EPCA report: 14

Special report on the introduction of an upgraded pollution under control certificate system in response to the Hon'ble court's order dated February 4, 2005

(**In the matter of W.P.(C) No.13029 of 1985; M.C. Mehta v/s UOI & others**)

(March 2005)

Environment Pollution (Prevention & Control) Authority
for the National Capital Region

1. Background

In August 2004, EPCA had submitted its report, "*Pilot project on the Inspection and Certification (I&C) Centre at Burari, Delhi: Introduction of loaded mode test procedures for measurement of in-use emissions*" to the Hon'ble court. This report brings out the rationale for introduction of the loaded mode tests procedures in the Burari inspection centre and why, to begin with, it is critical that Delhi adopts loaded mode tests procedures for its commercial vehicles.

The Hon'ble court after perusing the report, in its order dated October 8, 2004 stated, "Delhi government is directed to respond to the recommendations contained in the report of the EPCA of August 2004, at page 8 in paragraph 4, within four weeks." On the directions from the Hon'ble court, the Delhi government filed its affidavit in January 2005.

Based on the government's affidavit the Hon'ble court in its order dated, February 4, 2005 stated, "In the affidavit filed by Mr Rajeev Talwar, Commissioner-cum secretary, Department of Transport, Government of Delhi, on loaded mode emission test, the view point of the Automotive Research Association of India (ARAI), Pune has been reproduced. In this regard and also in respect of all the other technical aspects, including lambda measurement to test the catalytic converter, we feel it expedient to have the comments of EPCA."

Accordingly the report is been structured in 3 parts. Part A looks into the issue of introduction of the lambda regulations in the NCT of Delhi for petrol vehicles fitted with three way catalytic converters and a closed loop system, Part B caters to the lambda regulations for the CNG vehicles in the NCT of Delhi and Part C looks at the loaded mode tests procedures

A. Introduction of lambda test in the NCT of Delhi

In Delhi, Euro II emission-technology norms were introduced from April 1, 2000. As a result of which most of the vehicles were equipped with a three-way catalytic converter and a closed loop feedback system. It is very critical that the air/fuel ratio in these vehicles is maintained at the stoichiometric levels. This would ensure that the catalytic converters efficiency for converting all the three pollutants, carbon monoxide, hydrocarbons, and oxides of nitrogen is the highest.

It is well accepted by automobile companies that while for carbureted cars, simple idle test can identify malfunctioning systems, the same does not hold for cars, which are equipped with catalysts. Modern cars equipped with electronic fuel injection and ignition systems and three-way catalysts may have defects — such as defective sensors and degraded catalyst efficiency — that may not show up in idle tests. Thus given the inherent disadvantages of the idle tests, the first step should be to move towards an improved system which would mandate measurement of all the four gases and the lambda for catalyst-equipped cars at high idle (accelerated driving speeds).

1. Lambda tests and its importance

Lambda is a dimensionless value representative of the burning efficiency of an engine in terms of the air/fuel ratio in the exhaust gases and determined with a referenced standardized formula. Lambda represents actual to stoichiometric air/fuel ratio.

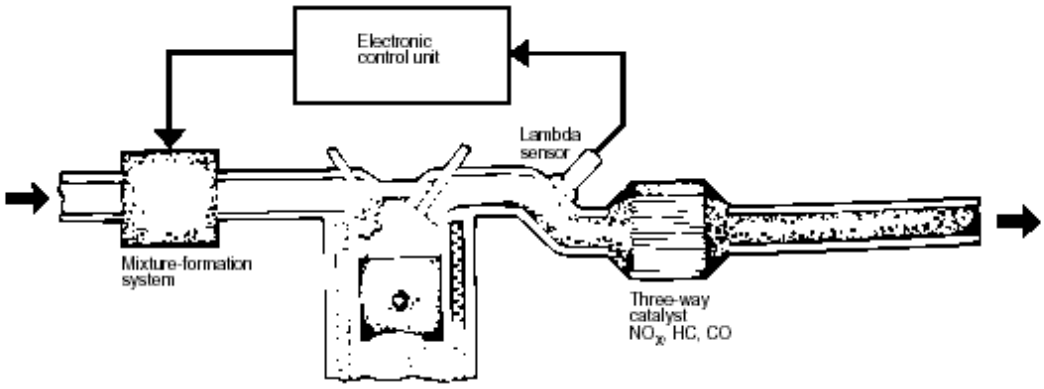
At the stoichiometric point, lambda = 1.000. A lambda value of 1.050 is 5.0% lean, and a lambda value of 0.950 is 5.0% rich. Once lambda is calculated, A/F ratio can be easily

determined by simply multiplying lambda times the stoichiometric A/F ratio for the fuel selected - e.g. 14.71 for gasoline, 15.87 for LPG, and 17.45 for CNG. Lambda measurement is absolutely critical, as the new generation vehicles fitted with catalytic converters requires that the lambda be maintained within its range.

Modern three-way catalysts require the air-fuel ratio (A/F) to be as close to stoichiometry (the amount of air and fuel just sufficient for nearly complete combustion) as possible. This is because three-way catalysts simultaneously oxidize HC and CO, and reduce NOx. Since HC and CO are oxidized during A/F operation slightly lean of stoichiometry, while NOx is reduced during operation slightly rich of stoichiometry, there exists a very small A/F window of operation around stoichiometry where catalyst conversion efficiency is maximized for all three pollutants. Said another way, three-way catalysts work with exhaust conditions where the net oxidizing and reducing chemistry of the exhaust is approximately equal, allowing the catalyst to promote complete oxidation/reduction reactions to the desired exhaust components, carbon dioxide (CO_2), water (H_2O) and nitrogen (N_2).

Contemporary vehicles have been able to maintain stoichiometry, or very close to it, by using closed-loop feedback fuel control systems. One of the important elements of the system is the oxygen or lambda sensor. The exhaust gas oxygen sensor (EGO or O_2), or lambda sensor, is the key sensor in the engine fuel control feedback loop. The computer uses the O_2 sensor's input to balance the fuel mixture. It would lean the mixture when the sensor reads rich and rich the mixture when the sensor reads lean *(See the Graph: How it works?)*.

How it works



Source: Asif Faiz et al, 1996, Air Pollution from motor vehicles, World Bank, Pg 68

With the help of the oxygen sensor, it is possible to maintain the vehicle at the stoichiometric conditions. As explained above, by maintaining the stoichiometry, the conversion efficiency for all the three pollutants is maximised. According to the website of Ford Car company: “The Lambda sensor, located in the exhaust system in front of the catalytic converter, constantly measures the remaining oxygen in the exhaust gases. It ensures the highest degree of effectiveness of the catalytic converter and at the same time lowest exhaust emissions.”

2. Lambda measurement

Lambda can be calculated by comparing the ratio of oxygen molecules to carbon and hydrogen molecules in the exhaust. With the help of the four gases, CO, CO_2, HC and O_2 in the exhaust using a four-gas analyser at high idle, lambda can be easily calculated.

Lambda measurement checks the performance of the fuel air mixture preparation system. For a well tuned/maintained vehicle lambda value should be 1 ± 0.03 in the range 0.97 to 1.03 as per international norms/practices. Any value beyond this range indicates faulty mixture preparation or poor performance of mixture preparation system. If the value were not in the specified lambda range, it would also result in sub optimal performance of the catalytic converter.

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_2, CO, O_2 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 checking the response of the lambda control system. 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 electronic lambda control circuit are measured and compared with auto manufacturers' specifications

3. What happens if the stoichiometry is not maintained

If the exhaust chemistry varies from stoichiometric conditions emission control is decreased. If the exhaust chemistry is net "fuel rich," meaning there is an excess of HC and CO emissions in comparison to the oxidation potential of the NOx and O_2 present in the exhaust, the excess HC and CO pollutants are emitted from the vehicle. Conversely, if the exhaust chemistry is net "oxygen rich" (lean burn), meaning there is an excess of NOx and O_2 in comparison to the reducing potential of the HC and CO present in the exhaust; the excess NOx pollutants are emitted from the vehicle. Thus it is very important that stoichiometry is maintained in a petrol vehicle.

4. The international experience on lambda tests

Internationally, lambda measurement is carried out in various countries and used as a regulatory tool. Lambda regulations are very easy to adopt and involves minimal costs. Thus this doesn't require a typical PUC operator to invest in new machines, as the current four gas analysers, which they are using to carry out the normal PUC tests, suffices.

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.

Similarly Hong Kong requires gasoline vehicles to be tested for low idle CO test for 0.5% by volume cut point or in accordance with manufacturers' specifications. In case of high idle test, the CO limit is 0.3 High idle, $\lambda = 1\pm 0.03$ or in accordance with manufacturers' specifications. Philippines has also introduced the similar test at high idle, with CO limit of 0.3% with lambda value of $\lambda = 1\pm 0.03$ is accordance with manufacturers specifications.

In UK for instance, two idle tests is applied to all petrol-fuelled vehicles first used on or after 1 August 1992. For cars subject to this procedure, the emissions are assessed during two separates tests. The first test consists of checking the emissions at 'high idle', which involves running the engine at the speed 2500–3000 rpm. During this high idle test the emissions of CO and HC will be checked and further check will be made on the lambda value.

The second test consists of a 'natural idle' test in which the engine will idle naturally between 450 and 1500 rpm, but for these vehicles only the CO emissions are assessed. The emissions limits are specified for both the high and low idle tests. At high idle CO <+0.3%, HC<+200ppm, and the lambda value will be between 0.97 and 1.03. At natural idle CO<0.5%. Where a failure is recorded during any element of the test, the analyser will automatically schedule an extended emission test.

Further the extended emissions test (e.g. vehicles with catalytic converters) applies to all petrol-fuelled cars fitted with advanced emissions control systems and which were first used on or after 1 August 1995, and to some petrol fuelled cars first used on or after 1 August 1992. The procedure is described below.

For cars subject to this procedure, the emissions are assessed during two separate tests. The first test consists of checking the emissions at 'high idle', which involves running the engine at speed typically 2500–3000 rpm. During this high idle test the emissions of CO and HC will be checked and a further check will be made on the Lambda value. The second test consists of the standard 'idle' test as described above but for these vehicles only the CO emissions are assessed. The vehicle must pass through the high and the normal idle emissions tests to secure a pass result.

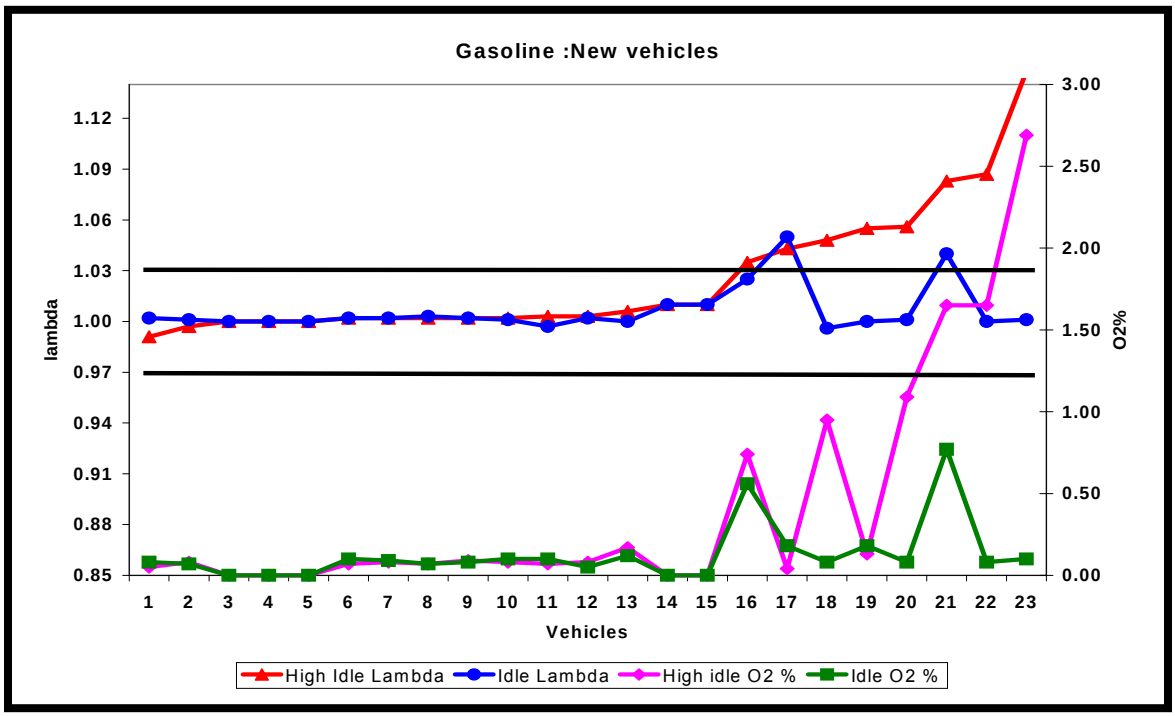
5. EPCA' review of Indian scenario and decisions taken

The Union Ministry of Shipping, Road Transport & Highways (MoRTH) in its notification dated February 10, 2004 GSR 111(E) said: "Provided that in case of petrol vehicles, fitted with 3-way closed loop catalytic converters, the government of the respective state of UT, as the case may be, may by notification in the official gazette, specify the introduction of measurement of LAMBDA (dimensionless value representing the burning efficiency of an engine in terms of the air/fuel ratio in the exhaust gases) and tighter emission norms for in-use vehicles…"

EPCA has been working to ensure that this regulation, provided by the ministry as an optional tool, to city governments is introduced in key hot spot cities of India. By making the lambda tests mandatory for all in-use petrol vehicles, which are fitted with the three-way catalytic converter and a closed loop system, and thereby maintaining the lambda at one, it would ensure the most efficient working of the catalytic converter. As explained above, if the lambda is maintained in its range, the conversion efficiency of the catalytic converter for all the three pollutants is maximised. Euro II was introduced in Delhi way back in the year 2000, as a result of which most of the petrol vehicles are already having three-way catalytic converter and a closed loop system. EPCA thus feels that it is very important that lambda be measured from these vehicles.

EPCA held various meetings with the ARAI on this issue. On the direction by EPCA, the ARAI conducted studies to gauge the lambda values from both the petrol and CNG vehicles and accordingly the ARAI conducted tests on the new and in-use vehicles.

Graph: New petrol vehicles failing



In an EPCA meeting with the ARAI held on October 16, 2004, ARAI presented the results of their studies, which were startling. It was observed that out of the 23 new gasoline vehicles tested by ARAI, close to 8 vehicles were failing on lambda. *(See Graph: New petrol vehicles failing)*.

This study therefore, found that it was possible to introduce lambda in the country, and in fact, it was imperative as even new vehicles were failing this basic regulatory test. EPCA is working on the mechanisms and modalities of how the lambda measurements should be introduced in the city. In December, EPCA wrote to all automobile manufacturers to know, at the earliest, if they have specifications for lambda value for their vehicles, which are different from the international practice of 1± 0.03. This would enable ECPA to proceed further, to implement the lambda test. This information was to be given to EPCA by January 15, 2005.

EPCA received two responses – from M/s Mahindra and Mahindra Ltd (M&M) and M/s General Motors Ltd (GM). M&M indicated that they would not be keen on the introduction of lambda in the city. The companies took the position that they are not in a position to give any specification of lambda value for their vehicles, as this was not a requirement so far. EPCA has noted this contention with considerable surprise; as it is evident if companies have been following international practice then they should have

been able to provide EPCA with a specified range for lambda, irrespective of the fact that the Indian government had not included it in the type approval certificate as yet.

The fact is that the new regulation of the government has already mandated the (optional) use of lambda. In the meeting convened on February 5, 2005, which was represented, by all the stakeholders- the SIAM, the Transport department, the PUC instruments manufacturers, and the ARAI it was therefore, agreed to implement the measure in Delhi, to begin with for all in-use petrol vehicles fitted with three-way catalytic converters, with a closed loop system. Based on this agreement certain key decisions were taken at the meeting so that lambda measurement could be implemented from May 15, 2005.

Taking the fact into consideration that Delhi would be the first city in the country to implement a mandatory lambda tests as part of the PUC programme, it was decided that to begin with a pilot study would be undertaken for a period of three months from February 15, to May 15, 2005. This period would be used to generate the necessary data for the introduction of the lambda tests in the NCT of Delhi.

EPCA feels it important to point out that this pilot study of 3 months has been initiated in spite of the fact that both the ARAI and the SIAM have over last few months already generated sufficient data on the lambda measurement. But on requests from ARAI and the automobile companies, represented by SIAM, EPCA thought it would be important to introduce a pilot study programme, so that more data would be gathered before introducing the lambda tests and the key steps for its implementation identified.

The schedule and action plan for implementation is as follows:

1. Lambda would be introduced as a regulatory norm with effect from May 15, 2005

2. The period from February 15, 2005 to May 15, 2005 would be used as a pilot study for the introduction of the lambda regulation. Lambda data would be generated to characterise the vehicle fleet for lambda regulation. This would help to map out the operational issues in the lambda measurement in the regular PUC. This exercise will also help to understand the repair solution if lambda is found off specification

3. The Delhi transport department would identify 10 pilot PUC centres in Delhi to start measuring lambda. These 10 PUC centres would represent various make of the PUC equipments. During the pilot phase lambda measurement would be conducted only to generate the necessary data. Vehicles won't be failed if the lambda is found to be off specification

4. Similarly the SIAM would also identify few authorised workshops of gasoline passenger car manufacturers in Delhi, which would measure lambda. This data along with the data generated from the pilot 10 PUC centres would serve as an input for introducing the norms

5. The ARAI would give the necessary protocol for the high idle lambda tests to be carried out in this pilot phase from February 15, 2005 to May 15, 2005

6. The PUC equipment manufacturers would provide the revolutions per minute (rpm) sensors to their respective centres, which fall among the 10 pilot PUC centres, at their own cost. This would enable measurement of lambda at high idle speed

7. The data generated from these pilot centres and automobile manufactures service centres, would be audited on a fortnightly basis by the ARAI, the transport department and the Centre for Science and Environment (CSE).

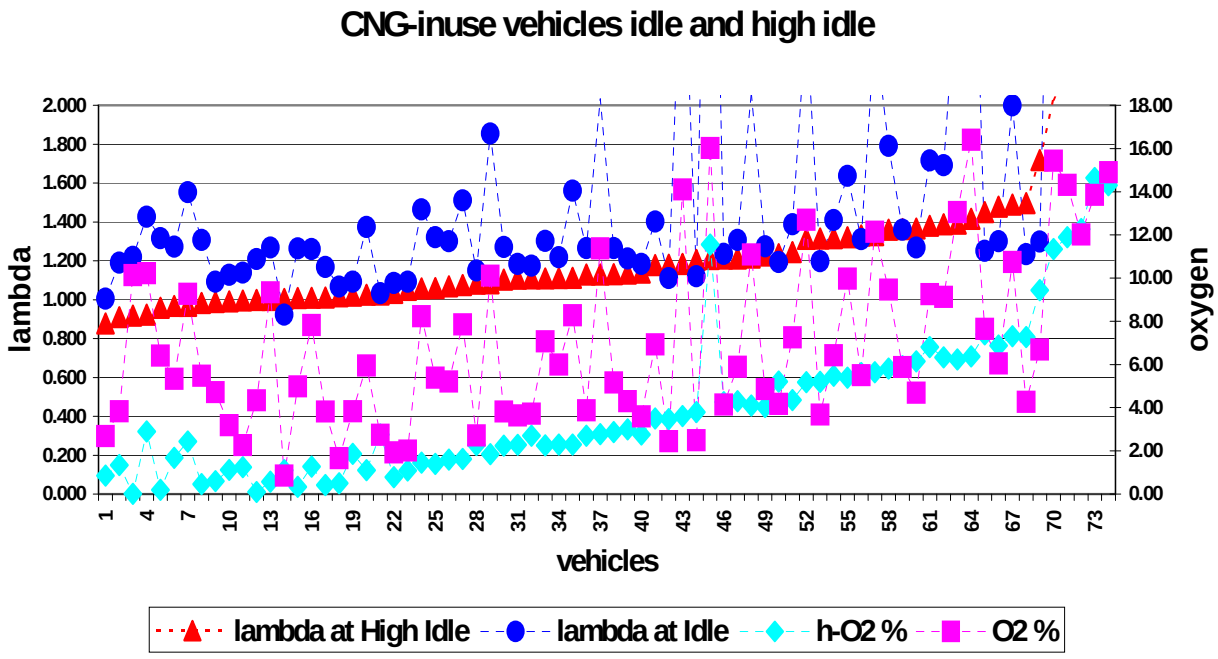
Thus the Transport department, the SIAM, ARAI, the PUC instrument manufacturers and so also CSE will work together to facilitate the introduction of lambda measurement in a time bound manner.

B. Introduction of lambda tests for CNG vehicles

Apart from the studies carried out on the new and in-use petrol vehicles, ARAI also tested Euro II CNG buses from Delhi, which are fitted with three-way catalytic converter and a closed loop system. These buses belonged mostly to the Delhi Transport Corporation (DTC).

The findings of the ARAI study were of concern. Most of the in-use vehicles had exhaust leakage *(See Graph: CNG buses are also failing lambda)*. Excess oxygen was noted in exhaust. ARAI explained that this could be due to the exhaust leakage.

Graph: CNG buses are also failing lambda



ARAI pointed out that during the initial trials carried out on the DTC buses, significant exhaust leakage was observed; with the result, it was found difficult to get valid reading of lambda on account of presence of excess oxygen in the exhaust. ARAI concluded from its study on CNG vehicles that the data validity is poor and hence, difficult to establish any relationship.

EPCA took a very stern note of the fact that CNG buses were failing the lambda tests conducted by ARAI. In the meantime ARAI has also written to the Transport department of

Delhi and advised them that before moving further it would be appropriate to take necessary steps for stopping the exhaust leakage from the DTC buses.

If the CNG buses plying in Delhi fitted with three-way catalytic converter were not able to remain within the lambda window, pollution from these CNG buses would obviously be of great concern. EPCA here would like to point out that in the study done jointly by the Minda Impco and the DTC, it was found that very few buses were actually running on the closed loop system. It is found that most of the operators have disabled the closed loop system. As the operators lean the mixture to pass the CO and HC tests or to increase the fuel economy of the vehicle, up to a point, NOx would automatically increase. To stop this it becomes very important that lambda is measured, as any tinkering with the mixture would automatically show up in the lambda value.

On discussions with the ARAI, EPCA was made to understand that as far as the introduction of lambda regulations for the petrol vehicles was concerned, it could begin soon without any problem, but for the CNG vehicles, it would still require time, as there was insufficient global experience on using lambda in CNG vehicles. Thus it was decided that while for petrol vehicles the lambda regulations could begin, the same for CNG vehicles could be done after more in-depth studies are undertaken.

EPCA would like to point out that as soon as the lambda regulations is enforced from May 15, 2005, for the petrol vehicles fitted with three way catalytic converters and a closed loop system, all the concerned stakeholders should again start a pilot study for the CNG vehicles in the city fitted with three-way catalytic converter and closed loop system. As a large proportion of the CNG buses are with the DTC, they too should be involved in the pilot study to ascertain the lambda. This would facilitate early and timely introduction of lambda regulations for the CNG vehicles.

Once lambda regulations are made mandatory for the CNG buses, it would help to keep a maintenance check on the buses operated by the DTC and so also the private operators.

C. Introduction of loaded mode tests procedures at Burari

Transport department of Delhi had signed an agreement with the Automotive Research Association of India (ARAI), Pune to provide the plan and technical assistance to set up the pilot demonstration project on inspection and certification centre at Burari. The plan that has been prepared includes facilities for both vehicle fitness and emissions tests. But the emissions test component is based on the current PUC system. EPCA has therefore intervened to demand addition of facilities that are required to measure emissions including NOx and PM. Over this EPCA has held series of meetings with ARAI and the Delhi government.

EPCA has reviewed the agreement on the *Pilot Demonstration System on the Inspection and Certification (I&C) Center at Burari'* between the Transport Department, NCT Delhi, and the Automotive Research Association of India, Pune. EPCA has noted with concern that I&C plan which includes both vehicle emissions and fitness tests is very weak on emissions test component. It is a status quo plan as it is based on the current provisions of PUC. This does not address the problem of NOx and PM emissions from in-use commercial fleet.

EPCA wanted to withhold the tendering process, which had already begun, based on the current plan, till the plan was revised to address these additional concerns. However, in view of the difficulties explained by the Delhi government EPCA has allowed the first phase of the tendering to commence.

Accordingly based on the requests from the transport department EPCA has split the revamping plan of the Burari centre into two phases. Thus Phase I would be the existing work carried out at the Burari and the Phase II would be the introduction of the loaded mode tests procedures.

But EPCA insisted that simultaneously the process of including the advance emissions tests as recommended by EPCA be initiated so that the entire I&C programme is implemented within the same time frame.

EPCA has already submitted to the Hon'ble court in August 2004 its report, "*Pilot project on the Inspection and Certification (I&C) Center at Burari, Delhi: Introduction of loaded mode test procedures for measurement of in-use emissions*." The key recommendations of the report were:

- Delhi government along with ARAI be directed to implement loaded mode test procedures for emissions measurement as agreed, in CNG and diesel commercial vehicles and this must be completed for full commercial operation by December 2005

- ARAI be directed to give a detailed technical plan and task flow with deadlines to implement loaded mode tests to EPCA

- In the meantime, as agreed, the PUC upgrade scheduled for implementation from October 2004 should include mandatory lambda measurement to test the health of the cat converters in CNG buses

The Delhi government in its affidavit filed in the Hon'ble court in January 2005 accepts the EPCA report. Accordingly the Delhi government clearly writes, "It is submitted that the GNCT of Delhi accepts the proposal of EPCA in present report on principle; however the actual implementation and execution of said directions depend upon the trial, research and development of pragmatic technology by ARAI." There is thus no difference of opinion on the issue of introduction of loaded mode tests procedures in the Burari centre.

Following the report, ARAI on the mandate given by the EPCA to introduce the loaded mode tests procedures, submitted a project proposal to the Delhi government. This phase II plan details out the equipment that would be purchased and the specifications of the same. The total cost is Rs 2 crore for the development of the methodology and its equipment for in-use emission tests for the heavy motor vehicles.

EPCA would like to note that the Delhi government has still not responded to the project proposal of the ARAI, and instead the transport department has written to the EPCA through a letter dated October 29, 2004 asking EPCA to "explore as to whether these projects can possibly be funded by the EPCA."

It is clear that this position is unacceptable. EPCA is not an executive agency, with funds. But, clearly, it has interest in ensuring that the tests are developed, as these are critical to check for growing NOx emissions from heavy vehicles. It is indeed strange, that government has not planned on the introduction of these tests, when it is clear that NOx emissions are on the increase in Delhi and in other cities as well. If we are to allow the use of vehicles in the country, we will also have to develop ways to be able to regulate and mitigate the problems that arise out of the use of these technologies. The cost to public health is in this situation, not accounted for.

Therefore, EPCA will continue its discussions with ARAI and Delhi government to negotiate the speedy implementation of the project. It is important that the Delhi government should raise the requisite funds for the implementation of the loaded mode tests procedures at Burari.

2. EPCA's conclusions

Given the current situation, EPCA would continuously monitor the implementation of the new in-use emission norms in the 8 critically polluted cities and so also work closely with the Delhi government and the ARAI to implement the loaded mode tests procedures.

The in-use emission programme is improving continuously under the guidance of EPCA and accordingly EPCA would review the programme at regular intervals and submit its progress report every six months.