Lessons on audit and quality assurance mechanisms

Our Credentials

The very first vehicle emissions standard that was published in Mexico was a noise regulation for diesel vehicles that I wrote in 1975. Since then, I have been heavily involved in developing most of the in-use vehicle emissions related standards that has been published and enacted in this country.

Currently we are developing, under contract with the National Ecology Institute, which is part of the Environment Ministry, a completely re-vamped set of federal standards for in-use vehicle emissions testing.

Whilst in the beginning, we focused principally on emissions standards development; over the last 12 years we have concentrated our efforts on the design and implementation of inspection and maintenance programs.

We are the leading independent vehicle emissions standards laboratory in Mexico. We audit on a regular basis the calibration of the emissions testing equipment using NIST traceable EPA protocol gas standards and NIST traceable filters to ensure that all the different testing stations generate comparable measurements. To date we have conducted over 21,000 audits.

We have developed and constantly maintain a full set of emissions inspection software for centralized testing that fully complies with the current specifications and has performed over 6 million tests.

This expertise enables us to assist equipment manufactures in meeting the different specifications. Many local authorities use our services to test and certify software and equipment from different suppliers against their required specifications.

This hands-on day-to-day experience keeps us in touch with the operational problems of the emissions program and highly involved in solving them.

Over these 12 years we have learnt many things that work and a lot of things that do not work.

Objective: - Harness Public Opinion

The objective of any vehicle emissions program is to maintain and improve air quality. To do that, gross emitters must be identified and repaired. Inspecting and repairing clean vehicles does not help.

A vehicle emissions program depends on public opinion. It directly involves a large sector of the population who both causes the contamination and benefits from cleaning it up. Thus they are very critical of its operation and of its effectiveness.

This is very different from industrial contamination where problems can be defined and solutions found amongst a select group of industry leaders.

The program can only survive if public opinion determines that it is doing a good job and that the benefits of having an emissions program far outweigh its social cost.

For public opinion to be on your side the program must be seen to be effective, totally objective, transparent and focused on the gross polluters.

Many authorities have made the mistake of implementing a laxly enforced program with strict limits. After a while, the test technicians find ways of getting vehicles through the test despite their being dirty – and the program loses the public support that it desperately requires.

You should only implement a vehicle emissions program for those vehicles that are a significant contributor to your air pollution problem and provided that you are willing and able to invest the resources, manpower and effort in auditing and supervising the program to guarantee its objectivity and transparency. It is not a commitment that can be taken lightly.

Implement a selective, strictly enforced program

You must implement a strictly enforced program, even though the limits are lax. It is preferable to focus entirely on the dirtiest vehicles, and not even enact a program for the others.

To maximize the social benefits from the program, the main investment in emissions control must be focused on the dirtiest vehicles.

Once those gross polluters are under control, the program should be extended to embrace the next level of high polluters, and so on until air quality is seen to improve.

If your main mobile sources of air pollution are diesel vehicles and 2 & 3 wheelers, I would suggest that the emissions program starts exclusively with them, and maybe only with the intensive usage vehicles.

An effective program requires a good test procedure that is well enforced, supervised and audited.

Test Centers and technicians, whether they are government employees or private sector, will always be presented with incentives to generate a pass certificate for a dirty vehicle.

These false passes critically damage public opinion and if it is easy to obtain a false pass the public opinion will be of a highly faulted program with little or no social value.

You need to invest in technically sound test procedures and equipment but the program relies on strong audit and supervision routines to control the generation of false passes.

The program must be designed from the outset to minimize false passes.

This implies choosing a test protocol that is difficult to cheat on or to bypass and implementing strong and rigorous audit and supervision schemes from the very beginning.

Voluntary Programs

There has been lot of discussion on implementing voluntary testing or voluntary “controlled repair programs”. Our experience is that in developing countries they are often not effective.

Unless the gross emitters have a very strong incentive to pass the emissions test they will not enter the program. The owner of a dirty vehicle who must spend money to clean it up will probably find ways to avoid making that expenditure unless the program is obligatory and well enforced.

Roadside Checks

We have had bad results in developing countries from mobile test stations and roadside checks. They are virtually impossible to supervise and control and the decision to pass or fail a vehicle often depends on the discretion of the test technicians involved. It is just too difficult to maintain the transparency and control that is required to ensure continuing public support for this type of program.

Test & Repair vs. Test-only Centers

Test and repair garages can be seen to be very convenient for the vehicle owners and easy to set up for the Authority but in practice prove to be highly flawed. No garage will tell his client that he does not have the technical ability to repair the vehicle and pass the test. To save face, he will always prefer to cheat on the test.

It is difficult for the Authority to control a large number of small operators so an emissions program based on test and repair garages may start well but in a short time often degenerates into a visibly flawed program with little or no public support.

The test-only centers are far easier for the government to supervise and allowed better technical and administrative control to be enforced.

Ten 5-lane test-only centers have the same test capacity as 120 test and repair centers and are obviously far easier to control. They facilitate the adoption of new technology and generate more uniform results between centers.

We prefer large industrial groups as Center owners vs. individual private operators or government. Established capitalized companies have the luxury of a longer-term view on business profitability whilst many private owners can look no further into the future than meeting the next payment on their bank loans. When the centers are government operated it can be difficult for the government to act when operating problems arise and so the quality of supervision suffers.

Design the program to generate high profitability for the Test-only centers. That ensures enough interest from the center owners to self-police. Do not install too much excess capacity. This hurts profitability. We have found that the centers need on average, to be operating at around 35 –40% of their installed capacity to give acceptable customer service without losing too much profitability.

Design a legal framework for contracting the services of each center that facilitates applying sanctions when fraudulent practices are detected. I have seen many programs where the legal basis so strongly favors the center owner that it is virtually impossible for the local authority to sanction the center. This does not favor self-policing.

Centralized Operation

To be effective, your test protocol must minimize the impact the test technician can have on the test's outcome. We have found that visual inspections of the vehicle can be eliminated. It is too easy for the test technician to turn a blind eye to any defects he discovers.

Specifying centralized operation in each test-only center allows "blind" tests to be performed. The test results should not be available to the tester in the test lane otherwise it is common practice for testers to prevent rejects from occurring by tampering with the lane computer, the test procedure and with the vehicle. On some systems, the availability of real-time emissions measurements even helps the tester generate a false-pass for vehicles that would otherwise have failed the test.

Remote Audits

The adoption of centralized databases make it possible to collect the data required for the supervision process and for statistical analysis. Electronic Data Transmission is essential for the Authority to have fresh data to work with, and unless he has fresh data from all tests performed he will be unable to effectively supervise and audit those test operations.

With multi-lane centralized operation, remote auditing is cost effective.

You should invest heavily in remote, computer based, auditing. It is cheaper and a lot more effective than an army of poorly paid inspectors. Do not try and constantly police all the centers. Go for systematic in-depth audits of those centers that show suspicious activity in your remote auditing – and take strong and immediate action.

Poorly paid on-site inspectors can easily succumb to temptation.

Important test centers and programs should go for real-time data transmission with the local authority offices. Centers in remote out-lying areas should at least transmit their test archives 4 times a day. Old information does not allow good surveillance.

Electronic security must be added via specific access codes for each operational function and checksum algorithms protecting all registers. These measures should be designed to restrict tampering of the test results by the personnel in the test center. Without this, the test centers can just fill in the certificates without even doing an emissions test and you will never know the difference.

You should insist on video surveillance of the test process with remote real-time video monitoring and bank-style recording equipment. Insist on the use of independent systems to detect the presence of vehicles in each test lane and time spent in each position. Analyze both of these inputs in conjunction with the distinct test databases to check for tampering, clean piping etc.

This remote surveillance is very useful, cost effective and highly recommended.

Test Protocols and Equipment

Firstly, the test must be computer controlled. This is the only way to be able to validate the data entry and get the databases that are essential for effective audit and supervision

of the program. We have yet to see, particularly in developing countries, a paper control system that allows effective supervision and program development.

Diesel Vehicles

Mexico is one of the few countries that require an annual emissions test for all diesel vehicles and we have done a lot of work on trying to develop a controllable and repeatable test procedure.

We have found that the use of full-flow exhaust smoke meters to be ineffective. It is too easy to generate a false pass with one of these. They can be used by trained personnel for research type work but not, in my experience, for generating a reliable and transparent pass/fail decision in developing countries.

Computer controlled, (and validated) partial flow meters are a great improvement and can be used with a free acceleration (or snap idle) test to effectively reduce the visible smoke from the diesel fleet however there is poor correlation between the visible smoke level determined in the snap-idle test and how the vehicle performs over the road. The correlation between visible smoke and PM or NOx emissions is also low. One of the main technical problems we have found in the field is getting a reliable and easy to obtain RPM reading from the engine, without which the test is easy to fool.

Whilst a diesel emissions program can usefully start with a free acceleration test using a partial flow meter, we believe that it must develop to a short dynamic lug-down or acceleration test on a dynamometer as soon as visible smoke is not your principal problem. This obviously requires a larger investment – but if your vehicle emissions problem is diesel, this is where the main investment should go.

A well maintained diesel engine that is not over-fuelled should not have visible smoke. Once the diesel fleet reaches this point, the measurement strategy needs to change.

2 and 3 Wheelers

Mexico implemented a bi-annual static emissions test for motorcycles. With 2 stroke vehicles we measured visible smoke and with 4 stroke vehicles HC and CO emissions. These static tests depended too much on the test technician, were not practical or effective and were stopped. It was easy to generate a false pass on this test.

I am convinced that the only effective and easy-to-apply test procedure requires a dynamometer test. This eliminates the need to measure engine RPM. A short, simple constant speed road-load or lug-down test will generate repeatable and reliable data. Either mass flow or concentration measurement can be used.

Gasoline

Up to 1996, Mexico City used the static BAR ‘90 type of test equipment and procedures. Whilst it can provide an easy means of obtaining emissions measurements from gasoline and gas vehicles, it is easy to generate a false pass on this type of test. It is very difficult to generate and maintain public support for an emissions program based on static testing.

Our experience is that dynamometers are essential to minimize false passes. NO must be measured to stop vehicle owners from tuning “Lean and Late” as a means of getting a false pass.

If possible, the emissions cut-points should be defined in terms of mass flow measurement (grams/ km). If the test specification measures exhaust gas concentrations (in ppm or percent), it can be updated to mass flow measurement (grams/ km) later.

The Test procedure can involve loaded-mode, constant-speed testing (Acceleration Simulated Mode) or a drive cycle test (IM240 or IG240).

Short steady-speed dynamic tests on a dynamometer are easy for an untrained technician to run and have been proven accessible in both investment and cost. They allow repeatable measurements to be made with acceptable measurement errors despite low technician skill levels.

Drive Cycle tests are longer and more difficult for a technician with low skill levels to operate.

Both test cycles can be run on an Inspection Grade test system. Since drive-cycle tests typically take almost twice as long as a constant-speed test, the capacity of each lane (tests per day) is effectively halved, doubling the investment.

There can be merit in starting with a constant-speed, loaded-mode test and upgrading it as necessary, at a later date to the drive-cycle version. If this allows investment to be made available for electronic data transmission, video and vehicle monitoring systems and computer audit programs the trade-off could be very beneficial.

Calibration audits

Frequent calibration audits performed by independent accredited materials standard laboratories must be required on each test lane.

These audits play a very important role in ensuring that the test equipment is correctly maintained and in eliminating the perennial problem of the same vehicle producing radically different test results in different centers.

Technical and Administrative audits

The program should help the centers validate and police their own personnel. Statistical analyses should be used from the very beginning to determine which centers are operating fraudulently and also to check individual technician performance. The centralized databases should be used to make sure that another does not hire a technician that has been removed from one center for incompetence or fraud.

The test procedures, test protocols and vehicle verification software must be designed to reduce to a minimum the technician’s impact on the test outcome. Master Reference Tables must be developed to validate data input and to determine test protocols and emissions cut-points. Forget about visual inspection as a cause of reject. Use encryption and hash algorithms to protect all the data files from tampering by the center.

Rigid recording and reporting rules must be enforced for the general operation of each center and for all incidents in the center. ISO 9000 certification helps this requirement.

Equipment Suppliers

One last area that I must touch on: Equipment suppliers.

Any effective emissions program is under continuous development. Unfortunately it has to be that way. This raises problems with the equipment suppliers who have to implement the software changes. Many of them have limited programming recourses, which they use mainly to generate new equipment sales. Hence updating the software for an existing program – which will not generate new sales – tends to get a lower priority and leads to clashes with the local authority.

I would strongly suggest that for a new program, the local authority develop or contract its own centralized software package and invite the equipment suppliers to provide lane equipment and software that interfaces with the centralized package via well defined procedures. This allows the centers to use multiple vendors whilst maintaining most of the updates in one software package – which the local authority controls. If we had managed to accomplish this at the beginning in the Mexico City program we could have saved at least 2-3 years worth of effort.

Lessons on Audit and Quality Assurance

Mechanisms

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Experience

- 26 years Vehicle Emissions Standards Development
- 12 years Vehicle Inspection Programs
- 21,000 Calibration Audits
- Emissions Software Development >6M̄ tests
- Software and Equipment Certification

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Harness Public Opinion

- Identify and repair gross emitters
- Program depends on public opinion
- Program benefits must be SEEN to outweigh social cost
- Must be SEEN to be effective, totally objective, transparent and focused on the gross polluters
- Implement selectivley

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Selective Program, Strictly Enforced

- Main investment must focus on dirtiest vehicles
- Use Good Test Procedure
- Well enforced, supervised and audited
- False Passes critically damage public opinion
- Design the Program to minimize False Passes from Day One

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Voluntary Programs

- Not Effective if Vehicle Owner has to pay

Roadside Checks

- Virtually impossible to supervise and control

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Test & Repair

- Very convenient for vehicle owners
- Very Difficult to Control
- Often Degenerates into a visibly flawed program with no Public Support

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Test Only - Centralized

- Good Technical and Administrative Control
- 10 x 5-lane centers = 120 test & repair centers
- Large industrial groups make good Center owners
- Design program for high profitability
- Legal framework to favor sanctions
- Minimize impact of technician on Results

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Remote Audits

- Electronic Data Transmission is essential
- Remote computer based auditing is cost effective
- Electronic and Database Security
- Video cameras with real-time remote audits
- Vehicle Monitoring Systems

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Diesel Test Protocols

- Full-flow exhaust smoke meters promote False Passes
- Computer validated Partial-flow smoke meters offer better control
- Dynamometer testing should be adopted as soon as visible smoke is not the principal problem

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2 and 3 Wheelers

- 2 & 4 stroke protocols
- Static tests promote False Passes and Failures
- Static Tests lead to Low Public Acceptance
- Short, Simple Dynamometer Test required

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Gasoline Protocols

- Easy to generate False Pass on Static Tests
- Dynamometers and NOx are essential to minimize False Passes
- Short loaded-mode, constant-speed test (ASM) easy to operate and accessible in investment and cost
- Drive Cycle tests technically better but more difficult for low-skill technicians and hurt profitability

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Thank You

Any Vehicle Emissions Program

requires

Strict Enforcement and Quality Assurance

to get Public Support

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