ZERO EMISSION VEHICLES

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Summary

In the last two decades, considerable reduction of major industrial emissions of polluting substances has been achieved. Public understanding of the problems has lead to the development of advanced technologies. For mobile sources, these include internal combustion engines and vehicles, which are at least twice more energy efficient and produce only several per cent of the emissions, characteristic for vehicles produced twenty years ago. Still sustainable development has not been achieved. The total emissions from mobile sources for many pollutants are increasing. Emissions of the primary greenhouse gas carbon dioxide have not been seriously addressed by modern pollution control technologies. Several international agreements concerning the reduction of these emissions have been negotiated. Although the Kyoto protocol has not been ratified by major developed countries yet, many of them have started practical initiatives for reduction carbon dioxide. The concept for zero emission vehicles is one of the strategically important steps towards the radical reduction of transportation emissions.

The term ‘zero emission vehicles’ is usually related to the year 1990 when the California Air Resources Board in the USA has adopted a strategy for introduction of zero emission vehicles. The new regulations envisaged that two per cent of all new passenger and light duty vehicles sold in 1998 should be without any emissions. The portion had to become five per cent by the year 2001, and ten per cent by the end of 2003. The first two milestones were reconsidered in 1996, and the third - in 2000. Still, the task for ensuring a significant impact of zero emission vehicles on the market and a

relevant influence on the environmental pollution remains.

This chapter outlines the major developments in environmental legislation and technology which lead to the introduction of zero emission vehicles. It also discusses in general the achievements and future problems facing zero emission vehicle technologies.

1. Introduction

Previous articles have outlined the main tendencies in the development of the world in the end of the 20th and the beginning of the 21st century. In the last two decades of the 20th century, considerable reductions of major industrial emission of polluting substances have been achieved. Advanced technologies have been developed. For mobile sources, these include engine modifications, post combustion treatment of exhaust gases, alternative fuels, reformulated gasoline, inspection and maintenance programs, etc. Internal combustion engines and vehicles today are at least twice more energy efficient, and produce only several per cent of the emissions, characteristic for the vehicles produced twenty years ago. Still sustainable development has not been achieved. The overall effect of the environmentally more compatible transportation technologies has been negated largely by increased transportation activities. The latter are projected to rise even steeper in the 21st century. Acquisition of new vehicles worldwide is following the same trend. Figure 1 illustrates the sharp increase in the driving activities in the USA.

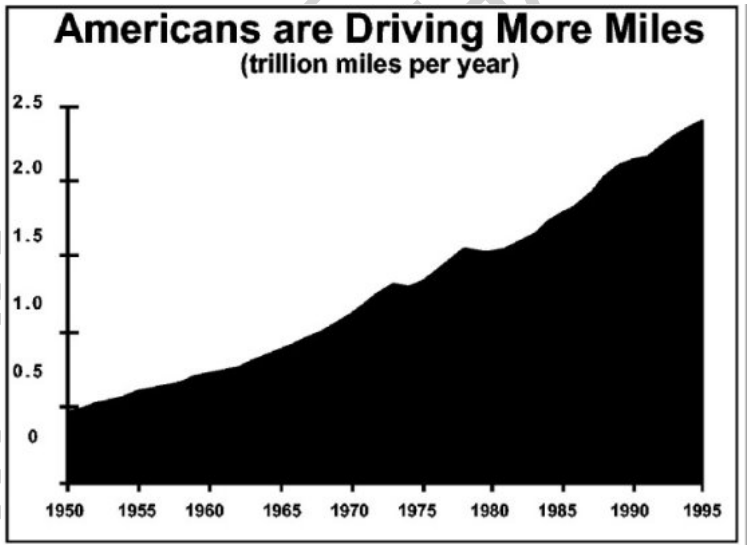

Figure 1: Driving Activities in the USA, Compensating the Effect of Vehicle Pollution Control.

The total emissions from mobile sources for many pollutants are still increasing. Emissions of the primary greenhouse gas carbon dioxide (CO_2) have not been seriously addressed yet by modern pollution control technologies. Several international agreements concerning the reduction of CO_2 emissions have been negotiated. Although the Kyoto protocol has not been ratified by the USA, all developed countries, have started practical initiatives for carbon dioxide reduction. One of the strategically

important steps towards the radical reduction of transportation emissions is the concept for zero emission vehicles. The practical introduction of the term zero emission vehicles (ZEVs) is usually related to the year 1990. In that year the California Air Resources Board (CARB) in the US has adopted a strategy for introduction of ZEVs. The new regulations envisaged that two per cent of all new passenger and light duty vehicles sold by six major manufacturers in California in 1998 should be without any emissions. The portion of zero emission vehicles had to become five per cent by the year 2001, and ten per cent by the end of 2003. The first two milestones were reconsidered in 1996, and the third – in 2000. The task for providing a significant impact of ZEV technologies on the market remains – ZEVs offered in California should gradually reach 16 % in 2018.

2. The Emerging of the Zero Emission Vehicles Concept

The achievement of zero anthropogenic emissions is the natural target of all environmentalists. However, the practical implementation of zero emission concepts requires not only a certain level of technological development but also development of the public understanding and motivation for the need of investment in such technologies. Market costs which are affordable for the average consumer are also an important pre-requisite. In this regard, it is interesting to follow in brief the US example of the road towards the introduction of the zero emission vehicles technologies.

2.1. Development of Emission Regulations towards ZEV

The development of emission regulations in the US in general was characterized by imposing stricter control of all significant pollutants emitted by the specific vehicle classes. It also gradually widened the types of pollutants and types of vehicles included. In order to save time and space, hereunder only the progressive reduction of the NO_x emissions from new cars and light duty trucks will be presented as a numerical illustration. The control of these emissions represents a specific challenge (see *Control of Exhaust Emissions from Internal Combustion Engined Vehicles* and *Catalytic Converters and Other Emission Control Devices*).

In 1970, the US Congress passed the Clean Air Act, which postulated the first standards for vehicle exhaust emissions. Three criteria pollutants were going to be controlled - carbon monoxide (CO), volatile organic compounds (VOC), and oxides of nitrogen (NO_x). The new standards implemented in 1975, for cars and light-duty trucks allowed the emission of 3.1 grams of NO_x per mile (one gram per mile, gpm = 0.62 g per kilometer).

In the period between 1977 and 1988, the US emission standards were tightened for the first time. Later, tightening of standard emissions became the normal behavior, which society expected from environmental agencies. In 1977, the US Congress amended the Clean Air Act providing for the achievement of the stricter emission standards in two steps. Firstly, between 1977 and 1979, the NO_x standard for new cars became 2.0 gpm. Then in 1981, the NO_x standard for cars was reduced to 1.0 gpm. From 1979, the US Environmental Protection Agency (EPA) tightened also the standards for new light-duty trucks to 2.3 gpm. Then in 1988, EPA introduced the first exhaust emission standards for heavier trucks, which were set at 1.7 grams of NO_x per mile. The standard for lighter

trucks was brought down to 1.2 gpm.

In 1990, the US Congress again amended the Clean Air Act. The NO_x standard became 0.6 gpm for cars, effective in 1994. The new set of standards was called "Tier 1". For trucks, Tier 1 allowed ranges from 0.6 to 1.53 gpm, depending on the weight of the vehicle. The Clean Air Act Amendments of 1990 also required EPA to develop a strategy for the future. The latter included the assessment of the air quality needs, cost - effectiveness, and feasibility of tighter emission standards for the 2004 model vehicles and beyond. The state of California and its Air Resources Board (ARB) in the mean time had decided to develop own advanced regulations, which were tighter than the federal regulations. The reason for this is the higher than average pollution in this state and – on the other hand, the considerable capabilities of the state to attract investments in environment protection. It was at this time that the CARB declared the zero emission vehicle program, calling for 20 000 ZEVs in 1998, 50 000 ZEVs in 2001 and 200 000 ZEVs beyond 2003. As already mentioned, after a careful assessment in 1996, the first two requirements were dropped out. However, ARB of California negotiated with seven manufacturers, participating in the zero emission vehicle programs, compensations for the expected emission reductions from ZEVs. The center of these was the voluntary advanced participation of the particular companies in the National Low Emission Vehicles (NLEV) program in 2001 instead of after 2003, and the commitment to further investments in the development of ZEVs.

In 1998, the NLEV voluntary agreement was signed by the US Administration, the auto industry and the Northeast states. The aim of the agreement was to put cleaner cars on the road before they were mandated under the Clean Air Act. The first NLEVs under the agreement were offered to consumers in New England in 1999. The rest of the states had these cars on the market in 2001. NLEV cars operate with a NO_x standard of 0.3 gpm, a 50 percent reduction from Tier 1 standards. The NLEV agreement also introduces a 0.5 gpm NO_x standard for lighter trucks, a 17 per cent reduction from Tier 1 requirements for these vehicles. In 1998, as required by the Clean Air Act Amendments of 1990, EPA issued the Tier 2 Report to Congress. The report provided evidence of the need, cost-effectiveness and feasibility for tighter tailpipe emission standards in the years after 2004. Three main factors were pointed out by EPA in support of the Tier 2 proposed regulations:

- Vehicles in 1998 make up 30 per cent of the smog-forming emissions in USA. The number of miles driven is increasing (up 127 per cent since 1970), so they will continue to be a significant contributor to pollution;
- Larger vehicles like sport utility vehicles (SUV), which are 50 per cent of the vehicles sold, pollute three to five times more than cars, while not being covered by the same emission standards.
- The cost-effective technology, which can meet the tighter standards, is available.

EPA also called for sulfur reductions in gasoline in order to enable the full performance of low emission-control devices.

In 1999, EPA published the proposed Tier 2 exhaust emissions standards. Their implementation had to begin in 2004. Both cars and light-duty trucks are subjected to the same pollution control system for the first time. The new standard for NO_x is 0.07

gpm, a 77-86 per cent reduction for cars and a 92-95 per cent reduction for trucks beyond the NLEV agreement. Seven "bins" were introduced as seven steps for reduction of pollutants. Table 1 illustrates one typical classification of vehicles in bins.

Bin No.	Nitrogen oxides (NO_x), g km^{-1}	Non-methane organic gases (NMOG), g km^{-1}	Carbon monoxide (CO), g km^{-1}	Aldehydes (HCHO), g km^{-1}	Particulate matter (PM), g km^{-1}
7	0.12	0.077	2.6	0.011	0.010
6	0.09	0.056	2.6	0.011	0.010
5	0.04	0.056	2.6	0.011	0.005
4	0.04	0.034	1.3	0.007	0.005
3	0.02	0.043	1.3	0.007	0.005
2	0.01	0.006	1.3	0.002	0.005
1[a]	0.00	0.00	0.0	0.000	0.000

Source: Adapted from the US Federal Register (1999). Part III. Environmental Protection Agency, 40 CFR Parts 80, 85 and 86. Air Pollution; Tier 2 Motor Vehicle Emission Standards and Gasoline Sulphur Control Requirements; Diesel Fuel Quality Controls; Proposed Rules.
[a] – Zero Emission Vehicle (ZEV).

Table 1: An Example of a Bin Tier 2 Exhaust Emission Standard for Light-Duty Vehicle Full Useful Life (120 000 miles = 193 120 km).

EPA also proposed a reduction in average sulfur levels of gasoline from the 300 ppm to an average of 30 ppm, with an allowed maximum of 80 ppm to achieve the full performance of catalytic emission control technologies. In 1999, an EPA announcement of proposed rule making, concerning the reduction of sulfur in diesel fuels was published. Gasolines and automotive diesel fuels sold in the USA, EU and the rest of the developed countries should have not more than 10 ppm sulfur in 2008.

As part of the Tier 2 standards, EPA has included several measures to ensure maximum flexibility and cost-effectiveness. These measures include:

- Allowing averaging to meet both the car emission and gasoline sulfur standards.
- Allowing extra time for larger vehicles and smaller refiners to meet their respective standard.
- Allowing for a market-based credit trading-and-banking system for both industries to reward those who lead the way in reducing pollution.

As a result of the above briefly described history, the amount of NO_x in exhaust emission of new cars was reduced from 3.1 in 1975 to 0.3 gpm in 1999. Under Tier2, NO_x will be further reduced for all cars, SUVs, light duty trucks, etc. to 0.07 gpm. Reductions for the other criteria pollutants follow a similar pattern. The reductions of the exhaust emissions in the state of California as usual are greater than the federal standards.

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Biographical Sketch

Georgi St. Cholakov is Associate Professor at the University of Chemical Technology and Metallurgy in Sofia. He received his first hands-on experience of ecological problems during compulsory his military service as the Head of the Fuels and Lubricants Unit of an airbase. His PhD dissertation was on development of replacements for lubricant additives synthesized from the sperm oil, obtained from blue whales. He did a post doctoral specialization in tribology at the University of Birmingham, U.K. Later he specialized in effective and ecological processing and use of petroleum derivatives at Imperial College, London, the French Institute of Petroleum, and other leading universities. The scientific and research interests of G. St. Cholakov are centered around petroleum processing and petroleum derivatives – environmentally compatible processes and products, process and product design for the petroleum industry, chemistry of combustion and ecology, etc. He is teaching advanced courses in related academic disciplines – alternative fuels and lubricants, air pollution management, chemistry of combustion and ecology, additives for fuels and lubricants, technological computation in petroleum processing, etc. He has contributed more than 50 papers in refereed international journals and co-edited the Bulgarian edition of Miall's Dictionary of Chemistry. He is member and has served in elective positions in different Bulgarian and Balkan professional organizations. He has been member of the editorial boards of two journals, published in Bulgaria in the English language.