motor vehicle emission regulations and fuel specifications part 2 detailed information and historic review (1970-1996)

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ABSTRACT

This report details the development of world-wide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption from circa 1970 to 1996. It describes legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes and legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions, plus automotive fuel specifications and fuel characteristics.

This comprehensive work of reference should be read in conjunction with Part 1, which has been issued as a separate volume. Part 1 summarises the most important legislation, either in place or shortly to be enacted. It is therefore intended that Part 1 will be updated annually, whereas this report - which reviews the history of automotive emissions legislation - will be revised at appropriate, longer term intervals.

KEYWORDS

Vehicle emissions, legislation, automotive fuels, specifications

CONTENTS

INTRODUCTION - HOW TO USE THIS REPORT

This report collects together in one place the most important worldwide laws and regulations relating to motor vehicle emissions and automotive fuel specifications. The amount of material to be covered has increased steadily over the years, and has lead to a bulky report which was becoming difficult to use and time consuming to update on an annual basis. In an attempt to resolve this problem, the 1995 update was restricted to Europe and North America, although this was acknowledged to be only a temporary solution. Consideration was also given to deleting the historical background, but this is a unique feature which it was considered important to retain.

Thus the 1996 report is once again comprehensive in its scope, and includes all the major oil consuming countries, plus the historical background contained in previous updates. However, considerable attention has been given to improving ease of use, the major result of which is that the report is now divided into two separate publications, as described below:

Part 1 is a summary of current and future automotive emissions legislation and fuel quality regulations.

All the major oil consuming countries from which information is available are included. To make the document easy to use, the amount of detail and background information contained in **Part 1** is limited; instead, references to the more comprehensive information contained in **Part 2** are included where appropriate. References to sections and tables in Part 2 will contain the prefix "A"; where there is no prefix, the reference will be found in Part 1.

Part 1 is divided into the following sections:

1. VEHICLE EMISSIONS LEGISLATION
2. EMISSIONS AND FUEL ECONOMY TEST PROCEDURES
   - in Part 1 only references to the detailed information contained in Part 2 are given
3. IN-SERVICE EMISSIONS LEGISLATION
   - including Inspection and Maintenance Programmes and On-Board Diagnostics
4. FUEL CONSUMPTION AND CO_2 REGULATIONS
5. FUEL QUALITY REGULATIONS
   - full details of fuel specifications are contained in Part 2
6. ACKNOWLEDGEMENT
7. GLOSSARY AND VEHICLE CLASSIFICATIONS
8. INDEX

It is intended that **Part 1** will be kept up to date with regular annual revisions.

Part 2 contains detailed supporting information and historical background.

It is a comprehensive reference document to be used in conjunction with Part 1. It is arranged by topic in the same way as Part 1:

A.1. VEHICLE EMISSIONS LEGISLATION
- including historical data going back to 1970

A.2. EMISSIONS AND FUEL ECONOMY CYCLES AND TEST PROCEDURES, I&M PROCEDURES

A.3. IN-SERVICE EMISSIONS PERFORMANCE LEGISLATION AND ON-BOARD DIAGNOSTIC SYSTEMS

A.4. FUEL CONSUMPTION AND CO_2 REGULATIONS

A.5. FUEL QUALITY REGULATIONS AND SPECIFICATIONS
- including detailed specification information and sales volume data

A.6. ACKNOWLEDGEMENT

A.7. GLOSSARY AND VEHICLE CLASSIFICATIONS

A.8. INDEX

Important additions to the information contained in Part 2 will be issued as appendices to the annual Part 1 updates. The complete Part 2 document will be re-issued from time to time (next planned update in 2000) or when justified by the amount of additional material available.

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SUMMARY

This report details the development of world-wide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption from circa 1970 to 1996. It describes legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes and legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions, plus automotive fuel specifications and fuel characteristics.

This comprehensive work of reference should be read in conjunction with Part 1, which has been issued as a separate volume. Part 1 summarises the most important legislation, either in place or shortly to be enacted. It is therefore intended that Part 1 will be updated annually, whereas this report - which reviews the history of automotive emissions legislation - will be revised at appropriate, longer term intervals.

Vehicle Emissions Legislation - Europe

Emissions regulations in Europe were formulated in the past primarily by the United Nations Economic Commission for Europe (UN-ECE). The ECE is supported by most European nations, including many Eastern European countries. Its role is to produce model standards which may be adopted by member nations, but it has no power to enforce compliance.

In its early years, the European Union generally adopted regulations which were technically identical with the ECE equivalents. This position has changed over time, with the European Community, now the European Union, gradually assuming a major role in formulating automotive emissions standards. UN-ECE is now unlikely to adopt any proposal which has not been agreed within the EU.

European Union regulations, published as Directives, have the force of law within EU Member States under the provisions of the Treaty of Rome. With the introduction of the "Consolidated Emissions Directive" implementation became mandatory for all EU Member States and is no longer left to the discretion of individual national governments.

Having joined in 1994, Austria, Finland and Sweden are being allowed a four-year transition period, ending on 1 January 1999, to harmonise legislation with the EU. Austria and Finland, together with Norway and Switzerland, have already adopted most of the EU Directives. Sweden retains US limits based on Federal test procedures and has also adopted stringent Low Emission Vehicle standards. The EU has agreed to admit Poland, Hungary and the Czech Republic as soon as their economic circumstances allow and these countries have adopted, or are in the process of adopting, EU environmental regulations.

Vehicle Emissions Legislation – United States

National exhaust emission limits for cars were first set in the Clean Air Act of 1968. However, in 1970 the US Congress passed amendments which required exhaust emission reductions of 90% from the then current levels to take effect in 1975-76. Implementation of these regulations was delayed until technology was available to meet them. This led to the establishment of interim standards for 1975 and 1976 which were subsequently extended to 1979. Oxidation catalysts were required for most vehicles to meet the 1975 and subsequent limits. As a result, unleaded gasoline was made widely available in 1975 to cater for catalyst cars.

In 1977 Congress amended the Clean Air Act. Under this amendment the EPA formulated National Ambient Air Quality Standards (NAAQS) which set the level of air cleanliness required throughout the US. Following the act, the EPA set revised standards to achieve a 90% HC reduction in 1980, plus a 90% CO and 75% NO_x reduction in 1981. This led to the widespread introduction of 3-way catalyst technology. The original 90% NO_x reduction (0.4 g/mile) was left as a research goal, although it was adopted in California and now forms part of the new Clean Air Act.

Separate emission limits for light-duty trucks were introduced in 1975, more severe limits were imposed in 1984 and 1988, requiring oxidation and 3-way catalysts respectively to meet the standards.

Emission limits for heavy duty engines were originally set in 1970 and, in the 1977 Clean Air Act, stringent reductions in HC and CO emissions were proposed to take effect in 1981. However, these standards were deferred until technology was available and were finally implemented in 1987, requiring catalysts on heavy duty gasoline engines. Further reductions in NOx and diesel particulate limits, implemented from 1990 to 1995, required 3-way catalysts for heavy duty gasoline engines and radical changes in diesel engine technology.

The US standards apply over the "useful life" of the vehicle, which for cars is defined as 50 000 miles (80 000 km) or 5 years. The durability of the emission control device must be demonstrated over this distance, within allowed deterioration factors, and in some cases over 100 000 miles (160 000 km). The heavy duty truck regulations for 1987 (and later) require compliance over longer periods, representative of the useful life of the vehicle.

The State of California has always been a leader in emission control legislation and has generally adopted limits more severe than the Federal (Clean Air Act) limits which apply in the rest of the USA. The main reason for this is the atmospheric smog and poor air quality in the Los Angeles area. As a consequence, California has introduced more stringent standards for light duty vehicles and trucks, with the progressive introduction of Low, Ultra Low and Zero Emissions Vehicles, although the introduction of the latter has been delayed. There are also proposals for hybrid electric vehicles with suitably low emissions to be classified as “Equivalent” Zero Emissions Vehicles. The CARB has developed an extension of its LEV programme to apply to heavy duty vehicles.

Vehicle Emissions Legislation – Other Countries

Emission control in Japan started in 1966 when simple CO limits were introduced, but the first long-term plan was established in 1970 by the Ministry of Transport (MOT). This plan proposed limits for CO, HC and NOx from 1973, with separate limits for different test cycles. In 1971 however, the Central Council for Environmental Pollution Control (CCEPC) submitted recommendations for much more stringent exhaust emission standards. This led to tough limits introduced in 1975 which required the use of catalysts on gasoline cars. These limits (with an NOx reductions in 1978) have not changed since then, but revisions to the test procedures have effectively made them more severe. Emissions limits for trucks, both gasoline and diesel were also introduced in 1974/5, but these limits have been tightened by varying degrees over the intervening years.

In December 1989 the CCEPC recommended new emission limits with both short-term and long-term targets. Their aim was to set up the most stringent standards which were technologically feasible, and to apply the same standards for both gasoline and diesel fuelled vehicles. Based on this proposal, the MOT revised the emission regulations in May 1991. Further legislation, focusing on diesel vehicles of less than 12 tons gvw, has been proposed.

Where it exists, legislation in other countries tends to follow (or adapt) US, European or Japanese standards and test methods.

Test Cycles and Procedures

Emissions and fuel economy tests and inspection and maintenance procedures continue to develop in terms of complexity, cost and time. Almost without exception, these procedures are designed to represent “real driving” more closely, to improve repeatability and reproducibility and to avoid the potential for “cycle beating”.

In-Service Emissions Testing - On-Board Diagnostics

Inspection and maintenance (I&M) programmes are receiving greater attention in many countries. In the US the Clean Air Act amendments required enhanced I&M programmes to be introduced from 1992. However many states considered the IM 240 test proposed by the EPA to be too expensive and have proposed their own programmes.

The EU proposes to introduce OBD systems on passenger cars and light duty vehicles from 1997. Manufacturers will be able to obtain type approvals according to EU, US or California regulations. In the United States OBD systems have been required on light duty vehicles and trucks since the 1994 model-year. In 1994, California updated earlier OBD requirements to the OBD ll standard.

Fuel Consumption & CO_2 Regulations

Progress in the development of fuel consumption and CO_2 regulations has remained slow. Europe has opted for voluntary agreements with the motor manufacturers and attempts to tighten US standards have been unsuccessful. Japan has fuel economy targets, but these are not mandatory.

Fuel Quality

EU unleaded gasolines comply with the CEN specification, EN 228, with 95 RON, 5%v/v benzene and 0.05%m/m sulphur. Austria, Denmark, Finland and Sweden are already totally unleaded and some countries stipulate lower benzene contents. The EU will phase out lead and reduce benzene and sulphur content by 2000. The sulphur content of CEN diesel fuels has been reduced from 0.2 to 0.05%m/m from 1 October 1996, with a further reduction scheduled for the year 2000.

In the US, Phase I of the reformulated gasoline programme began on 1 January 1995 and Phase II is scheduled for 1 January 2000. California has adopted more stringent Phase II requirements. Deposit control additives are required by the Clean Air Act. Gasolines in the US and Canada are totally unleaded. Diesel fuel sulphur was reduced to 0.05%m/m in October 1993. In California the supplier has to demonstrate by testing on a specific engine over the US heavy duty cycle that its fuel produces emissions at least as low as those of a particular reference fuel.

Elsewhere in the world, gasolines are totally unleaded in Japan, South Korea, and Thailand and unleaded grades are available in Brazil, Egypt, Hong Kong, Israel, Taiwan, Philippines, Malaysia, Mexico, Morocco, Singapore, South Africa and Tunisia. A trend towards reducing the sulphur content of diesel fuels is also emerging. World-wide interest in alternative automotive fuels remains muted, although niche markets are developing.

A.1. DETAILED REVIEW OF VEHICLE EMISSIONS LEGISLATION

A.1.1. EUROPEAN UNION (ECE/EU)

Historical Background

Emissions regulations in Europe were formulated in the past primarily by the United Nations Economic Commission for Europe (UN-ECE) through its technical advisory body GRPE (Group Rapporteurs Pollution and Energy). The ECE is supported by most European nations, including many Eastern European countries. Its role is to produce model standards which may be adopted by member nations, but it has no power to enforce compliance.

In its early years, the European Union generally adopted regulations which were technically identical with the ECE equivalents. This position has changed over time, with the European Community, now the European Union, gradually assuming a major role in formulating automotive emissions standards. GRPE is now unlikely to adopt any proposal which has not been previously discussed by the MVEG (the Motor Vehicle Emissions Group, an expert group of the European Commission) and agreed within the EU.

European Union regulations, published as Directives, have the force of law within EU Member States under the provisions of the Treaty of Rome. EU countries may not prohibit the marketing of vehicles which comply with the provisions of the Directives, but may prohibit vehicles which do not comply. With the introduction of the "Consolidated Emissions Directive" implementation became mandatory for all EU Member States and is no longer left to the discretion of individual national governments.

Present membership of the EU is: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom. A four year transitional period for environmental legislation, ending on 1st January 1999, has been agreed for countries which have recently joined, after which limits must either be harmonised to EU or further renegotiated.

Of the current members of the EU, Austria, Denmark, Finland and Sweden, were signatories to the "Stockholm Agreement" of July 1985 in which these countries, together with Canada, Norway and Switzerland, agreed to adopt US 1983 standards. All these countries also adopted heavy duty limits based on UN ECE R49 and full details will be found in **Sections A.1.1.3** and **A.1.2**.

Some of the countries which signed the Stockholm Agreement have subsequently adopted some or all of the EU regulations. In Amendment 40 to the KDV regulations issued on the 24 March 1995, Austria adopted EU Directives 94/12/EC, 93/59/EEC and 91/542/EEC for passenger cars, light duty and heavy duty vehicles respectively. However the limits for mopeds and motorcycles remain unchanged (see **Table A.1.17**). Finland adopted the requirements of Directive 91/441/EEC and 91/542/EC for cars and heavy duty vehicles respectively and Norway adopted all relevant EU directives.

Austria and Sweden still have some more stringent legislation in place and it remains to be seen whether the proposed Euro 3 standards will satisfy their needs with regard to exhaust emissions and whether some differences in fuel quality parameters, such as gasoline benzene content, can be resolved. The Accession Treaties do not state unequivocally that the EU must improve its standards and if agreement has not been reached by the deadline existing EU legislation will apply and the non-conforming countries will have to lower their environmental norms to comply with Community legislation.

The EU decided in December 1992 to admit Poland, Hungary, the Czech Republic and possibly other central and eastern European countries when their economic and political circumstances allow. Poland and Hungary submitted formal applications for membership on the 1 and 8 April 1995 respectively. A new organization is responsible for environmental matters in the Czech Republic since the split with Slovakia and ECE meetings on pollution and energy matters are regularly attended. It is understood that the Czech Republic have conformed to EU regulations since 1992/93 and that these regulations also apply in Slovakia. Poland has gradually tightened its motor vehicle emissions standards over the last five years, with a view to harmonizing the requirements with the EU. A revised regulation came into effect on July 1 1995 for passenger cars and light duty trucks, replacing one issued in 1993, which effectively completes the harmonization of all vehicle emissions regulations with those of the EU. See **Table A.1.25** for emissions regulations applicable to Eastern European countries.

Table A.1.1 Summary of EU Regulations and Directives on Vehicle Exhaust Emissions

EU Directive	Equivalent ECE Regulation	Vehicle Type and Emissions Control
70/156/EEC		Type approval framework Directive
70/220/EEC	ECE R15	Exhaust emissions for gasoline passenger cars and light duty vehicles
72/306/EEC	ECE R 24.03	Heavy duty diesel black smoke emissions
74/290/EEC	ECE R 15.01	Exhaust emissions for gasoline passenger cars and light duty vehicles
77/102/EEC	ECE R 15.02	Exhaust emissions for gasoline passenger cars and light duty vehicles
77/143/EEC		In-service emissions testing
78/665/EEC	ECE R 15.03	Exhaust emissions for gasoline passenger cars and light duty vehicles
83/351/EEC	ECE R 15.04	Exhaust emissions for gasoline and diesel passenger cars and light duty vehicles
87/77/EEC	ECE R 49.01	Heavy duty diesel exhaust emissions
88/76/EEC	ECE R 83	Exhaust emissions for passenger cars and light duty vehicles. Not implemented
88/77/EEC	ECE R 49.01	Exhaust emissions from heavy duty diesels
88/436/EEC		Revised Pm requirements for diesel passenger cars
88/449/EEC		In-service emissions testing
89/458/EEC		Revised CO and HC + NOx limits for passenger cars, implemented by 91/441/EEC
91/441/EEC	ECE R 83.01	Passenger cars; revised exhaust emissions plus evaporative emissions by ECE R15 + EUDC cycles (R 83 Type Approvals B and C for gasoline and diesel respectively)
91/542/EEC		EU Clean Lorry Directive for heavy duty diesel exhaust emissions
92/55/EEC		In-service emissions testing
93/59/EEC		Exhaust emissions for light commercial vehicles (M_1 and N_1)
93/116/EC		CO_2 and fuel consumption reporting for passenger cars
COM(94)558		Exhaust emissions for light commercial vehicles (M_1 and N_1) see 96/69/EC
94/12/EC		Passenger cars; revised exhaust emissions standards
96/1/EC		Amendments to 88/77/EEC (Production Conformity, Pm for "small engines")
96/27/EC		Type approval of motor vehicles
96/69/EC		Amends 70/220 & 93/59 exhaust emissions for passenger cars and LCV
no directive	ECE R 40	Motorcycle exhaust emissions
no directive	ECE R 47	Moped exhaust emissions

Directive 94/12/EC required that proposals be submitted and decided upon before 30 June 1996 for implementation of further reductions in exhaust emissions by 1 June 2000. Besides potential improvements in engine technology, the proposals were expected to include consideration of:

- improvements in test procedures; cold start, durability testing and evaporative emissions
- emissions control systems durability requirements
- new propulsion technologies, such as electric traction
- use of on-board diagnostic systems
- potential need for separate HC and NOx limits
- presently unregulated pollutants such as benzene and 1,3-butadiene

- improvements in fuel quality relating to emissions
- strengthening requirements for inspection and maintenance
- the use of fiscal incentives
- traffic management and enhanced urban transport systems

One of the major consequences of these guidelines was a EU Commission initiative, now generally referred to as the 'European Auto/Oil Programme'. This initiative was wide reaching and involved legislators, the European Parliament, academia, consumer groups, the oil industry and automotive manufacturers. The Programme was very comprehensive and adopted a rational approach to future automotive emissions and air quality legislation for the period 2000/2010. The project was designed to identify the obstacles to achieving the air quality targets (**Part 1, Table 1.6**) and to offer the best cost-effective solutions by the following means;

- Assess vehicle/fuel technology interactions with emissions. Review what was already understood, then conduct a research programme to fill gaps in the knowledge base.
- Develop a comprehensive emissions inventory.
- Model air quality and compare with possible future standards.
- Build into that model the effects of both currently planned measures and possible future options for legislation.
- Review the cost effectiveness of potential remedial actions.

The European Programme on Emissions, Fuels and Engines (EPEFE) set up as a result of the EU Commission's initiative, reviewed available data (including US AQIRP work) and designed projects to extend that knowledge base. An appropriate series of programmes was carried out, managed by the automotive industry (ACEA) and the European oil industry (EUROPIA). Fuel matrices were designed to study the effect of variations in the sulphur content, mid-range distillation (E100) and aromatics content of gasolines and the cetane number, poly-aromatics, density and back-end distillation (T95) of diesel fuel. Test vehicles/engines were selected to reflect the wide range of models found in Europe. They were equipped with prototype engine technologies then under development which improved upon the requirements of the 1995/96 European emissions legislation. In total, EPEFE examined 12 test gasolines with 16 gasoline vehicles, and 11 diesel fuels in 19 light duty vehicles and 5 heavy duty engines. More than 2,000 emission tests were run and over half a million data points were generated.

In addition an air quality monitoring exercise was coordinated by the European Commission and was conducted by recognized European experts. It relied on regional and individual base inventories for a number of cities, compiled in 1990. Thereafter accredited emissions forecasting tools were employed to predict future air quality levels. The models had the ability to accommodate detailed breakdowns by both stationary and mobile emission sources and incorporate the effects on emissions of enhanced vehicle technology, modified fuels, non-technical measures such as traffic management and fiscal policies, inspection and maintenance and the use of alternative fuels.

In accordance with the timetable laid down by Directive 94/12/EC, the Commission put forward on 18 June 1996 a number of measures and proposals before the Council of the European Union and the European Parliament arising from the Auto/Oil Programme. These can be summarised as follows:

- the implementation of new emissions standards for the year 2000 and indicative values to come into force in the year 2005 for gasoline and diesel passenger cars, light commercial and heavy duty vehicles (see Part 1). The legislation will include separate limits for NOx and hydrocarbon emissions. However, as the air quality standards for CO are expected to be met with existing measures, a cold start test procedure will not be introduced into the requirements for type approval of gasoline passenger cars as originally envisaged.
- The introduction of requirements for on-board diagnostic equipment and in-use testing for cars.
- The introduction of more rigorous periodic inspections and a re-call mechanism for vehicle models which do not perform to in-service requirements.
- The introduction of a more rigorous test procedure for evaporative loss measurements.
- A draft Directive has also been put forward imposing compositional constraints on gasoline and diesel fuel quality from year 2000. It also requires the introduction of a fuel quality monitoring system and a periodical review of fuel quality requirements to ensure fuel compatibility with future engine technology. This is discussed in more detail below.

The Commission also reviewed the ways in which other national and local initiatives, including excise duty and taxation, can influence consumer choice regarding car usage in favour of reduced emissions. Measures reviewed included road pricing, the expansion of public transportation systems and emissions related vehicle taxes affecting the consumption of unleaded and low sulphur fuels, the maintenance levels of cars and scrappage schemes for old vehicles. This is of significance because minimum rates of excise duty and derogations, allowed to promote environmentally friendly fuels, were due for review in 1996.

The Commission has been directed to put forward further proposals for tightening vehicle emissions regulations and fuel specifications, to be made at the latest by the end of 1998, to come into effect by 2005. In order to carry out the comprehensive assessment required, the Commission considers that it will be necessary to extend the concept of the Auto Oil Programme to a second phase. Specific aspects to be considered in the second phase will include;

- the use of particulate traps and de-NOx catalysts on diesel vehicles
- a review of fuel specifications, with reference to the influence of fuel quality on particulate matter, volatile organic compounds and NOx and the changes necessary to implement advances in vehicle emissions technology, with particular emphasis on sulphur content.
- There will also be a general review process in conjunction with Auto Oil II, taking into account inter alia the following considerations;
- trends in air quality
- technical developments in refinery and vehicle technologies
- the potential of alternative fuels such as CNG, LPG, DME and biofuels
- possible improvements in vehicle testing techniques, particularly the addition of a new test procedure at low test temperatures

- the potential for reduced emissions of traffic management, enhanced urban transport and vehicle scrappage schemes
- the contribution of selective and differentiated fiscal measures
- the effects of any measures to limit CO2 emissions
- the crude quality and supply situation
- emissions from stationary sources.

Directive 94/12/EC did not require that the Commission should evaluate alternative propulsion systems and this issue was not addressed by the Auto Oil programme. However in 1995 the Commission set up a separate “The Car of Tomorrow” Task Force and has come up with an Action Plan with the aim of focusing R&D initiatives towards the next generation of road vehicles, in particular those which are safe, energy efficient, low emitters and use cleaner fuels.

A.1.1.1. Light Duty Vehicles

Light duty vehicles (passenger cars) were the first to be regulated under the ECE process, and their limit values have subsequently been amended four times. Equivalent EU directives are:

Limits	Directive	Implementation Date
Original ECE 15	70/220/EEC	1970
ECE 15/01	74/290/EEC	1974
ECE 15/02	77/102/EEC	1977
ECE 15/03	78/665/EEC	October 1979
ECE 15/04	83/351/EEC	October 1984/86
New ECE 83	88/76/EEC	See **Table A.1.3**

ECE 15 exhaust emission regulations up to the 04 amendment are summarized in **Table A.1.2**.

Table A.1.2 European Exhaust Emission Limits - ECE Regulation 15

Vehicle Type Reference Wt. (kg)	**CO (g/test)**			**HC (g/test)**		**NOx (g/test)**		**HC+NOx (g/test)**
ECE 15 level	**02**	**03**	**04**	**02**	**03**	**02**	**03**	**04**
Type I Test								
Ó750	80	65	58	6.8	6.0	10.0	8.5	19.0
751-850	87	71	58	7.1	6.3	10.0	8.5	19.0
851-1020	94	76	58	7.4	6.5	10.0	8.5	19.0
1021-1250	107	87	67	8.0	7.1	12.0	10.2	20.5
1251-1470	122	99	76	8.6	7.6	14.0	11.9	22.0
1471-1700	135	110	86	9.2	8.1	14.5	12.3	23.5
1701-1930	149	121	93	9.7	8.6	15.0	12.8	25.0
1931-2150	162	132	101	10.3	9.1	15.5	13.2	26.5
Ò2150	176	143	110	10.9	9.6	16.0	13.6	28.0
Type II Test All vehicles	Maximum concentration of CO at end of last urban cycle: 02 levels 4.5%; 03 and 04 levels 3.5%							
Type III Test All vehicles	No crankcase emissions permitted							

- Regulation 15 applies to vehicles up to 3.5t GVW. Only gasoline-fuelled vehicles are covered by 01/02/03 Amendments, but the “04 Amendment also applies to diesel-powered vehicles.
- The constant volume sampling (CVS) measurement technique was introduced with the 04 Amendment. Fuel consumption and power measurement procedures are detailed in the Regulation, but do not include any limits.
- The 03 Amendment came into force on 1 October 1979 and the 04 Amendment on 1.10.84 for new models, 1.10.86 for existing models. Mandated introduction dates in individual countries vary and may be later than these dates.
- The limits quoted are those for Type Approval. Production vehicles are permitted to exceed these figures by up to 30% for HC, and up to 20% for CO and NOx. The tolerance for HC+NOx in the 04 Amendment is 25%.

The EU agreed further reductions from the 04 levels in gaseous exhaust emissions limits for vehicles less than 3.5 t GVW. Particulate limits for diesel vehicles were also agreed. This Directive, 88/76/EEC, was then adopted by ECE as Regulation ECE 83. The new Directive 88/76/EEC, which amends Directive 70/220/EEC, allows the certification of cars with an engine displacement above 1.4 litres on the basis of the 1983 US procedure and limits.

In practical terms, this regulation (**Table A.1.3**) was not implemented by any European country in anticipation of the adoption by EU of the Consolidated Emissions Directive (see **Table A.1.4**).

Table A.1.3 European Exhaust Emission Limits-ECE Regulation 83 (ECE R15 cycle)

Effective Date		Vehicle cubic capacity (cm^3)	Emission Limits (g/test)			
New Models	**All Production**		**CO**	**HC+NOx**	**NOx**	**Pm**
		Gasoline				
01.10.88	01.10.89	>2000	25	6.5	3.5	
01.10.91	01.10.93	1400-2000	30	8	-	
01.10.90	01.10.91	<1400	45	15	6	
01.10.92	01.10.93		30 (1)	8 (1)	-	
		Diesel				
01.10.88	01.10.89	>2000	30	8	-	1.1(3)
01.10.91(2)	01.10.93(2)	1400-2000	30	8	-	1.1(3)
01.10.90(2)	01.10.91(2)	<1400	45	15	6	1.1(3)
01.01.91			30	8	-	1.1(3)

(1) A further reduction to 19 g/test CO and 5 g/test HC + NOx was adopted by the EU Council in June 1989 as 89/458/EEC. However, it was superseded by the Consolidated Directive and is not included in ECE 83.

(2) Implementation dates for direct injection-engined vehicles are 1.10.94 for new models and 1.10.96 for all production.

(3) A separate EU Directive, 88/436/EEC, specifies the limits for particulates (Pm) as 1.1 g/test for Type Approval and 1.4 g/test for Conformity of Production, with implementation dates of 1.10.1989 for new models and 1.10.1990 for all production.

On 26 June 1991 the Council of Ministers of the European Community adopted the "*Consolidated Emissions Directive*", 91/441/EEC. This covers not only exhaust emission standards (including durability testing) but also limits for vehicle evaporative emissions (see **Section A.1.1.6**).

According to the directive, exhaust emission standards have to be certified on the basis of the combined ECE 15 (urban) cycle and EUDC (extra-urban) test cycle (see **Section A.2.1**). In contrast to previous directives, a common set of gaseous emission standards will apply to all private passenger cars (both gasoline and diesel-engined), irrespective of engine capacity. Limit values are shown in **Table A.1.4**. Directive 93/116/EC was published on 17 December 1993 applying to M1 vehicles only, which required manufacturers from 1 January 1996 to state CO_2 emissions and fuel consumption as obtained by the method given in **Section A.2.1**.

In December 1993 the Environment Council agreed more stringent limits for 1996 onwards and these were adopted as Directive 94/12/EC in March 1994. Compared with previous standards, separate limits are given for gasoline- and diesel-fuelled vehicles. These represent respectively reductions of 30% CO, 55% HC+NOx for gasoline cars and 68% CO, 38% HC+NOx and 55% particulate emissions for diesel vehicles. Implementation dates are 1 January 1996 for new models and 1 January 1997 for existing models. Slightly less stringent limits apply to DI diesels initially but they have to comply with the full standard by 30 September 1999. Contrary to the earlier standards, production vehicles must comply with the Type Approval Limits. The revised limits are shown in **Table A.1.4**.

Table A.1.4 Limits for the Consolidated Emissions Directives (91/441/EEC) and (94/12/EC) - for passenger cars up to 6 seats (Test Method ECE R15 + EUDC)

Vehicle Type	Effective Date	Type Approval				Conformity of Production			
		CO g/km	HC+NOx g/km	Pm g/km	Evap. g/test	CO g/km	HC+NOx g/km	Pm g/km	Evap g/test
All except DI diesels	01.07.92 (new models) 31.12.92 (all models)	2.72	0.97	0.14	2.0	3.16	1.13	0.18	2.0
DI diesels	until 30.6.94	2.72	1.36	0.19					
	01.07.94	2.72	0.97	0.14		3.16	1.13	0.18	
Gasoline	01.01.96 (new models) 01.01.97 (all models)	2.2	0.5	-	2.0	all production must meet Type Approval limits			
IDI diesels		1.0	0.7	0.08					
DI diesels		1.0	0.9	0.1					
DI diesels	1.10.99	1.0	0.7	0.08					

- From 01.07.92, Member States can no longer grant Type Approval against previous directives.
- Directive 93/116/EC requires manufacturers from 01.01.1996 to state CO2 and fuel consumption for type approval
- There is also a durability requirement for vehicles fitted with pollution control devices. This can take the form of either a durability test of 80 000 km driven on a test track or rollers of 11 repetitive cycles of 6 km each, or the application of deterioration factors. If the latter option is taken the actual emissions levels are compared with the legislated limits after being multiplied by the following factors:

Vehicle Type	HC + NOx	CO	Pm
Gasoline	1.2	1.2	-
Diesel	1.0	1.1	1.2

It should be noted that the implementation of the limit values by EU Member States is mandatory and no longer (as in previous exhaust emissions directives) left for the decision of individual national governments. GRPE is considering these limit values with a view to recommending that they are adopted by UN-ECE.

Proposals, based on the Auto/Oil study (see **Section A.1.1** above), take the form of firm proposals for implementation in 2000 and indications of more stringent limits for consideration for implementation in 2005. These are given in **Table A.1.5** as Proposals A and B.

The Commission's proposed Directive also includes requirements for on-board diagnostic systems, the recall of defective vehicles and a more rigorous test procedure for evaporative losses (see appropriate Sections). On the other hand as CO quality standards are expected to be met with existing measures it is not proposed to introduce a cold start test procedure as part of the type approval requirements.

Table A.1.5 Proposed EU Emissions Limits for passenger cars for 2000/2005

	CO (g/km)		**HC (g/km)**		**NOx (g/km)**		**HC + NOx (g/km)**		**Pm (g/km)**
	gasoline	diesel	gasoline	diesel	gasoline	diesel	gasoline	diesel	diesel
Proposal A (2000)	2.3	0.64	0.20	-	0.15	0.50	-	0.56	0.05
Proposal B (2005)	1.00	0.50	0.10	-	0.08	0.25	-	0.30	0.025
Proposal EU Parliament	1.00	0.5	0.1	0.1	0.1	0.30	-	-	0.04

A.1.1.2. Light Commercial Vehicles

These vehicles (Classes M_1 and N_1, see **Glossary**) are the subject of Directive 93/59/EEC, dated 28 June 1993. In this proposal the vehicles have been further classified according to their mass, to reflect the differences in their power train layouts and body shapes:

Class I: Reference mass equal or less than 1250 kg
Class II: Reference mass more than 1250 kg but less than 1700 kg
Class III Reference mass more than 1700 kg

Class I can comply with the limit values established by Directive 91/441/EEC for passenger cars, i.e. considered to be at least as severe as current US limits. *Classes II* and *III* should be considered to be of equivalent stringency to the present US "*Light Duty Truck*" standards.

Vehicles are tested over the ECE15 + EUDC test cycle. However, as many vehicles in these classes have low power-to-mass ratios and low maximum speeds, the following modification to the procedure was made:

- For vehicles with a power-to-mass ratio of not more than 40 kW/t and a maximum speed of less than 130 km/h, the EUDC maximum speed is reduced to 90 km/h.

The requirements relating to evaporative emissions and durability of anti-pollution devices specified in Directive 91/441/EEC also apply.

Table A.1.6 EU Emission Limits for Light Commercial Vehicles (93/59/EEC)[1] (Maximum Mass 3500 kg and heavier cars designed to transport more than 6 people)

Effective Date	Vehicle	Type Approval			Conformity of Production		
		CO g/km	HC+NOx g/km	Pm [2,3] g/km	CO g/km	HC+NOx g/km	Pm[2,3] g/km
01.01.93 (new models) **01.10.94 (all models)**	I RM ≤1250 kg	2.72	0.97	0.14	3.16	1.13	0.18
	II RM >1250 ≤1700 kg	5.17	1.40	0.19	6.0	1.6	0.22
	III RM >1700 kg	6.9	1.7	0.25	8.0	2.0	0.29

(1) Also applies to vehicles designed to carry more than six persons including the driver and vehicles with max. mass exceeding 2500 kg

(2) Applies to diesels only

(3) For N1 Direct Injection engines these limits are higher by a factor of 1.4 until October 1994 for type approval and October 1995 for initial entry into service

Directive 96/69/EC introduced further reductions in emissions limits previously notified in COM(94)558 (see **Table A.1.7**).

Table A.1.7 Directive 96/69/EC exhaust emissions limits for passenger cars and light commercial vehicles [1]

Effective Date		Vehicle [1]		Limit Values		
New Type Approvals	**New Registr'ns**	**Reference Mass (kg)**	**Type**	**CO (g/km)**	**HC + NOx (g/km)**	**Pm (g/km)**
01.01.1996	01.01.1997	Category M [3] passenger cars	Gasoline IDI Diesel DI Diesel [2]	2.2 1.0 1.0	0.5 0.7 0.9	- 0.08 0.10
01.01.1997	01.10.1997	Class I Category N_1 ≤ 1250	Gasoline IDI Diesel DI Diesel [2]	2.2 1.0 1.0	0.5 0.7 0.9	- 0.08 0.10
01.01.1998	01.10.1998	Class II Category N_1 1251-1700	Gasoline IDI Diesel DI Diesel [2]	4.0 1.25 1.25	0.6 1.0 1.3	- 0.12 0.14
01.01.1998	01.10.1998	Class III Category N_1 >1700	Gasoline IDI Diesel DI Diesel [2]	5.0 1.5 1.5	0.7 1.2 1.6	- 0.17 0.20

(1) Also applies to vehicles designed to carry more than six persons including the driver and vehicles with max. mass exceeding 2500 kg

(2) Until 30 September 1999 then IDI Diesel limits apply

(3) Except vehicles designed to carry more than six occupants or with maximum mass >2.5t. These vehicles are covered by the appropriate N category

A.1.1.3. Heavy Duty Vehicles

ECE Regulation 49 Heavy Duty Engine Gaseous Emission Limits

ECE Regulation 49 applies to gaseous emissions from diesel engines used in vehicles with GVW over 3.5 t. Limits are in g/kWh determined by using an engine test procedure based on the former US 13 mode test (see **Section A.2.2.3**). **Table A.1.8** shows both the original ECE 49 limits, and also those adopted in September 1989 as amendment 01 (these are identical with EU Directive 88/77 - see **Table A.1.10**).

Table A.1.8 ECE Regulation 49/49.01 Emission limits

	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)
ECE 49	14	3.5	18
ECE 49.01	11.2	2.4	14.4

With the introduction of ECE 15/04, diesel engined vehicles under 3.5t GVW must comply with ECE 15 limits.

ECE Regulation 24.03 Diesel Black Smoke Emissions

ECE Regulation 24.03 governing black smoke emissions from diesel engines is given in **Table A.1.9**. These were adopted in EU Directive 72/306/EEC but have been superseded by the particulate emissions requirements in the EU “Clean Lorry“ Directive 91/542/EEC (see following paragraphs and **Table A.1.10**).

Table A.1.9 Smoke Limits Specified in ECE Regulation 24.03 and EU Directive 72/306/EEC

(a) Smoke emission limits under steady state conditions.	
Nominal Flow (litres/second)	**Absorption Coefficient (m^{-1})**
42 100 200	2.26 1.495 1.065
Intermediate values are also specified.	
(b) Opacity under free acceleration should not exceed the approved level by more than 0.5 m^{-1}.	

Note: Although the free acceleration test was intended as a means of checking vehicles in-service it has not proved entirely successful. A number of different methods have been proposed by various countries, but there is no generally accepted alternative method of in-service checking.

EU Regulations for Heavy Duty Diesels

The European Council of Ministers, through Directive 88/77/EEC, adopted Type Approval limits for gaseous emissions from vehicles over 3.5 tonnes based on ECE regulation 24.03. This was permissive but not mandatory and the suggested application dates were from 1 April 1988 for new models and from 1 October 1990 for all production.

On 1 October 1991 the European Council adopted the “Clean Lorry” Directive which reduces in two phases the limit values for gaseous and particulate (Pm) emissions for diesel engines and other heavy utility vehicles. This sets norms, which will be compulsory throughout the EU, in two stages as shown in **Table A.1.10** (last two rows). The Council subsequently relaxed the particulate limit for vehicles with engines ≤ 0.7 dm^3 capacity to 0.25 g/kWh for the transitional period from 1 October 1995 to 30 September 1997 for new models but allowed Member States to give tax incentives for the small diesel engines meeting the 0.15 g/kWh limit before this date.

Table A.1.10 EU Limits for Heavy Duty Vehicles Directives 88/77/EEC and 91/542/EEC

Effective Date	**Type Approval (g/kWh)**				**Conformity of Production (g/kWh)**			
	CO	HC	NOx	Pm	CO	HC	NOx	Pm
1.04.88 (new models) 1.10.90 (all production)	11.2	2.4	14.4	(2)	13.2	2.64	15.8	(2)
1.04 92 (new models) 1.10.93 (all production)	4.5	1.1	8.0	0.36 (1)	4.9	1.23	9.0	0.4 (1)
1.10.95 (new models) 1.10.96 (all production)	4.0	1.1	7.0	0.15 (1,3)	4.0	1.1	7.0	0.15 (1,3)

(1) In the case of engines of 85 kW or less, the limit value for particulate emissions is increased by multiplying the quoted limit by a coefficient of 1.7

(2) Smoke according to ECE Regulation 24.03, EU Directive 72/306/EEC (see **Table A.1.9**)

(3) For engines with a cylinder swept volume of ≤ 0.7 dm^3 and a rated power speed >3000 min^{-1} the limit is 0.25 g/kWh max. until 30.09.1997 for new models and 30.09.1998 for all production respectively.

A.1.1.4. Agricultural and Forestry Tractors

The following describes the limit values adopted in Europe. The test cycle adopted is taken from ISO 8178-4, further details of which will be found in **Section A.2.3**.

European Union

Draft directives are under preparation to control emissions from off-highway engines, which will include agricultural and forestry tractors (see **Table A.1.11**). The limits are the same as those for the ECE proposals (see **Table A.1.12**).

Table A.1.11 Proposed EU emission limits for Agricultural and Forestry Tractors

Effective Date[(1)]	Power Band	CO g/kWh	HC g/kWh	NOx g/kWh	Pm g/kWh
Oct. 96	>130 kW	5.0	1.3	9.2	0.54
Oct. 97	75-130 kW	5.0	1.3	9.2	0.70
Oct. 98	37-75 kW	6.5	1.3	9.2	0.85

The effective dates are the dates at which all new tractor registrations must comply with the limits.

The directives are not yet finalized and changes to limits and dates may be made.

The test cycle is the 8-mode steady state, C1, cycle from ISO 8178-4.

It is proposed that Stage 2 limit values will be introduced 5 years after Stage 1, and that they will be equivalent to the EU on-highway truck levels of 7.0 NOx/0.15 Pm g/kWh.

The Stage 1 limit values must be met without the use of exhaust after-treatment. This requirement may be relaxed for Stage 2.

It is probable that the current Tractor Smoke Directive will be modified to make it more stringent

ECE Regulations

A regulation for the control of gaseous and particulate emissions from diesel powered agricultural and forestry tractors has been adopted and is awaiting publication.

Table A.1.12 ECE Limit Values for Emissions from Diesel Powered Agricultural and Forestry Tractors

Effective Date	Power Band	CO g/kWh	HC g/kWh	NOx g/kWh	Pm g/kWh
(1)	130-560 kW	5.0	1.3	9.2	0.54
(1)	75-130 kW	5.0	1.3	9.2	0.70
(1)	37-75 kW	6.5	1.3	9.2	0.85

Since this is a new regulation and adoption into national legislation is optional, it is not possible for introduction dates to be included in the text.

The test cycle is the 8-mode steady state cycle C1 from ISO 8187-4.

The limit values for engine >130 kW (175 bhp) are equivalent to the CARB '96 limits for engines >175 bhp, apart from the CO limit which is more stringent.

Stage 2 limit values have not yet been proposed.

The limit values must be met without the use of exhaust after-treatment.

There is currently no ECE smoke test for off-highway applications and none is under development.

A.1.1.5. Motor Cycles and Mopeds

ECE Regulation 40 was adopted in September 1979 and applies to two-wheeled and three-wheeled vehicles with an unladen weight of less than 400 kg. and having a maximum design speed exceeding 50 km/h. and/or a cylinder capacity exceeding 50 cubic centimetres. The vehicle is required to meet emissions limits over a driving cycle (Type **I** Test) and also at idle (Type **II** Test). The emission limit for the Type **II** test is 4.5% v/v CO. Separate limits are specified in the Type **I** test for certification and production vehicles, as shown in **Table A.1.13** and **Table A.1.14**.

Regulation 40 was amended on May 31 1988 to become ECE 40.01, with lower limits for both CO and HC emissions. The EU has yet to introduce legislation with respect to emissions from motor-cycles and mopeds. However, draft directives, based on ECE Regulations, are under preparation.

The following countries accept vehicles meeting ECE 40.01, or require mandatory compliance:

Germany	Hungary	France	Russian Federation (CIS)
Netherlands	Norway	Belgium	Finland
United Kingdom	Romania	Italy	Czech Republic and Slovakia

Table A.1.13 ECE Regulation 40/40.01 for Exhaust Emission Limits for Motorcycles with 4-stroke Engines.

Reference Weight R [1] (kg)	CO (g/km)		HC (g/km)	
	ECE 40 [2]	**ECE 40.**01 [2]	**ECE 40** [2]	**ECE 40.01** [2]
< 100	25 {30}	17.5 {21}	7 {10}	4.2 {6}
100 – 300	$25 + 25 \left(\frac{R-100}{200}\right)$	$17.5 + 17.5 \left(\frac{R-100}{200}\right)$	$7 + 3 \left(\frac{R-100}{200}\right)$	$4.2 + 1.8 \left(\frac{R-100}{200}\right)$
{100 - 300}	$\{30 + 30 \left(\frac{R-100}{200}\right)\}$	$\{21 + 21 \left(\frac{R-100}{200}\right)\}$	$\{10 + 4 \left(\frac{R-100}{200}\right)\}$	$\{6 + 2.4 \left(\frac{R-100}{200}\right)\}$
> 300	50 {60}	35 {42}	10 {14}	6 {8.4}

Table A.1.14 ECE Regulation 40/40.01 for Exhaust Emission Limits for Motorcycles with 2-stroke Engines.

Reference Weight R [1] (kg)	CO (g/km)		HC (g/km)	
	ECE 40 [2]	**ECE 40.01** [2]	**ECE 40** [2]	**ECE 40.01** [2]
< 100	16 {20}	12.8 {16}	10 {13}	8 (10.4)
100 – 300	$16 + 24 \left(\frac{R-100}{200}\right)$	$12.8 + 19.2 \left(\frac{R-100}{200}\right)$	$10 + 5 \left(\frac{R-100}{200}\right)$	$8 + 4 \left(\frac{R-100}{200}\right)$
{100 - 300}	$\{20 + 30 \left(\frac{R-100}{200}\right)\}$	$\{16 + 24 \left(\frac{R-100}{200}\right)\}$	$\{13 + 8 \left(\frac{R-100}{200}\right)\}$	$10.4 + 6.4 \left(\frac{R-100}{200}\right)\}$
> 300	40 {50}	32 {40}	15 {21}	12 {16.8}

Reference weight (R) = Motorcycle weight + 75 kg.

Limits are for Type Approval. Limits given in parenthesis { } apply to Conformity of Production.

ECE Regulation 47 was issued in August 1981 and applies to vehicles of less than 400 kg equipped with an engine having a cylinder capacity of less than 50 cubic centimetres, namely mopeds. Emission limits are given in **Table A.1.15**.

Table A.1.15 ECE Regulation 47 for Exhaust Emission Limits for Mopeds

Vehicle type	**2-Wheeled**		**3-Wheeled**	
Pollutant (g/km)	**CO**	**HC**	**CO**	**HC**
Licensing	8.0	5.0	15.0	10.0
Production	9.6	6.5	18.0	13.0

A.1.1.6. Evaporative Emissions Legislation

The European Commission stated its intention to control evaporative emissions from motor vehicles by requiring all gasoline cars to be fitted with small carbon canisters and by requiring the application of "*Stage I*" controls to the distribution system. Evaporative emission limits have thus been included in the EU Consolidated Emissions Directive (see **Section A.1.1.1**), with details as follows:

- Limit: 2 g/test for all cars.
- Test procedure based on SHED (Sealed Housing for Evaporative Determination) but differs from the US procedure, see **Section A.2.2.4**.
- Test includes diurnal emissions (temperature rise 16-30°C) and hot soak emissions (SHED temperature 23-31°C) but not running losses
- Test fuel volatility is 56-64 kPa (same as the exhaust emissions test reference fuel).

A.1.2. OTHER EUROPEAN REGULATIONS

At a meeting in Sweden in July 1985, a number of countries agreed in principle to adopt US 1983 standards. The signatories to the "*Stockholm Agreement* were Austria, Canada, Denmark, Finland, Norway, Sweden and Switzerland. Since then some of these countries have adopted EU regulations. Details for individual European countries are given below (see also **Part 1**).

Austria

US 1983 exhaust emission standards were introduced from 01.01.1987 for gasoline vehicles over 1500 cc displacement (Amendment 18 to KDV) and from 28.07.1987 for all gasoline and diesel vehicles up to 3500 kg weight (Amendment 22 to KDV). The US Standard for evaporative emissions became effective from 01.01.1989 for gasoline vehicles.

Slightly modified standards are applied for manufacturers who do not conduct an 80 000 km durability run.

For heavy duty vehicles, the following standards, based on the ECE 49 test procedure, were adopted with effect from 1 January 1991:

	g/kWh
CO	4.9
HC	1.23
NOx	9.0
Particulates	0.7
from 1.1.93	0.4

In Amendment 40 to KDV issued on 24 March 1995, Austria adopted the limits given in EU Directives 94/12/EEC, 93/59/EEC and 91/542/EEC for passenger cars, light duty trucks and heavy duty vehicles respectively. Black smoke absorption coefficients according to 72/306/EEC have also been adopted. The limits for mopeds and motorcycles remain unchanged and are given in **Table A.1.17**. The Austrian standards for other vehicles prior to the changes are given in **Table A.1.16**.

Table A.1.16 Austrian Emission Limits prior to adoption of EU limits

Vehicle	Effective Date	Limits (g/km)				Test Procedure
		CO	HC	NOx	Pm	
Passenger cars [2] **gasoline** **diesel**	01.01.89 25.05.86 01.10.93	2.1 2.1 2.1	0.25 0.25 0.25	0.62 0.62 0.62	- 0.37 0.12	FTP 75
Commercial Vehicles <3.5 tonnes GVW	01.01.89	6.2	0.5	1.43	0.37	FTP 75
		g/kWh	g/kWh	g/kWh	g/kWh[1]	
Commercial vehicles >3.5 tonnes GVW (limits in g/kWh)	01.01.89 01.01.91 01.01.93	11.2 4.9 4.9	2.8 1.23 1.23	14.4 9.0 9.0	- 0.7 0.4	ECE49

(1) Diesel black smoke according to ECE 24 limits and test procedure

(2) Deterioration factors of 1.3 after 80,000 km or as determined by manufacturer's tests.

Table A.1.17 Austrian Moped and Motorcycle Emission Limits

Vehicle	Effective Date		Limits (g/km)		
			CO	HC	NOx
Motorcycles (<50 cc>40 km/h)					
2 stroke	before	01.10.91	13	6.5	2
	from	01.10.91	8	7.5	0.1
4 stroke	before	01.10.91	18	6.5	1
	from	01.10.91	13	3.0	0.3
Motorcycles (>50cc)					
2 stroke	before	01.10.90	12-32	8-12	1
	from	01.10.90	8	7.5	0.1
4 stroke	before	01.10.90	17.5-35	4.2-6	0.8
	from	01.10.90	13	3.0	0.3
Mopeds (<50 cc<40 km/h)	from	01.10.88	1.2	1.0	0.2

Denmark

Denmark introduced emissions standards equivalent to US 1987 limits from 1 October 1990. Subsequently all vehicles meeting the limit values of the EU "*Consolidated Directive*" were permitted in Denmark.

Finland

Finland were signatories of the "Stockholm Agreement but have now adopted EU legislation. Prior Finnish legislation is given in **Table A.1.18**.

Table A.1.18 Finland - Emissions Regulations prior to adoption of EU regulations

Vehicle Category	Approval	Effective date	CO g/km	HC g/km	NOx g/km	Pm g/km	Evap g/test	Equiv. Reg.
All Cars [(1)]	new models all models	01.01.90 01.06.92	2.1	0.25	0.62	0.373	2.0	US 83
	all models	01.01.93	2.1	0.25	0.62	0.124	2.0	US 87
				HC + NOx				
Cars								
Gasoline	new models	01.01.96	2.2	0.5		-	2.0	91/441/EC
IDI Diesel	all models	01.01.97	1.0	0.7		0.08	-	
DI Diesel	all models		1.0	0.9		0.10	-	
All Diesels	all models	01.10.99	1.0	0.7		0.08	-	
Delivery Vehicles & Jeeps	all models	01.01.93	6.2	0.5	1.1	0.162	2.0	US 90
			g/kWh	**g/kWh**	**g/kWh**	**g/kWh**		
HDV [(3)]	new models[(2)] all models[(2)]	01.10.93	4.5 4.9	1.1 1.23	8.0 9.0	0.36 0.4		91/542/EC ECE49
	new models all models	01.10.95 01.10.96	4.0	1.1	7.0	0.15		
Motorcycles		01.01.93	Refer to **Tables A.1.13** and **A.1.14**					ECE40.01
Mopeds		01.01.93	Refer to **Table A.1.15**					ECE47

(1) Durability 80,000 km or 5 years

(2) Durability 160,000 km or 5 years

(3) In the case of engines of 85 kW or less, the limit value for particulate emissions is increased by multiplying the quoted limit by a factor of 1.7

Norway

Like Finland, Norway was a signatory to the "Stockholm Agreement" but has now adopted EU legislation.

Table A.1.19 Norway - Current and Planned Emissions Legislation

Vehicle Category	L1	L2	L3
Gross Weight (tonne) **Net Weight (kg)**	<3.5 >760	<3.5 >760	>3.5 -

Vehicle Category	Effective Date	Regulation	Limits
Passenger Cars Gasoline L1	01.01.89	US 83	See **Table A.1.30**
Lights Commercial & Light "Combined"	01.10.90	US 83	See **Table A.1.30**
All Diesel L1	01.10.90	US 87	See **Table A.1.30**
All LDV L2	01.10.92	US 90	See **Table A.1.31.1**
All Vehicles L1 & L2	01.01.95	91/441/EEC and 93/59/EEC	See **Table A.1.4** See **Table A.1.6**
All HDV L3	01.10.93 01.10.96	91/542/EEC (A) 91/542/EEC (B)	See **Table A.1.10** See **Table A.1.10**

Note: There are no regulations for motor-cycles and mopeds.

Sweden

Sweden has introduced more stringent limits for all vehicle categories as given in **Tables A.1.20** and **A.1.21**. Vehicle manufacturers must also meet conformity guarantees, as in US legislation.

In addition, limits have been published in the A14 Regulation of 18 March 1992 for Low Emitting Vehicles (LEVs). Voluntary adoption will be encouraged within the framework of taxes according to the two environmental categories - Classes C.1 and C.2, with C.1 having the more stringent levels. Tests are carried out according to the US FTP 75 or ECE + EUDC procedures. The limit values are based on US Clean Air Act Limits and are also given in **Tables A.1.22** and **A.1.23** for the US FTP 6 and ECE procedures, respectively.

The limits apply to spark-ignition engines (gasoline-, gaseous- and alcohol-fuelled or hybrid electric vehicles) or compression-ignition engines (diesel- and alcohol-fuelled or hybrid electric vehicles). Excluded from this legislation are motorcycles, vehicles with maximum speeds not exceeding 50 km/h and vehicles with GVWs exceeding 3500 kg.

Starting on April 1st 1996, the three largest cities in Sweden (Stockholm, Gothenburg and Malmö) restricted the types of heavy duty vehicles which could enter their city centres to those conforming to the Euro 2 emissions standards, those which are less than eight years old and older vehicles retrofitted with equipment to reduce emissions. The retrofit equipment, which has to be approved by Svensk Bilprovning, must be of one of two types depending on the age of the vehicle. The B Type kit applies to 1986 and older vehicles and must reduce particulate emissions and hydrocarbons by 80% and 60% respectively. 1986 and 1987 model-year vehicles can alternatively be fitted with Type A systems which reduce particulates and hydrocarbons by 20% and 60%. All 1980 model-year and older vehicles will be banned in 1996. In 1997, 1998, 1999, 2000 and 2001 the ban will further extended to 1981, 1982, 1983/4, 1985/86 and 1987/88 model-year vehicles respectively.

Table A.1.20 Swedish Emission Limits FTP Vehicle Categories

Vehicle Category A-14 Regulation Environmental Class 2	**GVW tonne**	**GVW-Service Wt kg**	**Maximum Speed km/h**	**Test Method**	**Useful Life (1) yrs/km**
L1 Passenger Car	<3.5	< 690	>50	1987 US FTP 75	10/160000
L2 Light Duty Vehicle	< 3.5	> 690	>50	1990 US FTP 75	10/160000 (1)
L3 Light Duty Vehicle	< 3.5	>690	>30	1990 US FTP 75	11/200000 (2)

Table A.1.21 Swedish Emissions Regulations by Vehicle category (Vehicle category according to test cycle)

Vehicle	**Class**	**Effective Date (model yr.)**	**CO g/km**	**HC g/km**	**NOx g/km**	**NOx (hwy) g/km**	**Pm (3) g/km**	**Evap g/test**	**Regulation /Procedure**
L1	C3	(1989)	2.1	0.25	0.62	0.75	0.124	2	A-13/FTP
L2	C3	(1992)	6.2	0.5	1.1	1.4	0.162	2	A-13/FTP
M1/N1	C3	01.01.95	as per 93/59/EEC (**Table A.1.6)**						A-13/ECE
			g/kWh	**g/kWh**	**g/kWh**		**g/kWh**		
HDV (>3.5t GVW)	C3	(1993)	4.9	1.2	9.0		0.4		A-30 ECE R49

See notes below **Table A.1.23**.

Table A.1.22 Low Emitting Vehicle (LEV)[1] Emissions Standards A 14 Regulation (FTP Categories and Cycle)

Category (Model Year)	Class	Dura-bility km	CO g/km	CO @-7ºC g/km	HC g/km	NMHC (4) g/km	NOx g/km	NOx hwy g/km	Pm (3) g/km	Evap g/test	HCHO (5) mg/km	Useful Life (yrs/km)
	C1	80k	2.1	6.2	0.25	0.08	0.25	0.33	0.05	2.0	9	
L1		160k	2.6			0.01	0.37		0.06	2.0	11	10/ 160,000
(1993)	C2	80k	2.1		0.25	0.16	0.25	0.33	0.05	2.0	9	
		160k	2.6			0.19	0.37		0.06	2.0	-	
L2	C1	80k	2.7	7.5		0.10	0.43		0.05	2.0	11	
(<2700 kg)		160k	3.4		0.50	0.12	0.61	1.2	0.06	2.0	14	10/ 160,000
(1993)	C2	80k	2.7			0.20	0.43		0.05	2.0	11	
		160k	3.4		0.50	0.25	0.61	1.2	0.06	2.0	-	
L3	C1	80k	2.7	7.5		0.10	0.43			2.0	14	
(>2700 kg)		200k	4.0		0.50	0.14	0.61	1.2	0.06	2.0	17	11/ 200,000
(1994)	C2	80k	2.7			0.25	0.43			2.0	14	
		200k	4.0		0.50	0.29	0.61	1.2	0.06	2.0	-	

Table A.1.23 Swedish Low Emitting Vehicle (LEV) Emissions Standards A-14 and A-31 Regulations: ECE Procedures

Class	CO g/km	HC+NOx g/km		Pm g/km	Evap g/test	Useful Life (yrs/km)
M1 C2 gasoline	2.2	0.5		-	2.0	5/80,000
M1 C2 IDI diesel	1.0	0.7		0.08	-	5/80,000
DI diesel	1.0	0.9		0.10	-	
		HC g/kWh	**NOx g/kWh**	**g/kWh**		
HDV C2 (1993)[2]	4.0	**1.1**	**7.0**	**0.15**	-	

(1) New LDVs approved according to ECE regulations. Other LDVs 11 years/200,000 km

(2) New HDV with service life: <200,000 km, 8 yrs/200,000 km; 200,000-500,000 km, 8 yrs/350,000 km; >500,000 km, 8 yrs/500,000 km

(3) Applies to diesel vehicles only, which also have smoke limits of 3.5 Bosch / 45 Hartridge.

(4) Expressed as NMOG for Class 1, NMHC for Class 2.

(5) For methanol fuelled vehicles (those designed to operate on more than 50% methanol) only. Also HC/NMOG/NMHC limits refer to “organic equivalents”.

Switzerland

Switzerland formally adopted the US 1977 standards using the FTP 75 procedure as a compulsory requirement from 1986. It has also implemented US 1983 exhaust emission standards, including particulates and evaporative emissions from October 1987 for cars and October 1988 for light commercial vehicles. Heavy trucks have been regulated against the ECE 49 procedure since October 1987. There are also stringent limits for motor cycles and mopeds, the latter requiring the use of catalysts. **Table A.1.24** summarizes the limits applicable until September 1995. From 1.10.95 Switzerland adopted EU emission limits as laid down in Directives 91/441/EEC, 94/12/EC, 91/542/EEC and 93/59/EEC. Switzerland will apply the same effective dates as those stipulated in the directives.

Table A.1.24 Swiss Emission Limits by Vehicle Category

Vehicle Category	Effective Date	CO g/km	HC g/km	NOx g/km	Pm g/km	Evap. g/test	Cycle
Cars <760 kg payload	01.10.86	9.3	0.9	1.2	-	-	FTP 72
	01.10.87	2.1	0.25	0.6	0.37	2.0	FTP 75
	01.10.88	2.1	0.25	0.62	0.12	2.0	FTP 75
Light Trucks >760 kg payload	01.10.88	6.2	0.5	1.4	0.37	2.0	
<3500 kg GVW	01.10.90	6.2	0.5	1.1	0.37	2.0	all
	01.10.92	6.2	0.5	1.1	0.16	2.0	FTP 75
>1400 kg payload	01.10.88	8.0	0.6	1.8	0.48	2.0	
<3500 kg GVW	01.01.91	6.2	0.5	1.1	0.37	2.0	
	01.10.92	6.2	0.5	1.1	0.16	2.0	
		g/kWh	**g/kWh**	**g/kWh**	**g/kWh**		
Heavy Trucks >3500 kg GVW	01.10.87	8.4	2.1	14.4	-		ECE 49
	01.10.91	4.9	1.2	9.0	0.7		
		g/km	**g/km**	**g/km**			
Mopeds	01.10.88	0.50	0.5	0.10			ECE 47
Motorcycles: 2-stroke	01.10.87	8.0	7.5	0.10			ECE 40
	01.10.90	8.0	3.0	0.10			
Motorcycles: 4-stroke	01.10.87	13.0	3.0	0.30			ECE 40

Vehicle Category	Effective Date	Idle (mogas only) CO %v	Idle (mogas only) HC ppm	Cross Country Cycle NOx (g/km)
Cars <760 kg payload	01.10.88	0.5	100	0.76
Light Trucks >760 kg payload <3500 kg GVW	01.10.90	1.0	200	1.8
Motorcycles 2 and 4-strokes		2.5		
		g/min		
Mopeds		0.1		

Eastern European Countries

Most East European countries apply some combination of ECE and EU regulations, as shown in **Table A.1.25**.

Table A.1.25 Summary of Vehicle Emissions Legislation in Eastern Europe

Country	Vehicle Type	Effective Date	Emission Limits	Reference
Bulgaria	passenger cars & light duty ≤ 3.5t	1975 1979	ECE R 24.03 ECE R 83.01	Table A.1.9 Table A.1.3
	heavy duty > 3.5t	1975 1981	ECE R 24.03 ECE R 49.02	Table A.1.9 Table A.1.10
	motorcycles	1979	ECE R 40.01	Table A.1.13
	mopeds	1982	ECE R 47	Table A.1.15
Commonwealth of Independent States (CIS)	passenger cars & light duty ≤ 3.5t	1987 1996 1987	ECE R 15.04 ECE R 83.02 ECE R 24.03	Table A.1.9 Table A.1.4 Table A.1.9
	heavy duty > 3.5t	1996 1987	ECE R 49.02 ECE R 24.03	Table A.1.10 Table A.1.9
	motorcycles	1987	ECE R 40.01	Table A.1.13
	mopeds	1987	ECE R 47	Table A.1.15
	see also **Tables A.1.26** to **A.1.28**			
Croatia	passenger cars & light duty ≤ 3.5t	1976 1985	ECE R 15.04 ECE R 83.02	Table A.1.9 Table A.1.4
	heavy duty > 3.5t	1985	ECE R 49.02	Table A.1.10
	motorcycles	1988	ECE R 40.01	Table A.1.13
	mopeds	1985	ECE R 47	Table A.1.15
Czech & Slovak Republics	passenger cars & light duty ≤ 3.5t	1986 1995	ECE R 24.03 ECE R 83.02	Table A.1.9 Table A.1.4
	heavy duty > 3.5t	1986 1992	ECE R 24.03 ECE R 49.02	Table A.1.9 Table A.1.10
	motorcycles	1988	ECE R 40.01	Table A.1.13
	mopeds	1982	ECE R 47	Table A.1.15
Hungary [1]	passenger cars & light duty ≤ 3.5t	1996 1997 2000	ECE R 24.03 ECE R 83.01A ECE R 83.01B/C	Table A.1.9 Table A.1.3 Table A.1.3
	heavy duty > 3.5t	1986 1996 1997	ECE R 49 ECE R 24.03 ECE R 49.01	Table A.1.8 Table A.1.9 Table A.1.8
	motorcycles	1988	ECE R 40.01	Table A.1.13
	mopeds	1996	ECE R 47	Table A.1.15
Poland	passenger cars & light duty ≤ 3.5t	1992 1995	ECE R 24.03 ECE R 83.02	Table A.1.9 Table A.1.4
	heavy duty > 3.5t	1992 1995	ECE R 24.03 ECE R 49.02	Table A.1.9 Table A.1.10
	motorcycles	1992	ECE R 40.01	Table A.1.13
	mopeds	1992	ECE R 47	Table A.1.15
Romania	passenger cars & light duty ≤ 3.5t	1996 1996 2000 2002	ECE R 24.03 ECE R 83 ECE R 83.01 ECE R 83.02	Table A.1.9 Table A.1.3 Table A.1.3 Table A.1.4
	heavy duty > 3.5t	1994 1.1.1996 2002	ECE R 49.01 ECE R 24.03 ECE R 49.02B	Table A.1.8 Table A.1.9 Table A.1.10
	motorcycles	1988	ECE R 40.01	Table A.1.13
	mopeds	1996	ECE R 47	Table A.1.15
Slovenia	passenger cars & light duty ≤ 3.5t	1994 1996	ECE R 24.03 ECE R 83.02	Table A.1.9 Table A.1.4
	heavy duty > 3.5t	1994 1994	ECE R 24.03 ECE R 49.02	Table A.1.9 Table A.1.10
	motorcycles	1995	ECE R 40.01	Table A.1.13
	mopeds	1985	ECE R 47	Table A.1.15

(1) Diesel engine free acceleration smoke limits

	Free acceleration from	Light absorption coefficient
Naturally aspirated	idle	3.5 m^{-1}
	1000 rev/min	1.5
Turbocharged	idle	2.5

Source: Current and Future Exhaust Emission Legislation, AVL List GmbH, March 1996

Table A.1.26 Russian Federation Exhaust Emission Limits
Regulation OST 37. 001. 054-86. Gasoline cars without catalytic converters

Vehicle Reference Mass (kg)	**Exhaust emission limits (g/test) Test Method: ECE 15**			
	CO		**HC+NOx**	
	Type Approval	**Conformity of Production**	**Type Approval**	**Conformity of Production**
< 1020	52	62	19.0	23.8
1021-1250	60	72	20.5	25.6
1251-1470	68	82	22.0	27.5
1471-1700	76	91	23.5	29.4
1701-1930	83	100	25.5	31.3
1931-2150	91	109	26.5	33.1
> 2150	99	119	28.0	35.0

The limits for off-road vehicles, trucks and buses are stipulated by multiplying the above values by the following factors:
for < 2000 kg: 1.25
for > 2000 kg: 2.00

Table A.1.27 Russian Federation Exhaust Emission Limits -
Regulation OST 37. 001. 054-86. Gasoline cars with catalytic converters

	Exhaust emission limits (g/test) Test Method: ECE 15					
	CO		**HC+NOx**		**NOx**	
Cubic Capacity (litres)	**Type Approval**	**Conformity of Production**	**Type Approval**	**Conformity of Production**	**Type Approval**	**Conformity of Production**
1.4-2.0	30	36	8.0	9.6	-	-
> 2.0	25	30	6.5	7.8	3.5	4.2

The limits for off-road vehicles, trucks and buses are stipulated by multiplying the above values by the following factors:
for < 2000 kg: 1.25
for > 2000 kg: 2.0

Table A.1.28 Russian Federation Exhaust Emission Limits -
Regulation OST 37. 001. 234-81. Diesel engines

Exhaust emission limits (g/bhp.h) Test Method: ECE R49 13-Mode		
CO	**HC**	**NOx**
9.5	3.4	14.35

Table A.1.29 Russian Federation Black Smoke Emission Limits - Regulation GOST 17. 2. 01-84. Diesel engines

Nominal Flow (litres/second)	Smoke Limits (opacity %)
<42	60
50	56
75	50
100	45
125	41
150	39
175	37
200	35
>200	34

The procedure consists of two stages:

- Full load
- Constant engine speeds between max. speed and 45% of max. speed, but no less than 1000 rpm.

Opacity under free acceleration should not exceed the maximum approved level under steady regimes for naturally aspirated engines, or more than by 10% for turbocharged engines.

A.1.3. UNITED STATES AND CANADA

Historical Background

National exhaust emission limits for cars were first set in the Clean Air Act of 1968. However, in 1970 the US Congress passed amendments to this Act which incorporated the so-called "*Muskie*" proposals. These amendments required exhaust emission reductions of 90% from the then current levels to take effect in 1975-76. After lengthy debate between the motor industry and the EPA, implementation of these regulations was delayed until technology was available to meet them. This led to the establishment of interim standards for 1975 and 1976 which were subsequently extended to 1979. Oxidation catalysts were required for most vehicles to meet the 1975 and subsequent limits. As a result, unleaded gasoline was made widely available in 1975 to cater for these catalyst cars.

In 1977 Congress amended the Clean Air Act. Under this amendment the EPA formulated National Ambient Air Quality Standards (NAAQS) which set the level of air cleanliness required throughout the US. Areas which failed these standards are declared non-attainment areas and are required to develop plans to bring the area into compliance. These State Implementation Plans (SIPs) include stationary and other sources in addition to vehicles. SIPs are submitted to the EPA and, if acceptable, provide a schedule for the implementation of clean air measures. If the plans were deemed insufficient to meet the standards the EPA are empowered to develop a Federal Implementation Plan (FIP) instead. Following the act, the EPA set revised standards to achieve a 90% HC reduction in 1980, plus a 90% CO and 75% NO_x reduction in 1981. This led to the widespread introduction of 3-way catalyst technology. The original 90% NO_x reduction (0.4 g/mile) was left as a research goal, although it was adopted in California and now forms part of the new Clean Air Act. **Table A.1.30** gives details of this legislation.

Separate emission limits for light-duty trucks were introduced in 1975, but these did not require the use of catalysts. However more severe limits were imposed in 1984 and 1988 limits requiring catalyst and 3-way catalyst respectively to meet the standards (see **Table A.1.31**).

Emission limits for heavy duty engines were originally set in 1970 and, in the 1977 Clean Air Act, stringent reductions in HC and CO emissions were proposed to take effect in 1981. However, these standards were deferred until technology was available and were finally implemented in 1987, requiring catalysts on heavy duty gasoline engines. Further reductions in NOx and diesel particulate limits, implemented from 1990 to 1995, required 3-way catalysts for heavy duty gasoline engines and radical changes in diesel engine technology. **Table A.1.32** provides details of emission limits for heavy duty vehicles.

The US standards apply over the "*useful life*" of the vehicle, which for cars is defined as 50 000 miles (80 000 km) or 5 years. The durability of the emission control device must be demonstrated over this distance, within allowed deterioration factors, and in some cases over 100 000 miles (160 000 km). The heavy duty truck regulations for 1987 (and later) require compliance over longer periods, representative of the useful life of the vehicle.

Table A.1.33 shows emission limits for motorcycles. Federal limits have not been updated since 1980, but Californian limits applied during the 1980s are more stringent.

Federal legislation introduced since the Clean Air Act Amendments of 1990 are dealt with in **Part 1**.

The State of California has always been a leader in emission control legislation and has generally adopted limits more severe than the Federal (Clean Air Act) limits which apply in the rest of the USA. The main reason for this is the atmospheric smog and poor air quality in the Los Angeles area. Although there has been a significant improvement in air quality over the last twenty years, Los Angeles still has the highest ozone levels of any city in the United States. As a consequence, the California Air Resources Board (CARB) has decided to implement even more stringent emission limits in California over the next ten years or so, culminating in the introduction of the "*Zero Emissions Vehicle*" early in the new century. Legislation up to 1990 is summarised in **Tables A.1.30** to **A.1.33,** and recent legislation is discussed fully in **Part 1**.

Table A.1.30 Historical Review of US Light Duty Vehicle Emissions Regulations

Federal						California					
Model Year	**CO g/mile**	**HC g/mile**	**NOx g/mile**	**Pm g/mile**	**Evap. g/test**	**Durability Mileage[13]**	**CO g/mile**	**HC g/mile**	**NOx g/mile**	**Pm g/mile**	**Evap. g/test**
Pre-control	90	15	6.2	-	6.0		15	90	6.2	-	6.0
1970[1]	34	4.1	-	-	-		34	4.1		-	6.0[2]
1971[1]	34	4.1		-	6.0[2]		34	4.1	6.2	-	6.0
1972[1]	28	3.0		-	2.0		28	2.8	3.2	-	2.0
1973-74[1]	28	3.0	3.1	-	2.0		28	2.8	2.0	-	2.0
1975-76	15	1.5	3.1	-	2.0		9.0	0.9	2.0	-	2.0
1977	15	1.5	2.0	-	2.0		9.0	0.41	1.5	-	2.0
1978-79	15	1.5	2.0	-	6.0[3]		9.0	0.41	1.5	-	6.0[3]
1980	7.0	0.41	2.0	-	6.0	50 000 [4]	9.0	0.39[5]	1.0[6]	-	2.0
						100 000 A	9.0	0.39	1.5	-	
						100 000 B	10.6	0.46	1.5	-	
1981	3.4[7]	0.41	1.0[8]	-	2.0	50 000 A	3.4	0.39	1.0	-	2.0
						50 000 B	7.0	0.39	0.7	-	
						100 000 A	3.4	0.39	1.5	-	
						100 000 B	4.0	0.46	1.5	-	
1982-83[9]	NC	NC	NC	0.6	NC	50 000 A	7.0	0.39	0.4	0.6	2.0
						50 000 B	7.0	0.39	0.7[10]	0.6	2.0
						100 000 A	7.0	0.39	1.5	0.6	2.0
						100 000 B	8.3	0.46	1.5	0.6	2.0
1984[11]	NC	NC	NC		NC	50 000 A	7.0	0.39	0.4	0.6	2.0
						50 000 B	7.0	0.39	0.7	0.6	2.0
						100 000 A	7.0	0.39	1.0	0.6	2.0
						100 000 B	8.3	0.46	1.0	0.6	2.0
1985	NC	NC	NC	NC	NC		NC	NC	NC	0.4	NC
1986	NC	NC	NC	NC	NC		NC	NC	NC	0.2	NC
1987-88	NC	NC	NC	0.2	NC		NC	NC	NC	NC	NC
1989-92	NC	NC	NC	NC	NC		NC	NC	NC	0.2	NC
1993-94	NC	NC	NC	NC	NC	50 000	3.4	0.25[12]	0.4	0.08	2.0
						100 000	4.2	0.31	0.7	0.08	2.0
for current and future limits see **Part 1**											

(1) Pre-1975 standards are expressed as equivalent 1975 test values.

(2) Carbon canister trap method.

(3) Sealed Housing Evaporative Determination (SHED) technique - 6.0 g/test by SHED method represents approximately 70% less emissions than 2 g/test by the carbon trap method.

(4) Refers to 50 000 mile and 100 000 mile Certification options.

(5) Non-methane HC. Compliance with total HC standard of 0.41 g/mile is an acceptable alternative.

(6) Maximum NOx emissions allowed during highway cycle: 1.33 x standard.

(7) Waivers up to 7.0 g CO/mile for 1981 were granted by EPA for some car models.

(8) Waivers up to 1.5 g NOx/mile were granted for some 1981 and 1982 diesel vehicles.

(9) High altitude standards for 1982 and 1983 - 0.57 HC, 1.0 NOx, 7.8 CO, 2.6 evap.

(10) This option (0.7 g NOx/mile standard for 1983 and later) requires limited recall authority for 7 years/75 000 miles.

(11) All cars must meet standards at all altitudes.

(12) Additional separate limits for formaldehyde (HCHO) (see **Table A.1.39**).

(13) "A" and "B" California emission limits refer to the limits at start and end of the durability test schedule.

(NC) No Change.

Table A.1.31 Historical Review of US light duty truck emissions regulations (less than 8500 lbs GVW)

Table 1.31.1 Federal Exhaust Emissions Standards by 1975 FTP [1]

Model Year	Weight Category (lbs)[2]	Durability Mileage	CO g/mile	HC g/mile	NOx g/mile	Pm g/mile
1970	<6000 GVW	Same as passenger cars				
1975	<6000 GVW		20	2.0	3.1	-
1976-77	<6000 GVW		NC	NC	NC	-
1978	<6000 GVW		NC	NC	NC	-
1979	<8500 GVW[3]		18	1.7	2.3	-
1980	<8500 GVW		NC	NC	NC	-
1981	<8500 GVW		NC	NC	NC	-
1982[7]	<8500 GVW		18	1.7	2.3	0.6
1983	<8500 GVW		NC	NC	NC	-
1984[9]	<8500 GVW		10	0.8	2.3	0.6
1985	<8500 GVW		NC	NC	NC	0.6
1986	<8500 GVW		NC	NC	NC	0.6
1987	<8500 GVW		NC	NC	NC	0.26[11]
1988[10]	<8500 GVW		10	0.8	1.2/1.7	0.26[11]
1989	<8500 GVW		NC	NC	NC	NC
1991	0-3750	120 000	10	0.8	1.2	0.26[11]
	3750-8500	120 000	10	0.8	1.7	0.13
1993	No Change					
For current and future limits see **Part 1**						

See notes following **Table A.1.31.2**

Table A.1.31.2 California Exhaust Emission Standards

Model Year	Weight Category (lb.)[2]	Durability Mileage[13]	CO g/mile	HC g/mile	NOx g/mile	Pm g/mile
1970	<6000 GVW		same as passenger cars			
1975	<6000 GVW		20	2.0	2.0	-
1976-77	<6000 GVW		17	0.9	2.0	-
1978	<6000 GVW		17	0.9	2.0	-
	6000-8500 GVW		17	0.9	2.3	-
1979	<4000 IW		9.0	0.41	1.5	-
	4000-5999 IW		9.0	0.50	2.0	-
	6000-8500 IW		17	0.9	2.3	-
1980	<4000 IW		9.0	0.39[4]	1.5/2.0[5]	-
	4000-5999 IW		9.0	0.50	2.0	-
	6000-8500 IW		17	0.9	2.3	-
1981	<4000 IW	50 000	9.0	0.39	1.0[6]	-
	4000-5999 IW		9.0	0.50	1.5	-
	6000-8500 IW		9.0	0.6	2.0	-
	<4000 IW	A 100 000	9.0	0.34	1.5	-
	<4000 IW	B 100 000	10.6	0.40	1.5	-
	4000-5999 IW		9.0	0.5	2.0	-
	6000-8500 IW		9.0	0.6	2.3	-
1982[7]	<8500 GVW		NC	NC	NC	0.6
1983	<4000 IW	A 50 000	9.0	0.39	0.4	0.6
	<4000 IW	B 50 000	9.0	0.39	1.0[8]	0.6
	4000-5999 IW		9.0	0.5	1.0	0.6
	6000-8500 IW		9.0	0.6	1.5	0.6
	<4000 IW	A 100 000	9.0	0.39	1.5	0.6
	<4000 IW	B 100 000	10.6	0.46	1.0	0.6
	4000-5999 IW		9.0	0.5	1.5	0.6
	6000-8500 IW		9.0	0.6	2.0	0.6
1984[9]	<8500 GVW		NC	NC	NC	NC
1985	<8500 GVW		NC	NC	NC	0.4
1986	<8500 GVW		NC	NC	NC	0.2
1987	<8500 GVW		NC	NC	NC	NC
1988[10]	<8500 GVW		NC	NC	NC	NC
1989	<8500 GVW		NC	NC	NC	0.08
1993	0-3750	50 000	3.4	0.25[12]	0.4	0.08
	"	100 000	4.2	0.31	"	"
	3750-5750	50 000	4.4	0.32	0.7	0.08
	"	100 000	5.5	0.40	"	"
for current and future limits see **Part 1**						

(1) Evaporative emission standards same as those for passenger cars.

(2) GVW - Gross Vehicle Weight IW - Inertia Weight.

(3) Prior to 1979 heavy duty standards applied to medium duty (6000 - 8500 lbs GVW) vehicles.

(4) Non-methane HC. Compliance with a total HC standard of 0.41 g/mile is an acceptable alternative.

(5) NOx standard of 2.0 g/mile for 4-wheel drive vehicles.

(6) Maximum NOx emissions allowed during highway cycle: 2.0 x standard.

(7) High altitude exhaust standard established for 1982 and 1983 - HC 2.0, CO 26, NOx 2.3 g/mile, evap. 2.6 g/test.

(8) This optional 1.0 g/mile NOx standard for 1983 and later requires limited recall authority for 7 years/75 000 miles.

(9) High altitude exhaust standard established for 1984 and later - HC 1.0, CO 14, NOx 2.3 g/mile, evap. 2.6 g/test. Light duty trucks may also be certified using half life option (1984 only).

(10) Maximum allowed NOx emission 1.2 g/mile for <6000 lbs GVW and 1.7 g/mile for 6000 - 8500 lbs GVW.

(11) The particulate (Pm) emission standards apply to diesel powered trucks only and were relaxed for vehicles over 3750 lbs GVW. Limits are 0.5 g/mile for 1987 model year and 0.45 g/mile for 1988-90.

(12) These are all NMHC (non-methane hydrocarbon) limits. Total HC limits of 0.38/0.46 apply over 50 000 miles.

(13) "A" and "B" California emission limits refer to the limits at start and end of the durability test schedule.

(NC) No change

Table A.1.32 Historical Review of US heavy duty vehicle emissions regulations (> 8500 lbs GVW)[1]

Year	Federal (g/bhp.h)						California (g/bhp.h)			
	CO	HC	NOx	HC+NOx	Pm	Evap g/test	CO	HC	NOx	HC+NOx
1969	-	-	-	-	-	-	63.6	6.55	-	-
1970-71	63.6	6.55	-	-	-	-	63.6	6.55	-	-
1972	63.6	6.55	-	-	-	-	41.1	4.21	-	-
1973	63.6	6.55	-	-	-	-	40	-	-	16
1974	40	-	-	16	-	-	30	-	-	10
1975	40	-	-	16	-	-	25	-	-	5
Or							25	1.0	7.5	-
1979	25	1.5[2]	-	10	-	-	25	1.5[2]	7.5	-
or	25	-	-	5	-	-	25	-	-	5
1980-83	25	1.5	-	10	-	-	25	1.0	-	6
or	25	-	-	5	-	-	25	-	-	5
1984[3]										
Transient	25	1.5	10.7	10	-	-	25	0.5	-	4.5
Idle	0.5%	-	-	-	-	-	-	-	-	-
Diesel Option	15.5	0.5	9.0	-	-	-	15.5	1.3	5.1	-
1985-86[4]										
A [8]	37.1	1.9	10.6	-	-	3.0[5]	No Change			
B [8]	40.0	2.5	10.7	-	-	3.0				
Diesels	15.5	1.3	10.7	-	-	-				
1987										
<14000 GVW	14.4	1.1	10.6	-	-	3.0	No Change			
Idle[6]	0.5%	-	-	-	-	-				
>14000 GVW	37.1	1.9	10.6	-	-	4.0				
Diesels	15.5	1.3	10.7							
Idle[6]	0.5%	-	-	-	-	-				
1990										
Both classes + Diesels	NC	NC	6.0	-	0.6[7]	4.0				
For model year 1991 forward see **Part 1**										

(1) Apply to engines in vehicles over 6000 or 8500 lbs for which no light duty of medium duty standard applies. Standards apply to gasoline vehicles only through 1972 for California and 1973 for Federal, and to gasoline and diesel thereafter. Test procedure is 13 mode cycle up to 1984.

(2) HC measurement method changed from NDIR to FID for gasoline engines (FID had been previously specified for diesels) resulting in higher readings for equivalent emissions. Optional use of former test procedures allowed for 1979 models.

(3) The HC and CO standards represent 90% reductions from the uncontrolled baseline. A new transient test procedure (EPA cycle) was introduced from 1984. The NOx standard shown is an interim standard to maintain the 1982 level of control with the revised test procedure.

(4) Different dynamometer schedules used for options A and B.

(5) Evaporative standard for 8 500-14 000 lbs. HDTs over 14 000 lbs must meet 4.0 g/test.

(6) For heavy duty gasoline engines utilizing catalyst technology.

(7) Diesels only.

(8) A and B limits apply at the start and end of the durability test cycle

(NC) No change

Table A.1.33 US Emissions Limits for Motorcycles over 50 cm^3 Capacity (Modified FTP 75)

Regulation	Model Year	Engine Capacity (cc)	CO g/km	HC g/km
Federal and California	1978-9	50-170	17.0	5.0
		170-750	17.0	5.0 + 0.0155(D-170)
		>750	17.0	14.0
	1980	all	12.0	2.0
California only	1982-4	50-279	12.0	1.0
		>280	12.0	2.5
	1985	50-279	12.0	1.0
		>280	12.0	1.4 (1)
	1988	280-699	12.0	1.0
		>700	12.0	1.4 (1)

(1) Applied as corporate average

A.1.3.1. The 1990 US Clean Air Act Amendments (CAAA) and beyond

The objective of US legislation has always been to improve air quality, particularly in large cities which have experienced problems of ozone formation in summer and high ambient CO concentrations in winter. It became apparent, however, that the 1977 Act had not achieved these objectives. Figures indicated that 9 cities have failed to meet the minimum standards for ozone and 41 failed to meet CO standards. This led to calls from a number of quarters for a revision of the 1977 Act.

In July 1989 President Bush proposed a major revision of the Act. Following protracted negotiations, a House and Senate conference reached a compromise agreement which was signed by President Bush in November 1990.

The full CAAA is a massive document which contains 7 "*Titles*" covering a wide range of emission sources and air quality issues. Title 2 of the CAAA relates to motor vehicles, fuels, and their emissions, and its major features are as follows:

- The imposition of tighter tailpipe emission standards.
- The establishment of compliance testing and maintenance programmes related to the above.
- The establishment of a reformulated gasoline programme.
- Legislation relating to clean fuels and clean fuels vehicles, which could lead to the introduction of alternative fuels.
- Legislation covering operators of vehicle fleets in areas with specific air quality problems.
- Reaffirmation of the rights of individual states with particular air quality problems to set more severe emission standards, but these must be identical to California limits.

Once the Amendments were approved, the EPA worked hard with the assistance of the oil and motor industries to develop detailed rules to put the legislation into place.

The most important of these are the 'Tier I' exhaust emissions limits for light duty vehicles, evaporative emissions procedures and limits, plus the rules for reformulated gasolines.

Since the 1990 amendment, the role of the EPA in establishing the air quality standards for California has not always been clear, with various legislative moves first involving and then omitting the EPA from the formulation of an implementation plan. In the event California went ahead with its own proposals which are now in force (see **Section A.1.3.3** and **Part 1**).

The twelve eastern states comprising the Ozone Transport Region have also adopted some elements of the California legislation (see **Section A.1.3.4** and **Part 1**) but the EPA are proposing a compromise solution which is more severe than the Tier I proposals but less severe than the California proposals.

A.1.3.2. Federal Exhaust Emission Legislation

Light Duty Vehicles (Cars and Trucks below 3750 lbs GVW)

There are two sets of standards defined in the CAAA, Tier I and Tier II (Tier 0 is the current legislation), and they are given in **Table A.1.34**. Tier I was covered by a final regulation, published 5 June, 1991 and was introduced progressively from 1994. Starting in 1996, vehicles must be certified up to 100 000 miles, or to the higher "*useful life*" limits.

In-use (recall) standards are also specified which must be met under randomized testing of in-service cars by the EPA. If the limits are not met an "*emissions recall*" may be triggered where the manufacturer has to recall and rectify any emissions defects.

Tier II emission limits have been proposed for 2004, which are 50% lower than the Tier I limits. However, these will only come into effect if the EPA Administrator decides, after a study as required by the Amendments, that they are necessary, technically feasible and cost-effective. Already alternative legislation has been put forward to satisfy the ozone standards of the twelve eastern states.

Table A.1.34 US Light Duty Vehicle Emissions Regulations

Effective Date (% Production)		CO (3) g/mile	NMHC (2) g/mile	NOx g/mile	Pm g/mile	Evap. g/test
Tier 0		3.4	0.41	1.0		2.0
US Tier I (1)	**Gasoline**	3.4 (4.2)	0.25 (0.31)	0.4 (0.6)	-	(4)
	Diesel	3.4 (4.2)	0.25 (0.31)	1.00 (1.25)	0.08 (0.10)	-
US Tier II (5)		1.7	0.125	0.2	0.08	(3)

(1) Limits are for an intermediate life of 5 years or 50, 000 miles with those for full useful life of 10 years or 100,000 miles in parentheses

(2) Tier 0 limit is for Total HC. For methanol-fuelled vehicles the THC and NMHC limits are for OMHCE and OMNMHCE respectively.

(3) A CO standard of 10 g/mile is specified at 20°F, commencing in 1994. However, if despite the “reformulated gasoline” programme six or more cities remain out of compliance with CO air quality targets between now and 1996, the more stringent limit of 3.4 g/mile will be phased in over three years, starting in 2001.

(4) See **Table A.1.37**

(5) Implementation scheduled for 2004 at the discretion of the EPA

Light Duty Trucks

Tier I emissions limits have been developed for light duty trucks and are being progressively introduced (**Table A.1.35**). Those for light light duty trucks were introduced in 1996, except for particulates limits for methanol- and diesel-fuelled diesel-cycle engines, where 80% of sales were required to conform by 1996 and all sales by 1997. For heavy light duty trucks, except cold start CO, 50% of sales were expected to conform to all requirements, by 1996 and 100% by 1997. The implementation of cold start CO for these vehicles was required to be completed by 1996.

Table A.1.35 US Federal emissions requirements for light and heavy duty light trucks

Vehicle	Category	Tier	CO (g/mile)	THC [(2)] (g/mile)	NMHC [(2)] (g/mile)	NOx (g/mile)	Pm [(3)] (g/mile)
Light LDT	lvw (lb)						
methanol & diesel	0-3,750 > 3,751	Tier 0 Tier 0					-- (0.26) -- (0.13)
gasoline & methanol	0-3,750 3,751-5 750	Tier 1 Tier 1	3.4 (4.2) 4.4 (5.5)	-- (0.8) -- (0.8)	0.25 (0.31) 0.32 (0.40)	0.4 (0.6) 0.7 (0.97)	0.08 (0.1) 0.08 (0.1)
diesel	0-3,750 3,751-5,750	Tier 1 Tier 1	3.4 (4.2) 4.4 (5.5)	-- (0.8) -- (0.8)	0.25 (0.31) 0.32 (0.40)	1.0 (1.25) -- (0.97)	0.08 (0.1) 0.08 (0.1)
Heavy LDT	lvw/alvw (lb)						
gasoline, methanol & diesel	0-3,750 >3,750	Tier 0 Tier 0	-- (10.0) -- (10.0)	-- (0.8) -- (0.8)	-- --	-- (1.2) -- (1.7)	-- (0.26) -- (0.13)
	3,751-5,750 >5,750	Tier 1 Tier 1	4.4 (6.4) 5.0 (7.3)	-- (0.8) -- (0.8)	0.32 (0.46) 0.39 (0.56)	0.7 (0.98) 1.1 (1.53)	-- (0.10) -- 0.12)

(1) Limits are intermediate life (5yrs or 50,000 miles whichever occurs first) with full life 11 yrs or 120,000 miles for Tier 0 and 10 yrs or 100,000 miles for Tier 1 in parentheses

(2) THC and NMHC are OMHCE and OMNMHCE (in g carbon) respectively for methanol-fuelled engines

(3) Diesel vehicles only

Cold Temperature CO Emissions for Light Duty Vehicles and Trucks

The Clean Air Act Amendments specify a CO standard at 20°F (-7°C) of 10 g/mile for light duty vehicles and light light duty trucks and of 12.5 g/mile for heavy light duty trucks, starting in 1994. However if, despite the oxygenate gasoline programme, six or more cities remain out of compliance with CO air quality targets between 1994 and 1996, the more stringent limit of 3.4 g/mile will be phased in over three years starting in 2001.

The EPA is reviewing its stance regarding whether it should allow the averaging of the results of CO emissions at low temperatures from a given manufacturer's product line. The present regulations require that 40 percent must meet the standard by 1994, 80 per cent by 1995 and all by 1996. Since the technology already exists to meet the limits, retaining the averaging option would allow manufacturers to produce cars easily meeting the limits while allowing heavy trucks, where compliance is more difficult, to exceed the standard. This would lead to higher than average CO emissions in the west where heavy trucks predominate.

Heavy Duty Vehicles

The first emissions limits for heavy duty engines were set in 1970. The reductions in NOx and diesel particulates, implemented from 1990 to 1995 required the use of three-way catalysts for heavy duty gasoline engines and major advances in diesel engine technology (see **Tables A.3.1.12, A.3.1.36**). Further reductions are required for 1998 and 2004.

The EPA put back the implementation of a 0.1 g/bhp.h particulate limit for urban buses from 1991 to 1993. However, on 4 March 1993, the EPA published a ruling reducing the limit further to 0.07 g/bhp.h in 1994/95 and 0.05 g/bhp.h in 1996. Coupled with this standard was a requirement for all diesel vehicles to use fuel containing 0.05% m/m sulphur. This helps engine manufacturers reduce particulate emissions when using catalytic converters or trap oxidizers.

In April 1993, the EPA issued a final rule establishing a retrofit programme for urban bus engines. It applies to 1993 and earlier model year buses which operate in metropolitan areas with populations of over 750,000 and have their engines rebuilt or replaced after 1 January 1995. The objective is to reduce particulate emissions from older buses by upgrading their particulate emission control systems. Operators must either upgrade engines, the standard required depending on cost and availability of components, or meet a fleet average target level for particulate emissions each year beginning in 1996.

The EPA, CARB and members of the automotive engine industry signed a SOP outlining their joint understanding of the future requirements for HC and NOx control from heavy-duty engines. A final rule was expected by the end of 1996. The proposals are estimated to reduce the NOx emissions from on-highway heavy-duty engines to levels approximating to 2.0 g/bhp.h by the beginning of 2004. They consist of alternative limits of NMHC + NOx of 2.4 g/bhp.h max. or NMHC + NOx of 2.5 g/bhp.h, plus NMHC of 0.5 g/bhp.h max. In agreeing to meet these limits the automotive industry require the EPA not to further reduce particulate standards for diesel engines, nor CO emissions requirements for spark-ignition engines. They also require the EPA to implement studies to assess the effect of fuel parameters on emissions, with the intention of legislating the necessary changes in fuel quality by October 2003. The technological feasibility will be reviewed before the end of 1999, with the view to amending the proposed standards if necessary. It is unlikely, however, that the limits will be raised beyond 2.9 g/bhp.h NMHC + NOx, or 3.0 g/bhp.h NMHC + NOx, plus a proportional increase in the NMHC cap.

Starting 1994, buses which operated more than 70% of the time in large urban areas were required to cut particulate emissions by 50%, i.e. to 0.05 g/bhp.h, although this might be relaxed to a 30% reduction. EPA will test buses meeting this standard to ensure compliance and if it determines that more than 40% of buses do not comply, they must establish a low pollution fuel requirement. This provision allows the use of exhaust after-treatment devices, provided they work in the field. If they fail, EPA will mandate alternative fuels.

Table A.1.36 Federal Heavy Duty Vehicle emissions limits(5)

Effective Date	Vehicle Type	GVW (lb)	CO (1) (g/bhp.h)	HC (2) (g/bhp.h)	NOx (g/bhp.h)	Pm (g/bhp.h)
current	gasoline	≤ 14,000 > 14,000	14.4 37.1	1.1 1.9	5.0 5.0	- -
	diesel		15.5	1.3	5.0	0.1 (0.07) (3)
1998	gasoline	≤ 14,000 > 14,000	14.4 37.1	1.1 1.9	4.0 4.0	- -
	diesel		15.5	1.3	4.0	0.1 (0.05) (4)

(1) Idle CO limit of 0.5% for gasoline fuelled engines with exhaust aftertreatment and all methanol fuelled engines

(2) OMHCE for methanol fuelled S.I. and diesel engines

(3) Figure in parentheses for urban buses

(4) Figure in parentheses for urban buses, 0.07 g/bhp.h for in-use testing

(5) Durability

Gasoline engines	8 yrs or 110,000 miles
light HD engines (approx. 70-170 hp)	8 yrs or 110,000 miles
medium HD diesel engines (approx. 170-250 hp)	8 yrs or 185,000 miles
heavy HD diesels engines (approx. over 250 hp)	8 yrs or 290,000 miles
heavy HD diesel urban bus particulates	10 yrs or 290,000 miles

Refuelling Emissions

A report published by The National Highway Traffic Safety Administrator (NHSTA) in September 1991 concluded that on-board refuelling controls are significantly less safe than the alternative Stage II vapour recovery systems. As a result, the EPA decided not to issue a rule requiring large carbon canisters to be fitted to vehicles. However, this decision was overturned by a Federal Court ruling that the EPA must comply with the Clean Air Act, which explicitly states that the EPA shall promulgate regulations requiring on-board controls.

The EPA issued its rule on the control of refuelling emissions on 24 January 1994. The rule requires on-board refuelling emissions controls for passenger cars and light trucks (e.g. pickups, mini-vans and most delivery and utility vehicles). It will not require on-board control of refuelling emissions for heavy duty vehicles and trucks over 8500 pounds GVW. The rule covers 97 per cent of new vehicles and 94 per cent of refuelling emissions.

For passenger cars the controls will be phased in over three model years with 40 per cent, 80 per cent and 100 per cent of new car production being required to meet the standard in model years 1998, 1999 and 2000, respectively. Comparable proportions of light trucks will require on-board controls over three-year periods, 2001-2003 (GVW <6000 lbs) and 2004-2006 (GVW 6000-8500 lbs).

The rule establishes a refuelling emission standard of 0.20 grams hydrocarbons (carbon for methanol fuelled vehicles) per gallon of dispensed fuel and is expected to yield a 95 per cent reduction over current uncontrolled levels.

Evaporative Emissions

The EPA issued regulations, effective from 23 April 1993, specifying revised procedures and limits for evaporative emissions, with implementation phased-in over the 1996 to 1999 model years. The regulations apply to light- and heavy-duty vehicles and heavy-duty engines fuelled with gasoline, methanol or gasoline/methanol mixtures.

The EPA also specified that, from 1 January 1996, the dispensing rates from gasoline and methanol pumps may not exceed 10 US gallons (37.9 litres) per minute. Facilities with throughputs below 10,000 gallons per month have been given a further two years to comply. This requirement is consistent with the dispensing rates specified in the new test measuring spillage during refuelling.

The current test procedure, which has changed little since its introduction, measures emissions from fuel evaporation during parking (diurnal emissions) and immediately following a drive (hot soak emissions).

The new procedures, described in detail in **Section A.2.2.4**, consist of vehicle preconditioning (including an initial loading of the carbon canister with fuel vapour), exhaust emission testing, a running loss test and three diurnal emissions cycles. Fuel spillage during refuelling (spitback) is also measured. A supplemental procedure omitting the running loss test but involving two diurnal cycles following the emissions cycles is included. This procedure ensures that all the emissions resulting from purging the evaporative canister are measured during the emission and diurnal cycles and do not escape during the running loss test. Because of its increased severity, the limits specified for this test are more relaxed than those for the three-diurnal sequence. The supplemental procedure can also be used in conjunction with the test procedures devised by the CARB, which are not yet in effect.

The procedures for heavy duty vehicles are similar except that the driving sequence for the running loss test consists of three consecutive UDDS cycles, which reflect the different driving pattern experienced in-service. The testing of heavy-duty engines, without the vehicle chassis or body, requires that the test engine be equipped with a loaded evaporative canister and will be expected to demonstrate a sufficient level of purge during engine testing.

The EPA has pointed out that it has powers to deny certification upon determination that a particular control system design constitutes a defeat device, i.e. an auxiliary emission control device that reduces the effectiveness of the system under conditions which may reasonably be expected to be encountered in normal vehicle operations. The limits are given in **Table A.1.37**.

Table A.1.37 US Federal evaporative emissions requirements for all vehicles from 1996 (3)

Implement-ation Schedule (1) % prodn.	Vehicle GVW lb.	Durability Mileage	3-Diurnal Hot Soak g/test	Supple-mentary 2-Diurnal g/test	Running Loss g/mile	Spitback g liquid /test
1996 20%	<6000 (4)	(2)	2.0	2.5	0.05	1.0
1997 40%	>6000 <8500	120 000	2.5	3.0	0.05	1.0
1998 90%	>8500 <14000	120 000	3.0	3.5	0.05	1.0
1999 100%	>14000	120 000	4.0	4.5	0.05	-

(1) Implementation for methanol-fuelled vehicles 1998 model year. Manufacturers selling less than 10,000 vehicles per year do not have to comply until the 1999 model year.

(2) Durability mileage: LDV 2 years or 24 000 miles if device cost less than $200, 8 years or 80,000 if deemed "specified major emission components", light-duty trucks <3,750lbs, 10 years or 100,000 miles, >3,750lb; 120,000 miles.

(3) Limits for methanol-fuelled vehicles in g/carbon per test or mile.

(4) Also vehicles 6 001-8 500 lb. with fuel tank capacity < 30 USG

Vehicle Maintenance & In-Service Testing (see also Section A.3.2).

The CAAA required the introduction, starting in 1994, of onboard diagnostic systems for light duty vehicles and trucks. These must cover at least the catalytic converter and the oxygen sensor, they must also alert the operator of any possible malfunction or need for repair to emission control parts.

The Amendments make provision for extended compliance testing starting in 1996. This will permit 25% higher CO and NMHC emissions and 50% higher NOx emissions for vehicles having covered between 50,000 and 100,000 miles.

Enhanced inspection and maintenance programmes were planned to be introduced in the most polluted areas from 15.11.92. They consist of a biennial inspection of all trucks and light vehicles from the 1984 model year and later.

The EPA issued a draft detailing the test procedures and related requirements for its controversial IM 240 test on the 5 April 1993, with the intention of promulgating them in the Code of Federal Regulations under Section 207(b) of the Clean Air Act as the official IM test. The EPA's recommended procedure includes three features (see **Part 1** and **Section A.3.2.3**).

- a pressure test of the evaporative emissions control system.
- a purge test of the evaporative emissions control system.
- a transient exhaust emissions test.

These procedures have attracted much criticism for two main reasons. Firstly, it is suggested that inspection and maintenance schemes can do nothing to prevent subsequent tampering. Conversely, roadside remote monitoring can both identify "gross polluters" and monitor the performance of large numbers of vehicles. Secondly, the cost of the sophisticated measuring equipment is claimed to be beyond the means of many of the small garages currently conducting inspection and maintenance tests. As a result, a number of areas are adopting their own procedures as alternatives to the EPA proposals (see **Part 1** and **Section A.3.2**).

Vehicles Using Alternative Fuels

As described in **Part 1** and **Section A.5.2.2** the Clean Air Act Amendments include legislation on fuel composition and emissions performance, as well as vehicle emission limits. President Bush's original proposal called for a major shift to the use of "clean alternative fuels", i.e. methanol, ethanol, CNG, LPG and hydrogen. However, as the debate progressed the emphasis shifted from alternatives to reformulated fuels, i.e. conventional gasoline whose composition had been modified to reduce exhaust emissions.

Therefore, contrary to President Bush's original proposals, the final version of the Clean Air Act Amendments contained no mandate for the introduction of alternative fuels. Instead it described performance criteria for "Clean alternative fuels" which may include:

> *"methanol and ethanol (and mixtures thereof), reformulated gasoline, natural gas, LPG, electricity and any other fuel which permits vehicles to attain legislated emission standards."*

Since the standards set in the CAAA appear likely to be achievable by future conventional vehicles it is likely that "*conventional*" gasoline and diesel will qualify as clean fuels under certain specific circumstances.

The Amendments do make provision for a Clean Fuels programme which will apply from 1998 to fleets of 10 or more vehicles that are capable of being centrally refuelled (but NOT including vehicles that are garaged at personal residences under normal circumstances) which operate in areas which have problems achieving air quality standards. This programme mandates emission standards for these vehicles which are the same as those specified in California's Low Emission Vehicle (LEV) programme.

This part of the CAAA also specifies a pilot programme for the introduction of lower emitting vehicles in California, beginning in 1996. Under this programme, 150 000 clean fuel vehicles must be produced for sale in California in 1996 and this figure will rise to 300 000 in 1999. These vehicles will initially be required to meet Transitional Low Emission Vehicle (TLEV) standards. These limits remain in force until 2000 when the LEV standards outlined above come into operation.

The EPA have developed a voluntary vehicle emissions classification, called the Inherently Low Emission Vehicle (ILEV) as part of the Clean Fuel Fleet Programme regulation to provide comparatively attractive emissions benefits through relatively low evaporative emissions. Vehicles likely to meet the ILEV requirement are dedicated LPG, methanol- and ethanol-fuelled vehicles and electric vehicles, although manufacturers have no current plans to introduce M100 or E100 vehicles.

Table A.1.38 US Emissions Limits for "Clean Alternative Fuels" Programme

Programme	Effective Date	Equivalent Standard	CO g/mile	NMHC g/mile	NOx g/mile	HCHO g/mile
Fleet Refuelled	1998	LEV	3.4	0.075	0.2	0.015
California Pilot Programme	1996	TLEV	3.4	0.125	0.4	0.015
	2000	LEV	3.4	0.075	0.2	0.015

Energy Policy Act (EPo Act)

The Energy Policy Act was originally conceived to reduce the dependence of the US on imported petroleum stocks and is primarily designed to displace a proportion of petroleum derived fuels irrespective of the vehicle's emissions performance. The Act does not require alternative fuel vehicles to meet specific standards and therefore some Alternative Fuel Vehicles (AFV) may not necessarily meet clean fuel emission standards. The vehicle manufacturers have been actively supporting the Federal Fleet Conversion Task Force and the Clean Cities Initiative to develop an AFV market.

Under the Act, the Department of Energy issued a final rule on 28 February 1995 applying to companies that produce alternative fuels and which operate in metropolitan areas with more than 250,000 inhabitants in 1980 with fleets of at least 20 light duty vehicles. The rule requires that at least 30 percent of the 1997 model-year vehicles purchased by these companies should run on the alternative fuel produced. The rule applies to electricity, ethanol, hydrogen, methanol, natural gas, neat biodiesel (a new addition to the list of alternative fuels) and other substitutes for petroleum based fuels. Marketable credits are allowed on such motor vehicles purchased beyond the legal requirement. State government fleets in the area must purchase at least ten percent of their 1997 model-year vehicles to run on alternative fuels.

A.1.3.3. California

Light Duty Vehicles

California has always set more stringent emission limits than the rest of the US, and established a plan for the progressive reduction of vehicle emissions designed to enable the state to achieve national air quality standards by the year 2010. This plan involves the progressive introduction of so-called Transitional Low Emission Vehicles (TLEV), Low Emission Vehicles (LEV), Ultra-Low Emission Vehicles (ULEV) and Zero Emission Vehicles (ZEV). ZEVs are defined as vehicles which have no exhaust or evaporative emissions of any pollutant. These vehicles can use gasoline, diesel fuel or any alternative fuel and include dual-fuelled and flexible-fuelled vehicles. The Federal Phase II reformulated gasoline was introduced in 1996 and is classified as a clean fuel. The standards for the various categories are defined in **Table A.1.39**.

Table A.1.39 Californian standards for low emissions light duty vehicles[1]; gasoline, diesel and dual/flexible-fuelled vehicles operating on alternative fuels

Category	CO (g/mile)	NMOG (6) (7) (g/mile)	NOx (g/mile)	HCHO (3) (g/mile)	Pm (4) (g/mile)
Tier I gasoline	3.4 (4.2)(2)	0.25 (0.31)	0.4 (0.6)	0.015 (--)	-- (--)
diesel	-- (4.2)	-- (0.31)	-- (1.0)	0.015 (--)	-- (0.08)
TLEV	3.4 (4.2)	0.125 (0.156)	0.4 (0.6)	0.015 (0.018	-- (0.08)
LEV	3.4 (4.2)	0.075 (0.090)	0.2 (0.3)	0.015 (0.018	-- (0.08)
ULEV	1.7 (2.1)	0.04 (0.055)	0.2 (0.3)	0.008 (0.011	-- (0.04)
ZEV	0.0	0.0	0.0	0.0	0.0
EZEV (5)	(0.17)	(0.004)	(0.02)		(0.004)

(1) Passenger cars and derivatives for 12 persons or less and light duty trucks with loaded vehicle weight 0-3 750 lb.

(2) Limits for 50 000 miles with 100 000 miles in parentheses

(3) HCHO = Formaldehyde (methanol and flexible fuelled vehicles only)

(4) Diesels only

(5) Compliance limits, FTP 75 cycle plus evaporative emissions, to be verified by in-use testing.

(6) NMOG emission limits for dual and flexible fuelled vehicles operating on gasoline, TLEV 0.125 (0.156), LEV 0.075 (0.090), ULEV 0.040 (0.055) g/mile.

(7) The NMOG levels of alternative fuelled vehicles are adjusted using a Reactivity Adjustment Factor (RAF) to reflect the ozone-forming potential of the particular NMOG produced (see **Table A.1.45**)

Manufacturers, selling more than a total of 3000 passenger cars, light duty trucks and medium duty vehicles, will be permitted to manufacture any combination of vehicles as long as sales-weighted emissions do not exceed a fleet average standard. This standard is defined in terms of non-methane organic gases (NMOG) emissions for the high emission, Tier 1, TLEV, LEV and ULEV vehicles comprising the fleet (see **Table A.1.40**). Manufacturers will also be able to accrue marketable credits for complying with or improving on the standards.

Furthermore, it was required that by 1998 ZEVs must account for 2% of manufacturers sales, this figure progressively rising to 10% in 2003. More recently this requirement has been relaxed, the obligation to begin selling any ZEVs being put back to 2003. This relaxation is however subject to Memoranda of Agreement between the CARB and the motor manufacturers to the effect that the required air quality improvements must still be achieved without the ZEVs and that the sale of cleaner cars nation-wide must begin with the 2001 model year, i.e. two years before they are required by federal law. In addition the CARB require a partnership agreement between itself and industry to continue with the development of advanced battery technology.

Table A.1.40 Original implementation schedule for Fleet Average NMOG and ZEVs for light duty vehicles

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NMOG (g/mile)	0.25	0.231	0.225	0.202	0.157	0.113	0.073	0.070	0.068	0.062
ZEV (%)					2	2	2	5	5	10

(1) Fleet average NMOG = ($NMOG_{nonHEV}$ + $NMOG_{HEV}$)/ total number of vehicles sold, where $NMOG_{nonHEV} = \sum_{\text{Tier 1, TLEV, LEV, ULEV}}$ (number of vehicles sold in each class x class factor), the class factors being, Tier 1 0.25, TLEV 0.125, LEV 0.075, ULEV 0.040 and where $NMOG_{HEV}$ is similarly calculated for the three classes of hybrid electric vehicle (HEV). The NMOG emissions are RAF adjusted.

(2) Fleet average NMOG for manufactures <3000 vehicle/annum is 0.075 g/mile starting 2000 model year

It has also been proposed by the CARB that any hybrid electric vehicle (HEV), which does not emit more pollutants per unit energy than would be emitted by a electric generating plant in the South Coast Air Basin region, should be classified as an equivalent zero emission vehicle (EZEV) and be given full ZEV credits in calculating the manufacturers fleet average. The evaporative emissions used in the calculations will include those arising from storage and transportation of the fuel in addition to those emitted during driving and refuelling.

California has also ruled that from 1994 "*major gasoline suppliers*", i.e. those companies having a refinery within California, which has a capacity greater than 50 000 barrels/day, and who own or lease more than 25 retail stations in the South Coast region, will be required to make available alternative fuels at retail outlets. However, the application of this rule will be subject to the availability of a reasonable number of suitable vehicles.

Light Duty Trucks

Emissions limits and introduction schedules are applied to light duty trucks in a similar way to those for light duty vehicles, except that there is no requirement for ZEVs (see **Tables A.1.41** and **A.1.42**).

Table A.1.41 Californian standards for low emissions light duty trucks[1]; gasoline, diesel and dual and flexible fuelled vehicles operating on alternative fuel

Category	CO (g/mile)	NMOG [(5)] (g/mile)	NOx (g/mile)	HCHO [(3)] (g/mile)	Pm [(4)] (g/mile)
Tier I gasoline	4.4 (5.5)	0.32 (0.40)	0.7 (0.97)	0.018 (--)	-- (--)
diesel	-- (5.5)	-- (0.40)	-- (1.5)	0.018 (--)	-- (0.08)
TLEV	4.4 (5.5)	0.160 (0.200)	0.7 (0.9)	0.018 (0.023)	-- (0.08)
LEV	4.4 (5.5)	0.100 (0.130)	0.4 (0.5)	0.018 (0.023)	-- (0.08)
ULEV	2.2 (2.8)	0.050 (0.070)	0.4 (0.5)	0.009 (0.013)	-- (0.04)
ZEV	0.0	0.0	0.0	0.0	0.0

(1) Loaded weight 3 750 - 5 750 lb. Light duty vehicle limits apply to LDT ≤3 750 lb.

(2) Limits for 50 000 miles with 100 000 miles in parentheses

(3) HCHO = Formaldehyde (methanol and flexible fuelled vehicles only)

(4) Diesels only

(5) NMOG emission limits for dual and flexible fuelled vehicles operating on gasoline, TLEV 0.32 (0.40), LEV 0.160 (0.200), ULEV 0.100 (0.130) g/mile.

Table A.1.42 Implementation schedule for Fleet Average NMOG for light duty trucks

	Fleet Average NMOG (g/mile)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NMOG (g/mile)	0.32	0.295	0.287	0.260	0.205	0.150	0.099	0.098	0.095	0.093

(1) Calculation of Fleet Average NMOG as for light duty vehicles (see **Table A.1.40**)

(2) Manufacturers selling ≤3000 vehicles/annum exempt until 2000. For 2000 and subsequent model years NMOG requirement is 0.100 g/mile

Medium Duty Trucks

Emissions limits and introduction schedules are applied to medium duty trucks in a similar way to those for light duty trucks. At the request of the natural gas industry, a new vehicle category, the Super Low Emission Vehicle (SLEV) is under consideration which could be used to obtain emissions credits. The limits according to loaded weight categories are given in **Table A.1.43** and **A.1.44** for all these categories. The CARB are proposing to relax the limits for ULEV by increasing the CO limits to those equal to current LEV values and by increasing the 120 000 mile NOx emissions limits by 0.1 g/mile. The CARB are also proposing different standards and introduction schedules for engine-certified as distinct from vehicle-certified LEV, ULEV and SLEV.

Table A.1.43 Californian standards for low emissions medium duty trucks.

Category	Test Weight (lb.)	CO (g/mile)	NMOG [4] (g/mile)	NOx [5] (g/mile)	HCHO [2] (g/mile)	Pm [3] (g/mile)
Tier 1	0-3 750 3 751-5 750 5 751-8 500 8 501-10 000 10 001-14 000	3.4 (5.0) 4.4 (6.4) 5.0 (7.3) 5.5 (8.1) 7.0 (10.3)	0.25 (0.36) 0.32 (0.46) 0.39 (0.56) 0.46 (0.66) 0.60 (0.86)	0.4 (0.55) 0.7 (0.98) 1.1 (1.53) 1.3 (1.81) 2.0 (2.77)	0.015 (--) 0.018 (--) 0.022 (--) 0.028 (--) 0.036 (--)	-- (0.08) -- (0.10) -- (0.12) -- (0.12) -- (0.12)
LEV	0-3 750 3 751-5 750 5 751-8 500 8 501-10 000 10 001-14 000	3.4 (5.0) 4.4 (6.4) 5.0 (7.3) 5.5 (8.1) 7.0 (10.3)	0.125 (0.180) 0.160 (0.230) 0.195 (0.280) 0.230 (0.330) 0.300 (0.430)	0.4 (0.6) 0.7 (1.0) 1.1 (1.5) 1.3 (1.8) 2.0 (2.8)	0.015 (0.022) 0.018 (0.027) 0.022 (0.032 0.028 (0.040) 0.036 (0.052)	-- (0.08) -- (0.10) -- (0.12) -- (0.12) -- (0.12)
ULEV	0-3 750 3 751-5 750 5 751-8 500 8 501-10 000 10 001-14 000	1.7 (2.5) 2.2 (3.2) 2.5 (3.7) 2.8 (4.1) 3.5 (5.2)	0.075 (0.107) 0.100 (0.143) 0.117 (0.167) 0.138 (0.197) 0.180 (0.257)	0.2 (0.3) 0.4 (0.5) 0.6 (0.8) 0.7 (0.9) 1.0 (1.4)	0.008 (0.012) 0.009 (0.013) 0.011 (0.016) 0.014 (0.021) 0.018 (0.026)	-- (0.04) -- (0.05) -- (0.06) -- (0.06) -- (0.06)
SLEV	3 751-5 750 5 751-8 500 8 501-10 000 10 001-14 000	2.2 (3.2) 2.5 (3.7) 2.8 (4.1) 3.5 (5.2)	0.05 (0.072) 0.059 (0.084) 0.069(0.10) 0.09 (0.13)	0.2 (0.3) 0.3 (0.45) 0.35 (0.5) 0.5 (0.7)	0.018 (0.027) 0.022 (0.032) 0.028 (0.040) 0.036 (0.052)	-- (0.05) -- (0.06) -- (0.06) -- (0.06)

(1) Limits for 50 000 miles with 120 000 miles in parentheses
(2) HCHO = Formaldehyde (methanol and flexible fuelled vehicles only)
(3) Diesels only
(4) NMHC for Tier 1 limits, ONMHE for alcohol fuelled vehicles. NMOG emission limits for dual and flexible fuelled vehicles operating on gasoline, LEV same as Tier 1 NMHC standards and ULEV same as LEV NMOG standards
(5) For dual and flexible fuelled vehicles, NOx emissions measured on the Federal Highway Fuel Economy test cycle must not be greater than 2.0 times the standard.

Table A.1.44 Implementation schedule for Fleet Average NMOG for medium duty trucks

Vehicle	Percentage of MDV Fleet Delivered for Sale					
Category	1998	1999	2000	2001	2002	2003
LEV	25	50	75	95	90	85
ULEV	2	2	2	5	10	15
Proposed LEV	25	50	75	80	70	60
ULEV	2	2	2	20	30	40

(1) Manufacturers selling ≤3000 vehicles/annum are exempt until 2001 model year when all fleet must be the 100% LEV

Table A.1.45 CARB Reactivity Adjustment Factors

CARB has introduced a procedure which enables the NMOG emissions of a vehicle operating on a fuel producing low reactivity NMOG components to be adjusted:

$$\text{Adjusted Emissions Test Result} = \frac{\text{Measured NMOG (g/mile)}}{\text{Reactivity Factor (RAF)}}$$

Each vehicle category/fuel combination will have a unique RAF determined by CARB. The reactivity adjustment factor (RAF) is given by:

$$\text{RAF} = \frac{\text{(g ozone/g NMOG) Alternative Fuel/Vehicle Combination}}{\text{(g ozone/g NMOG) Conventional Gasoline Vehicle}}$$

The reactivity (g ozone/g NMOG) for a passenger car operating on current conventional gasoline has been defined by CARB as 3.42 g ozone/g NMOG. CARB had defined the RAFs of M85, CNG, and LPG as 0.36, 0.18, and 0.15 for passenger cars respectively, but withdrew the figures for LPG and CNG because of a poor statistical basis and modified that for M85 to 0.41.

CARB has defined a 10% correction factor for alcohol and LPG RAFs to account for "*potential modelling and protocol biases*" which increases the RAF by 10%. The M85 of 0.41 includes this correction.

The RAF for "*reformulated gasoline/passenger cars*" was to be published in the summer of 1992. The RAFs for LPG and CNG will be clarified once a sufficiently large vehicle population has been tested to determine statistically reliable numbers. The RAFs for diesel and reformulated diesel are proving problematic to determine as the heavy hydrocarbons C_{12}-C_{20} are proving difficult to speciate. CARB is currently working on this problem.

A manufacturer can accept the RAF determined by CARB for each vehicle category and fuel combination during the durability vehicle/data vehicle certification process. Thus the manufacturer would apply two deterioration factors to the vehicles certification test results as follows:

Certification Value = Measured Emissions (4k miles) x RAF x RAFDF x DF

where RAFDF = Reactivity adjustment factor deterioration factor

and DF = Conventional deterioration factor applied to NMOG

then $$\text{RAFDF} = \frac{\text{(g ozone/g NMOG) 100 k miles}}{\text{(g ozone/g NMOG) 4 k miles}}$$

and $$\text{DF} = \frac{\text{g NMOG/100 k miles}}{\text{g NMOG/ 4 k miles}}$$

CARB has also published Incremental Reactivity Factors for various NMOG compounds to enable development engineers to establish the reactivity of the NMOG exhaust profiles from their vehicles.

Cold Start CO Emissions for Light Duty Vehicles, Light and Medium Duty Trucks

All 1996 and subsequent model-year vehicles, with the exception of natural gas, diesel fuelled, hybrid electric and zero emission vehicles, must meet a cold CO limit when tested over the full FTP 75 cycle at a nominal start and test temperature of 20°F (-7°C). The limit is 10 g/mile for light duty vehicles and medium duty trucks with a test weight < 3 750 lb. For other light and medium duty trucks the limit is 12.5 g/mile. The standard applies to the intermediate life of 50 000 miles.

Heavy Duty Vehicles

The CARB is required by the US Senate to adopt low-emission standards for transit buses. Limits of 4.0 and 0.05 g/bhp.h for NOx and particulates respectively were approved in June 1993 and adopted in 1996. Credits are allowed for NOx levels of 2.5 g/bhp.h NOx and above in 0.5 g/bhp.h increments, which can be sold to stationary sources under a mobile source credit programme developed by several Californian air districts. Each engine manufacturer would be allowed to apply for an exemption for up to 10 per cent of its output, if it could be demonstrated that not all of its engine models would meet the 1996 standards. Furthermore, low aromatic and low sulphur diesel fuels would be allowed for certification testing for the 1996 and 1997 model years.

Table A.1.46 Current California heavy duty vehicle emissions regulations (California Code of Regulations CCR Title 13 Section 1956.8)

Vehicle Category	Model Year	CO (2) (g/bhp.h)	NMHC (1) (g/bhp.h)	THC (1) (g/bhp.h)	NOx (3) (g/bhp.h)	Pm (4) (g/bhp.h)
Gasoline	1995-97 from 1998	37.1 37.1	1.7 1.7	1.9 1.9	5.0 4.0	- -
Diesel	1995-97 from 1998	15.5 15.5	1.2 1.2	1.3 1.3	5.0 4.0	0.10 0.10
Urban Buses	from 1996	15.5	1.2	1.3	4.0	0.05 (0.07)(5)

(1) NMHC are optional for all engines except methanol fuelled engines. For methanol engines THC limit is for OMHE. A 0.05 g/bhp.h max limit for HCHO applies to methanol engines from 1996.

(2) An idle limit of 0.5 %v CO applies to engines using exhaust aftertreatment

(3) Optional certification in 0.5 g/bhp.h NOx intervals below the limit allowed for the purpose of obtaining emissions credits. Useful life for NOx is 10 years for 1998 model year and later

(4) Diesel engine smoke opacity limits of 20 % in acceleration mode, 15 % in lugging mode and 50 % peak.

(5) In-use test value

CARB projections show that heavy-duty vehicle exhaust will contribute more than 50 per cent of NOx and more than 84 per cent of particulates emitted by all on-road vehicles by 2000. It has been calculated that the proposed Federal heavy-duty vehicle standards for 1998 will reduce NOx by only 20 per cent. This is considered insufficient for California to meet the National Air Quality Standards set by the Clean Air Act. CARB is therefore developing an extension of its LEV programme to apply to heavy-duty vehicles. Two options are being considered for introduction by the

2004 model year for gasoline engines, a NMHC + NOx of 2.4 g/bhp.h or a NMHC of 0.5 g/bhp.h combined with a NMHC + NOx of 2.5 g/bhp.h.

CARB is also proposing to change the GVW rating of buses from 14,000 to 33,000 pounds which would align its definition with that used by the EPA. At the same time it is proposing to introduce the 2004 Federal limit of 2.0 g/bhp-h NOx, but two years earlier in 2002. The weight revision will not affect large and medium sized transit companies, most of which generally operate buses over 33,000 pounds. It would, however, minimize the impact of the regulations on small transit districts which operate a greater proportion of smaller buses. The revised classification will not significantly affect control of NOx emissions as larger buses are the main contributors. It is the intention of the CARB and EPA to unify their HDV regulations by 2004.

All transit buses have been equipped with positive crankcase ventilation (PCV) systems beginning since 1996 model year. At present PCV systems are required on all heavy-duty vehicles except for turbocharged diesel engines. The cost of adding PCV systems is estimated at around USD 100 to 240 per vehicle but is claimed to result in a significant reduction in HC emissions.

Evaporative Emissions

The California evaporative emissions test is given in **Section A.2.2.4**. A proposal to allow the use of the Federal evaporative test procedure as an alternative to the Californian is under discussion. The SHED emission limit of 2 g/test is being replaced by limits including diurnal, hot soak and running losses according to the schedule given in **Table A.1.47** below. All diesel vehicles and CNG fuelled HDV are exempt. The California limits are similar to the Federal limits but the implementation schedule is quicker. From the 1996 model year, evaporative leaks as small as the equivalent of a 1 mm diameter orifice must be detected and the detection limit is reduced to 0.5 mm diameter from the 2000 model year. For medium duty vehicles (6000-8500 lb. GVW) the Federal refuelling emission legislation is also applied in California.

Table A.1.47 California evaporative emissions requirements from 1996 (California Code CCR Title 13 Section 1976)

Implementation Schedule [1] % prodn.	Vehicle GVW lb.	Durability Mileage	3-Diurnal Hot Soak g/test	Supplementary 2-Diurnal g/test	Running Loss g/mile	Spitback g liquid /test
1995 10%	<6000 [3]	useful life	2.0	2.5	0.05	1.0
1996 30% 1997 50%	>6000 <8500	useful life	2.5	3.0	0.05	1.0
after 1997 100%	>8500 <14000	useful life	3.0	3.5	0.05	1.0
	>14000	useful life	4.0	4.5	0.05	-

(1) Small volume manufacturers (≤3000 sales/annum are exempt

(2) Equivalent limits for alcohol fuelled vehicles are OMHCE measured in grams carbon

(3) Also vehicles 6 001-8 500 lb. with fuel tank capacity < 30 USG

A.1.3.4. State Autonomy and the Ozone Transport Region

The Clean Air Act reaffirms the authority of individual states to adopt more stringent emission standards if they wish to do so. However, they will only be permitted to adopt the standards set by California. This restriction was imposed in order to prevent motor manufacturers having to produce individual models for each state. Instead they will only need to produce two models, one complying with Federal standards and one complying with Californian standards.

Ozone Transport Region (OTR)

The Ozone Transport Commission (OTC), comprising the District of Columbia and the twelve eastern states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and Virginia was created by the Clean Air Act Amendments to coordinate the regional development of plans to control ground level ozone. In February 1993 it submitted a proposal to apply the California LEV limits to the Region. The EPA eventually adopted this proposal on 19 December 1994 and issued its Final Rule to be effective on 15 February 1995. The Rule will apply the California emissions regulations from the 1999 model year. The decision will allow, but not require, the OTC states to adopt zero emissions vehicles (ZEV). At the same time the EPA put forward an alternative National LEV Program (see below). New York State and Massachusetts have already adopted the California programme starting in 1996, including whatever ZEV programme is adopted.

National LEV Program

Although the EPA recognises that the OTC LEV programme will materially assist the north-east states in meeting their air quality goals, it has proposed a compromise LEV-equivalent programme in which all 49 States outside California adopt a phased introduction of LEVs. This would be less restrictive than the Californian schedule but more stringent than the current Tier I/Tier II legislation and would involve full adoption of the LEV limits by 2001 (see **Tables A.1.39** and **A.1.41**).

The EPA points out that vehicles to the LEV standard would have 66% lower VOC and 73% lower NOx tailpipe emissions than vehicles meeting the current Tier I standards and if applied to all 49 States would result in lower emissions overall. It would ease the problems of introducing cars of a variety of standards in different states and eliminate the problem of cross-border movement of cars manufactured to different emissions standards.

Under the proposals, all 2001 model-year cars outside California would be required to meet the California LEV limits. Until that time vehicle manufacturers would provide a mix of vehicles to meet a fleet average NMOG standard of increasing severity according to the schedule given in **Table A.1.48**. This translates into the fleet average limits given in **Table A.1.49**.

Table A.1.48 Proposed EPA LEV-equivalent program for passenger cars and light duty trucks

Model Year	**Sched. Equivalent NMOG emissions reductions**
1997-2000	40% TLEVs
1999	30% LEVs
2000	60% LEVs
2001	100% LEVs

Table A.1.49 EPA fleet average NMOG (g/mile) schedule

Vehicle Category	**Fleet Average NMOG (g/mile)**				
	1997	**1998**	**1999**	**2000**	**2001**
LDV & LLDT lvw ≤ 3750 lb.	0.20	0.20	0.148	0.095	0.075
LLDT lvw > 3750 lb.	0.256	0.256	0.190	0.124	0.100

The EPA however, has no authority under the Clean Air Act to promulgate such standards. Also states are precluded under the act from adopting any alternative programme other than the California programme. The implementation of the LEV-equivalent programme would therefore depend on the motor manufacturers and the OTC States reaching a voluntary agreement to comply. If the OTC states proceed with legislation to adopt the OTC recommendation they would also need to make their regulations flexible enough to allow the alternative programme. The EPA would have to address the implementation schedule for a voluntary programme and also how to establish a banking and trading mechanism, how to harmonise these proposals with California standards in order to reduce testing and design costs and how to incorporate California’s on-board diagnostic system within the scheme as intended.

The EPA proposals do not specifically mention vehicles equivalent to the ULEVs or ZEVs required in California legislation. However, the EPA expect that the automobile manufacturers and state governments would continue to cooperate within the working group of the Clean Air Act Advisory Committee to develop an advanced technology component for the LEV-equivalent programme that could include alternative fuel cars. If the CARB adopts more stringent standards for LEVs and ULEVs in the interim, then it is likely that the EPA would change the National LEV regulations to require the CARB “off-cycle “ limits to be met instead.

Table A.1.50 Summary of Current and Future US and California Exhaust Emission Standards and Categories.

Vehicle Type	Emission Category	Certification(A) Exhaust Emission Standards -- gpm: 5 Yrs. / 50,000 Miles						10 Yrs. / 100,000 Miles						11 Yrs. / 120,000 Miles					
		(B) THC	NMHC or(C) NMOG	CO	NOx	PM	HCHO	(B) THC	NMHC or(C) NMOG	CO	NOx	PM	HCHO	(B) THC	NMHC or(C) NMOG	CO	NOx	PM	HCHO
PC	Fe Tier 0	0.41	-	3.4	1.0	(1) 0.20	-												
	Fe Tier 1	0.41	0.25	3.4	(2) 0.4	0.08	-	-	0.31	4.2	(3) 0.6	0.10	-						
	Fe CFV 1	-	0.125	3.4	0.4	-	0.015	-	0.156	4.2	0.6	0.08	0.018						
	Fe Tier 2							-	0.125	1.7	0.2	-	-						
	Fe CFV 2	-	0.075	3.4	0.2	-	0.015	-	0.090	4.2	0.3	0.08	0.018						
	CA Tier 0	-	0.39	7.0	0.4	(1) 0.08	(4) 0.015												
	CA Tier 1	-	0.25	3.4	0.4	(1) 0.08	(4) 0.015	-	0.31	4.2	-	-	-						
	CA TLEV	-	0.125	3.4	0.4	-	0.015	-	0.156	4.2	0.6	(1) 0.08	0.018						
	CA LEV	-	0.075	3.4	0.2	-	0.015	-	0.090	4.2	0.3	(1) 0.08	0.018						
	CA ULEV	-	0.040	1.7	0.2	-	0.008	-	0.055	2.1	0.3	(1) 0.04	0.011						
	CA ZEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal & CA GVWR: 0 - 6000 lb.; LVW: 0 - 3750 lb.; LDT1	Fe Tier 0													0.80	-	10	1.2	(1) 0.26	-
	Fe Tier 1	-	0.25	3.4	(2) 0.4	0.08	-	-	0.31	4.2	(3) 0.6	0.10	-	0.80					
	Fe CFV 1	-	0.125	3.4	0.4	-	0.015	-	0.156	4.2	0.6	0.08	0.018						
	Fe Tier 2							-	0.125	1.7	0.2	-	-						
	Fe CFV 2	-	0.075	3.4	0.2	-	0.015	-	0.090	4.2	0.3	0.08	0.018						
	CA Tier 0	-	0.39	9.0	0.4	(1) 0.08	(4) 0.015												
	CA Tier 1	-	0.25	3.4	0.4	(1) 0.08	(4) 0.015	-	0.31	4.2	-	-	-						
	CA TLEV	-	0.125	3.4	0.4	-	0.015	-	0.156	4.2	0.6	(1) 0.08	0.018						
	CA LEV	-	0.075	3.4	0.2	-	0.015	-	0.090	4.2	0.3	(1) 0.08	0.018						
	CA ULEV	-	0.040	1.7	0.2	-	0.008	-	0.055	2.1	0.3	(1) 0.04	0.011						
	CA ZEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LVW: 3751 - 5750 lb.; LDT2	Fe Tier 0													0.80	-	10	1.7	(1) 0.13	-
	Fe Tier 1	-	0.32	4.4	(5) 0.7	0.08	-	-	0.40	5.5	0.97	0.10	-	0.80					
	Fe CFV 1	-	0.160	4.4	0.7	-	0.018	-	0.200	5.5	0.9	0.08	0.023						
	Fe CFV 2	-	0.100	4.4	0.4	-	0.018	-	0.130	5.5	0.5	0.08	0.023						
	CA Tier 0	-	0.50	9.0	1.0	(1) 0.08	(4) 0.018												
	CA Tier 1	-	0.32	4.4	0.7	0.08	(4) 0.018	-	0.40	5.5	-	-	-						
	CA TLEV	-	0.160	4.4	0.7	-	0.018	-	0.200	5.5	0.9	(1) 0.08	0.023						
	CA LEV	-	0.100	4.4	0.4	-	0.018	-	0.130	5.5	0.5	(1) 0.08	0.023						
	CA ULEV	-	0.050	2.2	0.4	-	0.009	-	0.070	2.8	0.5	(1) 0.04	0.013						
CA (not Tier 0) GVWR: 6001 - 14,000 lb. (D); Federal & CA Tier 0 GVWR: 6001 - 8500 lb; TW: 0 - 3750 lb; MDV1	Fe CFV	-	0.125	3.4	(5) 0.4	-	0.015							-	0.180	5.0	0.6	(1) 0.08	0.022
	CA Tier 0(6)	-	0.39	9.0	0.4	(1) 0.08	(4) 0.015												
	CA Tier 1	-	0.25	3.4	0.4	-	(4) 0.015							-	0.36	5.0	0.55	(1) 0.08	-
	CA LEV	-	0.125	3.4	0.4	-	0.015							-	0.180	5.0	0.6	(1) 0.08	0.022
	CA ULEV	-	0.075	1.7	0.2	-	0.008							-	0.107	2.5	0.3	(1) 0.04	0.012
TW: 3751 - 5750 lb; LDT3	Fe Tier 0(6)													0.80	-	10	1.7	(1) 0.13	-
	Fe Tier 1	-	0.32	4.4	(5) 0.7	-	-							0.80	0.46	6.4	0.98	0.10	-
	Fe CFV	-	0.160	4.4	(5) 0.7	-	0.018							-	0.230	6.4	1.0	0.10	0.027
MDV2	CA Tier 0(6)	-	0.50	9.0	1.0	(1) 0.08	(4) 0.018												
	CA Tier 1	-	0.32	4.4	0.7	-	(4) 0.018							-	0.46	6.4	0.98	(1) 0.10	-
	CA LEV	-	0.160	4.4	0.7	-	0.018							-	0.230	6.4	1.0	(1) 0.10	0.027
	CA ULEV	-	0.100	2.2	0.4	-	0.009							-	0.143	3.2	0.5	(1) 0.05	0.013
TW: 5751 - 8500 lb; LDT4	Fe Tier 0(6)													0.80	-	10	1.7	(1) 0.13	-
	Fe Tier 1	-	0.39	5.0	(5) 1.1	-	-							0.80	0.56	7.3	1.53	0.12	-
	Fe CFV	-	0.195	5.0	(5) 1.1	-	0.022							-	0.280	7.3	1.5	0.12	0.032
MDV3	CA Tier 0(6)	-	0.60	9.0	1.5	(1) 0.08	(4) 0.022												
	CA Tier 1	-	0.39	5.0	1.1	-	(4) 0.022							-	0.56	7.3	1.53	(1) 0.12	-
	CA LEV	-	0.195	5.0	1.1	-	0.022							-	0.280	7.3	1.5	(1) 0.12	0.032
	CA ULEV	-	0.117	2.5	0.6	-	0.011							-	0.167	3.7	0.8	(1) 0.06	0.016
TW: 8501 - 10,000 lb; MDV4	CA Tier 1	-	0.46	5.5	1.3	-	(4) 0.028							-	0.66	8.1	1.81	(1) 0.15	-
	CA LEV	-	0.230	5.5	1.3	-	0.028							-	0.330	8.1	1.8	(1) 0.12	0.040
	CA ULEV	-	0.138	2.8	0.7	-	0.014							-	0.197	4.1	0.9	(1) 0.06	0.021
TW: 10,001 - 14,000 lb; MDV5	CA Tier 1	-	0.60	7.0	2.0	-	(4) 0.036							-	0.86	10.3	2.77	(1) 0.18	-
	CA LEV	-	0.300	7.0	2.0	-	0.036							-	0.430	10.3	2.8	(1) 0.12	0.052
	CA ULEV	-	0.180	3.5	1.0	-	0.018							-	0.257	5.2	1.4	(1) 0.06	0.026
GVWR 8501 - 14,000 lb; MDV (OPT) (D)(F)(G)	CA Tier 1													-	(10) 3.9	14.4	(10)	(1) 0.10	(8) 0.10
	CA LEV													-	(10) 3.5	14.4	(10)	(1) 0.10	0.05
	CA ULEV													-	(10) 2.5	7.2	(10)	(1) 0.05	0.025
(E) 8501 - 14,000 GVWR; HD (F)	HDGE (G)													1.1	(11) 0.9	14.4	(7) 5.0	-	(8) 0.10
>14,000 GVWR	HDGE (G)													1.9	(11) 1.7	37.1	(7) 5.0	-	(8) 0.10
>8500 GVWR	HDDE (H)													1.3	(11) 1.2	15.5	(7) 5.0	(8) 0.25	(8) 0.10
8501 - 26,000 GVWR	Fe CFV (G)													-	(10) 3.15	(10)	(10)	(8) 0.10	-

Table A.1.51 Summary of US and California Exhaust Emission Implementation Schedule

Vehicle Type	Emission Category	Emission Standards Compliance Requirements -- by Model Year														
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
PC Federal & CA LDT1 Federal & CA GVWR: 0 - 6000 lb. LVW: 0 - 3750 lb.	Fe Tier 0	100%	100%	60% Max.	20% Max.	0%										
	Fe Tier 1[A]			40% Min.	80% Min.	100%	→	→	→	→	→	→	→	[1]100%	Undetermined	
	Fe Tier 2													[2]100%	Undetermined	
	Fe CFV 1[B]					[3]CA Pilot	CA Pilot	CA Pilot [5]30% CFV	[4]CA Pilot 50% CFV	CA Pilot 70% CFV						
	Fe CFV 2[B]										CA Pilot 70% CFV	CA Pilot →	CA Pilot →	CA Pilot →	CA Pilot →	CA Pilot →
	CA Tier 0	100%	60% Max.	20% Max.	0%											
	CA Tier 1		40% Min.													
	CA TLEV															
	CA LEV			80% Min. and 0.250 NMOG Fleet Avg.	0.231 NMOG Fleet Avg.	0.225 NMOG Fleet Avg.	0.202 NMOG Fleet Avg.	0.157 NMOG Fleet Avg.	0.113 NMOG Fleet Avg.	0.073 NMOG Fleet Avg.	0.070 NMOG Fleet Avg.	0.068 NMOG Fleet Avg.	0.062 NMOG Fleet Avg.	Undetermined		
	CA ULEV															
	CA ZEV							2% Min.	2% Min.	2% Min.	5% Min.	5% Min.	10% Min.	Undetermined		
LDT2 Federal & CA GVWR: 0 - 6000 lb. LVW: 3751 - 5750 lb.	Fe Tier 0	100%	100%	60% Max.	20% Max.	0%										
	Fe Tier 1[A]			40% Min.	80% Min.	100%	→	→	→	→	→	→	→	[1]100%	→	→
	Fe CFV 1[B]					CA Pilot	CA Pilot	CA Pilot [5]30% CFV	CA Pilot 50% CFV	CA Pilot 70% CFV						
	Fe CFV 2[B]										CA Pilot 70% CFV	CA Pilot →	CA Pilot →	CA Pilot →	CA Pilot →	CA Pilot →
	CA Tier 0	100%	60% Max.	20% Max.	0%											
	CA Tier 1		40% Min.													
	CA TLEV															
	CA LEV			80% Min. and 0.320 NMOG Fleet Avg.	0.295 NMOG Fleet Avg.	0.287 NMOG Fleet Avg.	0.260 NMOG Fleet Avg.	0.205 NMOG Fleet Avg.	0.150 NMOG Fleet Avg.	0.099 NMOG Fleet Avg.	0.098 NMOG Fleet Avg.	0.095 NMOG Fleet Avg.	0.093 NMOG Fleet Avg.	Undetermined		
	CA ULEV															
LDT3 & LDT4 Federal GVWR: 6001 - 8500 lb. TW: 0 - 8500 lb.	Fe Tier 0	100%	100%	100%	100%	50% Max.	0%									
	Fe Tier 1					50% Min.	100%	→	→	→	→	→	→	→	→	→
	Fe CFV							[5]30% CFV	50% CFV	70% CFV	→	→	→	→	→	→
MDV1 - MDV5 MDV (OPT) California GVWR: 6001 - 14,000 lb. TW. 0 - 14,000 lb.	CA Tier 0	100%	100%	100%	50% Max.	0%										
	CA Tier 1				50% Min.	100%	100%	73% Max.	48% Max.	23% Max.	0%					
	CA LEV							25% Min.	50% Min.	75% Min.	95% Max.	90% Max.	85% Max.	Undetermined		
	CA ULEV							2% Min.	2% Min.	2% Min.	5% Min.	10% Min.	15% Min.	Undetermined		
HD Federal & CA Tier 0 GVWR: >8500 lb. CA Tier 1 GVWR: >14,000 lb.	HDGE	100%	→	→	→	→	→	100% (NOx)	→	→	→	→	→	→	→	→
	HDDE	100%	→	100% (PM)	→	→	→	100% (NOx)	→	→	→	→	→	→	→	→
	Fe CFV							[5]50% CFV	→	→	→	→	→	→	→	→

Table A.1.50 Explanatory Notes.

(A) Different in-use exhaust standards may apply.
(B) OMHCE for methanol fuel.
(C) OMNMHE for methanol fuel.
(D) Optional certification available for all incomplete & all diesel.
(E) GVWR -CA: Tier 0 > 8 500, Tier 1 > 14 000, Federal: > 8 500.
(F) Standards in gm/bhp - hr.
(G) Useful life 8 yrs/110 000 miles.
(H) Useful life 8 yrs/110 000; 185 000; 290 000 miles as specified by manufacturer.
(1) Diesel only.
(2) Diesel through 2003 MY - 1.0.
(3) Diesel through 2003 MY - 1.25.
(4) Methanol fuelled vehicles only.
(5) Except diesel.
(6) Use LVW definition for TW.
(7) 4.0 NOx in 1998 MY.
(8) CA Methanol fuelled vehicles only - 0.05 in 1996 MY.
(9) 0.10 Pm in 1994 MY.
(10) Combined NMHC & NOx standard in g/bhp-hr.
(11) CA optional.
(12) HDGE or HDDE standard applies.

(Source: General Motors).

Table A.1.51 Legend and Explanatory Notes.

Legend:

Fe: Federal.
CA: California.
Tier 0: Existing Standards - Pre - Tier 1.
Tier 1: New, General Application Standards; CA 1993 MY, Fe 1994 MY.
CFV: Clean Fuel Vehicle Standards.
CFV 1: Phase 1 for PC, LDT1, LDT2.
CFV 2: Phase 2 for PC, LDT1, LDT2.
TLEV: Transitional Low Emission Vehicle (CA).
LEV: Low Emission Vehicle (CA).
ULEV: Ultra Low Emission Vehicle (CA).
ZEV: Zero Emission Vehicle (CA).
HDGE: Heavy Duty Gasoline Engine.
HDDE: Heavy Duty Diesel Engine.

Notes:

(A) PC & LDT1 combined with LDT2 for Tier 1 phase-in.
(B) PC & LDT1 combined with LDT2 for CFV requirements.

(1) NOx standard change for diesel.
(2) Tier 2 standards pending EPA study by 12/31/99.
(3) Percent of new vehicle purchases by centrally-fuelled fleets in 22 cities.

(Source: General Motors).

A.1.3.5. Canada

Canadian emission regulations have always followed US EPA test cycles and procedures, although from 1975-1987 less stringent limits were applied which did not require the use of catalysts. However, many Canadian vehicles were in fact identical to US specification vehicles and fitted with catalysts. In 1987 the Canadian legislation was brought into line with current US limits and emission limits for heavy duty trucks became the same as the 1988 US limits. An agreement signed in February 1992 between the Federal Transport Minister and the motor manufacturers and importers meant that engines supplied at that time were to the 1991 US emissions standards. Furthermore, the oil industry made 0.05%m/m sulphur diesel fuel available by October 1994 so that 1994 US specification engines could be supplied from that date. Another memorandum of understanding meant that cars sold in Canada from 1994 to 1995 were to the same emissions standards as those sold in the US. From model-year 1996 US Federal Tier 1 standards applied. A summary of Canadian emissions regulations is given in **Table A.1.52**.

Table A.1.52 Canadian Emissions Regulations

Vehicle Class	Year	Test Procedure	CO g/km	HC g/km	NOx g/km	Pm[(1)] g/km
Cars and Lt Trucks	1975-87	FTP 75	25.0	2.0	3.1	-
Cars	1988	FTP 75	2.11	0.25	0.62	0.12
Lt Trucks:						
<1700 kg	1988	FTP 75	6.2	0.20	0.75	0.16
>1700 kg	1988		6.2	0.50	1.1	0.16
Cars and Lt trucks	1994	US Tier 1 standards see **Table A.1.34**				
Motorcycles	1997	US Federal 1980 standards see **Table A.1.33**				
			g/bhp.h	**g/bhp.h**	**g/bhp.h**	**g/bhp.h**
HD Vehicles Gasoline:						
<6350 kg	1988	US Transient	14.4	1.1	6.0	-
>6350 kg	1988		37.1	1.9	6.0	-
Diesels	1988		15.5	1.3	6.0	0.6
	1994		15.5	1.3	5.0	0.1
HD Vehicles	1996	US Federal 1990 standards see **Table A.1.32**				

(1) Diesels only

A number of Province-controlled programmes have also been agreed:

- Vehicle inspection and maintenance programmes in provinces with ozone problems from 1992.
- A limit on summer gasoline RVP of 10.5 lb/in^2 (72 kPa) from 1990. Lower limits may be set in provinces with ozone problems.
- Regulation to control gasoline vapour emissions from distribution and marketing installations starting in 1991.

A.1.4. JAPAN

Emission control in Japan started in 1966 when simple CO limits were introduced, but the first long-term plan was established in 1970 by the Ministry of Transport (MOT). This plan proposed limits for CO, HC and NOx from 1973, with separate sets of limits for a 10-mode hot-start cycle and an 11-mode cold-start test. For heavy duty vehicles a 6-mode steady state test was introduced. In 1971 however, the Central Council for Environmental Pollution Control (CCEPC), an advisory body of Japan's Environment Agency (EA), recommended that legislation should follow the US "Muskie proposal" and submitted recommendations for much more stringent exhaust emission standards. This led to tough limits introduced in 1975 which required the use of catalysts on gasoline cars. These limits (with an NOx reductions in 1978) have not changed since then, but revisions to the test procedures (see below) have effectively made them more severe. Emissions limits for trucks, both gasoline and diesel were also introduced in 1974/5, but these limits have been tightened by varying degrees over the intervening years.

In December 1989 the CCEPC recommended new emission limits with both short-term and long-term targets. Their aim was to set up the most stringent standards which were technologically feasible, and to apply the same standards for both gasoline and diesel fuelled vehicles in the near future. Based on this proposal the MOT revised the emission regulations in May 1991 to incorporate the short-term limits. The major changes are as follows:

- Reductions in NOx emissions from commercial vehicles. Recently the major concern in Japan has been over NOx emissions.
- Introduction of particulate standards and more stringent smoke limits for diesel vehicles. Smoke limits were reduced by 20% in 1993 for light and medium duty diesel vehicles. Heavy duty and passenger vehicle limits follow suit in 1994.
- Revision of test cycles and measurement modes. The 10-mode light duty test cycle has been modified to include a high speed section, and is now called the 10-15 mode cycle and is applied to light duty gasoline and diesel vehicles. The 6-mode gasoline and diesel cycles have been replaced by two new 13-mode cycles with emission measurements changed from ppm to g/kWh. More details are given in **Section A.2.4**.

Japan currently has no limits for motorcycle emissions and the EA set up a committee in 1991 to consider the introduction of limits for motorcycles and "special" vehicles (e.g. off road).

More recently a joint MOT/MITI/EA study has proposed legislation to further reduce NOx in urban areas. These proposals had been discussed since spring 1992 and were adopted in December 1992, to take effect December 1993. The objective is to control both the population of older vehicles and impose even tougher emission limits for new vehicles. It is proposed that the regulations will apply to all diesel vehicles in the specified areas. However, there are a number of derogations for various classes of older vehicles.

In 1996 the MOT announced that it plans to implement more of the proposals of the Central Council for Environmental Pollution Control suggested back in December 1989. These measures will apply to NOx, particulate and smoke emissions from diesel vehicles of less than 12 tons gvw. A new durability driving test will also be required for heavy duty vehicles of GVW 2.5t-12t conforming to the new standards.

Early legislation which has now been superseded is given below in **Tables A.1.53** and **A.1.54**. Current and future limits, starting with the change in emissions test procedures, are given in **Part 1.**

Table A.1.53 Historical Japanese Gasoline and LPG Vehicle Emissions Legislation

Vehicle	Effective Date	Cycle Emissions Limits (1) (g/test) CO g/km	HC g/km	NOx g/km	Test Cycle
Passenger cars					
4-cycle gasoline	1973	26.0/18.4	3.80/2.94	3.00/2.18	10 mode
LPG		18.0/10.4	3.20/2.34	3.00/2.19	10 mode
	1975	2.70/2.10	0.39/0.25	1.60/1.20	10 mode
		(85/60)	(9.5/7.0)	(11/9.0)	11 mode
	1976	2.70/2.10	0.39/0.25	0.84/0.60	10 mode
		(85/60)	(9.5/7.0)	(8.0/6.0)	11 mode
2-cycle	1973	26.0/18.3	22.5/16.6	0.50/0.30	10 mode
	1975	2.70/2.10	0.39/0.25	0.50/0.30	10 mode
		(85/60)	(9.5/7.0)	(4.0/2.5)	11 mode
2- & 4-cycle	1978	2.70/2.10	0.39/0.25	0.48/0.25	10 mode
		(85/60)	(9.5/7.0)	(6.0/4.4)	11 mode
trucks & buses					
≤ 660 cc 4-cycle	1973	26.0/18.4	3.80/2.94	3.00/2.18	10 mode
	1975	17.0/13.0	2.70/2.10	2.30/1.80	10 mode
		(130/100)	(17/13)	(20/15)	11 mode
	1979	17.0/13.0	2.70/2.10	1.60/1.20	10 mode
		(130/100)	(17/13)	(11/9.0)	11 mode
	1982	17.0/13.0	2.70/2.10	1.26/0.90	10 mode
		(130/100)	(17/13)	(9.5/7.5)	11 mode
	1990	17.0/13.0	2.70/2.10	0.74/0.50	10 mode
		(130/100)	(17/13)	(7.5/5.5)	11 mode
≤ 660 cc 2-cycle	1973	26.0/18.3	22.5/16.6	3.00/2.18	10 mode
	1975	17.0/13.0	15.0/12.0	3.00/2.18	10 mode
		(130/100)	(70/50)	(4.0/2.5)	11 mode
light duty ≤ 1.7t	1973	26.0/18.4	3.80/2.94	3.00/2.18	10 mode
	1975	17.0/13.0	2.70/2.10	2.30/1.80	10 mode
		(130/100)	(70/50)	(4.0/2.5)	11 mode
	1979	17.0/13.0	2.70/2.10	1.40/1.00	10 mode
		(130/100)	(70/50)	(10/8.0)	11 mode
	1981	17.0/13.0	2.70/2.10	0.84/0.60	10 mode
		(130/100)	(70/50)	(8.0/6.0)	11 mode
	1988	2.70/2.10	0.39/0.25	0.48/0.25	10 mode
		(85/60)	(9.5/7.0)	(6.0/4.4)	11 mode
medium duty >1.7t gasoline	1973	26.0/18.4	3.80/2.94	3.00/2.18	10 mode
LPG		18.0/10.4	3.20/2.34	3.00/2.19	10 mode
	1979	17.0/13.0	2.70/2.10	1.60/1.20	10 mode
		(130/100)	(17/13)	(11/9.0)	11 mode
	1981	17.0/13.0	2.70/2.10	1.26/0.90	10 mode
		(130/100)	(17/13)	(9.5/7.5)	11 mode
	1989	17.0/13.0	2.70/2.10	0.98/0.70	10 mode
		(130/100)	(17/13)	(8.5/6.5)	11 mode
	1994	17.0/13.0	2.70/2.10	0.63/0.40	10 mode
		(130/100)	(17/13)	(6.6/5.0)	11 mode
		%v	**ppm**	**ppm**	
heavy duty > 2.5 t gasoline	1973	1.6/1.2	520/420	2200/1830	6 mode
LPG		1.1/0.8	440/350	2200/1830	
	1977	1.6/1.2	520/420	1850/1550	6 mode
	1979	1.6/1.2	520/420	1390/1100	6 mode
	1982	1.6/1.2	520/420	990/750	6 mode
	1989	1.6/1.2	520/420	850/650	6 mode
Current and future legislation is given in **Part 1**					

(1) All limits are given as max/mean, the maximum limits apply for production of < 2000 units/annum and the mean limits apply to production ≥ 2000 units/annum

Table A.1.54 Historical Japanese Diesel Vehicle Exhaust Emissions Legislation

Vehicle		Effective Date	Cycle Emissions Limits CO g/km (ppm)	HC g/km (ppm)	NOx g/km (ppm)	Test Cycle
all diesel vehicles						
DI		1974	(980/790)	(670/510)	(1000/770)	6 mode
		1977	(980/790)	(670/510)	(850/650)	6 mode
		1979	(980/790)	(670/510)	(700/540)	6 mode
		1983	(980/790)	(670/510)	(610/470)	6 mode
IDI		1974	(980/790)	(670/510)	(590/450)	6 mode
		1977	(980/790)	(670/510)	(500/380)	6 mode
		1979	(980/790)	(670/510)	(450/340)	6 mode
		1982	(980/790)	(670/510)	(390/290)	6 mode
Passenger cars						
small cars		1986 (1)	2.70/2.10	0.62/0.40	0.98/0.70	10 mode
		1990	2.70/2.10	0.62/0.40	0.72/0.50	10 mode
medium cars		1986 (1)	2.70/2.10	0.62/0.40	1.26/0.90	10 mode
		1992	2.70/2.10	0.62/0.40	0.84/0.60	10 mode
trucks and buses						
light duty ≤ 1.7t		1988	2.70/2.10	0.62/0.40	1.26/0.90	10 mode
medium duty >1.7t	DI	1988	(980/790)	(670/510)	(500/380)	6 mode
	IDI		(980/790)	(670/510)	(350/260)	6 mode
heavy duty > 2.5 t	DI	1988 (2)	(980/790)	(670/510)	(520/400)	6 mode
	IDI	1989	(980/790)	(670/510)	(350/260)	6 mode
Current and future legislation is given in **Part 1**						

(1) for cars with automatic transmission
(2) for vehicles > 3.5t

A.1.5. OTHER ASIAN COUNTRIES

The vehicle emissions regulations of other Asian countries are considered below by country in alphabetical order. The regulations are summarised in **Part 1, Table 1.31** at the end of this section.

A.1.5.1. China

Chinese emissions regulations were revised in 1993. The implementation dates and limits for Light Duty Vehicles (≤ 3.5t), according to Regulation No. GB-11641.1-93, are based on ECE 15.03 limits but with higher HC limits and are given in **Table A.1.55.** Those for Heavy Duty Vehicles (> 3.5t) according to Regulation No. GB-14761.2-93 are given in **Table A.1.56**. Regulations on gasoline engine idle emissions and diesel black smoke are given in **Table A.1.57.** Motorcycle emissions conform to the ECE R40 regulation (see **Tables A.1.13** and **A.1.14**) and the additional idle and smoke emission regulations are given in **Table A.1.58**.

Table A.1.55 Current Chinese light duty vehicle exhaust emission limits Regulation GB-14761.1-93 (Test Cycle ECE R 15/R 83 Part 1)

Vehicle Ref. Mass, kg	Type Approval (g/test)			Conformity of Production (g/test)		
	CO	HC	NOx	CO	HC	NOx
£750	65	10.8	8.5	78	14.0	10.2
751-850	71	11.3	8.5	85	14.8	10.2
851-1020	76	11.3	8.5	91	15.3	10.2
1021-1250	87	12.8	10.2	104	16.6	12.2
1251-1470	99	13.7	11.9	119	17.8	14.3
1471-1700	110	14.6	12.3	132	18.9	14.8
1701-1930	121	15.5	12.8	145	20.2	15.4
1931-2150	132	16.4	13.2	158	21.2	15.8
>2151	143	17.3	13.6	172	22.5	16.3

Note: For vehicles designed and manufactured from 01.07.1995, evaporative emissions: 2.0 g/test max

Table A.1.56 Chinese heavy duty gasoline vehicle exhaust emissions limits Regulation GB-14761.2-93 (Test Cycle Chinese 9-Mode)

Vehicle Category	Effective Date	Type Approval (g/kWh)		Conformity of Production (g/kWh)	
		CO	HC + NOx	CO	HC + NOx
Type approved before 1995	01.01.1996	54	22	96	38
	01.01.1998	34	14	96	38
	01.01.1999	34	14	54	22
Type approved after 1994	01.01.1996	54	22	65	26
	01.01.1998	34	14	65	26
	01.01.1999	34	14	41	17

Note: For vehicles designed and manufactured from 01.07.1996, evaporative emissions 4 g/test max

Table A.1.57 Chinese regulations on gasoline vehicle idle emissions and diesel smoke

Vehicle	Date	Type Approval					Conformity of Production				
		Gasoline Vehicle Idle Emissions			Diesel Smoke (Bosch)		Gasoline Vehicle Idle Emissions			Diesel Smoke (Bosch)	
		CO (%v)	4-stroke HC (ppm)	2-stroke HC (ppm)	free accel	full load	CO (%v)	4-stroke HC (ppm)	2-stroke HC (ppm)	free accel	full load
LDV ≤3.5t	1.7.95	3.0	600	6000	3.5	4.0	3.5	700	6500	4.0	4.5
HDV >3.5t	1.7.95	3.5	900	6500	3.5	4.0	4.0	1000	7000	4.0	4.5

Table A.1.58 Chinese regulations on motorcycle idle emissions

Category	Type Approval			Conformity of Production		
	CO (%v)	HC + NOx (ppm)		CO (%v)	HC + NOx (ppm)	
		4-stroke	2-stroke		4-stroke	2-stroke
Type approved before 1996	4.5	1500	7000	-	-	-
Produced before 1996	4.5	1500	7000	5.0	2000	7800
Type approved after 1995	4.5	1200	7000	4.5	1800	7000

A.1.5.2. Hong Kong

Vehicles are certified against US test procedures. Passenger and light duty vehicles must comply against the US Federal 1988 limits. The emission limits for heavy duty trucks are more relaxed than the US limits. Vehicles certified against 93/59/EEC are acceptable. Japanese 1978 and 1994, 10.15-mode and 13-mode limits are also acceptable for passenger gasoline, passenger diesel, light duty and heavy duty vehicles respectively. The regulations apply from 1 April 1995. The limits against US FTP 75 are given in **Table A.1.59** below.

Revised limits are under consideration for implementation from 1 April 1997. These are loosely based on US Tier I for cars and light duty gasoline vehicles, Federal 1991 and 1994 limits for light duty diesel vehicles (see **Part 1**). Alternative limits to the European 94/12/EC and 93/59/EEC and Japanese10.15 and 13 modes also can be applied.

Table A.1.59 Hong Kong exhaust emission limits for vehicles from 1st April 1995 (by US FTP 75 and HD cycles)

Vehicle		CO (g/km)	HC (g/km)	NOx (g/km)	Pm (1) (g/km)	Test Procedure
passenger cars and derivatives		2.1	0.26	0.63	0.12	FTP 75 (3)
		2.1	0.26	0.25		FTP 75 (2)
light duty gasoline & diesel	≤ 1.7t	6.2	0.5	0.75	0.16	FTP 75 (3)
	1.7 -2.5t	6.2	0.5	1.10	0.28	
	2.5-3.5t	6.2	0.5	1.10	0.28	
heavy duty gasoline	> 3.5t	49.7	2.55	6.7	-	HDGTC (3)
heavy duty diesel	> 3.5t	20.8	1.74	8.04	0.8 (4)	HDDTC (3)

(1) Diesel vehicles only

(2) All vehicles certified to 93/59/EEC, gasoline vehicles to Japan 78 and diesel vehicles to Japan 94 are also considered to comply

(3) Light and heavy duty vehicles to 93/59/EEC, light duty vehicles to Japanese 10.15 mode and heavy duty vehicles to Japanese 13 mode limits are considered to comply

(4) Diesel engine smoke limit value for free acceleration absorption coefficient: 1.2 m^{-1}

Table A.1.60 Hong Kong vehicle emissions regulation proposed for implementation by 1 April 1997
utilising US FTP 75 and Heavy Duty cycles

Vehicle			**CO** (g/km)	**HC** (g/km)	**NMHC** (g/km)	**NOx** (g/km)	**Pm** (g/km)
private cars taxis		gasoline	2.10	0.26	0.16	0.25	
		diesel	2.10	0.26		0.63	0.12
light goods	≤ 1.7t	gasoline	2.10		0.16	0.4	
buses		diesel	6.20	0.5		1.2	0.16
	1.7-2.5t	gasoline	2.73		0.20	0.43	
		diesel	6.20	0.5		1.10	0.28
	2.5-3.5t	gasoline	3.10		0.24	0.68	
		diesel	6.2 0	0.50		1.10	0.28
			(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)
heavy goods		gasoline	49.7	2.55		6.7	
	3.5-4.0t	diesel	20.8	1.74		8.04	0.80
buses							
	>4.0t	gasoline	49.7	2.55		6.70	
		diesel	20.8	1.74		6.70	0.13

(1) All vehicles must comply with free acceleration smoke light absorption coefficient of 1.00 m^{-}

(2) Limits according to European 94/12/EEC or 93/59/EEC and Japanese 10.15 and 13 modes also apply

A.1.5.3. India

Idle CO and smoke tests for gasoline and diesel vehicles respectively have been in force since 1986 in a number of states. Following the enactment by the Indian federal government of a revised Motor Vehicle Act in 1990, these types of tests became mandatory throughout India for both new and in-use vehicles. Limits for gasoline mass emissions and diesel full load and free acceleration smoke became effective in 1991 and mass emissions from diesel vehicles were controlled from 1992. Limits and test procedures for gasoline vehicles and light duty diesel vehicles, incorporating conformity of production limits, have been adopted from ECE R15-04 but modified, using an Indian driving cycle after a hot start (see **Table A.1.61**). Diesel smoke and alternative mass emissions have been adopted from ECE R24 and ECE R49 respectively (**Tables A.1.9** and **A.1.8**). The emissions limits were amended effective 1 April 1996 and will be further tightened from the year 2000. Currently no evaporative emissions limits and deterioration factors or endurance tests have been prescribed but diesel particulate limits are being introduced from 2000.

Table A.1.61 Emissions regulations for gasoline and diesel vehicles according to the Indian Driving Cycle

Vehicle Category	Reference Mass or Engine Size	Effective Date	Type Approval (g/km)		Conformity of Production (g/km)		Idle CO (%v)
			CO	HC	CO	HC	
Passenger and goods vehicles GVW ≤ 3.5t Gasoline	<1020 kg	before 1.4.1996	14.3	2.0	17.3	2.7	3
	1020-1250 kg		16.5	2.1	19.7	2.7	3
	1250-1470 kg		18.8	2.1	22.5	2.8	3
	1470-1700 kg		20.7	2.3	24.9	3.0	3
	1700-1930 kg		22.9	2.5	27.6	3.3	3
	1930-2150 kg		24.9	2.7	29.9	3.5	3
	>2150 kg		27.1	2.9	32.6	3.7	3
2- and 3-wheeled GVW≤ 1.0t	≤ 150 kg		12	8	15	10	4.5
	150-350 kg		(1)	(2)	(3)	(4)	4.5
	350 kg		30	12	40	15	4.5
			CO	HC+NOx	CO	HC+NOx	
Passenger and goods vehicles GVW≤ 3.5t Diesel	<1020 kg	before 1.4.1996	14.3	4.7	17.3	5.9	3
	1020-1250 kg		16.5	5.1	19.7	6.3	3
	1250-1470 kg		18.8	5.4	22.5	6.8	3
	1470-1700 kg	after 1.4.1996 (5)	20.7	5.8	24.9	7.3	3
	1700-1930 kg		22.9	6.2	27.6	7.7	3
	1930-2150 kg		24.9	6.5	29.9	8.2	3
	>2150 kg	2000 (6)	27.1	6.9	32.6	8.6	3
Passenger cars Gasoline	<1.4 litre	1.4.1996	8.68	3.0	10.4	3.6	3.0
	1.4-2.0 litre		11.2	3.84	13.4	4.6	3.0
	>2.0 litre		12.4	4.36	14.9	5.2	3.0
3-wheeled			6.75	7.43	5.4	6.5	3.0
2-wheeled			4.5	5.0	3.6	4.3	3.0
Passenger cars gasoline		2000	2.72	0.97	2.72	0.97	3.0
3-wheeled			4.0	1.5	4.8	1.8	3.0
2-wheeled			2.0	1.5	2.4	1.8	3.0

(1) Limit = 12 + 18 (R-150)/200 g/km

(2) Limit = 12 + 25(R-150)/200 g/km

(3) Limit = 8 + 4(R-150)/200 g/km

(4) Limit = 10 + 5(R-150)/200 g/km

(5) From 1996 conformity of production limits the same as for type approval

(6) From 2000 Pm 0.14 g/km max, otherwise 1996 and 2000 limits are the same

- Crankcase emissions are not allowed from any vehicle

Table A.1.62 Indian diesel vehicle emissions regulations by the ECE R49 Cycle

Vehicle	Effective date	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	Pm (g/kWh)
all vehicles	before 1.4 1996	14.0	3.5	18.0	-
all vehicles	after 1.4.1996	11.2	2.4	14.4	-
GVW ≤ 3.5t	2000	4.4	1.1	8.0	0.61
GVW >3.5t	2000	4.4	1.1	8.0	0.36

- Crankcase emissions are not allowed from any vehicle

A.1.5.4. Indonesia

The only current emissions control regulation in Indonesia (Minister of Communications No. KM 8/1989) controls idle CO and HC emissions from gasoline engines and free acceleration exhaust emissions from diesel engines as shown in **Table A.1.63**.

Table A.1.63 Indonesian exhaust emission regulations

Vehicle Category	**Engine Type**	**Gasoline Idle Emissions**		**Diesel Smoke**
		CO (%v)	**HC (ppm)**	**(opacity)**
4-wheeled		4.5	1200	50%
2-wheeled	4-stroke	4.5	2400	
	2-stroke	4.5	3000	

A.1.5.5. Malaysia

Malaysia introduced ECE 15.04 regulations in September 1992. In 1995 the ECE R 24.03 and 93/59/EEC regulations were adopted (see **Tables A.1.9** and **A.1.6**). The Department of the Environment has recommended to Parliament that all new passenger cars be fitted with catalytic converters.

A.1.5.6. Singapore

Singapore has adopted intermediate gasoline emissions limits from January 1992, i.e. European ECE 83 or Japanese 1978 limits. However, from July 1993 the authorities plan to introduce EU "*Consolidated Emissions Directive*" limits (**see Table A.1.4**). New diesel vehicles have had to comply with the ECE R24 smoke emission standard (see **Table A.1.9**) since 01.01.91. From 01.01.92 this requirement has been extended to include used vehicles imported for registration. Motorcycles have been required to comply with US EPA Standards (see **Table A.1.33**) since 1 October 1991.

Table A.1.64 Current vehicle emissions legislation for Singapore

Vehicle	Effective Date	Limits
Motor Cycles/ Scooters	01.10.91	US Federal Regulation 40 CFR 86.410-80
Gasoline	1986	UN ECE R15.04
	01.07.92	UN ECE R83 or Japanese Standard JIS 78
	01.07.94	91/441/EEC or JIS 78
Diesel	Before 01.01.91	<50 HSU at idle
	01.01.91	UN ECE R24.03
	1997 (proposed)	UN ECE R24.03 or Phase 1 of 91/542/EEC for HD vehicles with GVW >3.5t 93/59/EEC for LD vehicles

A.1.5.7. South Korea

Until July 1987, exhaust emission regulations in South Korea were based on Japanese test procedures. New regulations were introduced for spark ignition vehicles and diesel vehicles based on US and ECE R 49 procedures respectively as shown in **Table A.1.65**.

Table A.1.65 South Korean passenger and commercial vehicle emission standards

Type of Vehicle		**Date**	**CO**	**HC**	**NOx**	**Evap HC**	**Pm (Smoke)**	**Test**
			g/km	**g/km**	**g/km**	**g/test**	**g/km**	
Passenger mini-cars (gasoline and LPG)	≤ 800 cc	July 1987	8.0	1.5	1.5	4.0[1]	-	FTP 75
		Dec. 1996	4.5[7]	0.5[7]	1.25[7]	4.0[1]	-	FTP 75
		Jan 1998	2.11/4.0[8]	0.25/0.5[8]	0.62/1.0[8]	2.0		
		Jan 2000	2.11	0.16	0.25	2.0		
Passenger cars (gasoline and LPG)	>800 cc < 3.0 t	July 1987	2.11	0.25	0.62	2.0	-	FTP 75
		Jan 1998	2.11	0.25	0.42	2.0	-	FTP 75
		Jan 2000	2.11	0.16	0.25	2.0	-	
Passenger cars (diesel)	≥800 cc < 3.0 tons	Jan 1993	2.11	0.25	1.25	-	0.25	FTP 75
		Jan 1996	2.11	0.25	0.62[6]	-	0.08	FTP 75
		Jan 2000	2.11	0.25	0.62[6]	-	0.05	FTP 75
Light duty trucks (gasoline and LPG)	≤ 1.7 tons	July 1987	6.21	0.50	1.43	2.0	-	FTP 75
		Jan 1998	6.21	0.5	0.75	2.0	-	FTP 75
		Jan 2000	2.11	0.25	0.62	2.0	-	FTP 75
		Jan 2004	1.27	0.18	0.16	2.0	-	FTP 75
	1.7 - 3.0 tons	July 1987	6.21	0.50	1.43	2.0	-	FTP 75
		Jan 1998	6.21	0.5	1.06	2.0	-	FTP 75
		Jan 2000	2.74	0.29	0.43	2.0	-	FTP 75
		Jan 2004	1.65	0.24	0.30	2.0	-	FTP 75
Light duty trucks (diesel)	≤2.7 ton		**ppm**	**ppm**	**ppm**		**(%)**	
	DI	July 1987	980	670	850	-	(50)[2]	Jap 6-mode
	IDI	July 1987	980	670	450	-	(50)[2]	
	DI	Jan 1993	980	670	750	-	(40)	Jap 6-mode
	IDI	Jan 1993	980	670	350	-	(40)	
			g/km	**g/km**	**g/km**		**g/km**	
	≤ 1.7 t DI & IDI	Jan 1996	6.21	0.5	1.43	-	0.31	FTP 75
		Jan 1998	2.11	0.25	1.40	-	0.14	FTP 75
		Jan 2000	2.11	0.25	1.02	-	0.11	FTP 75
		Jan 2004	1.27	0.21	0.64	-	0.06	FTP 75
			g/km	**g/km**	**g/km**		**g/km**	
	1.7-3.0 t DI & IDI	Jan 1996	6.21	0.50	1.43	-	0.31	FTP 75
		Jan1998	2.11	0.50	1.40	-	0.25	FTP 75
		Jan 2000	2.11	0.50	1.40	-	0.14	FTP 75
		Jan2004	1.52	0.33	0.71	-	0.08	FTP 75
Heavy duty vehicles (gasoline and LPG)			**g/kWh**	**g/kWh**	**g/kWh**			Jap gasoline 13-mode
	> 2.7 t	July 1987	33.5	1.3	11.4			
	>3.0 t	Jan 2000	33.5	1.3	5.5			
Heavy duty vehicles (diesel)	>2.7 t		**ppm**	**ppm**	**ppm**		**g/kWh (%)**	
	DI	July 1987	980	670	850	-	(50)[3]	Jap 6-mode
	IDI	July 1987	980	670	450	-	(50)[3]	
	DI	Jan 1993	980	670	450	-	(40)	
	IDI	Jan 1993	980	670	450	-	(40)	
	> 3.0 t		**g/kWh**	**g/kWh**	**g/kWh**		**g/kWh (%)**	
	DI & IDI	Jan 1996	4.9	1.2	11.0	-	0.9 (40)	13-mode (ECE R49)
	DI & IDI	Jan 1998	4.9	1.2	6.0/9.0[5]	-	0.25[4] (25)	
	DI & IDI	Jan 2000	4.9	1.2	6.0		0.25[4] (25)	
	DI & IDI	Jan 2002	4.9	1.2	6.0		0.15[4] (25)	

(1) Reduced to 2.0 g/test WEF 01.01.1996.

(2) Reduced to 40% WEF 01.01.1991
(Note: Test Procedure - Japanese 3-mode or free acceleration).

(3) Reduced to 40% WEF 01.01.1992.

(4) Buses Pm 0.5 g/kWh in 1996 and 0.10 g/kWh 2000/2002

(5) 6.0 g/kWh for new type approvals; 9.0 g/kWh for all new registrations

(6) For vans < 8 passengers, NOx 0.14 and 0.11g/km for 1998 and 2000 respectively

(7) For new registrations for mini-cars previously certified

(8) Commercial mini-cars

(9) Emissions warranties; 5 years or 80k km for passenger cars and for light duty vehicles after Jan 2000, 40k km and 60k km for light duty vehicles before Jan 1998 (except diesels) and Jan 2000 respectively, no requirement for diesel light duty vehicles before Jan 1998. Other requirements for LPG vehicles

Legislation has also been introduced for 2-stroke and 4-stroke motorcycles which will require the use of catalysts. The limits are given in **Table A.1.66**, but the test procedure is not known.

Table A.1.66 South Korean Motorcycle Emission Standards (CO and HC emissions at idle)

Effective Date	Engine Size (cc)	2-stroke		4-stroke	
		CO (% v)	HC (%v)	CO (% v)	HC (%v)
Jan 1991		5.5	1.10	5.5	0.45
Jan 1993	≤ 125	4.5	1.10	4.5	0.45
	126 to 500	4.5	0.78	4.5	0.45
	> 500	4.5	0.45	4.5	0.12
Jan 1996	≤ 125	4.0	0.70	4.0	0.40
	126 to 500	3.6	0.45	3.6	0.25
	> 500	3.0	0.30	2.5	0.10
Jan 2000	ECE R 40.01 (see **Tables A.1.13, A.1.14**)				

A.1.5.8. Taiwan

Legislation in Taiwan required gasoline passenger vehicles to be certified to 1984 US Federal limits from July 1990. From July 1995 gasoline goods vehicles and buses with engine capacity greater than 1200 cc were certified against the 1984 US Federal standard for light duty trucks and this will be extended to all such vehicles in July 1998. It was required to certify light duty diesel vehicles against the US 1984 light duty truck limits including particulates from July 1993 and it is planned to certify these vehicles to the US 1994 LDT limits from 1998. Heavy duty truck particulate limits, based on the US transient test cycle, have also been adopted. Details are given in **Table A.1.67**. Taiwan has also introduced limits for motorcycles which required catalysts be fitted from 1991 and will probably require 3-way catalysts from 1998. Fuel economy standards are also required for passenger cars and motorcycles (see **Section A.4.4.2)**

Table A.1.67 Taiwan vehicle exhaust emissions by the US FTP 75 cycle

Vehicle		Effective date	CO	HC	NOx	Pm	Idle CO	Idle HC
			g/km	**g/km**	**g/km**	**g/km**	**(%v)**	**(ppm)**
Gasoline passenger vehicles (1) (5)	gvw ≤3.5t	1.7.1990	2.11	0.255	0.62		3.5	600
Gasoline goods vehicles & buses (1) (5)	≤ 1200 cc	1.7.1995	11.18	1.06	1.43		1.0	200
	≤ 1200 cc	1.7.1998	6.20	0.50	1.43		0.5	100
	> 1200 cc	1.7.1995	6.20	0.50	1.43		1.0	200
	> 1200 cc	1.7.1999	3.11	0.242	0.68		0.5	100
Motorcycles (2)		1991					4.5	7000
		1.1.1998					3.5	6000
Light duty Diesel	gvw≤ 2.5t	1.7.1993	6.20	0.5	1.43	0.38		
		1998 plan	2.125	0.156	0.25	0.05		
			g/bhp.h	**g/bhp.h**	**g/bhp.h**	**g/bhp.h**		
Heavy duty Diesel (6)	gvw >3.5t	current	10	1.3	6.0	0.7 (3)		

(1) Diesel engined passenger vehicles are not allowed

(2) 2 & 3 wheeled vehicles with a curb weight <400 kg and a maximum speed >50 km/h or engine displacement >50 cc

(3) Smoke limit 40% opacity under acceleration and full load

(4) Crankcase emissions are not allowed

(5) Evaporative emissions 2.0 g/test for gasoline vehicles

(6) Test cycle: Federal HD Transient Cycle

A.1.5.9. Thailand

ECE test cycles and limits have been proposed or adopted by Thailand for its emission regulations (**Table A.1.68**):

Table A.1.68 Thai Emission Standards

Vehicle	Effective Date	Thai Standard	Equivalent Limits
Passenger cars (gasoline)	01.04.1996	1280-2538	ECE R 83.01
Light duty (diesel £ 3.5 t)	before Jan 1996 01.01 1996	 1285-2538	ECE R 24.03 ECE R 83.01 C
Heavy duty (diesel > 3.5 t)	before Jan 1996 01.01.1996 01.01 1999		ECE R 24.03 91/542/EEC A 91/542/EEC and 96/1/EC
Motorcycles	15.03.1995	1185-2536	ECE R 40.01

A.1.6. CENTRAL AND SOUTHERN AMERICA

A.1.6.1. Argentina

The vehicle emissions regulations were published in the Official Bulletin No. 27.919 dated 27 June 1994. The limits for light duty vehicles closely follow Brazilian legislation but with later implementation dates.

Table A.A.1.69 Argentine vehicle emissions limits (US FTP 75 and HD cycles)

Vehicle		Effective Date	CO (g/km)	HC (g/km)	NOx (g/km)	Pm (g/km) (3)	CO at idle (2) (%v)	HC at idle (2) (ppm)	evaporative emissions (g/test) (2)
passenger cars	all vehicles	01.07.1994	-	-	-	-	3.0	600	-
light duty ≤ 2.8t	new	01.07.1994	24.0	2.1	2.0	-	3.0	600	6.0
	vehicles	01.01.1995	12.0	1.2	1.4	0.373	2.5	400	6.0
	all imports	01.01.1997(4)	2.0	0.3	0.6	0.124	0.5	250	6.0
	all new reg.	01.01.1998	6.2	0.5	1.43	0.16 (6)	0.5	250	-
heavy duty >2.8t	all vehicles	01.01.1995	11.2	2.4	14.4	0.4/0.68	3.0	600	-
		01.01.1997	11.2	2.4	14.4	0.4/0.68	2.5	400	-
	urban buses	01.01.1996	4.9	1.23	9.0	0.4/0.68	-	-	-
	all diesels	01.01.1998	4.0	1.1	7.0	0.15/0.255	-	-	-

(1) Crankcase emissions are not allowed from any naturally aspirated engine. For turbocharged engines, crankcase HC emissions are added to the exhaust emissions

(2) Gasoline engines only

(3) Diesel vehicles only, heavy duty smoke emissions to ECE r 24.01, dual limits apply to vehicles with max power above/below 85 kW

(4) 01.01.1999 for all new registrations

(5) Emissions compliance must be guaranteed for 80 000 km or 5 years for passenger cars and light duty vehicles and 160 000 km or 5 years for heavy duty vehicles, whichever occurs first. These guarantees are not required for vehicles certified at emission levels 10% below the applicable standards

(6) Pm 0.31 g/km for vehicles < 1700 kg

A.1.6.2. Brazil

Light Duty Vehicles

The original Brazilian emissions programme "*PROCONVE*" was published as an official "*resolution*" on May 6, 1989 having been drawn up by CONAMA, the National Environment Board. A month later CONAMA also established separate limits for aldehyde (formaldehyde and acetaldehyde) emissions for both “gasolina” and “alcool” fuelled vehicles (the composition of these fuels is described in **Table A.5.50**). The Brazilian Congress has more recently passed law No. 8723, effective 1 October 1993, setting strict emission standards for passenger vehicles covering the rest of the decade. The limits are measured using the US FTP 75. The limits set do not correspond exactly with US standards but the 1988 standard is roughly equivalent to US 1973 limits and the 1992 standard lies between US 1973 and 1975 limits. The 1997 standard is equivalent to US 1981 standard. More stringent limit values will be introduced by 2000 and will match the US standards.

A smoke emissions standard is under consideration and was to be confirmed by 31 December 1994, possibly with limits of 30 HSU and 40 HSU for naturally aspirated and turbocharged diesels respectively, under free acceleration conditions. Meanwhile manufacturers must report smoke emissions under wide open throttle acceleration conditions in certification tests.

The law also empowers state environmental agencies with more effective enforcement, including the operation of vehicle inspection stations. Another two regulations have been established by CONAMA. One requires manufacturers to provide the information needed for establishing tune-up and maintenance standards. The other establishes minimum requirements for inspection and maintenance programmes, which involves a two speed test with 30 seconds preconditioning. Sao Paulo will introduce the first inspection programme beginning in 1995. It is planned to require the annual inspection of cars more than two years old. Cars that exceed limits will not be permitted on the road until repaired.

Table A.1.70 Light Duty Emission Standards [5] - Brazil (US FTP - 75 Test Cycle)

Year	Vehicle [5]	CO	CO Idle [3]	HC	RCHO [1]	NOx	Pm [2]	Evap [4]
		g/km	%v	g/km	g/km	g/km	g/km	g/test
01.01.89	cars	24	3.0	2.1	-	2.0	-	-
01.01.90	utility	24	3.0	2.1	-	2.0	-	6.0
01.01.92	cars	24	3.0	2.1	0.15	2.0	-	6.0
01.01.92	utility	12	2.5	1.2		1.4		6.0
01.01.97	all	2.0	0.5	0.3	0.03	0.6	0.05	6.0
2000		proposed to bring limits in line with US limits						

(1) Aldehydes (RCHO) limit for alcohol fuelled vehicles only

(2) Particulate matter (Pm) for diesel fuelled vehicles only

(3) Idle CO for alcohol and gasoline vehicles only.

(4) Evaporative emissions expressed as propane for gasohol and ethanol for alcohol fuelled vehicles.

(5) Diesel engined passenger cars not allowed

Heavy Duty Vehicles

New emission standards were established for heavy duty vehicles by the National Environmental Council (CONAMA) on 31 August 1993 (see **Table A.1.71**). A revised implementation schedule introduces the limits in four Phases (I- IV), with a more rapid introduction for urban buses and imported vehicles. The limits for Phase IV will be confirmed by the end of 1994. Phase I, which is current, applies to all diesel vehicles and consists of a smoke limit of 2.5 k only (see **Table A.1.71** for a definition of k).

Manufacturers of light duty trucks, including utility vehicles, pick-ups etc., (over 2000 kg GVW) have the option to chose either the LDV or HDV test procedures for certification. Thereby light duty trucks with low speed diesel engines are still technically feasible while high speed diesels have to be tested by the FTP procedure and comply with the 0.05 g/km particulate emission standard. Although diesel engines are not presently allowed for most LDVs, a particulate standard has been adopted in case regulations change.

Table A.1.71 Heavy Duty Emission Standards - Brazil (ECE R49 test cycle)

Vehicle Class	Date	Phase	% Vehicles	CO g/kWh	HC g/kWh	NOx g/kWh	Pm g/kWh	Smoke k(2)
	01.03.94	II	80	11.2	2.45	14.4	-	2.5
All	01.01.96	II	20	11.2	2.45	14.4	-	2.5
Vehicles		III	80	4.9	1.23	9.0	0.4 (1)	2.5
	01.01.2000	III	20	4.9	1.23	9.0	0.4 (1)	2.5
		IV	80	4.0	1.1	7.0	0.15	-
	01.01.2000	IV	100	4.0	1.1	7.0	0.15	-
All	01.01.94	III	100	4.9	1.23	9.0	0.4 (1)	2.5
Imports	01.01.98	IV	100	4.0	1.1	7.0	0.15	-
Buses	01.03.94	II	20	11.2	2.45	14.4	-	2.5
		III	80	4.9	1.23	9.0	-	2.5
	01.01.96	III	80	4.9	1.23	9.0	0.4 (1)	-
	01.01.98	III	20	4.9	1.23	9.0	0.4 (1)	-
		IV	80	4.0	1.1	7.0	0.15	-
	01.01.2002	IV	100	4.0	1.1	7.0	0.15	-

(1) Particulate emissions (Pm) 0.7 g/kWh for engines up to 85 kWh, 0.4 g/kWh for engines up to 85 kWh.

(2) k = soot (g/m^3) x gas flow (l/sec)

(3) Crankcase emissions must be nil, except for some turbocharged diesel engines if there is a technical justification

(4) Emissions must be warranted for 80 000 km for LDVs, 160 000 km for HDVs, or alternatively emissions must be 10 per cent below the limits set.

A.1.6.3. Chile

Legislation has been implemented by del Ministerio de Transportes y Telecomumicaciones which requires all new cars to meet US emission limits. This applied from September 1993 to the greater Santiago area, which has a significant smog problem, and from September 1994 and 1995 respectively for heavy duty vehicles in the rest of the country. Such cars will be permitted to use the roads in Santiago at all times, while the existing non-catalyst cars will be subject to a 20% off-the-road restriction on weekdays. 91 RON unleaded gasoline will be made available for the new catalyst equipped cars. Retrofitting some of the older cars with catalysts is also under consideration.

Table A.1.72 Chilean vehicle emissions legislation

Vehicle		Effective Date	CO	HC	NOx	Pm [4]	Test Cycle
			(g/km)	(g/km)	(g/km)	(g/km)	
Passenger cars		1995	2.11	0.25	0.62	0.125	FTP 75
Light & medium duty	gvw <3860 kg	1995	6.20	0.50	1.43	0.16 [2]	FTP 75
			(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	
Heavy duty diesel	gvw ≥3860 kg	01.09.1994	4.5	1.1	8.0	0.36 [3]	ECE R 49 [1]
		01.09.1998	4.0	1.1	7.0	0.15	
			(g/bhp.h)	(g/bhp.h)	(g/bhp.h)	(g/bhp.h)	
		01.09.1994	15.5	1.3	6.0	0.36	US HDDTC [1]
		01.09.1998	15.5	1.3	5.0	0.10	
Heavy duty gasoline	gvw ≥3860 kg	current	37.1	1.9	5.0	-	US HDDTC
Santiago urban bus		01.09.1993	15.5	1.3	5.0	0.25	US HDDTC [1]
		01.09.1996	15.5	1.3	5.0	0.10	
			(g/kWh)	(g/kWh)	(g/kWh)	(g/kWh)	
		01.09.1993	4.5	1.1	8.0	0.36 [3]	ECE R 49 [1]
		01.09.1996	4.0	1.1	7.0	0.15	

(1) Alternative limits
(2) Pm 0.31 g/km for vehicles > 1700 kg curb weight
(3) For engines ≤ 85 kW the Pm limit is 0.61 g/kWh
(4) For diesel engines only
(5) For gasoline engines, no crankcase emissions allowed and evaporative emissions: 2 g/test for passenger cars, light and medium duty vehicles, 4 g/test for heavy duty vehicles

A.1.6.4. Costa Rica

Vehicle emissions regulations in Costa Rica were introduced in 1995 according to regulation Ley de Transito por Vias Publicas Terrestres, Section V. They can be specified according to US or ECE regulations. The limits for the US test methods are given in **Table A.1.74**.

Table AA.1.73 Current Costa Rican emissions regulations (1995)

Vehicle Category	Test Procedure [1]	Emission Limits [1]
Gasoline passenger car and light duty vehicles (gvw £ 3,500 lb)	FTP 75 ECE R 83	US 1981 91/441/EEC
Diesel passenger car and light duty vehicles (gvw £ 3,500 lb)	FTP 75 ECE R 83 ECE R 24	US 1988 91/441/EEC ECE R 24.03
Heavy Duty Vehicles > 3,500 lb	US HDDTC ECE R 49 ECE R 24	US 1991 91/542/EEC ECE R 24.03

(1) Optional US or ECE

Table A.1.74 Costa Rican vehicle emissions limits, implemented in 1995 according to US test procedures.

Vehicle	gvw	CO	NMHC	NOx	Pm
Gasoline	≤ 1800 kg	5.7 g/km	0.25 g/km	0.63 g/km	
	1800 - 2800 kg	6.2 g/km	0.50 g/km	1.10 g/km	
	2800 - 6400 kg	19.2 g/kWh	1.2 g/kWh	10.6 g/kWh	
	> 6400 kg	49.8 g/kWh	2.3 g/kWh	10.6 g/kWh	
Diesel	≤ 3500 kg				1.1 g/test
	> 3500 kg				0.36 g/kWh

A.1.6.5. Mexico

On June 6, 1988 the Mexican authorities announced a decision to introduce more stringent standards for light duty vehicles, culminating in full US 1981 limits by 1993. Interim standards for 1989 through 1992 are consistent with the proposal made by the automobile manufacturers. With respect to heavy duty vehicles, standards have been introduced for the years 1994 and 1998 equivalent to the US Federal 1994 and 1998 limits. The limits are given in **Table A.1.75**.

Also the Official Diary of 12th January 1996 specified CO and HC idle limits applicable to gasoline vehicles effective from the 1 January 1996 (see **Table A.1.76**).

Table A.1.75 Mexican Emissions Standards (US FTP 75 procedure)

Vehicle Type	Effective Date	CO (g/mile)	HC (g/mile)	NOx (g/mile)	Pm
Cars	1989 1990 1991 1993	35.2 28.8 11.2 3.4	3.20 2.88 1.12 0.41	3.68 3.20 2.24 1.00	
Light Duty Vehicle gvw <6012lb	1990 1994	35.2 14.0	3.20 1.00	3.68 2.30	
Light Duty Vehicles gvw 6013-6614lb	1990 1992 1994	56.0 35.2 14.0	4.80 3.20 1.00	5.60 3.68 2.30	
		(g/bhp.h)	**(g/bhp.h)**	**(g/bhp.h)**	**(g/bhp.h)**
Heavy Duty Trucks gvw > 8500 lb	1994 1998	15.5 15.5	1.3 1.3	5.0 4.0	0.10/0.07 (1) 0.10/0.05 (1)

(1) Lower limits for urban buses

Table A.1.76 Mexican Idle CO and HC limits effective from 1 January 1996

passenger cars light duty <2727 kg		
Model Year	CO (%v)	HC (ppm)
before 1980	4.0	450
1980-1986	3.5	350
1987-1993	2.5	300
after 1993	1.0	100

Vehicles >2727 kg		
Model Year	CO (%v)	HC (ppm)
before 1980	5.0	600
1980-1985	4.0	500
1986-1991	3.5	400
1992-1993	3.0	350
after 1993	2.0	200

Vehicles operating in the Mexico City area		
Model Year	CO (%v)	HC (ppm)
before 1987	2.00	200
1987-1993	1.00	150
after 1993	0.75	100

A.1.7. MIDDLE EAST & AFRICA

A.1.7.1. Israel

Israel has adopted EU legislation as shown in **Table A.1.77**.

Table A.1.77 Israeli exhaust emissions regulations

Vehicle Type		Effective Date	Emission Limits
Passenger vehicles gvw £ 3500 kg & light duty gvw £ 2349 kg	gasoline gasoline	current	88/76/EEC or 88/436/EEC or 89/458/EEC or 89/491/EEC or 91/441/EEC
	diesel	current	72/306/EEC + 91/441/EEC
Light duty 2350-3500 kg	gasoline	current	83/351/EEC
Buses gvw >4000 kg goods vehicles >3500 kg	diesel	current	72/306/EEC + 88/77/EEC

Source: Current and Future Exhaust Emission Legislation, AVL List GmbH, March 1996

A.1.7.2. Saudi Arabia

Saudi Arabia has adopted standards equivalent to ECE R15.03. Annual inspections of vehicle emission control systems is required in Jeddah, Riyadh and Dammam.

A.1.8. AUSTRALIA

Australia operates under a federal system of government, but contrary to the US situation, the Federal government does not have authority over motor vehicle legislation. This power, including the ability to introduce emissions regulations, lies with the various state governments.

The Australian Transport Advisory Council (ATAC) comprises federal and state transport ministers. It meets twice a year and can resolve the adoption of emissions and safety standards which, although not binding on the states, are usually adopted in state legislation. However, states have acted unilaterally when agreement within ATAC is not reached.

ATAC is advised on emissions matters, by a hierarchy of committees: the Motor Transport Groups (comprising senior federal and state public servants), the Advisory Committee on Vehicle Emissions and Noise (ACVEN) which comprises lower-level federal and state public servants, and the ACVEN Emissions Sub-Committee, which includes public servants, representatives from the automotive and petroleum industries as well as consumers. ACVEN also provides advice to the Australian Environment Council, which has some emissions responsibilities.

Petrol engined vehicles emission standards

Prior to 1986, passenger car emissions standards (ADR27) were based on the United States 1973-74 requirements. From January 1986, manufacturers are required to meet the ADR37 standard, which is equivalent to United States 1975 requirements. Current requirements for commercial gasoline-engined vehicles are based on the New South Wales 26(3) and Victorian 9 regulations. Details are given in **Tables A.1.78** and **A.1.79**.

Table A.1.78 Australian Passenger Car Emission Regulations

Regulation	Effective Date	CO (g/km)	HC (g/km)	NOx (g/km)	Test Procedure	Evaporative Emissions (g/test)
ADR27 A/B/C	July 1976	24.2	2.1	1.9	FTP 75	2.0 (canister)
	Jan 1982	22.0	1.91	1.73	FTP 75	6.0 (SHED)
ADR37 (1)	Jan 1986	9.3 *8.45*	0.93 *0.85*	1.93 *1.75*	FTP 75	2.0 (SHED) *1.9 (SHED)*

(1) The higher figures apply to production vehicles, which must meet the limits from 150 km to 80 000 km or for 5 years, whichever occurs first. The figures in italics apply to certification vehicles.

Table A.1.79 Australian Gasoline-Powered Commercial Vehicle Emission Regulations

Regulation (1)	Effective Date	CO (g/km)	HC (g/km)	NOx (g/km)	Test Procedure	Evaporative Emissions (g/test)
NSW (Clean Air Act) **VIC (Statutory Rules)**	Current	9.3	0.93	1.93	FTP 75	2.0 (SHED)

(1) Individual state regulations differ in some respects from these regulations.

Proposals have been made by the FCAI (Federal Chamber of Automotive Industries - representing both Australian vehicle manufacturers and the importers) to reduce emission limits in two stages in 1996 and 2000 as follows:

Passenger cars

Table A.1.80 Australian Proposed Legislation for Passenger Cars

Date	CO g/km	HC g/km	NOx g/km	Pm g/km
1996	4.34	0.26	1.24	2.0
2000	2.11	0.26	0.63	2.0

Commercial vehicles

Proposed legislation would allow engines to be used which meet current European, US or Japanese emission limits. Further reductions in emission limits to, say, US 1983 standards could be considered after the year 2000.

Diesel-engined vehicle emissions standards

Diesel exhaust smoke emission limits (ADR30 and ADR55) are set for the opacity of the exhaust smoke when the engine is tested under prescribed conditions. Three alternative test procedures are allowed, equivalent to 1974 British, European or United States standards:

- EPA (US) Federal diesel smoke regulations Part 85 and 86.
- BS AU 141a: 1971.
- ECE Regulation 24.

The above diesel regulations are currently under review but no proposals have yet been published.

A.2. EMISSIONS AND FUEL ECONOMY CYCLES AND TEST PROCEDURES, I&M PROCEDURES

The current laws, designed to limit the emission of exhaust gases by motor vehicles, prescribe throughout the world maximum emission standards for the following exhaust gas components:

- carbon monoxide (CO);
- hydrocarbons (HC);
- oxides of nitrogen (NOx);
- particulates (Pm).

It is also common practice to use part or all of an emissions cycle to measure fuel economy, calculated by mass balance in conjunction with carbon dioxide measurements.

The method of gauging emission rates is determined by statutory test procedures, the objective being to establish the mass of each exhaust component emitted during the test. The mass is computed from the measured concentrations of each pollutant in the known exhaust gas volume. Exhaust species are generated when the vehicle is operated on a chassis dynamometer according to certain standard driving cycles, which are designed to simulate driving conditions in urban traffic. A number of these urban cycles have been augmented with higher speed sections (e.g. the extra urban driving cycle - see **Figure A.2.2**).

The following represents an overview of the major exhaust test procedures for Europe and the United States. It shows that a large variety of test procedures exist and that there are substantial differences between them with respect to driving cycle (speed and distance), vehicle preconditioning, and analytical equipment.

Evaporative emissions from gasoline powered vehicles are also controlled. These emissions are determined either by collection in activated carbon traps, or by putting the vehicle in an airtight housing (SHED) and measuring the hydrocarbon concentration - this latter approach is favoured in Europe and the United States. These procedures are also reviewed.

A.2.1. EUROPE

A.2.1.1. ECE 15 and EUDC Cycle for Light Duty and Light Commercial Vehicles

ECE 15 defines an urban test cycle to be used for emission measurements, as shown in **Figure A.2.1**. The cycle was devised to be representative of city-centre driving (e.g. Rome) and thus has a maximum speed of only 50 km/h. The complete first ECE 15 emissions procedure consists of three tests, Type I, II and III, as follows:

Type I Test Emission test cycle:

Prior to testing the vehicle must be preconditioned by driving at least 3500 km (1800 miles). The vehicle is allowed to soak for at least 6 hours at a test temperature of between 20 and 30°C. It is then started and allowed to idle for 40 seconds. The 15 mode driving cycle (**Figure A.2.1**) is then repeated four times without interruption. This gives a total test cycle time of 780 sec., total distance of 4.052 km (2.5 miles) and thus an average speed of 19 km/h (11.8 miles/h). The EU will, in the year 2000, abandon the 40 second idle period and commence emissions testing with an engine start at the beginning of the first ECE 15 mode cycle.

Up to Amendment 15/04, total emissions were collected in one bag. CO and HC emissions were determined by NDIR (Non-Dispersive Infra-Red) analyzers and NOx by chemiluminescent technique. From 15/04, however, emissions were measured by the "*Constant Volume Sampling*" (CVS) technique, as used in the US procedure (**Figure A.2.8**). Hydrocarbon emissions are also determined by use of a FID (Flame Ionization Detector) analyzer.

The ECE 15 cycle is very low duty (maximum speed 50 km/h) and is thus not representative of many modes of driving. Specifically, it is felt to give unrealistically low figures for NOx emissions. After much discussion, an additional "*high speed*" test cycle, the Extra Urban Driving Cycle (EUDC), was agreed (see **Figure A.2.2**), with a maximum speed of 120 km/h. This test is carried out after the standard ECE 15 test. This combination of the ECE 15 and EUDC test cycles is required in the EU "Consolidated Emissions Directive".

Type II Test

Warmed-up idle CO test, conducted immediately after the fourth cycle of the Type I test; tailpipe sampling probe.

Type III Test

Chassis dynamometer procedure for crankcase emissions (idle and 50 km/h constant speed modes). The system is certified if the crankcase operates at partial vacuum (as in PCV systems), or if crankcase emissions meet specified standards.

Fuel Economy and Carbon Dioxide Emissions

Fuel economy (by mass balance) and carbon dioxide emissions are also measured over the ECE 15 and EUDC cycles. One figure for the combined cycle is reported for carbon dioxide, whereas fuel economy is reported separately for the two cycles and in combination.

Figure A.2.1 ECE 15 Test Cycle (repeated four times)

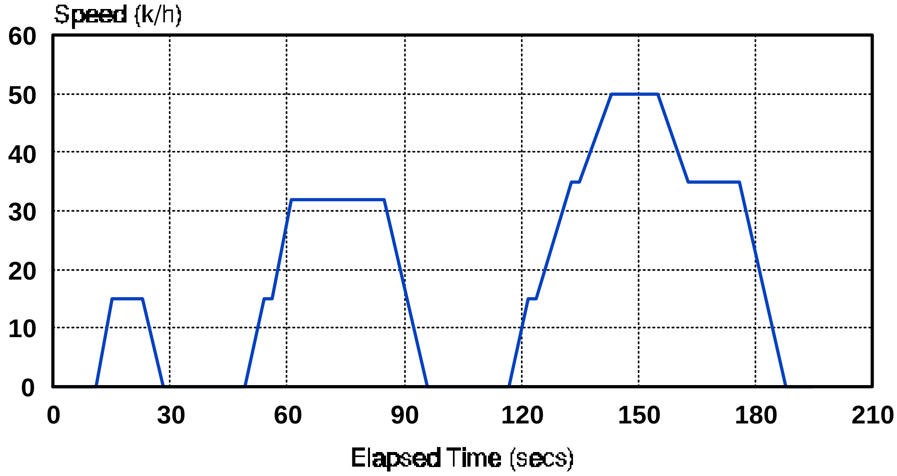
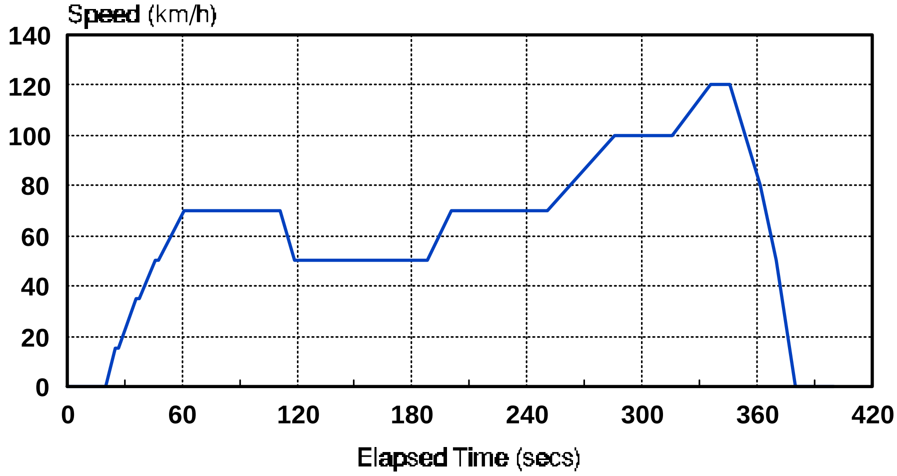


Figure A.2.2 Extra Urban Driving Cycle



<u>Characteristics</u>		<u>ECE 15 Cycle</u>	<u>EUDC Cycle</u>
Distance	km	4 x 1.013 = 4.052	6.955
Time	sec	4 x 195 = 780	400
Average Speed	km/h	19	62.6
Maximum Speed	km/h	50	120
Acceleration	% Time	21.6	-
Acceleration	m/s^2 (max.)	-	0.833
Deceleration	% Time	13.8	
Deceleration	m/s^2(max.)	-	-1.389
Idle	% Time	35.4	-
Steady Speed	% Time	29.3	-

A.2.1.2. ECE 49 Heavy Duty Engine Exhaust Emission Test Procedure

This procedure was developed as a test for medium and heavy duty diesel engines operating in Europe. Accordingly it is an engine rather than a vehicle test and basically follows the format of the obsolete US 13-mode procedure (see **Section A.2.2.3**). Differences are that the minimum load condition uses a figure of 10% (US 2%) and the weighting factors are changed to take into account the differences between European and US driving patterns. The modes employed are as follows:

Table A.2.1 ECE R49 Test Modes

Mode	Speed	Load %	Weighting Factor
1	Idle	0	0.083
2	Intermediate	10	0.080
3	Intermediate	25	0.080
4	Intermediate	50	0.080
5	Intermediate	75	0.080
6	Intermediate	100	0.250
7	Idle	10	0.083
8	Rated	100	0.100
9	Rated	75	0.020
10	Rated	50	0.020
11	Rated	25	0.020
12	Rated	10	0.020
13	Idle	0	0.083

The measuring analysers are as for the US test, whilst the calculation method follows the early US procedure based on measuring exhaust flow.

The major differences between the European and US 13 mode procedures therefore lie in the minimum load level employed and the different weighting factors. These have the effect of reducing the measured hydrocarbons but increasing the measured NOx (and CO). It is important that this should be taken into account when considering US legislation levels and translating them into a European context.

A.2.1.3. Proposed European Heavy Duty Engine Exhaust Emissions Test Procedure

A GRPE sub-group set up to develop a new exhaust emissions procedure for heavy duty vehicles for implementation with the Euro 3 emissions limits in 2000 reported its conclusions in May 1996. During the course of its work it compared five candidate cycles with the R49 and US transient cycles on eight modern engines at four laboratories. It proposed the adoption of two separate tests, each of about thirty minutes duration. One is a 13-mode steady state cycle with an additional dynamic load response test (for smoke measurements) and the other is a transient cycle. In a ranking procedure (taking into account precision, applicability to new technology and fuels, cost and ability to control emissions) both cycles offer a substantial improvement over the current ECE R49 test:

	New Transient	New 13-mode	US Transient	ECE R49
Merit marks min/ max	325/434	323/467	262/379	134/283
Ranking min/max (out of 7 tests)	1/2	2/1	4/4	7/6

Comparing the two cycles, the sub-group consider that the steady state cycle gives better protection against an engine being operated at worse levels of emission control outside the envelop defined by the cycle and it requires relatively minor changes to current test equipment. On the other hand the transient test cycle is more representative of actual driving patterns and furthermore is better suited to testing engines operating on alternative fuels.

The sub-group suggests that for the Euro 3 standards, to be adopted around 2000, conventional diesel engines would be tested by the steady state test cycle while diesel engines with advanced emission control systems and all positive-ignition engines would be tested by both procedures. For the Euro 4 standards, to be adopted around 2005, it is suggested that all engines should be tested by both procedures. With respect to emissions limit values, the sub-group recommends that one set of limits for CO, HC, NOx, particulates and smoke (specifically for the steady state test) should be established. These would be based on the steady state procedure, with the limits for the transient test cycle expressed as a product of the steady state limit values and a correction factor for each pollutant.

The operating conditions for both tests are summarised below.

13-Mode Cycle

For actual driving, the most important criterion is the available power at a given engine speed. The test speeds for the cycle were chosen following an investigation of the power curves of a number of modern engines, which showed that the usable speed range of an engine lies between 50 % and 70% of rated power, before and beyond the peak in the power curve respectively. The three test speeds are determined by dividing this speed range into four equal sectors (see lower diagram of **Figure A.2.3**).

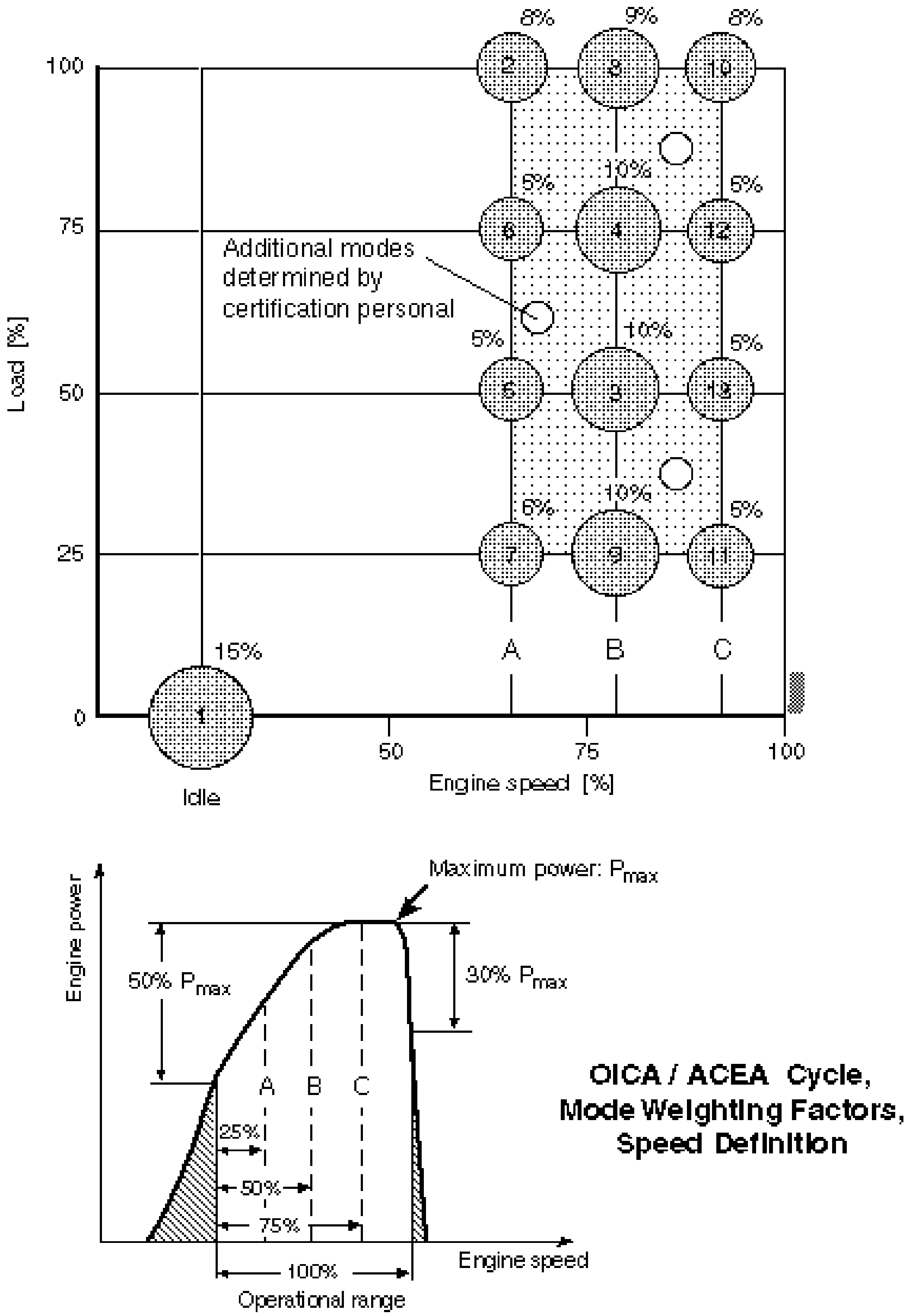
In addition to idle, the other 12 modes are set at a combination of the three speeds established above and at 25 %, 50 %, 75 % and 100 % load. Weighting factors are assigned to each mode as shown in **Figure A.2.3**. To ensure that there are no rogue operating conditions which give abnormally high emissions, three more modes can be selected within this operating envelope by the personnel certifying the engine. For acceptance, the values measured in these modes must correspond with the emission characteristics measured at the fixed cycle points within established tolerances. The test sequence is selected to test engines with exhaust gas treatment systems at realistic temperatures, it being considered sufficient to hold the engine under each condition for no longer than one minute to reproduce actual operating conditions.

For the dynamic load response test, the engine is preconditioned and then accelerated from 10 % load to full throttle at maximum acceleration. In this way the engine runs through all the fuel/air mixture conditions defined by the management system. It is intended that smoke emissions of diesel engines and CO, HC and NOx emissions of alternative-fuelled engines are measured in this way (**Figure A.2.5**).

Transient Cycle

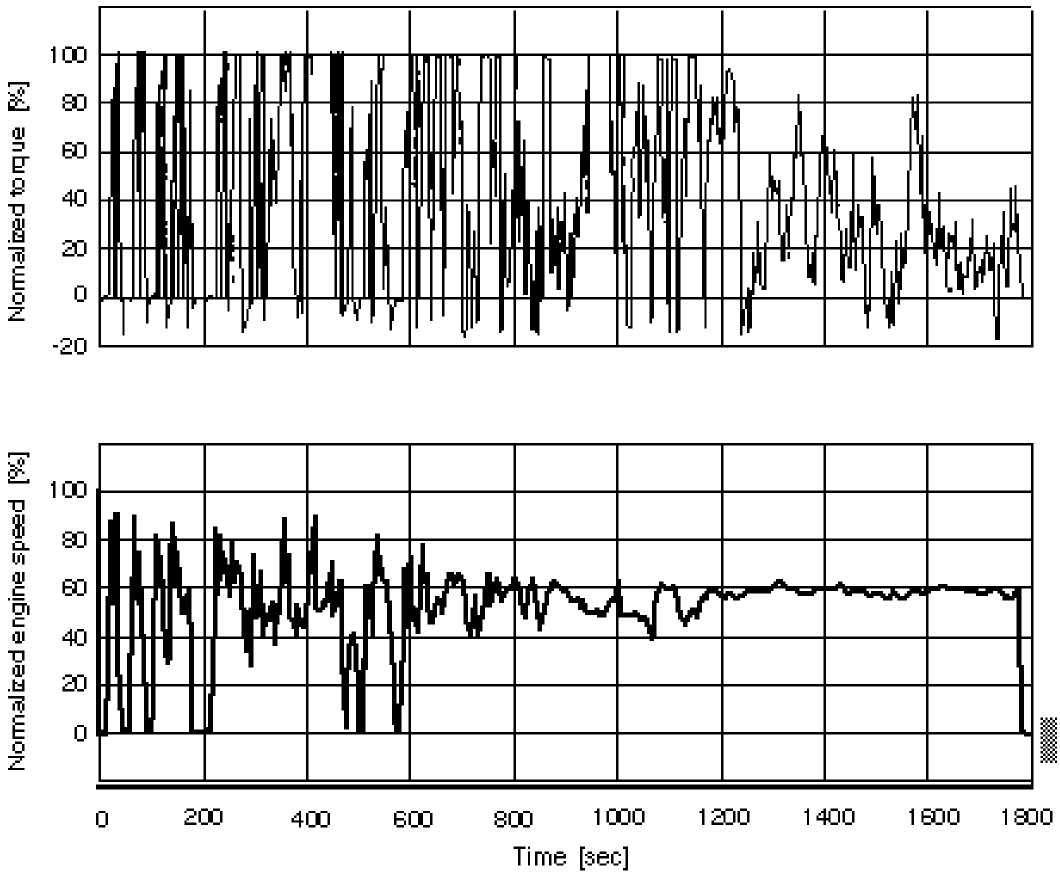
This cycle was developed from data of road speed/power curves of typical driving patterns collected in a collaborative project by German and Swiss authorities for the purpose of updating emissions factors. The data were analysed in terms of road type (motorway, rural and urban), traffic density, road gradients and vehicle weight, distances between congestion or stopping points and vehicle type (lorries, coaches and local buses). The time curve of vehicle speed was normalised for engine speed and torque (**Figure A.2.4**) assuming a vehicle weight of 28 tonnes. The normalised figures were at first integrated into three sub-cycles of 15 minutes each but were finally reduced to ten minutes each. The frequency pattern of the proposed cycle is in good agreement with the average data for local and long-distance lorries. For establishing limits, emissions from the three sub-cycles may be measured separately and combined using weighting factors.

Figure A.2.3 Proposed European heavy duty exhaust emissions procedure 13-mode cycle (OICA/ACEA procedure)



Source: AVL List GmbH

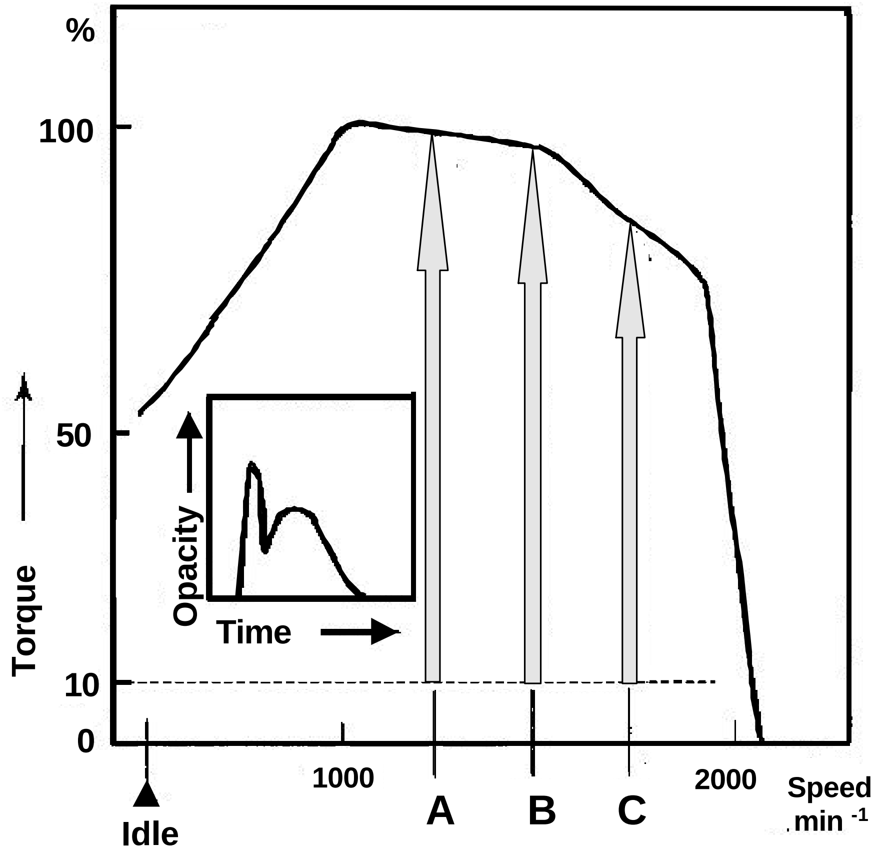
Figure A.2.4 Proposed European heavy duty exhaust emissions procedure Transient cycle (FIGE procedure)



FIGE Transient Cycle

Source: AVL List GmbH

Figure A.2.5 Proposed European dynamic response test for smoke emissions



A.2.1.4. Evaporative Emissions Tests

In Europe the SHED (Sealed Housing for Evaporative Determination) is used to determine evaporative emissions from vehicles.

"*The SHED*" method collects all evaporative emissions in a sealed enclosure which contains the test vehicle. The hydrocarbon concentration in the SHED atmosphere is measured and used to calculate total emissions. This technique has been used for many years in the US.

Evaporative emissions can be divided into three areas:

- ***Diurnal losses:*** these occur when the vehicle is stationary with the engine off and are due to emission of vapour from the fuel tank as a result of normal temperature changes which occur over a 24 hour period.
- ***Hot soak losses:*** these occur when a fully warmed up vehicle is left to stand, as engine heat is transferred to the fuel tank and/or fuel system.
- ***Running losses:*** these occur while the vehicle is being driven normally.

The current EU test procedure is based on the former EPA test procedure (**Table A.2.2**). A new EU procedure has been proposed for introduction in 2000 (see below).

Current Test Procedures

A summary of the current EU and former EPA test procedures is given in **Table A.2.2**. The major differences between the current EU and former EPA tests are summarized below (see also **Table A.2.2**).

- ***Preconditioning:*** The EU procedure uses a complex purge/load technique. The former US test does not precondition the canister apart from driving one LA-4 cycle. However, the new procedure will load the canister to breakthrough before driving the cold start test.
- ***Diurnal test:*** The current EU and former US procedures are similar. The new EPA procedure has three diurnal cycles over a higher temperature range (see **Table A.2.8**).
- ***Running losses:*** These are not measured in the EU test. They may be measured over the current EPA cycle, but in practice this is not usually carried out.
- ***Hot soak:*** There is a small difference in temperature ranges between EU and former EPA methods, but this is not significant in view of the high fuel temperature after the diurnal test.

Table A.2.2 Current EU Evaporative Emission Test Procedures and comparison with former EPA procedure

PREPARATION AND TESTING	EU PROCEDURE	FORMER US EPA PROCEDURE
CANISTER CONDITION	Unspecified	Unspecified
PRECONDITIONING	60 km/h for 30 min or equivalent air purge of canister. 2x diurnal heat build at 16-30°C. Drive ECE 15 + 2 EUDC cycles	1 x LA4 drive cycle
SOAK PARKING	10-36 hours at 20-30 °C	11-35 hours at 20-30 °C
FUEL DRAIN AND FILL	40 ±2 % of tank capacity, at 10-14 °C	40 ±2% of tank capacity
DIURNAL TEST	16-30°C (±1°C) over 60 ±2 mins. HC measured in SHED	15-29 °C in 1 hr. HC measured in SHED
DYNAMOMETER TEST	ECE 15 + EUDC driving cycles. Running losses not measured Exhaust emissions measurements optional	1.5 x LA4 drive cycles. Cold and hot exhaust tests. Running losses measured, with carbon traps if necessary.
HOT SOAK	One hour at 23-31°C in SHED	One hour at 20-30°C in SHED
FUEL DRAIN AND FILL	N/A	Ability to control Diurnal losses after soak not tested
END	Calculation of Total Emissions = Diurnal + Hot Soak	Calculation of Total Evaporative Emissions = Diurnal + Running Losses + Hot Soak

Proposed EU Evaporative Emissions Procedures

The proposed procedures are substantially different from both the current EU and the new EPA procedures and are summarised in **Table A.2.3** below.

Table A.2.3 Proposed EU Evaporative Emissions Test Procedure

VEHICLE PRECONDITIONING	3000 km run-in period with no excessive loading. Verification of age of canister.
FUEL DRAIN AND REFILL	Fill to 40 ± 2 % nominal capacity. Fuel temperature 10-14°C, ambient temperature 20-30°C
CANISTER LOAD TO BREAKTHROUGH	Starting temperature 20°C. Repeated diurnal heat builds up to 35°C until 2-gram HC breakthrough
FUEL DRAIN AND REFILL	As above
PRELIMINARY DRIVE	Drive one ECE 15 + two EUDC cycles, starting temperature 20-30°C
SOAK	12-36 hours at 20-30°C
TEST DRIVE	One ECE 15 + two EUDC cycles. Emissions tests optional
PRECONDITIONING DRIVE	One hot-start ECE 15 cycle
HOT SOAK TEST	Within 2 minutes of engine shut-off: 60 ± 0.5 minutes at 23-31°C in SHED
PRECONDITIONING SOAK	Duration 6 - 36 hours, with min 6 hours at 20 ± 2°C
DIURNAL TEST	24 hours; start temperature 20°C, maximum temperature 35°C in SHED
END	Calculation of total hydrocarbon evaporative emissions from Hot Soak and Diurnal tests

A.2.2. UNITED STATES

A.2.2.1. US Federal Light Duty Exhaust Emission and Fuel Economy Test Procedures

Since 1972 the US exhaust emission test procedure has been based on a transient cycle representative of driving patterns in Los Angeles (the LA-4 Cycle). The original 1972 test procedure (US-72) is a two-phase test (Phases I and II in **Figure A.2.6**), covering 7.5 miles in almost 23 minutes. From 1975 the procedure was modified such that Phase I is now repeated after a 10 minute hot soak, to form a third phase. The total test length was thus extended to 11.09 miles and the time to 31 minutes, plus 10 minutes for the hot soak.

The intention of this modified test is to produce a weighted average emission from cold start and hot start tests. It is assumed that after the first 505 seconds the engine will be stabilized, and so the stabilized portion is not repeated after the hot start, but assumed to be the same as for the cold start test. The calculation procedure weights the results from the three bags accordingly to give the required result.

The Highway Fuel Economy Test (HWFET) (**Figure A.2.7**) cycle is used to measure fuel economy for the CAFE standards (see **Section A.4**), but is also used to measure NOx emissions. In California, a standard is imposed equal to 1.33 times the city NOx limit. In the other 49 states, there is no standard for NOx over the HWFET, but data can be used to demonstrate to EPA that the vehicle is not equipped with "*cycle-beating*" devices.

Emissions are measured using a Constant Volume Sampling (CVS) system, as shown in **Figure A.2.8**, and collected in three bags, for each phase of the test, i.e.:

- Bag 1 0 - 505 seconds
- Bag 2 505 -1370 seconds
- Bag 3 0 - 505 seconds after 10 minute hot soak

The test begins with a cold start (at 20 - 30°C) after a minimum 12 hour soak. The diluted exhaust gas volume is determined for each bag and used to calculate the mass emissions. Weighting factors for each phase are then applied to give an overall emission figure.

Supplemental Federal Test Procedure (SFTP)

As required by the US Clean Air Act Amendments, EPA re-evaluated typical driving patterns and found that the FTP test cycle does not cover a significant proportion (about 15%) of driving conditions and behaviour. As a result the EPA issued on the 7 February 1995 a Notice of Proposed Rulemaking setting out suggested modifications, and following consultations with the motor industry and CARB, issued a Final Rule on the 15 August 1996. The main new element of the proposal is a Supplemental Federal Test Procedure (SFTP) covering the driving patterns not included in the current FTP procedure.

The SFTP includes two new single-bag emission test driving cycles, the US06, to represent aggressive and microtransient driving, and the SC03, to represent driving immediately following vehicle start-up (see **Figures A.2.9** and **A.2.10**). The US06 is run with the vehicle in the hot stabilized condition; that is, with the vehicle fully warmed up such that the engine and catalytic converter have reached typical operating temperatures but without air conditioning (A/C). The SC03 follows a 10-minute soak and is run with vehicle A/C or with proper simulation of air conditioning operation. The cycles of the SFTP can be run as a sequence to save on preconditioning and set-up time; however, separate runs of the cycles are permissible with the appropriate soak or preconditioning steps appended.

Hot stabilized condition is achieved by including several preconditioning options as part of the formal procedure immediately prior to the US06 Cycle. If the vehicle has undergone a soak of 2 hours or less, the preconditioning may be a 505 Cycle, the 866 Cycle, the highway cycle, a US06, or the SC03.[1] Following longer soaks, the final preconditioning cycle is an LA4.[2] For manufacturers who have concerns about fuel effects on adaptive memory systems, the rule allows manufacturers and, upon manufacturer request, requires EPA to run the vehicle over the US06 Cycle on the

[1] *505* refers to the driving cycle that consists of the first 505 seconds (seconds 1 to 505) of the EPA Urban Dynamometer Driving Schedule, *866* refers to last 866 seconds (seconds 505 to 1372) of the EPA Urban Dynamometer Driving Schedule. *SCO3* refers to the driving cycle run during air conditioning operation test requirement.

[2] *LA4* is the name commonly given to the Urban Dynamometer Driving Schedule.

certification test fuel before entering the formal test procedure. High–volume exhaust flow for heavier vehicles run on the US06 will dictate the use on some vehicles of a larger capacity constant volume sampler (CVS) than is needed for current FTP testing. Appropriate shift schedules for manual transmission vehicles are to be determined by the manufacturer and submitted to EPA for approval.

The rule includes adjustments to the US06 test cycle for low–performance LDVs and LDTs. These adjustments reflect the actual operation of low performance vehicles in use and are designed to minimize problems with high engine and catalyst temperatures. The adjustments are applied dynamically by the dynamometer for any vehicle after it has been at wide open throttle for 8 seconds (only the lowest performance vehicles constituting a small portion of the fleet remain at WOT for 8 seconds over any part of the US06 cycle). Load adjustments will be made only during the five most aggressive portions of the US06 Cycle. In addition, for US06 Cycle testing of Heavy Light-Duty Trucks (HLDTs), the truck is to be ballasted to curb weight plus 300 lbs with the dynamometer inertia weight determined from this same basis, while FTP testing remains at Adjusted Loaded Vehicle Weight.

The required elements for the SC03 include the preconditioning, soak period, test cycle, and air conditioning requirements. Prior to the 10-minute soak period, the vehicle is to be preconditioned to allow engine and catalyst temperatures to stabilise at typical warmed–up operating temperatures. The Agency believes that running the vehicle over EPA's Urban Dynamometer Driving Schedule (LA4) is adequate to achieve engine and catalyst stabilization regardless of the time period for which the vehicle was not operational prior to preconditioning. However, in the event the vehicle was shut off for less than two hours prior to preconditioning, any of a 505, 866, or SC03 cycle is adequate for preconditioning the vehicle.

Immediately following the preconditioning cycle, the vehicle's engine is turned off for a 10-minute soak period with cooling fans directed at the vehicle. The vehicle may be removed from the dynamometer, provided the vehicle is not subjected to unrepresentative cooling of the engine or catalyst. Following the soak period, the vehicle will be run over the SC03 cycle using a full environmental chamber, with vehicle A/C on, for proper representation of start driving, microtransient driving, and air conditioning operation. The ambient test conditions specified in the SC03 test are:

- air temperature of 95 °F;
- approximately 40 percent relative humidity;
- simulated solar heat intensity of 850 W/m^2
- air flow directed at the vehicle that will provide representative air conditioner system condenser cooling at all vehicle speeds.

Procedures in a standard test cell that simulate actual air conditioning effects will be allowed as an option to using full environmental chambers. The Agency is allowing these conditions as a cost–effective surrogate for testing in a fully controlled environmental chamber set to simulate ozone–exceedance conditions of ambient temperature, humidity, solar load, and pavement temperature. For MY2000 through MY2002, correlation with EPA-specified dynamometer simulations may be used. Starting with MY2003, only simulations that can demonstrate correlation with the use of a full environmental chamber will be allowed. The use of a fully controlled environmental chamber is permitted at any time.

Manufacturers who choose to use an air conditioning simulation beginning with MY2003 must submit a description of the simulation procedure, data supporting the correlation between the simulation and the full environmental chamber, and any vehicle specific parameters to EPA in advance. In general, EPA will conditionally approve any procedure, provided that the procedure can be run by EPA for SEA and in-use enforcement testing and available data, including past correlation testing, does not indicate a correlation problem. EPA may require the manufacturer to demonstrate emission correlation within stated criteria between the simulation and the full environmental chamber on up to five vehicles per model year (one for small volume manufacturers). The vehicles will be selected by EPA and two additional vehicles may be selected by EPA to demonstrate emission correlation for every vehicle that fails the correlation criteria.

A.2.2.2. US Federal Cold CO Test Procedure

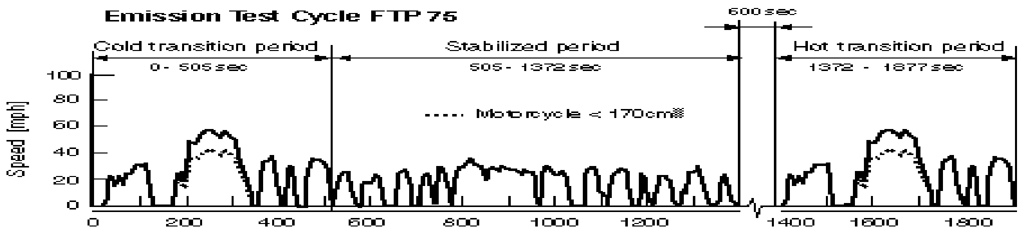
Table A.2.4 below outlines the sequence for the above procedure. This was published as a final rule in the Federal Register, Vol. 57 No. 138, dated Friday 17 July 1992.

Table A.2.4 US Federal Cold CO Test Procedure

Step	Notes
1.	Winter grade fuel (optional use of FTP fuel)
2.*	Full US FTP 75 Cycle (optional use of higher temperature)
3.	No time specifications; uniform vehicle cooling; Oil temperature 20°F±3°F
4.*	12-36 hours
5.*	1 hour minimum
6.	If vehicle leaves 20°F soak area to transfer to test area and passes through a warm area it must be restabilized for 6 times the period of exposure to warmer conditions
7.*	Full US FTP 75 Cycle
8.	On dynamometer
9.*	Phase 1 (505 secs.) of US FTP 75 Cycle

*** Temperature Specifications (°F)**	
Average	20 ± 5
Maximum Excursions	10(min), 30(max.)
Three-minute Excursions	15(min), 35(max.)

Figure A.2.6 US Federal City Cycles (Exhaust Emission and Fuel Consumption)



US - 72 Cycle :
Breakdown:

Length:	7.5 miles
Time:	1371 s
Av. velocity:	19.7 mph
Max. velocity:	56.7 mph
Idle:	17.4%
Steady speed:	20.0%
Acceleration:	34.0%
Deceleration:	28.8%

US - 72 Test:

Cycles/Test: 1
Test lengths: 11.09 miles
Test time: 1371 s
Cold start test procedure
Exhaust emission analysis in 2 bags
Bag 1: 0 - 505 s
Bag 2: 56-1371
Calculation of fuel consumption is derived from the emissions

US - 75 Cycle:
Breakdown:

Length:	11.09 miles
Time:	1877 + 600
Av. velocity:	21.3 mph
Max. velocity:	56.7 mph
Idle:	17.3%
Steady speed:	20.5%
Acceleration:	33.7%
Deceleration:	26.5%

US - 75 Test:

Cycles/Test: 1
Test lengths: 11.09 miles
Test time: 1371 s + (600 s stop) + 505 s
The US - 75 test is an expanded US - 72 test.
The first 505 s of the cycle will be repeated after a ten min. stop at 1371 s.
Calculation of fuel consumption is derived from the emissions.
The emission sampling is in 3 bags:
Bag 1: 0 - 505 s (43%)
Bag 2: 506 - 1371 s (100%)
Bag 3: 0 - 505 s (57%) after the 10 mins. stop

(Source: Ford Motor Company and AVL List GmbH)

Figure A.2.7 US Federal Highway Cycle (Fuel Consumption, NOx Emissions)

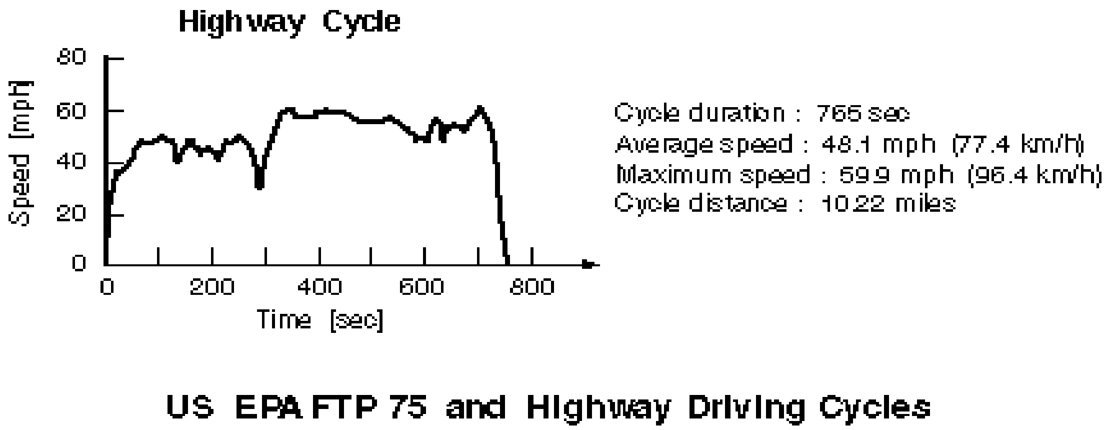
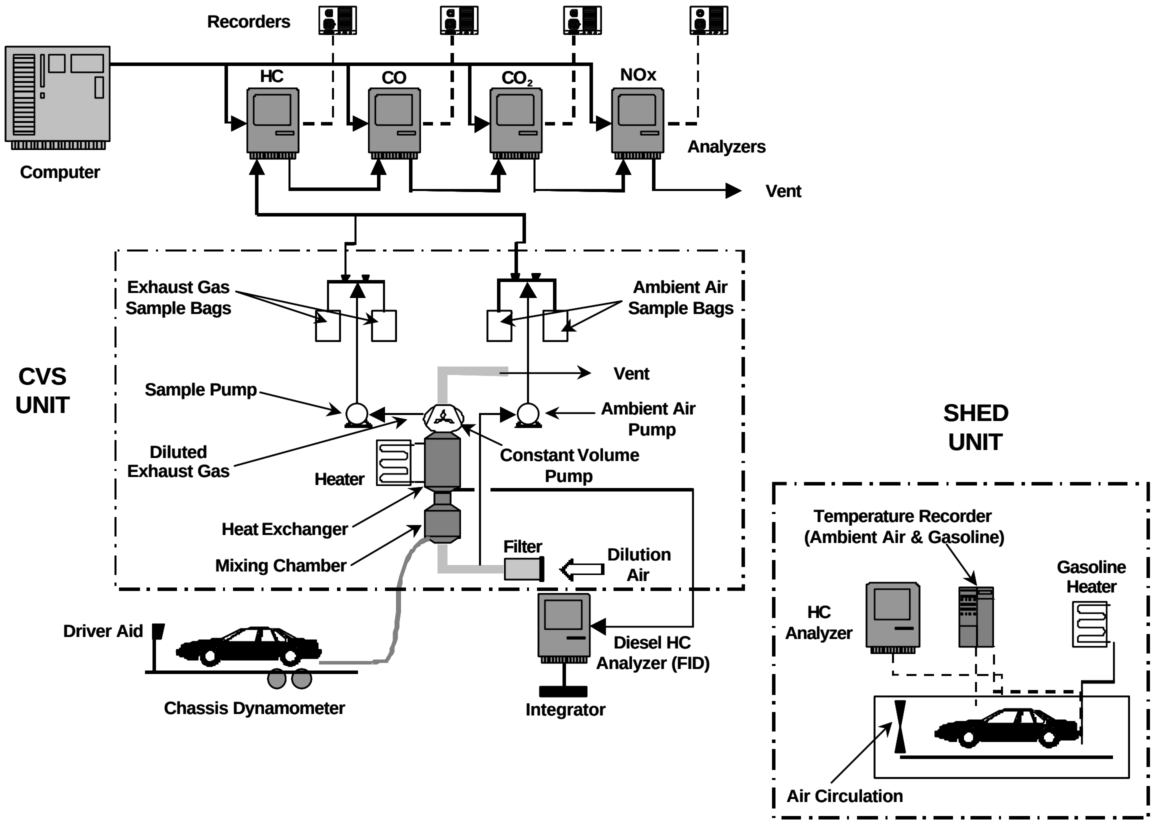


Figure A.2.8 Exhaust Gas Constant Volume Sampling (CVS) Procedure (complies with US 72, US 75, Japanese and current European test requirements)



Souce: Volkswagenwerk AG

Figure A.2.9 EPA US06 driving schedule

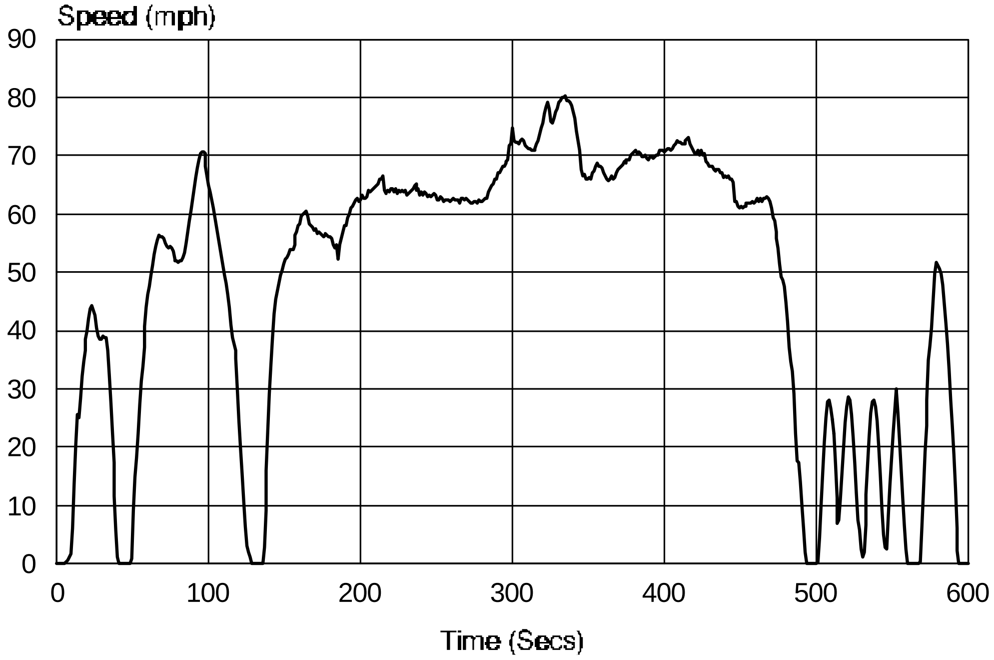
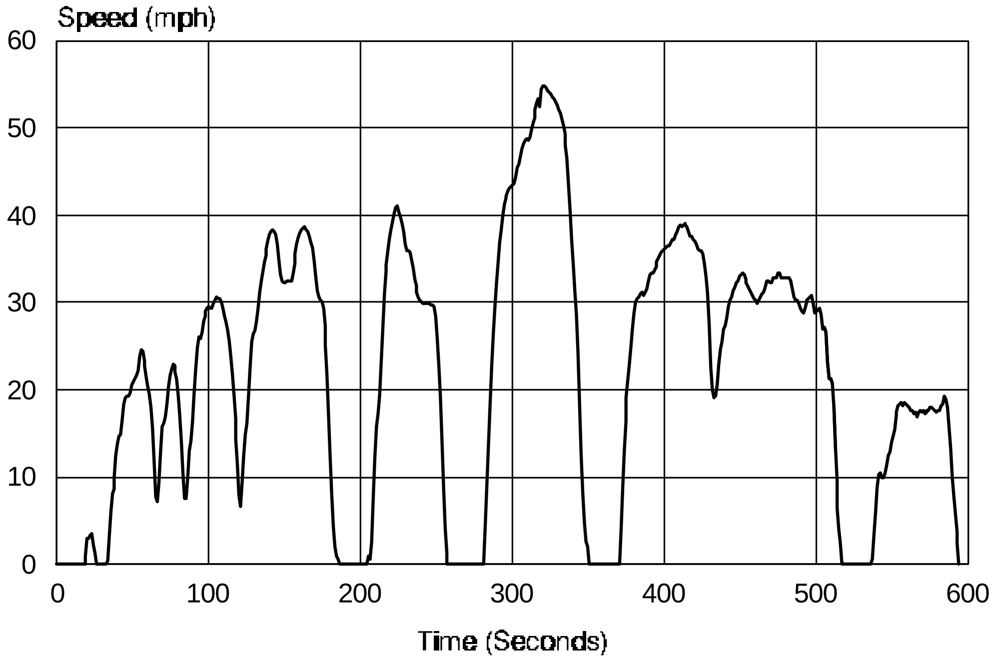


Figure A.2.10 EPA SC03 driving schedule



A.2.2.3. US Federal Heavy Duty Exhaust Emission Test Procedures

United States 13-Mode Test

From 1973 to 1984 the United States used a steady state test for the measurement of gaseous emissions from heavy duty engines. The main details of the test procedure are as follows:

Applicability: All heavy duty gasoline and diesel engines. That is, engines fitted to vehicles with a gross vehicle weight greater than 8500 lb., or a kerb weight greater than 6000 lb., or a frontal area of more than 45 square feet.

Type of Test: 13-mode steady state test bed cycle.

Table A.2.5 Details of US 13-Mode Test

Mode	Speed	Load (%)	Weighting Factor
1	Idle	0	0.06667
2	Intermediate	2	0.08
3	Intermediate	25	0.08
4	Intermediate	50	0.08
5	Intermediate	75	0.08
6	Intermediate	100	0.08
7	Idle	0	0.06667
8	Rated	100	0.08
9	Rated	75	0.08
10	Rated	50	0.08
11	Rated	25	0.08
12	Rated	2	0.08
13	Idle	0	0.06667

Each mode is held for a minimum of 4.5 minutes and a maximum of 6.0 minutes;

- Intermediate speed is the peak torque speed or 60% of the rated speed, whichever is the higher;
- During each mode the specified speed shall be held to within 50 rev/min and torque at each mode must be held at the specified value ± 2% of the observed maximum torque value;
- All data, including continuous emissions traces, are to be recorded during the last two minutes of each mode.

Measuring Instruments

- CO, CO_2 - NDIR
- HC - Heated FID
- NOx - Chemiluminescence analyzer

Test Parameters

- Fuel flow rate - volumetric or gravimetric determination
- Air flow rate - gravimetric determination

Allowed Temperature Ranges

- Air supply to engine - 5 to +25°C
- Fuel pump inlet - 5 to +37.8°C

United States - Transient Test

The US transient test was introduced as an option for certification of heavy duty vehicles in 1984. In 1985, it became mandatory, replacing the steady state test described above. The reasons for moving to a transient cycle were to make the test more representative of on-highway conditions and to improve repeatability.

It is a popular misconception that the US transient cycle is based on actual driving patterns assessed in the following scenario:

New York non-freeway

Los Angeles non-freeway

New York freeway

Los Angeles non-freeway (repeated)

Driving patterns were assessed from operational data measured in New York and Los Angeles, but the US transient cycle, as developed from these data, contains the following characteristics:

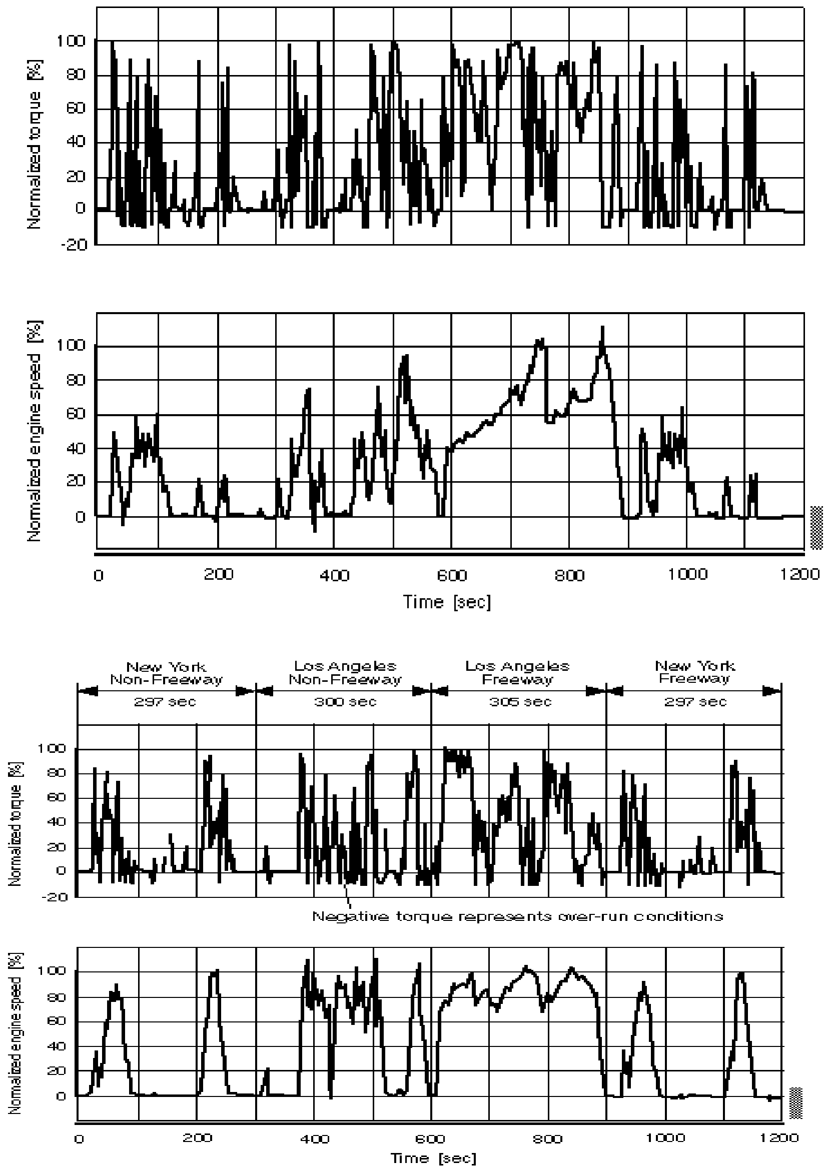
Cold Start	**Hot Start**
Congested urban	Congested urban
Uncongested urban	Uncongested urban
Expressway	Expressway
Congested urban	Congested urban

The US transient cycle tests the engine over a full range of load and speed conditions, with equal weighting within the cycle of all operational points. The cycle is run twice, first from a cold start and then, after a 20 minute soak, repeated with a hot start. These two cycles are weighted, 1/7 to 6/7 for the cold and hot cycles respectively.

The 178 seconds of motoring contained in the US transient cycle used to be considered very important. Motoring, or driving the engine by the dynamometer, tests the engine in conditions where, on the road, fuel delivery would not occur although the engine would still be rotating (travelling downhill with the accelerator closed, for example). In these cases it is important to test for fuel dribble from the injector nozzles. However, modern technology nozzles having low sac volume or valve covering the orifice (VCO) devices suffer from this to a lesser extent and the need for motoring may become open to question. Nevertheless, it seems unlikely that the EPA will alter the motoring requirement.

The emphasis is on urban driving, since any US air quality problems are most acute in major cities. The cycle is therefore not typical of average driving in either the US or Europe. Speed and load traces for heavy duty gasoline and diesel engines over the US Federal Transient Test Cycle are shown in **Figure A.2.11**.

Figure A.2.11 Speed and load traces for heavy duty gasoline (above) and diesel (below) engines over the US Federal Transient Test Cycle



Source: AVL List GmbH

EPA has conducted tests to assess the inter-laboratory repeatability of emissions measurement using the US transient procedure. Laboratories at Detroit Diesel, Ford, EPA and Navistar took part in the programme.

Table A.2.6, indicates average emission measurements for each laboratory in g/bhp.h.

Table A.2.6 Reproducibility of the US HD Transient Cycle

Emission	Detroit Diesel	Ford	EPA	Navistar	Standard Deviation	Variance
CO	1.162	1.114	1.66	1.20	0.219	0.048
HC	0.11	0.113	0.103	0.14	0.014	$197x10^{-6}$
NOx	5.277	5.647	5.29	5.09	0.202	0.041
Pm	0.169	0.17	0.169	0.166	0.0015	$2.25x10^{-6}$

The improvement in repeatability and reproducibility may be due to the transient cycle but is more likely to reflect the increased accuracy of control, both of the engine and general test conditions. The vastly increased number of data points must also play a large part. The test consists of three 20 minutes cycles (one cold start, one hot soak and one hot start cycle) and data relating to engine speed and torque, and the levels of gaseous emissions are monitored once per second. Engine control and data acquisition is by computer and the emissions results are integrated over the test cycle. Speed, torque and power data are subjected to regression analysis and must validate to within closely specified limits.

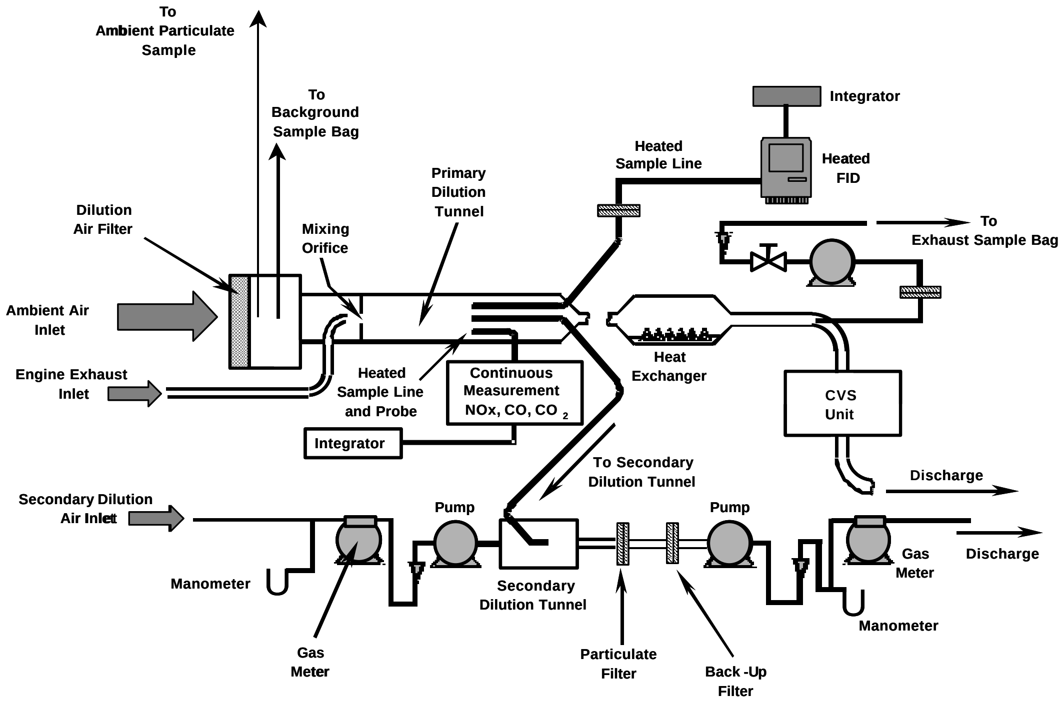
Gaseous emissions sampling is done from the primary dilution tunnel. A secondary dilution tunnel is used for the measurement of particulates. A general arrangement of a typical transient test facility is shown in **Figure A.2.12**.

The emissions results are processed in a "*wet*" form and a correction for humidity applied to NOx. The results are then weighted 1/7 and 6/7 for the cold/hot cycles respectively, and added to form an integrated result.

Particulates measurements are achieved by passing all the flow from the secondary tunnel through a 70 mm diameter Teflon coated glass fibre filter. After stabilizing in a controlled environment this is weighed. A reference paper allows correction for ambient particulates.

Full details of transient test requirements can be found in the US Federal Register 40 CFR 86 (1985).

Figure A.A.2.12 Double Dilution Particulate Measurement System



Source: Ricardo Consulting Engineers Ltd

A.2.2.4. Evaporative Emissions Tests

Two types of test methodology exist, the carbon canister (trap) method and the SHED (Sealed Housing for Evaporative Determination). The canister method employs weighed activated carbon traps which are connected to the fuel system at locations where fuel vapours may escape to the atmosphere (air cleaner, fuel tank vent, etc.) and is only applied in Japan (see **A.2.4.2**).

"*The SHED*" method collects all evaporative emissions in a sealed enclosure which contains the test vehicle. The hydrocarbon concentration in the SHED atmosphere is measured and used to calculate total emissions. This technique has been used for many years in the US, and has also been adopted for the European test procedure.

Evaporative emissions can be divided into three areas:

- ***Diurnal losses:*** these occur when the vehicle is stationary with the engine off and are due to emission of vapour from the fuel tank as a result of normal temperature changes which occur over a 24 hour period.
- ***Hot soak losses:*** these occur when a fully warmed up vehicle is left to stand, as engine heat is transferred to the fuel tank and/or fuel system.
- ***Running losses:*** these occur while the vehicle is being driven normally.

The former EPA test procedure is given in **Table A.2.7**. A new EPA procedure (see **Table A.2.8**) is being phased in over the period 1996-1999.

Former Test Procedures

A summary of the former EPA test procedure is given in **Table A.2.7**

Table A.2.7 Former EPA Evaporative Emission Test Procedure

PREPARATION AND TESTING	FORMER US EPA PROCEDURE
CANISTER CONDITION	Unspecified
PRECONDITIONING	1 x LA4 drive cycle
SOAK PARKING	11-35 hours at 20-30 °C
FUEL DRAIN AND FILL	40 ±2% of tank capacity
DIURNAL TEST	15-29 °C in 1 hr. HC measured in SHED
DYNAMOMETER TEST	1.5 x LA4 drive cycles. Cold and hot exhaust tests. Running losses measured, with carbon traps if necessary.
HOT SOAK	One hour at 20-30°C in SHED
FUEL DRAIN AND FILL	Ability to control Diurnal losses after soak not tested
END	Calculation of Total Evaporative Emissions = Diurnal + Running Losses + Hot Soak

New EPA Evaporative Emissions Procedures

The EPA issued regulations, effective from 23 April 1993, specifying revised procedures and limits for evaporative emissions, with implementation phased-in over the 1996 to 1999 model years. The regulations apply to light- and heavy-duty vehicles and heavy-duty engines fuelled with gasoline, methanol or gasoline/ methanol mixtures.

The EPA has also specified that, from the 1 January 1996, the dispensing rates from gasoline and methanol pumps may not exceed 10 US gallons (37.9 litres) per minute. Facilities with throughputs below 10,000 gallons per month have been given a further two years to comply. This requirement is consistent with the dispensing rates specified in the new test measuring spillage during refuelling.

The current test procedure, which has changed little since its introduction, measures emissions from fuel evaporation during parking (diurnal emissions) and immediately following a drive (hot soak emissions).

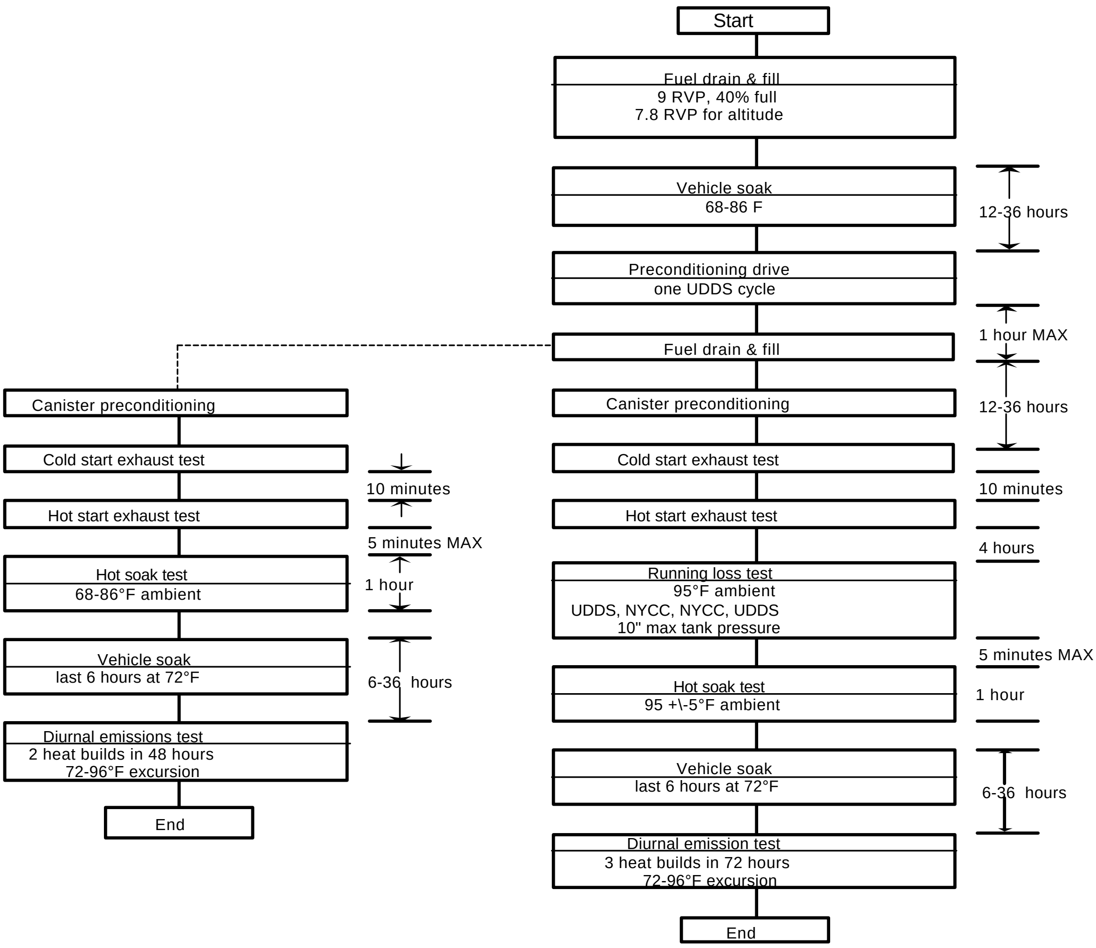
The new procedures consist of vehicle preconditioning (including an initial loading of the carbon canister with fuel vapour), exhaust emission testing, a running loss test and three diurnal emissions cycles (**Figure A.2.13**). The full test procedure takes 5 days to complete. Fuel spillage during refuelling (spitback) is also measured (see below). A supplemental procedure, omitting the running loss test, but involving two diurnal cycles following the emissions cycles is included. This procedure ensures that all the emissions resulting from purging the evaporative canister are measured during the emission and diurnal cycles and do not escape during the running loss test. Because of its increased severity, the limits specified for this test are more relaxed than those for the three-diurnal sequence. The supplemental procedure can also be used in conjunction with the test procedures devised by the CARB, which are not yet in effect.

The procedures for heavy duty vehicles are similar except that the driving sequence for the running loss test consists of three consecutive UDDS cycles, which reflect the different driving pattern experienced in-service. The testing of heavy-duty engines, without the vehicle chassis or body, requires that the test engine be equipped with a loaded evaporative canister and will be expected to demonstrate a sufficient level of purge during engine testing.

Table A.2.8 New US Federal Evaporative Emissions Procedure (Implementation begins with 1996 model year)

THREE DIURNAL TEST	
FUEL DRAIN/FILL	Drain tank, fill to 40% volume with test fuel (RVP 9 psi/62 kPa or 7.8 psi; 53.8 kPa for altitude testing)
SOAK PERIOD	Soak at 68-86ºF (20-30ºC) for 12-36h
PRECONDITIONING	Drive over the UDDS (FTP) cycle.
REFUEL/SOAK CANISTER LOADING	Fuel tank is drained and refilled. Soak for 12h (min) during which the canister is loaded with butane/nitrogen mixture (mass butane 1.5 times bed capacity)
EXHAUST EMISSIONS TEST	Full FTP Cold and Hot Start procedures
SOAK PERIOD	Vehicle stabilized at 95ºF (35ºC)
RUNNING LOSS	Consists of driving sequence of UDDS + NYCC + NYCC + UDDS cycles (Fuel temperature controlled according to a profile, predetermined by a drive under representative summer conditions)
HOT SOAK EMISSIONS	Measured for one hour at 95ºF
SOAK PERIOD	Vehicle stabilized at 72ºF (22.2ºC)
THREE DAY DIURNAL	Emissions measured after three 24h ambient temperature cycles 72 to 96ºF (22.2 to 35.6ºC). Air circulation and temperatures may be adjusted according to correct any major discrepancy compared with fuel temperatures under outdoor summer conditions.
SUPPLEMENTAL TWO-DIURNAL TEST	
CANISTER LOADING	Loaded with butane/nitrogen mixture until two-gram breakthrough
EXHAUST EMISSIONS TEST	Full FTP Cold and Hot Start procedures.
VEHICLE SOAK	6 hours at 72ºF (22.2ºC)
TWO DAY DIURNAL	Emissions measured after two 24h ambient temperatures cycles 72 to 96ºF (22.2 to 35.6ºC)

Figure A.2.13 New Federal US Evaporative Emissions Test

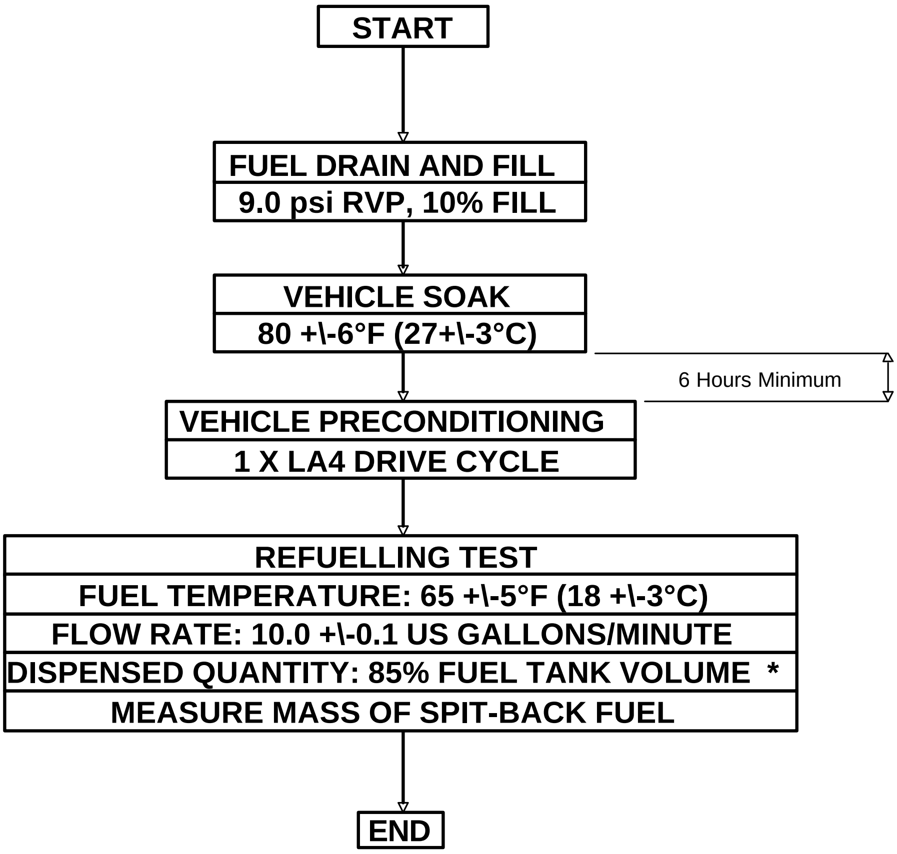


Refuelling - Fuel Spitback Procedure.

The vehicle is refuelled at a rate of 10 USG/minute (37.9 l/minute) to test for fuel spitback emissions. All liquid fuel spitback which occurs during the test is collected in a bag. The bag (impermeable to hydrocarbons or methanol) should be designed and used so that liquid fuel does not spit back onto the vehicle body etc. The bag must not impede the free flow of displaced gasoline vapour from the filler neck and must be designed to allow the dispensing nozzle to pass through the bag. The dispensing nozzle should be a commercial model, not fitted with vapour recovery equipment.

The sequence for the proposed spitback test is shown in **Figure A.2.14**.

Figure A.2.14 Proposed US Federal Spit-back Test Procedure



California Evaporative Emissions Test

In California, CARB has proposed a rigorous evaporative emissions test procedure which will take almost five days to carry out. The test is similar, but not identical to, the new US Federal procedure. This procedure is summarized in **Table A.2.9** and includes measurement of running losses and a three day "*real time*" diurnal emission test. It is not yet clear whether the running loss measurement must be made in a SHED mounted over a dynamometer or if a point source sampling technique can be used - the former method appears to be favoured.

Table A.2.9 Proposed CARB Evaporative Emission Test (from 1995)

Test Sequence	Details	Time (h)	Total time (h)
FUEL DRAIN/FILL	Drain tank, fill to 40% vol. with test fuel	0.3	0.3
SOAK PERIOD	Soak at 20-30°C for 12-36 h	12.0	12.3
PRECONDITIONING	Drive LA-4 cycle or 20-50 miles/day "typical" on-road driving	0.6	12.9
CANISTER PURGE	Purge with air at 25-75 grains/lb. humidity at 48 ft^3/h for 300 bed volumes	0.5	13.4
CANISTER LOAD	Load canister to 1.5 times nominal capacity with 50/50 butane/nitrogen at 15 g butane/h	10.0	23.4
FUEL DRAIN/FILL	Drain tank, fill to 40% v/v with test fuel	0.3	23.7
SOAK PERIOD	Soak at 20-30°C for 12-36 h	12.0	35.7
EXHAUST TEST	Conduct full 3 phase FTP Cold start exhaust emission test	1.1	36.8
STABILIZE FUEL	Stabilize fuel temp to 105°F(40°C) within 1 hour	1.2	38.0
RUNNING LOSS	Drive 3 LA-4 cycles at 105°F(40°C) using point source method or SHED on dyno. Fuel temp. profile must be matched to road	1.5	39.5
HOT SOAK	Within 5 min seal in SHED at105°F(40°C). Soak for 1 hour	1.1	40.6
STABILIZE FUEL	Stabilize fuel temp at 65°F(18°C) by artificial cooling	4.0	44.6
3 DAY DIURNAL	Park in SHED for 72 hours with SHED air temp cycles between 65°C(180°F) and 105°F(40°C) every 24 h. Measure HC emissions every 24 h.	72.0	116.6

A.2.2.5. Inspection and Maintenance Procedure US IM 240

The new US Clean Air Act required the introduction of enhanced inspection and maintenance programmes from 15 November 1992 in the most polluted areas (see **Section A.3.2.4**). The deadline for implementation was delayed until January 1995, a deadline which has not been met. The EPA published its proposals on 5 November 1992 and held discussions with manufacturers of I&M equipment prior to publishing its final rule at the end of April 1993. Objections following publication - primarily of the cost of implementation of the procedure compared with simpler methods. This resulted in a further rule being published in April 1995 giving modifications to the programme. These involve changes to the requirements for visual inspection and not to the IM240 procedure.

Test Procedures

Preconditioning

At the programme Administrator's discretion, vehicles may be preconditioned using any of the following methods:

a) non-loading preconditioning: increase engine speed to approximately 2500 rpm in neutral for up to 4 minutes

b) drive the vehicle on the dynamometer at 30 miles/h for up to 240 seconds at road load

c) drive a preliminary transient cycle

Measurement of Exhaust Emissions

The IM 240 procedure for exhaust emissions is a transient test based on 240 seconds of Federal test certification procedures (**Section A.2.2.1**). A trace of the vehicle emission test sequence is given in **Figure A.2.15**.

Emissions of CO, HC and NOx are measured second-by-second over the cycle. The results are summed over four modes and multiplied by a factor. These figures are averaged to give a composite result. If the vehicle fails the appropriate limit, a repeat calculation can be made where the results are calculated over two phases.

Composite Test	Mode	Cycle Portion
	1	0-60 secs
	2	61-119 secs
	3	120-174 secs
	4	175-239 secs
Repeat Calculation	**Phase**	**Cycle Portion**
	1	0-93 secs
	2	94-239 secs

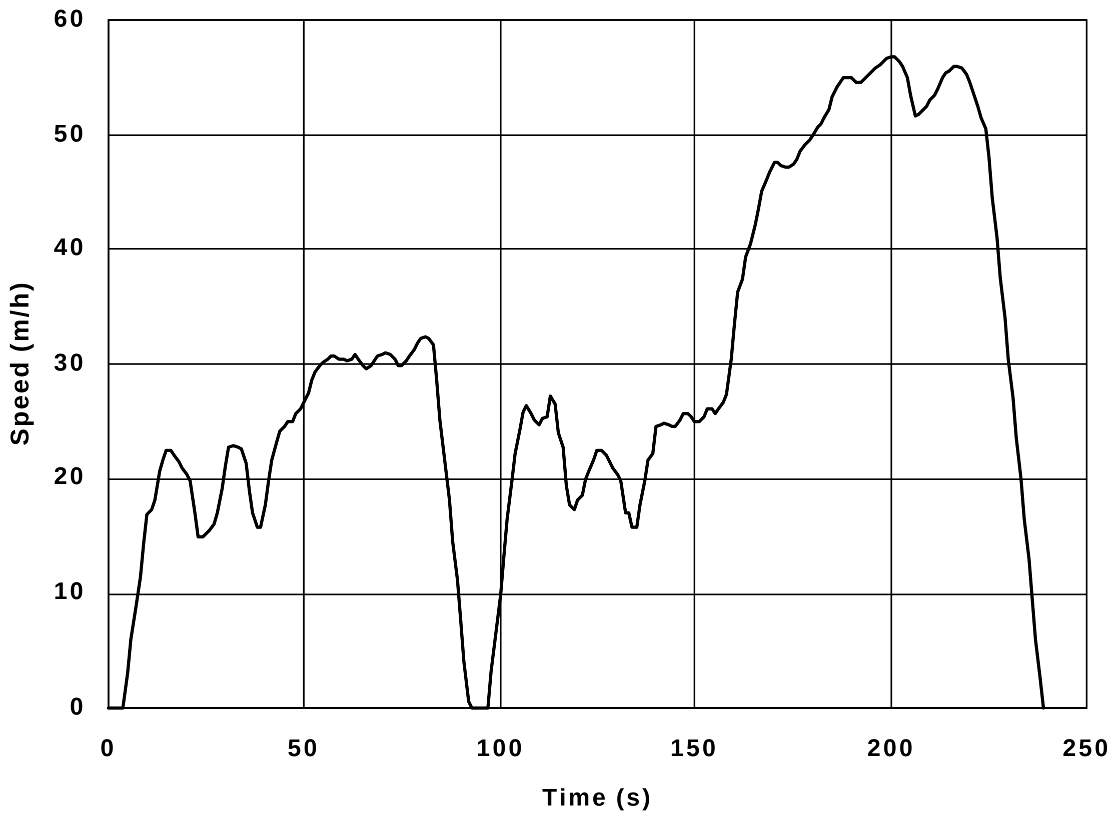
Examination of Evaporative Emissions Control System

The integrity of the evaporative emissions control system is checked by inspection. The canister purge is also tested for flow rate by connecting measuring equipment in series between the canister and the engine, preferably at the canister end of the hose.

Test Criteria and Calculation of Results

The vehicle passes the emissions test if the value for each pollutant is below the standard in the complete test. If for any pollutant the composite emission rate exceeds its standard then an additional analysis of the test results may be carried out which divides the driving cycle into two phases. The vehicle shall have deemed to have passed if the emission rate is below the standard limit in the composite result or in Phase 2 of the Repeat Calculation.

Figure A.2.15 US IM 240 Vehicle Emission Test Sequence



A.2.3. ISO 8178 TEST CYCLE

ISO 8178, Part 4 specifies test cycles for the measurement and evaluation of gaseous and particulate emissions from reciprocating internal combustion (RIC) engines under test conditions and, with certain restrictions, under site conditions. The test is steady state, using cycles according to the given application. For the sake of brevity, only the C1 cycle applicable to larger engines is shown in **Table A.2.10**.

Table A.2.10 ISO 8178-4 Test Cycle Type C1 for Off-road Vehicles, Industrial & Medium/High Load.

Measuring Point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Speed	**Rated Speed**				**Intermediate Speed**			**Low No-load Speed**
Torque	100	75	50	10	100	75	50	0
Weighting Factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15

A.2.4. JAPAN

A.2.4.1. Exhaust Emission And Fuel Economy Test Procedures

The exhaust emission test procedures in Japan are complex, but four main test procedures have been used in the past. However, new procedures were introduced in March 1991 and these are described following a review of the tests employed prior to that date.

(1) ***10 Mode test*** - a hot start urban driving cycle including accelerations up to 40 km/h, the principal cycle used for passenger cars and light vehicles powered by gasoline or LPG fuelled engines. From 1986 this procedure also applied to diesel vehicles up to 1700 kg GVW (see **Figure A.2.16**).

(2) ***11 Mode test*** - a cold start driving cycle test introduced in 1975 to supplement the 10 mode test. Speeds up to 60 km/h are reached during the cycle (see **Figure A.2.17**).

(3) ***6 Mode test*** - a test based on weighted average emissions over steady state modes. This test was used for vehicles over 2500 kg GVW and also for diesel-powered vehicles above 1700 kg GVW, different versions of the test being used for gasoline and diesel vehicles.

(4) ***Evaporative emission test*** - this is based on charcoal canisters to trap emitted vapours, similar to the original US test procedure. There are no plans to introduce a SHED procedure.

The exhaust emission test equipment is shown in **Figure A.2.8**.

The test procedures detailed above were replaced in the early 1990s. The new test cycles are illustrated in **Figure A.2.18** and **A.2.19**. These procedures have been modified to include a high speed cycle and measurements will be made in terms of g/km or g/kWh, instead of ppm. Details of the changes in cycle type, measurement mode, vehicles affected and implementation dates are given below:

10-Mode Replaced by 10·15-Mode (**Figure A.2.18*****)***

- Gasoline/LPG passenger cars, light and medium duty commercial vehicles, mini trucks and diesel passenger cars/light duty commercial vehicles.
- Implementation Date: 1991.

The 10.15-mode test is also used to measure fuel economy.

Gasoline/LPG 6-Mode Replaced by Gasoline/LPG 13-Mode (**Figure A.2.19.1*****)***

- Measurement Mode: ppm changed to g/kWh
- Gasoline/LPG heavy duty commercial vehicles.
- Implementation Date: 1992

Diesel 6-Mode Replaced by 10·15 Mode (**Figure A.2.18*****)***

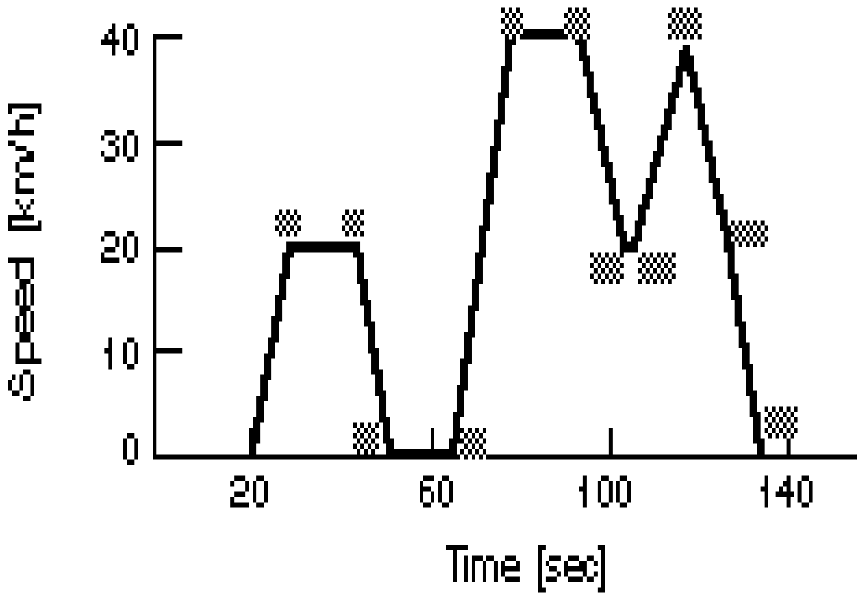
- Measurement Mode: ppm changed to g/km
- Diesel medium duty commercial vehicles.
- Implementation Date: 1993

Diesel 6-Mode Replaced by Diesel 13-Mode (Figure **A.2.19.2*****)***

- Measurement Mode: ppm changed to g/kWh
- Diesel heavy duty commercial vehicles.
- Implementation Date: 1994

Because of the differences in test procedures, a direct comparison of Japanese emission standards with those applied in the US and Europe cannot be made.

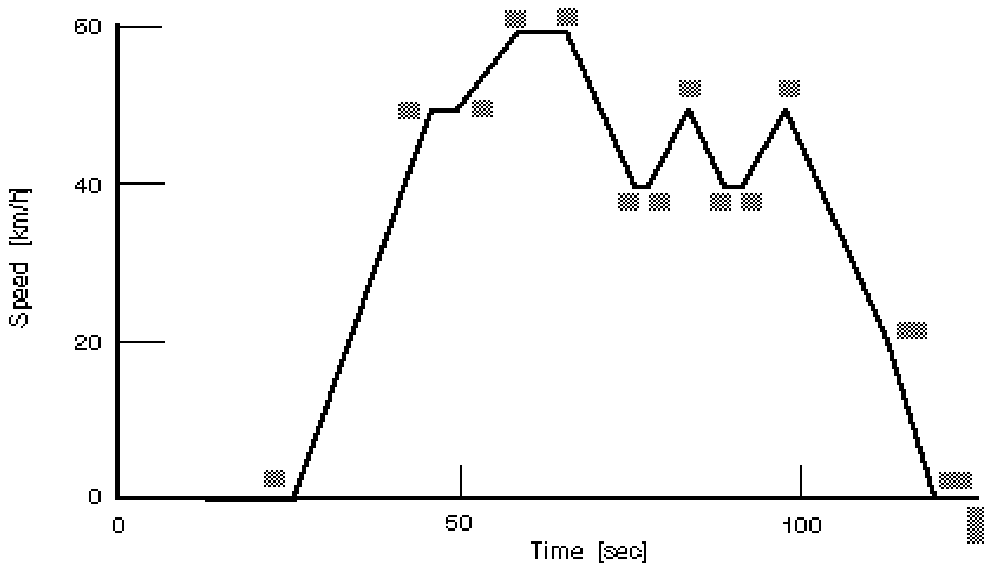
Figure A.2.16 Japanese 10-mode Cycle (Hot Test - from 1 April,1973)



Source: AVL List GmbH

1. Stabilized hot start cycle, repeated 6 times (including one pre-cycle)
2. Distance: 0.564 km/cycle. Test duration: 14 minutes
3. Continuous sampling of diluted exhaust gas into bag
4. Integral analysis (comparable to US 1972 Test)
5. Modal breakdown of results not possible
6. Determination of exhaust gas volume analogous to US 1972 Test
7. Theoretically developed driving schedule
8. Determination of evaporative emissions.

Figure A.2.17 Japanese 11-mode Cycle (Cold Test - from 1 April, 1976)

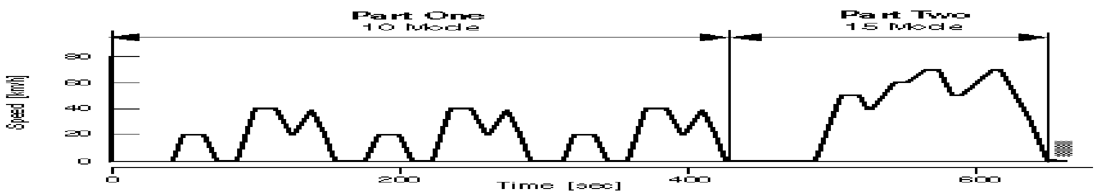


Cycle duration : 120 sec
Average speed : 30.6 km/h
Distance : 1021 m

Source: AVL List GmbH

1. Cold start cycle, repeated 4 times
2. Distance: 1.02 km/cycle. Test duration: 8 minutes
3. Continuous sampling of diluted exhaust gas into bag
4. Integral analysis (comparable to US 1972 Test)
5. Modal breakdown of results not possible
6. Determination of exhaust gas volume analogous to US 1972 Test
7. Similar to 10-Mode test, apart from cold start and increased power demand
8. Determination of evaporative emissions.

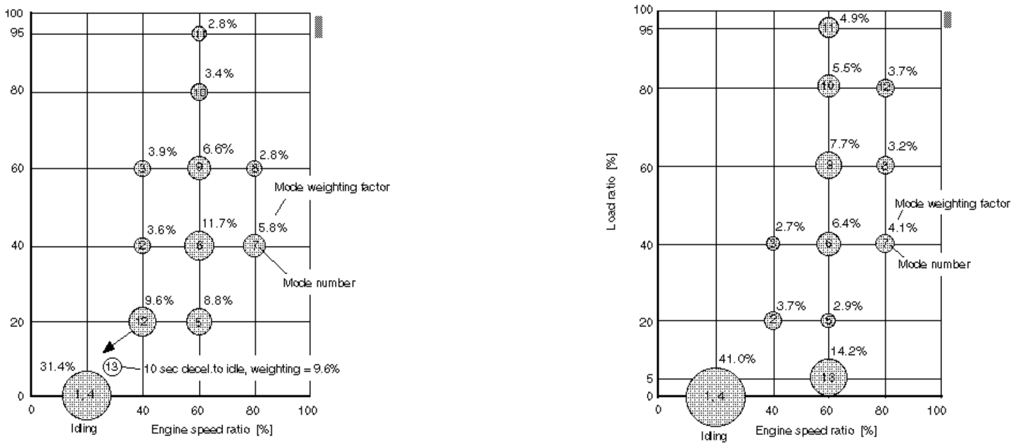
Figure A.2.18 Japanese 10.15 Light Duty Test Cycle
(from 1991 (gasoline), 1993 (diesel) onwards)



Cycle duration : 660 sec
Average speed : 22.7 km/h
Idling time : 31.4 %
Total distance : 4.16 km

Source: AVL List GmbH

Figure A.2.19.1 & A.2.19.2. Japanese 13-mode Test Cycles for Heavy Duty Engines
(from 1993 (gasoline & LPG cycle), 1994 (diesel cycle) onwards)



Source: AVL List GmbH

A.2.4.2. Japanese Evaporative Emissions Procedure

In Japan the carbon canister (trap) method is applied. The canister method employs weighed activated carbon traps which are connected to the fuel system at locations where fuel vapours may escape to the atmosphere (air cleaner, fuel tank vent, etc.). The vehicle is driven at 40 km/h ± 2 km/h under road conditions for 40 minutes on a chassis dynamometer at 25°C ± 5°C. Immediately after the engine is stopped, the exhaust is sealed and preweighed active carbon traps are connected to the fuel tank, air cleaner and any other fuel system vents. After 1 hour the traps are reweighed and the total increase in weight must be less than 2 grams. The test fuel used is the same as for the exhaust emission testing with an RVP of 0.57 to 0.60 kg/cm^2 (56 to 59 kPa)IN-SERVICE EMISSIONS performance LEGISLATION AND on-board diagnostic systems

A.3. IN-SERVICE EMISSIONS PERFORMANCE LEGISLATION AND ON-BOARD DIAGNOSTIC SYSTEMS

A.3.1. EUROPE

A.3.1.1. EU in-service emissions testing

Legislation with respect to in-service emissions testing for road vehicles within the EU was promulgated by Directive 77/143/EEC and subsequently amended by Directive 88/449/EEC. These Directives covered buses, coaches, light and heavy goods vehicles, trailers and semi-trailers over 3.5 tonnes, taxis and ambulances. Although the directives stipulated that noise and exhaust emissions should be incorporated in the roadworthiness tests, no limits were specified. Furthermore, passenger cars were not included in that legislation. Subsequently, Directive 92/55/EEC, dated 22 June 1992, set out limit values and test procedures for all vehicles including passenger cars. These are described in this section. In the intervening period, a number of EU countries introduced their own test regimes and limit values. These are detailed in **Section A.3.1.2**.

The following paragraphs describe the test procedures and limit values to be applied.

Spark Ignition Engined Vehicles

The test procedure consists of two elements:

(i) *A visual inspection to ensure that:*

- There are no leaks from the exhaust system
- If applicable, any emissions control system is present

(ii) *An idle CO test, details as follows:*

A no load idle test, carried out after the manufacturer's recommended engine pre-conditioning period. The limit values are shown in **Table A.3.1**. An additional "*increased idle speed*" test is required for vehicles fitted with 3-way catalysts and lambda control.

Table A.3.1 EU In-service Emission Limit Values - Gasoline Vehicles

Vehicle Description	Idle CO (% v/v)
All models not fitted with 3-way catalysts and lambda control	Initial type approval limit
Where these data are not available or Member States decide not to use these reference values the following alternative will apply:	
Manufactured prior to October 1986 (1)	4.5
Manufactured after 1 October 1986	3.5
All models fitted with 3-way catalysts and lambda control	*Either* initial type approval limit *or* 0.5 maximum (2)

(1) Or the date on which Member States required the vehicles on first registration to comply with the Type Approval Directive 70/220/EEC, as amended.

(2) An additional no load test is to be conducted at a minimum idle speed of 2000 rpm. The following limit values apply:
CO: 0.3% v/ v maximum
Lambda: 1 ± 0.03 or in accordance with the manufacturers specifications

Diesel Engined Vehicles

The test procedure consists of a free acceleration smoke test. That is, the engine is accelerated with the transmission in neutral (no load) from idle up to maximum (governor cut-off) speed and the smoke opacity is measured. The following maximum coefficient of light absorption is allowed:

Either:

Initial type approval limit according to 72/306/EEC

Or:

Where these data is not available, or Member States decide not to use these reference values, the following alternative maxima will apply:

Naturally aspirated diesel engines:	2.5 m^{-1}
Turbo-charged diesel engines:	3.0 m^{-1}

Periodicity of Testing

Table A.3.2 summarizes the ages of vehicles at which testing should commence and the frequency of that testing:

Table A.3.2 EU Periodicity of In-Service Emissions Testing

Vehicle Description	**Age (Years)**	**Test Frequency (Years)**
Spark Ignition Engined Passenger Cars	3	1
Heavy Commercial Vehicles, Taxis and Ambulances	1	1
Commercial Diesel Vehicles (Less than 3.5 tonnes)	4	2

A.3.1.2. Other European in-service emissions legislation

<u>Austria</u>

Regulation: KFG Article 57a/40. Amendment to KDV of 1967 from 24.03.95.

Frequency: Annual

Otto Engine/Type/Test/Limits:

77/143/EEC as amended by 92/55/EEC:
Without catalysts - CO at idle, max. 3.5% v/v
With 3-way catalysts:

- CO at idle manufacturer's limit or 0.5% v/v max.
- CO at idle at minimum 2000 rev/min $\leq$ 0.3% v/v, λ = 0.97 to 1.03

Diesel Engine/Type/Test/Limits:

77/143/EEC as amended by 92/55/EEC mandatory from 01.01.1997, except for cars first registered before 01.01.1990, or test in free acceleration with limit:

maximum measured value from type approval (+1 tolerance)
or if no measurement from type approval 6 Bacharach maximum

<u>Belgium</u>

All gasoline powered cars more than four years old have to be checked annually, or upon change of ownership, at one of 66 state operated test centres. The requirement of 4.5% v/v CO max. at idle must be met by all these cars, including those fitted with catalysts.

Although an opacity limit exists for diesel powered vehicles, no checks are made at the test centres on exhaust emissions from such vehicles.

Denmark

Regulation: In-service emissions testing is part of the roadworthiness test.

Scope: Cars - Inspection on change of vehicle ownership. Vans, Trucks & Buses - Periodic inspection

Frequency: Cars - As above, once vehicle is five years old.
Vans - Every other year, once vehicle is four years old.
Trucks & Buses - Annually after one year.

Gasoline Engine Test/Type/Limits:

Max. 5.5% v/v CO at idle for vehicles registered before 1984.
Max. 4.5% v/v CO at idle for vehicles registered after 1984.
Max. 0.5% v/v CO at idle for vehicles equipped with 3-way catalysts.

Diesel Engine Test/Type/Limits:

Max. 3.8 Bosch Smoke Units (trucks and buses) under free acceleration.

Inspections are carried out by state operated test centres. Road side spot checks are also included in the legislation.

Finland

A regulation for the in-service testing of gasoline cars was introduced, effective from 1 January 1993. Tests can be carried out at the same time as the normal roadworthiness test by an authorized institution, repair shop, or service station. The first test will be conducted four years after registration, the second after six years, and annually thereafter according to the following schedule. Diesel powered vehicles registered after 1.1.80 are tested by the smoke opacity method, using the limits given in Directive 92/55/EEC (see **Section A.3.1**)

Table A.3.3 Finnish in-service emissions testing

Vehicle Description	Idle CO % v/v	Idle HC ppm	Idle >2000 rpm CO %v/v	Idle >2000 rpm HC ppm	Lambda >2000 rpm high idle
Registered before 1.1.78	-	-	-	-	-
Registered 1.1.78-31.9.86	4.5	1000	-	-	-
Registered after 1.10.86	3.5	600	-	-	-
Low Emission Vehicles	0.5	100	0.3	100	0.97-1.03 (1)

(1) Or car manual values

France

No requirements.

Germany

The following table gives details of German in-service emissions test requirements, according to regulation Abgasuntersuchung AU (Article 47a StVZO), which became effective on 1 December 1993.

Table A.3.4 Germany - In-Service Emissions Test Requirements

Vehicle Type	Gasoline Oxidation catalysts or no catalysts	Gasoline 3-way catalysts	Diesel <3.5t	Diesel >3.5t
Frequency (months)	12	24	24	12
After (months)	12	36	36	12
Type Of Testing				
Visual Check	+	+	+	+
Idle Speed, low	+	+	+	+
Idle Speed, high	-	-	+	+
Spark Timing	+	+ (1)	-	-
Dwell Angle	+	-	-	-
EGR	+	-	-	-
Secondary Air System	+	-	-	-
CO Low Idle	+	+	-	-
CO High Idle	+	+	-	-
Lambda Sensor Circuit	-	+	-	-
Lambda Sensor Output	-	+	-	-
Full Load Stop	-	-	+	+
Opacity Free Acceleration	-	-	+	-

(1) **+** Limits as stipulated by the manufacturer and conformity of production limits.

(2) (1) If possible

Greece

From January 1995 An "Automotive Emissions" card is issued annually after the vehicle passes an emissions test. Failure to possess a card renders the vehicle owner liable to a fine.

Ministry Decision No. 50/93 350/4444 requires that diesel vehicles including passenger cars of up to 3.5 tonnes must be checked annually. Diesel taxis and trucks above 3.5 tonnes must be checked every six months

Italy

Regulation: Law No. 615 of 1966 (diesel engines only); no legal requirements for gasoline vehicles. Some local authorities, during air quality non-attainment days, only allow vehicles complying with emissions limits to operate in ***urban*** areas.

Scope: Diesel and gasoline vehicles.

Frequency: No nation-wide scheduled tests, but in most cities the local authorities strongly encourage vehicles to be checked annually in authorised workshops. Furthermore, diesel vehicles may be checked by means of road-side spot-checks for smoke opacity.

Test Type: Smoke opacity under free acceleration (diesel vehicles). CO at idle (gasoline vehicles)

Limits: 65% opacity for urban buses.
70% opacity for all other diesel vehicles.
Manufacturer's manual for CO of catalysts-equipped cars. 4.5% v/v CO and 3.5% v/v CO at idle for non-catalyst cars registered before 1986 and after 1992 respectively.

Penalty for non-compliance:
Fine and withdrawal of vehicle license until the owner resubmits the vehicle and it is found to comply.

Netherlands

Regulation: APK/"*Milieu*" (Environmental) Inspection

Scope: Passenger cars and light-duty spark ignition engined vans (3500 kg max.) aged three years or older have to be checked annually. Currently there are no legal limits for diesel cars, buses and heavy duty trucks. A diesel smoke opacity requirement is under consideration. Test work is also carried out to check that vehicles meet type approval limits and manufacturers are notified of the results.

Test Limits: Since 01.09.91, some cars have to meet the more stringent "Milieu" inspection requirements:

Gasoline and LPG vehicles registered since 1974:
Overall idle CO: 4.5% v/v max.

Cars with three-way catalysts, registered since 1986:
Idle CO: 0.5% v/v max.

Other cars (with and without uncontrolled catalysts) and registered since 1980:
An idle CO limit per car model and in line with quoted type approval limits.

Diesel cars and vans:
No limits

Vehicles failing to meet these requirements have to be adjusted and retested. Vehicles which can not achieve the limits are not allowed on the road.

Norway

Emissions tests are included in the normal roadworthiness tests - however, these are not conducted at fixed intervals. Emissions tests are also carried out at roadside controls. In the future, Norway plans to implement emissions tests according to EEC Directive 92/55/EEC.

Table A.3.5 In-service Inspection for Gasoline Cars in Norway [(1)]

Effective Date (car registration)	**Test at idle**	
	CO (% v/v)	**HC (ppm)**
before 01.01.74	-	-
after 01.01.74	4.5	-
after 01.10.79	3.5	-
Category L1 after 01.07.91	0.5	100
Category L2 after 01.10.92	1.0	200

(1) Diesel vehicles are inspected for “no excessive smoke” only

Poland

The following requirements are applicable to passenger cars, light duty vehicles, heavy duty vehicles and agricultural vehicles. Compliance is checked during mandatory periodical inspections and also nominally at random roadside checks. The frequency of periodical inspections depends on vehicle category and age as follows:

- three years from first registration, next after two years and then annually for passenger cars and light duty vehicles subject to type approval
- every year for passenger cars and light duty vehicles not subject to type approval
- every year for trucks having a maximum mass exceeding 3500 kg
- one year from the first registration and then every six months for buses having more than 15 seats

Vehicles equipped with SI engines

For vehicles first registered before 1 October 1986 and before 1 October 1986, the equivalent EU regulations apply as given in **Table A.3.1**.

The following regulations apply to vehicles registered on or after 1 July 1995, except for vehicles with engines <700 cc, which are exempt until 31 December 1996:

a) all vehicles except heavy duty vehicles (>3500 kg GVW) and motorcycles

CO and HC concentrations measured at idle should not exceed:

CO 0.5% v/v
HC 100 ppm (as hexane NDIR)

CO and HC concentrations measured at idle speed between 2000-3000 rpm should not exceed:

CO 0.3% v/v
HC 100 ppm (as hexane NDIR)

For vehicles fitted with a lambda probe, air-fuel equivalence ratio (lambda) measured at 2000-3000 rpm idle speed should be within 0.97-1.03.

b) motorcycles

CO concentration at idle should not exceed 4.5% v/v

Diesel Vehicles

The smoke level measured at free acceleration from low idle speed should not exceed;

naturally aspirated engines 2.5 m^{-1}
turbocharged engines 3.0 m^{-1}

Portugal

No requirements

Russian Federation

The Federation employs the following in-service limits:

Table A.3.6 Gasoline Engines, Regulation GOST 17. 2. 2. 03-87

Idle Speed (rpm)	CO (% v/v)	HC (ppm) £ 4 Cylinders	HC (ppm) > 4 Cylinders
Nmin	1.5	1200	3000
Nhigh	2.0	600	1000
Nmin	3.0*	-	-

Nmin: Minimum idle speed, according to manufacturer's manual
Nhigh Increased idle speed, according to manufacturer's manual
* Applies only to police and municipality roadworthiness checks

Table A.3.7 Diesel Engines, Regulation GOST 21393-75

Engine Regime	Smoke Emission Limits (Opacity %)
Idle	15
Free acceleration	40

Smoke opacity is measured in-service under police and municipal roadworthiness checks under no-load conditions (transmission in Neutral)

Spain

No requirements

Sweden

Passenger cars aged two years or older (see below) have to be inspected annually by the Swedish Motor Vehicle Inspection Company. The following limits apply:

Table A.3.8 Limits for 3-way catalyst equipped cars

	CO % v/v	HC ppm
L1	0.50	100
L2	1.0	200

Limits for 1976-1988 car models

EGR valves are not compulsory but must function if fitted. The annual test CO limit is about 4.5% v/v but the actual limit varies with model and engine. If the car fails there are certain threshold CO levels which will be reported to the vehicle owner but no further remedial action is required. These values vary between vehicle make, model and engine.

Failed vehicles have to be rectified and re-tested within one month. Vehicles which are not re-tested within that month are not allowed to be used on the road. Vehicles must be submitted for the annual test once they are five years old or have reached 80 000 km, whichever occurs first. It is expected that this limit will be extended to 160 000 km, equivalent to Californian regulations.

Switzerland

Gasoline Powered Passenger Cars/Other Light Duty Vehicles not Exceeding 3 500 kg GVW

Tested biannually at authorized garages. The test comprises:

- Idle speed
- Ignition timing (with and without vacuum advance)
- CO, HC and CO_2 - Limits vary from model to model, reflecting the engine calibration employed for emissions homologation.

The emissions test certificate must be carried on the vehicle. The police conduct random spot checks and if the certificate is not displayed or is out of date the vehicle owner is liable to a fine. Vehicles failing to pass the test are considered as "*not meeting the legal requirements*" and must be withdrawn from service.

All Vehicles with Diesel Engines

Smoke opacity under full rack acceleration in neutral is measured when the vehicle undergoes a regular check at an official Cantonal test station.
Test interval:

- 1 year for trucks transporting dangerous goods.
- 3 years for all other diesel vehicles.

Vehicles failing the test have to be re-submitted within two to three weeks.

United Kingdom

Emissions testing was introduced as part of the existing Department of Transport (DoT) roadworthiness tests conducted annually on cars more than three years old. Gaseous emissions standards were first introduced from 1 November 1991 for light duty vehicles. Smoke emissions standards were applied to heavy duty vehicles from 1 September 1992 and for light duty diesel vehicles from 1 February 1994. The more stringent requirements of EC Directive 92/55/EEC were promulgated by an amendment to Regulation 61 of the Road Vehicles Regulations of 1986 and were applied to all petrol and diesel engined vehicles from 25 September 1995 and to petrol engined cars with advanced emission control systems from 1 January 1996. Additional inspections of filler caps and pipes were introduced in 1996.

Tests are conducted with the engine warmed-up and at idle and the following limits apply:

Gasoline Vehicles:

first used before 01.08.75	no requirement
first used after 01.08.75	CO 4.5% v/v max., HC 0.12% v/v max. at normal idle
first used after 01.08.94 (after 01.08.92 for cars)	CO 3.5% v/v max., HC 0.12% v/v max. at normal idle speed
first used after 01.08.96 (after 01.08.94 for cars)	CO 0.5% v/v max. at normal idle speed and CO 0.3 %vol max., HC 0.02% v/v max. at λ 1$\pm$ 0.03 at >2500 <3000 rev/min (or manufacturers settings for λ and fast idle)

In addition, cars must not emit blue or black smoke after being fully warmed up. Vehicles will fail the complete DoT test even if emissions performance is the only item of failure. A free re-test will be allowed (if the vehicle has failed on emissions only) and provided the vehicle is returned to the same testing station "*within 14 days or so*". Emissions standards will also be the subject of road-side testing. Vehicles which fail to comply will be required to be rectified "*within 14 days or so*".

Diesel Vehicles:	
passenger cars and light commercial vehicles (<3500 kg) first used before 01.08.79	No blue or black smoke at idle by visual inspection
all other vehicles	The smoke level measured at free acceleration from low idle speed should not exceed: naturally aspirated engines 2.5 m^{-1} turbocharged engines 3.0 m^{-1}

A.3.1.3. On board diagnostic systems

An on-board diagnostic (OBD) system consists of a computer incorporated in a vehicle's electronics for the purpose of detecting operational malfunctions within the engine control system. When malfunctions are detected, a warning light illuminates on the instrument panel and a "trouble" code is stored in the computer memory, identifying the part of the system (i.e. catalyst, oxygen sensor, etc.) in which the fault has occurred. OBD systems are seen as a complement to traditional I/M programmes rather than a substitute.

The European Commission will legislate to introduce OBD systems for passenger cars and light duty vehicles as part of a package, to be proposed during 1997, including revised in-service testing requirements with provisions for recalling defective vehicles.

The draft proposals apply to category M_1 vehicles, except those of more than six seats and a maximum mass greater than 2 500 kg, and any other vehicles to which OBD equipment is fitted.

For positive-ignition engines the system must indicate;

- the failure of an emissions related component where the failure results in emissions above 3.2 g/km CO, 0.4 g/km HC and for positive ignition engines 0.6 g/km NOx.
- reduction in the efficiency of the catalytic converter with respect to HC emissions
- engine misfire within specified engine operating limits
- oxygen sensor deterioration
- circuit continuity of emission related powertrain components connected to the computer and the electronic evaporative emission purge control

For compression-ignition engines the system must indicate;

- reduction in the efficiency of the catalytic converter if fitted
- the functioning and integrity of the particulate trap
- the functioning and integrity of the fuel quantity and timing functions of the fuel injection system
- the failure of other emission control systems which may result in the tailpipe emissions exceeding 3.2 g/km CO and 0.4 g/km HC. (The limits for NOx and particulates have not yet been determined)

- circuit continuity of other emission-related powertrain components connected to the computer.

Manufacturers may alternatively obtain type-approval on the basis of the US Federal or California regulations given below.

A.3.2. US INSPECTION AND MAINTENANCE PROGRAMMES

A.3.2.1. In-Use Surveillance Testing: Non-Routine Testing

There are two aspects to US in-service emissions testing. The first involves surveillance testing to ensure compliance with certification durability requirements (i.e. conformity with the 50 000 or 100 000 mile limits). The second extends the rigour of existing inspection and maintenance programmes.

Random FTP-75 checks of in-use vehicles will be carried out by the administrator at mileages below 50/75 000 miles. Additionally, in California, an evaporative emissions test will be conducted, depending on the manufacturers certification procedure. (EPA Surveillance Test Programmes/Title 13 CCR, Section 2136 - 2140).

A.3.2.2. In-Use Surveillance Testing: Continuous Vehicle Surveillance

US Federal

From model year 1992, defects on certain emission-related components/systems of in-use vehicles have to be reported for a period of five years after the end of that model year. A report has to be filed once a maximum of 25 defects have occurred on an individual part. The report includes a specification of the defective component(s), a description of the failure and details of the corrective action taken. Based upon this report, the EPA may decide upon a model recall.

California

From model year 1990, defects on specified emissions-related components and systems of in-use vehicles have to be reported for a period of 5/10 years, or 50 000/100 000 miles, depending on the warranty period (Title 13, CCR). The reporting procedure consists of three steps, where each step requires more and more detailed information. The reporting requirements also ask for information with regard to the number of defects, analysis of those defects and the effects on exhaust emissions. CARB will decide upon a recall, based upon the second and third report stages.

California - Diesel Smoke Law

In April 1991 CARB introduced a new smoke law for road-side checks and enforcement began in November 1991. The inspection consists of a "*snap-idle*" test, employing a full flow, end-of-line opacity meter (SAE J1243, May 1988). Three accelerations to full governed speed are to be conducted - each acceleration should take approximately 5 to 7 seconds. The limit is set at 40% opacity as the average of three accelerations. However, some vehicles, for reason of age or "*special exemption*" will be allowed up to 55% opacity.

For the period April 1991 to April 1992:

1. Pre 1991 engines with opacity in the range 40-55% will be given a warning.

2. 1991 engines (or later) in excess of 40% opacity will be cited.

3. All trucks will be cited if their opacity exceeds 55%.

A series of penalties and fines, repair and re-certification is in place and, in extreme circumstances, the truck may be impounded. At the end of the first year CARB was planning to evaluate the results to decide whether to extend the 55% limit, or lower the opacity limit to 40% for all vehicles.

A.3.2.3. Inspection and Maintenance Testing

Summary of State Programmes Before the Clean Air Act 1990 Amendment

Nearly every state had formulated its own inspection and maintenance programme by the end of 1986. The type and frequency of testing and the means of enforcement were left to the discretion of each state, subject to EPA's approval that the necessary performance criteria would be met.

About 65 % of the programmes were performed by licensed local private garages or dealerships. Any vehicle which failed the inspection text was normally repaired at the same facility and re-inspected. The rest of the programmes involved testing vehicles at specialized test facilities run by the state, or contractors, and were capable of handling large numbers of vehicles. However, vehicles which failed had to be repaired elsewhere and returned to the test site for re-inspection. About three-quarters of the programmes limited the amount which owners had to pay to repair vehicles which did not comply. However, these ceilings did not normally apply to vehicles where the control systems had been tampered with. Most states required annual testing, although some, including California, specified biennial tests.

About half the states required compliance with the I/M requirements as a prerequisite for vehicle registration renewal. Most of the others required a sticker certifying compliance to be displayed on the windscreen, non-compliance resulting in a fine. The remainder relied on computer records to identify vehicles which had not been tested. Not all vehicles had to comply. For example, motorcycles, vehicles with a GVW over 8 500 lb. and vehicles using diesel or alternative fuels, such as ethanol and LPG, were exempt in most states. Also, some states exempted older vehicles, specified by either age or model-year - the most popular being 1968, which coincided with the first nation-wide introduction of exhaust emission control systems.

Most of the inspection tests measured CO and HC emissions at a single engine idle speed. A few programmes measured emissions in neutral at idle and at 2500 rpm. One state used a loaded mode test for pass/fail decisions. Five states relied on visual inspections and some states used combinations of the above methods. Nearly all the programmes had some check against tampering, most states allowing waivers for older vehicles not equipped with a catalyst. A number of programmes were conducted in conjunction with a safety inspection. Most of the states used the Federal Short Test limits for 1981 and newer vehicles of 1.2% CO and 220 ppm HC as n-hexane (known as the *Section 207(b) limits)* as a basis for judging compliance.

These limits could be modified, depending on a vehicle's make, age and emissions control systems.

Failure rates naturally varied, depending on the emissions limits selected, and a balance was generally sought between owner's costs and incremental gains in emissions benefits. EPA audits identified some programmes which appeared to be less effective than others. One major problem related to low failure rates in decentralized programmes with manual analyzers. The two major causes of the low failure rates were poor instrument quality control and cheating.

Enhanced Inspection and Maintenance Testing - The New Clean Air Act Amendments and the IM 240 Test Procedure

The new US CAAA called for the introduction of enhanced inspection and maintenance programmes from 15 November 1992 in the most polluted areas. These included certain "*serious*", "*severe*" and "*extreme*" ozone non-attainment areas with populations in excess of 200 000. The Act also mandated enhanced I/M in urban areas located in an "*ozone transport region*" with 100 000 or more residents. At that time this represented an increase in the number of areas requiring I/M programmes from 122 to 181. After long debate, and in response to a court order, the EPA issued its proposals for an I&M Programme on 13 July 1992.

These proposals were signed as a final rule during June 1993. States were required to submit their detailed inspection programme by November 1993 and promulgate the necessary state legislation.

The proposal required 181 areas of the country to establish emissions testing programmes. The 95 non-attainment areas with "moderate" air pollution problems were required to introduce a basic I&M programme, the 82 more polluted areas were required to implement an enhanced I/M programme. EPA estimated that the programme would reduce VOC emissions by 28%, at a cost of US $500/tonne. The rule "was expected to save $1.6 billion annually in clean air costs and 15 million barrels of oil a year as a result of improved fuel economy". The EPA and the Department of Transport also announced that states would be eligible to federal funds to help defray costs of the programme.

The performance standard proposed for Basic I&M is modelled after the original New Jersey programme (e.g. use of a simple idle test). States required to only have basic I&M programmes could opt for a more stringent programme and could build credits which could be used to offset other pollution control efforts.

The EPA proposed performance standards for Enhanced I&M was based on annual, centralized testing of all 1968 and later model year passenger cars and light duty trucks. A steady-state test could be used for 1968-1985 models, but the "high-tech" IM 240 test was required for 1986 and later model vehicles. Besides emissions tests, the I&M procedures also required a visual inspection for the presence and proper connection of the catalyst, fuel inlet restrictor and evaporative emissions control system. Pressure and purge checks were also required on the carbon canister.

Phase-in standards for the calendar years 1995 and 1996 were given, applying to 1984 model year and newer vehicles. Then followed two sets of final standards, the first applying to vehicles of the 1984 model year and newer, from calendar year 1997. The second standard applied to vehicles certified to Tier I limits (including those certified in model years 1994 and 1995), from calendar year 1996. The limits re given in **Table A.3.9**. The limits are the lowest standards that may be applied. Higher limits may be adopted if approved by the Administrator.

The IM 240 test is a transient test based on 240 seconds of the Federal certification test procedures and is claimed to be about three times more accurate in identifying vehicles exceeding emission standards than current tests. At the time of its proposal, EPA estimated that the test equipment for IM 240 would be about $150 000 and would probably cost the consumer $17 per vehicle to administer. Based on the effectiveness of the IM 240 test, EPA concluded that it would be acceptable to require the test only once every two years. Also, EPA proposed that states design the programme such that facilities are located within five miles of where 80% of the vehicle owners work or live and that adequate test lanes are present to ensure that there is no more than a 15 minute wait for testing.

Table A.3.9 IM 240 Short Test Emissions Standards

Standard	Effective Date	Vehicle	Age yrs	CO g/mile	HC g/mile	NOx g/mile
Phase-in	1995	LD Vehicle	<5	25.0	1.2	3.0
	1996	1984 or younger	>4	30.0	2.0	3.5
		LD Truck	<5	25.0	1.2	3.5
		1984 or younger	<4	30.0	2.0	4.0
Final	1997	LD Vehicle 1984-1995 but pre Tier I		15.0	0.8	2.0
		LD Truck 1984-1995 but pre Tier I		15.0	0.8	3.0
Final	1997	Tier I LD Vehicle (including 1994/5/6)		15.0	0.7	1.4
		Tier I LD Truck (including 1994/5/6)				
		<6000 lb. GVW		15.0	0.7	2.0
		>6000 lb. GVW		15.0	0.8	2.5

Evaporative Emissions Control System Purge Test Standard: The Vehicle shall pass the purge test when the total volume of flow exceeds one standard litre. If the total volume of flow is less than 1.0 standard litre at the conclusion of the transient driving cycle the vehicle shall fail.

Evaporative Emissions Control System integrity: Unless inaccessible, the canister and evaporative system shall be inspected for damage or incorrect connections. The evaporative emissions control system shall be subjected to a pressure test to ensure the absence of leaks.

Implementation of Enhanced I/M Testing

Following the publication of the EPA rule there was an outcry that the IM 240 test was too complicated and expensive to perform and that simpler tests could ensure compliance with emissions requirements. Congress concurred and agreed that states could adopt "Alternative Enhanced I&M" programmes in lieu of the model proposed by EPA, as long as emission reduction benefits of such alternatives were comparable to EPA's programme. As a result, EPA made it somewhat easier for states to adopt decentralized programmes. However, EPA's own studies suggested that such programmes, which allow both the test and repair to occur at the same facility, are only half as effective as programmes which require centralized, test-only facilities. States which chose the low-tech option therefore ran the risk of being required at a later date to convert to high-tech I&M if their programme was unsuccessful.

Following the compromise, states were required to implement decentralized basic I&M programmes by July 1, 1993 and centralized basic programmes by January 1, 1994. Enhanced I&M programmes were needed to be in place by July 1994, with the proposal that the number of vehicles covered could be phased-in (e.g. 30% in 1994 and 100% by 1996). The EPA also proposed that the cut-point for failing the I&M test be relaxed initially, with the full, more stringent cut-point applied by January 1, 1998.

In March 1994, the EPA was ordered by a court ruling to approve or disapprove by July 15 1994, all the state basic and enhanced automobile inspection and maintenance (I/M) programmes it had received. States that had not submitted adequate I/M programmes by that date could be immediately sanctioned. Federal sanctions include the loss of federal highway funds or a "two-for-one" emission offset requirement for new stationary air pollution sources. By this court decision the EPA lost its flexibility to extend mandatory Clean Air Act deadlines, thus forcing air regulators nation-wide to reassess their schedules for programme submissions. As a consequence, a wide range of local programmes, which vary in both complexity and stringency, remained in existence.

EPA was further hindered in its attempts to revise the I/M requirements by a Court ruling on 6 May 1994 supporting a NRDC contention that both visual and emissions testing was required on older 1968-1983 model-year vehicles. However, the Court upheld EPA's contention that testing every year was unnecessary.

In practice some states, such as Maryland, Delaware and Pennsylvania, put their I/M programmes on hold until the situation clarified while others, such as New Jersey and California, implemented their own schemes. New Jersey adopted a unique hybrid programme, using an acceleration simulation mode test, (ASM) 50/15, instead of IM240. In order to qualify for full credits it was required to implement modifications such as increased auditing, remote sensing and technician training. California carried out two major studies to assess the effectiveness of remote sensing and various testing options, including acceleration simulation models, ASM 50/15 and 25/25.

EPA believed that states, still subject to the enhanced I/M requirement and required to submit plans for their areas, are themselves in the best position to make decisions about the optimum strategy to meet their aims - as long as the I/M requirement is given proper consideration. To this end, EPA announced its intent to amend the I/M Program Requirements in December 1994 and published the resultant Proposed Rule on the 28 April 1995. This action created a second less stringent enhanced I/M performance standard. Such a standard could be used in areas that can demonstrate an ability to meet the 1990 Clean Air Act deadlines for “Reasonable Further Progress and Attainment”, of either the CO and/or ozone ambient air quality standards, while implementing an I/M programme that falls below the original enhanced I/M performance standard. This low enhanced performance standard is designed for areas that are required to implement enhanced I/M, but do not have a major mobile source component to the air quality programme, or can obtain adequate emission reductions from other sources to meet the 15% VOC emission reduction and demonstrate attainment.

The following changes were outlined in EPA’s proposals:

Under the EPA regulations, basic I/M programmes were required in moderate ozone and carbon monoxide non-attainment areas with populations of 50,000 or more. The new proposals relaxed the minimum population requirement to 200,000 and allowed areas with populations less than 200,000 to opt out of I/M testing completely.

The proposed low enhanced I/M performance standard allowed ozone non-attainment areas to adopt a biennial decentralised test-and-repair programme that included idle tailpipe testing, full visual checks, and pressure testing of the evaporative emission control system on all gasoline powered vehicles. For areas needing to meet the Act’s CO requirement, two-speed tailpipe emissions testing was required, but only visual checks on emissions control equipment were necessary unless ozone is also a problem. Alternatively, states using the full IM240 emissions, purge and pressure testing requirements could be exempt large proportions of the oldest or newest vehicles from the test.

To comply with the Court ruling of the 6 May 1994, the EPA required in the high enhanced performance standard procedures, a visual inspection of the PCV and EGR valves on all light-duty vehicles and light-duty trucks of 1968-71 and 1972-83 model years respectively.

The proposal limited waiver costs by extending the deadline for implementing the minimum expenditure to qualify for a waiver. It allowed the application of pre-inspection repairs towards meeting the waiver requirements in certain circumstances, allowing repairs by unqualified persons to primary emissions control equipment only. It also permitted more than one hardship exemption in a vehicle’s lifetime.

The EPA also took opinions on the efficacy of remote sensing systems for vehicle emissions assessment. It also looked at the action required of states which are eligible for re-designation to attainment of standards should a violation occur. In these cases a state is given the flexibility to select whichever contingency measures are best suited to correcting the problem - as long as upgrading the basic I/M procedures is considered as one of the options. It also sought views on the benefits of delaying the full implementation of waivers until 1 January 1998.

In the event, during the first half of 1996, Congress passed the National Highway System Act, granting states the right to set up their own tailor made I/M plans. The current requirements, being much different from the stringent testing regime previously proposed by the EPA, has left many states uncertain how to proceed. State legislatures are wary of approving State Implementation Plans (SIPs) based on the previous uncertainties and the EPA naturally seems unwilling to enforce any action. The latest situation regarding state implementation programmes is given in **Part 1, Section 3.2**.

A.3.2.4. On board diagnostic systems

An on-board diagnostic (OBD) system consists of a computer incorporated in a vehicle's electronics for the purpose of detecting operational malfunctions within the engine control system. When malfunctions are detected, a warning light illuminates on the instrument panel and a "trouble" code is stored in the computer memory, identifying the part of the system (i.e. catalyst, oxygen sensor, etc.) in which the fault has occurred. OBD systems are seen as a complement to traditional I/M programmes rather than a substitute.

US Federal

A final Federal rule has been established which required manufacturers to install on-board diagnostic (OBD) systems on light-duty vehicles and light-duty trucks beginning with the 1994 model year. The thresholds as defined in the FTP for OBD system identification of emissions-related malfunction or deterioration are as follows:

- *Emission related components (other than those listed below):* before it results in exhaust emission increases of 0.2 HC, 1.7 CO and 0.5 NOx (all in g/mile) or results in leakage or other malfunctions of the vapour recovery or purge systems that result in an evaporative emission increase of 2.0 g/test.
- *Catalyst deterioration:* before it results in an exhaust emissions increase greater than 0.4 HC, 3.4 CO, 1.0 NOx (all in g/mile).
- *Engine misfire:* before it results in an exhaust emission increase of more than 0.4 HC, 3.4 CO, or 1.0 NOx (all in g/mile).
- *Oxygen sensor deterioration:* before it results in an exhaust emissions increase greater than 0.2 HC, 1.7 CO or 0.5 NOx (all in g/mile).

In addition to detecting misfire, the system must also identify which cylinders are misfiring and if any other emission related powertrain systems or components have caused an exhaust emission increase. The OBD system must also detect the occurrence of any leakage or malfunction of the vapour recovery systems that result in an evaporative emissions increase of 3.0 g/test for LDVs and LDTs. The diesel OBD only requires monitoring of catalyst malfunction or deterioration of other emission related powertrain components.

Manufacturers are required to detect these malfunctions only if they occur in actual use. Therefore, if manufacturers are confident that any malfunction will not result in emission increases, they may choose to forego OBD monitoring. However, to ensure compliance the EPA will check in-use emissions.

This rule-making allows manufacturers to satisfy the Federal OBD requirement through the 1998 model year by installing systems meeting the California OBD II regulations. This means that manufacturers can concentrate on designing one system to meet both standards.

California

Whereas the EPA's enforcement strategy is based on in-use testing as a means of achieving the aim of reducing emissions from cars in use, the CARB approach is to place the emphasis on pre-production vehicle testing and on specifying the standard of the OBD system itself.

The original OBD regulation specified monitoring requirements for the oxygen sensor, EGR system and other emissions related components. In July 1990 the CARB adopted regulations, the so-called OBD II regulations, which required 1994 and subsequent model passenger cars, light-duty trucks and medium-duty vehicles and engines, to be fitted with on-board diagnostic systems to monitor catalyst efficiency, engine misfire, evaporative system integrity, secondary air injection, and chlorofluorocarbon (CFC) containment. These requirements were amended in 1991, 1993 and more extensively in 1995. These amendments allow manufacturers to take advantage of advances in technology in meeting the requirements and to allow more time to address the problems associated with low emissions vehicles, and vehicles with engines using diesel fuel, alternative fuels or with lean-burn combustion systems. The OBD II requirements are described in more detail below.

The regulations apply to all passenger cars, light duty trucks and medium duty vehicles or engines and the system must incorporate the features given below for the various vehicle and engine types.

General requirements:

For 1994 model and subsequent years, the OBD system requires a malfunction indicator light (MIL) located on the instrument panel. This must automatically inform the operator in the event of a malfunction of:

- Any powertrain components which can affect emissions,
- Any component that gives an input, or receives an output, from the on-board computer
- The computer itself.

An on-board diagnostic system must be capable of identifying the likely area of the malfunction by storing fault codes in the computer memory and providing a means of access to these codes.

Catalyst monitoring systems:

From 1994, a monitor is required for proper performance of the catalyst system, both for emissions performance and for proper catalyst heating. For non-LEVs, catalyst system deterioration must be detected before emissions increase by 1.5 times the standard compared to the emission level, using a representative catalyst system, aged by 4000 miles of operation. After 1998, fulfilment of federal OBD requirements will be an acceptable alternative. The requirements do not apply to diesel engines

For TLEV systems, the threshold malfunction criterion is twice the applicable FTP HC standard, plus the emissions from a test run with a representative 4000-mile catalyst system (or 125 hours of operation for medium-duty vehicle engines on a dynamometer).

For LEVs, a malfunction must be detected when the catalyst system average FTP NMHC efficiency falls below 50 per cent, as measured across the catalyst, or when the threshold value of 2.5 times the applicable FTP HC standard, plus the emission level with a representative 4000-mile catalyst system. From 1998, the severity of the latter requirement is increased to 1.5 times the applicable FTP HC standard without the additional catalyst system margin. There is, however, a phase-in period: 30 per cent, 60 per cent and 100 per cent being required to comply in 1998, 1999 and 2000 model-years respectively.

Provisional limits for ULEV applications have been set at 1.5 times the standard emission threshold and will be reviewed in 1998.

Engine misfire monitoring systems:

For gasoline vehicles from 1997, a monitoring system for engine misfire, either of a specific cylinder, or group of cylinders, each of which must be identified, will be required over all positive torque operating conditions. It must detect misfire (in 1000 revolution increments in a demonstration test) before it is frequent enough for emissions to exceed 1.5 times the standards, or before the misfire rate is sufficient to cause a vehicle to fail an Inspection and Maintenance test. It must also detect misfire rates (in 200 revolution increments) which are high enough to damage the catalyst. The requirements will be phased in with 50, 75, 90 and 100 per cent compliance over the 1997-2000 model-years.

Misfire detection for diesel vehicles is not required until the 1998 model-year and will require a monitor for misfire in a specific cylinder or number of cylinders, diagnosed on the basis of the absence of combustion. This is to be assessed once during the first engine start up portion of a cycle and once under driving cycle conditions.

Evaporative system integrity:

A diagnostic system is required from 1994, which verifies the air flow from the complete evaporative system. In addition from 1996, the diagnostic system shall also monitor the evaporative system for loss of HC vapour into the atmosphere by performing a pressure or vacuum check of the complete system.

The leakage to be detected is equivalent to that from a 0.04 inch diameter hole in any part of the evaporative system, excluding tubing and connections. Beginning with the 2000 model-year, manufacturers are required to phase in systems to detect leakage equivalent to that from a 0.02 inch diameter hole, with 50, 75 and 100 per cent coverage in the 2000, 2001 and 2002 model-years respectively.

Other monitoring requirements:

The diagnostic system is required to monitor for the malfunction of any electronic powertrain component or system which either supplies an input to, or receives commands from the on-board computer

The diagnostic system is required to monitor the output voltage, response rate and any other parameter which can affect emissions of all primary and secondary oxygen sensors. A check is required on the EGR system to ensure that it complies with manufacturers tolerances and complies with specified maximum and minimum flow rates. Any vehicle fitted with a secondary air system should be capable of monitoring the proper function of the secondary air delivery system and air switching valve. For each of the above systems a malfunction is indicated if the vehicle exceeds the applicable FTP standard by 1.5 times.

Chlorofluorocarbons will be phased out as air conditioning system refrigerants, but any vehicles employing such refrigerants must have a suitable monitoring system for leaks.

A.3.3. OTHER COUNTRIES

A.3.3.1. Japan

Emissions testing forms an integral part of the Japanese roadworthiness test ("Shaken"). Vehicles must be submitted for testing once they are three years old and thereafter every two years. The limits applied are:

CO:	4.5% vol max.
HC:	1200 ppm max. (4-stroke engines)
	7800 ppm max. (2-stroke engines)

The measurements are made by NDIR at idle. If the emissions exceed the prescribed limits then some re-tuning is permitted.

A.3.3.2. Mexico

Mexico City - Inspection and Maintenance

An I&M programme was introduced by the Mexico City Metropolitan Area (MCMA) in 1989. By June 1990 about 750 repair shops and 32 government stations were licensed by the government of the City (Departamento Del Distrito Federal or DDF) or the state of Mexico to carry out the inspections covering about 2.7 million vehicles.

Inspections are currently performed twice a year and consist of a brief visual inspection of emission control components, a visual check of exhaust smoke and an analysis of exhaust gas emissions for gasoline-powered vehicles. CO and HC emissions are measured at idle and at 2500 rpm in neutral. The analysers are manually operated units built to the specifications issued by the California Bureau of Automotive Repair (BAR) in 1974 and 1980 (BAR74 or BAR80). An inspector is responsible for issuing pass/fail certificates. Enforcement is by a visual sticker system. A dated window sticker is issued by the inspection station at the completion of the test. Display of an expired sticker results in a fine and impoundment of the vehicle for 24 hours.

The programme was reviewed at the end of 1995 as it was increasingly clear that many independent stations were not applying the tests impartially. In view of the importance that I/M testing has in achieving air quality standards in Mexico City, the DDF decided to close down private garage inspection stations and switch to a completely centralised system. In addition it was agreed that the State of Mexico would proceed along similar lines but with a delayed schedule. The upgraded programme will be implemented in three stages and will include the following improvements;

- inspections only at stations which do not have responsibility to repair vehicles (test only or large centralised centres)
- tighter standards for all vehicle categories
- improved, loaded mode testing of CO, HC and NOx emissions
- independent auditors at each station to monitor the quality and integrity of each inspection

A.3.3.3. South Korea

The limits which apply to in-service emissions testing in South Korea are given in **Table A.3.10** below.

Table A.3.10 South Korean in-service emissions limits

<table>
<tr><th colspan="2">Type of Vehicle</th><th>Model Year</th><th>CO (%v)</th><th>HC (ppm)</th><th>Smoke Opacity (%)</th></tr>
<tr><td rowspan="2">passenger cars (gasoline & LPG)</td><td rowspan="2">≥ 800 cc but < 2.7t</td><td>until 1987</td><td>4.5</td><td>1200</td><td>-</td></tr>
<tr><td>from 1987</td><td>1.2</td><td>220 (1)</td><td>-</td></tr>
<tr><td>passenger cars (gasoline & LPG)</td><td>< 800 cc or ≥ 2.7t</td><td rowspan="2">all models</td><td rowspan="2">4.5</td><td rowspan="2">1200</td><td rowspan="2">-</td></tr>
<tr><td>light duty trucks heavy duty trucks (gasoline & LPG)</td><td>all</td></tr>
<tr><td rowspan="3">passenger cars, light & heavy duty trucks(diesel)</td><td rowspan="3">all</td><td>until 09.1990</td><td>-</td><td>-</td><td>50</td></tr>
<tr><td>1990 - 1995</td><td>-</td><td>-</td><td>40</td></tr>
<tr><td>from 1995</td><td>-</td><td>-</td><td>35</td></tr>
</table>

(1) HC 400 ppm max for LPG passenger cars

A.4. FUEL CONSUMPTION & CO_2 REGULATIONS

The degree of control of fuel consumption exercised by legislators varies throughout the world. In the US, improvements in fuel consumption have been enforced. In Europe, government control is limited to mandatory publication of vehicle fuel consumption data (in France and the United Kingdom), and voluntary commitments have been made by motor manufacturers in several countries for improvements in fuel consumption. Taxes on CO_2 emissions and energy consumption are, however, being considered. Other measures which have been taken by some countries to reduce fuel consumption include lower speed limits, and higher taxes on vehicles with high fuel consumption.

A.4.1. EUROPE

A.4.1.1. European Union

Following consideration of CO_2 emissions and fuel consumption limits in the 1992/93 Work Programme of the MVEG (Motor Vehicle Emissions Group of the European Commission) the Commission approved on 1 January 1994 an amendment to Council Directive 80/1268/EC, relating to the measurement of fuel consumption of motor vehicles, to include the measurement and reporting of carbon dioxide emissions in its scope. Tests are carried out over the Urban and Extra Urban test cycles, as described in Directive 91/441/EEC, for exhaust emissions (see **Section A.2.1.1**). One figure for the combined cycle is reported for carbon dioxide, whereas fuel consumption is reported for the two cycles separately and in combination.

A.4.1.2. Other European countries

Switzerland

The Ministry of Transport and Energy has declared its intention to introduce regulations to reduce fuel consumption. It is considering several options for implementation:

- Assurance of, or voluntary conformance to, a limit jointly defined by the Ministry and the respective manufacturers or importers.
- Conditions imposed on each manufacturer/importer to reduce its fleet average fuel consumption in a series of steps.
- A credit system to achieve a national fleet average fuel economy level.

A.4.2. UNITED STATES

The Energy Policy and Conservation Act, passed in December 1975, amended the Motor Vehicle Information and Cost Saving Act to require improvements in passenger car fuel consumption up to a figure of 27.5 miles per US gallon (8.55 l/100 km) by 1985, as shown in **Table A.4.1**. Vehicle manufacturers are required to test sufficient vehicles to allow a fuel consumption figure to be assigned to each product line produced by them. From these figures a sales weighted average fuel consumption figure is calculated for all the passenger cars produced by the manufacturer concerned. This figure must be below the level specified for the appropriate model year. A manufacturer whose fleet average fuel consumption did not meet the standard was subject to a fine of $5 for each vehicle produced, for every 0.1 miles/US gal that the standard was exceeded. However, these fines could be offset by credits accrued in other model years.

The standards are based on the combined city/highway fuel consumption figures, and are known as the CAFE standards (Corporate Average Fuel Economy). From 1979 model year, the programme was expanded to cover light-duty trucks as well as passenger cars. By 1986 however, because of low oil prices and a return to larger cars, the US motor industry found it difficult to meet these limits. The US Department of Transportation therefore "*rolled back*" the limits for 1986-88 to 26 miles/USG (9.05 l/100 km) for passenger cars. Thus the US manufacturers were not forced to pay the fines described above. For 1989, the limit was set at 26.5 miles/USG (8.88 l/100 km), and in 1990 it returned to 27.5 miles/USG (8.55 l/100 km).

Each vehicle must carry a label specifying the vehicle fuel consumption as determined by EPA, an estimate of the annual fuel cost based on 15 000 miles of operation, and the range of fuel economy achieved by similar sized vehicles of other makes. The figures quoted are not expected to give an accurate estimate of the fuel consumption that the owner will achieve under normal driving conditions, but provide a comparison between different models of vehicle.

In calculating the CAFE fuel economy figure, a manufacturer may include in the fleet average figure any electric or hybrid vehicles produced. The procedures defined by EPA for calculating the equivalent fuel economy of electric vehicles take account only of the gasoline energy equivalent of the electricity which powers the vehicle, disregarding losses during electricity production and distribution. The calculated fuel economy figures are therefore high, (around 185 miles/US gal), giving an incentive for the development of such vehicles.

These provisions have been extended to include 'flexible-fuel' vehicles which can operate on gasoline, ethanol, methanol or any mixture of these fuels. A CAFE credit of up to 1.2 miles/US gal is allowed for such vehicles. The exact figure is calculated from a complex formula based on the difference in fuel economy between the vehicle running on alcohol and gasoline. This ruling is in effect from 1993-2005, but may be extended beyond that date. The credit of 1.2 miles/USG applies to a CAFE standard of 27.5 miles/USG, and is scaled down for lower standards as currently apply, but no lower than 0.7 miles/USG.

In addition to the average fuel economy figure required of each manufacturer, taxes are levied on vehicles which do not achieve certain minimum fuel economy figures. The minimum requirements and tax levels for 1991 and later are given in **Table A.4.1** (footnotes 6 and 7).

Proposals for a further drastic tightening of Corporate Average Fuel Economy limits were debated during 1990 but were blocked in September that year. The proposals set out to increase CAFE standards by 40% by the year 2001, improving average fuel economy for new cars from 27.5 miles/USG to 40.1 miles/USG (8.55 l/100 km to 5.87 l/100 km).

These proposals were re-introduced in 1991 and again ran into difficulties. A ruling in February 1992, in the US Appeal Court, held that CAFE restricted the production of larger cars, which are deemed safer. Conversely, a draft US Department of Energy report suggests that more fuel efficient cars offer the potential for large reductions in tailpipe emissions, moderate reductions in evaporative running loss emissions and small reductions in diurnal emissions. In the event there have been no further reductions from the 27.5 miles/USG standard.

Table A.A.4.1 US Fuel Consumption Standards in litres/100 km (miles/US gal)

Model year	Passenger cars	Light trucks[1] Combined	Light trucks[1,2] (2WD)	Light trucks[1,2] 4WD)
1978	13.07 (18.0)	-	-	-
1979	12.38 (19.0)	13.68 (17.2)	13.68 (17.2)	14.89 (15.8)
1980	11.76 (20.0)	16.8 (14.0)[3]	14.70 (16.0)	16.80 (14.0)[2]
1981	10.69 (22.0)	16.22 (14.5)[3]	14.08 (16.7)[4]	15.68 (15.0)[2]
1982	9.80 (24.0)	13.45 (17.5)	13.07 (18.0)[2]	14.70 (16.0)
1983	9.05 (26.0)	12.38 (19.0)	12.07 (19.5)	13.45 (17.5)
1984	8.71 (27.0)	11.76 (20.0)	11.59 (20.3)	12.72 (18.5)
1985	8.55 (27.5)	12.07 (19.5)[5]	11.94 (19.7)[5]	12.45 (18.9)[5]
1986	9.05 (26.0)	11.76 (20.0)	11.47 (20.5)	12.06 (19.5)
1987	9.05 (26.0)	11.47 (20.5)	11.20 (21.0)	12.06 (19.5)
1988	9.05 (26.0)	11.47 (20.5)	11.20 (21.0)	12.06 (19.5)
1989	8.88 (26.5)	11.47 (20.5)	10.94 (21.5)	12.38 (19.0)
1990	8.55 (27.5)	11.76 (20.0)	11.47 (20.5)	12.38 (19.0)
1991	8.55 (27.5)	11.65 (20.2)	11.37 (20.7)	12.32 (19.1)

(1) Light trucks defined as less than 6000 lbs GVW in 1979, less than 8500 lbs 1980 - 91.
(2) Separate 2WD/4WD standards or combined light truck standard may be used 1982-1991.
(3) Relaxation granted for 1980-81 trucks with engines not based on passenger cars.
(4) Revised mid-year to 18.0 mpg (13.02 l/100 km).
(5) Revised in October 1984 to 21.6 mpg for 2WD, 19.0 mpg for 4WD and 21.0 mpg combined.
(6) Maximum fuel consumption before attracting "Gas Guzzler" Car Tax:

Year	1980	1981	1982	1983	1984	1985	1986 on
mile/USG	15.0	17.0	18.5	19.0	19.5	21.0.	22.5

(7) "Gas Guzzler" Car Tax (1991 and later)

mile/USG	0.00-12.5	12.5-13.5	13.5-14.5	14.5-15.5	15.5-16.5	16.5-17.5
Tax (US$)	7 700	6 400	5 400	4 500	3 700	3 000
mile/USG	17.5-18.5	18.5-19.5	19.5-20.5	20.5-21.5	21.5-22.5	22.5 & over
Tax (US$)	2 600	2 100	1 700	1 300	1 000	0

A.4.3. JAPAN

In January 1993 fuel economy targets for passenger cars in the year 2000 were officially published. The targets were drawn up by MITI and MOT, based on recommendations of a committee set up in 1990. These are the first such guidelines since 1979, when fuel economy limits were set for 1985. Since then there has been a steady decline in fuel efficiency, especially over the last few years. This is due to the trend to larger engines and more widespread use of automatic transmissions etc. The current targets apply only to gasoline passenger cars but the government are believed to be considering similar regulations for trucks.

Formally the targets are expressed in terms of the weighted average fuel economy for vehicles within the specified weight ranges. They are not mandatory, will not become a regulation, and there is no suggestion of penalties such as a "gas guzzler" tax. However, for domestic manufacturers there is strong incentive to comply in order to maintain the goodwill of MITI. Fuel economy targets are specified over the new 10.15 mode cycle for three vehicle weight categories as shown in **Table A.4.2**. The estimated figure for the total car population is for information only and is not a target for individual manufacturers.

So as not to unfairly advantage or disadvantage OEM's whose car production is all at the top or bottom of one of the three main weight categories, these have been further subdivided into 6 sub-ranges as shown in **Table A.4.2.**

Table A.A.4.2 Japanese Passenger Car Fuel Economy Targets for 2000

Classification	Gross Vehicle Weight kg	Fuel Economy Target km/l	Improvement relative to 1990
Light cars	<827.5	19.0	7.3%
Small cars	827.5 - 1515.5	13.0	8.3%
Normal cars	>1515.5	9.1	11.0%
Estimate for total population		13.5	8.5%
Vehicle Weight sub-ranges			
Sub-Class 1	<702.5	19.2	6.5%
Sub-Class 2	702.5 - 827.5	18.2	7.0%
Sub-Class 3	827.5 - 1015.5	16.3	7.2%
Sub-Class 4	1015.5 - 1515.5	12.1	7.9%
Sub-Class 5	1515.5 - 2015.5	9.1	9.5%
Sub-Class 6	>2015.5	5.8	13.6%

A.4.4. OTHER ASIAN COUNTRIES

A.4.4.1. South Korea

The Korean Ministry of Energy and Resources issued a notice based on the Rationalisation of Energy Consumption Act on 17 August 1992. It requires manufacturers (excluding importers) to meet new fuel efficiency standards from 1 January 1996. More restrictive standards will be introduced from 1 January 2000. From the 1 September 1992 all manufacturers, including importers, have been required to display the level of fuel efficiency on their cars according to five classifications for each engine displacement class. Non-compliance results in a fine of 500 million Won.

Table A.A.4.3 South Korean Fuel Efficiency Requirements

Engine Displacement (cc)	**From 1.1.1996 km/l**	**From 1.1.2000 km/l**
<800	23.4	24.6
800-1100	20.3	21.3
1100-1400	17.3	18.1
1400-1700	15.4	16.1
1700-2000	11.4	12.0
2000-2500	9.9	10.4
2500-3000	8.5	8.9

South Korea also has fuel economy standards for motor cycles as follows

Table A.A.4.4 South Korean motorcycle fuel economy standards

Effective Date	Engine Size (cc)	Fuel Economy (km/l)
1991	≤ 50	41.0
	51 - 100	33.5
	> 100	32.5
01.01.1998	≤ 50	49.0
	51 - 100	48.0
	> 100	44.5

A.4.4.2. Taiwan

Taiwan has fuel economy regulations for passenger cars based on the combined US urban and highway cycles. It also has limits for motorcycles (2- and 3-wheeled vehicles with a curb weight of less than 400 kg and maximum speed greater than 50 km/h), which are due to be made more severe from January 1998.

Table A.A.4.5 Taiwanese Fuel Economy Regulations

Passenger cars	
Weight Class (kg)	**Fuel Economy (km/l)**
≤ 1046	14.7
1047-1276	12.0
1277-1496	10.1
1497-1726	8.7
1727-1956	7.7
1957-2176	6.9
>2176	5.3
Motorcycles	
Engine Displacement (cc)	**Fuel Economy (km/l)**
From 1991	
≤ 50	41.0
51-100	33.5
>100	32.5
from 1.1.1998	
≤ 50	49.0
51-100	48.0
>100	44.5

A.4.4.3. Australia

The FCAI have proposed reductions of the national average fuel consumption of the new car fleet with a target of 5% from 1989 levels by 1995 and further reductions thereafter as follows:

Table A.A.4.6 Australian fuel economy regulations

Year	1/100km
1995	8.7
2000	8.2
2005	8.0

A.5. FUEL QUALITY REGULATIONS AND SPECIFICATIONS

A.5.1. EUROPE

A.5.1.1. Introduction

CEN Standard Specifications

In 1988 the EU mandated the European Standards Organization (CEN) to develop comprehensive specifications for unleaded gasolines (premium and regular grades), diesel fuel and automotive LPG. The standards were circulated to the national bodies on 13 August 1992 for a formal vote before 13 October 1992. They were then officially ratified by CEN on 16 March 1993. Member States were required to adopt them as national standards by September 1993 and withdraw conflicting national standards by the same date. The specifications are given in full in **Tables A5.18, A.5.25** and **A.5.30**.

Following consideration of the Auto/Oil programme, in 1996 the EU Commission put forward proposals for changes in fuel quality which will require extensive revisions of the CEN gasoline and diesel fuel specifications (see **Part 1**).

Unleaded Gasoline - EN 228:1993

The 1988 EU mandate required the gasoline specifications to cover all major items and eliminate the three category classifications A, B and C in the 1987 CEN standard. In this specification the A category contained the mandatory limits, the B category included limits to be specified on a national level, and the optional C category defined other items which were allowed to be specified by national bodies.

Apart from the octane requirements of the regular grade, all relevant characteristics and test methods are specified in this European Standard. Provisions are included for national bodies to select seasonal grades from the eight volatility classes during a defined period of the year for a defined region of its country. These have to be specified in the national annex to the EN 228:1993 specification. Regular grade (if required) octane levels must also be included in the national annex. Details are given in **Tables A.5.18, A.5.19** and **Figure A.5.3**. Of the 18 CEN Member States, 14 voted in favour and 2 voted against the standard which, according to CEN/CENELEC rules, means that it was accepted.

Diesel Fuel - EN 590:1993

Of the 18 CEN Member States, 16 voted in favour of the standard. It was also agreed that the CEN Technical Committee 19, Diesel Working Group WG24, should work on a test method for aromatics and an alternative to the CFPP method, to better predict low temperature performance. The methods for ash content, cetane index, oxidation stability and particulate matter are also under review. The EN 590:1993 standard specifies six CFPP grades for temperate climates and five different classes for arctic climates. Each country shall detail requirements for summer and winter grades and may include intermediate and/or regional grades, which can be justified by national meteorological data. Details are given in **Tables A.5.25** and **A.5.26**.

Automotive LPG - EN 589:1993

Four grades are specified, based on seasonal limits for minimum vapour pressure during the winter months. Each country must specify which winter grade it adopts in an annex to its national standard. No minimum is set for the summer period. Details are given in **Table A.5.30**.

French Cahier des Charges/UTAC labelling systems

The French motor manufacturers developed an unofficial performance related fuel quality labelling system called the “Cahier des Charges”. In addition to meeting national specifications, oil companies could choose to submit a dossier of information to the motor industry and have their fuels approved. They could then claim that products are “approved by the French motor industry”. The scheme was introduced in 1989 and the specifications were updated annually.

Until 1994 the scheme was jointly administered by Renault and the PSA Group. However, on 11 March 1994 it was agreed that the French Transport Ministry Technical Advisory Committee (UTAC) would issue certificates of quality for gasoline and diesel fuel. The new labelling system was announced in June 1994 and was launched in September 1994.

A “Certification Committee” is in charge of the general administration of the scheme, and delivers certificates upon the recommendation of technical committees. These committees are also responsible for controlling conformity of production in-service and for recommending changes to the technical content of the UTAC label. Representatives of UTAC, the French administration, the oil industry, motor manufacturers and consumer associations are able to attend meetings of these committees.

The new system uses the norms and specifications of the “Cahier des Charges” for gasoline and diesel fuel which are summarized in **Tables A.5.23** and **A.5.28**. Since its introduction a requirement for valve deposit weight has been added to the requirements of the Mercedes M 102 E Intake Cleanliness Test for gasolines. A lubricity test and pour point limits have been added to the diesel fuel requirements but the requirements for density, total aromatics and total naphthenes have been deleted. Cetane Index is no longer specified but Cetane Number is retained.

The scheme incorporates a quality assurance system for final inspection, testing, storage and distribution of automotive fuels, equivalent to ISO 9003.

Unlike the “Cahier des Charges de Qualité”, companies producing fuels of the required quality will be able to claim that their products are “UTAC approved”. As with the previous system, approval is available to companies outside France. Today, several petroleum companies are “UTAC approved” for one or two unleaded grades. No one is approved for leaded gasoline. One company is approved for diesel fuel.

A.5.1.2. Gasoline

Lead Content

Within the EU, the maximum lead content of leaded gasolines is required to be within the range of 0.15 to 0.4 g/l by Directive 78/611/EEC. In practice, all countries are at 0.15 g/l maximum. In 1985 another Directive (85/210/EEC)allowed unleaded gasoline (0.013 g/l max.) to be marketed and, in addition, required the introduction of a premium unleaded grade of 95 RON/85 MON from 1 October 1989. This Directive also encouraged Member States to provide incentives (e.g. through taxation) to promote the use of unleaded grades. Subsequently several Member States banned leaded regular completely, as allowed by Directive 87/416/EEC.

Unleaded gasoline (95 RON Europremium) is widely available in all West European countries and sales are growing. In 1994 over 64% of gasoline sales in Europe were unleaded. Leaded regular has almost completely disappeared. Austria banned the manufacture of all leaded gasoline from February 1993 and sales from October 1993. The leaded 98 RON grade has been replaced by an unleaded 98 RON grade, which must contain valve seat recession (VSR) protection additives. Gasolines in Denmark, Finland and Sweden are now totally unleaded following a ban on leaded gasolines in 1995. A 98 RON grade containing valve seat recession (VSR) protection additives is sold for older vehicles. In Eastern Europe unleaded gasoline is available in all countries on a limited basis, generally as 95 RON Europremium, although there is some variation in octane levels.

The penetration of unleaded gasolines into the main western European markets, along with similar data for other OECD countries is given in **Tables A.5.15** to **A.5.17**.

Reformulated Gasolines

Both Sweden and Finland have introduced reformulated gasoline specifications with special requirements for volatility and composition.

Sweden

An ‘Environmental Classification’ system for diesel fuel was introduced in Sweden in 1991 (see **Section A.5.1.3**). During 1993, a similar classification was developed for gasolines, comprising 4 different classes. Class 4 is equivalent to CEN standard, and Class 3 to the current Swedish standard. Separate Class 2 gasoline specifications, for use in cars with and without catalyst, have been drawn up and were introduced from 1 December 1994. The specifications are optional and use will be encouraged by a tax relief of 6 ore/l for Class 2 gasolines. Tentative limits have been put forward for sulphur, E150, benzene and olefins content for a Class 1 specification, the final levels depending on the revision of the CEN specification.

Table A.5.1 Swedish Environmental Gasolines

Property	Class 1 (5)		Class 2		Class 3 (8)
	(6)	(7)	Catalyst	Non-Cat	Catalyst & Non-Cat
Sulphur %m (max.)	0.0075	0.0050	0.01	0.03	0.1
RVP (S/W) kPa (max.)			70/95	70/95	75/95
RVP (S/W) kPa (min)			45/65	45/65	45/65
E100 %v/v (min)			47/50	47/50	43/45
E150 %v/v (min)	80	85			
FBP ºC (max.)			205	200	215
Benzene %v/v (max.)	2	1	3	3	5
Empirical limit (1)			5.5	6	-
Oxygen %m/m (max.)			2	2	2
Olefins %v/v (max)	13	9			
Lead mg/l (max.)			5	5	13
Phosphorus mg/l (max.)			nil	2	nil
Additives			(2)	(2)	(2)
Inlet Valve Cleanliness			(3)	(3)	(3)
Fuel System Cleanliness			(4)	(4)	(4)

(1) Empirical Limit [$\frac{\text{Aromatics } \%v/v}{13}$ + Benzene % v/v] (max.)

(2) Additives according to the Law on Chemical Products 1994:1390, must not contain ash-forming constituents

(3) Minimum 9 demerits according to Mercedes M102E (CEC F-05-T-92)

(4) Maximum 4% according to Peugeot 205 GTI (GFC TAE I-87)

(5) Suggested values beyond Class 2 specification

(6) If future EU specification stipulates a benzene content of 2 %v/v max

(7) If future EU specification stipulates a benzene content of 1 %v/v max

(8) European standard

Finland

In Finland an interim reformulated gasoline “Citygasoline” was introduced commercially from January 1993, which was modestly supported with tax incentives, see **Table A.5.2**. In April 1994 a reformulated gasoline with a 1 %v/v benzene limit was introduced commercially. Marketing companies sell only unleaded gasoline because of an extra tax on leaded grades.

Table A.5.2 Finnish Reformulated Gasoline

Property	Reformulated Gasoline	Citygasoline	Standard Gasoline
Oxygen %m/m	2.0 - 2.7	2.0 - 2.7	-
Benzene %v/v (max.)	1.0	3.0	5.0
Sulphur ppm m (max.)	100	400	1000
RVP (S/W) kPa (max.)	70/90	70/90	80/100

Aromatics and Benzene

The EU Directive (85/210/EEC), which required the introduction of unleaded gasoline, also specifies a benzene level of 5% v/v maximum. From 1.10.89 this also applied to leaded grades marketed in EU countries. This limit is also generally accepted in other countries in Europe, including Norway and Switzerland. However, in some countries, notably Austria, Italy, Finland, Sweden and Germany, lower benzene and aromatics limits have either been introduced or are under consideration.

Austria reduced benzene content to 3% v/v maximum from 1 September 1990. (Regulation No. 239. Minister of Environment, Youth and Family, 5 March 1990, subsequently replaced by Regulation No. 123. Minister of Environment, Youth and Family, 1 March 1992). The oil industry agreed, on a voluntary basis to supply Super Plus RON 98 with 1 %v/v maximum from 1 June 1996 and other grades at 2 %v/v max from 1 February 1997. It has also been proposed that the maximum sulphur content of gasolines be reduced from 0.05 to 0.01 %m/m.

In Italy the benzene content of the total gasoline pool was limited to 3.0% v/v from 1 January 1993. This was on the basis of a three month sales weighted production average for each refinery by a voluntary agreement between the Environment Ministry and the oil companies. From January 1995 some companies distributed gasoline with benzene limited to 1.8% v/v max. On 30 September 1995, a Decree concerning the benzene content of gasolines and vapour recovery systems at service stations was adopted by the Italian government. The Decree has temporary validity for two months, during which time it can be approved by Parliament. It can, however, be renewed several times by the Government. From 1 July 1997 a maximum benzene limit of 1.4% v/v will apply to all gasolines. This limit will reduce to 1.0% v/v from 1 July 1999.

There is a lobby within the German Government that considers that the framework directive proposed by the EU Commission does not go nearly far enough in reducing aromatics and benzene contents. The German Ministry of the Environment (BMU) wants limits of 30 %v/v max aromatics and 1 % v/v max benzene for all gasoline grades. It is expected that they will try to introduce an optional specification, with a maximum benzene content of 1 % v/v, using fiscal incentives. Also since October 1995, Superplus gasoline with a 1% v/v benzene content has been made available on a voluntary basis by many oil companies.

Finland commercially introduced reformulated gasolines with benzene contents limited to 3% v/v from January 1993, the sale of which was encouraged by tax incentives. A new grade was introduced commercially in Finland from March 1994, containing less than 1% v/v benzene. Its current market share is approximately 95 per cent and it enjoys the same tax incentive as the 3% v/v benzene gasoline.

Oxygenates

The EU adopted in December 1985, Directive 85/536/EEC on oxygenates in gasoline. The Directive specifies that:

- by 1988 Member States must ensure that there are no legal and administrative obstacles to the sale of gasoline blends containing oxygenates, suitable for use in spark ignition engines designed to operate on gasoline.

- the components and concentrations which are deemed to meet this requirement are outlined in a Technical Annex.

- The following are acceptable for use as substitute fuel components:

- mono-alcohols with an atmospheric boiling point lower than the final atmospheric boiling point laid down in the national gasoline standards;

- ethers, with molecules containing 5 or more carbon atoms, and with atmospheric boiling points lower than the final atmospheric boiling point laid down in the national gasoline standards.

Member States must permit fuel blends containing levels of oxygenates not exceeding the level set out in column A of the table in the technical Annex to the Directive. If they so desire, they may authorize proportions of oxygenates above these levels.

However, if the levels so permitted exceed the limits set out in column B of the Annex table, the pumps which dispense the fuel blend must be very clearly marked accordingly, in particular to take account of variations in the calorific value of such fuels. The main points of the Annex table are set out in **Table A.5.3**.

Table A.5.3 Maximum Oxygenates limits set out in Directive 85/536/EEC

Description	A (% v/v) (3)	B (% v/v)
Methanol, suitable stabilizing agents must be added(1)	3	3
Ethanol, stabilizing agents may be necessary(1)	5	5
Isopropyl alcohol	5	10
Tertiary butyl alcohol	7	7
Iso-butyl alcohol	7	10
Ethers containing 5 or more carbon atoms per molecule(1)	10	15
Other organic oxygenates(2) defined in Annex Section I(1)	7	10
Mixture of any organic oxygenates defined in Annex Section I (1)	2.5% m/m oxygen, not exceeding the individual limits fixed above for each component	3.7% m/m oxygen, not exceeding the individual limits fixed above for each component

(1) In accordance with national specifications or, where these do not exist, industry specifications.

(2) Acetone is authorized up to 0.8% by volume when it is present as by-product of the manufacture of certain organic oxygenate compounds.

(3) Not all countries permit levels exceeding those in column (A) even if the pump is labelled.

A.5.1.3. Diesel fuel

Sulphur Content

European Union

The EU's Council of Environment Ministers, at a meeting in March 1987, agreed to a directive reducing the maximum sulphur content of all gas oils, except those used by shipping or for further processing, to 0.3% m/m and allowed Member States to set a stricter limit of 0.2% m/m in heavily polluted areas. Member States were required to implement the Directive EEC/85/716 by 1.1.89.

Additionally, the Commission was requested to come forward with a proposal before 1.12.91 to set a single limit to be applied throughout the Union. As a result of that request, Directive 93/12/EEC, dated 23.04.93 was adopted, requiring:

- A maximum limit of 0.2% m/m to be applied for all gas oils, including diesel fuel from 1 October 1994.
- A maximum limit of 0.05% m/m for diesel fuel to be implemented by 1 October 1996. Member States in the interim were required to ensure the "*progressive availability*" of a diesel fuel with a sulphur content of 0.05% m/m "*from 1 October 1995*". This was to allow the implementation of the second phase of the "*Clean Lorry*" Directive.
- For all gas oils and aviation kerosene, further reductions in sulphur content below 0.2% m/m were to be considered.

In Austria, under a regulation agreed on 01.03.92, the sulphur limit for diesel fuel was reduced from 0.15% m/m to 0.05% m/m, with effect from 01.10.95.

Denmark introduced tax differentiation for low sulphur (0.05% m/m) diesel fuels with effect from 01.07.92. Two grades were involved, (a CEN Euro standard grade and a Bus diesel fuel).

The sulphur content of diesel fuel in Finland had been limited in the national specification to 0.2% m/m since 1 January 1989 and qualities were also marketed with sulphur contents of 0.005% m/m maximum. Tax incentives were applied to a 0.005 % low-sulphur reformulated grade on 1 July 1993.

Germany introduced a maximum sulphur content of 0.05 %m/m on a voluntary basis from 1st October 1995.

Italy conformed in advance to the earlier EU 1994 limit of 0.2% m/m in the major cities and elsewhere by means of a voluntary agreement between the government and the oil companies (from 1.1.93 in northern and southern Italy, and from 1.10.93 in central Italy). Also the 0.05 %m/m EU limit was introduced earlier than mandated in January 1995, because two Italian companies started to distribute diesel fuel of this quality in the main cities upon the request of local authorities. The 0.05 %m/m limit became mandatory from 1st December 1995.

In Sweden from 1 January 1991 a tax levy of \$3.9/m^3 was imposed on gas oils with a sulphur content between 0.1 and 0.2% m/m. Also from the same date, environmental classifications for diesel fuel were introduced with tax relief for grades with sulphur contents of 0.001 and 0.005% m/m. However, in 1996 the 0.005% m/m sulphur grade was discontinued.

As explained above, all EU countries adopted the 0.05 %m/m limit from 1 October 1996.

Norway

Norway has also adopted the EU limit of 0.05 %m/m. Formerly the maximum sulphur content was 0.5% m/m for both automotive and industrial gas oils, although typical sulphur contents were around 0.2% m/m, due to the processing of North Sea crude oils. There was, however, a combined tax/duty levy which penalised high sulphur gas oils. Fuels with higher sulphur contents could be used in industrial installations with flue gas treatment at the expense of an additional tax/duty levy.

Switzerland

In Switzerland, the sulphur content of diesel fuel was reduced from 0.2% m/m to 0.05% m/m from 1 January 1994.

Special Grades

Denmark, Finland and Sweden have all been marketing special environmental grades by means of tax incentives. These grades have included both sulphur and compositional constraints. At the time of writing this report, it was not established how the change in EU sulphur regulations would affect the structure of the tax incentives. The earlier situation current at the time of writing is described below.

Denmark

A study was made following the introduction on July 1 1992 of an interim diesel fuel quality for public transportation buses. Based on the study, tax rebates were approved for low sulphur fuels, CEN quality with 0.05% m/m sulphur and an “ultra light” diesel. At the same time the diesel tax was increased in two steps - 1 July and 1 October, 1992 - to the EU minimum level. Also the right of VAT-registered business to deduct part of the tax was withdrawn. The low-sulphur CEN grade has now been superseded by the sulphur reduction in the standard CEN specification but the Bus Diesel as been retained. Details of the qualities are shown in **Table A.5.27**.

Finland

On the 1 July 1993, a grade of diesel fuel with low sulphur and aromatics contents and improved cetane number was introduced commercially, with tax incentives (see **Table A.5.27**).

Sweden

On 1 January 1991 two “Environmental Classifications”, EC1 and EC2, were introduced for diesel fuel with sulphur contents of 0.001 and 0.005 %m/m respectively and compositional constraints, but in 1996 the EC2 grade was discontinued. The EC1 grade is supported by a tax incentive compared with the standard European EN590 grade. See **Table A.5.27** for quality details.

A.5.1.4. Alternative Fuels

Vegetable Oil Methyl Esters (Biodiesel)

DG VII has put forward a draft proposal for a Council Directive for a specification for vegetable oil methyl esters (biodiesels) see **Table A.5.31**. The proposal is presented in the framework of EU's ALTENER Programme for the promotion of alternative fuels. Within this programme the EU has the objective of securing a five per cent market share of total motor fuel consumption for biofuels, of which it is expected that biodiesel will form the major share. Some countries, notably Austria and Italy, have already produced their own specifications (see **Tables A5.32** and **A.5.33**).

Rapeseed methyl ester diesel fuels are already sold in Italy but can only be marketed outside retail outlets. A Government Decree fixes a maximum of 125,000 tons per year to be exempted from gas oil excise tax.

In France some thirty cities are using blends incorporating 30% rape seed methyl ester (RME) in diesel fuel and a further thirty towns employ diesel fuel blended with between 5 and 20% RME. The French law on air quality states that a mandatory oxygen content in fuels will be issued in the year 2000. However, status quo could prevail as the RME producers are satisfied with the current position and are having difficulty satisfying demand. RME consumption represents about 1% of diesel fuel demand and pressure for a mandatory minimum oxygenate content is being sustained by the sugar beet industry.

A.5.2. UNITED STATES & CANADA

A.5.2.1. Standard Specifications

ASTM D4814-94 Gasoline Specification

A new specification was issued in 1988 to cover gasoline and its blends with oxygenates such as alcohols and ethers. This specification, which was further revised in 1993 and 1994, is not a legal requirement except in a few states which have adopted it as such. It can consequently be overruled by US Federal legislation on volatility. The specification still contains reference to the lead content and recommended octane level of leaded gasolines. With regard to volatility, six vapour pressure/distillation classes and five vapour lock protection classes are specified. Octane quality is not specifically controlled by the ASTM specification, being left to "*commercial practice*". However, EPA regulations do require a grade with a minimum antiknock index [(RON + MON)/2] of 87 to be sold (see **Table A.5.34**).

ASTM Specifications for Diesel Fuel and Automotive LPG

ASTM D975-94 covers specifications for two grades of 0.05 %m/m automotive gas oil (see **Table A.5.35**). It also has a specification (D1835) for automotive LPG which is technically equivalent to the GPA Standard 2140 HD-5 Grade (see **Table A.5.37**).

A.5.2.2. Gasoline

Lead Content

In the US the EPA imposed a drastic reduction in the permitted lead level in gasoline, from 1.1 g/USgal to 0.5 g/USgal (0.13 g/l) in 1985 and then to 0.1 g/USgal (0.026 g/l) from January 1986, which was considered to be the lowest lead level that would allow continued operation of older engines. Sales of leaded gasoline were banned in California from January 1992. Elsewhere in the United States sales of leaded regular declined to around 1.5% by 1993, and leaded gasoline was finally banned from January 1995. This date coincided with the requirement for reformulated gasoline to be sold in specified areas which did not meet ambient ozone targets.

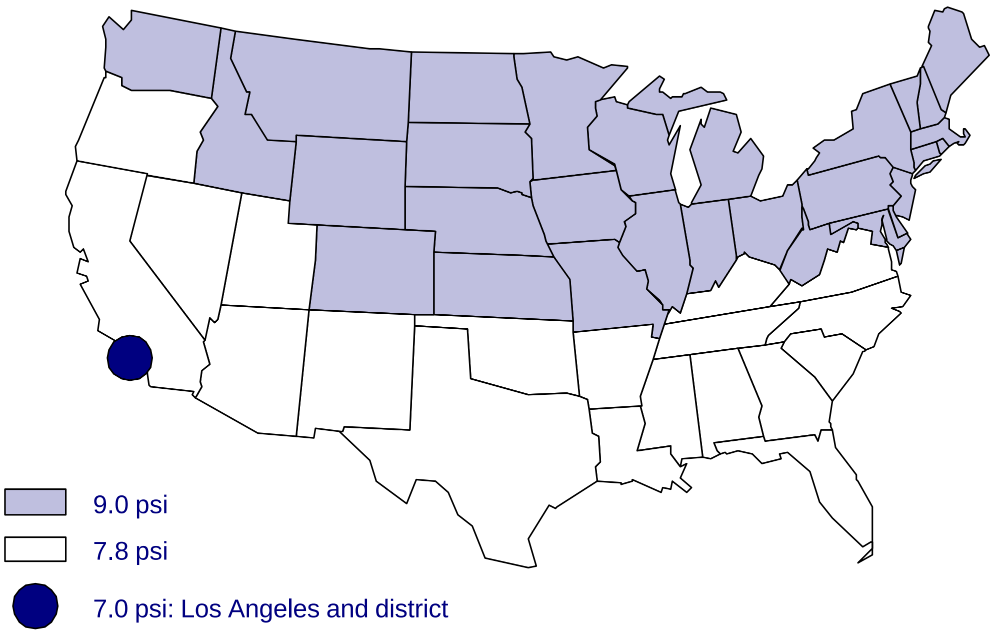
In Canada sales of leaded gasoline has been banned since December 1990.

Volatility

Since 1989 the EPA has imposed maximum limits on gasoline vapour pressure during the summer months (May-September) varying between 9.5 and 10.5 lb. RVP for different states. Since May 1992 these limits have been replaced by the more stringent Phase 2 limits given in **Figure A.5.1**. These are simplified into north and south zones with maximum RVPs of 9.0 psi (62.1 kPa) (May-Sept.) and 7.8 psi (53.8 kPa) (June-Sept.) respectively. A permanent waiver of 1 psi (7 kPa) is allowed for ethanol blends.

From 1 January 1995, RVP will be further restricted in those areas where legislation requires “reformulated gasolines” to 8.1 psi (55.8 kPa) and 7.2 psi (49.6 kPa) respectively. From 1996 an even lower limit of 7.0 psi (48.2 kPa) will be required in California for “Phase 2 reformulated gasolines”.

Figure A.5.1 EPA Phase II RVP Regulations



Canada

In Canada, provincial ministers agreed to limit gasoline volatility to 10.5 psi (72.5 kPa) starting summer 1990, and to institute vapour controls throughout the gasoline distribution and marketing system, also starting in 1990. Since then British Columbia has put a maximum summertime limit on RVP of 9 psi in the Lower Fraser Valley region, but proposals are being considered for waivers for the use of ethanol.

Sulphur Content

Standard gasoline sulphur content is specified at max. 1000 mg/kg/ppm according to ASTM D4814-94 (see **Table A.5.34**). In addition, supplies of conventional gasolines are not allowed to exceed their 1990 sulphur values by more than 25% to comply with the so-called "anti-dumping" rule of the Clean Air Act. Federal US Phase II reformulated gasoline is required not to exceed a refiner's 1990 average sulphur content (statutory baseline of 338 mg/kg - see also the section on **Reformulated Gasoline** below). Californian Phase 2 gasoline is limited to a maximum of 40 mg/km (flat limit, see **Table A.5.2**).

Benzene Content

In the USA benzene content was limited to 1% v/v maximum (or 0.95% v/v period average, with a 1.3% v/v absolute maximum) from 1 January 1995 by implementation of the regulations requiring "*reformulated*" gasoline (see **Section 7.2.2**). Total aromatics are indirectly controlled by the requirement to demonstrate a 15% reduction in the emissions of "air toxics".

In California, the "*Phase 2 Reformulated Gasoline*" required from March 1996 also has a 1% v/v benzene limit (or 0.8% v/v average, with an absolute maximum of 1.2% v/v). Total aromatics are also limited to 25% v/v (or 22% v/v average, absolute maximum of 30% v/v).

Reformulated Gasolines

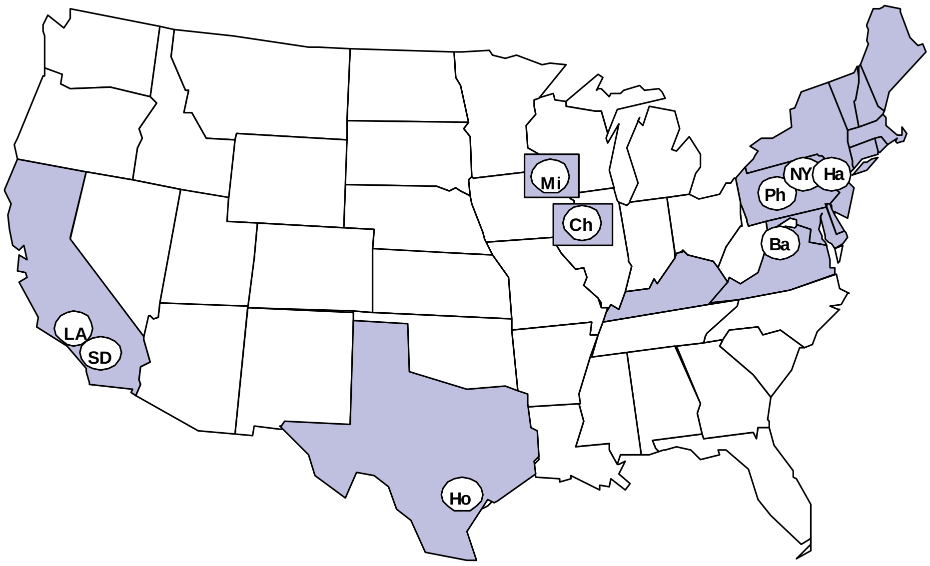
Federal States

The US Clean Air Act includes a requirement for "*Reformulated Gasoline*" to be sold in major cities which fail to meet ambient ozone standards. Other areas with similar problems can also opt into the programme. Following discussions with the oil industry (the so called “Reg-Neg” process) a NPRM was published in the Federal Register on 31 March 1992. The EPA announced the final rule for the reformulated gasoline programme on 15 December 1993.

The programme is being implemented in two phases. Phase I of the programme began on 1 January 1995 and Phase II begins on 1 January 2000. The EPA expects the Phase I programme to achieve a 15 to 17 per cent reduction in both volatile organic compounds (VOC) and in toxic emissions from motor vehicles compared with 1990. The Phase II programme will achieve a 25 to 29 per cent reduction in VOC, a 20 to 22 per cent reduction in toxics emissions and a 5 to 7 per cent NOx reduction. All reductions are relative to the average 1990 US baseline quality.

Reformulated gasoline is required to be sold in the nine worst ozone non-attainment areas (with populations over 250,000) which are: Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York, Philadelphia and San Diego. So far thirteen other states have opted to join the programme: Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Texas and Virginia. The cities and states listed above represent about 30 per cent of all gasoline sold in the United States. If all ozone non-attainment areas decide to opt into the programme, over 50 per cent of the gasoline sold in the US would have to be reformulated. Distribution patterns from terminals may result in a further 5 per cent being supplied to areas not requiring reformulated gasoline.

Figure A.5.2 US Non-attainment cities and "opt-in" states.



All reformulated gasoline must contain a minimum of 2.0% m/m oxygen, a maximum of 1.0% v/v benzene and must not contain heavy metals. Sulphur, T90E and olefins contents are not reduced, but may not be higher than a refiners' 1990 average. A summary of the regulation is given in **Table A.5.4**. In addition, they must meet certain VOC, air toxics and NOx emissions performance requirements, judged against qualities produced in 1990. Emissions performance will be calculated on the basis of empirical "models".

For the first three years (1995-1997), refiners are allowed to use a "simple model" to certify their reformulated gasolines. Besides the compositional constraints with respect to oxygen, benzene and heavy metals, the simple model is designed to reduce VOC emissions by limiting RVP (deemed to be equivalent to a 15% VOC reduction) and total air toxics. The latter are calculated from benzene, 1,3-butadiene, polycyclic organic, formaldehyde and acetaldehyde emissions using formulae given in **Tables A.5.5.1** to **A.5.5.4**

From 1 January 1998, refiners will be required to use a "complex model" for certification. The complex model is a set of equations correlating a gasoline's properties to its emissions characteristics. Refiners may also use this complex model for the first three years if they wish, which should give them more flexibility in meeting the requirements. Refiners can comply with the standards either on a batch (per gallon) basis or on a quarterly average basis. Average limits are more severe overall, but have more latitude on a per gallon basis.

The complex emissions model uses formulae to calculate total VOCs, air toxics and NOx reductions. The exhaust VOC formulae use regression equations based on the RVP, distillation parameters (E200 and E300, in °F) and sulphur, oxygen, aromatics and olefins contents within the ranges given in **Table A.5.7.6**, together with weighting factors based on the emissions characteristics of old and new technology vehicles (**Table A.5.7.2**). These weighting factors may be changed in future years to match the characteristics of the car population.

Calculations of NOx emissions are given in **Table A.5.6.1**, and are based on regression equations based on similar fuel properties to the VOC equations with acceptable ranges given in **Table A.5.7.7** and by applying the same weighting factors. Toxics emissions calculations are given in **Table A.5.6.6**, based on similar fuel properties to the VOC, plus benzene and oxygenate contents and the same weighting factors. They include exhaust emissions of benzene, formaldehyde, acetaldehyde, 1,3-butadiene and non-exhaust emissions of benzene.

The acceptable ranges of fuel properties are given in **Table A.5.7.3** and the allowable ranges of fuel properties for the purposes of the calculations are given in **Tables A.5.7.6** and **Table A.5.7.7** for VOC and NOx emissions respectively. The reader is referred to the Federal Register (Vol. 59 No 32, p.7820-21) for the corrections required to the formulae for fuel characteristics falling outside these ranges.

Supplies of conventional gasolines will also be regulated to prevent any increase in emissions (the so-called "anti-dumping" rule). For the first three years olefins, sulphur, and T90E will not be allowed to exceed their 1990 values by more than 25 per cent and aromatics and benzene will be controlled by means of a formula (BEE, see footnote to **Table A.5.4**). From 1997, emissions of benzene, toxics and NOx will not be allowed to exceed 1990 values and VOC emissions will be controlled by regional RVP limits

All refiners, blenders and importers, even those not supplying reformulated gasoline, are required to provide data of the characteristics of their gasoline production to the EPA for the baseline year 1990, in terms of batches of finished gasoline or components used in blending. Similar data is required for subsequent years. For refiners unable or unwilling to submit an individual baseline, the EPA has calculated a statutory 1990 baseline from market survey data. This data will be used by the EPA to judge a supplier's performance against the requirements of the Act and to prevent dumping of unsuitable components into the conventional gasoline pool. Incremental volumes will be judged against the parameters of the statutory baseline (see **Table A.5.4**).

This last provision applies particularly to foreign refineries, which must export to the US reformulated gasolines complying with the statutory baseline values for olefins, T90 and sulphur content. Therefore, while US refiners have been allowed to run their production at each refinery at usual levels, foreign producers have to comply with three more parameters. In particular, the olefins content limit of the EPA 1990 baseline of 9-12% v/v max. is difficult to meet in refineries with catalytic crackers. In 1994, Venezuela and Brazil complained about this provision, which they consider as a restriction to the free flow of trade towards the US, and have started procedures for settlement under the auspices of the GATT/WTO.

The EPA's Renewable Oxygen Rule (ROR) for a Renewable Oxygen Standard (ROS) was overturned by a federal appeals court. If the rule had stood it would have required reformulated gasolines to contain 15% renewable oxygenates, such as ethanol or ETBE by 1 January 1995 and 30% by 1 January 1996.

Table A.5.4 US Reformulated Gasoline Requirements

Fixed Specification Requirements

Parameter	Batch Basis	Average Basis
Benzene %v/v max.	1.0	0.95 1.3 allowed on a batch
Oxygen %m/m	2.0 - 2.7	
Heavy Metals	None without an EPA waiver	
T90E **Sulphur** **Olefins**	} Average no greater than refiners 1990 average	
Detergent Additives	Compulsory (see **Section A.5.1.2.6**)	

Phase I : Emission Targets (1995-1997 Simple and Complex Models)
(All emission reductions are relative to 1990 baseline quality)

	Simple model (1995-1997)		Simple + Complex	Complex Model (1995-1999)		
Parameter	**RVP** (psi, min)		**Toxics** (% redn)	**VOC** (% reduction) (min)		**NOx** (% reduction) (min)
Region	1 South*	2 North*	all	1 South	2 North	all
Batches	7.2	8.1	15.0	35.1*	15.6	0.0
Average	7.2	8.1	16.5	36.6*	17.1	1.5

(1) * Calculated relative to the Clean Air Act baseline of 8.7 psi.
Reduction relative to 7.8 psi is similar to Region 2

Table A.5.4 (cont.) US Reformulated Gasoline Requirements

Phase II (2000 onwards) - Complex Model
(All emission reductions are relative to 1990 baseline quality)

Parameters	**VOC (% reduction) (min)**		**Toxics (% redn)**	**NOx (% reduction) (min)**
Region	1 South*	2 North*	all	all
Batches	27.5	25.9	20.0	5.5
Average	29.0	27.4	21.5	6.8

* See map **Figure A.5.1**

Statutory Baseline Parameters - 1990 Average Quality

Gravity	59.1	Distillation	
Benzene	1.6 %v/v	T50	207ºF
Aromatics	28.6 %v/v	T90	332ºF
Olefins	10.8 %v/v	E200° F	46 %v
Sulphur	338 ppm	RVP	8.7 lb/in^2

Benzene Exhaust Emissions, BEE mg/mile
= 1.884 + (0.949 x % benzene) + (0.113 x [% aromatics - % benzene])
Cannot exceed 1990 values.

Table A.5.5 Formulae for Toxics Emissions, Simple Model [(1)]

Table A.5.5.1 Calculation of Total Toxics Reductions, Simple Model

$$\text{Total Toxics Reduction \%, Summer 1} = \frac{100\{53.2 - (\text{toxics emissions, summer1, mg/mile})\}}{53.2}$$

$$\text{Total Toxics Reduction \%, Summer 2} = \frac{100\{52.1 - (\text{toxics emissions, summer2, mg/mile})\}}{52.1}$$

$$\text{Total Toxics Reduction \%, Winter} = \frac{100\{55.5 - (\text{toxics emissions, winter, mg/mile})\}}{55.5}$$

The toxics emissions for the summer regions and winter are given in **Tables A.5.5.2** and **A.5.5.3**.

Table A.5.5.2 Calculation of Toxic Emissions, Summer, Regions 1 & 2, mg/mile (4)

Toxic emissions =
exhaust benzene + evaporative benzene + running loss benzene + refuelling benzene + formaldehyde + acetaldehyde + 1,3-butadiene + polycyclic organic matter

Exhaust benzene =

$$\{1.884 + 0.949(\text{benzene}) + 0.113\frac{(\text{aromatics - benzene})}{100}\} \times 1000[\text{exhVOC}]$$

Evaporative benzene emissions = Hot soak benzene + Diurnal benzene emissions

Hot soak benzene emissions =

$$(\text{benzene}) \times 0.679[\text{evapVOC}] \times 1000 \times \{1.4448 - \frac{0.0684(\text{MTBE})}{2.0} - \frac{0.080274(\text{RVP})}{100}\}$$

Diurnal benzene emissions =

$$(\text{benzene}) \times 0.321[\text{evapVOC}] \times 1000 \times \{1.3758 - \frac{0.0579(\text{MTBE})}{2.0}\} - \frac{0.080274(\text{RVP})}{100}\}$$

Running loss benzene emissions =

$$(\text{benzene}) \times [\text{runlossVOC}] \times 1000 \times \{1.4448 - \frac{0.0684(\text{MTBE})}{2.0} - \frac{0.080274(\text{RVP})}{100}\}$$

Refuelling benzene emissions =

$$(\text{benzene}) \times [\text{refuelVOC}] \times 1000 \times \{1.3972 - \frac{0.0591(\text{MTBE})}{2.0} - \frac{0.081507(\text{RVP})}{100}\}$$

1,3-Butadiene emissions = 5.56 x [exhVOC]

Polycyclic organic emissions = 3.15 x [exhVOC]

Formaldehyde (2,3) =

$$12.56[\text{exhVOC}] \times \{1 + \frac{0.421(\text{MTBE+TAME})}{2.7} + \frac{0.358(\text{EtOH})}{3.55} + \frac{0.137(\text{ETBE+ETAE})}{2.7}\}$$

Acetaldehyde (2,3) =

$$8.91[\text{exhVOC}] \times \{1 + \frac{0.078(\text{MTBE+TAME})}{2.7} + \frac{0.865(\text{EtOH})}{3.55} + \frac{0.867(\text{ETBE + ETAE})}{2.7}\}$$

(1) The formulae for the calculation of VOC emissions for Summer, Regions 1 and 2, and Winter are given in **Table A.5.5.4.**

Table A.5.5.3 Calculation of Winter Toxic Emissions, Simple Model, (mg/mile)[4]

Toxic emissions =
exhaust benzene + formaldehyde + acetaldehyde + 1,3-butadiene + polycyclic organic matter

Exhaust benzene =

$$\left\{1.884 + 0.949(\text{benzene}) + 0.113\frac{(\text{aromatics - benzene})}{100}\right\} \times 1000[\text{exhVOC}]$$

1,3-Butadiene emissions = 5.56 x [exhVOC]

Polycyclic organic emissions = 2.13 x [exhVOC]

Formaldehyde and acetaldehyde are calculated as for summer toxic emissions above using the summer exhaust VOC factors.

Table A.5.5.4 Calculation of VOC Emissions Terms, Simple Model, g/mile [4]

Summer Region 1 [5]

Exhaust non-methane VOC emissions [exhVOC] = $0.444 \times \left\{1 - \frac{0.127(\text{oxygen content})}{2.7}\right\}$

Evaporative VOC emissions [evapVOC] = $0.7952 - 0.2461(\text{RVP}) + 0.02293(\text{RVP})^2$

Running loss VOC emissions [runlossVOC] = $0.734 + 0.1096(\text{RVP}) + 0.002791(\text{RVP})^2$

Refuelling VOC emissions [refuelVOC] = $0.04 \times \{0.1667(\text{RVP}) - 0.45\}$

Summer Region 2 [5]

Evaporative VOC emissions [evapVOC] = $0.813 - 0.2393(\text{RVP}) + 0.021239(\text{RVP})^2$

Running loss VOC emissions [runlossVOC] = $0.2963 - 0.1306(\text{RVP}) + 0.016255(\text{RVP})^2$

Exhaust non-methane VOC [exhVOC] and Refuelling VOC [refuelVOC] emissions as per Summer Region 1

Winter [5]

Exhaust non-methane VOC emissions [exhVOC] = $0.656 \times \left\{1 \times \frac{0.127(\text{oxygen content})}{2.7}\right\}$

There are no terms for evaporative VOC [evapVOC], running loss VOC [runlossVOC] or refuelling VOC [refuelVOC] emissions for the winter period.

(1) The model may not be used to determine the VOC or toxics if the following parameters fall outside the limits shown; benzene 0 - 2.5% v/v, RVP 6.6 - 9.0 psi, oxygenates 0 -3.5% m, aromatics 10-45% v/v

(2) Formaldehyde and acetaldehyde calculated only on fuels containing oxygenates

(3) When calculating formaldehyde and acetaldehyde, oxygen in the form of alcohol homologues with molecular weights greater than ethanol shall be evaluated as ethanol. Oxygen in the form of methyl ethers other than TAME and MTBE shall be evaluated as MTBE. Oxygen in the form of ethyl ethers or non-methyl and non-ethyl ethers shall be evaluated as ETBE.

(4) Terms in curved ( ) brackets are fuel components in % v/v, oxygenates in % m/m or RVP in psi. Terms in square [ ] brackets are emissions quoted in g/mile.

(5) Summer period May 1 to September 15, Winter period September 16 to April 30

Table A.5.6 Complex Model Formulae

Table A.5.6.1 Calculation of NOx Emissions, Complex Model

NOx emissions, mg/mile = $NOx(b) + \frac{NOx(b) \times Y_{NOx}(t)}{100}$

where,

NOx(b) = baseline exhaust NOx emissions, mg/mile (see **Table A.5.7.1**)

$Y_{NOx}(t)$ = performance of target fuel (% change from baseline) = $\{w_1 \times \frac{\exp. n_1(t)}{\exp. n_1(b)} + w_2 \times \frac{\exp. n_2(t)}{\exp. n_2(b)} - 1\} \times 100$

w_1, w_2 = weighting factors for normal and higher emitters (see **Table A.5.7.2**)
$n_1(t), n_2(t)$ = NOx equations for normal and higher emitters, target fuel (1)
$n_1(b), n_2(b)$ = NOx equations for normal and higher emitters, base fuel (1)

n_1 = 0.0018571(oxygen) + 0.0006921(sulphur) + 0.0090744(RVP) + 0.0009310(E200) + 0.0008460(E300) + 0.0083632(aromatics) - 0.002774(olefins) - $6.63 \times 10^{-7}(\text{sulphur})^2$ - $0.000119(\text{aromatics})^2 + 0.0003665(\text{olefins})^2$

n_2 = 0.000252(sulphur) - 0.00913(oxygen) - 0.01397(RVP) + 0.000931(E200) - 0.00401(E300) + 0.007097(aromatics) - 0.00276(olefins) + $0.0003665(\text{olefins})^2 - 7.995 \times 10^{-5}(\text{aromatics})^2$

(1) For winter NOx emissions, RVP for both the baseline and target fuels is taken as 8.7 psi.

Table 5.6.2 Calculation of Exhaust Volatile Organic Compounds Emissions, Complex Model

Exhaust VOC Emissions, mg/mile = $VOC(b) + \frac{VOC(b) \times Y_{voc}(t)}{100}$, where

VOC(b) = baseline exhaust VOC emissions, mg/mile (see **Table A.5.7.1)**
$Y_{voc}(t)$ = % change VOC from baseline = $\{w_1 \times \frac{\exp. v_1(t)}{\exp. v_1(b)} + w_2 \times \frac{\exp. v_2(t)}{\exp. v_2(b)} - 1\} \times 100$

w_1, w_2 = weighting factors for normal and higher emitters (see **Table A.5.7.2**)
$v_1(t), v_2(t)$ = VOC equations for normal and higher emitters , target fuel (1)
$v_1(b), v_2(b)$ = VOC equations for normal and higher emitters , base fuel (1)

v_1 = 0.0005219(sulphur) - 0.003641(oxygen) + 0.0289749(RVP) - 0.01447(E200) + $0.0001072(E200)^2$ - 0.068624(E300) + $0.0004087(E300)^2$ + 0.0323712(aromatics) - 0.002858(olefins) - 0.0003481(aromatics x E300)

v_2 = 0.043295(RVP) - 0.003626(oxygen) - 0.000054(sulphur) - 0.013504(E200) - 0.062327(E300) + 0.0282042(aromatics) - 0.002858(olefins) + $0.000106(E200)^2 + 0.000408(E300)^2$ - 0.000287(aromatics)(E300)

(1) For winter exhaust VOC emissions, RVP for both the baseline and target fuels is 8.7 psi.

(2) For fuels with E200 and E300 exceeding the upper limit given in **Table A.5.7.6** the values are taken as equal to the upper limits.

(3) For fuels with E200, E300 and aromatics outside the limits given in **Table A.5.7.6** the value of $Y_{voc}(t)$ is modified by an additional term as given in Federal Register Vol. 59 No.32 p.7820-21.

Table A.5.6.3 Non-Exhaust VOC Emissions

Non-Exhaust VOC Emissions (g/mile)	Phase I (1995-1999)		Phase II (2000 and after)	
	Region I	**Region II**	**Region I**	**Region II**
Diurnal VOC	$0.00736(RVP)^2$ - 0.0790(RVP) + 0.2553	$0.006818(RVP)^2$ - 0.07682(RVP) +0.2610	$0.007385(RVP)^2$ - 0.08981(RVP) +0.3158	$0.004775(RVP)^2$ - 0.05872(RVP) + 0.21306
Hot soak VOC	$0.01557(RVP)^2$ - 0.1671(RVP) + 0.5399	$0.014421(RVP)^2$ - 0.16248(RVP) +0.5520	$0.006654(RVP)^2$ - 0.08009(RVP) +0.2846	$0.006078(RVP)^2$ -0.07474(RVP) +0.27117
Running loss VOC	$0.00279(RVP)^2$ - 0.1096(RVP) - 0.7340	$0.016255(RVP)^2$ -0.1306(RVP) +0.2963	$0.017768(RVP)^2$ -0.18746(RVP) +0.6146	$0.016169(RVP)^2$ - 0.17206(RVP) +0.56724
Refuelling VOC	0.006668(RVP) - 0.0180	0.006668(RVP) -0.0180	0.0004767(RVP) +0.011859	0.004767(RVP) +0.011859
Total non-exhaust VOC(1)	$0.02572(RVP)^2$ - 0.349032(RVP) + 0.0432	$0.037494(RVP)^2$ -0.363232(RVP) +1.0913	$0.031807(RVP)^2$ - 0.3568833(RVP) +1.226859	$0.027022(RVP)^2$ - 0.300753(RVP) + 1.063329

(1) Total non-exhaust VOC is sum of diurnal, hot soak, running loss and refuelling VOC emissions

Table A.5.6.4 Calculation of Winter Non-Exhaust VOC Emissions, Complex Model

Total non-exhaust VOC emissions shall be set at zero under winter conditions

Table A.5.6.5 Calculation of Change in Total VOC Emissions, Complex Model (1)

Change in Total VOC Emissions (%)	Formula (g/mile)	
	Phase I	**Phase II**
Summer, Region 1	$100 \times \frac{(\text{Total VOC} - 1.306)}{1.306}$	$100 \times \frac{(\text{Total VOC} - 1.4663)}{1.4663}$
Summer, Region 2	$100 \times \frac{(\text{Total VOC} - 1.215)}{1.215}$	$100 \times \frac{(\text{Total VOC} - 1.3991)}{1.3391}$
Winter	$100 \times \frac{(\text{Total VOC} - 0.660)}{0.660}$	$100 \times \frac{(\text{Total VOC} - 1.341)}{1.341}$

(1) Total VOC emissions, g/mile = [exhaust VOC (mg/mile)]/1000 + non-exhaust VOC (g/mile)

Table A.5.6.6 Calculation of Toxics Emissions

Summer toxics emissions = exhaust benzene + formaldehyde + acetaldehyde + 1,3-butadiene + polycyclic organic matter + non-exhaust benzene emissions

Exhaust benzene, formaldehyde, acetaldehyde and 1,3-butadiene emissions are calculated using an equation of the type:

$$\text{Emissions} = \frac{E(b) + E(b) \times YE(t)}{100} \quad \text{where,}$$

E(b) =	baseline emission, mg/mile (see **Table A.5.7.5**)
YE(t) =	$\{(W1 \times \frac{\exp E1(t)}{\exp E1(b)} + W2 \times \frac{\exp E2(t)}{\exp E2(b)}) - 1\}$
W1, W2	= weighting factors for normal and higher emitters (see **Table A.5.7.2)**
E1(t), E2(t)	= equations for normal and higher emitters, target fuel
E1(b), E2(b)	= equations for normal and higher emitters, base fuel

E1 for exhaust benzene, b1=	0.0006197(sulphur) - 0.003376(E200) + 0.0265500(aromatics)+ 0.2223900(benzene)
E2 for exhaust benzene, b2=	0.0003370(sulphur) + 0.0112510(E300) + 0.0118820(aromatics) + 0.2223180(benzene) - 0.096047(oxygen)
E1 for formaldehyde, f1	=0.0462131(MTBE) - 0.010226(E300) - 0.007166(aromatics)
E2 for formaldehyde, f2	=0.0462131(MTBE) - 0.010226(E300) -0.007166(aromatics) - 0.031352(olefins)
E1 for acetaldehyde, a1	=0.0002631(sulphur) + 0.0397860(RVP) - 0.012172(E300) - 0.005525(aromatics) - 0.009594(MTBE) + 0.3165800(ETBE) + 0.2492500(ethanol)
E2 for acetaldehyde, a2	=0.0002627(sulphur) - 0.012157(E300) - 0.005548(aromatics) - 0.055980(MTBE) + 0.3164665(ETBE) + 0.2493259(ethanol)
E1 for 1.3-butadiene, d1	=0.0001552(sulphur) - 0.007253(E200) - 0.014866(E300) - 0.004005(aromatics) + 0.0282350(olefins)
E2 for 1,3-butadiene, d2	=0.0436960(olefins) - 0.060771(oxygenate) - 0.007311(E200) - 0.008058(E300) - 0.004005(aromatics)
Polycyclic organic matter emissions	=0.003355 x VOC exhaust emissions

Non-exhaust benzene emissions	= diurnal + hot soak + running loss + refuelling benzene emissions, where:
Hot soak benzene emissions	=10 x (benzene) x (hot soak VOC emissions)(1) x {1.4448 - 0.0342(MTBE) - 0.080274(RVP)}
Diurnal benzene emissions	=10 x (benzene) x (diurnal VOC emissions)(1) x {1.3758 - 0.0290(MTBE) - 0.080274(RVP)}
Running loss benzene emissions	=10 x (benzene) x (running loss VOC emissions)(1) x {1.4448 - 0.0342(MTBE) - 0.080274(RVP)}
Benzene refuelling emissions	=10 x (benzene) x (refuelling VOC emissions)(1) x {1.3972 - 0.0296(MTBE) - 0.081507(RVP)}

(1) As calculated for appropriate Phase and Region in **Table A.5.6.3**

Table A.5.7 Baseline Data for Calculating Complex Equations

Table A.5.7.1 Baseline Exhaust Emissions

Exhaust Pollutant (mg/mile)	**Phase I (1995-1999)**		**Phase II (2000 and after)**	
	Summer	**Winter**	**Summer**	**Winter**
VOC	446	660	907	1341
NOx	660	750	1340	1540
Benzene	26.10	37.57	53.54	77.62
Acetaldehyde	2.19	3.57	4.44	7.25
Formaldehyde	4.85	7.73	9.70	15.34
1,3-Butadiene	4.31	7.27	9.38	15.84
Poly Organic Matter	1.50	2.21	3.04	4.50

Table A.5.7.2 Weighting Factors for Normal and Higher Emitters

	Phase I (1995-1999)		**Phase II (2000 and after)**	
	VOC+Toxics	**NOx**	**VOC+Toxics**	**NOx**
Normal Emitters (w_1)	0.52	0.82	0.444	0.738
Higher Emitters (w_2)	0.48	0.18	0.556	0.262

Table A.5.7.3 Baseline Fuel Properties and Acceptable Range for models

Baseline Fuel Properties			**Limits of Simple Model**	**Acceptable Range (Complex)**	
Fuel Property	**Summer**	**Winter**		**Reformulated**	**Conventional**
Oxygen (%w)	0.0	0.0	0 - 3.5	0.00 - 3.70	0.00 - 3.70
Sulphur (ppm)	339	338		0.0 - 500.0	0.0 - 100.0
RVP (psi)	8.7	11.5	6.6 - 9.0	6.4 - 10.0	6.4 - 11.0
E200 (%v)	41.0	50.0		30.0 - 70.0	30.0 - 70.0
E300 (%v)	83.0	83.0		70.0 - 100.0	70.0 - 100.0
Aromatics (v/v %)	32.0	26.4	10 - 45	0.0 - 50.0	00.0 - 55.0
Olefins (v/v %)	9.2	11.9		0.00 - 25.0	0.00 - 30.0
Benzene (v/v %)	1.53	1.64	0 - 2.5	0.0 - 2.0	0.0 -4.9

Table A.5.7.4 Baseline Non-Exhaust Emissions

Non-Exhaust Pollutant (mg/mile)	Phase I (1995-1999)		Phase II (2000 and after)	
	Region 1	Region 2	Region 1	Region 2
VOC	860.48	769.10	559.31	492.07
Benzene	9.66	8.63	6.24	5.50

Table A.5.7.5 Total Baseline Total VOC, NOx and Toxics Emissions

Pollutant (mg/mile)	Phase I (1995-1999)		Phase II (2000 and after)	
	Region I	Region II	Region I	Region II
Summer				
NOx	660.0	660.0	1340.0	1340.0
VOC	1306.5	1215.1	1466.3	1399.1
Toxics	48.61	47.58	86.34	85.61
Winter				
NOx	750.0	750.0	1540.0	1540.0
VOC	660.0	660.0	1341.0	1341.0
Toxics	58.36	58.36	120.55	120.55

Table A.5.7.6 Allowable Ranges of E200, E300 and Aromatics for Exhaust VOC Equations

Fuel Parameter	Phase I (1995-1999)		Phase II (2000 and after)	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
E200, %v	33.00	65.83	33.00	65.52
E300, %v	72.00	80.32 + {0.390 x (aromatics)}	72.00	79.75 + {0.385 x (aromatics)}
Aromatics, %v	18.00	46.00	18.00	46.00

Table A.5.7.7 Allowable Ranges of Sulphur, Olefins, Aromatics and E300 for NOx Equations

Fuel Parameter	**Phase I (1995-1999)**		**Phase II (2000 and after)**	
	Lower Limit	**Upper Limit**	**Lower Limit**	**Upper Limit**
Sulphur, ppm	10.0	450.0	10.0	450.0
E300, %v	70.0	95.0	70.0	95.0
Olefins, %v	3.77	19.0	3.77	19.0
Aromatics, %v	18.0	36.2	18.0	36.8

California

In California, "*Phase 1*" requirements for reformulated gasoline were introduced for some areas from January 1992 and comprised the following:

- RVP (summer) - 7.8 psi/53.8 kPa max.
- Sales of leaded gasoline were banned.
- Deposit control additives required (to meet the BMW test limits).

The Californian Air Resources Board (CARB) subsequently adopted more stringent limits "*Phase 2*" requirements to replace the previous grade at retail outlets by June 1996. The specification which includes limits on distillation, olefins content and a very stringent limit on sulphur content is detailed below in **Table A.5.8**. The incremental cost compared with Federal RFG has been estimated at $0.10/gal, mainly due to increased hydrodesulphurization costs.

Table A.5.8 California "Phase 2" Reformulated Gasoline Specifications compared with State limits for all gasolines

Parameter (Maximum Limits)	**Producer Limit (1)**	**Averaging Limit**	**All Gasolines Limit**
Volatility (2)	7.0 psi/48.3 kPa	6.8	7.0 psi/48.3 kPa
Sulphur (ppm/m)	40	30	80
Aromatics % v/v	25	22	30
Benzene % v/v	1.0	0.8	1.2
Olefins %v/v	6.0	4.0	10.0
Oxygen % m/m	1.8 - 2.2	2	1.8-2.7
Distillation			
T50 °F (°C)	210 (99)	200 (93)	220 (104)
T90 °F (°C)	300 (149)	290 (143)	330 (166)

(1) Limits set on each batch of fuel produced if averaging is not used.
(2) Summertime only, variable depending upon location.
(3) Deposit control additives are also required, meeting a range of performance tests.

Oxygenates

The use of new components in unleaded gasoline must be approved by the EPA, who must ensure that they will not adversely affect emission control systems.

In the case of oxygenates, the EPA has ruled that aliphatic alcohols and glycols, ethers and polyethers may be added to the fuel, provided that the amount of oxygen in the finished fuel does not exceed 2.7% m/m. However, note should be taken of new limits set out in the Clean Air Act Amendments. Methanol is excluded from this approval.

This is known as the "*substantially* similar" ruling, as these components are considered to be substantially similar to fuels in widespread use before the requirement for EPA approval. This EPA ruling originates from July 1981, when the oxygen content limit was set at 2.0% m/m max. In February 1991, in response to a request from the Oxygenated Fuel Association (OFA), EPA revised the ruling to increase the maximum oxygen limit to 2.7% m/m.

A number of specific proposals have been granted waivers allowing their use as follows:

- "*Gasohol*" consisting of gasoline with 10% v/v ethanol is permitted. This contains 3.5% m/m oxygen. (April 1979).

- A mixture of TBA and methanol up to a maximum concentration of 3.7% m/m oxygen, provided that methanol does not form more than 50% of the mixture. (November 1981).

- Methanol up to 5.0% v/v plus at least 2.5% v/v co-solvent (ethanol, propanols or butanols) plus a corrosion inhibitor, with maximum oxygen content of 3.7% m/m. This is known as the "*Dupont waiver*". (January 1985).

In addition to the foregoing, one section of the 1990 Clean Air Act calls for cities which do not meet ambient air CO level targets in winter to use gasoline containing oxygenates to give 2.7% m/m oxygen.

This has applied during four winter months (November-February) since 1992. In a few cities this requirement may be applied for a longer period. The area covered by the legislation includes 41 cities, which account for some 31 per cent of total winter US gasoline sales. The programme is being closely monitored by the EPA Administrator who has the power to delay implementation for up to 2 years in individual areas if he perceives specific oxygenate supply problems. Trading of oxygen credits within the area is permitted.

California has successfully applied for a waiver to allow the state to set the maximum oxygen level at 2% m/m. The state of Alaska suspended its oxygenates programme in Fairbanks and Anchorage after numerous complaints. The EPA and API have separately conducted new studies on the effects of MTBE on health.

A.5.2.3. Deposit Control Additives

Clean Air Act Amendments Requirement - Proposed Rule

The 1990 CAAA required that “effective January 1 1995, all gasolines in the US must contain additives to prevent the accumulation of deposits in engines and fuel supply systems”. The Act provided no definition of additives or deposits and no guidance as to which parts of the fuel system were to be considered. The final rule was to be promulgated by November 15 1992 and adopted before October 15 1994. In practice a NPRM proposing requirements was not issued by EPA until December 1993.

The EPA had some experience to work on because, since January 1 1992, all gasolines sold or supplied in California have been required to contain deposit control additives which are certified by the CARB for effectiveness.

As with the CARB requirements, the EPA proposal defined additive performance by requiring certification of additives in a port fuel injector (PFI) keep clean test and the BMW intake valve deposit (IVD) test, using fuels with certain minimum specification requirements. Note that, in addition, CARB requires a PFI clean up test.

The PFI keep clean test uses the 2.2-litre Chrysler turbocharged engine. Under the EPA’s proposal 10,000 miles must be accumulated on a vehicle using repetitions of a standard PFI test cycle comprising 15 minutes at 55 mph, followed by a 45-minute shutdown soak period. As the method is not yet fully standardised the EPA is proposing to use a draft ASTM procedure. The EPA will require a performance equivalent to the CARB standard; i.e., no injector may experience a flow restriction greater than 5%.

The BMW IVD Test uses a 1985 BMW 318i four-cylinder eight-valve naturally aspirated engine. Deposits are accumulated in a road driving cycle involving 70 per cent highway, 20 per cent suburban and 10 per cent city driving. The CARB pass requirement is a maximum average deposit on the four intake valves of not more than 100 mg after 10,000 miles. The EPA is considering alternative limits of 100 mg maximum on any single valve after 10,000 miles or 25 mg on any single valve after 5,000 miles. Either requirement is significantly more severe than the CARB requirement. The CARB, however, also stipulates a PFI clean-up requirement. In this test, deposits must be built up on at least one injector to give a minimum of 10 per cent flow restriction. Then the cleanliness of all injectors must be restored to less than 5 per cent flow restriction within a further 10,000 miles of test cycles using the test gasoline.

Recognizing that it would be impractical to fully certify all deposit control additives before the 1 January 1995 deadline, the EPA instituted an interim certification procedure. In this, the EPA proposed that all gasolines sold must contain a detergent additive, which has been given an interim certification number at a specified treatment level. Gasolines proved under the CARB programme will automatically qualify. Interim detergency certification numbers will be allocated to only four classes of deposit control additive with molecular weights of at least 900:

- polyalkylamines
- polyetheramines
- polyalkylsuccinimides
- polyalkylamino-phenols

To qualify, the additive manufacturers must recommend the minimum concentration of additive to meet the performance standards and provide a test method to identify the additive in its pure form.

Since 1 January 1996, all gasolines have to contain detergent additives certified by the EPA for effectiveness. The certification establishes the minimum amount of additive that must be used and limits for some properties of the base gasoline (T90E, olefins, aromatics, sulphur and oxygenates by type). The EPA is proposing four major generic categories for certification, depending on the definition of the base fuel quality i.e.:

- National
- Specific to the Petroleum Administration for Defense Districts (PADD)
- Fuel specific
- CARB (PADD V)

Gasolines blended with detergents certified under the generic national certification can be marketed anywhere in the US. However, the base gasoline cannot exceed the limits given in **Table A.5.9**. Such additive certification requires passing the BMW and PFI tests in four different test fuels, taken from four different refineries or distribution systems, and at least two different PADDs. **Table A.5.10** lists the minimum properties for each of these fuels. If the properties of the base gasoline exceed the limitations given in **Table A.5.9**, then an additive must be used meeting a more severe national certification level using fuels with higher values than those given in **Table A.5.10**.

Gasolines sold only within a given PADD must still have base gasoline qualities meeting the requirements given in **Table A.5.9** but the test fuel qualities can be restricted to those specified for that district. Like the national requirements, base gasolines having properties exceeding those in **Table A.5.9** must use deposit control additives certified in test fuels with properties representing the more severe base gasoline. Gasolines using detergents with fuel-specific certification must remain segregated from production through distribution to the end user. The test fuels in a segregated system must meet or exceed the segregated gasoline's 65th percentile level for critical fuel properties. Gasolines using detergents certified for deposit control effectiveness by CARB will automatically qualify for national certification in 1995 and PADD V certification in 1996. For each detergent blending facility, weekly gasoline samples must be taken and analyzed for the four critical properties. This data base serves to demonstrate that base gasolines continue to have properties within those detailed in **Table A.5.9**. If any single measurement exceeds specification, a statistical distribution curve for each property must be prepared (using the past year's data). The 65th percentile then becomes the minimum level for certification of the test fuel. Such an occurrence may require new testing and detergent certification.

New statistical distribution curves must be prepared twice a year, employing a full year's data. If the new 65th percentile for any property exceeds the previous 75th percentile, then the detergent must be certified with the test fuel at the new 65th percentile. The detergent blender has 90 days to comply with the new requirement.

Because it will be very difficult to enforce compliance by means of analytical testing for additive addition, the EPA propose to institute a system in which fuel marketers must maintain records of additive inventories and usage. For blending installations using automated additive injection equipment a weekly mass balance will be required. For non-automated systems an additive balance record must be obtained by recording every addition made (even to batches as small as road tankers). These records must be kept for at least five years and no tolerance below the amount stipulated for certification will be allowed. Weekly analyses of the critical fuel parameters must also be made, initially for six months to characterise the gasoline pool, and then indefinitely to ensure compliance.

Table A.5.9 Maximum Allowed Compositional Limits for Base Gasoline

Generic Certification	Sulphur %m/m	T90E °F	Olefins %v	Aromatics %v
National	0.085	356	18.7	41.2
PADD I	0.071	358	22.2	42.5
PADD II	0.089	352	14.4	38.3
PADD III	0.075	358	18.2	39.5
PADD IV	0.106	344	19.4	31.15
PADD V	0.04	352	11.5	44.2

Table A.5.10 Required Minimal Fuel Parameter Values for Certification

Test Fuel		Sulphur %m/m	T90E ° F	Olefins %v	Aromatics %v	MTBE %v	EtOH %v
National	TF 1	0.033	340	-	-	None	10
	TF 2	-	340	10.7	-	15	None
	TF 3	0.033	-	10.7	-	None	None
	TF 4	-	336	-	29.2	None	None
PADD I	TF 1	0.036	344	-	-	None	10
	TF 2	-	344	13.3	-	15	None
	TF 3	0.036	-	13.3	-	None	None
	TF 4	-	338	-	29.2	None	None
PADD II	TF 1	0.035	340	-	-	None	10
	TF 2	-	340	9.5	-	15	None
	TF 3	0.033	-	8.9	-	None	None
	TF 4	-	338	-	28.6	None	None
PADD III	TF 1	0.030	344	-	-	None	10
	TF 2	-	344	12.7	-	15	None
	TF 3	0.030	-	12.7	-	None	None
	TF 4	-	340	-	29.1	None	None
PADD IV	TF 1	0.052	329	-	-	None	10
	TF 2	-	329	11.2	-	15	none
	TF 3	0.045	-	10.5	-	None	None
	TF 4	-	331	-	24.6	None	none
PADD V	TF 1	0.015	335	-	-	None	10
	TF 2	-	336	7.0	-	15	none
	TF 3	0.016	-	7.0	-	None	None
	TF 4	-	332	-	32.3	None	none

(1) The Defense Districts comprise the following States:
PADD I; Connecticut, Delaware, District of Columbia, Florida, Georgia, Maine, Maryland, Massachusetts, New York, New Hampshire, New Jersey, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, West Virginia;
PADD II; Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Tennessee, Wisconsin;
PADD III; Alabama, Arkansas, Louisiana, Mississippi, New Mexico, Texas;
PADD IV; Colorado, Idaho, Montana, Utah, Wyoming;
PADD V; Arizona, California, Nevada, Oregon, Washington.

A.5.2.4. Alternative Anti-Knock Additives

The reformulated gasoline requirements also includes a ban on the use of other heavy metals without a specific waiver. The US Court of Appeals for the District of Columbia ruled on the 14 April 1995 that EPA must grant a waiver to the Ethyl Corporation to allow the use of MMT in gasoline, as EPA has a mandate to consider only emissions effects and not matters of public health. Following the decision, EPA pointed out that the additive must be registered before it can be sold and the Clean Air Act requires that fuel additives be tested and their health effects studied before they can be registered. EPA indicated that it will require the additive and its combustion products to be thoroughly tested for health effects during the registration process. EPA also stated that it has concerns regarding the effect of the additive on emissions control systems, particularly on-board diagnostic systems. The AAMA continue to lobby for a ban on MMT.

A bill before the Canadian Parliament to ban MMT failed to gain assent as it was decided to start proceedings afresh after the end of the last session. It is uncertain now what the situation will be in the new session regarding MMT or a proposal to introduce a national specification for gasolines. It is possible that the allowable concentration of 0.0625 g/gal will be halved in any new legislation.

A.5.2.5. Diesel Fuel

Sulphur Content

In the US a sulphur limit of 0.05% m/m has been adopted by the EPA and made effective from 1 October 1993 for on-highway diesel fuel. In California 0.05% m/m was introduced as part of a new specification.

California Compositional Specifications

In California, the California Air Resources Board (CARB) adopted a diesel fuel specification of 0.05% m/m sulphur and 10% v/v aromatics from 1 October 1993. The intention is to provide fuel quality that will ensure low emissions, and other fuels are allowed, provided the supplier can demonstrate equivalent emissions to a reference fuel from engine test data. The current specification for the reference fuel is shown in **Table A.5.11**

Table A.5.11 Californian Diesel Reference Fuel Specification

Property	Limit
Sulphur % m/m (max.)	0.05
Aromatics % v/v (max.)	10.0
Polycyclic aromatics, % m/m (max.)	1.4
Nitrogen, ppm m (max.)	10.0
Natural cetane number, (min)	48.0
API gravity	33-39
Viscosity at 40°C, mm^2/s	2.0-4.1
Flash Point °F (min)	130
Distillation °F (°C):	
IBP	550-610 (290-320)
10%	340-420 (170-215)
50%	400-490 (205-255)
90%	470-560 (245-295)
FBP	580-660 (305-350)

The reference fuel is produced from straight-run California fuel by hydro-dearomatization and testing is carried out over the hot start US Federal heavy-duty transient procedure (see **Section A.2**), in a 1991 US heavy duty emissions standard engine. A number of California fuel suppliers have certified *"low emissions"* diesel fuels with alternative compositions by demonstrating with testing that they produce emissions at least as low as the specified reference fuel. Such alternative grades generally have a much higher cetane number (48) and somewhat higher aromatics (10% v/v) than the reference fuel. The properties of one of these fuels is given in **Table A.5.12** below, showing that the strict limits given in **Table A.5.11** do not have to be complied with to achieve the required emissions levels.

Table A.A.5.12 Example of a Certified Diesel Fuel Formulation

Property	Specification	Test Method
Aromatics %m/m (max.)	19	ASTM D5186-91
Sulphur ppm m (max.)	54	ASTM D2622-82
Polycyclic Aromatic Hydrocarbons %m/m (max.)	2.2	ASTM D2425-83
Nitrogen ppm m (max.)	484	ASTM D4629-86
Cetane Number (min)	58	ASTM D613-84
Additives	No additive other than cetane improver	

A.5.2.6. Alternative Fuels

Contrary to President Bush's original proposals, the final version of the Clean Air Act Amendments contain no mandate for the introduction of alternative fuels. Instead it describes performance criteria for *"clean alternative fuels"* which may include *"methanol and ethanol (and mixtures thereof), reformulated gasoline, natural gas, LPG, electricity and any other fuel which permits vehicles to attain legislated emission standards".* The background to this is described in more detail in **Section A.1.3**.

With the exception of the specification for LPG given in **Table A.5.37**, there are no official ASTM specifications for alternative fuels.

Natural Gas

Variations in gaseous fuel composition can affect the level of pollutant emissions by affecting the air-fuel ratio. There is a good linear correlation between air-fuel ratio and the Wobbe index or number of a gas ($W = H/\sqrt{\rho}$, where H is the volumetric heating value and ρ is the specific gravity). Reasonable variations in Wobbe index have little effect on emissions from light-duty vehicles using modern engine technology with three-way catalysts and closed-loop feedback control.

However in addition to their effects on the Wobbe index, differences in the concentration of different hydrocarbons in the fuel can affect the species composition and reactivity of the HC emissions in the exhaust. The proportion of non-methane hydrocarbons in the fuel gas directly affects the level of NMHC emissions in the exhaust In order to limit the possible increase in pollutant emissions due to variation in natural gas properties, the California Air Resources Board has established specification limits for natural gas sold commercially as vehicle fuel. Both the Air Resources Board and the US EPA have also established limits for natural gas used in emissions certification testing. These limits are summarized in **Table A.5.38**.

Liquefied Petroleum Gas (LPG)

The effects of varying LPG composition on the exhaust hydrocarbon species and reactivity have not been documented. However, according to the Carter reactivity scale (used by the California Air Resources Board), olefins such as propene and butenes are much more reactive in contributing to ozone formation than paraffins such as propane and the butanes. It has been argued that increasing the olefin content of LPG will result in increased ozone-forming potential in the exhaust. In order to reduce the possibility of emissions increases due to variation in LPG composition, the California Air Resources Board therefore requires that LPG sold for automotive use in California comply with the HD-5 standard in the ASTM D 1835 (see **Table A.5.37**). Due to concerns about supply availability, the maximum 5% propene content required by the HD-5 specification has been delayed until 1 January 1997. In the intervening period, LPG containing up to 10% propene is permitted.

A.5.3. ASIA

A.5.3.1. Gasoline

The main trends for gasoline quality in Asian countries are given in **Part 1**. Details of the gasoline specifications are given in this section and **Tables A5.40** to **A.5.45**.

Hong Kong

Leaded premium, intermediate and regular grades are marketed (**Table A.5.41**). The country also has unleaded grades with similar properties to the leaded grades but there are proposals to introduce an unleaded premium by 1st October 1996, with benzene limited to 5 %v/v and with the option of adding oxygenates according to EU Directive 85/536/EEC (**Table A.5.3**).

India

The phasing out of lead is being programmed. Already unleaded regular has been introduced in Delhi, Madras, Bombay and Calcutta from 1 April 1995. An unleaded premium grade will be introduced from 2000 and the specification will include tighter volatility limits. The gasoline specifications make provision for gasoline/alcohol blends (**Table A.5.39**).

Indonesia

A leaded 88 octane "premium" is the only grade available but 10%v MTBE can be added at service stations to produce a 91.5 RON "Premix" (**Table A.5.38**).

Japan

Unleaded regular gasoline was introduced in 1975 and the market became totally unleaded in 1987. Following an amendment to the air pollution laws in April 1995, it was required that from 1 April 1996 gasoline specifications should include mandatory limits on sulphur (0.01 %m/m), benzene (5 %v/v), methanol (nil) and MTBE (7 %v/v max). There are, however, currently no specification limits on aromatics content or olefins content and typical values range from 25-47 %v/v and below 33 %v/v respectively. Sulphur contents average around 35 ppm, well below the 100 ppm limit. The limit on benzene content will be revised downwards by mid-1997, following a review of emissions legislation due to be completed by October 1996 (see **Table A.5.42**).

Malaysia

From 1st January 1995, the specified grades were reduced from three to two, a leaded regular (0.15 gPb/l) and an unleaded premium. There are plans to remove lead completely in the near future (see **Table A.5.42**).

Philippines

An unleaded 93 ON premium grade was introduced in 1994 alongside the standard 93 RON / 0.15 gPb/l grade. The unleaded specification also introduced limits on aromatics and benzene and allowed the use of ethers. Petronas production of these grades is produced to 95 RON, better than the minimum requirements of the standard specification (see **Table A.5.43**).

Singapore

Singapore has a leaded premium, with a lead content of 0.15 g/l max, and unleaded superpremium and regular grades. The government is likely to reduce the benzene content of gasolines to below 3 %v/v by 2000.

South Korea

South Korea has had unleaded grades since 1986/7 and became totally unleaded in 1993. The premium and regular unleaded grades have specified limits of 50.0 %v/v aromatics, 5.0 %v/v benzene and a requirement for the addition of a minimum of 0.75 %m/m oxygen as oxygenates. There are proposals to change these limits to 40.0 %v/v max 4.0 %v/v max and 1.0 %m/m min respectively during 1998 (see **Table A.5.42**).

Taiwan

Taiwan has a premium leaded grade and unleaded premium and regular, available since June 1990 and May 1986 respectively. The government are intending to reduce the lead content of the leaded grade from 0.08 to 0.026 g/l by July 1997 and be totally unleaded by January 2000. It is proposed to introduce a 30 %v/v aromatics limit by July 1996. It is also proposed to reduce the benzene contents of all grades from the present limit of 3.5 %v/v to 3.0 %v/v by July 1997 and to 1.0 %v/v by January 2000 (see **Table A.5.41**).

Thailand

Thailand introduced unleaded reformulated gasoline specifications on the 1 January 1993 incorporating a number of changes, including two types of premium leaded and unleaded grades, Type 2 for Bangkok and other cities and Type 1 for rural areas. The Type 1 specifications contain a number of compositional constraints including maximum limits for benzene (3.5 %v/v), aromatics (50 %v/v) and a minimum oxygenate addition of 5.5 %v/v. The aromatics limit will be reduced to 35 % v/v from 1 January 2000. Additives to control injector and inlet valve deposits are also required (see **Table A.5.13**). The Type 2 specifications in addition require a minimum concentration of MTBE. The specification for the regular grade also requires detergent additives from 1 January 1995 at the time when it becomes unleaded.

Table A.5.13 Thai Gasolines - Compositional Constraints

Property	Regular	Premium Leaded		Premium Unleaded	
		Type 1	Type 2	Type 1	Type 2
Lead content g/l	0.15[(1)]	0.15	0.15	0.013	0.013
Sulphur %m min	0.15	0.15	0.15	0.10	0.10
Benzene %v max	3.5	3.5	3.5	3.5	3.5
Aromatics %v max					
from 1.1.1994	-	50	50	50	50
from 1.1.2000	-	35	35	35	35
MTBE %v					
min	-	-	5.5	-	5.5
max	10.0	10.0	10.0	10.0	10.0
PFI/IVD Additive[(2)]					
before 1.1.1995	-	+	+	+	+
after 1.1.1995	+	+	+	+	+

(1) Reduces to 0.013 from January 1995

(2) Required to meet the Californian BMW 318i Test - see **Section A.5.2.3.**

A.5.3.2. Diesel Fuel

There is no specific legislation in Asian countries imposing compositional constraints on automotive diesel fuels. However, the former relatively high sulphur levels are gradually being reduced. Hong Kong is proposing to reduce the sulphur content of its diesel fuel from 0.2 to 0.05 from 1 April 1997. In India, it is proposed to reduce sulphur contents from 1.0 %m/m to 0.50 %m/m by 1998 and to 0.25 %m/m by 2000. Oil suppliers have been asked to make their best endeavours to reduce sulphur levels before 1998. The Japanese petroleum industry reduced the sulphur content of Japanese diesel fuel to 0.20 %m/m from October 1992 and has agreed to further reduce it to 0.05 %m/m from May 1997. In Malaysia, sulphur content is scheduled to be reduced from 0.5 %m/m to 0.2 %m/m by 1997 and to 0.05 %m/m by 2000. The sulphur content of automotive diesel fuel in Singapore was reduced from 0.5 %m/m to 0.3 %m/m on 1 July 1996. Taiwan reduced the sulphur content of diesel fuel from 0.5 %m/m to 0.3 %m/m in July 1993 and is planning to reduce it further to 0.05 %m/m, possibly by 1997. The Ministry of Commerce of Thailand issued a specification for diesel fuels on the 1 January 1993 giving a phased reduction of sulphur for diesel fuel used in cities from the level of ASTM 0.5 %m/m max current at that time to 0.25 %m/m from 01.01.96 and 0.05 %m/m from 01.01.2000. The sulphur content of diesel fuel used in country areas has been reduced from 1.0 %m/m to 0.5 %m/m max from 1 September 1993. Details of specifications are given in **Tables A.5.46** to **A.5.48**.

A.5.4. CENTRAL & SOUTH AMERICA

A.5.4.1. Gasoline

The grade structures and lead contents of gasolines sold in Central and South America are discussed in **Part 1**. Details of Mexican and Venezuelan gasoline specifications are given in **Table A.5.47**, specifications on ethanol grades for Brazil are given in **Table A.5.48** and gasoline grade structures for Argentina, Chile, Columbia and Ecuador in **Table A.5.49**.

A.5.4.2. Diesel Fuels

The quality trends of diesel fuels marketed in Central and South America are briefly discussed in **Part 1** Specifications are given for Brazil, Mexico, Puerto Rico and Venezuela in **Tables A.5.52** and **A.5.53**.

A.5.5. MIDDLE EAST & AFRICA

A.5.5.1. Gasoline

Lead Content

Unleaded grades are available in Iran, Israel, Morocco, Turkey, Tunisia and the UAE., South Africa planned to introduce unleaded grades in 1995, possibly with tax incentives. In coastal areas, leaded 97 octane would be retained but leaded 93 octane gasoline will be phased out and replaced by 95 octane unleaded. Inland 87 octane would be replaced by 91 octane unleaded, while leaded 95 octane will be retained (see **Tables A.5.56, A.5.57** and **A.5.17** for grade structures/lead contents and sales volumes respectively). South African gasoline specifications are detailed in **Tables A.5.54** and **A.5.55**.

A.5.5.2. Diesel Fuel

Sulphur contents are generally in the range 0.50 to 1.00 %m/m.

Table A.5.14 African and Middle Eastern diesel fuel sulphur contents

Country	Sulphur %m/m (typical or max)	Country	Sulphur %m/m (typical or max)	Country	Sulphur %m/m (typical or max)
AFRICA		AFRICA (cont.)		MIDDLE EAST	
Algeria	0.25	Morocco	1.00	Bahrain	1.00
Cameroon	1.00	Mozambique	0.55	Iran	1.00
Egypt	0.88	South Africa	0.50	Israel	0.20
Gabon	0.80	Tunisia	0.20	Jordan	0.60/ 1.25
Ghana	0.12	Zaire	1.00	Kuwait	1.00
Malawi	0.55	Zambia	0.50/1.00	Oman	0.50
Mauritius	1.00	Zimbabwe	0.55	Saudi Arabia	0.30
				Syria	0.70
				UAE	0.50

A.5.5.3. Alternative Fuels

In South Africa, 8-12% alcohol has been incorporated into the 93 RON grade manufactured by the SASOL oil-from-coal process for a number of years. The alcohol must contain a minimum of 85 %m/m ethanol, the balance being mainly iso-propanol and n-propanol. The new 95 RON and 91 RON unleaded gasoline specifications require a maximum of 2.8 or 3.7 %m/m oxygen (7.5 or 9.5 %v/v alcohol) respectively.

It has been difficult to obtain definitive information on gasoline and diesel fuel quality in most African and Middle Eastern countries. Limited information is discussed in **Part 1**.

A.5.6. AUSTRALASIA

A.5.6.1. Gasoline

Australia introduced unleaded gasoline in 1986 and benzene contents are limited to 5 %v/v. In New Zealand the lead content of leaded grades was limited in 1986 by agreement to a maximum of 0.45 gPb/l. A 91 RON unleaded regular was introduced in 1987 and a 96 RON grade has been available since the beginning of 1996, and a total ban on leaded gasoline is under consideration. New Zealand reduced its benzene limit to 3 %v/v in 1995. The introduction of the unleaded premium grade has resulted in problems with seals in fuel systems due to the high aromatics content and, following public concern, the oil companies limited aromatics content to 48 %v/v, with a maximum of 40 % toluene plus xylene.

The penetration of unleaded gasolines in the Australian and New Zealand markets for the years 1984 to 1995 are given in **Table A5.15**, together with those of other OECD countries.

A.5.6.2. Diesel Fuel

The sulphur content of diesel fuel in Australia is set at 0.40 %m/m. By agreement with suppliers, the sulphur content of automotive gas oil has been limited to 0.3 %m/m. The sulphur content of diesel fuel in New Zealand is also limited to 0.3 %m/m.

STATISTICAL DATA ON FUEL CONSUMPTION AND SHARES OF UNLEADED VERSUS LEADED FUELS

Table A.5.15 Consumption of Unleaded Gasoline in OECD Countries ('000 metric tonnes)

	1985	1986	1987	1988	1989	1990	1991	1992	1994	1995
Canada	11930	13656	15483	18247	21552	24051	24112	24460	36219	n/a
United States	187000	204957	233142	257845	280516	294182	296763	309484	337465	344053
Austria	N/A	570	722	886	1104	1313	1635	1791	2483	2393
Belgium	0	4	7	14	443	664	1028	1362	1843	1947
Denmark	0	152	443	506	621	913	1095	1262	2491	n/a
Finland	0	0	N/A	264	398	1033	1146	1394	1916	1897
France	0	2	13	47	435	2597	4306	5664	7537	7781
Germany(1)	N/A	704	6393	11570	15198	18517	24483	26692	27503	28468
Greece	0	0	0	0	10	44	234	434	740	n/a
Iceland	0	0	0	0	7	46	81	87	115	118
Ireland	0	0	0	0	60	168	234	314	484	578
Italy	0	0	0	89	273	667	1018	2135	5646	7033
Luxembourg	0	0	0	33	78	124	217	306	410	398
Netherlands	N/A	532	708	883	1294	1696	2067	2542	3139	n/a
Norway	N/A	280	330	402	485	639	809	937	1589	1581
Portugal	0	0	0	0	4	23	127	221	549	673
Spain	0	0	4	13	28	98	233	362	1946	2630
Sweden	N/A	280	625	1571	1893	2375	2417	2586	4237	4288
Switzerland	243	621	898	1250	1566	1885	2207	2579	2925	3000
Turkey	0	0	0	0	1	8	15	20	105	165
United Kingdom	0	0	18	258	4652	8255	9868	11204	13162	13831
OECD EUROPE	**243**	**3145**	**10161**	**17786**	**28550**	**41065**	**53220**	**61892**	**78820**	**85250**(2)
Australia	192	638	1328	2061	2599	3742	4139	4726	6905	7624
Japan	26878	27506	27987	29023	30782	32624	33683	34608	30620	n/a
New Zealand	0	0	80	128	203	379	597	708	935	1049
OECD TOTAL	**226243**	**249902**	**288181**	**325090**	**364202**	**396043**	**412514**	**435878**	**490964**	**510000**(2)

(1) Data for Germany exclude the new federal states prior to 1991

(2) Estimated

Table A.5.16 Consumption of Unleaded Gasoline in OECD Countries (per cent total gasoline)

	1985	1986	1987	1988	1989	1990	1991	1992	1994	1995
Canada	49.6	56.5	63.4	72.7	84.3	96.4	99.9	100.0	100.0	100.0
United States	64.5	69.0	75.9	81.7	88.8	94.7	96.5	98.5	100.0	100.0
Austria	N/A	23.2	28.9	34.6	42.6	51.3	58.5	67.0	100.0	100.0
Belgium	0.0	0.1	0.2	0.5	15.4	24.3	37.5	46.9	64.9	68.7
Denmark	0.0	10.0	29.0	32.6	40.7	56.9	64.4	70.7	100.0	100.0
Finland	0.0	0.0	N/A	14.5	20.5	52.0	57.8	70.0	99.8	100.0
France	0.0	0.0	0.1	0.3	2.5	15.3	25.8	35.0	45.8	50.2
Germany[(1)]	N/A	2.6	22.6	39.4	51.4	59.2	78.0	84.9	92.3	94.5
Greece	0.0	0.0	0.0	0.0	0.4	1.8	9.4	16.8	27.7	n/a
Iceland	0.0	0.0	0.0	0.0	5.6	34.3	58.3	64.4	83.9	86.7
Ireland	0.0	0.0	0.0	0.0	7.0	19.0	25.9	32.3	49.0	56.5
Italy	0.0	0.0	0.0	0.7	2.1	4.8	6.8	13.0	33.3	40.2
Luxembourg	0.0	0.0	0.0	10.1	20.7	30.1	44.9	58.5	67.8	79.1
Netherlands	N/A	15.3	20.8	26.3	37.9	49.2	59.8	70.8	80.6	n/a
Norway	N/A	16.5	18.8	22.6	27.2	35.7	46.6	55.2	92.3	93.1
Portugal	0.0	0.0	0.0	0.0	0.3	1.7	8.4	13.1	29.6	35.6
Spain	0.0	0.0	0.1	0.2	0.4	1.2	2.7	3.9	22.3	29.0
Sweden	N/A	7.1	15.3	37.0	43.0	57.0	56.9	59.4	100.0	100.0
Switzerland	7.9	19.2	26.9	36.1	44.4	50.6	57.2	64.5	78.9	83.8
Turkey	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.6	2.9	4.1
United Kingdom	0.0	0.0	0.1	1.1	19.4	34.0	41.1	46.9	57.6	63.0
OECD EUROPE	**0.2**	**2.8**	**8.9**	**14.9**	**23.5**	**32.8**	**42.0**	**47.8**	**66.32**	**70.0** [(2)]
Australia	1.7	5.4	11.3	17.0	20.7	28.9	33.4	37.9	52.9	58.0
Japan	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
New Zealand	0.0	0.0	4.7	7.1	10.8	19.7	30.9	35.9	45.7	49.9
OECD TOTAL	**49.1**	**52.8**	**59.1**	**64.6**	**71.7**	**77.9**	**81.4**	**84.3**	**90.1**	**93.0** [(2)]

(1) Data for Germany exclude the new federal states prior to 1991

(2) Estimated

Table A.5.17 Gasoline consumption ('1000mt) and percent unleaded gasoline for 1994/1995 for non-OECD Countries

Country	Consumption		% Unleaded		Country	Consumption		% Unleaded	
	1994	1995	1994	1995		1994	1995	1994	1995
Rest of Europe					**South America (continued)**				
Bulgaria	n/a	860	n/a	1.2	Colombia	5421	5554	100.0	100.0
Croatia	552	n/a	22.1	n/a	Ecuador	1194	1254	10.1	20.7
Cyprus	179	184	4.5	6.52	Mexico	21513	22000	46.0	60.0
Czech Republic	1673	1676	37.1	46.7	Venezuela	8103	8323	nil	nil
Macedonia	180	172	2.8	4.1	**Africa**				
Poland	4564	n/a	22.9	n/a	Algeria	2209	2075	nil	nil
Romania	1017	n/a	nil	n/a	Cameroon	297	308	nil	nil
Slovakia	494	520	81.2	97.5	Egypt	1878	1951	nil	nil
Asia					Gabon	30	34	nil	nil
Bangladesh	170	204	nil	nil	Ghana	370	n/a	nil	n/a
Brunei	192	205	38.0	40.0	Malawi	56	56	nil	nil
China	17422	n/a	33.1	n/a	Mauritius	79	85	nil	nil
Hong Kong	338	335	69.8	74.9	Morocco	1076	1022	10.4	10.6
India	3848	4200	nil	nil	Mozambique	34	39	nil	nil
Indonesia	6188	6569	nil	< 0.1	Nigeria	3478	n/a	nil	n/a
Pakistan	1154	n/a	nil	n/a	South Africa	7056	7439	nil	nil
Philippines	1790	n/a	7.7	n/a	Zambia	117	135	nil	nil
Singapore	586	590	63.0	62.7	**Middle East**				
South Korea	6009	6987	100.0	100.0	Bahrain	269	276	nil	nil
Taiwan	5669	6122	66.2	73.8	Israel	1868	2050	18.6	29.8
Thailand	5642	n/a	73.2	n/a	Jordan	453	479	nil	nil
Central & South America					Kuwait	1350	n/a	nil	n/a
Argentina	4900	n/a	3.1	n/a	Oman	584	627	nil	nil
Brazil	18397	n/a	100.0	n/a	Saudi Arabia	8245	8975	nil	nil
Chile	1910	2046	18.6	28.7	UAE	1352	1466	nil	nil

A.5.7. TABULATED FUEL SPECIFICATIONS

A.5.7.1. European gasoline specifications

Table A.5.18 Main elements of the CEN Unleaded Gasoline Specification (EN228:1993)

Property	Premium	Regular	Test Method (2)
RON (min)	95.0	(1)	ISO 5164
MON (min)	85.0	(1)	ISO 5163
Lead g/l (max.)	0.013		EN 237
Benzene %v/v (max.)	5.0		EN 238
Sulphur %m/m (max.)	0.05		EN 24260
Gum mg/100 ml (max.)	5		EN 5
Copper Corrosion	1		ISO 2160
Appearance	Clear and Bright		Visual
Oxidation Stability : Minutes (min)	360		ISO 7536
Density : kg/m^3	725-780		ISO 3675
Oxygenates	as per Directive 85/536/EEC		
Water Tolerance	no water segregation		
Acidity	(3)		ISO 1388

Volatility	**Class**							
(Notes 2, 3)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RVP hPa	350-700	350-700	450-800	450-800	550-900	550-900	600-950	650-1000
E70 % vol.	15-45	15-45	15-45	15-45	15-47	15-47	15-47	20-50
VLI max. (RVP +7E70)	900	950	1000	1050	1100	1150	1200	1250
E100 % vol.	40-65	40-65	40-65	40-65	43-70	43-70	43-70	43-70
E180 % vol. min	85	85	85	85	85	85	85	85
FBP °C max.	215	215	215	215	215	215	215	215
Residue %v max.	2	2	2	2	2	2	2	2

(1) Must be specified in National standard.

(2) Test methods, with the exception of RVP, to ISO 3405. RVP is tested according to EN 12, which is suitable for oxygenates contents meeting column A of EU Directive 85/536/EEC.

(3) See also Figure A.5.3.

(4) The use of dyes, markers and performance additives is allowed, but no phosphorous containing compounds.

Figure A.5.3 Relationship between RVP, E70 and VLI for the Eight Volatility Classes

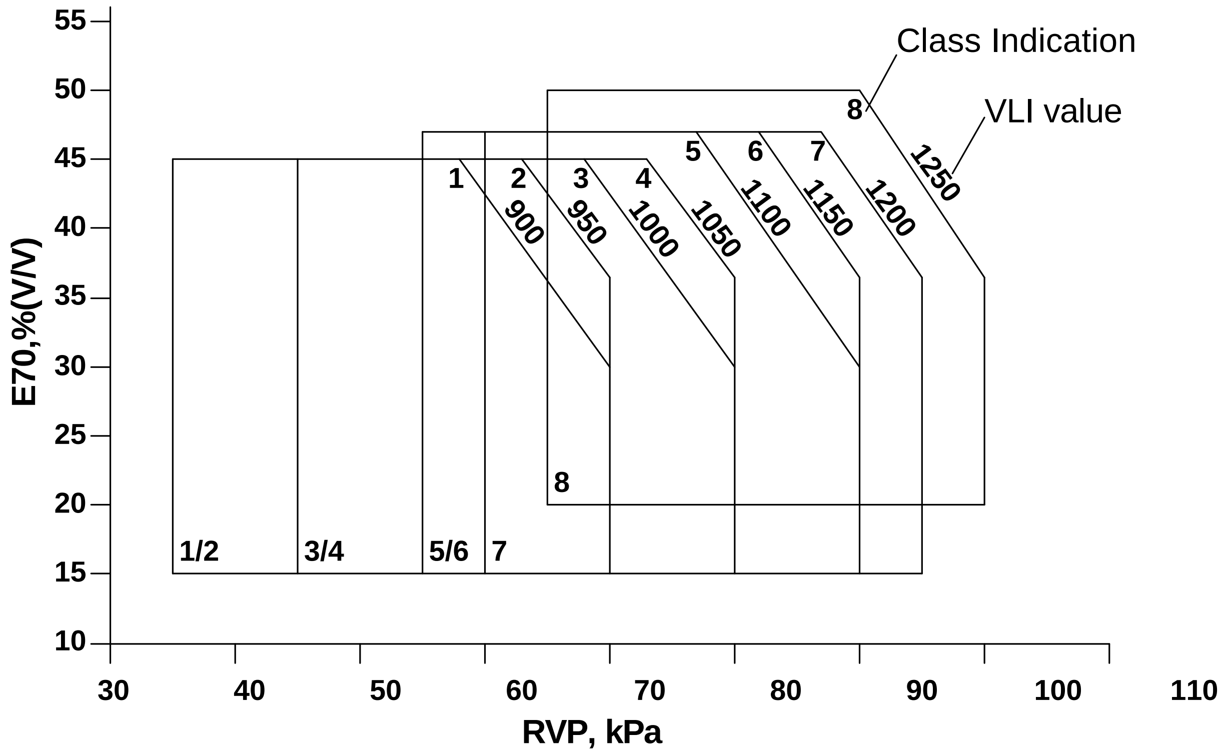


Table A.5.19 Octane and Volatility Classes of European National Specifications for Unleaded Motor Gasolines conforming to EN 228:1993

Country	Octane Quality			Density	Volatility		Reference
	Grade (1)	RON	MON		Period	Class	
Austria	S P R	98.0 95.0 91.0	87.0 85.0 82.5	725-780	W 01.11 - 31.03 I Apr. / Oct. S 01.05 - 30.09	6 mixtures 2	O-Norm EN 228 01.03.1994
Belgium (2)	S P R	98.0 95.0 90.0	88.0 85.0 80.0	730-780 725-775 720-770	W 01.10 - 31.03 I Apr./Oct. S 01.05 - 30.09	7 mixtures 4	NBN T-52- 705 1990
Denmark (4)	S P R	98.0 95.0 92.0	88.0 85.0 83.0	730-780 730-770 710-750	W 01.11 - 01.03 I 01.03 - 30.04 01.09 - 31.10 S 01.05 - 31.08	7 6 6 4	Danish Petroleum Institute 01/10/90
Finland	S P S (city) P (city)	98.0 95.0 99.0 95.0	88.0 85.0 88.0 85.0	725-780 725-770	W 01.09 - 31.05 S 01.04 - 30.10	8 **4** **Table A5.20**	SF EN 228 1993
France (2)	S P	 95.0	 85.0	 725-780	W 01.10 - 30.11 01.12 - 25.02 I 01.03 - 31.05 S 01.06 - 30.09	3 6 3 1 (5)	NF EN 228: 1993 (3)
Germany (2)	S P R	98.0 95.0 91.0	88.0 85.0 82.5	725-780	W 01.11 - 31.03 I Apr. / Oct. S 01.05 - 30.09	6 mixtures 2	EN 228:1993
Greece (3)	S P	98.0 95.0	87.0 85.0	725-780 725-780	W S	3 1	EN 228:1993
Italy	P	95.0	85.0	725-780	W 16.09 - 31.11 01.12 - 28.02 I 01.03 - 14.06 S 15.06 - 15.09	3 5 3 1	UNI-CUNA EN 228:1993
Netherlands (2)	P	95.0	85.0		W 01.10 - 31.03 I Apr. / Oct. S 01.05 - 30.09	7 mixtures 4	NEN-EN 228: 1993
Norway	S P	98.0 95.0	87.0 85.0	725-780	W 01.09 - 31.03 S 01.04 - 31.08	8 5	NS-EN228
Portugal	P	95.0	85.0	735-785	W 15.10 - 30.03 I 01.04 - 31.05 S 01.06 - 14.10	7 4 1	Porteria 125/89
Spain	S P	98.0 95.0	(7) 85.0	735-785 725-780	W 01.11 - 31.03 S 01.04 - 31.10		(8) (9)
Sweden	P	95.0	85.0	725-775	South W 01.10 - 13.04 S 14.04 - 30.09 North W 01.09 - 13.05 S 14.05 - 31.08	see **Table A5.20**	SIS SS-EN 228 (March 1994)
Switzerland	P	95.0	85.0	725-780	W 01.11 - 31.03 I Apr. / Oct. S 01.05 - 30.09	7 mixtures 2	SN EN 228:1993
United Kingdom (3)	S P	98.0 95.0	87.0 85.0	725-780	W 01.09 - 31.05 S 01.06 - 31.08	8 4	BS EN 228:1993 (01.10.94)

(1) S=ULG98, P=Premium, R=Regular

(2) volatility limits apply to unleaded gasolines only

(3) volatility limits apply to ULG95 only

(4) subject to ratification by the Danish EPA

(5) VLI 850 max

(6) sulphur 0.05 from 31.12.95

(7) (R+M)/2 = 93.0 (min)

(8) CIAS Agreement UNE EN228: 1994. (9) Royal Decree 398/1996 UNE EN228: 1994

Table A.5.20 European National Specifications for Unleaded Motor Gasoline with volatility requirements not conforming to an EN228:1993 classification

Country	Volatility							Density (kg/m³)	Sulphur % m/m	Reference
	RVP (bar)	VLI (1)	E70 % v	E100 % v	E180 % v	FBP °C	Residue % v			
Finland	S 0.6-0.7 I 0.7-0.8 W 0.8-0.9	<1000 <1100 <1200	20-40 23-43 25-45	43-63 45-66 48-70	91 min	210 max.	2 max.	725-770	0.01	(2)
Sweden	S 0.45-0.75 W 0.65-0.95	<1050 <1200	15-45 15-47	43-65 45-85	85 min	215 max.	2 max.	725-775	0.1	SIS SS-EN 228 (March 1994)

(1) VLI=RVP (kPa)x10+7E70, S = Summer, I = Intermediate, W = Winter

(2) Reformulated gasoline (see **Table A5.2**)

(3) Super grade (see **Table A5.18**)

Table A.5.21 European National Specifications for Leaded Motor Gasoline
(Leaded grades no longer available in Austria, Finland, Norway and Sweden)

Marketing Area	**RON (MON) min** [1]	**Density at 15ºC kg/m³**	**RVP (bar)**[3]	**VLI** [2]	**E70 % v**	**E100 % v**	**E180 %v (FBP ºC)**	**OxStab min (Exist Gum) mg/100ml**	**Sulphur %m max**	**Reference**
Belgium	P 97.5 (-)	720-770	0.45-0.95	-	15-45	40-70	90 min (215 max)	- (5 max)	0.10	NBN T52-705 1990
Denmark	P 98.0 (P 88.0)	730-770	S 0.45-0.80 I 0.58-0.90 W 0.70-0.95	700-1100 800-1200 900-1300	15 20 25	44-68 45-70 45-72	90 min (210 max)	480 min (4 max)	0.10	Danish Petroleum Inst. 10/90
France	P 97.0-99.0 (P 86.0)	720-770	S 0.45-0.79 I 0.50-0.86 W 0.55-0.99	= 900 = 1000 = 1150	10-47	40-70	85 min (215 max)	- (10 max)	0.15	CSR04-N Aug. 1991
Germany	P 98.0 (P 88.0)	730-780	S 0.45-0.70 W 0.60-0.90	-	S 15-40 W 20-45	S 42-65 W 45-70	90 min (215 max)	- (5 max)	0.10	DIN 51600 Jan 1988
Greece	P 96-98 (-) R 90 (-)	P 720-770 R 700-750	S 0.62 max W 0.80 max S 0.65 max W 0.80 max		10 min 10 min	30-65 30-65	85 min (215 max) 85 min (215 max)	360 min (4 max) 360 min (4 max)	0.10 0.15	Greek Gmnt Gazette P 556/93 R 581/91
Italy	P 97.0 (P 87.0)	725-770	S 0.40-0.74		10-45	30-70	85 min (220 max)	- (8 max)	0.20	NC 623-01 Nov. 1989
Netherlands [5]										
Portugal	P 98.0 (P 87.0) R 90.0	P 720-770 R 710-760	S 0.35-0.70 I 0.45-0.80 W 0.60-0.95		15-45 15-47	40-65 43-70	85 min (215 max)	360 min (5 max)	0.10	Ministério da Economia Portaria Feb. 1994
Spain	P 97.0 (P 87.0)	720-780	S 0.48-0.64 W 0.55-0.78		10-45	30-70	80 min (210 max)	240 min (5 max)	0.13	Royal Decrees 1485/1987 & 1513/1988
Switzerland	P 98.0 (P 88.0)	-	S 0.45-0.70 W 0.60-0.90	<990 <1230	S 15-42 W 20-47	S 40 min W 42 min	85 min (215 max)	240 min (5 max)	0.10	SN 18116/1 Jan 1987
UK and Ireland **4 star** [6] **3 star** **2 star**	97.0 (86.0) 93.0 (82.0) 90.0 (80.0)	-	[4] S 0.45-0.80 I 1.03 max W 0.6-1.15	[4] <1050 <1240 <1360	15-45	40-65	90 min (220 max)	240 min (5 max)	0.20	BS 4040 1968 (Amended 01/10/94)

(1) P = Premium, R = Regular.

(2) VLI is calculated as RVP (kPa) x 10 + (% at 70ºC) x 7.

(3) S = Summer, W = Winter, I = Intermediate.

(4) Recommended seasonal volatility characteristics, values equivalent to Figure 2 of BS4040.

(5) No national standard, but legal maxima for benzene (5% v/v), lead (0.15 g Pb/l) and oxygen content (3.7% m/m)

(6) Only the “4 star”, 97 RON grade, is generally available.

(7) All distillation residues 2.0 % vol max and all copper corrosions (3 h @ 50°C) 1 max

Table A.5.22 Grade structure and lead contents of gasolines in other European countries not covered by the above tables

Country	Unleaded Gasolines	Lead Content (gPb/l)	Leaded Gasolines	Lead Content (gPb/l)
Bulgaria	95	unleaded	96/93/86	0.15
Croatia	95/91	0.013	98	0.40 - 0.60
Cyprus	95	0.013	98/92	0.34-0.40/0.07-0.15
Czech Republic	98/95	0.013	96-97/91-92	0.1 - 0.14
Gibraltar	-	-	98	0.15
Hungary	98/95/91	0.013	98	0.09-0.15
Iceland	95/92	0.005	98	0.15
Luxembourg	98/95/91.5	0.013	98	0.15
Macedonia	93-95	0.013	94-98/86-89	0.10-0.60/0.07-0.52
Monaco	98/95	unleaded	97	0.15
Poland	98/95	0.013	98/94/86	0.15/0.15/0.30
Romania	95	unleaded	95/87	0.3/0.6
Russia	95	0.013	92	0.37
Slovakia	98/95/91	0.013	91	0.15
Turkey	95	0.013	95/91	0.40/0.15

Table A.5.23 French Gasoline Specification for UTAC Labelling [3]

Property	Leaded Gasoline	Unleaded 98	Unleaded 95
RON min	97	98	95
MON min	86.5	88	85
Distillation : E70 (% evaporated at 70°C)	= 40% from 1/6 to 30/9 = 45% from 1/12 to 28/2 = 43% for the other months		
VLI = RVP + 7 x E70	< 850 from 1/6 to 30/9 <1150 from 1/12 to 28/2 < 1000 for the other months		
Equivalent Vapour Pressure - Grabner at 37.8°C (hPa)	350-700 from 1/6 to 30/9 550-900 from 1/12 to 28/2 450-800 for the other months		
Oxygenates	No alcohols and no ketones, ethers = 15% v/v[1]		
Lead Content	0.08 - 0.15 g/l	5 mg/l max.	
Silicon Content	= 2 µg/ml		
Sulphur		= 200 ppm m	= 300 ppm m
Carburettor Cleanliness Renault R5 (CEC F-03-T-81)	Merit >8		
Injector cleanliness - 205 GTI (GFC-TAE-1-87)	Flow rate losses < 4%		
Intake valve cleanliness - Opel Kadett (CEC F-04-A-87)	Merit = 9		
- Mercedes M 102 E (CEC F-05-A-94)	Merit = 9 average deposit weight per valve ≤ 50 mg		
Octane requirement increase (Renault 22700, 22710 or BTC CEC PF 28)	KLSA[2] = 12°	KLSA = 8º	
Black sludge (DKA/M 102E, RL 140)	-	Merit = 9	
Camshaft Bearing Wear- Petter W1 (CFC-L-02 A 78, 36 h)	Bearing Weight loss = 25 mg		

(1) MTBE =15% v/v, ETBE =15% v/v with residual alcohols (ethanol, TBA etc.) =1% v/v

(2) KLSA = "Knock Limited Spark Advance"

(3) Gasoline must also meet administrative specifications and additives must be approved by DHYCA

Table A.5.24 Eastern European Unleaded Motor Gasoline Specifications

Property		**Hungary**	**Russia**	
			Regular	**Premium**
RON	min	98.0/95.0/91.0	93.0	95.0
MON	min	88.0/85.0/82.5	85.0	85.0
Lead content, g/l	max	0.013	0.013	0.013
Sulphur content, %m/m	max.	0.05	0.10	0.10
Gum, g/100ml	max		0.005	0.005
Distillation, °C				
10 %v/v evap.	max		70	75
50 %v/v evap.	max		115	120
90 %v/v evap.	max		180	180
FBP	max		205	205
%v/v evap at 70°C		S 15-42 W 20-47		
%v/v evap at 100°C		S 40-65 W 42-70		
%v/v evap at 180°C	min	85		
RVP @ 37.8 °C, kPa	max	S 45-70 W 60-90	66.7	66.7
VLI = 10RVP + 7E70	max			
Benzene content, %v/v	max	2.0	3.5	3.5
Aromatics content, %v/v	max		55.0	55.0
Oxidation Stability, min	min			
PFI/VDC Additives			-	Yes
Specification		MSZ 11793 ESZ-95	GOST 2084-77 (AK-93)	GOST 2084-77 (AK-95)

A.5.7.2. European diesel fuel specifications

Table A.5.25 CEN Diesel Fuel Specification EN 590:1993

All Grades						**Test Method**
Flash Point PMCC ºC (min)	55					ISO 2719
Ash %m/m (max.)	0.01					EN 26245
Water mg/kg (max.)	200(1)					ASTM D1744
Particulates mg/l (max.)	24					DIN 51419
Copper Corrosion 3h at 50ºC (max.)	1					ISO 2160
Oxidation Stability g/m^3 (max.)	25					ASTM D2274
Sulphur %m/m (max.)	0.20(2)					EN 24260/ISO 8754
Carbon Residue (10% btms) % m/m (max.)	0.30(3)					ISO 10370
Temperate Climate Grades (Grades A to F)						
CFPP (max.)	Note (4)					EN 116
Density at 15ºC kg/m^3	820-860					ISO 3675/ASTM D4052
Viscosity at 40ºC mm^2/s	2.00-4.50					ISO 3104
Cetane Number (min)	49					ISO 5165
Cetane Index (min)	46					ISO 4264
Distillation ºC:						
10 %v rec. at	report					ISO 3405
50%v rec. at	report					
65%v rec. at (min)	250					
85%v rec. at (max.)	350					
95%v rec. at (max.)	370					
Arctic Grades (Grades 0 to 4)						
Grade	**0**	**1**	**2**	**3**	**4**	
CFPP (max.)	-20	-26	-32	-38	-44	EN 116
Cloud Point ºC (max.)	-10	-16	-22	-28	-34	ISO 3015
Density at 15ºC kg/m^3 (min)	800	800	800	800	800	ISO 3675/ASTM D4052
Density at 15ºC kg/m^3 (max.)	845	845	840	840	840	
Viscosity at 40ºC mm^2/s (min)	1.50	1.50	1.50	1.40(5)	1.20(5)	ISO 3104
Viscosity at 40ºC mm^2/s (max.)	4.00	4.00	4.00	4.00	4.00	
Cetane Number (min)	47	47	46	45	45	ISO 5165
Cetane Index (min)	46	46	46	43	43	ISO 4264
Distillation ºC:						
10%v rec. at (max.)	180	180	180	180	180	ISO 3405
50%v rec. at	report	report	report	report	report	
95%v rec. at	340	340	340	340	340	

(1) A limit of 500 mg/kg may be specified by countries with inherently wet distribution systems until December 1995.

(2) Sulphur limit will be reduced towards 0.05% m/m. maximum, in line with EU directives or national standards.

(3) Based on fuel without ignition improver additives. if a higher value is found, fuel should be tested by ASTM D 4046 for presence of nitrates. If present, the limit does not apply.

(4) Six grades (A, B, C, D, E and F), with CFPP limits from plus 5ºC to minus 20ºC, in 5ºC intervals.

(5) Arctic classes may exhibit poor lubricity characteristics and corrective measures (lubricity additives) may have to be used.

Table A.5.26 European National Specifications for Automotive Diesel Fuel: Cold Flow Properties of Standards meeting EN 590

Market Area	**National Standard**	**Grade**	**CFPP Grade (1)**	**CFPP °C max**
Austria	Ö-Norm EN 590 (01.02.94)	Summer Intermediate Winter	A E F	+5 -15 -20
Belgium & Luxembourg	NBN	Summer Intermediate Winter	B C E	0 -5 -15
Denmark	EN 590	Summer Intermediate Winter		-24 -18 -12
Finland	SFS-EN 590	Summer Winter 1 Winter 2 Winter 3	C 1 3 4	-5 -26 -38 -44
France	EN 590: 1993	Summer Winter Grand Froid	B E F	0 -15 -20
Germany	DIN EN 590: 1993	Summer Intermediate Winter	B D F	0 -10 -20
Greece	EN 590: 1993	Summer Winter	A C	+5 -5
Ireland	IS EN 590: 1993	Summer Winter		- -12
Italy	UNI-CUNA EN 590:93 1/10/93	Summer Winter	B D	0 -10
Netherlands		Summer Intermediate Winter	B C E	0 -5 -15
Norway	NS EN590:	Summer Winter	D	-10 -24
Portugal	EN 590: 1993	Summer Winter	B	0 -6
Spain	Royal Decree 398/1996 UNE EN590	Summer Winter	B D	0 -10
Sweden	SIS 15 54 35 (13/03/91)	Summer (D 10) Winter 1 (D 26) Winter 2 (D 32) Winter 3 (D 38)	D 1 2 3	-10 -26 -32 -38
Switzerland	SN EN 590	Summer (1.5-30.9) All year	D F	-10 -20
UK	BS EN 590: 1993	Summer Winter	E	-15

(1) EN 590 grades (A, B, C, D, E, F)
(Arctic 0, 1, 2, 3, 4)

Table A.5.27 European National Specifications for Automotive Diesel Fuel: Special Low Sulphur and Low Aromatics Grades

Market Area	Grade	Cetane Number (Index) min	Cloud Point °C max.	CFPP °C max.	Density at 15°C kg/m³	kV @ 40°C mm²/sec	IBP °C (95%v oC) min	Sulphur %m/m max	Aromatics %v/v max	PAH %v/v max
Denmark (1)	Bus Diesel summer winter	50 (47)		-18 -25	820-855	2.0-4.5	(325)		5	-
Finland (2)	Reformulated Summer Winter	49 (49) 47 (47)	-5 -29	-15 -34	820-850 800-830	2.0-3.5 1.4-2.6	(350) (310)	0.005	20	
Sweden (3)	Urban Diesel EC1 *Summer* *Winter*	50 (50)	0 -16	-10 -26	800-820	1.2-4.0	180 (285)	0.001	5	not detectable

(1) Public Bus Service Ultra light Diesel; Tax incentive versus EN 590 Quality = 0.20 DKr/litre

(2) Reformulated Diesel; Tax incentive versus EN 590 Quality = 0.15 FIM/litre

(3) 1993 Diesel fuel classifications; Tax incentive versus EN 590 Quality: EC1 ≅ 470 SEK/m³

Table A.5.28 French Automotive Diesel Fuel and "Grand Froid" Specifications for UTAC Labelling [4]

Property		Specification	Test Method
Density CN			
Viscosity at 40ºC, mm²/s		2 - 4.5	
Distillation:			
evaporated at 250ºC, %v/v		<60	
evaporated at 350ºC, %v/v		>85	
evaporated at 370ºC, %v/v		>95	
Cetane Number		>50	
Potential gum, mg/100 ml.	max	1.5	ASTM D 2274
Anti-Corrosion	max	5% (moderate rusting)	ASTM D 655 A
Foaming Tendency		(2)	
Biological Property	max	light contamination	M 07070
Total Acid Number, mg/KOH/g	max	0.08	NF T 60 112
Lubricity, HFRR		report	ISO 12156-1
Detergents		(3)	
Cold Flow Properties(1)		1 Nov. to 31 March	
Cloud Point	max	- 5ºC	
CFPP	max	-15ºC	
Pour Point	max	-18°C	

(1) "*Grand Froid*" quality available in at least 30% of filling stations, from mid-December to the end of February (Cloud Point-5ºC max, CFPP-20ºC max, pour point -27OC max).

(2) Presence of additive to be confirmed by demonstration of efficiency.

(3) 15% maximum flow rate loss at 0.1 mm needle lift by test method CEC PF023.

(4) Diesel fuels must also meet administrative specifications and additives must be approved by DHYCA

Table A.5.29 Eastern European Diesel Fuel Specifications

Properties		Bulgaria	Hungary 0.01	Hungary 0.05	Romania
Cetane Index	min.	W 45 S 49	48	48	53 [1]
Density, g/l	max	820-860	820-860	820-860	850
Sulphur, %m/m	max	0.3	0.01	0.05	0.3
CFPP, °C	min		S/W +5/-15	S/W +5/-15	
Specification			MSZ 1627	MSZ 1627	
Test Methods			MSZ 1627	MSZ 1627	

(1) Diesel Index, normally equivalent to a Cetane Index of greater than 50

A.5.7.3. European alternative fuel specifications

Table A.5.30 CEN Automotive LPG Specification EN 589:1993.

Property	Specification	Test Method
Odour	Distinctive and unpleasant down to 20% LEL	Annex A EN 5589
Density	Optional	ISO 8973
Hydrogen Sulphide	Pass	ISO 8819
MON min	89.0	Annex B EN 589
Vapour Pressure Absolute		ISO 4256
kPa min	250(1)	
kPa max.	1550	
Dienes molar % max. (as 1,3 Butadiene)	0.5	ISO 7941
Sulphur mg/kg max. (after stenching)	200	EN 24260
Evaporative Residue mg/kg max.	100	NF-M 41-015
Copper Corrosion 1h at 40ºC, max.	1	ISO 6251 (2)
Water	none	by visual inspection
	pass	ASTM D2713

(1) Four Winter Grades A, B, C and D with minimum absolute vapour pressures of 250 kPa at -10, -5, 0 and +10ºC respectively. Grade and date range to be specified in national annexes to standard. No minimum vapour pressure for summer period.

(2) Addition of corrosion inhibitors for the sole purpose of biasing the test method is prohibited.

Table A.5.31 EU Draft Specification for Vegetable Oil Methylester Diesel Fuel (Biodiesel)

Properties		**Limit**	**Analytical Method**
A. Fuel Specific Properties	**Units**		
Density at 15 ºC	g/cm^3	0.86-0.90	ISO 3675
Kinematic viscosity at 40 ºC	mm^2/s	3.5-5.0	ISO 3104
Flash point	ºC	min. 100	ISO 2719
Cold filter plugging point CFPP	ºC	summer max. 0 winter max. < -15	DIN EN 116
Sulphur content	% m/m	max. 0.01	ISO 8754/DIN EN 41
Distillation:			
5% vol. evaporated at	ºC	to be indicated	ASTM-1160/ISO 3405
95% vol. evaporated at	ºC	to be indicated	
Carbon residue Conradson (10% by vol. residue on distillation at reduced pressure)	%m/m	max. 0.30	ISO 10370
Cetane number	-	min. 49	ISO 5165/DIN 51773
Ash content		max. 0.01	EN 26245
Water content (Karl Fischer)	mg/kg	max. 500	ISO 6296/ASTM D 1744
Particulate Matter	g/m^3	max. 20	DIN 51419
Copper corrosion (3h/50ºC)	corrosion-rating	max. 1	ISO 2160
Oxidation stability	g/m^3	max. 25	ASTM D 2274
B. Methyl Ester Specific Properties	**Units**		
Acid value	mg KOH/g	max. 0.5	ISO 660
Methanol content	%m/m	max. 0.3	DIN 51413,1
Monoglycerides	%m/m	max. 0.8	GLC
Diglycerides	%m/m		GLC
Triglycerides	%m/m		GLC
Bound glycerine	%m/m	max. 0.2	calculate
Free glycerine	%m/m	max. 0.03	GLC
Total glycerine	%m/m	max. 0.25	calculate
Iodine number	-	max. 115	DIN 53241/IP 84/81
Phosphorous content	mg/kg	max. 10	DGF C-VI 4

(1) Note : Many of the test methods have yet to be finalized.

Table A.5.32 Austrian Specification for Vegetable Oil Methylester Diesel Fuel (Önorm Vörnorm C1190, revised 01.01.95)

Property	Units	Limits	Test Method
Density @ 15°C	kg/m^3	0.87-0.89	ISO 3675/ASTM D4052
Flash point, PM	ºC.	100 min	ÖNORM EN 22719
CFPP (01.04-30.09)	ºC	0 max.	ÖNORM EN 116
(01.10-31.03)		-15 max.	
Kinematic viscosity at 20ºC	mm^2/s	6.5-8.0	ISO 3104
Sulphur content	%m	0.02 max.	ÖNORM EN 24260/ISO 8754
Sulphated Ash	%m	0.02 max.	ÖNORM C 1134
Carbon Residue, Conradson (CCR)	%m	0.05 max.	DIN 51 551
Cetane number		48 min	ISO 5165
Neutralisation value	mg KOH/g	0.60 max.	ÖNORM C 1146
Methanol content	%m	0.20 max.	DIN 51413
Free glycerine	%m	0.02 max.	GLC/enzymatic
Total glycerine	%m	0.24 max.	GLC/enzymatic
Phosphorus content	mg/kg	20 max.	ASTM D 3231

Table A.5.33 Italian Specification for Vegetable Oil Methylester Diesel Fuel

Property	Units	Limits	Test Method
Appearance	Visual	Clear & Bright	
Density	@ 15ºC kg/m^3	0.86-0.90	ASTM D1298/ISO 3675
Flash point	PM ºC, min.	100	ASTM D93
Cloud point	ºC max.	0	ASTM D97
Kinematic viscosity at 40ºC	mm^2/s	3.5-5.0	ASTM D189/ISO 3104
Distillation	ºC		ASTM D86
IBP min.		300	
95%v max.		360	
Sulphur content	%m/m max.	0.01	ASTM D1552/ISO 8754
Carbon Residue Conradson (CCR)	%m/m max.	0.5	ASTM D189/ISO 10370
Water content	ppm	700	ASTM D1744
Saponification number	mg/KOH/g min.	170	NGD G33-1976
Total acidity	mg/KOH/g max.	0.05	ASTM D664
Methanol content	%m/m max.	0.2	GLC
Methyl ester	%m/m min.	98	GLC
Monoglycerides	%m/m max.	0.8	GLC
Diglycerides	%m/m max.	0.2	GLC
Triglycerides	%m/m max.	0.1	GLC
Free glycerine	%m/m max.	0.05	GLC
Phosphorus	ppm max.	10	DGF GIII 16A-89

A.5.7.4. United States gasoline specifications

Table A.5.34 US National Specifications for Automotive Spark Ignition Engine Fuel (ASTM D4814-94d)

Volatility

Six vapour pressure/distillation classes and five vapour lock protection classes are specified. The appropriate fuel volatility is specified by a designation that uses a letter from each of the two tabulations according to the region and season of sale.

		Distillation temperature, °C at %v evaporated (1)						Vapour/liquid ratio (3)		Vapour lock
Vapour pressure/ distillation class	**Reid vapour pressure kPa max. (1,2)**	**10%v °C max.**	**50%v °C min**	**50%v °C max.**	**90%v °C max.**	**End point °C max.**	**Residue %v**	**Test temper-ature**	**V/L max.**	**protection class**
AA	54	70	77	121	190	225	2	-	-	-
A	62	70	77	121	190	225	2	60	20	1
B	69	65	77	118	190	225	2	56	20	2
C	79	60	77	116	185	225	2	51	20	3
D	93	55	77	113	185	225	2	47	20	4
E	103	50	77	110	185	225	2	41	20	5

(1) If Federal legislation restricts RVP to a level lower than specified in the standard, distillation limits shall be consistent with corresponding RVP limits as above.

(2) Dry test methods must be used for gasoline/alcohol blends

(3) Version of test D 2533 using mercury must be used for oxygenate blends

Octane Quality

Octane quality is not specifically controlled by the ASTM specification, being left to "*commercial practice*". However, EPA regulations do require a grade with a minimum antiknock index [(RON + MON)/2] of 87 to be sold. The ASTM specification lists current antiknock Indices in Current Practice (i.e. grades) as follows:

Antiknock Index [(RON + MON)/2]	Application
88	***Leaded Fuel*** For most vehicles that were designed to run on leaded fuel
87	***Unleaded Fuel*** Designed to meet antiknock requirements of most 1971 and later model vehicles
89 } 91 and above }	Satisfies vehicles with higher antiknock requirements

(1) As required by EPA (Reg. 40 CFR part 80), reductions in octane for altitude are allowed

(2) Unleaded gasoline with an antiknock index of 87 should also have a minimum MON of 82

(3) Permissible reductions in antiknock index for altitude and seasonal variation are given in tables in the specification

Other ASTM D 4814-94 Spark-Ignition Engine Fuel Specifications

Copper Strip Corrosion max.	Existent Gum (mg/100ml) max.	Sulphur Content (%m/m) max.		Oxidation Stability (min) min	Water Tolerance
		Unleaded	Leaded		
No.1	5	0.10	0.15	240	(1)

(1) Maximum phase separation temperatures are specified by region and by month.

Lead Content

Grades	Lead Content (g/USG) max.	Lead Content (g/l) max.
Leaded	4.2	1.1
Unleaded	0.05	0.013

(1) In addition, phosphorous is limited in unleaded gasoline to 0.005 g/US gal (0.0013 g/l)

A.5.7.5. United States diesel fuel specifications

Table A.5.35 US National Specifications for Automotive Diesel Fuels (ASTM D975-94) [(1)]

Grade	**No.1-D** Volatile distillate fuel oil for engines requiring frequent speed and load changes	**No.2-D** Distillate fuel oil of lower volatility for engines in industrial and heavy mobile service
Flash Point °C	38 min	52 min
Cloud Point °C	(2)	(2)
Water & Sediment %v	0.05 max.	0.05 max.
Ramsbottom Carbon Residue on 10% residue %m	0.15 max.	0.35 max.
Ash %m/m	0.01 max.	0.01 max.
Distillation 90% vol. °C	288 max. [(3)]	282-338
Viscosity Kinematic @ 40°C mm^2/s	1.3-2.4	1.9-4.1
Sulphur Content %m/m	0.05 max.	0.05 max.
Copper Strip Corrosion	No.3 max.	No.3 max.
Cetane Number	40 [(4)] min.	40 [(4)] min.
1) Cetane Index or	40 min.	40 min.
2) Aromatics Content %v/v	35 max.	35 max.

(1) To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller and manufacturer.

(2) It is unrealistic to specify low-temperature properties that will ensure satisfactory operation on a broad basis. Satisfactory operation should be achieved in most cases if the cloud point (or wax appearance point) is specified at 6ºC above the tenth percentile minimum ambient temperature for the area in which the fuel will be used. Appropriate low temperature operability properties should be agreed upon between the fuel supplier and purchaser for the intended use and expected ambient temperatures.

(3) When cloud point less than -12ºC is specified, the minimum viscosity shall be 1.7 cSt (or mm^2/s) and the 90% point shall be waived.

(4) Low atmospheric temperatures as well as engine operation at high attitudes may require use of fuels with higher cetane ratings.

A.5.7.6. United States alternative fuel specifications

Table A.5.36 Specifications of natural gas used for emissions certification and for general automotive use

Constituent (mole %)	CARB Certification Fuel	CARB In-Use Fuel	EPA Certification Fuel
Methane	90.1 ± 1.0	88.0 (min)	89.0 (min)
Ethane	4.0 ± 0.5	6.0 (max.)	4.5 (max.)
C_3 and higher	2.0 ± 0.3	3.0 (max.)	2.3 (max.)
C_6 and higher	0.2 (max.)	0.2 (max.)	0.2 (max.)
Hydrogen	0.1 (max.)	0.1 (max.)	-
Carbon Monoxide	0.1 (max.)	0.1 (max.)	-
Oxygen	0.5 ± 0.1	1.0 (max.)	0.6 (max.)
Inert Gases (CO_2 +N_2)	3.5 ± 0.5	1.5 - 4.5	4.0 (max.)

Table A.5.37 US National Specification for Automotive LPG (Special Duty Propane Grade, ASTM D 1835)

Property	Special Duty Propane [(1)]	ASTM Test Method
Vapour Pressure at 100°F (37.8°C), max. psig	208	D 1267 or
kPa	1430	D 2598
Volatile Residue evap temperature 95 % max. °F	-37	D 1837
°C	-38.3	
or		
Butane and heavier max., %v/v	2.5	D 2163
Propylene content max. %v/v	5.0	D 2163
Residual matter		
residue on evaporation 100 ml, max. ml	0.05	D 2158
oil stain observation	pass[(2)]	D 2158
Copper strip corrosion, max.	No.1	D 1838
Sulphur, max. ppm	120	D 2784
Moisture content	pass	D 2713

(1) Equivalent to GPA Standard 2140 HD-5 Grade which also requires 85 %v/v min propane content

(2) Shall not yield a persistent ring when 0.3 ml of solvent residue mixture is added to a filter paper in 0.1 ml increments and examined in daylight after 2 min

A.5.7.7. Asian gasoline specifications

Table A.5.38 Asian Gasoline Specifications: China and Indonesia

		China			Indonesia	
		Prem.	Reg.	ULR	Prem. 88	Premix[(1)]
Octane						
Research	min	97	91	91	88.0	91.5 [(1)]
(R+M)/2	min	92	87	87		
Volatility						
distillation						
IBP (°C)	max					
10% (°C)	max	70	70	70	74	74
50% (°C)	max	120	120	120	88-125	88-125
90% (°C)	max	190	190	190	180	180
FBP (°C)	max	205	205	205	205	205
residue	max	1.5	1.5	1.5	2.0	2.0
Vapour Pressure @ 37.8°C kPa	max	S 62 W 93	S 62 W 93	S 62 W 93	62	62
Composition						
sulphur (%m/m)	max	0.10	0.10	0.10	0.20	0.20
lead (g/l)	max	0.15	0.13 [1)]	0. 026	0.42	0.42
MTBE (%v/v)	max					10 [(1)]
Other Parameters						
density						
copper corrosion (3h/50°C)	max	No. 1	No.1	No.1	No.1	No.1
mercaptan S (%m/m)	max				0.002	0.002
doctor test		neg.	neg.	neg.	neg.	neg.
oxidation stability (min)	min	480	480	480	240	240
existent gum (mg/100ml)	max	5	5	5	4	4
colour		red	red	red	yellow	yellow
Specification		SINOPEC 001-1987				
Test Methods		ASTM/ISO/GB				

(1) Premix is Premium 88 mixed with 10%v MTBE

Table A.5.39 Asian Gasoline Specifications: India

		India (current)			India (proposed 2000)		
		Prem.	Reg.	ULR	ULP	ULR	Reg.
Octane							
Research or	min	93	87	87			
(R+M)/2	min	88	82	82	88	84	84
Volatility							
distillation							
IBP (°C)	max	report	report	report			
E70 (%v/v)		10-45	10-45	10-45	10-40	10-40	10-40
E100 (%v/v)		40-70	40-70	40-70	40-65	40-65	40-65
E180 (%v/v)	min	90	90	90	90	90	90
FBP (°C)	max	215	215	215	215	215	215
residue	max	2.0	2.0	2.0	2.0	2.0	2.0
Vapour Pressure @ 37.8°C kPa	max	35-70	35-70	35-70	35-60	35-60	35-60
VLI		950 (1)	950 (1)	950 (1)	950 (1)	950 (1)	950 (1)
Composition							
sulphur (%m/m)	max	0.20	0.20	0.20	0.10	0.10	0.20
lead (g/l)	max	0.80	0.56	0.013	0.013	0.013	0.15
benzene (%v/v)	max				5.0	5.0	5.0
oxygenates (%v/v)	max	(3)	(3)	(3)	(3)	(3)	(3)
Other Parameters							
density @ 15 °C	min max	report	report	report	700 750	700 750	700 750
copper corrosion (3h/50°C)	max	No. 1	No.1	No.1	No.1	No.1	No.1
mercaptan S (%m/m)	max						
doctor test							
water tolerance (4) (°C)	max	S 10 W 0 (2)	S 10 W 0 (2)	S 10 W 0 (2)	S 10 W 0 (2)	S 10 W 0 (2)	S 10 W 0 (2)
oxidation stability (min)	min						
potential gum (mg/100ml)	max	5	5	5	5	5	5
existent gum (mg/100ml)	max	4	4	4	4	4	4
colour		red	orange	none	red	none	orange
Specification		IS 2796:1995					
Test Methods		IS 1448					

(1) VLI 750 May-July central and northern plains
(2) WT -10°C winter northern hilly region
(3) Oxygenates permitted as per EU Directive 85/536/EEC (column A limits) (see **Table A.5.3**)
(4) For fuels containing oxygenates

Table A.5.38 Asian Gasoline Specifications: Pakistan, South Korea and Thailand

		Pakistan			**South Korea (7)**		**Thailand**	
		HOBC	Prem.	Reg.	UL Prem. (6)	UL Reg.	UL Prem. (6)	UL Reg.
Octane								
Research	min	97	87	80	96	91	95.0	87.0
Motor	min				87	83	84.0	76.0
Volatility								
distillation								
10% (°C)	max	70	70	70	70	70	70	70
50% (°C)	max	125	125	125	125	125	70-110	70-110
90% (°C)	max	180	180	180	190	190	170	170
FBP (°C)	max	205	2-5	205	225	225	200	200
residue	max	2.0	2.0	2.0	2.0	2.0		
RVP @ 37.8°C kPa	max	W 69	W 69	W 69	45-85 (8)	45-85 (8)	62	62
	max	S 62	S 62	S 62				
Composition								
sulphur (%m/m)	max	0.2	0.2	0.2	0.01	0.01	0.1	0.1
lead (g/l)	max	0.84	0.63	0.42	0.013 (7)	0.013 (7)	0.013	0.013
aromatics (%v/v)	max				50.0 (2)	50.0 (2)	50 (2)	50 (2)
benzene (%v/v)	max				5.0 (1)	5.0 (1)	3.5	3.5
MTBE (%v/v)	max						5.5-11.0 (4)	11.0 (4)
oxygenates (%m/m)	min				0.75 (1)	0.75 (1)		
phosphorus (g/l)	max				0.0013	0.0013	0.0013	0.0013
additives							(5)	
Other parameters								
density @ 15.4° C		0.69-0.74	0.69-0.74	0.69-0.74				
mercaptan S (%m/m)	max			0.001				
copper corrosion (3h/50°C)	max	1	1	1	1	1	1	1
water	max						none (3)	none (3)
water tolerance (°C)	max							
oxidation stability (min)	min			240	480	480	360	360
existent gum (mg/100ml)	max	4	4	4	4	4	4	4
colour		red	orange	yellow	coloured	yellow	green	red
Test Methods		ASTM					ASTM	

(1) from 1998 oxygen 1.0 %m/m min, aromatics 40.0 %v/v max, benzene 4.0 %v/v max

(2) aromatics 35 %v/v from 01.01.2000

(3) 0.7 %m/m water max in oxygenated blends

(4) 3.0 %v/v max in methanol blends

(5) valve seat protection additive specified in Type 2 with mandatory requirement to add additive to meet BMW 3181 unlimited mileage standard and Chrysler PFI standard

(6) Type 1 for rural areas (without an oxygenate minimum) and Type 2 for Bangkok and other cities

(7) leaded gasoline unavailable in market from Jan 1993

(8) RVP 98 kPa max available for cold weather operation

Table A.5.41 Asian Gasoline Specifications: Hong Kong, Taiwan & Philippines

		Hong Kong (1)(2)(6)			**Taiwan**			**Philippines** (5)	
		Prem.	UL Prem.	Reg. ULReg	Prem.	UL Prem.	UL Reg.	Prem.	UL Prem.
Octane Number									
Research	min	97	95.0	90	95	95	92	93	93
Motor	min		85.0						
(R+M)/2	min	92		85					
Volatility									
distillation									
10% (°C)	max	70		70	74	74	74	70	70
50% (°C)	max	120		120	127	127	127	77-121	77-121
90% (°C)	max	190		190	190	190	190	185	185
FBP (°C)	max	205		205	225	225	225	221	221
residue	max	2.0		2.0	2.0	2.0	2.0	2.0	2.0
RVP @ 37.8°C kPa	max	W 88 S 74		W 88 S 74	69	69	69	85	85
Composition									
sulphur (%m/m)	max	0.15	0.05	0.15	0.1	0.1	0.1	0.2	0.1
lead (g/l)	max	0.45	0.0025	0.35 (2)	0.08	0.015	0.015	0.15	0.013
aromatics (%v/v)	max								55 (4)
benzene (%v/v)	max		5						5
oxygenates	max		(3)						allowed
ethers (%v/v)	max								10
Other Parameters									
copper corrosion (3h/50°C)	max	1		1	1	1	1		
mercaptan S (%m/m)	max	0.001		0.001					
doctor test		pass		pass					
acidity mgKOH/100ml	max	3		3					
oxidation stability (min)	min	480		480	240	240	240		
existent gum (mg/100ml)	max	5		5	4	4	4	4	4
Test Methods			GB/T						

(1) Also an intermediate grade with RON 93 min, MON 89 min, lead 0.45 g/l max
(2) Also unleaded grade with same specifications except lead content 0.013 g/l max.
(3) oxygenates as per EU Directive 85/536/EEC (see Table A.5.3)
(4) Aromatics may increase to 65 %v/v max if no MTBE added
(5) There are also separate Petronas specifications for leaded and unleaded premium gasolines with RON 95 min and sulphur 0.05 %m/m max
(6) Alternative unleaded premium proposed for implementation on 1 October 1996

Table A.5.42 Asian Gasoline Specifications: Japan, Singapore & Malaysia

		Japan		Singapore			Malaysia	
		Prem.	Reg.	UL Super Prem.	Premium	UL Reg.	UL Prem.	Reg.
Octane Number								
Research	min	96.0	89.0	98.0	97.0	92.0	97.0	92.0
Volatility								
distillation								
IBP	max						40	40
10% (°C)	max	70	70				74	74
50% (°C)	max	125	125				75-115	85-115
90% (°C)	max	180	180				180	180
FBP (°C)	max	220	220				215	215
residue	max	2.0	2.0				2.0	2.0
RVP @ 37.8°C kPa	max	44-78 (1)	44-78 (1)				70	70
Composition								
sulphur (%m/m)	max	0.01	0.01				0.15	0.10
lead (g/l)	max	unleaded	unleaded	unleaded	0.15	unleaded	0.013	0.15
benzene (%v/v)	max	5.0	5.0					
MTBE (%v/v)	max	7.0	7.0					
methanol		none	none					
Other Parameters								
density @ 15 °C	max	0.783	0.783					
copper corrosion (3h/50°C)	max	1	1				1	
oxidation stability (min)	min	240	240				240	240
existent gum (mg/100ml)	max	5	5				4	4
colour		orange	orange				yellow	red
Specification		JIS K 2202						
Test Methods							MS/ASTM	

(1) RVP 95 kPa max for cold climates

Table A.5.43 Grade structure and lead contents of gasolines of other Asian countries

Country	Unleaded Gasolines	Lead Content (gPb/l)	Leaded Gasolines	Lead Content (gPb/l)
Bangladesh			96/80	0.70-0.84/0.45-0.50
Brunei	97	0.013	95/85	0.08

A.5.7.8. Asian diesel fuel specifications

Table A.5.44 Asian Automotive Diesel Fuel Specifications: China, Hong Kong, Singapore, Indonesia and Malaysia

		China			Hong Kong	Singapore	Indonesia	Malaysia
		No. 0	No. -10	Special	ADO		ADO	ADO
Cetane Number	min	45	45	50	50		45	45
or Cetane Index	min	45	45	50			48	47
Sulphur (%m/m)	max	0.5	0.5	0.3	0.2 (1)	0.3	0.5	0.5
Distillation								
40 %v/v rec. (°C)	max						300	
50 %v/v rec. (°C)	max	300	300	280				
90% v/v rec. (°C)	max	355	350	335	357			370
95% v/v rec. (°C)	max	365	365		(1)			
Cold Flow Properties								
Pour Point (°C)	max	5	-5	-7			18.3	15
Cloud Point (°C)	max			report				18
CFPP (°C)	max							
Other Parameters								
density @ 15°C		report	report					
sp gr. @ 15.6/15.6 °C					0.82-0.86		0.82-0.84	
viscosity @ 20°C (cSt)		3.0-8.0	3.0-8.0	3.5 min				
@ (37.8)40°C (cSt)					2.0-4.5		(1.6-5.8)	1.5-5.8
Flash Point PM (°C)	min	60	60	80	66		65.6	60
CCR 10% (%m/m)	max	0.3	0.2	0.2			0.1	0.2
Rams CR 10% (%m/m)	max							
water (%v/v)	max	0.03	0.03				0.05	0.05
water & sediment (%v/v)				0.05				
sediment (%m/m)	max						0.01	0.01
ash (%m/m)	max	0.025	0.025	0.01			0.02	0.01
copper corrosion 3h/100°C	max	1	1	1			1	1
Colour ASTM	max	2.0	2.0				3.0	2.5
TAN mgKOH/g	max	0.2	0.2	0.1			0.6	
SAN mgKOH/g	max						nil	

(1) quality proposed for 1 April 1997: sulphur 0.05 %m/m, 95%v/v distillation 370 °C max

Table A.5.45 Asian Automotive Diesel Specifications: Japan, Pakistan & Philippines

		Japan					Pakistan	Philippines
		Sp No.1	No.1	No.2	No.3	Sp No.3	HSD	AGO
Cetane Number	min	50	50	45	45	45		
or Cetane Index	min	50	50	45	45	45	45	47
Sulphur (%m/m)	max	0.20 (1)	0.20 (1)	0.20 (1)	0.20 (1)	0.20 (1)	1.0	0.5
Distillation								
90% v/v rec. (°C)	max	360	360	350	330 (2)	330	365	report
Cold Flow Properties								
Pour Point (°C)	max	+5	-2.5	-7.5	-20	-30	W 3 S 6 (3)	
Cloud Point (°C)	max		-1	-5	-2		W 6 S 9 (3)	
CFPP (°C)	max							
Other Parameters								
density @ 15°C g/ml	max							0.870
sp gr. @ 15.6/15.6 °C							report	
viscosity @ 40°C (cSt)								1.7-5.5
@ 37.8 (38)°C (cSt)	max	(2.7)	(2.7)	(2.0)	(2.0)	(1.8)	1.5-6.5	
Flash Point PM (°C)	min	50	50	50	50	50	66 max	52
CCR 10% (%m/m)	max	0.1	0.1	0.1	0.1	0.1	0.2	0.35
water (%v/v)	max						0.05	
water & sediment (%v/v)								0.10
sediment (%m/m)	max						0.01	
ash (%m/m)	max						0.01	
copper corrosion 3h/100°C	max						1	
Colour ASTM	max						3.0	
TAN (SAN) mgKOH/g	max						0.05 (nil)	

(1) 0.05 %m/m max from 1997

(2) if viscosity is ≥ 4.7 mm^2/sec, 90 % point should be <350 °C

(3) winter period November to February

Table A.5.46 Asian Automotive Diesel Specifications: India, South Korea, Singapore, Taiwan & Thailand

		South Korea	Taiwan		Thailand	India	
		No.2	prem.	reg.	Type 2 (1)	current	proposed 2000
Cetane Number	min				47	45	48
or Cetane Index	min	45	46	40	47	45	
Sulphur (%m/m)	max	0.1	0.5	1.0	0.25 (2)(3)	1.0 (8)	0.25
Distillation							
85% v/v rec. (°C)							350
90% v/v rec. (°C)	max	360	338	357	357	366	
95 %v/v rec. (°C)							370
end point (°C)	max		385				
Cold Flow Properties						(7)	(7)
CFPP °C	max					W[6] 9 S 21	W[6] 6 S 18
Pour Point (°C)	max	W -10 S 0	-4	-1	10	W[6] 6 S 18	W[6] 3 S 15
Other Parameters							
sp gr. @ 15.6/15.6 °C					0.81-0.87		
density @ 15°C						0.82-0.88	0.82-0.87
viscosity @ 40°C (cSt)					1.9-4.1	1.8-5.0	2.0-5.0
@ 37.8 (38)°C (cSt)	max	2.0-5.8	1.7-4.3	1.7-4.3			
Flash Point PM (°C)	min		50	54	52		
Flash Point Abel (°C)	min					32	35
CCR 10% (%m/m)	max	0.15	0.10	0.15	0.05		
Ramsbottom CR 10% %m/m	max					0.35	0.30
water %v/v	max					0.05	0.05
water & sediment (%v/v)			0.05	0.1	0.05		
sediment (%m/m)	max					0.05 [5]	0.05
ash (%m/m)	max	0.02	0.01	0.02	0.01	0.01	0.01
copper corrosion 3h/100°C	max	1	1	1	1	1	1
Colour ASTM	max				4.0		
additives					(4)		
inorganic acidity	max					nil	nil
total acidity	max					0.30	0.20
Specification						IS 1460	
Test Methods						IS 1448	

(1) Type 2 diesel fuel specified for Bangkok, Nonburi, Patumthani, Samuthprakarn, Samuthsakorn, Samuthsongkram, Phuket, Cholburi, Nakornpathom and Chachoengsao
(2) sulphur content to be reduced to 0.05 %m/m max by 1 January 2000
(3) sulphur content 1.0 %m/m for country areas outside towns specified for Type 2 diesel fuel
(4) detergency additive to meet Cummins L10 Superior in Caterpillar 1K fuel or equivalent required
(5) total sediment at the refinery before the addition of multi-functional additives 1.6 mg/100ml
(6) winter is November to February inclusive, other limits may apply in certain geographical areas
(7) Alternative pour point or CFPP limits may be agreed between supplier and customer
(8) sulphur content to be reduced to 0.50 by 1998

A.5.7.9. Central and South American specifications

Table A.5.47 Central & South American gasoline specifications

		Mexico				Venezuela	
		ULP	ULP [1]	Reg.	Reg. [1]	Optima	Popular
Octane							
Research	min	report	report	81	81		
Motor	min	82	82	report	report	87	80
(R+M)/2	min	87	87	report	report	91	84
Volatility							
distillation							
IBP (°C)	min					30	30
10% (°C)	max	65	65	70	70	70	70
50% (°C)	max	77-118	77-118	77-121	77-121	77-121	77-121
90% (°C)	max	190	190	190	190	195	195
E70 (%v/v)						report	report
E100 (%v/v)							
E180 (%v/v)	min						
End Pt (°C)	max	221	221	225	225	225	225
residue	max	2	2	2	2	2	2
vapour pressure @ 37.8°C kPa	max	45--66	45-66[2]	48-66	45-66[2]	65.5	65.5
IBV [5]	max					14	14
Composition							
sulphur (%m/m)	max	0.10	0.10	0.15	0.15	0.15	0.15
lead (g/l)	max	0.0026	0.0026	0.06-0.28	0.06-0.08	0.85	0.85
phosphorus (g/l)	max	0.001	0.001				
aromatics content (%v/v)	max	report	30		30		
olefins content (%v/v)	max	report	15 [3]		15		
benzene content (%v/v)	max	4.9	2		2		
alcohol content (%v/v)							
oxygen (%m/m)	max		1-2 [4]		1-2[4]		
detergent additive (kg/t)	min	0.28	0.28	0.28	0.28		
Other Parameters							
specific gravity 20°C/4°C		report					
copper corrosion (3h/50°C)	max	1	1	1	1		
mercaptan S (%m/m)	max	0.002	0.002				
doctor test		neg.	neg.				
water tolerance (°C)	max						
oxidation stability (min)	min	300	300	300	300	240	240
potential gum (mg/100ml)	max						
existent gum (mg/100ml)	max	4	4	5	5	5	5
colour		green	green	red	red	red	red
Specification		NOM-086-ECOL-1994				COVENIN 764:1995 (3rd rvn)	
Test Methods		ASTM				COVENIN	

(1) City Gasoline for Mexico City, Guadalajara and Monterray from 1998 and for Mexico City only from 1997

(2) RVP 45-59 for Mexico City

(3) olefins 15 %v/v max during 1997, 12.5 %v/v from 1998

(4) report type and concentration of oxygenate

(5) IBV = RVP - 0.13(E70)

Table A.5.48 Specifications for Brazilian Anhydrous Ethanol (AEAC) and Hydrated Ethanol (AEHC)

Property		**AEAC**	**AEHC**	**Method**
description		anhydrous ethanol, “gasolina” blendstock	hydrated ethanol “Alcool” fuel	
total acidity (as acetic acid), mg/l	max	30	30	MB-2606
electrical conductivity, µS/m	max	500	500	MB-2788
chloride, mg/kg	max		1	MB-3055
sulphate, mg/kg	max		4	
copper, mg/kg	max	0.07		MB-3054
iron, mg/kg	max	-	5	MB-3222
sodium, mg/kg	max	-	2	MB-2787
density(1) @ 20°C, kg/m^3	max	791.5	809.3 ± 1.7	MB-1533
density(2) @ 20°C, kg/m^3	max	-	808.0 ± 3.0	MB-1533
involatile material @ 105 °C, mg/l	max	30	30	MB-2123
pH			7.0 ± 1.0	MB-3053
residue on evaporation, mg/l	max	-	50	MB-2053
alcohol content	min	99.3	93.2 ± 0.6	MB-1533
alcohol content (with allowable gasoline of 30ml/l)		-	92.6 - 94.7	MB-1533
gasoline content (3), ml/l	max		30	MB-1533

(1) production specification
(2) distribution specification
(3) calculated by the formula, % gasoline = 2 (vol HC, ml) + 1

Table A.5.49 Grade structure and lead contents of gasolines of other South American countries

Country	**Unleaded Gasolines**	**Lead Content (gPb/l)**	**Leaded Gasolines**	**Lead Content (gPb/l)**
Argentina	96/85	unleaded	95	0.15
Chile	95/93	unleaded	93/81	0.34
Colombia	93/84	unleaded		
Ecuador	90/85	unleaded	80	0.04 - 0.80

Table A.5.50 South & Central American Automotive Diesel Specifications: Brazil, Mexico & Venezuela

		Brazil			Mexico		Venezuela
		A [(1)]	B [(1)]	C [(1)]	AGO	City [(3)]	AGO
Cetane Number	min	40	40	42		48	43
or Cetane Index	min	45	45	45	45	48	
Sulphur (%m/m)	max	1.00	0.50	0.30	0.5	0.05	1.0
Aromatics (%v/v)	max					30	
Distillation							
IBP						report	
10 %v/v rec.	max				report	275	
50 %v/v rec.	max	245-310	245-310	245-310		report	
85 % v/v rec. (°C)	max	370	370	360			
90% v/v rec. (°)	max				350	345	360
end point	max					report	
Cold Flow Properties							
Pour Point (°C)	max				W -5 S 0 [(4)]	W -5 S 0 [(4)]	0
Cloud Point (°C)	max				report	report	
CFPP (°C)	max	[(2)]	[(2)]	[(2)]			
Other Parameters							
density @ 20°C		0.82-0.88	0.82-0.88	0.82-0.88			report
viscosity @ 40°C (cSt)		1.6-6.0	1.6-6.0	1.6-6.0	1.9-4.1	1.9-4.1	1.6-5.2
Flash Point PM (°C)	min				41	45	60
CCR 10% (%m/m)	max						0.15
Rams CR 10% (%m/m)	max	0.25	0.25	0.25	0.25	0.25	
water (%v/v)	max						
water & sediment (%v/v)		0.05	0.05	0.05	0.05	0.05	0.10
ash (%m/m)	max	0.20	0.20	0.20	0.01	0.01	0.01
copper corrosion 3h/100°C	max	2	2	2	2	1	2
Colour ASTM	max	3.0	3.0	3.0	2.5	2.5	2.5
Test Methods		ADNT/ASTM			ASTM		COVENIN

(1) Implementation schedule

City or Area	Type A	Type B	Type C
Salvadore, São Paulo, Aracaju	-	1993	Oct. 1996
Santos, Cubajão	1993	-	Oct. 1996
Fortaleza, Recife, Rio de Janeiro, Curitiba, Pôrto Alegre, Belo Horizonte	-	1993	Oct. 1997
Belém, Campinas, São José dos Campos	1993	-	Oct. 1997
other regions	1993	1998	

(2) Cold Flow CFPP limits (°C), max

State	Dec-Mar	Apr, Oct, Nov	May-Sept
DF - GO - MG - BS - RJ	13	11	7
SP - MT - MS	12	9	5
Pr - SC - RS	11	8	2

(3) Implementation schedule; City of Mexico 1994, Guadalajara and Monterray 1995
(4) Winter period Nov-Apr., summer period Mar-Oct.

Table A.5.51 South & Central American Automotive Diesel Specifications Puerto Rico

Properties		Limit
Cetane Number	min	45
Cetane Index	min	45
Density, g/l	max	820-870
Sulphur (1), %m/m	max	0.05

(1) 0.5 %m/m sulphur grade available for off-highway and marine applications

A.5.7.10. African and Middle Eastern specifications

Table A.5.53 South African National Specification for Gasoline (SABS 299- 1972, revised 1988)

Property	Limits
Research Octane Number (5)	87 / 93(6) / 97
Distillation	
10%v/v °C, (max)	65
50 %v/v °C	77-115
90 %v/v °C (max)	185
FBP °C (max)	215
residue %v/v, (max)	2.0
RVP, kPa, (max)	75
Vapour/liquid ratio (2) @ 325 kPa (max)	
@ 50 °C	20
@ 55 °C	20
Induction period, min (min)	240
Lead content, gPb/l, max	0.4
Existent gum, mg/100ml, max	4.0
Potential gum, 2.5 h @ 100 °C mg/100ml (max)	4.0
Sulphur content, %m/m (max)	0.15
Copper strip corrosion, 3 h @ 100 °C (max)	1
Water tolerance (3)	pass
Total acidity (4) mgKOH/g (max)	0.03

(1) Applicable only to petrol supplied in coastal regions between 1 April and 30 September (inclusive).

(2) The V/L ratio calculated as described in ASTM D439 may be used as an approximation, but ASTM Method D2533 shall be the referee procedure. However, when blends containing alcohol(s) are tested in accordance with ASTM D2533, the method must be modified by substituting mercury for glycerine in the pressure control system.

(3) Applicable only to blends containing alcohol(s) or other oxygenated compounds or both.

(4) Applicable only to fuels derived from coal and to blends containing alcohol(s) or other oxygenated compounds or both.

(5) In any particular area only two of the three grades will be available. For the "*Coastal areas*" (nominally areas at altitudes below 1200 metres), 97 and 93 RON grades are usually supplied. Above this altitude, only the 87 and 93 RON fuels are generally marketed.

(6) The 93 RON grade manufactured in the SASOL oil-from-coal process contains 8-12% alcohols (mainly ethanol plus some higher alcohols)

Table A.5.53 South African Unleaded Gasoline Specifications (SABS 1598:1993 issued 6 December 1993)

Property		Coastal	Inland
		Grade 95	Grade 91
RON	min	95	91
MON	min	85	81
MON (blends with >0.2%v/v alcohol)	min	87	83
Density at 20ºC (kg/m^3)		710-785	710-785
Distillation ºC:			
E10	max	65	
E50		77-115	
E90	max	185	
FBP		215	
residue %v/v	max	2.0	
VLI summer max		950	890
winter max		1000	940
Lead Content gPb/l max		0.013	
Induction Period	min/min	360	
Existent Gum mg/100ml	max	4	
Potential Gum mg/100ml	max	4	
Sulphur Content %m/m	max	0.10	
Copper Strip Corrosion 3h at 50ºC	max	1	
Total Acidity (1) mgKOH/g	max	0.03	0.03
Oxygen Content (2) %m/m	max	2.8	3.7

(1) Applicable to gasolines containing alcohol only

(2) Any alcohol blend into the fuel shall contain a minimum of 85%m/m ethanol with the balance mainly iso- and n-propanol. Ethers containing 5 or more carbon atoms may be incorporated

Table A.5.54 Grade structure and lead contents of gasolines of African countries

Country	Unleaded Gasolines	Lead Content (gPb/l)	Leaded Gasolines	Lead Content (gPb/l)
Algeria			96/89	0.60/0.50
Cameroon			95	0.60
Egypt			90/81-83	0.23-0.28
Gabon			93/85	0.37/0.15
Kenya			93/83	0.40/0.25
Madagascar			95/87	0.50-0.60/0.10-0.20
Malawi			93	0.60
Mauritius			95	0.40
Morocco	95	unleaded	95/87	0.04-0.50
Mozambique			93	0.40
Nigeria			90	0.66
Tunisia	95	unleaded	96/89	0.50
Zaire			93	0.63
Zambia			93/87	0.71
Zimbabwe			93	0.84

Table A.5.55 Grade structure and lead contents of gasolines of Middle Eastern countries

Country	Unleaded Gasolines	Lead Content (gPb/l)	Leaded Gasolines	Lead Content (gPb/l)
Bahrain			98/90	0.40
Iran			95/87	0.56
Iraq			91/88	0.56
Israel	95/91	0.013	98/96/91	0.05-0.15
Jordan			95/87	0.12-0.38/0.03-0.13
Kuwait			98/90	0.53
Oman			97/90	0.45
Saudi Arabia			95	0.40
Syria			90/76	0.40
UAE			97/90	0.40

Table A.5.56 South African National Specification for Automotive Diesel Fuel

Property	
Cetane Number [1] (min)	45
CFPP (max)	-4 [2]
Density @ 15, kg/l	-
Flash point, PM (min)	55
Kinematic viscosity @ 40, mm^2/sec	1.6-5.3
Distillation 90 recovery (max)	362

(1) In the case of a fuel that does not contain an ignition improver the calculated cetane index (Method IP 218 - ASTM D976) may be used as an approximation but the cetane number shall be used in cases of dispute.

(2) A product with a maximum CFPP of (a) 0°C and supplied between 15 April and 14 May (inclusive) or between 1 September and 30 September (inclusive) (b) 3°C and supplied between 1 October and 14 April (inclusive) may be considered to be acceptable.

A.6. ACKNOWLEDGEMENT

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A.7. GLOSSARY AND VEHICLE CLASSIFICATIONS

Commonly Used Abbreviations

AAMA	American Automobile Manufacturers Association (formerly MVMA)
ACEA	Association des Constructeurs Europeans d'Automobiles (formerly CCMC see below)
AECD	Auxiliary Emission Control Device (device which modifies the action of any part of an emission control system - US EPA definition)
AGO	Automotive Gas Oil (diesel fuel)
ALVW	Adjusted Loaded Vehicle Weight (average of vehicle curb weight and gross vehicle weight rating (GVWR)
AKI	Anti-knock Index
API	American Petroleum Institute
AQIRP	US Auto/Oil Air Quality Improvement Research Program
ASM	Acceleration Simulation Model (US I/M tests)
ASTM	American Society for Testing and Materials
BS	British Standards
CAAA	1990 US Clean Air Act Amendments
CAAAC	Clean Air Act Advisory Committee (US)
CAFE	Corporate Average Fuel Economy (US fuel economy standard)
CARB	Californian Air Resources Board
CCEPC	Japanese Central Council for Environmental Pollution
CCMC	Comité des Constructeurs Européens d'Automobile du Marché Commun (now ACEA)
CEC	California Energy Commission **or** Coordinating European Council
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CFFP	Clean Fuel Fleet Programme (US Clean Air Act requirement)
CFPP	Cold Filter Plugging Point
CFR	Code of Federal Regulations **or** Cooperative Fuels Research
CI	Cetane index
CN	Cetane Number
CNG	Compressed Natural Gas
CP	Cloud Point
CRC	Coordinating Research Council
CO	Carbon monoxide
CO_2	Carbon dioxide
CONAMA	Brazilian National Environmental Council
CONCAWE	Conservation of Clean Air and Water in Europe (the oil companies' European organization for environment, health and safety)
CVS	Constant Volume Sampling System (FTP)
DGF	Deutsche Gesellschaft für Fettchemie - Einheitsmethoden Abtellung-Fette
DI	Direct Injection
DIN	Deutsches Institut für Normung (German Standards Institute)

DOE	US Department of Energy
E70	Per cent gasoline evaporated at 70°C
El00	Per cent gasoline evaporated at 100°C
E180	Per cent gasoline evaporated at 180°C
EA	Japanese Environmental Agency
EC	European Community (now EU)
ECE	United Nations Economic Commission for Europe
EDV	Emission Data Vehicle (vehicle used in EPA certification procedures)
EEC	European Economic Community (now EU)
EFEG	European Fuel Experts Group of the Commission of European Communities
EGR	Exhaust Gas Recirculation (to control NOx)
EMA	Engine Manufacturers Association (US)
EPEFE	European Programme on Emissions, Fuels and Engine Technologies
EP	Distillation End Point
EPA	US Environmental Protection Agency
ETBE	Ethyl Tertiary Butyl Ether
EtOH	Ethyl alcohol (ethanol)
EU	European Union (formerly EC)
EUDC	Extra-Urban Driving Cycle
EUROPIA	European Petroleum Industries' Association
EZEV	Equivalent Zero Emission Vehicle (CARB)
FBP	Distillation Final Boiling Point
FCAI	Australian Federal Chamber of Automotive Industries.
FIA	Fluorescence Indicator Absorption test (for gasoline composition)
FiGE	Forschungsinstitut Geräusche und Erschütterungen (German research institute for noise and vibration testing)
FFV	Flexible Fuelled Vehicle (methanol and/or gasoline)
FR	Federal Register (US legislation register)
FTP	Federal Test Procedure (US exhaust emissions test)
FVI	Flexible Volatility Index
GM	General Motors
GRPE	Groupe des Rapporteurs pour Pollution et Energie (UN ECE group)
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating (maximum gross laden weight)
HC	Hydrocarbons
HCHO	Formaldehyde
HDDTC	Heavy Duty Diesel Transient Cycle (US Federal)
HDGTC	Heavy Duty Gasoline Transient Cycle (US Federal)
HDS	Hydrodesulphurization
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
HOV	High Occupancy Vehicle (US highway lane restrictions)
HSDI	High Speed Direct Injection (diesel engine)
HSU	Hartridge Smoke Units
HWFET	Highway Fuel Economy Test (part of US FTP)
HWY	Highway
IDI	Indirect Injection (diesel engine)
IFP	Institut Française du Pétrole
IGO	Industrial Gas Oil

ILEV	Inherently Low Emission Vehicle (EPA definition)
I&M	Inspection and Maintenance Programme (US Clean Air Act)
IP	Institute of Petroleum (UK)
ISO	International Standards Organization
IVD	Intake Valve Deposits (also BMW IVD test)
JPI	Japanese Petroleum Institute
kPa	kiloPascals (unit of pressure)
KSLA	Knock Limited Spark Advance
LCV	Lower Calorific Value
LDT	Light Duty Truck
LDV	Light Duty Vehicle
LEV	Low Emission Vehicle (CARB emission standard)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LVW	Loaded Vehicle Weight (curb weight plus 300 lb)
MeOH	Methyl alcohol (methanol)
M10	Gasoline containing 10 per cent methanol
M85	Gasoline containing 85 per cent methanol
MDV	Medium Duty Vehicle
MI	Malfunction Indicator (for OBD systems)
MIRA	Motor Industry Research Association (UK)
MITI	Japanese Ministry of International Trade and Industry
MMT	Methyl Cyclopentadienyl Manganese Tricarbonyl
MON	Motor Octane Number
MTBE	Methyl tertiary butyl ether
MVEG	Motor Vehicles Emissions Experts Group of the Commission of the European Communities
MVMA	Motor Vehicle Manufacturers' Association of North America (now AAMA)
NA	Naturally Aspirated
NAAQS	National Ambient Air Quality Standard (US)
NDIR	Non-Dispersive Infra-Red
NESCAUM	Northeast States (of USA) for Coordinated Air Use Management
NMHC	Non-Methane Hydrocarbons
NMOG	Non-Methane Organic Gases
NOx	Nitrogen Oxides
NPAH	Nitrated Polycyclic Aromatic Hydrocarbons
NPRM	US Notice of Proposed Rule Making
NRDC	US Natural Resources Defence Council
NYCC	New York City Cycle (element of some EPA requirements)
OE	Organic Equivalent
OEM	Original Equipment Manufacturer
OICA	Organisation Internationale des Constructeurs d'Automobiles
OMHCE	Organic Material Hydrocarbon Equivalent (mass equivalent of organic emissions defined in EPA methanol vehicle emission standards)
OMNMHCE	Organic Material Non-Methane Hydrocarbon Equivalent
ON	Octane Number
OTC	Northeast Ozone Transport Region Committee
OTR	Northeast Ozone Transport Region
PADD	US Petroleum Administration for Defense Districts

PAH	Polycyclic Aromatic Hydrocarbon
Pm (PM)	Particulate Matter
POM	Polycyclic Organic Matter
PP	Pour Point
ppb	Parts per billion (thousand million)
ppm	Parts per million
RAF	Reactivity Adjustment Factor
RCHO	Aldehydes
RFP	Reasonable Further Progress (US CAAA requirement)
RIC	Reciprocating Internal Combustion (ISO definition)
(R+M)/2	Average of RON and MON (US pump posting of octane)
RM	Reference Mass (EU legislation)
RON	Research Octane Number
ROS	Renewable Oxygenate Standard (US EPA)
RVP	Reid Vapour Pressure
SCAQMD	South Coast Air Quality Management District (of California)
SHED	Sealed Housing for Evaporative Determination (evaporative emissions test for vehicles)
SIP	State Implementation Plan (non-Federal emissions requirement)
SOP	Statement of Principles (US EPA)
Stage I	Control of VOC emissions at depots and service stations during gasoline delivery
Stage II	Control of vehicle refuelling VOC emissions at service stations
SULG	Super Unleaded Gasoline
SLEV	Super Low Emission Vehicle (natural gas fuelled) (CARB)
T10E	Temperature at which 10% v/v gasoline has evaporated
T50E	Temperature at which 50% v/v gasoline has evaporated
T90E	Temperature at which 90% v/v gasoline has evaporated
TAME	Tertiary Amyl Methyl Ether
TBA	Tertiary Butyl Alcohol
TC	Turbocharged
THC	Total Hydrocarbons
TLEV	Transitional Low Emission Vehicle (CARB emission standard)
toe	tonnes oil equivalent
TOG	Total Organic Gas emissions (hydrocarbon and oxygenate)
$TP_{(cold)}$ $TP_{(hot)}$	Transition Period (cold and hot) (part of Federal city cycle)
UDDS	Urban Dynamometer Driving Schedule (FTP)
ULEV	Ultra Low Emission Vehicle (CARB emission standard)
ULG	Unleaded Gasoline
US FTP	United States Federal Test Procedure
UTAC	French Transport Ministry Technical Advisory Committee
VOC	Volatile Organic Compounds
ZEV	Zero Emission Vehicle (CARB emission standard)

Vehicle Categories according to EU Council Directive 70/156/EEC of 6.2.1970

CATEGORY M	Motor vehicles having at least 4 wheels, or having 3 wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of passengers
Category M_1	Vehicles used for the carriage of passengers and comprising no more than 8 seats in addition to the driver's seat
Category M_2	Vehicles used for the carriage of passengers, comprising more than 8 seats in addition to the driver's seat and having a maximum weight not exceeding 5 metric tons
Category M_3	Vehicles used for the carriage of passengers, comprising more than 8 seats in addition to the driver's seat and having a maximum weight exceeding 5 metric tons
CATEGORY N	Motor vehicles having at least 4 wheels, or having 3 wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of goods
Category N_1	Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 metric tons
Category N_2	Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 but not exceeding 12 metric tons
Category N_3	Vehicles used for the carriage of goods and having a maximum weight exceeding 12 metric tons

US Federal Vehicle Classifications

Light Duty Vehicles	Passenger cars and passenger car derivatives capable of seating no more than 12 passengers
Light Duty Trucks	Vehicles with GVWR ≤ 8 500 lb, curb weight ≤ 6 000 lb and frontal area ≤ 45 ft^2 designed for the transportation of goods or the carriage of more than 12 passengers
Light Light Duty Trucks	Light duty trucks with GVWR ≤ 6 000 lb
Heavy Light Duty Trucks	Light duty trucks with GVWR ≥ 6 000 lb
Heavy Duty Vehicles	Vehicle with GVWR > 8 500 lb or curb weight > 6 000 lb or frontal area > 45 ft^2

A.8. INDEX