Vehicle emission Control," EPA 400-F-92-017, Environmental Protection Agency. Fact Sheet OMS-15.

[12] Ibid.

[13] Rendahl and McClintock, op. cit., p. 9.
Smith, op.cit., p. 569.

[14] Klausmeier and McClintock, op. cit., p. 57.

[15] Rendahl and McClintock, op. cit., p.4, 9.
Klausmeier and Mclintock, op. cit., p. 25.

[16] Klausmeier and Mclintock, op. cit., pp. 11-19.

[17] Klausmeier and McClintock, op.cit., p.14.
1996 Remote Sensing Study Final Report, (Pub. # 97-0018, Hughes Aircraft Company, Santa Barbara Research Center, Goleta CA: 1995) p. 8.

[18] "Remote Sensing: A Supplemental Tool for Vehicle emission Control," EPA 400-F-92-017, Environmental Protection Agency. Fact Sheet OMS-15.

[19] Thomas C. Autsin (Sierra Research, Inc.) and Jay Gordon (Gordon-Darby, Inc.), "Analysis of Remote Sensing Device (RSD) and IM240 Data Collected in the Arizona "Clean Screen" Pilot Project." (Presentation given at the 13th Annual Mobile Source/Clean Air Conference, Steamboat Springs, Col., September, 1997.)
Walsh and Gertler, op.cit., p. 7-1.

[20] *Catalyitic Converters: The Theory of Operation and Functional Diagnosis Manual.* National Center for Vehicle Emissions Control and Safety, Colorado State University, Fort Collins, Co., 1992, p. 39

[21] Klausmeier and McClintock, op.cit., p.14.

[22] *1996 Remote Sensing Study Final Report*, (Pub. # 97-0018, Hughes Aircraft Company, Santa Barbara Research Center, Goleta CA: 1995) p. 8.

[23] Rendahl and McClintock, p. 9.

[24] Demonstration results pending. NWRO air quality program staff have prepared an experimental protocol for a road-test exercise to compare emissions from a representative sample of vehicle ages and weight classes under different engine loads resulting from variations in payload, tire pressure and accessory use. This experiment is scheduled for the spring of 1999. A write-up, data summary, and full data presentation on this experiment will be included as an appendix to this report.

[25] Demonstration results pending.

[26] Demonstration results pending.

[27] Klausmeier and McClintock, op. cit., pp. 40, 47,48.

[28] Jacob A. Weglin and Paul D. Sampson, *Remote Sensing Data Analysis Report*. Center for Statistical Consulting, University of Washington, Seattle: 1998. Pp. 24-28.

[29] pp. 13, 11-12.
Klausmeier and McClintock, op.cit., pp. 63-73.
OTHER RSD STUDIES where they talk about getting multiple hits.

[30] Frank W. Cox et al, *Laboratory Assesment of the Remote Sensing Device Program* (Draft). Arizona Department of Environmental Quality.

[31] Walsh and Gertler, p. 1-2.

[32] NOAA

[33] *Understanding Acceleration Simlulation Mode (ASM) and its Challenges to the Automotive Service/Repair Industry: Automotive Technician's Training Manual.* National Center for Vehicle Emissions Control and Safety, Department of Industrial Sciences, Colorado State University, Fort Collins, Co., 1996, p. 78.

[34] "Automobile Emissions: An Overview," EPA 400-F-92-007, August 1994, Fact Sheet OMS-5 (http://www.epa.gov/OMSWWW/05-autos.htm)

[35] Ibid.

[36] Ibid.

[37] Hwang, op. cit.

[38] "Remote Sensing: A Supplemental Tool for Vehicle emission Control," op. cit. "…RSD methods for measuring evaporative HC have not even been proposed."

[39] Thomas C. Austin and Phillip L. Herigs, *The Effectiveness of IM240 Testing, ASM Testing, and Remote Sensing Based on the California I/M Pilot Project*. Sierra Research. Paper presented at the 16th North American Motor Vehicle Emissons Control Conference, 1995, pp. 13-15.

[40] D.H. Stedman and G.A. Bishoop, "An Analysis of On-Road Remote Sensing as a Tool for Automobile Emissions Control," University of Denver, March 1990. Quoted in Austin and Herigs.

[41] Austin and Herigs, op. cit., p. 13.

[42] Ibid., p. 14.

[43] *1996 Remote Sensing Study Final Report*, (Pub. # 97-0018, Hughes Aircraft Company, Santa Barbara Research Center, Goleta CA: 1995) p. 9, App. C, D. Data collection occurred at different ramps, but two different sites within of I-5 Exit 189 were used, making seven sites in all.

[44] *1996 Remote Sensing Study Final Report*, (Pub. # 97-0018, Hughes Aircraft Company, Santa Barbara Research Center, Goleta CA: 1995) p. 13

[45] Wegelin and Sampson, op. cit., p. 11.

[46] Wegelin and Sampson, op. cit., abstract.

[47] Wegelin and Sampson, op. cit., pp. 19-21.

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[48] Hoovers Company Profiles (http://www.pathfinder.com/money/hoovers/corpdirectory/e/enr.html) http://www.theautochannel.com/news/press/date/19980720/press014733.html

[49] "Tracor Wins Texas DPS Pollution Monitoring Contract," (Tracor, Inc. News Release, Austin TX: May 8, 1998)

[50] Telephone conversation with Niranjan Vescio of RSTI (EnviroTest subsidiary), Oct 17, 1997.

[51] Ibid.

[52] Ibid.

[53] Arizona, Colorado, Idaho and Texas, among others, have tracked out-of-area vehicles in remote sensing studies.