U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF MOBILE SOURCES

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Remote Sensing:

A Supplemental Tool for Vehicle Emission Control

What is Remote Sensing?

Remote sensing is a way to measure pollutant levels in a vehicle's exhaust while the vehicle is traveling down the road. Unlike most equipment used to measure vehicle emissions today, remote sensing devices (RSD) do not need to be physically connected to the vehicle. The concept of an efficient tool to monitor the vehicle fleet and identify excessive polluters has great appeal as a complement to traditional mobile source emission control programs. A number of instrument manufacturers are actively developing RSD systems.

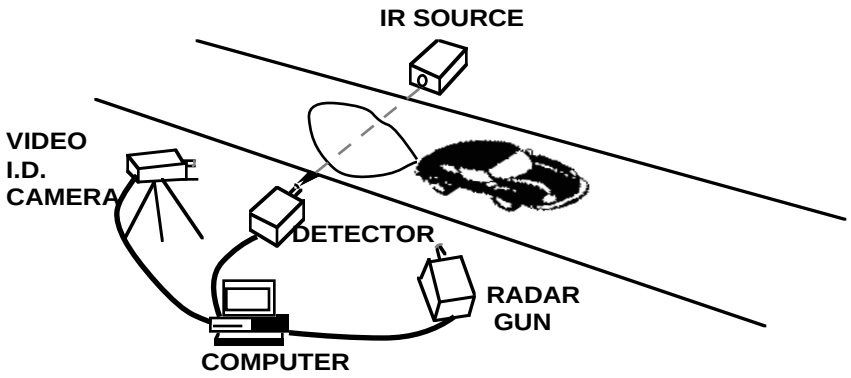
What Pollutants are Measured by RSD ?

Current RSD systems can measure hydrocarbons and carbon monoxide in the exhaust stream. Current systems cannot measure nitrogen oxides, another exhaust pollutant and important contributor to smog. However, researchers are actively developing RSD systems with this capability.

RSD also cannot measure "evaporative" emissions — gasoline vapors that vent into the air from hot engines and fuel systems. Fuel evaporation is a very significant source of hydrocarbon pollution that can exceed tailpipe emissions on hot days.

How does Remote Sensing Work?

Commercial RSD systems employ an infrared absorption principle to measure hydrocarbon (HC) and carbon monoxide (CO) emissions. These systems operate by continuously projecting a beam of infrared radiation across a roadway.



As a vehicle passes through the beam, the device measures the ratio of CO (and exhaust HC) to carbon dioxide in front of the vehicle and in the exhaust plume behind. The system uses the "before" measurement as a base and calculates the vehicle's CO emission rate by comparing the "behind" measurement to the expected ratio for ideal combustion.

Exhaust HC is calculated in a somewhat similar manner by comparing the total carbon content of exhaust HC, CO, and carbon dioxide to the total carbon content of the gasoline the car burns.

It is expected that RSD systems for nitrogen oxides (NOx) will use either a beam of ultraviolet light, or light from a tuneable diode laser projected across the road. The carbon dioxide to carbon monoxide ratio determined by current RSD systems will still be needed to calculate NOx emissions.

RSD systems employ a freeze-frame video camera and equipment to digitize an image of the license plate number so that it can be processed by a computer. This allows the computer to store emissions information for each monitored vehicle, based on the license plate number. Appropriate authorities can then identify and contact owners of vehicles with high RSD readings.

Methods to measure a vehicle's speed and acceleration as it passes through the infrared beam are under development. This is important because the operating mode (e.g. acceleration, cruise, etc.) can significantly affect the instantaneous emission level from a vehicle. Some types of operation during an RSD test may be cause for invalidating a particular test.

Computerized diagnostic technologies may also play a role in future RSD systems. Vehicle onboard diagnostic systems, capable of identifying certain malfunctions in a vehicle's emission control system, are required beginning with 1994 models. The malfunctions could be reported to roadside RSD systems by a small electronic device on the vehicle called a radio frequency transponder. Similar transponder concepts have been used to time runners in marathons and experimental transponder systems are being used to assess toll road fees.

Will Enhanced Inspection and Maintenance Programs Include RSD?

Yes. RSD and other "on-road" emission measurement methods will be an important part of EPA and state strategies to reduce emissions from motor vehicles. The 1990 Clean Air Act requires "enhanced" Inspection and Maintenance (I/M) programs in certain parts of the country where air pollution exceeds national standards. Enhanced I/M programs must include on-road emission testing of a portion of the eligible vehicle fleet. RSD technology is expected to play a major role in these supplemental emission measurements:

- RSD will likely be used to identify vehicles with malfunctioning emission

controls between scheduled I/M tests. Air quality benefits can result from early repair of vehicles that would otherwise not be identified or fixed until the next annual or biennial test.

- EPA studies have shown that properly repaired vehicles maintain low emissions for a long time. However, some individuals may tamper with their vehicle's emission control systems. The ability of the RSD to be easily moved from location to location provides a way to identify tampered vehicles between periodic I/M tests — and to enforce repair requirements on those found to be dirty. Other studies have found that RSD is more effective in identifying tampered vehicles than the currently used random roadside pull-overs.

- RSD can detect unregistered or improperly registered vehicles. This will allow authorities to pick out drivers who cheat on registration or register out of the area to avoid participating in an I/M program.

- To take advantage of RSD's potential to identify dirty cars, EPA is requiring enhanced I/M programs to conduct supplemental emission measurements on at least 0.5% of vehicles subject to I/M testing each year. Vehicles that fail an RSD test would be required to be re-tested by the regular I/M test. Repairs would be required for any vehicle failing this out-of-schedule I/M emissions check.

Can RSD Replace Enhanced Inspection and Maintenance Programs?

No. The Clean Air Act provides for use of RSD as a supplement to enhanced I/M programs but not as a substitute for periodic emission testing. While RSD can be extremely useful, it does have some limitations:

- RSD's capability to measure NOx has not been demonstrated and RSD methods for measuring evaporative HC have not even been proposed. The Clean Air Act requires enhanced I/M programs to be capable of testing both NOx and evaporative HC.

- The Clean Air Act mandates that enhanced I/M programs, beginning in 1995, include an interrogation of the onboard diagnostic system to check for emission control system malfunctions on 1994 and later model cars. Current RSD systems cannot interrogate the onboard diagnostic system.

- Studies by EPA and the California Air Resources Board have found that when RSD measurements are compared to emissions measurements made by EPA reference methods, the RSD incorrectly identifies clean cars as dirty. The reference methods typically involve measuring emissions over a driving cycle that includes a variety of driving modes such as acceleration, cruise, and braking.

The RSD mis-identification rate has been as high as 20% for CO and as high as 60% for HC. More importantly, for clean air, EPA studies indicate that RSD does not identify 80% to 90% of the dirty cars that need repair. EPA believes that these results do not reflect on the instantaneous measurement accuracy of the RSD. Rather, EPA believes these results are indicative of changes in vehicle emission levels that typically occur when a vehicle is operated under driving conditions different than those observed by the RSD. A bibliography of studies is attached.

Implementing RSD in Inspection and Maintenance Programs

There are a number of administrative factors to consider in establishing I/M programs that include RSD. Some RSD advocates have suggested that RSD is capable of monitoring much more than 0.5% of the fleet. EPA agrees that RSD could be used by the I/M programs to measure emissions from many more cars, given adequate resolution of the following issues:

- **Placement of Roadside Monitors:**
  Current RSD technology can only measure emissions of vehicles driving in a single lane of traffic. It is not easy to find enough sites where appropriate single traffic lanes exist to monitor the majority of vehicles subject to I/M testing. Restricting multiple lanes to a single lane for RSD measurement may not be practical in many cases, particularly during times of heavy traffic such as rush hour. Yet RSD testing during peak traffic periods would probably be necessary to avoid missing high-emitting cars that could be parked during business hours.

  EPA has successfully used RSD monitors along multiple lane roadways in some studies without restricting traffic to a single lane. But pylons had to be placed between the lanes to protect some of the RSD equipment. With such a set-up, drivers could potentially choose not to drive through the measuring lane.

  Another issue involves limiting RSD placement to locations where representative vehicle operation will be observed. It will be important for I/M programs to avoid creating situations where a measurable portion of vehicles fail RSD monitoring at one location but pass at another location. For example, sites of high acceleration would likely be avoided because emissions tend to be higher during acceleration than during steady-speed driving.

- **Appropriate Pass/Fail Levels:**
  A difficult issue involves selecting an emission failure level (cutpoint) for the RSD that will identify most of the truly dirty vehicles and minimize false failures of clean vehicles. EPA studies indicate that the mis-identification of clean vehicles as dirty ones by RSD is substantially reduced by measuring emissions from the same vehicle several times. However, multiple measurements also result in more dirty cars passing the test.

- **Notification:**
  Administrative systems need to be established so authorities can follow up with owners of vehicles that register high emissions during an RSD check. Whether vehicle owners are pulled over immediately at the time of the check or notified later by mail, oversight will be necessary to ensure that dirty vehicles undergo further testing and repair if necessary.

- **Driver Behavior:**
  To date, RSD emissions testing has occurred only in demonstration type projects with no consequences for drivers whose vehicles fail the test. In the future, RSD failures in enhanced I/M programs will result in mandatory re-testing and repair. These consequences may prompt drivers to change their driving route or regime (e.g., observing RSD testing on the way to work in the opposite direction, and choosing a different route on the way home), or otherwise alter their driving behavior to avoid passing an RSD monitor. The political implications of failing motorists, especially falsely, with this type of program are also yet to be realized.

The prototype studies conducted to date do not provide the type of practical information I/M program managers need to effectively use RSD on a day-to-day basis. However, EPA believes that most of these administrative issues will be resolved with experience, as states begin to integrate RSD into actual I/M programs. By starting out with a small fraction of the fleet (0.5%), I/M program offices can begin to develop administrative systems that will allow RSD to achieve its potential as a full player in the vehicle emission control program of the future

A bibliography of RSD studies is attached to this fact sheet. These studies are separated into three groups: (1) those where RSD measurements were compared to measurements made by an EPA reference method; (2) those that measured on-road vehicles, but did not include any reference method measurements; and (3) analytical studies which did not include any measurements (RSD or reference methods).

For More Information:

The Office of Mobile Sources is the national center for research and policy on air pollution from highway and off-highway motor vehicles and equipment. You can write to us at the EPA National Vehicle and Fuel Emissions Laboratory, 2565 Plymouth Road, Ann Arbor, MI 48105. Our phone number is (313) 668-4333.