CORINAIR WORKING GROUP ON EMISSION FACTORS FOR CALCULATING 1990 EMISSIONS FROM ROAD TRAFFIC

Volume 1: Methodology and emission factors

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Volume 1: Methodology and Emission Factors

DOCUMENT

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Volume 1 : Methodology and Emission Factors

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This report is part of the CORINAIR documentation provided to estimate emissions of pollutants into air for the year 1990. In case of any further questions, the reader is advised to contact:

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I INTRODUCTION

As a result of the Council Decision 85/338/EEC (Commission 1985), the Commission of the European Communities (DG XI) realized in the period 1987 to 1990 plans to gather EC wide information on emissions of pollutants into the air in a consistent form (Bouscaren et al.1986, Commission 1991). This information is broken down into several source categories, of which *"Road Traffic"* is an important part. In order to improve the consistency of the emission data, working groups were set up to assist estimation of these emissions by proposing emission factors for the most relevant source categories. The "CORINAIR Working Group on Emission Factors for Calculating Emissions from Road Traffic" developed a methodology, including appropriate emission factors, for the reference year 1985 (Eggleston et al. 1989). The methodology was transformed into a computer programme (Samaras et al. 1989a) and applied by many EC countries in the 1985 exercise (Samaras et al. 1989b).

In 1991 the group has been re-convened with the aim to propose to EC Member States a set of emission factors to be used for the 1990 inventory, including, where necessary a revision of the underlying methodology used for estimating the emissions.

This report describes the methodology developed by the working group and proposes emission factors which are needed for its application. In comparison to the 1985 approach the following major modifications have been made:

i) The vehicle category split has been revised, distinguishing now between Passenger Cars < 2.5 t and Light Duty Vehicles < 3.5 t (in 1985 they were combined in one group 'Vehicles < 3.5 t'). Moreover, two stroke engined passenger cars and off-road vehicles have been introduced as separate categories.

ii) Within the vehicle categories new classes of vehicles have been added in order to take into account the evolution of technology since 1985. In particular passenger cars equipped with open and closed 3 way catalysts (3-WC) have been added but also passenger cars using improved conventional technology.

iii) The methodology has been somewhat up-dated, in particular the cold start emission of the vehicle classes operated with closed loop 3-WC have required an approach different from conventional passenger cars. Moreover, cold start emission factors for diesel and LPG passenger cars < 2.5 t and for light duty vehicles have been proposed. Finally modifications have also been made with regard to evaporative emissions.

iv) The list of pollutants covered has been extended and revised. The report contains now emission factors for NOx, N_2O, SOx, VOC, CH_4, CO, CO_2, NH_3, diesel particulates and lead[(1)]. In the 1985 report only CO, VOC, NOx and diesel particulates were covered.

As in 1985, the results of this work have been translated into a menu-driven computer programme, called COPERT 90, which substantially facilitates the practical application of the methodology (see Samaras et al. 1991a).

Due to the modifications made, it is proposed to apply COPERT 90 also again for the 1985 emission estimates in order to obtain comparable trend data.

As in the 1985 approach, emissions from road transport are divided into three types. The first are the "hot emissions". These are the emissions from vehicles after they have warmed up to their normal operating temperature. The second are the so-called "cold-start emissions" which are the emissions from vehicles while they are warming up. The third type are evaporative emissions. These only occur in relevant quantities for gasoline vehicles in the form of NMVOC emissions. For some vehicle classes and some pollutants, the different types of emissions are lumped together into one emission factor, for some others, individual emission factors are proposed.

It should be noted that also refuelling losses exist. These are not included in this report as they are emitted at petrol stations. However, CORINAIR includes them in a separate category.

The rest of the report gives the details of the proposed emission calculation. Each country will have to use information relating to its vehicle fleet, while this report gives all the factors needed to estimate emissions.

Chapter II gives some general information about the problem.
Chapter III briefly discusses the vehicle category split.
Chapter IV briefly discusses the pollutants covered.
Chapter V describes the proposed methodologies.
Chapter VI has the detail of the emission factors themselves.

This report summarizes results obtained by the working group on road traffic emissions. It is addressed to CORINAIR experts responsible for the estimation of emissions at national level, but might be of interest to other experts who are working in the field of emission estimation.

II THE PROBLEM

The aim of the calculations described below is to estimate the 1990 emissions of NOx (sum of NO and NO_2), N_2O, NMVOC (total VOC minus methane), CH_4, CO, CO_2, SOx, NH_3, diesel particulates and lead from road traffic, differentiated into ten different major categories and 39 sub-categories, most of them separated into three types of roads

(1) List of abbreviations is given in chapter XI.

(urban, rural, highway), for each area, or territorial unit (NUTS III), as required by the CORINAIR framework methodology. Table II-1 displays the CORINAIR vehicle category split.

The basic data is therefore the 1990 emission of pollutant i, caused by vehicle category j at local area level (NUTS III) on roads of type k. In the ideal case, such information must be available for all pollutants, all categories at all territorial units and for all types of roads in order to estimate the emissions required by CORINAIR.

There are different ways of carrying out these calculations, depending on the available statistical data and the available emission factors. This, however, opens the way for differences between the calculated values, leading to incompatible results.

In order to avoid this and to meet the goals of the CORINAIR work, in particular that of improved quality and comparability of emission data, it seems to be most appropriate to define a baseline methodology which, in the ideal case, should be used by all countries, and then to allow national deviations from this methodology. Both baseline methodology and deviations have to be well described in order to fulfil the requirements mentioned above.

The baseline methodology has to take into account the knowledge and the statistical data available in all European countries, but at least in EC Member States. The application of this methodology requires input data. While the statistical data have to be collected by Member States individually, the set of emission factors should be as comparable as possible. The expert group therefore devoted a large amount of its time to the development of such emission factors.

III VEHICLE CATEGORY SPLIT

The vehicle category split required by CORINAIR 1990 does not meet all aspects of vehicle emissions considered important by the working group. In particular the age of vehicle (year of production) and the engine technology is not sufficiently reflected. Thus, for the purpose of the work only, a more detailed vehicle category split has been developed, see Table III-1. Major differences occur in the category Passenger Cars, where the different steps of international legal conformity are reflected (ECE classes). In addition national legislation is taken into account with the classes 'Improved Conventional', 'Open Loop' and 'Closed Loop'. Moreover the category 'Buses' is not part of the split because emission factors different from those of heavy duty vehicles could not be found.

In order to help identifying the vehicle categories, Table III-2 gives the classification of vehicles according to the UN-ECE. The main COPERT categories can be allocated to the UN-ECE classification as follows:

Passenger Cars - M1
Light Duty Vehicles - N1

Heavy Duty Vehicles	- M2, M3, N2, N3
Two Wheelers	- L1, L2, L3, L4, L5
Off-Road Vehicles	- no classification given

IV POLLUTANTS COVERED

In comparison to the 1985 inventory, the list of pollutants has been significantly extended and modified. The major reason for that is the great interest in the emission of substances contributing to acidification and the global warming. The working group agreed to apply the following definitions:

NOx (NO and NO_2) :	given as NO_2 equivalent
N_2O :	given as N_2O equivalent
SOx :	given as SO_2 equivalent
VOC :	given as $CH_{1.85}$ equivalent(1)
CH_4 :	given as CH_4 equivalent
CO :	given as CO equivalent
CO_2 :	given as CO_2 equivalent
NH_3 :	given as NH_3 equivalent
Particulate matter :	given as mass equivalent of filter measurements
Lead :	given as Pb equivalent

As requested by the CORINAIR nomenclature, total VOC emissions have to be split into NMVOC and methane. This is performed by deducting methane from the total VOC emissions. Work on a more detailed VOC split is under way but could not be included in this report.

In summary, the major task of the working group was to provide a set of emission factors for hot driving, cold start and evaporative emissions, based as far as possible on solid data, in such a way that they can be used directly or, if necessary, transformed by Member States into national emission factors.

V BASELINE METHODOLOGY

The 1985 baseline methodology has not been revised very much. Only a few details are changed. The methodology is defined in such a way that it uses the firm technical data and that national variations among Member States can be incorporated. The variations may include such things as composition of vehicle park, vehicle age, driving patterns, some fuel parameters and a few climatic parameters.

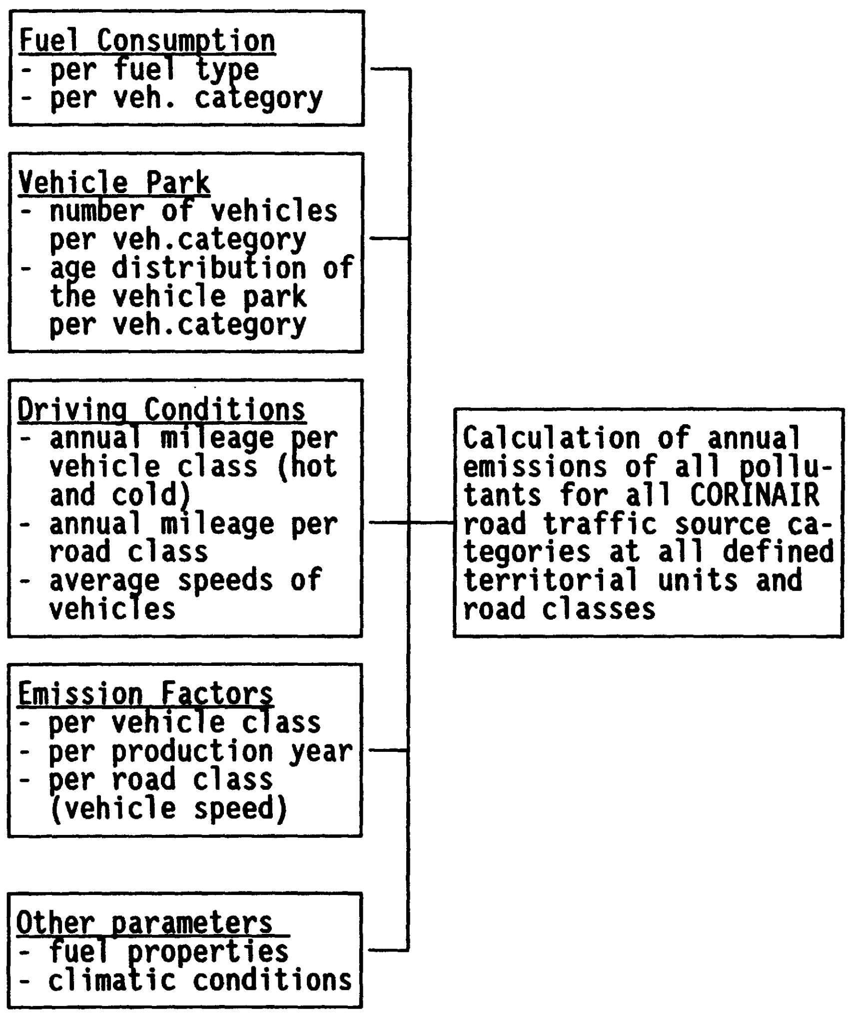
Other variations which may exist, for example, variations in vehicle maintenance, are not accounted for because there is not enough data available to do so.

(1) For evaporating emissions tank breathing is reported as $CH_{2.33}$ and hot soak as $CH_{2.20}$. These are the units used to report test protocols.

It is proposed to base the calculation on five main types of input parameters:

- total fuel consumption
- vehicle park
- driving condition
- emission factors
- other parameters

For these main types of input parameters, additional information (e.g. on vehicle classes, production years etc) is needed in order to carry out the calculations. The following picture shows the calculation scheme:



In order to meet the CORINAIR requirements, in particular the one that data should be suitable for advanced long-range dispersion models, this information should be available for the smallest territorial unit (NUTS III). However, this is not the case in most countries, so that it seems to be more appropriate for these countries to start at NUTS level 0 and to allocate emissions to other NUTS levels with the help of available surrogate data. This implies that certain local particularities within a certain country, e.g. mountains or climatic differences, cannot be taken into account. The attempt to do so by applying all sorts of "corrections" introduced at a later stage of the calculation failed because no sound set of "correction factors" could be identified. However, national particularities can be taken into account by this top-down approach via the composition of the vehicle park, the driving conditions and the temperature dependency of some emission factors.

For countries which have the required input available at smaller NUTS level (including for example traffic counting) it is proposed to make use of this information and to apply a bottom-up approach. However, the model should not be used for NUTSs much smaller than NUTS III because the vehicle speeds and driving modes are average values themselves and may not fit to particular local circumstances.

Finally, as it will be outlined in the next chapter, some categories can be lumped together (e.g. without distinguishing among production years or road classes), so that the total calculation effort is substantially reduced.

The actual calculation for the reference year 1990 should be carried out for all NUTS 0 as follows.

V.1 Hot Emissions

These emissions depend on a variety of factors including the distance that each vehicle travels, its speed (or road type), its age and engine size. As explained later, many countries do not have solid estimates of these data. Therefore a method to estimate the emissions from available solid data has been proposed. However, it is important that each country uses the best data they have available. This is an issue to be resolved by each individual country.

There are a number of other factors that may influence vehicle emissions, for example, state of maintenance, climate or altitude. However, there is so little data about the influence of these parameters on European vehicles that their influence cannot be taken into account.

The basic formula for estimating hot emissions using experimentally obtained emission factor is:

$$\text{Emissions [g]} = \text{emission factor [g/km]} \cdot \text{vehicle kilometres per year [km]}$$

The emission factors and vehicle kilometres are in most cases split into certain classes of road types and vehicle categories.

However, for many countries the only data known with any certainty is the total fuel consumption of petrol, diesel and LPG, not vehicle kilometres. It is therefore suggested that fuel consumption data are used to check vehicle mileage where they are known and to make a final fuel balance.

Since emission factors can be converted from [g/km] into [g/kg fuel], using consumption data for all vehicle classes and road types, the calculation can be carried out either on one or the other emission factor.

If fuel consumption is to be used, we have:

$$E_{hot;i,j,k} = g_{j,k,1} \cdot b_{j,1} \cdot e_{*,hot,1990;i,j,k} \tag{1}$$

where:

$E_{hot;i,j,k}$ = emissions of the pollutant i in [g], caused in the reference year 1990 by vehicles of category j driven on roads of type k with hot engines

$g_{j,k,1}$ = share of annual fuel consumption of type 1 used by vehicles of category j, driven on road type k

$b_{j,1}$ = total annual consumption of fuel type 1 in [kg] by vehicles of category j operated in 1990

$e_{*,hot,1990;i,j,k}$ = average 1990 fleet representative baseline emission factor in [g/kg fuel] for the pollutant i, relevant for the vehicle category j, operated on roads of type k with hot engines (please note: these factors have been derived from emission factors of individual cars which were grouped together according to the national car park).

and:

i (pollutants) = 1-10 for the pollutants covered

j (vehicle category) = 1-34 for the on-road categories defined in the vehicle category split (Table III-1)

k (road classes) = 1-3 for "urban", "rural", and "highway" driving (note that the road types imply certain speed patterns: see chapter VI.1.1.)

l (fuel type) = 1-3 for gasoline, diesel, LPG

The application of equation (1) requires statistical input data which are not available in many countries. Therefore, some data have to be estimated. It is proposed to apply as a principle for these estimations the rule that those parameters which are least known should be modified most. In practice this means to attribute uncertainties to parameters which are actually uncertain and to avoid modifications of parameters which are known somewhat more precisely. In the following, some practical explanations are given.

The factors $b_{j,1}$ and $g_{j,k,1}$ used in equation (1) cannot be introduced into the calculation from statistical data but have to be estimated with the help of other parameters. As outlined above, in most of the Member States the total fuel consumption is only known for different fuels, (e.g. gasoline, diesel, LPG) but not, as required, related to vehicle categories. In such a case it is proposed to distribute the total fuel figures to the vehicle categories in an iterating process, making assumptions concerning the average annual mileage driven per vehicle of a defined category and the distribution of the total annual mileage to different road types. The data on total fuel consumption of the different fuels, the number of vehicles in each category and the average fuel consumption for each vehicle category on the different road types remain the fixed points in this process. It is proposed to start with

$$m_j = h_j \cdot v_j \tag{2}$$

where:

m_j = total annual mileage in [km] of vehicle category j

h_j = number of vehicles of category j

v_j = average annual mileage driven by each vehicle of category j

While h_j is considered as a well-known statistical figure, v_j, is not available as independent statistical data in many countries and has to be estimated.

In the next step, m_j is introduced into the formula:

$$m_{j,k} = m_j \cdot d_{j,k} \tag{3}$$

where:

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k

$d_{j,k}$ = share of annual mileage driven on road class k by vehicle category j

The parameter $d_{j,k}$ is rarely available as independent statistical data in any EC country and therefore has to be estimated. The parameter $m_{j,k}$ should then be introduced into the formula:

$$b_{j,1} = \sum_{k=1}^{3} m_{j,k} \cdot c_{j,k} \tag{4}$$

where:

$b_{j,1}$ = total annual consumption of fuel of type 1 in [kg] by vehicles of category j operated in 1990

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

The figure $c_{j,k}$ is a measured value (figures can be taken from Tables or Figures given in this report), so that the calculation can be carried out easily.

The total fuel consumption of fuel type l per year is then:

$$O_l = \Sigma\, b_{j,l} \tag{5}$$

where:

O_l = total annual consumption of fuel type l

As a rule, the calculated O_l should be equal to the consumption statistic(1). If now the calculated O_1 does not match the true value, the "soft" input parameters should be modified. Since the availability of statistical data differs from one country to another, it is up to national experts to make the appropriate modifications. However, the authors have the impression that in most of the cases the parameters $d_{j,k}$ and/or v_l are those to which most attention should be given (Table V.1.1-1 provides an example of the values estimated by countries for the parameter $d_{j,k}$ in the 1985 exercise).

The factor $g_{j,k}$ can be calculated as follows:

$$\left.\begin{aligned} g_{j,urban} &= c_{j,urban} \cdot m_{j,urban} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad \text{for } k = \text{urban} \\ g_{j,rural} &= c_{j,rural} \cdot m_{j,rural} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad \text{for } k = \text{rural} \\ g_{j,highway} &= c_{j,highway} \cdot m_{j,highway} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad \text{for } k = \text{highway} \end{aligned}\right\} \tag{6}$$

where:

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k

All elements of these equations are known, so that the calculation can be carried out directly.

(1) However, it should be noted that in some countries there might be a difference between the fuel sold and the fuel actually consumed in this country due to vehicles in transit. The official statistics always correspond to the fuel sold in a country and therefore have to be corrected if there are clear indications for a substantial export of fuel. If such an export is identified, it is proposed that the CORINAIR team be informed about it because the consumption has to be attributed to another country.

The emission factor $e_{hot,1990;i,j,k}$, expressed in [g/km], can be taken from chapter VI and should be converted, wherever necessary, into [g/kg fuel] as follows:

$$e_{*.hot,1990;i,j,k} = e_{hot,1990;i,j,k} / c_{j,k} \quad (7)$$

where:

$e_{hot,1990;i,j,k}$ = average 1990 fleet representative baseline emission factor in [g/km] for the pollutant i for the vehicle category j, operated on roads of type k with hot engines

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

Values for $c_{j,k}$ are also given in chapter VI.

V.2 Cold Start Emissions

Cold starts, compared with the "hot emissions", result in additional emissions. They take place under all three driving conditions, however, they seem to be most likely for urban driving. In principle they occur for all vehicle categories. However, emission factors are only available or can be reasonably estimated for gasoline, diesel and LPG passenger cars and - assuming that these vehicles behave like passenger cars - light duty vehicles, so that just these categories are covered by the methodology. Moreover, they are considered not to be a function of vehicle age.

These emissions are calculated as an extra emission over the emissions that would be expected if all vehicles had only hot engines. A factor, the ratio of hot to cold emissions, is used and applied to the fraction of kilometres driven with hot to cold engines. These factors may vary from country to country. Different driving behaviour (varying trip lengths), as well as climate with varying time (and hence distance) required to warm up the engine affect the fraction of distance driven with cold engines. These factors can be taken into account, but again information may not be available to do this thoroughly in all countries, so that estimates have to close identified gaps.

The cold mileage is introduced into the calculation as additional emissions per km by using the following formula:

$$E_{cold;i,j} = \beta_j \cdot m_j \cdot e^{hot} \cdot (e^{cold} / e^{hot} - 1) \quad (8)$$

with:

$E_{cold;i,j}$ = emissions of the pollutant i due to cold starts (for reference year 1990), caused by vehicle category j (in the computer programme all cold start estimates are allocated to urban driving)

β_j = fraction of mileage driven with cold engines[1]

m_j = total annual mileage of the vehicle category j

e^{cold}/e^{hot} = ratio of emissions of cold to hot engines

The parameter β depends on ambient temperature t_a (for practical reasons the average monthly temperature is proposed to be used) and patterns of vehicle use, in particular the average trip length l_{trip}. However, since information on l_{trip} is not available in many countries for all vehicle classes, some simplifications have been introduced for some vehicle categories (see chapter VI).

The ratio e^{cold}/e^{hot} also depends on the ambient temperature and pollutant considered.

V.3 Evaporative VOC Emissions

There are three primary sources of evaporative emissions from vehicles:[2]

i) diurnal (daily) emissions;

ii) hot soak emissions; and

iii) running losses.

These are estimated separately. Again they are affected by factors that vary from country to country.

Diurnal Emissions

The evaporative emissions associated with the daily (diurnal) variation in ambient temperature result from the vapour expansion inside the gasoline tank that occurs as the ambient temperature rises during the daylight hours. Without an emission control system, some of the increasing volume of fuel vapour is vented to the atmosphere. At night, when the temperature drops, vapour contracts and fresh air is drawn into the gasoline tank through the vent. This lowers the concentration of hydrocarbons in the vapour space above the liquid gasoline, which subsequently leads to additional evaporation.

Hot Soak Emissions

Hot soak evaporative emissions are the emissions caused when a hot engine is turned off. Heat from the engine and exhaust system increases the temperature of the fuel in

(1) "cold" engines are defined as those with a water temperature below 70°C

(2) In US literature there is a fourth source mentioned: "Resting Loss Emissions" which result from vapour permeating parts of the evaporative control system. However, they are not taken into account explicitly in this paper.

the system that is no longer flowing. Carburettor float bowls are particularly significant source of hot soak emissions.

Running losses

Running losses are the result of vapour generated in gasoline tanks during vehicle operation. Running losses are most significant during periods of high ambient temperatures. The combined effect of high ambient temperature and exhaust system heat can generate a significant amount of vapour in the gasoline tank.

All three types of evaporative emissions are significantly affected by the volatility of the gasoline being used, the absolute ambient temperature and temperature changes, and vehicle design characteristics. For hot soak emissions and running losses the driving pattern is also of importance.

In general, the estimation of evaporative emissions from gasoline vehicles involves still a large number of uncertainties which can not be solved without carrying out further measurements. Therefore the 1990 methodology cannot overcome many of the problems, but can try only to improve on some specific aspects.

The COPERT 85 methodology for estimating evaporative emissions (Gorissen 1988) shows, inter alia, two shortcomings:

i) for the emission factor for 'running losses' only an order of magnitude estimate is provided;

ii) the correction for temperature and fuel volatility is made in a very simple fashion.

In fact, due to these shortcomings, the COPERT 85 software provided an option to use a methodology proposed by Concawe (1987), instead of the methodology described in the official report. A more recent publication by Concawe (1990) allows to modify the 1985 methodology as follows:

i) to delete the reference to unsealed plastic tanks because the problem could not be further substantiated(1);

ii) to insert temperature - and/or fuel volatility - dependencies for the emission factors e^{d}, $e^{s,\,hot}$, $e^{s,\,warm}$, e^{fi} and e^{r}.

Evaporative VOC emissions from gasoline fuelled vehicles add to total NMVOC emissions. The main equation for estimating the evaporative emissions is (Gorissen 1988):

---

(1) This does not mean that the problem as such does not exist. However, it was impossible to obtain an impression of the magnitude of emissions caused by the penetration of VOC through unsealed plastic tanks.

$$E_{eva;voc,j} = 365 \cdot a_j \, (e^d + S^c + S^{fi}) + R \qquad (9)$$

where:

$E_{eva;voc,j}$ = VOC emissions due to evaporative losses caused by vehicle category j

a_j = number of gasoline vehicles of category j

e^d = mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation, and fuel volatility (RVP)

S^c = average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor

S^{fi} = average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection

R = hot and warm running losses

and

$$S^c = (1-q)\,(p \cdot x \cdot e^{s,hot} + w \cdot x \cdot e^{s,warm}) \qquad (10)$$

$$S^{fi} = q \cdot e^{fi} \cdot x \qquad (11)$$

$$R = m_j \, (p \cdot e^{r,\,hot} + w \cdot e^{r,\,warm}) \qquad (12)$$

where:

q = fraction of gasoline powered vehicles equipped with fuel injection

p = fraction of trips finished with hot engine (dependent on the average monthly ambient temperature)

w = fraction of trips finished with cold or warm engine (shorter trips)(1)

x = mean number of trips of a vehicle per day, average over the year

$$x = v_j \,/\, (365 \cdot l_{trip}) \qquad (13)$$

$e^{s,hot}$ = mean emission factor for hot soak emissions (which is dependent on fuel volatility RVP)

$e^{s,warm}$ = mean emission factor for cold and warm soak emissions (which is dependent on fuel volatility RVP and average monthly ambient temperature)

(1) Engines are defined as "cold" or "warm" if the water temperature is below 70°C

e^{fi} = mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection

$e^{r,hot}$ = average emission factor for hot running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature)

$e^{r,warm}$ = average emission factor for warm running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature)

m_j = total annual mileage of gasoline powered vehicles of category j

Apart from the emission factors, the proposed methodology requires, a number of statistical data which are most likely not available in many countries, e.g. the parameters p, i, w and x. Therefore, a few indications will be given in chapter VI.3 concerning the values of these parameters.

The fraction of trips finished with cold and warm engine, w, is connected with the parameter β used in the calculation of cold start emissions: both depend, inter alia, on ambient temperature. In the absence of better data, the assumed relation between w and β is:

$$w \sim \beta$$

As outlined in chapter V.2, β depends on the average trip length l_{trip}.

This indicates that, for the calculation of the cold start emissions and soak emissions, the average trip length is of great importance. Finally it should be noted that the authors see a need to improve the proposed methodology further, in particular in order to take into account better the temperature and RVP dependencies of evaporative emissions for the different vehicle categories.

V.4 Application of the baseline methodology to the different vehicle categories and pollutants

Due to gaps in knowledge, the baseline methodology can not be applied in full and in the same way to all vehicle categories. Moreover, there are variations depending on the pollutant considered. In general, one can distinguish between four methods:

Method A: Hot emissions are calculated based on
- the total annual kilometres driven per vehicle;
- the share of kilometres driven under the driving modes 'urban', 'rural' and 'highway';
- the average speed of the vehicles under the driving modes 'urban', 'rural' and 'highway';
- speed-dependent hot emission factors.

Cold start emissions are calculated based on
- the average trip length per vehicle trip;
- the average monthly temperature;
- temperature and trip length dependent cold start correction factor.

Evaporative emissions are calculated based on
- the fuel volatility (RVP);
- the average monthly temperature and the average monthly temperature variation;
- fuel volatility and temperature dependent emission factors.

Method B: The total annual emissions per vehicle are calculated based on
- the total annual kilometres driven per vehicle;
- the share of kilometres driven under the driving modes 'urban', 'rural' and 'highway';
- the average speed of the vehicles under the driving modes 'urban', 'rural' and 'highway';
- speed-dependent emission factors.

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remark: for diesel passenger cars, cold start extra emissions for CO, NOx and NMVOC as well as extra fuel consumption are added using the method described under A. For LPG passenger cars a simplified method is used.

Method C: The total annual emissions per vehicle are calculated based on
- the total annual kilometres driven per vehicles;
- the share of kilometres driven under the driving modes 'urban', 'rural' and 'highway';
- driving mode dependent emissions factors.

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remark: For gasoline and diesel light duty vehicle cold start extra emissions for CO, NOx and NMVOC as well as fuel consumption are added using the method described under A.
For gasoline light duty vehicles NMVOC evaporative emissions are added using the method described under A

Method D: The total annual emissions per vehicle category are calculated based on
- the total annual fuel consumption of the vehicle category and/or the total annual kilometres driven by the vehicle category;
- fuel consumption and/or kilometre related emission factors.

remark: For two wheelers NMVOC evaporative emissions are added using the method described under A.

These methods are applied to the different vehicle categories and the different pollutants as shown in Table V.4-1

V.5 Spatial Allocation of Emissions

The working group did not consider the problem of spatial allocation of motor vehicle emissions because of the lack of any uniform data. However, as a part of the CORINAIR project Member States will have to do this.

Member States are best able to know, and use, the most appropriate information to do this allocation. This is a difficult task which should not be underestimated. Some approaches that have been used in the absence of vehicle use data in small areas are suggested below. It must be emphasized, however, that these examples should not be followed blindly; they are merely examples.

i) Urban emissions should be allocated to urban areas only, e.g. by localizing geographically all cities with more than 20.000 inhabitants and allocating the emissions via the population living in each of the cities (As far as the authors are informed, a list of these cities including their geographical coordinates can be provided by the statistical office of the EC in Luxemburg)

ii) Rural emissions should be spread all over the country, but only outside urban areas, e.g. by taking the non-urban population density of a country

iii) Highway emissions should be allocated to highways only, that means: all roads on which vehicles are driven in accordance with the "highway driving pattern", not necessarily what is called "Autobahnen" in F.R.Germany, "autoroutes" in France, "autostrade" in Italy and so on. As a simple distribution key, the length of such roads in the territorial unit can be taken.

Some of the statistical data needed for carrying out the allocation of emissions can be found in EUROSTAT publications but in general national statistics are more detailed.

A few countries may already have available the input data needed for the calculation scheme for a smaller NUTS than the whole of their country. These countries, of course, should directly apply the calculation scheme to the smaller units and subsequently build the national total by summing up emissions from the smaller units. However, in such cases it is recommended to cross-check the total obtained in this way with the total calculated by using the top-down approach in order to balance possible deviations in the statistics.

VI EMISSION FACTORS PROPOSED BY THE WORKING GROUP

The emission factors proposed can be distinguished into two classes: those for which detailed evaluations are necessary and possible and those for which only very simple "bulk" emission factors or equations have to be or can be provided. The pollutants SO_2, NH_3, Pb, CO_2 and partly N_2O fall under this category and are each treated separately in subsections of chapter VI (VI.4 - VI.9). Moreover, off-road vehicles are treated separately and in a simplified way, because only rough estimates of emission factors can be provided (see chapter VI.10). It should be noted that the reliability of emission factors differs substantially and this should be taken into account when interpreting the results of the emission estimates.

VI.1 Emission Factors for Hot Emissions

The emission factors proposed in the following were jointly worked out by the members of the working group, taking into account the results of comprehensive studies carried out in France, F.R.Germany, Greece, Italy, the Netherlands and the United Kingdom. In addition, some data measured in Austria, Sweden and Switzerland were incorporated. The working group believes that the emission factors represent the current state of the art in emission factors in EC Member States, but the working group sees a need to establish permanent up-dating procedures in order to better take into account the continuously growing knowledge.

For the application of the proposed methodology, one theoretically needs emission factors $e_{hot,1990;i,j,k}$ for:

- 10 pollutants (CO, NOx, N_2O, SO_2, VOC, CH_4, CO_2, NH_3, diesel particulates, lead)
- 10 vehicle categories
- 3 road types

In practice, the picture looks somewhat different because:

- for some pollutants (e.g. CO_2, SO_2, lead, NH_3, partly N_2O) and for off-road vehicles, emissions are calculated based on fuel consumption only so that no distinction with regard to road types is necessary,

- for some other pollutants, due to the lack of measured data, emissions can be reported only as fractions of other emissions (e.g. CH_4) or by applying lumped emission factors (partly N_2O) so that no separate full calculation is necessary,

- for some vehicle types (e.g. motorcycles), no distinction with regard to emission factors can be made for different road types,

- for all on-road vehicle categories with the exception of gasoline passenger cars, no differentiation can be made with regard to the production year of vehicles,

- for some pollutants no emission factor could be derived for certain vehicle categories,

so that the total number of emission factors is substantially smaller than theoretically necessary. It should be mentioned that the emission factors given in the 1985 report are also revised in some cases because the data base has been extended in the meantime due to the results of additional measurements made available after the completion of the 1985 report.

VI.1.1. Gasoline Passenger Cars <2.5 Tonnes

Gasoline passenger cars <2.5 tonnes certainly contribute to the largest part of emissions of road traffic in all EC Member States. Therefore, special attention was given to this vehicle category with regard to emission factors and the methodology. It is one of the few categories where, instead of simple emission factors for only one, two or three road types (driving modes), the emission factors are presented in a fully speed-dependent form.

Moreover, it is the only vehicle category in which the production year of vehicles has been taken into account by introducing different sub-categories, which reflect legislative steps (ECE) or technology steps ("improved conventional", "open loop" and "closed loop"). The technology steps are of importance in particular for those countries which introduced emission limits in national legislation which are more stringent than the ECE 15/04 limits, or implemented special incentive programmes for the purchase of such vehicles:

1. Gasoline Passenger Cars (<2.5 t, <1.4 l)

a. Improved Conventional
takes into account German and Dutch incentive programmes:
- Anl.XXIVC (only relevant for Germany). Effective date: 1.7.1985.
- NLG 850 (only relevant for the Netherlands). Effective date: 1.1.1986

It is assumed that the required emission standards can be met by applying improved conventional technology. This type of emission control technology has also started to appear in Denmark since 1.1.1988.

b. Open Loop
takes into account Greek and Dutch incentive programmes. It is assumed that the required emission standards can be met by applying open loop three way catalysts.
Effective dates: Denmark 1.1.1989, F.R.Germany 1.7.1985, Greece 1.1.1990, The Netherlands 1.1.1987.

c. Closed Loop
takes into account national incentive programmes (e.g. voluntary programmes in F.R.Germany carried out after 1.7.1985), where compliance with US 83 limits is required.

2. Gasoline Passenger Cars (<2.5 t, 1.4-2.0 l)

a. Improved conventional
takes into account vehicles which meet the limit values of the Directive 88/76/EEC (Commission 1988) by means of open loop catalysts. In practice relevant only for the national incentive programmes.
Effective dates of implementation are: Denmark 1.1.1987, F.R.Germany 1.7.1985, The Netherlands 1.1.1987.

b. Open Loop
takes into account vehicles which meet the limit values of the Directive 88/76/EEC by means of open loop catalysts. In practice relevant only to the national incentive programmes.
Effective dates of implementation are ; Denmark 1.1.1987, F.R.Germany 1.7.1985, Greece 1.1.1990, The Netherlands 1.1.1986.

c. Closed Loop
takes into account national incentive programmes (e.g. Anl. XXIII in F.R.Germany, effective date 1.7.1985) where compliance with US 83 limits is required.

3. Gasoline Passenger Cars (<2.5 t, >2.0 l)

a. Open Loop
takes into account vehicles which meet the limit values of the Directive 88/76/EEC by means of open loop catalysts. In practice relevant only to the national incentive programmes.
Effective dates of implementation are ; Denmark 1.1.1987, F.R.Germany 1.7.1985.

b. Closed Loop
takes into account EC legislation and national incentive programmes:
- 88/76/EEC (relevant for all countries). Effective date for new vehicles: 1.1.1990

- US 83 (only relevant for Denmark, F.R.Germany, Greece, The Netherlands). Effective date: Denmark 1.1.1987, F.R.Germany 1.7.1985, Greece 1.1.1989, The Netherlands 1.1.1987.
  It is assumed that the required emission standards can be met by applying closed loop three way catalysts.

The curves have been derived by regression analysis of all data available (Avella 1989, Biegstraten et al. 1984, Bundesamt fuer Umweltschutz 1984, CCMC 1989, Gorissen 1990, 1991, Hassel et al. 1987, 1991, Hollemans et al. 1987, Joumard 1990, Pattas et al. 1983, 1985, 1991, Rijkeboer 1982, 1985, Rijkeboer et al. 1989, 1990).

The emission factors $e_{hot;i,j,g}$, as well as fuel consumption factors, are displayed in Figures VI.1.1-1 to -27. The equations of the "best-fit" curves are given in Tables VI.1.1-1 to -4(1). They may be used, if necessary, for extrapolation purposes. However, it should be noted that the emission factors have been derived from general test cycles which are not specific for driving at speeds above 130 km/h or below 10 km/h. Therefore they should be not applied for driving at very high and very low speeds. Moreover, the emission factors should not be applied in cases in which the driving pattern differs too much from what is common, e.g. in traffic calming areas.

The emission factor $e_{hot,1990;i,j,k}$, introduced in equation (1) is by definition the average 1990 fleet representative factor of pollutant i, relevant for the vehicle category j (here this means vehicles with cylinder capacities of <1.4 l/1.4-2 l/>2 l), operated on roads of type k with hot engines. The emission factors presented in this chapter describe the emissions of pollutant i for each vehicle category j and six periods of legal conformity, that means: pre-ECE state and periods of application of ECE 15-00/01, 15-02, 15-03, 15-04 and three post 15-04 technologies: improved conventional, open loop, closed loop.

This presentation allows Member States to introduce into the calculation (one could say: as national variables) the composition of their 1990 fleet and "national driving patterns". The three road types (highway, urban, rural) are obviously synonyms for certain driving patterns which are to some extent typical, but not the same in all countries and cities, e.g. there are indications that highway driving in Germany takes place at a higher average speed than in Belgium, or urban driving in Athens takes place at a lower average speed than in Berlin, and so on(2).

VI.1.1.1. Accounting for Vehicle Speed

Vehicle speed, which is introduced into the calculation via the three road types, has a major influence on the emissions of the vehicles. Different approaches have been developed to take into account the driving patterns.

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(1) Please note: some of the curves have been slightly smoothened in order to avoid inconcistencies where the best fit curves meet.

(2) It is possible that driving patterns depend on additional parameters, such as age of the vehicle or cylinder capacity. However, such dependencies should only be taken into account if sound statistical data are available.

With the emission factors presented in this chapter, the authors propose two alternative methods:

- to select one single average speed, representative of each of the road types "urban", "rural" and "highway" (e.g. 20 km/h, 60 km/h and 100 km/h, respectively) and to apply the emission factors taken from the graphs or calculated with the help of the equations, or

- to define mean speed distribution curves $f_k(z)$ and to integrate over the emission curves, i.e.:

$$e_{hot;i,k,j,g} = \int e(z)\, f_k(z)\, dz \qquad (14)$$

where:

$e_{hot;i,k,j,g}$ = emission factor in [g/km] for pollutant i, relevant for vehicle category j, operated on roads of type k with hot engines, valid for regulatory step g

z = speed of gasoline vehicles <2.5 tonnes on road classes "rural", "urban" and "highway"

e(z) = mathematical expression (e.g. formula of "best fit" curve) of the speed-dependency of $e_{i.j.g.hot,z}$

$f_k(z)$ = equation (e.g.formula of "best fit" curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of gasoline vehicles <2.5 tonnes on road classes "rural", "urban" and "highway", $f_k(z)$ depends on road type k and also, possibly, on engine size. An example of a cumulative distributions are given in Figures VI.1.1.1-1

It is evident that the first approach mentioned above is much easier and most likely the one to be chosen by most of the countries. Table VI.1.1.1-1 shows as an example the speed selection of Member States applied in the 1985 exercise.

VI.1.1.2 Accounting for Vehicle Age

The emissions of vehicles have changed over time, mainly due to regulatory requirements. The composition of the 1990 national fleets differs because the evolution of national fleets and their replacement rates vary from one country to the other. Therefore, in a second step, it is proposed to use the following equation in order to calculate emission factors representative of the national 1990 fleet:

$$e_{hot,1990;i,j,k} = \sum_g s_{j,g} \cdot e_{hot;i,j,k,g} \qquad (15)$$

with:

$e_{hot,1990;i,j,k}$ = representative 1990 emission factor of vehicle category j for pollutant i, operated on road class k

$$s_{j,g} = \frac{a_{j,g}}{\sum_g a_{j,g}} \qquad (16)$$

for periods of legal or of technological conformity g with:

$a_{j,g}$ = number of vehicles of category j produced within the period of legal or technological conformity g (only vehicles <2.5 tonnes)

The application of this equation requires detailed knowledge of the composition of the national fleet with regard to age and cylinder capacity.

As mentioned above, the study analyzed with great care available emission data of individual vehicle tests. They were derived by grouping all available measurements carried out with on-road vehicles into periods of legal or technical conformity. In total, about 1,500 vehicles test data have been evaluated. As far as possible, only data obtained in transient mode test cycles were used. Only for high speed driving (80 km/h and more), data obtained under conditions of steady driving were taken into account as well.

VI.1.2. Diesel Passenger Cars <2.5 Tonnes

In comparison to the 1985 situation, the number of measured data on emissions of passenger cars <2.5 tonnes could be enlarged substantially (CCMC 1989, Joumard 1990, Gorissen 1990, 1991, Hassel et al.1987, Pattas et al.1985, Rijkeboer et al. 1989, 1990). It is therefore possible to differentiate between cylinder capacities and to present speed dependent emission factors (see Figures VI.1.2-1 to -5 and Table VI.1.2-1). It should be mentioned that apart from other parameters, the emission factors, in particular those for VOCs and particulates can vary substantially, depending on fuel quality and state of maintenance. It is up to national experts to correct, if necessary, the factors given in order to take such influences into account.

VI.1.3 LPG Passenger Cars <2.5 Tonnes

As in the case of gasoline and diesel passenger cars <2.5 tonnes, emission factors are provided for LPG fuelled cars (Joumard 1990, TNO 1980), see Figures VI.1.3-1 to -3 and Table VI.1.3-1. It should be mentioned that the given emission factors are valid for well-adjusted engines, otherwise they are the same order of magnitude of those valid for gasoline vehicles <2.5 tonnes.

VI.1.4 Gasoline Two-Stroke Passenger Cars

Few measured data are available (Appel et al. 1989, Jileh 1991, Pattas et al. 1983) which have been used to derive emission factors for urban, rural and highway driving for two-stroke gasoline powered cars.

The emission factors are given in Table VI.1.4-1. They are relevant mainly for some Eastern European countries (and to some extent for the F.R.Germany). However, it should be noted that due to the limited knowledge of the authors about the actual driving behaviour in Eastern European countries (e.g. average speed on urban and rural roads and on highways) and the limited number of test data, the emission factors are less reliable than, for example, those given for other gasoline passenger cars.

VI.1.5 Gasoline Light Duty Vehicles

Light duty vehicles have been newly introduced into the vehicle category split for the 1990 inventory. They are defined by UN-ECE under categories N_1; some of them, however, may also fall under category M_1 because in some countries passenger cars are operated as light duty vehicles for tax reasons. Therefore, attention has to be paid to the correct allocation of vehicle numbers.

The emission factors for gasoline light duty vehicles are given in Table VI.1.5-1. They are based on data of TNO, Greece and CCMC (Heaton et al. 1991, Kyriakis et al. 1991, CCMC 1989 respectively).

VI.1.6 Diesel Light Duty Vehicles

The category of light duty vehicles is similar to the one described in VI.1.5. Here, as well, attention has to be paid to allocate vehicles correctly because many of the small light duty trucks are in fact very similar to passenger cars and are operated with engines also used in passenger cars. As in the case of gasoline light duty vehicles, these vehicles should better be added to the passenger car fleet. Table VI.1.6-1 displays the emission factors proposed which have been derived from the same data sources as those for gasoline powered light duty vehicles.

VI.1.7 Heavy Duty Gasoline Vehicles >3.5 Tonnes

The working group believes that heavy duty gasoline vehicles > 3.5 tonnes play a negligible role in European emissions from road traffic. However, since the group is not sure about that, emission factors derived from an extrapolation of results from smaller vehicles are presented in Table VI.1.7-1.

VI.1.8 Heavy Duty Diesel Vehicles 3.5-16 Tonnes

In comparison to 1985 (Hassel 1983, Umweltbundesamt 1988), additional data are available on emissions from heavy duty vehicles (Eggleston 1991a). However, they are still not detailed enough to take into account all relevant parameters, e.g. different types of engines. Table VI.1.8-1 displays the proposed factors, which for some pollutants deviate significantly from those given in the 1985 report. However, there is still some uncertainty with the data, because recently measured values show somewhat lower emission factors for vehicles put on the market after about 1986 (Umweltbundesamt 1991). It should be mentioned that the cut-off point of 16 tonnes GVW is somewhat arbitrary. The values given may apply for a range of 12-18 tonnes GVW. It is up to Member States to select the appropriate cut-off point.

VI.1.9 Heavy Duty Diesel Vehicles > 16 Tonnes

The situation with regard to diesel vehicles > 16 tonnes GVW is the same as the one for vehicles < 16 tonnes (see above). Table VI.1.9-1 shows the emission factors proposed.

VI.1.10 Two Wheelers

As in 1985, two wheelers have been differentiated further into two classes: motor cycles <50cm^3 cylinder capacity (two stroke only) and motor cycles >50cm^3 cylinder capacity. Moreover, it has shown worthwhile to distinguish for the second group between two stroke and four stroke engines. While mopeds are driven under "urban" driving conditions only, motor cycles are also used for "rural" and "highway" driving. However, the emission data base for these two modes is quite small, so that no detailed breakdown into the three road types can be provided. Therefore, based on relatively rough assumptions, the values available for urban driving (Hartung et al. 1991, Gaudioso 1991, Pattas 1985, TNO 1988, EMPA) were somewhat corrected in order to take rural and highway driving into account. Table VI.1.10-1 displays the emission factors proposed. The expert group considers these values as relatively unreliable because they are to a large extent based on measurements taken under unrealistic driving conditions. However, it is believed that they nevertheless provide a starting point for the estimation work.

VI.2 Emission Factors for Cold Starts

Due to the lack of measured data, the methodology outlined in chapter V.2 cannot be fully applied to all vehicle categories. Cold start extra emissions are estimated separately for all types of passenger cars and light duty vehicles. For the other vehicle categories it is still not possible to provide emission factors. Since cold start emissions are quite sensitive to ambient temperatures, the estimates are made on a monthly basis (Joumard 1991).

VI.2.1 Conventional Gasoline Passenger Cars

All non-closed loop 3-way catalyst equipped vehicles belong to this category. The application of the methodology which was outlined in chapter V.2. requires values for the parameter β (cold mileage percentage) and the ratio e^{cold}/e^{hot}. Table VI.2.1-1 provides estimates for β. It should be mentioned that this table applies to all vehicle categories considered. Table VI.2.1-2 provides estimates for e^{cold}/e^{hot}. Both tables have been derived from French, German, Dutch and English measurements and are identical to those of the 1985 report (Delsey 1980, Vallet et al. 1982, Andre et al. 1987, Potter et al. 1983, Hassel et al. 1987, Joumard et al. 1990, Rijkeboer et al. 1989). For application of Table VI.2.1-1, Member States have to determine a value for the average trip length. Since some countries may not have appropriate statistics, Table VI.2.1-3 shows values taken by EC Member States in the 1985 project.

VI.2.2 Closed Loop 3-Way Catalyst Gasoline Passenger Cars

For closed loop 3-way catalyst gasoline passenger cars the extra cold start emissions differ significantly from those of conventional gasoline cars (Rijkeboer et al. 1989, AQA 1990, Laurriko et al. 1987). The methodology as such, however, does not require modifications (at least as long as no further measurements are available). Table VI.2.2-1 provides an overview of the cold start emission factors.

VI.2.3 Diesel Passenger Cars

The relative extra emissions of diesel passenger cars are shown in Table VI.2.3-1 (Joumard 1990, Gorissen 1990).

VI.2.4 LPG Passenger Cars

For LPG passenger cars the available data base is very small (AQA 1990, Hauger et al. 1991). It was therefore decided to provide a temperature dependent emission factor, assuming that the cold start behaviour of these cars is similar to that of conventional gasoline vehicles (Table VI.2.4-1).

VI.2.5 Light Duty Vehicles

Due to the lack of better data, gasoline and diesel light duty vehicles are treated in the same way as the corresponding passenger cars. This implies that the vehicle usage data for passenger cars are also applied for light duty vehicles. However, it should be underlined that this is a very rough approach, which was chosen only because the working group considered as more appropriate to allocate some cold start emissions to this category rather than to neglect them.

VI.3 Emission Factors for Evaporative Emissions

Due to the lack of data, evaporative emissions can be estimated only for gasoline passenger cars, light duty vehicles and two wheelers. However, only for gasoline passenger cars, the methodology outlined in chapter V.3 can be fully applied. For the other two vehicle categories simplifications have to be made. Since evaporative emissions are very sensitive to temperature, the estimates are made on a monthly basis.

VI.3.1 Gasoline Passenger Cars

The evaporative losses depend on the technology used, the fuel properties and the average ambient temperatures. The basic emission factors, which are necessary to apply the methodology proposed in chapter V.3, are listed in Table VI.3.1-1 for uncontrolled and controlled vehicles (based mainly on Concawe 1987, 1990, Eggleston 1991b, Heine 1987, US EPA 1990). However, it should be mentioned that the working group considers the data base as still as far too small, so that the reliability of the estimates obtained when using the emission factors is not very satisfactory.

The application of the proposed methodology requires detailed knowledge of driving behaviour and vehicle park composition. In order to help those Member States which have no, or only little, information about these input parameters, some data estimated in some EC counties are given in Table VI.3.1-2.

VI.3.2 Light Duty Vehicles

For estimating evaporative emissions of this category, all vehicles are treated like uncontrolled gasoline passenger cars with regard to emission factors and driving pattern. As in the case of cold start emissions, this is a drastic simplification, because it implies the assumption that light duty vehicles are used in the same way as passenger cars.

VI.3.3 Two Wheelers

For estimating evaporative emissions of two wheelers, they are treated like uncontrolled gasoline passenger cars with regard to the driving pattern. Due to the smaller fuel tanks of two wheelers, it is assumed that the emissions are 0.2 times those of passenger cars for motor cycles <50 cc and 0.4 times those of passenger cars for motor cycles >50 cc. Again this approach has to be considered as a drastic simplification, which has been chosen only because the required data are not available.

VI.4 Methane Emissions

Methane emission factors could be derived from the literature for all types of vehicles (Bailey et al. 1989, Volkswagen 1989, OECD 1991, Zajontz et al. 1991). It should be reminded that non methane VOC emissions are produced by deducting the CH_4

emissions from total VOC. Table VI.4-1 provides an overview of CH_4 emission factors. Additional cold start emissions are not taken into account separately but are assumed to be included in the bulk emission factors.

VI.5 Nitrous Oxide Emissions

Emission factors for N_2O are roughly estimated on the basis of literature review for all vehicle categories (Pringent et al. 1989, Perby 1990, de Reydellet 1990, Potter 1990, OECD 1991, Zajontz et al. 1991). Again these data are still quite unreliable and need further confirmation by measurements. Cold start emissions are not taken into account separately but are assumed to be already incorporated in the bulk emission factors. The emission factors are shown in Table VI.5-1.

VI.6 Carbon Dioxide Emissions

The emissions of CO_2 are estimated on the basis of fuel consumption, taking into account other emissions of C atoms in the form of CO, VOC and particulate emissions. The following formula is applied[1]:

$$\text{mass of } CO_2 = 44{,}011\,(\text{mass of fuel}/(12{,}011 + 1{,}008 \cdot r_{H/C}) - \text{mass of CO}/28{,}011 - \text{mass of VOC}/13.85 - \text{mass of particulates}/12{,}011) \qquad (17)$$

with

$r_{H/C}$ = the ratio of hydrogen to carbon atoms in the fuel (~1.8 for gasoline and ~2.0 for diesel)

VI.7 Sulphur Dioxide Emissions

The emissions of SO_2 are estimated by assuming that all sulphur in the fuel is transformed completely into SO_2 using the formula:

$$E_{SO2} = 2 \sum_j \sum_l k_{S,l}\, b_{j,l} \qquad (18)$$

with

$k_{S,l}$ = weight related sulphur content of fuel of type l [kg/kg]

$b_{j,l}$ = total annual consumption of fuel of type l in [kg] by vehicles of category j operated in 1990. For the actual $b_{j,l}$ the calculated fuel consumption is taken.

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(1) The calculated emissions differ from those measured in the exhaust gas when applying this formula.

VI.8 Ammonia Emissions

For estimating ammonia emissions average emission factors are given for conventional and closed loop gasoline passenger cars and light duty vehicles and diesel passenger cars and light duty vehicles, related to the total annual kilometres driven.

These emission factors are based on literature review only and should be considered as broad estimates (de Reydellet 1990, Volkswagen 1989). Table VI.8-1 shows the emission factors proposed. Appropriate emission factors for other vehicle categories could not be found.

VI.9 Lead Emissions

Emissions of lead are estimated by assuming that 75% of lead contained in the fuel is emitted into air (Hassel et al. 1987). It should be mentioned that the exact source of the 75% assumption could not be identified, however, over the years the factor has become a commonly accepted constant. The formula used is:

$$E_{Pb} = 0.75 \sum_j k_{Pb}\ b_j \qquad (19)$$

with

k_{Pb} = weight related lead content of gasoline in [kg/kg]

b_j = total annual consumption of gasoline in [kg] by vehicles of category j operated in 1990

For the actual figure of b_j the statistical fuel consumption should be taken.

VI.10 Emissions of Off-Road Vehicles

Only very few data could be found in the available literature on emissions of off-road vehicles (OECD 1991). Moreover, statistics on how these vehicles are used are in most cases unavailable. In fact only in some countries and for some of the off-road vehicles total fuel consumption figures could be found. It was therefore decided to simplify the methodology for this category drastically by providing broadly estimated total fuel consumption related emission factors only. Table VI.10-1 provides an overview of these proposed emission factors.

VII GAPS IN KNOWLEDGE AND OUTLOOK

The work on emission factors for traffic revealed once more that knowledge of these emissions is far from complete. The group therefore decided to list those points for which the gaps in knowledge seem to be most striking in order to encourage national administrations responsible for the emission inventory work, to carry out additional studies.

In particular the following points require further attention:

i) emission factors for heavy duty vehicles and motor cycles;

ii) definition of realistic transient driving modes for all vehicle categories, but in particular for heavy duty vehicles and motor cycles;

iii) description of driving behaviour (statistical data), e.g. average mileage per vehicle, number of trips per day, average trip length and so on;

iv) correction factors for local particularities, e.g. mountain regions, climatic particularities, local speed profiles;

v) quantitative determination of parameters relevant to evaporative emissions, e.g. fuel properties (Reid vapour pressure);

vi) evaporative emission factors for all vehicle categories;

vii) cold start emissions for all vehicle categories;

viii) independent estimations, e.g. nationwide surveys, of total annual mileage driven on the three road classes by each of the vehicle categories;

ix) methodology and statistical input for estimating the spatial allocation of vehicle emissions;

x) other pollutants (PAH, benzene)

Since the list of tasks is long and not everything can be done at once, Table VII-1 provides qualitative indications of the "precision" which can be allocated to the calculation of the individual emissions. The table is based on subjective estimates of the working group members. It should be mentioned that only where the indicator '1' is given the emission estimate is considered to be of satisfactory quantity (i.e. based on statistically significant number of measurements).

Moreover, it should be mentioned that the estimation of emissions from road traffic might be, more than in the case of other source categories, a task which requires permanent updating. This is due to the relatively large and rapid changes in this sector over short time periods, e.g. the turnover of fleets is rather short, legislation changes quickly, the number of vehicles increases steadily and so on. These changes not only require the continuation of the work on emission factors, but also the adaptation of the methodology.

Above all, there are additional requirements of scientists, e.g. modelers, concerning the description of emissions in time, space and composition. The group got the impression that these tasks can only be accomplished if the work on emission estimates for road traffic is enlarged and becomes a permanent topic in all Member States.

Finally, for many reasons, but in particular for the development of an efficient air pollution policy, the group is of the opinion that work on EC wide estimation techniques for the prediction of future emissions should be continued (Samaras et al. 1991b).

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7.1.1	HIGHWAY DRIVING
7.1.2	RURAL DRIVING
7.1.3	URBAN DRIVING
7.2	LIGHT DUTY VEHICLES <3.5 T
7.2.1	HIGHWAY DRIVING
7.2.2	RURAL DRIVING
7.2.3	URBAN DRIVING
7.3	HEAVY DUTY VEHICLES >3.5 T
7.3.1	HIGHWAY DRIVING
7.3.2	RURAL DRIVING
7.3.3	URBAN DRIVING
7.4	MOPEDS AND MOTORCYCLES <50 CM3
7.4	MOTORCYCLES > 50 CM3
7.4.1	HIGHWAY DRIVING
7.4.2	RURAL DRIVING
7.4.3	URBAN DRIVING
7.5	GASOLINE EVAPORATION FROM CARS

Table III-1: Revised Vehicle Category Split

PASSENGER CARS

1 Gasoline < 1.4 l

PRE ECE
ECE 15/00-01
ECE 15/02
ECE 15/03
ECE 15/04
Improved Conventional
Open Loop
Closed Loop

2 Gasoline 1.4 - 2.0 l

PRE ECE
ECE 15/00-01
ECE 15/02
ECE 15/03
ECE 15/04
Improved Conventional
Open Loop
Closed Loop

3 Gasoline > 2.0 l

PRE ECE
ECE 15/00-01
ECE 15/02
ECE 15/03
ECE 15/04
Closed Loop

4 Diesel

CC < 2.0 l
CC > 2.0 l

5 L P G

6 Two Stroke Gasoline Vehicles

7 LIGHT DUTY VEHICLES

Gasoline
Diesel

8 HEAVY DUTY VEHICLES

Gasoline Veh. > 3.5 t
Diesel Veh. 3.5 - 16 t
Diesel Veh. > 16 t

9 MOTORCYCLES

< 50 cm^3
> 50 cm^3 2 stroke
> 50 cm^3 4 stroke

10 OFF- ROAD VEHICLES

Agriculture
Forestry
Industry
Military

Table III-2: Classification of Vehicles according to UN-ECE

CATEGORY L: MOTOR VEHICLES WITH LESS THAN FOUR WHEELS

CATEGORY L1: TWO-WHELLED VEHICLES WITH AN ENGINE CYLINDER CAPACITY NOT EXCEEDING 50 CC AND A MAXIMUM DESIGN SPEED NOT EXCEEDING 40 KM/H.

CATEGORY L2: THREE-WHEELED VEHICLES WITH AN ENGINE CYLINDER CAPACITY NOT EXCEEDING 50 CC AND A MAXIMUM DESIGN SPEED NOT EXCEEDING 40 KM/H.

CATEGORY L3: TWO-WHEELED VEHICLES WITH AN ENGINE CYLINDER CAPACITY EXCEEDING 50 CC OR A DESIGN SPEED EXCEEDING 40 KM/H.

CATEGORY L4: VEHICLES WITH THREE WHEELS ASYMMETRICALLY ARRANGED IN RELATION TO THE LONGITUDINAL MEDIAN AXIS, WITH AN ENGINE CYLINDER CAPACITY EXCEEDING 50 CC OR A DESIGN SPEED EXCEEDING 40 KM/H (MOTOR CYCLES WITH SIDECAR).

CATEGORY L5: VEHICLES WITH THREE WHEELS SYMMETRICALLY ARRANGED IN RELATION TO THE LONGITUDINAL MEDIAN AXIS, WITH A MAXIMUM WEIGHT NOT EXCEEDING 1,000 KG AND EITHER AN ENGINE CYLINDER CAPACITY EXCEEDING 50 CC OR A DESIGN SPEED EXCEEDING 40 KM/H (MOTOR CYCLES WITH SIDECAR).

CATEGORY M: POWER DRIVEN VEHICLES HAVING AT LEAST FOUR WHEELS OR HAVING THREE WHEELS WHEN THE MAXIMUM WEIGHT EXCEEDS 1 METRIC TON, AND USED FOR THE CARRIAGE OF PASSENGERS

CATEGORY M1: VEHICLES USED FOR THE CARRIAGE OF PASSENGERS AND COMPRISING NOT MORE THAN EIGHT SEATS IN ADDITION TO THE DRIVER'S SEAT.

CATEGORY M2: VEHICLES USED FOR THE CARRIAGE OF PASSENGERS AND COMPRISING MORE THAN EIGHT SEATS IN ADDITION TO THE DRIVER'S SEAT, AND HAVING A MAXIMUM WEIGHT NOT EXCEEDING 5 METRIC TONNES.

CATEGORY M3: VEHICLES USED FOR THE CARRIAGE OF PASSENGERS AND COMPRISING MORE THAN EIGHT SEATS IN ADDITION TO THE DRIVER'S SEAT, AND HAVING A MAXIMUM WEIGHT EXCEEDING 5 METRIC TONNES.

CATEGORY N: POWER-DRIVEN VEHICLES HAVING AT LEAST FOUR WHEELS OR HAVING THREE WHEELS WHEN THE MAXIMUM WEIGHT EXCEEDS 1 METRIC TON, AND USED FOR THE CARRIAGE OF GOODS

CATEGORY N1: VEHICLES USED FOR THE CARRIAGE OF GOODS AND HAVING A MAXIMUM WEIGHT NOT EXCEEDING 3.5 METRIC TONNES.

CATEGORY N2: VEHICLES USED FOR THE CARRIAGE OF GOODS AND HAVING A MAXIMUM WEIGHT EXCEEDING 3.5 BUT NOT EXCEEDING 12 METRIC TONNES.

CATEGORY N3: VEHICLES USED FOR THE CARRIAGE OF GOODS AND HAVING A MAXIMUM WEIGHT EXCEEDING 12 METRIC TONNES.

<u>Table IV.4-1</u>: Summary of Calculation Methods applied for the different Vehicle Categories and Pollutants (for explanation of the indicators used see chapter V.4)

	Pollutant										Fuel
vehicle category	NO_x	CO	NM VOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	FC
Gasoline PC < 1.4 1,PRE-ECE	A	A	A	C	–	C	D	D	D	D	A
ECE 15/00-01	A	A	A	C	–	C	D	D	D	D	A
ECE 15/02	A	A	A	C	–	C	D	D	D	D	A
ECE 15/03	A	A	A	C	–	C	D	D	D	D	A
ECE 15/04	A	A	A	C	–	C	D	D	D	D	A
improved conventional	A	A	A	C	–	C	D	D	D	D	A
open loop	A	A	A	C	–	C	D	D	D	D	A
closed loop	A	A	A	C	–	C	D	D	D	D	A
Gasoline PC 1.4-2.01,PRE-ECE	A	A	A	C	–	C	D	D	D	D	A
ECE 15/00-01	A	A	A	C	–	C	D	D	D	D	A
ECE 15/02	A	A	A	C	–	C	D	D	D	D	A
ECE 15/03	A	A	A	C	–	C	D	D	D	D	A
ECE 15/04	A	A	A	C	–	C	D	D	D	D	A
improved conventional	A	A	A	C	–	C	D	D	D	D	A
open loop	A	A	A	C	–	C	D	D	D	D	A
closed loop	A	A	A	C	–	C	D	D	D	D	A
Gasoline PC > 2.0 1,PRE-ECE	A	A	A	C	–	C	D	D	D	D	A
ECE 15/00-01	A	A	A	C	–	C	D	D	D	D	A
ECE 15/02	A	A	A	C	–	C	D	D	D	D	A
ECE 15/03	A	A	A	C	–	C	D	D	D	D	A
ECE 15/04	A	A	A	C	–	C	D	D	D	D	A
open loop	A	A	A	C	–	C	D	D	D	D	A
closed loop	A	A	A	C	–	C	D	D	D	D	A
Diesel PC < 2.0 1	B	B	B	C	B	C	D	D	D	D	B
PC > 2.0 1	B	B	B	C	B	C	D	D	D	D	B
LPG PC	B	B	B	–	–	–	–	–	D	–	B
2-stroke PC	C	C	C	C	–	C	D	D	D	D	C

Table IV.4-1 (cont.): Summary of Calculation Methods applied for the different Vehicle Categories and Pollutants (for explanation of the indicators used see chapter V.4)

vehicle category		Pollutant										Fuel
		NO_x	CO	NM VOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	FC
Gasoline	LDV	C	C	C	C	–	C	D	D	D	D	C
Diesel	LDV	C	C	C	C	C	C	D	D	D	–	C
Gasoline	HDV	C	C	C	C	–	D	D	D	D	D	C
Diesel	HDV 3.5-16 t	C	C	C	C	C	D	D	D	D	–	C
	> 16 t	C	C	C	C	C	D	D	D	D	–	C
TW	< 50 cc	D	D	D	D	–	–	–	D	D	D	D
	> 50 cc,2-Stroke	D	D	D	D	–	–	–	D	D	D	D
	> 50 cc,4-Stroke	D	D	D	D	–	–	–	D	D	D	D
Evaporation	PC conventional	–	–	A	–	–	–	–	–	–	–	–
	PC closed loop	–	–	A	–	–	–	–	–	–	–	–
	LDV	–	–	C	–	–	–	–	–	–	–	–
	TW < 50 cc	–	–	D	–	–	–	–	–	–	–	–
	TW > 50 cc, 2-S	–	–	D	–	–	–	–	–	–	–	–
	TW > 50 cc, 4-S	–	–	D	–	–	–	–	–	–	–	–
Cold Start	PC conventional	A	A	A	–	–	–	–	–	A	A	A
	PC closed loop	A	A	A	–	–	–	–	–	A	A	A
	Diesel PC	A	A	A	–	A	–	–	–	A	–	A
	PC-LPG	B	B	B	–	–	–	–	–	B	–	B
	Gasoline LDV	C	C	C	–	–	–	–	–	C	C	C
	Diesel LDV	C	C	C	–	C	–	–	–	C	–	C
Off Road	Agriculture	D	D	D	D	D	D	D	D	D	–	D
	Forestry	D	D	D	D	D	D	D	D	D	–	D
	Industry	D	D	D	D	D	D	D	D	D	–	D
	Military	D	D	D	D	D	D	D	D	D	–	D

Table V.1.1-1: Examples of Estimated Share of Mileage (in %) Driven by Different Gasoline Vehicles <2.5 t on Different Road Classes as used by EC Member States in COPERT 85

			Road Class	
Country	Vehicle Category	Urban	Rural	Highway
B	< 1.4 l	26.92	48.88	24.20
	1.4 - 2.0 l	26.92	48.88	24.20
	> 2.0 l	26.92	48.88	24.20
D	< 1.4 l	30.90	43.60	25.50
	1.4 - 2.0 l	30.90	43.60	25.50
	> 2.0 l	30.90	43.60	25.50
DK	< 1.4 l	50.00	40.00	10.00
	1.4 - 2.0 l	50.00	40.00	10.00
	> 2.0 l	50.00	40.00	10.00
E	< 1.4 l	37.72	39.51	22.77
	1.4 - 2.0 l	37.72	39.51	22.77
	> 2.0 l	37.72	39.51	22.77
F	< 1.4 l	40.00	50.00	10.00
	1.4 - 2.0 l	40.00	50.00	10.00
	> 2.0 l	40.00	50.00	10.00
GR	< 1.4 l	44.00	42.00	14.00
	1.4 - 2.0 l	44.00	42.00	14.00
	> 2.0 l	44.00	42.00	14.00
I	< 1.4 l	54.00	41.00	5.00
	1.4 - 2.0 l	33.00	58.00	9.00
	> 2.0 l	20.00	60.00	20.00
IRL	< 1.4 l	25.00	55.00	20.00
	1.4 - 2.0 l	25.00	55.00	20.00
	> 2.0 l	25.00	55.00	20.00
L	< 1.4 l	45.00	35.00	20.00
	1.4 - 2.0 l	45.00	35.00	20.00
	> 2.0 l	45.00	35.00	20.00
NL	< 1.4 l	32.70	38.00	29.30
	1.4 - 2.0 l	32.70	38.00	29.30
	> 2.0 l	32.70	38.00	29.30
P	< 1.4 l	44.00	56.00	-
	1.4 - 2.0 l	44.00	56.00	-
	> 2.0 l	44.00	56.00	-
UK	< 1.4 l	46.60	41.30	12.10
	1.4 - 2.0 l	46.60	41.30	12.10
	> 2.0 l	46.60	41.30	12.10

Table VI.1.1-1: Speed Dependency of CO Emission Factors for Gasoline Vehicles <2.5t

VEHICLE CATEGORY	CYLINDER CAPACITY	SPEED RANGE	CO EMISSION FACTOR [g/km]	R2
PRE ECE	ALL CATEGORIES	10-100	281*V^(-0.630)	0.924
	ALL CATEGORIES	100-130	0.112*V+4.32	-
ECE 15-00/01	ALL CATEGORIES	10-50	313*V^(-0.760)	0.898
	ALL CATEGORIES	50-130	27.22-0.406*V+0.0032*V^2	0.158
ECE 15-02	ALL CATEGORIES	10-60	300*V^(-0.797)	0.747
	ALL CATEGORIES	60-130	26.260-0.440*V+0.0026*V^2	0.102
ECE 15-03	ALL CATEGORIES	10-20	161.36-45.62*ln(V)	0.790
	ALL CATEGORIES	20-130	37.92-0.680*V+0.00377*V^2	0.247
ECE 15-04	ALL CATEGORIES	10-60	260.788*V^(-0.910)	0.825
	ALL CATEGORIES	60-130	14.653-0.220*V+0.001163*V^2	0.613
IMPROVED	CC < 1.4 l	10-130	14.577-0.294*V+0.002478*V^2	0.781
CONVENTIONAL	1.4 l < CC < 2.0 l	10-130	8.273-0.151*V+0.000957*V^2	0.767
OPEN LOOP	CC < 1.4 l	10-130	17.882-0.377*V+0.002825*V^2	0.656
	1.4 l < CC < 2.0 l	10-130	9.446-0.230*V+0.002029*V^2	0.719
CLOSED LOOP	ALL CATEGORIES	10-130	2.913-0.085*V+0.000873*V^2	0.7

V : Average speed expressed in km/h
R2: Correlation coefficient

Table VI.1.1-2: Speed Dependency of VOC Emission Factors for Gasoline Vehicles <2.5 t

VEHICLE CATEGORY	CYLINDER CAPACITY	SPEED RANGE	VOC EMISSION FACTOR [g/km]	R2
PRE ECE	ALL CATEGORIES	10-100	30.34*V^(-0.693)	0.980
	ALL CATEGORIES	100-130	1.247	
ECE 15-00/01	ALL CATEGORIES	10-50	24.99*V^(-0.704)	0.901
	ALL CATEGORIES	50-130	4.85*V^(-0.318)	0.095
ECE 15-02/03	ALL CATEGORIES	10-60	25.75*V^(-0.714)	0.895
	ALL CATEGORIES	60-130	1.95-0.019*V+0.00009*V^2	0.198
ECE 15-04	ALL CATEGORIES	10-60	19.079*V^(-0.693)	0.838
	ALL CATEGORIES	60-130	2.608-0.037*V+0.000179*V^2	0.341
IMPROVED CONVENTIONAL	CC < 1.4 l	10-130	2.189-0.034*V+0.000201*V^2	0.766
	1.4 l < CC < 2.0 l	10-130	1.999-0.034*V+0.000214*V^2	0.447
OPEN LOOP	CC < 1.4 l	10-130	2.185-0.0423*V+0.000256*V^2	0.636
	1.4 l < CC < 2.0 l	10-130	0.808-0.016*V+0.000099*V^2	0.49
CLOSED LOOP	ALL CATEGORIES	10-130	0.165-0.002*V+0.000019*V^2	0.092

V: Average speed expressed in km/h
R2: Correlation coefficient

Table VI.1.1-3: Speed Dependency of NOx Emission Factors for Gasoline Vehicles <2.5 t

VEHICLE CATEGORY	CYLINDER CAPACITY	SPEED RANGE	NOx EMISSION FACTOR [g/km]	R2
PRE ECE	CC < 1.4 l	10-130	1.173+0.0225*V-0.00014*V^2	0.916
ECE 15-00/01	1.4 l < CC < 2.0 l	10-130	1.360+0.0217*V-0.00004*V^2	0.960
	CC > 2.0 l	10-130	1.5+0.03*V+0.0001*V^2	0.972
	CC < 1.4 l	10-130	1.479-0.0037*V+0.00018*V^2	0.711
ECE 15-02	1.4 l < CC < 2.0 l	10-130	1.663-0.0038*V+0.00020*V^2	0.839
	CC > 2.0 l	10-130	1.87-0.0039*V+0.00022*V^2	-
	CC < 1.4 l	10-130	1.616-0.0084*V+0.00025*V^2	0.844
ECE 15-03	1.4 l < CC < 2.0 l	10-130	1.29 * exp(0.0099*V)	0.798
	CC > 2.0 l	10-130	2.784-0.0112*V+0.000294*V^2	0.577
	CC < 1.4 l	10-130	1.432+0.003*V+0.000097*V^2	0.669
ECE 15-04	1.4 l < CC < 2.0 l	10-130	1.484+0.013*V+0.000074*V^2	0.722
	CC > 2.0 l	10-130	2.427-0.014*V+0.000266*V^2	0.803
IMPROVED	CC < 1.4 l	10-130	-0.926+0.719*ln(V)	0.883
CONVENTIONAL	1.4 l < CC < 2.0 l	10-130	1.387+0.0014*V+0.000247*V^2	0.876
OPEN LOOP	CC < 1.4 l	10-130	-0.921+0.616*ln(V)	0.791
	1.4 l < CC < 2.0 l	10-130	-0.761+0.515*ln(V)	0.495
CLOSED LOOP	ALL CATEGORIES	10-130	0.260-0.0036*V+0.000061*V^2	0.752

V: Average speed expressed in km/h
R2: Correlation coefficient

Table VI.1.1-4: Speed Dependency of Fuel Consumption Factors for Gasoline Vehicles <2.5 t

VEHICLE CATEGORY	CYLINDER CAPACITY	SPEED RANGE	FUEL CONSUMPTION FACTOR [g/km]	R2
PRE ECE	CC < 1.4 l	10-60	521*V^(-0.554)	0.941
		60-80	55	-
		80-130	0.386*V+24.143	-
	1.4 l < CC < 2.0 l	10-60	681*V^(-0.583)	0.936
		60-80	67	-
		80-130	0.471*V+29.286	-
	CC > 2.0 l	10-60	979*V^(-0.628)	0.918
		60-80	80	-
		80-130	0.414*V+46.867	-
ECE 15-00/01	CC < 1.4 l	10-60	595*V^(-0.63)	0.951
		60-130	95-1.324*V+0.0086*V^2	0.289
	1.4 l < CC < 2.0 l	10-60	864*V^(-0.69)	0.974
		60-130	59-0.407*V+0.0042*V^2	0.647
	CC > 2.0 l	10-60	1236*V^(-0.764)	0.976
		60-130	65-0.407*V+0.0042*V^2	-
ECE 15-02/03	CC < 1.4 l	10-50	544*V^(-0.63)	0.929
		50-130	85-1.108*V+0.0077*V^2	0.641
	1.4 l < CC < 2.0 l	10-50	879*V^(-0.72)	0.950
		50-130	71-0.7032*V+0.0059*V^2	0.830
	CC > 2.0 l	10-50	1224*V^(-0.756)	0.961
		50-130	111-1.333*V+0.0093*V^2	0.847
ECE 15-04	CC < 1.4 l	10-25	296.7-80.21*ln(V)	0.518
		25-130	81.1-1.014*V+0.0068*V^2	0.760
	1.4 l < CC < 2.0 l	10-60	606.1*V^(-0.667)	0.907
		60-130	102.5-1.364*V+0.0086*V^2	0.927
	CC > 2.0 l	10-60	819.9*V^(-0.663)	0.966
		60-130	41.7+0.122*V+0.0016*V^2	0.650
IMPROVED CONVENTIONAL	CC < 1.4 l	10-130	80.52-1.41*V+0.013*V^2	0.954
	1.4 l < CC < 2.0 l	10-130	111.0-2.031*V+0.017*V^2	0.994
OPEN LOOP	CC < 1.4 l	10-130	85.55-1.383*V+0.0117*V^2	0.997
	1.4 l < CC < 2.0 l	10-130	109.6-1.98*V+0.0168*V^2	0.997
CLOSED LOOP	CC < 1.4 l	10-130	82.4-1.278*V+0.0107*V^2	0.994
	1.4 l < CC < 2.0 l	10-130	106.43-1.862*V+0.0156*V^2	0.994
	CC > 2.0 l	10-130	140.5-2.655*V+0.0223*V^2	0.994

V: Average speed expressed in km/h
R2: Correlation coefficient.

Table VI.1.1.1-1: Examples of Vehicle Speed (in km/h) considered as Representative for the Characterization of the Driving Behaviour of Gasoline Vehicles <2.5 t on Different Road Classes as used by EC Member States in COPERT 85

			Road Class	
Country	Vehicle Category	Urban	Rural	Highway
B	< 1.4 l	25	50	103
	1.4 - 2.0 l	25	50	105
	> 2.0 l	25	50	110
D	< 1.4 l	37	75	106
	1.4 - 2.0 l	37	75	116
	> 2.0 l	37	75	125
DK	< 1.4 l	30	60	90
	1.4 - 2.0 l	30	60	90
	> 2.0 l	30	60	90
E	< 1.4 l	20	60	83
	1.4 - 2.0 l	20	60	83
	> 2.0 l	20	60	83
F	< 1.4 l	30	70	95
	1.4 - 2.0 l	30	70	105
	> 2.0 l	30	70	115
GR	< 1.4 l	19	60	90
	1.4 - 2.0 l	19	60	90
	> 2.0 l	19	60	90
I	< 1.4 l	20	65	105
	1.4 - 2.0 l	20	65	115
	> 2.0 l	20	65	125
IRL	< 1.4 l	30	50	85
	1.4 - 2.0 l	30	50	85
	> 2.0 l	30	50	85
L	< 1.4 l	40	60	95
	1.4 - 2.0 l	40	60	95
	> 2.0 l	40	60	95
NL	< 1.4 l	25	60	100
	1.4 - 2.0 l	25	60	100
	> 2.0 l	25	60	100
P	< 1.4 l	30	70	-
	1.4 - 2.0 l	30	70	-
	> 2.0 l	30	70	-
UK	< 1.4 l	40	77	115
	1.4 - 2.0 l	40	77	115
	> 2.0 l	40	77	115

Table VI.1.2-1: Speed Dependency of Emission Factors for Diesel Vehicles <2.5 t

POLLUTANT	CYLINDER CAPACITY	SPEED RANGE	EMISSION FACTOR [g/km]	R2
CO	ALL CATEGORIES	10-130	5.413*V^(-0.574)	0.745
NOx	CC < 2.0l	10-130	0.918-0.014*V+0.000101*V^2	0.949
	CC > 2.0l	10-130	1.331-0.018*V+0.000133*V^2	0.927
VOC	ALL CATEGORIES	10-130	4.61*V^(-0.937)	0.794
TPM	ALL CATEGORIES	10-130	0.45-0.0086*V+0.000058*V^2	0.439
FC	ALL CATEGORIES	10-130	118.489-2.084*V+0.014*V^2	0.583

V: Average speed expressed in km/h
R2: Correlation coefficient

Table VI.1.3-1: Speed Dependency of Emission Factors for LPG Vehicles <2.5 t

POLLUTANT	CYLINDER CAPACITY	SPEED RANGE	EMISSION FACTOR [g/km]	R2
CO	ALL CATEGORIES	10-130	12.523-0.418*V+0.0039*V^2	0.893
NOx	ALL CATEGORIES	10-130	0.77*V^(0.285)	0.598
VOC	'ALL CATEGORIES	10-130	26.3*V^(-0.865)	0.967
FC	ALL CATEGORIES	URBAN	59	-
		RURAL	45	-
		HIGHWAY	54	-

V: Average speed expressed in km/h
R2: Correlation coefficient

Table VI.1.4-1: Emission Factors for Gasoline Two-Stroke Vehicles <2.5 t

	CO [g/km]	NOx [g/km]	VOC [g/km]	CONSUMPTION [g/km]
URBAN	20.65	0.30	15.35	111.52
RURAL	7.50	1.02	7.20	66.00
HIGHWAY	8.70	0.72	5.90	56.93

Table VI.1.5-1: Emission Factors for Gasoline Light Duty Vehicles <3.5 t

	CO [g/km]	NOx [g/km]	VOC [g/km]	CONSUMPTION [g/km]
URBAN	30.00	3.00	3.60	120.0
RURAL	15.00	2.70	1.70	67.5
HIGHWAY	12.00	3.20	1.00	63.75

Table VI.1.6-1: Emission Factors for Diesel Light Duty Vehicles <3.5 t

	CO [g/km]	NOx [g/km]	VOC [g/km]	PARTICULATES [g/km]	CONSUMPTION [g/km]
URBAN	2.00	1.60	0.40	0.25	106.25
RURAL	0.80	1.20	0.25	0.25	68.00
HIGHWAY	0.60	1.25	0.13	0.16	63.75

Table VI.1.7-1: Emission Factors for Heavy Duty Gasoline Vehicles >3.5 t

	CO [g/km]	NOx [g/km]	VOC [g/km]	CONSUMPTION [g/km]
URBAN	70.00	4.50	7.00	225
RURAL	55.00	7.50	5.50	150
HIGHWAY	55.00	7.50	3.50	165

Table VI.1.8-1: Emission Factors for Heavy Duty Diesel Vehicles 3.5 - 16 t[1]

	Particulates[2] g/kg fuel (g/km)	CO[2] g/kg fuel (g/km)	VOC[2] g/kg fuel (g/km)	NOx[2] g/kg fuel (g/km)	FC l/100 km[3] (g/km)
urban	4.3	82.8	12	38.5	27.5
	(0.95)	(18.8)	(2.75)	(8.7)	(227)
rural	4.3	38.6	4	39.1	22.9
	(0.82)	(7.3)	(0.76)	(7.4)	(189)
highway	4.3	27.1	4	38.9	18.7
	(0.66)	(4.2)	(0.6)	(6.0)	(154)

(1) The 16 tonne split is somewhat arbitrary. Figures may apply for vehicles in the range of 12 to 18 tonnes.

(2) There are only very few data available; some test bench data recently measured (nine engines) indicate that vehicles put on the market after 1985 emit less (Umweltbundesamt 1991):

Particulates:	2.9 g/kg fuel
CO:	18.6 g/kg fuel
VOC:	8.1 g/kg fuel
NOx:	36.1 g/kg fuel

irrespective of road type.

(3) Assumed density 0.825 kg/l

Table VI.1.9-1: Emission Factors for Heavy Duty Diesel Vehicles > 16 t[1]

	Particulates[2] g/kg fuel (g/km)	CO[2] g/kg fuel (g/km)	VOC[2] g/kg fuel (g/km)	NOx[2] g/kg fuel (g/km)	FC l/100 km[3] (g/km)
urban	4.3	51.4	16	44.2	44.4
	(1.6)	(18.8)	(5.8)	(16.2)	(366)
	(1.4)	(17.0)	(5.3)	(16.5)	(Busses: 330)
rural	4.3	22.2	8	45.2	39.7
	(1.4)	(7.3)	(2.6)	(14.8)	(328)
	(1.2)	(6.2)	(2.2)	(18.2)	(Busses: 280)
highway	4.3	14.2	8	45.8	35.6
	(1.25)	(4.2)	(2.3)	(13.5)	(294)
	(0.9)	(3.0)	(1.7)	(13.9)	(Busses: 215)

(1) The 16 tonne split is somewhat arbitrary. Figures may apply for vehicles in the range of 12 to 18 tonnes.

(2) There are only very few data available; some test bench data recently measured (six engines) indicate that vehicles put on the market after 1985 emit lesser particulates, CO and VOC, but somewhat more NOx (Umweltbundesamt 1991):

Particulates: 2.1 g/kg fuel
CO: 19.3 g/kg fuel
VOC: 5.3 g/kg fuel
NOx: 49.1 g/kg fuel

irrespective of road type.

(3) Assumed density 0.825 kg/l

Table VI.1.10-1: Emission Factors for Motor Cycles

	CO [g/km]	NOx [g/km]	VOC [g/km]	CONSUMPTION [g/km]
< 50 cc	10.00	0.05	6.00	18.00
> 50 cc 2 Stroke	22.00	0.08	15.00	30.00
> 50 cc 4 Stroke	20.00	0.30	3.00	38.00

Table VI.2.1-1: Cold Mileage Percentage β (Share of Mileage Driven with Cold Gasoline Powered Engines)

	Factor Beta
Estimated l(trip)	0.647 - 0.025 * l(trip) - (0.00974 - 0.000385 * l(trip)) * ta
Measured l(trip)	0.698 - 0.051 * l(trip) - (0.01051 - 0.000770 * l(trip)) * ta

Table VI.2.1-2: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for Conventional Gasoline Powered Engines and temperature range of -10 °C to 30 °C)

Conventional Gasoline Powered Vehicles	e(cold)/e(hot)
CO	3.7 - 0.09 * ta
NOx	1.14 - 0.006 * ta
VOC	2.8 - 0.06 * ta
FC	1.47 - 0.009 * ta

Table VI.2.1-3: Examples of Values for Average Estimated Trip Length l_{trip} as taken by EC Member States in COPERT 85

COUNTRY	TRIP LENGTH [km]
B	12
DK	9
D	14
F	12
GR	12
IRL	14
I	12
L	15
NL	13.1
P	12
E	6.31
UK	10

Table VI.2.2-1: Relative Emission Factors e^{cold} / e^{hot} (Only valid for Closed Loop Gasoline Powered Engines and temperature range of -10 °C to 30 °C)

Closed Loop Gasoline Powered Vehicles	e(cold)/e(hot)
CO	9.04 - 0.09 * ta
NOx	3.66 - 0.006 * ta
VOC	12.59 - 0.06 * ta
FC	1.47 - 0.009 * ta

Table VI.2.3-1: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for Diesel Passenger Cars and temperature range of -10 °C to 30 °C)

Diesel Passenger Cars	e(cold)/e(hot)
CO	1.9 - 0.03 * ta
NOx	1.3 - 0.013 * ta
VOC	3.1 - 0.09 * ta (1)
TPM	3.1 - 0.1 * ta (2)
FC	1.34 - 0.008 * ta

(1) VOC: if ta > 29°C then e(cold)/e(hot) > 0.5
(2) TPM: if ta > 26°C then e(cold)/e(hot) > 0.5

Table VI.2.4-1: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for LPG Passenger Cars and temperature range of -10 °C to 30 °C)

LPG Passenger Cars	e(cold)/e(hot)
CO	3.66 - 0.09 * ta
NOx	0.98 - 0.006 * ta
VOC	2.24 - 0.06 * ta (1)
FC	1.47 - 0.009 * ta

(1) VOC: if ta > 29°C then e(cold)/e(hot) > 0.5

Table VI.3.1-1: Summary of Emission Factors for Estimating Evaporative Emissions of Gasoline Powered Vehicles (all RVP in kPa, all temperatures in °C)

Emission factor (units)	Uncontrolled vehicle	Small carbon canister controlled vehicle
Diurnal (g/day)	$9.1 \cdot \exp(0.0158\,(RVP-61.2) + 0.0574\,(t_{a,min} - 22.5) + 0.0614 \cdot (t_{a,rise} - 11.7))$	$0.2 \cdot$ uncontrolled
warm soak (g/procedure)	$\exp(-1.644 + 0.01993\,RVP + 0.07521\,t_a)$	$0.2 \cdot \exp(-2.41 + 0.02302\,RVP + 0.09408\,t_a)$
hot soak (g/procedure)	$3.0042 \cdot \exp(0.02\,RVP)$	$0.3 \cdot \exp(-2.41 + 0.02302\,RVP + 0.09408\,t_a)$
warm and hot soak for fuel injected vehicles (g/procedure)	0.7	none
warm running losses (g/km)	$0.1 \cdot \exp(-5.967 + 0.04259\,RVP + 0.1773\,t_a)$	$0.1 \cdot$ uncontrolled
hot running losses (g/km)	$0.136 \cdot \exp(-5.967 + 0.04259\,RVP + 0.1773\,t_a)$	$0.1 \cdot$ uncontrolled

Table VI.3.1-2: Examples of Statistical Input Data Relevant for Estimating Evaporative Emissions

Country	Vehicle Category	Vehicles equipped with evaporative control [%]	Vehicles equipped with fuel injection [%]
B	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	3.1
	> 2.0 l	0	1.8
D	< 1.4 l	0.2	8.4
	1.4 - 2.0 l	0.2	8.4
	> 2.0 l	0.2	8.4
DK	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	0.0
	> 2.0 l	0	0.0
E	< 1.4 l	0	4.9
	1.4 - 2.0 l	0	4.9
	> 2.0 l	0	4.9
F	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	4.2
	> 2.0 l	0	15.5
GR	< 1.4 l	0	1.0
	1.4 - 2.0 l	0	1.0
	> 2.0 l	0	1.0
I	< 1.4 l	0	5.0
	1.4 - 2.0 l	0	5.0
	> 2.0 l	0	5.0
IRL	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	0.0
	> 2.0 l	0	0.0
L	< 1.4 l	0	5.0
	1.4 - 2.0 l	0	10.0
	> 2.0 l	0	15.0
NL	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	0.0
	> 2.0 l	1	10.0
P	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	10.0
	> 2.0 l	0	30.0
UK	< 1.4 l	0	0.0
	1.4 - 2.0 l	0	0.0
	> 2.0 l	0	0.0

Table VI.4-1: Methane (CH_4)Emission Factors for all Vehicle Categories

CH4 EMISSION FACTORS [g/km]	URBAN	RURAL	HIGHWAY
PASSENGER CARS			
Conventional	0.268 - 0.00573 * V + 0.0000331 * V^2		
Closed Loop	0.020	0.020	0.020
Diesel			
CC < 2.0 l	0.005	0.005	0.005
CC > 2.0 l	0.005	0.005	0.005
L P G	0.080	0.035	0.025
2-stroke	0.150	0.040	0.025
LIGHT DUTY VEHICLES			
Gasoline	0.150	0.040	0.025
Diesel	0.005	0.005	0.005
HEAVY DUTY VEHICLES			
Gasoline Veh. > 3.5 t	0.140	0.110	0.070
Diesel Veh. 3.5 - 16 t	0.085	0.023	0.020
Diesel Veh. > 16 t	0.175	0.080	0.070
MOTORCYCLES			
< 50 cc	0.100	0.100	0.100
> 50 cc 2 stroke	0.150	0.150	0.150
> 50 cc 4 stroke	0.200	0.200	0.200

Table VI.5-1: Nitrous Oxide (N_2O) Emission Factors for all Vehicle Categories

N2O EMISSION FACTORS [g/km]	URBAN	RURAL	HIGHWAY
PASSENGER CARS			
Conventional	0.005	0.005	0.005
Closed Loop	0.050	0.050	0.050
Diesel			
CC < 2.0 l	0.010	0.010	0.010
CC > 2.0 l	0.010	0.010	0.010
L P G	na	na	na
2-stroke	0.005	0.005	0.005
LIGHT DUTY VEHICLES			
Gasoline	0.006	0.006	0.006
Diesel	0.017	0.017	0.017
HEAVY DUTY VEHICLES			
Gasoline Veh. > 3.5 t	0.006	0.006	0.006
Diesel Veh. 3.5 - 16 t	0.030	0.030	0.030
Diesel Veh. > 16 t	0.030	0.030	0.030
MOTORCYCLES			
< 50 cc	0.001	0.001	0.001
> 50 cc 2 stroke	0.002	0.002	0.002
> 50 cc 4 stroke	0.002	0.002	0.002

na: not available

Remark: Emission factors are still quite uncertain and may need revision as soon as more information becomes available.

Table VI.8-1: Ammonia (NH_3) Emission Factors for all Vehicle Categories

NH3 EMISSION FACTORS [g/km]	URBAN	RURAL	HIGHWAY
PASSENGER CARS			
Conventional	0.002	0.002	0.002
Closed Loop	0.070	0.100	0.100
Diesel			
CC < 2.0 l	0.001	0.001	0.001
CC > 2.0 l	0.001	0.001	0.001
L P G	na	na	na
2-stroke	0.002	0.002	0.002
LIGHT DUTY VEHICLES			
Gasoline	0.002	0.002	0.002
Diesel	0.001	0.001	0.001
HEAVY DUTY VEHICLES			
Gasoline Veh. > 3.5 t	0.002	0.002	0.002
Diesel Veh. 3.5 - 16 t	0.003	0.003	0.003
Diesel Veh. > 16 t	0.003	0.003	0.003
MOTORCYCLES			
< 50 cc	0.001	0.001	0.001
> 50 cc 2 stroke	0.002	0.002	0.002
> 50 cc 4 stroke	0.002	0.002	0.002

na: not available

Remark: Emission factors are still quite uncertain and may need revision as soon as more information becomes available.

Table VI.10-1: Emission Factors for Off Road vehicles

EMISSION FACTORS [g/kg fuel]	CO	NOx	VOC	PARTICULATES
Agriculture	20.0	50.0	8.0	4.0
Forestry	20.0	50.0	8.0	4.0
Industry	20.0	50.0	8.0	4.0
Military	20.0	50.0	8.0	4.0

EMISSION FACTORS [g/kg fuel]	CH4	N2O	NH3
Agriculture	0.40	0.10	0.005
Forestry	0.40	0.10	0.005
Industry	0.40	0.10	0.005
Military	0.40	0.10	0.005

Remark: Emission factors are still quite uncertain and may need revision as soon as more information becomes available.

Table VII-1: Summary of Precision Indicators of the Emission Estimate for the different Vehicle Categories and Pollutants

Legend:

1: Statistically significant emission factors based on a sufficiently large set of measured and re-evaluated data

2: Emission factors non statistically significant based on a small set of measured data which have been re-evaluated

3: Emission factors estimated on the basis of available literature

4: Emission factors estimated applying similarity considerations and/or extrapolation.

	Pollutant										Fuel
vehicle category	NO_x	CO	NM VOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	FC
Gasoline PC < 1.4 l, PRE-ECE	1	1	1	1	–	3	3	1	1	2	1
ECE 15/00-01	1	1	1	1	–	3	3	1	1	2	1
ECE 15/02	1	1	1	1	–	3	3	1	1	2	1
ECE 15/03	1	1	1	1	–	3	3	1	1	2	1
ECE 15/04	1	1	1	1	–	3	3	1	1	2	1
improved conventional	1	1	1	1	–	3	3	1	1	2	1
open loop	1	1	1	1	–	3	3	1	1	2	1
closed loop	1	1	1	2	–	3	3	1	1	2	1
Gasoline PC 1.4-2.0 l, PRE-ECE	1	1	1	1	–	3	3	1	1	2	1
ECE 15/00-01	1	1	1	1	–	3	3	1	1	2	1
ECE 15/02	1	1	1	1	–	3	3	1	1	2	1
ECE 15/03	1	1	1	1	–	3	3	1	1	2	1
ECE 15/04	1	1	1	1	–	3	3	1	1	2	1
improved conventional	1	1	1	1	–	3	3	1	1	2	1
open loop	1	1	1	1	–	3	3	1	1	2	1
closed loop	1	1	1	2	–	3	3	1	1	2	1
Gasoline PC > 2.0 l, PRE-ECE	1	1	1	1	–	3	3	1	1	2	1
ECE 15/00-01	1	1	1	1	–	3	3	1	1	2	1
ECE 15/02	1	1	1	1	–	3	3	1	1	2	1
ECE 15/03	1	1	1	1	–	3	3	1	1	2	1
ECE 15/04	1	1	1	1	–	3	3	1	1	2	1
open loop	1	1	1	1	–	3	3	1	1	2	1
closed loop	1	2	1	2	–	3	3	1	1	2	1
Diesel PC < 2.0 l	1	1	1	2	1	3	3	1	1	–	1
PC > 2.0 l	1	1	1	2	1	3	3	1	1	–	1
LPG PC	1	1	1	–	–	–	–	–	1	–	1
2-stroke PC	2	2	2	4	–	4	4	1	2	2	2

Table VII-1 (cont.): Summary of Precision Indicators of the Emission Estimate for the different Vehicle Categories and Pollutants

vehicle category		Pollutant										Fuel
		NO_x	CO	NM VOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	FC
Gasoline	LDV	1	1	1	3	–	4	4	1	1	2	1
Diesel	LDV	1	1	1	3	2	4	4	1	1	–	1
Gasoline	HDV	4	4	4	4	–	4	4	4	4	4	4
Diesel	HDV 3.5-16 t	2	2	2	4	2	4	4	2	2	–	2
	> 16 t	2	2	2	4	2	4	4	2	2	–	2
TW	< 50 cc	2	2	2	4	–	–	–	2	2	2	2
	> 50 cc,2-Stroke	2	2	2	4	–	–	–	2	2	2	2
	> 50 cc,4-Stroke	2	2	2	4	–	–	–	2	2	2	2
Evaporation	PC conventional	–	–	3	–	–	–	–	–	–	–	–
	PC closed loop	–	–	3	–	–	–	–	–	–	–	–
	LDV	–	–	4	–	–	–	–	–	–	–	–
	TW < 50 cc	–	–	4	–	–	–	–	–	–	–	–
	TW > 50 cc, 2-S	–	–	4	–	–	–	–	–	–	–	–
	TW > 50 cc, 4-S	–	–	4	–	–	–	–	–	–	–	–
Cold Start	PC conventional	2	2	2	–	–	–	–	–	2	2	2
	PC closed loop	3	3	3	–	–	–	–	–	2	2	3
	Diesel PC	3	3	3	–	3	–	–	–	3	–	3
	PC-LPG	3	3	3	–	–	–	–	–	3	–	3
	Gasoline LDV	4	4	4	–	–	–	–	–	4	4	4
	Diesel LDV	4	4	4	–	4	–	–	–	4	–	4
Off Road	Agriculture	4	4	4	4	4	4	4	4	4	–	4
	Forestry	4	4	4	4	4	4	4	4	4	–	4
	Industry	4	4	4	4	4	4	4	4	4	–	4
	Military	4	4	4	4	4	4	4	4	4	–	4

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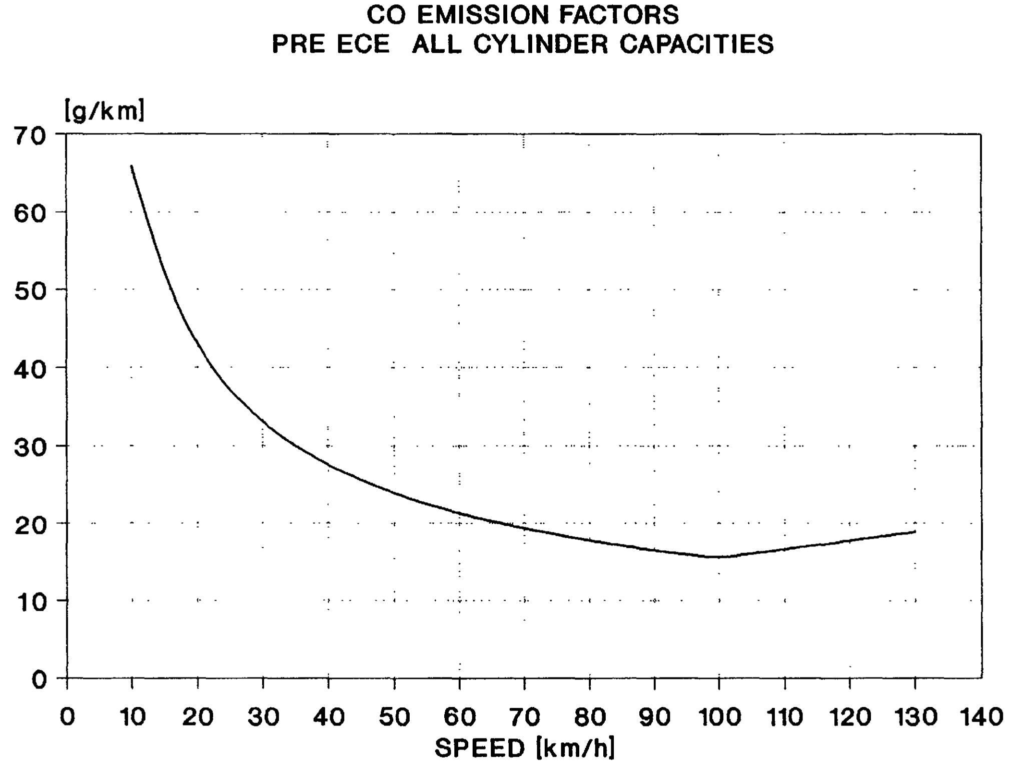
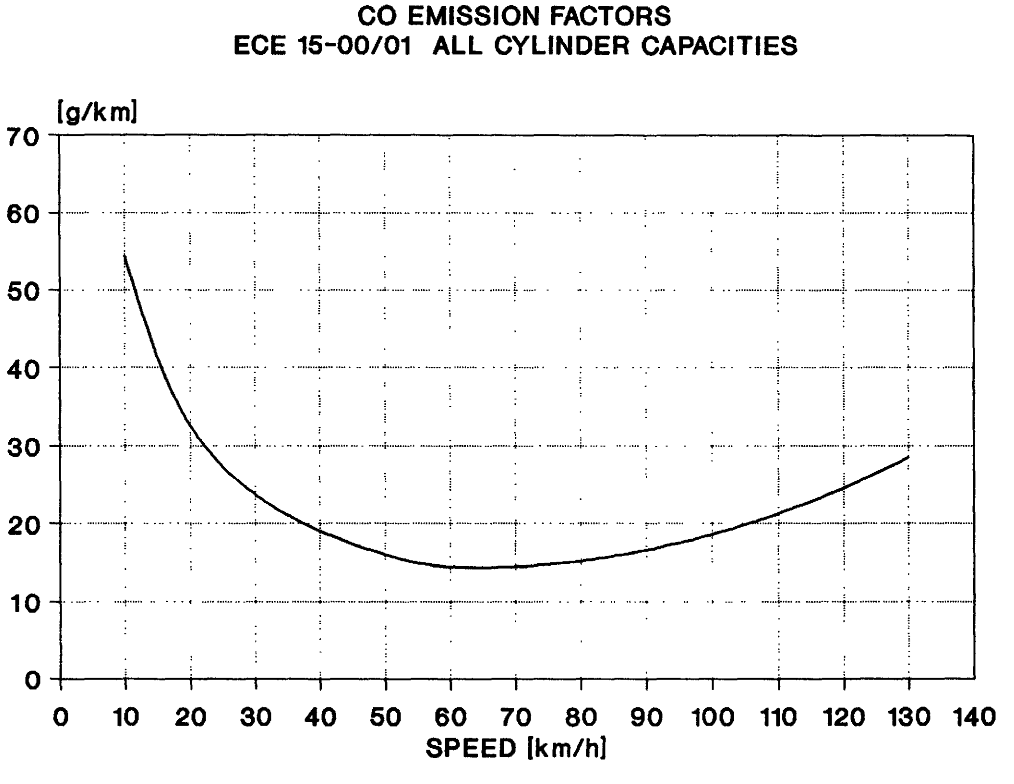


Figure VI.1.1-2: Speed-Dependent CO Emission Factor of Gasoline Vehicles <2.5 t for ECE 15-00 and 15-01 Homologation, Valid for All Cylinder Capacities



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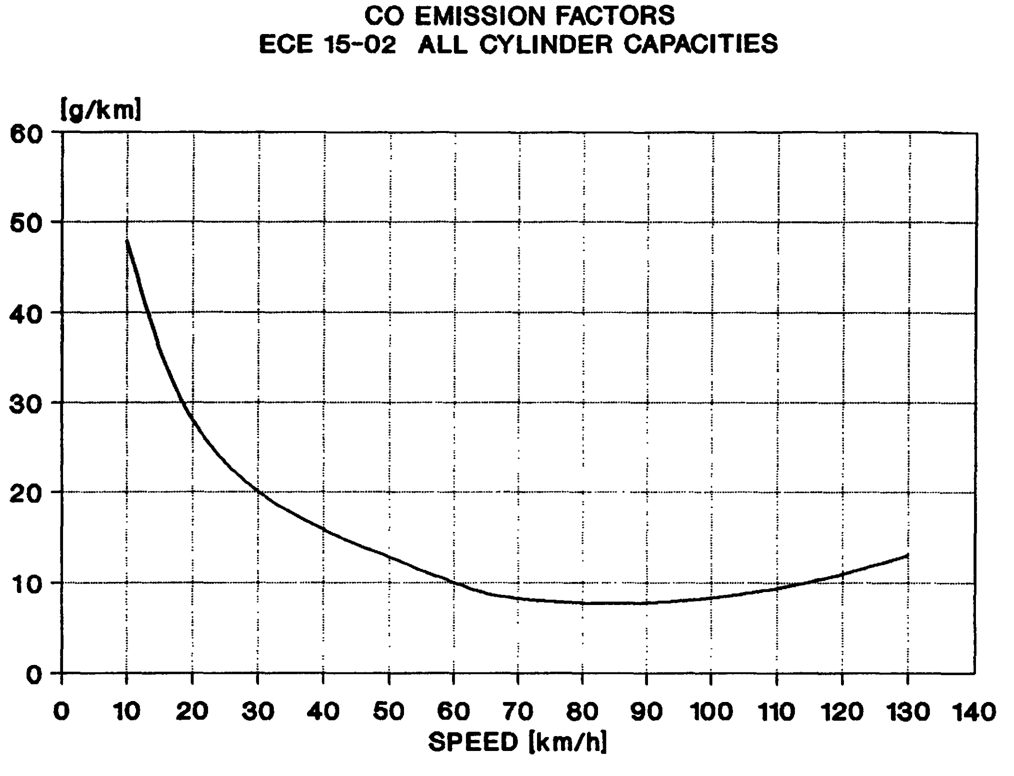

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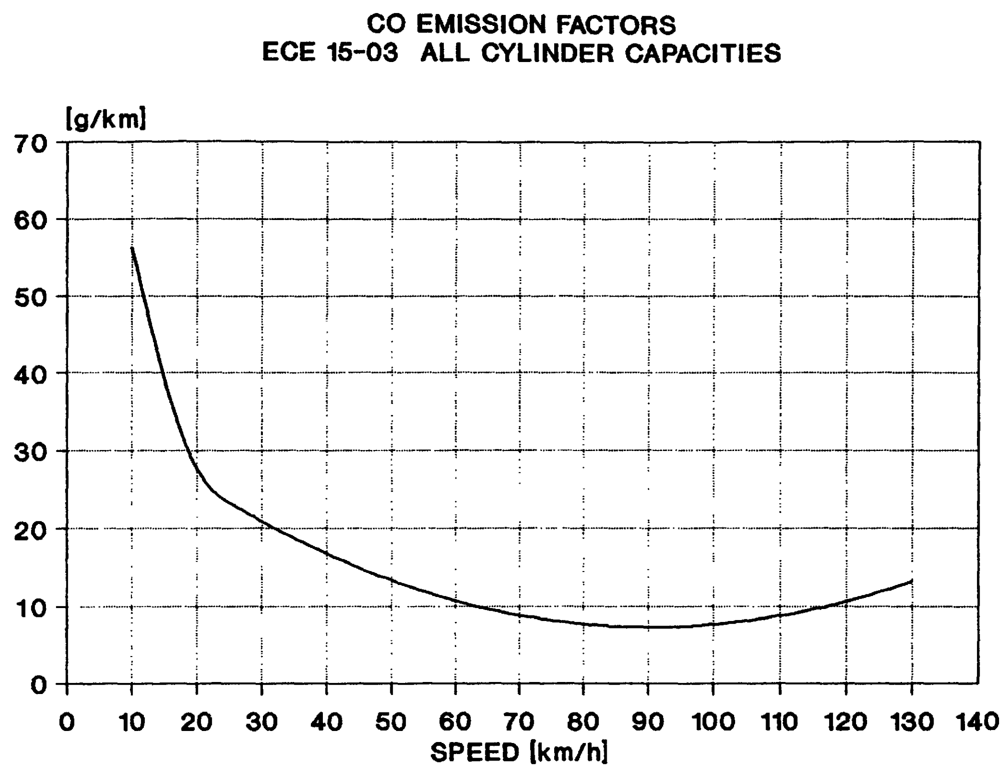

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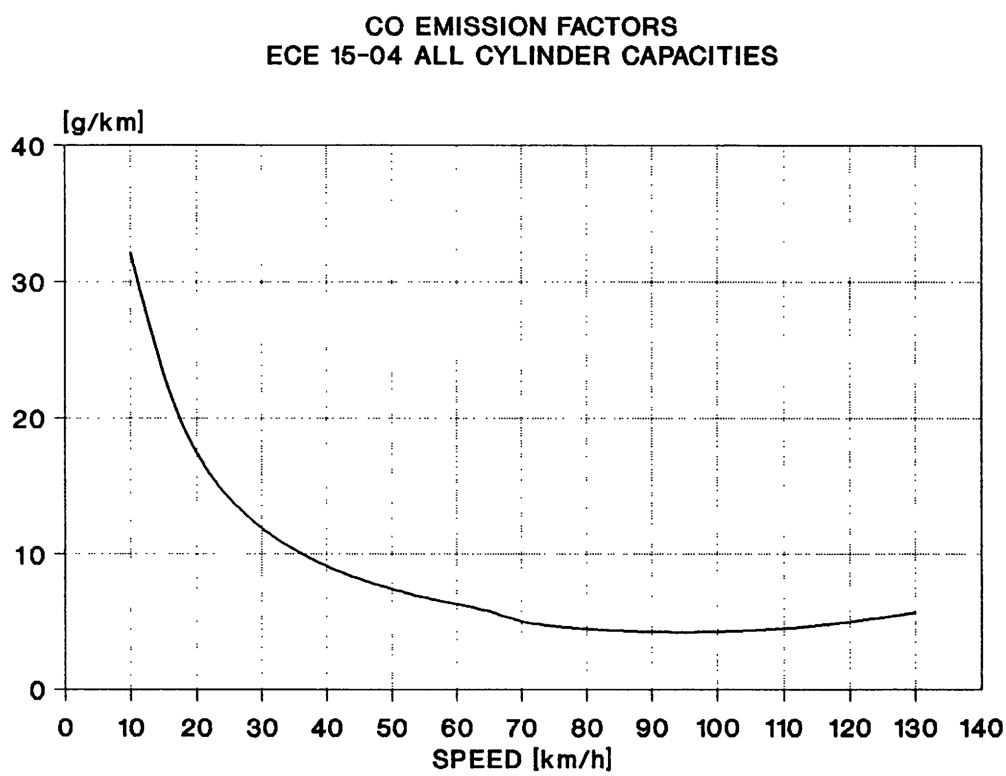

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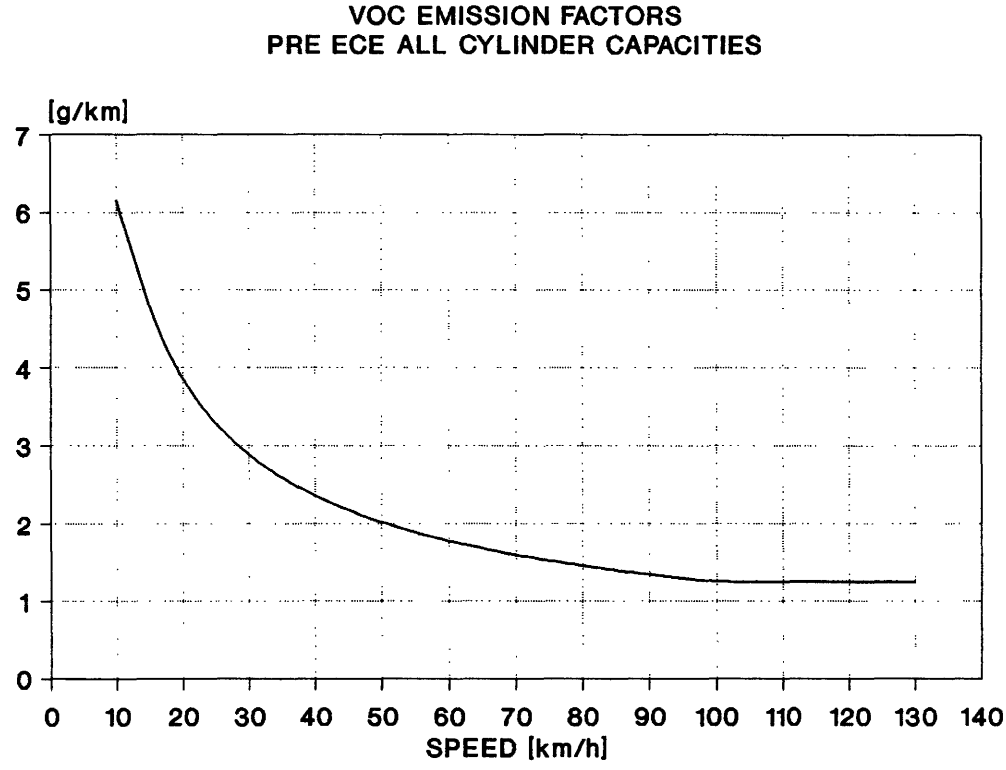
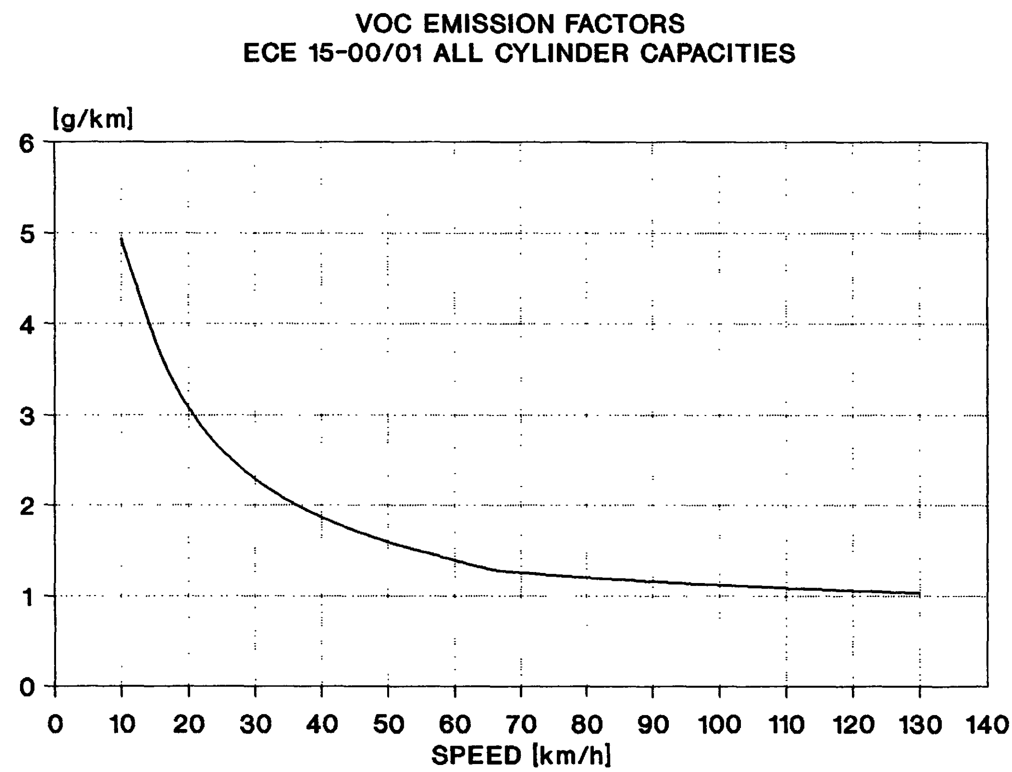


Figure VI.1.1-7: Speed-Dependent VOC Emission Factor of Gasoline Vehicles <2.5 t for ECE 15-00 and 15-01 Homologation, Valid for All Cylinder Capacities



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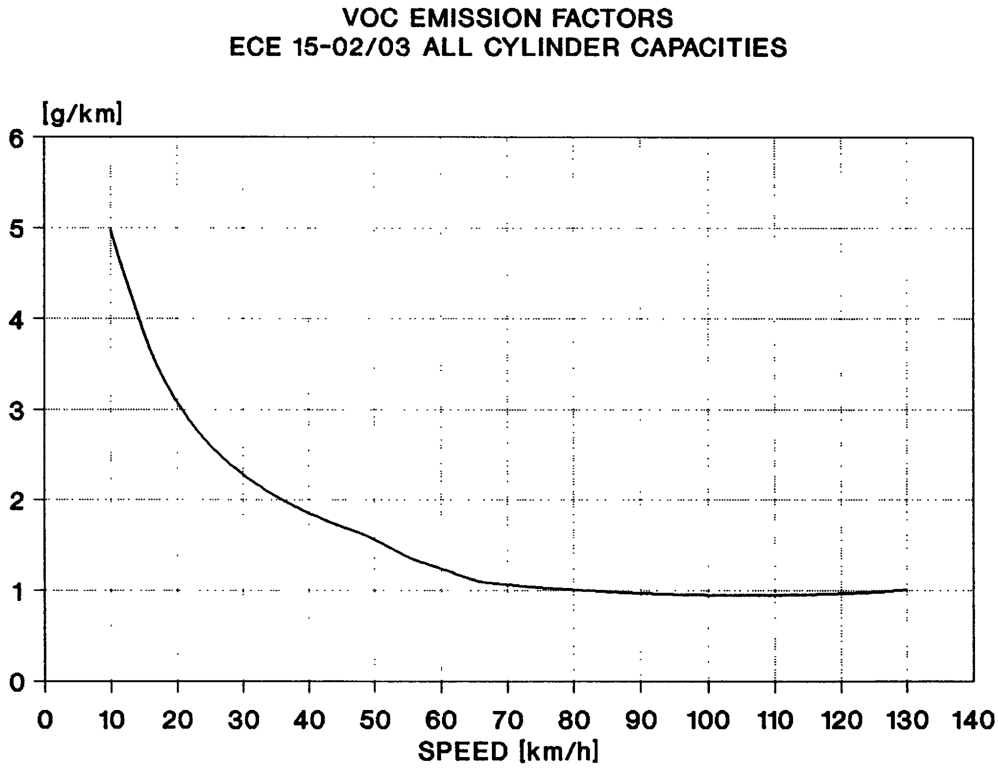

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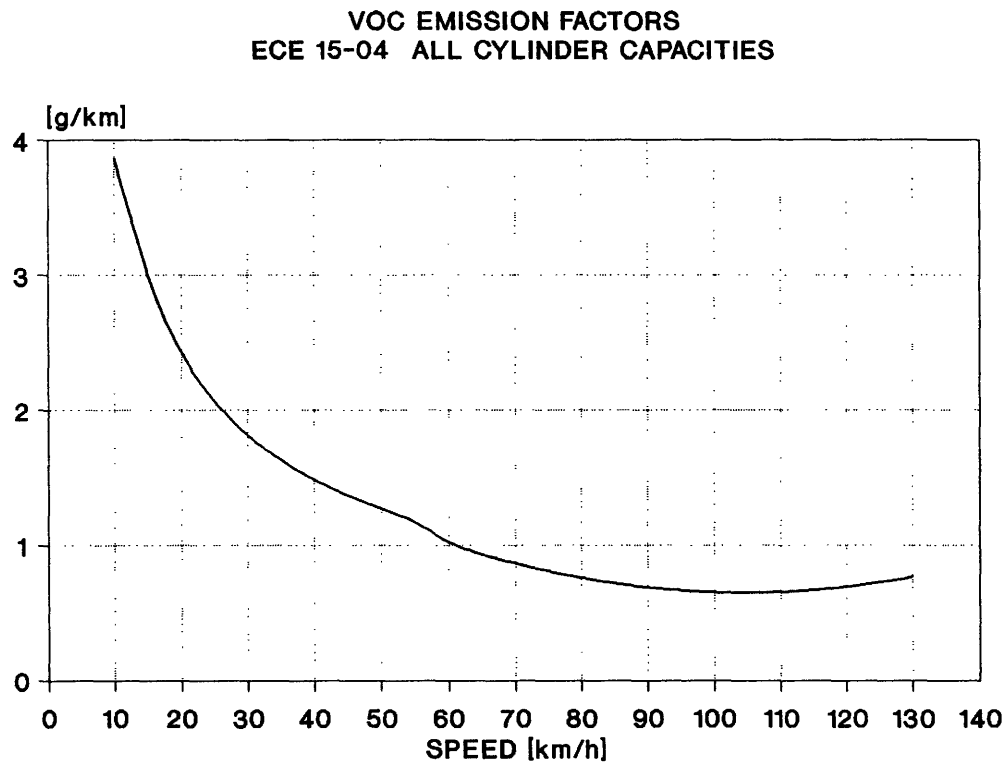

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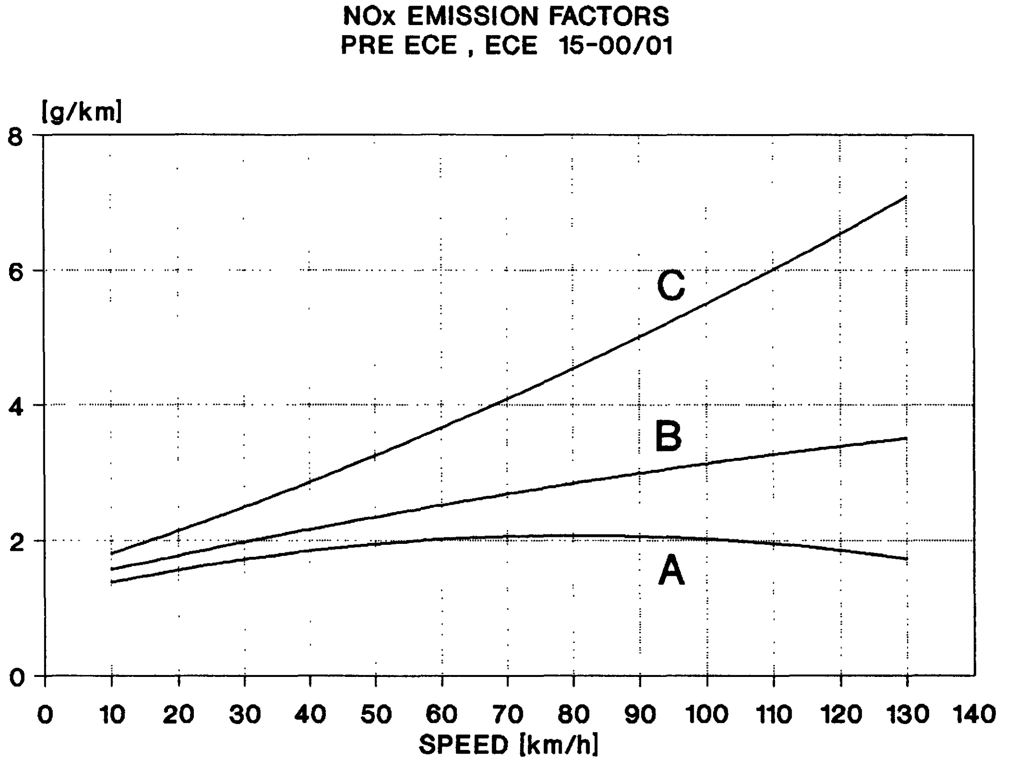

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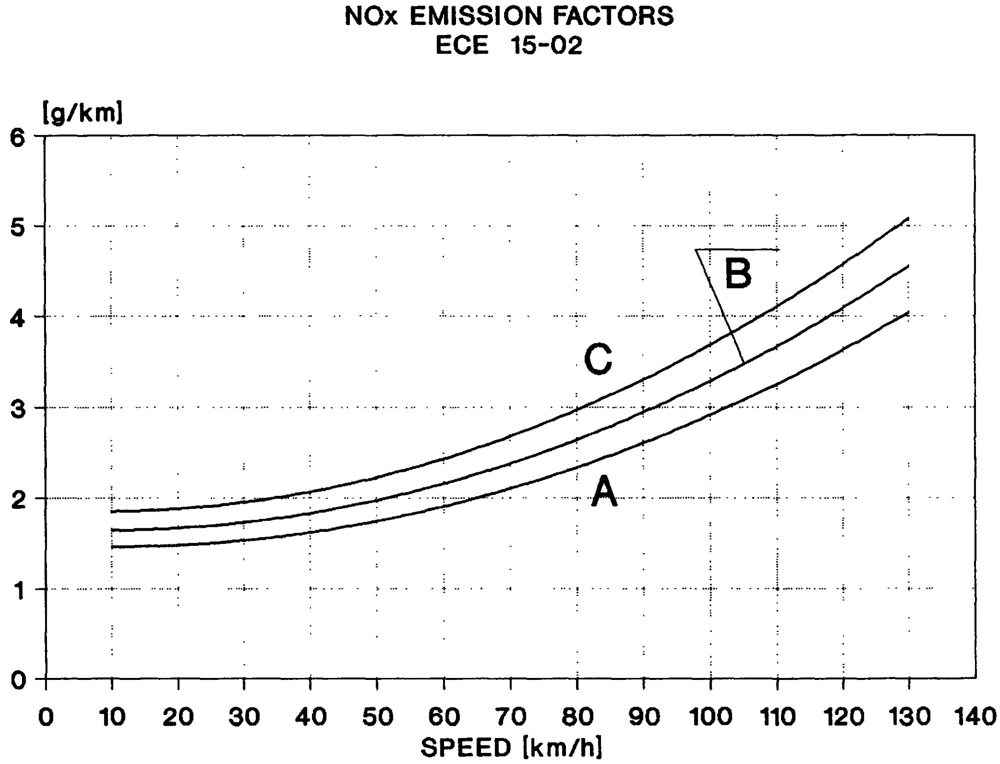

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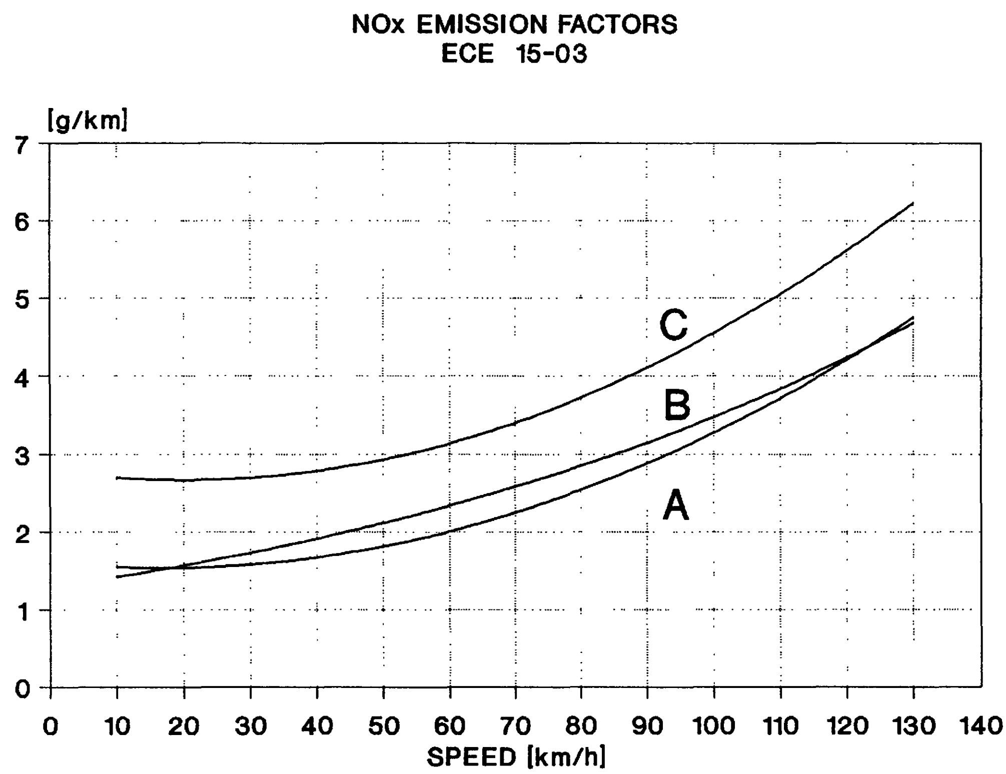

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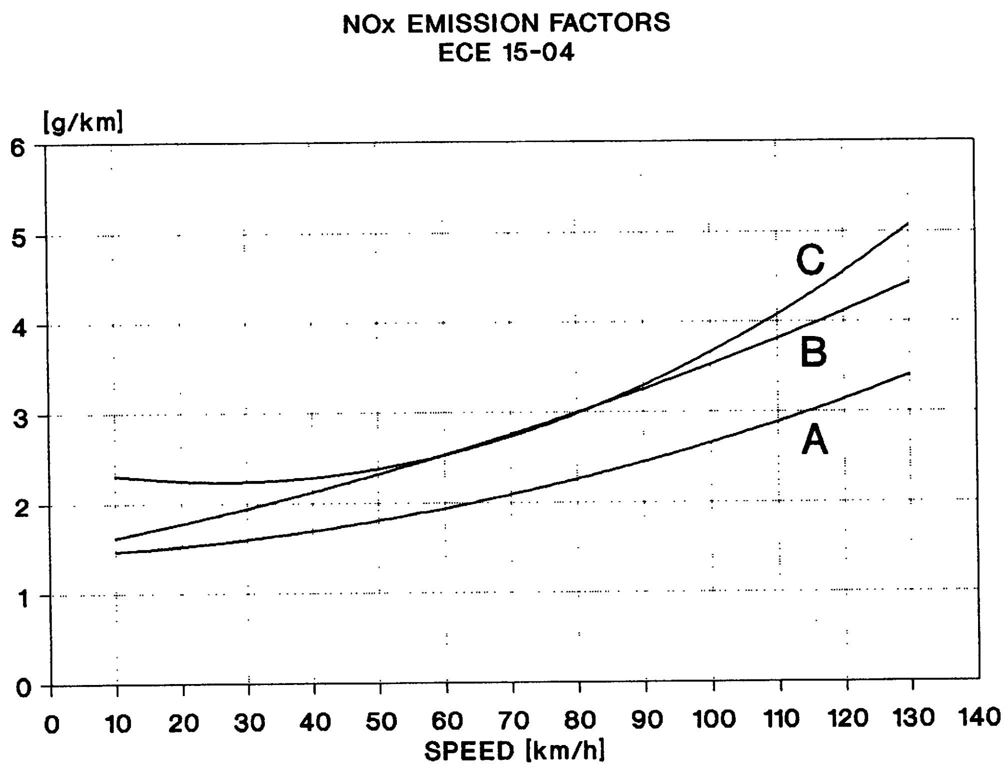

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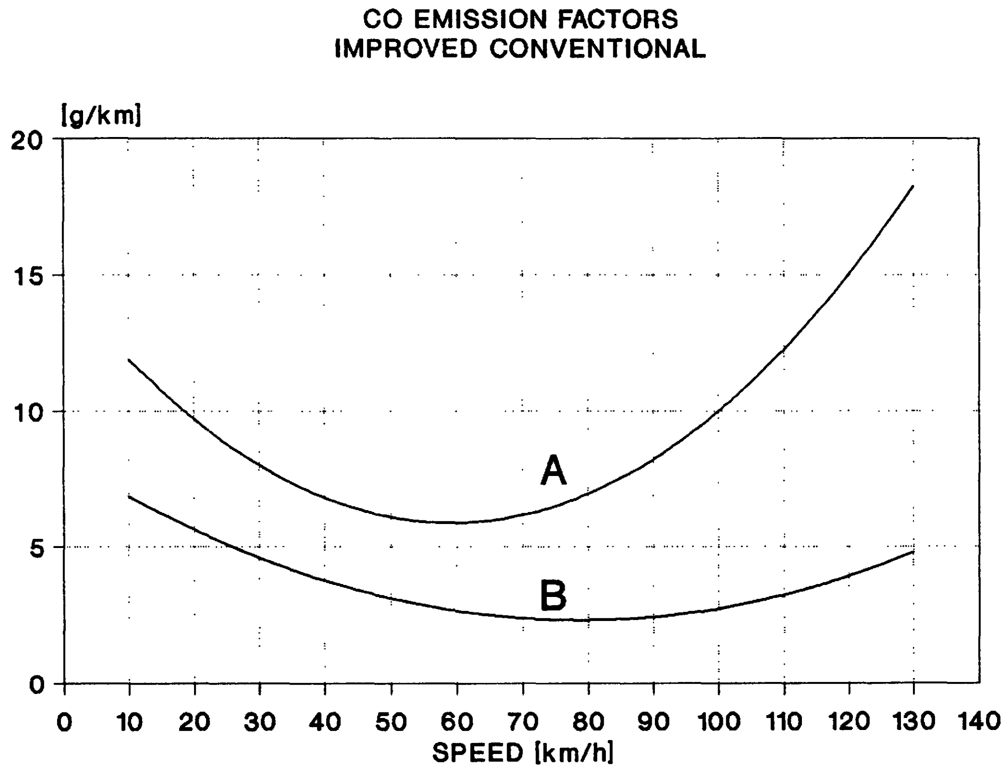

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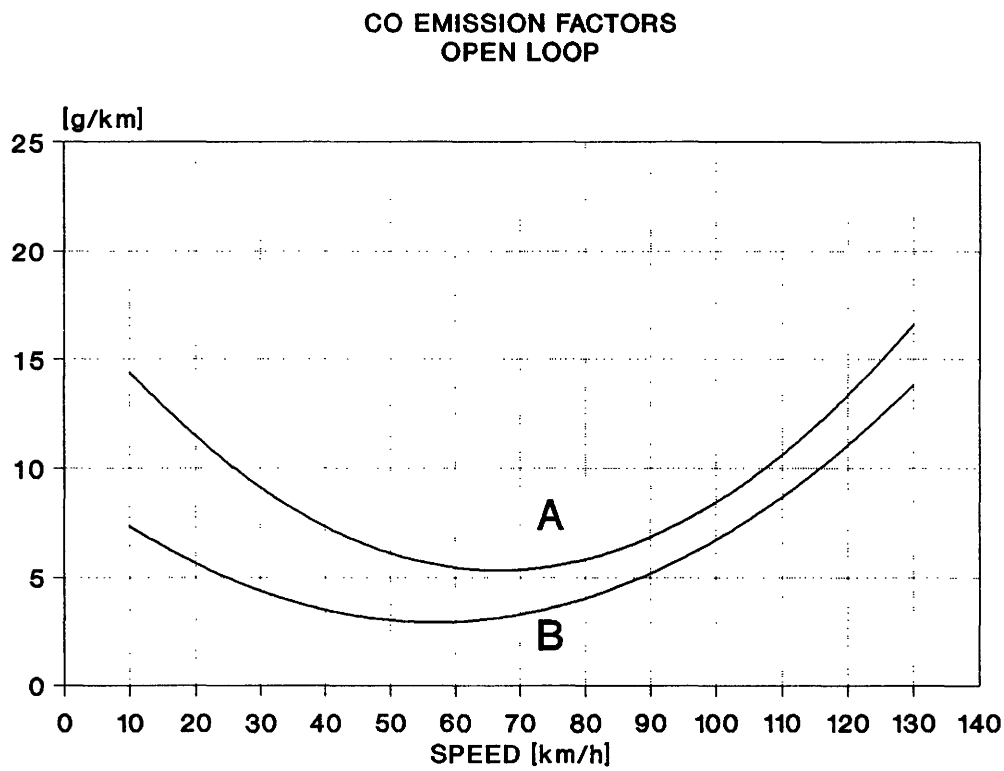

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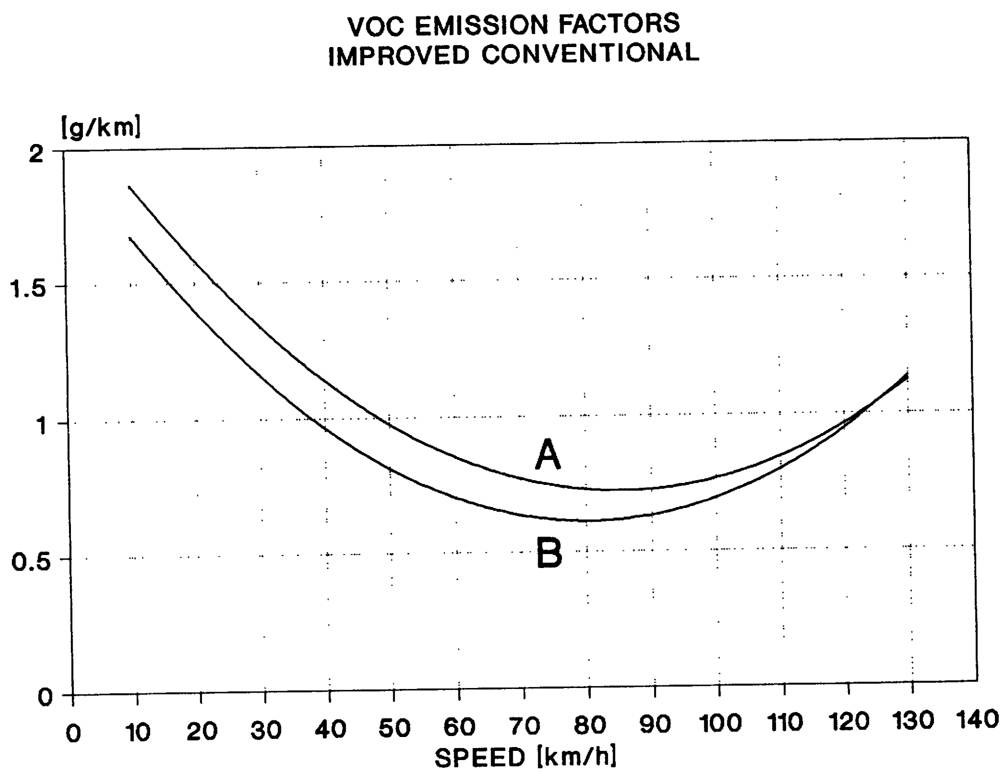

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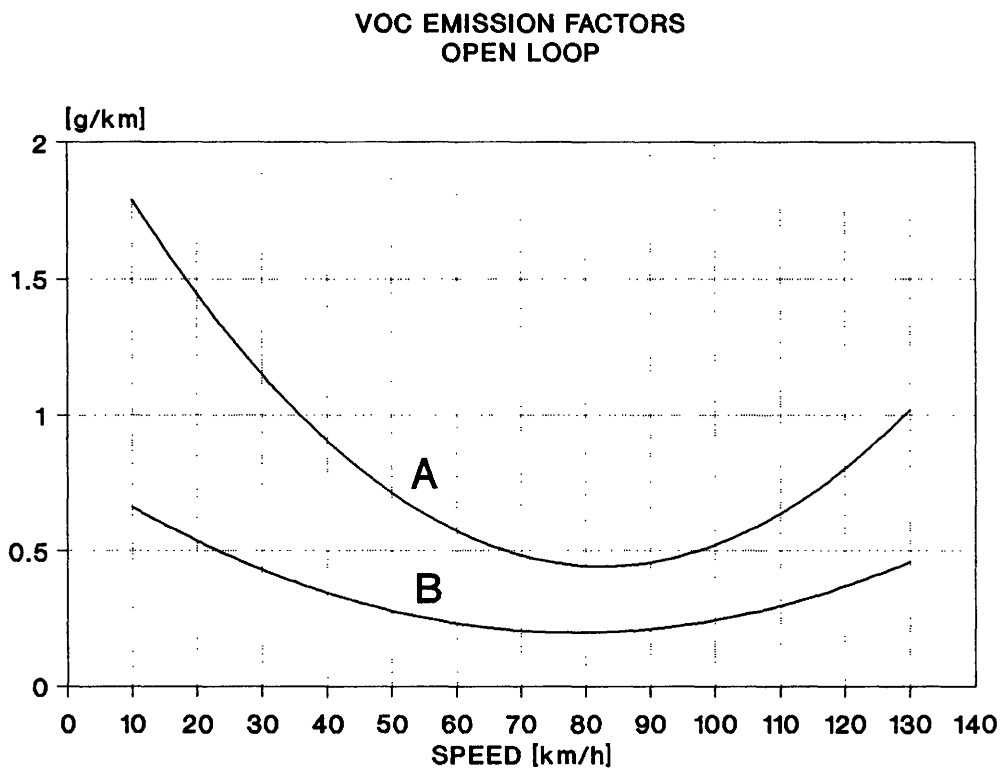

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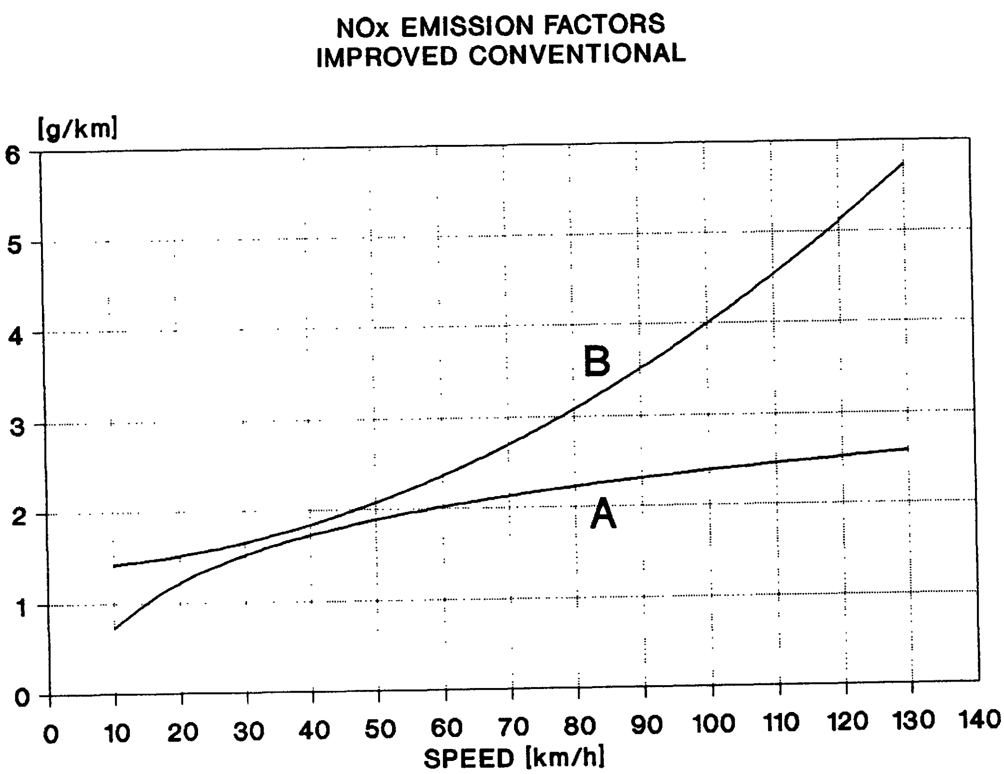


Figure VI.1.1-19: Speed-Dependent NOx Emission Factors of Gasoline Vehicles <2.5 t with a Cylinder Capacity of <1.4 l (A) and 1.4 - 2.0 l (B) for the Sub-Category "Open Loop"

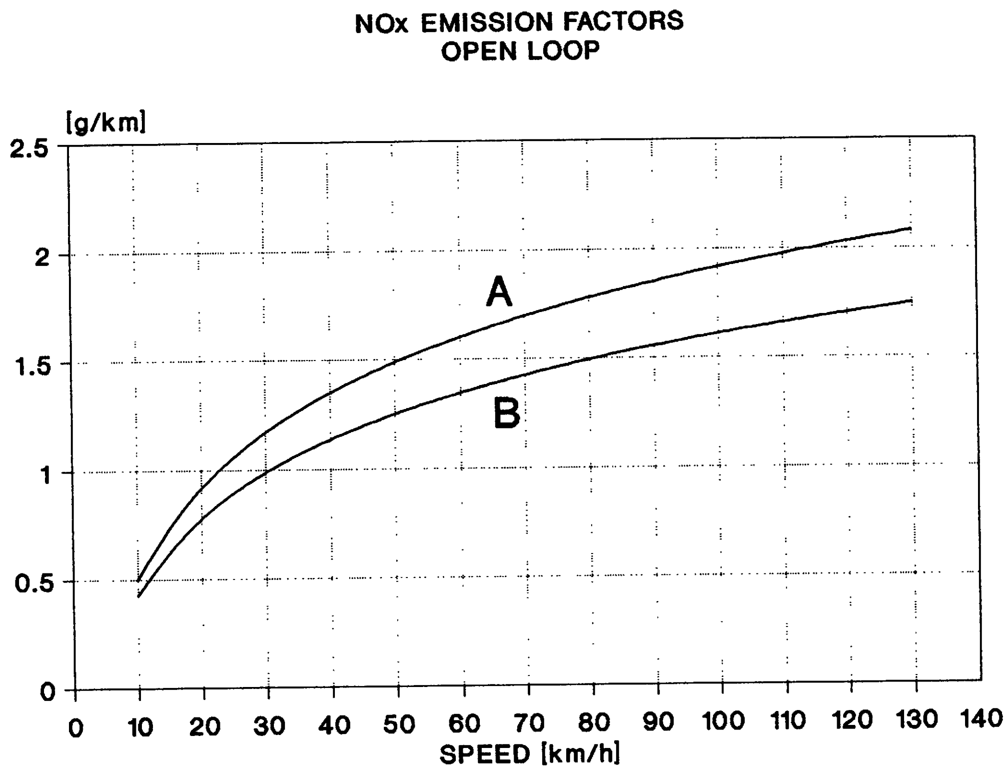


Figure VI.1.1-20: Speed-Dependent CO Emission Factors of Gasoline Vehicles <2.5t irrespective of Cylinder Capacity for the Sub-Category "Closed Loop"

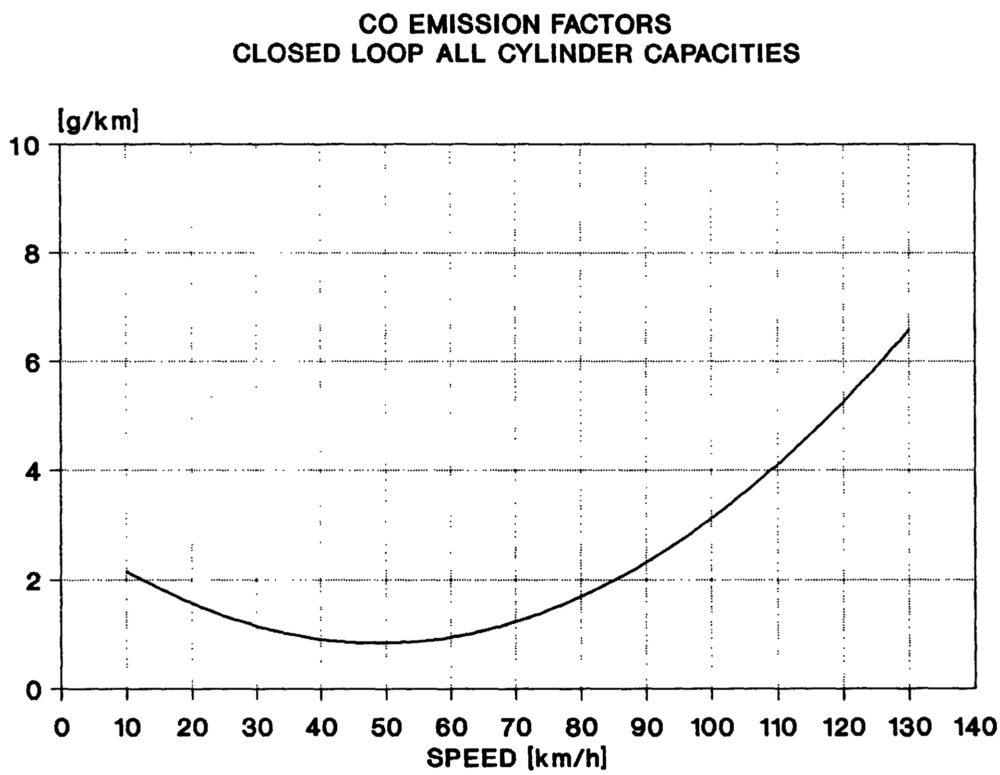


Figure VI.1.1-20 (cont.): Speed-Dependent VOC Emission Factors of Gasoline Vehicles <2.5t irrespective of Cylinder Capacity for the Sub-Category "Closed Loop"

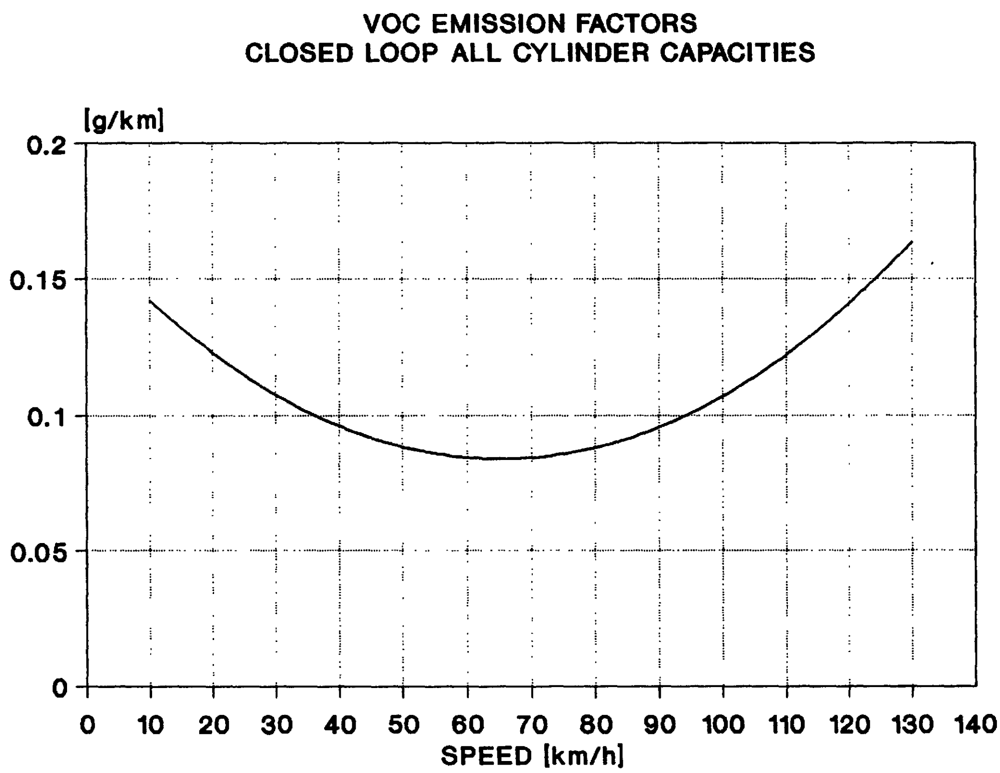


Figure VI.1.1-20 (cont.): Speed-Dependent NOx Emission Factors of Gasoline Vehicles <2.5t irrespective of Cylinder Capacity for the Sub-Category "Closed Loop"

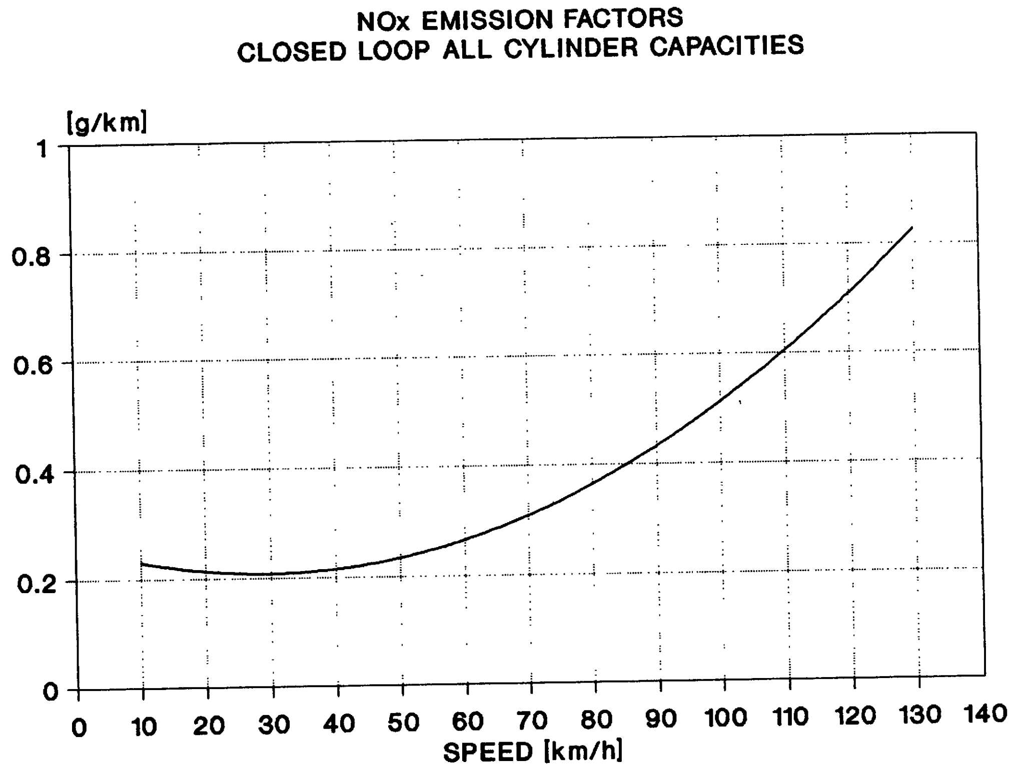
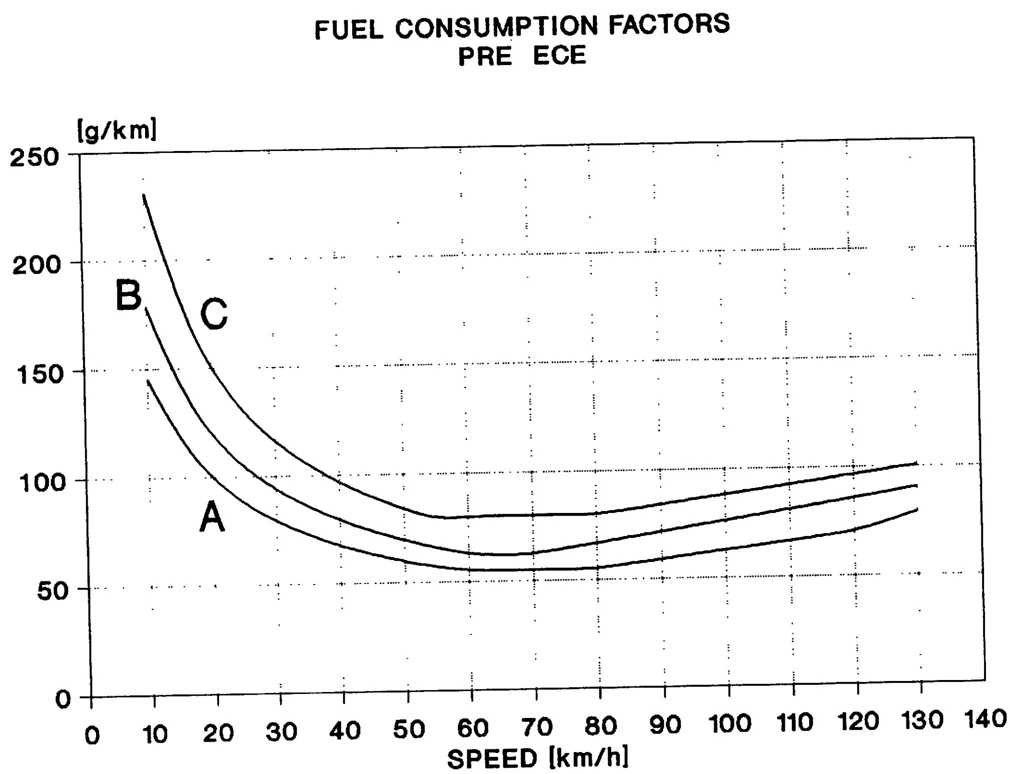


Figure VI.1.1-21: Speed-Dependent Fuel Consumption of Gasoline Vehicles <2.5 t for pre-ECE and Vehicles with Cylinder Capacity <1.4 l (A), 1.4 - 2 l (B) and >2 l (C)



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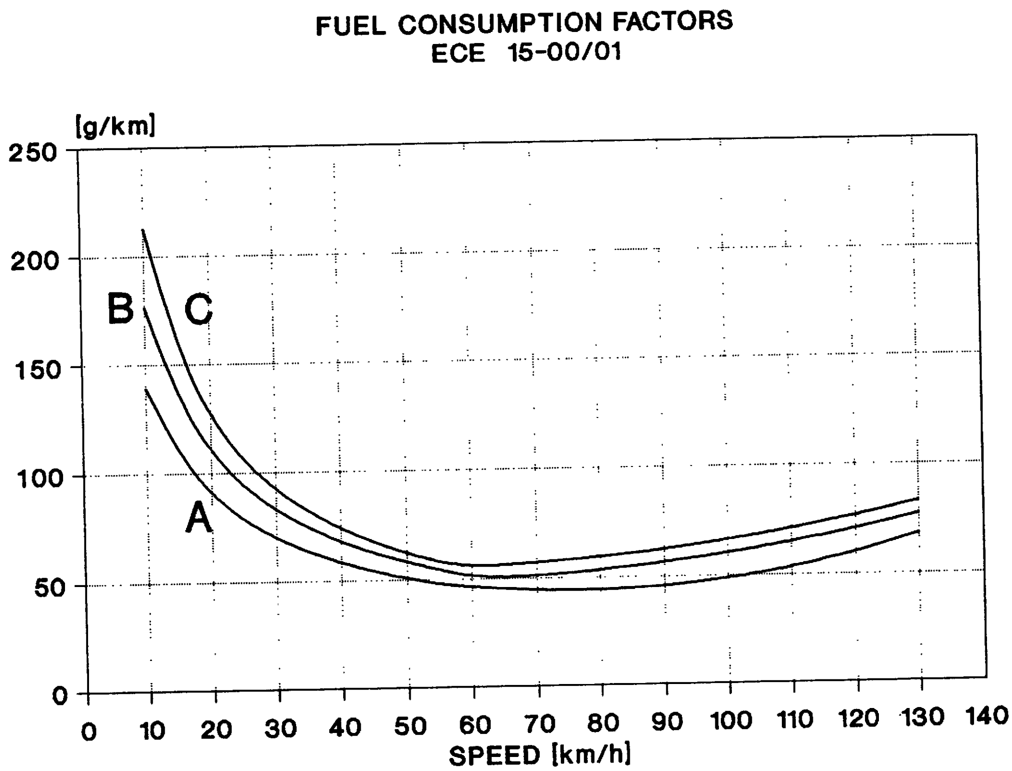

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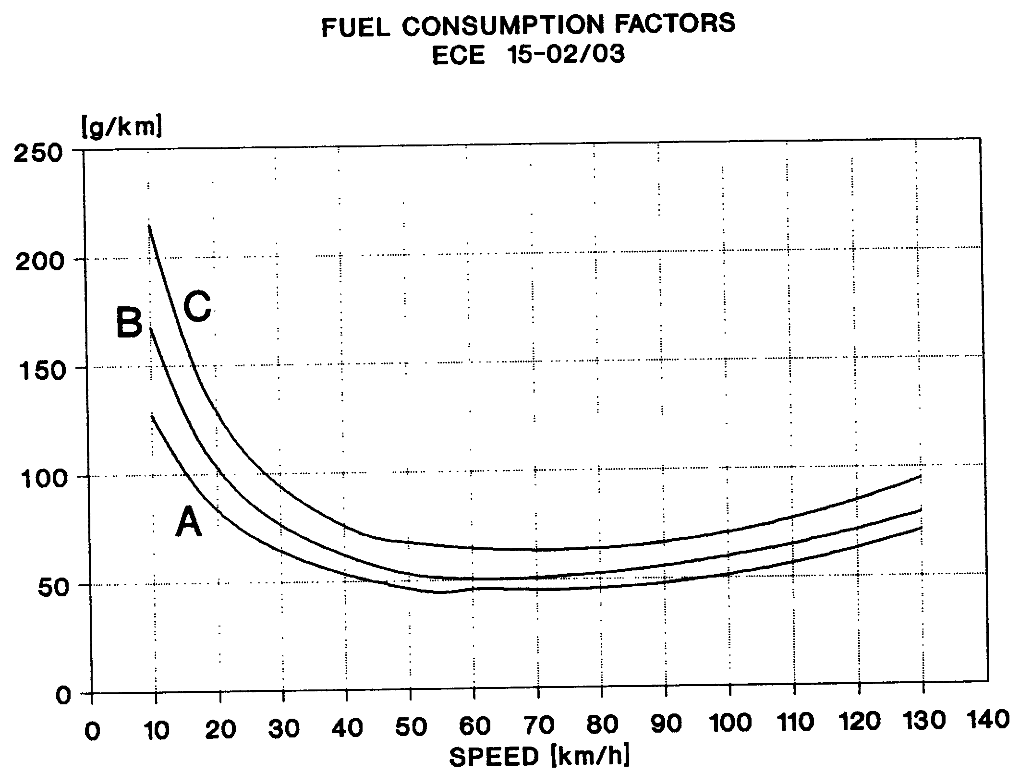

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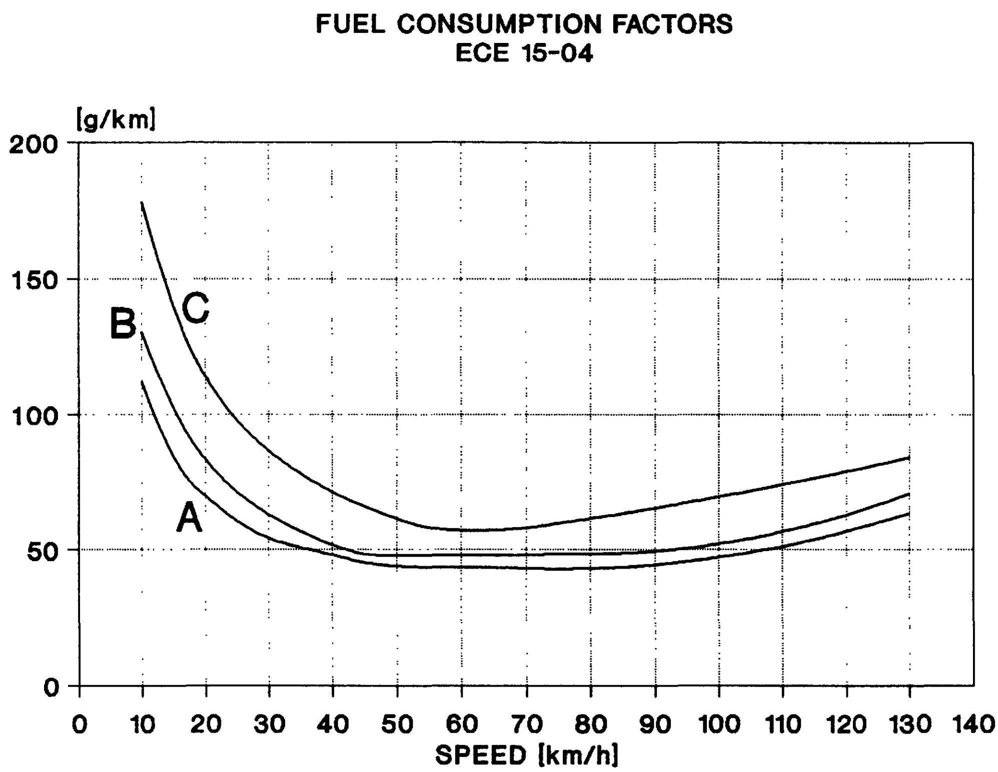

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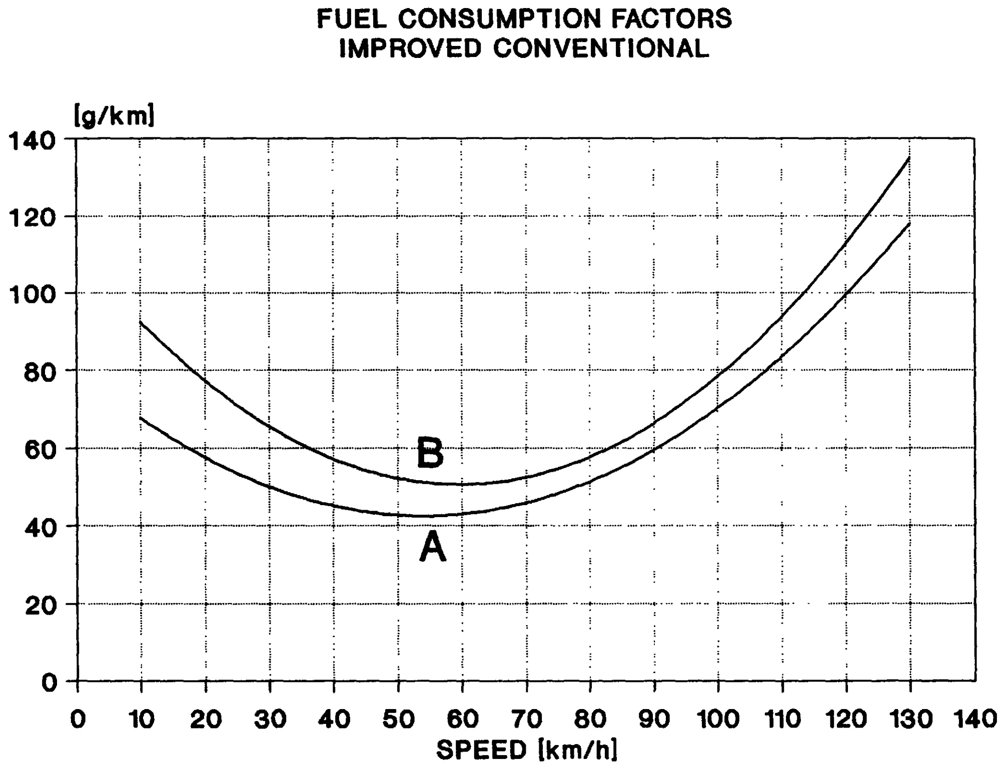

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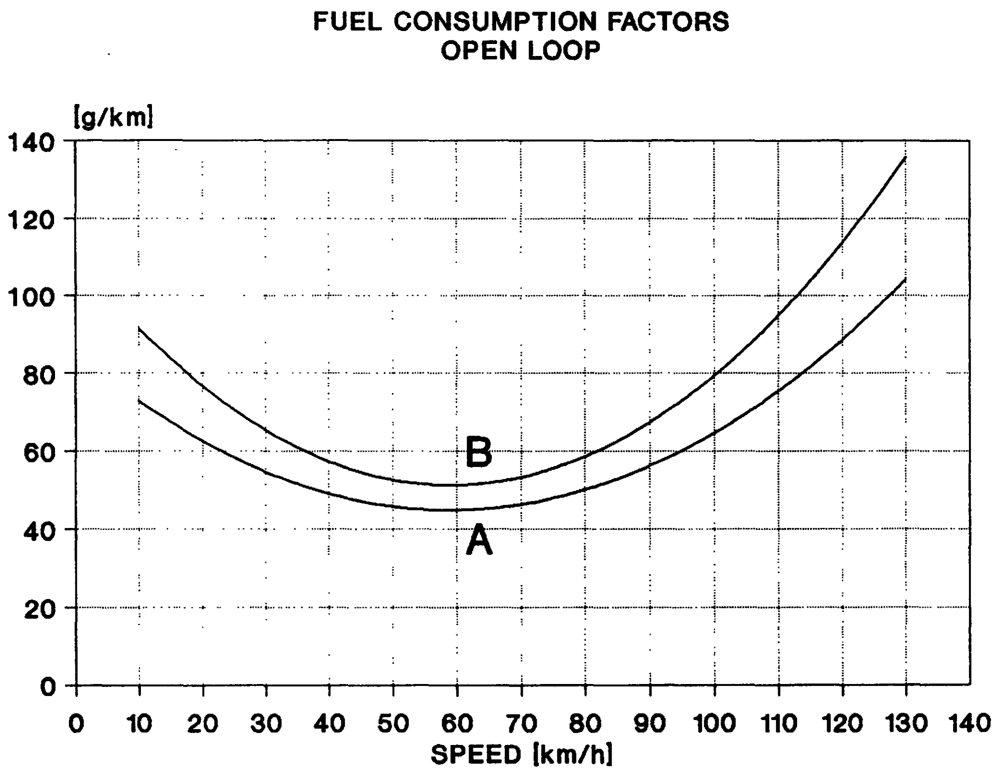

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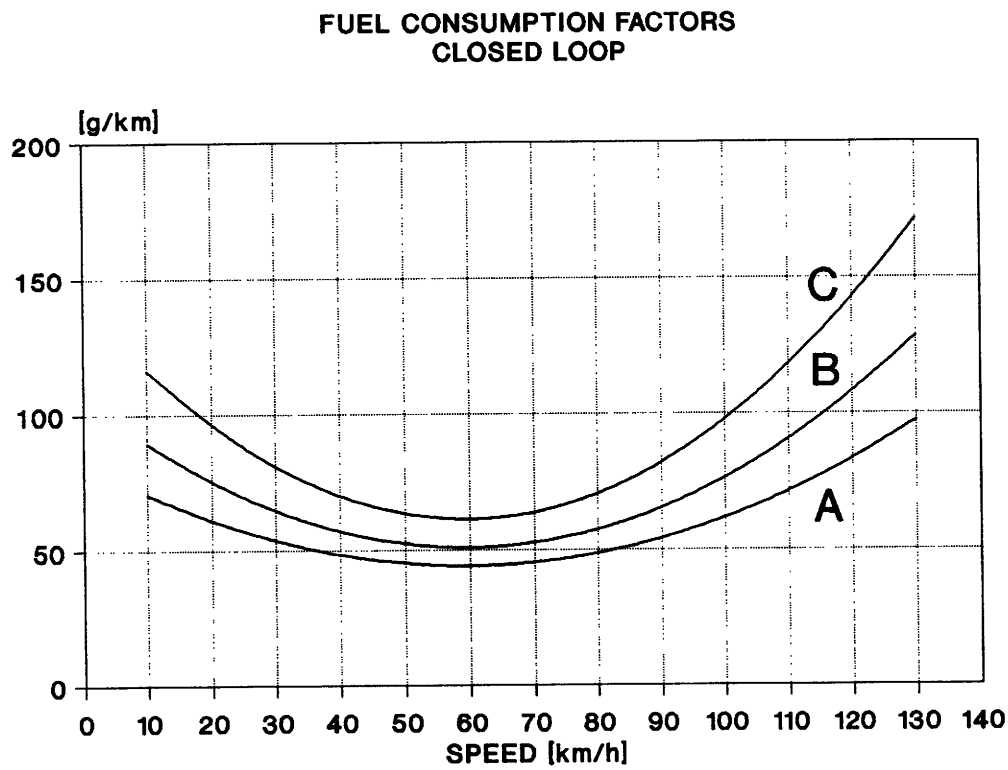

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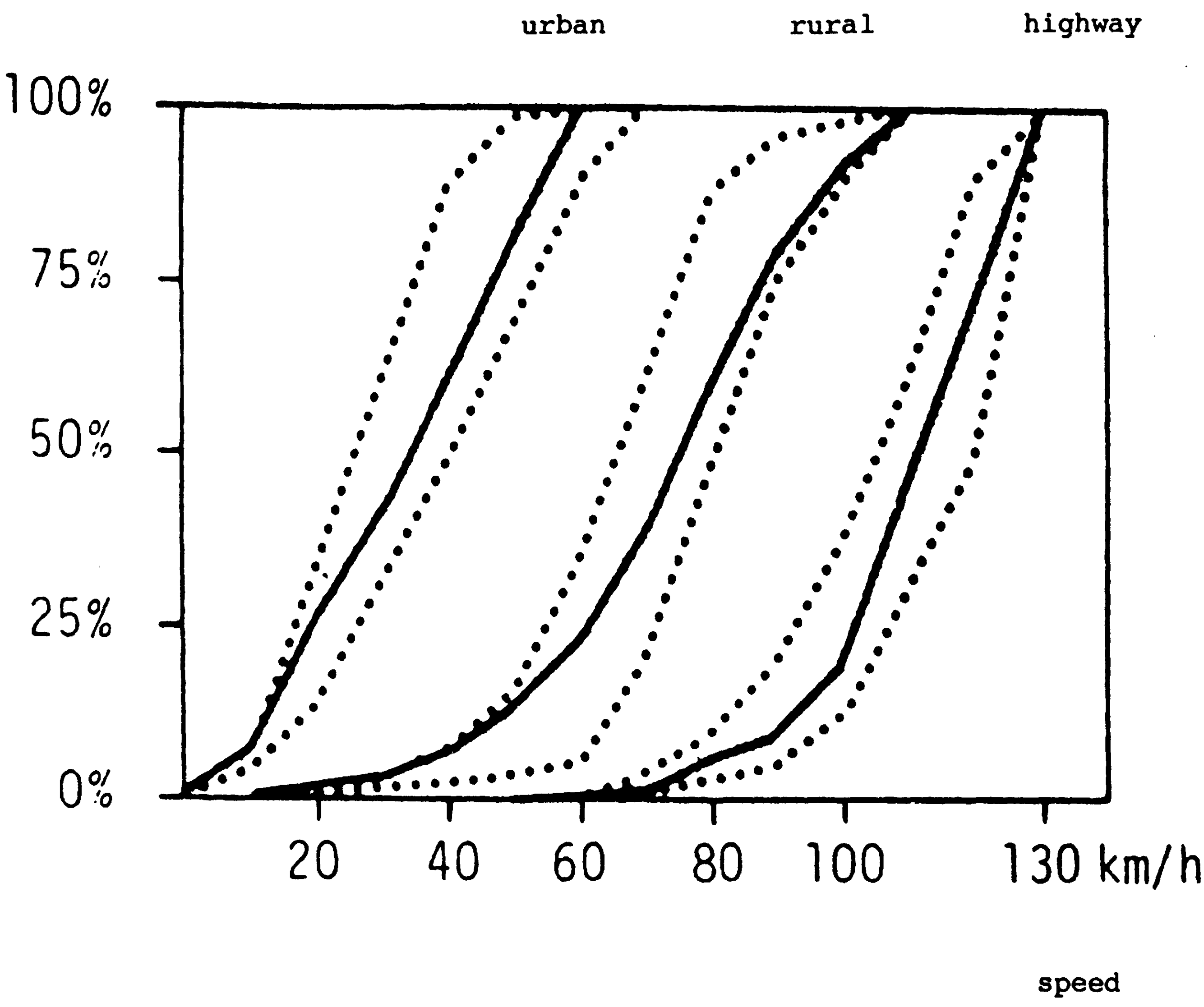


Figure VI.1.2-1: Speed-Dependent CO Emission Factors of Diesel Vehicles <2.5 t Irrespective of Cylinder Capacity

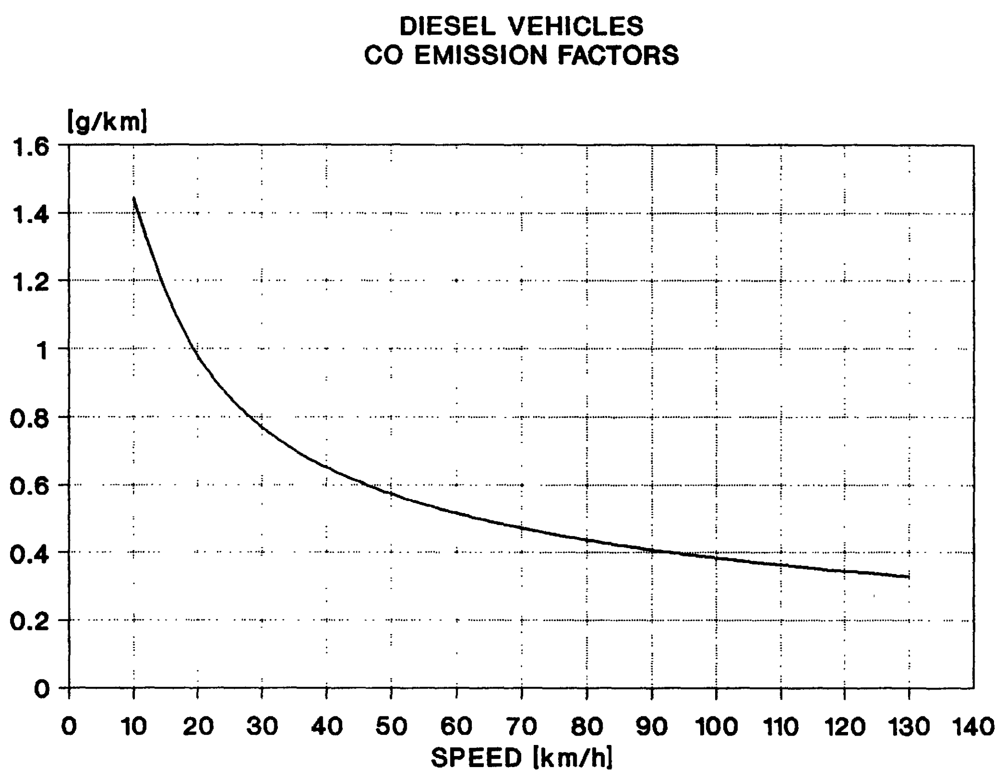
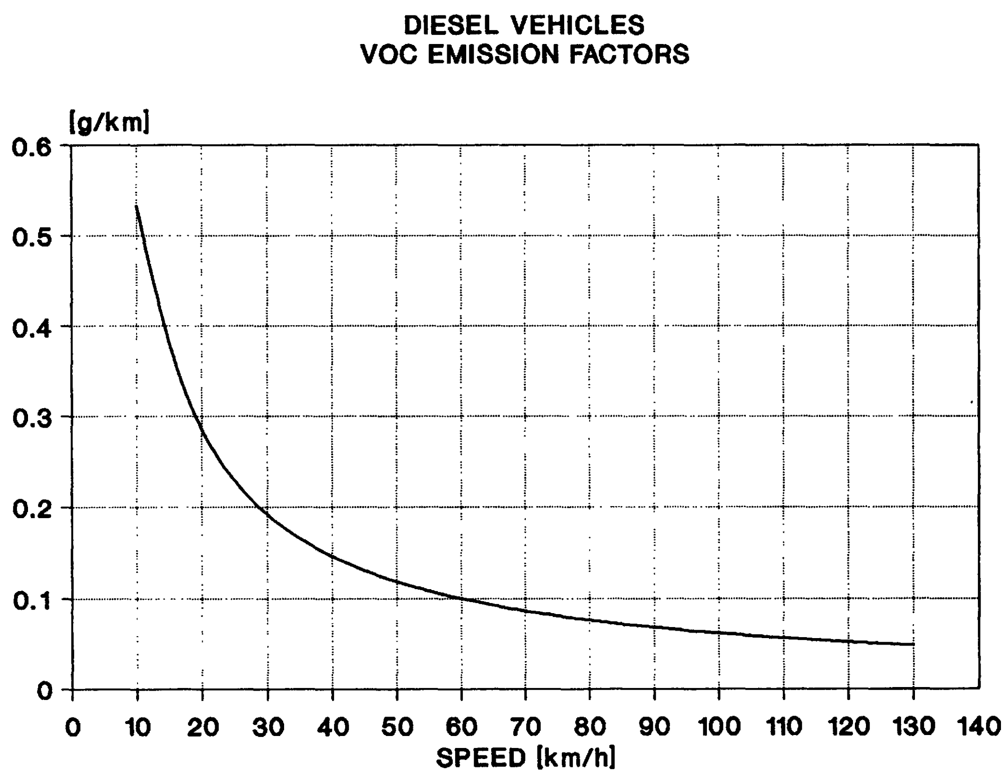


Figure VI.1.2-2: Speed-Dependent VOC Emission Factors of Diesel Vehicles <2.5 t Irrespective of Cylinder Capacity



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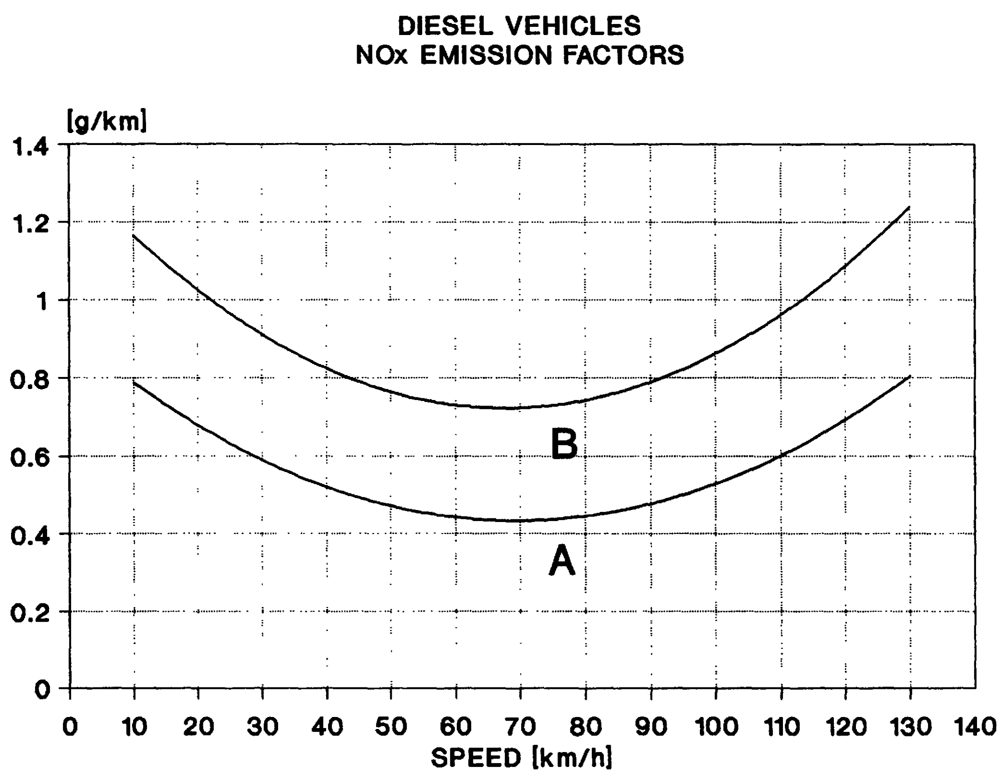


Figure VI.1.2-4: Speed-Dependent Particulate Emission Factors of Diesel Vehicles <2.5 t Irrespective of Cylinder Capacity

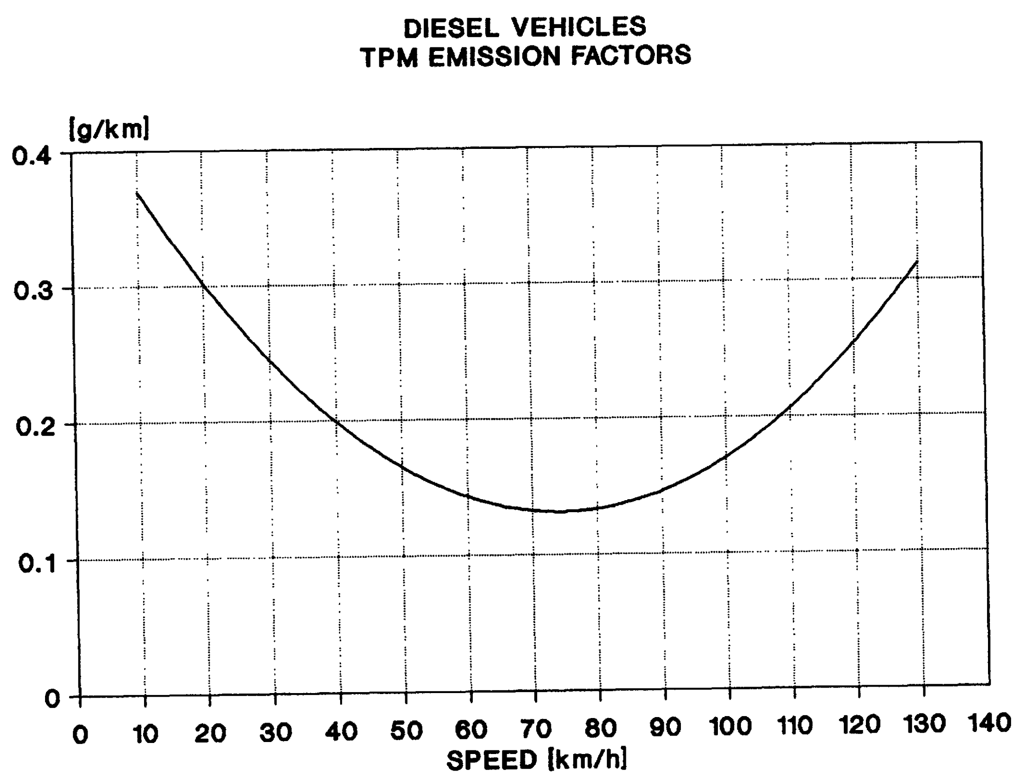


Figure VI.1.2-5: Speed-Dependent Fuel Consumption Factors of Diesel Vehicles <2.5 t

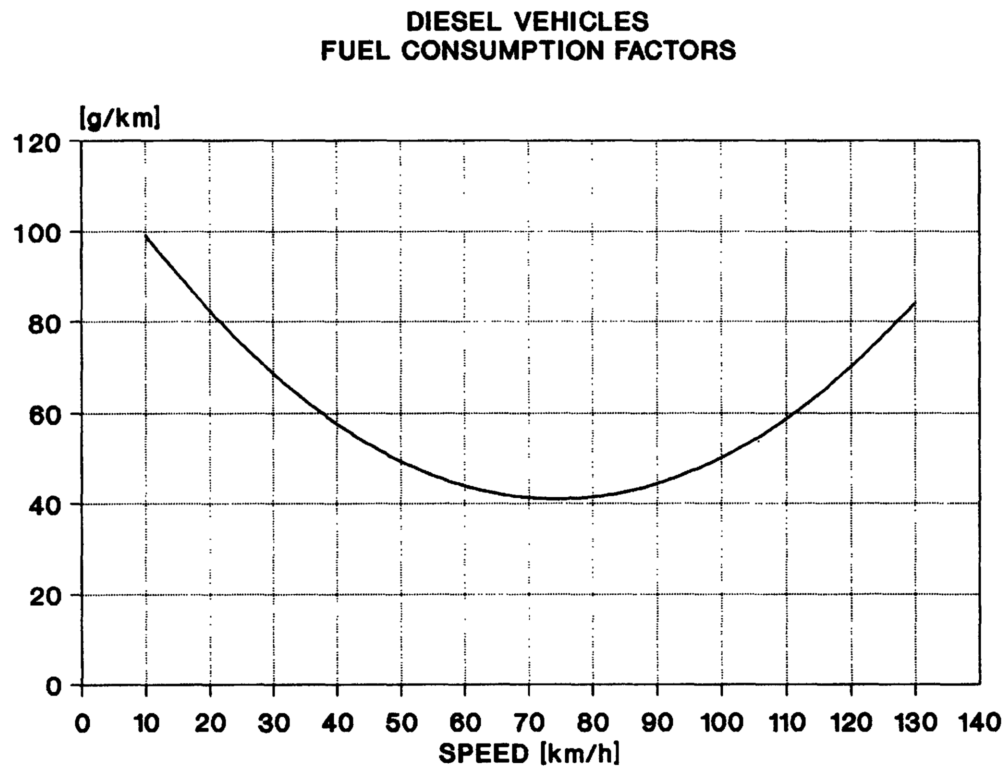


Figure VI.1.3-1: Speed-Dependent CO Emission Factors of LPG Vehicles <2.5 t Irrespective of Cylinder Capacity

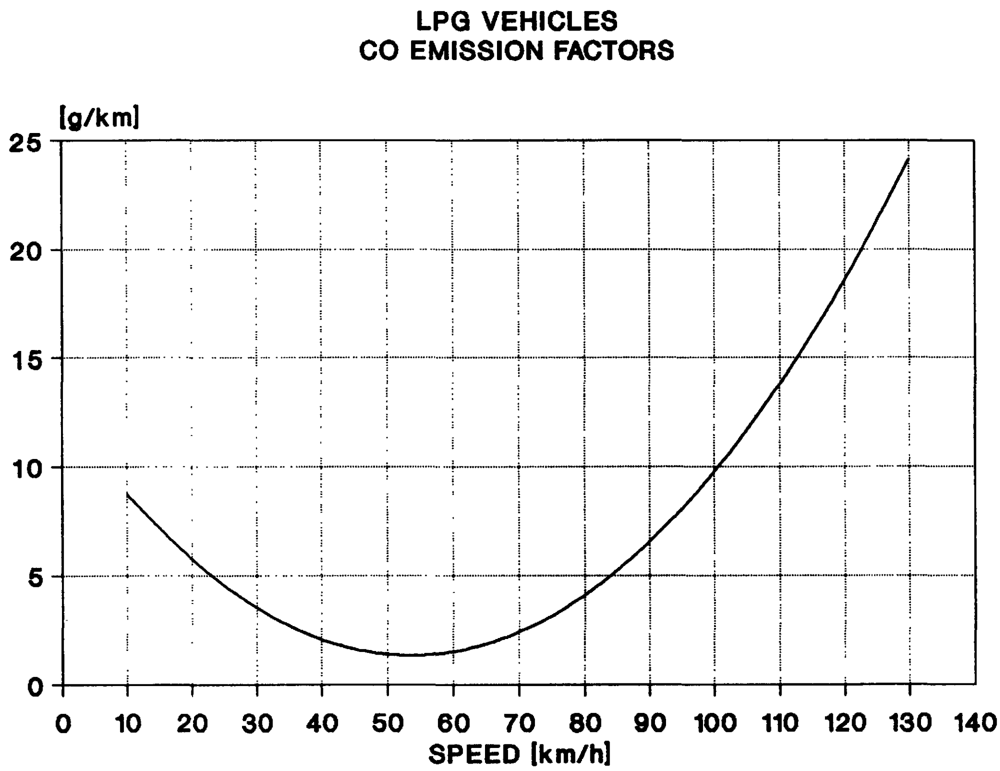


Figure VI.1.3-2: Speed-Dependent VOC Emission Factors of LPG Vehicles <2.5 t Irrespective of Cylinder Capacity

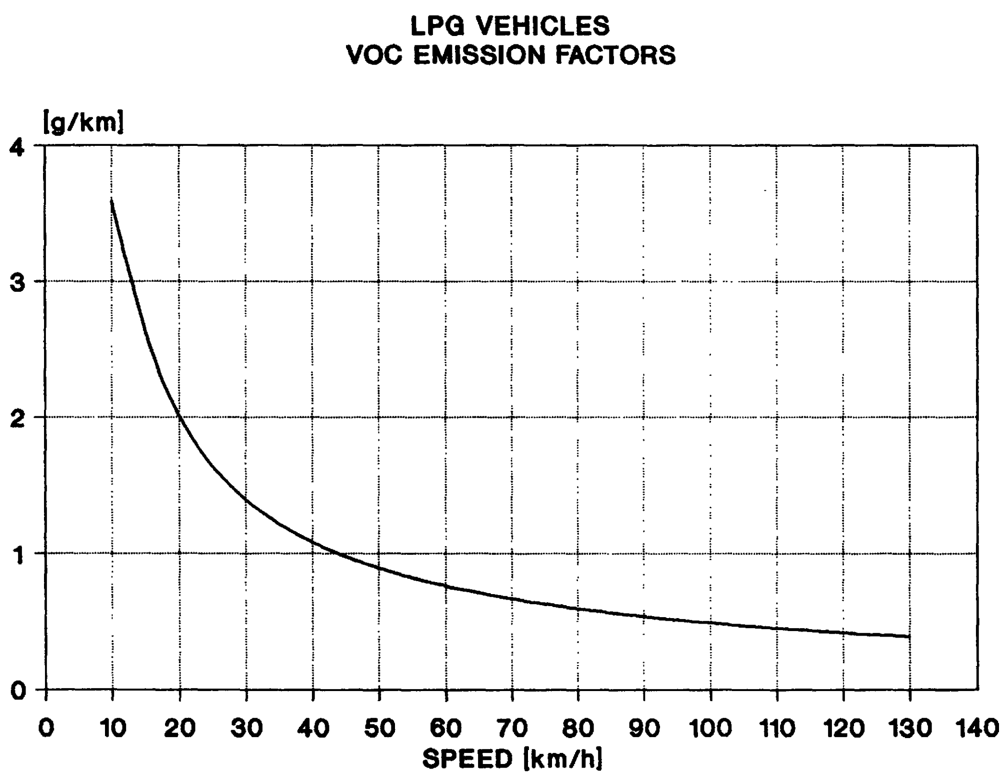
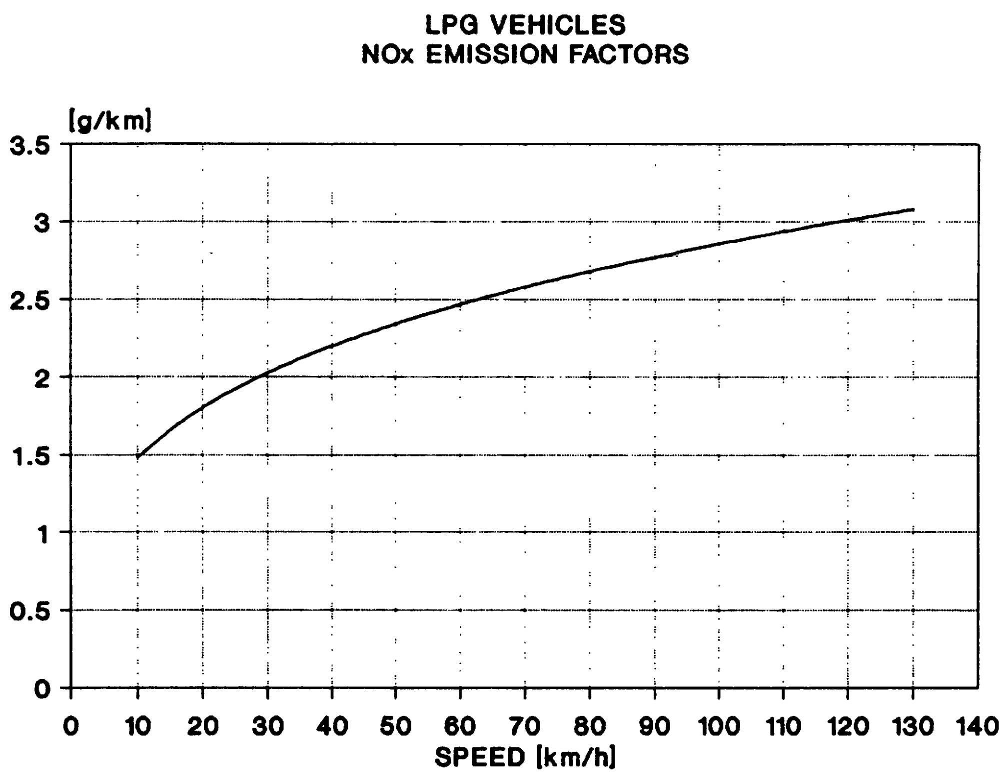


Figure VI.1.3-3: Speed-Dependent NOx Emission Factors of LPG Vehicles <2.5 t Irrespective of Cylinder Capacity



XI LIST OF ABBREVIATIONS

CC: Cylinder Capacity of the Engine

CH_4: Methane

CO: Carbon Monoxide

CO_2: Carbon Dioxide

FC: Fuel Consumption

GVW: Gross Vehicle Weight

NH_3: Ammonia

NMVOC: Non-Methane Volatile Organic Compounds

N_2O: Nitrous Oxide

NOx: Nitrogen Oxides (sum of NO and NO_2)

NUTS: Nomenclature of Territorial Units for Statistics (0 to III). According to the EC definition, NUTS 0 is the territory of individual Member States

Pb: Lead

RVP: Reid Vapour Pressure (standardised vapour pressure measurement, made at 38 °C, with a vapour:liquid ratio 4:1)

SOx: Sulphur Oxides

VOC: Volatile Organic Compounds

XII LIST OF SYMBOLS AND INDICES

XII.1 Symbols

a_j = number of gasoline vehicles of category j, operated in 1990

$a_{j,g}$ = number of vehicles of category j produced within the period of ECE legal conformity g or belonging to a distinct technology step (only vehicles <2.5 tonnes)

$b_{j,l}$ = total annual consumption of fuel of type l in [kg] by vehicles of category j operated in 1990

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

$d_{j,k}$ = share of annual mileage driven on road class k by vehicle category j

$e_{hot,1990;i,j,k}$ = average 1990 fleet representative baseline emission factor in [g/km] for the pollutant i, for the vehicle category j, operated on roads of type k with hot engines.

$e_{*,hot,1990;i,j,k}$ = average 1990 fleet representative baseline emission factor in [g/kg fuel] for the pollutant i, relevant for the vehicle category j, operated on roads of type k with hot engines.

e^{d} = mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly weighted temperature, temperature variation and fuel volatility (RVP)

$e^{s,hot}$ = mean emission factor for hot soak emissions

$e^{s,warm}$ = mean emission factor for cold and warm soak emissions

e^{fi} = mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection

$e^{r,hot}$ = average emission factor for hot running losses of gasoline powered vehicles

$e^{r,warm}$ = average emission factor for warm running losses of gasoline powered vehicles

e^{cold}/e^{hot} = ratio of emissions of cold to hot engines

$e_{hot;i,j,k,g}$ = emission factor in [g/km] for pollutant i, for the vehicle category j, operated on roads of type k with hot engines, valid for regulatory step g

$e(z)$ = mathematical equation (e.g. formula of best fit curve) of the speed dependency of $e_{hot,z;i,j,g}$

$f_k(z)$ = equation (e.g. formula of "best fit" curve) of the speed distribution which corresponds to the driving patterns of gasoline vehicles < 2.5 t on road classes "rural", "urban" and "highway"

$g_{j,k,l}$ = share of annual consumption of fuel of type 1 used by vehicles of category j, driven on road type k

h_j = number of vehicles of category j

$k_{s,e}$ = weight related sulphur content of fuel of type l in [kg/kg]

k_{Pb} = weight related lead content of gasoline in [kg/kg]

l_{trip} = average trip length

m_j = total annual mileage in [km] of vehicle category j

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k

p = fraction of trips, finished with hot engine (depending on the average monthly ambient temperature)

q = fraction of gasoline powered vehicles equipped with fuel injection

$r_{H/C}$ = ratio of hydrogen to carbon atoms in the fuel

$s_{j,g}$ = share of vehicles of category j of total national fleet, belonging to a period of legal conformity g (only applicable for gasoline vehicles < 2.5 t)

t_a = monthly mean ambient temperature in [°C]

$t_{a,min}$ = monthly mean minimum ambient temperature in [°C]

$t_{a,rise}$ = monthly mean of the daily ambient temperature rise in [°C]

v_j = average annual mileage driven by each vehicle of category j

w = fraction of trips, finished with cold or warm engine

x = mean number of trips of a vehicle per day, average over the year

y = total number of trips of a vehicle per day

z = the speed of gasoline vehicles <2.5 t on road classes "rural", "urban" and "highway"

β_j	=	fraction of mileage driven with cold engines
$E_{hot;i,j,k}$	=	emissions of the pollutant i in [g] caused in the reference year 1990 by vehicles of category j driven on roads of type k with hot engines
$E_{cold;i,j}$	=	emissions of the pollutant i due to cold starts in urban areas, caused by vehicles of category j
$E_{eva;VOC,j}$	=	VOC emissions due to evaporative losses, caused by vehicles of category j under urban driving conditions
O_l	=	total annual consumption of fuel [kg] of type l
R	=	hot and warm running losses
S^c	=	average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor
S^{fi}	=	average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection
V	=	vehicle speed in [km/h]

XII.2 Indices

g = indicator of regulatory situation applicable to vehicle ECE regulation steps 0 - 4 or earlier (1 - 6, only relevant for gasoline powered vehicles <2.5 t) or technology steps

i (pollutants) = 1 - 10 for the pollutants covered

j (vehicles category) = 1 - 39 (or 34 if only on-road vehicles are considered) for the vehicle categories defined in the COPERT 90 nomenclature

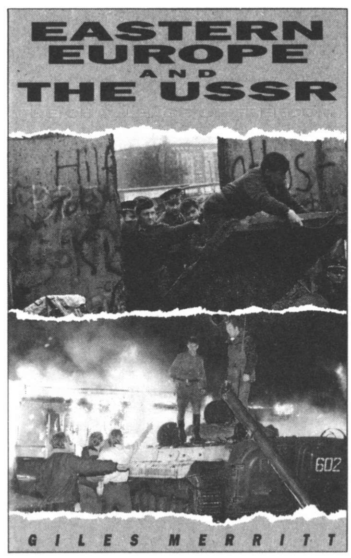
k (road classes) = 1 - 3 for "urban", "rural" and "highway" driving pattern

l = fuel type (1 - 3 for gasoline, diesel, LPG)

Eastern Europe and the USSR

THE CHALLENGE OF FREEDOM

GILES MERRITT



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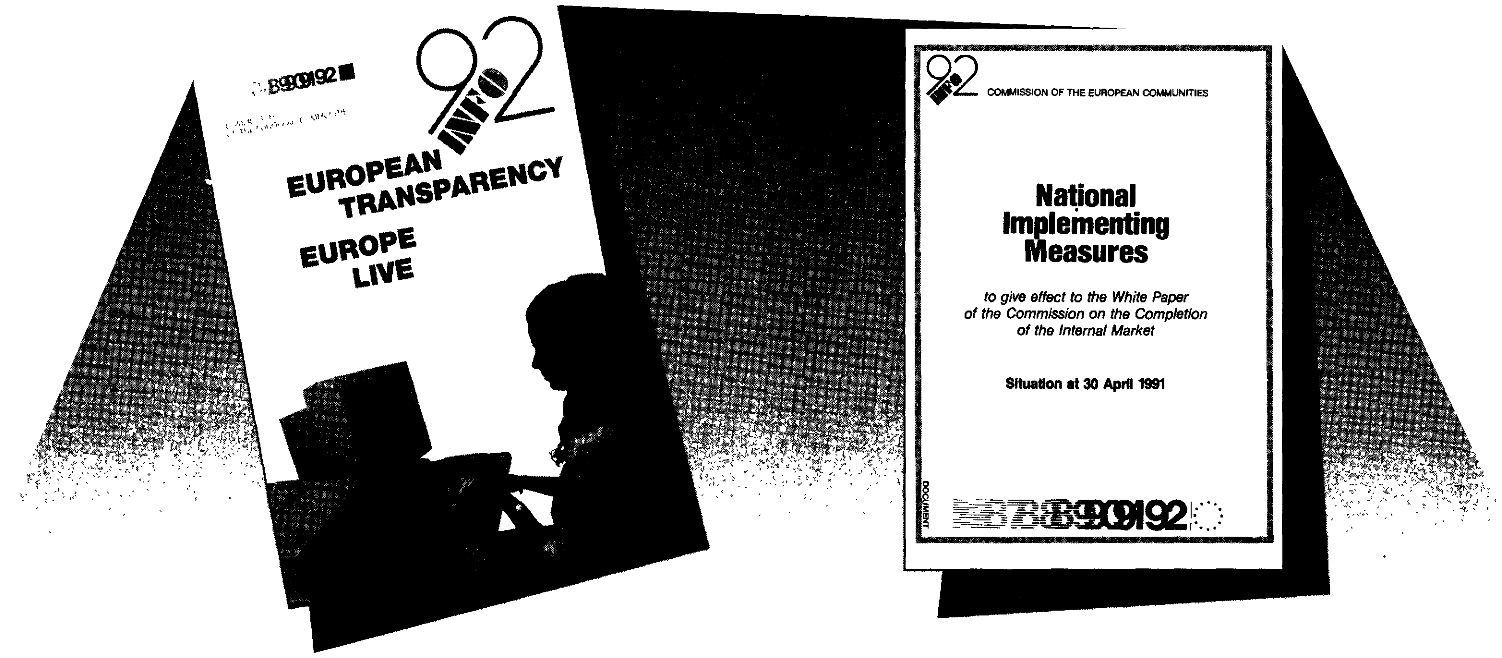

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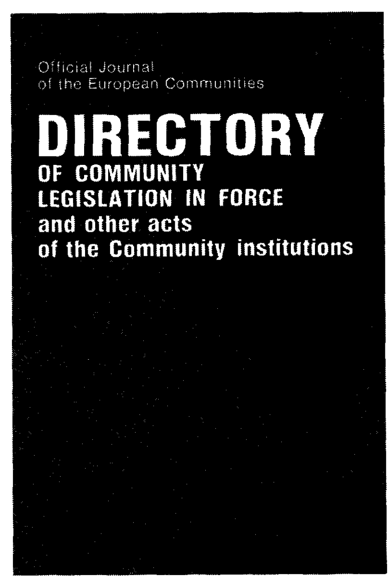

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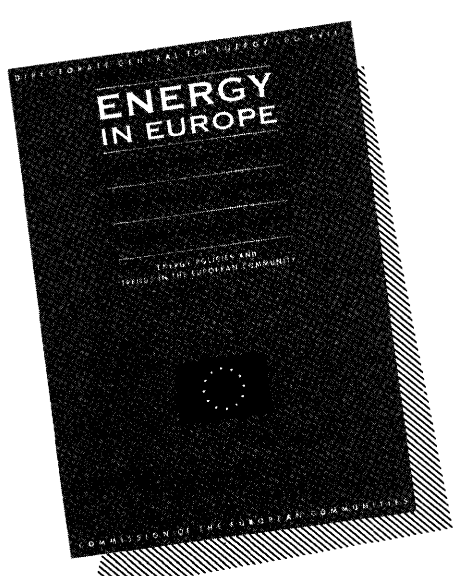

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