

Motor Vehicle Inspection  
In the National Capital Region (NCR) of India

Recommendations for  
Short-, Medium-, and Long Terms

**“A Plan for Progress”**

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Prepared for

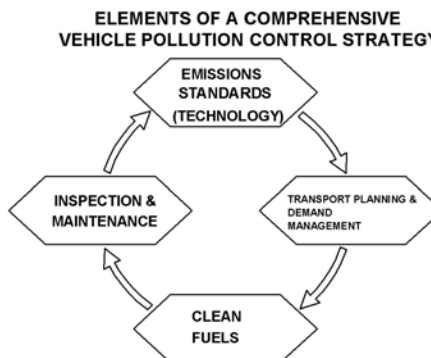
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## 1. Background and Introduction

The goal of a motor vehicle pollution control program is to reduce emissions from motor vehicles in-use to the degree reasonably necessary to achieve healthy air quality as rapidly as possible. A comprehensive strategy to achieve this goal includes four key components: increasingly stringent emissions standards for new vehicles, specifications for clean fuels, programs to assure proper maintenance of in-use vehicles, and transportation planning and demand management. These emission reduction goals should be achieved in the most cost effective manner available.



Although significant measures have been carried out in recent years to control mobile source emissions in Delhi, is still much to accomplish to reach acceptable levels of ambient air quality. Some of the steps carried out in recent years include tightening of new vehicle emission standards, lowering sulphur in diesel fuel to 500 ppm, lowering benzene in gasoline to 1 percent, and shifting public transport vehicles from diesel to compressed natural gas (CNG). These have lowered particulate and other toxic emissions from vehicles and improved air quality. However, air quality levels remain well above healthy levels and additional control measures are needed. One of the most important of the remaining potential measures that could bring about significant additional emissions reductions is to upgrade the existing I/M program.

The remainder of this paper will review the role of I/M in a Comprehensive motor vehicle pollution control strategy, summarize the international experience with a good I/M program, Review and critique the current PUC program and the steps currently underway to improve it, and a similar review and critique of the Fitness check and inspection of commercial vehicle. Finally the report will conclude with a series of recommendations to create a fully successful I/M program.

## 2. The Role of I/M In a Comprehensive Motor Vehicle Pollution Control Strategy

Safer traffic conditions and optimal respect for the environment are clearly dependent on the general condition of vehicles as well as other factors such as the behaviour of the driver and road conditions. In addition to improving safety, the experience from projects all over the world demonstrates that one of the cheapest and fastest ways to improve the ambient air quality is to introduce a system for vehicle inspection or to enhance an already existing system and further improve the quality or type of fuel used. A vehicle inspection program involves checking the general conditions of a vehicle at regular intervals to assure that it is in a good state of repair and that any existing pollution controls are functioning properly. Today's internal combustion engines rely on effective

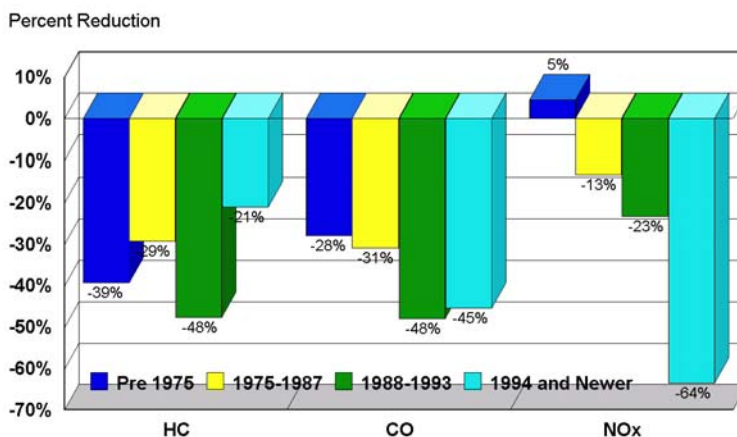
functioning of emissions controls to keep pollution levels low. Minor malfunctions in the emissions control system can increase emissions significantly and major malfunctions can cause emissions to skyrocket. The overriding purpose of an I/M program is to assure that a vehicle is properly maintained and used. Experience shows that a relatively small number of vehicles with serious malfunctions can be responsible for significant fraction of overall emissions. The major objective is to identify these dirtiest (high emitting) and unsafe (with major malfunctions on vital components) vehicles and get them repaired. But it is rarely obvious which vehicles fall into this category, as the emissions themselves may not be noticeable and emissions control malfunction do not necessarily affect vehicles driveability. Effective I/M programmes can identify problem vehicles and assure their repair. I/M can play a very important role in ensuring that in-use vehicles actually achieve what they are technically capable of.

### 3. Demonstrated Impact of I/M on Air Quality

It has been well established that properly designed and operated I/M programs are capable of significantly reducing emissions. For example in one recent evaluation of the long term benefits of the British Columbia I/M program, it was determined that over the first 8 years of the program, HC emissions were reduced by 34.3%, CO by 38.4% and NOx by 10.3%.<sup>1</sup>

In an effort to determine the mass emissions reductions from the program, a sample of 957 vehicles was tested in the laboratory before and after normal repairs with the results summarized in the figure below.

### Emissions Reductions Following Repairs of Failed Vehicles



Substantial decreases in average emissions are evident in all cases but one. An increase in average NOx emissions of 4.5% was observed among the oldest vehicles. The newest vehicles on the other hand tended to show the percent reduction in NOx.

In addition to the emissions reductions, the audit program found that fuel economy for the failed vehicles improved by approximately 5.5% for an estimated annual savings of \$72 per year per vehicle.

1. <sup>1</sup> "Results and Observations Relating to the First Eight Years of Operation (1992-2000)", by Stewart, Gourley and Wong, December 2001.

The audit program also demonstrated that the centralized program was resulting in a very high quality test program. For example, after reviewing over 2 million tests, the auditor concluded that in only 1.1% were incorrect emissions standards applied. Not one instance was found where a vehicle was given a conditional pass or waiver inappropriately.<sup>2</sup> About 1% of the failed vehicles were found to be receiving waivers even though their emissions are excessive, i.e., they exceed either 10% CO, 2,000 ppm HC or 4,000 ppm NOx. If the cost limits were increased such that these percentages were halved, the auditor concluded that HC and CO reductions from the program would each increase by about 5%.

Available data also indicates that many vehicles are repaired sufficiently that they remain low emitting. For example, almost 53,000 vehicles that failed the test the first year were repaired well enough to pass the following year.

Overall these data confirm that I/M programs when properly performed in a centralized facility using a loaded mode test can and do achieve a substantial reduction in emissions. Substantial fuel savings accompanies these reductions. According to the auditor, improvements to the program such as including evaporative testing, reducing or eliminating cost waivers, adding the IM240 test or tightening the standards could all increase the overall benefits significantly.<sup>3</sup>

As vehicle technology advances, more sophisticated test procedures are necessary including loaded mode tests that use a dynamometer to simulate the work, which an engine must perform in actual driving.

Substantial advances are occurring in I/M programs. For the most advanced vehicles, those equipped with electronic controls of air-fuel and spark management systems and equipped with catalytic converters to reduce CO, HC and NOx, a transient test which includes accelerations and decelerations typical of actual driving can provide additional emissions reduction benefits.

As a general matter, maximum I/M effectiveness occurs with centralized I/M systems. These programs also cost much less overall and are more convenient to the public.

The US NAS has recently recommended several improvements to I/M programs<sup>4</sup> A variety of issues were identified by the Academy as requiring careful attention – site selection, effects of engine load, attention to quality assurance and quality control, and achieving adequate coverage of the in use fleet – were specifically highlighted.

Summarized in Appendix C are the various test procedures that can be used in I/M programs.

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2. If the vehicle is taken to an authorized technician and spends at least \$200 on repairs, it can receive a conditional pass or waiver even if it does not meet the emissions standards.
  3. Effective January 1, 2001, the AirCare program was enhanced in several significant ways including: IM240 Testing for most 1992 and newer vehicles and biennial inspections for these vehicles
  4. "Evaluating Vehicle Emissions Inspection and Maintenance Programs", National Research Council of the National Academies, July 2001.

#### 4. Review of the Pollution Under Control (PUC) Programme in Delhi

Technical revisions and measurements of vehicles must be done in a way that everyone is convinced that the measure is truly an objective test and there is no self-interest in

carrying out these tests. It must be a high quality inspection and the equipment must be calibrated to the degree needed to ensure that the equipment is in working order. The personnel doing the inspection must be well trained and must be familiar with the reasons for the inspection. Test procedures must be appropriate for the technology being tested.



Contrast these principles with the actual experience in Delhi with the PUC programme.

Currently, there are about 400 Pollution Under Control (PUC) centres authorized by the Delhi transport department to carry out prescribed emission tests for all types of private vehicles. The locations of the PUC centres are either at the premises of gasoline filling stations or service workshops. There are no well-defined criteria for authorising or registering PUC centres.

Organisational structure is not conducive to objective, high quality tests. The authority responsible for authorizing and registering PUC centres does not carry out a sufficient number of audits at the PUC centres. Further, no systematic procedure for collection of results from testing for further analyses exists.

Another major problem with the PUC centres is the maintenance and calibration of the instruments. One pre condition for authorization or registration of the Centres is that the operator must have a signed contract with the manufacturer of instrument to assure regular calibration and maintenance (AMC requirement). In reality this seems to be rarely implemented or enforced.

Another and perhaps fatal drawback of this system is that only 15 – 20 % of the vehicle population comes to the PUC centres and is subjected to the PUC check. The reasons can be summarized as follows:

- Lack of enforcement
- Poor system for identifying vehicles not visiting the centres
- Imperfect system for auditing

Perhaps the most important reason of all is that there is no public confidence in the system.

## 5. Review of the Present System for “Fitness Check” and Inspection of Commercial Vehicles



According to the instructions issued by the Government of National Capital Territory of Delhi Transport Department in April 2002, “*Inspection and Certificate of Fitness (COF) is mandatory for every transport vehicle at the time of registration, which is valid for two years from the date of issuance*”. The COF must thereafter be renewed by a new fitness check every year.

A total of 30 tests and checks are prescribed under the rules and fulfilment of the requirement should be checked and the result should be entered and stored into a computer. All of the tests are listed, as a checklist for the inspector to follow during the inspection; however no detailed description how to carry out each test nor information about pass/fail criteria is available. The following items should be checked, if/when applicable:

- i) Brakes
- ii) Steering Gears
- iii) Suspension
- iv) Engine
- v) Overall dimensions of the Vehicle
- vi) Horn
- vii) Lamps/Signals
- viii) Chassis Embossing
- ix) Speedometer
- x) Paint
- xi) Wiper
- xii) Dimensions
- xiii) Body
- xiv) Fare Meter
- xv) Electrical

- xvi) Finishing
- xvii) Road Test
- xviii) Pollution
- xix) Transmission
- xx) Safety Glasses
- xxi) Rear View Mirror
- xxii) Spark Plugs
- xxiii) High Tension Cable
- xxiv) Head Lamp Beam
- xxv) Other Lights
- xxvi) Reflectors
- xxvii) Silencers
- xxviii) Dash Board Equipment
- xxix) Suppressor Cap.
- xxx) Other

The checklist provides space for making notes of deviations or remarks. After the inspection, the checklist is signed by “Inspector 1” and “Inspector 2” (working in a team) and also a representative of the vehicle (owner/driver). The intent is that all concerned parties should come to an agreement about the deviations.

Discussions with the inspectors indicates that at present only 8 inspectors (4 teams) are working and the time for inspection of a diesel fuelled truck was estimated to be 5-10 minutes, a diesel bus 5-15 minutes and a CNG bus as much as 45 minutes. However, a special team assigned by STA carries out control of the installation of the various CNG components on the vehicle.

According to the information available from the Manager of the Burari facility, the number of vehicles coming to the Burari inspection centre each year for a fitness check are about 150 000 with an additional 6 000 vehicles that come for follow up on type approval and pre-registration tests before they are allowed to be sold. The latter inspection is carried out on request of the representative for the vehicle manufacturer. A simple calculation estimating an 8-hour working day and 300 working days per year and 10 inspectors, gives the average time for one inspection as 9.2 minutes.

While all commercial vehicles are supposedly required at present to undergo a mandatory annual “Fitness Check” at the Burari Inspection Centre, the present system is completely inadequate with regards to either traffic safety or emission checks. During our visits to Burari Inspection Centre only visual inspections of safety items was carried out and **no** test equipment was in working condition. As examples we observed one school bus without brakes on one of the rear wheels, and another bus with the rear shock absorber hanging loose. It is presumed that a majority of vehicles would fail if a control of the braking force on a brake tester were carried out. This should be of special concern for India where fatal accidents involving heavy-duty vehicles are common.

The actual “Fitness check” at the Burari inspection centre is today carried out without any of the necessary equipment or instruments. While earlier visits showed some signs of a “computerized test lane”, at this visit the consultants were just told that the instruments are not working.

One inspector described the inspection procedure and the information given indicates that the procedures themselves are fundamentally flawed. For example, the owner/driver takes the vehicle through the whole inspection procedure thereby giving him the possibility to strongly influence the result of the inspection. Test officials carry out no test drive of the vehicle; rather the driver was only given “leading” questions, such as -- the speedometer is working Ok, isn’t it? Just asking the driver to drive through the inspection lane for the brake test, and “brake as hard as you can and we will look for imprints” is considered a sufficient test. The steering was checked by the inspector when turning the steering wheel back and forth (5-10 cm), and at the same time observing the movements of the wheels. Needless to say that the present inspection system does not even approach the requirements for high quality.

The consultants were informed that the failure rate, despite the poor quality, was 4-5 %, which is somewhat alarming in itself compared to the international experience. For example, consider the recent statistics from Sweden. About 33 % of all tested passenger cars in Sweden must be re-inspected after adjustments. Out of the 33 %, about 20 % had failure in the braking system. About 25 % of all tested buses had severe malfunctions in the brake system requiring a re-inspection of the vehicle after repair. The corresponding figure for light and heavy-duty trucks is 40 %.

Emissions tests of all commercial vehicles are apparently combined with the mandatory annual fitness check that are conducted in the state owned Burari Inspection centre. During a visit to Burari earlier in 2002, the consultants were informed that measurements of tailpipe emissions were no longer carried out at Burari. Instead the drivers first had to visit a PUC centre for measurement of the tailpipe emissions, obtain a certificate issued by the centre and then present it at the Burari inspection centre as a proof of passing the emission test that was conditional for the fitness check. This time the consultants observed that emission tests for commercial vehicles was brought back to Burari, but there seems to be confusion among vehicle owners where to go since the consultants noted that some commercial vehicles still used the PUC centres for testing.

## **6. A Plan for Progress: Detailed Recommendations Related to the “New System of I/M”**

The main recommendations for further improvement of the present system and the introduction of a new enhanced system for vehicle inspection are summarized below. A Gantt chart describing the steps necessary to implement these recommendations is attached as well as Appendix B. The principle recommendations are as follows:

- As a first step we recommend to upgrade the Burari centre for commercial vehicles combining emission measurement with safety control. In parallel, the program for improving the emission inspection at PUC centres of private vehicles must be upgraded, which will be discussed in a later section
- We propose a phase in plan for centralised inspection system with commensurate test procedures and norms for all categories of vehicles in Delhi. A complete phase out of the numerous existing testing centres that are difficult to control and supervise must be scheduled. *Even while upgrading the PUC system, institute and announce the plan to completely centralize & privatise the system in a given time frame.* Focus on the most polluting categories like the

commercial vehicles initially. Then continue with remaining high emitters such as motorcycles with 2-stroke engines and vehicles with advanced emission control systems such as vehicles with catalytic converters. Give CNG buses the highest priority for moving them to centralised centres where more advanced testing facilities will be available. Since commercial vehicles already need to go through routine annual fitness checks and emissions tests, start immediately to develop the upgrade of Burari inspection centre.

#### **A. Recommendations: Inspection of Commercial Vehicles**

We propose a three steps approach to carry out inspection of commercial vehicles in Delhi.

##### ***i. Step 1: Substantially Upgrade Burari Inspection Centre***

- 3 fully equipped lanes with a capacity of 60,000 tests/annum per 8-hour shift should be installed.
- 1 additional lane for 3 wheelers with a capacity of 30,000 tests/annum per 8-hour shift should also be installed.
- It is estimated that the cost per each lane will be approximately 10-15 million rupees.
- Construction of the facility and purchase and installation of the equipment could be completed within a year or less
- It is strongly recommended that the facility be built and operated by a private contractor selected through a competitive bidding process

An International Tender Document should be developed and released where internationally recognized inspection companies together with local counterparts are asked to establish three new fully equipped inspection lanes for 4-wheel driven commercial vehicles and one new fully equipped inspection lane for 3-wheelers (auto-rickshaws).

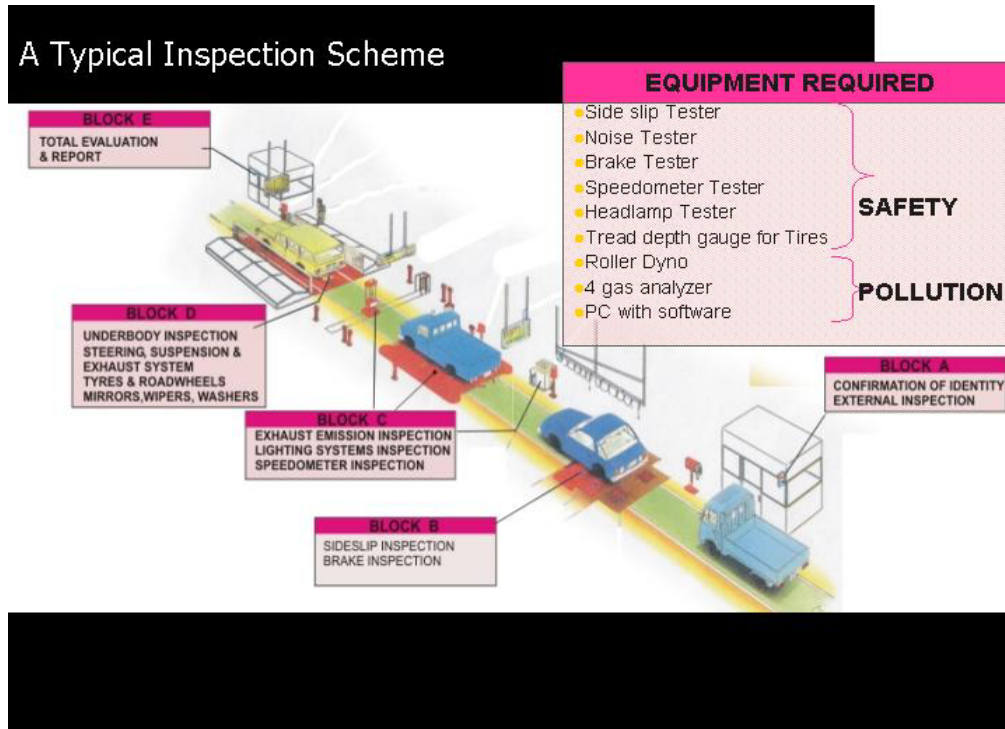
The Burari centre should be privatised and to assure long-term transfer of know-how the tender should describe in detail how this will be managed. The new Burari Inspection Centre should be in full operation one year after the issuance of the tender.

##### ***ii. Step 2: Add a New Privately Built and Operated Inspection Centre for Trucks.***

As soon as the tendering process for the Burari inspection centre is initiated a new tender should be released with the focus on inspection of trucks. The technical capability of the inspection lanes should be the same as for the Burari inspection centre, but preferably the location of this second inspection centre should be in the “south” part of Delhi to reduce the travel distance for having the vehicle inspected. The new second inspection centre should also be in full operation one year after the issuance of the tender document and close to the opening of the Burari centre.

- 3 lanes focused on trucks should be included with a capacity to test 60,000 vehicles/annum per shift.

A typical, centralized inspection scheme, which could serve as a model for these facilities is illustrated in the figure below.



*iii. Step 3: Add A Third New Privately Built and Operated Inspection Centre for Commercial Light Duty Vehicles and 3-wheelers.*

The third inspection centre should be tendered at the same time as the second and in the same way as the other two. Two inspection lanes should be built for light duty vehicles and one inspection lane for 3-wheelers. With the third inspection centre in operation the test demand for commercial vehicles should have been fulfilled. Inspection centre number three can be put in operation by middle of 2004.

- 2 lanes focused on light duty vehicles and one lane for 3-wheelers should be included.

**B. Upgrade of PUC Centres**

Several improvements to the present PUC centres are critically needed until the centralised inspection centres are established. It has been roughly estimated that instead of the 400 centres that exist today, about 100 centres would suffice to meet the

volume of demand for emissions tests in Delhi. Some immediate major steps are required to upgrade the current PUC centres:

- Each centre must be computerized. For measurement of gasoline and CNG fuelled vehicles, 4-gas analysers (CO, CO<sub>2</sub>, HC and O<sub>2</sub>) certified for all four gases must be mandated. With 4-gas analysers and the possibility to calculate the  $\lambda$ -value, it will be possible to identify leaking and therefore faulty exhaust systems as well as incorrect insertion of the test probe. Analysers should be approved by concerned organization according to Indian and international standards. All measured values and calculation of the  $\lambda$ -value (air/fuel ratio) should be stored in the computer system for future analyses.
- For measurement of diesel fuelled vehicles upgraded instruments and test procedures are needed comprising measurement of engine rpm, oil temperature, automatic indication whether the test itself is acceptable or not, and storage of test results, etc.
- Further the PUC centres should be equipped with a web-camera taking a picture of the registration plate during the actual measurement. At the same time a new developed test protocol should be printed comprising the actual measured values, relevant limit values, photo of the registration plate, vital vehicle data and an “automatic” Pass/Fail decision.
- An integrated network of PUC centres must be created with independent management of each centre. Even for PUC centres it is necessary to set up a bidding process. Those operating the PUCs should have no direct involvement in the repair of vehicles.
- Introduce annual registration of PUC centres based on availability of proper equipment and infrastructure, maintenance and calibration status of equipment, availability of trained operator, test records, audit reports, and availability of sufficient space.
- The individual inspectors must be trained to perform the test properly, maintain the equipment and follow the methodology and schedule for calibration of the instruments. A picture of the trained inspectors as well as the certificate regarding their training should be displayed at the PUC at all times.
- Training of PUC operators: Training should be carried out both by the manufacturer of the instrument as well as the competent authority responsible for supervising the system. A “license” should be issued and displayed together with a photo of the operator so that customers know that the operator is trained. Training should include regular mandatory training courses covering test procedure, revised norms, precautions to be taken while testing, health hazard etc.

For gasoline and CNG fuelled vehicles, adequate new limit values for idle measurement and “high idle” measurement should be developed. Initiate a pilot project with the target to identify suitable cut-points for each group of vehicles following a timetable for a

gradual phase in of relevant limits for various vehicle types. For vehicles with two-stroke engines new techniques must be developed measuring the smoke during controlled conditions.

For diesel fuelled vehicles measurement of opacity must be improved. Measurement of engine rpm and oil temperature should be mandated and used for verification of properly warmed engine. The opacity meter should be capable of identifying when a sufficient number of repeatable test cycles has been carried out and to validate if the test sequences are acceptable or not. The instrument should store test results or transfer them to the computer to be included in the certificate from the PUC test. If measurement is carried out according to regulations it is not necessary to modify the limit values before the new test procedure with a loaded mode test is implemented.

A shift towards a system for privatised and centralized PUC centres should be introduced and with no connection to the gas filling stations or workshops which today is the most common location for the centres. These should be under independent management. New requirements for the centres should be introduced such as requirements for regular calibration of instruments (AMC requirement) and training of personnel.

### **C. Gradual Shift from PUC Centres to Centralized Lanes For All Vehicles**

As soon as the three facilities for inspection of commercial vehicles are completed, other types of vehicles should be introduced into the new system.

- Replace the smaller PUC centres with fewer centralised but bigger centres capable of testing large number of vehicles at a time and keep them under strict surveillance. As centralised inspection facilities expand, keep phasing out the smaller centres.
- The frequency of measurement should be changed from once every three month to once a year for private vehicles in the improved system, but with no higher total cost for the vehicle owner. In this context it must be made clear for all operators that this system is a temporary transition to a permanent centralized system.

Inspection centres for passenger cars should be introduced and spread around the city. The size of those centres should be smaller than the ones for commercial vehicles but still large enough to cope with a significant number of passenger cars and 2-wheelers each day. As in the case for the already existing centres for commercial vehicles, the small centres should be operated by private enterprises and tendered in the same way as mentioned above. A phase-in program needs to be determined, but it is recommended to start the inspection program for new catalyst vehicles in order to maintain the low emissions as long as possible and for two-wheelers, specifically those with 2-stroke engine, since they are a big contributor to the poor air quality. The target for a complete conversion to a centralized inspection system will be 2006.

## **7. Instrumentation**

The instrument used for emission measurement of gasoline and CNG fuelled vehicles at the centres must be approved. At present it is only ARAI giving the approval of the instrument. The base requirements for the analyser is the ISO 3930 standard with some deviations of which the most important is higher working temperature for conditions in India (+50°C). Unfortunately, as of yet, no instrument has been approved for measurement of HC. It is recommended by the consultants to extent the possibility to have analysers approved for all pollutants that can be measured on a single unit (4-gas, or 2-gas analyser). In addition, a system for approval of opacity measurement instrument must be arranged for, if not already in place.

## **8. The New Fitness Check**

The detailed program for inspection of traffic safety related items is not elaborated further in this report, but one of the measures to be decided in the near future is to establish suitable programs for the inspection, plans for training of personnel and detailed planning of the inspection centres. In addition, enhancement of institutional arrangements is a high priority measure. Today, privately owned passenger cars are subjected to a "Fitness check" when the vehicle is new, then this control is not repeated before the vehicle reach an age of 15 years, and at that age it is not possible to verify whether the concerned vehicle have been tested again or not!

We wish to note that the same components should also be controlled in the new inspection and maintenance system as in the present "Fitness check"; however the method for control and classification of "pass" or "fail" must be substantially different compared with today.

## **9. Special Focus on Safety Inspection of CNG Buses: Control of CNG Installations**

Significant improvement has been implemented since the previous visit of the consultants to evaluate safety inspection of CNG buses in Delhi. A new organization is given responsibility for inspection of the CNG installations. The new organization had been in place only for about two weeks at the time of the most recent consultant's visit and during that time had inspected about 35 buses; 28 of these were found to have significant problems. The most common failure was gas leakage (identified by a methane analyser), bad clamping of the gas pipes, pipes crossing each other, electrical wires not fixed to the chassis as required, gas pipes not fully visible, and protection for gas cylinders not properly arranged. Another failure was inadequate identification of gas cylinders. When talking to the inspectors they indicated that they consider themselves to still be in the process of learning. The new system seems to have a good potential for the future although some administrative routines need to be looked over, such as:

- What is the best way to inform the owner about discrepancies or that the vehicle passed the inspection (according to contract the result should be submitted to STA for further actions)
- How to keep the owner away from the physical inspection procedure (we can foresee a risk that the owner is trying to convince the inspector to neglect the deviations)

- How to arrange suitable feedback to STA, Burari, ARAI
- How to assure high competence and skill of assigned personnel (a program for regular training must be in place)
- How and by whom to audit the system with control of CNG installation

## **10. Government Responsibilities**

This part will elaborate our recommendation for modifications of administrative system, responsibility and auditing of the system.

Government investments should focus on development and implementation of a comprehensive enforcement and auditing system rather than on vehicle inspections at the commercial facilities. Supervising instead of inspecting.

With regard to enforcement, it is clear that at present most vehicles are not even subjected to the periodic emission inspections at the PUC centres. A new system needs to be put in place that will deny the annual insurance certificate for vehicles that don't have proof of having passed a valid inspection. For some vehicles, such as high mileage taxicabs, which will need to be inspected more than once each year, a "sticker system" will also be required. However, it is not considered useful to have a "paper" requirement stipulating that private vehicles must be inspected at the PUC centres several times each year; rather this should be replaced by a requirement for only one inspection as long as it is a high quality inspection which is rigorously enforced.

Regarding the inspection stations themselves, the government must put in place a system for auditing the entire process. Elements of this system should include covert as well as overt audits, calibration checks, training oversight and strict enforcement and penalties where fraud or "cheating" are identified.

To assist in this auditing function, a new system of databases for validating the program, assessing the results and making the system responsive and adaptive to the learning and feedback that flow from the audits.

It has been demonstrated that the actual vehicle registration data available from the state transport authority is not representative of actual number of vehicles on road. As a result it is difficult to arrive at a realistic estimate of actual volume of inspection that would be required annually from the registration data. For example, according to the registration data the total number of registered buses in Delhi are about 41 483. But after the phase out of the diesel buses the actual number of CNG buses on road are only 7 400.

It will not be out of place to observe that for a good I/M programme a proper vehicle registration system should be in place to record actual vehicles in use. For inspection and re-inspection of vehicles, registration office must be able to trace problem vehicles and track their inspection status. The registration system should also detect vehicles that have not been inspected on time or have failed. It is advisable to rationalise the registration system to meet these objectives.

## **11. Institutional Arrangements.**

To operate a program for mandatory vehicle inspection in a cost effective way require a lot of activities by the local government or administration. As soon as the upgrade of Burari inspection centre and the improvement of the PUC centres are started, activities to enhance the system must be implemented and relevant measures carried out. The concerned local authorities must further shift their present focus from carrying out the inspection to supervise, analyse and when applicable modify the system.

As examples of important measures are:

- a. Introduction of a system with a sticker where vehicles passing the inspection can be identified on the road as well as those vehicles not inspected at all
- b. Modification of the system for registering vehicles in the concerned area (Delhi), identifying vehicles that should have been inspected
- c. Assignment of competent team for auditing various function of the system
- d. Identification of responsibilities for concerned authorities
- e. Introduction of legal possibilities to fine owners not following given rules and regulations
- f. Establishment of a network where essential information from the PUC centres are collected for further analyses
- g. Establishment of databases where result can be analysed
- h. Establishment of channels for adjustments/modifications of the system
- i. Launching campaigns for making people aware of what's going on (Public awareness should not be underestimated)

## **12. Emissions Warranty and Recall Program**

The problem with poor durability of the engine will also raise the question whether it is time to introduce a "Recall program" in India/Delhi where the vehicle manufacturer will be responsible for adjusting /rebuilding vehicles not fulfilling set standards for emissions and durability. When systematic errors in the emission control system are verified in an in-use compliance test program, the manufacturer of the vehicles has to modify all vehicles on the market free of charge within a limited number of years or limited driving distance. In the European emission directive (98/69/EC) for motor vehicles the responsibility for the vehicle manufacturers are included. The Mashelkar Committee has already advocated a system of emission warranty, manufacturers responsibility and a recall program.

## **13. Acknowledgements**

We wish to express our appreciation for the time and attention given to us by the many organizations with whom we have met, and to the CSE staff for their efforts in organizing these meetings. This work has been supported in part by the Swedish International Development Cooperation Agency (SIDA).

## 14. Appendix A: PowerPoint Presentation

## 15. Appendix B: Gantt Chart

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## 16. Appendix C: Testing Options

### A. No-Load Short Tests

The term denotes all tests during which no external load is exerted and the car operates with the transmission in neutral position.

#### *i. Idle / fast idle test*

The test involves carbon monoxide (CO), hydrocarbons (HC) and eventually carbon dioxide (CO<sub>2</sub>) concentration measurements in the raw exhaust gas at idle speed and/or a higher engine speed (2000 - 3000 rpm). The test could last from less than one minute in the case of a one-speed idle test without pre-conditioning to about 10 minutes in the case of a two-speed test with "second chance" test including pre-conditioning.<sup>6, 7</sup> A garage-type non-dispersive infrared (NDIR) analyser capable of measuring CO, HC and CO<sub>2</sub> concentrations is sufficient.

Today idle / fast idle tests are still widely used tests in I/M programs because they are the fastest, cheapest and easiest to perform with the minimum possible testing equipment. For carburetted cars they can effectively identify malfunctioning mixture preparation systems by checking the performance of the carburettor's idle mixture orifice in the idle test and the main fuel-metering orifice in the fast idle test. However, modern cars equipped with electronic fuel injection and ignition systems and three-way catalysts may have a defect (such as defective sensors and degraded catalyst efficiency<sup>8</sup>,) that cannot be detected through their pollutant emissions at idle; even worse, the great bulk of emissions may be generated during transient engine operation. An additional very significant drawback is the negligible amount of NO<sub>x</sub> emissions at idle.

#### *ii. Idle / fast idle tests with lambda test*

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5. Tierney E.J., E.W. Herzog and L.M. Snapp, (1991), Recommended I/M Short Test Procedures for the 1990's: Six Alternatives. U.S. EPA Technical Report EPA-AA-TSS-I/M-90.
  6. Laurikko J. (1994), In-Use Vehicle Emissions Control in Finland: Introduction and Practical Experience. SAE Paper 940930.
  7. Pidgeon W.M. and N. Dobie (1991), The IM240 Transient I/M Dynamometer Driving Schedule and the Composite I/M Test Procedure, US EPA Report AA-TSS-91-1.

For catalyst equipped cars a lambda test may be coupled with an idle / fast idle test in order to check the performance of the mixture preparation system. Three types of tests can be performed:

1. The air/fuel ratio is indirectly determined through measurement of CO<sub>2</sub>, CO, O<sub>2</sub> and HC concentrations at fast idle (2000 - 3000 rpm) in the raw exhaust.
2. The air/fuel ratio is artificially modified by adding oxygen, propane or recirculated exhaust gas to the intake air, or by tampering and then the response of the lambda control system is checked. Long response times would imply that the oxygen sensor is degraded, while no response would mean that the lambda control system is out of operation.
3. One or more of the characteristics of the electronic lambda control circuit are measured and compared with auto manufacturers' specifications.

Germany has adopted since December 1993 a test that involves both test types 1 and 2; preliminary investigations have shown that the test performs fairly well with excess emitters. A combined idle / fast idle / lambda test (involving lambda test types 1 and 2) is also in force in Austria, where it has also demonstrated satisfactory effectiveness (Pucher et al. 1990). A similar test (but with lambda test type 1 only) is also foreseen for three-way catalyst cars in all EU countries with Directive 92/55/EC, which came into force in 1997.

## **B. Steady-state loaded tests**

As NO<sub>x</sub> emissions at no-load conditions are negligible, a loaded test is therefore necessary in order to measure NO<sub>x</sub> emission levels, which constitute a critical issue for urban air pollution and are an important pollutant in Delhi. The simplest loaded tests are the steady-state loaded tests. These involve a dynamometer with steady-state power absorption. A simulation of the car's inertia weight is not required because there is no transient phase in the emission test: the car is driven at constant speed and load, and pollutant concentrations (CO, HC, NO<sub>x</sub> and CO<sub>2</sub>) are measured during the load phase.

Already in the seventies several loaded tests were developed in the US such as the Federal 3-Mode Test, the Clayton Key-Mode Test and the CalVIP. However their implementation was limited due to the high cost of the dynamometer and the NO<sub>x</sub> analyser.

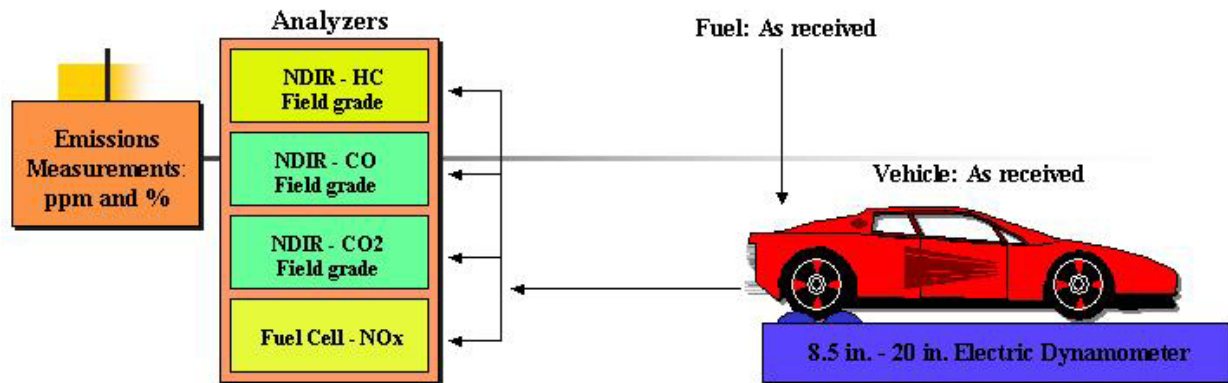
More recently and due to the introduction of 3-way catalyst equipped cars, the Acceleration Simulation Mode (ASM) Tests were developed and evaluated. According to the ASM principle the car is driven on a chassis dynamometer at a constant speed and steady-state power absorption that is equal to the actual road load of the car during acceleration. Thus one can achieve a realistic simulation of the car's load at a specific driving mode without the need of flywheels for inertia simulation. However, at high speed / high acceleration combinations the required power absorption is too high to be achieved without engine overheating problems.<sup>9</sup> Pollutant concentrations (CO, HC, NO<sub>x</sub>) are in principle measured in the raw exhaust. Each steady-state test mode would require about 10 minutes for preparation, pre-conditioning, actual testing and documentation.

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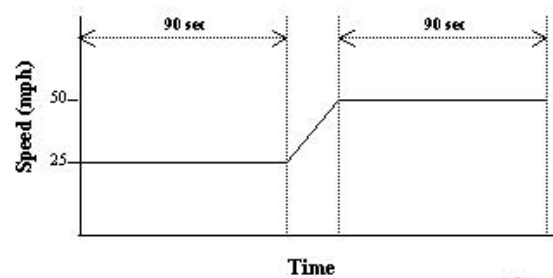
8. Austin T.C. and Sherwood L. (1989), Development of Improved Loaded-Mode Test Procedures for Inspection and Maintenance Programs. SAE Paper 891120.

Austin et al. compared several speed / load combinations with idle tests and already developed steady-state loaded tests as well as with transient loaded test. The best results were obtained from the ASM 5015 test, which has a constant speed of 15 mph (24 km/h) and a steady-state load equal to 50% of the load required to accelerate at 1.47 m/s<sup>2</sup> (the maximum acceleration rate on the FTP) at the speed of 15 mph.

## Test Type: ASM 2



ASM 2 Test Cycle: Steady-state, loaded mode



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In the late 80s in Europe the association of the German TÜV also investigated a similar loaded test. The car is driven at 50 km/h and at 7 kW dynamometer power absorption in the third gear (position "D" for cars with automatic transmission) and then idles; pollutant concentrations (CO, HC, NO<sub>x</sub>) in the raw exhaust are measured at the end of both the loaded and the idling phases.<sup>10</sup> Vehicle preparation, pre-conditioning, test phase and documentation take on the average about 10 minutes. The study concluded that the test is much more appropriate for the inspection of catalyst cars than a simple idle / fast idle test. The authors point out that, in order to improve the performance of the test, type-specific reference values (and not fixed values) have to be used as cut-points that determine whether a car passes or fails the short test.

### C. Transient loaded tests

9. Voss H. -J, Hassel D., Neppel H. -P., Richter A., Heckötter N. and Friedrich A. (1987), Periodic Inspection of Exhaust Emissions from Low Pollutive Otto Engine Vehicles and Diesel Engine Vehicles. SAE Paper 871084.

In transient tests cars are driven on the dynamometer according to a specific driving schedule; their main differences from type approval tests are the duration of the driving cycle and the hot start.<sup>11</sup> Since exhaust gas emissions are expressed in mass units, a CVS system and laboratory-quality analysers are required in order to detect low pollutant concentrations in the diluted exhaust sample. A multiple-curve dynamometer with flywheels is also required in order to simulate the instantaneous road load and the necessary power to accelerate the inertia masses of each car.

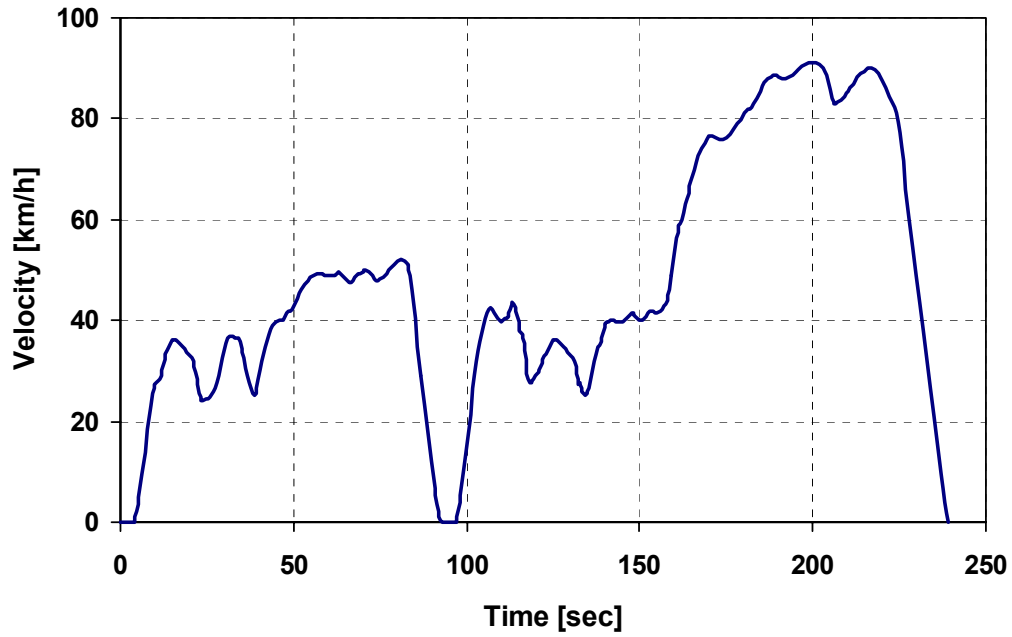
A number of transient loaded short tests were developed in the 70s in the United States and were examined as to their correlation with FTP 75. However, the cost of the implementation of such tests for generalised I/M programs was prohibitive, and thus the idea was abandoned. The fact that cars equipped with three-way catalysts were just starting to enter the U.S. market in the late 70s and the performance of these tests with such cars had not been examined also played a role in that decision.

More recently though the interest for transient short tests was renewed. Thus first the CDH 226 test was developed by the Colorado Department of Health (CDH) and aimed at achieving high correlation with the FTP, especially for three-way catalyst cars. Numerous studies have demonstrated correlation coefficients of 0.79 to 0.96 for all three pollutants.<sup>12, 13, 14</sup> Excess emission identification rates were about 90% for all three pollutants at 5% errors of commission.<sup>15</sup>

However, the U.S. EPA decided to develop a more transient alternative to the CDH 226 in order to better simulate the FTP and therefore came up with the IM 240, illustrated below.<sup>16</sup> Emissions in the diluted exhaust gas are normally derived on a mass basis with a CVS and the test takes in total about 10 minutes to perform. The IM 240 showed correlation coefficients ( $R^2$ ) with the FTP hot start portion of 0.89 to 0.97 for all three pollutants; another test sample had coefficients of 0.54 to 0.82 with the full FTP including cold starts.<sup>17</sup>

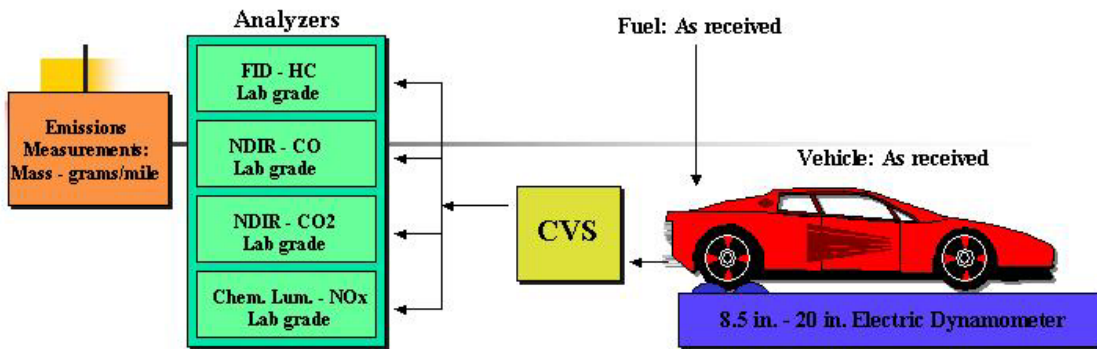
The EPA proposed that states or regions, which will have to implement the so-called "Enhanced I/M Schemes", enforce the IM240 at least for the cars of the newest model years.

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10. It is unlikely that a short cycle will detect shortcomings in the cold start behaviour
  11. Ragazzi R.A., J.T. Stokes and G.L. Gallagher (1985), An Evaluation of A Colorado Short Vehicle Emission Test (CDH-226) in Predicting Federal Test Procedure (FTP) Failures. SAE Paper 852111.
  12. Austin T.C. and Sherwood L. (1989), Development of Improved Loaded-Mode Test Procedures for Inspection and Maintenance Programs. SAE Paper 891120.
  13. Klausmeier R. (1994), Analysis of I/M Test Alternatives. Paper presented at the International Conference 'Ozone Control Strategies for the Next Decade (Century)', San Francisco.
  14. Ragazzi R.A., J.T. Stokes and G.L. Gallagher (1985), An Evaluation of A Colorado Short Vehicle Emission Test (CDH-226) in Predicting Federal Test Procedure (FTP) Failures. SAE Paper 852111.
  15. Pidgeon W.M. and N. Dobie (1991), The IM240 Transient I/M Dynamometer Driving Schedule and the Composite I/M Test Procedure, US EPA Report AA-TSS-91-1.
  16. Klausmeier R. (1994), Analysis of I/M Test Alternatives. Paper presented at the International Conference 'Ozone Control Strategies for the Next Decade (Century)', San Francisco.

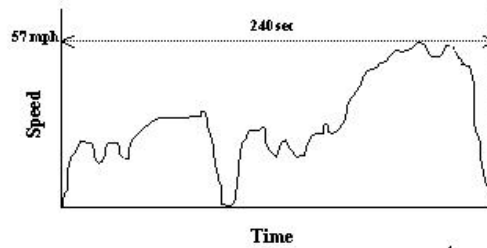


The IM240 short driving cycle

## Test Type: IM240



IM240 Test Cycle: Transient, loaded mode

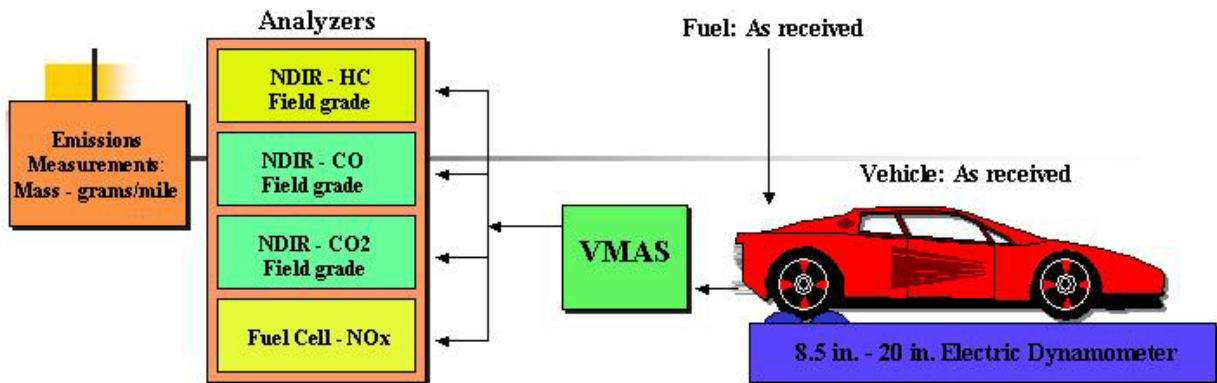


Running the IM240 procedure requires a constant volume sampler and laboratory grade analysers for CO, HC, NOx and CO<sub>2</sub>.

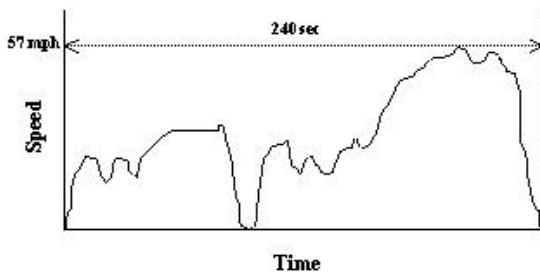
In order to reduce the cost, several states including New York and Massachusetts investigated an alternative test that used less expensive equipment but gave similar results as the IM240 procedure. The test that was developed used field grade analysers and a less expensive dynamometer and was capable of driving several different transient driving cycles as illustrated below.

This procedure evolved into the VMass test procedure, which has demonstrated very close correlation with the IM240 test but at much lower cost.

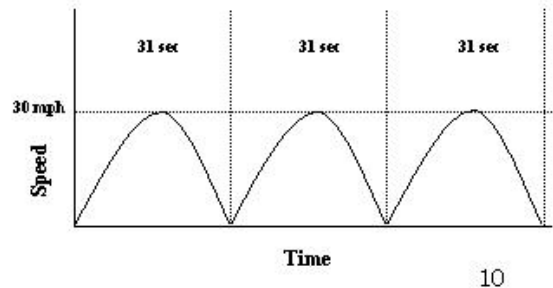
## Test Type: Mass 31 or IM240



IM240 Test Cycle: Transient, loaded mode

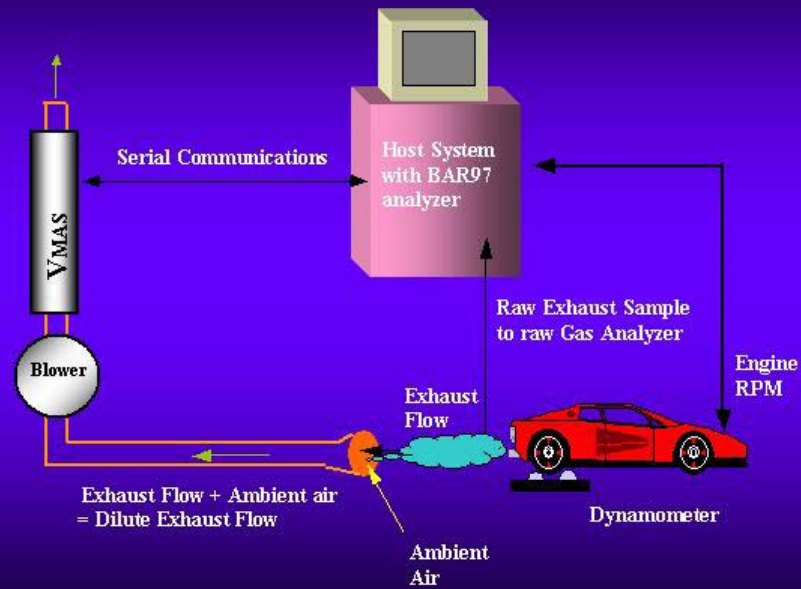


MASS 31 Test Cycle: Transient, loaded mode

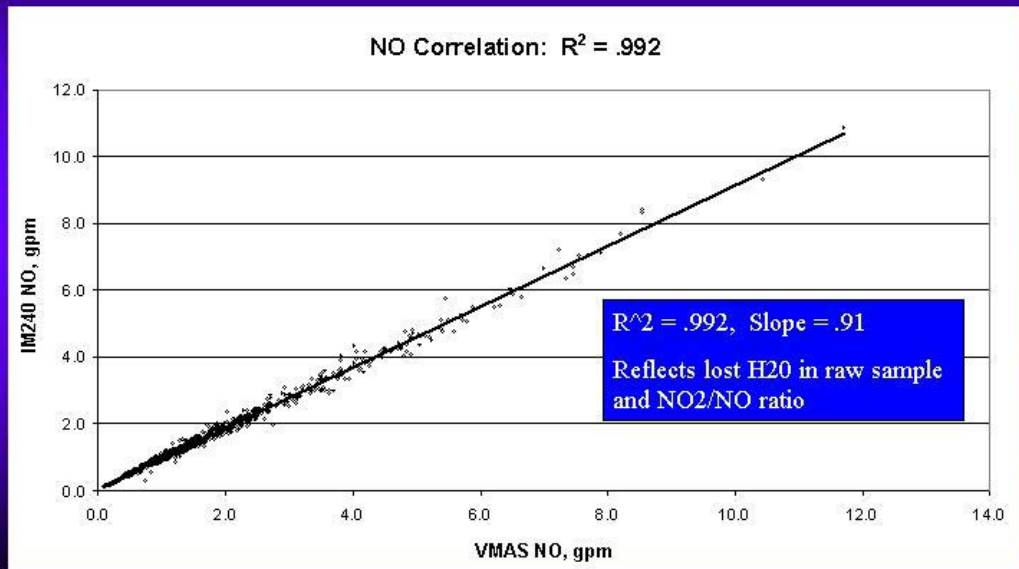


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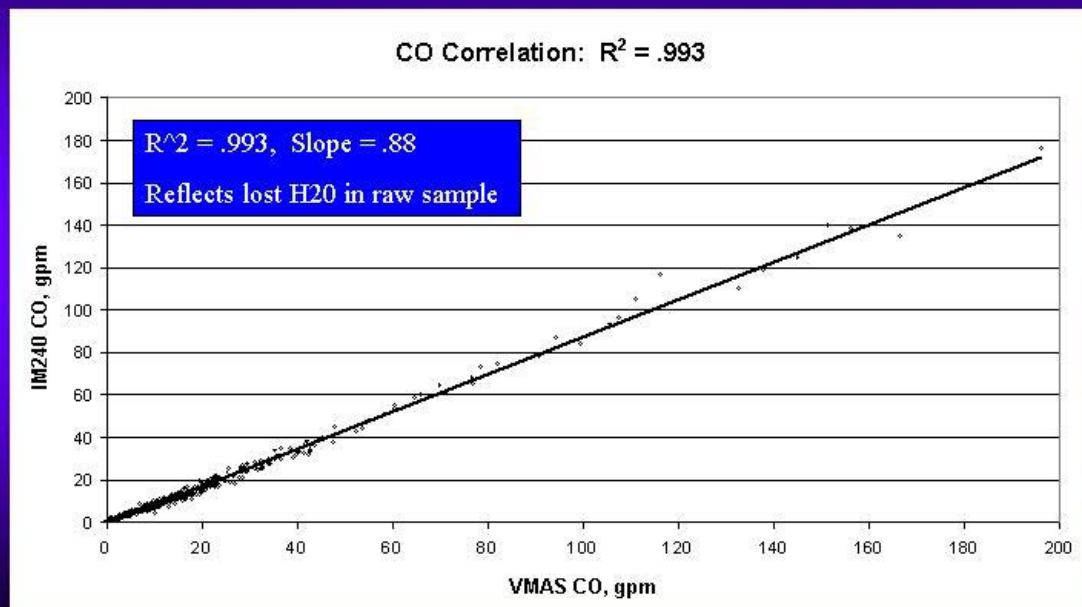
## Typical System with VMAS™



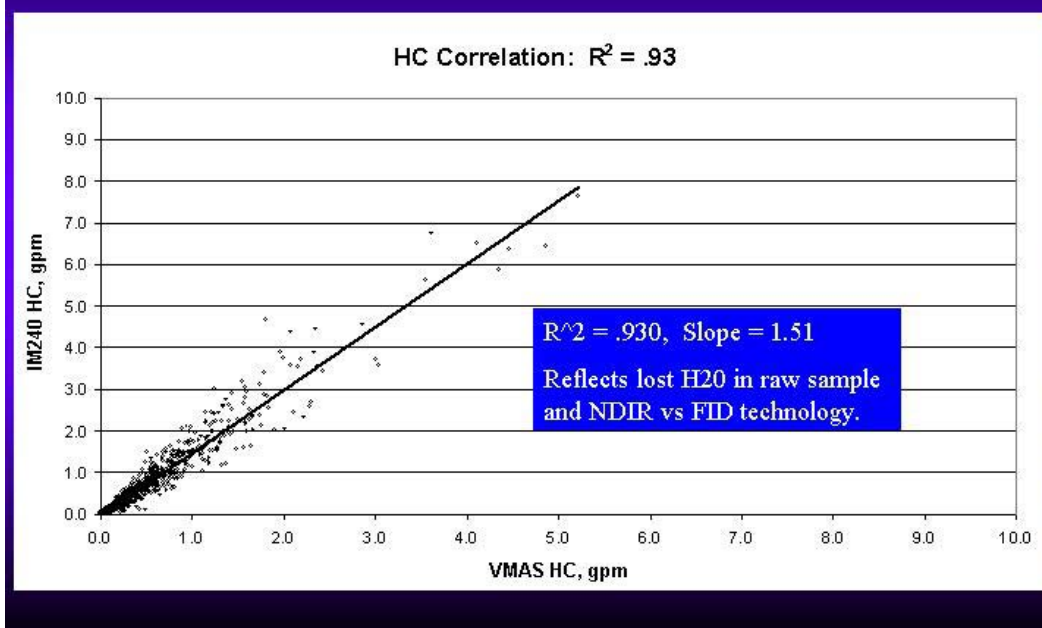
## VMAS™ Study Results: NOx



## V<sub>MAS</sub><sup>TM</sup> Study Results: CO



## V<sub>MAS</sub><sup>TM</sup> Study Results: HC

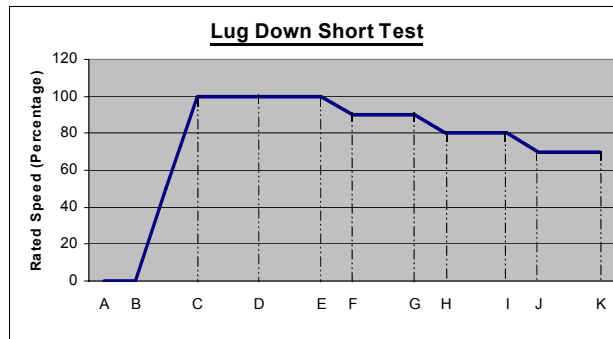


## D. Diesel Tests

The lack of robust, commercially available equipment for quickly and accurately measuring diesel PM emissions has meant that regulators have been obliged to focus diesel I/M programs on smoke opacity. Smoke is a highly undesirable pollutant in its own right, and reducing opacity levels may also tend to reduce particulate emissions. However, available data indicate that smoke opacity, even when measured under a controlled load on a dynamometer, has a poor correlation with particulate emissions measured under the same conditions.<sup>18</sup> High smoke emissions can result from serious engine problems such as worn out injectors or a dirty air cleaner that affect PM emissions **throughout** the driving cycle, or they may result from problems such as tampering with the puff smoke limiter that affect emissions only during transient accelerations and thus have much less impact on PM emissions over an entire driving cycle.<sup>19</sup>

The two most commonly run smoke tests are:

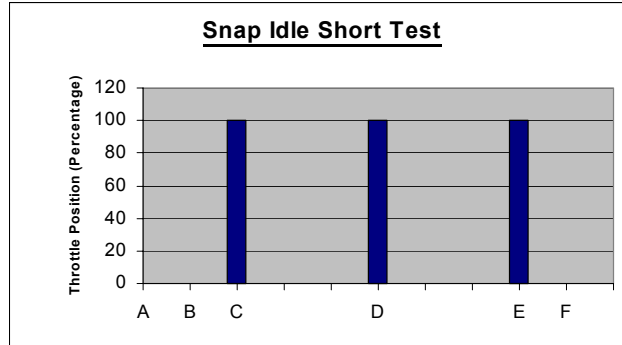
The **Lug Down** test, which is performed at full throttle, with the dynamometer load gradually increased to pull back engine speed so that the engine is labouring, or "lugging". This test is sometimes run at roadside without a dynamometer by using the vehicle brake.



The **Snap-Idle** (SAE J1667 Free Acceleration) test simply involves fully depressing the accelerator pedal while the transmission is in neutral, and measuring the maximum smoke. The test requires no dynamometer.

17. <sup>18</sup> Development Of A Practical In-Use Emissions Test For Diesel Road Vehicles, Parsons Australia Pty Ltd, 1 Short, St. Auburn, NSW 2141, Australia, P. Anyon, S. Brown, D. Pattison, J. Beville-Anderson, G. Walls, M. Mowle

18. <sup>19</sup> "Diesel Emissions Factors and Control Measures For Colorado", Engine, Fuel, and Emissions Engineering, Inc., February 5, 1997.



The short test evaluations have shown that dynamometer-based short tests with transient acceleration segments are considerably more effective than unloaded or steady state tests in estimating "real world" emissions of all regulated pollutants.

Smoke opacity measured during the free acceleration test (SAE J1667), or any of the steady-state tests, does not correlate well with particulate emissions generated during the transient dynamometer test cycle. Smoke opacity is basically a measure of visual amenity only.

#### **E. Overall Conclusions Regarding Test Procedures**

- On the basis of the available test data, the idle test is ineffective for catalyst-equipped cars. It can identify only 15% of the high polluters, while the environmental benefit from it does not exceed 4% reduction in any of the pollutants involved. Especially as regards the lambda test, it was found to add in the direction of NOx emitter's identification, having the drawback of increasing the errors of commission.
- Of all the short tests used, the transient short cycles have the greatest potential in terms of environmental benefit. They can identify practically all gross polluters (i.e. vehicles emitting more than 50% above the emission standards) and offer an emission reduction potential of the order of 15 to 20% for all pollutants CO, HC and NOx on the basis of the random vehicle sample.
- Cost-effectiveness analysis has shown that as soon as there is a high share of catalyst equipped cars in the fleet dynamic testing over a short driving cycle turns out to be the most effective I/M test.
- VMass testing correlates very well with the IM240 test but is much less expensive. The ASM test is only slightly less expensive than VMass but its correlation with IM240 is much poorer.

#### **17. Appendix D: Recommendations: Emission Measurements and Test Procedures:**

To meet present and future requirements for adequate test procedures for the inspection it should as soon as possible be established how the various tests should be carried out and what limit values should be applied. A detailed inspection program for each group of vehicles must be established and also related training programs for personnel responsible for the inspection. For the measurement of exhaust emissions it is strongly recommended in this early stage to introduce loaded mode test procedure for heavy-duty vehicles and also later on for light duty vehicles. Measurement of only idle

conditions is insufficient in the longer term when engine technology will be more sophisticated.

We recommend the following improvements for different categories of commercial vehicles.

#### **A. Diesel Fuelled Heavy Duty Trucks (Buses and Trucks)**

Consultants observe that there is still no clear official proposal to upgrade the test procedure for diesel vehicles. Consultation with ARAI indicates that they have considered regulating operational parameters of free acceleration smoke test that are currently conducted in the PUC centres. But there is nothing firm on advancing the test procedures to loaded mode tests to address the special concerns in diesel emissions.

Since heavy-duty goods vehicles and interstate diesel buses are a great contributor to the poor ambient air quality in Delhi, they should be included in the new I/M program from the very start and subjected to the inspection at the upgraded Burari Inspection Centre (buses) and at the "Second Facility" (trucks). The test procedure for emission measurement should be a transient loaded mode test focusing on measurement of particulates and oxides of nitrogen (NO<sub>x</sub>). When the test procedure is decided and before the start of the program, new emission standards must be made official and used in the program. An organisation in India should be appointed as responsible for the development of suitable test program including limit values, for example ARAI in Pune. In this context experience from other countries in Europe or USA should be looked for.

#### **B. Taxis**

Taxis in Delhi can be of various configurations and be fuelled by gasoline, diesel, compressed natural gas (CNG) or liquefied petroleum gas (LPG). From a technical perspective the group of taxis (light duty vehicles) should be handled exactly in the same manner as other vehicles using the same type of fuel. Taxis should be introduced to the I/M program much faster than private cars. This group of vehicles should meet strict emission limit values from the very beginning and there is no need to use a phase in of limit values. The policy in Delhi should be to only use newer taxis meeting new standards.

Taxis should be inspected more than once per year since they accumulate significant longer driving distance than private passenger cars.

For diesel taxis free acceleration method is not sufficient as the measurement is not representative of actual emissions on roads. For both diesel and gasoline taxis loaded transient test should be developed together with appropriate limit values. A feasibility study could be a proper way to start the development of the new test procedure. When the test procedure is finalized, new emission standards must be established. Until the new I/M program is established, taxis should be subjected to the enhanced PUC control discussed later.

Taxis should be moved to advanced I/M program when the "Third facility" is erected, estimated to be within 1 – 1.5 year from the start of the project.

### **C. Auto-rickshaws (3-wheelers)**

Auto-rickshaws, both gasoline and CNG, are considered to be “Commercial Vehicles”, and subjected to the mandatory annual fitness and idle CO emission tests. Older vehicles with 2-stroke engine are scrapped or have moved out of the city. The major manufacturer of CNG 4-stroke 3-wheeler is Bajaj Auto Ltd. CNG conversion has helped to deal with the problem of high hydrocarbon and particulate emissions from gasoline 2-stroke 3-wheelers in the city. Now, issues are being raised with regards to the quality of the conversion and the durability of the engine. CNG 3-wheelers and even new 4-stroke CNG engines are emitting so called “white smoke”. Based on experience from development of CNG engines, the “quality” of the piston rings appears to be an important factor. With poor quality piston rings it is possible that lubrication oil is leaking from the oil sump to the combustion chamber causing smoke. Experience from other countries with a great deal of 2-, and 3-wheeler using engines with small cylinder displacement show that engines must be overhauled (as example change of piston rings) up to twice every year or every 30 000 km.

The test procedure for emission measurement for three wheelers should preferably be a transient loaded mode test. When the test procedure is decided and before the start of the program, new emission standards must be developed and used in the program. It is essential that the selected limit values correspond to the vehicle technology. However, for this group of vehicles a phase in program of the limit values could be considered. Such a measure could meet the objectives of maximum 20 % failure rate and thereby be more accepted by owners. The limit values must then regularly be adjusted to reach to the set target within a specified time. Until the new I/M program is applicable for auto-rickshaws they should of course be subjected to the enhanced PUC control discussed in the report.

### **D. CNG buses**

CNG buses are today subjected to three different controls such as control of the gas installation on the vehicle, the “Fitness Check” and the verification of emission performance. There is, in addition a need for a further control that in the future might be a part of the control of the gas installation and that is to verify full identity of essential components installed on the vehicle compared to those subjected to the type approval of the “conversion kit” carried out by ARAI.

The system for control of the gas installation on the buses has been improved recently. Originally the control was carried out by own staff at the Burari Inspection Centre but is now contracted out to a third party private company. Still, this system is time-consuming and can be considered as a “bottle-neck”. It is therefore proposed to introduce a system where trained teams of inspectors could visit bus operators and carry out this part of the “Fitness Check” at their premises or at other suitable locations.

As noted earlier, upgraded efforts have recently been initiated to improve the inspection of CNG vehicles to assure that no leaks or other safety problems exist. These efforts need to be rapidly expanded so that every CNG vehicle gets a thorough inspection very quickly and then periodically thereafter. A detailed discussion of this issue is contained in the bus safety report.

These CNG safety inspections need not wait for the installation of the new and upgraded commercial vehicle inspection centres but should rather be initiated immediately. Two points are worth noting:

- It is possible to carry out the checks at the existing DTC stations.
- An increase in the number of teams approved to carry out the checks and their training should be given a very high priority.

CNG buses are checked for the maximum idle CO of 3.0 %. This is far too lenient, especially when all buses are equipped with a catalytic converter. During an earlier visit to the Burari Inspection Centre we were shown statistics from about 300 emission measurements, indicating that 18 % of the tested buses had CO idle values of more than 3.0 % and about 60 % of the buses had CO values of more than 1.0 %. Those values should be compared with emission limits for CNG vehicles in the US where maximum 0.5 % CO at idle is accepted for buses. It is advisable to reconsider the present limit value of 3.0 %.

During visits to the manufacturer of chassis/engines for CNG buses the issue of durability was discussed. This raises the concern whether it is time to introduce a “Recall program” in India/Delhi. Manufacturer of CNG engines must include a catalytic converter in the exhaust emission control system in order to fulfil the standards for new vehicles/engines, but on the other hand they only warrant the performance of the catalytic converter for maximum of 72 000 km. What is happening after this mileage is reached is unclear and according to our knowledge there is no requirements for changing the converter at specified driving distances and no specific control is carried out during the annual fitness check. The warranty period of 72 000 km should be compared with the European requirements for manufacturers responsibility and warranty, which is 8 years or up to 500 000 km.

CNG vehicles and especially buses must be included in the advanced inspection program immediately. Buses should be of highest priority at the new upgraded Burari Inspection Centre. The test procedure for emission measurement should be a transient loaded mode test focusing on the measurement of NO<sub>x</sub>. When the test procedure is decided and before the start of the program, new emission standards must be developed and used in the program. Until the new I/M program is fully applicable for the various groups of vehicles fuelled by CNG they should of course be subjected to the enhanced control carried out at the PUC centres discussed in the report. Specially trained mobile teams will take care of the control of gas installation on vehicles at suitable locations to increase the total capacity.

Consultants have not assessed the LPG vehicles separately. LPG is not commonly used in Delhi though the consultants noticed that conversions are already underway. Vehicles using LPG as fuel must have an engine that is rebuilt from an original gasoline engine. We are told that ARAI is now working with the development of a regulatory system and a process to have LPG conversion approved in the same way as CNG installations. The fuel itself can also create problem depending upon the properties. LPG is heavier than air and when a leakage is at hand the gas will remain on the ground and not evaporate as CNG, thereby increase the risk for explosion if the mixing rate between air and LPG is unfavourable. To summarize LPG is more “dangerous” than CNG as a fuel.

Consultants would like to recommend that LPG vehicles are also included in the I/M program in the same manner as others. Comprehensive regulations for conversions (e.g. type approval system) should be introduced and applicable both to the LPG installation on the vehicle as well as the emission performance when the gasoline engine is converted to operate on LPG.

### **E. Gasoline Passenger cars**

Delhi has introduced tighter emission requirements for new passenger cars, mandating advanced engine management control systems, catalytic converters and the use of unleaded gasoline. It is now vital to introduce test methods for those vehicles that makes it possible to verify that essential parts and systems are in working order and that the vehicle meets requirements which are technically possible to reach e.g. the same standards as when the vehicle was brand new.

For carburetted cars simple idle test can identify malfunctioning systems. But modern cars equipped with electronic fuel injection and ignition systems and three-way catalysts may have a defect -- such as defective sensors and degraded catalyst efficiency -- that may not show up in idle tests.

An intermediate approach towards moving to centralised I/M system is introduction of both idle and high idle tests. Idle is measured when the engine is at idle (700 – 900 rpm), while high idle is measured when the engine speed is more than 2000 rpm.. As recommended above 4-gas analysers (CO, CO<sub>2</sub>, HC and O<sub>2</sub>) certified for all four gases must be mandated and lambda measurement adopted for catalyst-equipped cars at least at high idle measurement

Consultants have had the opportunity to review the new limit values under consideration for gasoline-fuelled vehicles in Delhi. For 4-wheelers without catalytic converter the limit values for idle CO and HC are 3.0 % respectively 1500 ppm. For modern passenger cars with catalytic converters the corresponding limit values are 0.5 % respectively 750 ppm. We understand that there is also a proposal for measurement of lambda for vehicles fitted with closed loop three-way catalytic converters. The proposed HC values of 1 500 ppm respectively 750 ppm is from a strict technical point of view to lenient

Studies all over the world for comparable vehicle technology as in Delhi shows that the level of HC at idle of more than 1 000 ppm is very rare. For all light duty vehicles below 3 500 kg gross vehicle weight ratio (GVWR) without catalytic converter corresponding level for HC should be in the range of 600 – 700 ppm. Similarly, from a technical point of view, passenger cars equipped with catalytic converters should at idle not be allowed to emit more than 0.5 % of carbon monoxide and 100 ppm of hydrocarbons.

Even other light duty gasoline vehicles equipped with catalytic converters such as small trucks and “pick-ups” with a GWVR of maximum 3 500 kg should not be allowed to emit more than 1.0 % of CO and 200 ppm of HC. Those values can easily be met with a working catalyst and measured according to specifications. Limit values for HC in Europe are not mandatory, but those countries in Europe implementing them are normally using the above values.

It is recommended that high idle test is adopted and limit values for such test, together with  $\lambda$ -value (air/fuel ratio) for gasoline vehicles with catalytic converter should be introduced. Limit values for CO for passenger cars in Europe is maximum 0.3 % at an engine rpm above 2 000 and the  $\lambda$ -value is specified to  $1.00 \pm 0.03$ . High idle measurement and calculation of  $\lambda$  is to verify that the converter is working under moderate engine load. A  $\lambda$ -value will also reveal if the exhaust pipe is leaking or not and that the measurement is carried out in an acceptable way.

The experience in Europe is that a value for passenger cars less than 0.15 % of CO at idle indicates that the converter is working and values less than 0.3 % indicates that something is wrong. If levels reach 0.5 % the converter is usually not working at all, but because of sophisticated electronic control of the air/fuel ratio the idle value is still relatively low. In order to avoid problems during the measurement, a limit value of 0.5 % CO at idle should still be implemented.

As is commonly known the bulk of emissions may be generated during transient engine operation that cannot be captured in idle tests. Moreover, NO<sub>x</sub> emissions at idle is negligible. To remedy this, loaded mode test (measurement during part load of the engine) is recommended.

A number of transient loaded short tests were developed in the US and evaluated for correlation with type approval tests. Different types of loaded mode test can be used in an I/M program such as transient tests (IM 240, inspection and maintenance, test duration 240 seconds, VMAS, vehicle mass analysis system) or steady state tests (ASM, acceleration simulation mode test procedure in which measurement is carried out during various speeds and vehicle load – see discussion above).

The advantage of a full transient loaded mode test in comparison with an ASM test is that during a transient test sequence failure of the fast regulation of the  $\lambda$ -sensor during acceleration and retardation and thereby not achieving a proper air/fuel mixture easily could be detected. There are ongoing discussions to decide the future test methods and principals for emission measurements at mandatory vehicle inspection programs. The focus is to find a cost-effective method and at the same time with a good correlation with real world driving. A recent study in Europe “The Inspection of in-use cars in order to attain minimum emissions of pollutants and optimum energy efficiency”, elaborates different methods, related costs and feasibility. One of the conclusions from the project valid for vehicles with catalytic converter is **“Of all the short tests used, the transient short cycles were found to have the greatest potential in terms of environmental benefits. They can identify practically all gross polluters (i.e. vehicles emitting more than 50 % above emission standards) and offer an emission reduction potential of the order of 15 to 20 % for all pollutants CO, HC and NO<sub>x</sub> on the basis of the random vehicle sample”**.

We recommend that privately owned passenger cars are gradually included in a privatised and centralized (inspection only) program. The start of the program should be with the priority to include newer vehicles with catalytic converter and a phase in of older passenger cars. The test procedure for emission measurement should be a loaded mode test and preferably a transient test. When the test procedure is decided and before the start of the program, new emission standards must be developed and implemented. Background material for the development of new standards (cut points) might be

available at ARAI or at other internationally recognized test institutions. However, for small groups of vehicles with a low annual driving distance a phase in also of the limit values could be recommended. Such a measure will meet the objectives of maximum 20 % failure rate. The limit values must then regularly be adjusted to reach the set target within a specified time. Until the new I/M program is applicable for passenger cars they should of course be subjected to the enhanced PUC control discussed in the report.

#### **F. Diesel passenger cars**

As mentioned earlier in the report we have not noticed that there is any clear official proposal how to upgrade the test procedure for diesel vehicles. As in Europe the emission measurement of diesel vehicles is carried out by measuring the opacity by the use of the free acceleration method the shortcomings of which were discussed above.

There are not many diesel fuelled passenger cars in Delhi, but they still are contributing to the poor ambient air quality. The quality of the diesel fuel plays an important role for the emissions from diesel vehicles, but in the Delhi region the content of sulphur in the fuel has been decreased. On the other hand the use of adulterated fuel is a topic in Delhi.

Emissions of big concern from diesel vehicles are oxides of nitrogen (NO<sub>x</sub>) and particulates. Measuring the opacity can identify none of those pollutants. It is recommended to develop a new test method where the focus should be measurement of NO<sub>x</sub> and particulate. Since NO<sub>x</sub> mainly is produced in the engine during high load and causing high temperature in the combustion chamber, the most feasible test method is a loaded transient test method.

The method for measuring the emissions could be the same as for measurement of gasoline fuelled passenger cars elaborated above. However, new test equipment measuring particulate and NO<sub>x</sub> must be incorporated in the system. When the test procedure is decided, new emission standards must be developed and implemented. Background material for the development of new standards (cut points) could either be obtained via a feasibility study or might be available at ARAI or at other internationally recognized test institutions.

The diesel fuelled passenger cars could be inspected in the same test centres as gasoline fuelled vehicles.

#### **G. Two wheelers**

Motorcycles are equipped with 2-, or 4-stroke engines. The target must be to establish limit values related to the engine technology used on the vehicle. The large number of motorcycles in Delhi/India requires greater focus on the development of emission regulations and I/M program for these vehicles.

The new limit values under consideration for idle CO and HC for 2-wheelers are HC 9 000 ppm for 2-stroke engines, and 4 500 ppm for 4-stroke engines and 3.5 percent CO for all 2-wheelers. The proposed HC norms are too lenient for newer 2-wheelers and the proposal should be reconsidered to match the engine technology. A small survey made by ARAI show clearly that no new motorcycles would fail at the PUC centres using the

new set of standards. In view of the fact that limit values should correspond to the engine technology and that 20 % failure rate is acceptable, there is a strong need for reconsidering the proposed new limit values at the latest when the proposed I/M program will start.

ARAI is developing a simplified test method for two wheelers. The system consists in general of a driver's aid, a computer including software and a simple single roller dynamometer. The driving pattern to follow during the test procedure and displayed on the driver's aid, could for example be the Indian driving cycle repeated more than once. During the test sequence exhaust emissions will be collected from the tailpipe and calculated as grams per kilometre (mass emissions) instead of concentrations expressed as percent or ppm. This system is very promising but need further development before a decision can be made whether it is possible to use the system in the new I/M program for 2-wheeler.

Recommendation for motorcycles is to include them in the system of I/M program at the same sequence as for privately owned passenger cars. The test procedure for emission measurement should preferably be a transient loaded mode test. When the test procedure is decided and before the start of the program, new emission standards must be developed and used in the program. It is essential that the selected limit values correspond to the vehicle technology. Source for development of suitable cut-points (limit values) might be available at recognized test organizations. Until the new I/M program is applicable for motorcycles they should of course be subjected to the enhanced PUC control discussed in the report.