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January 1993

REGIONAL NETWORK ON CONTROL AND REGULATORY MEASURES CONCERNING MOTOR VEHICLE EMISSION

DP/RAS/89/057

ASIA-PACIFIC REGION

Guidelines */

for In-use Motor Vehicle Inspection for Emission Control in the Asia-Pacific Region

Prepared for countries of the Asia-Pacific Region
by the United Nations Industrial Development Organization
acting as Executing Agency for the
United Nations Development Programme

Based on the work of S. Radzimirski UNIDO Consultant

Backstopping officer: H. Seidel
Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

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SUMMARY

Today, the Asia-Pacific region has probably the most rapid motor vehicle growth in the world. As a result, countries of the region are now starting to experience severe air pollution problems. To address vehicle emission problems, the regional cooperation is required. It should in lude, among others, the gradual harmonization of inspection procedures for in-use vehicle emission control. The present "Guidelines" specify terms of such a harmonization, emphasis being laid on common test methods, test equipment and emission limits for countries of the region.

Countries participating in the project differ very much in respect of conditions affecting the emission level, including the in-use vehicle inspection for emission control. Therefore, three options of emission requirements are specified for the initial phase of harmonization: for uncontrolled, reduced-emission and low-emission vehicles. The ultimate goal is, however, to have common standards specified for low-emission vehicles.

Inspections of in-use motor vehicles for emission control include:

- mandatory periodical inspection,
- random inspections/checks.

The inspection procedure comprises:

- checks of smoke level at free acceleration from engine low idle speed for diesel vehicles,
- checks of CO or CO and HC or CO, HC and air fuel ratio (depending on emission reduction option and vehicle category) for vehicles equipped with SI engines.

Moreover, visual checks of devices/systems affecting emissions are specified for both vehicle types.

In the region as a whole, the potential of in-use vehicle inspection with regard to emission reduction is not taken sufficient advantage of. It is possible to considerably reduce emissions by upgrading the standard of current vehicle inspection and by extending the inspection on further vehicle categories significantly contributing to total air pollution. This reduction can be achieved with lower costs of initial investment than other reduction options.On the average, it is also cost-neutral or even cost-efficient for vehicles owners.

In order to assist in harmonization of inspection procedures and upgrading the standard of inspection for in-use vehicle inspection control, it is recommended to set up a regional training and test center. Inventories of vehicle emission determined under actual conditions should be established for individual countries and the region as a whole.

"Expert Group Meeting on In-use Motor Vehicle Inspection for Emission Control in the Asia-Pacific Region" held in Seoul in October 1992 recommended to phase in the harmonization in lines with the present "Guidelines".

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Annex 4A. ISO Standard 3930-1976. Road vehicles - Carbon monoxide analyser equipment - Technical specifications.

Annex 4B. ISO Document ISO/TC22/SC5/WG6. Instrumentation for measurement of gaseous exhaust emissions, produced during inspections or maintenance tests.

Annex 5. ECE Regulation No. 24, Revision 2. E/ECE/TRANS 505. Rev.1/Add.23/Rev.2. Annex 8: Characteristics of opacimeters.

1. INTRODUCTION

The present "Guidelines for in-use motor vehicle inspection for emission control in the Asia-Pacific region" were prepared in the framework of UNDP/UNIDO project DP/RAS/89/057 "Regional network on control and regulatory measures concerning motor vehicle emission". The following countries of the region have declared their participation or interest in the project: People's Republic of China, Hong Kong, India, Indonesia, Iran, Republic of Korea, Malaysia, the Philippines, Singapore, Sri Lanka and Thailand.

The main objectives of the project are as follows:

- in a short term, to initiate, develop and promote the cooperation among participating countries in the area of motor vehicle emission control, to establish working contacts between organizations dealing with motor vehicle emission control in these countries and to set up the nucleus of the operational regional network which would develop recommendations for common standards and policy in the mentioned area,
- in a longer term, to introduce common standards for motor vehicle emission control at least for certain groups of countries within the region.

For this purpose, a series of guidelines for vehicle emission related issues requiring a common approach within the region will be prepared to assist the individual governments to address motor vehicle emission problems. These guidelines will take into account region -specific conditions which affect potential solutions of common problems such as vehicle design, vehicle population structure and density, road traffic, vehicle maintenance, economic situations, atmospheric conditions, current air quality etc.

At the "Expert Group Meeting on Control and Regulatory Measures Concerning Motor Vehicle Emission in the Asia-Pacific Region" held in Seoul from 21 to 24 August 1990 during the preparatory phase of the project the following issues to be dealt with by a common regional approach were identified:

- emissions standards for new vehicles,
- procedures for inspection of in-use vehicles,
- fuel quality standards,
- practical policies to improve the maintenance of vehicles.

Guidelines will be prepared for each of the above issues. They will be discussed and agreed upon at workshops arranged in the framework of the project.

The present "Guidelines" are the first in the series of four guidelines to be prepared under the project. They are devoted to the problem of in-use motor vehicle inspection for emission control. Their main objective is to lay down terms for the gradual harmonization of emission inspection procedures, in particular:

- common emission limits,
- common test methods,
- common equipment

for in-use motor vehicle emission control in the region.

The draft "Guidelines" were prepared by the UNIDO consultant on the basis of:

i) "Report of the expert group meeting on control and regulatory measures concerning motor vehicle emissions in the Asia-Pacific region [1]",

ii) results of his fact-finding missions to the region and comments of concerned organizations in visited countries to his suggestions and recommendations with regard to in-use motor vehicle inspection for emission control in the region,

iii) experience of countries conducting comprehensive and effective motor vehicle emission reduction programmes and practices being followed in these countries.

The draft "Guidelines" were distributed to the national focal points of all the aforementioned countries and presented at "Expert group meeting on in-use motor vehicle inspection for emission control in the Asia-Pacific region" held in Seoul in October 1992. This meeting reviewed in great detail the draft and recommended to introduce some amendments with regard to the form and content as well as to specified emission limits and test methods [15]. The meeting adopted the amended terms of "Guidelines" with regard to in-use motor vehicle inspection system and procedure for emission control, common test methods, emission limits and equipment. Amendments made and accepted by the meeting have been incorporated in the present, final version of "Guidelines". The meeting recommended to gradually harmonize control system, in particular test methods, equipment and emission limits for in-use motor vehicles in lines with the terms of the present "Guidelines".

2. SCOPE

The present "Guidelines" apply to technical inspections for emission control of in-use vehicles driven by internal combustion engines (hereinafter referred to as "motor vehicles"). They are concentrated on technical and organizational aspects of these inspections, emphasis being placed on test methods, emission limits and test equipment. In principle, the "Guidelines" do not concern policy measures as special, separate guidelines will be devoted to this issue.

3. CLASSIFICATION OF MOTOR VEHICLES

Country papers presented at the "Expert Group Meeting" in Seoul in August 1990 [1] and findings of the consultant's mission show that the definitions of individual motor vehicle categories are not identical in participating countries. Therefore, it is considered advisable, as the first step towards common policy and standards with regard to emissions, to adopt the common classification of motor vehicles.

For the purpose of "Guidelines" the whole vehicle population is divided into:

- categories with regard to design, size and application,
- groups with regard to emission level.

The splitting into categories is as follows:

- mopeds (engine displacement below 50 cc and maximum speed not exceeding 50 km/h),
- motorcycles,
- cars (up to 8 passenger seats),
- light duty vehicles (LDV) (maximum mass not exceeding 3500 kg),
- medium and heavy duty vehicles (M/HDV)(maximum mass exceeding 3500 kg),
- others.

With regard to their emission level, motor vehicles are divided into the following three groups:

- uncontrolled vehicles,
- reduced (medium) - emission vehicles,
- low - emission vehicles.

The first group includes:

- vehicles which have been registered before any emission standards for new vehicles and type certification were introduced (technically uncontrolled),
- vehicles which were first registered after such standards and certification had been introduced but according to regulations in force are exempted from compliance with emission standards.

The second group comprises vehicles in which special technical measures are used in the process of manufacturing in order to reduce emission level and which belong to types officially approved in individual countries either by own emission certification procedures or by recognition of emission conformity certificates issued in other countries. The reduced-emission group includes also vehicles which have been retrofitted with emission reducing devices.

Emission level of reduced-emission vehicles corresponds to that set for instance:

- for cars and LDV - in ECE Regulation 15/00 - 15/04 and Regulation 83/01 approval A,
- for M/HDV - in ECE Regulations 49/00 - 49/01 and 24/00 - 24/03,
- for mopeds - in ECE Regulation 47/00,
- for motorcycles - in ECE Regulation 40/00 - 40/03.

The group of low-emission vehicles comprises vehicles fitted with state of the art emission controls, e.g. three-way catalytic converters for cars, and complying with standards in force in the leading countries at the beginning of the nineties e.g. ECE

Regulation 83/01 (approval B and C), American and Japanese standards. These vehicles may be fitted with such controls when new or retrofitted. The low-emission vehicles are often referred to as "high-tech" vehicles.

The exact requirements with regard to emission level to be complied with by reduced-emission and low-emission vehicles will be specified in the guidelines for emission standards for new vehicles.

4. STATUS OF IN-USE VEHICLE INSPECTION FOR EMISSION CONTROL AROUND THE WORLD

4.1. General information

The emission level of in-use vehicles depends very much on routine maintenance which, in turn, is affected by such factors as vehicle reliability and durability, fuel and lubricant quality, operating conditions etc. A proper maintenance should ensure that the technical condition of vehicles and therefore their emissions will not deteriorate excessively in relation to those when they were new. To encourage and enforce a proper maintenance and use of vehicles many countries conducting motor vehicle emission control programmes have introduced inspections of in-use motor vehicles with regard to emissions. Experience has indicated that such inspections can bring about considerable reduction of emissions. They have demonstrated to lower emissions in three ways:

a) by detecting and bringing about the repair of vehicles which fail the tests as a result of excessive emissions levels,

b) by encouraging owners to take better care of their vehicles in order to avoid potential costs of repairing and penalties,

c) by deterring owners/drivers to temper antipollution devices and to misfuel their vehicles.

4.2. Inspection systems for in-use vehicles

In-use vehicle technical inspections with regard to emissions used in individual countries differ considerably in terms of such details as test procedures, limits, implementation and enforcement mechanism, frequency etc. Technical inspections may be conducted as:

a) mandatory periodical inspections,

b) random on-road checks:
  - road-side pull-overs with subsequent emission tests on the spot,
  - on-road spotting and/or road-side pull-overs with emission tests conducted in inspection stations.

Periodical inspections may:
- be combined with safety inspections i.e. be part of overall

roadworthiness inspection (in the majority of countries),
- form separate, independent inspections (e.g. in India, in some American programmes).

The following main models for implementing in-use vehicle periodical inspections have evolved:

a) decentralized model (often called garage system) in which the inspection is carried out by local filling stations or service workshops licensed by the competent authority, either central or local depending on local-state relationships (some American, e.g. Californian, programmes, Germany, India, Poland, Hungary),

b) centralized models:
   - state-owned stations especially installed for this purpose (some American programmes, Thailand, Malaysia),
   - centralized stations run by private contractors in which the total expense of setting up and running the facilities is paid off by fees charged to vehicle owners (Sweden, Singapore).

In the decentralized model, the test and repair functions are often combined. On the other hand the centralized model usually separates these two functions.

The experience collected up till now seems to show that the centralized system in which emission inspections are separated from safety inspections and the test functions are separated from repair functions is more effective than others. American EPA has lately concluded that the efficiency of "test only" system is double as compared to "test and repair" one.

It is practically not possible to check all, or at least a significant percentage of, in-use vehicles for full compliance with the emission standards used for type approval or conformity of production verification as the complete compliance tests tend to be too complex, time consuming and expensive. In addition, they impose very hard conditions with regard to equipment and manpower. Therefore short simplified tests have been developed to check the technical conditions of in-use vehicles. These tests are different for petrol - and diesel vehicles. It is worth noting that all currently used short inspection tests are "concentration" but not "mass emissions" tests.

Test procedures for in-use vehicle inspection with regard to emissions vary from country to country. The applicability of the procedure is usually a compromise between:

- efficiency characterized for instance by excess emission identification rate, failure rate, emission rate etc.,
- technical aspects e.g. repeatability, reproducibility, simplicity, risk of damage to the vehicle,
- economic considerations e.g. costs of investment for test equipment, personnel cost depending on the number of personnel required, amount of the time for the whole test etc.,
- legal aspects e.g. liability of the test personnel in the

case of damage to the vehicle.

It may be noted that inspection programmes conducted in developped countries, unlike those in countries participating in the project, have been concentrated on vehicles equipped with SI engines , in particular cars and LDV. Other motor vehicle categories, particularly mopeds and motorcycles are often exempted from emission inspection. Diesel vehicle periodical inspections for emission control are still not conducted in some developed countries.

4.3. Test procedures

4.3.1. Test procedures for vehicles equipped with SI engines

The basic component of all currently used test procedures for in-use vehicles equipped with SI engines is a check of carbon monoxide (CO) concentration at low idle engine speed. It has been selected for the following reasons:

a) CO emissions at idle contribute very much to air pollution, in particular in urban traffic when vehicles wait at light signals at intersections,
b) tailoring of carburetor or injection system at idle, characterized by CO concentration, affects average mass emissions of all regulated pollutants and average fuel consumption, in particular in urban driving,
c) CO concentration at idle is a good indicator of technical conditions of some (but not all) engine systems/components affecting the emissions.

In order to improve the efficiency of inspections their scope is extended by:

a) checks of HC concentrations at idle,
b) checks not only at low idle but also at raised idle speed.

Background information on idle emissions from vehicles equipped with SI engines e.g. the effect of operating variables, in particular air fuel mixture, on engine idle operation, effect of idle adjustment on average emissions, methods of idle adjustment, effect of engine malfunctions, idle test method are presented in great detail in Annex 2. This Annex gives also examples of emission standards for in-use vehicles in some countries. As the majority of vehicles equipped with SI engines in the region are uncontrolled - and reduced emission vehicles, the emphasis is laid on these two groups.

In order to further increase the efficiency of inspections, checks of pollutant concentrations at idle are in some programmes complemented by:

a) checks of some other operating variables which affect emission level,
b) checks (visual or functional) of some vehicle systems and anti-pollution devices.

Operating variables checked during inspections may include:
- engine idle speed (parallely with CO/HC measurement),
- spark timing at idle,
- ignition breaker dwell at idle,
- air fuel equivalence ratio (for low-emission vehicles).

The checking of vehicle systems/anti-pollution devices may comprise:
- exhaust system,
- inlet system (e.g. air filters),
- ignition system (e.g. spark plugs),
- exhaust gas recirculation system,
- "pulse air" valves, air pumps, dashpots, throttle positioners etc.,
- crankcase ventilation system,
- evaporative control devices,
- catalytic converters and λ-probes.

Experience has shown that the inspection programmes based on the above presented test procedure are efficient in achieving CO and HC emission reductions. In addition, they reduce fuel consumption at least in the case of uncontrolled and reduced-emission vehicles. Their effect on NO_x is usually marginal.

The following (achieved or expected) reductions have been reported:
- some current American basic I/M programmes: 16% CO, 5% HC, 3.5% fuel consumption,
- Germany: 20% CO, 10% HC, 5% fuel consumption,
- Holland: 25% CO, 15% HC,
- proposed enhanced American I/M programmes: 25-30% CO, 10-25% HC, 8-12% fuel consumption (depending on options).

The fact that the fuel economy improves makes the emission inspection programmes cost-neutral or even cost-advantageous for vehicle owners as increased expenses for maintenance are usually made up for by a decrease in fuel costs.

4.3.2. Test procedures for diesel vehicles

The main component of all test procedures for diesel vehicles is the smoke check. It is used in short inspection tests for the following reasons:

a) smoke measurement is relatively simple as compared with that of other diesel engine pollutants (particulates, oxides of nitrogen etc.),
b) smoke is a very good indicator of technical conditions of diesel engines,
c) smoke level coincides well with particulate emissions,
d) smoke obscures visibility and therefore its limitation is necessary from the point of view of traffic safety,
e) smoke intensity affects fuel economy.

Annex 3 comprises the description of smoke test methods, smokemeters, effect of operating variables on smoke intensity; dependance between smoke level and other pollutant emissions. Moreover, it gives information on smoke standards in force in individual countries.

The main test methods which come into account for in-use vehicle inspection are as follows:

a) free acceleration method:
   - from low idle speed (Belgium, France, Hungary, draft of ECE Directive, California, countries of the region),
   - from raised idle speed (Switzerland, Austria, Hungary),

b) steady single-speed method (Sweden, ISO Standard 7645, India, Thailand),

c) lug-down method (not applied, ISO Standard 7644).

The method a) is most applicable as it is the cheapest and simplest. The methods b) and c) are more expensive and time consuming. They impose, in particular c), harder conditions to equipment and manpower. However, they offer better correlation with tests used for vehicle type certification and usually with real traffic situation.

In current inspection programmes, smoke checks are often complemented by:

a) measurement of engine operating variables,

b) checks (functional or visual) of selected engine/vehicle systems or anti-pollution devices.

Operating variables measured during inspections may include:
- injection timing,
- maximum no-load (run-out) speed.

The checking of vehicle systems/devices may comprise:
- exhaust system,
- inlet system,
- injection system, in particular sealing of fuel load stop adjustment screw in the injection pump governor,
- anti-pollution devices such as EGR.

The inspection programmes for diesel vehicles are, like those for vehicles equipped with SI engines and for the same reason, usually cost-neutral or even cost-efficient.

4.4. Situation in countries participating in the project

The status of in-use vehicle inspection for emission control in countries participating in the project is given in great detail in Annex 1.

The following elements of inspection are presented:
- organizational structure and types of conducted inspections,
- vehicle categories subjected to inspection,

- emission limits for particular vehicle categories,
- test methods,
- used equipment,
- effectiveness of inspection.

5. OUTLINE OF THE MOTOR VEHICLE EMISSION CONTROL SYSTEM FOR COUNTRIES PARTICIPATING IN THE PROJECT

5.1. General description

Experiences of many countries have shown that the best efficiency of the emission reduction can be achieved if all measures taken up for this purpose are not conducted separately but form a comprehensive and uniform motor emission control system. In such a system the vehicle emission control consists in:
- new vehicle control,
- in-use vehicle inspection,
- fuel quality control.

The system is formed by the following elements:
- legislation empowering competent authorities to carry out control and specifying its rules and procedures,
- standards (regulations) for new - and in-use vehicles and standards for fuel quality, specifying limits and test methods,
- network of test centres and inspection stations,
- supportive and enforcement elements such as vehicle registration system, economic measures: e.g. taxation, custom-duties, incentives etc., enforcing measures: e.g. sanctions and penalties, maintenance and repair network.

The outline of the suggested system to be aimed at by countries participating in the project is shown in Fig. 1. There are two streams of vehicles influx for the registration, called for the purpose of these guidelines:

a) vehicles subjected to type certification (approval),
b) vehicles exempted from type certification.

The group a) includes new vehicles supplied in larger quantities:
- produced by local manufactures,
- imported by companies/dealers.

The other group includes:
- new vehicles imported by companies/dealers in small quantities and by private persons,
- second-hand vehicles imported by companies/dealers/private persons,
- vehicles assembled locally in small quantities (e.g. from spare parts).

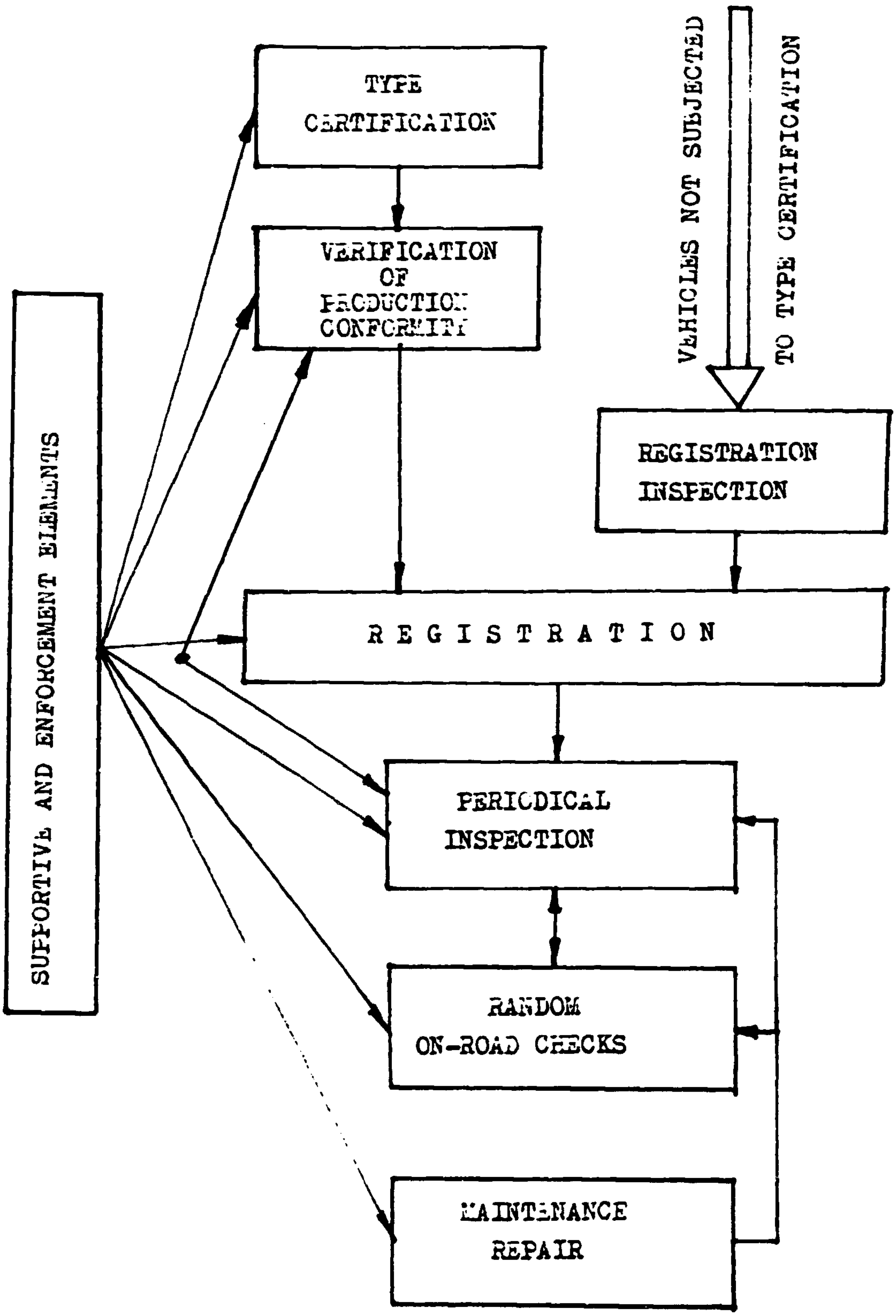

Fig. 1. Motor vehicle emission control system

The national administration can affect the share and structure of both the groups, when needed, for instance by:

- specifying the quantity of the same type vehicles above which the certification is required,
- limiting the age of imported second-hand vehicles or taxing them in a function of their age,
- imposing stringent technical requirements for the group b).

The group a) of vehicles is subjected to the type certification which is granted when the requirements specified in regulations/standards are complied with. It is also subjected to the production conformity verification.

The compliance of every vehicle of group a) with the requirements with regard to emissions has to be certified by the manufacturer. Vehicles of this group are not subjected to registration inspections. On the other hand, every vehicle of group b) is to be inspected prior to the registration and its registration can be granted only if it meets the emission requirements. To detect defects of vehicles affecting emission level and bring about their repair, inspections of in-use vehicles are conducted.

5.2. Functions of main components of the system

5.2.1. Vehicle type certification

In the recommended system the vehicle manufacturer or his representative apply to the competent authority (administrative department) for the approval of a vehicle type with regard to limitation of emissions. "Vehicle type" means motor vehicles which do not differ in such respects as:

- engine characteristics: main technical data, intake system, fuel system, ignition system, exhaust system, additional anti-pollution devices, engine performances etc.,
- vehicle characteristics: main technical data, transmission etc.

A vehicle representative of the vehicle type to be approved is submitted to technical services responsible for conducting the approval tests. It should be accompanied, among others, by:

- description of the vehicle type,
- owners manual.

The authorized technical services:

- check that the submitted vehicle conforms to the supplied description,
- conduct emission tests in accordance with the emission standard(s),
- identify vehicle components that are liable to affect emissions and that should be checked during periodical inspections,
- check that the owner's manual comprises all information necessary for proper vehicle maintenance with regard to emissions,

- verify whether the manufacturer is able to ensure that every manufactured vehicle will conform to the approved type and comply with emission requirements.

The technical service prepares a test report and, if all the requirements, both formal and technical, are met, the competent authority grants the type approval and issues an approval certificate.

5.2.2. Conformity of production

Every manufactured vehicle should conform to the type approved with regard to components affecting emissions and should meet the emission requirements. The manufacturer certifies this conformity by affixing to the vehicle an approval mark or by issuing a written certificate.

The manufacturer of the approved vehicle type is, among others, obligated to:

- conduct functional tests with regard to emission affecting components and systems,
- perform quality audit tests on a limited number of production vehicles,
- take all necessary steps to reestablish the conformity of production if vehicles have failed tests.

The competent authority which has granted the type approval is empowered to verify the conformity of production. The verification is made by:

- checking that the manufacturer is conducting functional and quality tests,
- checking that vehicles conform to the type description,
- conducting emissions tests on a number of randomly-selected serially-manufactured vehicles (surveillance tests).

5.2.3. Registration inspection

As mentioned above, vehicles of group b) (Fig. 1) should undergo the (pre-first) registration inspection. Its extent depends on emission standards in force.

If the requirements set in the standards are of "reduced-emission" level, vehicles should be subjected to the same tests and satisfy the same requirements as specified for periodical inspections. After the introduction of "low emission" standards, it is suggested to differentiate the inspection depending on whether vehicles:

a) belong under types approved,
b) belong to types not approved.

Vehicles referred to in a) are to undergo the tests specified for periodical inspection. Vehicles referred to in b) should be tested in accordance with the procedure specified for type approval/conformity of production. Such a procedure is necessary to limit the influx in the country of reduced-emission or even uncontrolled vehicles, considerably cheaper and therefore overcompetitive in terms of price.

The registration is some sort of transmitter of information about the vehicle to the inspection authority. As emission requirements depend on vehicle characteristics, the registration certificate should comprise data enabling inspectors to determine tests to which the vehicle is to be subjected.

5.2.4. Inspection of in-use vehicles

Inspections of in-use vehicles for emission control include:
a) mandatory periodical inspection,
b) random inspections/checks.

In principle, in a long term the periodic inspection should be mandatory for all vehicle categories. The exception to this rule can only be categories whose contribution to air pollution is marginal e.g. mopeds, motorcycles in some countries. As the frequency of periodical inspection depends on many variables different for countries participating in the project, general recommendations in this respect can not be given. It should be determined, to some extent, by the method of "trials and errors", cost effectiveness being, among others, a factor. One of the criteria for the efficiency of periodical inspection is the discrepancy between its failure rate and that of random checks. A high discrepancy shows that this efficiency, among others because of insufficient frequency, is too low. Another criterium is vehicle kilometrage travelled per year. In this respect, there is a great difference between commercial vehicles and those used for private purpose. In the former case, vehicle kilometrage travelled is considerably higher and therefore inspections should be more frequent which is usually the case in the majority of countries participating in the project.

It is recommended that the periodical inspection is conducted on "test only" basis. Any repairs should not be performed by inspection stations. The only exception to this rule is the CO adjustment for uncontrolled - and reduced-emission vehicles if the limit is exceeded. Passing the periodical inspection with regard to emissions should be a precondition for renewal of registration certificate.

Random inspections can be conducted as:
a) road-side pull-overs with subsequent emission tests on the spot,
b) road-side pull-overs without emission tests on the spot; in this case, a ticket/order is issued requiring the owner/driver to submit the vehicle for testing to an inspection station,
c) spotting without subsequent road-side pull-overs, a ticket/order being mailed to the owner/driver requiring him to

submit the vehicle for testing to an inspection station.

It is worth noting that random inspections are usually more effective for diesel driven - than for petrol-driven vehicles because the excessive smoke is visible. All the above random inspection types have advantages and defects and the selection of one of them depends very much on local conditions e.g. such as vehicle registration and registration renewal system, discipline and respect of law among vehicle owners/drivers, powers of inspection authority with regard to vehicle stopping on the road and levying sanctions etc.

The type a) is usually not very practicable in congested urban traffic as it may result in traffic congestion. Moreover, the accuracy of measurement on the road-side is usually lower than in inspection stations. However, it compels owners/drivers to take better care of their vehicles in order to avoid potential penalties.
The type c) of random inspection is effective in the case of diesel driven vehicles, in particular when the permissible smoke limit is higher than the visibility threshold. Its effectiveness for petrol driven vehicles is usually lower, in particular when the CO limit is only in force. Moreover, it is more practicable when the registration system is computerized.

The annual share of vehicles checked during random inspections should be at least 5% of total number. If this share is lower, the efficiency of the emission reduction suffers. It is worth noting that for smoke control this share was for instance (Annex 1):

- in Thailand - about 30% (1991),
- in Malaysia - about 12% (1990).

In spite of this, the percentage of vehicles which emit excessive smoke is still very high in these two countries.

Two kinds of limits are set:

- basic limits,
- "prohibition" limits.

The vehicle which fails the periodical inspection, because it exceeds the basic limit, is given a repair order. The owner is obliged to have the defects repaired and to submit the vehicle for reinspection within the specified period, usually a fortnight. If the test value ranges between the basic and "prohibition" limit, the vehicle can be used during this period but, if it exceeds the "prohibition" limit, the use of the vehicle is forbidden. It is only permitted to drive it the shortest way to a repair station and back to the inspection station. If the vehicle fails the reinspection, its registration/inspection certificate is cancelled and it can not be used any longer.

If the vehicle fails a random emission check, irrespective of the type applied, a repair order is issued. The vehicle should be submitted for reinspection within a specified period, usually a fortnight. Like in the periodical inspection, if the test value ranges between the basic and "prohibition" limit, the vehicle can be used during this period. However, if the "prohibition" limit is exceeded, the use of the vehicle is not allowed. The vehicle which fails the reinspection should have its registration/inspection certificate cancelled.

A system of fines should be laid down in order to enforce the compliance with emission requirements. The owner/driver is fined in the following cases:

- during the random inspection, the emission level exceeds the basic limit for diesel vehicles or "prohibition" limit for vehicles equipped with SI engines,
- the vehicle, which was given a ticket during the random inspection of type b) or c), is not submitted for testing within the prescribed period,
- the vehicle is submitted for reinspection (if it has failed the periodical or random inspection) after the prescribed date,
- full load stop screw sealing is removed (in diesel vehicles).

The basic and "fine" limits for smoke are the same as in this case the owner/driver is able to see that the vehicle is in poor technical conditions. However, it is recommended to set the "fine" limit at "prohibition" limit for vehicles equipped with SI engines.

There should be a feed back between new vehicle control and in-use inspections. Technical services carrying out the certification should identify vehicle devices/systems to be checked during inspections. On the other hand, inspection services should identify vehicle types for which the failure rate is high. The information should be fed back to services responsible for production conformity verification, allowing them to focus this verification on the most appropriate types.

There should be a good cooperation between services conducting periodical inspections on one hand and random on-road checks on the other. These services often report to different authorities. They, in particular, should:

- use the same test methods,
- use the same "passed" and "failed" criteria,
- exchange information.

Random check results should be used to monitor the performance of individual inspection stations. Stations for which the failure rate during these checks is high are to come under special surveillance. Their equipment is to be checked for malfunctions and calibration. Penalties should be introduced for violation.

5.2.5. Maintenance and repair

Maintenance and repairs play a very important role in the system. As a matter of fact, periodical inspections and random checks do not serve a purpose if they are not supported by efficient repairs. A precondition for efficient repairs is availability of:

- inexpensive genuine spare parts for systems/components which

are liable to affect emissions,
- skillful mechanics,
- test equipment similar to that which is used for inspections.

In some countries the system of so called "recommended" repair stations is used with success. If the vehicle fails the inspection, it is sent to such a station for repair.

5.3. Technical services for motor vehicle emission control system

Organizational structures of technical services may differ depending on country conditions. An example of structure which has proved successful is shown in Fig.2.

The main competencies and responsibilities of the emission control centre are:

a) to conduct vehicle type approval procedure with regard to emissions under authorization of the competent authority in charge of vehicle emission control (usually environment protection or transport department):
   - to conduct emission tests,
   - to identify systems/devices to be checked during in-use vehicle inspection,
   - to inspect whether the manufacturer is able to ensure the conformity of production with the approved type,
   - to prepare a technical report for the competent authority;

b) to carry out the verification of production conformity:
   - to select vehicles which should be subjected to the verification, among others, on the basis of in-use inspection results,
   - to check the compliance with the type description approved during the type certification,
   - to select serially-manufactured vehicles to be subjected to full emission tests and to conduct such tests,
   - to check that the vehicle manufacturer performs quality control, uses proper equipment, methods, etc.;

c) to assist the competent authority(ies):
   - in formulating policy with regard to emission control,
   - in preparing emission standards for new vehicles, for in-use vehicles and fuel quality standards,
   - in promoting emission control,
   - in improving the efficiency of emission control;

d) to develop, improve and update emission test procedures,

e) to carry out trainings of:
   - senior inspectors of regional inspection services,
   - inspectors of regional fuel quality stations,

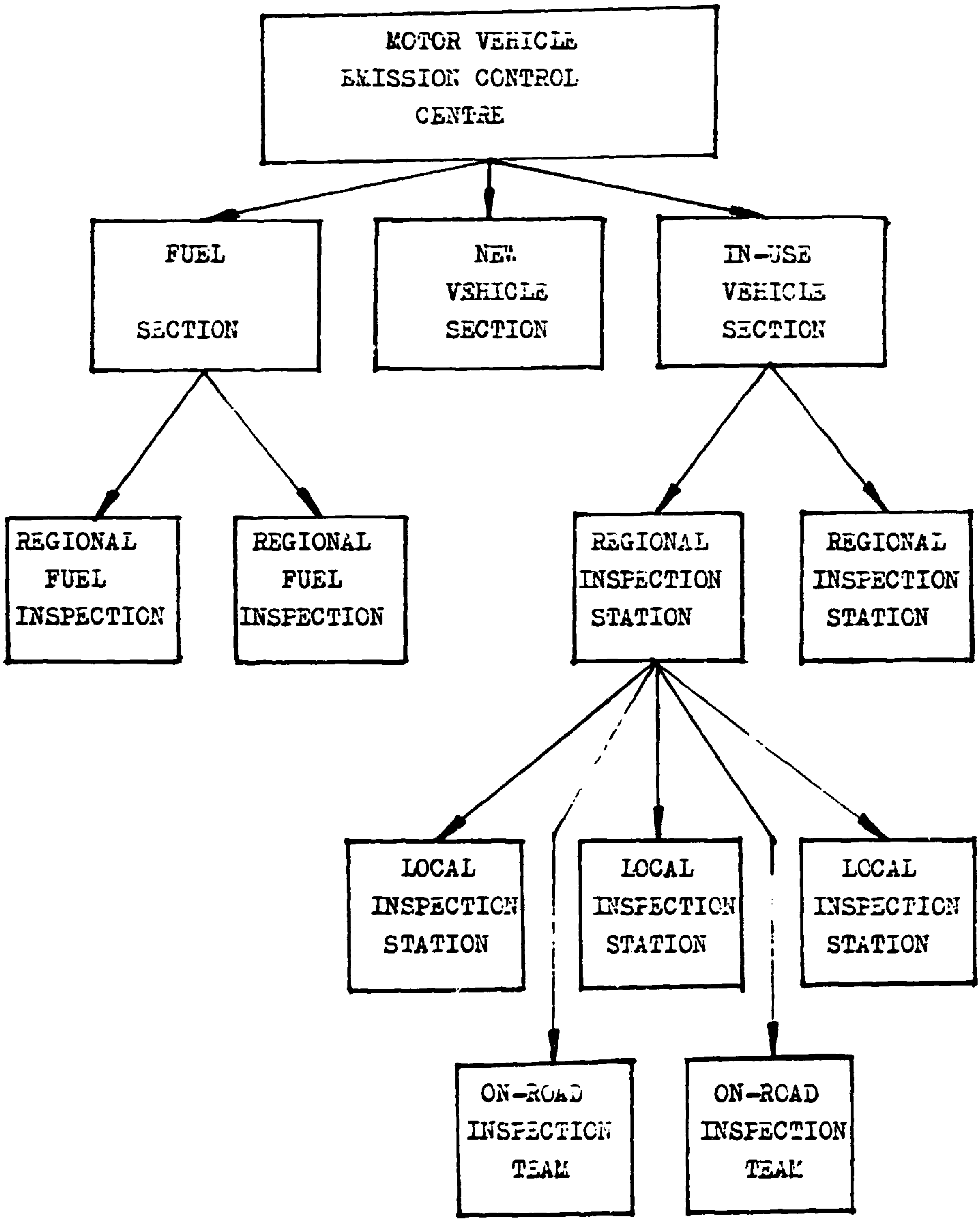

Fig.2. Organizational structure of technical services

f) to lay down requirements to be met by the test equipment and to certify the type of test equipment to be used in regional/local inspection stations and by vehicle manufacturers,
g) publish an overview of the inspection results.

The main tasks of regional inspections are:
a) to supervise local inspection stations (quality of inspection, methods, technical conditions of the equipment),
b) to conduct training of:
   - mobile teams conducting random checks,
   - local station inspectors,
   - mechanics of maintenance/repair stations,
c) to provide equipment service for local inspection stations, maintenance/repair stations, random inspection teams (repairs, periodic calibration),
d) to assess the performance of individual local inspection stations,
e) to participate in, or cooperate with, road-side inspection teams,

f) set up the rules for the participating of maintenance/repair stations in I/M programmes.

In small countries, regional inspection stations may be not required. Their tasks will be taken up by the emission control centre.

The local inspection stations are:
a) to conduct periodical inspections in full accordance with standards/regulations,
b) to keep records of inspection results over time agreed upon with the competent authority.

The testing equipment (smokemeters, exhaust gas analysers) used in inspection stations should be periodically checked by the independent authorized institution. The frequency of check depends on many factors e.g. quality and type of equipment, number of tested vehicles etc. It is usually conducted every 6-12 months. A certificate of fitness confirming the compliance with requirements should be issued.

6. EMISSION TEST PROCEDURES FOR IN-USE MOTOR VEHICLES IN THE REGION

6.1. General

Countries participating in the project differ very much in respect of conditions affecting the emission level. Consequently, the implementation of stiff common emission standards for in-use vehicles in the initial phase of the project does not seem to be realistic. Therefore three options for requirements are recommended:

- for uncontrolled vehicles,
- for reduced-emission vehicles,
- for low-emission vehicles.

It is the responsibility of the competent authority in individual countries to specify, in the framework of their own regulations, which level of requirements and since when should be met by particular vehicle categories. The ultimate goal is, however, to have common standards specified for low-emission vehicles.

Two kinds of emission limits are specified:

- basic limit,
- "prohibition" limit.

Their definitions and cases when they are used are given in point 5.2.4. above.

In the recommended inspection procedures, some emphasis is laid on visual checks of vehicle devices/systems. As the standard of vehicle maintenance in some countries is generally poor, such checks are regarded useful for the reduction of emissions. In the first place it concerns uncontrolled vehicles. The scope of visual checks is subject to such factors as vehicle technical conditions, standard of maintenance and repair etc. in individual countries.

6.2. In-use vehicles equipped with SI engines

6.2.1. Scope and limits

Uncontrolled vehicles

A. Visual checks:

- exhaust system,
- inlet system,
- ignition system,
- oil and fuel leaks.

B. Check of carbon monoxide (CO) concentration at (low) idle speed.

Basic limit: 4.5% vol. (6% vol.),
Prohibition limit: 8% vol.

If the CO concentration at idle exceeds 4.5% vol., the idle adjustment should be performed by means of the components provided for this purpose and specified in the owner's manual. If the idle can not be adjusted properly, the vehicle is given a repair order (see point 5.2.4.). However, if the engine operation below 4.5% vol. is not smooth (vibrations, stalling, speed fluctuations) with the mixture needle not fully turned in and visual checks have not detected any defects, the vehicle is given the "grace" limit 6.0% vol.

Reduced-emission vehicles

A. Visual checks:
- exhaust system,
- inlet system,
- ignition system,
- oil and fuel leaks,
- crankcase ventilation system,
- anti-pollution devices.

B. Check of pollutant concentrations at (low) idle speed
Step I
CO concentration
Basic limit: 4.5% vol. within the engine idle speed range specified by the manufacturer and approved during the type certification.
Prohibition limit: 8.0% vol.

Step II (for cars and light duty vehicles)
CO and HC concentrations
Basic limit: for CO - 4.5% vol., for HC (as n-hexane) - 1200 ppm within the engines idle speed range specified by the manufacturer and approved during the type certification.
Prohibition limit: for CO 8.0% vol., for HC (as n-hexane) - 3000 ppm.

If the measured CO/HC values exceed the specified limits or the engine idle speed is not within specified range, the idle adjustment should be performed by means of components provided for this purpose and specified in the owner's manual. If the idle can not be adjusted properly, the vehicle is given a repair order (see point 5.2.4.).

Low-emission vehicles

A. Visual checks:
- exhaust system,
- inlet system,
- ignition system,
- crankcase ventilation system,
- anti-pollution devices, in particular catalytic converter and λ - probe.

B. Checks of pollutant concentrations
Two steps of requirements for low-emission vehicles are set:
- step I - basic requirements,
- step II - enhanced requirements.

The details are given in Table 1. For low-emission vehicles any idle adjustments are not performed. If the vehicle fails to meet any requirements, a repair order is given.

Requirements for low-emission vehicles Table 1

Specification	Step I	Step II
1. CO concentration at low idle *		
(% vol.):		
- basic limit	1.2	0.5
- prohibition limit	4.5	3.0
2. HC concentration at low idle *		
(ppm as n-hexane):		
- basic limit	220	100
- prohibition limit	800	800
3. CO concentration at raised idle		
speed 2500 rpm (% vol.):		
- basic limit	---	0.3
- prohibition limit	---	3.0
4. HC concentration at raised idle		
speed of 2500 rpm (ppm as		
n-hexane):	---	100
- basic limit	---	800
- prohibition limit		
5. Air fuel equivalence ratio at raised idle speed of 2500 rpm	---	1 ± 0.03

* Low idle speed should be within the range specified by the manufacturer and approved during type certification.

6.2.2. Test methods

6.2.2.1. Visual checks

Exhaust system

Exhaust system should be reasonably leakproof. Visual checks are conducted to detect:

- damaged gaskets between the exhaust manifold and cylinder head, exhaust pipe and exhaust manifold etc.,
- leaky connections of exhaust pipe components,
- perforation, fracture etc. of exhaust components (e.g. due to corrosion, mechanical failure).

Checks are carried out at raised idle speed.

Intake system

Checks are carried out to detect:

- that the vehicle is equipped with an air filter (cartridge) and the filter is in good condition (not leaky),

- other components, e.g. air preheating system, are not damaged.

Ignition system

Checks that the vacuum advance control is connected to the intake manifold/carburetor and that the vacuum and centrifugal advances are able to operate.

Oil and fuel leaks

Any fuel dripping from the fuel system (tank, lines, pump, filter(s), carburetor(s), injector(s) etc.) and oil dripping from engine, gear box and final drive is not allowed. Any droplet should not come off these components during one minute when the vehicle is warm. Wet spots are permissible.

Crankcase ventilation system

Checks should be performed to detect that:
- the engine is fitted with the crankcase ventilation system and all components of the system are in place,
- the system is leakproof, undamaged and its components are securely mounted.

Anti-pollution devices

Checks are conducted to detect that the vehicle is fitted with all devices provided by the manufacturer to reduce emissions and selected for the in-use inspection during the type certification. The following is a non-exhaustive list of such devices:
- EGR,
- air pump, puls-air valves,
- dash-pot, fuel shut-off valve,
- catalytic converter,
- λ - probe,
- evaporative system.

Visual checks are also performed to detect that these components are properly connected, not damaged and securely mounted.

6.2.2.2. Pollutant measurement for uncontrolled - and reduced-emission vehicles

The test procedures for these engines include:
- instrument preparation,
- vehicle preparation,
- actual CO/HC measurement at idle.

Instrument preparation:

- checking that all connections of the gas sampling system are leakproof, filters are reasonably clean, condensate traps are in good condition, sample line and probe are free from

contaminants,
- carrying out zero and span calibration.

The frequency of these operations should be compatible with good functioning of instruments.

Vehicle preparation:

- checking that the manual choke control is in the rest position,
- shifting the manually operated air preheating device, if any, of the air filter(s) into the position compatible with the actual ambient temperature at the inspection spot (the system should usually be in "summer" position),
- switching off all equipment like rear window heating, air conditioning system which are not necessary for the vehicle operation at idle; however, external lights should be switched on if the driving on lights is required by the regulations in force (up till now such a requirement is not in force in any visited country),
- checking that the gas sampling probe can be inserted into the exhaust pipe to a depth of at least 30 cm for four-stroke engines and 60 cm for two-stroke engines; if this proves impossible due to the tail pipe configuration, a suitable, reasonably leakproof, extension or correction of measurement results by means of correction graph should be applied (Annex 2, point 5),
- checking that the vehicle has attained its normal thermal conditions and, if necessary, warming-up the vehicle (Annex 2, point 5),
- connecting the engine speed measuring device.

Measurement

The measurement is performed:
- with gear lever in neutral position and clutch engaged for vehicles with manually-operated or semi-automatic gear boxes,
- with gear selector in park or neutral position for vehicles with automatic transmission.

Immediately prior to actual measurement, the engine should be accelerated to a speed of about 2/3 of maximum rated speed (usually to about 3000-4000 rpm) by slightly depressing the accelerator pedal and maintained at that speed for about 30 s. Then the pedal should be released. The sampling probe should be inserted in the exhaust pipe (or its extension) as deeply as possible but not less than specified above in "Vehicle preparation".

CO/HC readings should be taken after about 20-30 s. If the vehicle has multiple exhaust outlet, the arithmetic average of concentrations in each outlet is taken as a final result. The engine speed is read at the same time as CO/HC content.

6.2.2.3. Pollutant measurement in low-emission vehicles

The analyser preparation and vehicle preparation do not differ from those described in point 6.2.2.2. The same applies to the measurement of CO/HC concentrations at (low) idle speed.

The measurement at raised idle speed immediately follows that at low idle. The raised idle is obtained by slightly depressing the accelerator pedal. Readings of CO/HC concentrations and λ-value should be taken after about 30 s from the moment the required engine speed has been achieved. During the measurement this speed should be kept within 2500 ± 200 rpm.

6.2.3. Exhaust gas analysers

NDIR exhaust gas analyser are used for inspection of in-use vehicles equipped with SI engines:

- mono-component (CO) analyser for uncontrolled and reduced-emission vehicles (step I),
- bi-component (CO/HC) analyser for reduced-emission vehicles (step II),
- bi - or multi - component analyser(s) for low-emission vehicles.

The detailed technical specifications for such analysers are laid down:

- in ISO Standard 3930-1976: Road vehicles - Carbon monoxide analyser equipment - Technical specifications (Annex 4A),
- in ISO Document ISO/TC22/SC5/WG6: Instrumentations for measurement of gaseous exhaust emissions, produced during inspections or maintenance tests (Annex 4B).

These documents can be used for the selection of suitable analysers.

6.3. In-use diesel vehicles

6.3.1. Scope and limits:

A. Visual checks:
   - exhaust system,
   - injection system,
   - inlet system,
   - oil and fuel leaks,
   - anti-pollution devices.

B. Check of smoke intensity by free acceleration method from low idle speed.

Uncontrolled vehicles

Basic limit:	- 65HSU ($2.44m^{-1}$)
Prohibition limit:	- 80HSU ($3.74m^{-1}$)

Reduced-emission vehicles

Basic limit:	- 50HSU ($1.6m^{-1}$)
Prohibition limit:	- 70HSU ($2.8m^{-1}$)

Low-emission vehicles

Basic limit:	value measured and approved during the type certification increased by a lump figure of 10HSU ($0.4m^{-1}$) but not higher than 40HSU ($1.18m^{-1}$)
Prohibition limit:	- 60HSU ($2.13m^{-1}$).

The above limits are expressed in HSU. However, it does not mean that only Hartridge smokemeters can be used. Other types can be applied providing the limits are equivalent to those specified above.

In periodical inspections, the full-load stop adjustment screw of the injection pump governor is sealed after the vehicle has passed the test. The sealing makes it difficult to decrease the fuel delivery before the inspection and to increase it, and therefore the smoke level, after the inspection which is sometimes the case. If any repair of the injection pump requiring the removal of sealing is performed between two consecutive inspections, the vehicle must be taken to an inspection station, immediately after the repair has been completed, for a smoke check and sealing. Vehicles can not be used without the screw properly sealed (see point 5.2.4. above).

6.3.2. Test methods

6.3.2.1. Visual checks

Exhaust system, intake system, fuel and oil leaks - see point 6.2.2.1. above.

Fuel system

A check is conducted that the full-load stop-adjustment screw is properly sealed.

Anti-pollution devices

Checks are conducted to detect that the vehicle is fitted with all devices provided by the manufacturer to reduce emissions and selected for in-use inspections during the type certification and these devices are not damaged, disconnected etc. Checks may include for instance:

- EGR,
- catalytic converters,
- trap oxidizers.

6.3.2.2. Smoke measurements by means of opacimeters

As basic recommended smokemeters are partial sampling opacimeters, the description of smoke measurement is limited to this type. The test method for determination of smoke level by means of partial sampling opacimeters includes:

- vehicle preparation,
- instrument preparation and installation,
- actual measurement.

Vehicle preparation

For the test, the vehicle should be at normal thermal conditions, in particular engine oil and water temperatures must be approximately at normal stabilized levels. The vehicle should be warmed-up if these conditions are not met.

Instrument preparation and installation

The sampling probe is an open-end tube. The ratio of its cross-sectional area to that of the exhaust pipe should not be less than 0.05. The probe should be centered, with the open end facing the exhaust stream, approximately in the axis of the exhaust pipe. It should be inserted in the exhaust pipe at least to a depth of 2-3D (D - exhaust pipe diameter), but not less than 20 cm. It is recommended to set a requirement in Motor Vehicle (Construction) Rules that the final portion of the tail pipe should be straight at a length of about 4-6D.

The connecting pipe should be inclined upwards from the probe to the opacimeter. Sharp bends where the soot may accumulate should be avoided. The opacimeter should be calibrated in accordance with the manufacturer specifications. Zero should be checked before each test.

Measurement

During the measurement, the gear box is in neutral position and the drive between the engine and gear box engaged. The engine is at (low) idle. The accelerator pedal is depressed fully and quickly but not violently so as to obtain maximum delivery from the injection pump. This position of the pedal is maintained until the maximum no-load engine speed is reached, in practice for about 4-5 s. Afterwards, the pedal is released. The engine is resuming its idle speed. The total length of one cycle is about 12-15 s. The pedal should be operated by a trained operator.

3 preliminary accelerations should be carried out to clean the engine combustion chamber and exhaust system, as well as to adjust the pressure in the smokemeter. The actual measurement consists of 3 aforementioned cycles. The arithmetical mean of these 3 readings is taken as the final result. When one or two of the readings exceed the prescribed smoke limit and the others are lower and when the maximum difference is higher than 5 HSU, the test should be repeated.

In cases where the vehicle has several exhaust outlets, measurements are carried separately on each of them. The arithmetical mean is taken as the final result.

Standards for type approval specify six to ten consecutive acceleration cycles in order to get satisfactory accuracy, repeatability and reproducibility. 3 preliminary accelerations and 3 cycles for actual measurement are regarded as a good compromise for in-use vehicle inspections.

6.3.2.3. Equipment

The detailed technical specifications for opacimeters used in the test described above are given in Annex 8 to ECE Regulation No. 24, Revision 2 (Annex 5 to "Guidelines").

7. IMPLEMENTATION OF COMMON IN-USE MOTOR VEHICLE INSPECTION PROCEDURES FOR EMISSION CONTROL IN THE REGION

In-use motor vehicle inspection for emission control has two main aspects:

a) formal and organizational aspect comprising such elements as:
   - organizational structure of the control system,
   - functions, responsibilities and competences of individual institutions empowered to conduct the control,
   - type of inspections and inspection models,
   - powers to levy penalties, kind of such penalties, amount of fines etc.,

b) technical aspect including:
   - vehicle categories subjected to inspections,
   - emission limits for particular categories,
   - test methods,
   - testing equipment.

Changes with regard to formal and organizational aspect of in-use vehicle inspection are a long lasting and difficult process. Consequently an extensive harmonization of inspection in this respect does not seem to be realistic at least in a short - and intermediate term. Some of the aforementioned elements will be included in the guidelines devoted to practical policy measures for the reduction of vehicle emission to be worked out under the project. Therefore, only general recommendations in this respect are given in Chapter 5 of the present "Guidelines".

Emphasis in the present "Guidelines" is placed on the harmonization of in-use motor vehicle emission inspection with regard to technical aspect (chapter 2). Such a harmonization is expected to assist in the reduction of motor vehicle emissions in the region by:

- improving the standard of inspection,
- increasing the market volume and power and, as a result, by making it easier for vehicle suppliers to meet common

requirements on one hand and by making it easier to force these suppliers to comply with common requirements on the other hand,

- reducing the cost of testing equipment as a result of its standardization.

The situation in the region with regard to in-use vehicle inspection for emission control varies from country to country. In some countries, any emission inspections have not been conducted up till now or even any emission standards have not been set. In some others, inspections are conducted, however, according to the legislation only small part of vehicle population, usually commercial ones, has to undergo them. In yet other countries, comprehensive emission inspection programmes have been launched, including all vehicle categories which significantly contribute to total vehicular emissions.

In the majority of countries which do not conduct comprehensive emission programmes, there is a need for the introduction of in-use vehicle inspection for all categories accounting for considerable shares of emissions. In some of these countries the technical condition of in-use vehicles is bad on the average and such an in-use vehicle inspection should be introduced as soon as possible. However, in other countries, the technical condition of vehicles is relatively good, comparable to that in some developed countries. It results, among others, from the fact that the dynamic growth in vehicle population, in particular cars, started only recently. As a result, the average age of vehicles is low. The situation will however deteriorate with time when the age of vehicles increases. As the setting up of efficient inspections is a long process, it should start well in advance.

The following main factors should be taken into account when selecting vehicle categories to be subjected to inspections:

- air quality in the country,
- projections of motor vehicle population and emission growth,
- contribution of motor vehicles as a whole and individual vehicle categories to air pollution, both local (e.g. in great cities) and nation-wide,
- efficiency of inspection,
- cost effectiveness of inspection and costs to motorists.

Inventory of vehicle emissions determined under actual country conditions should be made for this purpose. Factors such as: traffic conditions, vehicle population structure by types and categories, vehicle age, maintenance and repair quality, ambient conditions etc. being taken into account. Such an inventory is available so far only for one country. It may be noted that inventories based on emission factors representative of developed countries, usually USA, taken from foreign technical literature are usually of a little use and may even be misleading. The inventory will be a data base for the assessment of effectiveness of motor vehicle emission reduction options and the identification of the most suitable ones. It is also required to establish an inventory for the region as a whole.

Irrespective of differences in vehicle population, its technical conditions etc., in all countries participating in the project, priority should be given to inspection for emission control of the following categories (see chapter 3):

a) diesel vehicles:
   - light duty,
   - medium/heavy duty,

b) vehicles equipped with SI engines:
   - cars,
   - light duty.

For the above categories, the harmonization is possible in the first place.

In the majority of countries participating in the project emphasis is laid on the reduction of emissions (particulates and smoke) from diesel vehicles. The free acceleration method from low idle speed is used in all countries which have already laid down emission standards for these vehicles. In two countries, India and Thailand, single steady speed tests are parallely specified but not implemented in practice. The smoke measurement is performed be means of two types of smokemeters:

- opacimeters with partial flow sampling (usually Hartridge Mark 3) in India, Malaysia, Singapore (in part of stations), Philippines (for random on-road checks), Hong Kong,
- filter-type smokemeters, Bosch smokemeters being mainly used in Thailand, Indonesia (in part of stations) and smokemeters of Japanese makes or their derivatives in Korea, Philippines (for periodical inspection), Singapore (in other stations), Indonesia (in other stations), China.

Smoke limits range (Annex 1):

- when the measurements are conducted by means of opacimeters: from 50 to 65HSU,
- when the measurements are conducted by means of filter-type smokemeters: from 4.0^{o} to 5.0^{o}B.

The above limits for opacimeters correspond to recommended in the present "Guidelines" for uncontrolled and reduced-emission vehicles (point 6.3). For the harmonization of the smoke limits in the region in lines with the "Guidelines" it is necessary to determine the correlation between opacimeter and filter-type smokemeter readings for free-acceleration measurement methods, representative for the actual population of these two groups of vehicles and to correct the limits for filter-type smokemeters accordingly. Moreover, some corrections of the test methods used in countries applying these type of smokemeters may be necessary.

The limit of 40HSU for low-emission diesel vehicles laid down in the "Guidelines" is very stringent. It corresponds approximately to the smoke level specified for in-use vehicle inspection in Sweden (Annex 3). Such a low limit is considered to be necessary in order to address particulate emissions. Up till now, no countries in the region have introduced such stringent requirements, however this limit is under consideration in some of them (e.g. in Hong

Kong). In this case, the harmonization is particularly desirable as special vehicle design is necessary to meet the requirements.

As regards vehicles equipped with SI engines, measurements of either only CO - (India, Thailand, Singapore) or both CO and HC (China, Korea, Indonesia, Philippines) concentrations at idle are conducted for the inspection of uncontrolled - and reduced-emission vehicles in the region. The limits are as follows:

- for CO: 3% vol. (India), 4.5% vol. (Korea, Indonesia, Singapore), 6% vol. (China, Philippines),
- for HC (vehicle with four stroke engines): 1200 ppm (Korea, Indonesia, Philippines), 3000ppm (China).

In the majority of countries which have already started the inspection of in-use uncontrolled - and reduced-emission vehicles equipped with SI engines, the limits in force approximately correspond to those laid down in the "Guidelines". Prospects for the nearly full harmonization are very good in this case. It could be achieved if countries, which have not started the inspection, introduced limits, test method and equipment specified in point 6.2. above.

Emission standards for new vehicles equipped with SI engines requiring the use of catalytic converters to comply with are already in force in Korea, Hong Kong and Singapore. Some other countries (e.g. Thailand) are considering their introduction. However, special limits for in-use inspection of such vehicles have been introduced only in Korea. They correspond to the step I limits specified in the present "Guidelines". It is recommended to other above mentioned countries to introduce such limits for emission control of in-use vehicles fitted with catalytic converters.

In the majority of countries participating in the project, the potential of in-use vehicle inspection with regard to emission is not taken sufficient advantage of. It is possible to considerably reduce emissions from motor vehicles by upgrading the standard of current inspections. It is to note that the reduction of emissions through enhanced inspections can be achieved with lower costs of initial investment than other reduction options. On the average, it may be in many cases cost-neutral to motorists as costs of inspections and repairs are compensated by lower fuel costs resulting from an improvement in vehicle fuel economy.

In some countries test methods are not specified in a sufficient way in regulations/standards. In some cases, only limits and a summary of test method are given in these documents. This is considered to be one of the reasons for many shortcomings and errors committed during tests, in particular test of diesel vehicles and motorcycles, conducted in periodical inspection stations (Annex 1). A great number of errors is usually made in smoke tests conducted by means of filter-type smokemeters. Shortcomings and errors result also from the fact that the test specifications are often not followed by inspectors.

As a result of many shortcomings and errors the efficiency of periodical inspections is usually considerably lower than potentially possible. This is particularly striking in the case of diesel vehicles. There is usually a great discrepancy between the failure rate in the periodical inspection on one hand (usually lower than 10%), this rate in the road-side checks (on the order of 20%) and estimated shares of vehicles which emit excessive smoke in actual driving (sometimes more than 30%) on the other hand. The cause of this discrepancy requires careful study. It may result not only from the above mentioned shortcomings and errors but for instance from too low frequency of inspection and also from the fact that drivers adjust fuel delivery before the inspection as the fuel load stop screw is not sealed.

By upgrading the standard of periodical inspections it would be possible to considerably reduce emissions, in particular particulates emissions, without any significant increase of investment costs. For this purpose, better training of inspectors and better supervision of their activity may be also required.

To sum up, in order to upgrade the technical standard of current inspections the following main steps should be taken up:

- to specify in detail and /or to correct test methods,
- to enforce inspection stations to conduct test according to specifications through trainings of inspectors, supervision and sanctions,
- to introduce checks and certification of test equipment.

Detailed recommendations concerning measures to be taken up in order to upgrade the standard of inspections in individual countries are given in Annex 1.

The harmonization of limits, test methods and equipment for in-use vehicle inspection with regard to emissions requires a good cooperation among institutions dealing with the problem in individual countries, in particular technical services. Some research works will be necessary e.g. to determine the correlation between different types of smokemeters or to clarify technical details of test methods. Moreover, in some countries there is shortage or even lack of skillful and competent personnel to supervise and conduct inspections. Trainings of senior technical inspectors in accordance with lines of the present "Guidelines" is desirable. To solve all these problems it is suggested to set up a common regional test and training center. The region as a whole have sufficient expertise and proper testing facilities for this purpose.

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Annex 1

STATUS OF IN-USE VEHICLE INSPECTION IN VISITED COUNTRIES

1. India

In accordance with the Central Motor Vehicles Rules, 1989 (rule 115) every motor vehicle should be manufactured and maintained in such conditions and should be so driven that smoke, visible vapour etc do not emit from it. From 1 March 1990 every motor vehicle should comply with the following standards:

a) for all four wheeled petrol driven vehicles CO concentration at idle should not exceed 3% vol.,

b) for all two - and three wheeled petrol driven vehicles CO concentration at idle should not exceed 4.5% vol., *

c) for all diesel fuel driven vehicles smoke intensity should not exceed the limits given in Table A1/1.

Smoke standards in India — Table A1/1

Method of test		Maximum smoke density		
		Light absorption coefficient m-1	Bosch Units	Hartridge Units
(a)	Full load at a speed of 60% to 70% of maximum engine rated speed declared by the manufacturer	3.1	5.2	75
(b)	Free acceleration	2.3	---	65

In India motor vehicles used for private (not commercial) purposes are not subjected to any periodical inspections. Commercial (transport) vehicles must however undergo periodical inspections in order to obtain the certificate of fitness. This certificate is valid for the following period:

a) new transport vehicles - 2 years,

* Vehicles having less than four wheels fitted with engines of displacement not exceeding 35 cc are not regarded as motor vehicles. Therefore the requirement does not apply to some

mopeds.

b) vehicles more than 2 years old (renewal of certificate) - 1 year

The certificate of fitness is issued or renewed by testing stations authorized by Motor Vehicles Department of the State Government.

As private vehicles are not subjected to periodical inspections with regard to overall safety, their checks are conducted only for emissions. However, for commercial vehicles emission checks may be combined with periodical inspection for issuing or renewing certificates of fitness.

In India state authority is in charge of the implementation of emission inspections in accordance with the above mentioned standards. Further on, the inspection system in Delhi is presented. To conduct vehicular emission checks Delhi authority has licenced 115 private workshops (filling stations, repair/maintenance stations). Moreover, checks are carried out by 7 centres of Directorate of Transport. Every motor vehicle must be subjected to the inspection every 6 months. Vehicles which have passed the inspection obtain:

a) Pollution Control Check Certificate which must be carried on the vehicle and produced at the request of inspector (Att. 1),

b) "Pollution under Control" sticker which must be affixed, conspicuously and in readily accessible place, to the vehicle (Att. 2).

Private workshops licenced for emission checks usually conduct adjustments and/or repairs if the vehicle has not passed the test. The fee for the emission check is 10 Rps.

Starting from March 1990, the vehicles owners have had to submit their vehicles for checks according to vehicle registration numbers as per a prescribed time schedule. Altogether 1,4 mln vehicles were checked for emission in Delhi from March 1990 to April 1992. About 30% of checked vehicles needed adjusting in order to bring their emission level within prescribed limits.

To enforce the compliance with the standards, road-side inspections are carried out. If the vehicle is found emitting pollutants beyond the limits, a repair order is served to the owner/driver. 14 days notice is given for carrying out necessary corrective measures. If the vehicle still shows an emission level beyond the permissible limits, the registration may stand suspended. Moreover, the owner/driver may be punished for the first offence with a fine of 1000 Rps and for any subsequent offence with a fine of 2000 Rps. Pollution control check certificates and stickers are valid for 6 months, however the authority advice the vehicle owner/driver to recheck the emission level after 3 months (see Att. 1).

Two smoke measurement methods: free acceleration and constant speed/full load method are specified in the Rules. It is worth noting that these methods do not yield equivalent results and the correlation between their results is usually poor. In practice, only the free acceleration method is used for smoke checks.

The following equipment is used for emission checks:

a) petrol vehicles:
- Horiba Exhaust Gas Analyser,
- Skription Analyser,
- Sugi Analyser,

b) diesel vehicles:
- Hartridge Smokemeter,
- AVL Smokemeter.

The CO test procedure and smoke test procedure to be used during the checks are not specified in detail in the standard. In inspection stations, checks are conducted in accordance with specifications given in the analyser/smokemeter operating instructions.

Visits to 3 stations carrying out CO checks showed the following shortcomings in the measurement procedure:

a) the sampling probe was inserted into the tailpipe to a depth of 20-25 cm for cars (in all 3 stations),

b) the sampling probe was inserted into the tailpipe to a depth of 10-20 cm for two-wheelers (in all 3 stations),

c) the analyser was not zeroed (1 station).

The committed errors may significantly affect the readings. It is particularly true of two-wheelers equipped with two-stroke engines. In such a case, the insertion of the probe to a depth 10-20 cm causes read values being lower by 3-5 times than true values which makes checks practically worthless.

CO limits specified for four wheeled petrol driven vehicles in India are very stringent. In writer's view, a significant part of older vehicles, properly maintained and in good technical conditions, may not be capable of satisfying the specified limits because they were not designed and manufactured to meet such a requirement.

To improve the standard of in-use vehicle inspections for emission control it is recommended:

1. To delete full-load steady-speed method for smoke measurements from Central Motor Vehicles Rules 1989 (rule 115).
2. To apply CO limits specified in rule 115 for petrol driven vehicles only to vehicles manufactured after 1 March 1990. "Grace" limits of up to 6% vol. should be allowed for older vehicles (see point 6.2.1. above).
3. To specify detailed test methods for CO and smoke measurements and to include them as annexes in Central Motor

Vehicles Rules 1989.

4. To complement the inspection with visual checks of vehicle systems affecting emissions.
5. To gradually increase the extent of on-road checks.
6. To enforce licensed inspection stations to conduct tests as per specifications (see item 3 above). This could be achieved by training of personnel, supervision and sanctions for noncompliance.
7. To introduce the sealing of full-load stop screw of the injection pump in diesel vehicles.
8. To introduce periodical checks and certification of test equipment used for emission control in licensed stations.

2. Korea

In Korea, emission standards for in-use vehicles and in-use vehicle inspections were introduced in 1979. The standards which have been in force in the period 1979-1992 are shown in Table A1/2.

Emission standards for in-use vehicles in Korea Table A1/2

Vehicle type	Period	Pollutants			Remarks
		CO	HC	Smoke	
Gasoline and LPG vehicles	1979 - 1984. 6	4.5%	---	---	
	1984.7 - 1987.7	4.5%	1200ppm	---	
	As of July 1987	4.5%	1200ppm	---	Old model vehicles
		1.2%	220ppm	---	New model gasoline cars
		1.2%	400ppm	---	New model LPG cars
Diesel vehicles	1979 - 1990	--	---	50%	
	As of Jan. 1991	--	---	40%	

* Test Method: CO/HC: idling; NDIR analysers, HC as hexane,
smoke: free acceleration; filter-type smokemeter.

Both periodical inspections and road-side inspections are conducted. The former are carried out by centralized stations belonging under Ministry of Transportation. The inspections with regard to emission level are combined with roadworthiness inspections. Their frequency varies from 6 months to 2 year depending on the vehicle category and age (Table A1/3).

Types of motor vehicle subjected to inspection nd the frequency of inspection

Table A1/3

Vehicles		Period of validity of motor Vehicle Inspection Certificate
Private passenger cars	Used vehicles less than 10year old	2 year
	Used vehicles not less than 10 year old	1 year
Commercial passenger cars		1 year
Light duty trucks	Used vehicles less than 2 year old	1 year
	Used vehicles not less than 2 year old	6 months
Other motor vehicles	Used vehicles less than 2 year old	1 year
	Used vehicles not less than 2 year old	6 months

Up to 1992, vehicles to be inspected in the inspection stations had to be subjected to some sort of mandatory pre-checks in so called first class licenced private repair/maintenance workshops. The purpose of such pre-checks was to prepare vehicle to the formal inspection. The scope of pre-checks was similar to that conducted during the inspections, CO/HC or smoke measurements included. If any malfunctions were found, repairs were conducted on the spot in the workshop. The fact that the pre-check had been conducted and the vehicle had passed it was certified in the vehicle registration certificate. The mandatory pre-checks were cancelled in 1992.

In addition to periodical inspections, random road-side inspections are carried out either by full-time mobile inspection teams belonging under the Ministry of Environment or by temporary inspection teams set by city and provincial administrative and prosecution authorities. Altogether there are in Korea 40 full-time inspection teams, 12 of them working in Seoul. Those teams are composed of 3 or 4 members: engineer, operator/technician, driver. One team checks about 50-100 vehicles per day. 5% of in-use vehicles should be checked every year in road-side inspections.

A vehicle that exceeds the specified limit during a road-side inspection is given maintenance/repair order. It should be repaired and submitted for a reinspection within 15 days (20 days if it is less than 1 year old and it has been driven less than 20000 km). If the so called "fine threshold" is exceeded, the driver of a private vehicle is fined to a maximum of 2000000 W. In the case of company vehicles, both the owner and the driver are fined to a maximum of 4000000 W altogether.

Furthermore, the vehicle can be given a "suspension of operation" order. Details of the penalty provisions are given in Table A1/4.

Table A1/4

Penalty provisions for road-side inspection

Pollutant	Model Year	Kind of Fuel	Type of vehicles	Standards	Penalty Provision		
					Maintenance Order	Suspension of Operation	Fine
Smoke	All Model	Diesel fuel	All Vehicles	40%	41%	60-70% :1day 70-80% :2days Min.80%:5days	41%
CO	87 Model Year or older	Gasoline and LPG	All Vehicles	4.5%	4.6%	Excess % of standards -400-500% : 2 days -min. 500% : 3 days	9.1%
	88 Model Year or newer	Gasoline and LPG	Passenger Cars	1.2%	1.3%		4.5%
			Others	4.5%	4.6%		9.1%
HC	87 Model Year or older	Gasoline and LPG	All Vehicles	1200ppm	1201ppm		4800ppm
	88 Model Year or newer	Gasoline	Passenger Cars	220ppm	221ppm		881ppm
		LPG	Passenger Cars	400ppm	401ppm		1601ppm
		Gasoline and LPG	Others	1200ppm	1201ppm		4801ppm

The following equipment is mainly used for vehicle emission inspections:

a) smokemeters:
- Bosch,
- AVL,
- Diesel Kiki,
- Bonzai,
- Komyo ST-100,

b) CO/HC analyser (NDIR):
- Horiba Mexa 201F (CO) and 224F (HC),
- Horiba Mexa 119,
- Sun,
- Komyo Urex 3110.

Ministry of Environment has licenced Korea Academy of Industrial Technology (KAIT) to check all equipment used for inspections with regard to vehicle emissions. The checks are conducted every 6 months.

CO/HC test procedure for petrol driven vehicles and smoke test procedure for Diesel vehicles are specified in an instruction (standard) issued by the Ministry of Environment.

Smoke emission is measured by free acceleration test from low idle speed using a filter-type smokemeter. During the check 3-4 acceleration cycles are conducted (Fig.A1/1). The first 2-3 of them are performed to clean the exhaust system. The actual exhaust sampling takes place during the last cycle. The accelerator pedal should be fully depressed during 4s. The probe should be inserted in the tailpipe to a depth of at least 20 cm.

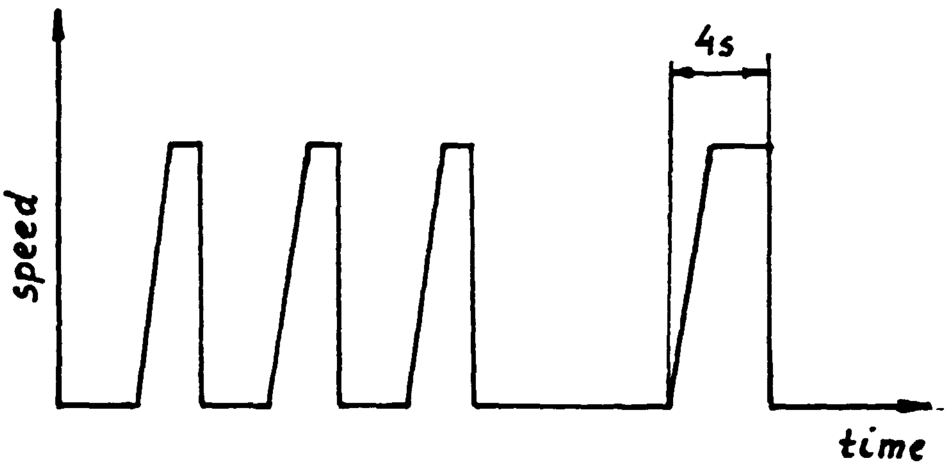

Fig. A1/1. Smoke test cycle used in Korea.

CO/HC measurement is conducted by means of NDIR analysers, HC concentration being expressed as hexane. It is specified that the probe should be inserted at least 30 cm and the engine water temperature should be 40-90 C.

Visits to 2 inspection stations showed that measurement of both CO/HC and smoke emission were not conducted according to test procedure specifications. The following shortcomings were found:

a) The accelerator pedal was depressed by the vehicle driver, not by an inspector during smoke measurements,
b) Probes were inserted less deep than specified (10 cm for Diesel vehicles, 20 cm for petrol vehicles),
c) 2-3 preliminary cycles were not performed during smoke measurements,
d) Probes were often removed from tailpipes before the suction of exhaust gas had been completed,
e) The suction time of individual smokemeters was different,
f) The smokemeters suction device was sometimes put into operation at a very high engine speeds,
g) CO analysers with a range of 0-10% vol. were used for vehicles for which the permissible limit is 1.2% vol.

Due to the above mentioned shortcomings, the readings were sometimes lower than 20% while the engine was emitting very heavy smoke.

It is recommended:

1. To correct the test method for smoke measurement in lines with specifications given in point 6.3.2.3. above.
2. To complement the requirements for smokemeters by specifying the suction time and to control it during periodical checks of smokemeters.
3. To gradually replace mono-range CO analysers (only 0-10% vol. range) with double-range analysers more suitable for low-emission vehicle checks (see Annex 4B).
4. To enforce inspection stations to conduct measurements in accordance with specifications (see Annex 1).
5. To introduce the sealing of the full load stop screw of the injection pump in diesel engines during the periodical inspection.
6. To place more emphasis on visual checks of devices/systems affecting emissions.

3. Malaysia

In accordance with Motor Vehicles (Control of Smoke and Gas Emission) Rules 1977, no motor vehicle equipped with compression

ignition engine which emits smoke of a density exceeding 50 Hartridge Smoke Units or its equivalent can be used. The compliance with limits is tested by a free acceleration method from low idle speed. The following smokemeters are specified in the Rules:

a) the Hartridge MK.3 smokemeter which is constructed to receive a volume of exhaust gas of a motor vehicle within a pressure range of 40 mm - 65 mm of water and a temperature range from 140 degrees Centigrade to 210 degrees Centigrade and to measure the density or opacity of its smoke content from 0 to 100 Hartridge Smoke Units (H.S.U.);

b) a device constructed to receive a volume of exhaust gas from a motor vehicle within specified pressure and temperature ranges and to measure the complete range of density or opacity of its smoke content in Absolute Units of Light Absorption from clear to total darkness or in such other correlated light absorption units;

c) any other equivalent device which may from time to time be prescribed by the Minister as a smokemeter.

Only Hartridge MK3 smokemeters have been used for inspection purpose so far. Some repair stations, large transport operators and public transport corporations are also equipped with smokemeters.

The Road Transport Act 1987 empowers the Road Transport Department (RTD) to take every necessary action to ensure that all registered and licensed vehicles comply with the legal requirements. Up till now only commercial vehicles are required to undergo regular periodical inspections while the private-owned ones are inspected on an "as - and - when needed" basis. The details of motor vehicle system in force in Malaysia are given in Table A1/5 and A1/6.

Inspections are conducted by 17 regular inspection stations (called centres) run by Road Transport Department (RTD) and located in the state capitals and major towns. Moreover 14 mobile inspection teams give services in certain small towns.

The inspections with regard to emissions and general safety are combined. The total inspection is carried out in 3 stages:

a) the static inspection (including, among others, the exhaust system and oil leaks),

b) the road test,

c) the smoke test (for diesel-driven vehicles).

If the vehicle fails the inspection, it should be repaired and submitted for a re-inspection within 10 days. If the owner fails to do it, he may be fined to a maximum of 300 M$.

The detailed smoke test procedure is not specified in a form of instruction or standard. 3 acceleration cycles are carried out:

- the first one is used to set the pressure in smokemeter,
- the second and third are measurement cycles.

KIND OF MOTOR VEHICLE INSPECTION

Table A1/5

	KIND OF INSPECTION	CONTENTS
1	Initial inspection	Inspection to be taken to ensure that the motor vehicle complies with the legal requirements on construction and use. It is carried out to both new and used commercial vehicles when it is to be licensed by a permit holder for the first time.
2	Periodic inspection	Inspection to be taken to ensure that the motor vehicle is mechanically sound and roadworthy.
3	Reinspection	Inspection to be taken to ensure that the defects found in an inspection is rectified.
4	Special inspection	Inspection to be taken when a motor vehicle has been modified, or detained (out of enforcement action on the road) for not complying with the legal requirements.
5	Accident vehicle inspection	Inspection to be taken when a motor vehicle has been involved in a serious accident.

FREQUENCY OF INSPECTION

Table A1/6

KIND OF INSPECTION	CATEGORY OF MOTOR VEHICLES	FREQUENCY	FEE (M$)
Initial inspection	All commercial vehicles (i.e. taxis, buses, and lorries)	Once only (on a new permit/licence holder)	40.00
Periodic inspection	All commercial vehicles	Lorries and buses - Yearly inspection for the first 2 years - Half-yearly inspection thereafter	20.00
		Taxis - Half-yearly inspection throughout	20.00
Reinspection	All categories of motor vehicles	Whenever a defect is found in an inspection	Free of charge
Special inspection	All categories of motor vehicles	As and when necessary	Free of charge
Accident vehicle inspection	All categories of motor vehicles	Whenever involved in a serious accident	Free of charge

The average value of these two measurements is taken for the comparison with the limit. Test results are recorded on a Test Certificate which is issued to the vehicle owner (Att.3).

Smokemeters in inspection stations are calibrated according to the manufacturer's instructions and cleaned by means of a centrifugal air blower after about 40 tests. Repair of smokemeters are performed by technicians from RTD. Every 6 months the smokemeter has to be certified by Standard Industrial Research Institute of Malaysia (SIRIM). A sticker is affixed to the smokemeter to certify the compliance with the requirements.

A visit to one of the inspection stations showed that measurements were conducted properly. The only reservation was that the pedal was depressed a little bit to slowly.

To enforce the compliance with the standard road-side checks are carried out by:

a) Road Transport Department,

b)Department of Environment (DOE).

RTD teams have a power to stop the vehicle, measure the smoke level and fine the owner/driver. Checks are performed by uniformed inspectors. DOE teams have a power to measure the smoke level, but not to stop the vehicle and fine. Therefore, they are accompanied by policemen. The results of road-side checks conducted in a period of 1988-1990 are summed up in Table A1/7. It is worth noting that road-side inspections apply to all vehicles, not only commercial vehicles subjected to mandatory periodical inspections.

The failure rate is 16-19%. The average failure rate during the periodical inspections (of commercial vehicles) is about 10%. The share of vehicles which emit visible smoke on the road is estimated to be more than 30%.

In accordance with the Motor Vehicle (Control of Smoke and Gas Emission) Rules 1977, every motor vehicle driven by a four-stroke petrol engine (other than a motorcycle) is to be so constructed or equipped with such device as to prevent the escape of gas from the crankcase into the atmosphere. The compliance of this requirement is checked only during the initial inspection.

From 1 June 1992 the new standard for emission from petrol driven vehicles set by DOE came into force in Malaysia. It specifies the following limits:

- CO - 4.5% vol.
- HC -800 ppm (probably as hexane).

The DOE allowed motorists 3 months grace period to comply with the set requirements. In this period, DOE will license private workshops to carry out checks. Details of the new rules were not known during the writer's visit to Malaysia.

Table A1/7

Malaysia: Enforcement of Motor Vehicles (Control of Smoke and Gas Emission) Rules 1977, 1988 - 1990

Subject	Year														
	1988					1989					1990				
Total Number of Diesel Vehicles Registered [1]	275,913					298,177					332,080				
Number of Enforcement Campaigns	440					445					439				
Total Number of Vehicles Stopped for Inspection	44,978					42,284					38,322				
Type of Vehicles	L	B	T	O	PC	L	B	T	O	PC	L	B	O	T	PC
Number of Summons Issued	2821	1080	1268	1291	900	2470	1726	1205	1165	519	2506	1900	1175	1160	458
Total Number of Summons Issued	4,712					7,085					7,199				
Type of Vehicles	L	B	O	T	PC	L	B	O	T	PC	L	B	O	T	PC
Percentage Compliance	88	85	80	77	67	89	78	78	75	74	87	76	76	71	66
Overall Percentage of Compliance (%)	84					83					81				

1
Source: Road Transport Department, Malaysia

Note:

Type of Vehicles

B = Bus
T = Tax
L = Lorry
PC = Private Car
O = Others

It is recommended:

1. To set emission standards and introduce both periodical and on-road inspections for selected categories of vehicles equipped with SI engines.
2. To introduce periodical inspections of private diesel vehicles.
3. To introduce the sealing of the full-load stop screw of the injection pump in diesel engines during periodical inspections.
4. To specify in detail the smoke test method in lines with point 6.3.2.2. above and to include the specification in Motor Vehicles (Control of Smoke and Gas Emission) Rules 1987 as annex.

4. Singapore

In accordance with Motor Vehicles (Construction & Use) Rules 1974, the following emission standards for in-use vehicles are in force:

- diesel-driven vehicles - smoke level 50HSU (free acceleration test from low idle speed),
- petrol-driven vehicles - CO content at idle 4.5% vol.

In addition, all petrol-driven vehicles (except motorcycles) are required to be fitted with a closed crankcase ventilation system to eliminate hydrocarbon emissions from the crankcase.

The following inspections are carried out to check the compliance of vehicles with the above requirements:

- registration inspections,
- periodical inspections,
- road side inspections.

Before the first registration, the vehicle must be subjected to a registration inspection (called "mechanical inspection") at the Registrar of Vehicles in order to check whether it meets the requirements of Motor Vehicles (Construction and Use) Rules 1974, emission requirements included. Moreover, a certificate of compliance with emission standards for new vehicles must be submitted for the vehicle to be registered. This certificate must be endorsed either by the vehicle manufacturer or by the reputable test laboratory.

The smoke checks for diesel-driven vehicles are conducted at ROV by means of Hartridge MK3 smokemeters. The smoke test procedure as well CO test procedure are not specified in detail in any standards or instructions. Since 1982, all in-use vehicles are required to undergo mandatory periodical inspections. The frequency of the inspections depends on vehicle category and age. It is specified in Table A1/8.

Table A1/8.

Mandatory Motor Vehicle Inspection

Type of Vehicle	Frequency		
	Below 3 years	3 to 10 years	10 years & above
All motorcycles and scooters	Nil	Annually	Annually
All cars and station-wagons	Nil	Biennially	Annually
All tuition cars	Annually	Annually	Annually
All private hire cars	Annaully	Annually	NA
All public service vehicles			
Taxis	6-monthly	6-monthly	NA
SBS buses	6-monthly	6-monthly	6-monthly
TIB buses	6-monthly	6-monthly	6-monthly
CSS buses	6-monthly	6-monthly	6-monthly
Other buses	Annually	Annually	6-monthly
All light goods vehicles (MLW 3,000 kg & below)	Annually	Annually	6-monthly
All heavy goods vehicles (MLW 3,001 kg & above)	Annually	Annually	6-monthly
All other heavy vehicles	Annually	Annually	6-monthly

ROV has authorized 3 private inspection centres (contractors):

- AA Private Ltd,
- SAE Inspection Services (SIS),
- Vehicle Inspection Company (VICOM),

to carry out inspections on its behalf.

In all centres emission checks are performed together with overall safety inspections. The inspections are automated. The failure rate for exhaust emission checks for individual vehicle categories as compared with failure rate for overall safety is given in Table A1/9. This failure rate varies from 0.1% for busses to 31% for cars.

Table A1/9

Breakdown of defects by assemblies in 1989

Type of vehicles	Above Carriage	Under Carriage	Side-slip Test	Brake Test	Exhaust Emission	Headlight Test
Cars	9.3	10.8	6.2	6.5	31.4	95.3
Motorcycles	7.0	-	1.3	2.3	16.9	97.5
Taxis	6.8	7.7	2.9	2.6	11.5	89.8
LCVs	37.8	24.8	7.8	8.5	34.6	96.6
HGVs	62.0	46.7	4.4	23.3	13.0	78.9
SBS buses	0.2	0.4	6.0	0.2	0.1	0.2
TIB Buses	4.5	7.1	1.0	3.9	1.9	65.9
CSS Buses	4.1	4.9	0.0	1.6	0.8	62.3
School Buses	84.8	75.0	6.1	21.3	21.7	95.9
Other Buses	79.9	57.9	4.6	16.6	15.7	92.0
Others	86.5	79.2	7.7	50.4	25.2	92.6

The smoke measurement during periodical inspections is performed by means of filter-type smokemeters (Bosch-type) and not of opacimeters. In this connection the limit was changed from 50HSU to 4.2^{o} (Bosch). This limit was determined on the basis of the correlation between Bosch and Hartridge smokemeters given in SAE Information Report J 255a. It is worth noting that the correlation in this report was determined for steady-state smoke measurements and not for free acceleration procedures. It does not take account of the fact that the maximum smoke value is measured by means of Hartridge smokemeter and the integrated one in the case of Bosch apparatus. Furthermore, it does not take in account that a certain portion of exhaust gas sampled by Bosch-type smokemeters comes from engine idle operation and not from acceleration (i.e full load operation). In writer's view the Bosch limit corresponding to 50HSU is about 3.0^{o}.

3 acceleration cycles from low idle speed are performed to measure the smoke level. The average value is taken for the comparison with the limit. If the difference between the readings exceeds 0.5^{o} (Bosch), the test is repeated.

One of the inspection centers was visited. The following equipment was used:

- for petrol-driven vehicles - Yanako KIOTO NDIR CO/HC analyser; CO range - 0-10% vol.; HC ranges - 0-2000ppm and 0-10000ppm as hexane,

- for diesel-driven vehicles - Yanako smokemeter (filter-type).

The following shortcomings in the measurements were found:
- for some petrol-driven cars the probe was inserted only to a depth of less than 20 cm,
- for the majority of motorcycles the probe was inserted to a depth of less than 10-15 cm.

As it has been already mentioned for motorcycles equipped with two-stroke engines, the read value is equal to about 20-30% of actual value if the probe is inserted only 10 cm. Readings for HC content in the exhaust gases of motorcycles tested in the visited center were lower than 2000ppm which shows that CO readings were badly affected. The shortcomings in the CO measurements may be one of the reason of low failure rate for motorcycles (see Table A1/9).

To enforce the compliance with the emission standards, ROV conducts road-side inspections, particularly for diesel-driven vehicles. These inspections are conducted by mobile teams equipped with Hartridge smokemeters. If the vehicle fails the test, both the owner and driver can be penalised, the penalties ranging from fines to being charged in court. If the smoke level exceeds 70 HSU, the vehicle is given a "prohibition of use" order. After being repaired, it must be tested by ROV before it can be used on the road again.

It is to note that different types of smokemeters are used for periodical and road-side inspections. For reasons discussed above it may happen that the vehicle which has passed the periodical inspection is stopped and fails the road-side tests. It may lead to disputes between drivers and inspectors and impair the credibility of the whole inspection system.

It is recommended:
1. To use the same smoke test method for mandatory periodical inspections and random on-road checks of diesel vehicles.
3. To upgrade the standard of periodical inspections with regard to emission in order to remove existing shortcomings in measurements.

5. Sri Lanka

In Sri lanka no emission standards either for new - or in-use vehicles are in force, therefore no control with regard to emissions is carried out. The existing inspection system, after some modifications, could be a good basis for emission control if any requirements were introduced.

In Sri Lanka, motor vehicles are subjected to mandatory inspections at the first registration conducted by examiners of motor vehicles. Vehicles belonging under the certified type are exempted from such inspections. During the inspections particulars necessary for the registration are checked (e.g. chassis/engine number, dimensions, weight etc.).

All commercial vehicles should be subjected to mandatory annual inspections in order to obtain a fitness certificate. This certificate is issued by licensed examiners at workshops (garages). Examiners of Department of Motor Traffic (DMT) issue certificates for governmental vehicles. The fitness certificate has to be produced at the Registrar of Motor Vehicles to obtain the annual revenue licence. Both the certificate and licence should be displayed on the vehicle windscreen. The inspection includes, among others, visual checks of components affecting the emission level: fuel injection system and exhaust system.

Private vehicles are not subjected to any periodical inspections. Examiners of motor vehicles in collaboration with Police Department conduct road-side checks of vehicles with regard to their roadworthiness. So far these checks have been concentrated on commercial vehicles. Vehicles which have failed the checks may obtain orders of "prohibition of use". These vehicles are expected to be repaired and produced for the reinspection within a specified period. However there is no compulsion for the owner to repair such a vehicle and submit it for reinspection. Unless the vehicle is detected while being used on the road no action could be taken to compel the owner to rectify the defects specified in the order of prohibition. Owners/drivers of defective vehicles may be fined up to 200 Rps. The order of prohibition may be issued during road-side checks also in case the vehicle emits very heavy smoke which is regarded as a threat from the point of view of traffic safety.

It is recommended:

1. To set emission standards for diesel vehicles in lines with point 6.3 above. Motor Traffic (Construction of Vehicles) Regulations 1983 should be amended for this purpose.
2. To introduce emission checks for commercial diesel vehicles during mandatory annual inspections for a fitness certificate and for all diesel vehicles during random on-road checks.
3. To amend Part IX of Motor Traffic Act in order to take provision enabling competent authorities to penalize the vehicle owner if the vehicle for which the order of prohibition has been issued is not repaired and submitted for inspection within the prescribed period.

6. Thailand

The following emissions standards for in-use vehicles are in force in Thailand:

i) petrol-driven vehicles - CO content at idle - 6% vol.

ii) diesel-driven vehicles smoke level:

- measured by free acceleration method - 50% (Bosch),
- measured at full-load at 60% of maximum rated speed: 40% (Bosch) or 52% HSU.

The compliance with the above standards is checked:
- during periodical (registration) inspections,
- during road-side inspections.

All motor vehicles covered by Land Transport Act (fixed route busses, chartered buses, private busses, common carrier trucks, private trucks, small rural trucks) and the following vehicles covered by Motor Vehicle Act: interprovincial taxis, urban taxis, fixed route taxis, motortricycle taxis, hotel taxis, tour taxis and cars for hire must undergo technical inspections before the registration and payment of tax. These inspections are conducted annually by inspection centers under the Department of Land Transport. The inspections include four groups of checks:

1 brakes, engine, chassis, emission and noise
2 lighting, electric system, glasses and mirrors,
3 steering, undercarriage,
4 body, seats, dimensions.

Other vehicles covered by Motor Vehicle Act i.e. cars (up to 7 passengers), microbusses and passenger pick-ups, vans, motortricycles, motorcycles are not subjected to any periodical inspections. They have to undergo an inspection only in the following cases:

- change of ownership,
- change of colour,
- transfer from one province to another.

Draft Regulation No.37 from 8 April 1992 concerning the periodical inspection of this group of vehicles was prepared. Private workshops are to be licensed for this purpose.
The implementation of the requirements depends on the decision of the government. Moreover, there are plans to increase the frequency of inspections for taxis to 2 times per year.

In 1991 there were in Thailand 39 fully equipped centers for vehicles covered by Land Traffic Act. In addition, 18 centers were under construction. It is planned to increase the number of centers to 75 in 1993.

The result of the annual inspection fall into two categories: either "vehicle accepted" or "checks failed". If the vehicle has failed the inspection, all unaccepted items have to be repaired. If the vehicle is submitted for reinspection within 15 days, only unaccepted items are rechecked. The results of the emission inspection carried out at the centers under Department of Land Transport in 1991 are summarised in Table A1/10.

Table A1/10

Results of CO and smoke periodical inspection in Thailand in 1991

	Number of vehicles inspected	Number of vehicles which failed	Failure rate (%)
CO *	530 015	2896	0.5
smoke **	38 892	290	0.7

* vehicles covered by Motor Traffic Act,
** vehicles covered by Land Transport Act; only inspections by Central Office in Bangkok.

To enforce the compliance with the standards in force, road-side inspections are conducted by uniformed officers of Department of Land Transport. If a vehicle does not meet the set requirements with regard to smoke level or CO content, its owner/driver can be fined up to 500 baht (for motorcycles only 100 baht).

The results of road-side inspections of diesel-driven vehicles in 1991 are shown in Table A1/11.

Results of smoke road-side inspections in Thailand in 1991. Table A1/11

Number of inspected vehicles	Number of vehicles which failed			Failure rate (%)	Rate of vehicles which had smoke between 40-50%
	Busses	Trucks	Total		
79457	10177	3243	13420	16.9	78.0

As it has been mentioned, two methods for smoke measurements are specified in the standard. The set limits for these measurement methods, i.e. 50% Bosch at free acceleration and 40% Bosch or 52% HSU under full load steady speed conditions do not correspond with each other. The latter are very stringent and can not be met by the majority of in-use uncontrolled and medium-emission vehicles. They correspond to about 30% Bosch at free acceleration (the correlation between the results of both methods is not good). Therefore, if is recommended to delete the load method and limits from the standard. Although two methods are specified, only the free acceleration method is used for the inspection of in-use vehicles.

Two measurements (acceleration cycles) are conducted and the maximum value is taken as the final result.

The test procedures for CO and smoke measurements are not described in detail in the standard. The following equipment is used for the inspection:

i) for CO measurements (NDIR analysers):
   - Riken CO/HC (CO range: 0-2 and 0-10% vol.; HC range: 0-300, 0-2000 and 0-10000 ppm as hexane)
   - Sun,
   - Horiba,

ii) for smoke measurements:
   - Bosch smokemeters.

The visit to one of the inspection centers showed that the following shortcomings were committed in emission tests:

a) the suction time of used smokemeters was different and varied from about 2.5 s to 5.5 s;

b) the accelerator pedal was depressed by one of the inspectors and the smokemeter was operated by another, with no contact between them; as a result the suction device of the smokemeter was usually put into operation too late;

c) probes were inserted not deep enough into vehicles tailpipes.

It is recommended:

1. To make uniform the emission limits and measuring methods specified in the regulations issued by Police Department on one hand and on the other hand by Department of Land Transport (DLT) and Office of the National Environment Board (ONEB).
2. To delete the full-load smoke measurement method for diesel vehicles in regulations issued by DLT and ONEB as it does not yield equivalent results with free acceleration method.
3. To specify in detail emission measuring methods for both diesel vehicles and vehicles equipped with SI engines in DLT/ONEB regulations in lines with points 6.2.2.2., 6.3.2.3. and 6.3.2.4. above. This is particularly important for smoke where the lack of detailed specifications results in some shortcomings in measurements (see Annex 1).
4. To introduce the sealing of full load stop screw in the injection pump during the periodical inspection of diesel vehicles. To complement this inspection by checks of vehicle systems affecting emission level.
5. To upgrade the standard of checks during the periodical inspection in order to remove committed shortcomings and errors (see Annex 1).
6. To gradually introduce mandatory periodical inspections for selected categories/groups of vehicle covered by Motor Traffic Act.

7. China

According to "Emission standard at idle for road vehicles equipped with petrol engines" No. GB 3842-83, emissions from petrol driven motor vehicles should not exceed the limits given in table below.

Table A1/11

CO and HC limits for petrol driven vehicles at idle in China.

Pollutant	Vehicle category	Allowable limits
CO	new vehicle	≤ 5%
	in-use vehicle	≤ 6%
	imported vehicle	≤ 4.5%
HC*	new vehicle	≤ 2500 ppm
	in-use vehicle	≤ 3000 ppm
	imported vehicle	≤ 1000 ppm

* Expressed as n-hexane.

The measurement are conducted in accordance with standard 3845-83 "Measurement method for pollutant emissions at idle speed from road vehicles equipped with petrol engines".

The standard specifies:

- requirements to be met by measurement instruments (for both components NDIR method),
- instrument preparation and calibration,
- vehicle preparation for measurement,
- measurement method.

Provisions of the standard are comprehensive and in line with those of points 6.2.2.2 and 6.2.3 of Guidelines as well as with Annex 4. The only reservation is that a period of 5s during which, according to point 6.1 of the standard, the engine should be maintained at a middle speed, is too short. International standards, e.g ISO 3929-1976, usually specifies at least 15s (see also point 6.2.2.2 of Guidelines). Moreover, requirements with regard to the position of manually operated preheating device in the engine inlet system ("summer" position) should be added in point 2.1 of the standard.

According to "Emission standard for smoke at free acceleration for road vehicles equipped with diesel engines" No. GB 3843-83, the smoke level of diesel driven vehicles should not exceed the limits given in Table A1/12.

The measurements are conducted in accordance with the standard GB 3846-83 "Smoke measurement method at free acceleration for road vehicles equipped with diesel engines". A filter-type smokemeter is specified for measurement. Its scheme is shown in attachment 4.

Table A1/12.

Smoke limits for diesel driven vehicles in China.

Vehicle category	Limits (^{o}B)
new vehicles *	5.0
imported vehicles	5.0
in-use vehicles	6.0

* for new vehicles in Beijing - 3.0^{o}B.

The suction volume of the plunger-type pump is 330 ± 15 cm^3 and the specified suction time is equal to 1.4 ± 0.2 s. Free accelerations are run from low idle speed. The standard specifies that the accelerator pedal should be depressed for about 4 s and the total cycle (acceleration, deceleration and idle) should last about 15 s. 3 preliminary cycles are conducted to clean the exhaust system and 3 cycles for actual measurements. The average of these 3 readings is taken as the final value.

After each acceleration the probe and sampling line are purged with air (see attachment 4). When the suction commences, the pure air enters the pump in the first place. As a result readings depend very much on the total volume of the sampling line (see Annex 3). However, this volume is not precisely determined as the standard does not specify the precise inner diameter of the line but reads that it should not be less than 4 mm. The reproducibility of the measurement method would be considerably improved if a precise requirement with regard to this diameter were given in the standard. All other specifications with regard to the smokemeter and measurement method are correct and fully satisfactory.

As regards motorcycles (which are not defined as "motor vehicles"), the following emission limits at idle are in force:

i) for motorcycles equipped with 2-stroke engines:
CO - 4.5% vol., HC - 8000 ppm,

ii) for motorcycles equipped with 4-stroke engines:
CO - 5.5% vol., HC - 2200 ppm.

The measurement method is specified in the standard GB 5466-85 "Measurement method for pollutant emission from motorcycle at idle speed".

The above emission standards came into force beginning from 1 April 1984. They initially applied to vehicle control in manufacturers production lines. They have been applying to in-use vehicle inspection since 1986.

The standards for motor vehicles equipped with both petrol and diesel engines were drafted by Beijing Automotive Research Institute and Highway Research Institute. The standard for motorcycle was drafted by Chungchun Automobile Research Institute. All standards were approved by the Ministry of Urban and Rural Construction and Environmental Protection.

The compliance with the requirements laid down in aforementioned standards is checked:

- during pre-registration inspections,
- during mandatory periodical inspections,
- during random road-side checks.

Before the first registration in China, every vehicle has to undergo a technical inspection, the scope of which is as follows:

- appearance,
- tachometer and odometer,
- side slip,
- brakes,
- emissions,
- horn and headlights.

The inspection is conducted at stations licenced by the Ministry of Public Security. The vehicle should meet the limits for new vehicles listed in Tables A1/11 and A1/12. If the vehicle passes the inspection, a certificate is issued which has to be produced to the registration office.

Every in-use vehicle should be submitted to annual safety inspection carried out also by stations licenced by the Ministry of Public Security. The scope of these inspections is similar to that of pre-registration inspections. Furthermore, commercial passenger vehicles (taxis, long-distance buses etc.) undergo inspections for technical conditions. They are run by so called "comprehensive" inspection stations licenced by the Ministry of Communications. Their scope is larger than those of safety inspections. Additional items such as measurement of power and fuel consumption are included. Vehicles subjected to annual safety inspections or inspections for technical conditions should satisfy the "in-use" limits (Tables A1/11 and A1/12).

The traffic police together with environment protection centres occasionally conduct vehicle road-side checks which include emission measurements.

Apart from the aforementioned inspections, emissions are checked during so called second class maintenance services which are carried, together with adjustments, after every 13000 - 15000 km. However, this applies in the first place to commercial vehicles run by governmental transport enterprises.

Altogether there are in China about 300 inspection stations, 150 being under the Ministry of Public Security. The following equipment is used for emission measurement:

- CO/HC NDIR analysers, model Mexa-324 manufactured by Fushan plant of analytic instruments,
- filter-type smokemeters, model FQD-201 manufactured by a factory in Wenzhou and model FBY produced by a plant in Fushan.

The instruments are checked once a year by Technical Certificate Board. A special sticker is attached to the instrument to certify its compliance with requirements.

The aforementioned standards are being revised. The proposal limits for petrol driven vehicles are listed in Table below.

Table A1/13

Proposed revised emission limits for petrol driven vehicles in China

Vehicle category	Low idle speed			Raised idle speed of 1500-2500r/min
	CO [%]	HC [ppm]		CO [%]
		4 stroke engine	2 stroke engine	
Date of issue				
New-model M.V.	4	1500	5500	2.5
Newly manufactu-red M.V.	4.5	2000	6500	3
In-use M.V.	5.5	2500	7500	4
After Jan,1.1995				
Newly manufactu-red M.V.	4	1500	6000	2.5
In-use M.V. de-livered after Jan,1.1995	4.5	2000	7000	3.5
After 2000				
New-model M.V.	3.5	1000	5000	2
In-use M.V. de-livered before Jan,1.1995	5	2500	7500	4

In order to improve the effectiveness of current motor vehicle inspection for emission control it is recommended:

1. To introduce the following amendments to the standard GB 3845-83:
   - to specify the position of air preheating device in point 2.1,
   - to increase the time specified in point 6.1 from 5 s to at least 15 s,
2. To specify precisely the inner diameter of the sampling line (or its volume) in point 3.4 of the standard GB 3846-83,
3. To check the suction time and the sampling line diameter/ volume during annual attestation of smokemeters.

8. Hong Kong

According to Road Traffic (Construction and Maintenance of Vehicles) Regulations 1983, every motor vehicle shall be so constructed and maintained that no excessive smoke or visible vapour is emitted form it. The smoke or visible vapour is deemed to be excessive if exceeds the level of:

$$60HSU \text{ or } 2.13\ m^{-1}$$

when measured by means of Hartridge MK3 smokemeter. There are no provisions with regard to emissions of gaseous pollutants (CO,HC) from petrol driven vehicles.

The compliance with the aforementioned requirement with regard to smoke level is checked:

- in the framework of "Smoky Vehicles Control Programme"'
- during mandatory periodical inspections.

"Smoky Vehicles Control Programme" has been run by Vehicle Emission Control Section (VECS) of Environmental Protection Department (EPD) since 1988. Up to September 1991 smoke tests were carried out by a testing centre operated by VECS. The testing capacity was then expanded by licencing private testing centres to conduct inspections. The current number of these centres is 19.

The control of vehicle smoke emission is conducted through a spotting - calling up - testing procedure. Smoke spotters are: accredited persons, police officers and EPD staff. All of them are volunteers trained by VECS according to a special programme. They usually travel in vehicles or are stationery at cross roads. When spotting a smoky vehicle, they fill in a special report form (attachment 5) and send it to VECS. After receiving a report,VECS compares particulars of the spotted vehicle with those obtained from Transport Department (register of vehicles) through computer link. If these particulars correspond to each other, an emission testing notice is prepared and post to vehicle owner(s) by registered mail. The case may be dropped if:

- spotting particulars are incorrect or incomplete,
- the vehicle is already under EPD or Transport Department (DOT) action.

Furthermore, the action is not taken in the case of franchise buses, government vehicles and army vehicles (so called "referral cases"). If the action is taken against the vehicle, a computer code is added to the vehicle register to prevent the vehicle under action from licence renewal or transfer. The owner who has received the emission testing notice is required to correct any defects affecting smoke level and to submit the vehicle for testing within 18 days. Tests of heavy duty vehicles (trucks and double-deck buses) are conducted by EPE testing center (one in Hong Kong). Other vehicles are tested in private testing centres, the vehicle owner being able to select anyone of them. The test procedure is specified in great detail in Code of Practice for Designated Vehicle Testing Centre. The centre determines whether the vehicle has passed or failed the tests and records the data on an emission test form. The centres are required to forward reports all emission test forms and daily summary) to EPD within 3 working days after the test.

If the vehicle passes the test, a certificate of compliance is issued by the testing centre. After receiving the report, EPD removes the computer code from the vehicle register. If the vehicle is not able to pass the test or it is not submitted for testing within 18 days, its registration may be cancelled.

The free acceleration from low idle speed is used for smoke testing. Three preliminary acceleration cycles are conducted to clean the exhaust system and check that the pressure in the Hartridge smokemeter is within specification. Afterwards three cycles for actual measurement are performed. The average of the 3 readings is the smoke value. The maximum spread should not exceed 5HSU.

The used measurement method differs from that applied in some other countries in the following respects:

- the by-pass valve is closed after each acceleration and open immediately before next acceleration,
- if the vehicle has two (or more) exhaust outlets, the highest (not average) result is the smoke value.

The centre may refuse to test the vehicle if the vehicle is unable to attain the maximum speed specified by the manufacturer, is slow in picking up speed or shows any signs of abnormal adjustment or tempering. The vehicle may be tested visually in the following cases:

- smoke level at idle is unreasonably high,
- the exhaust pipe is broken or leaky,
- the sampling pressure is too low,
- exhaust pipe is too small for the probe or obstructed.

The mandatory periodical inspections are performed by inspection stations operated or licenced by Transport Department. The smoke level of diesel driven vehicles is one of the items to be inspected. The following vehicles undergo such inspections:

- private cars older than 6 years - annually in private stations licenced by DOT,
- light goods vehicles older than 4 years - annually in private stations licenced by DOT,
- medium/heavy duty goods vehicles older than 10 years - annually in private stations run by DOT,
- light buses, buses, taxis - annually in inspection stations run by DOT.

The effectiveness of smoky vehicle control programme in Hong Kong is very high. The whole programme is comprehensive and original. A further improvement of effectiveness may be achieved by preventing from the tempering of fuel injection equipment e.g. by sealing the injection pump stop screw.

9. Philippines

According to "Rules and Regulations for the Prevention, Control and Abatement of Air Pollution from Motor Vehicle (1979)" issued by National Pollution Control Commission pursuant to

Presidential Decree No. 1181, the following emission standards for in-use vehicles (called "registered vehicles") are in force:

i) diesel-fueled vehicles:
light absorption coefficient of exhaust gas (smoke level) should not exceed 2.5 m^{-1} (equivalent to 65HSU),

ii) gasoline-fueled vehicles:
carbon monoxide and hydrocarbons concentrations at idle should not exceed the limits specified in Table below.

Table A1/14

CO and HC limits for in-use gasoline-fueled vehicles in the Philippines.

Vehicle model year	CO [% vol.]	HC [ppm]
1976 - 1981	4.5	1000
1971 - 1975	5.0	1000
1965 - 1970	5.5	2000
1964 and later	6.0	2000
2-stroke engine	6.0	7800

The road-side inspection is conducted by Department of Environment and Natural Resources (DENR) - Environmental Management Bureau. At present, it is in practice limited to control of smoke emissions from diesel-fueled vehicles, in particular in Metro Manila. Smoke standard is enforced by anti-smoke teams which, after spotting smoky vehicles, pull them over and conduct visual checks using a Ringelman chart. The limit for road-side inspections is number "5" in Ringelman scale. If the vehicle fails the test, its registration plate is confiscated and a ticket issued instructing the owner/driver to have the vehicle properly tuned or repaired and requesting him to report to DENR Motor Vehicle Test Center in Quenzon City for final testing. However, this testing is not mandatory. The owner/driver has two options:

i) to pay a fine at DENR office and have the registration plate returned,

ii) to submit the vehicle for testing.

In the latter case, the test is conducted by means of Hartridge MK3 smokemeter. The limit is 65HSU in accordance with the standard in force.

If the vehicle passes the test at DENR centre, the certificate of compliance is issued which is valid for 6 months. No penalties can be imposed during this period even when the vehicle is caught when emitting excessive smoke. If the vehicle is submitted for testing within 24 hours after apprehension and passes the test, no fine is levied. However if it is submitted after 24 hours the fine must be paid even if the test has been passed. In both the cases, the registration plate is returned upon presentation of the certificate of compliance.

If the vehicle fails the test, a so called "grounding" or "prohibition of use" order is issued but it is often ignored. Also in this case, the registration plate is returned after the fine has been paid.

Fines for excessive smoke emissions are as follows:

- for first offence - 200 pesos,
- for second offence - 500 pesos,
- for third and further offence - 1000 pesos.

The free acceleration test from low idle speed is used for smoke measurement. It is specified in Annex 1 to the aforementioned "Rules and Regulations". Three acceleration cycles are prescribed, the test result being the arithmetic mean of the 3 stabilized values. Measurement values are regarded as stabilized if they are within a band width of 0.3 m^{-1} and do not form a decreasing sequence. Before the test, drivers are instructed to warm-up the vehicle and to carry out preliminary accelerations to clean the exhaust system. Like in Hong Kong, the by-pass valve of smokemeter is closed after each acceleration.

The mandatory periodical inspection of in-use vehicles with regard to emissions is conducted by LTO. Its rules are specified in Administrative Order No. AQ-91-005 establishing the new inspection system of in-use motor vehicles.

At present, the inspection under the new system is limited to the following categories:

a) all "for hire" motor vehicles, except tricycles, in Metro Manila,

b) all "for hire" provincial buses whose authorized routes include Metro Manila.

The inspection with regard to emission is part of overall roadworthiness inspection. The emission limits are as follows:

a) petrol-fueled vehicles:

carbon monoxide	- 6% vol.
hydrocarbons	
- vehicles with 4-stroke engines	- 1200 ppm,
- vehicles with 2-stroke engines	- 7800 ppm,
- vehicles with rotary engines	- 3300 ppm,

b) diesel-fueled vehicles:

smoke level	- 2.5 m^{-1} or 65HSU or 4.8°Bosch unit.

The limits for petrol-driven vehicles differ slightly from that specified in the aforementioned "Rules and Regulations". As regards smoke, filter-type smokemeters are used for measurement. Three acceleration cycles are performed and the arithmetic mean is taken as the test value. The sampling probe and line are purged with air after each acceleration. The limit for Bosch smokemeter was determined on the basis of correlation between Bosch and Hartridge smokemeters given in SAE Information Report J 255a. It is to note that this correlation is valid for steady-state and not for free acceleration measurement (see point 4 of this Annex).

The frequency of the inspection is as follows:

- for buses and jeepneys - every year,
- for taxis - every six months.

Moreover, the vehicles should undergo inspections in the following cases:
- change of ownership,
- change of engine or chassis.

In spite of the fact that, as regards the number of inspected vehicles, a far-flung anti-smoke campaign is conducted in Metro Manila, in particular by DENR (Table A1/15), its result are not satisfactory. The majority of in-use diesel vehicles emits excessive smoke. The main reason for relatively low effectiveness seems to result from the fact that the testing of apprehended vehicles in order to check whether they have been properly tuned up/repaired is not mandatory. Many vehicle owners/drivers prefer to pay fines instead of putting their vehicles into compliance with the standard. Moreover, it is worth noting that the apprehension limit is very lenient ("5" Ringelman number means a very dense black smoke of more than 90HSU). The registration number of vehicles which do not comply with the smoke standard are sent to Land Transportation Office (LTO) with a request to refuse the renewal of registration, however no action is taken in this respect.
In order to improve the standard and effectiveness of in-use vehicle inspections for emissions control it is recommended:

Table A1/15

Yearly summary of anti-smoke campaign in Metro Manila in the period 1977-1991

Year	Number of apprehended vehicles*	Number of vehicles which have passed the tests**
1977	657	349
1978	5060	1860
1979	5780	1730
1980	3096	809
1981	9948	2173
1982	18054	3543
1983	16224	5366
1984	12584	3160
1985	13371	5297
1986	7520	1726
1987	9190	2047
1988	2436	1484
1989	26551	19592
1990	42088	16827
1991	27781	16609

* which have failed road-side tests (limit: "5" Reingelman number),

** tests at DENR center (limit: 65 HSU).

1. To introduce common, uniform emissions limits for both road-side checks and periodical inspections,
2. To establish the correlation between readings of Bosch and Hartridge smokemeters and to correct the limit for Bosch smokemeters and, as ultimate goal, to use the same smoke test method and instruments for both mandatory periodical inspections and random road-side checks,
3. To specify the smoke test method more comprehensively and in line with point 6.3.2 of Guidelines,
4. To strengthen the cooperation between DENR and LTO in the area of emission control,
5. To introduce the provision that all vehicles, which have failed the road-side checks, should undergo tests at testing centres (the registration plate should be returned only if the certificate of compliance with smoke requirements is produced),
6. To gradually reduce the limit for road-side inspections to "4" Ringelman number.

10. Indonesia

According to Decree of Minister of Communications No. KM8 issued on 20 February 1985 concerning requirements for roadworthiness of motor vehicles, trailers, semitrailers and components the maximum emission level should not exceed:

i) motor vehicles fueled with premium petrol having research octane number higher than 87:
   - carbon monoxide - 4.5% vol.,
   - hydrocarbons - 1200 ppm,

ii) motor vehicles fueled with diesel oil having cetane number higher than 45:
   - smoke level - 50% .

The test procedure for emission is specified in Decree No.AJ402/8/5 issued by Director General of Land Transport on 11 September 1990. The procedure for measurement of CO and HC is similar to that laid down in ISO standard 3929-1976. No specifications are given for measurement of emissions from 2-stroke engines. As regards smoke, the free acceleration method from low idle speed is prescribed. Filter-type smokemeters are used for measurement. They should meet the following requirements:

- suction volume - 330 ± 15 cm^3,
- suction time - 1.4 ± 0.2 s.

2-3 preliminary accelerations are prescribed for cleaning the exhaust system. The measurement cycle lasts 15 s and is composed of:

- operation with the accelerator fully depressed - 4 s,
- operation with the accelerator released - 11 s.

The measurement cycle is repeated 3 times and the average is taken as a test value. It is specified that the acceleration and suction should start at the same time.

According to Act Number 14 of 1992 concerning Traffic and Road Transport all in-use motor vehicles should undergo mandatory periodical inspections (called "regular" inspections). For the time being, such inspections are conducted for taxis, goods vehicles, buses, trailers and semitrailers. Emission checks is one of the inspection items.

Inspections of the above mentioned vehicles are carried out by stations run by Department of Home Affairs. There are two kind of stations:

- so called "mechanical" stations, having equipment for testing, exhaust gas analysers and smokemeters included,
- so called "conventional" stations, where checks are conducted visually.

The total number of mechanical stations is 67. Portable Horiba Mexa and Komyo Urex analysers are usually used for CO and HC measurements. As regards smoke level, the measurement are conducted by means:

i) Bosch smokemeters (24 stations in West Java),
ii) Japanese filter-type smokemeters, mainly Isaga, Anzem, Banzai Kiki.

It is to note that Bosch and Japanese smokemeters do not yield the same results when used for free acceleration measurements. The difference in readings may exceed 20-40% of the measured value. It is due to the following reasons:

i) volumes of sampling lines are different,
ii) sampling probe and line are purged with compressed air after each acceleration in Japanese smokemeters,
iii) in japanese smokemeters the suction pump is put into operation by means of a switch attached to the accelerator pedal, therefore the suction beginning corresponds to the beginning of acceleration, in Bosch smokemeters this condition is not always met. In this connection, different smoke limits should be specified for Bosch and Japanese smokemeters (Fig. 3/7 in Annex 3).

A visit to one of the inspection stations showed that specifications laid down in the test procedure are not fully followed in practice. This applies in the first place to smoke measurements.

Requirements with regard to motor vehicle emissions are laid down not only in the aforementioned Decree No. 8/1989 but also in the following documents:

i) Decree No. 1222/1990 issued by Governor DKI Jakarta (Table A1/16),
ii) Decree No. KEP-02/MENKLH/I/1988 issued by Minister of Population and Environment
(CO - 4.5% vol., HC - 3300 ppm for two-wheelers).

Random inspections, e.g. road-side ones, for emission are in practice not conducted. The Ministry of Population and Environment is now considering launching "Blue Sky Programme" in which checks with regard to smoke level would be introduced.

Table A1/16

Basic standards for motor vehicle emissions in Jakarta.

Type of vehicles	Type of fuel	Emission limit			
		CO [%]	NO_x [ppm]	HC [ppm]	Smoke [%]
Passenger car	gasoline or premix	4.5	1,200	1,200	-
	diesel fuel	-	1,200	1,200	50
	gasoline 2-stroke	4.5	1,200	1,200	50
	CNG	3.0	-	-	-
Goods vehicle	gasoline or premix	4.5	1,200	1,200	-
	diesel fuel	3.0	1,200	1,200	50
	CNG	4.5	-	-	-
Bus	gasoline or premix	4.5	1,200	1,200	-
	diesel fuel	-	1,200	1,200	50
	CNG	3.0	-	-	-
Motorcycle	gasoline or premix	4.5	2,800	2,400	-
	gasoline 2-stroke	4.5	3,600	3,000	-

In order to improve the standard of motor vehicle inspections for emission control, it is recommended:

1. To harmonize requirements concerning emissions from motor vehicles issued by different institutions,
2. To establish the correlation between smoke readings of different smokemeters used in inspection stations and to correct limits accordingly. Only smokemeters type-approved by competent authority should be use in these stations,
3. To introduce the specifications with regard to vehicles equipped with 2-stroke engines into the test procedure,
4. To enforce inspection stations to conduct tests as per specifications by training of personnel and supervision,
5. To introduce and gradually increase the extent of random side-road checks, in particular with regard to smoke level.

अधिकृत केन्द्र कोड
Authorised Station Code

0	9	1

प्रदूषण नियंत्रण आंच प्रमाण पत्र
POLLUTION CONTROL CHECK CERTIFICATE

परिवहन निदेशालय, दिल्ली प्रशासन द्वारा अधिकृत
AUTHORISED BY
DIRECTORATE OF TRANSPORT, DELHI ADMINISTRATION

No. 16750

वाहन पंजी सं०
Vehicle Regn. No. DIU 6510

मेक :
Make : Bj Priya

वर्ष :
Year : 1985

निर्धारित मानक PRESCRIBED STANDARD	मापित स्तर Measured Level
पेट्रोल चालित वाहनों के लिए आइडलिंग गति पर CO उत्सर्जन स्तर Idling CO Emission Limit For Petrol Driven Vehicles :	आइडलिंग गति पर CO उत्सर्जन पर Idling CO Emission Level
चौपहिया वाहनों के लिए Four Wheeled Vehicles - 3% आयतन द्वारा (By Volume)	2.5
दुपहिया व तिपहिया वाहनों के लिए Two & Three Wheeled Vehicles - 4.5% आयतन द्वारा (By Volume)	______ % आयतन द्वारा (By Volume)

प्रमाणित किया जाता है कि इस वाहन का CO उत्सर्जन स्तर के मो वा.अधिनियम, 1989 के नियम 115 (2) में निर्धारित स्तर के अनुसार है।
Certified that this vehicle's CO emission level conforms of the standards prescribed under Rule 115 (2) of CMV Rules, 1989.

टिप्पणी : यदि आप को कोई शिकायत है तो कृपया प्रदूषण नियंत्रण शाखा, परिवहन निदेशालय 5/9, अंडरहिल रोड, दिल्ली-110054 को लिखें।

Note ; In case of any complaint, please write to Pollution Control Division, Directorate of Transport, 5/9 Under Hill, Road, Delhi-110054

पुन:निरोक्षण 90 दिन बाद करवाएं
Advised Re-check after 90 days
छह माह के लिए मान्य
VALID FOR 6 MONTHS

RAM PARKASH CHOUDHRY
अधिकृत हस्ताक्षर कर्ता : PARAMJIT SINGH
AUTHORISED SIGNATORY :
MALCHA FILLING STATION
Palam Marg, Vasant Vihar New Delhi-57
दिनांक :
DATE : 17-2-92
समय :
TIME : 1730 Hrs.


POLLUTION UNDER CONTROL
030

SCHEDULE C

(Rule 3 (2))

MOTOR VEHICLE SMOKE EMISSION TEST CERTIFICATE

Serial No..............................

Registration No. of Motor Vehicle..

Time..Date..

Make of Vehicle..............................Testing Station..............................

Class..at..

Type..

Make Model and serial number of Smoke Meter used for test..........................

Date last calibrated..

Type of Test: *Free Acceleration.*

RECORD OF SMOKE EMISSION TEST

Test No. 1..Smoke Units

Test No. 2..Smoke Units

RESULTS:

Average Test No. (   ) and Test No. (   ) ....Smoke Units

I certified that the above-mentioned motor vehicle has been tested for smoke emission capability and found to emit a smoke density of.................... Smoke Units which does not exceed/*exceeds the smoke limit of.................. ....Smoke Units permitted under paragraph (1) of rule 3 of the Motor Vehicle (Control of Smoke and Gas Emission) Rules 1977.

Issued and Signed by......................................

Name (Block Letters)......................................

and

Designation of Testing Officer........................

TEST CERTIFICATE ISSUED TO

Owner/*driver of motor vehicle (name)..

of (Address)..

Time....................a.m./*p.m. Date.............................Place..............................

To whom issued: Owner/*driver (signature)...

Driving Licence No..Expiring..............................

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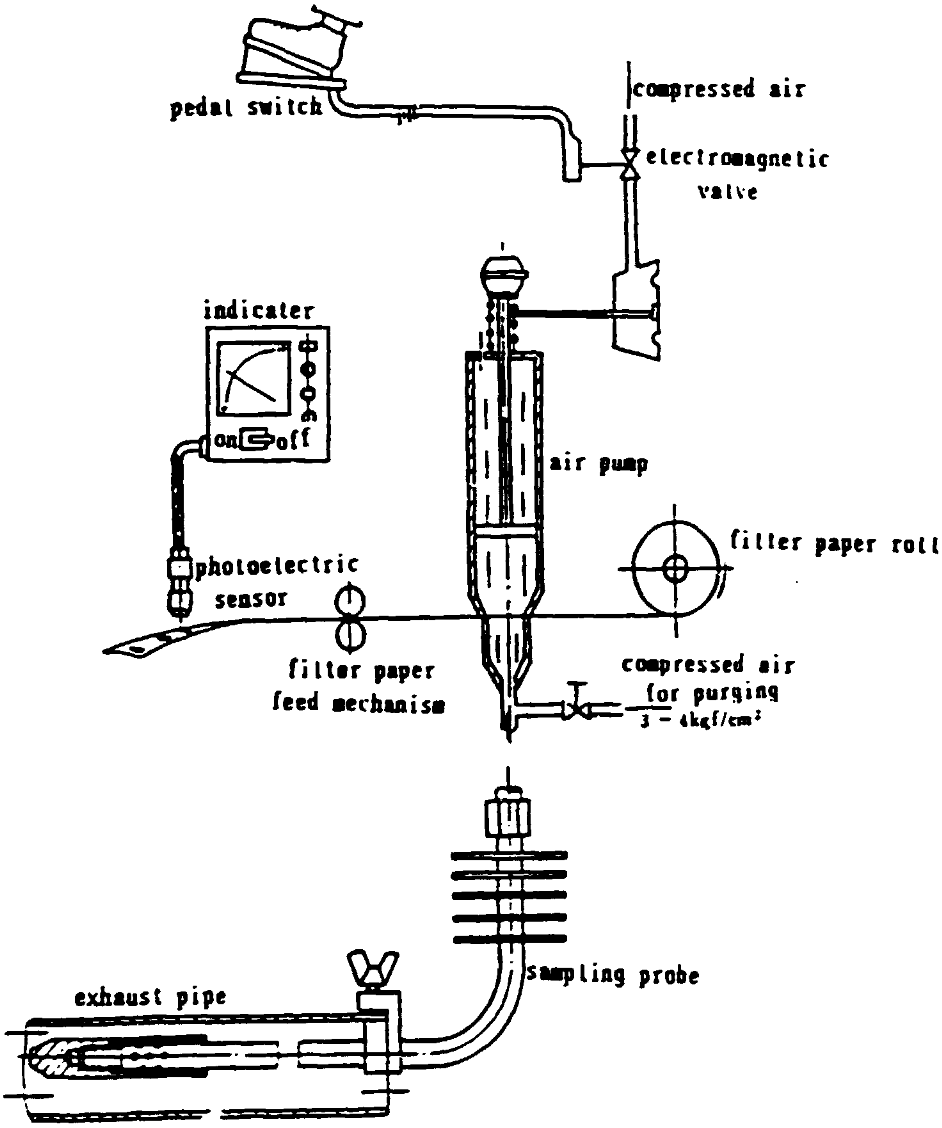
* Delete where applicable.


pedal switch
compressed air
electromagnetic
valve
indicater
on
off
air pump
filter paper roll
photoelectric
sensor
filter paper
feed mechanism
compressed air
for purging
3 - 4kgf/cm²
sampling probe
exhaust pipe

ENVIRONMENTAL PROTECTION DEPARTMENT

SMOKY VEHICLE REPORT FORM

REGISTRATION MARK

CLASS OF VEHICLE

1. ☐ LORRY	4. ☐ VAN	7. ☐ PUBLIC LIGHT BUS
2. ☐ FRANCHISE BUS	5. ☐ COACH	8. ☐ PRIVATE CAR
3. ☐ TAXI	6. ☐ MOTOR CYCLE	9. ☐ OTHERS

COLOUR

1. ☐ RED	5. ☐ GREEN	9. ☐ BLACK
2. ☐ YELLOW	6. ☐ BLUE	10. ☐ GOLD
3. ☐ ORANGE	7. ☐ WHITE	11. ☐ SILVER
4. ☐ GREY	8. ☐ BROWN	12. ☐ ________

DATE OF SPOTTING ____________________

TIME ____________

LOCATION ____________________

____

____

DEGREE OF SMOKE ☐ SERIOUS ☐ VERY SERIOUS

SPOTTER NO. ____________ **SIGNATURE** ____________

Please return completed form to:
Environmental Protection Department,
28/F., Southorn Centre, 130 Hennessy Road, Hong Kong.

EPD 33

POLLUTANT EMISSIONS FROM SI ENGINES AT IDLE SPEED

1. Effect of engine design and operating variables on emission.

The level of undesirable exhaust emissions from SI engines depends on the mixture formation and combustion processes. It is affected by many engine design and operating variables. The predominant role is played by air-fuel equivalence ratio (called also mixture strength) of the fresh charge supplied to the engine, symbolized by the Greek letter lambda (λ). With lambda equal to 1, the engine is receiving a stoichiometric air-fuel mixture. The effect of air-fuel equivalence ratio λ on engine performance and pollutant emissions is shown, in a simplified, qualitative way, in Fig.A2/1. What is characteristic is that individual parameters reach the extremum (minimum or maximum) values at different mixture strength which makes it difficult to properly tailor the fuel supply device, be if carburetor or injection system.

The engine power output is maximum at a mixture richer by about 10-15% than stoichiometric, i.e. at lambda equal to about 0.85-0.90. Mixture enleanment and enrichment result in power drop. This drop is particularly considerable with enleanment. The minimum fuel consumption occurs at mixture significantly leaner than that corresponding to maximum power. The optimum lambda is in this case usually on the order of 1.00-1.20. At the mixture strength corresponding to the best fuel consumption, the power output is lower by 10-15% than maximum and vice versa the fuel consumption at lambda values at which the maximum power occurs is higher by 15-20% than minimum. As regards emissions, carbon monoxide emissions decrease when the mixture gets leaner. Hydrocarbon emissions also drop with enleanment however only to so called lean limit. When this limit is exceeded, they steeply increase due to incomplete flame propagation and misfiring. This increase is accompanied by unstable engine operation resulting in surge and poor driveability which preclude such a lean carburetion. The effect of mixture strength on NO_x emissions is to some extent reverse. The maximum NO_x emissions occur at lambda by 5-10% higher than stoichiometric and fall off with both mixture enleanment and enrichment.

Trends concerning the effect of air fuel equivalence ratio on engine parameters, shown in Fig.A2/1, are typical of all SI engines irrespective of their design and operating variables. However these variables affect concrete characteristic values of lambda at which extremum values of power, fuel consumption, NO_x and HC occur. Moreover, they affect the rate of change of these parameters in a function of lambda. It is worth noting that CO and CO_2 concentrations in the exhaust gas depend relatively little on variables other than lambda.

As far as engine operation at idle is concerned, the maximum (indicated) power, minimum fuel consumption and lean limit usually occur at mixtures richer than those corresponding to load

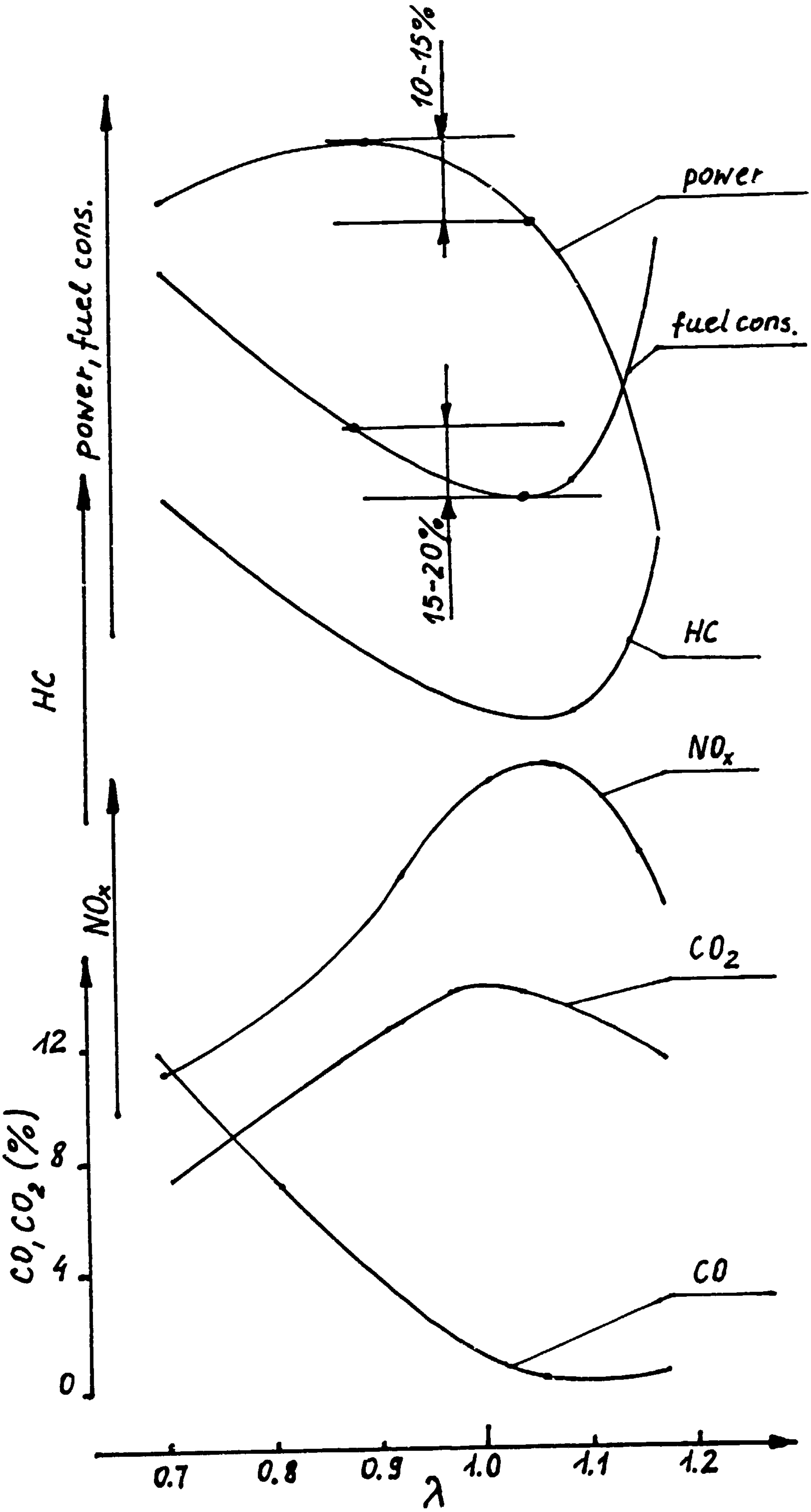


Fig. A2/1. Engine performances and emissions versus air fuel ratio.

conditions. Furthermore, HC concentrations are higher and those of NO_x considerably lower. This is particularly true of two-stroke engines where HC emissions are very high due to misfiring and scavenging the cylinder with air-fuel mixture, part of which blows through the cylinder directly into the exhaust and escapes the combustion process.

2. Idle adjustment

The engine idle operation is characterized by two interdependent main variables:

- engine speed (rpm),
- air fuel equivalence ratio.

The fuel system metering, particularly at idle, changes with time. The same applies to engine internal friction losses. Therefore, both carburetors and injection systems are provided with components for idle adjustments i.e. controls for changing the idle conditions of the engine. In carburetted vehicles, the operation at idle can be adjusted by means of:

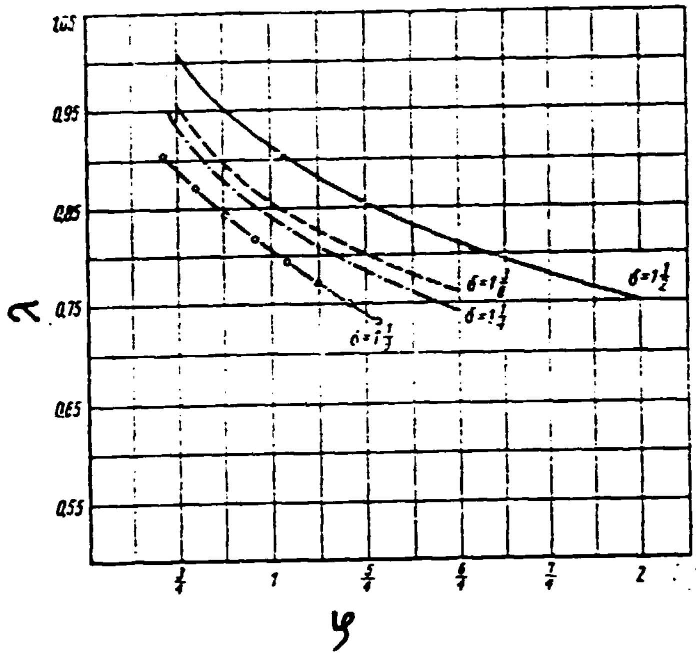
- idle mixture control needle,
- throttle stop control screw.

Injection systems are provided with equivalent controls. The adjustment of the above controls affects all engine parameters at idle. This is shown in Fig.A2/2. In this figure:
φ (the Greek letter phi) - means the position of the idle mixture control needle expressed as a number of turns by which this needle is turned out from the fully closed position,
δ (the Greek letter delta) - means the position of the throttle stop control screw expressed as a number of turns by which this screw is turned in from the position corresponding to the fully closed throttle.

It can be seen that with turning out the mixture needle:

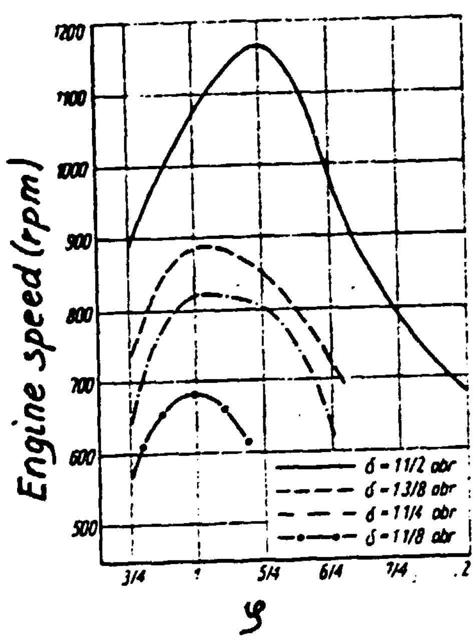
- air fuel mixture gets richer (Fig.A2/2a),
- engine speed initially increases, levels off at λ = 0.75-0.85 and corresponding CO concentrations about 5-6% vol. and drops afterwards; this trend results from the effect of lambda on power output shown in Fig.A2/1,
- fuel consumption increases (Fig.A2/2c),
- measured CO concentration increases (Fig.A2/2d); however when the mixture gets very rich, some drop in CO concentration may occur due to very high HC emissions resulting from partial misfiring,
- HC concentration gradually decreases, levels off and starts to increase (Fig.A2/2f),
- CO_2 concentration gradually decreases which is due to the fact that the mixture is richer than stoichiometric (Fig.A2/2e),
- the sum of CO and CO_2 increases and tends to level off; it may drop when the mixture gets too rich.

The effect of mixture control on idling parameters, shown in Fig.A2/2, is typical of engines equipped with carburetors with so a



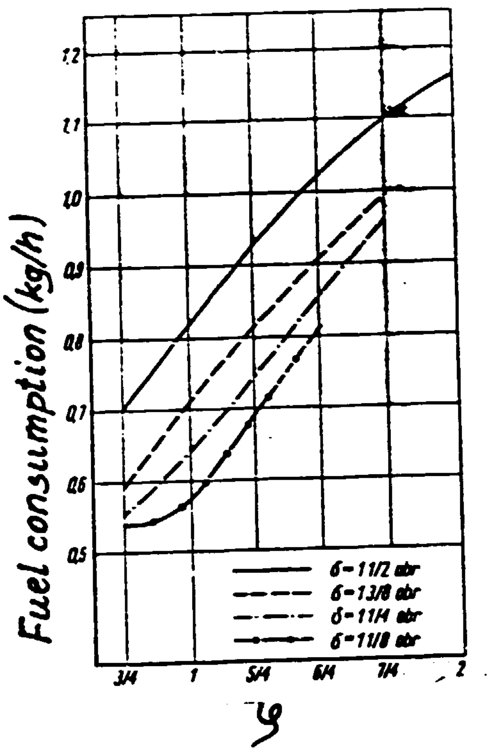
0.95
0.85
0.75
0.65
0.55
λ
φ
3/4
1
5/4
6/4
7/4
2
δ=1 1/2
δ=1 3/8
δ=1 1/4
δ=1 1/8

b

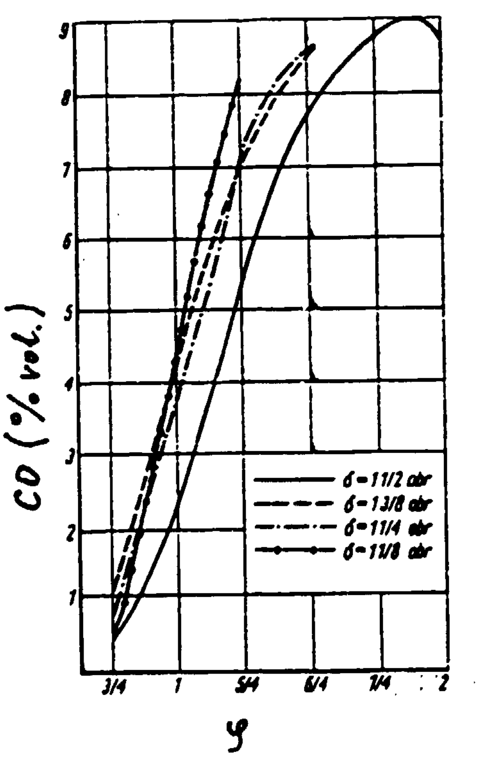


Engine speed (rpm)
1200
1100
1000
900
800
700
600
500
3/4
1
5/4
6/4
7/4
2
φ
δ = 11/2 abr
δ = 13/8 abr
δ = 11/4 abr
δ = 11/8 abr

c


Fuel consumption (kg/h)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
δ=11/2 abr
δ=13/8 abr
δ=11/4 abr
δ=11/8 abr
3/4
1
5/4
6/4
7/4
2
φ

d


CO (% vol.)
9
8
7
6
5
4
3
2
1
δ=11/2 abr
δ=13/8 abr
δ=11/4 abr
δ=11/8 abr
3/4
1
5/4
6/4
7/4
2
φ

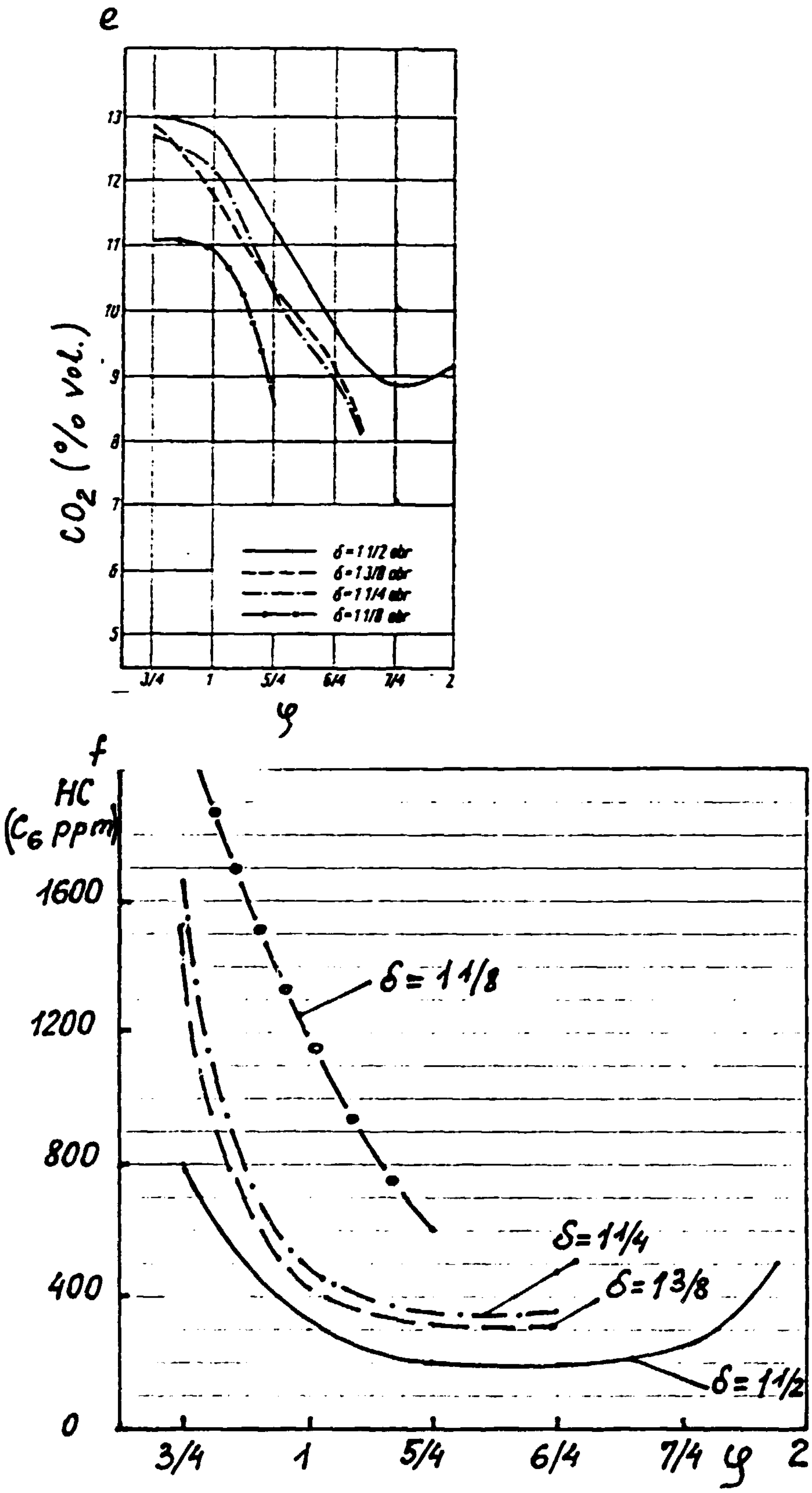


Fig. A2/2. Effect of idle adjustment on engine performances and emissions at idle.

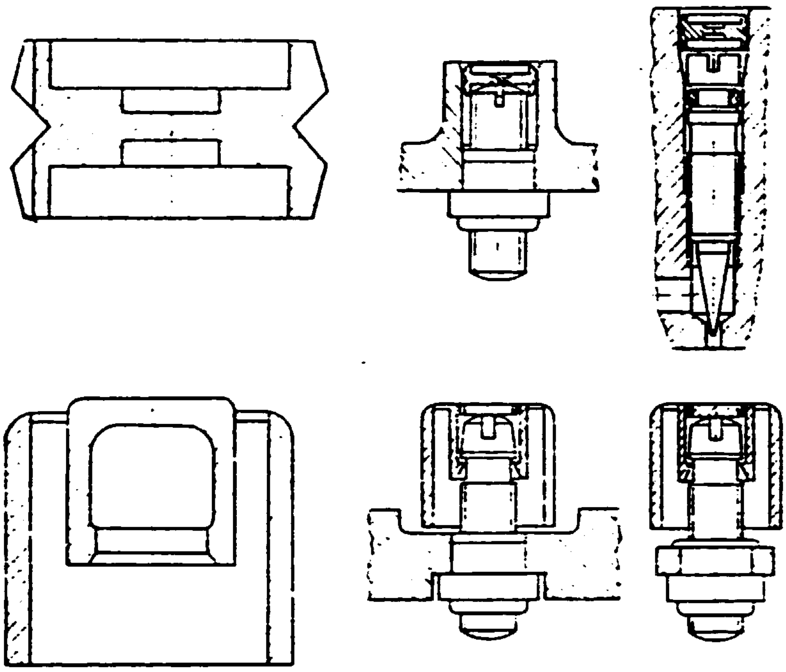


Fig.A2/3. Sealing of mixture needle

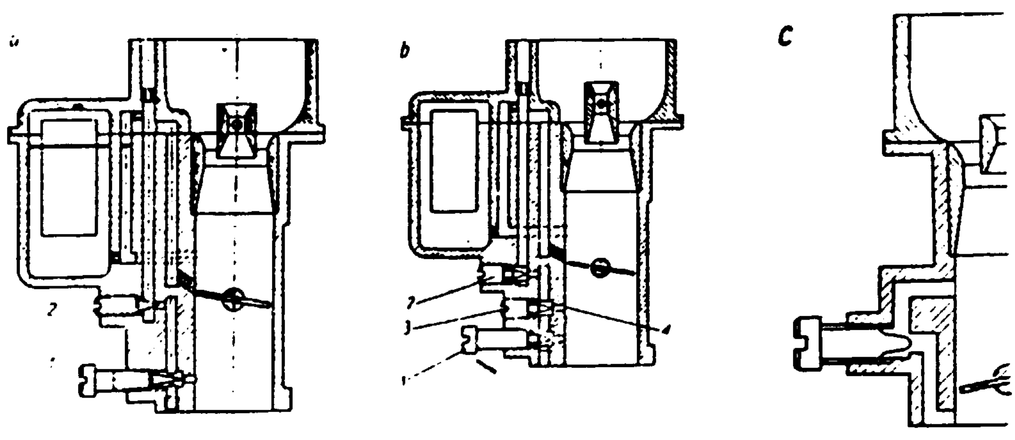


Fig. A2/4. Low-emission idle systems of carburetors

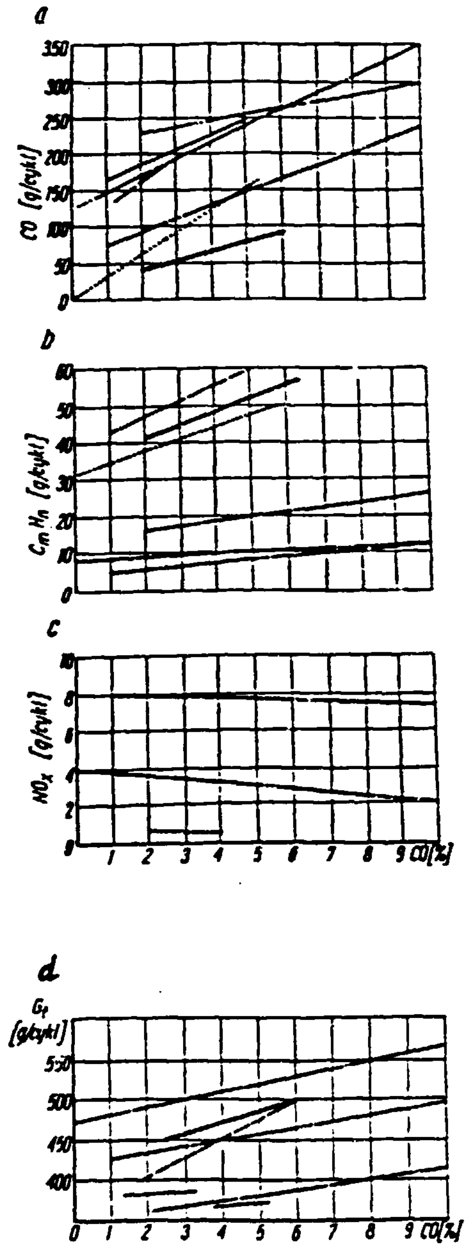


Fig.A2/5. Effect of CO concentration at idle on:
a - CO emission, b- HC emission,
c- NO_x emission, d- fuel consumption.

called "mixture idle adjustment". It results from mixture enrichment when the needle is being turn out. The effect of the other control, i.e. throttle stop screw, varies from engine to engine. In some cases the mixture gets richer with closing the throttle and in others mixture enleanment occurs. In Fig.A2/2, lean limit occurs at a position of about 3/4 turns. The corresponding CO concentration is about 1% vol. In some uncontrolled vehicles of old design, particularly when the engine operates at low speed, this limit may occur at considerably higher CO, sometimes even as high as 3-4.5% vol. which makes the adjustment with regard to low CO difficult.
It is worth noting that it does not serve a purpose to excessively enlean mixture at idle as it may give rise to an undesirable increase in HC emissions (Fig.A2/2f).

Carburetors of reduced-emission vehicles, their idle systems included , have undergone many modifications in order to meet the emissions standards. As it can be seen from Fig.A2/2, CO concentrations exceeding 10% vol. are possible if no special measures are taken. Such concentrations are not acceptable from the point of view of pollution. Therefore the idle adjustment range has been limited in controlled vehicles so that excessively rich mixture can not be obtained. This has been achieved by sealing the mixture needle (Fig.A2/3) or by carburetor idle system modifications. Fig.A2/4 shows sketches of some selected designs.

3. Effect of idle adjustment on pollutant emissions.

The idle adjustment affects vehicle performances not only at idle itself but also under other operating conditions, in particular during acceleration and low speed cruising. Emissions of regulated pollutants (CO, HC, NO_x) and fuel consumption in ECE urban cycle versus CO idle concentration is shown in Fig.A2/5 for some uncontrolled and reduced-emission vehicles. Increasing CO idle concentration increases CO emissions in the cycle, the rate of this increase depending on engine design, e.g. type of fuel system, vehicle mass-power ratio etc. A change of CO at idle by 1% vol. usually results in a change of CO cycle emissions by 5-15%. In the majority of cases, increasing CO at idle results in an HC cycle emission increase, the rate of this increase being usually lower than for CO. However, in some vehicles, an excessive decrease in CO at idle may cause higher HC cycle emissions. This occurs in uncontrolled vehicles when lean limit is at relatively rich mixture or in controlled vehicles with very lean overall carburation. The effect of CO at idle on NO_x cycle emissions is usually low.

CO content at idle affects vehicle fuel consumption in cycle. A CO decrease by 1% vol. corresponds to an improvement in fuel economy by about 1-3%. Thanks to this improvement, maintenance/inspection programmes for uncontrolled and reduced-emission vehicles are usually cost neutral as the reduction in fuel cost makes up for additional costs incurred by vehicle owners.

The effect of CO at idle on emissions and fuel consumption in extra urban driving is lower than that in urban driving. It decreases with increase in average speed. This is illustrated in Table A2/1 below.

Table A2/1

Average improvement in emissions and fuel consumption resulting from a decrease in CO concentration at idle by 1% vol. (reduced-emission car equipped with 4-stroke 4-cylinder carbureted engine).

Driving conditions	Improvement in %			
	CO	HC	NO_x	fuel consumption
ECE cycle	18	15	-4	3.5
70 km/h	8	6	-3	1.5
90 km/h	6	4	-3	0
120 km/h	2	1	0	0

The effect of CO content at idle on performances and emissions of vehicles fitted with petrol injection is usually lower than in the case of carburetor. This is one of advantages of the injection from the point of view of emissions and fuel economy. It results from the fact that air fuel ratio under load conditions does not usually depend on the mixture strength at idle. Furthermore, the fuel supply during deceleration is often cut off.

The adjustment of idle affects very much CO/HC emissions and fuel consumption in two-and three-wheelers equipped with two-stroke engines. In some vehicles of old designs the improvement in fuel economy and HC emissions resulting from a decrease of CO at idle by 1% vol. may exceed 5% and that in CO emissions - 20%.

4. Engine malfunctions affecting engine idle operation.

4.1. Uncontrolled and reduced-emission vehicles

SI engine idle operation characterized by CO content and speed may be considerably affected by malfunctions of engine components. Therefore these two parameters are good indicators of technical conditions of these components and of the engine as a whole.

The main reason for CO content at idle being higher than the specified limit (see point 6 of this Annex) is idle maladjustment. It can be corrected by means of controls provided for this purpose. However in some vehicles such a correction may not be possible. The following main symptoms of engine malfunctions can occur in such a case:

a) it is possible to reduce CO content below the limit by means of the controls, but the engine operation is not smooth (e.g. misfiring, vibration, stalling etc),

b) CO content is higher than specified with mixture control needle (screw) fully turned in,

c) CO content is lower than specified with mixture control needle turned out to a position where it does not control the mixture flow,

d) idle speed is too high with the carburetor throttle fully closed (throttle stop control screw turned out).

The majority of uncontrolled SI engines can run properly at idle at the mixture strength corresponding to CO content lower than 3-4.5% vol. If the engine operation under such conditions is not smooth, it shows that the engine technical state is not correct due e.g. to excessive component wear, incorrect valve timing, defective ignition system etc. However some uncontrolled engines of obsolete design, even in good technical conditions, may not run properly at CO idle content lower than 3.0-4.5% vol. as they were not designed and manufactured for this purpose. It is often the case for two-stroke single cylinder engines.

It is worth noting that manufacturer's specifications for idle adjustment of uncontrolled engines are often not correct from the point of view of low emission. Some specifications recommend to adjust idle in such a way that the engine runs smoothly at a possibly low speed which implies relatively rich mixture with CO exceeding often 5% vol.

In order to obtain smooth idle operation of uncontrolled engines below CO limit it is sometimes necessary to increase their idle speed above the value recommended by the manufacturer. However this speed should not be toc high as if affects fuel consumption and mass emissions. In controlled vehicles, the symptom mentioned above under a) shows that the engine is in poor technical conditions.

If CO content at idle is higher than the set limit with mixture control needle fully turned in (symptom b), it shows that the air fuel mixture is too rich (fuel supply too high). The main reasons for it are:

a) too high fuel level in the float chamber:
   - incorrect float fuel level adjustment,
   - too high pressure of fuel pump,
   - deformed float lever bracket,
   - deformed or perforated float,

b) fuel supply by the starting device:
   - choke is not fully open due to incorrect cable adjustment or damages to automatic control (carburetors with butterfly starting valve),
   - cold starting unit is not fully closed or starting valve is leaky (carburetors with Solex-type unit),

c) throttle situated above off-idle port (usually as a result of improper repair),

d) cone of the mixture needle or/and its seat are damaged or badly worn out.

If CO idle content is lower than the limit specified by the manufacturer (reduced-emission vehicles) with the mixture needle turned out (symptom c), possible defects are as follows:

a) too small fuel flow through the idle system:
   - too low fuel level in the float chamber, usually due to incorrect adjustment or distorted float lever,
   - dirty fuel metering jet or passages in the idle system,

b) "false" air inflow into the inlet system:
   - excessive wear of the throttle spindle and/or its guide in the carburetor body,
   - damage of gaskets in the inlet system,
   - fissure in the carburetor body or inlet manifold,
   - too large opening of the throttle in the second stage of two-barrel carburetor,
   - throttle distortion,
   - damage (excessive wear, sticking) of PCV valve.

Defects mentioned above under b) can be a reason of too high engine idle speed (symptom d). Measuring CO idle content makes it possible to detect many, but by no means, all defects that may impair vehicle fuel economy or emissions. Therefore, in order to increase the efficiency of the inspection, its scope is sometimes extended by HC and CO_2 measurement.

Too high HC concentration at idle shows that the combustion is incomplete, usually due to:

- poor condition of the ignition system (spark plugs, distributors etc),
- excessively lean or rich air fuel mixture,
- very large amount of exhaust residual in the cylinder (e.g. because of incorrect valve timing, clogged exhaust system),
- too low engine temperature.

A certain improvement of inspection efficiency can be also achieved by the adding of CO_2 measurement. In this case, no limits are set for CO_2 content. If the total of CO and CO_2 contents is higher than:

- for four-stroke engines $CO + CO_2 > 15\%$ vol.
- for two-stroke engines $CO + CO_2 > 10\%$ vol.

the measured value of CO is taken as the final results. However, if this total is lower than 15% vol. or 10% vol. respectively, CO concentration is corrected by means of the following formulas:

- for four-stroke engines

$$CO_{cor} = CO \cdot \frac{15}{CO + CO_2}$$

- for two-stroke engines

$$CO_{cor} = CO \cdot \frac{10}{CO + CO_2}$$

where:
CO_{cor} - corrected CO content,
CO - measured CO content,
CO_2 - measured CO_2 content.

The total of CO and CO_2 lower than 10% or 15% vol. may indicate that:

a) exhaust system is leaky and as a result, the exhaust gas is diluted by air,

b) the measurement has not been properly conducted because of:
  - dilution of the exhaust gas in the sampling system or analyzer itself (leaky pipes, connections, filters etc.),
  - too short insertion of the sampling probe into tailpipe (see point 5 of this Annex),
  - defective analyser or faulty calibration,

c) combustion is not complete (very high HC emissions).

A further improvement of inspection efficiency is possible by the introduction of checks not only at (low) idle speed but also at so called raised idle speed, usually in the range of 2000-3000 rpm. In this case, defects of the main carburetor system may be detected. Its operation has a considerable effect on pollutant emissions and fuel consumption. On the other hand defects of this system are not as frequent as those of carburetor components mentioned above.

The measurement of pollutant content in the exhaust at idle makes it also possible to detect defects of the petrol injection system affecting the mixture strength such as faulty injectors, sensors, control unit etc. The injection systems have an advantage of better reliability and durability as compared with carburetors. Therefore, their defects are usually less frequent.

4.2. Low-emission vehicles

Low emission vehicles are more complex and sophisticated as compared to uncontrolled and reduced-emission ones. Therefore, their emission inspection needs to keep pace with this progress if their technical condition is to be properly diagnosed and repairs performed efficiently. At the beginning, the inspection scope of these vehicles was similar to that of medium-emission ones i.e it included only CO/HC measurement at low idle. The permissible limits were however lower, usually 1.2% vol. for CO and 220 ppm for HC (see point 6 of this Annex).

This procedure proved to be not very efficient as it did not make it possible to properly check the functioning of two main components of the antipollution system i.e. catalytic converter and λ-probe. In some modern vehicles CO and HC concentrations at idle may be lower that the specified limits even when these components are defective. Therefore more complex methods have been developed for this purpose. For vehicles equipped with catalytic converters with closed loop control the inspection usually includes:

- checks at low idle, limits being equal to respectively about 0.5% vol. and 100 ppm (see point 6 of this Annex),
- CO (and HC) checks at raised idle, the engine speed being in the range 2000-3000 rpm (or as specified by the vehicle manufacturer) and the limits usually lower than at low idle,
- checks of λ-probe at raised idle speed by determining the air fuel equivalence ratio on the basis of exhaust gas (CO, CO_2, HC and O_2) composition measurement, the limit being equal to 1 ± 0.03.

Checks of λ-probe are introduced because the measurement of CO/HC content at both low and raised idle speeds is not sufficient for the detection of defects of the closed loop control system. If this system has failed but the catalytic converter is in good condition, the CO/HC content at idle may be within limits, however the air-fuel ratio usually exceeds the specified limit (1 ± 0.03) which affects emissions under load conditions.

Yet more complex inspection test procedures are now under development. They would include:

- an exhaust mass emission (instead of concentration measurement) transient short test run on an inertial and power-absorbing dynamometer (e.g. IM240 exhaust test),
- a pressure test of the vehicle's evaporative system, consisting of inert gas injecting into this system in order to detect the presence of a leak and confirm its ability to hold pressure,
- a purge test of vehicle's evaporative system to detect whether the petrol vapours adsorbed on the charcoal in the canister are recycled to the cylinders to be combusted; the purge test is conducted on the same dynamometer and using the same cycle as the exhaust mass emission test.

5. Determination of pollutant concentrations at idle speed.

The test procedure for determination of pollutant (CO, HC, CO_2) concentrations at idle speed during in-use vehicle inspections is specified in great details in point 6.2.2.2. of guidelines. In this Annex only some factors which affect the measurement are discussed. These factors are:

a) the depth to which the sampling probe is inserted into tailpipe,

b) thermal conditions of the vehicle.

The depth to which the sampling probe is inserted into the tailpipe has a considerable effect on measured values. The effect of this depth results from pressure fluctuations in the tailpipe which, in turn, result in air suction and exhaust gas dilution even when the exhaust system is perfectly leakproof. The dilution ratio and consequently the read value depends, among others, on:

- working principle (two-stroke/four-stroke),
- number of cylinders,
- engine speed.

The effect of the depth to which the probe is inserted on CO concentration in a four-stroke engine is shown in Table A2/2. The selected engine was very sensitive to the sampling probe insertion.

Table A2/2

Relative CO concentration versus the depth to which the probe has been inserted (1.0 is equal to the maximum CO value; four-stroke, four-cylinder 1500cc engine)

Engine speed / rpm /	Probe insertion / cm /					
	10	30	60	90	120	150
450÷ 500	0,09	0,20	0,48	0,64	0,83	1,00
630÷ 660	0,21	0,49	0,78	0,91	1,00	1,00
730÷ 770	0,31	0,67	0,97	1,00	1,00	1,00
1000÷1050	0,53	0,69	1,00	1,00	1,00	1,00
1480÷1540	0,73	0,90	1,00	1,00	1,00	1,00
2000÷2050	0,99	1,00	1,00	1,00	1,00	1,00

The minimum depth specified by test procedures for four-stroke engines varies from 30 cm (in the majority of standards) to 60 cm (standard of former USSR). As it can be seen from Table A2/2 in some cases only about 70% of the actual concentrations is measured when the depth is 30 cm.

The effect of sampling depth is usually even higher in two-stroke, in particular single-cylinder, engines (Table A2/3).

Table A2/3

CO concentration versus the depth to which the probe has been inserted (two-stroke, single-cylinder 150 cc engine; engine speed 1200 rpm)

Depth (cm)	10	30	60	75	100	150
CO (%)	1.6	2.6	4.4	5.1	5.6	6.0

For two-stroke engines the depth specified in standards varies from 60 to 75 cm.

In some vehicles it is not possible to insert the sampling probe to the specified depth due to the exhaust pipe configuration. Two ways may be followed in such a case:

- using an extension of appropriate dimensions to the tailpipe (the connection of both pipes should be reasonably leakproof),
- using a correction graph.

The example of a correction graph is shown in Fig.A2/9.It gives the correction coefficient by which the read value should be multiplied in order to calculate the actual concentration. Separate graphs should be worked out for four-stroke and two-stroke engines.

The insertion of the sampling probe not deep enough is one of the common errors committed during pollutant measurements at idle (see Annex 1).

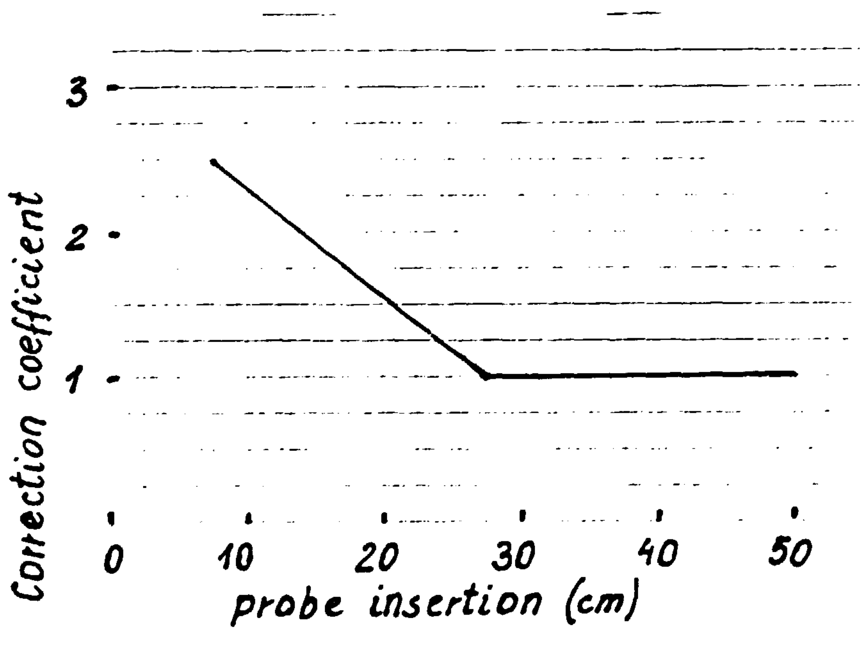


Fig.A2/9. Graph for correction of CO readings at idle versus probe insertion /four-stroke engine/

Pollutant measurement at idle should be conducted after the vehicle has achieved its normal thermal conditions. The normal thermal conditions are defined as those achieved by an engine and drive line after a run of at least 15 min. under normal traffic conditions. A good indicator of thermal condition is engine oil temperature. It should not be lower than 60°C. A dipstick gague can be used for measurement. The thermal condition can also be checked by means of coolant temperature (temperature gauge should indicate approximately "normal" temperature or at least 70°C) or engine oil pressure (pressure below 0.5-0.6 kPa at idle indicates that oil is sufficiently warmed up).

The thermal condition effects:

- engine speed and therefore the air fuel ratio of mixture supplied by the carburetor (in the injection system, a constant speed is usually maintained)
- distribution of air fuel mixture and combustion.

The thermal condition exerts a particular effect on HC idle concentration. Low engine temperature increases HC emissions from the cylinder. In some cases hydrocarbons may condense in the exhaust system when it is not properly warmed-up. All this affects measured values. Therefore much attention should be paid to the vehicle thermal conditions, in particular at low ambient temperatures, when HC measurements are conducted.

6. Limits for in-use vehicles

Limits for CO, HC and lambda at idle specified for in-use vehicles in some countries not participating and all the countries participating in the project are listed in Table A2/4.

Table A2/4

Exhaust emission standards for in-use vehicles equipped with SI engines

Country	Category of motor vehicles	Limits			Remarks
		CO % vol.	HC ppm	λ	
1	2	3	4	5	6
Countries not participating in the project					
European Community	all motor vehicles having at least four wheels:				draft
	a) not equipped with three way catalysts				
	- manufactured in the period 1970-1986	4.5 1)	---	---	
	- manufactured after 1 October 1986	3.5 1)	---	---	
	b) equipped with three way catalysts				
	- at low idle	0.5 1)	---	---	
	- at raised idle (more than 2000 rpm)	0.3 1)	---	1±0.03	
Germany	all motor vehicles having at least four wheels put into service after 1 July 1969	3.5+1 2)	---	---	vehicles fitted with two-stroke engines are exempted
Sweden	model year 1975	5.5 3)	---	---	
		7.0 4)	---	---	
	model year 1976-1984	4.5 3)	---	---	
		5.5 4)	---	---	
	model year 1985-1988	3.5 3)	---		
		4.5 4)	---	---	
	model year 1989-	0.5	100	---	

1	2	3	4	5	6
Hungary	motor vehicles with GVW not more than 3500 kg				
	a) not equipped with catalysts				
	- at low idle	2.5-4.5 5)	1000 6)	---	
	- at raised idle (60% of maximum rated speed)	---	1000 6)	---	
	b) equipped with three way catalysts				
	- at low idle	0.4	---	---	
	- at raised idle (60% of maximum rated speed)	0.4	250	---	
	c) equipped with other catalysts				
	- at low idle	1.0	---	---	
	- at raised idle (60% of maximum rated speed)	1.0	400	---	
Poland	all motor vehicles except motor cycles				
	- effective up to 1992	4.5	---	---	
	- effective after 1992	3.5	---	---	
	motorcycles				
	- effective up to 1992	5.5	---	---	
	- effective after 1992	4.5	---	---	
Austria	cars equipped with three way catalysts				
	- at low idle	0.3	---		
	- at raised idle (3000±100rpm)	0.3	---	1±0.03	
Finland	cars equipped with three way catalysts				draft
	- at low idle	0.3	100		
	- at raised idle (2500 rpm)	0.3	100	1±0.03	
USA	LDV	1.2	220	---	in some I/M programmes

1	2	3	4	5	6
California	LDV				
	- at low idle	1.0	100	---	
	- at raised idle (2500 rpm)	1.2	220	---	
Former USSR	all				
	- at low idle	4.5	---	---	
	- at raised idle (60% of maximum rated speed)	2.0	---	---	
Countries participating in the project					
China	all motor vehicles except motorcycles	6.0	3000	---	
Hong-Kong					no requirements
India	all four wheeled vehicles	3.0	---	---	
	all two - and three wheeled vehicles	4.5	---	---	
Indonesia	all except private cars	4.5	1200	---	
Iran					
Korea	all motor vehicles except motor cycles				
	a) first registration before July 1987	4.5	1200	---	
	b) first registration after July 1987 (only cars)				
	- petrol driven	1.2	220	---	
	- LPG driven	1.2	400	---	
Malaysia					no requirements
Philippines	all except private vehicles 7)				
	- with four-stroke engines	6.0	1200		
	- with two-stroke engines	6.0	7800		

1	2	3	4	5	6
Singapore	all	4.5	---	---	
Sri Lanka					no requirements
Thailand	all except private vehicles	6.0	---	---	

Notes
1) values specified by the vehicle manufacturer but not exceeding the ste limit,

2) values specified by the vehicle manufacturer but not exceeding the limit, 1% vol. allowance for measurement inaccuracy,

3) repair recommendation; no need for inspection,

4) repair order; the vehicle must be submitted for reinspection,

5) depending on the vehicle type,

6) this limit does not apply to vehicles equipped with two-stroke engines.

7) limits applied for mandatory periodical inspections

SMOKE MEASUREMENT OF DIESEL-DRIVEN VEHICLES

1. Smoke formation

The exhaust gas of diesel-driven vehicles comprises, besides gaseous constituents, some amount of visible components forming so called smoke. Diesel smoke is composed of particles, including aerosols, suspended in the engine exhaust stream which obscure, reflect and/or refract light. The smoke is usually divided into two categories:

- black smoke consisted mainly of irregularly shaped, agglomerated fine carbon particles (soot), usually less than 2 μm in size, formed from the hydrocarbon fuel under high temperature condition in the absence or insufficiency of oxygen,
- white and blue smoke composed mainly of liquid fuel droplets and droplets resulting from the incomplete combustion of fuel or lubricating oil.

The smoke intensity in the diesel exhaust is affected by many design and operating variables. One of the main variables is fuel delivery rate expressed for instance in mm^3/cycle. Its effect is shown in simplified form in Fig.A3/1 for an engine in good mechanical condition. The smoke is approximately level in range of low and medium delivery rate. Its intensity is low on the order of 7-15% Hartridge Smoke Units (HSU) or 0.7-1.5 Bosch units (°B). Under such conditions the smoke is practically invisible. Increasing the delivery gradually increases the smoke intensity, the increase rate being higher and higher. This increase is accompanied by deterioration in fuel economy and a gradual reduction of power output increase rate. At very high smoke levels (higher then about 8.0 °B or 95 HSU) the power output levels off and drops with a further rise in fuel delivery. The smoke increase is accompanied by a rise in CO, particulates and usually HC emissions but at the same time by a drop of NO^x emissions.

The smoke level of in-use vehicles may considerably exceed that of new ones due to unavoidable wear of engine components and poor maintenance. The main factors affecting the increase in smoke level are:

a) factors reducing the amount of air charge in the cylinder at the time of injection and combustion:
   - clogging air filters,
   - change of valve timing and lift due to the wear of valve operating mechanism,
   - wear of cylinder liners, pistons and piston rings, resulting in an increase in blow-by from the cylinder to the crankcase, and/or valve seats,

b) factors affecting the fuel injection (delivery, atomization, spray penetration, spray formation etc):
   - setting of the full load stop adjustment screw in the injection pump,

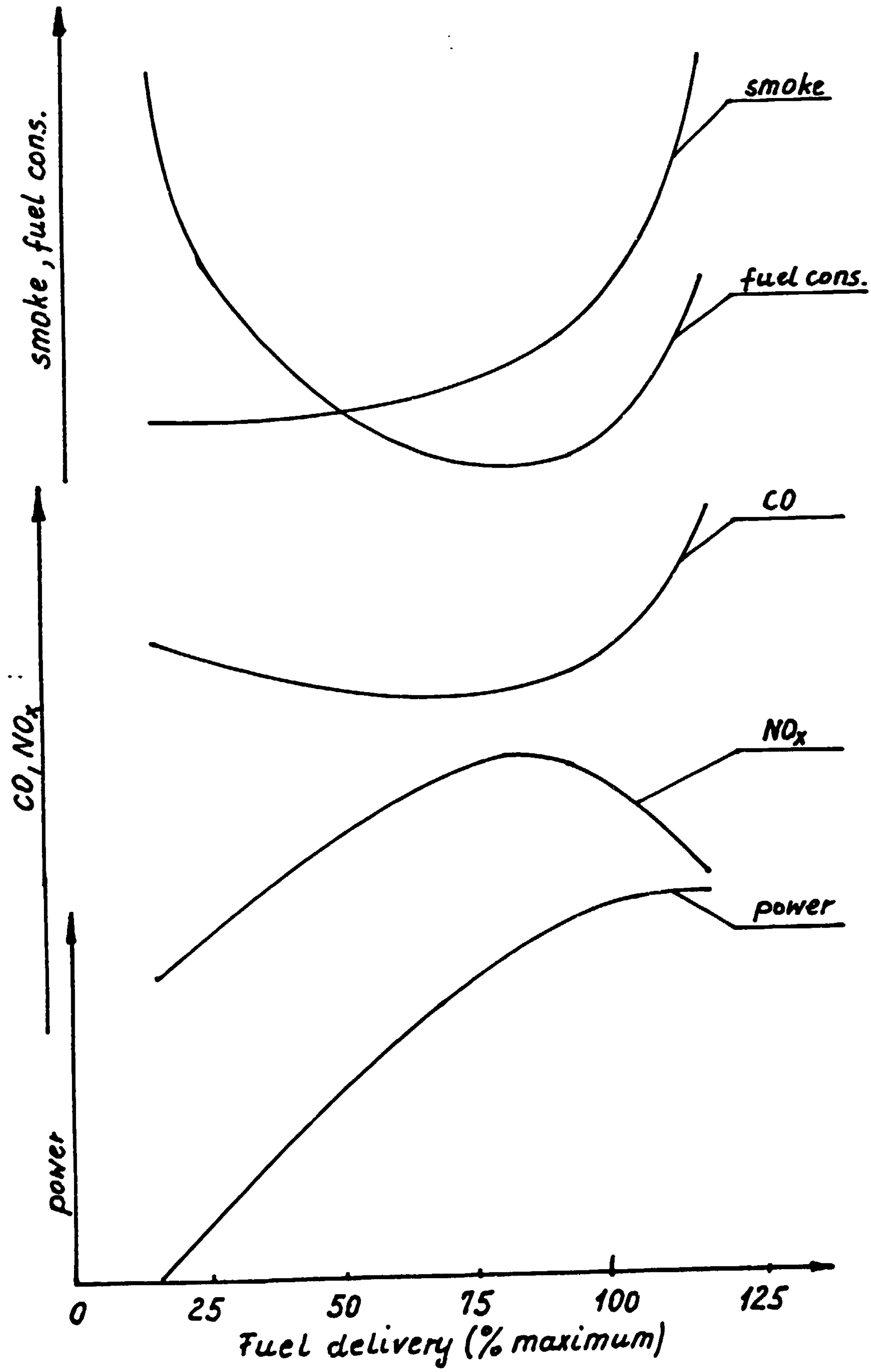


Fig. A3/1. Diesel engine performance and emissions versus fuel delivery.

- retarding of the injection timing as a result of the wear of injection pump driving mechanism, including injection advance timing device, and injection pump itself,
- decrease in injection pressure as a result of maladjustment, wear of nozzles, nozzle holder spring, injection pump etc.,
- deterioration of fuel atomization and rate of injection due to a nozzle wear and coking (e.g. so called dribbling i.e. fuel leakage past the valve seat when the nozzle is closed), injection pump wear (barrel, delivery valve) etc.

The effect of the mentioned factors on the smoke intensity is usually different. The group a) increases this intensity in the first place under high load (fuel delivery) conditions.
The group b) affects it not only under high loads but at part load as well. This is illustrated in Fig.A3/2. The increase in smoke level is accompanied by a drop in power output and deterioration in fuel economy.

The full load smoke curve versus engine speed is shown in Fig.A3/3. Three distinctive regions can be marked off in it.
At very low speeds (region I), smoke is very very high due to the fact that supplementary fuel is supplied by the cold-start device. This device is switched off at a speed of about 15-20% of maximum rated speed which causes the smoke to considerably drop. In some modern engines, this device gets inoperational after engine has started. In the region II, the engine operates at full fuel delivery. The smoke intensity versus engine speed depends very much on its design.

It is worth noting that the smoke tests for type approval and conformity of production checks are conducted for speeds from 40-60% to 100% of rated speed. Below this range the smoke intensity is usually not measured. When the speeds exceeds 100%, the governor comes into action and fuel cut-off starts (region III).

Due to the dependance between fuel delivery and smoke illustrated in Fig.A3/2, the maximum smoke intensity in traffic occurs under full load conditions:

- during vehicle accelerations,
- during up-slope driving,
- at vehicle high speeds, in particular when hauling trailers,
- when starting from a standstill in a gear higher than specified (in this case, the engine speed in the first phase of moving may be very low even comparable to idling speed but at high load).

The above mentioned effects of engine components contribute not only to an increase in the smoke intensity but affect very much other pollutant emissions and fuel economy. This is shown in Table A3/1.

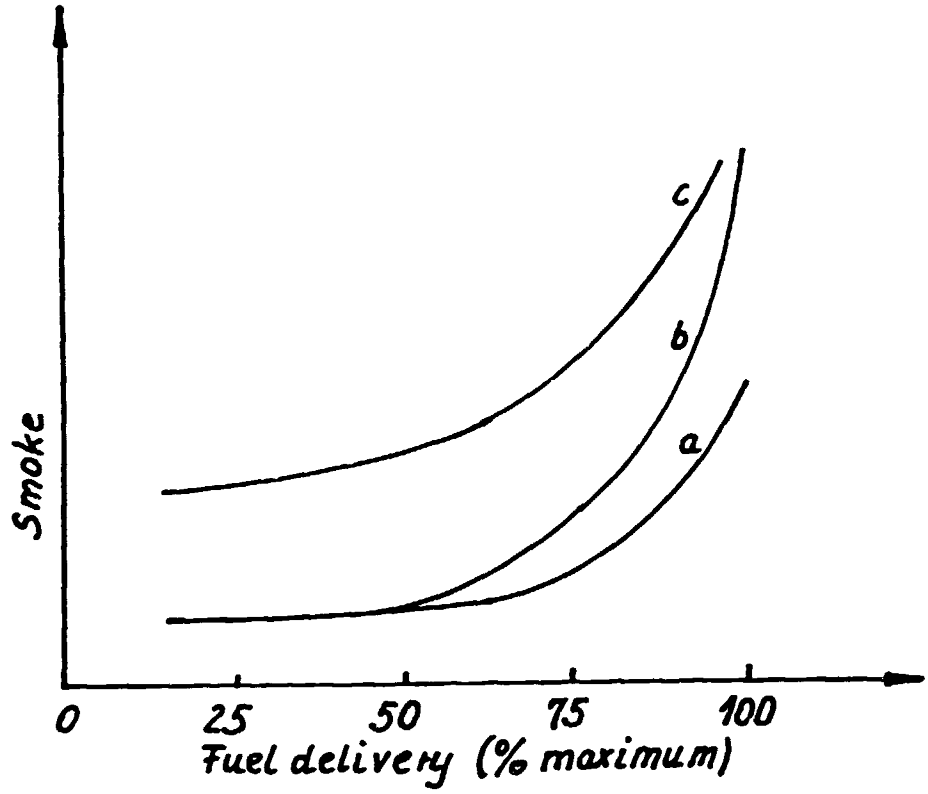


Fig. A3/2.Smoke level versus fuel delivery for: a- engine in good condition, b- clogged air filter, c- defective injectors.

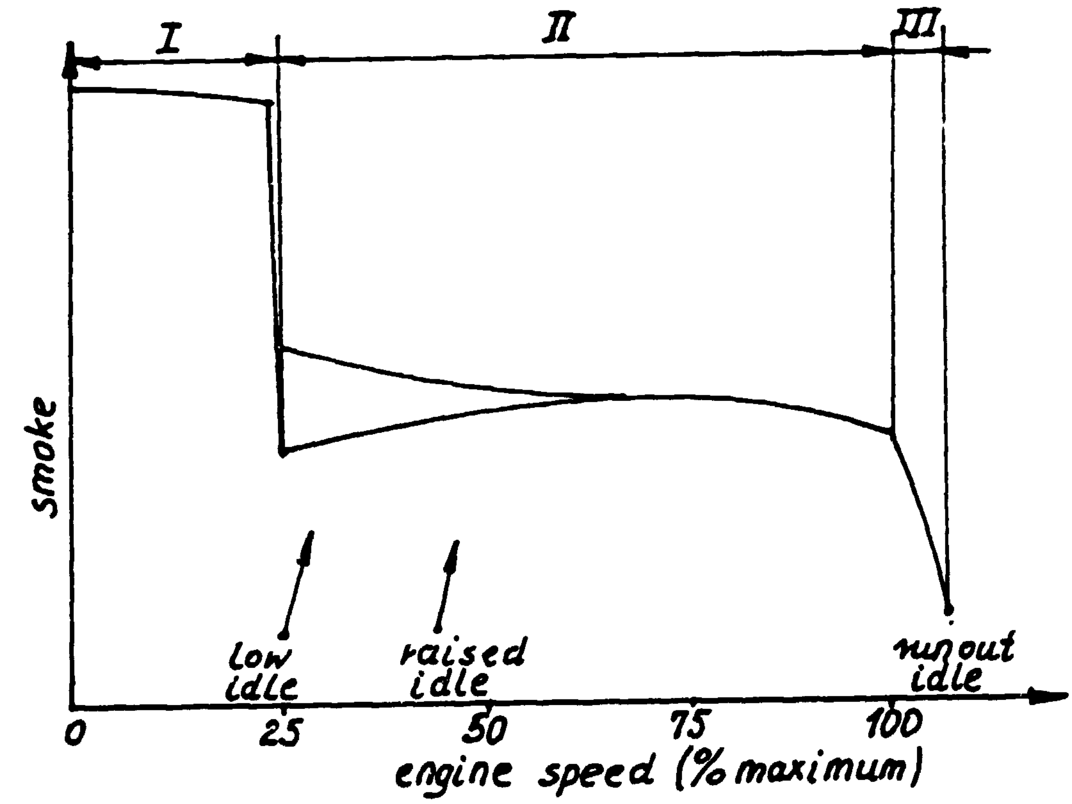


Fig. A3/3. Full load smoke curve versus engine speed.

Table A3/1

The effect of engine defects on emissions and fuel economy in 13-mode ECE cycle (6-cylinder DI 6.8 l engine).

Engine condition	CO	HC	NOx	PM	smoke	fuel consumption
good mechanical condition	100	100	100	100	100	100
clogged air filter	109	104	94	121	127	106
faulty nozzles (dribbling)	137	111	92	147	187	119

2. Smoke measuring instruments

Smoke measuring instruments (smokemeters) can be divided into two broad categories:

a) opacimeters,
b) filter-type apparatus.

The principle of measurement of opacimeters consists in passing a beam of light through a certain length of the exhaust gas to be measured. The proportion of the incident light reaching the receiver is used to assess the opacity of the gas. Opacimeters measure continuously all components of exhaust gas which lead to an impairment of visibility, not only soot (black smoke). The opacity of exhaust gas can be expressed:

- in percent N of linear scale (0% - at total light flux, 100% - at total obscuration),
- in absolute units k of light absorption from 0 to ∞ (m^{-1}).

The relationship between these two parameters is expressed by the equation:

$$k = \frac{1}{L} \ln \frac{1}{1 - N}$$

where:
L - the effective optical path length in meters.

In filter-type apparatus, the measuring method is based on the evaluation of the blackening of a filter paper by the exhaust gas. To this purpose the exhaust gas is sucked through the filter by means of a suitable suction device. The evaluation of the blackening is made by photoelectric means. One of the defects of such smokemeters is that the measurement can not be conducted continuously.

The visibility of smoke depends, among others, on exhaust flow rate which, in turn, is affected by engine power output (actual at the moment of check, not nominal). This is shown in Fig. A3/5.
As the engine load is usually low or medium at constant speed in urban traffic, visible smoke emitted during such a driving shows that the engine is in poor technical conditions.

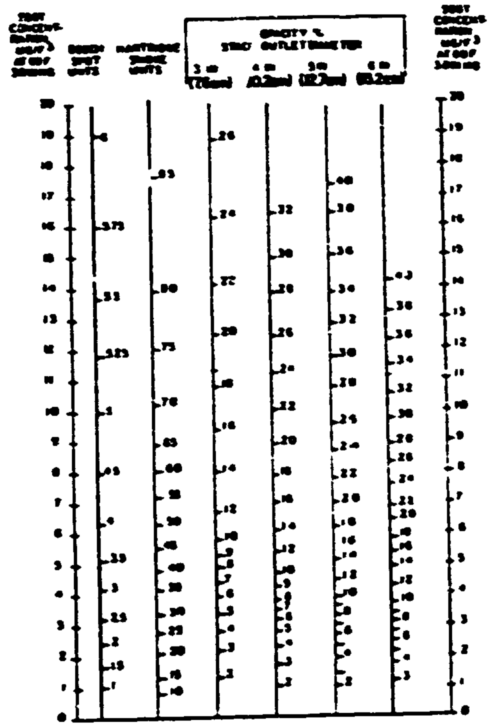


Fig.A3/4. Correlations between smokemeters.

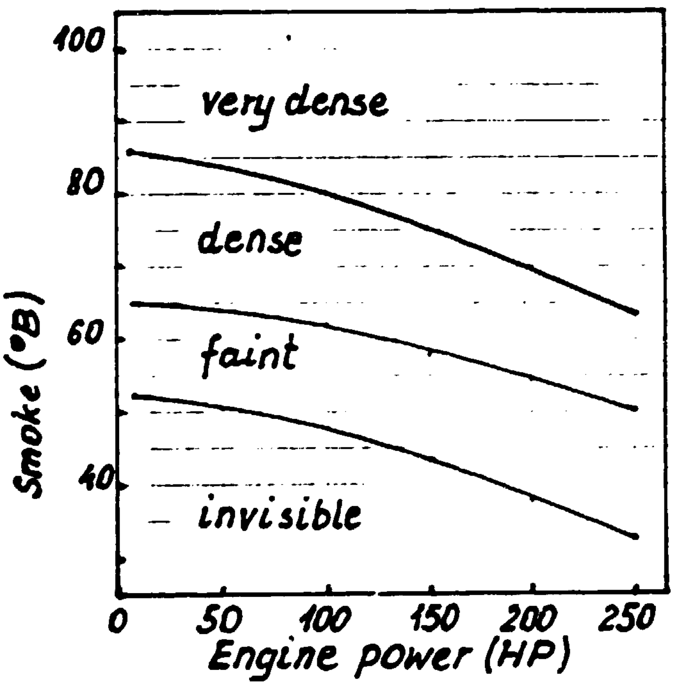


Fig.A3/5. Smoke level versus engine power

In respect of exhaust sampling method, opacimeters can be constructed as:

- full flow device,
- partial flow device,
- free flow device.

In full flow sampling the entire smoke volume passes through the measuring opacimeter. Full flow sampling offers the greatest confidence that the measuring is representative of the whole gas flow on condition that the connection between the exhaust system and opacimeter is reasonably airproof.

In partial flow sampling a certain test volume is taken from the exhaust gas and conducted to the measuring instrument. In order to ensure that the sample is representative of the entire exhaust gas, special precautions concerning the smokemeter, in particular sampling probe, installation must be taken.

The ratio of the cross-sectional area of the probe to that of the exhaust pipe should not be less than 0.05. The probe should be a tube with the open end facing the exhaust stream. It should be situated approximately in the axis of the exhaust pipe and inserted in this pipe as deeply as possible, but at least 3D from the end (D - exhaust pipe diameter). The section of the exhaust pipe in the approximity of the sampling point should be straight at least 6D in length upstream and 3D in length downstream.

In some in-use vehicles these requirements with regard to probe installation can not be met. Therefore, some deviations from the above specifications are allowed for inspection tests (see point 6.3.2.2. of Guidelines).

In free flow sampling, measuring is performed across the whole exhaust stream. The opacimeter should be installed in such a way that the light passes through the centers of the plume, in a specified distance from the end of tailpipe. The measuring results are affected by the effective length of measurement which, in turn, depends on the exhaust pipe diameter. The effective length is very difficult to measure due to dilution of the exhaust gas with air. Moreover, if the straight portion of the tailpipe is not sufficiently long, the sample may not be fully representative.

For filter type instruments only partial flow sampling is feasible. The requirement for the sampling probe installation is similar to that for opacimeters.

Smokemeters in-use at present usually originate from three following basic models:

- full flow opacimeters	- Celesco 107,
- partial flow opacimeters	- Hartridge MK3,
- filter type instrument	- Bosch EFAW.

These three models are internationally acknowledged and accepted and their scales are used for expressing smoke intensity in many other smokemeters. Correlations between these smokemeters indications and exhaust soot content for steady-state smoke measurement are represented in Fig. A3/4. It may be noted that the opacity measured by means of full flow Celesco smokemeter depends on the diameter of exhaust pipe.

3. Smoke tests methods

3.1. General requirements

A smoke test method for the inspection of in-use vehicles should meet several, often contradictory, requirements. Such a method should:

a) ensure adequate repeatability and reproducibility of test results,
b) offer good correlation between inspection test results and smoke intensity in traffic on one hand and between inspection results and type approval/conformity of production results on the other hand,
c) require the use of inexpensive, simple in operation and maintenance, reliable equipment,
d) be simple in operation so that it could be performed by moderately skilled and experienced inspection personnel,
e) can be used for both periodical and road-side inspections.

Many methods have been developed or are under development for the measurement of smoke intensity in diesel-driven vehicles. Some of them are described below.

3.2. Free acceleration test

During the test, the vehicle is stationery with the gear box in its neutral position and clutch engaged. The accelerator pedal is depressed fully and quickly but not violently so as to obtain maximum delivery from the injection pump. This pedal position is maintained until the maximum engine speed is reached (Fig.A3/3) and the injection pump governor comes into action. After this speed has been reached the pedal is released and the engine gradually resumes its idling speed. The pedal is depressed for about 4-5 s and the total cycle lasts about 15 s. In the test, the engine is in a transient phase. The time of acceleration from the initial to maximum speed is usually on the order of 0.7-2.0 s depending on the engine design (inertia moment of rotating and reciprocating masses, power output, speed range etc.). During the acceleration the engine is loaded by mass inertia.

There are two variants of this tests (Fig. A3/3):

- acceleration from low (normal) idle speed,
- acceleration from raised idle speed.

In the first case, the range of speed is higher. It covers also low speeds at which the engine is not tested under steady conditions. These low speeds are used (at high load) only in case the vehicle starts from a standstill in a higher gear. In some engines, the smoke level is maximum at these very speeds.

In the second variant, the engine speed is raised above the "normal" idling speed before acceleration. The initial acceleration speed is usually not defined. The relevant specifications say that the speed should be increased by slightly depressing the pedal. In this case it is difficult to obtain good repeatability and reproductability of test results, in particular when the maximum smoke occurs at low engine speeds.

All four smokemeter types can be used for free acceleration tests. Basis for smoke evaluation is:

- for opacimeters - highest read opacity value,
- for filter-type instruments - integrated value over the sampling period.

The smoke values measured on the same vehicle engine under the same operating conditions may differ according to the type of opacimeters. This is illustrated in Table A3/2.

Table A3/2

Smoke values measured by three types opacimeters.

Opacimeter type	Smoke value (m-1)	
	Vehicle A	Vehicle B
Full flow	2.4	2.9
Partial flow	2.0	2.5
Free flow	2.1	2.2

Main factors which affect the results are: the shape of smoke curve versus engine speed, opacimeter design, e.g. length, volume of the sampling line (if any), physical response time, electrical response time.

When the filter-type smokemeters is used, the sampling begins in the course of acceleration. The sampling volume comes from:

- the acceleration period at full load, when the smoke is high,
- the period of part load operation (after the governor has come into action until the maximum speed is reached),
- the period of idle operation (at maximum speed) when the smoke intensity is relatively low.

The measured values depends on:

- actual acceleration time which, in turn, is affected by engine design variables and engine thermal condition (Fig. A3/6),
- sampling time (Fig.A3/8),
- sapling delay i.e. the beginning of the sampling in relation to the beginning of acceleration (Fig. A3/7),
- smoke intensity in the respective sampling periods.

It is worth noting that the filter-type smokemeter may considerably undervalue the smoke intensity of engines where acceleration time is short (Fig. A3/6). The free acceleration method using filter-type smokemeters can give satisfactory repeatability and reproducibility only when the following conditions are complied with:

- vehicle is fully warmed-up to its normal operating temperature,
- the sampling period is exactly specified (2.5 - 3.0 s) and

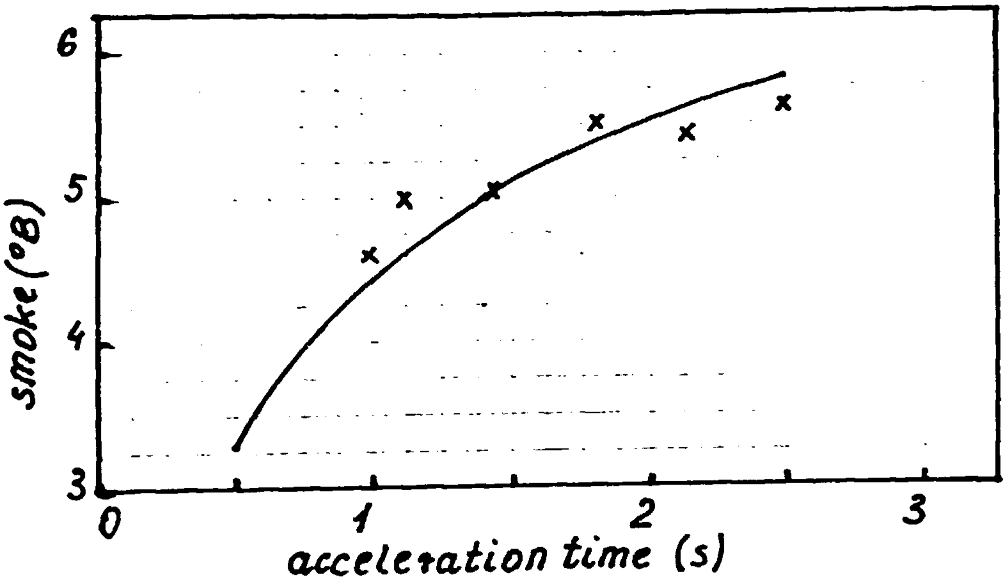


Fig. A3/6. Smoke level versus acceleration time.

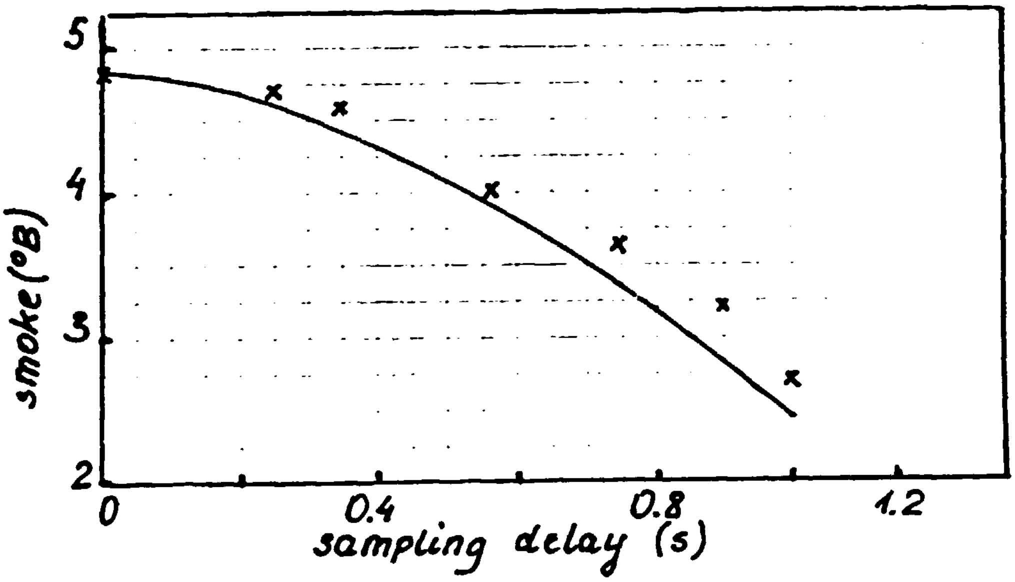


Fig.A3/7. Smoke level versus sampling delay.

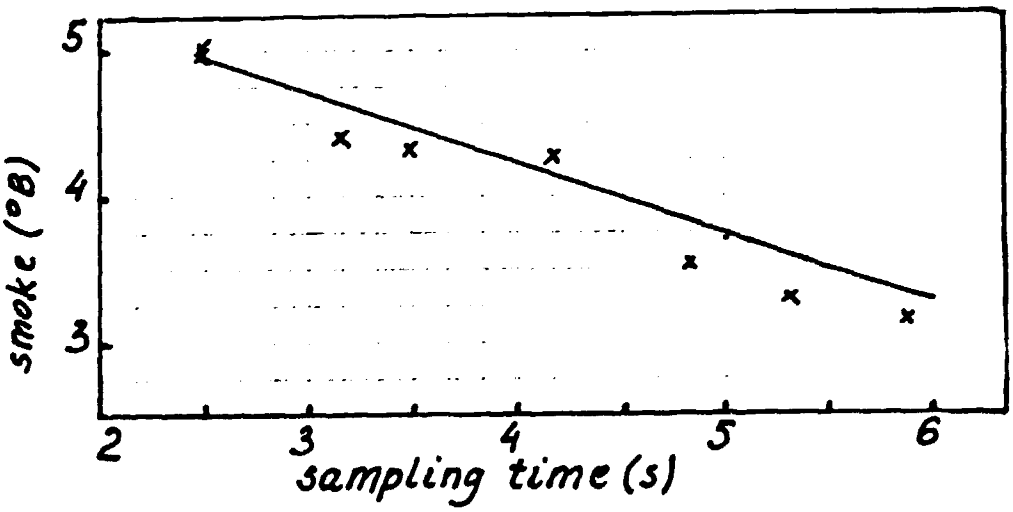


Fig.A3/8. Smoke level versus sampling time.

regularly checked,

- the sampling starts at an exactly specified time in relation to the acceleration beginning.

If the above set requirements are met, the correlation between the results measured by means of a opacimeter and a filter-type instrument is satisfactory for vehicles equipped with the same engine type. However due to the fact that smoke results measured by means of filter-type instrument depend very much on the engine acceleration time and smoke versus speed curve, this correlation for the whole population of diesel-driven vehicles is usually poor (Fig. A3/9).

The free acceleration method requires lower initial investments for equipment than others (point 3.3 and 3.4 of this Annex). No risk of damaging the vehicle is involved. It is relatively simple however some basic requirements for execution must be met. Its disadvantage is that it is generally not satisfactorily representative of real operating conditions, particularly with turbocharged engines.

3.3. Steady speed test

This test may be carried out:

- on the road,
- at stationary vehicle with the driving wheels on free roller stand.

During the test the engine speed is as constant as possible within the range of 50% to 90% of the maximum rated speed and corresponds to the speed at which the highest smoke value is observed for the given engine type. This highest smoke speed is determined during the type approval test for emission - controlled vehicles or on the basis of vehicle manufacturer data for uncontrolled ones. Some standards (e.g. Swedish) do not specify the engine speed. Measurements can be performed at any speed within the specified range.

According to existing regulations (e.g ISO Standard 7645), the vehicle is usually tested in the highest gear compatible with obtaining the selected engine speed below vehicle speed limit set by national regulations in the case of road tests (usually not more than 90 km/h) or by safety measures in the case of tests on roller stand (usually not more than 50-80 km/h depending on vehicle category). The smoke intensity is measured at full load i.e. with the accelerator pedal depressed. The selected engine/vehicle speed is maintained by actuation of the vehicle footbrake. The maximum permissible duration of the time when the brake is applied varies from 8-10 s on roller stand to 12 s on the road. After this time the brake application should be discontinued and at least 2 min allowed to elapse before the test is repeated.

Only one repetition is allowed. A waiting time of 15 min should be respected before the next two measurements start. These requirements should be strictly respected for safety reasons as a prolonged operation may result in brake failures. A higher time on the road is allowed because in this case the engine power is absorbed by the brakes on all wheels whereas only drive axle(s)

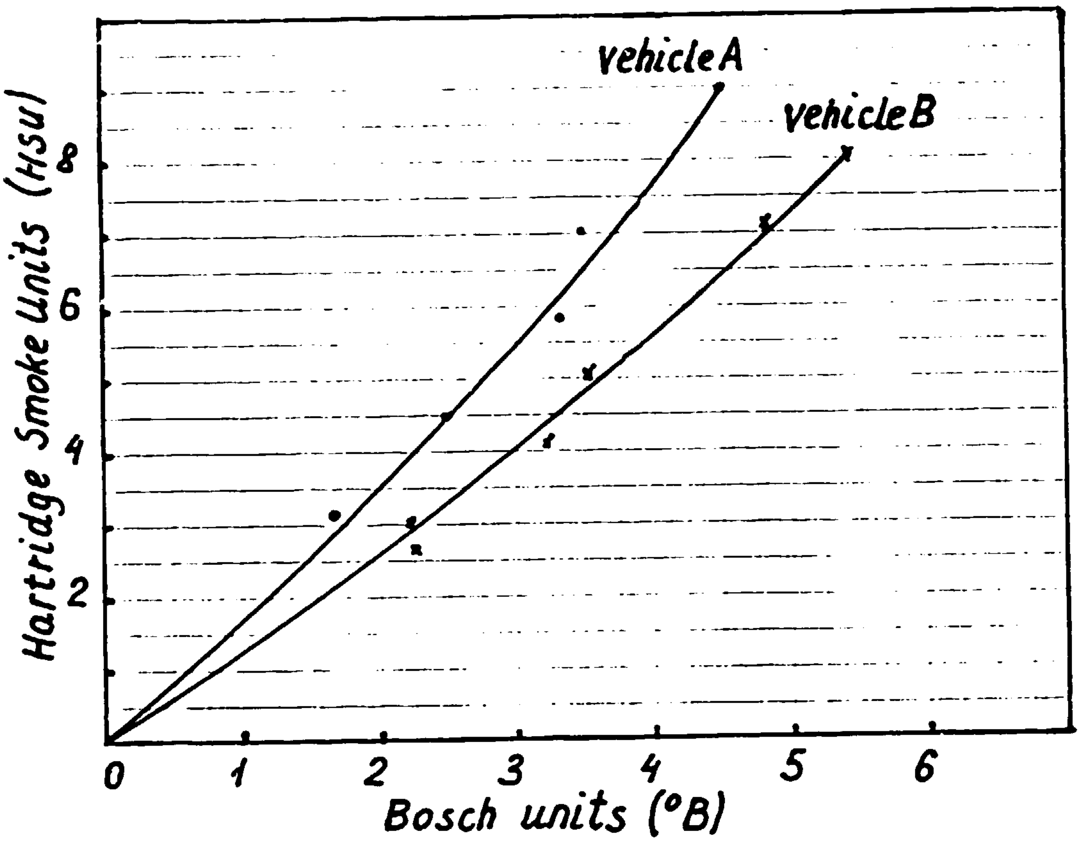


Fig.A3/9. Correlation between Hartridge and Bosch smokemeters for the free acceleration from low idle speed.

brakes are used on roller stand.

The limitation of this test method is that it can be used only under conditions where the available brake torque is higher than the power torque at the driving axle(s). In the first place the limitation applies to passenger cars with high power/mass ratio tested on the roller stand.

The latest German proposals for full load smoke tests on the road for in-use vehicle inspections specify the test conditions different from the mentioned above:

- driving at midrange gear, instead of at high gear,
- driving speed about 15-20 km/h,
- duration of test about 10 s,
- distance necessary for testing about 50-70 m.

These proposals apply only to trucks. They impose very hard requirement for vehicle brakes.

Both steady speed smoke tests i.e. on the road and on roller stand may be used for both periodical and road-side inspections. In the latter case, a transportable roller stand is required. Special provisions should be taken to prevent movements of the roller stand frame. Tests on the road have an advantage of lower costs of investments for test equipment. Its main disadvantages are as follows:

- for safety reasons, measurements can be carried out only on test tracks or on public roads with thin traffic; such tracks or roads may not be available in the proximity of the inspection station; for this reason the possibility of road-side checks is also limited,
- measurement can not be conducted during rain or snowfalls which makes the method not very much suitable for periodical inspections,
- there are some safety risks when the test is carried out on wet, slippery roads e.g. locking brakes on non-driving wheels,
- legal problems may arise when an accident occurs subsequent to the test.

Tests on the roller stand are not subject to atmospheric conditions. They usually ensure better reproducibility of results. Disadvantages of such a method are:

- higher outlays for the investment (purchase of stands) and maintenance of equipment are required,
- risks of brake overheating and failure is greater than on the road, in particular for vehicles with high power to mass ratio,
- problems may arise with vehicles having more than one driving axle.

All four types of smokemeter (point 2 of this Annex) can be used for tests on the roller stand. For tests on the road, smoke-meters with partial flow sampling are preferable.

3.4. Lug-down test

In this test, the measurement of smoke intensity is performed during a lug-down at full load over the normal operating speed range of the engine, usually between 100% and 45% of maximum rated speed. The test is conducted on free roller stand. The gear is engaged at which a vehicle speed of 50-80 km/h (according to vehicle category) corresponds to maximum engine run-out speed. The accelerator pedal is fully depressed so that the engine speed reaches its maximum . Then the footbrake is actuated and the vehicle is decelerated for about 10 s until it reaches a speed corresponding to about 40% of engine rated speed. During the deceleration the change of engine speed should be as uniform as possible and its rate about 15% of runout speed per second which corresponds to speed gradient 2.5-6.0 s^{-2}. At about 40% of rated speed, the brakes and pedal are released. Conditions for repetition are similar to those in steady-speed tests.

For this test, only opacimeters, in particular partial flow opacimeters, are specified (ISO Standard 7644). The necessary equipment includes, besides an opacimeter and free-roller stand, deceleration measuring device, time measuring device and recorder for exhaust smoke. This method makes it possible to identify the actual maximum smoke over the normal operating range of speeds. Moreover, it ensures relatively good comparability with steady speed tests used for type approval and conformity of production verification. However, it requires higher investment and is more complicated and difficult for execution, in particular in road-side inspections. Therefore it is not used yet for inspection purposes.

4. Smoke standards for in-use vehicles in selected countries.

Smoke standards for in-use vehicles in some countries not participating in the project and in all countries participating in the project are listed in Table A3/3.

Smoke standards for in-use diesel-driven motor vehicles

Table A3/3

Country	Vehicle category	Smoke limit	Test method	Remarks
European Community	all motor vehicles manufactured after 1 January 1970	values measured during the type approval plus $0.5m^{-1}$; if these values are not available: $2.5m^{-1}$ for naturally aspirated engines $3.0m^{-1}$ for turbo-charged vehicles	free acceleration from low idle speed;	proposals of EC Commission
Hungary	all motor vehicles a) GVW less than 3500kg b) GVW of or more than 3500kg -naturally aspirated engines -supercharged engines	 $2.5m^{-1}$ (1) $1.5m^{-1}$ (2) $3.5m^{-1}$ (1) $1.5m^{-1}$ (2) $3.5m^{-1}$ (1) $1.5m^{-1}$ (2)	1) free acceleration from low idle speed 2) free acceleration from raised idle speed or steady speed method	
Poland	all motor vehicles a)effective up to 1992 b)effective after 1992 - naturally aspirated engines - turbo charged engines	 70 HSU $2.5m^{-1}$ $3.0m^{-1}$	free acceleration from raised idle speed free acceleration from low idle speed	

Country	Vehicle category	Smoke limit	Test method	Remarks
Sweden	buses with more than 30 seats other vehicles	2.5° B (3) 3.5° B (4) 3.5° B (3) 4.5° B (4)	single steady speed method with not defined speeds; tests on roller stands; Bosch-type smoke-meters.	(3)if measured value is in the range 2.5-3.5° B or 3.5-4.5° B recommendation for repair; reinspection not required. (4)if measured value exceeds3.5 or 4.5° B injun-ction for rein-spection
California	heavy duty trucks	40% - 55%	free acceleration from low idle speed; free flow opacimeter	40% basic limit; some vehicles may be allowed to have up to 55% (age and special exem-ption).
Former USSR	trucks and buses	a) 40%-for natu-rally aspirated engines; 50% - for char-ged engines b) 15%	a)free accelera-tion from low idle speed; b)measurement at maximum (runout) engine speed with no load; partial flow opacimeter for both tests.	

Countries participating in the project

Country	Vehicle category	Smoke limit	Test method	Remarks
China	all	6.0° B	free acceleration from low idle speed; filter - type smokemeter	
Hong Kong	all	60 HSU	free acceleration from low idle speed; partial flow opacimeter (Hartridge)	
India	all	2.3 m^{-1} or 65HSU (5) 3.1 m^{-1} or 5.2° B or 75 HSU (6)	(5) free acceleration from low idle speed; partial flow opacimeter (6) steady speed within 60-70% of maximum rated speed; partial flow opacimeter or filter-type smokeemeter	
Indonesia	all except private cars	5.0 ° B (50%)	free acceleration from low idle speed; filter (Bosch)-type smokemeter	

Country	Vehicle category	Smoke limit	Test method	Remarks
Iran Korea	all	4.0° B	free acceleration from low idle speed: filter-type smokemeter	
Malaysia	all	50 HSU	free acceleration from low idle speed; Hartridge MK3	
Philippines	all	4.8° B 65 HSU	free acceleration from low idle speed; filter-type smokemeter for periodical inspection Hartridge MK3 for on-road inspection	
Singapore	all	50 HSU (7) 4.2° B (8)	free acceleration from low idle speed 7) Hartridge MK3 for side-road inspections 8) filter-type smokemeter for periodical inspe-ction	

Country	Vehicle category	Smoke limit	Test method	Remarks
Sri Lanka				no standards
Thailand	all except private cars	5.0° B	free acceleration from low idle speed; filter-type smokemeter (Bosch)	

Road vehicles — Carbon monoxide analyser equipment — Technical specifications

1 SCOPE AND FIELD OF APPLICATION

This International Standard lays down technical specifications for the analyser equipment used for the determination of the concentration of exhaust carbon monoxide (CO) emissions from road vehicles equipped with spark-ignition engines.

2 REFERENCE

ISO 3929, *Road vehicles — Determination of exhaust carbon monoxide concentration at idle speed.*

3 GENERAL

The carbon monoxide analyser shall be compatible with all types of motor vehicle operating environments and shall operate under the conditions and performance requirements listed in clauses 4 and 5.

4 PERFORMANCE CRITERIA

4.1 Analyser accuracy

The carbon monoxide analyser shall have an accuracy of ± 3 % of full scale, as determined by analysing known standard gases.

4.2 Interference effects

The sum of the individual effects on the reading of the analyser from other gases and particulates in concentration close to those existing in the engine exhaust gas shall be less than 0,2 unit.

4.3 System response time

The analyser concentration indication shall reach 90 % of the final stabilized reading within 10 s after a step change in concentration level is initiated at the sample probe inlet.

4.4 Drift

Zero and span drift of a warmed-up instrument shall not be greater than ± 3 % of full scale during 1 h of operation.

4.5 Repeatability

Analyser repeatability shall be within ± 2 % of full scale during five successive samples of the same gas source.

4.6 Warm-up time

Unless otherwise indicated on the instrument, the analyser shall reach stabilized operation within 30 min from "power on".

4.7 Span

The instrument shall have the capability of being spanned using both calibration gas bottles and electro-mechanical or electronic methods.

Instrument operation shall be as specified herein using either or both methods.

4.8 Sample handling system

The sample handling materials that are in contact with the gas sample shall not contaminate or change the character of the gases to be analysed.

All sampling system internal surfaces shall be corrosion-resistant to motor vehicle exhaust gases.

The sample handling system shall provide for particulate and water removal as required to prevent these contaminants from affecting gas analysis. The filtering and water removal components shall be designed for easy maintenance.

4.9 Safety requirements

The construction, materials, and electrical systems used in the instrument system shall comply with local provisions. Each analyser sy tem shall be constructed and shall incorporate safety devices for the protection of personnel and nearby equipment.

4.10 Temperature sensitivity

The instrument shall be suitable for ambient temperatures between + 5 °C and + 40 °C. Between these two limits, the result of the measurement shall not differ from that obtained at a temperature of 20 °C (± 2 °C) by more than 0,2 unit.

5 DESIGN CHARACTERISTICS

5.1 Instrument construction

The instrument shall be designed and constructed to provide reliable and accurate service in the motor vehicle repair garage environment.

5.1.1 *Mobility*

The instrument may be permanently mounted, portable, or mobile.

5.1.2 *Identification*

The identification of the instrument shall be permanently attached to the outer surface of the analyser enclosure. The identification shall include the model and serial number, name and address of the instrument manufacturer, production date, electrical power requirements and operating voltage range.

5.1.3 *Electrical design*

Analyser operation shall be unaffected by an electrical voltage variation of ± 10 %.

5.1.4 *Controls*

The span and zero controls should be readily accessible but protected against accidental misadjustment.

5.1.5 *Electromagnetic isolation*

The instrument system shall be capable of providing unaffected operation in electromagnetic radiation or conductive interference produced by vehicle ignition systems and building electrical systems.

5.1.6 *Vibration and shock protection*

System operation shall be unaffected by the vibration and shock encountered under the normal operating conditions in a motor vehicle repair garage.

5.1.7 *Operating instructions*

Concise operating instructions, including calibration procedures and instrument calibration curves, shall be supplied by the manufacturer with the instrument.

5.2 Sampling system

The vehicle exhaust gas sampling system shall consist of an exhaust pipe probe and an analysis system and may include a water removal system and/or filter(s). The sampling line shall be a minimum of 3 m in length.

5.2.1 *Probe*

The probe design shall be such that it will not slip out of the motor vehicle exhaust pipe when in use for analysis. A thermally insulated, comfortable hand grip shall be provided on the sample probe handle. The probe should be flexible enough to extend into the tailpipe at least 300 mm.

5.2.2 *Water removal system*

If a water removal system is required to remove vehicle exhaust gas water vapour from the sample gas prior to its entering the instrument analysers, the collection vessel shall be visible to the operator and a draining provision shall be provided.

5.3 Analytical system

The accuracy, system response time, drift, repeatability, and warm-up time shall be as specified in the performance criteria (clause 4).

5.3.1 *Instrument range*

The instrument read-out shall have a range of 0 to 10 % CO or less.

5.3.2 *Span techniques*

The instrument system shall have provisions for adjustment of the zero and span setting by calibration gas. A second type of span adjustment may be provided for electro-mechanical, electrical, electronic or other acceptable method.

If the instrument is not self-compensated for non-standard conditions of altitude and ambient temperature, or not equipped with a manually controlled system of compensation, the scale calibration shall be performed using calibration gas.

The carrier gas should be dry nitrogen. The accuracy of the span gas blends should be within ± 2 % of the concentration stated.

ISO STANDARD : CD/ 3930 - ROAD VEHICLES
Instrumentations for measurement of gaseous exhaust emissions, produced during inspections or maintenance tests

INDEX

1 - SCOPE

This International Standard lays down technical specifications for the instrument used for direct measurement of the concentration of exhaust gas emissions, defined in Annexes , Clause 1, from road vehicles equiped with 4 stroke positive ignition engine, Wankel engines included, and of mass up to 3.5 tons. The aim of this standard is to define instruments (from now called analysers) for :

- checking or adjusting in service stations ;
- periodic inspections in official stations ;
- official control at road side (i.e. by police, etc.).

when used according to the procedure defined in Standard ISO 3929(*)

These technical specifications should help the users to check the necessary technical prescriptions of these instruments, totally or partially

Analysers according to this standard may not be suitable for :

- laboratory and developpment use ;
- vehicle type approval ;
- vehicle production conformity ;
- end of line inspection.

2 - NORMATIVE REFERENCE

ISO 3929	Road Vehicles - Determination of exhaust CO concentration at idle speed (*) ;
ISO/TR 7637	Road Vehicles - Electrical interference by conduction an coupling ;
OIML	International Recommendation - Vehicle exhaust emission measuring instruments ;
ISO/BPIM/CEI	International Vocabulary of Basic and General terms in Metrology.

3 - DEFINITIONS

3.1 Absolute error of measurement

The result of a measurement minus the (conventional) true value of the measurand.

3.2 Accuracy

Of a measurement, is the closeness of the agreement between the result of a measurement and the (conventional) true value of the measurand.

3.3 Adjustement

The operation intended to bring a measurement into a state of performance and freedom from bias suitable of its use.

(*) under revision

3.4 Analog (measuring instrument)

A measuring instrument in which the output or display is continuous function of the value of the measurand.

3.5 Calibration

The set of operations which establish, under specified conditions, the relationship between values indicated by the instrument and the corresponding known values of a measurand.

3.6 Checking facilities

The facilities incorporated within a measuring instrument that enable significant faults to be indicated and acted upon.

3.7 Digital (measuring instrument)

A measuring instrument which provides a digitized output and/or display.

3.8 Drift

The slow variation with time of a metrological characteristic of a measuring instrument.

3.9 Maximum permissible error

The extreme values of an error permitted by specifications.

3.10 Measurand

A quantity subjected to measurement.

3.11 Measurement

The set of operations having the object of determining the value of the quantity.

3.12 Range

For a given scale, the range of scale values between the extreme scale marks.

3.13 Control conditions

Ambient conditions for verification of a measuring instrument.

- Temperature 293 K ± 2 K
- Relative humidity 65% ± 15 %
- Atmospheric pressure : stable and between 100 kPa ± 2,5 kPa

3.14 Relative error

The absolute error of measurements divided by the (conventional) true value of the measurand.

3.15 Repeatability

The closeness of the agreement between the result of successive measurements of the same measurand carried out subject to all of the following conditions :

- the same method of measurement ;
- the same observer ;
- the same measuring instrument ;
- the same location ;
- the same conditions of use ;
- repetition over a short period of time.

Repeatability may be expressed quantitatively in term of dispersion of the results.

3.16 Resolution (of an indicating device)

A quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent values of the indicated quantity.

3.17 Response time

The time interval between the instant when a stimulus is subjected to a specific abrupt change and the instant when the response reaches and remains whithin specified limits of its final steady value.

3.18 Scale

An ordered set of scale marks, together with any associated numbering, forming a part of an indicating instrument.

3.19 Span

The modulus of the difference between the two limits of a nominal range of a measuring instrument.

3.20 Test

A series of operations intended to verify the compliance of the equipement with prescribed technical requirements.

3.21 True value (of a quantity)

The value which characterizes a quantity perfectly defined, in the conditions which exist when that quantity is considered.

3.22 Zero (of a measuring instrument)

The direct indication of a measuring instrument when the instrument is in use with zero value of the measurand, any auxiliary power supply required to operate the instrument being switched on.

3.23 Warm up time

The elapsed time between switching on the measuring instrument and the moment the measuring instrument complies with the metrological requirements.

3.24 Handheld analyser

Type of analyser handheld by 1 person with all its standard accessories and without deterioration of its characteristics, according to the prescriptions of each national regulations.

3.25 Portable analyser

Type of analyser, easy to be carried and moved, with all its standard accessories, without deteriorations of its characteristics, according to the prescriptions of each national regulations.

4 - TECHNICAL SPECIFICATIONS

4.1 Design characteristics

4.1.1 General

With consideration of the intended application field, the type of analyser shall be :

. handheld or portable ;
. simple for use by unqualified people ;
. easy to span up ;
. designed to respond to the specific gas constituent to be measured ;
. designed for expected and specific applications ;
. capable of indicating directly unambiguous measuring results ;
. easily resettable to primary calibration, if specified after transportation and handling ;
. correlable with the analysers used by the manufacturer to control its own production ;
. designed to prevent any other action than those required for adjustment and measurement. In the case of destruction of the protection, measurement shall be invalidated ;
. designed and manufactured in such a way that, when exposed to any unwanted operation listed below, it is able to interrupt the measurement readings :
- warm up time defined by the manufacturer in conformity with clause 4.1.25 ;
- power supply default ;
- water separator saturation ;
- electronic defaults.

4.1.2 Identification

The analyser shall be provided with permanent and easily readable nameplate giving the following particulars :

a) manufacturer's trade mark/corporate name ;
b) year of manufacture ;
c) pattern approval mark and model number ;
d) serial number of the instrument and if necessary the measuring transducer ;
e) minimum and nominal flowrate, (if necessary) ;
f) main voltage, frequency and power absorption.

Furthermore, the propane/hexane conversion factor and the warm up time shall be indicated on a separate plate fixed at the front panel of the instrument.

4.1.3 Operating instructions

The documentation shall be supplied by the manufacturer with the analyser in the official language of the country where the analyser is used. This documentation includes :

a) a description of its general principle of the measurement ;
b) a list of its essential components with their characteristics ;
c) a description of its essential components with drawings and diagrams ;
d) the general information on the software for a microprocessor equipped analyser
e) the leakage procedure ;
f) the operating instructions, including those concerning the periodical calibration and maintenance.

The manufacturer must clearly explain the kind of the span gas to be used for the HC analyser. If a span gas other than Hexane is used, the manufacturer must indicate the conversion factor.

4.1.4 Span adjustment

The analyser shall have the capability of being spanned using span gas bottle method and possibly electro-mechanical or electronic methods.

4.1.5 Adjustment facilities

The analyser shall be equipped with a zero setting facility.
The analyser shall be equipped with a span adjustment facility.
The adjustment shall neither influence the adjusted zero nor the linearity of the system.

4.1.6 Sample handling system

All components of the gas handling system shall be made of corrosion-resistant material, in particular the material of the sampling probe shall be resistant to the exhaust gas temperature. The design and the materials of the equipment shall not influence the composition of the gas sample.

4.1.7 Water removal system

The gas handling system shall contain a water separator which prevents water condensation in the measuring transducer. In the case of saturation of the separator, the operation shall be automatically stopped.

4.1.8 Probe

The probe design shall be such that it will not slip out of the motor vehicle exhaust pipe when in use for analysis. The probe, at least 300 mm long, shall be flexible enough to be introduced into the tail-pipe and robust enough to withstand being driven over or trodden on.

4.1.9 Filter system

The gas handling system shall contain a filter unit with reusable or replaceable filter elements capable of removing particles in excess of 5 μm. It shall be possible to observe the filter contamination and to replace the filter easily without tools and without the risk of leakage.

4.1.10 Pump system

The pump conveying the exhaust gas shall be mounted so that it does not cause vibrations which affect the measurements. It shall be possible to turn the pump off separately.

4.1.11 Low flow rate proctection

The measuring instrument shall be equipped with a device, which, when a drop of the gas flow rate reaches a level which causes the analysis to exceed the response time or the maximum permissible error on verification, interrupts measurement readings.

4.1.12 Measuring ranges

The analyser measuring ranges are specified in Annexes, clause 1.

4.1.13 Analyser accuracy

The accuracy of the analyser is specified in Annexes, clause 1.

4.1.14 Repeatability

After 20 consecutive measurements the repeatability shall be ≤ 2%.

4.1.15 Zero and span drift

Zero and span drift of a warmed analyser shall not be greater than :
- 2 maximum permissible error for category I
- 1 maximum permissible error for category II
during 4h of operation.
An automatic compensation may be used.

4.1.16 System response time

The analyser concentration indication shall reach 90% of the final stabilized reading within 10 s after that the exhaust gas sampling is initiated at the sample probe inlet.

4.1.17 Measuring indicator

The volume fractions on the gas components shall be indicated in "%" and in "ppm" according to the annexes, clause 1.

The inscriptions "% vol (gas)" and "ppm vol (gas)" shall be unambiguously assigned to the indication.

For Category I : the scale shall be as linear as possible ;
For Category II : the scale shall be linear

4.1.18 Fault detection

The analyser shall be equipped with checking facilities for detecting faults due to disturbances. These checking facilities may be either automatic or non-automatic. Upon detection of a fault, the analyser shall produce a signal to warn the operator. It shall be possible to check the presence and to determine the correct functioning of the checking facilities.

4.1.19 Detecting gas residues

(Only for HC analyser). The analyser shall be equipped with a facility for detecting HC gas residues. This serves to ascertain whether the value indicated is less than 20 ppm n-hexane when an ambient air sample is taken through the probe.

4.1.20 Temperature

The analyser shall be suitable for ambient temperatures between 278 and 313 K.

4.1.21 Pressure

The analyser shall be suitable for atmospheric pressure between 86 kPa and 106 kPa.

4.1.22 Humidity

The analyser shall be suitable for relative humidity between 10% and 95%.

4.1.23 Safety

The construction, materials and electrical systems used in the analyser shall comply with local provisions. The analyser shall incorporate safety devices for the protection of personel and nearby equipment.

4.1.24 Controls

The span and zero controls shall be ready accessible but protected against unintentional misadjustment.

4.1.25 Warm up time

The analyser warm up time shall not exceed 30 min.

4.1.26 Data output

- Category I : The requirement applicable to category II may be recommanded.
- Category II : The analyser shall be equipped with output suitable for data printing or computer processing (i.e. as RS 423 or RS 232 C). The data output shall be so designed that the transmitted data cannot be falsified. If a checking facility detects a fault or a malfunction of the instrument, the data transmission must be interrupted.

4.2 Influencing factors

4.2.1 Interference of other gases

The accuracy of the analyser shall not be influenced by more than 1.5 maximum permissible error by other gas components present as interference gas mixtures defined in annexes, clause 3.
Each single gas of interference gas mixtures, with the same concentration, defined in annexes clause 3 can be used. In this case the sum of errors shall not be more than 1.5 maximum permissible error of the values measured.

4.2.2 Interference of water vapor saturated air

The accuracy of the analyser shall not be influenced by more than 1.5 maximum permissible error by the water vapour saturated air.

4.2.3 Temperature

At the extreme stable ambient temperatures, defined in clause 4.1.20, the accuracy of the analyser shall not exceed 1 maximum permissible error.

4.2.4 Pressure

At the extreme stable atmospheric pressures, defined in clause 4.1.21, the accuracy of the analyser shall not exceed 1 maximum permissible error.

4.2.5 Humidity

At the extreme stable ambient relative humidity values, defined in clause 4.1.22, the accuracy of the analyser shall not exceed 1 maximum permissible error.

4.2.6 Supply voltage

The accuracy of the analyser operating under an electrical power supply voltage variation of ± 10%, shall not exceed :

- 1.5 maximum permissible error for Category I
- 1 maximum permissible error for Category II.

4.2.7 Supply frequency

The accuracy of the analyser, operating under an electrical power supply frequency variation of ± 2 Hz shall not exceed :

- 1.5 maximum permissible error for Category I
- 1 maximum permissible error for Category II

4.2.8 Electromagnetic interferences

The accuracy of the analyser, operating under electromagnetic radiation or conductive interference produced by vehicle ignition system and/or building electric systems, shall not exceed 1.5 maximum permissible error.

4.2.9 Vibration and shock protection

The accuracy of the analyser shall not be affected by more than 1.5 maximum permissible error by the vibrations and shocks encountered under the normal operating conditions.

5 - VERIFICATION PROCEDURE

The temperatures shall be measured with an accuracy of ± 2 K.
The pressure shall be measured with an accuracy of ± 1 kPa.
The relative humidity shall be measured with an accuracy of ± 5%.
The time shall be measured with an accuracy of ± 1 s.

5.1 Measuring ranges

Check that the indicator of the analyser is in accordance with the analyser requirements of the annexes, clause 1.
The calibration gases are defined in annexes, clause 2.1

5.2 Accuracy

5.2.1 Under control conditions

Following the warm up time and the adjustement procedure, as described by the manufacturer, the test consists in introducing a calibration gas into the analyser through the sampling inlet.

Verify the accuracy of the analyser at least on 3 points of each range (included 0 and 80% of the full scale, the other (s) value (s) shall be uniformely distributed.

After 60 s of stabilization verify the conformity with clause 4.1.13.
Each measurement shall be repeated at least twice.

At the end of the test, if necessary, adjust the analyser and in this case repeat the whole test.
The calibration gases are defined in annexes, clause 2.2

5.2.2 Under extreme stabilized conditions

Following the warm up time and the adjustement procedure, as described by the manufacturer, the test consists in introducing a calibration gas into the analyser, through the sampling inlet, under the requirements of clauses 4.1.20, 4.1.21, 4.1.22, 4.2.

After 60 s of stabilization, verify the conformity with clause 4.1.13.

Each measurement shall be repeated at least twice.

At the end of the test, if necessary, adjust the analyser and in this case repeat the whole test.
The calibration gases are defined in annexes, clause 2.1

5.3 Repeatability

After 20 consecutive measurements, the following relation must be satisfied.

$$\frac{t \,.\, \sigma \,.\, 100}{x \,.\, \sqrt{20}} \leq 2\%$$

Where :

t for 20 measurements = 2.2
σ = standard deviation
x = arithmetic average value of the 20 measurements.

In each consecutive measurement under control condition or extreme stabilized condition requirements of clauses 4.1.20, 4.1.21, 4.1.22, the same calibration gases are used by the same operator with the same analyser at relatively short time intervals.

The calibration gases are defined in annexes, clause 2.1

5.4 Zero span drift

Following the warm up time and the adjustment procedure, as described by the manufacturer, the test consists in introducing a zero and calibration gas into the analyser through the sampling inlet, under control conditions or extreme stabilized condition requirements of clauses 4.1.20, 4.1.21, 4.1.22.

Measurements of the calibration gases are performed at least every hour for 8 hours to verify the conformity with clause 4.1.15. The calibration gases are defined in annexes, clause 2.1

5.5 Response time

Under control conditions the measurement shall be made to verify the time neccessary to the analyser to reach 90% of the calibration gas concentration value after the sampling zero gas is supplied at the probe.
A means for instantly changing from the sampling zero gas to the sampling calibration gas through the probe shall be employed. The calibration gas and the zero gas are supplied to the probe in a manner that the pressure, at the probe, shall not be increased or descreased by more than 750 Pa from ambient pressure.

The results of the measurement shall conform to the requirements of clause 4.1.16.
The calibration gases are defined in annexes, clause 2.1

5.6 Ambient temperature variation influence

After the warm up time and the adjustment procedure, as described by the manufacturer, the test consists of following steps :

1) Under control condition, at least 3 measurements of calibration gases are made;
2) Calculate the mean value ;
3) Get the ambient temperature to the lowest extreme temperature, specified in clause 4.1.20, in 2 hours ;
4) Stabilize the analyser at the lowest extreme temperature for 30 minutes ;
5) At least three measurements of the calibration gases are made ;
6) Calculate the mean value ;

7) Get the ambient temperature to the highest extreme temperature, specified in clause 4.1.20 in 2 hours ;
8) Stabilize the analyser at the highest temperature for 30 minutes ;
9) Repeat steps 5 and 6.
10) Compare the three mean values.

The difference between the highest and lowest mean value shall not exceed :

- 2 maximum permissible error for Category I
- 1.7 maximum permissible error for Category II

During the test the other ambient parameters shall be those indicated for control conditions.
The calibration gases are defined in annexes, clause 2.1

5.7 Ambient pressure influence

After the warm up time and the adjustment procedure, as described by the manufacturer, the test consists of following steps :

1) Under control condition, at least 3 measurements of calibration gases are made;
2) Calculate the mean value ;
3) Get the ambient pressure to the lowest extreme pressure, specified in clause 4.1.21, in 2 hours ;
4) Stabilize the analyser at the lowest extreme pressure for 30 minutes ;
5) At least three measurements of the calibration gases are made ;
6) Calculate the mean value :
7) Get the ambient pressure to the highest extreme pressure, specified in clause 4.1.21 in 2 hours ;
8) Stabilize the analyser at the highest pressure for 30 minutes ;
9) Repeat steps 5 and 6.
10) Compare the three mean values.

The difference between the highest and lowest mean value shall not exceed :

- 2 maximum permissible error for Category I
- 1.7 maximum permissible error for Category II

During the test the other ambient parameters shall be those indicated for control conditions.
The calibration gases are defined in annexes, clause 2.1

5.8 Ambient humidity variation influence

After the warm up time and the adjustment procedure, as described by the manufacturer, the test consists of following steps :

1) Under control condition, at least 3 measurements of calibration gases are made;
2) Calculate the mean value ;
3) Get the ambient humidity to the lowest extreme humidity, specified in clause 4.1.22, in 2 hours ;
4) Stabilize the analyser at the lowest extreme humidity for 30 minutes ;
5) At least three measurements of the calibration gases are made ;
6) Calculate the mean value :
7) Get the ambient humidity to the highest extreme humidity, specified in clause 4.1.22 in 2 hours ;
8) Stabilize the analyser at the highest humidity for 30 minutes ;
9) Repeat steps 5 and 6.
10) Compare the three mean values.

The difference between the highest and lowest mean value shall not exceed :

- 2 maximum permissible error for Category I
- 1.7 maximum permissible error for Category II

During the test the other ambient parameters shall be those indicated for control conditions.
The calibration gases are defined in annexes, clause 2.1

5.9 Warm up time

Under control conditions at least 3 measurements of calibration gases are made.
The test consists of the following steps :

1) stabilize the analyser in "switch off" condition ;
2) "switch on" the analyser and simultaneously start counting time ;
3) let the analyser warm up for the period declared by the manufacturer or for the maximum period defined in clause 4.1.25 ;
4) calibrate the analyser as described by the manufacturer ;
5) at least three measurements of the calibration gas and of the time are made ;
6) calculate the mean values of the measurements.

The mean value shall be conform to the requirements of clause 4.1.13
The calibration gases are defined in annexes, clause 2.1

5.10 Interference of other gases

Under control conditions at least 3 measurements of calibration gases are made.
The test consists of the following steps :

1) after the warm up time, check three times the analyser as described by the manufacturer ;
2) calculate the mean value of the measurements of the calibration gas ;
3) introduce three times the interference gas mixtures into the analyser through the sampling inlet ;
4) calculate the mean value of the measurements of the interference gas mixtures

The mean value shall be conform to the requirements of clause 4.2.1.
The interference gas mixtures are defined in annexes, clause 3.

5.11 Interference of water vapor saturated air

Under control conditions at least 3 measurements of calibration gases are made.
The test consists of the following steps :

1) after the warm up time, calibrate three times the analyser as described by the manufacturer ;
2) calculate the mean value of the measurements of the calibration gas ;
3) connect the sampling inlet of the analyser to an impringer with water ;
4) introduce the calibration gas into the analyser through the impringer ;
5) check the bubbling of the calibration gas through the water ;
6) calculate the mean value of the measurements of the calibration gas influenced by water vapor satured.

The mean value shall be conform to the requirements of clause 4.2.2.
The calibration gases are defined in annexes, clause 2.1

5.12 Supply voltage and frequency

Under control conditions at least 3 measurements of calibration gases are made. The test consists of the following steps :

1) after the warm up time, adjust the instrument as described by the manufacturer ;
2) introduce the calibration gas into the analyser through the sampling inlet ;
3) submit the analyser to the lowest values of voltage and frequency defined in clauses 4.2.6, 4.2.7.
4) after a period of stabilization of 30 s at least three measurements of the calibration gases are made ;
5) calculate the mean value ;
6) submit the analyser to the highest value of voltage and frequency defined in clause 4.2.6 and 4.2.7 ;
7) after a period of stabilization of 30 s, at least three measurements of the calibration gas are made ;
8) calculate the mean value.

The mean values shall be conform to the requirements of clause 4.2.6 and 4.2.7. The calibration gases are defined in annexes, clause 2.1

5.13 Electromagnetic interference

Under control conditions, check this item according to procedures described in ISO TR 7637. The results of the measurements of calibration gas shall conform to the requirements of clause 4.2.8.
The calibration gases are defined in annexes, clause 2.1

5.14 Vibration and shock protection

Under control conditions at least 3 measurements of calibration gases are made. The instrument is placed in its normal orientation of use on a rigid surface. It is tilted on one bottom edge and then allowed to fall, freely on the test surface, as follows :

. height of fall (*) mm 25
. number of falls 2

The test shall be repeated on each bottom edge.

Before and after this test, measurements of zero and span drift are made according to clause 5.4.
The results of the measurements shall conform to the requirement of clause 4.2.9. The calibration gases are defined in annexes, clause 2.1

(*) Note :

Distance between the elevated edge of the measuring instrument and the test surface. However, the angle made by the bottom of the instrument with the test surface shall not exceed 30°.

ANNEX A

1 - ANALYSER SPECIFICATIONS

	METER	EXHAUST GAS	SCALE RANGE (%) recommended (1)	RESOLUTION (%) recommended	MAXIMUM PERMISSIBLE ERROR (3) RELATIVE (2) %	MAXIMUM PERMISSIBLE ERROR (3) ABSOLUTE %
CATEGORY I	ANALOG	CO	0-7 (4)	0.2 (5)	$\pm$ 5	$\pm$ 0.15
		CO_2	0-16	0.4		$\pm$ 0.5
	DIGITAL	CO	0-10 (4)	0.1	$\pm$ 5	$\pm$ 0.15
		CO_2	0-16	0.1		$\pm$ 0.5
CATEGORY II	ANALOG	CO	0-1 (4)	0.02	$\pm$ 5	$\pm$ 0.03
			0-3 (6) (7)	0.05		$\pm$ 0.05
		CO_2	0-16	0.2		$\pm$ 0.3
	DIGITAL	CO	0-1 (4)	0.01	$\pm$ 5	$\pm$ 0.03
			0-3 (6) (7)	0.01		$\pm$ 0.05
		CO_2	0-16	0.1		$\pm$ 0.3

NOTES :

1) Scale ranges can be subdivided into subranges : in digital instrument subranges are not always neccessary.
2) All values of relative error are indicated as relative values % to the measured value.
3) Whichever is greater.
4) Maximum scale range.
5) Maximum value.
6) The scale shall be manually selected and the selector must show clearly the scale selected.
7) This range is not applicable for readings below 1%.

2 - CALIBRATION GASES

2.1 For clauses

5.1, 5.2.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.11, 5.12, 5.13, 5.14

The concentrations shall be about 80% of the full scale range considered and have an accuracy of ± 2% in N_2 as complement. If necessary other (s) concentration (s) should be used in addition.

2.2 For clause

5.2.1

The concentrations shall be 0, closed to 80% of the full scale range considered and to the points according to clause 5.2.1, and have an accuracy of ± 2% in N_2 as complement.

3 - INTERFERENCE GAS MIXTURES

	RECOMMENDED GAS MIXTURE IN N_2	
MEASURAND	CATEGORY I 1)	CATEGORY II 1)
CO / CO_2	(80% Fs) CO+14% CO_2 + 1600 ppm HC (*)	(80% Fs) CO+14% CO_2+160 ppm HC (*)
CO / CO_2	300 ppm NO	

(*) Equivalent Hexane C_6H_{14}

NOTE :

1) The accuracy of the components of the gas mixtures in N_2 are :

- CO : ± 2%
- CO_2 : ± 5%
- HC : ± 5%
- O_2 : ± 5%
- NO : ± 5%

ANNEX B

1 - ANALYSER SPECIFICATIONS

	METER	EXHAUST GAS	SCALE RANGE (ppm) recommended (1)	RESOLUTION (ppm) recommended	MAXIMUM PERMISSIBLE ERROR (3) RELATIVE (%) (2)	ABSOLUTE (ppm)
CAT. I	ANALOG	HC (4)	0 - 2000	50	± 5	± 20
	DIGITAL			10		
CAT. II	ANALOG	HC (4)	0 - 200	10	± 5	± 10
	DIGITAL			2		

NOTES :

1) Scales ranges can be subdivided into subranges : in digital instrument subranges are not always neccessary.
2) All values of relative error are indicated as relative values % to the measured value.
3) Whichever is greater.
4) Equivalent Hexane $C_6 H_{14}$

2 - CALIBRATION GASES

2.1 For clauses

5.1, 5.2.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.11, 5.12, 5.13, 5.14

The concentrations shall be about 80% of the full scale range considered and have an accuracy of ± 2% in N_2 as complement. If necessary other (s) concentration (s) should be used in addition.

2.2 For clause

5.2.1

The concentrations shall be 0, closed to 80% of the full scale range considered and to the points according to clause 5.2.1, and have an accuracy of ± 2% in N_2 as complement.

3 - INTERFERENCE GAS MIXTURES

	RECOMMENDED GAS MIXTURE IN N_2	
MEASUR.	CATEGORY I 1)	CATEGORY II 1)
HC	(80% Fs) HC(*)+14% CO_2 + 3% CO	(80% Fs) HC(*)+14% CO_2 +5% O_2 + 3% CO
HC	300 ppm NO	

(*) Equivalent Hexane C_6H_{14}

NOTE :

1) The accuracy of the components of the gas mixtures in N_2 are :

- CO : ± 2%
- CO_2 : ± 5%
- HC : ± 5%
- O_2 : ± 5%
- NO : ± 5%

ANNEX C

1 - ANALYSER SPECIFICATIONS

	METER	EXHAUST GAS	SCALE RANGE (%) recommended (1)	RESOLUTION (%) recommended	MAXIMUM PERMISSIBLE ERROR (3)	
					RELATIVE % (2)	ABSOLUTE %
CAT. I	ANALOG	NOT APPLICABLE				
CAT. I	DIGITAL	NOT APPLICABLE				
CAT. II	ANALOG	O_2	0 - 6	0.1	± 5	± 0.2
CAT. II	ANALOG	O_2	0 - 21	0.2	± 5	± 0.3
CAT. II	DIGITAL	O_2	0 - 6	0.01	± 5	± 0.2
CAT. II	DIGITAL	O_2	0 - 21	0.1	± 5	± 0.3

NOTES :

1) Scales ranges can be subdivided into subranges : in digital analysers subranges are not always neccessary.
2) All values of relative error are indicated as relative values % to the measured value.
3) Whichever is greater.

2 - CALIBRATION GASES

2.1 For clauses

5.1, 5.2.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.11, 5.12, 5.13, 5.14

The concentrations shall be about 80% of the full scale range considered and have an accuracy of ± 2% in N_2 as complement. If necessary other (s) concentration (s) should be used in addition.

2.2 For clause

5.2.1

The concentrations shall be 0, closed to 80% of the full scale range considered and to the points according to clause 5.2.1, and have an accuracy of ± 2% in N_2 as complement.

3 - INTERFERENCE GAS MIXTURES

	RECOMMENDED GAS MIXTURE IN N_2	
MEASUR.	CAT. I 1)	CATEGORY II 1)
O_2	---	(80% Fs) O_2+14% CO_2+5% CO + 300 ppm NO + 200 ppm HC (*)
O_2	300 ppm NO	

(*) Equivalent Hexane C_6H_{14}

NOTE :

1) The accuracy of the components of the gas mixtures in N_2 are :

- CO : ± 2%
- CO_2 : ± 5%
- HC : ± 5%
- O_2 : ± 5%
- NO : ± 5%

Annex 8

CHARACTERISTICS OF OPACIMETERS

1. SCOPE

This annex defines the conditions to be met by opacimeters used in the tests described in annexes 4 and 5 to this Regulation.

2. BASIC SPECIFICATION FOR OPACIMETERS

2.1 The gas to be measured shall be confined in an enclosure having a non-reflecting internal surface.

2.2 In determining the effective length of the light path through the gas, account shall be taken of the possible influence of devices protecting the light source and the photoelectric cell. This effective length shall be indicated on the instrument.

2.3 The indicating dial of the opacimeter shall have two measuring scales, one in absolute units of light absorption from 0 to ∞ (m^{-1}) and the other linear from 0 to 100; both scales shall range from 0 at total light flux to full scale at complete obscuration.

3. CONSTRUCTION SPECIFICATIONS

3.1 General

The design shall be such that under steady-speed operating conditions the smoke chamber is filled with smoke of uniform opacity.

3.2 Smoke chamber and opacimeter casing

3.2.1 The impingement on the photoelectric cell of stray light due to internal reflections or diffusion effects shall be reduced to a minimum (e.g. by finishing internal surfaces in matt black and by a suitable general layout).

3.2.2 The optical characteristics shall be such that the combined effect of diffusion and reflection does not exceed one unit on the linear scale when the smoke chamber is filled with smoke having an absorption coefficient near 1.7 m^{-1}.

3.3 Light source

The light source shall be an incandescent lamp with a colour temperature in the range 2,800 to 3,250°K.

3.4 Receiver

3.4.1 The receiver shall consist of a photoelectric cell with a spectral response curve similar to the photopic curve of the human eye (maximum response in the range 550/570 nm; less than 4 per cent of that maximum response below 430 nm and above 680 nm).

3.4.2 The construction of the electrical circuit, including the indicating dial, shall be such that the current output from the photoelectric cell is a linear function of the intensity of the light received over the operating-temperature range of the photoelectric cell.

3.5 Measuring scales

3.5.1 The light-absorption coefficient k shall be calculated by the formula $\phi = \phi_o . e^{-kL}$, where L is the effective length of the light path through the gas to be measured, ϕ_o the incident flux and ϕ the emergent flux. When the effective length L of a type of opacimeter cannot be assessed directly from its geometry, the effective length L shall be determined

Either by the method described in paragraph 4. of this annex;

or

Through correlation with another type of opacimeter for which the effective length is known.

3.5.2 The relationship between the 0-100 linear scale and the light-absorption coefficient k is given by the formula

$$k = - \frac{1}{L} \text{Log}_e \left(1 - \frac{N}{100}\right)$$

where N is a reading on the linear scale and k the corresponding value of the absorption coefficient.

3.5.3. The indicating dial of the opacimeter shall enable an absorption coefficient of 1.7 m^{-1} to be read with an accuracy of 0.025 m^{-1}.

3.6 Adjustment and calibration of the measuring apparatus

3.6.1 The electrical circuit of the photoelectric cell and of the indicating dial shall be adjustable so that the pointer can be reset at zero when the light flux passes through the smoke chamber filled with clean air or through a chamber having identical characteristics.

3.6.2 With the lamp switched off and the electrical measuring circuit open or short-circuited, the reading on the absorption-coefficient scale shall be ∞, and it shall remain at ∞ with the measuring circuit reconnected.

3.6.3 An intermediate check shall be carried out by placing in the smoke chamber a screen representing a gas whose known light-absorption coefficient k, measured as described in paragraph 3.5.1 is between 1.6 m^{-1} and 1.8 m^{-1}. The value of k must be known to within 0.025 m^{-1}. The check consists in verifying that this value does not differ by more than 0.05 m^{-1} from that read on the opacimeter indicating dial when the screen is introduced between the source of light and the photoelectric cell.

3.7 <u>Opacimeter response</u>

3.7.1 The response time of the electrical measuring circuit, being the time necessary for the indicating dial to reach 90 per cent of full-scale deflection on insertion of a screen fully obscuring the photoelectric cell, shall be 0.9 to 1.1 second.

3.7.2 The damping of the electrical measuring circuit shall be such that the initial overswing beyond the final steady reading after any momentary variation in input (e.g. the calibration screen) does not exceed 4 per cent of that reading in linear scale units.

3.7.3 The response time of the opacimeter which is due to physical phenomena in the smoke chamber is the time taken from the start of the gas entering the chamber to complete filling of the smoke chamber; it shall not exceed 0.4 second.

3.7.4 These provisions shall apply solely to opacimeters used to measure opacity under free acceleration.

3.8 <u>Pressure of the gas to be measured and of scavenging air</u>

3.8.1 The pressure of the exhaust gas in the smoke chamber shall not differ by more than 75 mm (water gauge) from the atmospheric pressure.

3.8.2 The variations in the pressure of the gas to be measured and of the scavenging air shall not cause the absorption coefficient to vary by more than 0.05 m^{-1} in the case of a gas having an absorption coefficient of 1.7 m^{-1}.

3.8.3 The opacimeter shall be equipped with appropriate devices for measuring the pressure in the smoke chamber.

3.8.4 The limits of pressure variation of gas and scavenging air in the smoke chamber shall be stated by the manufacturer of the apparatus.

3.9 Temperature of the gas to be measured

3.9.1 At every point in the smoke chamber the gas temperature at the instant of measurement shall be between 70°C and a maximum temperature specified by the opacimeter manufacturer such that the readings over the temperature range do not vary by more than 0.1 m^{-1}, when the chamber is filled with a gas having an absorption coefficient of 1.7 m^{-1}.

3.9.2 The opacimeter shall be equipped with appropriate devices for measuring the temperature in the smoke chamber.

4. EFFECTIVE LENGTH "L" OF THE OPACIMETER

4.1 General

4.1.1 In some types of opacimeter the gas between the light source and the photoelectric cell, or between transparent parts protecting the source and the photoelectric cell, is not of constant opacity. In such cases the effective length L shall be that of a column of gas of uniform opacity which gives the same absorption of light as that obtained when the gas is normally admitted into the opacimeter.

4.1.2 The effective length of the light path is obtained by comparing the reading N of the opacimeter operating normally with the reading N_o obtained with the opacimeter modified so that the test gas fills a well defined length L_o.

4.1.3 It will be necessary to take comparative readings in quick succession to determine the correction to be made for shifts of zero.

4.2 Method of assessment of L

4.2.1 The test gas shall be exhaust gas of constant opacity or a light-absorptive gas of a gravimetric density similar to that of exhaust gas.

4.2.2 A column of length L_o of the opacimeter, which can be filled uniformly with the test gas, and the ends of which are substantially at right angles to the light path, shall be accurately determined. This length L_o shall be close to the effective length of the opacimeter.

4.2.3 The mean temperature of the test gas in the smoke chamber shall be measured.

4.2.4 If necessary, an expansion tank of sufficient capacity to damp the pulsations and of compact design may be incorporated in the sampling line as near to the probe as possible. A cooler may also be fitted. The addition of the expansion tank and of the cooler should not unduly disturb the composition of the exhaust gas.

4.2.5 The test for determining the effective length shall consist in passing a sample of test gas alternately through the opacimeter operating normally and through the same apparatus modified as indicated in paragraph 4.1.2.

4.2.5.1 The opacimeter readings shall be recorded continuously during the test with a recorder whose response time is equal to or shorter than that of the opacimeter.

4.2.5.2 With the opacimeter operating normally, the reading on the linear scale of opacity is N and that of the mean gas temperature expressed in Kelvin degrees is T.

4.2.5.3 With the known length L_o filled with the same test gas, the reading on the linear scale of opacity is N_o and that of the mean gas temperature expressed in Kelvin degrees is T_o.

4.2.6 The effective length will be

$$L = L_o \frac{T}{T_o} \frac{\log\left(1 - \frac{N}{100}\right)}{\log\left(1 - \frac{N_o}{100}\right)}$$

4.2.7 The test shall be repeated with at least four test gases giving readings evenly spaced between the readings 20 and 80 on the linear scale.

4.2.8 The effective length L of the opacimeter will be the arithmetic average of the effective lengths obtained as stated in paragraph 4.2.6. for each of the gases.