88-96.6

PRESENTED AT THE 81st APCA
ANNUAL MEETING & EXHIBITION
JUNE 19-24, 1988
DALLAS, TEXAS, USA

A CONCEPT FOR AUTOMOTIVE EMISSION CONTROL IN DEVELOPING COUNTRIES

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Abstract

A significant number of cities, in Brazil, are facing serious motor vehicle generated air pollution. In an effort to address this problem, the National Environment Council (Conselho Nacional do Meio Ambiente) enacted, on May 6th 1986, Resolution Nº 18, which establishes, nationwide, the automotive emission control program, which has been named PROCONVE. This paper outlines this emission control program and offers its design concept as a model for select developing countries.

Introduction

The world motor vehicle fleet approached, in 1985, 500 million cars, trucks, buses, motorcycles and mopeds (1). This massive usage of motor vehicles, besides the mobility it provides and the significant contribution it brings to the economy, is also accompanied by an undesirable environmental impact - air pollution.

The recognition that motor vehicle generated air pollution has been imposing socioeconomic costs and environmental damage in the industrialised countries led the governments of these countries to take action trough the enforcement of emission control regulations. This action was needed because the governments could not rely on the good will of the motor industry, or on external effects such as market pressures, for the development of technology to reduce the noxious emissions. As the result of these "technology forcing regulations", today's vehicles are significantly cleaner than their uncontrolled predecessors reaching, in certain countries, emission reduction levels above 90%.

It is generally recognised that the motor vehicle air pollution problem observed in a considerable number of developing countries has been caused by the fast and continuous urbanization process, resulting from rapid industrialisation. Cities such as São Paulo, Rio de Janeiro, Seoul, Mexico City, Athens, Calcutta, Bangkok and Santiago, just to mention a few, are now facing air pollution problems similar to, and in some cases worse, than those of the developed countries.

In attempting to examine the feasibility of actions directed to regulation and control of automotive emissions in developing countries, one must understand the cultural and socioeconomic realities of nations emerging from underdevelopment. The blanket term "developing countries" is used in an indistinguishable way to refer to countries such as Bangladesh and Brazil, which have little in common. Therefore, it is apparent that there is no a "standard" approach to regulate and control automotive emissions in these countries. However, since the production of motor vehicles is a worldwide business and since in its operation, any motor vehicle burns fuel and emits the byproducts into the atmosphere, there are general principles that apply to any automotive emission control program.

This paper outlines the Brazilian automotive emission control program and offers its design concept as a model for select developing countries.

The Brazilian Automotive Emission Control Program

In Brazil, important metropolitan areas, such as São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, Recife, Porto Alegre and Curitiba, with a collective population of approximately 40 million, have been experiencing increased motor vehicle air pollution especially during the last two decades. The São Paulo Metropolitan Area (SPMA) is probably the worst case. Its fleet of approximately 3 million vehicles is responsible for the degradation of the air quality that about 15 million people breathe.

In 1987, CETESB - the Environment Control Agency for the State of São Paulo, recorded, in the City of São Paulo, 38,6 ppm (8 h average) of carbon monoxide (CO). This high concentration represents about 4 times the present air quality standard of 9 ppm (8 h average) for CO, and it exceeds the 15 ppm and 30 ppm (8 h average) Attention and Alert levels, of the Air Pollution Acute Episode Criteria for the State of São Paulo. The emergency level, which requires a complete halt to all motor vehicle activities is at 40 ppm (8 h average) and, in this episode, it was almost reached. Table I presents the peak concentrations for various pollutants recorded in the City of São Paulo during the years of 1981-1987 (2).

For comparison purposes, Table II shows the air quality standards adopted in Brazil.

Table I. Peak concentrations of ambient air pollutants in the City of São Paulo.

Pollutant	Peak concentrations	
carbon monoxide (8 h average)	38,6	ppm
oxidants (as ozone, 1 h average)	0,226	ppm
sulfur dioxide (24 h average)	0,15	ppm
total suspended particulates(24 h average)	759	$\mu g/m^3$
nitrogen oxides (annual average)	0,509	ppm
nitrogen dioxide (annual average)	0,066	ppm
non-methane hydrocarbons (3 h average)	4,0	ppmC
aldehydes (as formaldehyde, 24 h average)	0,159	ppm

Table II. National air quality standards

Pollutant	Sampling time (h)	Standard	Reference method
carbon monoxide	1[a] 8[a]	35 ppm 9 ppm	NDIR[d]
oxidants (as ozone)	1[a]	0,08 ppm	Chemiluminescence
sulfur dioxide	24[a] AAM[c]	0,14 ppm 0,03 ppm	Pararosaniline
total suspended particulates	24[a] AGM[b]	240 $\mu g/m^3$ 80 $\mu g/m^3$	Hivol sampler

[a]Not to be exceeded more than once a year

[b]Annual geometric mean

[c]Annual arithmetic mean

[d]Non dispersive infra red

The contribution of motor vehicles to air pollution in the SPMA can be seen in Table III. It is clear that motor vehicles are the major source of CO, hydrocarbons (HC) and nitrogen oxides (NO_x), and less important contributors of sulfur oxides (SO_x) and particulates (PM). Although PM is emitted mainly from industrial sources, the PM emitted by motor vehicles, particularly from diesel vehicles, due to their tiny size, chemical properties, emission at street level and persistence in the atmosphere, may pose a greater risk to public health than some of the particulates emitted in greater quantities from industrial sources.

Evaluation of automotive contribution to air pollution in Brazil has, in general, been based on available data regarding fleet size, emission factors, fuel quality, vehicle maintenance, traffic conditions and meteorology, rather than on air quality data, because of the inadequacy or inexistence of air quality monitoring networks. One exception is the SPMA, which has had such a network in operation since 1981. To date, the air quality data monitored in the SPMA and a few other places, complemented by estimatives of motor vehicle emission, indicate that motor vehicle air pollution is probably severe in many areas and may become a problem in the foresseable future in other areas.

In order to cope with this situation, CETESB presented to the Federal government, in 1984, a technical proposal for the establishment of a national emission control program. This proposal was designed to address the following local peculiarities:

a) Brazil has a well-established motor vehicle industry, which exports parts, components and vehicles to several countries, including the U.S.A. and Italy, which have ongoing automotive emission control programs. Therefore, the motor vehicle industry has some experience in emission control.

b) Brazil has its own oil refining industry, however,the country still depends on oil imports.
Because of the huge external debt, low quality oil is usually imported, resulting in fuels with a high sulfur content (up to 1,3% in diesel fuel and up to 0,25% in gasoline).

c) The National Alcohol Program, launched in 1975, has been responsible for a considerable reduction in the use of lead as an octane booster. Lead has been replaced by a blend of 22% anhydrous ethanol to gasoline, however, due to the operation of a few old refinaries and sporadic shortages in the alcohol supply, lead is still added to gasoline in a number of places in varying concentrations.

The extensive use of alcohol, either as a blending component in gasohol or as a straight fuel, requires the development and use of appropriate materials and coatings for automotive parts. In addition, certain emission control technologies, such as fuel injection and catalytic conversion, must be adapted to the use of alcohol and tested for pollution reduction efficiency, durability and reliability.

About 95% of light duty vehicle sales are alcohol fueled vehicles, however, there is no guarantee that this proportion will continue because of the considerable reduction of new investments in alcohol production.

An additional question related to alcohols is their capability of producing aldehydes during combustion and the effect of these compounds on air quality.

d) The instruments and equipment used in automotive emission testing, besides being expensive, are imported. Therefore, unless manufacturers are forced by legislation or pressed by export sales, they will not invest in laboratories and testing fields for emission control research and development.

e) Brazilian cities have no inspection and maintenance programs, either for safety or for emission control. In addition, repair shops are staffed with semi-skilled personnel, who generally rely on a trial-and-error self experience rather than on technical knowledge and analytical instruments, for diagnosis and repair. This situation results in erroneous tune ups and general poor vehicle maintenance.

f) Fuel retailers have been found to alter fuel specifications by mixing water and other substances with the commercial fuels.

g) The average life of light duty vehicles is, acoording to CETESB's evaluation, 12 years.

h) The Federal and State governments have had some difficulties in obtaining the desirable human and material resources to deal with automotive emission control.

After two years of intense technical and discussions involving the Federal and State Governments, the National Motor Vehicle Manufacturer's Association (ANFAVEA) and other interested parties, some modifications were introduced in CETESB's proposal. The regulatory text was then submitted to the National Environment Council (Conselho Nacional do Meio Ambiente - CONAMA) which enacted, on May 6th 1986, Resolution nº 18, which establishes, nationwide, the Brazilian automotive emission control program, which has been named PROCONVE (3).

The Program is based on successful international experiences, that were adapted to local conditions, and it was conceived according the following key lines:

- Only new engines and vehicles are required to comply with the established emission limits;
- Emission limits that progressively become more stringent are phased in according to a schedule which is based on the state of technology in Brazil and the international experience;
- Emission test methodologies follow international trends and therefore promote standardisation;
- Prototype, assembly-line and aftermarket parts certification is required in order to guarantee product quality and conformity;
- Manufacturers are required to warrant emission conformity to guarantee the emission control systems durability;
- Adjustable components which may significantly affect emission are required to be sealed by the manufacturer or incorporate inviolable limiting devices for the permissible gauging range to avoid maladjustments during tune-ups;

- Manufacturers are required to present, semi-annually, emission data from their quality control programs; based on this data, production approval for certain engines or vehicle configurations may be withdrawn, therefore optimizing the certification process.
- State or City Administrations are authorized at their discretion to implement inspection and maintenance programs (I/M) in order to verify the effectiveness of the emission control systems in consumer use and to foster adequate maintenance;
- New types of fuels and modification of present fuel specifications may be adopted after approval by the Administration;
- The Administration may order a recall, if through special checks or inspection and maintenance programs, it is verified that adequately maintained vehicles in use do not comply with the emission limits. All costs involved in such action are borne by the manufacturer;
- Due to the use of ethanol as an automotive fuel, the Administration may establish emission limits for the so-called unregulated compounds, such as aldehydes, alcohols and other organic compounds. As for hydrocarbons, this class of pollutants is defined as the total amount of organic substances, including unburned fuel fractions and combustion byproducts occurring in exhaust gas, and which are detected by the flame ionisation detector;
- To promote public awareness with respect to the program and the issue of air pollution by motor vehicles, the manufacturers are required to furnish specifications and recommendations to the owner, the service network and to the public through the owner's and service guides, the media and labels placed on all vehicles;
- The National Petroleum Board (CNP) is requested to establish a program for reducing the total sulfur content from the diesel fuel, to specify and oversee the total exclusion of lead in the ethanol/gasoline blend and to ensure that ethanol is not

contaminated by lead during transport or storage;

. For the purposes of management and permanent evaluation, the National Environment Council instituted the "PROCONVE Follow-Up and Evaluation Committee", coordinated by the Special Secretary for Environment Affairs (SEMA) and composed of eleven top government officials who are qualified to identify and propose measures for optimizing the program, deliberate on penalties to be imposed, supervise and control the enforcement of the program, grant exemptions, waivers etc.

Table III presents the emission test procedures adopted in Brazil. They were chosen because of their proved suitability to Brazilian conditions and because they represent the confidence that considerable investments in emission laboratories will not be lost in a few years due to obsolescence. In fact, the U.S. emission test procedures for light duty vehicles and the European test procedures for diesel engines are, presently, the best combination of cost-effectiveness and state-of-the-art applicability. The use of modern emission test procedures, such as those adopted in Brazil, discourage the use of second-rate vehicle production technology, still in use in many developing countries.

Table III. Emission test procedures adopted in Brazil

Type of emission	Type of vehicle	Emission test procedure
Exhaust	LDV [a] - Otto engine	U.S. 75 Federal test procedure
	LDV - Diesel engine	Europen "13 Mode" test procedure
	HDV [b] - Diesel engine	Europen full-load steady state test procedure (smoke)
	HDV - Otto engine	U.S."9 Mode" Federal test procedure
Evaporative	LDV - Otto engine	U.S. SHED Federal test procedure

a LDV - light duty vehicles

b HDV - heavy duty vehicles

Tables IV and V present the established emission limits for light duty vehicles (LDV) and for heavy duty vehicles (HDV), respectively, and Table VI shows the required emission limits warranty for both LDV and HDV. More details about the PROCONVE are described elsewhere (4).

Table IV. Emission limits for Brazilian alcohol and gasoline light duty vehicles.

Type of emission	Effective date	Remarks	Emission limits g/km CO	HC	NO_x	% Idle CO
Exhaust	Jun 1st, 88.	Brand new vehicle configurations	24,0	2,1	2,0	3,0
	Jan 1st, 89.	50% of sales is the minimum required				
	Jan 1st, 90.	100% of sales except LDT [b]				
	Jan 1st, 92.	Only LDT				
	Jan 1st, 92.	100% of sales except LDT	12,0	1,2	1,4	2,5
	Jan 1st, 97.	All LDV [a]	2,0	0,3	0,6	0,5
Evaporative	Jan 1st, 90	All LDV	–	g/test 6,0	–	–
Crankcase	Jan 1st, 88.	All LDV	emission shall be nill under any engine operating conditions			

[a] LDV – light duty vehicles

[b] LDT – light duty trucks

Table V. Emission limits for Brazilian heavy duty vehicles.

Type of emission	Effective date	Remarks	Emission limits
Exhaust	Oct. 1st, 87.	only for urban buses powered by Diesel engines	k = 2,5 (smoke)
	Jan. 1st, 89	all vehicles powered by Diesel engines	
	to be proposed until December 31, 1988.	- only for vehicles powered by Diesel engines	k = 2,0 (smoke)
		- for vehicles powered by either Diesel or Otto engines	shall be proposed until December 88 for CO, HC, NO_x
Evaporative	to be proposed	only for vehicles powered by Otto engines	to be proposed
Crankcase	Jan. 1st, 88	only for urban buses powered by Diesel engines	emission shall be nil under any engine operating conditions
	to be proposed until December 31, 1987	all vehicles powered by Diesel engines	
	Jan. 1st, 89	all vehicles powered by Otto engines	

[a] The light duty vehicles powered by Diesel engines follow the same prescriptions established for the heavy duty vehicles.

[b] The smoke limit was established according to the European procedure, which is based on the equation $c = k\sqrt{G}$, where c is the carbonic concentration, in g/m^3, G is the exhaust gas flow in l/s and k is a constant that represents the smoke level.

Table VI. Emission limits warranty

Type of vehicle	Warranty requirements	Remarks
Light duty vehicles	80,000 km/5 years, whichever occurs first	Testing procedures to be established; in the meantime, the warranty may be replaced by a 10% reduction in the emission limits, except for idle CO.
Heavy duty vehicles	160,000 km/5 years, whichever occurs first or equivalent results on a dynamometric testing procedure	

Applicability for Developing Countries

The concept and structure utilized in the design of Brazilian automotive emission control, could be of use in most Latin American countries and possibly, in other developing countries, particularly those which already import vehicles from Brazil. The reasons are the following:

a) Emission limits and other complementary requirements are based on modern test procedures, are established in a progressive multi-step process and are regulated well in advance, according to the local state of technology. This allows, in the long run, adequate planning for product development and investments, which are, generally, crucial issues in developing countries;

b) Periodically, the manufacturers have to provide emission data reports which characterize the "typical" emission of their vehicles. This production control approach is very cost-effective, because it goes hand-in-hand with the standard quality control procedures used by the manufacturer. Therefore, extensive emission testing by both, government and industry, can be considerably reduced. In addition, the emission data reports provide valuable information for a permanent follow-up of the automotive technological development in the country.

c) Recognizing that technological harmonization can have a positive effect on the regional economy (5), it seems advantagecus, for each country in Latin America, to adopt emission control requirements that are based on an existing control program, which is sufficiently close to local needs und socioeconomic and cultural realities.
Not only does this save the manufacturers the costs and the problems related with the production of special products for each country but allows vehicles and parts to be used interchangeably.

d) Most Latin American countries import vehicles from Brazil, therefore, they could take advantage of the technological development which is being incorporated into the vehicles for sale in Brazil.
This also applies to countries like Argentina, which is starting to use alcohol as an automotive fuel and could share the Brazilian experience with alcohols.

Conclusions

1) The Brazilian automotive emission program is a product of a regulatory philosophy that, although considering the constraints of a developing country, places the use of best available technology as a feasible goal. Additionally, it incorporates some very cost effective requirements, such as the manufacturer's quality control emission data reports, which considerably reduce extensive emissions testing and optmize both, the certification process and the establishment of enforcement schedules.

2) Despite cultural and socioeconomic characteristics, which differentiate each developing country, there are certain general emission regulation principles that apply to all countries. Therefore, the Brazilian automotive emission program could be the nuclei of a regional program in Latin America. This proposal could be associated with the establishment of an intergov-

ernmental association which would assist its Latin American partners in managing local emission programs, would run emission tests and would promote technological harmonization.

3) Countries that already import vehicles from Brazil can benefit from the automotive emission control program, either by requiring export cars to meet the Brazilian emission limits and durability requirements or by adapting the emission program to local conditions.

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