PROTOCOL

to the 1979 Convention on long-range transboundary air pollution concerning the control of emissions of nitrogen oxides or their transboundary fluxes

THE PARTIES,

Determined to implement the Convention on long-range transboundary air pollution,

Concerned that present emissions of air pollutants are causing damage, in exposed parts of Europe and North America, to natural resources of vital environmental and economic importance,

Recalling that the executive body for the Convention recognized at its second session the need to reduce effectively the total annual emissions of nitrogen oxides from stationary and mobile sources or their transboundary fluxes by 1995, and the need on the part of other States that had already made progress in reducing these emissions to maintain and review their emission standards for nitrogen oxides,

Taking into consideration existing scientific and technical data on emissions, atmospheric movements and effects on the environment of nitrogen oxides and their secondary products, as well as on control technologies,

Conscious that the adverse environmental effects of emissions of nitrogen oxides vary among countries,

Determined to take effective action to control and reduce national annual emissions of nitrogen oxides or their transboundary fluxes by, in particular, the application of appropriate national emission standards to new mobile and major new stationary sources and the retrofitting of existing major stationary sources,

Recognizing that scientific and technical knowledge of these matters is developing and that it will be necessary to take such developments into account when reviewing the operation of this Protocol and deciding on further action,

Noting that the elaboration of an approach based on critical loads is aimed at the establishment of an effect-oriented scientific basis to be taken into account when reviewing the operation of this Protocol and at deciding on further internationally agreed measures to limit and reduce emissions of nitrogen oxides or their transboundary fluxes,

Recognizing that the expeditious consideration of procedures to create more favourable conditions for exchange of technology will contribute to the effective reduction of emissions of nitrogen oxides in the region of the Commission,

Noting with appreciation the mutual commitment undertaken by several countries to implement immediate and substantial reductions of national annual emissions of nitrogen oxides,

Acknowledging the measures already taken by some countries which have had the effect of reducing emissions of nitrogen oxides,

HAVE AGREED AS FOLLOWS:

Article 1

Definitions

For the purpose of the present Protocol:

1. 'Convention' means the Convention on long-range transboundary air pollution, adopted in Geneva on 13 November 1979;
2. 'EMEP' means the cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe;
3. 'Executive Body' means the executive body for the Convention constituted pursuant to Article 10 (1) of the Convention;
4. 'geographical scope of EMEP' means the area defined in Article 1 (4) of the Protocol to the 1979 Convention on long-range transboundary air pollution, on long-term financing of the cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP), adopted in Geneva on 28 September 1984;
5. 'Parties' means, unless the context otherwise requires, the parties to the present Protocol;
6. 'Commission' means the United Nations Economic Commission for Europe;
7. 'critical load' means a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specified sensitive

elements of the environment do not occur according to present knowledge;

8. 'major existing stationary source' means any existing stationary source the thermal input of which is at least 100 MW;

9. 'major new stationary source' means any new stationary source the thermal input of which is at least 50 MW;

10. 'major source category' means any category of sources which emits or may emit air pollutants in the form of nitrogen oxides, including the categories described in the Technical Annex, and which contribute at least 10 % of the total national emissions of nitrogen oxides on an annual basis as measured or calculated in the first calendar year after the date of entry into force of the present Protocol, and every fourth year thereafter;

11. 'new stationary source' means any stationary source the construction or substantial modification of which is commenced after the expiration of two years from the date of entry into force of this Protocol;

12. 'new mobile source' means a motor vehicle or other mobile source which is manufactured after the expiration of two years from the date of entry into force of the present Protocol.

Article 2

Basic obligations

1. The Parties shall, as soon as possible and as a first step, take effective measures to control and/or reduce their national annual emissions of nitrogen oxides or their transboundary fluxes so that these, at the latest by 31 December 1994, do not exceed their national annual emissions of nitrogen oxides or transboundary fluxes of such emissions for the calendar year 1987 or any previous year to be specified upon signature of, or accession to, the Protocol, provided that in addition, with respect to any party specifying such a previous year, its national average annual transboundary fluxes or national average annual emissions of nitrogen oxides for the period from 1 January 1987 to 1 January 1996 do not exceed its transboundary fluxes or national emissions for the calendar year 1987.

2. Furthermore, the Parties shall in particular, and no later than two years after the date of entry into force of the present Protocol:

(a) apply national emissions standards to major new stationary sources and/or source categories, and to substantially modified stationary sources in major source categories, based on the best available technologies which are economically feasible, taking into consideration the Technical Annex;

(b) apply national emission standards to new mobile sources in all major source categories based on the best available technologies which are economically feasible, taking into consideration the Technical Annex and the relevant decisions taken within the framework of the Inland Transport Committee of the Commission; and

(c) introduce pollution control measures for major existing stationary sources, taking into consideration the Technical Annex and the characteristics of the plant, its age and its rate of utilization and the need to avoid undue operational disruption.

3. (a) The Parties shall, as a second step, commence negotiations, no later than six months after the date of entry into force of the present Protocol, on further steps to reduce national annual emissions of nitrogen oxides or transboundary fluxes of such emissions, taking into account the best available scientific and technological developments, internationally accepted critical loads and other elements resulting from the work programme undertaken pursuant to Article 6;

(b) To this end, the Parties shall cooperate in order to establish:

(i) critical loads;

(ii) reductions in national annual emissions of nitrogen oxides or transboundary fluxes of such emissions as required to achieve agreed objectives based on critical loads, and

(iii) measures and a timetable commencing no later than 1 January 1996 for achieving such reductions.

4. Parties may take more stringent measures than those required by the present Article.

Article 3

Exchange of technology

1. The Parties shall, consistent with their national laws, regulations and practices, facilitate the exchange of technology to reduce emissions of nitrogen oxides, particularly through the promotion of:

(a) commercial exchange of available technology;

(b) direct industrial contacts and cooperation, including joint ventures;

(c) exchange of information and experience; and

(d) provision of technical assistance.

2. In promoting the activities specified in subparagraphs (a) to (d) above, the Parties shall create favourable conditions by facilitating contacts and cooperation among appropriate organizations and individuals in the private and public sectors that are capable of providing technology, design and engineering services, equipment or finance.

3. The Parties shall, no later than six months after the date of entry into force of the present Protocol, commence

consideration of procedures to create more favourable conditions for the exchange of technology to reduce emissions of nitrogen oxides.

Article 4

Unleaded fuel

The Parties shall, as soon as possible and no later than two years after the date of entry into force of the present Protocol, make unleaded fuel sufficiently available, in particular cases as a minimum along main international transit routes, to facilitate the circulation of vehicles equipped with catalytic converters.

Article 5

Review process

1. The Parties shall regularly review the present Protocol, taking into account the best available scientific substantiation and technological development.

2. The first review shall take place no later than one year after the date of entry into force of the present Protocol.

Article 6

Work to be undertaken

The Parties shall give high priority to research and monitoring related to the development and application of an approach based on critical loads to determine, on a scientific basis, necessary reductions in emissions of nitrogen oxides. The Parties shall, in particular, through national research programmes, in the work plan of the executive body and through other cooperative programmes within the framework of the Convention, seek to:

(a) identify and quantify effects of emissions of nitrogen oxides on humans, plant and animal life, waters, soils and materials, taking into account the impact on these of nitrogen oxides from sources other than atmospheric deposition;

(b) determine the geographical distribution of sensitive areas;

(c) develop measurements and model calculations including harmonized methodologies for the calculation of emissions, to quantify the long-range transport of nitrogen oxides and related pollutants;

(d) improve estimates of the performance and costs of technologies for control of emissions of nitrogen oxides and record the development of improved and new technologies; and

(e) develop, in the context of an approach based on critical loads, methods to integrate scientific, technical and economic data in order to determine appropriate control strategies.

Article 7

National programmes, policies and strategies

The Parties shall develop without undue delay national programmes, policies and strategies to implement the obligations under the present Protocol that shall serve as a means of controlling and reducing emissions of nitrogen oxides or their transboundary fluxes.

Article 8

Information exchange and annual reporting

1. The Parties shall exchange information by notifying the executive body of the national programmes, policies and strategies that they develop in accordance with Article 7 and by reporting to it annually on progress achieved under, and any changes to, those programmes, policies and strategies, and in particular on:

(a) the levels of national annual emissions of nitrogen oxides and the basis upon which they have been calculated;

(b) progress in applying national emission standards required pursuant to Article 2, subparagraph 2 (a) and (b), the national emission standards applied or to be applied and the sources and/or source categories concerned;

(c) progress in introducing the pollution control measures required pursuant to Article 2, subparagraph 2 (c), the source concerned and the measures introduced or to be introduced;

(d) progress in making unleaded fuel available;

(e) measures taken to facilitate the exchange of technology; and

(f) progress in establishing critical loads.

2. Such information shall, as far as possible, be submitted in accordance with a uniform reporting framework.

Article 9

Calculations

EMEP shall, utilizing appropriate models and in good time before the annual meetings of the executive body, provide to the executive body calculations of nitrogen budgets and also of transboundary fluxes and deposition of nitrogen oxides within the geographical scope of EMEP. In areas outside the geographical scope of EMEP, models appropriate to the particular circumstances of Parties to the Convention therein shall be used.

Article 10

Technical Annex

The Technical Annex to the present Protocol is recommendatory in character. It shall form an integral part of the Protocol.

Article 11

Amendments to the Protocol

1. Any Party may propose amendments to the present Protocol.

2. Proposed amendments shall be submitted in writing to the Executive Secretary of the Commission who shall communicate them to all Parties. The executive body shall discuss the proposed amendments at its next annual meeting provided that these proposals have been circulated by the Executive Secretary to the Parties at least 90 days in advance.

3. Amendments to the Protocol, other than amendments to its Technical Annex, shall be adopted by consensus of the Parties present at a meeting of the Executive Body, and shall enter into force for the Parties which have accepted them on the 90th day after the date on which two-thirds of the Parties have deposited their instruments of acceptance thereof. Amendments shall enter into force for any Party which has accepted them after two-thirds of the Parties have deposited their instruments of acceptance of the amendment, on the 90th day after the date on which that Party deposited its instrument of acceptance of the amendments.

4. Amendments to the Technical Annex shall be adopted by consensus of the Parties present at a meeting of the Executive Body and shall become effective 30 days after the date on which they have been communicated in accordance with paragraph 5 below.

5. Amendments under paragraphs 3 and 4 above shall, as soon as possible after their adoption, be communicated by the Executive Secretary to all Parties.

Article 12

Settlement of disputes

If a dispute arises between two or more Parties as to the interpretation or application of the present Protocol, they shall seek a solution by negotiation or by any other method of dispute settlement acceptable to the Parties to the dispute.

Article 13

Signature

1. The present Protocol shall be open for signature at Sofia from 1 November to 4 November 1988 inclusive, then at the Headquarters of the United Nations in New York until 5 May 1989, by the Member States of the Commission as well as States having consultative status with the Commission, pursuant to paragraph 8 of Economic and Social Council resolution 36 (IV) of 28 March 1947, and by regional economic intregration organizations, constituted by sovereign States, members of the Commission, which have competence in respect of the negotiation, conclusion and application of international agreements in matters covered by the Protocol, provided that the States and organizations concerned are Parties to the Convention.

2. In matters which their competence, such regional economic integration organizations shall, on their own behalf, exercise the rights and fulfil the responsibilities which the present Protocol attributes to their Member States. In such cases, the Member States of these organizations shall not be entitled to exercise such rights individually.

Article 14

Ratification, acceptance, approval and accession

1. The present Protocol shall be subject to ratification, acceptance or approval by Signatories.

2. The present Protocol shall be open for accession as from 6 May 1989 by the States and organizations referred to in Article 13 (1).

3. A State or organization which accedes to the present Protocol after 31 December 1993 may implement Articles 2 and 4 no later than 31 December 1995.

4. The instruments of ratification, acceptance, approval or accession shall be deposited with the Secretary-General of the United Nations, who will perform the functions of depositary.

Article 15

Entry into force

1. The present Protocol shall enter into force on the 90th day following the date on which the 16th instrument of ratification, acceptance, approval or accession has been deposited.

2. For each State and organization referred to in Article 13 (1) which ratifies, accepts or approves the present Protocol or accedes thereto after the deposit of the 16th instrument of ratification, acceptance, approval, or accession, the Protocol shall enter into force on the 90th day following the date of deposit by such Party of its

instrument of ratification, acceptance, approval, or accession.

Article 16

Withdrawal

At any time after five years from the date on which the present Protocol has come into force with respect to a Party, that Party may withdraw from it by giving written notification to the depositary. Any such withdrawal shall take effect on the 90th day following the date of its receipt by the depositary, or on such later date as may be specified in the notification of the withdrawal.

Article 17

Authentic texts

The original of the present Protocol, of which the English, French and Russian texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

In witness whereof the undersigned, being duly authorized thereto, have signed the present Protocol.

Done at Sofia this thirty-first day of October one thousand nine hundred and eighty-eight.

TECHNICAL ANNEX

1. Information regarding emission performance and costs is based on official documentation of the executive body and its subsidiary bodies, in particular documents EB.AIR/WG.3/R. 8, R. 9 and R. 16, and ENV/WP.1/R. 86, and Corr. 1, as reproduced in chapter 7 of *Effects and Control of Transboundary Air Pollution* (1). Unless otherwise indicated, the technologies listed are considered to be well established on the basis of operational experience (2).

2. The information contained in this Annex is incomplete. Because experience with new engines and new plants incorporating low emission technology, as well as with retrofitting existing plants, is continuously expanding, regular elaboration and amendment of the Annex will be necessary. The Annex cannot be an exhaustive statement of technical options; its aim is to provide guidance for the Parties in identifying economically feasible technologies for giving effect to the obligations of the Protocol.

I. CONTROL TECHNOLOGIES FOR NO_x-EMISSIONS FROM STATIONARY SOURCES

3. Fossil fuel combustion is the main stationary source of anthropogenic NO_x emissions. In addition, some non-combustion processes can contribute relevant NO_x emissions.

4. Major stationary source categories of NO_x emissions may include:

   (a) combustion plants;

   (b) industrial process furnaces (e.g., cement manufacture);

   (c) stationary gas turbines and internal combustion engines; and

   (d) non-combustion processes (e.g. nitric acid production).

5. Technologies for the reduction of NO_x emissions focus on certain combustion/process modifications, and, especially for large power plants, on flue gas treatment.

6. For retrofitting of existing plants, the extent of application of low-NO_x technologies may be limited by negative operational side-effects or by other site-specific constraints. In the case of retrofitting, therefore, only approximate estimates are given for typically achievable NO_x emission values. For new plants, negative side-effects can be minimized or excluded by appropriate design features.

7. According to currently available data, the costs of combustion modifications can be considered as small for new plants. However, in the case of retrofitting for instance at large power plants, they ranged from about 8 to 25 Swiss francs per kW_{el} (in 1985). As a rule, investment costs of flue gas treatment systems are considerably higher.

8. For stationary sources, emission factors are expressed in milligrams of NO_2 per normal (0 °C, 1013 mb) cubic metre (mg/m^3), dry basis.

Combustion plants

9. The category of combustion plants comprises fossil fuel combustion in furnaces, boilers, indirect heaters and other combustion facilities with a heat input larger than 10 MW, without mixing the combustion flue gases with other effluents or treated materials. The following combustion technologies, either singly or in combination, are available for new and existing installations:

(1) Air Pollution Studies No 4 (United Nations publication, sales No E.87.II.E.36).

(2) It is at present difficult to provide reliable data on the costs of control technologies in absolute terms. For cost data included in the present Annex, emphasis should therefore be placed on the relationship between the costs of different technologies rather than on absolute cost figures.

(a) low-temperature design of the firebox, including fluidized bed combustion;

(b) low excess-air operation;

(c) installation of special low-NO_x burners;

(d) flue gas recirculation into the combustion air;

(e) staged combustion/overfire-air operation; and

(f) reburning (fuel staging) (1).

Performance standards that can be achieved are summarized in Table 1.

Table 1:

NO_x performance standards (mg/m^3) that can be achieved by combustion modifications

		Plant type (a)	Uncontrolled baseline	Existing plant retrofit (b)		New plant	O_2 (%)
				Range	Tropical value		
Solid Fuels	10 (c) to 300 MW	Grate combustion (coal)					
		Fluidized bed combustion	300-1 000	—	600	400	7
		(i) stationary	300-600	—	—	400	7
		(ii) circulating	150-300	—	—	200	7
		Pulverized coal combustion					
		(i) dry bottom	700-1 700	600-1 100	800	< 600	6
		(ii) wet bottom	1 000-2 300	1 000-1 400	—	< 1 000	6
	> 300 MW	Pulverized coal combustion					
		(i) dry bottom	700-1 700	600-1 100	—	< 600	6
		(ii) wet bottom	1 000-2 300	1 000-1 400	—	< 1 000	6
Liquid Fuels	10 (c) to 300 MW	Distillate oil combustion	—	—	300	—	3
		Residual oil combustion	500-1 400	200-400	400	—	3
	> 300 MW	Residual oil combustion	200-1 400	200-400	—	—	3
Gaseous Fuels	10 (c) to 300 MW		150-1 000	100-300	—	< 300	3
	> 300 MW		250-1 400	100-300	—	< 300	3

(a) Capacity numbers refer to MW (thermal) heat input by fuel (lower heating value).
(b) Only approximate values can be given due to site-specific factors and greater uncertainty for retrofitting of existing plant.
(c) For small (10 to 100 MW) plants a greater degree of uncertainty applies to all figures given.

10. Flue gas treatment by selective catalytic reduction (SCR) is an additional NO_x emission reduction measure with efficiencies of up to 80 % and more. Considerable operational experience from new and retrofitted installations is now being obtained within the region of the Commission, in particular for power plants larger than 300 MW (thermal). When combined with combustion modifications, emission values of 200 mg/m^3 (solid fuels, 6 % O_2) and 150 mg/m^3 (liquid fuels, 3 % O_2) can be easily met.

11. Selective non-catalytic reduction (SNCR), a flue gas treatment for a 20 to 60 % NO_x reduction, is a cheaper technology for special applications (e. g. refinery furnaces and base load gas combustion).

(1) There is limited operational experience of this type of combustion technology.

Stationary gas turbines and internal combustion (IC) engines

12. NO_x emissions from stationary gas turbines can be reduced either by combustion modification (dry control) or by water/steam injection (wet control). Both measures are well established. By these means, emission values of 150 mg/m³ (gas, 15 % O_2) and 300 mg/m³ (oil, 15 % O_2) can be met. Retrofit is possible.

13. NO_x emissions from stationary spark ignition IC engines can be reduced either by combustion modifications (e.g. lean-burn and exhaust gas recirculation concepts) or by flue gas treatment (closed-loop three-way catalytic converter, SCR). The technical and economic feasibility of these various processes depends on engine size, engine type (two-stroke/four-stroke), and engine operation mode (constant/varying load). The lean-burn concept is capable of meeting NO_x emission values of 800 mg/m³ (5 % O_2), the SCR process reduces NO_x emissions well below 400 mg/m³ (5 % O_2), and the three-way catalytic converter reduces such emissions even below 200 mg/m³ (5 % O_2).

Industrial process furnaces — Cement calcination

14. The precalcination process is being evaluated within the region of the Commission as a possible technology with the potencial for reducing NO_x concentrations in the flue gas of new and existing cement calcination furnaces to about 300 mg/m³ (10 % O_2).

Non-combustion processes — Nitric acid production

15. Nitric acid production with a high pressure absorption (>8 bar) is capable of keeping NO_x concentrations in undiluted effluents below 400 m³. The same emission performance can be met by medium pressure absorption in combination with a SCR process or any other similar efficient NO_x reduction process. Retrofit is possible.

II. CONTROL TECHNOLOGIES FOR NO_X EMISSIONS FROM MOTOR VEHICLES

16. The motor vehicles considered in this Annex are those used for road transport, namely: petrol-fuelled and diesel-fuelled passenger cars, light-duty vehicles and heavy-duty vehicles. Appropriate reference is made, as necessary, to the specific vehicle categories (M_1, M_2, M_3, N_1, N_2, N_3) defined in EEC Regulation No 13 pursuant to the 1958 Agreement concerning the adoption of uniform conditions of approval and reciprocal recognition of approval for motor vehicles equipment and parts.

17. Road transport is a major source of anthropogenic NO_x emission in many Commission countries, contributing between 40 and 80 % of total national emissions. Typically, petrol-fuelled vehicles contribute two-thirds of total road transport NO_x emissions.

18. The technologies available for the control of nitrogen oxides from motor vehicles are summarized in Tables 3 and 6. It is convenient to group the technologies by reference to existing or proposed national and international emission standards differing in stringency of control. Because current regulatory test cycles only reflect urban and metropolitan driving, the estimates of relative NO_x emissions given below take account of higher speed driving where NO_x emissions can be particularly important.

19. The additional production cost figures for the various technologies given in Tables 3 and 6 are manufacturing cost estimates rather than retail prices.

20. Control of production conformity and in-use vehicle performance is important in ensuring that the reduction potential of emission standards is achieved in practice.

21. Technologies that incorporate or are based on the use of catalytic converters require unleaded fuel. Free circulation of vehicles equipped with catalytic converters depends on the general availability of unleaded petrol.

Petrol-fuelled and diesel-fuelled passenger cars (M_1)

22. In Table 2, four emission standards are summarized. These are used in Table 3 to group the various engine technologies for petrol vehicles according to their NO_x emission reduction potential.

Table 2

Definition of emission standards

Standard	Limits	Comments
A. ECE R. 15-04	HC + NO_x: 19-28 g/test	Current ECE standard (Regulation No 15, including the 04 series of amendments, pursuant to the 1953 Agreement referred to in paragraph 16 above), also adopted by the European Economic Community (Directive 83/351/EEC). ECE R. 15 urban test cycle. Emission limit varies with vehicle mass.
B. 'Luxembourg 1985'	HC + NO_x: 1,4-2,0 l: 8,0 g/test This standard only used to group technology (< 1,4 l: 15,0 g/test; >2,0 l: 6,5 g/test)	Standards to be introduced during 1988 to 1993 in the European Economic Community, as discussed at the 1985 Luxembourg meeting of the EEC Council of Ministers and finally agreed upon in December 1987. ECE R. 15 urban test cycle applies. Standard for engines > 2 l is generally equivalent to US 1983 standard. Standard for engines < 1,4 l is provisional, definite standard to be elaborated. Standard for engines of 1,4-2,0 applies to all diesel cars > 1,4 l.
C. 'Stockholm 1985'	NO_x: 0,62 g/km NO_x: 0,76 g/km	Standards for national legislation based on the 'master document' developed after the 1985 Stockholm meeting of Environment Ministers from eight countries. Matching US 1987 standards, with the following test procedures: US Federal Test Procedure (1975); highway fuel economy test procedure.
D. 'California 1989'	NO_x: 0,25 g/km	Standards to be introduced in the State of California, United States from 1989 models onwards. US Federal Test Procedure.

Table 3

Petrol engine technologies, emission performance, costs and fuel consumption for emission standard levels

Standard	Technology	Composite (a) NO_x reduction (%)	Additional (b) production cost (1986 in Swiss francs)	Fuel consumption index (a)
A.	Baseline (Current conventional spark-ignition engine with carburettor)	(c)	—	100
B.	(a) Fuel injection + secondary air (d)	25	200	105
	(b) Open-loop three-way catalyst (+ EGR)	55	150	103
	(c) Lean-burn engine with oxidation catalyst (+ EGR) (e)	60	200-600	90
C.	Closed-loop three-way catalyst	90	300-600	95
D.	Closed-loop three-way catalyst (+ EGR)	92	350-600	98

(a) Composite NO_x reduction and fuel consumption index estimates are for an average-weight European car operating under average European driving conditions.
(b) Additional production costs could be more realistically expressed as a percentage of the total car cost. However, since cost estimates are primarily for comparison in relative terms only, the formulation of the original documents has been retained.
(c) Composite NO_x emission factor = 2,6 g/km.
(d) 'EGR' means exhaust gas recirculation.
(e) Based entirely on data for experimental engines. Virtually no production of lean-burn engined vehicles exists.

23. The emission standards A, B, C and D include limits on hydrocarbon (HC) and carbon monoxide (CO) emissions as well-as NO_x. Estimates of emission reductions for these pollutants, relative to the baseline ECE R. 15-04 case, are given in Table 4.

Table 4

Estimated reductions in HC and CO emissions from petrol-fuelled passenger cars for different technologies

Standard	HC-reduction (%)	CO-reduction (%)
B.	(a) 30-40 (b) 50-60 (c) 70-90	50 40-50 70-90
C.	90	90
D.	90	90

24. Current diesel cars can meet the NO_x emission requirements of standards A, B and C. Strict particulate emission requirements, together with the stringent NO_x limits of standard D, imply that diesel passenger cars will require further development, probably including electronic control of the fuel pump, advanced fuel injection systems, exhaust gas recirculation and particulate traps. Only experimental vehicles exist to date. (See also Table 6, footnote (a)).

Other light-duty vehicles (N_1)

25. The control methods for passenger cars are applicable but NO_x reductions, costs and commercial lead time factors may differ.

Heavy-duty petrol-fuelled vehicles (M_2, M_3, N_2, N_3)

26. This class of vehicle is insignificant in western Europe and is decreasing in eastern Europe. US 1990 and US 1991 NO_x emission levels (see Table 5) could be achieved at modest cost without significant technology advancement.

Heavy-duty diesel-fuelled vehicles (M_2, M_3, N_2, N_3)

27. In Table 5, three emission standards are summarized. These are used in Table 6 to group engine technologies for heavy-duty diesel vehicles according to NO_x reduction potential. The baseline engine configuration is changing, with a trend away from naturally aspirated to turbo-charged engines. This trend has implications for improved baseline fuel consumption performance. Comparative estimates of consumption are therefore not included.

Table 5

Definition of emission standards

Standard	NO_x limits (g/kWh)	Comments
I. ECE R. 49	18	13 mode test
II. US-1990	8,0	Transient test
III. US-1991	6,7	Transient test

Table 6

Heavy-duty diesel engine technologies, emission performance (a), and costs for emission standard levels

Standard	Technology	NO_x reduction estimate (%)	Additional production (cost (1984 US$)
I.	Current conventional direct injection diesel engine	—	—
II. (b)	Turbo-charging + after-cooling + injection timing retard (combustion chamber and port modification) (naturally-aspirated engines are unlikely to meet this standard)	40	$115 ($69 attributable to NO_x standard) (c)
III. (b)	Further refinements of technologies listed under II together with variable injection timing and use of electronics	50	$404 ($68 attributable to NO_x standard) (c)

(a) Deterioration in diesel fuel quality would adversely affect emission and may affect fuel consumption for both heavy- and light-duty vehicles.
(b) It is still necessary to verify on a large scale the availability of new components.
(c) Particulate control and other considerations account for the balance.