DOC.NO.: MoRTH/CMVR/TAP-115/116
Issue No. 4

# DOCUMENT ON TEST METHOD, TESTING EQUIPMENT AND RELATED PROCEDURES

# FOR

## TESTING TYPE APPROVAL AND CONFORMITY OF PRODUCTION (COP) OF VEHICLES FOR EMISSION AS PER CMV RULES 115, 116 AND 126

MINISTRY OF ROAD TRANSPORT AND HIGHWAYS,
GOVERNMENT OF INDIA
March, 2010

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# Summary of Applicable Emission Norms for Different Catagories of Vehicles and Engines

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# INTRODUCTION

## DOC.NO.: MoRTH/CMVR/TAP-115-116
## Issue No. 4

This document prescribes the test method, testing equipment and other related procedure for the purpose of testing motor vehicles for verifying compliance to Rule 115 and 126A of CMVR for Type Approval and Conformity of Production. This document covers Bharat Stage-I,II, III & IV norms for 2-wheeler, 3-wheeler and motor cars and diesel engines wherever applicable, Trem-II, Trem-III & Trem IIIA norms for agriculture, power tiller and emission norms for construction equipment vehicles. [Concerned G.S.R. Notification nos. are 493(E), 77(E), 284(E), 286(E), 675(E), 788(E), 853(E), 83(E), 686(E), 720(E),589(E),276(E),84(E)]. This also contains the total procedure for checking of the in-service vehicles for idling CO/HC for vehicles fitted with petrol / CNG / LPG engines or free acceleration smoke for vehicles fitted with diesel engines.

The emission regulation limits will be as notified by MoRTH under CMVR from time to time.

This document is at present divided into 15 parts.

Parts I and II are the procedures for checking idling CO and HC, free acceleration smoke on in-service petrol / diesel vehicles. These are based on which are originally intended for the type-approval for rule 115(2).

Parts III, IV and V covers the test procedure for rules 115(3), (4) and (5) respectively, which are Annexure III, IV and V of Ranganathan Committee Report, incorporating some changes as were felt necessary from the experience gained so far.

Part VI is the administrative procedure for COP and is based on decision taken by SCOE from time to time.

Part VII has been prepared to cover the testing procedures for crankcase and evaporative emissions and are based on the corresponding EEC.

Part VIII is the procedure for type-approval of instruments for checking the emission from in-service vehicles.

Part IX is the procedure for tail pipe emissions from petrol, CNG, LPG and diesel engine vehicles effective from the year 2000.

Part X is the procedure for gaseous pollutants from compression ignition, natural gas, LPG engines with effective from 1.4.2000.

Part X, Sub Part A is the procedure for diesel engine agricultural tractors and construction equipment vehicles engines testing.

Part X, Sub Part A is the details of standards of visible and gaseous pollutants from diesel engines for construction equipment vehicles

Part XI is the Details of Standards for tailpipe Emissions from Petrol, CNG, LPG and Diesel Engined Vehicles and Test Procedures effective from the 01-04-2005.

Part XII is the Details of Standards for Emissions of Visible and Gaseous pollutants from Compression Ignition (CI), Natural Gas (NG) & Liquefied Petroleum Gas (LPG) Engined Vehicles and Test Procedures effective from the 01-04-2005.

Part XIII is the Details of Standards for Tailpipe Emissions from Petrol, CNG, LPG and Diesel Engined Vehicles and Test Procedures Effective for Mass Emission Standards (Bharat Stage III) for Two / Three Wheeled Vehicles

Part XIV is the Details of Standards for Tailpipe Emissions from Petrol, CNG, LPG and Diesel Engined Vehicles and Test Procedures Effective for Mass Emission Standards (Bharat Stage IV) for M and N Category Vehicles not exceeding 3.5 tons GVW

Part XV is the details of standards for emissions of visible and gaseous pollutants from compression ignition (ci), natural gas (ng) & liquified petroleum gas (lpg) engined vehicles and test procedures effective for mass emission standards (bharat stage iv) for vehicle above 3.5 tons gvw

Part XV sub part (A) details of standards of visible and gaseous pollutants from diesel engines for agriculutaral tractors

# PART I : DETAILS OF STANDARDS AND TEST PROCEDURS FOR MEASUREMENT OF CARBON MONOXIDE AND HYDRO CARBON EMISSIONS AT IDLING FOR IN-SERVICE VEHICLES FITTED WITH SI ENGINES

1. Scope & Field of application:

1.1 This Part applies to the emissions of carbon monoxide and hydro carbon at idling from in-service vehicles fitted with spark ignition engines, as referred in CMVR-115 (2)(a) and for issue of "Pollution under control certificate" to be issued by authorised agencies under CMVR-115 (7).

1.2 This part specifies standard and test procedure for the determination of the volumetric concentration of exhaust carbon monoxide (CO) and hydrocarbon (HC) emissions from road vehicles equipped with spark ignition engines running at idle speed.

2. Definitions:

2.1 Spark Ignition Engine: Means an internal combustion engine in which the combustion of the air/fuel mixture is initiated at given instants by a hot spot, usually an electric spark.

2.2 Idle Speed: Means the engine rate, in revolution per minute, with fuel system controls (accelerator and choke) in the rest position, transmission in neutral and clutch engaged in the case of vehicles with manual or semi-automatic transmission or with selector in park or neutral position when an automatic transmission is installed, as recommended by the manufacturer.

2.3 Normal Thermal Conditions: Means the thermal conditions attained by an engine and its drive line after a run of at least 15 min. on a variable course, under normal traffic conditions.

3.0 Test Procedure:

3.1 Instrument

3.1.1 The Instrument used for the measurement of CO and HC shall be a type approved instrument as given in CMVR-116 (3) and meeting the requirements specified in Part-VIII. For measurement of idling CO and HC emissions of in-use 2, 3 and 4 wheeler (other than Bharat Stage II and above compliant) vehicles, 2 Gas analyser type approved as per Chapter II of Part VIII shall be used. For measurement of idling CO and HC emissions of in-use 4 wheeler vehicles (Bharat Stage II and above compliant), 4 Gas analyser type approved as per Chapter III of Part VIII shall be used. The tachometer to measure engine idling speed shall have an accuracy of ± 50 rpm.

3.1.2 The Instrument shall be prepared, used and maintained following the directions given in the instrument manufacturer's operation manual, and it shall be serviced and calibrated at such intervals as to ensure accuracy.

3.1.3 The electronic calibration shall be carried out at least once after switching on the instrument and thereafter a maximum time period of four hours. The span calibration using gas bottle shall be carried out at least once in four months and whenever instrument is moved to a different place. The total record of calibration shall be maintained and if it is observed during calibration that the calibration is shifted more than the accuracy, the calibration period shall be suitably reduced.

The calibration shall be performed well away from the exhaust of motor vehicles whose engines are running.

3.1.4 If the sample handling system is not integral with the analyser, the effectiveness of the condensate traps and all connections of the gas sampling system shall be checked. It shall be checked that filters are clean; that filter holders are fitted with their gaskets and that these are in good conditions.

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

3.1.6 It shall be ensured that the sample handling line and probe are free from contaminants and condensates.

3.2 Vehicle Preparation

3.2.1 It shall be checked that the road vehicle exhaust system is leak proof and that the manual choke control has been returned to the rest position.

3.2.2 It shall be checked that the gas sampling probe can be inserted into the exhaust pipe to a depth of at least 300 mm. If this proves impossible owing to the exhaust pipe configuration, a suitable extension to the exhaust pipe(s), making sure that the connection is leak proof, shall be provided.

3.2.3 The vehicle shall have attained normal thermal conditions as defined in 2.3, immediately prior to the measurement.

3.2.4 The vehicle idling speed shall be checked and set as per 2.2, as prescribed by the manufacturer, with all the accessories switched off.

3.3 Measurement

3.3.1 Immediately preceding the measurement, the engine is to be accelerated to a moderate speed with no load, maintained for at least 15 seconds, then returned to idle speed as set in 3.2.4.

3.3.1.1 While the engine idles, the sampling probe shall be inserted into the exhaust pipe to a depth not less than 300 mm.

3.3.3 After the engine speed stabilises, the reading shall be taken.

3.3.4 The value of CO and HC concentration reading shall be recorded.

3.3.5 In cases where gadgets or devices are incorporated in the exhaust system, for dilution of the exhaust, both CO and CO2 shall be measured using an instrument having facility to measure both CO and $CO_2$. If the total of the measured values of CO and $CO_2$ (T. CO and T. $CO_2$) concentration exceed 15% for four stroke engines and 10% for two stroke engines, the measured value of CO shall be taken as carbon monoxide emissions from the vehicle.

If it does not, the corrected value (T corrected) shall be taken, as given below: -

T corrected = T CO x 15/ (T CO + T $CO_2$)
For 4-stroke engines
= T CO x 10/ (T CO + T $CO_2$)
For 2-stroke engines

3.3.6 Multiple exhaust outlets shall be connected to a manifold arrangement terminating in a single outlet. If a suitable adopter is not available, the arithmetic average of the concentrations from the multiple pipes may be used.

3.3.7 If the measurement is to be repeated, the entire procedure of para 3.0 shall be repeated.

3.3.8 For the purpose of PUC (Pollution Under Control) certification, if the idling CO and/or HC are not within limits as per 4.0 below, the testing shall be discontinued and the vehicle owner shall be advised to resubmit the vehicle after repair / service.

4.0 Test Limits :

4.1 The vehicle when tested as per 3.0 above shall meet the following limits.

| Sr. No. | Vehicle Type (Petrol) | CO % | *HC (n – hexane equivalent) ppm |
|---|---|---|---|
| 1. | 2&3—Wheeler (2/4-stroke) (Manufactured on and before 31st March 2000) | 4.5 | 9000 |
| 2. | 2&3—Wheeler (2-stroke) (Manufactured after 31st March 2000) | 3.5 | 6000 |
| 3. | 2&3 – Wheeler (4-stroke) (Manufactured after 31st March 2000) | 3.5 | 4500 |
| 4. | 4-wheelers manufactured as per Pre Bharat Stage-II norms | 3.0 | 1500 |
| 5. | 4-Wheelers manufactured as per Bharat Stage-II, Bharat Stage-III or subsequent norms | 0.5 | 750 |

***NOTES :**

(i) Idling emission standards for vehicles when operating on CNG shall replace Hydrocarbon (HC) by Non Methane Hydrocarbon (NMHC). NMHC may be estimated by the following formula:

NMHC = 0.3 x HC

Where HC = Hydrocarbon measured (n – hexane equivalent)

(ii) Idling emission standards for vehicles when operating on LPG shall replace Hydrocarbon (HC) by Reactive Hydrocarbon (RHC). RHC may be estimated by the following formula:

RHC = 0.5 x HC

Where HC = Hydrocarbon measured (n – hexane equivalent)

5.0 Code of Practice for Authorised PUC Test Agencies :

The PUC test agencies authorised for issue of "Pollution Under Control Certificate" as per CMVR-115(7) shall comply with following Code of Practice.

5.1 The Type Approval certificate supplied by PUC equipment manufacturer / supplier shall be displayed in the PUC center.

5.2 The operator training certificate issued by PUC equipment manufacturer / supplier shall be displayed in the PUC center.

5.3 PUC operator shall submit the monthly report of all tested in-use vehicles along with test printout in original to the Transport Department.

5.4 PUC operator shall enter into AMC for a period of 5 years with the respective PUC equipment manufacturer based on the finalized charges.

6.0 Renewal of PUC Operator Licence

The licence of PUC operator shall be renewed by the concerned Transport Authorities provided the PUC operator follows Code of Practice as per 5.0 above.

## PART II : DETAILS OF STANDARS AND TEST PROCEDURES FOR MEASUREMENT OF SMOKE LEVELS BY FREE ACCELERATION FOR IN-SERVICE VEHICLES FITTED WITH DIESEL ENGINES

1. Scope and Field of Application

1.1 This part applies to the emissions of visible pollutants from in-service compression ignition (diesel) engine vehicles, when subjected to a free acceleration test as referred in CMVR-115 (2)(b) and for issue of "Pollution under control certificate" to be issued by the authorised agencies under CMVR-115 (7).

1.2 This part specifies standard and test procedure for the determination of smoke levels by free acceleration from road vehicles equipped with compression ignition engines.

2. Definitions

2.1 Compression Ignition Engine: means an Internal Combustion Engine that operates on compression ignition principle (Diesel Engines).

2.2 Smoke Density: means the light absorption coefficient of the exhaust gases emitted by the vehicle expressed in terms of $m^{-1}$ or in other units such as Bosch, Hartidge, % opacity etc.

2.3 Opacity Meter: means an Instrument for continuous measurement of the light absorption coefficient of the exhaust gases emitted by vehicles.

2.4 Maximum Rated Speed: means the maximum speed permitted by governor at full load.

2.5 Free Acceleration Test: means the test conducted by abruptly but not violently, accelerating the vehicle from idle to full speed with the vehicle stationary in neutral gear.

3.0 Test Procedure

3.1 Test Instrument

3.1.1 The opacimeter, the Instrument used for the measurement of smoke should be a type approved instrument as given in CMVR -116(3) and meeting the requirements specified in Part-VIII.

3.1.2 The Instrument should be prepared, used and maintained following the directions given in the instrument manufacturer's operation manual and it should be serviced and calibrated at such intervals as to ensure accuracy.

3.2 Sampling Opacimeter

3.2.1 Installation for tests under Free Acceleration

3.2.1.1 The ratio of cross sectional area of the probe to that of the exhaust pipe shall not be less than 0.05.

3.2.1.2 The probe shall be a tube with an open end facing forward in the axis of exhaust pipe or of the extension pipe, if one is required. It shall be situated in a section where the distribution of smoke is approximately uniform. To achieve this, the probe shall be placed as far downstream in the exhaust pipe as possible or if necessary in an extension pipe so that, if D is the diameter of exhaust pipe at the opening, the end of probe is situated in a straight portion at least 6 D in length upstream of the sampling point and 3 D in length downstream. If an extension pipe is used, no air shall be allowed to enter the joint.

3.2.1.3 The sampling system shall be such that at all engine speeds, pressure of the sample at the opacimeter is within the limits specified. This may be checked by noting the sample pressure at engine idling and maximum no load speeds. Depending on the characteristics of the opacimeter, control of sample pressure can be achieved by a fixed restriction or butterfly valve in the exhaust pipe or extension pipe. Whichever method is used, the backpressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).

3.2.1.3 The pipes connecting the opacimeter shall also be as short as possible. The pipe shall be inclined upwards from the sampling point to the opacimeter and sharp bends where soot might accumulate shall be avoided. A bypass valve may be provided upstream of opacimeter to isolate it from the exhaust gas flow when no measurement is being made.

3.2.1.4 The temperature probe for the measurement of oil temperature shall be inserted in place of oil dipstick.

3.2.1.5 The engine speed measurement sensor shall be appropriately installed on to the engine of the vehicle.

3.3 Full Flow Opacimeter

The only general precautions to be observed in free acceleration tests are the following:

3.3.1 Joints in the connecting pipes, if any, between the exhaust pipe and the opacimeter shall not allow air to enter from outside.

3.3.1.2 The pipes connecting the opacimeter shall be as short as possible, as prescribed in the case of sampling opacimeter. The pipe system shall be inclined upwards from the exhaust pipe to the opacimeter, and sharp bends where soot might accumulate shall be avoided. A by-pass valve may be provided upstream of the opacimeter to isolate it from the exhaust gas flow when no measurement is being made.

3.3.3 A cooling system may also be required upstream of the opacimeter.

3.4 Vehicle Inspection

3.4.1 The Exhaust device shall not have any orifice through which the gases emitted by the engine might be diluted.

3.4.2 In cases where an engine has several exhaust outlets; these shall be connected to a single outlet in which opacity measurement shall be made. If it is not possible, to combine all exhaust outlets in one, the smoke shall be measured in each and an arithmetical mean of the values shall be recorded at each outlet. The test shall be taken as valid only if the extreme values measured do not differ by more than $0.15m^{-1}$

4.4.3 The engine shall be in normal working condition prescribed by the manufacturer.

4.5 Measurement Procedure

4.5.1 Free Acceleration Test

4.5.1.1 The test shall be carried out on a vehicle.

4.5.1.2 The engine of the vehicle shall be warmed-up to attain oil temperature of 60 °C. The test shall be carried out as soon as this engine condition is reached.

4.5.1.3 The combustion chamber shall not have been cooled or fouled by a prolonged period of idling preceding the test.

4.5.1.4 The vehicle gear change control shall be set in the neutral position and the drive between engine and gearbox engaged. With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the opacimeter reverts to the corresponding conditions. Typically the maximum time for acceleration shall be 5s and for the stabilization at maximum no load speed shall be 2s. The time duration between the two free accelerations shall be between 5-20s.

4.5.1.5 The operation described in 4.5.1.4 above shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustments of the apparatus. During this operation the sample probe shall not be inserted in to the vehicle exhaust system.

4.5.1.6 The free acceleration smoke test as per operation in 4.5.1.4 shall be carried out with sample probe inserted in to the vehicle exhaust system. The maximum no load rpm reached during this operation shall be within ± 500 rpm in respect of 3 wheeler vehicles and ± 300 rpm for all other categories of vehicles, of the average value obtained in the last four of the six flushing cycles in 4.5.1.5. If for any reason the speed is not within the specified tolerance band the particular smoke reading shall be considered as invalid and shall be discarded. The above operation shall be repeated till the peak smoke values recorded in four successive accelerations are valid and are situated within a bandwidth of 25 % of the arithmetic mean (in m-1 unit) of these values or within a bandwidth of 0.25 K, whichever is higher and do not form a decreasing sequence.

The absorption coefficient to be recorded shall be the arithmetic mean of these four valid readings. The vehicle should be considered meeting the requirement if the absorption coefficient thus recorded is less than the prescribed limits.

In case the valid readings are not obtained within the 10 free-accelerations, the testing shall be discontinued and the vehicle owner shall be advised to re-submit the vehicle after the same is repaired / serviced.

4.5.1.7 For the purpose of PUC certification if the smoke is not within limits as per 5.0 below, the testing shall be discontinued and the vehicle owner shall be advised to re-submit the vehicle after the same is repaired / serviced.

5 Test Limits :

| Method of Test | Maximum Smoke Density | |
|---|---|---|
| | Light absorption co-efficient (1/m) | Hartidge units |
| Free acceleration test for turbo charged engine and naturally aspirated engine | 2.45 | 65 |

6.0 Code of Practice for Authorised PUC Test Agencies :

The PUC test agencies authorised for issue of "Pollution Under Control Certificate" as per CMVR-115(7) shall comply with following Code of Practice.

6.1 The Type Approval certificate supplied by PUC equipment manufacturer / supplier shall be displayed in the PUC center.

6.2 The operator training certificate issued by PUC equipment manufacturer / supplier shall be displayed in the PUC center.

6.3 PUC operator shall submit the monthly report of all tested in-use vehicles along with test printout in original to the Transport Department.

6.4 PUC operator shall enter into AMC for a period of 5 years with the respective PUC equipment manufacturer based on the finalized charges.

7.0 Renewal of PUC Operator License

The license of PUC operator shall be renewed by the concerned Transport Authorities provided the PUC operator follows Code of Practice as per 5.0 above.

# PART III : DETAILS OF STANDARDS FOR EMISSION OF GASEOUS POLLUTANTS FROM PETROL ENGINED VEHICLES AND TEST PROCEDURES EFFECTIVE FROM 1ST APRIL 1991

CHAPTER 1 : OVERALL REQUIREMENTS

CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

CHAPTER 3 : TYPE I TEST ON SI ENGINES (VERIFYING THE AVERAGE EMISSIONS OF GASEOUS POLLUTANTS)

CHAPTER 4 : RESISTANCE TO PROGRESS OF A VEHICLE -MEASUREMENT METHOD ON THE ROAD - SIMULATION ON A CHASSIS DYNAMOMETER

CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

CHAPTER 6 : GAS SAMPLING SYSTEMS

CHAPTER 7 : CALIBRATION OF CHASSIS DYNAMOMETERS, CVS SYSTEM AND GAS ANALYSIS SYSTEM AND TOTAL SYSTEM VERIFICATION

CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

CHAPTER 9 : TYPE II TEST ON SI ENGINES (VERIFYING CARBON MONOXIDE EMISSION AT IDLING)

CHAPTER 10 : CHARACTERISTICS OF REFERENCE FUEL

## CHAPTER 1 : OVERALL REQUIREMENTS

1. Scope :

1.1 This Part applies to the emission of gaseous pollutants from spark ignition engined (petrol) vehicles effective from 1st April, 1991. The method of test for mass emission given in this Part may also be used at the manufacturer's option for compression ignition engined vehicles with Gross Vehicle Weight (GVW) not exceeding 3500 kg, instead of Part V.

2. Definitions :

2.1 Spark Ignition Engine : Means an internal combustion engine in which the combustion of the air/fuel mixture is initiated at given instants by a hot spot, usually an electric spark.

2.2 Idle Speed : Means the engine rate, in revolution per minute, with fuel system controls (accelerator and choke) in the rest position, transmission in neutral and clutch engaged in the case of vehicles with manual or semi-automatic transmission, or with selector in park or neutral position when an automatic transmission is installed, as recommended by the manufacturer.

2.3 Normal Thermal Conditions : Means the thermal conditions attained by an engine and its drive line after a run of at least 15 minutes on a variable course, under normal traffic conditions.

2.4 Gaseous Pollutants : Means carbon monoxide, hydrocarbons (assuming a ratio of $CH_{1.85}$ ) and oxides of nitrogen, (being expressed in Nitrogen dioxide NO2 equivalent.)

2.5 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90% full and the usual set of tools and spare wheel on board where applicable.
In the case of 3-wheeled tractors, designed for coupling to a semi-trailer, the unladen mass will be that of the drawing vehicle.

2.6 Reference Mass : Means the "Unladen Mass" of the vehicle increased by a uniform figure of 75 Kg for 2 wheeled vehicles; and 150 Kg for all other vehicles.

2.7 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer.

In case of the 3 wheeled vehicles designed to be coupled to a semi-trailer, the mass GVW to be taken into consideration when classifying that vehicle, shall be the maximum weight of the tractor in running order, plus the weight transferred to the tractor by the laden semi-trailer in static condition.

2.8 Cold Start Device : Means a device which enriches the air fuel mixture of the engine temporarily and thus to assist engine start up like choke.

2.9 Starting Aid : Means a device which assists engine start up with- out enrichment of the fuel mixture, e.g. glow plug, change of injection timing for fuel-injected spark ignition engine, etc.

2.10 Type Approval of a vehicle : Means the type approval of a vehicle model with regard to the limitation of the emission of gaseous pollutants from the engine.

2.11 Vehicle Model : Means a category of power-driven vehicles which do not differ in such essential respects as the equivalent inertia determined in relation to the reference weight of engine and vehicle characteristics which effects the vehicular emission and listed in Chapter 2 of this Part.

2.11 Vehicle for Type Approval Test : Means the fully built vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

2.13 Vehicle for Conformity of Production : Means a vehicle selected at random from a production series of vehicle model which has already been type approved.

3. Application for Type Approval :

3.1 The application for type approval of a vehicle model with regard to limitation of the emission of gaseous pollutants from its engine shall be submitted by the vehicle manufacturer with a description of the engine and vehicle model comprising all the particulars referred to in Chapter 2 of this Part.

A vehicle representative of the vehicle model to be type approved shall be submitted to the testing agency responsible for conducting tests referred in para 5 of this Part.

4. Type Approval :

If the vehicle submitted for type approval pursuant to these rules, meet the requirements of para 5 below, approval of that vehicle model shall be granted. The approval of the vehicle model pursuant to this part shall be communicated to the vehicle manufacturer and nodal agency by the testing agency in the form of certificate of compliance to the CMVR, as envisaged in Rule-126 of CMVR.

5. Specification and Tests :

5.1 General : The components liable to affect the emission of gaseous pollutants shall be so designed, constructed and assembled to enable the vehicle, in normal use, despite the vibrations to which they may be subjected to comply with the provisions of this rule.

5.2 Specifications concerning the emissions of pollutants

5.2.1 The vehicle shall be subjected to tests of Type I and II as specified below according to the category it belongs.

5.2.2 Type I Test: (Verifying the average emission of gaseous pollutants)

5.2.2.1 The vehicle shall be placed on a dynamometer bench equipped with a means of load and inertia simulation. A test lasting a total of 648 seconds and comprising six cycles as described in Chapter 3 of this Part shall be carried out, without interruption. During the test the exhaust gases shall be diluted with air and a proportional sample collected in one or more bags. The contents of the bags will be analysed at the end of the test. The total volume of the diluted exhaust must be measured.

5.2.2.2 The test shall be carried out by the procedure described in Chapter 3 of this Part. The methods used to collect and analyse the gases shall be those prescribed. Other analysis methods may be approved if it is found that they yield equivalent results.

5.2.2.3 Subject to the provisions of para 5.2.2.7 the test shall be repeated three times.

5.2.2.4 For a spark ignition engined vehicle of a given category and given reference weight, the mass/km of the carbon monoxide and hydrocarbons obtained shall not be more than the amounts shown in paragraph. For spark ignition engined vehicles the value of NOx will be measured and recorded during the test, but no limits are set for NOx at present.

5.2.2.5 Emission Standard for Type I Test :

5.2.2.5.1 Three Wheeled Vehicles and its derivatives, including tractors for semi trailers of GVW not exceeding 1000 kg and 2 wheeled vehicles

THREE WHEELED VEHICLES AND ITS DERIVATIVES INCLUDING TRACTORS FOR SEMI TRAILERS OF GVW NOT EXCEEDING 1000Kg. AND TWO WHEELED VEHICLES

| Reference mass , more than | R (Kg) Upto and including | CO (g/km) | HC (g/km) |
|---|---|---|---|
| ---- | 150 | 12 | 8 |
| 150 | 350 | $12 + \frac{18(R-150)}{200}$ | $8 + \frac{4(R-150)}{200}$ |
| 350 | ---- | 30 | 12 |

5.2.2.5.2 ALL OTHER VEHICLES

| Reference mass, more than | R (Kg) Upto and including | CO (g/km) | HC (G/km) |
|---|---|---|---|
| ---- | 1020 | 14.3 | 2.0 |
| 1020 | 1250 | 16.5 | 2.1 |
| 1250 | 1470 | 18.8 | 2.1 |
| 1470 | 1700 | 20.7 | 2.3 |
| 1700 | 1930 | 23.0 | 2.5 |
| 1930 | 2150 | 24.9 | 2.7 |
| 2150 | ---- | 27.1 | 2.9 |

5.2.2.6 Nevertheless, for each of the pollutants referred to in the foregoing para, not more than one of the three results obtained may exceed by not more than 10% the limit prescribed in that para for the vehicle concerned, provided the arithmetical mean of the three results rounded off to the second decimal place is not exceeding the prescribed limit. Where the prescribed limits are exceeded for more than one pollutant (carbon monoxide and hydrocarbons), it shall be immaterial whether this occurs in the same test or in different tests.

5.2.2.6.1 If one of the three results obtained of each of the pollutants exceeds by more than 10% the limit prescribed in Para for the vehicle concerned, the test may be continued as specified in Para 5.2.2.6.1 below.

5.2.2.6.2 The number of tests prescribed in Para 5.2.2.3 above may, on the request of the manufacturer, be increased to 10 tests provided that the arithmetical mean (x ) of the three results for carbon monoxide and/or for the emissions of hydrocarbons (rounded off to the second decimal place) falls between 100 and 110% of the limit (L). In this case, the decision, after testing, shall depend exclusively on the average results obtained from all 10 tests (rounded off to the second decimal place)i.e. $x < L$.

5.2.2.7 The number of tests prescribed in Para 5.2.2.3 above shall be reduced in the conditions hereinafter defined, where $V_1$ is the result of the first test and $V_2$ the result of the second test for each of the pollutants referred to in Para 5.2.2.4 above.

5.2.2.7.1 Only one test shall be performed if $V_1$ readings of carbon monoxide as well as the hydrocarbon are less than or equal to L i.e. $V_1 <= 0.70$ L.

5.2.2.7.2 Only two tests shall be performed if the results of $V_1$ readings of both the carbon monoxide and hydrocarbons are $V_1 <0.85$ L, and if, at the same time, one of these values is $V_1 > 0.70$ L. In addition, the $V_2$ readings of both the carbon monoxide and hydrocarbon must satisfy the requirement that - $(V_1 + V_2) <=$ 1.70 L and $V_2 <=$ L.
Fig.1 depicts the scheme.

5.2.3 Type II Test (Test for carbon monoxide emissions at idling speed)

5.2.3.1 This is applicable only for spark ignition engined vehicles.

5.2.3.2 The carbon monoxide content by volume of the exhaust gases emitted with the engine idling must not exceed 4.5%, for three wheeled vehicles and its derivatives, including tractors for semi-trailers of GVW not exceeding 1000 kg and two wheeled vehicles and 3.0% for all other vehicles when a test is made in accordance with the provisions of Chapter 9 of this Part.

6. Modifications of the vehicle Model :

6.1 Every modification in the essential characteristics of the vehicle model shall be intimated by the vehicle manufacturer to the test agency which type approved the vehicle model. The test agency may either

6.1.1 Consider that the vehicle with the modifications made may still comply with the requirement, or Require a further test to ensure further compliance.

6.2 In case of 6.1.1 above, the testing agency shall extend the type approval covering the modified specification or the vehicle model shall be subjected to necessary tests. In case, the vehicle complies with the requirements, the test agency shall extend the type approval.

6.3 Any changes to the procedure of PDI and running in concerning emission shall also be intimated to the test agency by the vehicle manufacturer, whenever such changes are carried out.

7. Model Changes :

7.1 Vehicle models of Different Reference Weights and coast down coefficients :

Approval of a vehicle model may under the following conditions be extended to vehicle models which differ from the type approved only in respect of their reference weight.

7.1.1 Approval may be extended to vehicle model of a reference weight requiring merely the use of the next higher or next lower equivalent inertia.

7.1.2 If the reference weight of the vehicle model for which extension of the approval is requested requires the use of a flywheel of equivalent inertia higher than that used for the vehicle model already type approved, extension of the approval shall be granted.

7.1.3 If the reference weight of the vehicle model for which extension of the type approval is requested requires the use of a flywheel of equivalent inertia lower than that used for the vehicle model already approved, extension of the type approval shall be granted if the masses of the pollutants obtained from the vehicle already approved are within the limits prescribed for the vehicle for which extension of the approval is requested.

7.1.4 If different body configurations are used with the same power plant & drive line & the change in the load equation due to changes in the coefficient of resistances that is less than that would be caused by the change of inertia to one step lower or one step higher than the inertia setting of the type approved vehicle, the approval may be extended.

7.2 Vehicle models with Different Overall Gear Ratios :

7.2.1 Approval granted to a vehicle model may under the following conditions be extended to vehicle models differing from the type approved only in respect of their overall transmission ratios;

7.2.1.1 For each of the transmission ratios used in the Type I Test, it shall be necessary to determine the proportion

$$E = (V_2 - V_1)/V_1,$$

where $V_1$ and $V_2$ are respectively the speed at 1000 rev/min of the engine of the vehicle model type approved and the speed of the vehicle model for which extension of the approval is requested.

7.2.2 If for each gear ratio E <= 8%, the extension shall be granted without repeating the Type I Tests.

7.3 Vehicle models of Different Reference Weights, coefficient of coast down and Different Overall Transmission Ratios

Approval granted to a vehicle model may be extended to vehicle models differing from the approved type only in respect of their reference weight, coefficient of coast down and their overall transmission ratios, provided that all the conditions prescribed in Para 7.1 and 7.2 above are fulfilled.

7.4 Note : When a vehicle type has been approved in accordance with the provisions of Para 7.1 to 7.3 above, such approval may not be extended to other vehicle types.

8 Conformity of Production :

8.1 Every produced vehicle of the model approved under this rule shall conform, with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved. The procedure for carrying out conformity of production tests is given in Part VI of this document.

8.2 Type I Test : Verifying the average emission of gaseous pollutants : For verifying the conformity of production in a Type I Test, the following procedure is adopted :-

8.2.1 The vehicle sample taken from the series, as described in 8.1 is subjected to the test described in para 5.2.2 above. The mass/km of the Carbon monoxide and Hydrocarbon emitted by the vehicle shall not be more than the limit values given in para (instead of para 5.2.2.5) for the category and given reference weight.

8.2.2 Limit Values for Conformity of Production Tests for Spark Ignition Engined Vehicles

8.2.2.1 THREE WHEELED VEHICLES AND ITS DERIVATIVES INCLUDING TRACTORS FOR TRAILERS , GVW NOT EXCEEDING 1000Kg. AND TWO WHEELED VEHICLES

| Reference mass R (Kg), more than | Reference mass R (Kg) Upto and including | CO (g/km) | HC (g/km) |
|---|---|---|---|
| ---- | 150 | 15 | 10 |
| 150 | 350 | $15 + \frac{25(R-150)}{200}$ | $10 + \frac{5(R-150)}{200}$ |
| 350 | ---- | 40 | 15 |

8.2.2.2 ALL OTHER VEHICLES

| Reference mass, more than | R (Kg) Upto and including | CO (g/km) | HC (G/km) |
|---|---|---|---|
| ---- | 1020 | 17.3 | 2.7 |
| 1020 | 1250 | 19.7 | 2.7 |
| 1250 | 1470 | 22.5 | 2.8 |
| 1470 | 1700 | 24.9 | 3.0 |
| 1700 | 1930 | 27.6 | 3.3 |
| 1930 | 2150 | 29.9 | 3.5 |
| 2150 | ---- | 32.6 | 3.7 |

8.2.3 If the vehicle taken from the series does not satisfy the requirements of para 8.2.2 above, the manufacturer may ask for measurements to be performed on a sample of vehicles taken from the series and including the vehicle originally taken. The manufacturer shall specify the size n of the sample subject to 'n' being minimum 2 and maximum 10, including the vehicle originally taken. The vehicles other than originally tested shall be subjected to single Type I test. The result to be taken into consideration for the vehicle taken originally is the arithmetical mean of the three Type I tests carried out on the vehicle. The arithmetical mean $\bar{x}$ of the results obtained with the sample and the standard deviation S of the sample shall then be determined for each gaseous pollutant (rounded off to the second decimal point) The production of the series shall then be deemed to conform if the following condition is met :

$$\bar{x} + k.S <= L$$

where $S^2 = \Sigma (x - \bar{x})^2 / (n-1)$

x - any one of the individual results obtained with the sample n.

L - the limit value prescribed in para 8.2.2 above for each gaseous pollutant considered; and

k - a statistical factor dependent on n and given by the following table :

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| k | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

If $n >= 20$, $k = 0.860 / \sqrt{n}$

8.2.4 Alternatively if the manufacturer requests so, the conformity of production can be verified by the following alternative sampling plan.

8.2.4.1 A failed vehicle is one whose test results, lead to one or more of the limit values in Para 8.2.4.2 being exceeded.

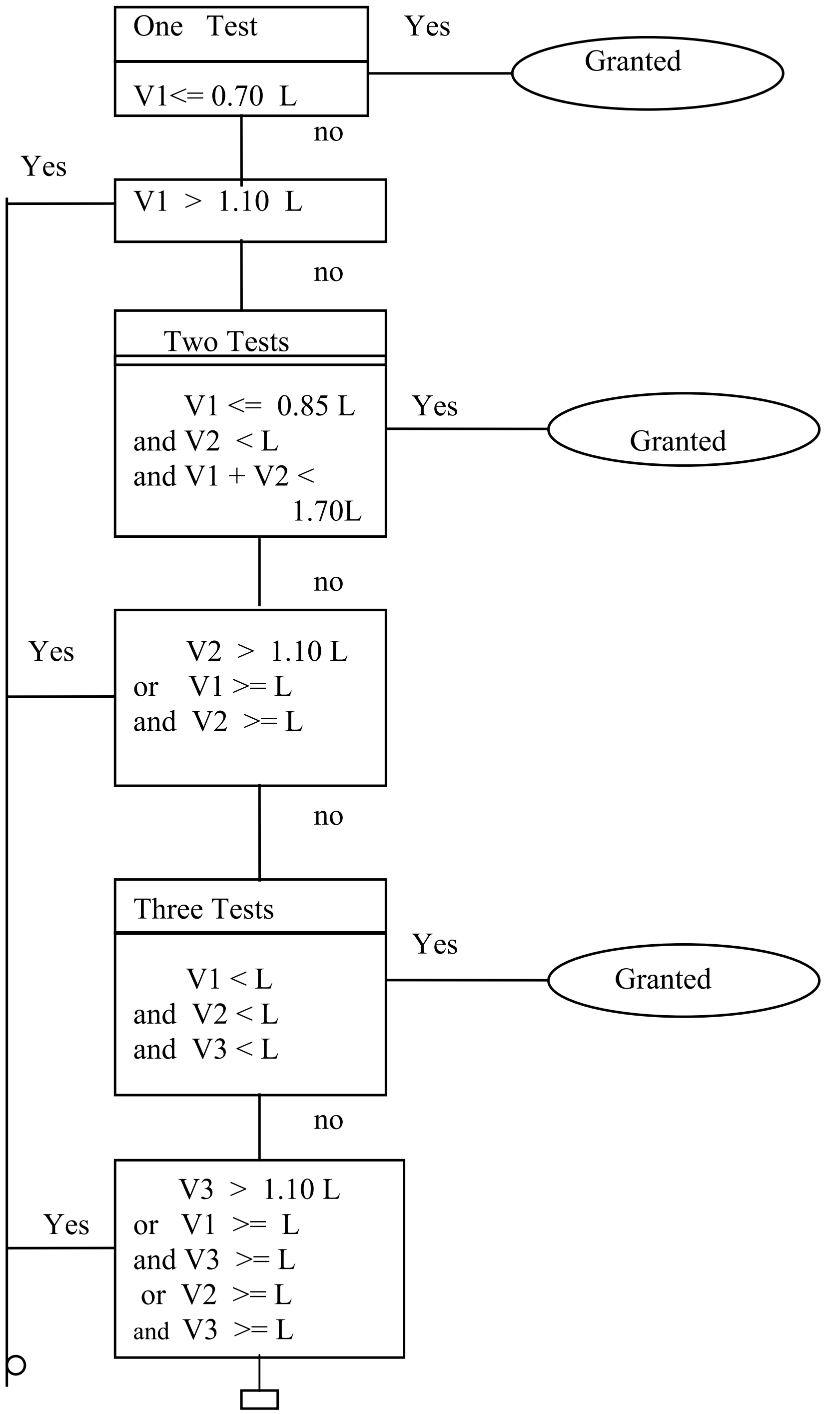
8.2.4.2 The production of the series is deemed to conform or not to conform by testing vehicles comprising a test sample until a

pass decision is reached for all limit values or a fail decision is reached for one limit value. A pass decision is reached when the cumulative number of failed vehicles as defined in Para 8.2.4.1 for each limit value is less than or equal to pass decision number appropriate to the cumulative number of vehicles tested. A fail decision is reached when the cumulative number of failed vehicles for one limit value is greater than or equal to the fail decision number appropriate to the cumulative number of vehicles tested. Once a pass decision has been made for a particular limit value the number of vehicles whose results exceed that limit values must not be considered any further for the purposes of checking conformity of production The pass and fail decision numbers associated with the cumulative number of vehicles tested are illustrated in the figure 2 given in the following table.

8.3 Type II Test : Carbon-monoxide emission at idling speed

When the vehicle taken from the series for the type I test mentioned in 8.2 para above, subjected to the test described in Chapter 9 of this Part for verifying the carbon monoxide emission at idling speed should meet the limit values specified in para 5.2.3.2 above. If it does not, another 10 vehicles shall be taken from the series at random and shall be tested as per Chapter 9 of this Part. At least 9 vehicles should meet the limit values specified in para 5.2.3.2 above. In addition, two vehicles at random should be selected from the above lot of 10 and subjected to a Type I test mentioned in para 8.2 above and they should meet the requirements of para 8.2.2 above. Then the series is deemed to conform.

Fig.1 :- FLOW SHEET FOR THE TYPE APPROVAL / COP TESTS
(Please ref. para. 5.2.2.7.3 of chapter 1 of Part 3)



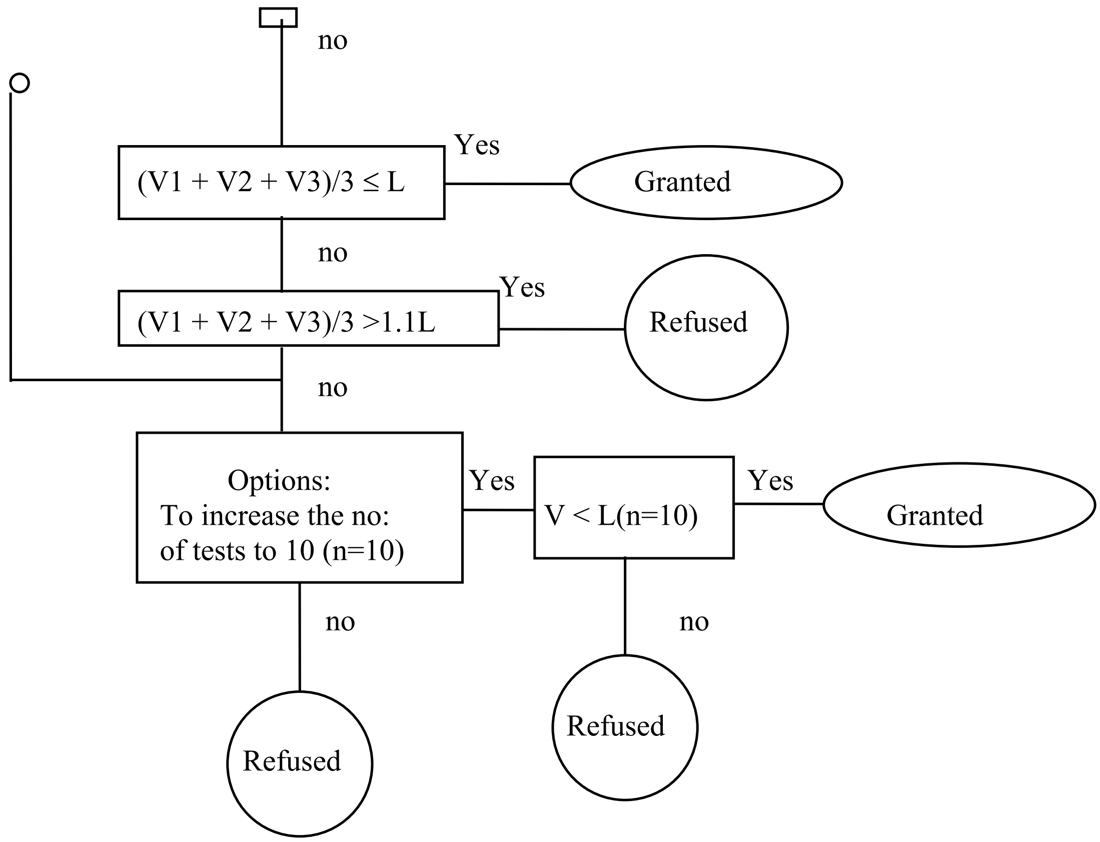

no
(V1 + V2 + V3)/3 ≤ L
Yes
Granted
no
(V1 + V2 + V3)/3 >1.1L
Yes
Refused
no
Options:
To increase the no:
of tests to 10 (n=10)
Yes
V < L(n=10)
Yes
Granted
no
no
Refused
Refused

FIG. 2 :-TABLE : PASS FAIL CRITERIA (See para. 8.2.4.2 of chapter 1 of Part 3)

| Cumulative number vehicles tested | Pass decision (No. of failures) | Fail decision (No. of failures) | Cumulative number of vehicles tested | Pass decision ( No. of failures) | Fail decision (No. of failures) |
|---|---|---|---|---|---|
| 1 | (‘) | (:) | 31 | 14 | 20 |
| 2 | (‘) | (:) | 32 | 14 | 21 |
| 3 | (‘) | (:) | 33 | 15 | 21 |
| 4 | (‘) | (:) | 34 | 15 | 22 |
| 5 | 0 | (:) | 35 | 16 | 22 |
| 6 | 0 | 6 | 36 | 16 | 23 |
| 7 | 1 | 7 | 37 | 17 | 23 |
| 8 | 2 | 8 | 38 | 17 | 24 |
| 9 | 2 | 8 | 39 | 18 | 24 |
| 10 | 3 | 9 | 40 | 18 | 25 |
| 11 | 3 | 10 | 41 | 19 | 26 |
| 12 | 4 | 10 | 42 | 19 | 26 |
| 13 | 4 | 11 | 43 | 20 | 27 |
| 14 | 5 | 11 | 44 | 21 | 27 |
| 15 | 5 | 12 | 45 | 21 | 28 |
| 16 | 6 | 12 | 46 | 22 | 28 |
| 17 | 6 | 13 | 47 | 22 | 29 |
| 18 | 7 | 13 | 48 | 23 | 29 |
| 19 | 7 | 14 | 49 | 23 | 30 |
| 20 | 8 | 14 | 50 | 24 | 30 |
| 21 | 8 | 15 | 51 | 24 | 31 |

| | | | | | |
|---|---|---|---|---|---|
| 22 | 9 | 15 | 52 | 25 | 31 |
| 23 | 9 | 16 | 53 | 25 | 32 |
| 24 | 10 | 16 | 54 | 26 | 32 |
| 25 | 11 | 17 | 55 | 26 | 33 |
| 26 | 11 | 17 | 56 | 27 | 33 |
| 27 | 12 | 18 | 57 | 27 | 33 |
| 28 | 12 | 19 | 58 | 28 | 33 |
| 29 | 13 | 19 | 59 | 28 | 33 |
| 30 | 13 | 20 | 60 | 32 | 33 |

(,) SERIES NOT ABLE TO PASS AT THIS STAGE

(:) SERIES NOT ABLE TO FAIL AT THIS STAGE

# CHAPTER 2

## Essential characteristics of the vehicle and engine and information concerning the conduct of tests

1.0 Description of the Vehicle ---------------------------------------

1.1 Trade name or mark of the vehicle ---------------------------------------

1.2 Vehicle Type ---------------------------------------

1.3 Manufacturer's name and address ---------------------------------------

1.4 Unladen mass of vehicle ---------------------------------------

1.4.1 Reference mass of vehicle ---------------------------------------

1.4.2 Gross Vehicle Weight ---------------------------------------

1.5 Gear box ---------------------------------------

1.5.1 Manual or automatic ---------------------------------------
(If it is automatic give all pertinent technical data)

1.5.2 Number of gears ---------------------------------------

1.5.3 Transmission ratio ---------------------------------------

First Gear ---------------------------------------

Second Gear ---------------------------------------

Third Gear ---------------------------------------

Fourth Gear ---------------------------------------

Over Drive ---------------------------------------

Gear Shifting Pattern ---------------------------------------

1.6 Final drive ratio ---------------------------------------

1.7 Tyres ---------------------------------------

1.7.1 Dimensions ---------------------------------------

1.7.2 Dynamic rolling circumference --------------------------------------

1.7.3 Type ---------------------------------------

1.7.4 Ply Rating ---------------------------------------

1.7.5 Tyre Pressure ---------------------------------------

Front ---------------------------------------

Rear ---------------------------------------

1.8 Wheel drive :

Front ---------------------------------------

Rear ---------------------------------------

1.9 Vehicle performance (declared by manufacturer)

1.9.1 Vehicle max. speed ---------------------------------------

1.9.2 Acceleration, max ----------------------------------m/s$^2$

2.0 Description of engine

2.1 Make ---------------------------------------

2.2 Type ---------------------------------------

2.3 Working principle : ---------------------------------------

four-stroke / two-stroke :

2.4 Bore ----------------------------------mm

2.5 Stroke ----------------------------------mm

2.6 Number and layout of cylinders and firing order ---------------------------------------

2.7 Cylinder capacity ----------------------------------cm$^3$

2.8 Compression ratio ------------------------------------

(Specify the tolerance)

2.9 Drawings of combustion chamber and piston crown ---------------------

2.10 Minimum cross-sectional area of inlet and outlet ports ----------------------

2.11 Cooling system : liquid / air cooling ----------------------

2.11.1 Characteristics of liquid-cooling system ----------------------

2.11.1.1 Nature of liquid
Circulating pump: yes/no ----------------------

2.11.1.2 Characteristics of make(s) and type(s) ----------------------

2.11.1.3 Drive ratio ----------------------

2.11.1.4 Thermostat: setting ----------------------

2.11.1.5 Radiator : drawing(s) or make(s) and type(s) ----------------------

2.11.1.6 Relief valve : pressure setting : ----------------------

2.11.1.7 Fan : Characteristics of make(s) and type(s) ----------------------

2.11.1.8 Fan drive system Drive ratio: ----------------------

2.11.1.9 Fan cowl: ----------------------

2.11.2 Characteristics of air-cooling system ----------------------

2.11.2.1 Blower : Characteristics of make(s) and type(s) ----------------------

2.11.2.2 Drive ratio: ----------------------

2.11.2.3 Air ducting (standard production): ----------------------

2.11.2.4 Temperature regulating system:
yes/no/ Brief description ----------------------

2.11.3 Temperature permitted by the manufacturer ----------------------

2.11.3.1 Liquid cooling: max. temperature at engine outlet ----------------------

2.11.3.2 Air cooling: Reference pt ----------------------

Max. temperature at reference pt ----------------------

Max. outlet temperature of the inlet intercooler ----------------------

2.11.3.4 Max. exhaust temperature ----------------------

2.11.3.5 Fuel temperature: --------------------min -----------------max

2.11.3.6 Lubricant temperature: ---------------------min-----------------max

2.12 Supercharger: yes/no / ( Description of the system ) -----------------------------

2.13 Intake System : ------------------------------

2.13.1 Intake manifold: Description ------------------------------

2.13.2 Air filter: Make &Type: ------------------------------

2.13.3 Intake silencer: Make &Type: ------------------------------

2.14 Device for recycling crank-case gases : ------------------------------

Description and diagrams ------------------------------

3.0 Additional anti-pollution devices (if any, and if not covered by another heading ) ------------------------------

Description and diagrams ------------------------------

4.0 Air intake and fuel feed- ------------------------------

4.1 Description and diagrams of inlet pipes and their accessories (dash pot, heating device, additional air intakes, etc.) ------------------------------

4.2 Fuel feed ------------------------------

4.2.1 By carburettor(s) number ------------------------------

4.2.1.1 Make ------------------------------

4.2.1.2 Type ------------------------------

4.2.1.3 Adjustments ------------------------------
(Specify the tolerance)

| | | |
|---|---|---|
| 4.2.1.3.1 Jets<br>4.2.1.3.2 Venturis<br>4.2.1.3.3 Float-chamber level<br>4.2.1.3.4 Mass of float | OR | Curve of fuel delivery plotted against air flow and settings required to keep to the curve |

4.2.1.3.5 Float needle ------------------------------

4.2.1.3.6 Dimensions Mixture Duct ------------------------------

4.2.1.4 Manual / automatic choke , Closure setting -------------------------------

4.2.1.5 Feed pump -------------------------------

Pressure or characteristic diagram -------------------------------
(Specify the tolerance)

4.2.2 By fuel injection -------------------------------

System description
Working principle : Intake manifold / direct injection / Injection prechamber / swirl chamber

4.2.2.1 Fuel pump -------------------------------

4.2.2.1.1 Make -------------------------------

4.2.2.1.2 Type -------------------------------

4.2.2.1.3 Delivery: $mm^3$ per stroke at a pump of rpm -------------------------------
(Specify the tolerance)
or, alternatively, a characteristic diagram -------------------------------
(Specify the tolerance)
Calibration procedure: test bench / engine -------------------------------

4.2.2.1.4 Injection timing -------------------------------

4.2.2.1.5 Injection curve -------------------------------

4.2.2.2 Injectors : -------------------------------

Make -------------------------------

Type -------------------------------

Opening Pressure (specify tolerance) -------------------------------

4.2.2.3 Governor -------------------------------

4.2.2.3.1 Make -------------------------------

4.2.2.3.2 Type -------------------------------

4.2.2.3.3 Cut-off point under load /min -------------------------------

4.2.2.3.4 Max.speed without load /min -------------------------------

4.2.2.3.5 Idle speed -------------------------------

4.2.2.4 Cold start device -------------------------------

4.2.2.4.1 Make -------------------------------

4.2.2.4.2 Type -------------------------------

4.2.2.4.3 System description -------------------------------

4.2.2.5 Starting aid -------------------------------

4.2.2.5.1 Make -------------------------------

4.2.2.5.2 Type -------------------------------

4.2.2.5.3 System description -------------------------------

5.0 Valve timing or equivalent data -------------------------------

5.1 Maximum lift of valves, angles of opening and closing, or timing details of alternative distribution systems, in relation to top dead centre -------------------------------

5.2 Reference and/or setting ranges -------------------------------

5.3 Distribution by ports -------------------------------

5.3.1 Volume of crank-case cavity with piston at tdc -------------------------------

5.3.2 Description of reed valves if any (with dimensional drawing) -------------------------------

5.3.3 Description (with dimensional drawing) of inlet ports, scavenging and exhaust, with corresponding timing diagram -------------------------------
The drawings should include one representing the inner surface of the cylinder.

6.0 Ignition -------------------------------

6.1 Ignition system type -------------------------------

6.1.1 Make -------------------------------

6.1.2 Type ------------------------------

6.1.3 Ignition advance curve (Specify the tolerance) -------------------------------

6.1.4 Ignition timing -------------------------------
(Specify the tolerance)

6.1.5 Contact point gap and dwell-angle -------------------------------
(Specify the tolerance)

7.0 Exhaust system -------------------------------
Description and diagrams

8.0 Lubrication system_ -------------------------------

8.1 Description of systems- -------------------------------

8.1.1 Position of lubricant reservoir -------------------------------

8.1.2 Feed system
(pump, injection into intake, mixing with fuel, etc.) -------------------------------

8.2 Lubricating pump- ------------------------------

8.2.1 Make -------------------------------

8.2.2 Type -------------------------------

8.3 Lub oil mixed with fuel Yes/No -------------------------------

8.3.1 Percentage ------------------------------

8.4 Oil cooler: yes/no -------------------------------

8.4.1 Drawing(s) or make(s) and type(s) -------------------------------

9.0 Electrical equipment- -------------------------------
Generator/alternator: characteristics or make(s) and type(s)
(Specify the tolerance)

10.0 Other auxiliaries fitted on the engine -------------------------------
(Enumeration and brief description if necessary)

11.0 Additional information on test conditions -------------------------------

11.1 Sparking plugs- -------------------------------

11.1.1 Make -------------------------------

11.1.2 Type -------------------------------

11.1.3 Spark-gap setting ------------------------------

11.2 Ignition coil- ------------------------------

11.2.1 Make -------------------------------

11.2.2 Type -------------------------------

11.3 Ignition condenser- -------------------------------

11.3.1 Make -------------------------------

11.3.2 Type -------------------------------

11.4 Radio interference suppression equipment -------------------------------

11.4.1 Make -------------------------------

11.4.2 Type -------------------------------

12.0 Engine performance (declared by manufacturer) -------------------------------

12.1 Idle rpm -------------------------------
(Specify the tolerance)

12.1.1 Idling system :Description of setting and relevant requirements -------------------------------

12.2 Carbon monoxide content by volume in the exhaust gas with the engine idling - per cent (manufacturer's standard) -------------------------------

12.3 Rpm at max, power -------------------------------
(Specify the tolerance)

12.4 Max. power - KW -------------------------------

13.0 Lubricant used -------------------------------

13.1 Make -------------------------------

13.2 Type -------------------------------

NOTES:

1) Strike out what is not applicable.
2) In addition to the names of suppliers of items such as ignition coil, magneto,CB point, Air filter, Silencer etc., mentioned above, the manufacturers shall inform the test agency that carried out the type approval, the names of new alternate suppliers for these items as and when they are being introduced.

## CHAPTER 3 : TYPE I TEST ON SI ENGINES (VERIFYING THE AVERAGE EMISSIONS OF GASEOUS POLLUTANTS)

1. This chapter describes the procedure for the Type I test defined in paragraph 5.2.2 of Chapter 1 of this Part.

2. Operating Cycle on the Chassis Dynamometer :

2.1 Description of the Cycle : The operating cycle on the chassis dynamometer shall be that indicated in Table I and depicted in Figure 2. The breakdown by operations is given in Table II.

2.2 General Conditions under which the Cycle is carried out : preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximately to the theoretical cycle within the prescribed limits.

2.3 Use of the Gear Box : The use of the gear box shall be as specified by the manufacturer. However, in the absence of such instructions, the following points shall be taken into account.

2.3.1 Manual Change Gear Box :

2.3.1.1 During each phase at constant speed, the rotating speed of the engine shall be, if possible, between 50 and 90% of the speed corresponding to the maximum power of the engine. When this speed can be reached in two or more gears, the vehicle shall be tested with the higher gear engaged.

2.3.1.2 During acceleration, the vehicle shall be tested in whichever gear is appropriate to the acceleration imposed by the cycle. A higher gear shall be engaged at the latest when the rotating speed is equal to 110% of the speed corresponding to the maximum power of the engine.

2.3.1.3 During deceleration, a lower gear shall be engaged before the engine starts to idle roughly, at the latest when the engine revolutions are equal to 30% of the speed corresponding to the maximum power of the engine. No change down to first gear shall be effected during deceleration.

2.3.1.4 Vehicles equipped with an overdrive which the driver can actuate shall be tested with the overdrive out of action.

2.3.1.5 When it is not possible to adhere to the cycle, the operating cycle will be modified for gear change points, allowing 2 seconds time interval at constant speed for each gear change keeping the total time constant. Figure 1 shows the operating cycle with recommended gear positions.

2.3.2 Automatic Gear Box : Vehicles equipped with automatic shift gear boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order.

2.4 Tolerances

2.4.1 A tolerance of ± 1 km/h shall be allowed between the indicated speed and the theoretical speed during acceleration, during steady speed and during deceleration, when the vehicle's brakes are used. If the vehicle decelerates more rapidly without the use of the brakes, then the timing of the theoretical cycle shall be restored by constant speed or idling period merging into the following operation. Speed tolerances greater than those prescribed shall be accepted, during phase changes provided that the tolerances are never exceeded for more than 0.5 second on any one occasion.

2.4.2 Time tolerances of ± 0.5 second shall be allowed. The above tolerances shall apply equally at the beginning and at the end of each gear changing period.

2.4.3 The speed and time tolerances shall be combined as indicated in Figure 2.

3. Vehicle and Fuel

3.1 Test Vehicle :

3.1.1 The vehicle presented shall be checked that it is the same model as specified as per format of chapter 2 of this annexure. It shall have been run-in as per manufacturer's specification before the test.

3.1.2 The exhaust device shall not exhibit any leak likely to reduce the quantity of gas collected, and this shall be the same emerging from the engine.

3.1.3 The air intake system should be leak proof.

3.1.4 The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer. This requirement also applies, in particular, to the settings for idling and for the cold start device, automatic choke, and exhaust gas cleaning systems, etc.

3.1.5 The vehicle to be tested, or an equivalent vehicle, shall be fitted, if necessary with a device to permit the measurement of characteristic parameters necessary for the chassis dynamometer setting.

The testing agency may verify that the vehicle conforms to the performance of power, acceleration, maximum speed etc., stated by the manufacturer and that it can be used for normal driving and more particularly that it is capable of starting when cold and when hot.

3.2 Fuel : The reference fuel as defined in Chapter 10 of this Part shall be used for testing. If the engine is lubricated by a mixture, the oil added to reference fuel shall comply as to grade and quality with the manufacturer's recommendation.

4. Test Equipment :

4.1 Chassis Dynamometer :

4.1.1 The dynamometer must be capable of simulating road load and of one of the following classifications:

4.1.1.1 Dynamometer with fixed load curve, i.e., a dynamometer whose physical characteristics provide a fixed load curve shape. This is not a preferred type of dynamometer.

4.1.1.2 Dynamometer with adjustable load curve, i.e. a dynamometer with at least two road load parameters that can be adjusted to shape the load curve. This is a preferred type of dynamometer.

4.1.2 The chassis dynamometer may have one or two rollers. In the case of a single roller, the roller diameter shall not be less than 400 mm for 2-wheelers and 1200 mm for other vehicles.

4.1.3 The setting of the dynamometer shall not be affected by the lapse of time. It shall not produce any vibrations perceptible to the vehicle and likely to impair the vehicle's normal operations.

4.1.4 It shall be equipped with means to simulate inertia and load. These simulators shall be connected to the front roller, in the case of a two roller dynamometer.

4.1.5 The roller shall be fitted with a revolution counter with reset facility to measure the distance actually covered.

4.1.6 Accuracy :

4.1.6.1 It shall be possible to measure and read the indicated load to an accuracy of ± 5 per cent.

4.1.6.2 In the case of dynamometer with a fixed load curve the accuracy of the load setting at 40 km/h shall be ± 5 per cent. In the case of a dynamometer with adjustable load curve, the accuracy of matching dynamometer load to road load shall be within 5 per cent at 30, 40 and 50 km/h and 10 per cent at 20 km/h. Below this, the dynamometer absorption must be positive.

4.1.6.3 The total equivalent inertia of the rotating parts (including the simulated inertia where applicable) must be known and within ± 20 kg of the inertia class for the test, in case of 4-wheeler vehicles; for 2-wheeler vehicles within ± 2 per cent.

4.1.6.4 The speed of the vehicle shall be measured by the speed of rotation of the roller (the front roller in the case of a two roller dynamometer). It shall be measured with an accuracy of ± 1 km/h at speeds above 10 km/h.

4.1.7 Load and Inertia Setting :

4.1.7.1 Dynamometer with adjustable load curve: the load simulator shall be adjusted in order to absorb the power exerted on the driving wheels at various steady speeds.

4.17.2 Chassis Dynamometer with fixed load curve: the load simulator shall be adjusted to absorb the power exerted on the driving wheels at a steady speed of 40 km/h.

4.1.7.3 The means by which these loads are determined and set are described in Chapter 4 of this Part.

4.1.7.4 Chassis Dynamometers with electrical inertia simulation must be demonstrated to be equivalent to mechanical inertia systems.

The means by which equivalence is established is described in Chapter 5 of this Part.

4.1.8 Chassis Dynamometer Calibration :

4.1.8.1 The dynamometer should be calibrated at least once a month or performance verified at least once a week and then calibrated as required. The calibration shall consist of the manufacturers' recommended procedure and a determination of the dynamometer frictional power absorption at 40 km/h. One method for determining this is given in Chapter 7. Other methods may be used if they are proven to yield equivalent results.

4.1.8.2 The performance check consists of conducting dynamometer coast down time at one or more inertia power setting and comparing the coast down time to that recorded during the last calibration. If the coast down time differs by more than 1 second, a new calibration is required.

4.2 Exhaust Gas-sampling System :

The exhaust gas-sampling shall be designed to enable the measurement of the true mass emissions of vehicle exhaust. A Constant Volume Sampler System wherein the vehicle exhaust is continuously diluted with ambient air under controlled conditions should be used. In the constant volume sampler concept of measuring mass emissions, two conditions must be satisfied - the total volume of the mixture of exhaust and dilution air must be measured and a continuously proportional sample of the volume must be collected for analysis. Mass emissions are determined from the sample concentrations, corrected for the pollutant content of the ambient air and totalized flow, over the test period.

4.2.1 The flow through the system shall be sufficient to eliminate water condensation at all conditions which may occur during a test, as defined in Chapter 6 of this Part.

4.2.2 Figure 6, 7 & 8 gives a schematic diagrams of the general concept. Examples of three types of Constant Volume Sampler systems which will meet the requirements are given in Chapter 6 of this Part.

4.2.3 The gas and air mixture shall be homogenous at point S2 of the sampling probe. (Figure 3)

4.2.4 The probe shall extract a true sample of the diluted exhaust gases.

4.2.5 The system should be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the diluted exhaust gas. Should any component (heat exchanger, blower, etc.) change the concentration of any pollutant gas in the diluted gas, then the sampling for that pollutant shall be carried out before that component, if the problem cannot be corrected.

4.2.6 If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connection tubes shall be connected as near as possible to the vehicle.

4.2.7 Static pressure variations at the tail pipe(s) of the vehicle shall remain within ± 1.25 kPa of the static pressure variations measured during the dynamometer driving cycle and with no connection to the tailpipe(s). Sampling systems capable of maintaining the static pressure to within ± 0.25 kPa will be used if a written request from a manufacturer to the authority granting the approval substantiates the need for the closer tolerance. The back-pressure shall be measured in the exhaust pipe as near as possible to its end or in an extension having the same diameter.

4.2.8 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

4.2.9 The gas samples shall be collected in sample bags of adequate capacity. These bags shall be made of such materials as will not change the pollutant gas by more than ± 2% after twenty minutes of storage.

4.3 Analytical Equipment :

4.3.1 Pollutant gases shall be analysed with the following instruments :

4.3.1.1 Carbon monoxide (CO) and carbon dioxide (CO2) analysis. The carbon monoxide and carbon dioxide analysers shall be of the NON-DISPENSIVE INFRA RED (NDIR) absorption type.

4.3.1.2 Hydrocarbon (HC) analysis - GASOLINE VEHICLES. The hydrocarbons analyser shall be of the FLAME IONISATION (FID) type calibrated with propane gas expressed equivalent to carbon atoms.

4.3.1.3 Hydrocarbons (HC) analysis - DIESEL VEHICLES. The hydrocarbon analyser shall be of the Flame Ionisation type Detector with valves , pipe work etc. heated to 463K ± 10K (HFID). It shall be calibrated with propane gas expressed equivalent to carbon atoms ($C_1$ ).

4.3.1.4 Nitrogen oxide (NOx) analysis.

The nitrogen oxide analyser shall be of the CHEMILUMINESCENT (CLA) type with an NOx-NO converter.

4.3.1.5 Accuracy

The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants: Measurement errors shall not exceed ± 3 per cent disregarding the true value of the calibration gases. For concentrations of less than 100 ppm the measurement error shall not exceed ± 3 ppm. The ambient air sample shall be measured on the same analyser and range as the corresponding diluted exhaust sample.

4.3.1.6 Ice-trap

No gas drying device shall be used before the analysis unless it is shown that it has no effect on the pollutant content of the gas stream.

4.3.2 Particular requirements for compression ignition engines :

4.3.2.1 A heated sample line for a continuous HC-analysis with the heated flame ionisation detector (HFID), including recorder (R) is to be used.

4.3.2.2 The average concentration of the measured hydrocarbons shall be determined by integration. Throughout the test, the temperature of the heated sample line shall be controlled at 463K ± 10K. The heated sampling line shall be fitted with a heated filter ($F_H$’) (99% efficient with particle < 0.3 um) to extract any solid particles from the continuous flow of gas required for analysis.

4.3.2.3 The sampling system response time ( from the probe to the analyser inlet) shall be no more than 4 s.

4.3.2.4 The HFID must be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.3.3 Calibration :

4.3.3.1 Each analyser shall be calibrated as often as necessary and in any case in the month before type approval testing and at least once every six months for verifying conformity of production.

4.3.3.2 The calibration method that shall be used is described in Chapter 7 for the analysers indicated in para 4.3.1 above.

4.4 Volume measurement :

4.4.1 The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to within ± 2 per cent.

4.4.2 Constant Volume Sampler Calibration :

4.4.2.1 The Constant Volume Sampler system volume measurement device shall be calibrated by a suitable method to ensure the prescribed accuracy and at a frequency sufficient to maintain such accuracy.

4.4.2.2 An example of a calibration procedure which will give the required accuracy is given in Chapter 7 of this Part. The method shall utilise a flow metering device which is dynamic and suitable for the high flow rate encountered in Constant Volume Sampler testing. The devices shall be of certified accuracy traceable to an approved national or international standard.

4.5 Gases :

4.5.1 Pure Gases :

The following pure gases shall be available when necessary, for calibration and operation:

Purified nitrogen (purity < 1ppm C, < 1ppm CO, < 400 ppm $CO_2$,<0.5 ppm NO);

Purified synthetic air (purity < 3 ppm C, < 1ppm CO, < 400 ppm$CO_2$,< 0.5 ppm NO)

Oxygen content between 18 and 21 percent vol;

Purified oxygen ( purity > 99.5 per cent Vol $O_2$ );

Purified hydrogen (and mixture containing hydrogen)
( Purity < 1ppm C, < 400 ppm $CO_2$).

4.5.2 Calibration and span gases :

Gases having the following chemical compositions shall be available $C_3 H_8$ and purified synthetic air, as in para 4.5.1 above ;CO and purified nitrogen;$CO_2$ and purified nitrogen;NO and purified nitrogen (the amount of $NO_2$ contained in this calibration gas must not exceed 5 percent of the NO content)

4.5.3 The true concentration of a calibration gas shall be within ± 2% of the stated figure.

4.5.4 The concentrations specified in Chapter 7 of this Part may also be obtained by means of a gas divider, diluting with purified nitrogen or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined within ± 2%.

4.6 Additional equipment :

4.6.1 Temperature : The temperature indicated in Chapter 8 of this Part shall be measured with an accuracy of ± 1.5K.

4.6.2 Pressure : The atmospheric pressure shall be measurable to within ± 0.1 kPa.

4.6.3 Absolute Humidity : The absolute humidity (H) shall be measurable to within ± 5 percent.

4.7 The exhaust gas-sampling system shall be verified by the method described in para 3 of Chapter 7 of this Part. The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured shall be 5 per cent.

5. Preparations for the test :

5.1 Adjustment of inertia simulators to the vehicle's translatory inertias : An inertia simulator shall be used enabling a total inertia of the rotating masses to be obtained proportional to the reference weight within the following limits given in Table III.

5.2.1 Setting of dynamometer :

5.2.2 The load shall be adjusted according to methods described in paragraph 4.1.7 above.

5.2.2 The method used and the values obtained (equivalent inertia, characteristic adjustment parameter) shall be recorded in the test report.

5.3 Four wheel drive vehicles will be tested in a two-wheel drive mode of operation. Full time four-wheel drive vehicles will have one set of drive wheels temporarily disengaged by the vehicle manufacturers. Four-wheel drive vehicles which can be manually shifted to a two-wheel drive mode will be tested in the normal on highway two-wheel drive mode of operation.

6. Procedure for Chassis Dynamometer Test :

6.1 Special conditions for carrying out the cycle :

6.1.1 During the test, the cell temperature shall be between 298K and 313K. The absolute humidity (H) of either the air in the test cell or the intake air of the engine shall be such that

$$5.5 \le H \le 18.0 \text{ g } H_2O/\text{kg dry air}$$

6.1.2 The vehicle shall be approximately horizontal during the test so as to avoid any abnormal distribution of the fuel.

6.1.3 The tyre pressure shall be the same as that indicated by the manufacturer and used for the preliminary road test for data collection for adjustment of chassis Dynamometer. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting in the case of a two roll dynamometer . The actual pressure used shall be recorded in the test report.

6.1.4 Cooling of the Vehicle :

6.1.4.1 For vehicles with liquid cooled engines the test shall be carried out with the bonnet raised unless this is technically impossible. An auxiliary ventilating device acting on the radiator (water cooling) or on the air intake (air cooling) may be used if necessary, to keep the engine temperature normal.

6.1.4.2 For vehicles with air cooled engines throughout the test, an auxiliary cooling blower shall be positioned in front of the vehicle, so as to direct cooling air to the engine. The blower speed shall be such that, within the operating range of 10 km/h to 50 km/h the linear velocity of the air at the blower outlet is within ± 5 km/h of the corresponding roller speed. At roller speeds of less than 10 km/h, air velocity may be zero, the blower outlet shall have a cross section area of at least 0.4 $m^2$ and the bottom of the blower outlet shall be between 15 and 20 cm above floor level. The blower outlet shall be perpendicular to the longitudinal axis of the vehicle between 30 and 45 cm in front of its front wheel.

6.1.4.3 As an alternative, an auxiliary cooling blower may be positioned in front of the vehicle. The blower outlet shall have a cross sectional area of at least 0.4 $m^2$ and shall be perpendicular to the longitudinal axis of the vehicle between 30 and 45 cm in front of its front wheel. The device used to measure the linear velocity of the air shall be located in the middle of the stream at 20 cm away from the air outlet. The air velocity shall be 25 km/h ± 5 km/h. This velocity shall be as nearly constant as possible across the whole of the blower outlet surface.

6.1.5 During the test, the speed shall be recorded with respect to time so that the correctness of the cycles performed can be assured.

6.2 Starting up the engine :

6.2.1 The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions, as incorporated in the driver's handbook of production vehicles.

6.2.2 Warming up of the vehicle will be done on the chassis dynamometer as per manufacturer's instructions by using the operating test cycles. The test cycle shall begin at the end of this warming up period.

6.2.3 If the maximum speed of the vehicle is less than the maximum speed of the driving cycle, that part of the driving cycle, where speed is exceeding the vehicle's maximum speed, the vehicle will be driven with the throttle fully open.

6.3 Idling :

6.3.1 Manual-shift or semi-automatic gear-box :

6.3.1.1 During periods of idling, the clutch shall be engaged and gears in neutral.

6.3.1.2 To enable the accelerations to be performed according to normal cycle the vehicle shall be placed in first gear, with clutch disengaged, 5 seconds before the acceleration following the idling period considered.

6.3.1.3 The first idling period at the beginning of the cycle shall consist of 11 seconds of idling in neutral with the clutch engaged and 5 seconds in first gear with the clutch disengaged.

6.3.2 Automatic-shift gear-box : After initial engagement, the selector shall not be operated at any time during the test except in accordance with paragraph 6.4.2 below.

6.4 Accelerations :

6.4.1. Manual Shift Gear Box :

6.4.1.1 Accelerations shall be so performed that the rate of acceleration is as constant as possible through the phase.

6.4.1.2 If an acceleration cannot be carried out in the prescribed time, the extra time required shall be deducted from the time allowed for changing the combination, if possible, and in any case, from the subsequent steady-speed or deceleration period.

6.4.2 Automatic-shift gear-boxes : If an acceleration cannot be carried out in the prescribed time the gear selector shall be operated in accordance with requirements for manual-shift gear-boxes.

6.5 Decelerations :

6.5.1 All decelerations shall be effected by closing the throttle completely. The clutch shall be disengaged, at around a speed of 10 km/h.

6.5.2 If the period of deceleration is longer than that prescribed for the corresponding phase, the vehicle's brakes shall be used to enable the timing of the cycle to be abided by.

6.5.3 If the period of deceleration is shorter than that prescribed for the corresponding phase, the timing of theoretical cycle shall be restored by constant speed or idling period merging into the following operation.

6.5.4 At the end of the deceleration period (halt of the vehicle on the rollers) the gears shall be placed in neutral and the clutch engaged.

6.6 Steady Speeds :

6.6.1 "Pumping" or the closing of the throttle shall be avoided when passing from acceleration to the following steady speed.

6.6.2 Periods of constant speed shall be achieved by keeping the accelerator position fixed.

7. Procedure for Sampling and Analysis :

7.1 Sampling : Sampling shall begin at the beginning of the test cycle as defined in para 6.2.2 above and end at the end of the sixth cycle.

7.2 Analysis :

7.2.1 The exhaust gases contained in the bag shall be analysed as soon as possible and in any event not later than 20 minutes after the end of the test cycle.

7.2.2 Prior to each sample analysis the analyser range to be used for each pollutant shall be set to zero with the appropriate zero gas.

7.2.3 The analysers shall then be set to the calibration curves by means of span gases of nominal concentrations of 70 to 100 percent of the range.

7.2.4 The analysers' zeros shall then be re-checked. If the reading differs by more than 2 percent of range from that set in paragraph 7.2.2 above, the procedure shall be repeated.

7.2.5 The samples shall then be analysed.

7.2.6 After the analysis zero and span points shall be re-checked using the same gases. If these re-checks are within 2 percent of those in paragraph 7.2.3, then the analysis shall be considered acceptable.

7.2.7 For all the points in this section, the flow rates and pressure of the various gases must be the same as those used during calibration of the analysers.

7.2.8 The figure adopted for the content of the gases in each of the pollutants measured shall be that read off after stabilisation of the measuring device. Diesel hydrocarbon mass emissions shall be calculated from the integrated HFID reading corrected for varying flow, if necessary as shown in Chapter 6 of this Part.

8. Determination of the Quantity of Gaseous Pollutants Emitted :

8.1 The volume Considered : The volume to be considered shall be corrected to conform to the conditions of 101.3 kPa and 293 K.

8.2 Total Mass of Gaseous Pollutants Emitted : The mass, M, of each pollutant emitted by the vehicle during the test shall be determined by obtaining the product of the voluminal concentration and the volume of the gas in question, with due regard for the following densities at the above mentioned reference condition. In the case of carbon monoxide (CO)d = 1.164 kg/$m^3$ In the case of hydrocarbons ($CH_{1.85}$ )d = 0.5768 Kg/$m^3$ In the case of nitrogen oxides ($NO_2$ )d = 1.913 kg/$m^3$.

8.3 Chapter 8 of this Part describes the calculations for the various methods to determine the quantity of gaseous pollutants emitted.

TABLE 1

OPERATING CYCLE ON THE CHASSIS DYNAMOMETER

(Please ref. Para. 2.1chapter 3 ,Part 3)

| No. of operation | | Acceleration (m/sec$^2$) | Speed (Km/h) | Duration of each operation (S) | Cumulative time(s) |
|---|---|---|---|---|---|
| 01. | Idling | -- | --- | 16 | 16 |
| 02. | Acceleration | 0.65 | 0-14 | 6 | 22 |
| 03. | Acceleration | 0.56 | 14-22 | 4 | 26 |
| 04. | Deceleration | -0.63 | 22-13 | 4 | 30 |
| 05. | Steady speed | -- | 13 | 2 | 32 |
| 06. | Acceleration | 0.56 | 13-23 | 5 | 37 |
| 07. | Acceleration | 0.44 | 23-31 | 5 | 42 |
| 08. | Deceleration | -0.56 | 31-25 | 3 | 45 |
| 09. | Steady speed | -- | 25 | 4 | 49 |
| 10. | Deceleration | -0.56 | 25-21 | 2 | 51 |
| 11. | Acceleration | 0.45 | 21-34 | 8 | 59 |
| 12. | Acceleration | 0.32 | 34-42 | 7 | 66 |
| 13. | Deceleration | -0.46 | 42-37 | 3 | 69 |
| 14. | Steady speed | -- | 37 | 7 | 76 |
| 15. | Deceleration | - 0.42 | 37-34 | 2 | 78 |
| 16. | Acceleration | 0.32 | 34-42 | 7 | 85 |
| 17. | Deceleration | -0.46 | 42-27 | 9 | 94 |
| 18. | Deceleration | -0.52 | 27-14 | 7 | 101 |
| 19. | Deceleration | -0.56 | 14-00 | 7 | 108 |

TABLE II

BREAK DOWN OF THE OPERATING CYCLE USED FOR THE TYPE 1 TEST
(Please ref. para. 2.1 chapter 3, Part 3)

A: BREAK DOWN BY PHASES

| Sr. No. | Particulars | Time(s) | Percentage |
|---|---|---|---|
| 1 | Idling | 16 | 14.81 |
| 2 | Steady speed periods | 13 | 12.04 |
| 3 | Accelerations | 42 | 38.89 |
| 4 | Deceleration's | 37 | 34.26 |
| | | 108 | 100 |

A: AVERAGE SPEED DURING TEST : 21.93 Km/h

C: THEORETICAL DISTANCE COVERED PER CYCLE : 0.658 Km.

D: EQUIVALENT DISTANCE FOR THE TEST (6 cycles) : 3.948 Km.

TABLE III
(Please refer para. 5.1 Chapter 3 ,Part 3)

| REFERENCE MASS OF VEHICLE R(kg) MORE THAN | REFERENCE MASS OF VEHICLE R(kg) UPTO AND INCLUDING | Equivalent inertia 1 Kg |
|---|---|---|
| ---- | 105 | 100 |
| 105 | 115 | 110 |
| 115 | 125 | 120 |
| 125 | 135 | 130 |
| 135 | 145 | 140 |
| 145 | 165 | 150 |
| 165 | 185 | 170 |
| 185 | 205 | 190 |
| 205 | 225 | 210 |
| 225 | 245 | 230 |
| 245 | 270 | 260 |
| 270 | 300 | 280 |
| 300 | 330 | 310 |
| 330 | 360 | 340 |
| 360 | 395 | 380 |
| 395 | 435 | 410 |
| 435 | 475 | 450 |
| 475 | 515 | 490 |
| 515 | 555 | 530 |
| 555 | 595 | 570 |

| | | |
|---|---|---|
| 595 | 635 | 610 |
| 635 | 675 | 650 |
| 675 | 715 | 690 |
| 715 | 750 | 730 |
| 750 | 850 | 800 |
| 850 | 1020 | 910 |
| 1020 | 1250 | 1130 |
| 1250 | 1470 | 1360 |
| 1470 | 1700 | 1590 |
| 1700 | 1930 | 1810 |
| 1930 | 2150 | 2040 |
| 2150 | -- | 2270 |

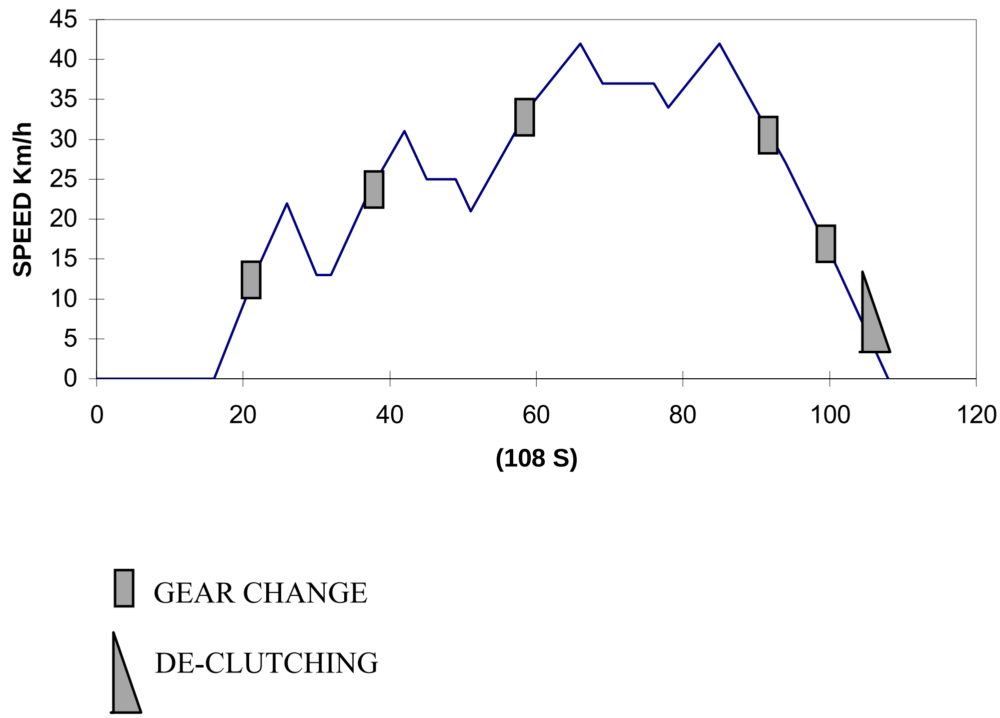
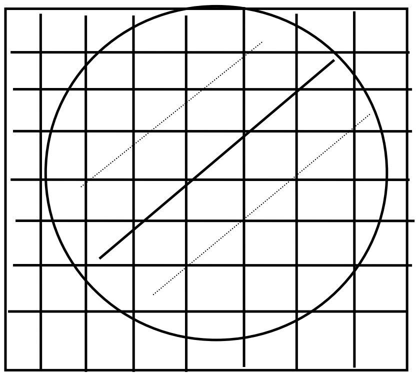



Fig 1 : OPERATING CYCLE WITH RECOMMENDED GEAR POSITION
(Pl. ref. para 2.3.1.5 of chapter 3 ,Part 3)



SPEED AND TIME TOLERANCES

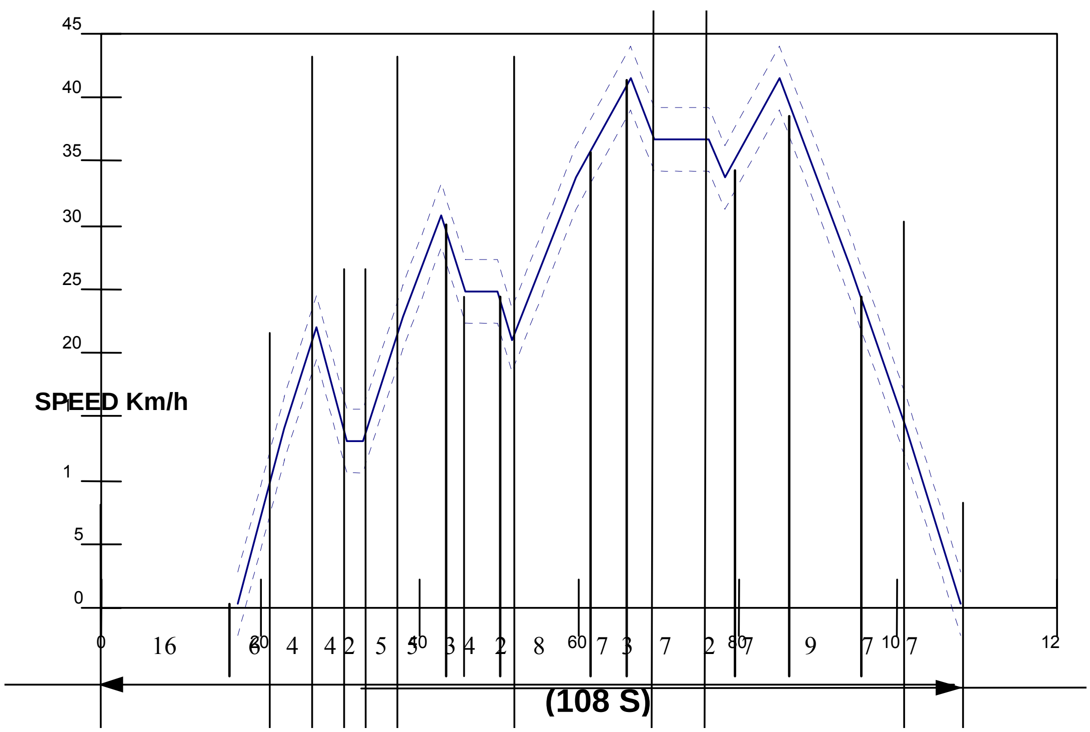
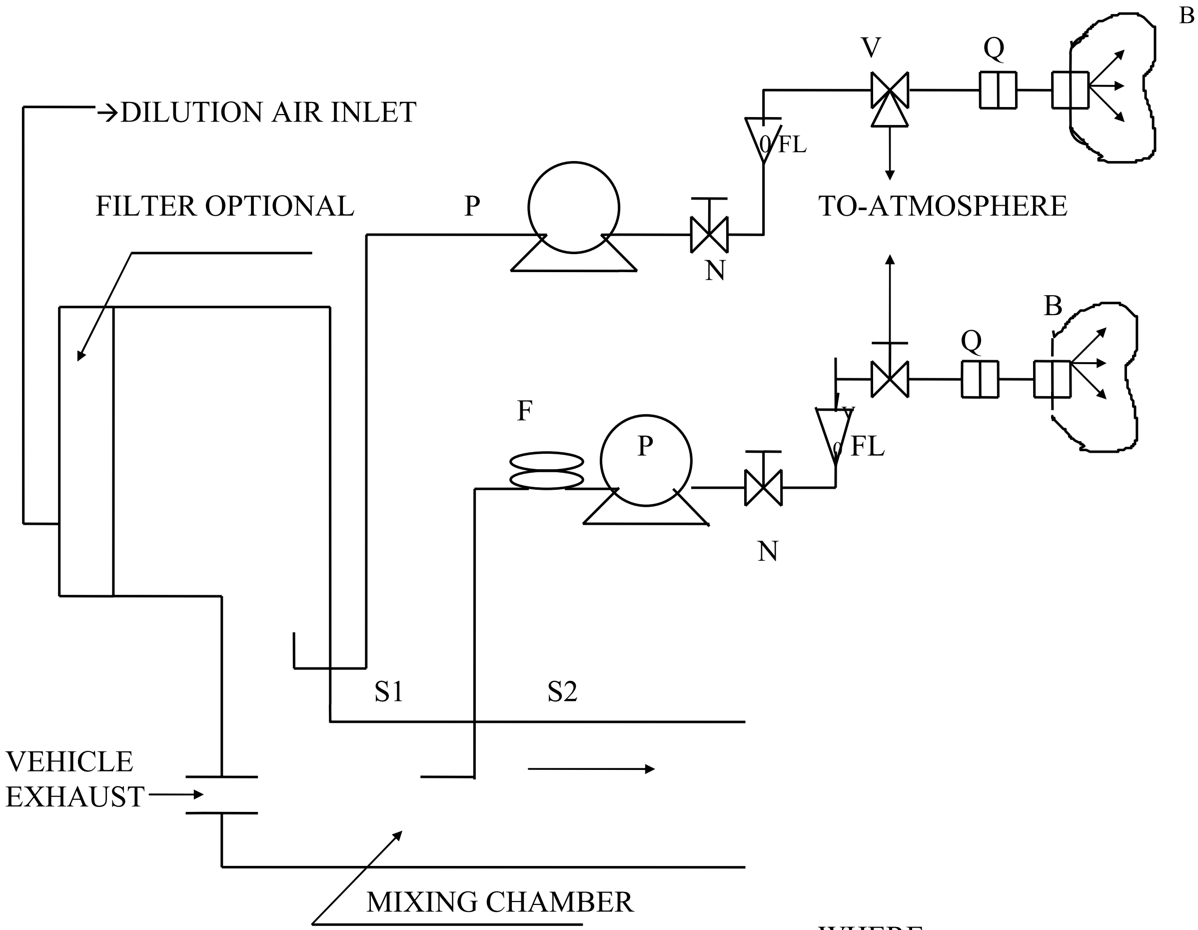



Fig 2: Operating cycle with speed and time tolerances
(Pl. ref. para 2.1 & 2.4.3 of chapter 3 ,Part 3)

FIGURE 3 : SCHEMATIC OF EMISSION MEASUREMENT SET-UP

(PL. REF. PARA. 4.2.3. OF CHAPTER 3 ,Part 3)




WHERE

S1,S2 -- SAMPLING PROCESS
P -- SUCTION PUMPS
F -- FILTERS
FL -- FLOW METERS
N -- FLOW CONTROLLERS
V -- QUICK CHANGING SOLENOID VALVES TO DIVERT FLOW INTO BAGS /VENTS
Q --QUICK ACTING COPLERS
B --BAGS FOR COLLECTING SAMPLES

# CHAPTER 4 : RESISTANCE TO PROGRESS OF A VEHICLE - MEASUREMENT METHOD ON THE ROAD - SIMULATION ON A CHASSIS DYNAMOMETER

1. Scope :

This Chapter describes the methods to measure the resistance to the progress of a vehicle at stabilised speeds on the road and to simulate this resistance on a chassis dynamometer with adjustable and fixed load curves in accordance with paragraph 4.1.7.3 of Chapter 3 of this Part.

2. Definition of the road :

2.1 The road shall be level and sufficiently long to enable the measurements specified below to be made. The longitudinal slope shall not exceed 1.5% and shall be constant within ± 0.1 % over the measuring strip.

3. Atmospheric Conditions :

3.1 Wind : Testing must be limited to wind speeds averaging less than 3 m/s with peak speeds less than 5 m/s. In addition, the vector component of the wind speed across the test road must be less than 2 m/s. Wind velocity should be measured 0.7 m above the road surface.

3.1 Humidity : The road shall be dry .

3.3 Pressure - Temperature : Air density at the time of the test shall not deviate by more than ± 7.5 percent from the reference conditions:
P = 100 kPa & T = 298K

4. Vehicle Preparation :

4.1 Running in : The vehicle shall be in normal running order and adjusted after having been run-in as per manufacturer's specifications. The tyres shall be run in at the same time as the vehicle or shall have a tread depth within 90 and 50 percent of the initial tread depth.

4.2 Verifications : The following verifications shall be made in accordance with the manufacturer's specifications for the use considered :

wheel, wheel trims, tyres (make, type, pressure),
front axle geometry,
brake adjustment (elimination of parasitic drag)
lubrication of front and rear axles,
adjustment of the suspension and vehicle level, etc.

4.3 Preparation for the test

The vehicle shall be loaded to its reference mass. The level of the vehicle shall be that obtained when the centre of gravity of the load is situated midway between the "R" points of the front outer seats and on a straight line passing through those points.

4.3.1 In case of road tests, the windows of the vehicle shall be closed. Any covers of air climatization systems, headlamps, etc., shall be in the non-operating position.

4.3.2 The vehicle shall be clean.

4.3.3 Immediately prior to the test the vehicle shall be brought to normal running temperature in an appropriate manner.

5. Methods for chassis dynamometer with adjustable load curve

5.1 Energy variation during coast-down method :

5.1.1 On the road :

5.1.1.1 Accuracies of test equipment

Time shall be measured accurate to within 0.1 s. Speed shall be measured accurate to within 2 percent.

5.1.1.2 Test procedure

5.1.1.2.1 Accelerate the vehicle to a speed of 10 km/h greater than the chosen test speed, V.

5.1.1.2.2 Place the gear box in "neutral" position.

5.1.1.2.3 Measure the time taken for the vehicle to decelerate from

$V2 = V + \Delta V$ km/h to $V1 = V - \Delta V$ km/h : t1

$\Delta V \leq 5$ km/h

5.1.1.2.4 Make the same test in the opposite direction : $t_2$

5.1.1.2.5 Take the average T, of the two times $t_1$ and $t_2$.

5.1.1.2.6 Repeat these tests several times such that the statistical accuracy (p) of the average

$$T = 1/n \sum_{i=1}^{n} Ti$$

is equal to or less than 2 percent ($p \leq 2$ percent).

The statistical accuracy p is defined by :

$$p = \frac{t.s}{n} \times \frac{100}{T}$$

Where

t = coefficient given by the table below

s = standard deviation $= \sqrt{\sum (Ti - T)^2 / (n-1)}$

n = number of tests

| n | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | 3.2 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| t/n | 1.6 | 1.25 | 1.06 | 0.94 | 0.85 | 0.77 | 0.73 | 0.66 | 0.64 | 0.61 | 0.59 | 0.57 |

5.1.1.2.7 Calculate the power by the formula :

$$P = m * V * \Delta V / 500T$$

Where

P is expressed in KW
V = speed of the test in m/s
$\Delta$V= speed deviation from speed V, in m/s
m = reference mass in kg
T = time in seconds

5. 1.2 On the chassis dynamometer :

5.1.2.1 Measurement equipment and accuracy : The equipment shall be identical to that used on the road.

5.1.2.2 Test procedure

5.1.2.2.1 Install the vehicle on the test dynamometer.

5.1.2.2.2 Adjust the tyre pressure (cold) of the driving wheels as required by the chassis dynamometer.

5.1.2.2.3 Adjust the equivalent inertia of the chassis dynamometer.

5.1.2.2.4 Bring the vehicle and chassis dynamometer to operating temperature in a suitable manner.

5.1.2.2.5 Carry out the operations specified in paragraph 5.1.1.2 with the exception of paragraphs 5.1.1.2.4 and 5.1.1.2.5 and with changing M by I in the formula of paragraph 5.1.1.2.7 above.

5.1.2.2.6 Adjust the chassis dynamometer to meet the requirements of paragraphs of 4.1.6.1 of Chapter 3 of this Part.

5.2 Torque measurements method at constant speed :

5.2.1 On the road:

5.2.1.1 Measurement equipment and error :

Torque measurement shall be carried out with an appropriate measuring device, accurate to within 2 percent. Speed measurement shall be accurate to within 2 percent.

5.2.1.2 Test procedure

5.2.1.2.1 Bring the vehicle to the chosen stabilised speed, V.

5.2.1.2.2 Record the torque c(t) and speed over a period T(of at least 10 s) by means of class 1000 instrumentation meeting ISO standard No. 970, over small intervals of time t.

5.2.1.2.3 Differences in torque, and speed relative to time shall not exceed 5 percent for each second of the measurement period. The torque $C_{T1}$ is the average torque derived from the following formula

$$C_{T1} = \int_{t}^{t+\Delta t} C(t)\, dt / \Delta t$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. $C_{T2}$.

5.2.1.2.5 Determine the average of these torques $C_{T1}$ and $C_{T2}$ i.e $C_T$.

5.2.2 On the chassis dynamometer

5.2.2.1 Measurement equipment and error

The equipment shall be identical to that used on the road.

5.2.2.2 Test procedure

5.2.2.2.1 Perform the operations specified in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

5.2.2.2.2 Adjust the chassis dynamometer setting to meet the requirements of paragraph 4.1.6.1. of Chapter 3 of this Part.

5.3 Integrated torque over vehicle driving pattern :

5.3.1 This method is a non-obligatory complement to the constant speed method described in paragraph 5.2 above.

5.3.2 In this dynamic procedure the mean torque value M is determined. This is accomplished by integrating the actual torque values,M(t) , with respect to time during operation of the test vehicle with a defined driving cycle. The integrated torque is then divided by the time difference $t_2$ - $t_1$, The result is : Mavg = $_{t1}\sum^{t2} M(t)\,dt / (t_2 - t_1)$ with M(t) > 0, M is calculated from six sets of results.

It is recommended that the sampling rate of M be not less than samples per second.

5.3.3 Dynamometer setting The dynamometer load is set by the method described paragraph above. if Mavg (dynamometer) does not then match Mavg (road) the inertia setting shall be adjusted until the values are equal within ± 5 percent.

Note : This method can only be used for dynamometers with electrical inertia simulation or fine adjustment.

5.3.3.1 Acceptance criteria :

Standard deviation of six measurements must be less than or equal to 2 percent of the mean value.

5.4 Method by deceleration measurement by gyroscopic platform :

5.4.1 On the road :

5.4.1.1 Measurement equipment and accuracy speed shall be measured with an accuracy better than 2 percent deceleration shall be measured with an accuracy better than 1 percent; the slope of the road shall be measured with an accuracy better than 1 percent; time shall be measured with an accuracy better than 0.1 s. The measurement of the level of the vehicle on a reference horizontal ground: By comparison, it is possible to find the slope of the road ( $\alpha$ 1)

5.4.1.2 Test procedure :

5.4.1.2.1 Accelerate the vehicle to a speed 5 km/h greater than the chosen test speed V.

5.4.1.2.2 Record the deceleration between V + 0.5 km/h and V - 0.5 km/h.

5.4.1.2.3 Calculate the average deceleration attributed to the speed V by the formula:

$$\bar{Y}1 = 1/t * [\int_0^t Y1 (t)\, dt] - g \sin \alpha_1$$

Where

$\bar{Y}1$ = average deceleration value at the speed V in one direction of the road

t = time between V + 0.5 kmph and V - 0.5 kmph

Y1 (t) = deceleration recorded with the time

g = 9.81 $m/s^2$.

5.4.1.2.4 Perform the same test in the other direction $\bar{Y}2$

5.4.1.2.5 Calculate the average declaration i.e.

$$\gamma i = (Y1 + Y2)/2$$

5.4.1.2.6 Perform a sufficient number of tests as specified in paragraph 5.1.1.2.6 above replacing T by where

$$\gamma = [\sum_{i=1}^{n} \gamma i ]/n$$

5.4.1.2.7 Calculate the average force absorbed F=m*y ,where m =vehicle reference mass in kg & y=average deceleration calculated as above.

5.4.2 On the chassis dynamometer :

5.4.2.1 Measuring equipment and accuracy

The measurement instrumentation of the chassis dynamometer itself shall be used as defined in para 5.1.2.1 of this Part.

5.4.2.2 Test procedure

Adjustment of the force on the rim under steady speed.
On chassis dynamometer, the total resistance is of the type:

$F_{total} = F_{indicated} + F_{driving\ axle\ rolling}$

With

$F_{total} = F_{road}$

$F_{indicated} = F_{road} - F_{driving\ axle\ rolling}$

$F_{indicated}$ is the force indicated on the force indicating device of the chassis dynamometer, $F_{road}$ , ($F_R$)is known , $F_{driving\ axle\ rolling}$ , can be measured on chassis dynamometer driving axle rolling able to work as generator. The test vehicle, gear box in neutral position, is driven by the chassis dynamometer at the test speed; the rolling resistance, $R_R$, of the driving axle is then measured on the force indicating device of the chassis dynamometer.

Determination on chassis dynamometer unable to work as a generator.

For the two-roller chassis dynamometer, the $R_R$ value is the one which is determined before on the road.

For the single-roller chassis dynamometer, the $R_R$ value is the one which is determined on the road multiplied by a coefficient R which is equal to the ratio between the driving axle mass and the vehicle total mass.
Note : $R_R$ is obtained from the curve F = f(v).

5.4.2.2.1 Calibrate the force indicator for the chosen speed of the roller bench as defined in para 2 Chapter 5 of this Part.

5.4.2.2.2 Perform the same operation as in paragraphs 5.1.2.2.1 to above.

5.4.2.2.3 Set the force, $F_A = F - F_R$ on the indicator for the speed chosen.

5.4.2.2.4 Carry out a sufficient number of tests as indicated in paragraph 5.1.1.2.6 above, replacing T by $F_A$ .

5.5 Deceleration Method applying coastdown techniques :

5.5.1 On the Road

5.5.1.1 Accuracies of the test instrument shall be the same as specified in 5.1.1.1.

5.5.1.2 Drive the vehicle at a constant speed of about 10 km/h more than the chosen test speed, V km/h, along a straight line.

5.5.1.3 After this speed is held steady for a distance of at-least 100 m, disconnect the engine from the drive line by bringing the gear to neutral or by other means in the case of vehicle where manual shifting to neutral is not possible.

5.5.1.4 Measure the time taken (t1 sec) for the speed to drop from V + $\Delta$ V km/h to V - $\Delta$ V km/h. The value of $\Delta$V shall not be less than 1 km/h or more than 5 km/h. However, same value of $\Delta$ V shall be used for all the tests.

5.5.1.5 Repeat the test in the opposite direction and record the time ( $t_2$ sec.).

5.5.1.6 Repeat the test 10 times such that the statistical error of the time $t_i$ (arithmetic average of $t_1$ and $t_2$ ) is equal to or less than 2%.

5.5.1.7 The statistical error 'p' is calculated as -

$$p = 24.24 * (t_i - t_m)^2 / t_m$$

where - t = average time for each consecutive set of reading, $(t_1 + t_2) / 2$

$t_m$ = Arithmetic average of 10 such $t_i$ .

5.5.1.8 The basic equation of motion to calculate the road load resistance force, F, is

$$F = ( W + W2 )*V / (3.6 * t_m * g)$$

Where

F - in N

W - the weight of the test vehicle in N

W2 - equivalent inertia weight of rotating axle ( 0.035 x mass of the test vehicle for four-wheeled vehicles) in N

V - vehicle speed difference during the coast down, in km/h

$t_m$ - coast down time, in seconds

g - acceleration due to gravity, 9.81 m/s².

5.5.1.9 Using least square curve fitting method and values of F and V, the coefficient of aerodynamic and rolling resistance of the vehicle viz. a and b respectively are found from the following equation :

$$F = a * v^2 + b$$

5.5.2 Chassis Dynamometer Setting : The values of a and b are set on the dynamometer.

5.6 Alternate Method of Two-Wheelers

With the manufacturers` agreement for this method, the following values of a and b are set on the dynamometer as per the following equation :

$F = aV^2 + b$

where - F = the load, in N

a = 0.0225 for 2-wheeled vehicles with engines less than 50 cc capacity and 0.0250 for other 2-wheeled vehicles .

b = 0.18 x reference weight of vehicle, in kg

6 Methods for Chassis Dynamometer with Fixed Load Curve :

6.1 In the event that the resistance to progress on the road can not be reproduced on the chassis dynamometer between speeds of 10 and 50 km/h, the chassis dynamometer should meet the following characteristics :

6.1.1 Having set the load at 40 km/h by one of the methods described in paragraph 6.2 below, the characteristic of the chassis dynamometer K can be determined from Pa = KV where Pa is the power absorbed by the chassis dynamometer in kW and V is the vehicle speed in km/h. The power absorbed (Pa) by the chassis dynamometer and the chassis internal frictional effects from the reference setting to a vehicle speed of 40 km/h are as follows :

If V > 12 km/h :

$P_a = KV^3 +/- 5\% \; KV^3{}_{12} - 5\% \; PV_{40}$

(without being negative)

If V < 12 km/h:

$P_a$ will be between 0 and

$P_a = KV^3{}_{12} + 5\% \; KV^3{}_{12} + 5\% \; PV_{40}$

where - $PV_{40}$ is the power absorbed at 40 km/h

- K is a characteristic of the chassis dynamometer.

Please refer Fig.4 of this chapter..

6.1.2 Verification of the power absorption curve of the roller bench from a reference setting to a speed of 40 km/h :

6.1.2.1 Place the vehicle on dynamometer or device some other method of starting up the dynamometer.

6.1.2.2 Adjust the dynamometer to the absorbed power $P_a$ at 40 km/h

6.1.2.3 Note the power absorb at 30-20-10 km/h

6.1.2.4 Draw the curve $P_a$ verses V and verify that it meets the requirements of para 6.2 above.

6.1.2.5 Repeat the procedure of para 6.1.2.1 to 6.1.2.4 for other values of power $P_a$ at 40 km/h and for other values of inertia.

6.1.3 The same procedure will be used for force or torque calibration.

6.2 Vacuum method :

6.2.1 Introduction : This method is not a preferred method and should be used only with fixed load curve type dynamometers for determination of load setting at 40 km/h for four wheelers.

6.2.2 Test Instrumentation and Accuracy : The vacuum (or absolute pressure) in the intake manifold of the vehicle shall be measured to an accuracy of ± 0.25 kPa. It shall be possible to record continuously this reading or at intervals of not more than 1 second. The speed shall be recorded continuously with a precision of +/- 0.4 km/h.

6.2.3 Road test : Drive the vehicle at a steady speed of 40 km/h recording speed and vacuum (or absolute pressure) within the requirement of paragraph 6.2.2 above.

6.2.4 Repeat procedure of paragraph 6.2.3 above three times in each direction. All six runs must be completed within four hours.

6.2.5 Data reduction and acceptance criteria :

6.2.5.1 Review results obtained in accordance with paragraphs 6.2.3 and 6.2.4 (speed must not be lower than 39.5 km/h or greater than 40.5 km/h for more than 1 second). For each run, read vacuum level at 1 second intervals, calculate mean vacuum (v) and standard deviation (s). This calculation shall consist of not less than 10 readings of vacuum.

6.2.5.2 The standard deviation shall not exceed 10 percent of mean for each run.

6.2.5.3 Calculate the mean value (v) for the six runs (three runs in each direction).

6.2.5.4 Chassis Dynamometer Setting :Perform the operations specified in paragraphs 5.1.2.2.1 to above.

6.2.5.5 Setting : After warm-up, drive the vehicle at a steady speed of 40 km/h and adjust dynamometer load to reproduce the vacuum reading (v) obtained in accordance with paragraph 6.2.3. Deviation from this reading shall be not greater than 0.25 kPa.

6.3 Additional setting methods for 2-wheeler vehicles :

6.3.1 The brake shall be so adjusted as to reproduce the operation of the vehicle on the level road at a steady speed between 35 and 45 km/h (or maximum speed in case of mopeds).

6.3.2 Road test :

6.3.2.1 Accuracies of test equipment : Time shall be measured accurate to within 0.1 s. Speed shall be measured accurate to within 2 percent.

6.3.2.2 An adjustable stop limiting the maximum speed to between 35 km/h and 45 km/h shall be mounted in the fuel-feed regulating device. The speed of the vehicle shall be measured by means of precision speedometer or computed from the time measured over a given distance on a level dry road in both directions, with the stop applied.

6.3.2.3 The measurements, which shall be repeated at least three times in both directions, shall be taken over a distance of at least 200 m and with a sufficiently long acceleration distance. The average speed shall be determined.

6.3.2.4 In case of 2-wheeler vehicles with maximum speed around 40 km/h, the maximum attainable speed on the road with throttle fully opened shall be measured within ± 1 km/h. This maximum attainable speed on the road shall not differ from the maximum design speed specified by the manufacturer by more than ± 2 km/h. In the case where the vehicle is fitted with a device to regulate its maximum road speed, the effect of the regulator will be taken into account.

6.3.3 Chassis Dynamometer setting :

6.3.3.1 Perform the operations specified in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

6.3.3.2 The vehicle shall then be placed on the dynamometer bench and the brake so adjusted as to obtain the same speed as that reached in the road test (fuel-feed regulating device, if used, in stop position and same gear box ratio). This brake setting shall be maintained throughout the test. After adjusting the brake, the stop in the feed device, if used, shall be removed.

6.4 Alternative method for 2-wheeler vehicles : With the manufacturer's agreement the following method may be used :

The brake is adjusted so as to absorb the power at the driving wheel at a constant speed of 40 km/h in accordance with the following equation :

$$P_a = (aV^3 + bV)/3600$$

where

$P_a$ = power absorbed, in kW

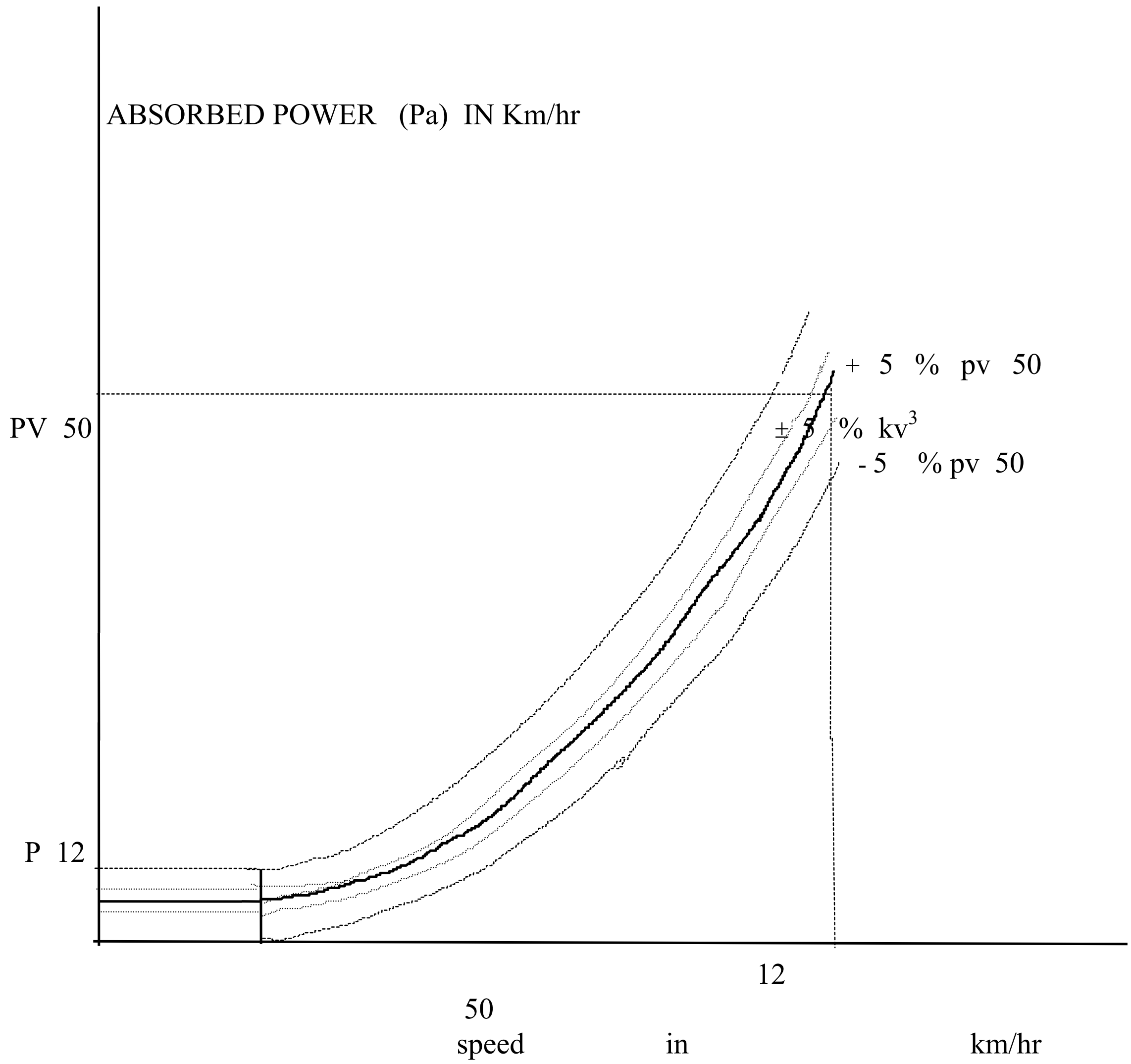
V = Vehicle speed in km/h

a = 0.0225 for 2-wheeled vehicles with engine less than 50cc capacity and

= 0.0250 for other 2-wheeler vehicles.

b = 0.18 x m (where m = reference weight of vehicle in kg.)

Fig. 4 : CHARACTERISTIC OF CHASSIS DYNAMOMETER WITH FIXED LOAD CURVE(PL.REF. PARA. 6.1.1. OF CHAPTER 4 PART 3)



## CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

1 Scope :

1.1 This Chapter describes the method to check that the simulated total inertia of the dynamometer is carried out satisfactorily in the running phases of the operating cycle.

2 Principle :

2.1 Drawing up working equations :

2.1.1 Since the chassis dynamometer is subjected to variations in the rotating speed of the roller(s), the force at the surface of the roller(s) can be expressed by the formula:

$F = I * Y = I_M * (Y + F_I)$

Where
F = force at the surface of the roller(s)

I = total inertia of the chassis dynamometer (equivalent inertia of the vehicle as in tables III of Chapter 3 of this Part).

$I_M$ = inertia of the mechanical masses of the chassis dynamometer

Y = tangential acceleration at roller surface

$F_I$ = inertia force

2.1.2 The total inertia is expressed as follows :

$I = I_M + (F_I / Y)$

Where
$I_M$ can be calculated or measured by traditional methods
$F_I$ can be measured on the bench
Y can be calculated from the peripheral speed of the rollers

2.1.3 The total inertia "I" will be determined during an acceleration or deceleration test with values higher than or equal to those obtained on an operating cycle.

2.2 Specification for the calculation of total inertia :

The test and calculation methods must make it possible to determine total inertia I with a relative error ( $\Delta I / I$) or less than 2 per cent.

3 Specification :

3.1 The mass of the simulated total inertia I must remain the same as the theoretical value of the equivalent inertia (paragraph 5.1 of Chapter 3 of this Part ) within the following limits:

3.1.1 ± 5 percent of the theoretical value for each instantaneous value.

3.1.2 ± 2 percent of the theoretical value for the average value calculated for each sequence of the cycle.

3.2 The limit given in paragraph 3.1.1 is brought to ± 50 percent for one second when starting and, for vehicles with manual transmission, for two seconds during gear changes.

4 Verification Procedure :

4.1 Verification is carried out during each test throughout the cycle defined in paragraph 2.1 above.

4.2 However, if the provisions of paragraph 3 above are met, with instantaneous accelerations which are at least three times greater or smaller than the values obtained in the sequences of the theoretical cycle, the verification described above will not be necessary.

5 Technical Note :

Explanation of drawing up working equations:

5.1 Equilibrium of the forces on the road,

$CR = k_1 * J r_1 * (dO_1 / dt) +$

$k_2 * J r_2 * (dO_2 / dt) +$

$k_3 * M * Y * r_1 +$

$k_3 * F_s * r_1$

5.2 Equilibrium of the forces on dynamometer with mechanical simulated inertias

$C_m = k_1 * J r_1 * (dO_1 / dt) +$

$k_3 * J R_m * (dW_m / dt) * r_1 / Rm + k_3 * F_s * r_1$

$= k_1 * J r_1 * (dO_1 /dt) + k_3 * I * Y * r_1 + k_3 * F_s * r_1$

5.3 Equilibrium of the forces of dynamometer with non-mechanically simulated inertias

$C_e = k_1 * J r_1 * (dO_1 / dt) +$

$r_1 * k_3 * (J Re * (dWe /dt) + C1 ) / Re + k_3 * F_s * r_1$

$= k_1 * J r_1 * (dO_1 /dt) + k_3 * (I_m Y + F_1 ) * r_1 + k_3 * F_s * r_1$

In these formulae :

CR = engine torque on the road

$C_m$ = engine torque on the chassis dynamometer with mechanically simulated inertias

$C_e$ = engine torque on the chassis dynamometer with electrically simulated inertias

$J_{r1}$ = Moment of inertia of the vehicle transmission brought back to the driving wheels

$J_{r2}$ = Moment of inertia of the non-driving wheels

$J_{rm}$ = Moment of inertia of the bench with mechanically simulated inertias

$J_{re}$ = Moment of mechanical inertia of the chassis dynamometer with electrically simulated inertias

M = Mass of the vehicle on the road

I = Equivalent inertia of the chassis dynamometer with electrically simulated inertias

$I_m$= Mechanical Inertia of the chassis dynamometer with electrically simulated inertia.

$F_s$ = Resultant force at stabilized speed.

$C_1$ = Resultant torque from electrically simulated inertias

$F_1$ = Resultant force from electrically simulated inertias

$\frac{dO_1}{dt}$ = Angular acceleration of the driving wheels

$\frac{dO_2}{dt}$ = Angular acceleration of the non-driving wheels

$\frac{dW_m}{dt}$ = Angular acceleration of the mechanical chassis dynamometer

$\frac{dW_e}{dt}$ = Angular acceleration of the electrical chassis dynamometer

Y = Linear acceleration

$r_1$ = Radius under load of the driving wheels

$r_2$ = Radius under load of the non-driving wheels

$R_m$ = Radius of the rollers of the mechanical chassis dynamometer

$R_e$ = Radius of the rollers of the electrical chassis dynamometer

$k_1$ = Coefficient dependent on the gear reduction ratio and the various inertias of transmission and "efficiency"

$k_2$ = Ratio transmission * (r1/r2) * "efficiency"

$k_3$ = Ratio transmission * "efficiency"

5.4 Supposing the two types of bench (Paragraphs 5.2 and 5.3 above) are made equal and simplified, one obtains :

$k_3 * (I_m * Y + F_1) * r_1 = k_3 * I * Y * r_1$

where -

$I = I_m + (F_1 / Y)$

# CHAPTER 6 : GAS SAMPLING SYSTEMS

1. Scope :

1.1 This Chapter describes two types of gas sampling systems in paragraphs 2.1 and 2.2 meeting the requirements specified in para 4.2 of Chapter 3 of this Part. Another type described in paragraph 2.3, may be used if it meets these requirements.

1.2 The laboratory shall mention, in its communications, the system of sampling used when performing the test. Systems not described in this appendix could be used, if it is proven to give equivalent results.

2. Description of Devices :

2.1 Variable Dilution Device with Positive Displacement Pump (PDP-CVS)

2.1.1 The Positive Displacement Pump - Constant Volume Sampler (PDP-CVS) satisfies the requirements by metering at a constant temperature and pressure through the pump. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling with pump, flow meter and flow control valve at a constant flow rate.

2.1.2 Figure 6 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawings is not essential. Additional components such as instruments, valves, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

2.1.3 The collecting equipment shall consist of :

2.1.3.1 A filter (D) for the dilution air, which can be preheated, if necessary. This filter shall consist of activated charcoal sandwiched between two layers of paper, and shall be used to reduce and stabilise the hydrocarbon concentrations of ambient emissions in the dilution air.

2.1.3.2 A mixing chamber (M) in which exhaust gas and air are mixed homogeneously.

2.1.3.3 A heat exchanger (H) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust gas mixture measured at a point immediately upstream of the positive displacement puÿp is within ± 6K of the designed operating temperature. This device shall not affect the pollutant concentrations of diluted gases taken off for analysis.

2.1.3.4 A temperature control system (TC), used to preheat the heat exchanger before the test and to control its temperature during the test, so that deviations from the designed operating temperature are limited to ± 6 K.

The positive displacement pump (PDP), used to transport a constant volume flow of the air exhaust - gas mixture. The flow capacity of the pump shall be large enough to eliminate water condensation in the system under all operating conditions which may occur during a test, this can be generally ensured by using a positive displacement pump with an adequate flow capacity twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle or sufficient to ensure that the CO2 concentration in the dilute exhaust sample bag is less than 3 percent by volume.

2.1.3.5 A temperature sensor (T1) (accuracy and precision ± 1° C) fitted at a point immediately upstream of the positive displacement pump. It shall be designed to monitor continuously the temperature of diluted exhaust gas mixture during the test.

2.1.3.6 A pressure gauge (G1) (accuracy and precision ± 0.4 kPa) fitted immediately upstream of the volume meter and used to register the pressure gradient between the gas mixture and the ambient air.

2.1.3.7 Another pressure gauge (G2) (accuracy and precision ± 0.4 kPa) fitted so that the differential pressure between pump inlet and pump outlet can be registered.

2.1.3.8 Two sampling outlets ($S_1$ and $S_2$ ) for taking constant samples of the dilution air and of the diluted exhaust gas/air mixture.

2.1.3.9 A filter (F), to extract solid particles from the flow of gas collected for analysis.

2.1.3.10 Pumps (P), to collect a constant flow of the dilution air as well as of the diluted exhaust-gas/air mixture during the test.

2.1.3.11 Flow controllers (N), to ensure a constant uniform flow of the gas samples taken during the course of the test from sampling probes $S_1$ and $S_2$ , and flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (about 10 l/min.)

2.1.3.12 Flow meters (FL), for adjusting and monitoring the constant flow of gas samples during the test.

2.1.3.13 Quick-acting valves (V), to divert a constant flow of gas samples into the sampling bags or to the outside vent.

2.1.3.14 Gas-tight, quick-lock coupling elements (Q) between the quick-acting valves and the sampling bags; the coupling shall close automatically on the sampling-bag side; as an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).

2.1.3.15 Bags (B), for collecting samples of the diluted exhaust gas and of the dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

2.1.3.16 A digital counter (C), to register the number of revolutions performed by the positive displacement pump during the test.

2.1.4 Additional equipment required when testing diesel engined vehicles.

2.1.4.1 The additional components shown within the dotted lines of Figure 6 shall be used when testing Diesel Engined Vehicles.

$F_h$ is a heated filter

$S_3$ is a sample point close to the mixing chamber

$V_h$ is a heated multiway valve

Q is a quick connector to allow the ambient air sample BA to be analysed on the HFID

HFID is a heated flame, ionisation analyser.

R & I are a means of integrating and recording the instantaneous hydrocarbon concentrations.

$L_h$ is a heated sample line

All heated components will be maintained at 190 ± 10 deg.C.

2.1.4.2 If compensation for varying flow is not possible then a heat exchanger (H) and temperature control system (TC) as described in Paragraph 2.1.3 of this Chapter will be required to ensure constant flow through the ventury (MV) and thus proportional flow through S3.

2.2 Critical-flow venturi dilution device/(CFV-CVS)

2.2.1 Using a critical-flow venturi in connection with the CVS sampling procedure is based on the principles of flow mechanics for critical flow. The variable mixture flow rate of dilution and exhaust gas is maintained at sonic velocity which is directly proportional to the square root of the gas temperature. Flow is continually monitored, computed, and integrated over the test. If an additional critical-flow sampling venturi is used the proportionality of the gas samples taken is ensured. As both pressure and temperature are equal at the two venturi inlets, the volume of the gas flow diverted for sampling is proportional to the total volume of diluted exhaust gas mixture produced, and thus the requirements of this test are met.

2.2.2 Figure 7 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawing is not essential. Additional components such as instruments, valve, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

2.2.3 The collecting equipment shall consist of :

2.2.3.1 A filter (D), for the dilution air, which can be preheated if necessary; the filter shall consist of activated charcoal sandwiched between layers of paper, and shall be used to reduce and stabilize the hydrocarbon background emission of the dilution air.

2.2.3.2 A mixing chamber (M), in which exhaust gas and air are mixed homogeneously.

2.2.3.3 A cyclone separator (CS), to extract particles.

2.2.3.4 The sampling probes ($S_1$ and $S_2$ ), for taking samples of the dilution air as well as of the diluted exhaust gas.

2.2.3.5 A sampling critical flow venturi (SV), to take proportional samples of the diluted exhaust gas at sampling probe, $S_2$.

2.2.3.6 A filter (F), to extract solid particles from the gas flows diverted for analysis.

2.2.3.7 Pump (P), to collect part of the flow of air and diluted exhaust gas in bags during the test.

2.2.3.8 A flow controller (N), to ensure a constant flow of the gas samples taken in the course of the test from sampling probe S1. The flow of the gas samples shall be such, that at the end of the test, the quantity of the samples is sufficient for analysis (about 10 l/min)

2.2.3.9 Flow meters (FL), for adjusting and monitoring the flow of gas samples during tests.

2.2.3.10 A scrubber (PS), in the sampling line.

2.2.3.11 Quick-acting solenoid valves (V), to divert a constant flow of gas samples into the sampling bags or to the vent.

2.2.3.12 Gas-tight, quick-lock coupling elements (Q), between the quick acting valves and the sampling bags; the couplings shall close automatically on the sampling bag side. As an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcock, for instance).

2.2.3.13 Bags (B), for collecting samples of the diluted exhaust gas and the dilution air during the test; they shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

2.2.3.14 A pressure gauge (G), which shall be precise and accurate to within 0.4 kPa.

2.2.3.15 A temperature sensor (T), which shall be precise and accurate to within 1K and have a response time of 0.1 seconds to 62 percent of a temperature change (as measured in silicone oil).

2.2.3.16 A measuring critical flow venturi tube (MV), to measure the flow volume of the diluted exhaust gas.

2.2.3.17 A blower (BL), of sufficient capacity to handle the total volume of diluted gas.

2.2.3.18 The capacity of the CFV-CVS system shall be such that under all operating conditions which may possibly occur during a test there will be no condensation of water. This is generally ensured by using a blower whose capacity is;

2.2.3.18.1 Twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle or

2.2.3.18.2 Sufficient to ensure that the $CO_2$ concentration in the dilute exhaust sample bag is less than 3 percent by volume.

2.2.4 Additional equipment required when testing diesel engined vehicles.

2.2.4.1 The additional components shown within the dotted lines of Figure 7 shall be used when testing Diesel Engined Vehicles.

Fh : is a heated filter

$S_3$ : is a sample point close to the mixing chamber

Vh : is a heated multiway valve

Q : is a quick connector to allow the ambient air sample BA to be analysed on the HFID

HFID is a heated flame, ionisation analyser.

R & I are a means of integrating and recording the instantaneous hydrocarbon concentrations.

Lh : is a heated sample line

All heated components will be maintained at 190 ± 10 deg.C.

2.2.4.2 If compensation for varying flow is not possible then a heat exchanger (H) and temperature control system (TC) as described in Paragraph 2.1.3 of this Chapter will be required to ensure constant flow through the ventury (MV) and thus proportional flow through $S_3$.

2.3 Variable dilution device with constant flow control by orifice (CFO-CVS) (Figure 8)

2.3.1 The collection equipment shall consist of :

2.3.1.1 A sampling tube connecting the vehicle's exhaust pipe to the device itself;

2.3.1.2 A sampling device consisting of a pump for drawing in the diluted mixture of exhaust gas and air;

2.3.1.3 A mixing chamber (M) in which exhaust gas and air are mixed homogeneously.

2.3.1.4 A heat exchanger (H) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust gas mixture measured at a point immediately before the positive displacement of the flow rate measuring device is within ± 6° K. This device shall not alter the pollutant concentration of diluted gases taken off for analysis. Should this condition not be satisfied for certain pollutants, sampling will be effected before the cyclone for one or several considered pollutants.

If necessary, a device for temperature control (TC) is used to preheat the heat exchanger before testing and to keep up its temperature during the test within ± 6° K of the designed operating temperature.

2.3.1.5 Two probes ($S_1$ and $S_2$) for sampling by means of pumps (P), flowmeters (FL) and, if necessary, filters (F) allowing for the collection of solid particles from gases used for the analysis.

2.3.1.6 One pump for dilution air and another one for diluted mixture.

2.3.1.7 A volume-meter with an orifice.

2.3.1.8 A temperature sensor (T1) (accuracy and precision ± 1 K) fitted at a point immediately before the volume measurement device. It shall be designed to monitor continuously the temperature of the diluted exhaust gas mixture during the test.

2.3.1.9 A pressure gauge (G1) (capacity and precision ± 0.4 kPa) fitted immediately before the volume meter and used to register the pressure gradient between the gas mixture and the ambient air.

2.3.1.10 Another pressure gauge ($G_2$) (accuracy and precision ± 0.4 kPa fitted so that the differential pressure between pump inlet and pump outlet can be registered.

2.3.1.11 Two controllers (N) to ensure a constant uniform flow of gas samples taken during the course of the test from sampling outlets $S_1$ and $S_2$ . The flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (about 10 l/min).

2.3.1.12 Flow meters (FL) for adjusting and monitoring the constant flow of gas samples during the test.

2.3.1.13 Three-way valves (V) to divert a constant flow of gas samples into the sampling bags or to the outside vent.

2.3.1.14 Gas-tight, quick lock sampling elements (G) between the three-way valves and the sampling bags. The coupling shall close automatically on the sampling bag side. Other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).

2.3.1.15 Bags (B) for collecting samples of diluted exhaust gas and of dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

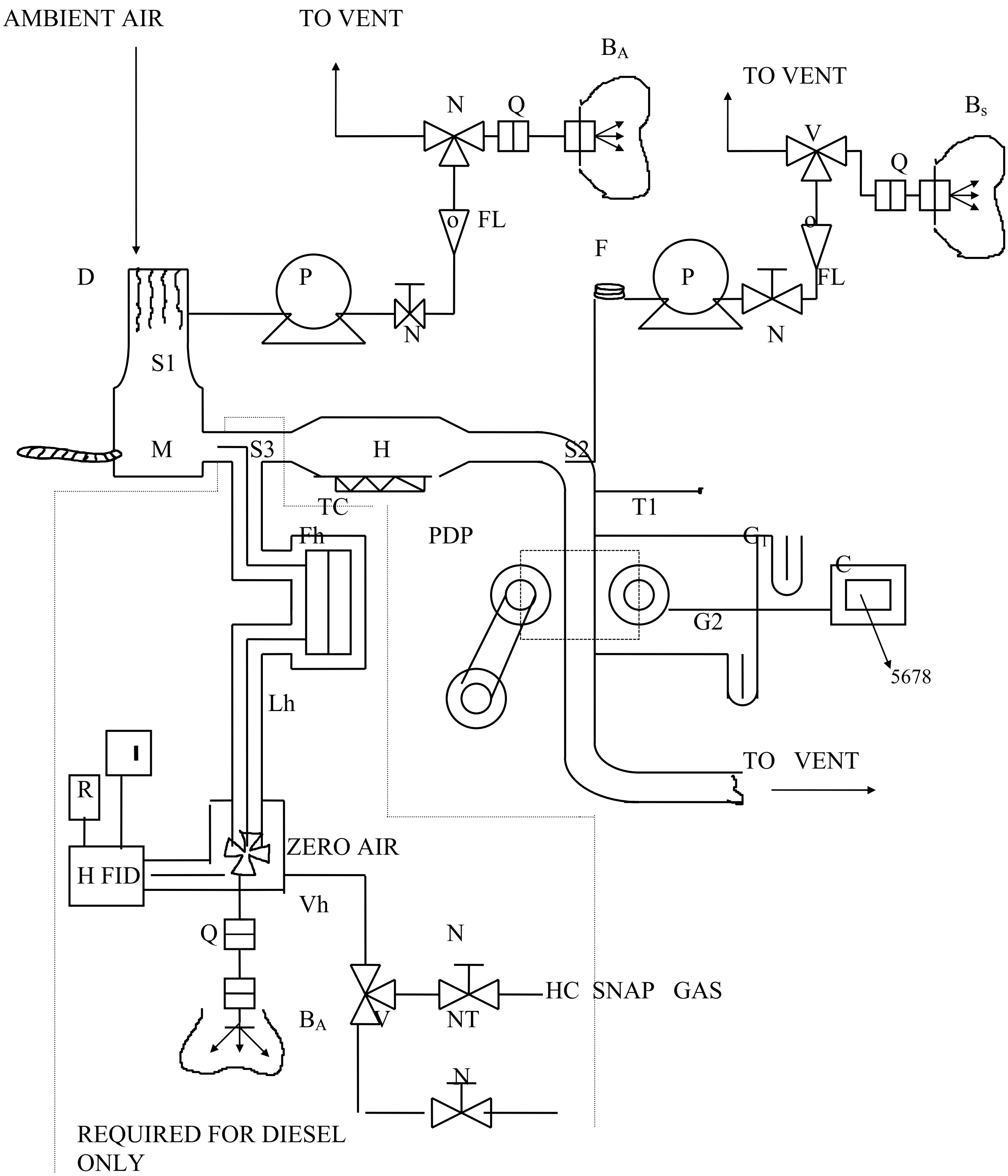



FIG.6 -- SCHEMATIC CONSTANT VOLUME SAMPLES WITH POSITIVE DISPLACEMENT PUMP (PDP-CVS) (PL. REF. PARA. 2.1.2. OF CHAPTER 6 Part 3)

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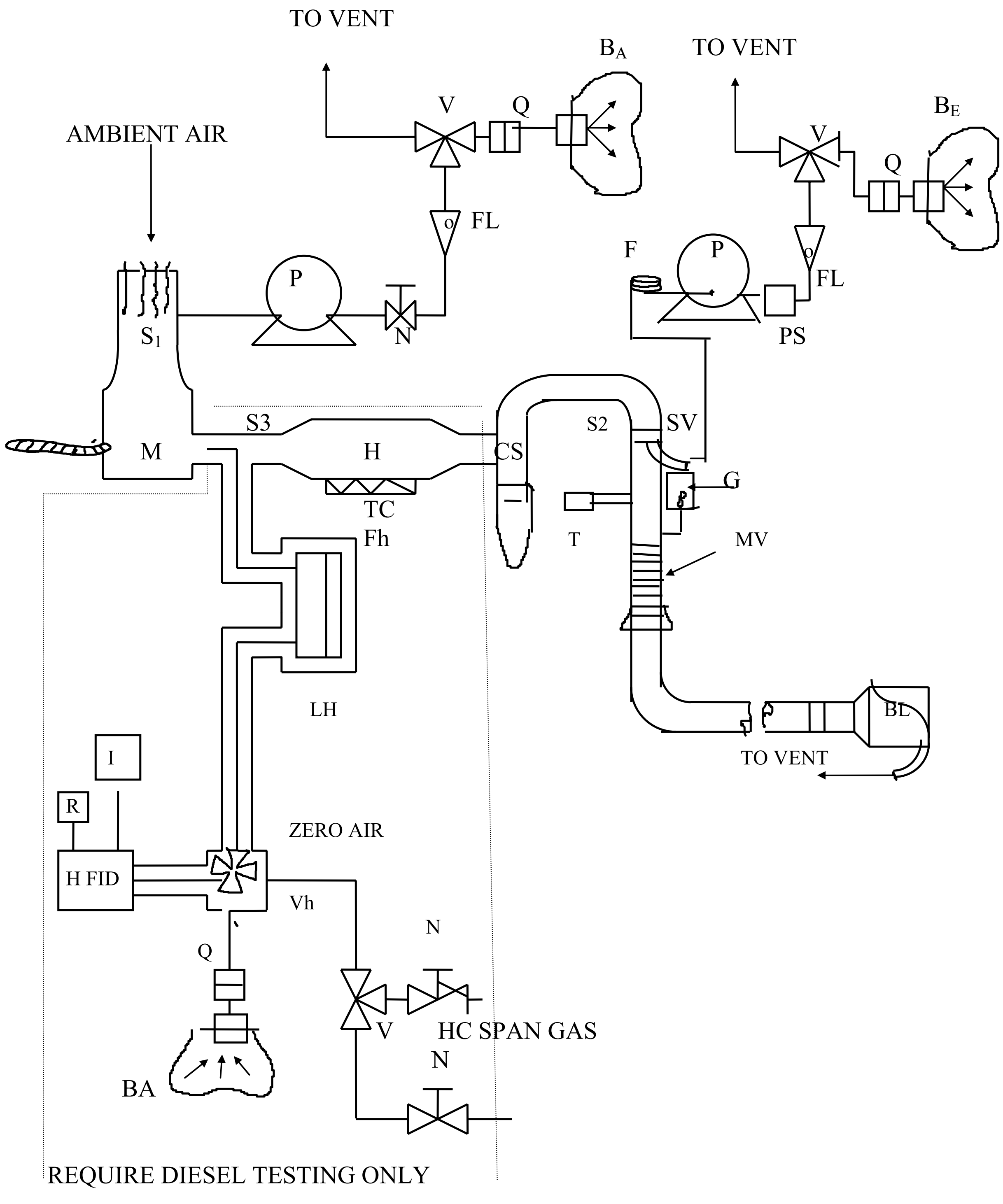



FIG 7: SCHEMATIC --CONSTANT VOLUME SAMPLER WITH CRITICAL FLOW VENTURI (CFV-CVS)(PL.REF.PARA. 2.2.2 OF CHAPTER 6 Part 3)

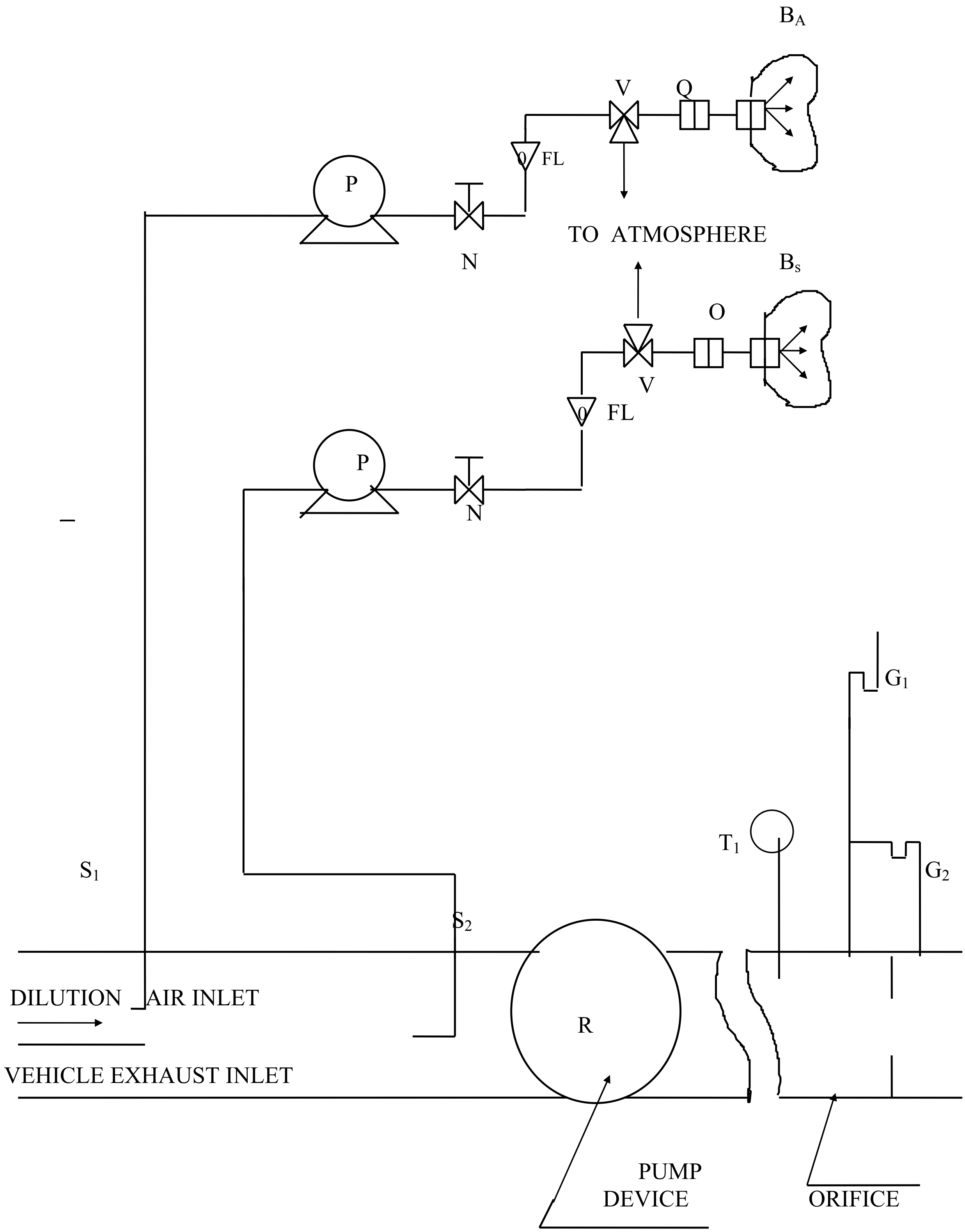



FIG: 8 SCHEMATIC OF VARIABLE DILUTION DEVICE WITH CONSTANT FLOW CONTROL BY ORIFICE (CFO-CVS) (PL.REF. PARA. 2.3 OF CHAPTER 6)

**CHAPTER 7 : CALIBRATION OF CHASSIS DYNAMOMETERS, CVS SYSTEM AND GAS ANALYSIS SYSTEM AND TOTAL SYSTEM VERIFICATION**

1. Scope :

1.1 This Chapter describes the methods used for calibrating, and verifying the Chassis Dynamometers, CVS System and Analysis System.

2. Methods of Calibration of Chassis Dynamometer :(The method to be used to determine the power absorbed by a dynamometric brake)

2.1 The power absorbed by chassis dynamometer comprises the power absorbed by frictional effects and the power absorbed by the power absorption device. The chassis dynamometer is brought into operation beyond the range of test speeds. The device used for starting up the chassis dynamometer is then disconnected; the rotational speed of the driven rollers decreases. The kinetic energy of rollers is dissipated by the power absorption unit and by the frictional effects. This method disregards variations in the roller's internal frictional effects caused by rollers with or without the vehicle. The frictional effects of the rear roller shall be disregarded when this is free.

2.2 Calibrating the power indicator to 40 km/h as a function the power absorbed The following procedure shall be used:

2.2.1 Measure the rotational speed of the roller if this has not already been done. A fifth wheel, a revolution counter or some other method may be used.

2.2.2 Place the vehicle on the dynamometer or connect the device for starting up the dynamometer.

2.2.3 Use the fly-wheel or any other system of inertia simulation for the particular inertia class to be used.

2.2.4 Bring the dynamometer to a speed of 40 km/h.

2.2.5 Note the power indicated (Pi).

2.2.6 Bring the dynamometer to a speed of 50 km/h.

2.2.7 Disconnect the device used to start up the dynamometer.

2.2.8 Note the time taken by the dynamometer to attain a speed of 35 km/h from a speed of 45 km/h.

2.2.9 Set the power absorption device at a different level.

2.2.10 The requirements of paragraphs 2.2.4 to 2.2.9 above shall be repeated sufficient number of times to cover the range of road power used.

2.2.11 Calculate the power absorbed, using the formula:

$$P_a = M_1 * (V_1^2 - V_2^2) / 2000t$$

Where
$P_a$ = power absorbed in kW

$M_1$ = equivalent inertia in kg (excluding the inertial effects of the free rear roller)

$V_1$ = initial speed in m/s (45 km/h = 12.5 m/s)

$V_2$ = final speed in m/s (35 km/h = 9.72 m/s)

t = time taken by the roller to pass from 45 km/h to 35 km/h in s.

2.2.11.1 The requirements of paragraphs 2.2.3 to 2.2.11 shall be repeated for all inertia classes to be used.

2.3 Calibration of the power indicator as a function of the absorbed power for other speeds :

The procedures of paragraph 2.2 shall be repeated sufficient number of times for the chosen speeds.

2.4 Verification of the power-absorption curve of the roller bench from a reference setting to a speed of 40 km/h :

2.4.1 Place the vehicle on the dynamometer or devise some other method of starting up the dynamometer.

2.4.2 Adjust the dynamometer to the absorbed power Pa, at 40 km/h.

2.4.3 Note the power absorbed at 30-20-10 km/h.

2.4.4 Draw the curve Pa versus V and verify that it meets the requirements of paragraph 2.4 above.

2..4.5 Repeat the procedure of para 2.4.1 to 2.4.4 for other values of power Pa at 40 km/h and for other values of inertia.

2.5 The same procedure will be used for force or torque calibration.

3. Calibration of the CVS System :

3.1 The CVS system shall be calibrated by using an accurate flow meter and a restricting device. The flow through the system shall be measured at various pressure readings and the control parameters of the system measured and related to the flows.

Various types of flow meter may be used, e.g. calibrated venturi, laminar flow meter, calibrated turbine meter provided that they are dynamic measurement systems and can meet the requirements of paragraphs 4.2.2 and 4.2.3 of Chapter 3 of this Part.

3.1.1 The following sections give details of methods of calibrating PDP and CFV units, using a laminar flow meter, which gives the required accuracy, together with a statistical check on the calibration validity.

3.2 Calibration of the Positive Displacement Pump (PDP) :

3.2.1 The following calibration procedure outlines the equipment the test configuration, and the various parameters which shall be measured to establish the flow rate of the CVS-pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow meter which is connected in series with pump. The calculated flow rate (given in $m^3$ /min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

3.2.2 This calibration procedure is based on the measurement of the absolute values of the pump and flow meter parameters that relate the flow rate at each point. Three conditions must be maintained to ensure the accuracy and integrity of the calibration curve as given below :

3.2.2.1 The pump pressures shall be measured at tappings on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top centre and bottom centre of the pump drive headplate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials.

3.2.2.2 Temperature stability shall be maintained during the calibration. The laminar flow meter is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes of ± 1 K in temperature are acceptable as long as they occur over a period of several minutes.

3.2.2.3 All connections between the flow meter and the CVS pump shall be free of any leakage.

3.2.3 During an exhaust emission test, the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

3.2.3.1 Figure 9 in this chapter shows one possible test set-up. Variations are permissible, provided that they are approved by the Authority granting the approval as being of comparable accuracy. If the set-up shown in Fig.9 is used, the following data shall be found within the limits of precision given :

| | |
|---|---|
| Barometric pressure (corrected (PB) | ± 0.03 kPa |
| Ambient temperature (T) | ± 0.2 °K |
| Air temperature at LFE (ETI) | ± 0.15 °K |
| Pressure depression upstream of LFE(EPI) | ± 0.01 kPa |
| Pressure drop across the LFE matrix (EDP) | ± 0.0015 kPa |
| Air temperature at CVS pump inlet (PTI) | ± 0.2 K |
| Air temperature at CVS pump outlet (PTO) | ± 0.2 K |
| Pressure depression at CVS pump inlet (PPI) | ± 0.22 kPa |
| Pressure head at CVS-pump outlet (PPO) | ± 0.22 kPa |
| Pump revolutions during test period (n) | ± 1 rev. |
| Elapsed time for period (min 250 sec) (t) | ± 0.1 sec |

3.2.3.2 After the system has been connected, as shown in Figure 9, the variable restrictor is set in the wide-open position and the CVS pump run for 20 minutes before starting the calibration.

3.2.3.3 The restrictor valve is adjusted in steps to get an increment of pump inlet depression (about 1 kPa) that will yield a minimum of six data points for the total calibration. The system is allowed to stabilize for three minutes and the data acquisition repeated.

3.2.3 Data analysis :

3.2.4.1 The air flow rate, Qs, at each test point is calculated in standard $m^3$ /min from the flow meter data using the manufacturer's prescribed method.

3.2.4.2 The air flow rate is then converted to pump flow, Vo, in $m^3$ per revolution at absolute pump inlet temperature and pressure.

Qs Tp 101.33

Vo = ------- x --------- x -------
n 293 Pp

Where,

Vo = pump flow rate at Tp and $Pp_o$ given in $m^3$ /rev

Qs = air flow at 101.33 kPa and 293 K given in $m^3$ /min

Tp = pump inlet temperature (K)

Pp = absolute pump inlet pressure, in kPa

n = pump speed in revolutions per minute

To compensate the interaction of pump speed, pressure variations at the pump and the slip rate, the correlation function (Xo) between the pump speed (n), the pressure differential from the pump inlet to pump outlet and the absolute pump outlet Pressure is then calculated as follows :-

$Xo = \sqrt{} (\Delta Pp/Pe)/n$

Where,

Xo = correlation function

$\Delta$ Pp = pressure differential from pump inlet to pump outlet (kPa)

Pe = absolute pump outlet pressure (PPO + PB) (kPa)

A linear least square fit is performed to generate the calibration equations which have the formula

$V_o = D_o - (M^*X_o)$

$n = A - (B * \Delta Pp)$

where -

$D_o$ , M, A and B are the slope-intercept constants describing the lines.

3.2.4.3 A CVS system that has multiple speeds shall be calibrated on each speed used. The calibration curves generated for the ranges should be approximately parallel and the intercept values, Do, should increase as the pump flow decreases.

3.2.4.4 If the calibration has been performed carefully, the calculated values from the equation should be within ± 0.5 percent of the measured value of $V_o$. Values of M should vary from one pump to another. Calibration shall be performed at pump start-up and after major maintenance.

3.3 Calibration of the Critical-Flow Venturi (CFV) :

3.3.1 Calibration of the CFV is based upon the flow equation for a critical venturi

$Qs = Kv * P/\sqrt{T}$

Where,
Qs = Flow

Kv = Calibration coefficient

P = Absolute pressure (kPa)

T = Absolute temperature (K)

Gas flow is a function of inlet pressure and temperature. The calibration procedure described below establishes the value of the calibration coefficient at measured value of pressure, temperature and air flow.

3.3.2 The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

3.3.3 Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given :

| | |
|---|---|
| Barometric pressure (corrected) (PB) | ± 0.03 kPa |
| LFE air temperature flowmeter (ETI) | ± 0.15 K |
| Pressure depression up-stream (LFE) (EPI) | ± 0.01 kPa |
| Pressure drop across (EDP) LFE matrix | ± 0.0015 kPa |
| Air Flow (Qs) | ± 0.5 % |
| CFV inlet depression (PPI) | ± 0.02 kPa |
| Temperature at venturi inlet (Tv) | ± 0.2 K |

3.3.4 The equipment shall be set up as shown in figure 10 and checked for leaks. Any leaks between the flow measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

3.3.5 The variable flow restrictor shall be set to the "open" position, the blower shall be started and the system shall be stabilised. Data from all instruments shall be recorded.

3.3.6 The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

3.3.7 The data recorded during the calibration shall be used in the following calculations. The air flow rate, Qs, at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

Values of the calibration coefficient Kv for each test point is calculated as below -

$$K_v = Q_s * \sqrt{T_v} / P_v$$

Where,

Qs = flow rate in cu. m /min at 293 K and 101 kPa

Tv = temperature at the venturi inlet ( K)

Pv = absolute pressure at the venturi inlet (kPa)

Plot Kv as a function of venturi inlet pressure. For sonic flow Kv will have a relatively constant value. As pressure decreases (vacuum increases) the venturi becomes unchocked and Kv decreases.

The resultant Kv changes are not permissible.

For a minimum of eight points in the critical region and average Kv and the standard deviation in calculated.

If the standard deviation exceeds 0.3 per cent of the average Kv, corrective action shall be taken.

4. Calibration of Gas Analysis System :

4.1 Establishment of Calibration Curve

4.1.1 The analyser calibration curve shall be established by at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90% of the full scale.

4.1.2 The calibration curve is calculated by the least square method. If the degree of the polynomial resulting from the curve is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

4.1.3 The calibration curve shall not differ by more than ± 2% from the nominal value of calibration gas of each calibration point.

4.1.4 The different characteristic parameters of the analyser, particularly the scale, the sensitivity, the zero point and the date of carrying out the calibration should be indicated on the calibration curve.

4.1.5 It can be shown to the satisfaction of the testing authority, that alternative technology e.g. computer, electronically controlled range switch etc., can give equivalent accuracy, then these alternatives may be used.

4.2 Verification of Calibration

4.2.1 The calibration procedure shall be carried out as often as necessary and in any case within one month preceding the type approval emission test and once in six months for verifying conformity of production.

4.2.2 The verification should be carried out using standard gases. The same gas flow rates shall be used as when sampling exhaust.

4.2.3 A minimum of two hours shall be allowed for warming up the analysers.

4.2.4 The NDIR analyser shall be tuned, where appropriate, and the flame combustion of the FID analyser optimised.

4.2.5 Using purified dry air ( or nitrogen ), the CO and Nox analysers shall be set at zero; dry air shall be purified for the HC analyser. Using appropriate calibrating gases mentioned in 3.4 of chapter 3 or part V, the analysers shall be reset.

4.2.6 The zero setting shall be rechecked and the procedure described in Para 4.2.4 and 4.2.5 above repeated, if necessary.

4.2.7 The calibration curves of the analysers should be verified by checking at least at five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90% of the full scale. It should meet the requirement of para 4.1.3 above.

4.2.8 If it does not meet, the system should be checked, fault, if any, corrected and a new calibration curve should be obtained.

4.3 Pre-test Checks

4.3.1 A minimum of two hours shall be allowed for warming up the infra-red NDIR analyser, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

4.3.2 Each normally used operating range shall be checked prior to each analysis.

4.3.3 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser.

4.3.4 Span gas having a concentration of the constituent that will give a 75-95% full-scale deflection shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure.

4.3.5 The nominal value of the span calibration gas used shall remain with ± 2% of the calibration curve.

4.3.6 If it does not, but it remains within ± 5% of the calibration curve, the system parameters such as gain of the amplifier, turning of NDIR analysers, optimisation of FID analysers etc. may be adjusted to bring within ± 2%.

4.3.7 If the system does not meet the requirement of 4.3.5 and 4.3.6 above, the system should be checked, fault, if any corrected and a new calibration curve should be obtained.

4.3.8 Zero shall be checked and the procedures described in para 4.3.4 above repeated, if required.

4.4 System Leak Test :

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.5 Efficiency Test of the NOx Converter :

4.5.1 The efficiency of the converter used for the conversion of $NO_2$ into NO is tested as follows :

4.5.1.1 Using the test set up shown in Figure 11 and the procedure described below, the efficiency of converters can be tested by means of an ozonator.

4.5.2 Calibrate the CLA analyser in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which should amount to about 80 percent of the operating range and the $NO_2$ concentration of the gas mixture shall be less than 5 percent of the NO concentration). The NOx analyser shall be in the NO mode so that span gas does not pass through the converter. Record the indicated concentration.

4.5.3 Via a T-fitting, oxygen or synthetic air is added continuously to the gas flow until the concentration indicated is about 10 percent less than the indicated calibration concentration given in paragraph 3.1 above. Record the indicated concentration (c). The ozonator is kept deactivated throughout this process.

4.5.4 The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20 percent (minimum 10 percent) of the calibration concentration . Record the indicated concentration (d).

4.5.5 The NOx analyser is then switched to the NOx mode which means that the gas mixture (consisting of NO, NO2, O2 and N2) now passes through the converter. Record the indicated concentration (a). The ozonator is now deactivated.

4.5.6 The mixture of gases described in paragraph 4.5.3 above passes through the converter into the detector. Record the indicated concentration (b).

4.5.7 With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NOx reading of the analyser shall then be no more than 5 percent above the figure in paragraph 4.5.2

4.5.8 The efficiency of the NOx converter is calculated as follows :
Efficiency (%) = ( 1 + (a - b) / (c - d) ) * 100

4.5.9 The efficiency of the converter shall not be less than 95%.

4.5.10 The efficiency of the converter shall be tested at least once a week.

5. Total System Verification :

5.1 To comply with the requirements of paragraph 4.7 of Chapter 3 of this Part, total accuracy of the CVS, sampling and analytical systems shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated as if during a normal test and then analysing and calculating the pollutant mass according to the formulae in chapter 8 except that the density of propane shall be taken as 1.833 $Kg/m^3$ at standard conditions. The following two techniques are known to give sufficient accuracy :-

Metering a constant flow of pure gas (CO or $C_3H_8$ using a critical flow orifice device) is fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow rate q, which is adjusted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceed by 5 percent, the cause of the malfunction shall be located and determined. Then CVS system operated as in an exhaust emission test for about 5 to 10 minutes. The gas collected in the sampling bag is analysed by the usual equipment and the results compared to known quantity of pure gas.

5.2 Metering a limited quantity of pure gas ( CO or $C_3H_8$ ) by means of a gravimetric technique. The following gravimetric procedure may be used to verify the CVS system. The mass of a small cylinder filled with either carbon monoxide or propane is determined with a precision of ± 0.01 gram. For about 5 to 10 minutes the CVS system is operated as in a normal exhaust emission test, while CO or propane is injected into the system. The quantity of pure gas involved is determined by means of differential weighing. The gas accumulated in the bag is then analysed by means of the equipment normally used for the exhaust gas analysis. The results are then compared to the concentration figures computed previously.

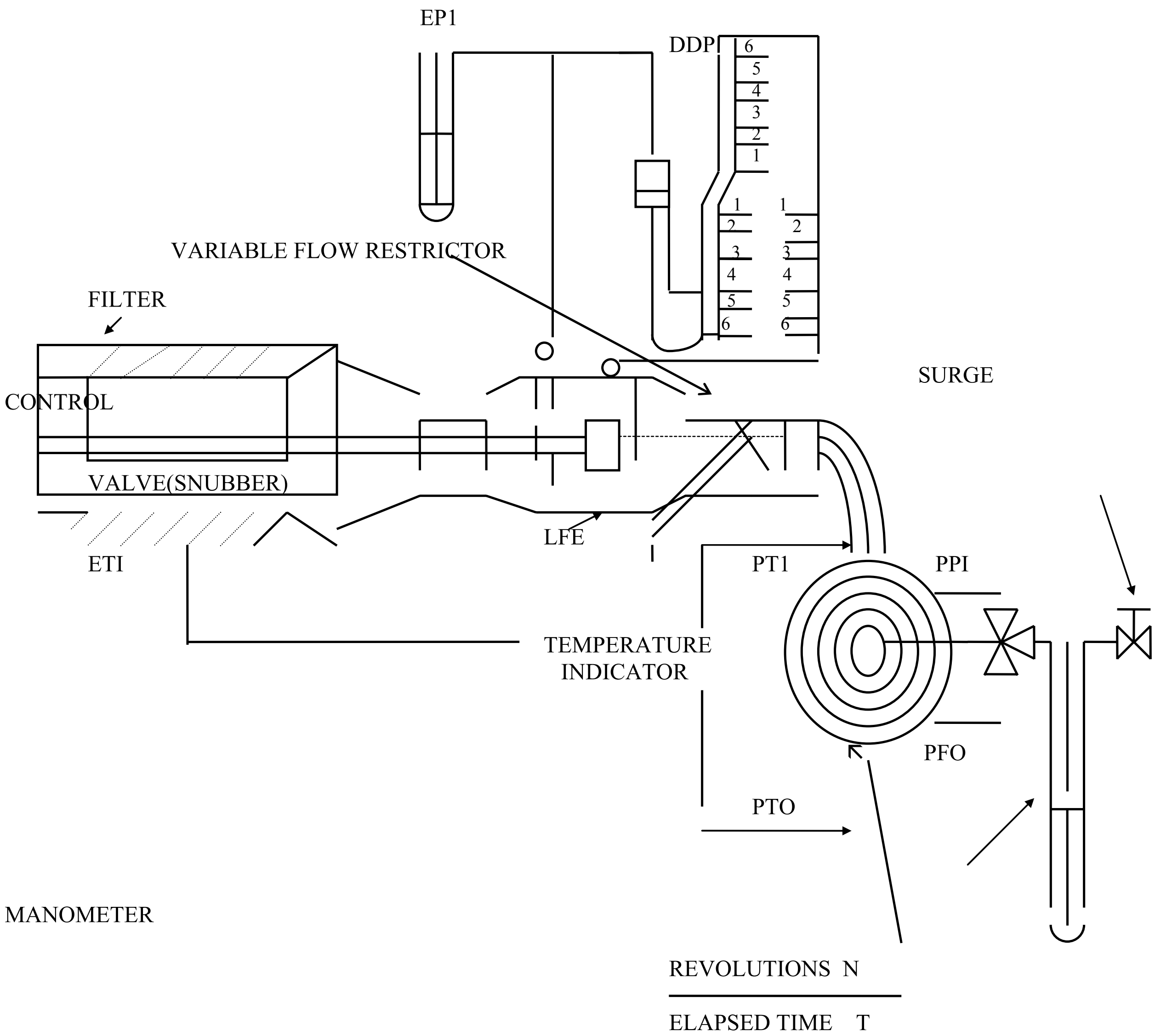



FIG 9: PDP--CVS CALIBRATION SET UP -SCHEMATIC (PL. REF. PARA. 3.2.3.1 OF CHAPTER 7 ,Part 3)

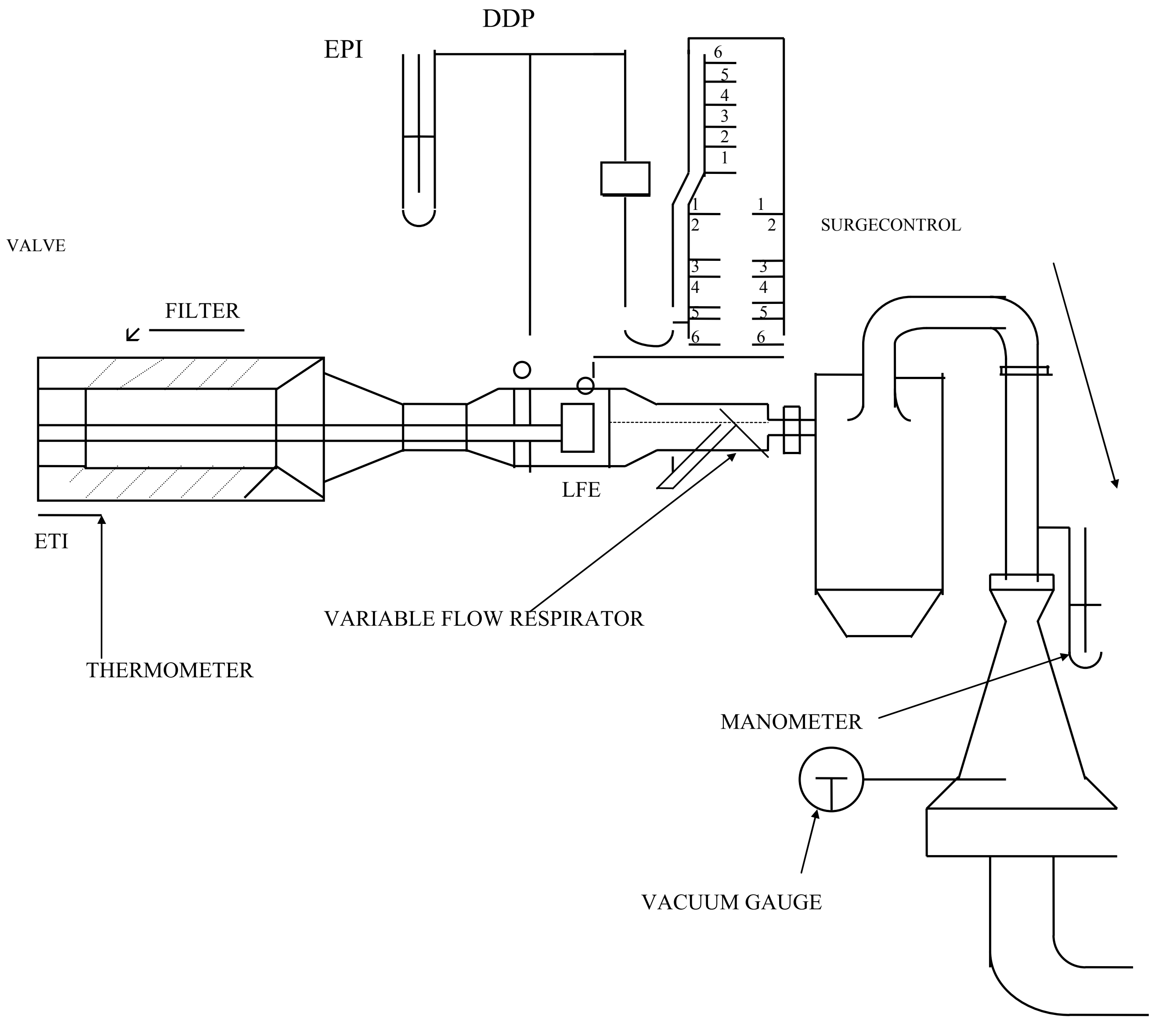



FIG 10. CFS--CVS CALIBRATION SET UP -- SCHEMATIC (PL. REF. PARA. 3.3.4.OF CHAPTER 7 ,Part 3)

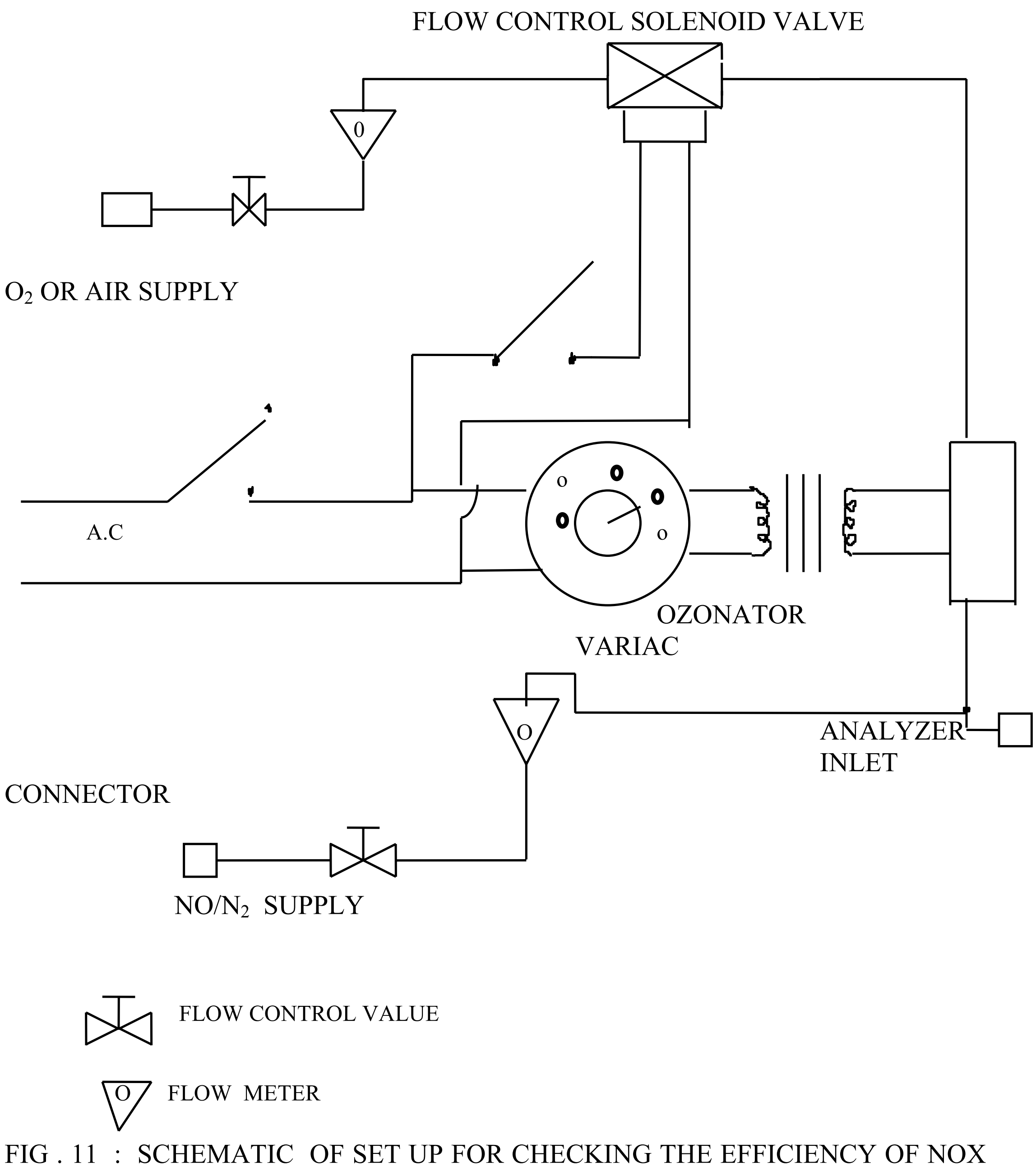



FIG . 11 : SCHEMATIC OF SET UP FOR CHECKING THE EFFICIENCY OF NOX CONVERTER (Pl.ref. para.4.5.1.1 of chapter7 part III)

## CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

1. Scope : This chapter describes the calculation procedures for the mass emission of pollutants and correction for humidity for oxides of nitrogen.

2. The mass emission of pollutants are calculated by means of the following equation :

$M_i = V_{mix} * Q_i * k_H * C_i * 10^{-6} / Ds$

$M_i$ = Mass emission of the pollutant i in g/km

$V_{mix}$ = Volume of the diluted exhaust gas expressed in cu.m/test and corrected to standard conditions 293 K and 101 kPa

Ds = distance covered in km

$Q_i$ = Density of the pollutant i in kg/cu.m at normal temperature and pressure (293 K and 101 kPa)

$k_H$ = Humidity correction factor used for the calculation of the mass emissions of oxides of nitrogen. There is no humidity correction for HC and CO.

$C_i$ = Concentration of the pollutant i in the diluted exhaust gas expressed in ppm and corrected by the amount of the pollutant i contained in the dilution air.

3. VOLUME DETERMINATION :

3.1 Calculation of the volume when a variable dilution device with constant flow control by orifice or venturi is used. Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

3.2 Calculation of volume when a positive displacement pump is used .

The volume of diluted exhaust gas in systems comprising a positive displacement pump is calculated with the following formula :

$V = V_o * N$

Where,

V = Volume of diluted exhaust gas expressed in cu.m/test (prior to correction)

$V_o$ = Volume of gas delivered by the positive displacement pump on testing conditions, in cu.m/rev.

N = Number of revolutions per test.

3.3 Correction of the diluted exhaust gas volume to standard conditions . The diluted exhaust gas volume is corrected by means of the following formula :

$V_{mix} = V * K_1 *( P_B - P_1)/ T_P$ (2)

in which :

$K_1 = 293 K/101 kPa = 2.9009 (K.kPa^{-1})$ (3)

Where,

$P_B$ = Barometric pressure in the test room in kPa

$P_1$ = Vacuum at the inlet to the positive displacement pump in kPa relative to the ambient barometric pressure.

$T_P$ = Average temperature of the diluted exhaust gas entering the positive displacement pump during the test.

4. Calculation of the Corrected Concentration of Pollutants in the Sampling_Bag

$$C_i = C_e - \left( C_d * \left( 1 - \frac{1}{Df} \right) \right)$$

Where,

$C_i$ = Concentration of the pollutant i in the diluted exhaust gas, expressed in ppm and corrected by the amount of i contained in the dilution air.

$C_e$ = Measured concentration of pollutant i in the diluted exhaust gas, expressed in ppm.

$C_d$ = Measured concentration of pollutant i in the air used for dilution, expressed in ppm.

Df = Dilution factor

The dilution factor is calculated as follows :

$$Df = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO}) * 10^{-4}}$$

where

$C_{CO_2}$ = Concentration of $CO_2$ in the diluted exhaust gas contained in the sampling bag, expressed in percentage volume.

$C_{HC}$ = Concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent.

$C_{CO}$ = Concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm.

5. Determination of the $NO_x$ Humidity Correction Factor :

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

$k_H$ = 1/(( 1-0.0329 * ( H-10.71) )
in which :
H = 6.211 * $R_a$ * $P_d$ / (( $P_B$ - ($P_d$ * $R_a$ * $10^{-2}$ ) )
Where,
H = Absolute humidity expressed in grams of water per kg of dry air
$R_a$ = Relative humidity of the ambient air expressed in per cent
$P_d$ = Saturation vapour pressure at ambient temperature expressed in kPa
$P_B$ = Atmospheric pressure in the room, expressed in kPa

## CHAPTER 9 : TYPE II TEST ON SI ENGINES (VERIFYING CARBON MONOXIDE EMISSION AT IDLING)

1 Scope :

This Chapter describes the procedure for the TYPE II test for verifying carbon monoxide emission at idling of spark ignition engined vehicles, as defined in para 5.2.3 of Chapter 1 of this Part.

2 Test Instrument

2.1 The instrument used for the measurement of CO should meet the requirements given in Para 5.0.

2.2 The instrument should be prepared, used and maintained following the directions given in the instrument manufacturer's operation manual, and it should be serviced at such intervals as to ensure accuracy.

2.3 Within a period of 4 hours before the instrument is first used, and each time the instrument is moved or transferred to a new environment, a "span and zero" calibration should be carried out using calibration gas. The calibration shall be performed well away from the exhaust of motor vehicles whose engines are running.

2.4 If the sample handling system is not integral with the analyser, the effectiveness of the condensate traps and all connections of the gas sampling system should be checked. It should be checked that filters are clean, that filter holders are fitted with their gaskets and that these are in good conditions.

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

2.6 It should be ensured that the sample handling line and probe are free from contaminants and condensates.

3 Vehicle and Fuel :

3.1 This test should be carried out immediately after the sixth operating cycle of the Type I test, with the engine at idling speed, the cold start device not being used. Immediately before each measurement of the carbon monoxide content, a TYPE I test operating cycle as described in Chapter 3 of this Part shall be carried out.

3.1.1 In case the Type II test is carried out without Type I test, the following steps are to be taken for vehicle preparation :It should be checked that the road vehicle/engine in all its parts, components and systems conform to the declared particulars in the application for type approval.

3.1.2 It should be checked that the road vehicle exhaust system is leakproof and that the manual choke control has been returned to the rest position.

3.1.3 It should be checked that the gas sampling probe can be inserted into the exhaust pipe to a depth of at least 300 mm. If this proves impossible owing to the exhaust pipe configuration, a suitable extension to the exhaust pipe(s), making sure that the connection is leakproof, should be provided.

3.1.4 The vehicle shall have attained normal thermal conditions as defined in 2.3 of chapter 1 of this part immediately prior to the measurement, by running the vehicle on chassis dynamometer with specified number of warming up cycles declared by the manufacturer and six driving cycles.

3.1.5 The vehicle idling speed should be checked and set as per Para 2.2.1 chapter 1 with all the accessories switched off.

3.2 Fuel :

The fuel shall be the reference fuel whose specifications are given in Chapter 10 of this Part. If the engine is lubricated by mixture, the oil added to the reference fuel shall comply as to create and quantity with the manufacturer's recommendations.

4 Measurement :

4.1 Immediately preceding the measurement, the engine is to be accelerated to a moderate speed with no load, maintained for at least 15 seconds, then returned to idle speed.

4.2 While the engine idles, the sampling probe should be inserted into the exhaust pipe to a depth not less than 300 mm, if the probe prescribed in para 5.3.2.1 is used.

4.3 After the engine speed stabilises the reading should be taken. In the case of 2 & 3 wheeled vehicles fitted with air cooled engines, this stabilised speed may be outside the range specified by the manufacturer.

4.4 The value of CO concentration reading should be recorded.

4.5 In cases where gadgets or devices are incorporated in the exhaust system, for dilution of the exhaust, both CO and $CO_2$ should be measured using an instrument having facility to measure both CO and $CO_2$ . If the total of the

measured values of CO and $CO_2$ ($T_{CO}$ and $T_{CO2}$ ) concentrations exceed 15% for four stroke engines and 10% for two stroke engines, the measured value of CO should be taken as carbon mono-oxide emissions from the vehicle. If it does not, the corrected value (T corrected ) should be taken, as given below :-

$T_{corrected} = T_{CO} \times 15/ (T_{CO} + T_{CO2})$ for 4 stroke engines.

$= T_{CO} \times 10/ (T_{CO} + T_{CO2})$ for 2 stroke engines.

4.6 Multiple exhaust outlets should be connected to a manifold arrangement terminating in a single outlet. If a suitable adapter is not available, the arithmetic average of the concentrations from the multiple pipes may be used.

4.7 If the measurement is to be repeated, the entire procedure of para 4 shall be repeated.

5 Technical Specifications of Carbon Monoxide Analyser/Equipment for Road Vehicles

5.2 General : The carbon monoxide analyser shall be compatible with all types of motor vehicle operating environments and shall meet under the conditions and performance requirements listed uses 5.2 and 5.3.

5.2 Performance Criteria :

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

5.2.2 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.

5.2.3 System response time : The analyser concentration indication shall reach 90% of the final stabilised reading within 10 seconds after a step change in concentration level is initiated at the sample probe inlet.

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

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

5.2.6 Warm-up time : Unless otherwise indicated on the instrument, the analyser shall reach stabilised operation within 30 minutes from "power on".

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

5.2.8 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 effecting gas analysis. The filtering and water removal components shall be designed for easy maintenance.

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

5.2.10 Temperature sensitivity : The instrument shall be suitable for ambient temperatures between 278K and 318K. Between these two limits, the result of the measurement shall not differ from that obtained at a temperature of 303K ± 2K. by more than 0.2 unit.

5.3 Design Characteristics :

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

5.3.1.1 Mobility : The instrument may be permanently mounted, portable, or mobile.

5.3.1.2 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.

5.3.1.3 Electrical design : Analyser operation shall be unaffected by an electrical voltage variation of ± 10%.

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

5.3.1.5 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.

5.3.1.6 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.

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

5.3.2 Sampling system : The vehicle exhaust gas sampling 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 3 metres in length.

5.3.2.1 Probe : The probe design shall be such that it will not slip out of the motor vehicle exhaust pipe when in use of 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.

5.3.2.2 Alternatively the sampling probe etc can be placed in the pipe connecting the exhaust with CVS system and as close to the exhaust as possible. However, even after the test, if the manufacturer request so, test with this probe shall be considered invalid and in such cases a retest shall be carried out with the probe prescribed in para 5.3.2.1.

5.3.2.3 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.

5.3.3 Analytical system : The accuracy, system response time, drift, repeatability, and warm-up time shall be as specified in the performance criteria in para 5.2 above.

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

5.3.3.2 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 electromechanical, 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.

5.4 Instruments with facility for carbon-di-oxide measurement, also for applications mentioned in 4.5 shall meet all the above performance criteria mentioned for CO, except that the instrument read-out shall have a range of 0 to 20% CO2 or less (clause 5.3.3.1).

## CHAPTER 10 : SPECIFICATIONS OF REFERENCE FUEL TO BE USED FOR EMISSION TESTING OF VEHICLES EQUIPPED WITH A PETROL ENGINE

1 Scope :

This Chapter specifies the characteristics of the reference fuel to be used for the test mentioned in para 3.2 of Chapter 3 and para 3.2 of Chapter 9 of this Part.

2 The reference fuel viz. leaded gasoline, to be used for emission testing of vehicles equipped with spark ignition engine should meet the following specifications :

| | Characteristics | Limits | Method of test (Ref. to P: IS 1448) |
|---|---|---|---|
| 2.1 | Research Octane Number | 87.0 min | P:26 |
| 2.2 | Specific Gravity at 288° K | 0.73-0.75 | P:16 |
| 2.3 | Reid Vapour pressure, kg/cm² | 0.45 to 0.65 | P:39 |
| 2.4 | Distillation,<br>Initial boiling point<br>10 % recovery<br>50 % recovery<br>90 % recovery<br>Final boiling point<br>Residue, % vol. | K<br>298 - 318<br>323 - 343<br>358 - 378<br>393 - 433<br>473 max.<br>2 max. | P:18 |
| 2.5 | Hydrocarbon analysis, % vol.<br>Olefins<br>Aromatics<br>Saturates | <br>20 max<br>45 max<br>balance | P:23 |
| 2.6 | Oxidation stability, minutes | 480 min. | P:28 |
| 2.7 | Existant gum, mg/100 ml | 4.0 max | P:29 |
| 2.8 | Sulphur content, % mass | 0.10 max. | P:34 |
| 2.9 | Lead content, g/1 | 0.40 max. | P:38 or 82 |

# PART IV : DETAILS OF STANDARDS FOR EMISSION OF VISIBLE POLLUTANTS FROM DIESEL ENGINED VEHICLES AND TEST PROCEDURES EFFECTIVE FROM 1 ST APRIL1991


CHAPTER 1 : OVERALL REQUIREMENTS

CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

CHAPTER 3 : TEST AT STEADY SPEEDS OVER THE FULL-LOAD CURVE

CHAPTER 4 : TEST UNDER FREE ACCELERATION

CHAPTER 5 : SPECIFICATIONS OF REFERENCE FUEL PRESCRIBED FOR EMISSION TESTING OF VEHICLES EQUIPPED WITH A DIESEL ENGINE

CHAPTER 6 : METHOD OF MEASURING NET POWER OF CI ENGINES

CHAPTER 7 : SMOKE METERS AND THEIR INSTALLATIONS

## CHAPTER 1 : OVERALL REQUIREMENTS

1 Scope :

This Part applies to the emissions of visible pollutants from compression ignition engined (diesel) vehicles, effective from 1st April 1991.

2 Definitions :

2.1 Compression Ignition Engine : Means an internal combustion engine which operates on compression ignition principle (Diesel) Engines.

2.2 Smoke Density : Means the light absorption coefficient of the exhaust gases emitted by the vehicle expressed in terms of $m^{-1}$ or in other units such as Bosch, Hartridge, % Opacity, etc. Fig.1 shows the relation between light absorption coefficient, expressed in m % Opacity, Hartridge Smoke Unit (HSU) and Bosch Smoke units.

2.3 Opacity Meter : Means an instrument for continuous measurement of the light absorption coefficient of the exhaust gases emitted by vehicles.

2.4 Maximum Rated Speed : Means the maximum speed permitted by governor at full load.

2.5 Minimum Rated Speed : Means either the highest of the following three engine speeds 45% of maximum net power speed, 1000 rev/min, minimum speed permitted by the idling control,
OR
such lower speed as the manufacturer may request.

2.6 Net Power : Means the power of a C.I. engine as defined in Chapter 6 of this Part.

2.7 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank full 90% and the usual set of tools and spare wheel on board where applicable.

2.8 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer.

2.9 Cold Start Device : Means a device which enriches the airfuel mixture of the engine temporarily and thus to assist engine start up.

2.10 Starting Aid : Means a device which assists the engine start up without enrichment of the fuel mixture, e.g. glow plug, change of injection timing, etc.

2.11 Type Approval of Vehicles : Means the type approval of a vehicle model with regard to the limitation of the emission of visible pollutants from the engine.

2.12 Vehicle Model : Means a category of power driven vehicles which do not differ in such essential respects of the vehicle characteristics which affects the vehicular emission and listed in Chapter 2 of this Part.

2.13 Vehicle for Type Approval Test : Means the fully built test vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

2.14 Vehicle for Conformity of Production : Means a vehicle selected at random from a production series of vehicle model which has already been type approved.

3 Application for Type Approval :

3.1 The application for type approval of a vehicle model with regard to limitations of the emission of visible pollutants from its engine shall be submitted by the vehicle manufacturer with a description of the engine and vehicle model comprising all the particulars referred to in Chapter 2 of this Part.

3.2 A vehicle representative of the vehicle model to be type approved shall be submitted to the testing agency responsible for conducting tests referred in para 5 below.

4 Type Approval :

If the vehicle submitted for approval pursuant to these rules, meet the requirements of para 5.0 below, approval of vehicle model shall be granted. The approval of the vehicle model pursuant to this part shall be communicated to the vehicle manufacturer and nodal agency by the testing agency in the form of certificate of compliance to CMVR, as envisaged in Rule-126 of CMVR.

5 Specifications and Tests :

5.1 General : The components liable to affect the emission of visible pollutants shall be so designed, constructed and assembled to enable the vehicle in normal use, despite the vibration to which it may be subjected, to comply with the provisions of this Rule.

5.2 Emissions at steady speeds over full load :

5.2.1 The test shall be carried out on an engine.

5.2.2 The power of the engine shall be measured on a test bench at steady speeds of the engine as detailed in full load curve as detailed in Chapter 6 of this Part. The measured power may differ from the power specified by the manufacturer in Chapter of this Part as given below.

5.2.2.1 For Type Approval :

- For Single cylinder engines, ± 5% at maximum power point and ± 10% at other measurement points and for all other engines by ± 2% at maximum power point and + 6% and - 2% at other measurement points.

5.2.2.2 For Conformity of Production : At maximum power point by ±10% for single cylinder engines and - 5% / + 8% for other engines.

5.2.3 In the case of a test on a vehicle it should be established that the fuel flow is not less than that declared by the manufacturer.

5.2.4 The emissions of visible pollutants when tested as detailed in Chapter 3 of this Part shall not exceed the limit values of light absorption coefficient given below for various nominal flows (from 1-4-1996):

| Nominal Flow | Light Absorption CoefficientK(1/m) | Nominal Flow G(1/s) | Light Absorption Coefficient K(1/m) |
|---|---|---|---|
| <=42 | 2.26 | 120 | 1.37 |
| 45 | 2.19 | 125 | 1.345 |
| 50 | 2.08 | 130 | 1.32 |
| 55 | 1.985 | 135 | 1.30 |
| 60 | 1.90 | 140 | 1.27 |
| 65 | 1.84 | 145 | 1.25 |
| 70 | 1.775 | 150 | 1.205 |
| 75 | 1.72 | 160 | 1.19 |
| 80 | 1.665 | 165 | 1.17 |
| 85 | 1.62 | 170 | 1.155 |
| 90 | 1.575 | 175 | 1.14 |
| 95 | 1.535 | 180 | 1.125 |
| 100 | 1.495 | 185 | 1.11 |
| 105 | 1.465 | 190 | 1.095 |
| 110 | 1.425 | 195 | 1.08 |

| | | | |
|---|---|---|---|
| 115 | 1.395 | >200 | 1.065 |

5.3 Emissions under free acceleration :

5.3.1 This is applicable for naturally aspirated and supercharged (turbocharged) engines.

5.3.2 The test shall be carried out on an engine installed on a test bench or on a vehicle. If the engine test is a bench test, it shall be carried out as soon as possible after the test for measurement of opacity under full load at steady speed. In particular the cooling water and the oil shall be at the normal temperature stated by the manufacturer. If the test is carried out on a stationary vehicle, the engine shall first be brought to normal operating conditions during a road run or on a dynamic test. The test shall be carried out as soon as possible after completion of this warming up period.

5.3.3 The emissions of visible pollutants under free acceleration, when tested according to the procedure detailed in Chapter 4 shall not exceed 2.45/m when expressed as light absorption coefficient.

5.3.4 At the request of the manufacturer additional tests described in Chapter 4 of this Part shall be performed to obtain free acceleration values for derivatives of the approved engine permitted by 7.0 below.

5.3.4.1 If the engine manufacturer desires to have the visible pollutants measured over a smaller range of torque and/or speed than is allowed by Para 7.0 below, then the approval of the engine type will be for the limited range of torque and speed.

5.3.4.2 If at a later stage it is desired to extend the approval of the engine to cover the whole of the torque/speed range allowed by Para 7.0 below then a further engine would have to be submitted for test so that the visible pollutants can be established for that part of the load/speed range which has previously been omitted.

5.3.5 If in order to meet some parts of the torque and speed ranges it is necessary to have additional specifications then these shall be declared in the format of Chapter 2 of this Part.

5.3 .6 The value of the free acceleration absorption coefficient for the engine will be appropriately chosen in accordance with iterated speed and torque from the matrix of values established by the method in Chapter 4 of this Part.

5.4 Equivalent measuring instruments shall be allowed. If an instrument other than those described in Chapter 7 of this Part used, its equivalent for the engine considered shall be required to be proved.

6. Modification of the engine/vehicle model :

6.1 Every modification in the essential characteristics of the vehicle model shall be intimated by the vehicle manufacturer to the test agency which type approved the vehicle Engine model. The test agency may consider that the vehicle/Engine model with the modifications either

6.1.1 comply with requirements

OR

6.1.2 require a further test to ensure compliance.

6.2 In case of 6.1.1 above, the testing agency shall extend the type approval covering the modified specifications. In case of 6.1.2 above, the vehicle/Engine model shall be subjected to necessary tests. In case the vehicle complies with the requirements, the test agency shall extend the type approval. Any changes to the procedure of PDI and running in concerning emission shall also be intimated to the test agency by the vehicle manufacturer, whenever such changes are carried out.

7 Model Changes :

The approval may be extended without carrying out any type test for the following conditions ;

7.1 Maximum rated speed not greater than 100% nor less than 75% of that of the engine in the type approval test;

7.2 Minimum rated speed not less than that of the engine in the type approval test;

7.3 Rated torque not greater than 100%, nor less than 70% of that of the engine at the speed in the type approval test;

7.4 Steady state absorption values are not greater than 1.1 times the values obtained in the type approval test and do not exceed the prescribed limits in 5.2.4 of this Part.

7.5 Exhaust back pressure not greater than that of the engine in the type approval test;

7.6 Exhaust system volume does not differ by more than 40%;

7.7 Intake depression not greater than that of the engine in the type approval test;

7.8 Moment of inertia of a new combined fly wheel and transmission is within ± 15% of the fly wheel and transmission system approved.

8 Conformity of production :

8.1 Every produced vehicle of the model approved under this rule shall conform, with regard to components affecting the emission of visible pollutants by the engine to the vehicle model type approved. The procedure for carrying out conformity of production tests, is given in Part VI of this document.

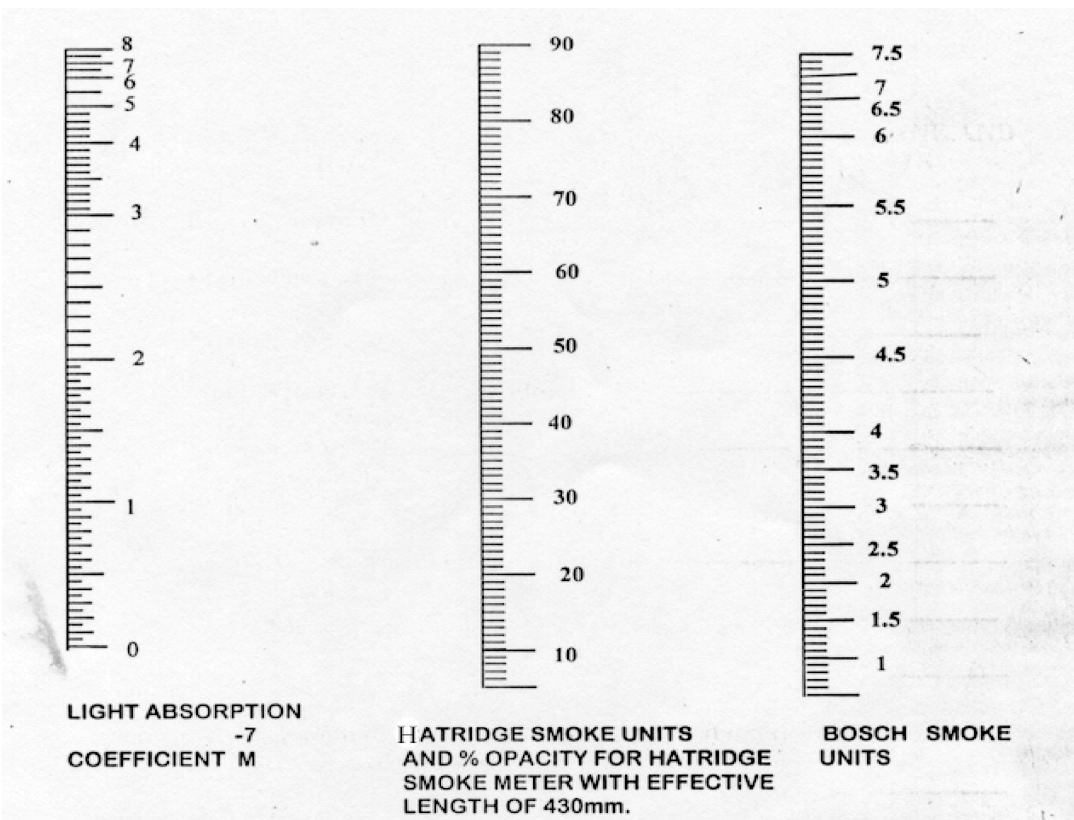
8.1.1 For verifying the conformity of production in the case of a vehicle with a naturally aspirated/supercharged (turbocharged) compression ignition engine, the vehicle selected at random from the series production should be subjected to the free acceleration test described in para 5.3 above and Chapter 4 of this part without running in of the vehicle or after running in of the engine in case the engine is offered, and the light absorption coefficient shall be below 2.45/m. On the request of the manufacturers, commercially available fuel may be used instead of reference fuel.

8.1.2 If it does not, another 10 engines/vehicles shall be taken from the series at random and shall be tested as per Chapter 4 of this Part. At least 9 engines/vehicles should meet the limit values specified in para 5.3 above.

Further, two engines/vehicles selected at random from the above lot of 10 should be subjected to emissions at steady speeds over full load*, prescribed in para 5.2 above and described in Chapter 3 of this Part. If both the samples meet the requirements of para 5.2 above the series is deemed to conform.

8.1.3 If the net power does not full fill the requirements of 5.2.2.2, two more engines are tested in the same way.

8.1.3.1 If the net power figure does not full fill the requirements of 5.2.2.2, the production shall be considered not to confirm the requirements of regulations.




(NOT TO THE SCALE)

Fig.1 Diesel Engine Exhaust Smoke Value Correlation Chart
(Ref. Para 2.2 of Chapter 1 of Part 4)

NOTE : THE CORRELATION BETWEEN BOSCH SMOKE UNITS AND OTHER HAS BEEN ESTABLISH ED ONLY FOR STEADY STATE CONDITIONS. HENCE THIS IS NOT APPLICABLE FOR THE FREE ACCELERATION TESTS

## CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

1.0 Description of the Vehicle -------------------------------

1.1 Trade name or mark of the vehicle -------------------------------

1.2 Vehicle type -------------------------------

1.3 Manufacturer's name and address -------------------------------

1.4 Unladen mass of vehicle(kN) -------------------------------

1.4.1 Reference mass of vehicle -------------------------------

1.4.2 Gross Vehicle Weight -------------------------------

1.5 Gear box -------------------------------

1.5.1 Manual or automatic -------------------------------

(If it is automatic give all pertinent technical data)

1.5.2 Number of gears -------------------------------

1.5.3 Transmission ratio : -------------------------------

1.5.3.1 First Gear -------------------------------

1.5.3.2 Second Gear -------------------------------

1.5.3.3 Third Gear -------------------------------

1.5.3.4 Fourth Gear -------------------------------

1.5.3.5 Over Drive -------------------------------

1.5.3.6 Gear Shifting Pattern -------------------------------

1.6 Final drive ratio -------------------------------

1.7 Tyres -------------------------------

1.7.1 Dimensions -------------------------------

1.7.2 Dynamic rolling circumference -------------------------------

| | |
|---|---|
| 1.7.3 Type | ------------------------------ |
| 1.7.4 Ply Rating | ------------------------------ |
| 1.7.5 Tyre Pressure : | ------------------------------ |
| Front | ------------------------------ |
| Rear | ------------------------------ |
| 1.8 Wheel drive : | ------------------------------ |
| Front | ------------------------------ |
| Rear | ------------------------------ |
| 1.9 Vehicle performance (declared by manufacturer) | ------------------------------ |
| 1.9.1 Vehicle max. speed | -----------------------km/h |
| 1.9.2 Acceleration max. | ----------------------m/sec$^2$ |
| 2.0 Description of engine- | ------------------------------ |
| 2.1 Make : | ------------------------------ |
| 2.2 Type : | ------------------------------ |
| 2.3 Working principle : | ------------------------------ |
| four-stroke/two-stroke : | ------------------------------ |
| 2.4 Bore : | -------------------------mm |
| 2.5 Stroke : | -------------------------mm |
| 2.6 Number and layout of cylinders and firing order | ------------------------------ |
| 2.7 Cylinder capacity : | -------------------------cm$^3$ |
| 2.8 Compression ratio (Specify the tolerance) | ------------------------------ |
| 2.9 Drawings of combustion chamber and piston crown | ------------------------------ |
| 2.10 Minimum cross-sectional area of inlet and outlet ports | ------------------------------ |
| 2.11 Cooling System : liquid / air cooling- | ------------------------------ |

2.11.1 Characteristics of liquid-cooling system- -------------------------------

2.11.1.1 Nature of liquid Circulating pump : Yes/No -------------------------------

2.11.1.2 Characteristics of make(s) and type(s) -------------------------------

2.11.1.3 Drive ratio -------------------------------

2.11.1.4 Thermostat: setting -------------------------------

2.11.1.5 Radiator :drawing(s) or make(s) and type(s) -------------------------------

2.11.1.6 Relief valve : pressure setting -------------------------------

2.11.1.7 Fan : Characteristics or make(s)and type(s) ------------------------------

2.11.1.8 Fan drive system Drive ratio : -------------------------------

2.11.1.9 Fan cowl : -------------------------------

2.11.2 Characteristics of air-cooling system- -------------------------------

2.11.2.1 Blower :characteristics or make(s)and type(s) -------------------------------

2.11.2.2 Drive ratio(s) : -------------------------------

2.11.2.3 Air ducting (standard production): -------------------------------

2.11.2.4 Temperature regulating system :
yes/no / Brief description -------------------------------

2.11.3 Temperature permitted by the manufacturer -------------------------------

2.11.3.1 Liquid cooling :max.temperature at engine outlet -------------------------------

2.11.3.2 Air cooling:Reference point -----------------------------

2.11.3.3 Max.temperature at reference point -------------------------------

2.11.3.4 Max.outlet temperature of the inlet intercooler -------------------------------

2.11.3.5 Max. exhaust temperature at the point in the exhaust pipe(s) adjacent in outlet flange(s) of the exhaust manifolds. -------------------------------

2.11.3.6 Fuel temperature : -----------------min-------------max.

2.11.3.7 Lubricant temperature: -----------------min ------------max.

2.12 Supercharger : yes/no (Description of the system) ------------------------------

2.13 Intake System : -------------------------------

2.13.1 Intake manifold : Description -------------------------------

2.13.2 Air filter : Make: Type: -------------------------------

2.13.3 Intake silencer: Make: Type: -------------------------------

2.14 Device for recycling crank-case gases : -------------------------------

Description and diagrams -------------------------------

3.0 Additional anti-pollution devices
(if any, and if not covered by another heading) -------------------------------

Description and diagrams -------------------------------

4.0 Air intake and fuel feed- -------------------------------

4.1 Description and diagrams of inlet pipes and their
accessories (dash pot, heating device,
additional air intakes, etc.) -------------------------------

4.1.1 Maximum permitted depression of air intake at
characteristic place. --------------------------kPa
(Specify location of measurement)
(Specify the tolerance) (Specify range if applicable)

4.2 Fuel feed

4.2.1 Feed pump
Pressure or characteristic diagram -------------------------------
(Specify the tolerance)

4.2.2 Injection System -------------------------------

System description -------------------------------

Working principle : Intake manifold/direct injection/
Injection prechamber / swirl chamber. -------------------------------

4.2.2.1 Pump -------------------------------

4.2.2.1.1 Make(s) -------------------------------

| | |
|---|---|
| 4.2.2.1.2 Type(s) | ------------------------------- |
| 4.2.2.1.3 Delivery :<br>stroke at a pump speed of | -----------------------mm$^{-3}$ /<br>------------------rpm at full. |
| Injection or characteristic diagram<br>(Specify the tolerance) | ------------------------------- |
| 4.2.2.1.4 Calibration procedure : On engine/<br>On pump bench | ------------------------------- |
| 4.2.2.1.5 If boost control is supplied, state the characteristic fuel delivery and boost pressure versus engine speed. | ------------------------------- |
| 4.2.2.1.6 Injection timing | ------------------------------- |
| 4.2.2.1.7 Injection advance curve | ------------------------------- |
| 4.2.2.1.8 Injection advance<br>(Specify the tolerance) | ------------------------------- |
| 4.2.2.2 Injectors : | ------------------------------- |
| 4.2.2.2.1 Make : | ------------------------------- |
| 4.2.2.2.2 Type : | ------------------------------- |
| 4.2.2.2.3 Opening Pressure<br>or characteristic diagram<br>(Specify the tolerance) | ------------------------MPa |
| 4.2.2.3 Injection Piping | ------------------------------- |
| 4.2.2.3.1 Length | ------------------------------- |
| 4.2.2.3.2 Internal diameter | ------------------------------- |
| 4.2.2.4 Governor | ------------------------------- |
| 4.2.2.4.1 Make(s) : | ------------------------------- |
| 4.2.2.4.2 Type(s) : | ------------------------------- |
| 4.2.2.4.3 Cut off point under load | --------------------------rpm |
| 4.2.2.4.4 Max. speed without load | --------------------------rpm |
| 4.2.2.4.5 Idle speed | --------------------------rpm |

4.2.2.5 Cold start device -------------------------------

4.2.2.5.1 Make (s) : -------------------------------

4.2.2.5.2 Type (s) : -------------------------------

4.2.2.5.3 System description -------------------------------

4.2.2.6 Starting aid -------------------------------

4.2.2.6.1 Make : -------------------------------

4.2.2.6.2 Type : -------------------------------

4.2.2.6.3 System description -------------------------------

5.0 Valve timing or equivalent data: -------------------------------

5.1 Maximum lift of valves, angles of opening and closing, or timing details of alternative distribution systems, in relation to top dead center (Specify the tolerance and range) -------------------------------

5.2 Reference and/or setting ranges -------------------------------

6.0 Exhaust System -------------------------------

6.1 Description of exhaust equipment if the test is made with the complete equipment provided by the engine or vehicle manufacturer ------------------------------

6.2 Specify the back pressure at maximum net power and the location of measurement (Specify the tolerance and range) ---------------------------kPa

6.3 Indicate the effect volume of the exhaust (Specify the tolerance and range) --------------------------$cm^3$

7.0 Lubrication system -------------------------------

7.1 Description of systems -------------------------------

7.1.1 Position of lubricant reservoir -------------------------------

7.1.2 Feed system (pump, injection into intake, mixing with fuel, etc.) -------------------------------

7.2 Lubricating pump -------------------------------

| | | |
|---|---|---|
| 7.2.1 | Make : | ------------------------------- |
| 7.2.2 | Type : | ------------------------------- |
| 7.3 | Mixture with fuel | ------------------------------- |
| 7.3.1 | Percentage | ------------------------------- |
| 7.4 | _Oil cooler : yes/no | ------------------------------- |
| 7.4.1 | Drawing(s) or make(s) and type(s) | ------------------------------- |
| 8.0 | Electrical equipment | ------------------------------- |
| | (Generator/alternator : characteristics or make(s) and | |
| 9.0 | Other engine driven auxiliaries | ------------------------------- |
| | (Enumeration and brief description if necessary) | ------------------------------- |
| 10.0 | Transmission | ------------------------------- |
| 10.1 | State movement of inertia of combined flywheel and transmission at condition when no gear is engaged (Specify the range if applicable) | ------------------------------- |
| 11.0 | Engine performance (declared by the manufacturer) | |
| 11.1 | Idling speed : (Specify the tolerance) | --------------------------rpm |
| 11.2 | Maximum rated speed : (Specify the tolerance) | --------------------------rpm |
| 11.3 | Minimum rated speed : (Specify the tolerance) | --------------------------rpm |
| 11.4 | Max.net torque of engine on bench : (Specify the tolerance) | ------------------Nm at rpm |
| 11.5 | Max.net power of engine on bench : Indicate power absorbed by fan (Specify the tolerance) | ------------------kW at rpm<br>---------------------------kW |
| 11.6 | Test on bench Declared powers at the points of measurement referred to in Chapter 3 shall be stated in Table 1. | ------------------------------- |

Declared speeds and powers of the engine/vehicle
(strike out what does not apply) submitted for approval

Table I
(Speeds to be agreed with the testing agency)

| Measurement Points * | Engine Speed : n ( rpm) | Power : P ** kW | Vehicle Speed and gear position |
|---|---|---|---|
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |

(NOTE : STRIKE OUT WHAT IS NOT APPLICABLE)
* See Chapter 3 of Part IV
** Net power according to Chapter 6 of Part IV

## CHAPTER 3 : TEST AT STEADY SPEEDS OVER THE FULL-LOAD CURVE

1 Scope :

This Chapter describes the method of determining emissions of visible pollutants at different steady speeds over the full load curve to be carried out either on an engine or on a vehicle, as defined in para 5.2.4 of Chapter 1 of this Part.

2 Measurement Principle :

2.1 The opacity of the exhaust gases produced by the engine shall be measured with the engine running under full-load and at steady speed.

2.2 A sufficient number of measurements will be carried out ranging between the maximum rated speed and the minimum rated speed. The extreme points of measurement shall be situated at the limits of interval defined above and one point of measurement will coincide with the speed at which the engine develops its maximum power and the speed at which it develops maximum torque.

3 Test Conditions :

3.1 Vehicle or engine :

3.1.1 The engine or the vehicle shall be submitted in good mechanical condition. The engine/vehicle shall have been run in as recommended by the manufacturer.

3.1.2 The engine shall be tested with the equipment prescribed in Chapter 6 of this Part.

3.1.3 The settings of the engine shall be those prescribed by the manufacturer and shown in Chapter 2 of this Part.

3.1.4 In the case of a test on an engine the power of the engine shall be measured in accordance with Chapter 6 of this Part and it should meet the requirements of para 5.2.2 of Chapter 1 of this Part. In the case of a test on a vehicle, it should be established that the fuel flow is not less than that declared by the manufacturer.

3.1.5 The exhaust device shall not have any orifice through which the gases emitted by the engine might be diluted. In cases where an engine has several exhaust outlets, these shall be connected to a single outlet in which the opacity measurement shall be made.

3.1.6 The engine shall be in the normal working condition prescribed by the manufacturer. In particular, the cooling water and the oil shall each be at the normal temperature prescribed by the manufacturer.

3.2 Fuel : The fuel used shall be the reference fuel as specified in the gazette notification.

3.3 Test Laboratory :

The absolute temperature T of the air (The test may be carried out in air-conditioned test rooms where the atmospheric conditions may be controlled) at the inlet to the engine measured within 0,15 m upstream of the point of entry to the air cleaner, or if no air cleaner is used, within 0,15 m of the air inlet manifold expressed in degrees Kelvin, and the atmospheric pressure Ps, expressed in Kilopascals, shall be measured, and the atmospheric factor F shall be determined as give below :Naturally aspirated and mechanically super charged engines :-

$$F = (99/Ps) * (T/298)^{0.7}$$

Turbo super charge engines with or without cooling of inlet air

$$F = (99/Ps)^{0.7} * (T/298)^{1.5}$$

3.3.1 From the date 1-4-96 , as per the notification, F shall be such that - it is between 0.98 and 1.02.

3.4 Sampling and measuring apparatus : The light-absorption coefficient of the exhaust gases shall be measured with an opacimeter satisfying the conditions laid down in Chapter 7 of this Part and installed in conformity with the conditions laid down therein.

4 Evaluation of the Absorption Coefficient :

4.1 For each of the six engine speeds at which the absorption coefficient is measured pursuant to Paragraph 2.2 above, the nominal gas flow shall be calculated by means of the following formulae :

for two-stroke engines $G = V * n/60$

for four-stroke engines $G = V * n/120$
where -
G - nominal gas flow, in liters per second, (l/s)
V - cylinder capacity of the engine, in liters, (l)
n - engine speed, in revolutions per minute (rpm ),

4.2 Correction of Exhaust gas opacity: For the correction factor description please refer paras 4.2.1 to 4.2.5. This is not applicable since 01.04.96.

4.2.1 The smoke density should be corrected to reference atmospheric conditions of 100 kpa and 298K.

4.2.2 Correction data exist only for certain proprietary instruments. The light obscuration smokemeter for which correction data is given in Fig.2, is the Hartridge opacimeter with an effective exhaust gas column length of approximately 0.43 m and applicable for Four stroke naturally aspirated engines only. The correction shall be applied as follows :

Corrected exhaust gas opacity = observed exhaust gas opacity ± Opacity correction

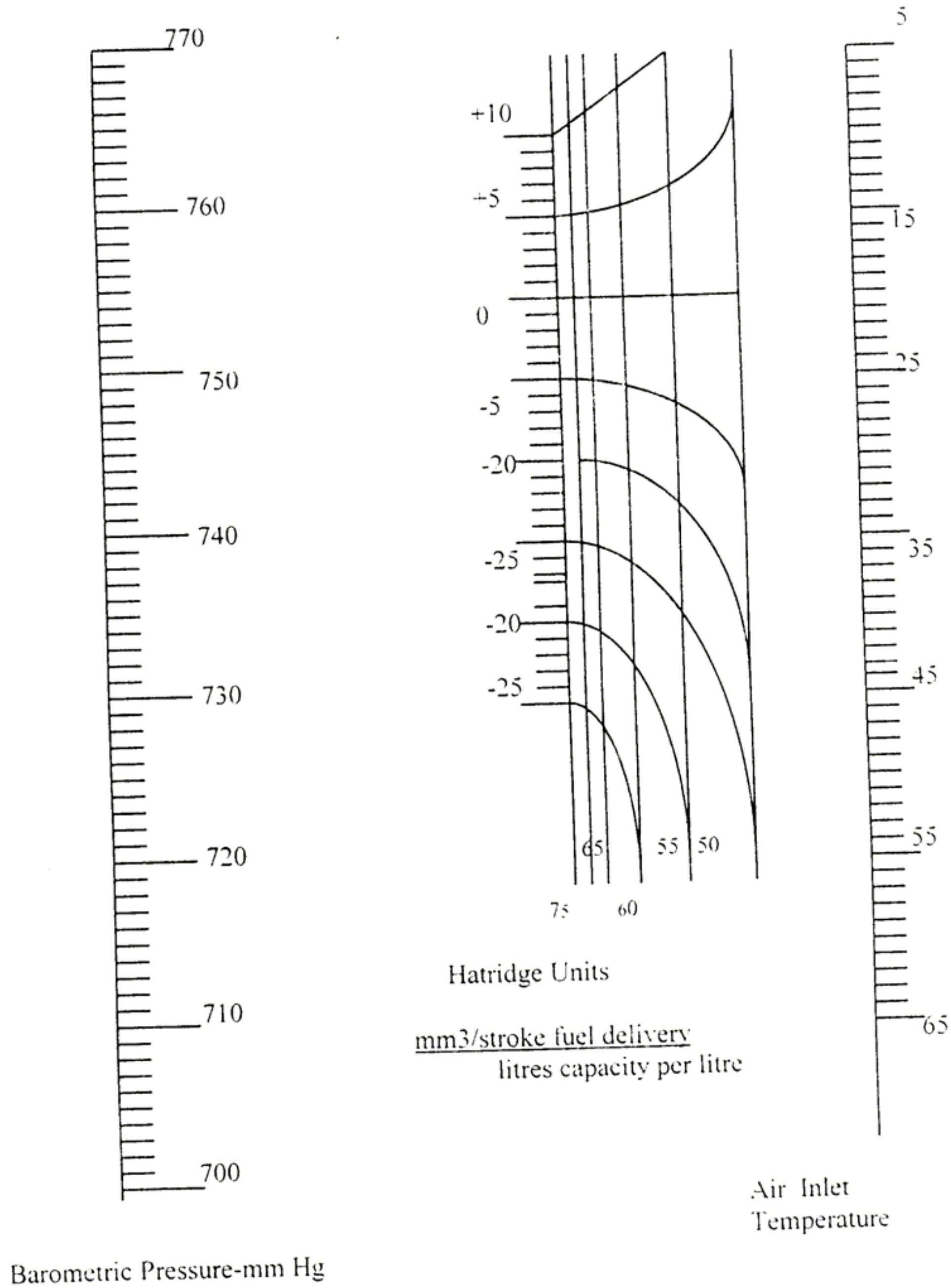
4.2.3 For test atmospheric conditions outside the limits covered by the nomogram given in Fig.2, the maximum possible correction factor from the nomogram will be applied.

4.2.4 For engines other than Four-stroke naturally aspirated engines, no correction shall be applied, but if the inlet air density (ignoring humidity) is more than 5 % different from that given by the standard conditions, mention shall be made of it but no values are specified at present as there is insufficient data for such engines. This will be supplemented at a later stage.

4.2.5 When the exhaust gas opacity is less than 20 or greater than 80 Hartridge smoke units, no correction shall be applied, and the observed readings shall be stated. If the corrected exhaust gas opacity shall be stated ‘as less than 20’ or ‘greater than 80’ Hartridge smoke units, as appropriate.

4.3 Where the value of the nominal flow is not one of those given in the table in Chapter 1 of this Part, the limit value applicable shall be obtained by interpolation on the principle of proportional parts.

4.4 Fig.1of chapter 1 shows the correlation between light absorption coefficient expressed in m , % opacity, Hartridge Smoke Units (HSU) and BoschSmoke Units (BSU).




(fig. not to the scale)

FIG2. Correlation For Hartridge Smoke(Four -Stroke Naturally Aspirated Engines) At Steady State Conditions (Pl.Ref. Para. 4.2.3 Of Chapt. 3 Of Part Iv)

## CHAPTER 4 : TEST UNDER FREE ACCELERATION

θ 1 Scope : This Chapter describes the method of determining the emissions of visible pollutants during the free acceleration test as defined in para 5.3 of Chapter 1 of this Part. This is applicable for naturally aspirated and supercharged (turbocharged) engine/vehicles.

2 Test Conditions :

2.1 The test shall be carried out on an engine installed on a test bench or on a vehicle.

2.1.1 If the engine test is a bench test it shall be carried out as soon as possible after the test for measurement of opacity under full load at steady speed. In particular, the cooling water and the oil shall be at the normal temperatures stated by the manufacturer.

2.1.2 If the test is carried out on a stationary vehicle the engine shall first be brought to normal operating conditions during a road run or on a dynamic test. The test shall be carried out as soon as possible after completion of this warming up period.

2.2 The combustion chamber shall not have been cooled or fouled by a prolonged period of idling preceding the test.

2.3 The test conditions prescribed in Paragraph 3.1, 3.2 and 3.3 of Chapter 3 of this Part shall apply.

2.4 The conditions prescribed with regard to the sampling and measuring apparatus in para 3.4 of Chapter 3 of this Part shall apply.

3 Test Methods :

3.1 The visible pollutants during free acceleration shall be measured with the engine in the maximum rated speed and maximum power condition.

3.2 At the request of the manufacturer, measurements shall also be made over a matrix of up to five other power/speed combinations for the engines de-rated for speed/power to cover the range of speed and power allowed for in Para 5.3.4 of Chapter 1 of this Part covering the modification of an engine type. In this case the steady state visible pollutants will also be measured with the engine rated at these other points, by the method described in Chapter 3 of this Part, to enable the free acceleration absorption coefficient to be corrected in accordance with Paragraph 4 below. These values shall be recorded in the approval certificate.

3.3 The Table and diagram below shows the six possible measuring points of the matrix and the range of power and speed governed by each point.

| % of maximum rated speed | % of maximum torque at that speed |
|---|---|
| 100 | 100 |
| 90 | 100 |
| 100 | 90 |
| 90 | 90 |
| 100 | 80 |
| 90 | 80 |

3.4 Each measuring points governs the power and speed area to the left of and below that point and is the measuring point for any engine rated in that area. For example the measuring point at "A" which is for the 90% full load line and 100% rated speed applies to the rated power/speed area bounded by ABCD on the diagram (Dia -1of chapter 4 , part 4 )

3.5 If the test is a bench test, the engine shall be disconnected from the brake, the latter being replaced either by the rotating parts driven when no gear is engaged or by an inertia substantially equivalent to that of the said parts.

3.6 If the test is carried out on a vehicle, the gear-change control shall be set in the neutral position and the drive between engine and gear-box engaged.

3.7 With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the opacimeter reverts to the corresponding conditions.

3.7.1 The sequence mentioned in para 3.7 for complete cycle for measurement can be defined based on time.

1) Acceleration time from idle to fly up speed :- 5 sec (max)
2) Stabilising time at maximum speed :- 2 sec (max)
3) De-acceleration Phase :- Engine comes back to idle speed by its own natural time
4) Idling Phase :- Operator to start next acceleration within 5 to 20 secs.
5) Repeat 1) to 4) above.

3.8 The operation described in Para 3.6 above shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustment of the apparatus. The maximum opacity values read in each successive acceleration shall be noted until stabilised values are obtained. No account shall be taken of the values read while, after each acceleration, the engine is idling. The values read shall be regarded as stabilised when four of them consecutively are situated within a band width of 25% of the arithmetic mean of these four readings or within a band width of 0.25K whichever is higher and do not form a decreasing sequence. The absorption coefficient XM to be recorded shall be the arithmetical mean of these four values.

3.9 In cases where the engine has several exhaust outlets. the tests shall be carried out with all the outlets joined in an adequate device ensuring mixture of the gases and ending in a single orifice. Free acceleration tests, however, may be carried out on each outlet. In this case the value to be used for calculating the correction to the absorption coefficient shall be the arithmetical mean of the values recorded at each outlet, and the test shall be regarded as valid only if the extreme values measured do not differ by more than 0.15 $m^{-1}$ .

4 Determination of the Corrected Value of the Absorption Coefficient : Applicable where steady speed absorption coefficient has been effectively established on the same engine derivative.

4.1 Notation :

$X_M$ - value of the absorption coefficient under free acceleration measured as prescribed in Paragraph 3.8 above;

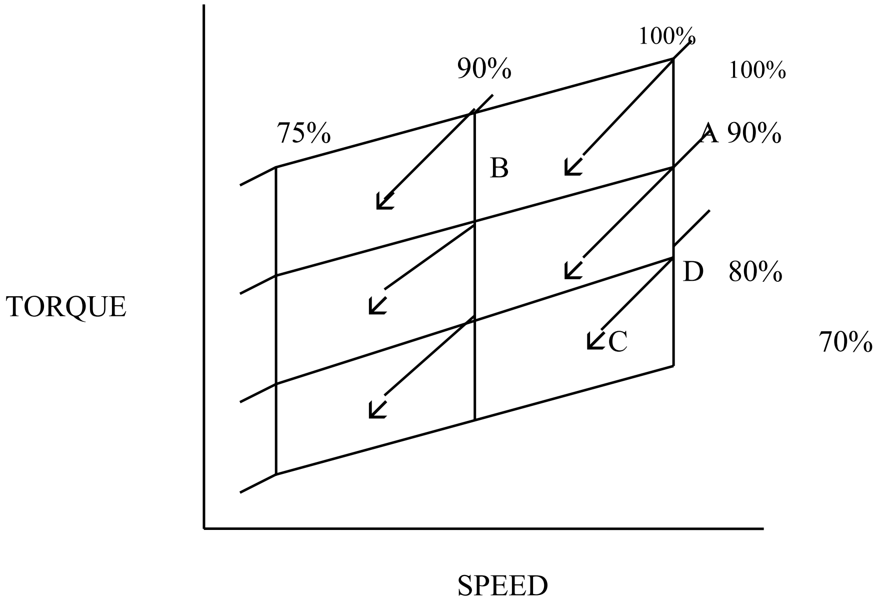
$X_L$ - corrected value of the absorption coefficient under free acceleration;

$S_M$ - value of the absorption coeff. measured at steady speed as prescribed in Para 2.2 of Chapter 3 of this Part which is closest to the prescribed limit value corresponding to the same nominal flow;

$S_L$ - value of the absorption coefficient as prescribed in Paragraph 4.1 of Chapter 3 of this Part, for the nominal flow corresp. to the point of measurement which gave the value $S_M$;

4.2 The absorption coefficients being expressed in $m^{-1}$.The corrected value X is given by the smaller of the following two expressions :

$$X_L = S_L * X_M / S_M \quad \text{or} \quad X_L = X_M + 0.5$$




Dia - 1 of chapter 4 of part 4

## CHAPTER 5 : SPECIFICATIONS OF REFERENCE FUEL PRESCRIBED FOR EMISSION TESTING OF VEHICLES EQUIPPED WITH A DIESEL ENGINE

1 Scope : This Chapter specifies the reference fuel to be used for power and emission measurements, as mentioned in para 3.2 of Chapter 3 and 2.3 of Chapter 4 and para 4.4 of Chapter 6 of this Part and para 4.4 of Chapter 3 of Part V to this Rule.

2 Specifications of reference fuel : The reference fuel should meet the following requirements :

| | Characteristics | Limits | Method of test (Ref. Part of IS 1448) |
|---|---|---|---|
| 2.1 | Specific Gravity at 288K | 0.835-0.850 | P:32/P:16 |
| 2.2 | Cetane Number or Cetane Index | 45 min. | P:9 |
| 2.3 | Distillation,K<br>50%Vol. recovery<br>90%Vol. recovery<br>Final Boiling Point | <br>518 min<br>583-613<br>643 max. | <br>P:18 |
| 2.4 | Kinematic Viscosity cSt at 313K | 2.5-4.0 | P:25 |
| 2.5 | Sulphur Content, % mass | 0.3-0.5 | P:33 |
| 2.6 | Flash point,K | 305 min. | P:20 |
| 2.7 | Pour point,K | 279 max. | P:10 |
| 2.8 | Conradson carbon residue on 10% dist. residuum, % mass | 0.20 max. | P:8 |
| 2.9 | Ash content, % mass | 0.01 max | P:4 |
| 2.10 | Water Content,% mass | 0.05 max | P:40 |
| 2.11 | Copper corrosion 373 Deg.K | 1 max | P:15 |
| 2.12 | Acidity, total, in terms of mg of KOH/g | 0.50 | P:2 |

## CHAPTER 6 : METHOD OF MEASURING NET POWER OF C.I. ENGINES

1 Scope : This Chapter describes the method for measuring the curve of the power at full load of an internal combustion engine as a function of engine speed and applies to compression ignition engines used for the propulsion of the vehicles, as defined in para 5.2.2 of Chapter 1 of this Part and para 5.2.2 of Chapter 1 .of Part V to this Rule.

2 Definitions :

2.1 "Net power" means the power obtained on a test bench at the end of the crankshaft or its equivalent (if power measurement can be carried out only on an engine with the gear box mounted, the efficiency of the gear-box shall be taken into account) at the corresponding engine speed with the auxiliaries listed in Table I;

2.2 "Standard production equipment" means any equipment provided by the manufacturer for a particular engine application.

3 Equipment :

3.1 Dynamometer and Engine Equipment :

The following equipment shall be used for emission tests of engines on engine dynamometers:

3.1.1 An engine dynamometer with adequate characteristics to perform the test described in Paragraph 4.5 below.

3.1.2 Measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and section flow resistance, air inlet temperature, atmospheric pressure, fuel temperature and humidity. The accuracy of these instruments shall satisfy the requirements given in 3.2 below.

3.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;

3.1.4 A non-insulated and uncooled exhaust system extending at least 0.5 m past the point where the exhaust probe is located, and presenting an exhaust back pressure within ± 650 Pa of the upper limit at the maximum rated power, as established by the engine manufacturer's sale and service literature for vehicle application;

3.1.5 An engine air inlet system presenting an air inlet restriction within + 300 Pa of the upper limit for the engine operating condition which results in maximum air flow, as established by the engine manufacturer for an air cleaner, for the engine being tested.

3.2 Accuracy of Measurements :

3.2.1 Torque : ± 1% of measured torque.

(The torque measuring system shall be calibrated to take friction losses into account. The accuracy in the lower half of the measuring range of the dynamometer bench may be ± 2% of measured torque.)

3.2.2 Engine speed : ± 0,5% of measured speed.

3.2.3 Fuel consumption : ± 1% of measured consumption.

3.2.4 Fuel temperature : ± 2 $^0$K. Air temperature : ± 2 $^0$K.

3.2.5 Barometric pressure : ± 100 Pa.

3.2.6 Pressure to intake duct : ± 50 Pa

3.2.7 Pressure in exhaust duct : ± 200 Pa

4 Test for Measuring Net Engine Power :

4.1 Auxiliaries :

4.1.1 Auxiliaries to be fitted : During the test, the auxiliaries necessary for the engine operation in the intended application ( as listed in Table I) shall be installed on the test bench as far as possible in the same position as in the intended application.

4.1.2 Auxiliaries to be removed : Certain vehicle accessories necessary only for the operation of the vehicle and which may be mounted on the engine shall be removed for the test. The following non-exhaustive list is given as a sample.

- Air compressor for brakes;
- Power steering compressor;
- Suspension compressor;
- Air-conditioning system.

Where accessories cannot be removed, the power they absorb in the unloaded condition may be determined and added to the measured engine power.

4.1.3 Compression ignition engine starting auxiliaries : For the auxiliaries used in starting compression ignition engines, the two following cases shall be considered :

4.1.3.1 Electrical starting : The generator is fitted and supplies, where necessary, the auxiliaries indispensable to the operation of the engine;

4.1.3.2 Starting other than electrical : If there are any electrically operated accessories indispensable to the operation of the engine, the generator is fitted to supply these accessories. Otherwise, it is removed.

4.1.3.3 In either case, the system for producing and accumulating the energy necessary for starting is fitted and operates in the unloaded condition.

4.2 Setting Conditions : The setting conditions for the test to determine the net power for the following -

- Setting of injection pump delivery system;

- Ignition or injection timing (timing curve);

- Governor setting;

- Anti-pollution devices;

are to be in accordance with the manufacturer's production specifications and used without further alteration for the particular application.

4.3 Test conditions :

4.3.1 The net power test shall consist of a run at fixed full- load fuel injection pump setting for diesel engines, the engine being equipped as specified in Table I.

4.3.2 Performance data shall be obtained under stabilised operating conditions with an adequate fresh air supply to the engine. The engines must have been run-in in accordance with the manufacturer's recommendations. Combustion chambers may contain deposits, but in limited quantity. Test conditions, such as inlet air temperature, shall be selected as near to reference conditions mentioned in para 5.2 below as possible in order to minimise magnitude of the correction factor.

4.3.3 The temperature of the inlet air to the engine (ambient air)shall be measured within 0,15 m upstream of the point of entry to the air cleaner, or if no air cleaner is used, within 0,15 m of the air inlet horn. The thermometer or thermocouple shall be shielded from radiant heat and placed directly in the stream. It shall also be shielded from fuel spray back.A sufficient number of locations shall be used to give a representative average inlet temperature.

4.3.4 No data shall be taken until torque, speed and temperatures have been maintained substantially constant for at least 1 minute.

4.3.5 The engine speed during a run or reading shall not deviate from the selected speed by more than ± 1% or ± 10 per min,whichever is greater.

4.3.6 Observed brake load, fuel consumption and inlet air temperature data shall be taken simultaneously and shall be the average of two stabilised consecutive values which do not vary more than 2% for the brake load and fuel consumption.

4.3.7 The temperature of the coolant at the outlet from the engine shall be kept within ± 5 deg.K from the upper thermostatically controlled temperature specified by the manufacturer. If no temperature is specified by the manufacturer, the temperature shall be 353 deg.K ± 5deg.K. For air-cooled engines, the temperature at a point indicated by the manufacturer shall be kept within ± 20 deg.K of the maximum value specified by the manufacturer in the reference conditions.

4.3.8 The fuel temperature shall be measured at the fuel injection system and maintained within the limits established by the engine manufacturer.

4.3.9 The temperature of the lubricating oil measured in the oilsump or at the outlet from the oil cooler, if fitted, shall be maintained within the limits established by the engine manufacturer.

4.3.10 An auxiliary regulating system may be used if necessary to maintain the temperatures within the limits specified in Paragraphs 4.3.7, 4.3.8 and 4.3.9 above.

4.4 Fuel : The fuel used shall be the reference fuel as per Chapter 5 of this Part.

4.5 Test procedure : Measurements shall be taken at a sufficient number of engine speeds to define correctly the power curve between the maximum and the minimum rated speeds recommended by the manu-facturer. This range of speeds must include the speed of revolution at which the engine produce its maximum power. The average of at least two stabilised measurements is to be determined.

4.6 Data to be recorded : Data to be recorded are those indicated in the Table II.

5 Power Correction Factors :

5.1 Definition : The power correction factor is the coefficient by which the measured power must be multiplied to determine the engine power under the reference atmospheric conditions specified in Para 5.2.

$Po = \propto P$

where :

Po is the corrected power (i.e. power under reference atmospheric conditions);

$\propto$ is the correction factor

P is the measured power (test power).

5.2 Reference atmospheric conditions :

5.2.1 Temperature (T ) :298° K

5.2.2 Dry pressure ( $P_{S0}$ ) : 99 kPa.

Note : The dry pressure is based on a total pressure of 100 kPa and a water vapour pressure of 1 kPa.

5.3 Test atmospheric conditions :
The atmospheric conditions during the test shall be the following :

5.3.1 Temperature (T) : Between 283K and 313K

5.3.2 Pressure (P ) : Between 80 kPa and 110 kPa

5.4 Determination of correction factor :

(The tests may be carried out in air-conditioned test rooms where the atmospheric conditions may be controlled.)

5.4.1 The power correction factor $\propto$ for diesel engines at constant fuel delivery is obtained by applying the formula :

$\alpha = fa^{fm}$

where

fa - the atmospheric factor

fm - the characteristic parameter for each type of engine and adjustment

5.4.2 Atmospheric factor (fa) :

5.4.2.1 This factor indicates effect of environmental conditions (pressure, temperature and humidity) on the air drawn-in by the engine. The atmospheric factor differs according to the type of the engines.

5.4.2.2 Naturally aspirated and mechanically pressure charged engines :

$fa = (99/Ps) * (T/298)^{0.7}$

5.4.2.3 Turbocharged engines with or without cooling of charge air :

$fa = (99/Ps)^{0.7} * (T/298)^{1.5}$

5.4.3 Engine Factor (fm) :

fm is a function of Qc (fuel flow corrected) as follows :

fm = 0.036 Qc - 1.14

where

Qc - Q/r and

Q - the fuel delivery in milligrams/cycle per litre of engine swept volume (mg/l.cycle)

r is the pressure ratio of compressor outlet and compressor inlet (r=1 for naturally aspirated engines)

This formula is valid when Qc is 40≤ Qc≤ 65.

For Qc values lower than 40, a constant value of fm equal to 0.3(fm=0.3) will be taken.

For Qc values higher than 65, a constant value of fm equal to 1.2(fm=1.2) will be taken, as given below:

5.4.4 Limitations in use of correction formula : This correction formula is only applicable if $0.9 \leq \alpha \leq 1.1$.

5.4.5 If these limits are exceeded, the corrected value obtained shall be given, and the test conditions (temperature and pressure) precisely stated in the Test Report.

6 Test Report : The test report shall contain the results and all the calculations required to find the net power, as listed in theTable II below, together with the characteristics of the engine listed in Chapter 2 to this Part.

TABLE I - Auxiliaries to be fitted for the test to determine net power of engine

| No. | Auxiliaries | Fitted for net power test |
|---|---|---|
| 1. | Intake system | |
| | Intake manifold<br>Crankcase emission control system | Yes, standard production equipment |
| | Air filter<br>Intake silencer<br>Speed limiting device | Yes, standard production equipment |

(The complete intake system shall be fitted as provided for the intended application :

Where there is a risk of an appreciable effect on the engine power;

In the case of two-stroke and positive-ignition engines; When the manufacturer requests that this should be done.

In other cases, an equivalent system may be used and a check should be made to ascertain that the intake pressure does not differ by more than 100 Pa from the limit specified by the manufacturer for a clean air filter).

2. Induction heating device of intake manifold — Yes, standard production equipment. If possible, to be set in the most favourable position.

3. Exhaust system

| | |
|---|---|
| Exhaust purifier<br>Exhaust manifold<br>Supercharging device<br>Connecting pipes *<br>Silencer *<br>Tail pipe *<br><br>Exhaust brake :<br>If an exhaust brake is incorporated in the engine, the throttle valve must be fixed in a fully open position. | Yes, standard production equipment |

* The complete exhaust system shall be fitted as provided for the intended application : Where there is a risk of an appreciable effect on the engine power;

In the case of two-stroke and positive-ignition engines; When the manufacturer requests that this should be done.

In other cases, an equivalent system may be installed provided the pressure measured at the exit of the engine exhaust system does not differ by more than 1 000 Pa from that specified by the manufacturer. The exit from the engine exhaust system is defined as a point 150 mm down-stream from the termination of the part of the exhaust system mounted on the engine.

4. Fuel supply pump :
Yes, standard production equipment The fuel pressure may be adjusted,if necessary to reproduce the pressures existing in the particular engine application (particularly when a fuel return system is used).

5. Fuel injection equipment

| | |
|---|---|
| Prefilter<br>Filter<br>Pump<br>High Pressure pipe<br>Injector<br>Air intake valve * | Yes, standard production equipment |

If fitted

Electronic control system,
Air flow meter, etc
(if fitted)
Governor/Control system
Automatic full-load stop
for the control rack
depending on atmospheric
conditions.

* The air intake valve is the control valve for the pneumatic governor of the injection pump. The governor of the fuel injection equipment may contain other devices which may affect the amount of injected fuel.

6. Liquid cooling equipment

| | |
|---|---|
| Engine bonnet<br>Bonnet air outlet<br>Radiator | No |
| * Fan<br>Fan cowl<br>Water pump | Yes, standard production equipment |

* Thermostat

(*) The radiator, the fan, the fan cowl, the water pump and the thermostat shall be located on the test bench in the same relative positions as on the vehicle. The cooling liquid circulation shall be operated by the engine water pump only.

Cooling of the liquid may be produced either by the engine radiator or by an external circuit, provided that the pressure loss of this circuit and the pressure at the pump inlet remain substantially the same as those of the engine cooling system. The radiator shutter, if incorporated, shall be in the open position.

Where the fan, radiator and cowl system cannot conveniently be fitted to the engine, the power absorbed by the fan when separately mounted in its correct position in relation to the radiator and cowl (if used), must be determined at the speeds corresponding to the engine speeds used for measurement of the engine power either by calculation from standard characteristics or by practical tests. This power, corrected to the reference atmospheric conditions defined in paragraph 5.2, should be deducted from the corrected power. Where a disconnectable or progressive fan or blower is corporated, the test shall be made with the disconnectable fan (or blower) disconnected or with the progressive fan or blower running at maximum slip.

(**) The thermostat may be fixed in the fully open position.

7. Air cooling

| | |
|---|---|
| Cowl | Yes, standard production |

equipment

* Blower

Temperature regulating device } Yes, standard production equipment

(*) The radiator, the fan, the fan cowl, the water pump and the thermostat shall be located on the test bench in the same relative positions as on the vehicle. The cooling liquid circulation shall be operated by the engine water pump only.

Cooling of the liquid may be produced either by the engine radiator or by an external circuit, provided that the pressure loss of this circuit and the pressure at the pump inlet remain substantially the same as those of the engine cooling system. The radiator shutter, if incorporated, shall be in the open position.

Where the fan, radiator and cowl system cannot conveniently be fitted to the engine, the power absorbed by the fan when separately mounted in its correct position in relation to the radiator and cowl (if used), must be determined at the speeds corresponding to the engine speeds used for measurement of the engine power either by calculation from standard characteristics or by practical tests. This power, corrected to the standard atmospheric conditions defined in Paragraph 5.2, should be deducted from the corrected power.

Where a disconnectable or progressive fan or blower is incorporated, the test shall be made with the disconnectable fan (or blower) disconnected or with the progressive fan or blower running at maximum slip.

8. Electrical equipment — Yes, standard production equipment.

Minimum power of the generator : the power of the generator shall be limited to that necessary for the operation of accessories which are indispensable for the operation of the engine If the connection of a battery is necessary, a fully charged battery in good order must be used.

9. Supercharging equipment

(if fitted)

Compressor driven either directly by the engine, and/or by the exhaust gases } Yes, standard production equipment

* Charge air cooler

Coolant pump or fan (engine driven)

Coolant flow control }

devices (if fitted)

(*) Charge air cooled engines shall be tested with charge air cooling, whether liquid or air cooled, but if the engine manufacturer prefers, a test bench system may replace the air cooled cooler. In either case, the measurement of power at each speed shall be made with the same pressure drop and temperature drop of the engine air across the charge air cooler on the test bench system as those specified by the manufacturer for the system on the complete vehicle.

| | | |
|---|---|---|
| 10. | Auxiliary test bench fan | Yes, if necessary |
| 11. | Anti-pollution devices | Yes, standard production equipment |

They may include, for example, EGR (Exhaust Gas recirculation system, catalytic converter, thermal reactor, secondary air supply system and fuel evaporation protecting system.

TABLE - II : STATEMENT OF THE RESULTS OF TESTS FOR MEASURING NET ENGINE POWER

This information is to be supplied by the manufacturer simultaneously with the identification sheet constituting Chapter 2 to this Part. If the test under this Rule is a bench test of the engine, this form shall be completed by the laboratory performing the test.

| | | |
|---|---|---|
| 1.0 | Test Conditions | ------------------------------- |
| 1.1 | Pressures measured at maximum power | ------------------------------- |
| 1.1.1 | Total barometric pressure | --------------------------- Pa |
| 1.1.2 | Water vapour pressure | --------------------------- Pa |
| 1.1.3 | Exhaust pressure | ------------------------------ |
| 1.2 | Temperatures measured at maximum power | -----------------------------k |
| 1.2.1 | of the intake air | ---------------------------- K |
| 1.2.2 | at the outlet of the engine intercooler | ---------------------------- K |
| 1.2.3 | of the cooling fluid : | ------------------------------- |
| 1.2.3.1 | at the engine cooling fluid outlet | ---------------------------- K |
| | (strike out what does not apply) | |
| 1.2.3.2 | at the reference point in the case of air cooling (strike out what does not apply) | -----------------------------K |
| 1.2.4 | of the lubricating oil deg.K (indicate point of measurement) | ------------------------------- |
| 1.2.5 | of the fuel | ---------------------------- K |
| 1.2.5.1 | of the fuel pump inlet | ---------------------------- K |
| 1.2.5.2 | in the fuel-consumption measuring device | ---------------------------- K |
| 1.3 | Characteristics of the dynamometer : | ------------------------------- |
| 1.3.1 | Make : | ------------------------------- |
| | Model: | ------------------------------- |
| 1.3.2 | Type : | ------------------------------- |

| | | |
|---|---|---|
| 2.0 | Fuel | ------------------------------- |
| 2.1 | Make : | ------------------------------- |
| 2.2 | Specification of fuel used : | ------------------------------- |
| 2.3 | Cetane index (IS1448 Part 9) | ------------------------------- |
| 2.4 | Specific density : | -----------.g/cm$^3$ at 288$^0$ K |
| 2.5 | Lower calorific value : | -----------------------kJ/kg |
| 3.0 | Lubricant | ------------------------------- |
| 3.1 | Make : | ------------------------------- |
| 3.2 | Specification : | ------------------------------- |
| 3.3 | SAE viscosity : | ------------------------------- |
| 4.0 | Detailed results of measurements | ------------------------------- |
| 4.1 | Statements of results of net power measurement test (The characteristic curves of the net power and the net torque shall be drawn as a function of the engine speed) | ------------------------------- |
| 4.1.1 | Engine speed, 1/min | ------------------------------- |
| 4.1.2 | Measured torque, Nm | ------------------------------- |
| 4.1.3 | Measured power, kW | ------------------------------- |
| 4.1.4 | Measured fuel flow, g/kWh | ------------------------------- |
| 4.1.5 | Measured smoke index, m | ------------------------------- |
| 4.1.6 | Barometric pressure, kPa | ------------------------------- |
| 4.1.7 | Water vapour pressure, kPa | ------------------------------- |
| 4.1.8 | Inlet air temperature,$^0$ K | ------------------------------- |
| 4.1.9 | Power to be added for auxiliaries in excess of Table I, kW — No.1 | ------------------------------- |
| | No.2 | ------------------------------- |
| | No.3 | ------------------------------- |

-------------------------------

4.1.10 Power correction factor, -------------------------------

4.1.11 Corrected brake power, kW (with/without fan) -------------------------------

4.1.12 Power of fan, kW (to be subtracted if fan not fitted) -------------------------------

4.1.13 Net power, kW -------------------------------

4.1.14 Net torque, Nm -------------------------------

4.1.15 Corrected specific fuel consumption g/kWh (Calculated with the net power for compression ignition and positive-ignition engines, in the latter case multiplied by the power correction factor). -------------------------------

4.1.16 Smoke index $m^{-1}$ -------------------------------

4.1.17 Cooling liquid temperature at outlet, K -------------------------------

4.1.18 Lubricating oil temperature at measuring point, K -------------------------------

4.1.19 Air temperature after supercharger, K (If applicable) ---------------------------

4.1.20 Fuel temperature at injection pump inlet, K -------------------------------

4.1.21 Air temperature after charge air cooler, K (If applicable) ------------------------

4.1.22 Pressure after supercharger, kPa (If applicable) -------------------------------

4.1.23 Pressure after charge air cooler, kPa -------------------------------

4.2 Maximum net power : --------------------- kW at 1/ .min

4.3 Maximum net torque: --------------------- Nm at 1/ .min

5.0 Engine submitted for testing on : -------------------------------

6.0 Technical Agency conducting tests: -------------------------------

## CHAPTER 7 : SMOKE METERS AND THEIR INSTALLATIONS

1 Scope : This Chapter covers the requirements of smoke meters and their installation on engines for full load and free acceleration tests, mentioned in para 3.4 of Chapter 3 and para 2.4 of Chapter 4 of this Part.

2 Technical Specifications of Opacimeters

2.1 General

2.1.1 The gas to be measured shall be confined in an enclosure having a non-
2.1.2 reflecting internal surface in the instrument.

2.1.2 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.

2.1.3 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.

2.1.4 The design shall be such that under steady-speed operating conditions the smoke chamber is filled with smoke of uniform opacity.

2.2 Construction specifications

2.2.1 Smoke chamber and opacimeter casing

2.2.1.1 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 mat black and by a suitable general layout).

2.2.1.2 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 per meter..

2.2.2 Light source

The light source shall be an incandescent lamp with a colour temperature in the range 2,800K to 3,250K.

2.2.3 Receiver.

2.2.3.1 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% of that maximum response below 430 nm and above 680 nm).

2.2.3.2 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.

2.2.4 Measuring Scales

2.2.4.1 The light-absorption coefficient k shall be calculated by the formula $F = Fo.e^{(-k*L)}$ where L is the effective length of the light path through the gas to be measured, Fo the incident flux and F 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 2.7 of this Part

or

- through correlation with another type of opacimeter for which the effective length is known.

2.2.4.2 The relationship between 0 - 100 linear scale and the light absorption coefficient k is given by the formula

$$k = (-1/L)*(\text{Log}_e\ (1-N/100))$$

where N is the reading on the linear scale and k the corresponding value of the absorption coefficient.

2.2.4.3 The indicating dial of the opacimeter shall enable an absorption coefficient of 1.7/m to be read with an accuracy of 0.025/m.

2.3 Adjustment and calibration of the measuring apparatus

2.3.1 The electrical circuit of the photoelectric cell and of the indicating dial shall be adjustable so that the pointer can be reset at 0 when the light flux passes through the smoke chamber filled with clean air or through a chamber having identical characteristics.

2.3.2 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.

2.3.2 An intermediate check shall be carried out by placing in the smoke chamber a
2.3.3 screen representing a gas whose known light absorption coefficient k, measured
2.3.4 as described in paragraph 2.2.4.1 is between 1.6/m and 1.8/m. The value of k

2.3.5 must be known to within 0.025/m. The check consists in verifying that this does

2.3.6 not differ by more than 0.05/m from that read on the opacimeter indicating dial

2.3.7 when the screen is introduced between the source of light and the photoelectric

2.3.8 cell.

2.4 Opacimeter Response

2.4.1 The response time of electrical measuring circuit, being the time necessary for the indicating dial to reach 90% of full scale deflection on insertion of a screen fully obscuring the photoelectric cell, shall be 0.9 to 1.1 second.

2.4.2 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 (eg. calibration screen) does not exceed 4% of that reading in linear scale units.

2.4.3 The response time of 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.

2.4.4 These provisions shall apply solely to opacimeters used to measure opacity under free acceleration.

2.5 Pressure of the Gas to be measured and of scavenging air

2.5.1 The pressure of the exhaust gas in the smoke chamber shall not differ by more than 75 mm (water gauge) from the atmospheric pressure.

2.5.2 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 in the case of a gas having an absorption coefficient of 1.7/m.

2.5.3 The opacimeter shall be equipped with appropriate devices for measuring the pressure in the smoke chamber.

2.5.4 The limits of pressure variation of gas and scavenging air in the smoke chamber shall be stated by the manufacturer of the apparatus.

2.6 Temperature of the Gas to be measured

2.6.1 At every point in the smoke chamber the gas temperature at the instant of measurement shall be between 70 deg. 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 when the chamber is filled with a gas having an absorption coefficient of 1.7/m.

2.6.2 The opacimeter shall be equipped with appropriate devices for measuring the temperature in the smoke chamber.

2.7 Effective Length "L" of the Opacimeter

2.7.1 In some types of opacimeters, 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.

2.7.2 The effective length of the light path is obtained by comparing the reading N of the opacimeter operating normally with the reading N obtained with the opacimeter modified so that the test gas fills a well defined length Lo

2.7.3 It will be necessary to take comparative readings in quick succession to determine the correction to be made for shifts of zero.

2.7.4 Method of assessment of L

2.7.4.1 The test gas shall be an exhaust gas of constant opacity or a light absorptive gas of a gravimetric density similar to that of exhaust gas.

2.7.4.2 A column of length Lo 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 Lo shall be close to the effective length of the opacity meter.

2.7.4.3 The mean temperature of the test gas in the smoke chamber shall be measured.

2.7.4.4 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.

2.7.4.5 The test for determining the effective length shall consist in passing a sample of test gas alternately through opacity meter operating normally and through the same apparatus modified as indicated in paragraph 2.7.2.

2.7.4.6 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.

2.7.4.7 With 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.

2.7.4.8 With the known length Lo filled with the same test gas, the reading on the linear scale of opacity is No and that of the mean gas temperature expressed in Kelvin degrees is To.

2.7.4.9 The effective length will be

L = Lo *(T*(Log(1-N/100))/(To*(Log(1-No/100))))

2.7.4.10 The test shall be repeated with at least 4 test gases giving readings evenly spaced between the readings 20 and 80 on the linear scale.

2.7.4.11 The effective length L of the opacimeter will be the arithmetic average of the effective lengths obtained as stated in paragraph 2.7.4.9 for each of the gases.

3 Installation of the Opacimeter :

3.1 The instrument should be prepared, used and maintained following the directions given in the instrument manufacturer's operation manual,and it should be serviced and calibrated at such intervals as to ensure accuracy.

3.2 Sampling Opacimeter :

3.2.1 Installation for full load tests

3.2.1.1 The ratio of the cross-sectional area of the probe to that of the exhaust pipe shall not be less than 0,05. The back pressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).

3.2.1.2 The probe shall be a tube with an open end facing forward in the axis of the exhaust pipe, or of the extension pipe if one is required. It shall be situated in a section where the distribution of smoke is approximately uniform. To achieve this, the probe shall be placed as far downstream in the exhaust pipe as possible, or, if necessary, in an extension pipe so that, if D is the diameter of the exhaust pipe at the opening, the end of the probe is situated in a straight portion at least 6D in length upstream of the sampling point and 3 D in length downstream. If an extension pipe is used, no air shall be allowed to enter the joint.

3.2.1.3 The pressure in the exhaust pipe and the characteristics of the pressure drop in the sampling line shall be such that the probe collects a sample sensibly equivalent to that which would be obtained by isokinetic sampling.

3.2.1.4 If necessary, an expansion tank of compact design and of sufficient capacity to damp the pulsations may be incorporated in the sampling line as near to the probe as possible. A cooler may also be fitted. The design of the expansion tank and cooler shall not unduly disturb the composition of the exhaust gas.

3.2.1.5 A butterfly valve or other means of increasing the sampling pressure may be placed in the exhaust pipe at least 3 D downstream from the sampling probe.

3.2.1.6 The connecting pipes between the probe, the cooling device, the expansion tank (if required) and the opacimeter shall be as short as possible while satisfying the pressure and temperature requirements prescribed. The pipe shall be inclined upwards from the sampling point to the opacimeter, and sharp bends where soot might accumulate shall be avoided. If not embodied in the opacimeter, a by-pass valve shall be provided upstream.

3.2.1.7 A check shall be carried out during the test to ensure that the requirements of para 2.5, concerning pressure and those of para 2.6 concerning temperature in the measuring chamber are observed.

3.2.2 Installation for tests under free acceleration :

3.2.2.1 The ratio of cross sectional area of the probe to that of the exhaust pipe shall not be less than 0.05. The back pressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).

3.2.2.2 The probe shall be a tube with an open end facing forward in the axis of exhaust pipe, or of the extension pipe if one is required. It shall be situated in a section where the distribution of smoke is approximately uniform. To achieve this, the probe shall be placed as far downstream in the exhaust pipe as possible or if necessary in an extension pipe so that, if D is the diameter of exhaust pipe at the opening, the end of the probe is situated in a straight portion at least 6 D in length upstream of the sampling point and 3 D in length downstream. If an extension pipe is used, no air shall be allowed to enter the joint.

3.2.2.3 The sampling system shall be such that at all engine speeds, the pressure of the sample at the opacimeter is within the limits specified. This may be checked by noting the sample pressure at engine idling and maximum no load speeds. Depending on the characteristics of the opacimeter, control of sample pressure can be achieved by a fixed restriction or butterfly valve in the exhaust pipe or extension pipe. Whichever method is used, the back pressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).

3.2.2.4 The pipes connecting with the opacimeter shall also be as short as possible. The pipe shall be inclined upwards from the sampling point to the opacimeter and sharp bends where soot might accumulate shall be avoided. A bypass valve may be provided upstream of opacimeter to isolate it from the exhaust gas flow when no measurement is being made.

Full Flow Opacimeter

The only general precautions to be observed in steady-speed and free acceleration tests are the following :

3.2.3 Joints in the connecting pipes, if any, between the exhaust pipe and the opacimeter shall not allow air to enter from outside.

The pipes connecting with opacimeter shall be as short as possible, as prescribed in the case of sampling opacimeters. The pipe system shall be inclined upwards from the exhaust pipe to the opacimeter, and sharp bends where soot might accumulate shall be avoided. A by-pass valve may be provided upstream of the opacimeter to isolate it from the exhaust gas flow when no measurement is being made.

3.2.4 A cooling system may also be required upstream of the opacimeter.

4 Any other method/equipment may be approved, if it is found that they yield equivalent results.

# PART V : DETAILS OF STANDARDS FOR EMISSION OF GASEOUS POLLUTANTS FROM DIESEL ENGINED VEHICLES AND TEST PROCEDURES EFFECTIVE FROM 1ST APRIL 1992


CHAPTER 1 : OVERALL REQUIREMENTS

CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

CHAPTER 3 : TEST PROCEDURE FOR MEASUREMENT OF GASEOUS POLLUTANTS FROM DIESEL ENGINES

CHAPTER 4 : ANALYTICAL SYSTEMS

## CHAPTER 1 : OVERALL REQUIREMENTS

1 Scope :

This Part applies to the emission of gaseous pollutants from diesel engines used for driving motor vehicles. Diesel engined vehicles, GVW of which does not exceed 3500 kg, may be approved on the basis of test procedure of Part III as opted by the manufacturer.

2 Definitions :

2.1 Compression Ignition Engine : Means an internal combustion engine which operates on compression ignition principle (Diesel Engines).

2.2 Maximum Rated Speed : Means the maximum speed permitted by governor at full load.

2.3 Minimum Rated Speed : Means either the highest of the following three engine speeds -
45% of maximum net power speed,
1000 rev/min,
minimum speed permitted by the idling control or
such lower speed as the manufacturer may request.

2.4 Per Cent Load : Means the fraction of the maximum available torque at an engine speed.

2.5 Intermediate Speed : Means the speed corresponding to the maximum torque value if such speed is within the range of 60 to 75 % of rated speed; in other cases it means a speed equal to 60 % of rated speed.

2.6 Net Power : Means the power of a C.I. engine as defined in Chapter 6 of Part IV of this rule.

2.7 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90% full and the usual set of tools and spare wheel on board where applicable.

2.8 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer.

2.9 Gaseous Pollutants:means carbon monoxide, hydrocarbons ( assuming a ratio of $CH_{1.85}$) and oxides of nitrogen (expressed in nitrogen dioxide $NO_2$ equivalent).

2.10 Cold Start Device : Means a device which enriches the airfuel mixture of the engine temporarily and thus to assist engine start up.

2.11 Starting Aid : Means a device which assists the engine start up without enrichment of the fuel mixture, e.g. glow plug, change of injection timing, etc.

2.12 Type Approval of a Vehicle : Means the type approval of a vehicle model with regard to the limitation of the emission of gaseous pollutants from the engine.

2.13 Vehicle Model : Means a category of power driven vehicles which do not differ in such essential respects of the vehicle characteristics which affects the vehicular emission and listed in Chapter 2 of this Part.

2.14 Vehicle for Type Approval Test : Means the fully built vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

2.15 Vehicle for Conformity of Production : Means a vehicle selected at random from a production series of vehicle model which has already been type approved.

2.16 Abbreviations and Units

| | | |
|---|---|---|
| P | kW | net power output non-corrected |
| CO | g/kWh | Carbon Monoxide emission |
| HC | g/kWh | hydrocarbon emission |
| NOx | g/kWh | emission of oxides of nitrogen |
| conc | ppm | concentration (ppm by volume) |
| mass | g/h | pollutant mass flow |
| WF | | weighting factor |
| $G_{EXH}$ | kg/h | exhaust gas mass flow rate on wet basis |
| $V'_{EXH}$ | $m^3/h$ | exhaust gas volume on dry basis |
| $V''_{EXH}$ | $m^3/h$ | exhaust gas volume on wet basis |
| $G_{AIR}$ | kg/h | intake air mass flow rate |
| $V_{AIR}$ | m3/h | intake air volume flow rate |
| $G_{FUEL}$ | kg/h | fuel mass flow rate |
| FID | | flame ionisation detector |
| NDIR | | non-dispersive infra-red |
| CLA | | chemiluminescent analyser |

3 Application for Type Approval :

3.1 The application for type approval of a vehicle model with regard to limitations of the emission of gaseous pollutants from its engine shall be submitted by the vehicle manufacturer with a description of the engine and vehicle model comprising all the particulars referred to in Chapter 2 of this Part.

3.2 A vehicle representative of the vehicle model to be type approved shall be submitted to the testing agency responsible for conducting tests referred in para 5 below.

4 Type Approval :
If the vehicle submitted for approval pursuant to these rules, meet the requirements of para 5.0 below, approval of vehicle model shall be granted. The approval of the vehicle model pursuant to this part shall be communicated to the Vehicle Manufacturer & Nodal Agency by the testing agency in the form of Certificate of Compliance to CMVR,as envisaged in Rule-126 of CMVR.

4 Specifications and Tests :

5.1 General : The components liable to affect the emission of gaseous pollutants shall be so designed, constructed and assembled as to enable the engine, in normal use, despite the vibration to which it may be subjected, to comply with the provisions of this Rule.

5.2 Specifications Concerning the Emission of Pollutants :

The emission of pollutants by the engine submitted for testing shall be measured by the method described in Chapter 3 of this Part. Other methods may be approved if it is found that they yield equivalent results.

5.2.1 The power of engine measured at the test bench during the test at steady speeds of the engine as detailed in the full load curve, as detailed in Chapter 6 of Part IV may differ from the power specified by the manufacturer in Chapter 2 of this Part :

5.2.1.1 For Type Approval :
For single cylinder engines,± 5 % at Max.Power point & ± 10% at other measurement points, and for other engines by ± 2% at Max.Power Point & +6% & -2% at other measurement points.

5.2.1.2 For Conformity of Production : For Single Cylinder engines by ± 10% & for other engines by - 5% / + 8% at maximum power point.

5.2.2 The mass of the carbon monoxide, the mass of the hydrocarbons and the mass of the nitrogen oxides obtained when tested as per details given in Chapter 3 of this Part shall not exceed the amounts shown in the table below:-

| Mass of Carbon Monoxide(CO) g/kWh | Mass of Hydro Carbons(HC) g/kWh | Mass of Oxides of Nitrogen (Nox) g/kWh |
|---|---|---|

| | | |
|---|---|---|
| 14 | 3.5 | 18 |

5.3 In case of diesel engined vehicles of GVW less than 3500 kg, if the manufacturer opts to meet the requirements as per Part the requirements of 5.2.2 and 5.2.3 above need not be met, but the requirement given in 5.3.1 below should be met, when tested as per procedure given in Chapter 1 and Chapter 3 of Part III.

Emission Standards for Type I test for compression ignition engined vehicles :

| Reference mass R (kg) more than | Reference mass R (kg) upto and including | CO (g/km) | Combined emission of HC+NOx(g/km) |
|---|---|---|---|
| --- | 1020 | 14.3 | 4.7 |
| 1020 | 1250 | 16.5 | 5.1 |
| 1250 | 1470 | 18.8 | 5.4 |
| 1470 | 1700 | 20.7 | 5.8 |
| 1700 | 1930 | 23.0 | 6.2 |
| 1930 | 2150 | 24.9 | 6.5 |
| 2150 | --- | 27.1 | 6.9 |

6 Modifications of the vehicle Model :

6.1 Every modification in the essential characteristics of the Vehicle shall be intimated by the Vehicle Manufacturer to the test agency which Type approved the Vehicle model. The test agency may either :

6.1.1 Consider that the Vehicle with the modifications made may still comply with the requirement, or

6.1.2 Require a further test to ensure compliance.

6.2 In case of 6.1.1 above, the testing agency shall extend the type approval covering the modified specification.

In case of 6.1.2 above, the vehicle model shall be subjected to necessary test. In case the vehicle complies with the requirements, the test agency shall extend the type approval.

6.3 Any changes to the procedure of PDI and running in concerning emission shall also be intimated to the test agency by the vehicle manufacturer, whenever such changes are carried out.

7 Conformity of Production :

7.1 Every produced vehicle of the model approved under this rule shall conform, with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved.The procedure for carrying out conformity of production tests is given in Part VI of this Document.

7.2 For verifying the conformity of the engine in a test, the following procedure is adopted:-

7.2.1 An engine is taken from the series and subjected to the test described in Chapter 3 of this Part.

7.2.1.1 If the engine taken from the series does not satisfy the requirements of Paragraph 5.2.2 and 5.2.3 above, the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The Manufacturer shall specify the size n of the sample subject to n being minimum 2 and maximum 10, including the engine originally taken. The engines other than originally tested shall be subjected to single Type I test. The result to be taken into consideration for the engine taken originally is the arithmetical mean ' $\bar{x}$ ' of the results obtained with the sample and the standard deviation S of the sample shall then be determined for each gaseous pollutant. The production of the series shall then be deemed to conform if the following condition is met :-

$$\bar{x} + k.S \le L$$

where :-

$$S^2 = \Sigma\ (x - \bar{x})^2 / (n - 1)$$

x = any one of the individual results obtained with the sample n.

L = the limit value laid down in Paragraph 5.2.3 for each gaseous pollutant considered; and

k = a statistical factor depending on 'n' and given in the following table:-

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| k | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

7.2.1.2 Alternatively if the Manufacturer requests so, the Conformity of Production can be verified by the following alternative sampling plan.

7.2.1.3 A failed Engine is one whose test results, lead to one or more of the limit values in Para 7.2.1 being exceeded.

7.2.1.4 The production of the series is deemed to conform or not to conform by testing engines comprising a test sample until a pass decision is reached for all limit values or a fail decision is reached for one limit value. A pass decision is reached when the cumulative number of failed engines as defined in Para 7.2.1.2. for each value is less than or equal to the pass decision number appropriate to the cumulative number of engines tested. A fail decision is reached when the cumulative number of engines for one limit value is greater than or equal to the fail decision number appropriate to the cumulative number of engines tested. Once a pass decision has been made for a particular limit value the number of engines whose results exceed that limit value must not be considered any further for the purposes of checking conformity of production. The pass and fail decision numbers associated with the cumulative number of engines tested are illustrated in the fig.2 given in the following Table.

7.2.1.5 The testing agency responsible for verifying the conformity of production shall carry out tests on engines which have been run-in partially or completely, according to the manufacturer's specifications.

7.3 In the case of engine type approved as per 5.3, the conformity of production test procedure will be as per 8.4 of Chapter 1 of Part III and the limits will be as per 7.3.1 below :

7.3.1 Emission Standards for Type I Tests for Compression Ignition Engined Vehicles.

| Reference mass R (kg) more than | Reference mass R (kg) upto and including | CO (g/km) | Combined emission of HC+NOx(g/km) |
|---|---|---|---|
| --- | 1020 | 17.3 | 5.9 |
| 1020 | 1250 | 19.7 | 6.3 |
| 1250 | 1470 | 22.5 | 6.8 |
| 1470 | 1700 | 24.9 | 7.3 |
| 1700 | 1930 | 27.6 | 7.7 |
| 1930 | 2150 | 29.9 | 8.2 |
| 2150 | --- | 32.6 | 8.6 |

Fig. 2:-TABLE : PASS FAIL CRITERIA (See para. 7.2.1.4 chapter 1 part 5)

| Cumulative number vehicles tested | Pass decision (No.of failures) | Fail decision (No. of failures) | Cumulative number of vehicles tested | Pass decision ( No. of failures) | Fail decision (No. of failures) |
|---|---|---|---|---|---|
| 1 | (‘) | (:) | 31 | 14 | 20 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | (‘) | (:) | 32 | 14 | 21 |
| 3 | (‘) | (:) | 33 | 15 | 21 |
| 4 | (‘) | (:) | 34 | 15 | 22 |
| 5 | 0 | (:) | 35 | 16 | 22 |
| 6 | 0 | 6 | 36 | 16 | 23 |
| 7 | 1 | 7 | 37 | 17 | 23 |
| 8 | 2 | 8 | 38 | 17 | 24 |
| 9 | 2 | 8 | 39 | 18 | 24 |
| 10 | 3 | 9 | 40 | 18 | 25 |
| 11 | 3 | 10 | 41 | 19 | 26 |
| 12 | 4 | 10 | 42 | 19 | 26 |
| 13 | 4 | 11 | 43 | 20 | 27 |
| 14 | 5 | 11 | 44 | 21 | 27 |
| 15 | 5 | 12 | 45 | 21 | 28 |
| 16 | 6 | 12 | 46 | 22 | 28 |
| 17 | 6 | 13 | 47 | 22 | 29 |
| 18 | 7 | 13 | 48 | 23 | 29 |
| 19 | 7 | 14 | 49 | 23 | 30 |
| 20 | 8 | 14 | 50 | 24 | 30 |
| 21 | 8 | 15 | 51 | 24 | 31 |
| 22 | 9 | 15 | 52 | 25 | 31 |
| 23 | 9 | 16 | 53 | 25 | 32 |
| 24 | 10 | 16 | 54 | 26 | 32 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 11 | 17 | 55 | 26 | 33 |
| 26 | 11 | 17 | 56 | 27 | 33 |
| 27 | 12 | 18 | 57 | 27 | 33 |
| 28 | 12 | 19 | 58 | 28 | 33 |
| 29 | 13 | 19 | 59 | 28 | 33 |
| 30 | 13 | 20 | 60 | 32 | 33 |

(‘) Series not able to pass at this stage

(:) Series not able to fail at this stage

## CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

| | |
|---|---|
| 1.0 Description of the Vehicle | ------------------------------- |
| 1.1 Trade name or mark of the vehicle | ------------------------------- |
| 1.2 Vehicle type | ------------------------------- |
| 1.3 Manufacturer's name and address | ------------------------------- |
| 1.4 Unladen mass of vehicle(kN) | ------------------------------- |
| 1.4.1 Reference mass of vehicle | ------------------------------- |
| 1.4.2 Gross Vehicle Weight | ------------------------------- |
| 1.5 Gear box | ------------------------------- |
| 1.5.1 Manual or automatic<br>(If it is automatic give all pertinent technical data) | ------------------------------- |
| 1.5.2 Number of gears | ------------------------------- |
| 1.5.3 Transmission ratio : | ------------------------------- |
| 1.5.3.1 First Gear | ------------------------------- |
| 1.5.3.5 Over Drive | ------------------------------- |
| 1.5.3.6 Gear Shifting Pattern | ------------------------------- |
| 1.6 Final drive ratio | ------------------------------- |
| 1.7 Tyres | ------------------------------- |
| 1.7.1 Dimensions | ------------------------------- |
| 1.7.2 Dynamic rolling circumference | ------------------------------- |
| 1.7.3 Type | ------------------------------- |
| 1.7.4 Ply Rating | ------------------------------- |
| 1.7.5 Tyre Pressure : | ------------------------------- |
| Front | ------------------------------- |

| | | |
|---|---|---|
| | Rear | ------------------------------ |
| 1.8 | Wheel drive : | ------------------------------ |
| | Front. | ------------------------------ |
| | Rear | ------------------------------ |
| 1.9 | Vehicle performance (declared by manufacturer) | ------------------------------ |
| 1.9.1 | Vehicle max. speed. | ------------------------------ |
| 1.9.2 | Acceleration max. | --------------------- $m/sec^2$ |
| 2.0 | Description of engine | ------------------------------ |
| 2.1 | Make : | ------------------------------ |
| 2.2 | Type : | ------------------------------ |
| 2.3 | Working principle : | ------------------------------ |
| | four-stroke/two-stroke : | |
| 2.4 | Bore : | -------------------------mm |
| 2.5 | Stroke : | ------------------------- mm |
| 2.6 | Number and layout of cylinders and firing order | ------------------------------ |
| 2.7 | Cylinder capacity : | ------------------------- $cm^3$ |
| 2.8 | Compression ratio | ------------------------------ |
| | (Specify the tolerance) | |
| 2.9 | Drawings of combustion chamber and piston crown | ------------------------------ |
| 2.10 | Minimum cross-sectional area of inlet and outlet ports | --------------------------- |
| 2.11 | Cooling System : liquid / air cooling | ------------------------------ |
| 2.11.1 | _Characteristics of liquid-cooling system | ------------------------------ |
| 2.11.1.1 | Nature of liquid Circulating pump : Yes/No | ------------------------------ |
| 2.11.1.2 | Characteristics of make(s) and type(s) | ------------------------------ |

2.11.1.3 Drive ratio -------------------------------

2.11.1.4 Thermostat: setting -------------------------------

2.11.1.5 Radiator : drawing(s) or make(s) and type(s) -------------------------------

2.11.1.6 Relief valve : pressure setting -------------------------------

2.11.1.7 Fan : Characteristics or make(s) and type(s) -------------------------------

2.11.1.8 Fan drive system Drive ratio : -------------------------------

2.11.1.9 Fan cowl : -------------------------------

.
2.11.2 Characteristics of air-cooling system -------------------------------

2.11.2.1 Blower : characteristics or make(s) and type(s) -------------------------------

2.11.2.2 Drive ratio (s) : -------------------------------

.
2.11.2.3 Air ducting ( standard production): -------------------------------

2.11.2.4 Temperature regulating system : yes/no / Brief description -------------------------------

2.11.3 Temperature permitted by the manufacturer -------------------------------

2.11.3.1 Liquid cooling : max. temperature at engine outlet -----------------------------

2.11.3.2 Air cooling: Reference point -------------------------------

2.11.3.3 Max. temperature at reference point -------------------------------

2.11.3.4 Max. outlet temperature of the inlet intercooler -------------------------------

2.11.3.5 Max. exhaust temperature at the point in the exhaust pipe(s) adjacent in outlet flange(s) of the exhaust manifolds ---------------------------

2.11.3.6 Fuel temperature : min .max -------------------------------

2.11.3.7 Lubricant temperature: min .max -------------------------------

2.12 Supercharger : yes/no (Description of the system) -------------------------------

2.13 Intake System : -------------------------------

2.13.1 Intake manifold : Description -------------------------------

2.13.2 Air filter : Make: Type: -------------------------------

2.13.3 Intake silencer: Make: Type: -------------------------------

2.14 Device for recycling crank-case gases : -------------------------------
Description and diagrams

3.0 Additional anti-pollution devices (if any, and if not covered by another heading) -------------------------------
Description and diagrams

4.0 Air intake and fuel feed -------------------------------

4.1 Description and diagrams of inlet pipes and their accessories ------------------------------
(dash pot, heating device, additional air intakes, etc.)

4.1.1 Maximum permitted depression of air intake at characteristic place. (Specify location of measurement) kPa ------------------------------
(Specify the tolerance) (Specify range if applicable)

4.2 Fuel feed -------------------------------

4.2.1 Feed pump -------------------------------
Pressure or characteristic diagram .
(Specify the tolerance)

4.2.2 Injection System -------------------------------
System description
Working principle : Intake manifold / direct injection /
Injection prechamber / swirl chamber.

4.2.2.1 Pump -------------------------------
.

4.2.2.1.1 Make (s) -------------------------------

4.2.2.1.2 Type (s) -------------------------------

4.2.2.1.3 Delivery : $mm^{-3}$ per stroke or cycle at a pump of ------------------------- rpm at full. Injection or characteristic diagram -----------------------------
(Specify the tolerance)

4.2.2.1.4 Calibration procedure : On engine/ On pump bench -----------------------------

4.2.2.1.5 If boost control is supplied, state the characteristic fuel delivery and boost pressure versus engine speed. -----------------------------

4.2.2.1.6 Injection timing ------------------------------

4.2.2.1.7 Injection advance curve -------------------------------

4.2.2.1.8 Injection advance -------------------------------
(Specify the tolerance)

4.2.2.2 Injectors : -------------------------------

4.2.2.2.1 Make : -------------------------------

4.2.2.2.2 Type : -------------------------------

4.2.2.2.3 Opening Pressure ------------------------ MPa
or characteristic diagram
(Specify the tolerance)

4.2.2.3 Injection Piping -------------------------------

4.2.2.3.1 Length -------------------------------

4.2.2.3.2 Internal diameter -------------------------------

4.2.2.4 Governor -------------------------------

4.2.2.4.1 Make (s) : -------------------------------

4.2.2.4.2 Type (s) : -------------------------------

4.2.2.4.3 Cut off point under load ------------------------- rpm

4.2.2.4.4 Max. speed without load ------------------------- rpm

4.2.2.4.5 Idle speed ------------------------- rpm

4.2.2.5 Cold start device -------------------------------

4.2.2.5.1 Make(s) : -------------------------------

4.2.2.5.2 Type(s) : -------------------------------

4.2.2.5.3 System description -------------------------------

4.2.2.6 Starting aid -------------------------------

4.2.2.6.1 Make : -------------------------------

4.2.2.6.2 Type : -------------------------------
4.2.2.6.3 System description -------------------------------

| | | |
|---|---|---|
| 5.0 | Valve timing or equivalent data: | ------------------------------ |
| 5.1 | Maximum lift of valves, angles of opening and closing, or timing details of alternative distribution systems, in relation to top dead centre (Specify the tolerance and range) | ------------------------------ |
| 5.2 | Reference and/or setting ranges | ------------------------------ |
| 6.0 | Exhaust System | ------------------------------ |
| 6.1 | Description of exhaust equipment if the test is made with the complete equipment provided by the engine or vehicle manufacturer | ------------------------------ |
| 6.2 | Specify the back pressure at maximum net power and the location of measurement kPa (Specify the tolerance and range) | ------------------------------ |
| 6.3 | Indicate the effective volume of the exhaust (Specify the tolerance and range) | ------------------------$cm^3$ |
| 7.0 | Lubrication system | ------------------------------ |
| 7.1 | _Description of systems | ------------------------------ |
| 7.1.1 | Position of lubricant reservoir | ------------------------------ |
| 7.1.2 | Feed system (pump, injection into intake, mixing with fuel, etc.) | ------------------------------ |
| 7.2 | Lubricating pump | ------------------------------ |
| 7.2.1 | Make : | ------------------------------ |
| 7.2.2 | Type : | ------------------------------ |
| 7.3 | Mixture with fuel | ------------------------------ |
| 7.3.1 | Percentage | ------------------------------ |
| 7.4 | Oil cooler : yes/no | ------------------------------ |
| 7.4.1 | Drawing(s) or make(s) and type(s) | ----------------------------- |
| 8.0 | Electrical equipment (Generator/alternator : characteristics or make(s) and type(s) | ------------------------------ |
| 9.0 | Other engine driven auxiliaries | ------------------------------ |

(Enumeration and brief description if necessary)

10.0 Transmission -------------------------------

10.1 State movement of inertia of combined flywheel and transmission at condition when no gear is engaged -------------------------------
(Specify the range if applicable)

11.0 Engine performance (declared by the manufacturer) -------------------

11.1 Idling speed : --------------------------rpm
(Specify the tolerance)

11.2 Maximum rated speed : ------------------------- rpm
(Specify the tolerance)

11.3 Minimum rated speed : ------------------------- rpm
(Specify the tolerance)

11.4 Max. net torque of engine on bench : Nm at .rpm -------------------------------
(Specify the tolerance)

11.5 Max. net power of engine on bench : kW at rpm -------------------------------
Indicate power absorbed by fan kW
(Specify the tolerance)

11.6 Test on bench -------------------------------
Declared powers at the points of measurement referred to in Chapter 3 shall be stated in Table 1.

Declared speeds and powers of the engine/vehicle (strike out what does not apply) submitted for approval

(Speeds to be agreed with the testing agency)

| Measurement Points * | Engine Speed : n ( rpm) | Power : P ** KW | Vehicle Speed and gear position |
|---|---|---|---|
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |
| --------------- | --------------- | --------------- | --------------- |

(NOTE : STRIKE OUT WHAT IS NOT APPLICABLE)

* See Chapter 3 of Part IV

** Net power according to Chapter 6 of Part IV

## CHAPTER 3 : TEST PROCEDURE FOR MEASUREMENT OF GASEOUS POLLUTANTS FROM DIESEL ENGINES

1 Scope : This chapter describes the method of determining emissions of gaseous pollutants from the engine to be tested, as defined in para 5.2 of Chapter 1 of this Part.

2 Measurement Principle : The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer. The gaseous emissions from the exhaust of the engine include hydrocarbons, carbon monoxide and oxides of nitrogen. During a prescribed sequence of warmed up engine operating conditions the amounts of the above gases in the exhaust shall be examined continuously. The prescribed sequence of operations consist of a number of speed and power modes which span the typical operating range of diesel engines. During each mode the concentration of each pollutant, exhaust flow and power output shall be determined and the measured values weighted and used to calculate the grams of each pollutant emitted per kilowatt hour, as described in this part.

3 Equipment :

3.1 Dynamometer and Engine Equipment

The following equipment shall be used for emission tests of engines on engine dynamometers:

3.1.1 An engine dynamometer with adequate characteristics to perform the test cycle described in Paragraph 4.1 below.

3.1.2 Measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and section flow resistance, air inlet temperature, atmospheric pressure, fuel temperature and humidity. The accuracy of these instruments shall satisfy the method of measuring the power of the internal combustion engines of road vehicles, given in Chapter 6 of Part IV of this Rule.

3.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;

3.1.4 A non-insulated and uncooled exhaust system extending at least 0.5m past the point where the exhaust probe is located, and presenting an exhaust back pressure within ± 650 Pa of the upper limit at the maximum rated power, as established by the engine manufacturer's sale and service literature for vehicle application;

3.1.5 An engine air inlet system presenting an air inlet restriction within ± 300 Pa of the upper limit for the engine operating condition which results in maximum air flow, as established by the engine manufacturer for an air cleaner, for the engine being tested. When an engine is tested for exhaust emissions, the complete engine shall be tested with all standard accessories which might reasonably be expected to influence emissions to the atmosphere installed and functioning as listed in Chapter 6 of Part IV of this regulation.

3.2 Exhaust Gas Sampling System :

3.2.1 The exhaust gas sampling system shall be designed to enable the measurement of the true mass emissions of the exhaust.

3.2.2 The probe shall extract a true sample of the exhaust gases.

3.2.3 The system should be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the diluted exhaust gas. Should any component (heat exchanger, blower, etc.) change the concentration of any pollutant gas in the diluted gas, then the sampling for that pollutant shall be carried out before that component, if the problem cannot be corrected.

3.2.4 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

3.3 Analytical Equipment :

3.3.1 Pollutant gases shall be analysed with the following instruments

3.3.1.1 Carbon monoxide (CO) and carbon dioxide ($CO_2$) analysis.

The carbon monoxide and carbon dioxide analysers shall be of the NON-DISPERSIVE INFRA RED (NDIR) absorption type.

3.3.1.2 Hydrocarbon (HC) analysis

The Hydrocarbon analyser shall be of the Flame Ionisation type with the whole FID system maintained at a temperature between 453K to 473K. It shall be calibrated with propane gas of equivalent to carbon atoms (C1 ).

3.3.1.3 Nitrogen oxide (NOx) analysis.

The nitrogen oxide analyser shall be of the heated Chemiluminescent (HCLA) type with an NOx-NO converter or equivalent .

3.3.1.4 Accuracy

The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants. Measurement errors shall not exceed ±3 % disregarding the true value of the calibration gases. For concentrations of less than 100 ppm the measurement error shall not exceed ±3 ppm. The ambient air sample shall be measured on the same analyser and range as the corresponding diluted exhaust sample.

3.3.1.5 Chapter 4 of this Part describes the analytical systems recommended. Other systems of analysers which have proved to give equivalent results may be used.

3.4 Gases

3.4.1 The following pure gases shall be available when necessary, for calibration and operation :

Purified nitrogen (purity < 1ppm C,< 1ppm CO, < 400ppm $CO_2$, < 0.5ppm NO);

Purified synthetic air (purity < 3ppm C, < 1ppm CO, < 400ppm $CO_2$,< 0.5ppm NO);

Oxygen content between 18 and 21 percent vol.;

Purified oxygen (purity > 99.5 percent Vol. $0_2$) ;

Purified hydrogen (and mixture containing hydrogen) (Purity < 1ppm C, < 400ppm $CO_2$).

3.4.2 Calibration and span gases :

Gases having the following chemical compositions shall be available $C_3H_8$ and purified synthetic air (see paragraph 3.4.1 above); CO and purified nitrogen; $CO_2$ and purified nitrogen; NO and purified nitrogen ( the amount of $NO_2$ contained in this calibration gas must not exceed 5 percent of the NO content)

3.4.3 The true concentration of a calibration gas shall be within ± 2%of the stated figure.

3.4.4 The concentrations specified in Para 4.3 below may also be obtained by means of a gas divider, diluting with purified nitrogen or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined within ± 2%.

4 Test Procedure :

4.1 Test Cycle :

The following 13-mode cycle shall be followed in dynamometer operation on the test engine:-

| Mode No. | Engine Speed | % Load |
|---|---|---|
| 1 | Idle | ---- |
| 2 | intermediate | 10 |

| | | |
|---|---|---|
| 3 | ,,,, | 25 |
| 4 | ,,,, | 50 |
| 5 | ,,,, | 75 |
| 6 | ,,,, | 100 |
| 7 | Idle | ---- |
| 8 | rated | 100 |
| 9 | ,,,, | 75 |
| 10 | ,,,, | 50 |
| 11 | ,,,, | 25 |
| 12 | ,,,, | 10 |
| 13 | Idle | ----- |

4.2 Measurement of Exhaust Gas Flow :

For calculation of the emission it is necessary to know the exhaust flow, as given in Para 4.8.1 below. For determination of exhaust flow either of the following methods may be used:-

4.2.1 Direct measurement of the exhaust flow by flow nozzle or equivalent metering system.

4.2.2 Measurement of the air flow and the fuel flow by suitable metering systems and calculation of the exhaust flow by the following equations :

$G_{EXH} = G_{AIR} + G_{FUEL}$

or

$V'_{EXH} = V_{AIR} - 0.75\ G_{FUEL}$

or

$V''_{EXH} = V_{AIR} + 0.77\ G_{FUEL}$

4.2.3 The accuracy of exhaust flow determination shall be ±2.5% or better.

4.2.4 The concentration of carbon monoxide and nitric oxide are measured in the dry exhaust. For this reason the CO and Nox emissions shall be calculated using the dry exhaust gas volume $V'_{EXH.}$ If the exhaust mass flow rate ($G_{EXH}$) is used in the calculation the CO and NOx concentrations shall be related to the wet exhaust.

Calculation of the HC emission shall include $G_{EXH}$ and $V''_{EXH}$ according to the measuring method used.

4.3 Operating and Calibrating Procedure for Analysers and Sampling System :

The operating procedure for analysers shall follow the startup and operating instructions of the instrument manufacturer. The following minimum requirements shall be included.

4.3.1 Establishment of Calibration Curve

4.3.1.1 The analyser calibration curve shall be established by at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90% of the full scale.

4.3.1.2 The calibration curve is calculated by the least square method. If the degree of the polynomial resulting from the curve is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

4.3.1.3 The calibration curve shall not differ by more than ±2% from the nominal value of calibration gas of each calibration point.

4.3.1.4 The different characteristic parameters of the analyser, particularly the scale, the sensitivity, the zero point and the date of carrying out the calibration should be indicated on the calibration curve.

4.3.1.5 It can be shown to the satisfaction of the testing authority, that alternative technology e.g. computer, electronically controlled range switch etc., can give equivalent accuracy, then these alternatives may be used.

4.3.2 Verification of Calibration

4.3.2.1 The calibration procedure shall be carried out as often as necessary and in any case within one month preceding the type approval emission test and once in six months for verifying conformity of production.

4.3.2.2 The verification should be carried out using standard gases. The same gas flow rates shall be used as when sampling exhaust.

4.3.2.3 A minimum of two hours shall be allowed for warming up the analysers.

4.3.2.4 The NDIR analyser shall be tuned, where appropriate, and the flame combustion of the FID analyser optimised.

4.3.2.5 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser. Using appropriate calibrating gases mentioned in 3.4 above. the analysers shall be reset.

4.3.2.6 The zero setting shall be rechecked and the procedure described in Para 4.3.2.4 and 4.3.2.5 above repeated, if necessary.

4.3.2.7 The calibration curves of the analysers should be verified by checking at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90% of the full scale. It should meet the requirement of para 4.3.1.3 above.

4.3.2.8 If it does not meet, the system should be checked, fault, if any, corrected and a new calibration curve should be obtained.

4.3.2.9 Efficiency test of the $NO_x$ Converter Refer 4.5 of Chapter 7, Part 3

4.3.3 Pre-test Checks

4.3.3.1 A minimum of two hours shall be allowed for warming up the infra-red NDIR analyser, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

4.3.3.2 Each normally used operating range shall be checked prior to each analysis.

4.3.3.3 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser.

4.3.3.4 Span gas having a concentration of the constituent that will give a 75-95% full-scale deflection shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure.

4.3.3.5 The nominal value of the span calibration gas used shall remain with ± 2% of the calibration curve.

4.3.3.6 If it does not, but it remains within ±5% of the calibration curve, the system parameters such as gain of the amplifier, turning of NDIR analysers, optimisation of FID analysers etc. may be adjusted to bring within ±2%.

4.3.3.7 If the system does not meet the requirement of 4.3.3.5 and 4.3.3.6 above, the system should be checked, fault, if any corrected and a new calibration curve should be obtained.

4.3.3.8 Zero shall be checked and the procedures described in para 4.3.3.3 and 4.3.3.4 above repeated, if required.

4.4 System Leak Test :

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.5 Fuel

The fuel shall be the reference fuel specified in Chapter 5 of Part IV to this rule.

4.6 Test Laboratory

4.6.1 The absolute temperature T of the laboratory expressed in degrees Kelvin and the dry atmospheric pressure ps expressed in Kilopascals shall be measured and the parameter F shall be determined by the formula

Naturally aspirated and Mechanically supercharged engines :

$$F = (99/Ps) * (T/29)^{0.7}$$

Turbo supercharged engines with or without cooling of inlet air:

$$F = (99/Ps)^{0.7} * (T/298)^{1.5}$$

4.6.2 For a test to be recognised as valid, the parameter F shall be between 0.98 and 1.02 as per the notification issued by MOST from 1/4/96.

4.7 Test Run

During each mode of the test cycle, the specified speed shall be held to within ± 50 rpm and the specified torque shall be held to within ± 2% of the maximum torque at the test speed. The fuel temperature at the injection pump inlet shall be 311 ± 5K. The governor and fuel system shall be adjusted as established by the manufacturer's sales and service literature. The following steps shall be taken for each test :-

4.7.1 Instrumentation and sample probes shall be installed as required;

4.7.2 The cooling system shall be started;

4.7.3 The engine shall be started and warmed up until all temperatures and pressures have reached equilibrium;

4.7.4 The torque curve at full load shall be determined by experimentation to calculate the torque values for the specified test modes;

4.7.5 The emission analysers shall be set at zero and spanned;

4.7.6 The test sequence as given in para 4.1 above shall be started The engine shall be operated for six minutes in each mode, completing engine speed and load changes in the first minute. The responses of the analysers shall be recorded on a strip chart recorder for the full six minutes with exhaust gas flowing through the analysers at least during the last three minutes. the engine speed and load, intake air temperature and vacuum exhaust back pressure, fuel flow and air or exhaust flow shall be recorded during the last five minutes of each mode, with the speed and load requirements being met during the last minute of each mode;

4.7 .7 Any additional data required for calculation shall be read and recorded as given in para 4.7 .

4.7.8 The zero and span settings of the emission analysers shall be checked and reset, as required, at least at the end of the test. The test shall be considered satisfactory if the adjustment necessary after the test does not exceed the accuracy of the analysers prescribed in Paragraph 3.3 above.

4.8 Chart Reading

During the last 60 seconds of each mode the average chart reading for HC, CO and NOx shall be determined. The concentration of HC, CO and NOx during each mode shall be determined from the average chart readings and the corresponding calibration data or any other equivalent method.

4.9 Calculations

4.9.1 The final reported test results shall be derived through the following steps :-

The exhaust gas mass flow rate $G_{EXH}$ or $V'_{EXH}$ and $V''_{EXH}$ shall be determined as given in Para 4.2 above for each mode. When applying $G_{EXH}$ , the measured carbon monoxide and nitric oxide concentration shall be converted to a wet basis according to 4.10 below. The NOx concentration shall be corrected according para 4.11 below. The pollutant mass flow for each mode shall be calculated as follows :

$NOx_{mass} = 0.001587 * (NOx_{conc}) * (G_{EXH})$
$CO_{mass} = 0.000966 * (CO_{conc}) * (G_{EXH})$
$HC_{mass} = 0.000478 * (HC_{conc}) * (G_{EXH})$
or
$NOx_{mass} = 0.00205 * (NOx_{conc}) * (V'_{EXH})$
$CO_{mass} = 0.00125 * (CO_{conc}) * (V'_{EXH})$
$HC_{mass} = 0.000618 * (HC_{conc}) * (V''_{exh})$

4.9.2 The emissions shall be calculated in the following way :

$$\overline{NOx} = \Sigma(NOx_{mass} * WF_i) / \Sigma(P_i * WF_i)$$

$$\overline{CO} = \Sigma(CO_{mass} * WF_i) / \Sigma P_i * WF_i$$

$$\overline{HC} = \Sigma (HC_{mass} * WF_i) / \Sigma P_i * WF_i$$

The weighting factors used in the above calculation are according to the following table :

| Mode No | WF |
|---|---|
| 1 | 0.25/3 |
| 2 | 0.08 |
| 3 | 0.08 |
| 4 | 0.08 |
| 5 | 0.08 |
| 6 | 0.25 |
| 7 | 0.25/3 |
| 8 | 0.10 |
| 9 | 0.02 |
| 10 | 0.02 |
| 11 | 0.02 |
| 12 | 0.02 |
| 13 | 0.25/3 |

4.10 Conversion of CO and NOx Concentration to a Wet Basis. The CO and NOx exhaust gas concentration as measured in this procedure are on a dry basis. To convert the measured values to the concentrations present in the exhaust (wet basis), the following relationship may be employed :-

ppm (wet basis) = ppm (dry basis) * $(1-(1.85 * G_{FUEL} / G_{AIR}))$

Where :-
$G_{FUEL}$ = is the fuel flow (kg/s )
$G_{AIR}$ = is the air flow (kg/s)

4.11 Correction Factor for Nitric Oxide for Humidity. The values of the nitric oxides shall be multiplied by the following humidity correction factor :-

$1/(1+ A* (7m -75) + 1.8 * B * (T-302))$

Where $A = 0.044 * ( G_{fuel} / G_{air} ) - 0.0038$.

$B = 0.0053 + 0.116 * (G_{fuel} / G_{air})$

m = humidity of the inlet air in grams of water per kilogram of dry air

T = temperature of the air in degree K.
$G_{Fuel} / G_{Air}$ = Fuel air ratio (dry air basis)

## CHAPTER 4 : ANALYTICAL SYSTEMS

1 Scope :

1.1 This chapter describes the analysis system mentioned in para 3.3 of Chapter 3 of this Part.

2 Analytical System

A schematic diagram of the analytical and sampling system using HCLA or equivalent systems for measuring NOx is shown in Figure 1.

SP - Stainless steel sample probe to obtain samples from exhaust system. A closed end, multi-hole straight probe extending at least 80% across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K (70$^{o}$ C).

HSL 1 - Heated sampling line, temperature shall be kept at 453 K - 473 K (180$^{o}$ C 200$^{o}$ C): the line shall be made in stainless steel of PTFE.

F1 - Heated pre-filter, if used; temperature shall be the same as HSLI.

T1 - Temperature readout of sample streams entering oven compartment.

V1 - Suitable valving for selecting snmple, span gas or air or gas flow to the system. Tile valve shall be in the oven compartment or heated to the temperature of the sampling line HSL1.

V2,V3 - Needle valves to regulate calibration gas and zero gas.

F2 - Filter to remove particulates. A 70 rnm diameter glass fibre type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.

PI - Heated sample pump

G1 - Pressure gauge to measure pressure in sample line HC-analyser.

R3 - Pressure regulator valve to control pressure in sample line and flow to detector.

HFID - Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept at 453 K - 473 K (180$^{o}$ C - 200$^{o}$ C).

FL1,FL2,FL3 - Flow meter to measure sample by-pass flow.

RI,R2 - Pressure regulators for air and fuel.

HSL2 - [Icated sampling line, temperature shall be kept between 368 K - 473 K ($95^o$ C - $200^o$ C); the line shall be made in stainless steel or PTFE.

HCLA - Heated chemiluminescence analyser for oxides of nitrogen.

T2 - Temperature readout of sample stream entering HCLA analyser.

T3 - Temperature readout of $NO_2$ - NO converter.

V9, V10 - Three~way valve to by-pass $NO_2$ - NO converter.

V11 - Needle valve to balance flow through NO2 - NO converter and by-pass.

SL - Sample line. The line shall be made in PTFE or in stainless steel. It may be heated or unheated.

B - Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 K - 277 K (0' C - 4' C) by ice or refrigeration...

C - Cooling coil and trap sufficient to condense and collect water vapour optional witli water insensitive analyser).

T4 - Temperature readout of bath temperature.

V5,V6 - Toggle valves to drain condensate traps and bath.

R4,R5 - Pressure regulator to control sample flow.

V7,V8 - Bail valve or solenoid valves to direct sample, zero gas or calibrating gas streams to the analysers.

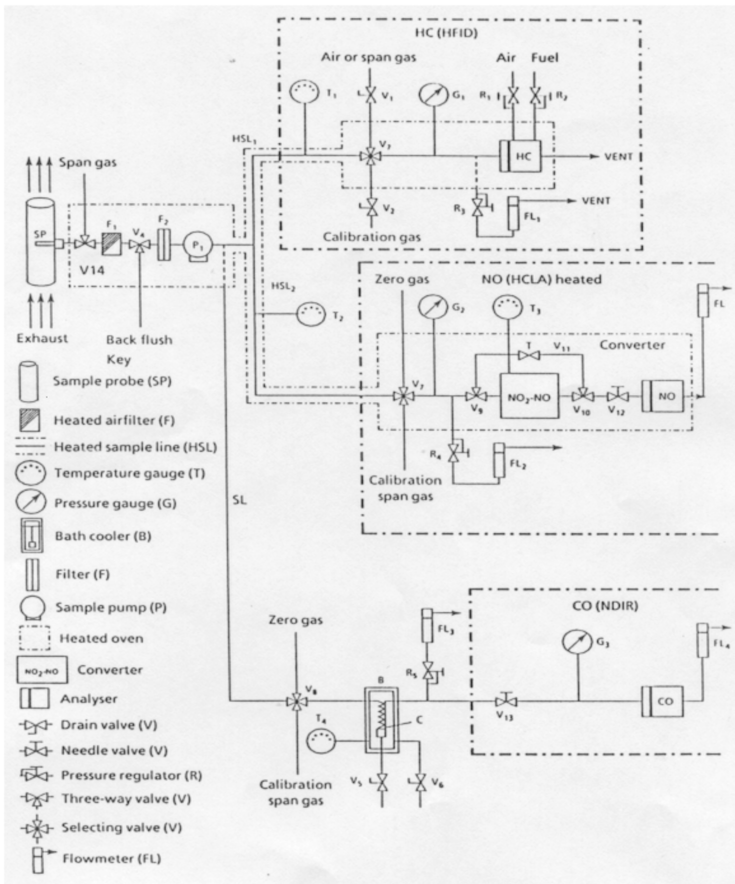
V12, V13 - Needle valves to regulate flows to the analysers.

CO - NDIR analyser for carbon monoxide.

NOx - HCLA analyser for oxides of nitrogen.

FL4,FL5 - By-pass flowmeter.

V4, V 14 - Three-way ball or solenoid valves. The valves shall be in an oven compartment or heated to the temperatures of the sampling line LISLI.




FLOW DIAGRAM OF EXHAUST GAS ANALYSIS SYSTEM FOR CO, NOx AND HC (ANALYSIS BY HCLA AND HEATED SAMPLE LINE)
FIGURE 1 CHAPTER 4 PART 5.

# PART VI : Administrative Procedure for Type Approval and Conformity of Production for Bharat Stage IV M and N Category Vehicles and Bharat Stage III Two and Three Wheelers

| Section | Details |
|---|---|
| **1.** | GENERAL |
| **2.** | COP TEST AGENCY |
| **3.** | COP PERIOD AND SELECTION OF RANDOM SAMPLE |
| **4.** | EXEMPTIONS FROM COP |
| **5.** | COP TESTING |
| **6.** | COP CERTIFICATE |
| **7.** | EXTENDED COP TESTS |
| **8.** | CONSEQUENCES OF FAILURE |

GENERAL

1 The Ministry of Road Transport and Highways is the nodal agency for implementation of emission legislation in both its aspects of Type Approval and Conformity of Production.

2 This procedure contains administrative guidelines for carrying out Conformity of Production tests in implementation of Emission Legislation. This has to be read in conjunction with Part IV, IX & X, XI, XII, XIII, XIV, XV of this Document which contain the technical procedures and guidelines for the implementation.

3 The Standing Committee on implementation of Emission Legislation has been constituted by the MoRTH under the Chairmanship of Joint Secretary - MoRTH, to advise the Nodal agency in such implementation.

4 The functions of Standing Committee are to advise the Nodal Agency on all matters pertaining to the implementation of Emission Legislation in general, and particularly

4.1 To formulate, monitor and control the policy and actions for Type Approval and Conformity of Production Testing System and Procedures.

4.2 To co-ordinate all such activities relating to implementation of the Emission Legislation.

4.3 To deal with certification, withdrawal and restoration of Type Approval.

4.4 To deal with all other technical, administrative or legal matters in this regard.

5 A list of members of the Standing committee are circulated by Ministry of Road Transport & Highways from time to time.

COP TEST AGENCY

6 The test agencies specified in Rule 126(A) of CMVR 1993 will be responsible for carrying out the COP tests in addition to the Type Approval tests.

7 Initially the vehicle/engines Manufacturer has the option of choosing the Test Agency for Type Approval of its specific model from among those listed in Rule 126(A) of CMVR 1993. On completion of first COP by the same test agency, the manufacturer can change the test agency if so desired.

8 In case the vehicle manufacturer desires to change the COP Test Agency, a formal request should be made to the new test agency under intimation to the previous Test Agency and nodal agency. This request should be made at least one month before the beginning of the next COP period along with all relevant documents concerning type approval/previous COP and also the latest information as per para 17 of the procedure.

9 On receipt of intimation of requests for a change, the previous COP Test Agency will authenticate all the relevant documents of that model and forward to the new test agency. The new test agency will carry out the process of selection & testing of the vehicle/engine for the COP as per the procedure and will consult the previous Test Agency if required about the test findings and results before issuing the final COP Certificate.

10 No change of Test Agency will be allowed in the cases covered by Para 32, until the procedure required under that Rule are finally completed.

COP PERIOD AND SELECTION OF RANDOM SAMPLE

11 a) Bharat Stage II 4 wheeler vehicles and greater than 3500 kg GVW engines : The COP period for vehicle/engine model shall be every Six months viz. April to September and October to March or, production/ Import of 25,000 vehicles/engines in the case of other vehicles (other than 2&3 wheelers) whichever is earlier.

However if production / Import of a model including its variants in a year (i.e. two consecutive COP periods of Six months each) is less than 5,000 in the case of other vehicles (other than 2/3 wheelers) the COP interval shall be one year.

b) For 2 & 3 wheelers (Bharat Stage II & Bharat Stage III) COP frequency and samples:

| Sr. No. | Type of Vehicle | Annual Production / Import | | COP Frequency |
|---|---|---|---|---|
| | | Exceeding | Upto | |
| (1) | (2) | (3) | (4) | (5) |
| 1. | Two-wheeler and three wheeler | 250 per 6 months | 10000 per year | Once every year |
| 2. | Two-wheeler | 10000 per year | 150000 per 6 months | Once every 6 months |
| 3. | Two-wheeler | 150000 per 6 months | --- | Once every 3 months |
| 4. | Three wheeler | 10000 per year | 75000 per 6 months | Once every 6 months |
| 5. | Three wheeler | 75000 per 6 months | ---- | Once every 3 months |

c) For 4 wheelers and greater than 3500 kg GVW engines COP frequency is once in a year for Bharat Stage III & Bharat Stage IV compliance (April to March)

d) The period between commencement of production/Import of a new model and beginning of next rationalized COP period is less than 2 months; the same would be merged with the rationalized COP period.

e) COP period for agricultural tractor, power tiller & construction equipment engines.

For agricultural tractor, power tiller & construction equipment with annual production/ Import upto 200 nos., it shall be once in two years per family/model.

For agricultural tractor, power tiller & construction equipment with annual production / Import exceeding 200 nos., it shall be once in every year per family/model.

11.1 The number of a specific vehicle model and its variants produced/ Imported were less than 250 in any consecutive period of six months in a year, COP should be carried out as per Chapter 1, Clause 8 of Part XIII for 2/3 Wheeler vehicles, Part XIV for 4 Wheeler vehicles & Chapter 1, Clause 9 of Part XV for Diesel & gas engines.

"Provided that in case the number of vehicles sold in India for a given base model and its variants (manufactured in India or imported to India) are less than 250 in any consecutive period of six months in a year, then such base model and its variants need not be subjected to the above test, if at least one model or its variants manufactured or imported by that manufacturer or importer, as the case may be, is subjected to such tests at least once in a year;

Provided further that, in case the number of base models and its variants manufactured / imported is more than one and if the individual base model and its variants are less than 250 in any consecutive period of six months in a year, then the testing agencies can pick up one of the vehicles out of such models and their variants once in a year for carrying out such test".

11.2 The Vehicle manufacturer conducts the COP tests needed in addition to those conducted by Testing Agency.

11.3 The vehicle manufacturer is having a valid certificate of compliance to ISO 9001-2000 or equivalent for the plant manufacturing that model.

11.4 Their emission test facilities, on which tests are conducted have been approved by one of the test agencies referred to in Rule 126 of CMVR,

11.5 Their test procedure which is a part of the certified quality system is followed. This procedure should be approved by a test agency referred to in Rule 126 of CMVR , for its adequacy of covering the applicable requirements of the COP test procedure including the procedure of selection of Vehicle, Calibration of test facilities etc.

In such cases the testing agency will issue the COP certificate based on satisfactory conclusion of tests conducted by them and audit the reports of the COP test conducted by the manufacturer. In case the test agency is not satisfied after auditing the manufacturer's test report, additional testing should be conducted by the test agency.

11.6 The test facility to be re-certified within 3 years from the date of issue of approval certificate by the testing agency.

11.7 The manufacturer will submit one model every year for COP evaluation at the premises of the testing agencies. The selection of the model will be at the discretion of the test agency.

12 A vehicle is considered to be produced when the vehicle has passed the final inspection stage as declared by the manufacturer.

13 Three random sample of the vehicle/engine model type approved will be selected by the test agency for the COP test, before the completion of the COP period defined in Para 11.0. In the case of diesel engines, three engine will be selected both for Part IV and Part X or Part XII, or Part XV tests.
Further, in case of vehicle model and its variants produced less than 250 in any consecutive period of six months in a year, as mentioned in clause 11.1 one vehicle shall be tested

14 The vehicle/engine manufacturer should inform the Nodal and concerned Test Agency -

14.1 Production/ Import plan for each model including its variants (with respect to the Type Approval Certificates and the previous COP Certificate) within 8 weeks from the start of production of type approved vehicle model or resumption of production of a vehicle or start of the COP period for that model.

14.2 Any subsequent change in such Production/ Import Plan, which would affect time schedule for random selection referred to in Para 18.

14.3 Likely and approximate last date before which COP will have to be completed, at least one to two months before such a date is likely to arrive.

14.4 Stoppage of production/ Import of a specific model, in case this has not been anticipated at the start of the COP period. This should be intimated well in advance so that COP selection of vehicle/engine can be completed by the test Agency before stoppage of production/ Import.

15 Manufacturer should request the Test Agency when they would like to make random selection of vehicles/engines and to seek their time table for completing the COP test.

16 Manufacturer should provide all the assistance required by the Test Agency for completing the tests.

17 The latest updated technical specifications, procedure of Pre-Delivery Inspection (PDI), running-in and servicing of the vehicle/engine, shall also be submitted before the vehicle/engine selection, if there has been revisions after the previous COP/Type Approval.

18 The Test Agency will inform the vehicle/engine Manufacturer, its time schedule for the selection of random sample and for carrying out the COP tests. If the vehicle/engine manufacturer has a problem for this time table for reason such as,

that particular model is not likely to be scheduled for production at that time, or enough number of vehicles/engines may not be available etc., the time schedule should be modified based on mutual convenience of the manufacturer and test agency.

EXEMPTIONS FROM COP

19 In the following cases, vehicle/engine models are exempted from COP tests :-

19.1 A batch of new/modified vehicles/engines produced for field trials upto a maximum of 500 vehicles/engines. (Not sold to customer)

20 In case of resumption of production of a model, after a stoppage of production, the manufacturer shall inform the test and nodal agencies, within two weeks of the resumption of the production and the COP period shall be as given in Para 11.

If the stoppage of production of the model has been without conducting the COP for that period, the nodal agency may, at the request of the manufacturer, waive COP for that period. In such cases, where COP has been waived, the selection of vehicle for the first COP after resumption shall be carried out within one month of resumption of production.

COP TESTING

21 The sampling size shall be one days average production subject to a minimum of 10 and maximum of 100.

For vehicle model and its variants produced less than 250 in the half yearly period as mentioned in clause 11.1 sample size may be one.

22 Petrol vehicles and diesel vehicles with Gross Vehicle Weight less than 3500 kg, vehicles type approved on the basis of Chassis Dynamometer tests as per Part IX or Part XI, XIII, XIV, of this Document ,produced in plants of the same manufacturer of different locations are to be considered as an independent unit for COP purposes and offered for COP. The results of the COP will affect only that unit. However, this criteria is exempted for a specific vehicle model and its variants produced less than 250 in the half yearly period as mentioned in clause 11.1 of this part.

23 In the case of vehicles/engines type approved based on the engine tests as per the requirements of Part IV and X or Part XII OR Part XV of this Document, the plants manufacturing engines of the same manufacturer will be considered as independent units for COP purposes and the engines would be offered for COP. These will be tested with the worst case configurations of the exhaust system of the models of the vehicles/engines type approved, based on this engine.

24 The procedure prescribed in Part IX, XI, IV and X, XII,XIII XIV, XV of this Document shall apply for carrying out COP tests-viz. Para 8.0 Chapter 1of Part IX and para 8 of chapter 1 of Part XI / PART XIII/ PART XIV for Petrol/ Diesel vehicles and para 8.0 of Chapter 1 of Part IV and Para 7.0of Chapter 1 of Part X, XII, XV & 2.10 clause 6 of part XV subpart A for diesel engine.

25 The COP will be determined on the basis of conformity of the make and specifications of the components used in the randomly selected vehicles/engines to those declared in chapter 2 of the relevant Part of this Document , for the vehicle/engine model type approved under Rule 126 of CMVR and tests on vehicles/engines as described below.

26 Pre-delivery inspection will be carried out by the manufacturer as per the procedure declared at the time of type approval, and as amended and intimated to the concerned test agency from time to time, on the selected vehicles/engines, under the control of the test agency.

27 The running in of the vehicle/engine shall be carried out as per the manufacturer's recommendation submitted during type approval. This should be carried out as amended and intimated to the concerned test agency from time to time, under the control of test agency. After this, the manufacturer will be permitted by the test agency to carry out all the adjustments recommended in his user's/service manual and as amended and intimated to the concerned test agency from time to time, under the control of test agency.

28 The facilities with the manufacturers or elsewhere, meeting the specified requirements for testing of emissions according to this document, may be used for COP, by the test agency in addition to those with the test agency.

29 In the case of failure of any major component during the running-in or testing, the testing agencies may permit to replace the components, only once, which have failed and which do not affect the performance and emission of engine/vehicle. In the case of components affecting the performance and emissions of the engine/vehicle, random selection should be done once again and the testing will be done. If the randomly selected vehicle/engine or replaced components also fails, it would be reported to the Nodal Agency by the concerned Test Agency and the agency will await instructions from the Nodal Agency for further action.

COP CERTIFICATE

30 If the vehicle/engine meets the requirements of COP, the test agency will issue a COP certificate to the manufacturer. The certificate for COP will cover the vehicle/engine model and its variants produced/planned to be produced during the COP interval. The test agency will also send the copies of the COP certificate to other testing and Nodal Agencies.

EXTENDED COP TESTS

31 If the test for COP on the vehicle/engine model has to be continued as per para 8.4 of Chapter 1 of part IX for BS II for 4 wheeler vehicles and para 8.2.2.8 of chapter 1 of part XI for BS II and for 2/3 wheeler vehicles for BS III for 4 wheeler vehicles. Para 8.4.11 of chapter 1 of part XIII for BS III for 2/3 wheeler

vehicles, part XIV for 4 wheeler vehicles, Para 3.2.1.2 of part XV subpart A for agricultural tractor/construction equipment engines, para 8.2.1 of chapter 1 of part IV, para 7.2.2.5 chapter 1 for BS II diesel engine and para 9.1.1.1.1 and Chapter 1 part XII for BS III diesel engines, Appendix 1 of Chapter 1 of part XV for BSIV engines, the test agency will immediately inform the manufacturers with copies to the Nodal and other Test Agencies about this. All the subsequent tests to this model for COP will be carried out by the same test agency for that COP. If the testing is not completed till the end of the next COP period, then, a sample of the vehicle/engine produced in the next COP period will be selected and taken up for testing after the earlier test has been completed.

32 In the case when action as per para 31.0 has to be taken, the manufacture should offer adequate number of vehicles/engines for random selection of the above 'n'/10 vehicles/engines, or N/32 vehicles/engines as the case may be, immediately within 2 weeks unless its production/ Import is not then scheduled. In that event, the samples should be offered for random selection from the first lot of production/ Import within 2 weeks of start of production/ Import without implementing any design/production modifications which would affect emission performance.

33 The test agency should endeavour to complete further testing of the samples of the vehicles/engines selected according to para 31.0 within 6 weeks from the date of selection of the samples. If the vehicle/engine selected as per para 31.0 meet the requirements of COP, the test agency will issue a COP certificate to the manufacturer.

CONSEQUENCES OF FAILURE

34 If the vehicle/engine fails to meet the requirements of COP, the testing agency shall send the copies of the test report to the nodal agency and the manufacturer. The nodal agency will make a decision and convey the same to the manufacturer and test agencies within 4 weeks of the receipt of the failure report of the COP, after calling for a Standing Committee meeting to discuss and advise the nodal agency. The vehicle/engine manufacturer will be given an opportunity to present his case to the committee before advising the nodal agency. Based on the recommendations of the committee, the nodal agency may issue the order for withdrawal of type approval certificate and stop dispatch of the vehicles/engines by the manufactures from his works.

35 In case the type approval certificate has been withdrawn as per Para 34.0 above, the manufacturer can subsequently identify the reason for not meeting the COP and necessary corrective measures. Then they should inform the same to the Nodal and concerned test Agency and offer the rectified vehicle/engine for testing. The test agency will carry out a complete test as per the relevant type approval procedure on this rectified vehicle/engine. If the modifications are only in the production process without involving any model change, it should meet the COP norms. If the modifications call for changes resulting in a model change, it should meet the type approval norms. If the modified vehicle/engine passes the relevant norms, the manufacturer will write to the Nodal and concerned Test

Agency which has carried out the test, the modifications which are to be finally carried out on the vehicles/engines to be produced/ Imporetd in future and the vehicles/engines which require retrofitting/rectifications. Type approval will be restored by the nodal agency subject to Para 38.0. Further, a special COP will be carried out within a month, if a regular COP is not scheduled within that period. If the regular COP is scheduled within that period, a special COP need not be carried out.

36 The manufacturer can also offer the rectified vehicle/engine from serially produced vehicles/engines, for random selection if the changes do not constitute a model change. In case the manufacturer offers serially produced vehicle/engine for random selection instead of a submitted sample, the special COP mentioned above need not be carried out.

37 If a manufacturer identifies the reason for not meeting the COP and the necessary corrective actions (if the corrective measures do not constitute a model change), when actions under Para 31.0 to 36.0 are on-going, the manufacturer should inform the same to the Nodal and concerned test Agency and request to abort the actions on-going under Para 31.0 to 36.0 and offer the vehicle/engine for carrying out the tests as per Para 35.0 and 36.0. Then the testing agency will carry out the test as per Para 35.0 and 36.0 and report the results to the nodal agency. If the vehicle/engine meets the requirements, then the nodal agency will instruct the test agency to issue the COP certificate along with instructions to the manufacturer to carry out corrective actions, if any, within a stipulated period as per Para 38.0. The COP certificate will be issued by the test agency after the special COP vehicle / engine meets the requirements, if the case calls for it. If the vehicle/engine does not meet the requirements, action under Para 34.0 will follow.

38 It is the responsibility of the manufacturer to ensure at his cost that the modifications/modified components are carried out / retrofitted, within a period specified by the nodal agency, on all the vehicles / engines produced / dispatched in the period between the dates of which the COP became due as per Para 11.0 and restoration of the type approval by the nodal agency as per Para 35.0 or when the nodal agency has informed the test agency and the manufacturer as per Para 37.0.

# PART VII : DETAILS FOR STANDARDS FOR EMISSIONS OF EVAPORATIVE AND CRANK-CASE EMISSIONS FROM PETROL ENGINES EFFECTIVE FROM 1.4.1996


CHAPTER 1 : TYPE III TEST
(VERIFYING EMISSIONS OF CRANKCASE GASES)

CHAPTER 2 : TYPE-IV TEST
(THE DETERMINATION OF EVAPORATIVE EMISSIONS FROM VEHICLES WITH SPARK-IGNITION ENGINES)

CHAPTER 3 : CALIBRATION OF EQUIPMENT FOR EVAPORATIVE EMISSION TESTING

## CHAPTER 1: DETAILS FOR STANDARDS FOR EMISSIONS OF EVAPORATIVE AND CRANK-CASE EMISSIONS FROM PETROL ENGINES EFFECTIVE FROM 1.4.1996

TYPE III TEST
(Verifying Emissions of Crankcase Gases)

1 INTRODUCTION:

This chapter describes the procedure for the Type III test.

This is applicable for the passenger cars manufactured from 1.4.1996.

While preparing this standard considerable assistance has been taken from:

a) 91/441/EEC Air pollution by emission from motor vehicles.

2 GENERAL PROVISIONS:

2.1 Type III Test is carried out on the vehicle fitted with petrol engine subjected to the type I and the type II test.

2.2 The engines tested must include leak-proof engines other than those so designed that even a slight leak may cause unacceptable operating faults (such as flat-twin engines).

3 TEST CONDITIONS:

3.1 Idling must be regulated in conformity with the manufacturer's recommendations.

3.2 The measurement are performed in the following three sets of conditions of engine operation:

| Condition No. | Vehicle Speed (km/h) |
|---|---|
| 1 | Idling |
| 2 | 50 ± 2 (in 3rd gear or "drive") |
| 3 | 50 ± 2 (in 3rd gear or "drive") |

| Condition No. | Power absorbed by brake |
|---|---|
| 1 | Nil |
| 2 | That corresponding to the settings for type I tests |
| 3 | That for conditions No.2 multiplied by a factor of 1.7 |

4 TEST METHOD:

4.1 For the operation conditions as listed in 3.2 reliable function of the crankcase ventilation system must be checked.

5 METHOD OF VERIFICATION OF THE CRANKCASE VENTILATION SYSTEM: (Refer also to Figure 1)

5.1 The engine's apertures must be left as found.

5.2 The pressure in the crankcase is measured at an appropriate location. It is measured at the dipstick hole with an inclined tube manometer.

5.3 The vehicle is deemed satisfactory if, in every condition of measurement defined in 3.2, the pressure measured in the crankcase does not exceed the atmospheric pressure prevailing at the time of measurement.

5.4 For the test by the method described above, the pressure in the intake manifold is measured to within ± 1kPa.

5.5 The vehicle speed as indicated at the dynamometer is measured to within ± 2 km/h.

5.5 The pressure measured in the crankcase is measured to within ± 0.01 kPa.

5.7 If in one of the conditions of measurement defined in 3.2 the pressure measured in the crankcase exceeds the atmospheric pressure, an additional test as defined in para 6 is performed if so requested by the manufacturer.

6 ADDITIONAL TEST METHOD:

6.1 The engine's apertures must be left as found.

6.2 A flexible bag impervious to crankcase gases and having a capacity of approximately five litres is connected to the dip stick hole. The bag must be empty before each measurement.

6.3 The bag must be closed before each measurement. It must be opened to the crankcase for five minutes for each condition of measurement prescribed in 3.2

6.4 The vehicle is deemed satisfactory if in every condition of measurement defined in 3.2 no visible inflation of the bag occurs.

6.5 Remark:

6.5.1 If the structural layout of the engine is such that the test cannot be performed by the methods described in para 6.1 - the measurements must be effected by that method modified as follows:

6.5.2 Before the test, all apertures other than that required for the recovery of the gases are closed.

The bag is placed on a suitable take-off which does not introduce any additional loss of pressure and is installed on the recycling circuit of the device directly at the engine-connection aperture.

## CHAPTER 2 : TYPE-IV TEST

(The Determination of Evaporative Emissions from Vehicles with Spark-Ignition Engines)

1 INTRODUCTION:

This chapter describes a method for the determination of the loss of hydrocarbons by evaporation from the fuel systems of vehicles with spark ignition engines.

This is applicable for the passenger cars manufactured from 1.4.1996.

While preparing this standard considerable assistance has been taken from:

a) 91/441/EEC Air pollution by emission from motor vehicles.

2 DESCRIPTION OF TEST:

The evaporative emission test (Figure 1) consists of four phases:
- test preparation,
- tank breathing loss determination,
- Modified Indian Driving cycle (Part I and Part II)
- hot soak loss determination.

Mass emissions of hydrocarbons from the tank breathing loss and the hot soak loss phases are summed to provide an overall result for the test.

4 VEHICLE AND FUEL:

3.1 Vehicle

3.1.1 The vehicle must be in good mechanical condition and have been run in and driven at least 3000 km or less as per manufacturer's choice before the test. The evaporative emission control system must be connected and functioning correctly over this period and the carbon canister subjected to normal use, neither undergoing abnormal purging nor abnormal loading.

3.2 Fuel

3.2.1 The tests shall be conducted with the reference fuel as specified in the applicable gazette notification. However, at the manufacturer's request the tests may be carried out with the commercial fuel.

4 TEST EQUIPMENT

4.1 Chassis dynamometer

The chassis dynamometer must meet the requirements of Part-III.

4.2 Evaporative emission measurement enclosure.

The evaporative emission measurement enclosure must be a gastight rectangular measuring chamber able to contain the vehicle under test. The vehicle must be accessible from all sides and the enclosure when sealed must be gas tight in accordance with Appendix-I. The inner surface of the enclosure must be impermeable to hydrocarbons. At least one of the surfaces must incorporate a flexible impermeable material to allow the equilibration of pressure changes resulting from small changes in temperature. Wall design must be such as to promote good dissipation of heat. The temperature of the wall must not drop below 293 K (20°C) at any point during testing.

4.1 Analytical systems

4.3.1 Hydrocarbon analyser

4.3.1.1 The atmosphere within the chamber is monitored using a hydrocarbon detector of the flame ionisation detector (FID) type. Sample gas must be drawn from the midpoint of one side wall or roof of the chamber and any bypass flow must be returned to the enclosure, preferably to a point immediately downstream of the mixing fan.

4.3.1.2 The hydrocarbon analyser must have a response time to 90% of final reading of less than 1.5 seconds. Its stability shall be better than 2% of full scale at zero and at 80 ± 20% of full scale over a 15-minute period for all operational ranges.

4.3.1.3 The repeatability of the analyser expressed as one standard deviation shall be better than 1% of full scale deflection at zero and at 80 ± 20% of full scale on all ranges used.

4.3.1.4 The operational ranges of the analyser must be chosen to give best resolution over the measurement, calibration and leak checking procedures.

4.3.2 Hydrocarbon analyser data recording system:

4.3.2.1 The hydrocarbon analyser must be fitted with a device to record electrical signal output either by strip chart recorder or other data-processing system at a frequency of at least once per minute. The recording system must have operating characteristics atleast equivalent to the signal being recorded and must provide a permanent record of results. The record shall show a positive indication of the beginning and end of the fuel tank heating and hot soak periods together with the time elapsed between start and completion of each test

4.4 Fuel tank heating

4.4.1 The fuel in the vehicle tank(s) must be heated by a controllable source of heat, for example a heating pad of 2000 W capacity is suitable. The heating system must apply heat evenly to the tank walls beneath the level of the fuel so as not to cause local overheating of the fuel. Heat must not be applied to the vapour in the tank above the fuel.

4.4.2 The tank heating device must make it possible to evenly heat the fuel in the tank by 14 K from 289K ( 16 °C) within 60 minutes, with the temperature sensor position as in section 5.1.1. The heating system must be capable of controlling the fuel temperature to ± 1.5 K of the required temperature during the tank heating process.

4.5 Temperature recording

4.5.1 The temperature in the chamber is recorded at two points by temperature sensors which are connected so as to show a mean value. The measuring points are extended approximately 0.1m into the enclosure from the vertical centre line of each side wall at a height of 0.9 ± 0.2m.

4.5.2 The temperatures of the fuel tank(s) shall be recorded by means of the sensor positioned in the fuel tank as in section 5.1.1.

4.5.3 Temperatures must, throughout the evaporative emission measurements, be recorded or entered in to a data processing system at a frequency of at least once per minute.

4.5.4 The accuracy of the temperature recording system must be within ± 1.0 K and the temperature must be capable of being resolved to 0.4 K.

4.5.5 The recording or data processing system must be capable of resolving time to ± 15 seconds.

4.6 Fans

4.6.1 By the use of one or more fans or blowers with the SHED door(s) open it must be possible to reduce the hydrocarbons concentration in the chamber to the ambient hydrocarbon level.

4.6.2 The chamber must have one or more fans or blowers of likely capacity 0.1 to 0.5 $m^3$ /s with which to thoroughly mix the atmosphere in the enclosure. It must be possible to attain an even temperature and hydrocarbon concentration in the chamber during measurements. The vehicle in the enclosure must not be subjected to a direct stream of air from the fans or blowers.

4.7 Gases

4.7.1 The following pure gases must be available for calibration and operation:

- purified synthetic air (purity: < 1 ppm $C_1$ equivalent, ≤ 1 ppm CO, ≤ 400 ppm $CO_2$ , ≤ 0.1 ppm NO)
: oxygen content between 18 and 21% by volume.

- hydrocarbon analyser fuel gas (40 ± 2% hydrogen, and balance

helium with less than 1 ppm $C_1$ equivalent hydrocarbon, less than 400 ppm CO ).

- propane ($C_3H_8$ ), 99.5% minimum purity.

4.7.2 Calibration and span gases shall be available containing mixtures of propane ($C_3H_8$ ) and purified synthetic air. The true concentrations of a calibration gas must be within ± 2% of the stated figures. The accuracy of the diluted gases obtained when using a gas divider must be to within ± 2% of the true value. The concentrations specified in Chapter-3 may also be obtained by the use of a gas divider using synthetic air as the diluent gas.

4.8 Additional equipment

4.8.1 The absolute humidity in the test area must be measurable to within ± 5%.

4.8.2 The pressure within the test area must measurable to within ± 0.1 kPa.

5 TEST PROCEDURE

8.2 Test preparation

5.1.1 The vehicle is mechanically prepared before the test as follows:

- The exhaust system of the vehicle must not exhibit any leaks,

- The vehicle may be steam cleaned before the test,

- The fuel tank of the vehicle must be equipped with a temperature sensor to enable the temperature to be measured at the midpoint of the fuel in the fuel tank when filled to 40% of its capacity.

- Additional fittings, adapters of devices must be fitted to allow a complete draining of the fuel tank.

5.1.2 The vehicle is taken into the test area where the ambient temperature is between 293 and 303 K (20°and 30°C).

5.1.3 The canister of the vehicle is purged for 30 minutes by driving the car at 60 km/h at the dynamometer setting prescribed in Chapter-3 of Part-III or by passing air (at room temperature and humidity) through the canister at a flow rate which is identical to the actual air flow through the canister when operating the car at 60 km/h. The canister is subsequently loaded with two diurnal emissions tests.

5.1.4 The fuel tank(s) of the vehicle is (are) emptied using the fuel tank drain(s) provided. This must be done so as not to abnormally purge nor abnormally load the evaporative control devices fitted to the vehicle. Removal of the fuel cap(s) will normally be sufficient to achieve this.

5.1.5 The fuel tank(s) is(are) refilled with the specified test fuel at a temperature of between 283 and 287 K (10° and 14°C) to 40% ± 2% of its/their normal fuel capacity. The vehicle's fuel cap(s) must not be replaced at this point.

5.1.6 In the case of vehicles fitted with more than one fuel tank, all the tanks must be heated in the same way, as described below. The temperatures of the tanks must be identical to within ± 1.5K.

5.1.7 The fuel may be initially heated to the starting temperature of 289 K (16°C) ± 1 K.

As soon as the fuel reaches a temperature of 287 K (14°C), the fuel tank(s) must be sealed. When the temperature of the fuel tank reaches 289 K (16°C) ± 1K a linear heat build of 14 ± 0.5 K over a period of 60 ± 2 minutes begins. The temperature of the fuel during the heating shall conform to the function below to within ± 1.5 K:

$T_F = T_0 + 0.2333 * t$

where:

Tf = required temperature (K)

$T_0$ = initial temperature of tank (K)

t = time from start of the tank heat build in minutes.

The elapsed time of the heat build and temperature rise is recorded.

5.1.8 After a period of not more than one hour, the operations of fuel draining and filling begin according to 5.1.4, 5.1.5, and 5.1.7.

5.1.9 Within two hours of the end of the first tank heating period the second fuel tank heating operation begins as specified in and must be completed with the recording of the temperature rise and elapsed time of the heat build.

5.1.10 Within one hour of the end of the second tank heat build the vehicle is placed on a chassis dynamometer and is driven through one Part One and two Part Two Driving cycles on chassis dynamometer. Exhaust emissions are not sampled during this operation.

5.1.11 Within five minutes of completing the preconditioning operation specified in 5.1.11 the engine bonnet must be completely closed and the vehicle driven off the chassis dynamometer and parked in the soak area. The vehicle is parked for a minimum of 10 hours and a maximum of 36 hours. The engine oil and coolant temperatures must have reached the temperature of the area of within ± 2 K at the end of the period.

5.2 Tank breathing evaporative emission test

5.2.1 The operation of 5.2.4 may begin not less than nine hours not more than 35 hours after the preconditioning driving cycle.

5.2.2 The measuring chamber shall be purged for several minutes immediately before the test until a stable background is obtainable. The chamber mixing fan(s) must be switched on at this time also.

5.2.3 The hydrocarbon analyser must be zeroed and spanned immediately before the test.

5.2.4 The fuel tank(s) must be emptied as in 5.1.4 and refilled with test fuel at a temperature of between 283 and 287 K (10° and 14°C) to 40 ± 2% of the tank's normal volumetric capacity.

5.2.5 The fuel cap(s) of the vehicle must not be fitted at this point.

In the case of vehicles fitted with more than one fuel tank, all the tanks shall be heated in the same way,as described below. The temperatures of the tanks must be identical to within ± 1.5 K.

5.2.6 The test vehicle shall be brought into the test enclosure with the engine switched off and the windows and luggage compartment open. The fuel tank sensors and the fuel tank heating device, if necessary, shall be connected. Immediately begin recording the fuel temperature and the air temperature within the enclosure. The purging fan if still operating is switched off at this time.

5.2.7 The fuel may be artificially heated to the starting temperature of 289 K (16°C) ± 1 K.

5.2.8 As soon as the fuel temperature reaches 287 K (14°C) the fuel tank(s) must be sealed and the chamber sealed so that it is gas-tight.

5.2.9 As soon as the fuel reaches a temperature of 289K (16°C) ± 1 K.

- the hydrocarbon concentration, barometric pressure and the temperature are measured to give the initial readings $C_{HCi}$ , $P_i$ and $T_i$ , for the tank heat build test.

- a linear heat build of 14 ± 0.5 K over a period of 60 ± 2 minutes shall begin. The temperature of the fuel during the heating shall conform to the function below to within ± 1.5 K:

$T_f = T_o + 0.2333 * t$

where:
$T_f$ = required temperature (K)
$T_o$ = initial temperature of tank (K)
t = time from start of the tank heat build in minutes.

5.2.10 The hydrocarbon analyser is zeroed and spanned immediately before the end of the test.

5.2.11 If the temperature has risen by 14 K ± 0.5 K over the 60 ± 2 minutes period of the test the final hydrocarbon concentration in the enclosure is measured ($C_{HCf}$ ). The time or elapsed time Hcf of this together with the final temperature and barometric pressure $T_f$ and $P_f$ for the hot soak is recorded.

5.2.12 The heat source is turned off and the enclosure door unsealed and opened. The heating device and temperature sensor are disconnected from the enclosure apparatus. The vehicle doors and luggage compartment may now be closed and the vehicle removed from the enclosure with the engine switched off.

5.2.13 The vehicle is prepared for the subsequent driving cycle and hot soak evaporative emission test. The cold start test must follow the tank breathing test by a period of not more than one hour.

5.2.14 The testing agency may consider that the design of the vehicle's fuel system may allow losses to the outside atmosphere at any point. In this case an engineering analysis must be carried out to the satisfaction of the testing agency to establish that vapours are vented to the carbon canister and that these vapours are adequately purged during vehicle operation.

5.3 Driving Cycle:

5.3.1 The determination for evaporative emissions is concluded with the measurement of hydrocarbon emissions over a 60 minute hot soak period following modified Indian Driving cycle i.e. through one Part One and Part Two Driving cycles on chassis dynamometer. Following the tank breathing losses test, the vehicle is pushed or otherwise manoeuvred onto the chassis dynamometer with the engine switched off. It is then driven through an urban driving cycle as described in Part-III. Exhaust emissions may be sampled during this operation but the results are not used for the purpose of exhaust emission type approval.

5.4 Hot soak evaporative emissions test:

5.4.1 Before the completion of the test run the measuring chamber must be purged for several minutes until a stable hydrocarbon background is obtained. The enclosure mixing fan(s) must also be turned on at this time.

5.4.2 The hydrocarbon analyser must be zeroed and spanned immediately prior to the test.

5.4.3 At the end of the driving cycle the engine bonnet must be completely closed and all connections between the vehicle and the test stand disconnected. The vehicle is then driven to the measuring chamber with a minimum use of the accelerator pedal. The engine must be turned off before any part of the vehicle enters the measuring chamber. The time at which the engine is switched off is recorded on the evaporative emission measurement data recording system and temperature recording begins. The vehicle's windows and luggage compartments must be opened at this stage, if not already opened.

5.4.4 The vehicle must be pushed or otherwise moved into the measuring chamber with the engine switched off.

5.4.5 The enclosure doors are closed and sealed gas-tight within two minutes of the engine being switched off and within seven minutes of the end of the driving cycle.

5.4.6 The start of a 60 ± 0.5 minute hot soak period begins when the chamber is sealed. The hydrocarbon concentration, temperature and barometric pressure are measured to give the initial readings $C_{HCi}$ , $P_i$ and $T_i$ for the hot soak test. These figures are used in the evaporative emission calculation, section 6. The ambient SHED temperature T must not be less than 296 K and not more than 304 K during the 60 minute hot soak period.

5.4.7 The hydrocarbon analyser must be zeroed and spanned immediately before the end of the 60 ± 0.5 minute test period.

5.4.8 At the end of the 60 ± 0.5 minute test period measure the hydrocarbon concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings $C_{HCf}$ , $P_f$ and $T_f$ for the hot soak test used for the calculation in section 6. This completes the evaporative emission test procedure.

6 CALCULATION:

6.1 The evaporative emission tests described in section 5 allow the hydrocarbon emissions from the tank breathing and hot soak phases to be calculated. Evaporative losses from each of these phases is calculated using the initial and final hydrocarbon concentrations, temperatures and pressures in the enclosure, together with the net enclosure volume.

The formula below is used:

$$M_{HC} = k * V * 10^{-4} [ C_{HCf} * P_f / T_f - C_{HCi} * P_i / T_i]$$

where:

$M_{HC}$ = mass of hydrocarbon emitted over the test phase (grams).

$C_{HC}$ = measured hydrocarbon concentration in the enclosure (ppm(volume)C equivalent).

V = net enclosure volume in cubic metres corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of $1.42 m^3$ is subtracted.

T = ambient chamber temperature, K.

P = barometric pressure in kPa.

H/C = hydrogen to carbon ratio.

k = 1.2 (12 + H/C):
when:
i is the initial reading.

f is the final reading.

H/C is taken to be 2.33 for tank breathing losses.

H/C is taken to be 2.20 for hot soak losses.

6.2 Overall results of test

The overall hydrocarbon mass emission for the vehicle is taken to be:

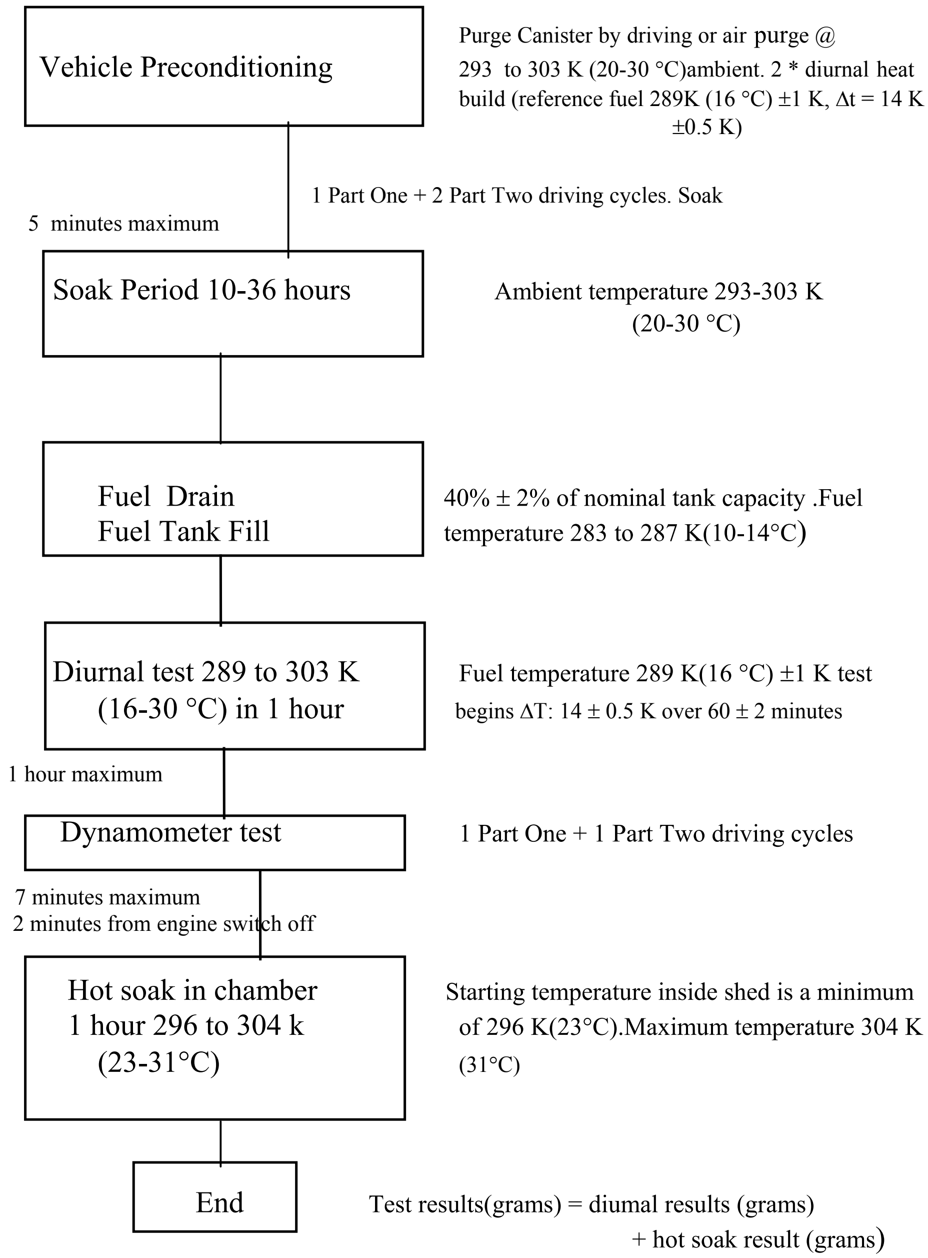
$M_{total} = M_{TH} + M_{HS}$

$M_{total}$ = overall mass emissions of the vehicle (grams).

$M_{TH}$ = hydrocarbon mass emission for the tank heat build (grams).

$M_{HS}$ = hydrocarbon mass emission for the hot soak (grams).

FIGURE 1. EVAPORATIVE EMISSION DETERMINATION
3000 km run-in period (no excessive purge /load ) as per manufacturer's choice , Steam clean of vehicle (if necessary)




Note:

1. Tailpipe emissions may be measured during dynamometer test ,but these are not used for certification

7 EXTENSION OF TYPE APPROVAL

7.1 Approval granted to a vehicle type equipped with a control system for evaporative emissions may be extended under the following conditions :

7.2 The basic principle of fuel/air metering (e.g. single point injection, carburettor)must be the same.

7.3 The shape of the fuel tank and the material of the fuel tank and liquid fuel hoses must be identical. The worst-case family with regard to the cross-section and approximate hose length must be tested. Whether non-identical vapour liquid separators are acceptable is decided by the test agency responsible for the type approval tests. The fuel tank volume must be within a range of ± 10 %. The setting of the tank relief valve must be identical.

7.4 The method of storage of the fuel vapour must be identical, i.e. trap form and volume, storage medium, air cleaner(if used for evaporative emission control), etc.

7.5 The carburettor bowl fuel volume must be within a 10 millilitre range.

7.6 The method of purging of the stored vapour must be identical(e.g. air flow, start point or purge volume over driving cycle).

7.7 The method of sealing and venting of the fuel metering system must be identical.

7.8 Further notes :

(i) different engine sizes are allowed;
(ii) different engine powers are allowed;
(iii) automatic and manual gear boxes, two and four wheel transmissions are allowed;
(iv) different body styles are allowed;
(v) different wheel and tyre sizes are allowed;

8.0 CONFORMITY OF PRODUCTION:

8.1 For routine end of production-line testing, the holder of the approval may demonstrate compliance by sampling vehicles which shall meet the following requirements.

8.2 Test for leakage:

8.2.1 Vents to the atmosphere from the emission control system shall be isolated.

8.2.2 A pressure of 370 ± 10 mm of $H_2O$ must be applied to the fuel system.

8.2.3 The pressure must be allowed to stabilize prior to isolating the fuel system from the pressure source.

8.2.4 Following isolation of the fuel system, the pressure must not drop by more than 50 mm of $H_2O$ in five minutes.

8.3 Test for Venting:

8.3.1 Vents to the atmosphere from the emission control must be isolated.

8.3.2 A pressure of 370 ± 10 mm of $H_2O$ must be applied to the fuel system.

8.3.3 The pressure must be allowed to stabilize prior to isolating the fuel system from the present source.

8.3.4 The venting outlets from the emission control systems to the atmosphere must be reinstated to the production condition.

8.3.5 The pressure of the fuel system must drop to below 100 mm of $H_2O$ in not less than 30 seconds but within two minutes.

8.3.6 At the request of the manufacture the functional capacity for venting can be demonstrated by equivalent alternative procedure. The specific procedure should be demonstrated by the manufacturer to the technical service during the type approval procedure.

8.4 Purge Test:

8.4.1 Equipment capable of detecting an airflow rate of 1.0 litres in one minutes must be attached to the purge inlet and a pressure vessel of sufficient size to have negligible effect on the purge system must be connected via a switching valve to the purge inlet, or alternatively.

8.4.2 The manufacturer may use a flow meter of his own choice, if acceptable to the competent authority.

8.4.3 The vehicle must be operated in such a manner that any design features of the purge system that could restrict purge operation is detected and the circumstances noted.

8.4.4 Whilst the engine is operating within the bounds note in 8.4.3 the air flow must be determined by either.

8.4.4.1 The device indicated in 8.4.1 being switched in. A pressure drop from atmosphere to a level indicating that a volume of 1.0 litres of air has flowed into the evaporative emission control system within one minute must be observed: or

8.4.4.2 If an alternative flow measuring device is used, a reading of no less than 1.0 litre per minute must be detectable.

8.4.4.3 At the request of the manufacturer an alternate purge test procedure can be used, if the procedure has been presented to and has been accepted by the technical service during type approval procedure.

8.5 If the requirements of 8.2, 8.3 & 8.4 are not met, the manufacturers must ensure that all necessary steps are taken to re-establish the Conformity of Production as rapidly as possible but in no case exceeding two months by conducting a test on a randomly selected vehicle as per Part VII Chapter 2.

## CHAPTER 3 : CALIBRATION OF EQUIPMENT FOR EVAPORATIVE EMISSION TESTING

1 CALIBRATION FREQUENCY AND METHODS

1.1 All equipment must be calibrated before its initial use and then calibrated as often as necessary and in any case in the month before type-approval testing. The calibration methods to be used are described in this Appendix.

2 CALIBRATION OF THE ENCLOSURE:

2.1 Initial determination of enclosure internal volume

2.1.1 Before its initial use, the internal volume of the chamber must be determined as follows. The internal dimensions of the chamber are carefully measured, allowing for any irregularities such as bracing struts. The internal volume of the chamber is determined from these measurements.

2.1.2 The net internal volume is determined by subtracting 1.42 $m^3$ from the internal volume of the chamber. Alternatively the volume of the test vehicle with the luggage compartment and windows open may be used instead of the 1.42$m^3$ .

2.1.3 The chamber must be checked as in item 2.3. If the propane mass does not agree with the injected mass to within ± 2% then corrective action is required.

2.2 Determination of chamber background emissions

This operation determines that the chamber does not contain any materials that emit significant amounts of hydrocarbons. The check must be carried out at the enclosure's introduction to service, after any operation in the enclosure which may affect background emissions and at a frequency of at least once per year.

2.2.1 Calibrate the analyser (if required), then zero and span.

2.2.2 Purge the enclosure until a stable hydrocarbon reading is obtained. The mixing fan is turned on if not already on.

2.2.3 Seal the chamber and measure the background hydrocarbon concentration, temperature and barometric pressure. These are the initial readings $C_{HCi}$ , Pi and Ti used in the enclosure background calculation.

2.2.4 The enclosure is allowed to stand undisturbed with the mixing fan on for a period of four hours.

2.2.5 At the end of this time use the same analyser to measure the hydrocarbon concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings $C_{HCf}$, $P_f$ and $T_f$ .

2.2.6 Calculate the change in mass of hydrocarbons in the enclosure over the time of the test according to section 2.4 The background emission of the enclosure must not exceed 0.4 g.

2.3 Calibration and hydrocarbon retention test of the chamber:

The calibration and hydrocarbon retention test in the chamber provides a check on the calculated volume in 2.1 and also measures any leak rate.

2.3.1 Purge the enclosure until a stable hydrocarbon concentration is reached. Turn on the mixing fan, if not already switched on. The hydrocarbon analyser is zeroed, calibration if required, and spanned.

2.3.2 Seal the enclosure and measure the background concentration, temperature and barometric pressure. These are the initial readings $C_{Hci}$ , $P_I$ and $T_I$ used in the enclosure calibration.

2.3.3 Inject a quantity of approximately 4 grams of propane into the enclosure. The mass of propane must be measured to an accuracy and precision of ± 0.5% of the measured value.

2.3.4 Allow the contents of the chamber to mix for five minutes and then measure the hydrocarbon concentration, temperature and barometric pressure. These are the final readings $C_{HCf}$ , $P_f$ and $T_f$ for the calibration of the enclosure.

2.3.5 Using the readings taken in 2.3.2 and 2.3.4 and the formula in 2.4, calculate the mass of propane in the enclosure. This must be within ± 2% of the mass of propane measured in 2.3.3.

2.3.6 Allow the contents of the chamber to mix for a minimum of four hours. At the end of this period measure and record the final hydrocarbon concentration, temperature and barometric pressure.

2.3.7 Calculate using the formula in 2.4, the hydrocarbon mass from the readings taken in 2.3.6 and 2.3.2. The mass may not differ by more than 4% from the hydrocarbon mass given by 2.3.5.

2.4 Calculation

The calculation of net hydrocarbon mass change within the enclosure is used to determine the chamber's hydrocarbon background and leak rate. Initial and final readings of hydrocarbons concentration, temperature and barometric pressure are used in the following formula to calculate the mass change.

$$M_{HC} = k * V * 10^{-4} [ C_{HCf} * P_f / T_f - C_{HCi} * P_i / T_i ]$$

where:

$M_{HC}$ = hydrocarbon mass in grams.

$C_{HC}$ = hydrocarbon in the enclosure (ppm Carbon (NB: ppm carbon = ppm propane *3)),

V = enclosure volume in cubic metres.

T = ambient temperature in the enclosure, K.

P = barometric pressure in kPa.

k = 17.6 :

when:

i is the initial reading.

f is the final reading.

3 CHECKING OF FID HYDROCARBON ANALYSER:

3.1 Detector response optimization:

The FID must be adjusted as specified by the instrument manufacturer. Propane in air should be used to optimize the response on the most common operating range.

3.2 Calibration of the HC analyser:

The analyser should be calibrated using propane in air and purified synthetic air. See section 4.5.2 of Part III (Calibration and span gases).

Establish a calibration curve as described in sections 4.1 to of this Chapter.

3.3 Oxygen interference check and recommended limits:

The response factor (R ) for a particular hydrocarbon species f in the ratio of the FID C reading to the gas cylinder concentration, expressed as ppm C . The concentration of the test gas must be at a level to give a response of approximately 80% of full scale deflection, for the operating range. The concentration must be known, to an accuracy of ± 2% in reference to a gravimetric standard expressed in volume. In addition the gas cylinder must be preconditioned for 24 hours at a temperature between 293 K and 303 K (20° and 30°C). Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The reference gas to be used is propane with balance purified air which is taken to give a response factor of 1.00.
The test gas to be used for oxygen interference and the recommended response factor range are given below:

Propane and nitrogen $0.95 \leq Rf \leq 1.05$.

4 CALIBRATION OF THE HYDROCARBON ANALYSER

Each of the normally used operating ranges are calibrated by the following procedure:

4.1 Establish the calibration curve by at least five calibration points spaced at evenly as possible over the operating range. The nominal concentration of the calibration gas with the highest concentration to be at least 80% of the full scale.

4.2 Calculate the calibration curve by the method of least squares. If the resulting polynominal degree is greater than then the number of calibration points must be at least the number of the polynominal degree plus 2.

4.3 The calibration curve must not differ by more than 2% from the nominal value of each calibration gas.

4.4 Using the coefficients of the polynominal derived from 3.2, a table of indicated reading against true concentration shall be drawn up in steps of no grater than 1% of full scale. This is to be carried out for each analyser range calibrated. The table shall also contain other relevant data such as:
date of calibration, span and zero potentiometer readings (where applicable)
nominal scale, reference data of each calibration gas used.

The actual and indicated value of each calibration gas used together with the percentage differences.

FID fuel and type,
FID air pressure

4.5 If it can be shown to the satisfaction of the Regulatory Agency that alternative technology (e.g. computer, electronically controlled range switch) can give equivalent accuracy, then those alternative may be used.

| MoRTH/CMVR/ TAP-115/116 | STANDARDS FOR TESTING OF SMOKE METERS AND GAS ANALYSERS | |
|---|---|---|
| ISSUE NO. 4 | | PART VIII |

# PART VIII : STANDARDS FOR TESTING OF SMOKE METERS AND GAS ANALYSERS

CHAPTER-I : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF SMOKE METERS

CHAPTER-II : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF 2-GAS ANALYSERS.

CHAPTER-III : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF 4-GAS ANALYSERS.

CHAPTER-IV : TEST PROCEDURE FOR CARRYING OUT CONFORMITY OF PRODUCTION TEST ON SMOKEMETERS

CHAPTER-V : TEST PROCEDURE FOR CARRYING OUT CONFORMITY OF PRODUCTION TEST ON 2-GAS ANALYSERS

CHAPTER-VI : TEST PROCEDURE FOR CARRYING OUT CONFORMITY OF PRODUCTION TEST ON 4-GAS ANALYSERS

## TESTING OF
## SMOKE METERS AND GAS ANALYSERS

INTRODUCTION

The Central Motor Vehicle Rule (CMVR) 116 requires that the field testing of vehicles as per CMVR-115(2) (a & b) shall be carried out with a meter which is type approved by the specified agencies provided that such a testing agency shall follow ISO or ECE Standards and Procedure for approval of measuring meters. As there were some problems in following the ISO and ECE Standards, MOST had constituted a Committee to formulate a uniform test procedure and specifications for measuring meters. The finalised test procedures and specifications approved by the MOST and amended from time to time, which are being used for the type testing of meters from 31st Oct 95 are given in chapter I, II and III. MOST has also introduced the conformity of production (COP) testing of these meters from 1st Jan 1997 and the test procedure for the same is given in chapter IV ,V and VI.

ADMINISTRATIVE PROCEDURE FOR COP TESTING

1.0 The Ministry of Surface Transport, New Delhi (MOST) is the Nodal Agency for implementation of Emission Legislation.

2.0 The MOST had constituted a Committee under the Chairmanship of Joint Secretary (Transport) to formulate a standard uniform procedure for testing of smoke meters, etc. This Committee has finalised the test specifications and procedure for type testing of smoke meters and Gas analysers (henceforth referred to as instrument).

3.0 This Committee has also decided to introduce conformity of production (COP) testing for the instrument manufactured / supplied in India to keep a check on the production quality of the instrument.

4.0 There is a Standing Committee on implementation of emission legislation constituted by MOST to advise the Nodal Agency in such implementation.

At present this Standing Committee is looking into the aspects of vehicle testing. It is proposed that the same Committee can function for the testing of the instruments. If found necessary, the instrument manufacturer's / suppliers representative may be invited for the Committee meeting.

COP TEST AGENCIES

1.0 The test agencies carrying out the type testing will be responsible for carrying out the COP test.

2.0 Initially, the instrument manufacturer / supplier has the option of choosing the test agency for type approval of its specific model. On completion of first COP by the same test agency, the manufacturer can change the test agency if so desired.

3.0 In case the instrument manufacturer / supplier desires to change the COP test agency, a formal request shall be made to the new test agency under intimation to the previous test agency and nodal agency. This request shall be made atleast one month before the next COP is due along with all relevant documents concerning type approval / previous COP.

4.0 On receipt of intimation of request for a change, the previous COP test agency will authenticate all the relevant documents of that model and forward to the New test agency. The new test agency will carry out the process of selection And testing of the instruments for COP as per the procedure and will consult the previous test agency if required about the test findings and results before issuing the final COP certificate.

COP PERIOD

1.0 The COP period for an instrument model will be 2.5 years from the date of type approval certification or supply of 200 units of the type approved instrument model or resumption of supply of the model or end of last COP period for that model whichever is earlier. If the production and supply of an instrument model is discontinued, it should either concide with COP test or COP test should be performed before the instrument model is discontinued even though COP criteria is not applicable. The instrument manufacturer / supplier may request the Nodal Agency for relaxation of the above period with justification. The Nodal Agency will take a decision based on the merit of the case.

2.0 An instrument is considered to be supplied when the instrument has been dispatched from the instrument manufacturer / supplier's premises.

3.0 The instrument manufacturer / supplier shall inform the Nodal Agency and concerned test agency as soon as 180 units have been supplied, and/or, after twenty eight months have passed from the date of type approval certificate. The concerned test agency keeps the track regarding this and in case the information is not received from the manufacturer / supplier, informs the Nodal Agency accordingly.

4.0 Test agency will ask for an instrument model type approved for COP testing before the COP period. The instrument manufacturer / supplier will submit the first available unit after the receipt of this request. The instrument manufacturer / supplier shall provide sufficient documents along with the instrument to support the fact that this is the first available unit after the receipt of request. The documents could be production final check documents showing the instrument serial number, bill of entry / purchase order in case of imported equipments, etc.

COP TESTING

The COP testing procedure for smoke meter and Gas analyser are given in Chapter IV,V and VI.

MODEL CHANGE AND VARIANCE

1.0 Generally, whenever there is a change in sensor, detector, electronic circuits, software, it shall be treated as new model and separate model number shall be given by the manufacturer / supplier. If any part is indigenised or there is any minor modification subsequent to the type approval testing, which will not affect the function of the instrument, the instrument manufacturer / supplier shall inform the details to test agency and test agency will decide whether the retesting is to be carried out.

COP CERTIFICATE

1.0 If the instrument meets the requirements of COP testing, the test agency will issue a COP Certificate to the manufacturer / supplier for the particular instrument model. The test agency will also send the copies of the COP certificate to other testing agencies and Nodal Agency.

CONSEQUENCE OF COP FAILURE

1.0 If the instrument fails to meet the requirements of COP, the testing agency shall send the copies of the test report to the Nodal Agency and the manufacturer / supplier. The Nodal Agency will take a decision and convey the same to the manufacturer / supplier and test agencies within 4 weeks of the receipt of The failure report of COP. The Nodal Agency may decide to call a meeting of the Standing Committee to discuss and advise the Nodal Agency. The instrument manufacturer / supplier may be given an opportunity to present his case to the Committee before advising the Nodal Agency. Upon reaching the decision the Nodal Agency will issue the order for withdrawal of Type Approval Certificate and stop dispatch of the instruments by the manufacturer / supplier from his works.

2.0 In case the type approval certificate has been withdrawn, as per point 1 above, the manufacturer / supplier can subsequently identify the reasons for not meeting the COP and necessary corrective measures. Then they shall inform the same to the Nodal Agency and concerned test agency and offer the rectified instrument for testing. The test agency carry out a complete test as per the Type approval procedure on the rectified instrument passes the relevant norms, the manufacturer / supplier will write to the Nodal Agency and concerned test agency which has carried out the test, the modifications which are to be finally carried out on the instruments to be supplied in future and the instruments which require retrofitting rectifications.

Type approval will be restored by the Nodal Agency subject to the point 3.0 below. Further a special COP will be carried out after 10 number of units have been supplied, using standard COP procedure.

**3.0 It is responsibility of the instrument manufacturer / supplier to ensure at his cost that the modifications / modified components are carried out / retrofitted within a period, specified by the Nodal Agency on all instruments supplied during the period between the dates test agency has sent the test report and restoration of the type approval by the Nodal Agency as per point 2 above.**

CODE OF PRACTICE FOR PUC EQUIPMENT MANUFACTURER / SUPLLIER

Based on the decision adopted in the Standing Committee on Emissions (SCOE) meeting held on 28th March 2003, every PUC equipment manufacturer / supplier shall comply with the following Code of Practice and submit an affidavit for the same along with the instrument model submitted for type approval to the respective Test Agency.

1. PUC equipment manufacturer/supplier shall include the description of the test procedure described in Part I or Part II, whichever is applicable, amended from time to time of the document MOST/CMVR/TAP 115/116 shall be included in the user's manual of the PUC equipment.

2. PUC equipment manufacturer/ supplier shall supply copy of type- approval certificate with date of validity along with the PUC equipment.

3. The validity of the type approval certificate of the PUC equipment shall be 5 years, after the expiry of which the PUC equipment manufacturer/ supplier shall get it re-validated from the test agency.

4. PUC equipment manufacturer / supplier shall provide the status of production/ supply of PUC equipment at a regular interval of 1 year to the test agency from where the equipment has been certified.

5. PUC equipment manufacturer / supplier shall submit the equipment for COP as per procedure mentioned above.

6. PUC equipment manufacturer/ supplier shall enter into AMC for a period of 5 years with the authorised PUC test agency based on agreed charges. The AMC shall be comprehensive (including spare parts) but does not include maintenance of PC/PC peripherals of the computerized PUC equipment. This AMC contract shall include 3 visits and equipment calibration as per field calibration procedure given in Annexure-1. PUC equipment manufacturer/ supplier shall provide calibration certificate as per format given in the Annexure-2.

7. PUC equipment manufacturer / supplier shall train minimum 3 operators of PUC test agency and shall provide training certificate as per format given in Annexure 3.

STANDARD FORMAT FOR TYPE APPROVAL TEST CERTIFICATE FOR PUC EQUIPMENT

Based on the decision adopted in the Standing Committee on Emissions (SCOE) meeting held on 28th March 2003, every test agency shall issue Type Approval Certificate for PUC Equipment as per format in Annexure- 4.

# Annexure - 1
# FIELD CALIBRATION PROCEDURE FOR TESTING OF

# GAS ANALYSERS

1.0 INTRODUCTION

This procedure has to be carried out on gas analysers after they are commissioned in the field and for the subsequent calibration.

2.0 TESTING

The test procedure for gas analysers is as follows :

i) Check that the power supply is as per specifications of the manufacturer and electrical earthing is proper.

ii) Check that all the accessories as per manufacturer are available and are functioning properly.

iii) Check the span and zero calibration using sample gas of suitable value for CO as well as HC.

iv) Check the electrical calibration.

v) Check that the sampling system is leakproof.

vi) The printer is working correctly and the print out details are correct.

vii) Checking of 1 no. of vehicle for idling emission measurement using this analyzer.

FIELD CALIBRATION PROCEDURE FOR TESTING OF

SMOKE METERS

## 3.0 INTRODUCTION

This procedure has to be carried out on meters after they are commissioned in the field and for the subsequent calibration.

## 4.0 TESTING

The test procedure for smoke meters is as follows :

i) After the warm-up of the meter, the calibration of the meter has to be checked at zero and midscale point with the neutral density filter available. The value must lie within 0.1 $m^{-1}$.

ii) The meter shall have the standard accessories as specified by the manufacturer. It shall be checked that the sample hose, internal pipes etc are not deteriorated or damaged to ensure that there is no leakage.

iii) The functionality of oil temperature and RPM sensor.

iv) The heating system for the optical chamber is functioning.

v) The purge air system is working correctly.

vi) Visual displays are functioning correctly.

vii) The printer is working correctly and the print out details are correct.

viii) The instrument casing is proper and has proper electrical earthing.

ix) Free acceleration test is carried out using a vehicle and the print out details are checked.

## Annexure – 2
## CALIBRATION CERTIFICATE FORMAT

| | | |
|---|---|---|
| 1.0 | Component: | |
| 2.0 | PUC Center<br>Registration No. : | |
| 3.0 | Objective of the test : To carry out Physical check and calibration of gas Analyser / Smoke meters as per the test procedure specified in Annexure 1 of CMVR / TAP 115-116 Part-8. | |
| 4.0<br>4.1<br><br>4.2 | Detailed Observations<br>Checking of supply/ earthing<br><br>Checking of accessories : Details of accessories checked. | |
| 4.3 | Span Calibration<br><br>2. Details of span gas concentration__________%<br>3. Calibration gas cylinder No.:__________<br>4. Calibration gas cylinder make:___________<br>5. Calibration gas validity date:___________<br><br>OR<br><br>1. Details of Natural Density filters used for mid point calibration | |
| 4.4 | Electrical Calibration OK/ Not OK | |
| 4.5 | Leak test : | Passed/ Failed |
| 5.0 | One no of petrol / diesel vehicle checked for idling Emission / Free acceleration, measurement | |
| 6.0 | Conclusion : | |
| 7.0 | Next Calibration Due Date: | |

**Signature & Seal of manufacturer/ Supplier**

## Annexure -3
## ***TRAINING CERTIFICATE***

| PUC Operator Photograph |
|---|
| |

**It is to certify that Mr. / Mrs. ______________________________________ has attended the training and knows all required operation of the smoke meter / Gas Analyser model _________________________ to perform PUC tests.**

Training is given in the following areas :
Understanding of procedure for testing of Idling emission/ free acceleration smoke as CMVR/ TAP/ 115/116 procedure.

1. Normal thermal condition of the vehicle
2. Actual testing procedure
3. Procedural understanding of issue of PUC certificate

**Operation of smoke meter / Gas analyzer**

1. Vehicle testing mode ☐
2. Zero Calibration ☐
3. Span calibration ☐
4. Electronic calibration ☐
5. Leak test ☐

Maintenance

1 Replacement of filters ☐
2 General maintenance ☐

Authorized Signature & seal of manufacturer / supplier

## Annexure - 4

Certificate No:___________________________
Dated : *Certificate date*

**CERTIFICATE**

**FOR**

**COMPLIANCE TO THE CENTRAL MOTOR VEHICLES RULES**

*Exhaust gas analyzer/ Opacimeter* Model ___________, bearing Sr. No. ______ from *(Supplier)*_____________________was examined and tested as per the test procedure finalized for *exhaust gas analyzer / Opacimeter* given in CMVR / TAP 115-116, Part 8.

Based on the above, it is certified that the *exhaust gas analyzer/ Opacimeter* Model _________manufactured by *(Manufacturer)*______________________________(and marketed_________________) meets the requirements of the provisions of Rule 116(3) of the Central Motor Vehicles Rules 1989, as amended up-to-date, for the *exhaust gas analyzer/ free acceleration test / free acceleration and full load test.*

The first Conformity of Production testing will be due after 2 years or production of 100 *exhaust gas analyzers / Opacimeter* from the date of this Certificate, whichever is earlier.

This Type Approval certificate is valid for the period of 5 years from the date of this Certificate subject to compliance to attached Code of Practice.

**Authorised signatory**

**CHAPTER I : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF SMOKE METERS**

2 SMOKE METER SPECIFICATIONS

1.1 Type of Tests

Smoke meter shall be suitable for conducting full load and free acceleration tests or only free acceleration test on different types of diesel vehicles as per Central Motor Vehicle Rules 115 (2) C and 115 (4). The smoke meter shall be labelled accordingly.

⌦ *The smoke meter shall have probes of sufficient length (minimum 2 meter) to facilitate easy attachment to the tailpipe of vehicles. According to the test procedure for free acceleration tests, the ratio of cross sectional area of the probe to that of exhaust pipe shall not be less than 0.05. Considering the exhaust pipe diameter of 4 inch, the equipment shall be supplied with at least one probe of internal diameter not less than 2.25 cm.*

1.2 Display

The smoke meter shall indicate light absorption coefficient 'K' directly or in case of end of line full flow meter when it may not be possible to indicate light absorption coefficient directly, it shall be easily possible to calculate value of 'K' based on the display reading using either a formula or a suitable table. The instrument shall have peak hold facility to display/print the maximum smoke reading obtained during free acceleration test.

1.3 Oil temperature measurement system

1.4 The oil temperature measurement system shall have measurement range of at least 0 to 150° C. The oil temperature measurement shall have resolution of 1°C with accuracy of at least ±3°C. Temperature probe arrangement shall be such that it can be used for all types of diesel vehicles with different oil dipstick lengths. The temperature probe shall have a sleeve for fixing in to the oil probe assembly.

1.5 Engine speed measurement system

The speed measurement shall be carried out with an easily attachable speed sensor. The speed measurement range shall be minimum from 200 to 6000 rpm with the resolution of 10 rpm. The accuracy of speed measurement shall be ±20 rpm or ±2% of the reading, whichever is greater, and the rpm display shall be updated at least at 0.5 s time interval

⌦ 1.3 Printer

*The instrument shall be provided with a printer. It shall print all the smoke readings and mean of the valid smoke readings in English along with measured oil temperature and maximum no load speed when tested for free-acceleration test. The printer shall also print the average value of the maximum no load speed determined during the flushing cycle. The printer shall print the date and time of the test. A software provision shall be made so that maximum of two print outs can be taken after each test.*

*A facility to print the reading along with date and time when calibrated using neutral density filter shall also be provided.*

1.4 Heating

The condensation in the smoke chamber shall be avoided. If necessary, instrument shall have heating facility for the same.

1.5 Temperature & Pressure

The smoke meters used for full load test shall have the pressure and mean temperature indication of the smoke into the smoke chamber. Smoke reading shall be corrected for reference pressure of 100 kPa and reference temperature of 373 K and displayed.

1.6 Markings

The meter shall be fitted with a permanent and easily readable label giving its model number, serial number, name and address of the manufacturer, electrical power requirements, year and month of manufacture and operating voltage range, in English language.

1.7 Scale

The scale shall be zero to at least 6 $m^{-1}$ for light absorption coefficient.

1.8 Resolution

The smoke meter shall have a resolution of at least 0.1 $m^{-1}$ between the range 0 to 4 $m^{-1}$.

1.9 Calibration

The smoke meter shall have facility to adjust zero reading when the smoke meter is filled with clean air. Each smoke meter shall be supplied with a neutral density filter of known value to accuracy of ± 0.05 $m^{-1}$ light absorption coefficient (along with the calibration certificate) in the region of 1.5 to 2.5 $m^{-1}$. It shall be possible to calibrate the smoke meter easily in the field using this filter.

1.10 Linearity

The linearity of the smoke meter shall be within ± 0.1 $m^{-1}$.

1.11 Drift

The instrument zero drift and span drift with neutral density filter having value between 1.5 to 2.5 $m^{-1}$, shall not exceed ± 0.1 $m^{-1}$ for four hours after warming up.

1.12 Repeatability

The repeatability of the instrument shall not exceed ± 0.1 $m^{-1}$ during five successive calibration tests with the neutral density filter having value between 1.5 to 2.5 $m^{-1}$.

1.13 Light Source

The light source shall be an incandescent lamp with a colour temperature in the range 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The smoke meter shall be supplied with spectral response characteristics of the light source received from a reputed organisation.

1.14 Light Detector

It shall be a photo cell or photo diode (with filter if necessary). Any other equivalent device can be used if the equivalence is established by the manufacturer. In the case of an incandescent light source, the detector shall have a peak spectral response in the range 550 to 570 nm and shall have gradual reduction in response to value less than 4 % of the peak response value below 430 nm and above 680 nm. The smoke meter shall be supplied with spectral response characteristics of the detector received from a reputed organisation.

1.15 Response Time

1.15.1 Physical Response Time

This is due to physical phenomena in the smoke chamber and 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 seconds.

1.15.2 Electrical Response time

The response time of electrical measuring circuit, being the time necessary for the indicating dial to reach 90 % of full scale deflection on insertion of a screen fully obscuring the photoelectric cell, shall be maximum 1.1 second.

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 (eg. calibration screen) does not exceed 0.1 $m^{-1}$ with neutral density filter having value between 1.5 to 2.5 $m^{-1}$.

1.16 Soiling of Light Source and Receiver

The smoke meter shall be capable of being used for a period sufficient to take measurements without soiling of the light source and receiver. This is considered satisfactory if the overall drift of the instrument is less than 0.2 $m^{-1}$ for over 1 hour when used on diesel engine/vehicle producing smoke of light absorption coefficient between 2 to 4 $m^{-1}$.

1.17 Warm Up Time

Unless otherwise indicated on the meter, the smoke meter shall be stabilised for operation within half an hour after power 'ON".

1.18 Environmental Conditions

The smoke meter shall withstand following environmental conditions :

Supply voltage variation of 230 V ± 10%. The instruments powered by battery shall have the battery condition indication and shall withstand indicated voltage variation.

1.1.8.2 Temperature range of 278 K to 323 K.

1.1.8.3 The meter shall withstand the vibrations encountered in the normal garage environment. The test agency may decide suitable method to test this. The recommended levels as per IS 9000 Part-VIII 1981, are

| | | |
|---|---|---|
| Frequency : | 5 to 9 Hz | Amplitude ± 3 mm |
| | 9 to 150 Hz | Amplitude ± 1 g |

Duration : 1 hour

Sweep rate : 1 octave per minute

1.18.4 Drop test

The meter shall withstand drop test of 2 falls on each edge from a height of 50 mm. Any other electric or electronic components, which are carried by operator during operation( e.g Remote Control Unit) shall withstand a drop test of 2 falls from a height of 0.5 meter.

1.19 Electromagnetic Isolation

The smoke meter is required to be capable of providing unaffected operation in electromagnetic radiation or conductive interference produced by vehicle ignition systems and building electrical systems.

1.20 Correlation to Reference Smoke Meter

The meter shall be correctable for the full load and free acceleration tests or only free acceleration test depending on intended use of the smoke meter with the reference standard meter meeting ECE regulation 24 requirements.

For the time being, Hartridge Mark-3 smoke meter will be used as a reference standard meter. This may be reviewed after a suitable time.

1.21 Documentation

When the smoke meter is submitted for testing, the smoke meter shall be accompanied with following information in English :

a) All technical specifications of the smoke meter

b) a description of the general principle of measurement

c) a list of essential components with their characteristics

d) a description of the essential components with drawings and diagrams that are necessary for testing and maintenance

e) general information on the software required for a microprocessor equipped measuring instrument

f) the operating instructions that shall be provided to the user

g) details of how calculations are performed

h) a fully documented calibration procedure and a set of calibration filters

i) a photograph of the instrument.

⌦ *j) The operating manual supplied with every smoke meter shall include the description of the test procedure described in Part-II of the document MOST/CMVR/TAP-115/116 (Details of Standards and Test Procedures for Smoke Levels by Free-acceleration for In-service vehicles fitted with Naturally Aspirated Diesel Engines).*

2.0 SMOKE METER TEST PROCEDURE

Physical Check

It shall consist of checking -

1) Suitability and label on the instrument for the intended use.
2) Identification of the instrument consisting of model, serial number, name and address of the manufacturer, electrical power requirement, year and month of manufacture and operating voltage range specified in English language.
3) Scale, resolution, display.
4) Peak hold facility.
5) Heating facility.
6) Calibration facility.
7) Printout specifications.
8) Oil temperature sensor probe
9) Engine speed sensor clamp / attachment.
10) Documentation.
11) Checking of probe

2.2 Linearity

1) Smoke measurement :

The linearity of smoke measurement shall be checked at minimum 4 points (5 points to include a full scale point, In case meter full scale corresponds to the total light cut-off) including the zero point. This will be checked by three different neutral density filters of known value within $\pm 0.05m^{-1}$ in the specified range given below, supplied by the smoke meter manufacturer or his representative along with Calibration Certificate from a reputed organisation. The neutral density filter shall have flat response (preferably within ± 2 % tolerance in absolute value) between the wavelength range 430 to 680 nm and the response at spot frequency between 550 to 570 nm as recommended by the manufacturer will be considered for linearity test. The test agency may decide to test the accuracy of the filter prior to the test.

one filter having $K \leq 1\ m^{-1}$

one filter having K between 1.5 and $2.5\ m^{-1}$

one filter having $K \geq 3\ m^{-1}$.

2) Engine speed measurement:

The linearity of engine speed measurement shall be checked at minimum 4 points, which shall include at least one point, which is more than 80% of the required full scale range. The linearity shall be checked using engine speed measurement system with the accuracy of at least ± 3 rpm.

3) Oil temperature measurement:

The linearity of oil temperature measurement shall be checked at minimum 4 points, uniformly distributed over the full-scale range. The linearity shall be checked using temperature measurement system, preferably oil bath, with the accuracy of at least ± 0.5°C.

2.3 Drift

Both zero drift and span drift shall be checked for four hours with readings taken at every half an hour interval. Span drift shall be tested using neutral density filter having light absorption coefficient in the range 1.5 to 2.5 $m^{-1}$

2.4 Repeatability

Repeatability shall be checked five times with the neutral density filter having light absorption coefficient in the range 1.5 to 2.5 $m^{-1}$.

2.5 Light Source

Check that with voltage variation specified in clause 1.18.1 , the colour temperature of the light source is between 2800 to 3250 K or verify that a green light emitting diode (LED) is used by checking the spectral peak between 550 and 570 nm.

2.6 Light Detector

Check that the combined receiver and filter characteristics have a maximum response in the range 550 to 570 nm, and less than 4% of that maximum response below 430 nm and above 680 nm, or verify that a green LED is used in conjunction with a photodiode; since the wavelength is set by the green light emitting diode (LED). It is not necessary to check the photodiode when used with a green light emitting diode (LED).

2.7 Response Time

2.7.1 Physical Response Time

Smoke meter manufacturer or its representative shall provide sufficient data and sample calculations to verify the physical response time. Test agencies will calculate the same at minimum and maximum flow conditions based on this data.

2.7.2 Electrical Response Time

Smoke meter manufacturer or representative shall provide the sufficient supporting documents to meet the specifications. Damping of the electrical measuring circuit shall be checked by inserting the neutral density filter having value between to 2.5 $m^{-1}$.

2.8 Soiling of Light Source and Receiver

After calibration, the meter will be continuously used for 1 hour on an engine/vehicle producing smoke of light absorption coefficient between 2 to 4 $m^{-1}$. The zero reading after the test shall be checked and compared. The difference shall not be more than 0.2 $m^{-1}$.

2.9 Environmental Testing

2.9.1 Voltage Variation

Smoke meter zero and span(with a neutral density filter having value between1.5 and 2.5 $m^{-1}$) reading shall be checked at 230 V ± 10 % value. In case of the instruments powered by battery, voltage shall be varied within the indicated voltage range. The difference in the reading shall be less than 0.1 $m^{-1}$.

2.9.2 Temperature

The smoke meter shall be maintained at 278 K and 323 K temperature. Span reading with neutral density filter having value between 1.5 to 2.5 $m^{-1}$ at both these temperatures shall be within 0.1 $m^{-1}$ from the reading obtained at the room temperature of 303 ± 2 K.

2.9.3 Vibration

The smoke meter shall be checked for the vibrations as per clause 1.18.3 preferably with electrical power 'ON' condition. A span measurement with neutral density filter having value between 1.5 to 2.5 $m^{-1}$, shall be taken before and after the test and the difference in the reading shall be within 0.1 $m^{-1}$. In case the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

2.9.4 Drop Test

Part-I : The meter components (except those which are wall mounted) shall be positioned in their normal orientation of use on a rigid surface. They shall be tilted on one bottom edge and then allowed to fall freely on to the test surface. All covers shall be fitted properly. They shall be subjected to two falls on each edge from a height of 50 mm, measured from the elevated edge of the unit to the test surface.

A span measurement with neutral density filter having value between 1.5 to 2.5 $m^{-1}$, shall be taken before and after the test and the difference in the reading shall be within 0.1 $m^{-1}$. As the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

Part-II : This part applies only to those parts of the meter which contain electrical or electronic components and which are carried by the operator during normal use, for example any part which attaches to the vehicle exhaust or a remote control unit etc.

The test consists of subjecting the relevant component to two falls from a height of 0.5 m onto a smooth hard rigid surface of either concrete or steel. A span measurement with neutral density filter having value between 1.5 to 2.5 $m^{-1}$, shall be taken before and after the test and the difference in the reading shall be within 0.1 $m^{-1}$. As the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

2.10 Electromagnetic Isolation

This test shall be conducted in the vicinity of minimum five number of SI engine vehicles operating within approximate distance of 3 to 5 metres from the equipment. The vehicles shall not be fitted with ignition suppression devices. A span measurement with neutral density filter having the value between 1.5 to 2.5 $m^{-1}$ shall not vary by more than 0.1 $m^{-1}$ after switching on the SI engine vehicles.

2.11 Correlation Tests

2.11.1 Full Load Test

The smoke meter under test and reference smoke meter shall be installed on an engine or a vehicle and full load test will be carried out. If it is not possible to install both the meters simultaneously, the testing will be carried out at first with reference smoke meter and subsequently with the meter under testing. The test shall be repeated to measure smoke of different 'K' values (minimum five points) approximately evenly spaced over the range 0 to 4 $m^{-1}$. If required the air system or the fuel system of the engine shall be adjusted to get smoke of different 'K' values. The difference in the reading shall be within percentage specified in the table below.

| Mean value of test in K ($m^{-1}$) | % Difference allowed |
|---|---|
| <= 1 | 5 } or 0.1 $m^{-1}$ whichever is higher |
| >1, <= 2 | 7.5 } or 0.1 $m^{-1}$ whichever is higher |
| >2,<=3 | 10 |
| >3 | 12.5 |

2.11.2 Free Acceleration Test

The test shall be carried out on at least five different diesel vehicles/engines as below :

a) one engine used for car/jeep application

b) four different engines used for LCV/HCV application

The correlation tests shall be performed using either engines or complete vehicles. If the test is carried out on an engine mounted on test bench, the engine shall be decoupled from the dynamometer. If the test is carried out on a vehicle, the gear change control shall be set in the neutral position and the drive between engine and gearbox engaged. Test engines shall be warmed up to attain oil temperature of minimum 60°C.The test shall be carried out only after this engine condition is reached.

The free acceleration test shall be conducted as below: With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the speed governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the smoke meter reverts to the corresponding conditions. Typically the maximum time for acceleration shall be 5s and for the stabilization at maximum no load speed shall be 2s. The time duration between the two free accelerations shall be between 5-20s.

The operation described above shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustments of the apparatus. During this flushing cycle operation the sample probe shall not be inserted in to the vehicle exhaust system.

The operation described above shall then be carried out with sample probe inserted in to the vehicle exhaust system. The maximum no load rpm reached during this operation shall be within $\pm$ 500 rpm in respect of 3 wheeler vehicles and $\pm$ 300 rpm for all other categories of vehicles, of the average value obtained in the last four of the six flushing cycles above. If for any reason the speed is not within the specified tolerance band the particular smoke reading shall be considered as invalid and shall be discarded. The above operation shall be repeated till the peak smoke values recorded in four successive accelerations are valid and are situated within a bandwidth of 25 % of the arithmetic mean (in m-1 unit) of these values or within a bandwidth of 0.25 K, whichever is higher and do not form a decreasing sequence. The absorption coefficient to be recorded shall be the arithmetic mean of these four valid readings.

Zero drift shall be checked after the test and if drift is greater than 0.2 $m^{-1}$ this test shall be taken as invalid and repeated.

If the drift is 0.2 $m^{-1}$ or less and positive, it shall be subtracted from the mean of the last valid reading.

A sequence of four free acceleration tests as per the procedure above shall be conducted with smoke meters as given below :

Test 1 With reference smoke meter.

Test 2 Subject meter installed on its own in the vehicle tailpipe and calibrated according to manufacturer's instructions using a neutral density filter.

Test 3 As per Test 2.

Test 4 As per Test 1.

Based on the mean of valid four readings in each test :

a) A test sequence is valid only if 'K' value of Test does not vary from Test 1 by more than 0.3 $m^{-1}$.

b) The percentage difference between the mean of the test 1 and 4 and the mean of test 2 and 3, for five vehicles, shall be less than figures given in the table below

| Mean value of test 1 & 4 K ($m^{-1}$) | % Difference allowed | | |
|---|---|---|---|
| | ( 3 vehicles ) | | ( 2 vehicles) |
| <= 1 | 5 | or 0.1 $m^{-1}$ whichever is higher | 10 |
| >1<= 2 | 7.5 | | 15 |
| >2, <=3 | 10 | | 20 |
| >3 | 12.5 | | 25 |

c) The result of Test 2 and 3 must lie within ± 10% of the mean of the two tests.

d) In case correlation test does not meet the tolerances specified above in only one of the vehicles/engines, additional two correlation tests each consisting of five tests as mentioned above shall be carried out on different vehicles / engines (vehicles/engines other than used in the first series of correlation tests). The meter can be considered satisfactory if it meets these additional correlation tests.

**CHAPTER II: TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF 2 GAS ANALYSER**

1 SCOPE AND FIELD OF APPLICATION

This standard lays down technical specification for the analyser equipment used for the determination of concentration of exhaust carbon monoxide (CO) and Hydro carbon (HC) emissions from road vehicles equipped with the spark ignition engines. The type approval of the CO part of the 2 gas analyzer shall be carried out as per the test procedure given below. The HC part of the 2 gas analyzer shall be tested as per Annexure-I to this chapter.

2 REFERENCE

ISO 3930, 1976.

**3 PERFORMANCE CRITERIA**

3.1 Analyser Accuracy

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

This accuracy of ± 3% of full scale shall be checked with the calibration gases of known concentration at minimum five points covering zero to full scale range. Calibration points shall be uniformly spaced as far as possible. It is preferred to test at ten points with five points below 5% of CO.

3.2 Interference effects

The sum of the individual effects on the reading of the analyser from other gases and particularly in concentration closed to those existing in the engine exhaust gas shall be less than 0.2 units.

Interference of Carbon-di-oxide (CO2) and water shall be checked with CO2 gas between 12 to 16% concentration by flowing :

a) Only CO2 gas;
b) CO2 gas bubbled through water;
c) Nitrogen bubbled through water;
d) CO bubbled through water;
or known mixture of above all gases.

3.3 System Response Time

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

3.4 Drift

Zero and span drift of a warm up instrument shall not be greater than ± 3% of full scale during one hour of operation. This test shall be conducted by passing a span gas having concentration more than 60% of the full scale.

3.5 Repeatability

Analyser repeatability shall be within ± 2% of full scale during five successive samples of the same gas source. This test shall be conducted by passing a span gas having concentration more than 60% of the full scale.

3.6 Warm up Time

Unless otherwise indicated on the instrument, the analyser shall reach stabilised operation within 30 minutes from 'power on'.

3.7 Span

The instrument shall have the capability of being spanned using both calibration gas bottles and electromechanical or electronic methods. For the instruments having automatic zero and span adjustments, its equivalence to the electro-mechanical or electronic methods has to be established by the manufacturer.

⌦ *If the instrument does not have the facility to check and adjust the span calibration by electronic or electromechanical means, the manufacturer shall prove that the span calibration by the means of calibration gas remains stable with time, ambient temperature, barometric pressure, aging of IR source, aging of IR detector, aging of the electronic components and other relevant parameters manufacturer, whichever is higher. The manufacturer shall provide the supporting data and documents to prove the stability.*

⌦ *The instrument shall have a suitable provision for connection to the pressurized 10 / 47 litre gas cylinders by the means of $^{1}/_{4}$" Teflon tube and compression tube fitting.*

3.8 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.

⌦ *The instrument shall have provision of testing the leak into the complete sample handling system including probe. This can be provided by means of vacuum switch with closing cap on the probe or through the flow indicator with closing cap or any other means. The vacuum switch setting or the flow meter* *range shall be designed so that any small leakage, which affects the readings, can be detected.*

3.9 Safety requirements

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

3.10 Temperature Sensitivity

The instrument shall be suitable for ambient temperatures between 278 K and 318 K. Between these two limits the result of the measurement shall not differ from that obtained at a temperature of 303 K ( ± 2 K) by more than 0.2 units.

This test shall be conducted by passing a span gas having concentration more than 60% of the full scale. This test shall be conducted in the temperature controlled chamber and readings shall be taken after allowing two hours stabilisation time after attaining specified temperature. Any other drift like zero drift/span drift with time (if observed) shall be compensated for this time interval.

4.0 DESIGN CHARACTERISTICS

4.1 Instrument construction

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

4.1.1 Mobility

The instrument may be permanently mounted, portable or mobile.

4.1.2 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.

4.1.3 Electrical design

Analyser operation shall be unaffected by an electrical voltage variation of 230 V ± 10%. The instruments powered by battery shall have battery condition indication and the battery voltage shall be varied within the indicated range.

4.1.4 Controls

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

4.1.5 Electromagnetic Isolation

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

This test shall be conducted in the vicinity of minimum five number of SI engine vehicles operating within approximate distance of 3 to 5 metres from the equipment. The vehicles shall not be fitted with ignition suppression devices.

4.1.6 Vibration Test

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

Vibration test shall be conducted as per IS 9000 Part VIII 1981. Analyser may be subjected to vibration in normal mounting axis for 5 to 9 Hz ± 3 mm displacement and 9 to 150 Hz ± g acceleration amplitude, preferably with electrical power 'ON' condition. The span reading with span gas having concentration more than 60 % of full scale, before and after the test, shall not differ by more than 1 % of full scale.Any other drift like zero drift/ span drift with time (if observed) shall be compensated.

4.1.7 Drop Test

The meter components (except those which are wall mounted) shall be positioned in their normal orientation of use on a rigid surface. They shall be tilted on one bottom edge and then allowed to fall freely on to the test surface. All covers shall be fitted properly. They shall be subjected to two falls on each edge from a height of 50 mm, measured from the elevated edge of the unit to the test surface.

As the electrical power is switched off, the instrument shall be warmed up and initial electronic calibration shall be carried out. The span reading with span gas having concentration more than 60 % of full scale, before and after the test, shall not differ by more than 1 % of full scale.

4.1.8 Operating Instructions

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

The manufacturer shall supply following information for certification :

a) Detailed specifications of the equipment along with standard accessories/standard fittments.

⌦ b) *The operating manual supplied with every CO analyser shall include the description of the test procedure described in Part-I of the document MOST/CMVR/TAP-115/116 (Details of Standards and Test Procedures for Carbon Monoxide Emissions at idling for In-service vehicles fitted with Petrol Engines). The manual shall also specify the recommended calibration interval.*

c) Service manual.
d) Flow schematic diagrams.
e) Details of sample handling system material.
f) Photograph of the instrument.

4.2 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 three meters in length.

4.2.1 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 shall be flexible enough to extend into the tailpipe atleast 300 mm.

⌦ *Every CO analyser shall also be supplied with an exhaust extension pipe as a standard accessory. The extension pipe connection shall be universally adaptable to the exhaust pipe of all petrol engine vehicles.*

4.2.2 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 analyser, the collection vessel shall be visible to the operator and a draining provision shall be provided.

4.3 Analytical System

The accuracy, system response time, drift, repeatability, warm up time shall be as specified in the performance criteria.

4.3.1 Instrument Range

The instrument full scale range shall be between 8 to 10 % of CO.

4.3.2 Span Techniques

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

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

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

5.0 Instruments with facility for carbon-di-oxide measurement shall meet all the above performance criteria mentioned for CO analysers, except that the instrument read-out shall have a range of 0 to 20 % or less.

⌦ *6.0 The instrument shall be provided with a printer. It shall print the CO reading in English when tested as per the procedure followed for CMVR 115 (2) a and b. The printer shall also print the date and time of the test. A software provision shall be made so that maximum of two print outs can be taken for each test.*

*A facility to print the CO reading after calibration along with the date and time of calibration shall also be provided.*

## ANNEXURE-I
## TECHNICAL SPECIFICATION AND TEST PROCEDURE FOR HC PART OF PRESENT 2 GAS ANALYSER

**1. Instrument range and resolution**

The instrument full-scale range for HC measurement shall be 10,000 ppm with resolution of at least 10 ppm.

***2. Propane/hexane equivalency factor***

The content of hydrocarbons shall be expressed in ppm vol *n*-hexane ($C_6H_{14}$) equivalent. The adjustment may be carried out using propane ($C_3H_8$). Therefore, a conversion factor referred to as "C3 /C6 Equivalence Factor", or PEF, shall be permanently and conspicuously marked or easily displayed on each instrument. Alternatively, display of an array of conversion factors is allowed provided that the associated volume fractions are also displayed. The manufacturer shall provide the conversion factor(s) for each individual instrument to three significant figures. If the gas-sensitive element is replaced or repaired, the new conversion factor(s) shall be attached to the Instrument.

3.0 PERFORMANCE CRITERIA

**3.1 Analyser Accuracy**

The HC part of 2-Gas analyser shall have an accuracy of ± 30 ppm absolute or ± 10% relative, whichever is greater determined by analysing known standard gases.

This accuracy shall be checked with the calibration gases of known concentration at minimum five points covering zero to full-scale range. Calibration points shall be uniformly spaced as far as possible. It is preferred to test at ten points with five points below 5000 ppm of HC.

**2.2 Interference effects**

The sum of the individual effects on the reading of the analyser from other gases and perticularly in concentration closed to those existing in the engine exhaust gas shall be less than 15 ppm.

Interference of Carbon dioxide ($CO_2$) and water shall be checked with $CO_2$ gas between 12 to 16% concentration by following :

a) Only $CO_2$ gas;
b) $CO_2$ gas bubbled through water;
c) Nitrogen bubbled through water;
d) CO bubbled through water or known mixture of above all gases

**2.3 System Response Time**

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

## 2.4 Drift

Zero and span drift of a warmed up instrument shall not be greater than ± 30 ppm absolute or ± 10% relative, whichever is greater during one hour of operation. This test shall be conducted by passing a span gas having concentration more than 60% of the full scale.

## 2.5 Repeatability

Analyser repeatability shall be within ± 30 ppm absolute or ± 10% relative, whichever is greater during five successive samples of the same gas source. This test shall be conducted by passing a span gas having concentration more than 60% of the full scale.

## 2.6 Temperature Sensitivity

The instrument shall be suitable for operation at ambient temperatures between 278 K and 318 K. Between these two limits the result of the measurement shall not differ from that obtained at a temperature of 303 K ( ± 2 K) by more than ± 30 ppm absolute or ± 10% relative ,whichever is greater

This test shall be conducted by passing a span gas having concentration more than 60% of the full scale. This test shall be conducted in the temperature controlled chamber and readings shall be taken after allowing two hours stabilisation time after attaining specified temperature. Any other drift like zero drift/span drift with time (if observed) shall be compensated for this time interval.

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## CHAPTER III : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF 4 GAS ANALYSER

### 1. PURPOSE

The introduction of stringent emission regulation for post year 2000 vehicles in India requires exhaust gas instrument capable of measuring gasoline vehicle exhaust emissions under idling conditions with high accuracy and lower detectable values of CO, HC emissions. The new generation vehicles require lambda measurement to ensure efficient working of closed loop electronic engine management system fitted with 3-way catalytic converter and lambda sensor. This document based on the ISO 3930:2000 (E) is prepared for such exhaust gas analysers.

### 2. SCOPE

This document specifies the metrological, technical requirements and tests for measuring instruments [hereafter termed "instrument(s)"],that serve to determine the volume fractions of certain components of the exhaust gases emanating from motor vehicles, and establishes the conditions with which such instruments must comply in order to meet any CMVR performance requirements.

It is applicable to instruments particularly to those used according to the procedure defined in CMVR TAP Document intended for the inspection and maintenance of vehicles having spark ignition engines. (both 2 and 4 stroke)

These instruments are used to determine the volume fraction of one or more of the following exhaust gas components:

_ Carbon monoxide (CO)

_ Carbon dioxide (CO 2)

_ Hydrocarbons (HC, in terms of n-hexane) and

_ Oxygen (O2)

at the moisture level condition of the sample as analyzed .

This document covers instruments whose principle of detection is based on infrared absorption in gases for CO, CO2 and HC. Oxygen is generally measured with a fuel cell. It is not intended, however, to exclude any other types of instruments that although based on other principles of detection meet the specified metrological and technical requirements and satisfy the associated tests.

Reference : This document is based on the 'ISO 3930:2000(E) : Instruments for measuring vehicular exhaust gas emissions'.

### 3.0 TERMS AND DEFINITIONS

For the purposes of this documentation, the following terms and definitions shall apply.

#### 3.1 Sampling probe

Tube that is introduced into the exhaust tail pipe of a vehicle to take gas samples, 3.2 Water Separator

Water separator device that removes water to a level that prevents condensation within the gas handling system downstream from its location

**3.3 Filter unit**

Device that removes particulate matter from the exhaust gas sample

3.4 Gas Handling System

All instrument components from the sampling probe to the gas sample outlet, through which the exhaust gas sample is conveyed by the pump.

3.5 Adjustment (of a measuring Instrument)

Operation of bringing a measuring instrument into a state of performance suitable for its use (VIM:1993,4.30)

3.6 User adjustment (of a measuring Instrument)

Adjustment employing only the means at the disposal of the user. (VIM:1993, 4.31)

3.7 Manual adjustment facility

Facility allowing the adjustment of the instrument by the user

3.8 Semi-automatic adjustment facility

Facility allowing the user to initiate an adjustment of the instrument without having the possibility of influencing its magnitude whether the adjustment is automatically required or not.

Note : For those Instruments that require the values of the calibration gas to be entered manually, the facility is considered to be semi-automatic.

3.9 Automatic adjustment facility

Facility performing the adjustment of the instrument as programmed without the intervention of the user, to initiate the adjustment or its magnitude.

**3.10 Zero-setting facility**

Facility to set the indication of the instrument to zero.

3.11 Calibration gas adjustment facility

Facility to adjust the instrument to the value of a calibration gas.

3.12 Internal adjustment facility

Facility to adjust the instrument to a designated value without the use of an external calibration gas.

3.13 Warm-up time

Elapsed time between the instant powers is applied to an instrument and the instant at which the instrument is capable of complying with the metrological requirements.

3.14 Response time

Time interval between the instant when the instrument is subjected to a specified abrupt change in gas mixture composition and the instant when the response reaches within specified limits of its final steady value.

3.15 Error (of indication)

Indication of a measuring instrument minus a true value of the corresponding input quantity. (VIM:1993, 5.20)

3.16 Intrinsic error

Error of a measuring instrument, determined under reference conditions. (VIM:1993, 5.24)

3.17 Absolute error of measurement

Result of a measurement minus the conventional true value of the measurand.

3.18 Relative error

Absolute error of measurement divided by the conventional true value of the measurand.

3.19 Fault

Difference between the error of indication and the intrinsic error of the instrument.

3.20 Significant fault

Fault, the magnitude of which is greater than the magnitude of the maximum permissible error on initial verification.

NOTE : The following faults are considered not to be significant.

a) Fault arising from simultaneous and mutually independent causes in the instrument itself or in its checking facilities

b) Faults implying the impossibility to perform any measurement

c) Transitory faults being momentary variations in the indication, which cannot be interpreted, recorded or transmitted as a measurement result and

d) Faults giving rise to variations in the measurement results that are so large as to be noticed by all users of the instruments.

3.21 Influence quantity

Quantity that is not the measurand but which affects the result of the measurement. (VIM:1993, 2.7)

3.22 Rated operating conditions

Conditions of use giving the ranges of the influence quantities for which the metrological characteristics of an instrument are intended to lie within the specified maximum permissible errors.

3.23 Influence factor

Influence quantity having a value within the rated operating conditions of the instrument.

3.24 Disturbance

Influence quantity having a value within the limits specified in this document but outside the rated operating conditions of the instrument.

3.25 Reference conditions

Conditions of use prescribed for testing the performance of Instrument or for inter-comparison of results of measurements. (VIM:1993, 5.7)

3.26 Checking facility

Facility that is incorporated in the instrument and that enables significant faults to be detected and acted upon.

NOTE : "Acted upon" means any adequate response by the Instrument (luminous or acoustic signal, by blocking of process, etc.)

**3.27 Automatic checking facility**

Checking facility operating without the intervention of the user.

**3.27.1 Permanent automatic checking facility (type P)**

Automatic checking facility operating during each measurement cycle.

**3.27.2 Intermittent automatic checking facility (type I)**

Automatic checking facility operating at certain time intervals or per fixed number of measurement cycles.

3.28 Test

Series of operations intended to verify the compliance of the Equipment under test (EUT) with specified requirements.

3.29 Lambda

Dimensionless value representative of the burning efficiency of an engine in terms of the air/fuel ratio in the exhaust gases and determined with a referenced standardized formula.

3.30 Calibration gas

Stable gas mixture of known concentration used for periodic calibration of the instruments and for various performance tests.

3.31 Modulus (of a number) absolute value

Value of the number without regard to its sign.

**3.32 Hand-held instrument**

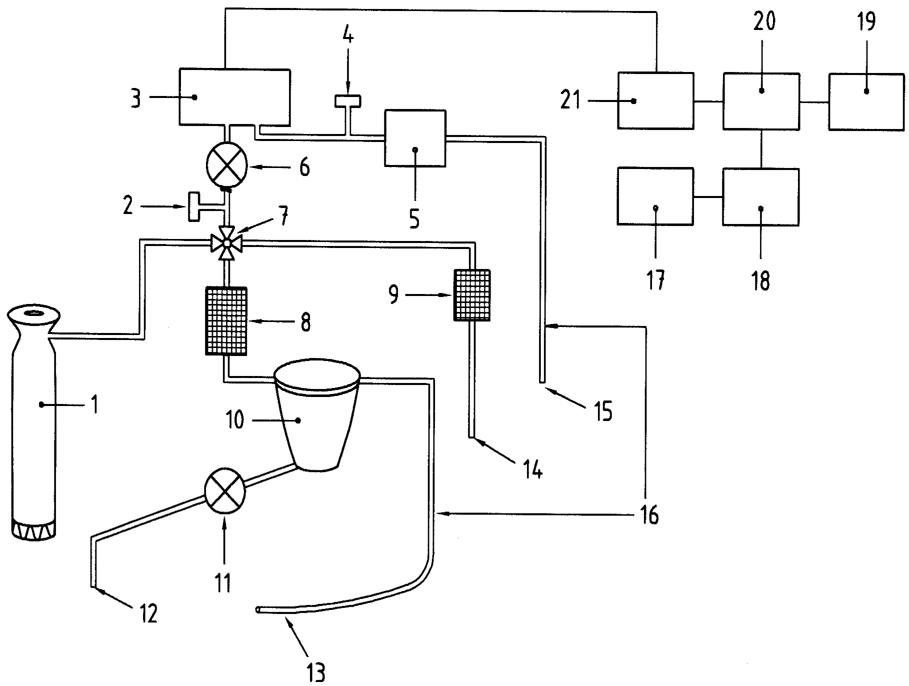
Type of portable instrument that can be transported by one person with its standard accessories, and that rests on a suitable surface during use or mounted on a suitable trolley.

**4.0 DESCRIPTION OF THE INSTRUMENTS**

4.1 **Generally, the instruments shall provide a means for sampling and then measuring the exhaust gases emitted from the tail pipe of a motor vehicle. A pump shall be provided to transport the gas sample through a gas sample handling system. One or more detection devices may be used and incorporated in the gas handling system to analyze the sample and provide signals related to the volume fractions of gas components of interest, namely CO, CO2, HC and O2 . The detector signals are then electrically processed to display and record the results of a measurement in volumetric units of the gas components together with other important related information such as a lambda value calculation.**

**4.2** Acceptable overall performance of the Instrument is dependent upon its various components for the associated characteristics.

**An example of an instrument using gas calibration for adjustment is shown in Fig 1.**




**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Calibration gas input (6.1.5) | 8 | Filter gas (6.1.3) | 15 | Gas output |
| 2 | Differential pressure sensor (6.1.7) | 9 | Charcoal filter (6.1.5) | 16 | Gas handling system (6.1.8) |
| 3 | CO, $CO_2$ and HC analysis | 10 | Water separator (6.1.4) | 17 | Seals (6.3.8) |
| 4 | Atmospheric pressure sensor | 11 | Water pump | 18 | Adjustment facilities (6.2) |
| 5 | $O_2$ analysis | 12 | Water output | 19 | Interfaces (6.1.9) |
| 6 | Gas pump (6.1.6) | 13 | Sampling probe (6.1.2) | 20 | Indicating device (6.2 and 6.3) |
| 7 | Electrovalve | 14 | Gas input for zero-setting (6.1.5) | 21 | Signal conversion |

**Figure 1 — Diagrammatic illustration of an instrument for measuring vehicle exhaust emissions (references in parenthesis are to the relevant subclauses in the text)**

**4.3 The major Instrument components are as follows:**

- a sampling probe introduced in the tail pipe of an operating motor vehicle to collect the exhaust gas sample
- a hose with associated tubing connected to the probe to provide a path for the gas sample to enter, pass through and exit the Instrument
- a pump to convey the gases through the Instrument
- a water separator to prevent water condensation from forming in the Instrument

**- a filter to remove particulate matter that could cause contamination of various sensitive parts of the Instrument**

- Ports downstream from the water separator and filter to introduce ambient air and calibration gas when required by the technology used. The calibration gas port should have a suitable provision for connection to the pressurized 10 / 47 litre gas cylinders by the means of ¼" Teflon tube and compression tube fitting.
- Detection devices to analyze the gas sample into its components according to volume fractions
- a data system to process the signal and an indicating device to display the results of a measurement and
- a control facility to initiate and check Instrument operations and a manual, semi-automatic, or automatic adjustment facility to set Instrument operating parameters within prescribed limits.

Either a built-in printer and/or an RS 232 serial interface through which the data can be transferred to a PC.

**4.4** The instrument will be supplied with an exhaust extension pipe as a standard accessory. The extension pipe connection should be leak proof and should be universally adaptable to the exhaust pipe, where probe insertion of 300mm is not possible.

## 5.0 METROLOGICAL REQUIREMENTS

### *5.1 Indication of the measured result*

The volume fractions of the gas components shall be expressed as a percentage (% vol) for CO, $CO_2$ and $O_2$ and in parts per million (ppm vol) for HC. The permanent inscriptions for these units or electronic display shall be assigned unambiguously to the indication, for example "%vol CO", "%vol $CO_2$ ", "% vol $O_2$ " and "ppm vol HC"

### *5.2 Measuring range*

The minimum indicating ranges shall be as:

CO: 0-5 %vol

CO2: 0-16 %vol

HC: 0-10000 ppm vol

O2: 0-21 %vol

### 5.3 Resolution of indication

5.3.1 Digital indication

Digital figures shall be at least 5 mm high. The least significant figure of the display shall provide a resolution equal to or one order of magnitude higher than the values given below:

*Minimum resolutions*:

CO: 0.01 %vol

CO2: 0.1 %vol

HC: 1 ppm vol

O2: 0.02 %vol for measurand values <= 4 %vol

0.1 % vol for measurand values > 4 %vol

5.4 Maximum permissible errors

### *5.4.1 Maximum permissible intrinsic errors*

Maximum permissible errors shall apply for an Instrument under the reference conditions.

CO: Absolute:± 0.06 %vol Relative:± 3 % whichever is greater

CO2: Absolute:± 0.4 %vol Relative:± 4 % whichever is greater

HC: Absolute:± 12 ppm vol Relative:± 5 % whichever is greater

O2: Absolute:± 0.1 %vol Relative:± 3 % whichever is greater

### *5.4.2 Maximum permissible errors on initial verification*

Maximum permissible errors shall apply for an Instrument at initial verification under the Rated Operating conditions.

CO: Absolute:± 0.06 %vol Relative:± 5 % whichever is greater

$CO_2$: Absolute:± 0.5 %vol Relative:± 5 % whichever is greater

HC: Absolute:± 12 ppm vol Relative:± 5 % whichever is greater

$O_2$: Absolute:± 0.1 %vol Relative:± 5 % whichever is greater

### *5.4.3 Maximum permissible errors on subsequent verification*

The maximum permissible errors on subsequent verification shall be equal to the errors on initial verification.

### 5.5 Influence quantities

#### 5.5.1.1 Reference conditions

a) Temperature: 25 °C ± 2 °C

b) Relative Humidity : 60 % ± 10 %

c) Atmospheric Pressure : Stable ambient

d) Mains voltage: ± 2% Nominal voltage ± 1%, Nominal frequency

e) Presence of influencing gas components: None except the measurands in $N_2$

NOTE : In case of Infrared technology, a relative humidity range from 30% to 60% is acceptable.

#### 5.5.1.2 Rated Operation Conditions

a) Temperature: 5°C to 45°C

b) Relative Humidity : up to 90 %

c) Atmospheric Pressure: :860 hPa to 1060 hPa

d) Mains voltage variation :– 15 % to + 10 % of the nominal voltage, ± 2 % of the nominal frequency.

If a battery is used to power the instrument, the limits of power supplied shall be within the instrument manufacturer's specifications. In case the battery power drops outside the limits, there should be an indication on the instrument and it should not be possible to make any measurement with the instrument. If a portable generator is used, its requirements shall comply with the specifications for the mains voltage.

### 5.5.3 Influence of gases other than the measurand (cross sensitivity)

The design of the instruments shall be such that measurements do not vary by more than half the modulus of the maximum permissible error on initial verification when gases other than the measurand are present in the following maximum volume fractions:

16 %vol $CO_2$

6 %vol CO

0.3 %vol NO

5 % vol. $H_2$

10 % vol $O_2$

5000 ppm vol HC (as n-hexane)

water vapor up to saturation.

*However the presence of $H_2$ is not necessary for testing the $O_2$ channel and the presence of $H_2$ and $O_2$ is not necessary in case of Infrared technology.*

### *5.6 Disturbances*

Significant faults as defined in (Significant fault) shall not occur or shall be detected and acted upon by means of checking facilities for the following disturbances:

a) Mechanical shock and vibrations

b) Short time power reductions

c) Bursts from the mains (transients)

d) Electrostatic discharges

e) Radiated radio frequency electromagnetic fields

f) Mains frequency magnetic fields.

### *5.7 Response time*

For measuring CO, $CO_2$ and HC, Instrument including the specified gas handling system shall indicate 95 % of the final value (as determined with calibration gases) within 15 s or less after changing from a gas with zero content. For measuring $O_2$ the instruments shall indicate a value differing less than 0.1 % vol. of the final value within 60 s after changing from air to oxygen-free calibration gas.

### *5.8 Warm-up time*

After the warm-up time, the Instruments shall meet the metrological requirements as stated in this document. – Instruments shall have the means to prevent measurement and an indication of measured gas volume fractions during the warm-up time. Instruments shall have a warm-up time not exceeding 10 min.

### *5.9 Propane/hexane equivalency factor*

The content of hydrocarbons shall be expressed in ppm vol *n*-hexane (C6 H14 ) equivalent. The adjustment may be carried out using propane (C3 H8). Therefore, a conversion factor referred to as "C3 /C6 Equivalence Factor", or PEF, shall be permanently and conspicuously marked or easily displayed on each instrument. Alternatively, display of an array of conversion factors is allowed provided that the associated volume fractions are also displayed. The manufacturer shall provide the conversion factor(s) for each individual instrument to three significant figures. If the gas-sensitive element is replaced or repaired, the new conversion factor(s) shall be attached to the Instrument. For Instruments with one single conversion factor, the measuring values obtained when tested with *n*-hexane shall not differ by more than the applicable maximum permissible error from the curve established with propane. For instrument capable of displaying an array of conversion factors, the measuring values obtained when tested with *n*-hexane shall not differ by more than half the value of the applicable maximum permissible error from the curve established with propane.

NOTE: The value for this factor is usually between 0.490 and 0.540.

### *5.10 Lambda calculation*

Instruments equipped with a lambda indication shall carry out the appropriate calculation for different fuel options such as petrol, CNG, LPG with a suitable formula for lambda values between 0.8 and 1.2, the maximum permissible error in the calculation with respect to the resolution and the application of the chosen formula shall not exceed 0.3 %. For this purpose, the conventional true value will be calculated according to the following formula:

$$\lambda = \frac{[CO_2] + \frac{[CO]}{2} + [O_2] + \left\{ \left( \frac{H_{cv}}{4} \times \frac{3,5}{3,5 + \frac{[CO]}{[CO_2]}} - \frac{O_{cv}}{2} \right) \times ([CO_2] + [CO]) \right\}}{\left(1 + \frac{H_{cv}}{4} - \frac{O_{cv}}{2}\right) \times \left\{ ([CO_2] + [CO]) + (K_1 \times [HC]) \right\}}$$

Where

[ ] is the concentration in %vol, for HC only in ppm vol

$K_1$ is the conversation factor for HC if expressed in ppm vol n-hexane (C6H14) equivalent. Its value in this formula is 6 x $10^{-4}$

$H_{cv}$ is the atomic ratio of hydrogen to carbon in the fuel. The arbitrary value is 1.7261

$O_{cv}$ is the atomic ratio of oxygen to carbon in the fuel. The arbitrary value is 0.0176

The lambda value shall be displayed digitally to four figures and shall be identified by an appropriate symbol or sign (e.g. lambda or λ) in any of the following format:

Lambda = x.xxx

OR

λ= x.xxx

For analysers not equipped with oxygen channel but capable of calculating A/F ratio (air to fuel) an A/F / Lambda indication shall be carried out using a suitable formula. The details of the formula will be provided.

For lambda values between 0.8 and 1.2, the maximum permissible error in the calculation with respect to the resolution and the application of the chosen formula shall not exceed 0.3 %. For this purpose, the conventional true value will be calculated according to the following formula.

Lambda = 1 /AF

$$A/F = 2.088 \times \frac{100 + 0.46\, CO_2 - 0.060\, CO - THC}{CO_2 + CO + THC}$$

Where CO, $CO_2$ are vol % and THC in Vol % C1.

### 5.11 *Stability with time or drift*

When used in accordance with the manufacturer's operating instructions, the measurements made by the Instruments, under stable environmental conditions and after adjustment using a calibration gas or the internal adjustment facility, shall remain within the maximum permissible errors on initial verification for at least 4 h without the need for calibration gas or internal readjustments by the user.

If the Instruments are equipped with a means for drift compensation, such as automatic zero or automatic internal adjustment, then the action of such adjustments control shall not produce an indication/display that can be confused with a measurement of an external gas. It should not be possible to pass the gas sample and measure the same while the automatic adjustments are in process.

### 5.12 *Repeatability*

For 20 consecutive measurements, using the same calibration gas mixture, carried out by the same person with the same Instrument within relatively short time interval the experimental standard deviation of the 20 results shall not be greater than one third of the modulus of the "maximum permissible error on initial verification" taken from 5.4.2 for the relevant gas mixture.

5.13 **Engine Speed Measurement System**

The speed measurement range of the measurement system shall be minimum from 200 to 6000 rpm with the resolution of 10 rpm. The accuracy of speed measurement shall be ±20 rpm or ±2% of the reading, whichever is greater and the rpm display shall be updated at least at 0.5 s time interval."

## *6.0 TECHNICAL REQUIREMENTS*

### *6.1 Construction*

**6.1.1** All components of the sample gas handling system shall be made of corrosion-resistant material in particular, the material of the sampling probe shall withstand the exhaust gas temperature. The materials used shall not influence the composition of the gas sample.

**6.1.2** The sampling probe shall be so designed that it can be inserted at least 300 mm into the exhaust tail pipe of the vehicle and held in place by a retaining device regardless of the depth of insertion.

**6.1.3** The sample gas handling system shall contain a filter with reusable or replaceable filter elements capable of removing dust, soot or like particles larger than 5 µm in diameter. It shall be possible to use the Instruments for a period of at least 15 minutes with exhaust gas from a specially adjusted test engine having an HC fraction concentration of approximately 6000 ppm . It shall be possible to observe the degree of a filter's contamination without its removal, and it shall also be possible to replace, when necessary, this filter easily without special tools.

**6.1.4** The sample gas handling system shall contain a water separator to prevent water condensation from forming in the measuring transducer. In the case of saturation of the separator, it shall empty automatically or manually. In any case the measurement operation shall be automatically stopped if there is a danger of water going inside the measuring transducer with water filled in the water separator.

**6.1.5** In addition to the probe, Instruments equipped with an HC measurement channel shall have:

A port for drawing in ambient air or other gas without hydrocarbons to provide a reference for zero-setting of the measuring instrument. For this purpose, ambient air shall pass through a charcoal filter or equivalent system. Instruments without an HC channel may also be equipped with this additional port. Oxygen measuring cells cannot use ambient air for zero-setting. if zero-setting is required an oxygen-free gas should be used.

Another additional port shall be provided in the sample gas handling system for introducing calibration gas.

Both ports shall be located downstream of the water separator and filter unit in order to minimize potential contamination of the gases introduced.

A means shall be provided to maintain the same pressure within the detector during zero setting, gas calibration, and sampling.

**6.1.6** The sampling pump conveying the exhaust gas shall be mounted so that its vibrations do not affect the measurements. It shall be possible to turn the pump on and off separately from the other instrument components by the user however, it shall not be possible to make a measurement when the pump is switched off. Instrument is required to purge and back-flush the sample gas handling system automatically with ambient air before the pump is switched off.

**6.1.7** The instruments shall be equipped with a device that indicates when the gas flow rate decreases to a level that would cause the detection to exceed the response time and/or half the modulus of the maximum permissible error on initial verification and when that limit is reached, the device shall prevent measurements.

**6.1.8** The sample gas handling system shall be airtight to such an extent that the influence of dilution with ambient air on the measuring results shall not be more than:

_ for CO, CO2 and HC: half the modulus of the "maximum permissible error on initial verification"

_ for O 2 :0.1 %vol.

A leakage test system / device along with procedure with sufficient accuracy to detect this specific maximum leakage shall be provided in the manufacturer's operating instructions.

Instruments shall not be able to make a measurement if this value is exceeded.

**6.1.9** The Instrument shall be equipped with an RS 232 interface permitting coupling to any peripheral devices or instruments. An interface shall not allow the metrological functions of the instruments or their measurement data to be inadmissibly influenced by the peripheral devices, by other interconnected instruments, or by disturbances acting on the interface. Functions that are performed or initiated via an interface shall meet the relevant requirements and conditions of the Clause "Technical requirements".

If the Instrument are connected to a data printer then the data transmission from the Instrument to the printer shall be designed so that the results cannot be falsified. It shall not be possible to measure and or print out a document or test report or test certificate for legal purposes, if the

Instrument checking facility(ies) detect(s) a significant fault or a malfunction Instrument.

### *6.2 Adjustment facilities*

**6.2.1** The Instrument shall have an adjustment facility that provides operations for zero-setting, gas calibration (if applicable), and internal adjustment.

**6.2.2** The facility shall be automatic for zero-setting and internal adjustment.

**6.2.3** The internal adjustment shall neither influence the adjusted zero nor the linearity of the response of the Instruments and these shall be coupled to any adjustment made with a calibration gas. A method for coupling shall be provided such that each time a gas calibration is conducted, the gas value and the internal adjustment value are adjusted and the indication equals the calibration gas value.

**6.2.4** Instrument shall be provided with a means to observe negative indications near zero for certain tests.

### 6.3 Security of operation

**6.3.1** The instruments shall be designed and manufactured such that when exposed to any of the disturbances listed in 5.6

Significant faults do not occur or are detected and acted upon by means of a checking facility. If this is achieved by the use of automatic self-checking facilities, then it shall be possible to check the correct functioning of such facilities.

**6.3.2** The Instruments with an HC-channel shall be equipped with a checking facility for detecting HC gas residues. This facility serves to ascertain that before a measurement is made the value indicated is less than 20 ppm vol *n*-hexane for an ambient air sample taken through the probe.

**6.3.3** Instrument shall not be able to make a measurement if the HC residue value exceeds 20 ppm vol *n*-hexane. If the measuring instrument are provided with the measuring cycle, this requirement shall be fulfilled at the beginning of each measuring cycle otherwise the manufacturer shall indicate what constitutes the beginning of the measurement.

**6.3.4** Instruments with an O2-channel shall be equipped with a device for automatically recognizing any malfunctioning of the sensor due to aging or a break in the connecting line.

**6.3.5** Instrument shall be controlled by an automatic self-checking facility that shall operate in such a way that before a measurement can be indicated or printed, all internal adjustments, calibration gas adjustments, and all other checking facility parameters shall be confirmed for proper values or status (i.e. within limits). The Semi or Automatic checking facility for the Instrument, as a minimum requirement shall cover following:

Warm-up check: Permanent Automatic

Low flow and Leak check: Always on POWER ON

Gas calibration check : once in a day

HC residue check : Always on POWER ON and before each measurement.

**6.3.6** Instruments and peripheral devices like PC equipped with an automatic adjustment facility or a semi-automatic adjustment facility shall not be able to make a measurement until correct adjustments have been completed.

**6.3.7** Instruments and peripheral devices like PC equipped with a semi-automatic adjustment facility shall not be able to make a measurement when an adjustment is required.

**6.3.8** A means for warning of a required adjustment may be provided for both automatic and semi-automatic adjustment facilities.

**6.3.9** Effective sealing devices shall be provided on all parts of the Instrument that cannot be materially protected in another way against operations liable to affect the accuracy or the integrity of the instruments. This applies in particular to:

_ adjustment means

_ peripheral hardware

- software integrity

_ disposable oxygen fuel cell.

**6.3.10** For instruments without a pressure-compensating device, daily calibration is required. The operating instructions shall contain this requirement.

**6.3.11** A battery-operated instrument shall either continue to function correctly or not indicate any values whenever the voltage is below the manufacturer's specified value.

## *7.0 INSCRIPTIONS AND OPERATING INSTRUCTIONS*

### *7.1 Inscriptions*

**7.1.1** The instruments shall have a permanent and easily readable label or labels giving the following information:

a) Manufacturer's trade mark/corporate name

b) Year of manufacture

c) CMVR type approval designation

d) Type approval certificate number & model number

e) Serial number of the instrument and of the measuring transducer

f) Minimum and nominal flow rate

g) Nominal mains voltage, frequency and power required

h) Gas components and respective maximum measured value

i) Type description and model of the oxygen fuel cell.

**7.1.2** Furthermore, the value of the propane/hexane equivalency factor for each Instrument hall be marked permanently on the front panel of the Instrument or shall be displayable on the indicating device. In the case where more than one single propane/ hexane equivalency factor is available, these factors shall be displayed with the associated concentrations.

***7.2 Operating instructions***

**7.2.1** The manufacturer shall provide written operating instructions for each instrument in the English language.

**7.2.2** The operating instructions shall include:

a) The time intervals and the procedures for adjustment and maintenance that shall be followed to comply with the maximum permissible errors

b) A description of the leakage test procedure

c) An instruction for the user to conduct an HC-residue check prior to each HC measurement, including a description of the HC-residue check procedure

d) The maximum and minimum storage temperatures

e) A specification of the voltage and frequency required of any portable generator consistent with 5.5.2, taking into account varying load conditions typical of those encountered at the location of use

f) A statement of the rated operating conditions

g) In case a lambda value is calculated, a description of the applied formula and

h) An instruction for the replacement of the oxygen fuel cell.

i) The description of the possible errors along with test data if the instrument is used for the temperature up to 50 °C and frequency variations of 48 to 52 Hz.

## 8.0 METROLOGICAL CONTROLS

### *8.1 Type approval*

### 8.1.1 Documentation

The documentation for an Instrument supplied by the manufacturer when applying for type approval shall include:

a) A description of its general principle of measurement

b) A list of its essential components with their characteristics

c) A description of its essential components with drawings and diagrams that is necessary for testing and maintenance

d) The general information on the software required for a microprocessor equipped measuring Instrument

e) For Lambda calculation or A/F calculation or as included, a description of the applied formula with the values of the parameters and physical constants incorporated and evidence showing that the requirement of 5.10 is met shall be indicated in operating manual.

f) The operating instructions that shall be provided to the user.

Along with an application for type approval, the manufacturer shall provide any data or other information that may support the assertion that the design and construction of the Instrument complies the requirements.

**8.1.2 General requirements**

Type approval shall be carried out on at least one and normally not more than three units, which represent the definitive pattern. The evaluation shall consist of the tests specified here under:

**8.1.3 Inspection and tests**

The inspection and testing of Instrument is intended to verify compliance with the requirements of Clauses 4.3, 5, 6 & 7.

As a rule, tests should be carried out on the complete Instrument or along with its connected peripheral devices like PC if these devices need to be compulsorily used for operating the instruments. However, if these devices are used only for printing / data acquisition purposes, the tests will be carried out on the instruments. The peripheral devices will not be subjected to all the environmental conditions but will be verified by the test agencies for the proper operation. If the size or configuration of the Instrument do not render it suitably to being tested as a unit, or, if only a particular component or device of the Instrument is concerned, a test may be carried out on the component or device separately. Such tests may only be performed if a simulated measurement set-up can be achieved that reflects the rated operating conditions of the component or device.

The contents of gas mixtures used during type approval shall conform to those specified in annex. A (normative) (generally a measurand gas in N2). For initial verification, subsequent verification and routine testing, the use of more realistic gas mixtures containing CO, CO2 and HC in N2 when applicable, should be considered.

Note It is not intended that the instrument or it's components should be dismantled for a test.

**8.1.3.1** An Instrument shall be given a visual inspection to obtain a general appraisal of its design and construction.

**8.1.3.2** An Instrument shall be tested according to clause 9 to determine its correct functioning.

**8.1.3.3** The manufacturer's written operating instructions for an Instrument shall be checked to ensure that correct procedures are clearly indicated, especially those specified in 7.2.

## 8.2 Initial verification

### 8.2.1 General requirements

A new Instrument shall undergo initial verification only after type approval. The verification shall be carried out using suitable testing means and certified calibration gases.

### 8.2.2 Inspection and tests

**8.2.2.1** Initial verification of an Instrument includes a visual inspection to determine conformance with the approved type approval. NOTE: Procedures should be provided for initial verification. An example of such a procedure is given in Annexure-C (Informative).

**8.2.2.2** After adjusting an Instrument according to the routine adjustment procedure described in the manufacturer's operating instructions, tests to determine its errors shall be carried out under rated operating conditions at several values over the measuring range. The tests shall be performed using gas mixtures of at least three different volume fractions within the nominal ranges of the measurands as listed below:

Gas Concentrations Nominal range

CO : 0.5 %vol to 5 %vol

CO2 : 4 %vol to 16 %vol

HC : 100 ppm vol to 10000 ppm vol as *n*-hexane

For all classes Oxygen channel should be tested for zero reading and span reading using a calibration gas without oxygen (only CO and/or CO2 and/or HC in N2) and a calibration gas containing 20.9 %vol O2 .

The calibration gases shall be introduced at the sample probe inlet at ambient pressure (to within 750 Pa). The errors observed shall be within the limits of the maximum permissible error of 5.4.2 on initial verification for each measurement.

## 8.3 Subsequent verification

**Clear and unambiguous Instructions about requirements and intervals for subsequent verification and advice about routine testing shall be provided in the Operating manuals and all other related documents for e.g. Service Manual, etc.**

Note : Examples of procedures for subsequent verification for routing testing are given in Annexes D & E (Informative) respectively.

Note 2 –The user should be informed that measurements of volume fractions below the lower limits specified during initial verification will result in large relative errors, even though the absolute errors may remain within acceptable limits. The user should be promptly informed of current applicable lower limit values. These large relative errors should be carefully considered before using such low volume fractions to evaluate vehicle emission performance.

## *9.0 PERFORMANCE TESTS FOR APPROVAL*

Prior to the type approval tests and as specified in the manufacturer's operating instruction manual provided (under 8.1.1.F), to be supplied with each Instrument, the instrument shall be adjusted with calibration gases according to these instructions provided. The calibration gases shall be supplied at the sample probe inlet at ambient pressure (to within 750 Pa).

### 9.1 Check of the calibration curve

This test shall be carried out according to Clause A.2, under reference conditions. During this test, the errors shall not exceed the maximum permissible intrinsic error of 5.4.1 for any measurement.

### 9.2 Stability with time or drift

This test shall be carried out according to Clause A.3, under reference conditions. During this test, the requirements of 5.11 shall be met.

### 9.3 Repeatability

This test shall be carried out according to Clause A.4 under reference conditions. During this test, the requirements of 5.12 shall be met.

### 9.4 Effect of influence quantities

As a rule, only one influence quantity shall be varied during a test while all others are kept at their reference values.

### 9.4.1 Environmental conditions and electrical supply

The indications of the Instruments shall remain within the maximum permissible error on initial verification during the following tests covering the rated operating conditions specified in 5.5.2 except for power supply variations that shall not cause a variation of indication larger than half the modulus of the maximum permissible error on initial verification.

a. Dry heat : See Clause A.5

b. Cold : See Clause A.6

c. Damp heat, steady state : See Clause A.7

d. Atmospheric pressure : See Clause A.8

e. Power supply variation : See Clause A.9

**9.4.2 Influence of gas components other than the measurand (cross sensitivity).**

This test shall be carried out under reference conditions except for 5.5.1E

During this test, the requirements of 5.5.3 shall be met where the absolute value of the variation of the indication found shall not exceed half the modulus of the maximum permissible error on initial verification.

**9.5 Disturbances**

Significant faults shall not occur, or shall be detected by means of checking facilities during the following tests when carried out to verify the requirements of 5.6 for the instruments under rated operating conditions (as specified in 5.5.2)

a) Mechanical shock and vibrations (See Point A.11)

b) Short time power reductions (See Point A.12)

c) Bursts from the mains (transients) (See point A.13)

d) Electrostatic discharges (See point A.14)

e) Radiated radio frequency electromagnetic fields (See Point A.15)

f) Mains frequency magnetic fields. (See Point A.16)

**9.6 Other important technical and metrological requirements**

The Instrument shall be tested for conformity to the following Requirements:

a) Warm up time according to 5.8 : See Clause A.17

b) Response time according to 5.7 : See Clause A.18

c) Low flow according to 6.1.7 : See Clause A.19

d) Leakage according to 6.1.8 : See Clause A.20

e) HC residue according to 6.3.2 : See Clause A.21

f) Filter unit according to 6.1.3 : See Clause A.22

g) Water separator according to 6.1.4 : See Clause A.23

h) Propane / Hexane equivalency factor according to 5.9 : See Clause A.24

i) Engine Speed Measurement System: See Clause A.25

### 9.7 Source of power for Pattern Evaluation

The appropriate source of power for field use of Instruments shall be specified in the manufacturer's operating instructions. If a source of power is specified in addition to the mains, for example a battery or Portable generator, then the Instrument shall undergo type approval tests with each source of power with which it is intended to operate.

Each specified test in Annexure – A (normative / mandatory) shall be started and completed without changing or recharging the power source.

*ANNEXURE – A (NORMATIVE / MANDATORY)*

# DESCRIPTION OF PERFORMANCE TESTS FOR TYPE APPROVAL

## A.1 General

The HC volume fractions specified for these tests are expressed in terms of N-hexane, however, propane may be used as the HC component of the calibration gas as required for each performance test except the one specified in Clause A.24 (See Clause 1 and 5.9).

## A.2 Calibration Curve

The errors of the Instruments shall be determined separately for each measurand and for at least three values within their measuring range using the recommended volume fractions.

The measurements shall be performed successively.

| | **1st** | **2nd** | **3rd** |
|---|---|---|---|
| CO | 0.5 % vol | 1 % vol | 3.5 % vol and/or 5% vol |
| CO2 | 6 % vol | 10 % vol | 14 % vol |
| HC | 1000 ppm vol | 5000 ppm vol | 7000 ppm vol |
| O2 | 0.5 % vol | 10 % vol | 20.9 %vol. |

The measurements shall be performed successively.

## A.3 Stability with Time or Drift

This test shall be conducted for a period of 4 h following the warm-up time. Measurements shall be performed at least every half-hour using the following Gas Mixtures.

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

**A.4 Repeatability**

The test procedure specified in 5.12 shall be carried out with the recommended volume fractions.

Measurand Volume fraction of measurand

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

**A.5 Dry Heat Test:**

A.5.1 **This test consists of exposure of the Instruments to a temperature of 45 °C under "free air" conditions for 2 h (the time duration specified begins after the Instrument has reached temperature stability). During the test, the rate of change in temperature shall not exceed 1 °C/min during heating up and cooling down, and the relative humidity in the testing atmosphere shall not exceed 50%.**

**A.5.2** The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using the two mixtures composed of the recommended volume fractions.

| | **1st mixture** | **2nd mixture** |
|---|---|---|
| CO | 0.5 % vol | 3.5 % vol |
| CO2 | 14 % vol | 14 % vol |
| HC | 1000 ppm vol | 5000 ppm vol |
| O2 | 0.5 % vol | 0.5 % vol |

The tests will be repeated at 50° C also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

**A.6 Cold Test**

A.6.1 **This test consists of exposure of the Instruments to a temperature of 5 °C under "free air" conditions for 2 h (the time duration specified begins after the Instruments have reached temperature stability). During the heating up or cooling down of the Instrument, the rate of change in temperature shall not exceed 1 °C/min.**

The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using two mixtures composed of the recommended volume fractions.

| | **1st mixture** | **2nd mixture** |
|---|---|---|
| CO | 0.5 % vol | 3.5 % vol |
| CO2 | 14 % vol | 14 % vol |
| HC | 1000 ppm vol | 5000 ppm vol |
| O2 | 0.5 % vol | 0.5 % vol |

A.7 Damp Heat, Steady State test:

**A.7.1** This test consists of exposure of the Instruments to a constant temperature of 30 °C and a constant relative humidity of 85 % for two days. The exposure shall be such that water does not condense on the Instruments. The temperature is deemed to be steady when the difference between the extreme temperatures does not exceed 5 °C, and the rate of change does not exceed 5 °C/h.

**A.7.2** The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test, one measurement shall be performed every day using two mixtures composed of the recommended volume fractions.

| | **1st mixture** | **2nd mixture** |
|---|---|---|
| CO | 0.5 % vol | 3.5 % vol |
| CO2 | 14 % vol | 14 % vol |
| HC | 1000 ppm vol | 5000 ppm vol |
| O2 | 0.5 % vol | 0.5 % vol |

**A.8 Atmospheric Pressure test**

**A.8.1** The test consists of measurements under the extreme pressures of the rated operating conditions or extreme pressures outside these limits when specified by the manufacturer. The extreme values shall be reached gradually from stable ambient pressure conditions and shall then be kept stable during 30 min before starting the measurements as specified in 8.2.

**A.8.2** Test gases shall be supplied at the probe at ambient test pressure (to within 750 Pa). At least two measurements shall be performed at each extreme pressure value using two mixtures composed of the recommended volume fractions.

The errors observed shall be within the limits of the maximum permissible errors as specified in Table 4 on initial verification for each measurement.

NOTE: If an automatic or semi-automatic adjustment is part of the pressure compensation process, care must be taken to ensure that the measurements at both extreme pressure values are performed after such adjustment has been carried out.

| | **1st mixture** | **2nd mixture** |
|---|---|---|
| CO | 0.5 % vol | 3.5 % vol |
| CO2 | 14 % vol | 14 % vol |
| HC | 1000 ppm vol | 5000 ppm vol |
| O2 | 0.5 % vol | 0.5 % vol |

A.9. Power Supply Variation Test:

A.9.1 **The A.C. power supply test consists of exposure of the Instruments to extreme values of the nominal power supply voltage and nominal frequency for a period long enough to perform the required measurement under following variation conditions.**

Voltage: Nominal Voltage (230V), +10% ~ -15%

Frequency: Nominal Frequency (50 Hz), ± 1 Hz.

The AC power supply test will be repeated with frequency of 50 Hz ±2 Hz also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

**A.9.2** The D.C. Power Supply test consists of exposure of the Instruments to the specified power supply conditions for a period long enough to perform the required measurement. The upper tolerance limit shall be as specified by the manufacturer. The lower tolerance limit shall be the lowest voltage at which the Instrument provides measurement results.

**A.9.3** While the Instruments are exposed separately to each type of mains variation as indicated in A.9.1 or A.9.2 above the measurements shall be performed using following volume fractions of Gas Mixtures.

CO: 0.5 % vol

$CO_2$: 14 %vol

HC: 1000 ppm vol

$O_2$: 0.5 %vol

The AC power supply test will be repeated at 50° C also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

**A.10** Influence of gas components other than the measurands (cross sensitivity)

A.10.1 **The cross sensitivity shall be determined by the following two tests.**

A.10.1.1 **Test with $N_2$ alone:**

a) Supply the Instrument with $N_2$ alone.

b) Supply the Instrument successively with each influencing gas alone in $N_2$ at its maximum value as specified in 5.5.3.

c) Compare the "zero" responses of the Instruments determined in a) and b) for each measurand. The difference of indications shall meet the requirement specified in 5.5.3 for "ZERO" .

**A.10.1.2** Test with all measurands in $N_2$ :

a) Supply the Instrument with a measurand in $N_2$ alone. Repeat the operation for the other measurands.

b) Supply the Instrument with all measurands together in $N_2$ .

c) For each measurand, the difference between the errors of the Instruments determined in a) and the error determined in b) shall meet the requirements specified in 5.5.3.

A.10.2 **For above test and for Instruments that detect with infra red absorption and for $O_2$ channel, the following volume fractions of gas mixture is required**

<u>For the measurands in $N_2$</u> :

_ 3.5 %vol CO

_ 14 % vol $CO_2$

_ 1000 ppm vol HC and

_ water up to saturation.

Referring to 5.5.3, if the presence of $O_2$ and $H_2$ is necessary, two different gas mixtures shall be used to avoid explosive risk. The recommended volume fractions for the measurands in $N_2$ are the following.

Mixture A : 3.5 % vol CO

14 % vol $CO_2$

1000 ppm HC

10 % $O_2$

Mixture B : 3.5 % vol CO

14 % vol $CO_2$

5000 ppm HC

5 % $H_2$

**A.11 Mechanical shock and Vibrations Test:**

**A.11.1** For mechanical shock testing, the tested Instrument shall be placed in its normal position of use on a rigid surface. It shall be tilted on one bottom edge and then allowed to fall freely onto the test surface.

The following conditions shall be applied:

_ Height of fall: 25 mm

**_ Number of falls: 1 on each bottom edge.**

See IEC 60068-2-31.

**A.11.2** Vibration test should be conducted as per IS 9000 Part VIII 1981. Analyser may be subjected to vibration in normal mounting axis for 5 to 9 Hz ± 3 mm displacement and 9 to 150 Hz ±1 g acceleration amplitude, preferably with electrical power 'ON' condition. This test should be repeated for other two axes also. However, during the test the instrument shall be mounted in its normal position only.

**A.11.3** Before and after the test, measurements shall be performed using Following volume fractions of gas mixture.

CO: 0.5 %vol

$CO_2$: 14 %vol

HC: 1000 ppm vol

$O_2$: 0.5 %vol

**A.12 Short Time Power Reductions Test:**

A.12.1 **A test generator suitable for reducing the amplitude of the A.C. mains voltage is used. It shall be adjusted before being connected to the Instruments. The mains voltage interruptions and reductions shall be repeated 10 times with an interval of at least 10 s between successive disturbances. 100 % reductions shall be effectuated for duration of 10 ms 50 % reductions shall be effectuated for duration of 20 ms.**

**A.12.2** During the test, measurements shall be performed using the following volume fractions of gas mixture:

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

A.13 Bursts from the mains (transients):

**A.13.1** The test consists of exposure of the Instruments to bursts of voltage spikes of 1 kV and having a double exponential waveform. Each spike shall have a rise time of 5 ns and a half amplitude duration of 50 ns. The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300 ms. Repetition frequency of the impulses and peak values of the output voltage on 50 Ω load: 5 kHz ± 1 kHz. The transient generator shall have an output impedance of 50 Ω and shall be adjusted before connecting the Instrument. At least 10 positive and 10 negative bursts randomly phased shall be applied. Insertion of blocking filters in the cables to the Instrument may be necessary to prevent the burst energy being dissipated in the mains.

**A.13.2** During the test, measurements shall be performed using the following volume fractions of gas mixture.

CO : 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

A.14 Electrostatic discharges test:

**A.14.1** A capacitor of 150 pF shall be charged by a suitable DC voltage source of 6 kV in contact mode and 8 kV in air mode. Then it shall be discharged through the Instrument by connecting one terminal to the Instrument's ground chassis and the other through a 330 Ω resistance to the Instrument's surfaces that are normally accessible to the user. At least 10 successive discharges shall be applied with a time interval between discharges of at least 10 s. An Instrument not equipped with a grounding terminal shall be placed on a grounded plane surface that projects beyond the Instrument by at least 0.1 m on all sides. The associated grounded connection to the capacitor shall be as short as possible.

**A.14.2** In the contact discharge mode, to be carried out on conductive surfaces, the electrode shall be in contact with the Instrument and the discharge shall be actuated by the discharge switch of the generator. In the air discharge mode, on insulating surfaces, the electrode is approached to the Instrument and the discharge occurs by spark.

**A.14.3** During the test, measurements shall be performed using the following volume fractions of gas measurand.

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

**A.15 Radiated, radio frequency, electromagnetic fields test**

**A.15.1** Instruments shall be exposed to electromagnetic field strength as follows:

_ Frequency range: 26 MHz to 1000 MHz

_ Field strength: 10 V/m

_ Modulation: 80 % AM, 1 kHz sine wave.

A.15.2 **The field strength may be generated in the following ways:**

a) A strip line for low frequencies for small instruments from DC to 150 MHz

b) A TEM cell (Transverse Electromagnetic Mode cell) for higher frequencies, up to 1 GHz

c) A biconical antenna (26 MHz to 300 MHz)

d) A log periodic antenna (100 MHz to 1000 MHz).

The specified field strength shall be established prior to the actual testing (without the Instruments in the field). When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference to radio communications care needs to be taken to handle reflections from walls. Anechoic shielding may be necessary.

**A.15.3** During the test, measurements shall be performed using the following volume fractions of gas mixture.

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

See IEC 61000-4-3.

NOTE : The attention of the experts is drawn to the fact that IEC 61000-4-3 refers to the frequency range from 80 MHz to 1000 MHz.

The lower frequencies are covered by IEC 61000-4-6.

**A.16 Mains Frequency Magnetic Fields Test:**

The Instrument tested shall be exposed in all directions to a magnetic field of 30 A/m at mains frequency. During the test, measurements shall be performed using the following volume fractions of gas measurand.

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5%vol

A.17 **Warm-up time:**

**A.17.1** At reference conditions and at 5 °C, the warm-up time test to verify compliance with 5.8 shall consist of the following steps:

a) Stabilize the Instrument at each temperature

b) Let the Instrument warm up

c) Immediately after either the manufacturer's prescribed warm-up period has elapsed or an automatic warm-up lockout has been de-activated, perform a volume fraction measurement (with any necessary internal adjustment being performed prior to this measurement)

d) At time intervals of 2 min, 5 min and 15 min after warm-up, perform a measurement with the same calibration gas as above.

The difference between any of the measured values above shall not exceed the modulus maximum permissible error on initial verification.

NOTE: At reference conditions, the warm-up time test may be included with the drift test.

## A.18 Response time

**A.18.1** A measurement shall be taken to determine the time required for an Instrument to respond to a calibration gas after sampling ambient air supplied at the probe. A means shall be employed for instantly changing from sampling ambient air to sampling calibration gas through the sample gas inlet probe. The gases shall be supplied at the probe inlet at ambient pressure (to within 750 Pa). The response time shall not exceed the appropriate values specified in 5.7.

**A.18.2** The following recommended volume fractions shall be used.

CO : 0.5 %

CO2 : 14 %

HC : 1000 ppm

O2 : 0.5 %

## A.19 Low flow

**A.19.1** A measurement shall be performed with a calibration gas that is initially supplied to the gas handling system at a gas flow rate greater than the minimum required by the tested Instrument. During the measurement, the gas flow rate shall be reduced until the low flow indicator responds according to requirements of 6.1.7.

**A.19.2** The following recommended volume fractions shall be used.

CO: 0.5 %vol

CO2: 14 %vol

HC: 1000 ppm vol

O2: 0.5 %vol

## A.20 Leakage

**A.20.1** When following gas mixture is used, the adjustment of the leakage and the test shall be performed successively for each component.

**A.20.2** An adjustable leak shall be introduced artificially into the gas handling system near the pump where a leak of an appropriate orifice size will have the greatest effect on the measurement. With this artificial leak closed, a calibration gas shall be supplied at the probe at ambient pressure (to within 750 Pa).

**A.20.3** While sampling the calibration gas, record the indication, then adjust the leakage rate so that the indication of the calibration gas differs from the value indicated previously (without the leak) by an amount equal to the requirement of 6.1.8.

Without disturbing the artificial leak, remove the calibration gas supplied at the probe, and conduct the leakage test procedure as described in the manufacturer’s operating instructions.

NOTE: Since the leakage test is performed by introducing air in to the system, the calibration gas supplied at the probe should have a volume content of O2 close to 0 %.

**A.20.4** The following volume fractions shall be used.

CO : 0.5 % vol

CO2 : 14 % vol

HC : 1000 ppm vol

O2 : 0 % vol.

**A.21 HC residue**

**A.21.1** The exhaust of a specially adjusted test engine shall be sampled for at least 5 min by an Instrument in thermal equilibrium at 5 °C. The exhaust gas shall contain at least 5 % CO and 3000 ppm HC. Immediately after the sampling, conduct an HC residue check as described by the manufacturer’s operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with the requirement of 6.3.2.

**A.21.2** Then following calibration gases shall be supplied at the probe at ambient pressure (to within 750 Pa) to check compliance with the maximum permissible error on initial verification.

CO: 3.5 %vol

HC: 5000 ppm vol

**A.22 Filter unit**

**A.22.1** At reference conditions, the Instrument shall be exposed to exhaust gases from a specially adjusted test engine for a period of at least 15 min. The exhaust gas shall contain at least 5 % CO and 6000 ppm HC. Immediately after the sampling, conduct an HC residue check as described by the manufacturer's operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with requirements of 6.3.2. The Instrument shall be checked immediately with a calibration gas that shall be supplied to the gas handling system at ambient pressure (to within 750 Pa). The Instrument shall comply with the requirements for the maximum permissible error on initial verification and for the response time.

**A.22.2** The test shall be carried out using the following gas mixture:

CO: 3.5 %vol

$CO_2$ : 14 %vol

HC: 1000 ppm vol

$O_2$ : 0.5 %vol

**A.23 Water separator**

**A.23.1** The water separator shall be subjected to the following two tests.

a) High temperature test:

_ Stabilize the Instrument at 45 °C, and

_ Expose the Instrument to water saturated $N_2$ at 45 °C, or water saturated ambient air at 45 °C, supplied to the gas handling system for 30 min.

b) Low temperature test:

_ stabilize the Instrument at a low ambient temperature within the rated operating conditions, and

_ expose the Instrument to exhaust gases from any car attached to the probe for 30 min.

**A.23.2** After each test, the Instrument shall be checked immediately with the following gas mixture:

CO: 3.5 %vol

$CO_2$: 14 %vol

HC: 5000 ppm vol

$O_2$: 0.5 %vol

It shall comply with the requirements of the maximum permissible error on initial verification and with the response time requirements of 5.7, before and after the test.

**A.24 Propane/hexane equivalency factor**

**A.24.1** The test procedure is as follows:

a) Make a measurement for each of the following recommended volume fractions of propane calibration gas: 2000 ppm vol and 10000 ppm vol

b) Calculate the absolute error of the Instruments for each of these two volume fractions of propane calibration gas.

To this end, the true value is determined as follows:

$I_{true} = C \times PEF$

Where, *C* is the true value of the volume concentration of propane, and

PEF is the value of the propane/hexane equivalency factor given by the Manufacturer

c) Make a measurement for each of the following recommended fractions of hexane calibration gas: 1000 ppm vol and 5000 ppm vol

d) Calculate the absolute error of the Instrument for each of these two volume fractions of hexane

f) For each of the two volume fractions, calculate the difference between the error obtained with propane and that obtained with hexane.

**A.24.2** The difference between the errors shall not exceed (according to the case ---- see 5.9) the applicable maximum permissible intrinsic error or half of the applicable maximum permissible intrinsic error.

NOTE: It is assumed that the error of the Instruments are constant both near 100 ppm vol and near 1000 ppm vol.

CAUTIONARY NOTE : Because of its low vapour pressure, Hexane can condense at ordinary temperatures of shipment, storage and use. Such condensation would invalidate the certified gas mixture concentration. Therefore, extreme care shall be taken at all times during shipment, storage and use to ensure that Hexane cylinders are maintained sufficiently above the condensation temperature for the specified gas volume fraction at the cylinder pressure.

## A.25 Engine Speed Measurement System

The linearity of engine speed measurement shall be checked at minimum 4 points, which shall include at least one point, which is more than 80% of the required full scale range. The linearity shall be checked using engine speed measurement system with the accuracy of at least ±3 rpm.

## *ANNEXURE – B*

## *DESIGNATION OF CALIBRATION GASES AND*

## *THEIR COMPOSITION*

**B.1** **General requirements**

**B.1.1** The calibration gases shall be supplied either in gas cylinders or by dynamic blending.

a) Each gas cylinder shall be identified with the following information included as a mark, label and/or certificate):

_ Supplier of the gas cylinder and serial number

_ Composition of the gas mixture

_ Temperature limits for use and storage

_ Date of analysis and expiration date

_ Testing authority and

_ The marking "calibration gas mixture".

**b) Blended gases shall meet the requirements of ISO 6145 and 7395 or of B.1.2 and B.2.**

**B.1.2** The composition of calibration gases used for Type approval and verification shall be certified as complying with the requirements of B.2 by a competent authority and as being traceable to national, regional or international standards.

**B.1.3** Calibration gases for all purposes except type approval and verification shall be certified by the supplier of the gases and shall be traceable to the appropriate standards.

**B.1.4** The material of gas cylinders shall be inert to the gases contained therein.

**B.1.5** The appropriate safety regulations shall be followed in the handling of the gases.

**B.2** **Specifications and uncertainties of composition of the gas mixtures:**

**B.2.1** The unit for the quantity of gases contained or delivered shall be either in molar or volume fractions. (See 5.1)

**B.2.2** The blend / preparation tolerances of the calibration gas mixtures shall not exceed 15 % of the volume fraction of each component.

**B.2.3** For gas mixtures the uncertainty/analytical accuracy in the composition shall be 1 % or less of the volume fraction of each measurand except for HC of 1000 ppm and below, where the uncertainty shall be 2 % or less for gas calibration and tests such as calibration curve, propane/hexane equivalency factor. For the remaining tests, the uncertainty/analytical accuracy of the gas mixtures may be 2% of the volume fraction of each measurand. The composition of each component not subject to measurement shall have an uncertainty of 5% or less.

The specified uncertainty values are values relative to the Standards referred to in B.1.2.

### *B.3 Preparation of gases in special cases*

**B.3.1** Propane shall be used for calibration gas mixtures requiring HC therefore the propane/hexane equivalency factor shall be taken into account.

B.3.2 **Volume fractions of O2, H2, NO, and water vapor shall be blended with the other gases as required during the tests. The volume fraction of water vapor required should not be supplied in high-pressure gas cylinders because of instability and corrosion effects, and mixtures of O2 shall only be blended with N2.**

**B.3.3** Ambient air shall be drawn through a charcoal filter or equivalent system when it is used to set zero for instruments measuring HC.

## *ANNEXURE - C (INFORMATIVE)*

## *PROCEDURE FOR INITIAL VERIFICATION*

The initial verification of the Instruments may include the following tests.

a) Check the power supply voltage and frequency at the location of use to determine compliance with the specifications on the measuring Instrument's label.

b) Check the activation of the warm-up lockout Instruments by attempting to make a measurement within 1 min of initial power-on of the Instruments.

c) After the Instruments have warmed up, perform the calibration curve check as described in 8.2.2.2.

d) Check the air-tightness of the system by performing a leak check as described in the manufacturer's operating instructions.

e) Check for HC residues with the procedure described in the manufacturer's operating instructions.

f) Check for the activation of the low gas flow device (and also for the low flow lockout) by restricting the gas flow supplied to the probe while sampling ambient air.

g) Check the response time of the CO channel.

## *ANNEXURE - D (INFORMATIVE)*

## *PROCEDURE FOR SUBSEQUENT VERIFICATION*

Subsequent verification of an Instrument at the same location may include the following tests.

a) For short-term subsequent verification, perform all tests included in the initial verification except for the power check and the warm-up check.

**b) For short-term subsequent verification, perform the calibration curve check using the number of gas mixtures required for initial verification unless the responsible legal authority specifies fewer mixtures**

c) For long-term subsequent verification, perform all tests included in the initial verification.

d) When the Instruments have been moved to a new location (e.g. change in business address as defined by the responsible legal authority), or have undergone repairs other than replacement of components as defined in Step E of Annex-E or in the manufacturer’s operating instructions, perform all tests included in the initial verification.

## ANNEXURE – E (INFORMATIVE)

## PROCEDURE FOR ROUTINE TESTING

A routine test of the Instruments should consist of at least the following.

**a)** **Perform an internal adjustment check within 1 hour after performing each vehicle test.**

b) Check for HC residues before testing each vehicle.

c) Check the Instrument's gas calibration and internal adjustment with a calibration gas at intervals specified by the responsible legal authority or recommended in the manufacturer's operating instruction manual.

d) Perform a leak check at least once a day. Repair any leaks and conduct a successful leak check before testing any vehicle.

e) Conduct a leak check after each disassembly of the gas handling system (e.g. a probe or filter element replacement). Repair any subsequent leaks and conduct a successful leak check before testing any vehicle.

## *ANNEXURE-F (NORMATIVE / MANDATORY)*

## *LAMBDA CALCULATION*

F.1 Introduction : The value of lambda is determinant for the burning efficiency of an engine. The value depends on the composition of the fuel, the air that is used for the combustion and on the combustion products as found in the exhaust gases.

A basic formula, taking into account:

_ Components of the fuel: carbon, hydrogen, oxygen and water content

_ Water content of the air

**_ Components of the exhaust gases: carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxide has been developed by J. Brett Schneider.**

**A simplified formula derived from the basic formula and based on the assumption that the water content of fuel and air and the NOx content in the exhaust gases are negligible, allows the computation of lambda when certain components of the exhaust are measured.**

F.2 Simplified Lambda formula : **For lambda calculation, based upon measurements of CO, CO2, HC and O2 the following formula is standardised.**

$$\lambda = \frac{[CO_2] + \frac{[CO]}{2} + [O_2] + \left\{ \left( \frac{H_{cv}}{4} \times \frac{3,5}{3,5 + \frac{[CO]}{[CO_2]}} - \frac{O_{cv}}{2} \right) \times \left( [CO_2] + [CO] \right) \right\}}{\left( 1 + \frac{H_{cv}}{4} - \frac{O_{cv}}{2} \right) \times \left\{ \left( [CO_2] + [CO] \right) + \left( K_1 \times [HC] \right) \right\}}$$

Where

[ ] is the concentration in %vol, for HC only in ppm vol

$K_1$ is the conversation factor for HC if expressed in ppm vol n-hexane (C6H14) equivalent. Its value in this formula is $6 \times 10^{-4}$

$H_{cv}$ is the atomic ratio of hydrogen to carbon in the fuel. The arbitrary value is 1.7261

$O_{cv}$ is the atomic ratio of oxygen to carbon in the fuel. The arbitrary value is 0.0176

NOTE : The simplified lambda calculation is only valid for measurements on cars with negligible NOx concentrations in the exhaust gas.

**F.3** **Other Formulae :** Other formulae may also be applied. As specified in 7.2.2 the operating instructions shall include the applied model.

**CHAPTER IV : CONFORMTY OF PRODUCTION PROCEDURE FOR TESTING OF SMOKE METER.**

1 Physical Check

It shall consist of checking -

1) Suitability and label on the instrument for the intended use.
2) Identification of the instrument consisting of model, serial number, name and address of the manufacturer, electrical power requirement, year and month of manufacture and operating voltage range specified in English language.
3) Scale, resolution, display.
4) Peak hold facility.
5) Heating facility.
6) Calibration facility.
7) Printout specifications, if provided with a printer.
8) Documentation.
9) Verification of the following specifications :
   - accessories provided
   - light source / detector / optical bench type & model no.
   - smoke tube dimensions
   - all printed circuits boards (model nos., sizes, quantity)
   - display : type, no. of digits
   - input/output connectors, cables
   - front panel controls
   - calibration filter value
   - software programme version
10) Oil temperature sensor probe
11) Engine speed sensor clamp / attachment.
12) Any other checks as found relevant

2.0 Linearity

1) Smoke measurement :

The linearity of smoke measurement shall be checked at minimum 4 points (5 points to include a full scale point, In case meter full scale corresponds to the total light cut-off) including the zero point. This will be checked by three different neutral density filters of known value within $\pm$ 0.05$m^{-1}$ in the specified range given below, supplied by the smoke meter manufacturer or his representative along with Calibration Certificate from a reputed organisation. The neutral density filter shall have flat response (preferably within $\pm$ 2 % tolerance in absolute value) between the wavelength range 430 to 680 nm and the response at spot frequency between 550 to 570 nm as recommended by the manufacturer will be considered for linearity test. The test agency may decide to test the accuracy of the filter prior to the test.

one filter having $K \leq 1\ m^{-1}$

one filter having K between 1.5 and 2.5 $m^{-1}$

one filter having K ≥ 3 $m^{-1}$.

2) Engine speed measurement :
The linearity of engine speed measurement shall be checked at minimum 4 points, which shall include at least one point, which is more than 80% of the required full scale range. The linearity shall be checked using engine speed measurement system with the accuracy of at least ± 3 rpm.

3) Oil temperature measurement:
The linearity of oil temperature measurement shall be checked at minimum 4 points, uniformly distributed over the full-scale range. The linearity shall be checked using temperature measurement system with the accuracy of at least ± 0.5°C.

3.0 Temperature Sensitivity

The smoke meter shall be maintained at 278 K and 323 K temperature. Span reading with neutral density filter having value between 1.5 to 2.5 $m^{-1}$ at both these temperatures shall be within 0.1 $m^{-1}$ from the reading obtained at the room temperature of 303 ± 2 K.

Separate drift and repeatability tests are not included as these aspects will be partly verified during temperature tests.

4.0 CORRELATION TESTS

4.1 Full Load Test

The smoke meter under test and reference smoke meter shall be installed on an engine or a vehicle and full load test will be carried out. If it is not possible to install both the meters simultaneously, the testing will be carried out at first with reference smoke meter and subsequently with the meter under testing. The test shall be repeated to measure smoke of different 'K' values (minimum five points) approximately evenly spaced over the range 0 to 4 $m^{-1}$. If required the air system or the fuel system of the engine shall be adjusted to get smoke of different 'K' values. The difference in the reading shall be within percentage specified in the table below.

| Mean value of test in K ($m^{-1}$) | % Difference allowed | |
|---|---|---|
| <= 1 | 5 | or 0.1 $m^{-1}$ whichever is higher |
| >1, <= 2 | 7.5 | |
| >2,<=3 | 10 | |
| >3 | 12.5 | |

4.2 Free Acceleration Test

The test shall be carried out on at least five different diesel vehicles/engines as below :

a) one engine used for car/jeep application

b) four different engines used for LCV/HCV application

The correlation tests shall be performed using either engines or complete vehicles. If the test is carried out on an engine mounted on test bench, the engine shall be decoupled from the dynamometer. If the test is carried out on a vehicle, the gear change control shall be set in the neutral position and the drive between engine and gearbox engaged. Test engines shall be warmed up to attain oil temperature of minimum 60°C.The test shall be carried out only after this engine condition is reached.

The free acceleration test shall be conducted as below: With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the speed governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the smoke meter reverts to the corresponding conditions. Typically the maximum time for acceleration shall be 5s and for the stabilization at maximum no load speed shall be 2s. The time duration between the two free accelerations shall be between 5-20s.

The operation described above shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustments of the apparatus. During this flushing cycle operation the sample probe shall not be inserted in to the vehicle exhaust system.

The operation described above shall then be carried out with sample probe inserted in to the vehicle exhaust system. The maximum no load rpm reached during this operation shall be within $\pm$ 500 rpm in respect of 3 wheeler vehicles and $\pm$ 300 rpm for all other categories of vehicles, of the average value obtained in the flushing cycle above. If for any reason the speed is not within the specified tolerance band the particular smoke reading shall be considered as invalid and shall be discarded. The above operation shall be repeated till the peak smoke values recorded in four successive accelerations are valid and are situated within a bandwidth of 25 % of the arithmetic mean (in m-1 unit) of these values or within a bandwidth of 0.25 K, whichever is higher and do not form a decreasing sequence. The absorption coefficient to be recorded shall be the arithmetic mean of these four valid readings.

Zero drift shall be checked after the test and if drift is greater than 0.2 $m^{-1}$ this test shall be taken as invalid and repeated.

If the drift is 0.2 $m^{-1}$ or less and positive, it shall be subtracted from the mean of the last valid reading.

A sequence of four free acceleration tests as per the procedure above shall be conducted with smoke meters as given below :

Test 1 With reference smoke meter.

Test 2 Subject meter installed on its own in the vehicle tailpipe and calibrated according to manufacturer's instructions using a neutral density filter.

Test 3 As per Test 2.

Test 4 As per Test 1.

Based on the mean of valid four readings in each test :

a) A test sequence is valid only if 'K' value of Test does not vary from Test 1 by more than 0.3 $m^{-1}$.

b) The percentage difference between the mean of the test 1 and 4 and the mean of test 2 and 3, for five vehicles, shall be less than figures given in the table below

| Mean value of test 1 & 4 K ($m^{-1}$) | % Difference allowed | |
|---|---|---|
| | ( 3 vehicles ) | ( 2 vehicles) |
| <= 1 | 5 } or 0.1 $m^{-1}$ whichever is higher | 10 |
| >1<= 2 | 7.5 } | 15 |
| >2, <=3 | 10 | 20 |
| >3 | 12.5 | 25 |

c) The result of Test 2 and 3 must lie within ± 10% of the mean of the two tests.

d) In case correlation test does not meet the tolerances specified above in only one of the vehicles/engines, additional two correlation tests each consisting of five tests as mentioned above shall be carried out on different vehicles / engines (vehicles/engines other than used in the first series of correlation tests). The meter can be considered satisfactory if it meets these additional correlation tests.

5.0 In addition to above conformity tests, the test agencies at their sole descretion may determine to carry out any other test, if found necessary.

## CHAPTER V : CONFORMITY OF PRODUCTION PROCEDURE FOR TESTING OF 2 GAS ANALYSER

1 PHYSICAL CHECKING AND VERIFICATION

i) Instrument Model number
ii) List of accessories
iii) Sensor detector type and model number
iv) Sample cell dimensions
v) All PCB model numbers, size and quantity
vi) Display : type, number of digits, scale and resolution
vii) Probe length and diameter
viii) Input/output connectors and cables
ix) Printout sample
x) Front panel controls
xi) Electrical calibration
xii) Software programme version

2 Analyser Accuracy

The gas analyser shall have an accuracy of ± 3% of full scale for CO part and ±30 ppm absolute or ± 10% relative whichever is greater for HC part as determined by analysing known standard gases.

This accuracy shall be checked with the calibration gases of known concentration at minimum five points covering zero to full scale range. Calibration points shall be uniformly spaced as far as possible. It is preferred to test at ten points with five points below 5% for CO and 5000 ppm for HC.

3 Interference effects

The sum of the individual effects on the reading of the analyser from other gases and perticularly in concentration closed to those existing in the engine exhaust gas shall be less than 0.2 units for CO and 15 ppm for HC.

Interference of Carbon-di-oxide (CO2) and water shall be checked with CO2 gas between 12 to 16% concentration by flowing :

a) Only CO2 gas;
b) CO2 gas bubbled through water;
c) Nitrogen bubbled through water;
d) CO bubbled through water;
or known mixture of above all gases.

4.0 Temperature Sensitivity

The instrument shall be suitable for ambient temperatures between 278 K and 318 K. Between these two limits the result of the measurement shall not differ from that obtained at a temperature of 303 K ( ± 2 K) by more than 0.2 units for CO and ±30 ppm absolute or ± 10% relative whichever is greater for HC.

This test shall be conducted by passing a span gas having concentration more than 60% of the full scale. This test shall be conducted in the temperature controlled chamber and readings shall be taken after allowing two hours stabilisation time after attaining specified temperature. Any other drift like zero drift/span drift with time (if observed) shall be compensated for this time interval.

Separate drift and repeatability test are not included as these aspects will be partly verified during temperature sensitivity tests.

5.0 In addition to above conformity test, the test agencies at their sole discretion may determine to carry out any other test, if found necessary.

## CHAPTER VI : CONFORMITY OF PRODUCTION PROCEDURE FOR TESTING OF 4 GAS ANALYSER

1 PHYSICAL CHECKING AND VERIFICATION

i) Instrument Model number
ii) List of accessories
iii) Sensor detector type and model number
iv) Sample cell dimensions
v) All PCB model numbers, size and quantity
vi) Display : type, number of digits, scale and resolution
vii) Probe length and diameter
viii) Input/output connectors and cables
ix) Printout sample
x) Front panel controls
xi) Electrical calibration
xii) Software programme version

2 Following tests as per type approval test procedure for 4 gas analyzer given in chapter III shall be carried out for Conformity of Production test.

1. Check of the calibration curve (Clause 9.1 of chapter III)
2. Environmental condition and electrical supply (Clause 9.4.1 of chapter III)
3. Influence of gas components other than the measured. (Cross sensitivity)(Clause 9.4.2 of chapter III)

3 In addition to above conformity test, the test agencies at their sole discretion may determine to carry out any other test, if found necessary.

# PART IX : DETAILS OF STANDARDS FOR TAILPIPE EMISSIONS FROM PETROL, CNG, LPG AND DIESEL ENGINED VEHICLES and Test Procedures Effective from the Year 2000.


CHAPTER 1 : OVERALL REQUIREMENTS

CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

CHAPTER 3 : TYPE I TEST ON S.I. ENGINES, CNG, LPG AND DIESEL ENGINED VEHICLES (VERIFYING THE AVERAGE EMISSIONS OF GASEOUS AND PARTICULATE POLLUTANTS)

CHAPTER 4 : RESISTANCE TO PROGRESS OF A VEHICLE - MEASUREMENT METHOD ON THE ROAD – SIMULATION ON A CHASSIS DYNAMOMETER

CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

CHAPTER 6 : GAS SAMPLING SYSTEMS

CHAPTER 7 : CALIBRATION OF CHASSIS DYNAMOMETERS, CVS SYSTEM AND GAS ANALYSIS SYSTEM AND TOTAL SYSTEM VERIFICATION

CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

CHAPTER 9 : TYPE II TEST ON SI ENGINES (VERIFYING CARBON MONOXIDE EMISSION AT IDLING)

# CHAPTER 1 : OVERALL REQUIREMENTS

1. **Scope :**

1.1 This Part applies to the tailpipe emission of vehicles equipped with spark ignition engines (Petrol,CNG,LPG) and compression ignition engines(Diesel,CNG,LPG).

1.2 The method of test for mass emission given in this Part may also be used at the manufacturer's option for compression ignition engined vehicles wherever applicable with Gross Vehicle Weight (GVW) not exceeding 3500 kg, instead of Part X.

1.3 This Part should be read in conjunction with the applicable Gazettee Notification for which the vehicle is subjected to test.

2. Definitions :

2.1 Spark Ignition Engine : Means an internal combustion engine in which the combustion of the air/fuel mixture is initiated at given instants by a hot spot, usually an electric spark.

2.2 Compression Ignition Engine : Means an engine which works on the compression-ignition principle (e.g. diesel engine).

2.3 Idle Speed : Means the engine rate, in revolution per minute, with fuel system controls (accelerator and choke) in the rest position, transmission in neutral and clutch engaged in the case of vehicles with manual or semi-automatic transmission, or with selector in park or neutral position when an automatic transmission is installed, as recommended by the manufacturer.

2.4 Normal Thermal Conditions : Means the thermal conditions attained by an engine and its drive line after a run of at least 15 minutes on a variable course, under normal traffic conditions.

2.5 Gaseous Pollutants : Means carbon monoxide, hydrocarbons (assuming a ratio of $CH_{1.85}$ ) and oxides of nitrogen, (being expressed in Nitrogen dioxide [$NO_2$] equivalent.)

2.6 Particulate Pollutants : Means components of exhaust gas which are removed from the diluted exhaust gas at a maximum temperature of 52°C (325 K) by means of filters described in Chapter 3 of this part.

2.7 Tailpipe emissions means

- For positive ignition engines, the emission of gaseous pollutants
- For compression ignition engines, the emission of gaseous and particulate pollutants.

2.8 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90% full and the usual set of tools and spare wheel on board where applicable. In the case of 3-wheeled tractors, designed for coupling to a semi-trailer, the unladen mass will be that of the drawing vehicle.

2.9 Reference Mass : Means the "Unladen Mass" of the vehicle increased by a uniform figure of 75 kg for 2 wheeled vehicles; and 150 kg for all other vehicles.

2.10 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer. In case of the 3 wheeled vehicles designed to be coupled to a semi-trailer, the mass GVW to be taken into consideration when classifying that vehicle, shall be the maximum weight of the tractor in running order, plus the weight transferred to the tractor by the laden semi-trailer in static condition.

2.11 Cold Start Device : Means a device which enriches the air fuel mixture of the engine temporarily and, thus, to, assist engine start up like choke.

2.12 Starting Aid : Means a device which assists engine start up without enrichment of the fuel mixture, e.g. glow plug, change of injection timing for fuel-injected spark ignition engine, etc.

2.13 Engine capacity means : For reciprocating piston engines, the nominal engine swept volume.

2.14 Anti pollution device : means those components of the vehicles that control and / or limit tail pipe and evaporative emissions

2.15 Type Approval of a vehicle : Means the type approval of a vehicle model with regard to the limitation of tailpipe emissions from the vehicles.

2.16 Vehicle Model : Means a category of power-driven vehicles which do not differ in such essential respects as the equivalent inertia determined in relation to the reference weight of engine and vehicle characteristics which effects the vehicular emission and listed in Chapter 2 of this Part.

2.17 Vehicle for Type Approval Test : Means the fully built vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

2.18 Vehicle for Conformity of Production : Means a vehicle selected at random from a production series of vehicle model which has already been type approved.

3. Application for Type Approval :

3.1 The application for type approval of a vehicle model with regard to limitation of tialpipe emissions from the vehicles shall be submitted by the vehicle manufacturer with a description of the engine and vehicle model comprising all the particulars referred to in Chapter 2 of this Part.

A vehicle representative of the vehicle model to be type approved shall be submitted to the testing agency responsible for conducting tests referred in para 5 of this Chapter.

4. Type Approval :

If the vehicle submitted for type approval pursuant to these rules, meet the requirements of para 5 below, approval of that vehicle model shall be granted. The approval of the vehicle model pursuant to this part shall be communicated to the vehicle manufacturer and nodal agency by the testing agency in the form of certificate of compliance to the CMVR, as envisaged in Rule-126 of CMVR.

5. Specification and Tests :

5.1 General : The components liable to affect the tailpipe emissions of gaseous pollutants shall be so designed, constructed and assembled to enable the vehicle, in normal use, despite the vibrations to which they may be subjected to comply with the provisions of this rule.

5.2 Specifications concerning the emissions of pollutants

5.2.1 The vehicle shall be subjected to tests of Type I and II as specified below according to the category it belongs.

5.2.2 Type I Test: (Verifying the average tailpipe emissions)

5.2.2.1 The vehicle shall be placed on a Chassis dynamometer bench equipped with a means of load and inertia simulation.

5.2.2.2 For 2&3-wheel vehicles, a test lasting a total of 648 seconds and comprising of six cycles as described in Chapter 3 of Part III shall be carried out, without interruption.

5.2.2.3 For all 4-wheel vehicles, a test lasting a total of 19 minutes and 40 seconds made up of two parts, One and Two, shall be performed without interruption. An unsampled period of not more 20 seconds may, with the agreement of the manufacturer, be introduced between the end of Part One and the beginning of Part Two in order to facilitate adjustment of the test equipment.

5.2.2.3.1 Part One of the test cycle is made up of 4 elementary urban cycles. Each elementary urban cycle comprises 15 phases (idling, acceleration, steady speed, deceleration ).

5.2.2.3.2 Part Two of the test cycle is made up of one extra urban cycle. The extra urban cycle comprises 13 phases (idling, acceleration, steady speed, deceleration ).

5.2.2.4 During the test the exhaust gases shall be diluted with air and a proportional sample collected in one or more bags. The contents of the bags will be analysed at the end of the test. The total volume of the diluted exhaust shall be measured. Carbon monoxide (CO), hydro carbon (HC) and nitrogen oxide emissions ($NO_X$), and in addition particulate matter (PM) the case of vehicles equipped with compression ignition engines shall be recorded. Carbon dioxide shall also be recorded for the purpose of calculation of fuel consumption.

5.2.2.5 The test shall be carried out by the procedure described in Chapter 3 of Part IX. The methods used to collect and analyse the gases and to remove and weigh the particulates shall be as prescribed.

5.2.2.6 Subject to the provisions of the paragraphs 5.2.2.8 & 5.2.2.9, the test shall be repeated three times, the test results shall be multiplied by appropriate deterioration factors The resulting masses of gaseous emission and, in the case of vehicles equipped with compression-ignition engines, the mass of particulates obtained in each test shall not exceed the applicable limits.

5.2.2.7 Type Approval and Conformity of Production Mass Emission Standards for Type I test :

5.2.2.7.1 Mass emission standards for vehicles manufactured on and after 1st April 2000 (India Stage I norms) shall be as per the details given in Rule no. 115(10) of CMVR, as amended from time to time for petrol and diesel vehicles. For CNG and LPG vehicles, this rule should be read in conjunction with Rule 115(B) and 115(C).

5.2.2.7.2 Mass emission standards (Bharat Stage II) shall be as per the details given in Rule No.115(11) of CMVR, as amended from time to time, for petrol and diesel vehicles. For CNG and LPG vehicles, this rule should be read in conjunction with the rule 115(B) and 115(C)

5.2.2.8 Nevertheless, for each of the pollutants or combination of pollutants one of the three results obtained may exceed by not more than 10% of the applicable limits prescribed for the vehicle concerned, provided the arithmetical mean of the three results is not exceeding the prescribed limit. Where the prescribed limits are exceeded for more than one pollutant, it shall be immaterial whether this occurs in the same test or in different tests.

5.2.2.9 The number of tests prescribed in Para 5.2.2.8 above shall be reduced in the conditions hereinafter defined, where $V_1$ is the result of the first test and $V_2$ the result of the second test for each of the pollutants referred to in Para 5.2.2.6 above.

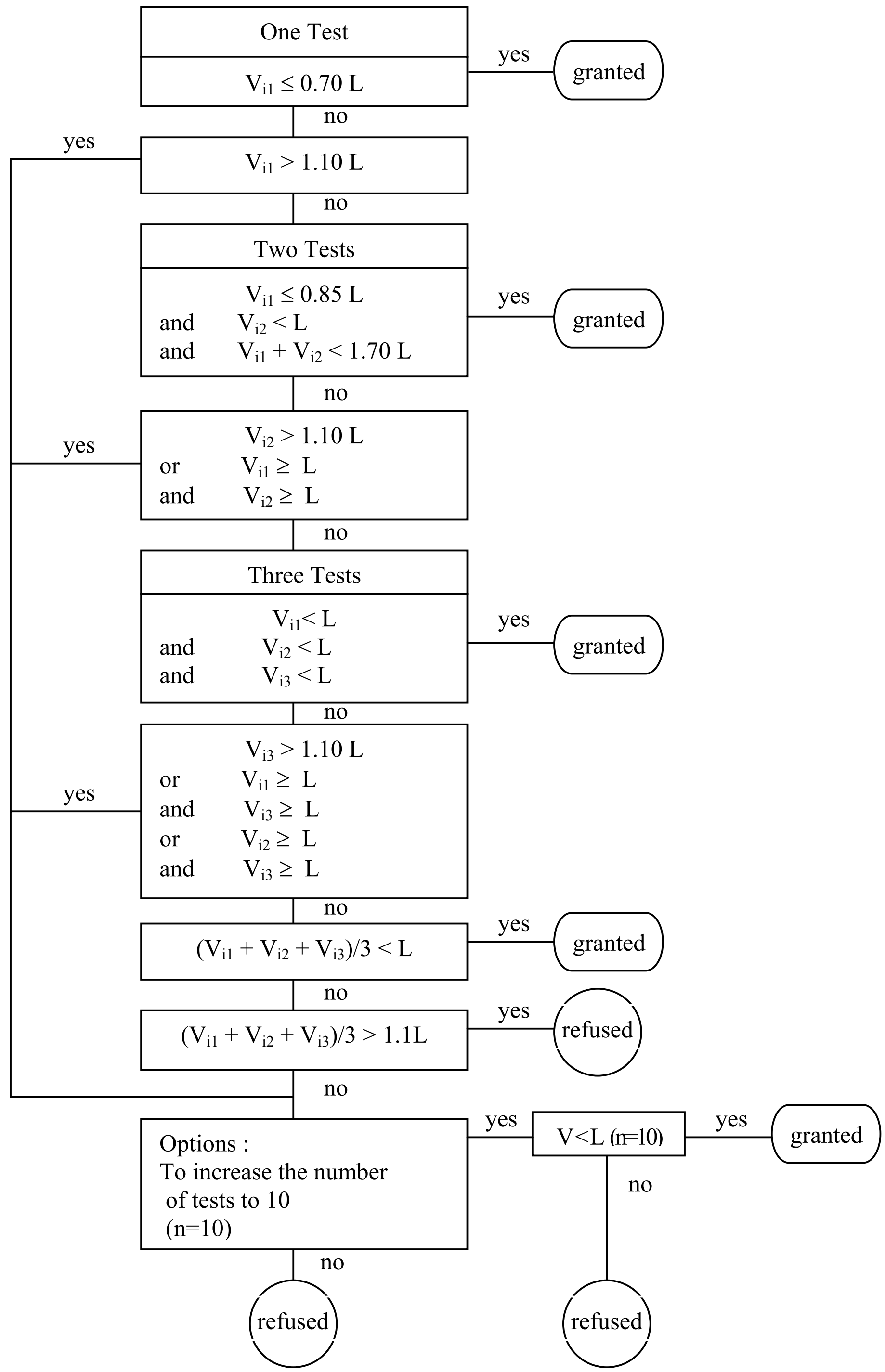
5.2.2.9.1 Only one test shall be performed if the result obtained for each pollutant or the sum of values for pollutants in case of the limit is so specified (e.g. HC & $NO_x$) is less than or equal to 0.7 L i.e. $V_1 \leq 0.70$ L.

5.2.2.9.2 If the requirements of 5.2.2.9.1 is not satisfied, only two tests are performed if for each pollutant or s or the sum of values for pollutants in case of the limit is so specified (e.g. HC & NOx), the following requirements are met.

$V_1 \leq 0.85$ L and $V_1 + V_2 < 1.7$ L and $V_2 \leq$ L.

Fig.1 depicts the scheme.

**Figure 1 : <u>Flow Sheet for the Type Approval and COP Tests as per India Stage-I and Type Approval Test as per Bharat Stage II</u>**



5.2.3 Type II Test (Test for carbon monoxide emissions at idling speed)

5.2.3.1 This is applicable only for spark ignition engined vehicles.

5.2.3.2 The carbon monoxide content by volume of the exhaust gases emitted with the engine idling must not exceed 4.5%, for three wheeled vehicles and its derivatives, including tractors for semi-trailers and two wheeled vehicles and 3.0% for all other vehicles when a test is made in accordance with the provisions of Chapter 9 of this Part.

6. Modifications of the vehicle Model :

6.1 Every modification in the essential characteristics of the vehicle model shall be intimated by the vehicle manufacturer to the test agency which type approved the vehicle model. The test agency may either

6.1.1 Consider that the vehicle with the modifications made may still comply with the requirement, or Require a further test to ensure further compliance.

6.2 In case of 6.1.1 above, the testing agency shall extend the type approval covering the modified specification or the vehicle model shall be subjected to necessary tests. In case, the vehicle complies with the requirements, the test agency shall extend the type approval.

6.3 Any changes to the procedure of PDI and running in concerning emission shall also be intimated to the test agency by the vehicle manufacturer, whenever such changes are carried out.

7. Model Changes :

7.1 Vehicle models of Different Reference Weights and coast down coefficients :

Approval of a vehicle model may under the following conditions be extended to vehicle models which differ from the type approved only in respect of their reference weight.

7.1.1 Approval may be extended to vehicle model of a reference weight requiring merely the use of the next two steps higher or any lower equivalent inertia.

7.1.2 If the reference weight of the vehicle model for which extension of the type approval is requested requires the use of a flywheel of equivalent inertia lower than that used for the vehicle model already approved, extension of the type approval shall be granted if the masses of the pollutants obtained from the vehicle already approved are within the limits prescribed for the vehicle for which extension of the approval is requested.

7.1.3 If different body configurations are used with the same power plant and drive line and the change in the load equation due to changes in the coefficient of resistances that is within the limits that would be caused by the change of inertia as permitted by Clause 7.1.1 above the approval may be extended.

7.2 Vehicle models with Different Overall Gear Ratios :

7.2.1 Approval granted to a vehicle model may under the following conditions be extended to vehicle models differing from the type approved only in respect of their overall transmission ratios;

7.2.1.1 For each of the transmission ratios used in the Type I Test, it shall be necessary to determine the proportion

$$E = (V_2 - V_1)/V_1,$$

where $V_1$ and $V_2$ are respectively the speed at 1000 rev/min of the engine of the vehicle model type approved and the speed of the vehicle model for which extension of the approval is requested.

7.2.2 If for each gear ratio $E \leq 8\%$, the extension shall be granted without repeating the Type I Tests.

7.2.3 If for at least one gear ratio, $E > 8\%$ and if for each gear ratio $E \leq 13\%$ the Type I test must be repeated, but may be performed in laboratory chosen by the manufacturer subject to the approval of the test agency granting type approval. The report of the tests shall be submitted to the test agency by the manufacturer. .

7.3 Vehicle models of Different Reference Weights, coefficient of coast down and Different Overall Transmission Ratios Approval granted to a vehicle model may be extended to vehicle models differing from the approved type only in respect of their reference weight, coefficient of coast down and their overall transmission ratios, provided that all the conditions prescribed in Para 7.1 and 7.2 above are fulfilled.

7.4 Note : When a vehicle type has been approved in accordance with the provisions of Para 7.1 to 7.3 above, such approval may not be extended to other vehicle types.

7.5 Vehicle model with different makes of emission related components:

7.5.1 the names of suppliers of items such as ignition coil, magneto, CB point, air filter, silencer, etc. mentioned above, the manufacturers shall inform the test agency that In addition to carried out the type approval, the names of new alternate suppliers for these items as and when they are being introduced.

7.5.2 At the time of first type approval or for a subsequent addition of a make for a particular part, work out the combinations of tests in such a way that each make of such parts are tested at least once.

8 Conformity of Production :

8.1 Every produced vehicle of the model approved under this rule shall conform, with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved. The administrative procedure for carrying out conformity of production is given in Part VI of this document.

8.2 Type I Test : Verifying the average emission of gaseous pollutants : For verifying the conformity of production in a Type I Test, the following procedure is adopted :-

8.2.1. The vehicle sample taken from the series, as described in 8.1 is subjected to the test described in para 5.2.2 above. The results shall be multiplied by the appropriate deterioration factors The result masses of gaseous emissions and in addition in case of vehicles equipped with compression ignition engines, the mass of particulates obtained in the test shall not exceed the applicable limits.

8.2.2 For compliance of India Stage I norms :

If the vehicle taken from the series does not satisfy the requirements of the applicable standards, the manufacturer may ask for measurements to be performed on a sample of vehicles taken from the series and including the vehicle originally taken. The manufacturer shall specify the size ‘n’ of the sample subject to 'n' being minimum 2 and maximum 10, including the vehicle originally taken. The vehicles other than originally tested shall be subjected to single Type I test. The result to be taken into consideration for the vehicle taken originally is the arithmetical mean of the three Type I tests carried out on the vehicle. The arithmetical mean $\bar{x}$ of the results obtained with the random samples and the standard deviation S of the samples shall then be determined for the carbon monoxide emissions, the combined hydrocarbon and nitrogen oxide emissions and the particulate emissions. The production of the series shall then be deemed to conform if the following condition is met :

$$\bar{x} + k.S \leq L$$

where $$S^2 = \frac{\sum (x_i - \bar{x})^2}{(n-1)}$$

$x_i$ - the individual results obtained with the sample 'n'.

L - the limit value prescribed for the vehicle for each pollutant considered; and

k - a statistical factor dependent on 'n' and given by the following table :

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| K | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

8.3 Type II Test : Carbon-monoxide emission at idling speed

When the vehicle taken from the series for the type I test mentioned in 8.2 para above, subjected to the test described in Chapter 9 of this Part for verifying the carbon monoxide emission at idling speed should meet the limit values specified in para 5.2.3.2 above. If it does not, another 10 vehicles shall be taken from the series at random and shall be tested as per Chapter 9 of this Part. At least 9 vehicles should meet the limit values specified in para 5.2.3.2 above. In addition, two vehicles at random should be selected from the above lot of 10 and subjected to a Type I test mentioned in para 8.2 above and they should meet the requirements of para 5.2.2.7 above. Then the series is deemed to conform.

8.4 Procedure for Conformity of Production as per Bharat Stage-II

8.4.1 Conformity of production shall be verified as per Bharat Stage-II emission norms as given in para 5.2.2.7.2 and with the procedure given below.

8.4.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted :

8.4.2.1 Minimum of three vehicles shall be selected randomly from the series with a sample lot size.

8.4.2.2 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in Part VI.

8.4.2.3 First vehicle out of three randomly selected vehicles shall be tested for Type - I test as per Para 5.2.2 of chapter 1 of this part.

8.4.2.4 Only one test ($V_1$) shall be performed if the test results for all the pollutants meet 70 % of their respective limit values (i.e. $V_1 \leq 0.7L$ & L being the COP Limit)

8.4.2.5 Only two tests shall be performed if the first test results for all the pollutants doesn't exceed 85% of their respective COP limit values (i.e. $V_1 \leq 0.85L$) and at the same time one of these pollutant value exceeds 70% of the limit (i.e. $V_1 > 0.7L$) In addition, to reach the pass decision for the series, combined results of $V_1$ & $V_2$ shall satisfy such requirement that : $(V_1 + V_2) < 1.70L$ and $V_2 \leq L$ for all the pollutants.

8.4.2.6 Third Type - I ($V_3$) test shall be performed if the para 8.4.2.5 above doesn't satisfy and if the second test results for all pollutants are within the 110% of the prescribed COP limits, Series passes only if the arithmetical mean for all the pollutants for three type I tests doesn't exceed their respective limit value (i.e. $(V_1 + V_2 + V_3)/3 \leq L$)

8.4.2.7 If one of the three test results obtained for any one of the pollutants exceed 10% of their respective limit values the test shall be continued on Sample No. 2 & 3 as given in the Figure - 2 of chapter 1 of this part, as the provision for extended COP and shall be informed by the test agency to the nodal agency.
These randomly selected sample No.2 & 3 shall be tested for only one Type - I test as per para 5.2.2.

8.4.2.8 Let $X_{i2}$ & $X_{i3}$ are the test results for the Sample No.2 & 3 and $X_{i1}$ is the test result of the Sample No.1 which is the arithmetical mean for the three type - I tests conducted on Sample No. 1

8.4.2.9 If the natural Logarithms of the measurements in the series are $X_1, X_2, X_3 \ldots\ldots\ldots X_j$ and $L_i$ is the natural logarithm of the limit value for the pollutant, then define :

$d_j = X_j - L_i$

$$d_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n}(d_j - \overline{d_n})^2$$

8.4.2.10 Table I of Chapter 1 of this part shows values of the pass ($A_n$) and fail ($B_n$) decision numbers against current sample number. The test statistic is the ratio $\overline{d}_n / V_n$ and must be used to determine whether the series has passed or failed as follows :

- Pass the series, if $\overline{d}_n/V_n \geq A_n$ for all the pollutants
- Fail the series if $\overline{d}_n/V_n \geq B_n$ for any one of the pollutants.
- Increase the sample size by one, if $A_n < \overline{d}_n/V_n \leq B_n$ for any one of the pollutants. When a pass decision is reached for one pollutant, that decision will not be changed by any additional tests carried out to reach a decision for the other pollutants.
- If no pass decision is reached for all the pollutants and no fail decision is reached for one pollutant, a test shall be carried out on another randomly selected sample till a pass or fail decision is arrived at.

8.4.2.11 Running in may be carried out at the request of the manufacturer either as per the manufacturers recommendation submitted during type approval or with a maximum of 3000 km for the vehicles equipped with a positive ignition engine and with a maximum of 15000 km for the vehicles equipped with a compression ignition engine.

8.4.2.12 All these tests shall be conducted with the reference fuel as specified in the applicable gazette notification. However, at the manufacturer's request, tests may be carried out with commercial fuel.

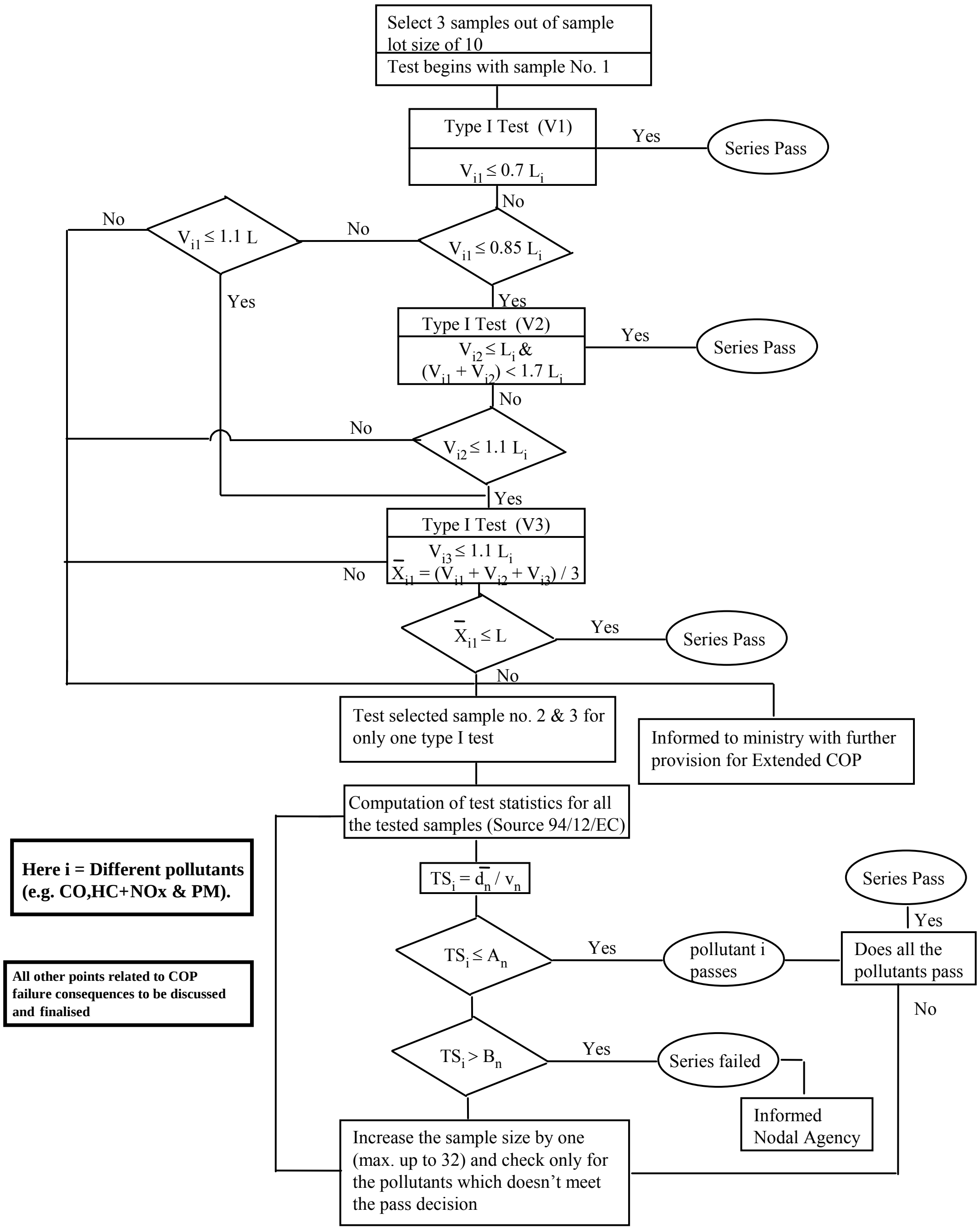



**Figure 2 : <u>COP Test Procedure as per Bharat Stage II</u>**

**Table I : Applicable for COP Procedure as per Bharat Stage II**

| Sample size (n) | Pass decision threshold ($A_n$) | Fail decision threshold ($B_n$) |
|---|---|---|
| 3 (including first sample) | -0.80381 | 16.64743 |
| 4 | -0.76339 | 7.68627 |
| 5 | -0.72982 | 4.67136 |
| 6 | -0.69962 | 3.25573 |
| 7 | -0.67129 | 2.45431 |
| 8 | -0.64406 | 1.94369 |
| 9 | -0.61750 | 1.59105 |
| 10 | -0.59135 | 1.33295 |
| 11 | -0.56542 | 1.13566 |
| 12 | -0.53960 | 0.97970 |
| 13 | -0.51379 | 0.85307 |
| 14 | -0.48791 | 0.74801 |
| 15 | -0.46191 | 0.65928 |
| 16 | -0.43573 | 0.58321 |
| 17 | -0.40933 | 0.51718 |
| 18 | -0.38266 | 0.45922 |
| 19 | -0.35570 | 0.40788 |
| 20 | -0.32840 | 0.36203 |
| 21 | -0.30072 | 0.32078 |
| 22 | -0.27263 | 0.28343 |
| 23 | -0.24410 | 0.24943 |
| 24 | -0.21509 | 0.21831 |
| 25 | -0.18557 | 0.18970 |
| 26 | -0.15550 | 0.16328 |
| 27 | -0.12483 | 0.13880 |
| 28 | -0.09354 | 0.11603 |
| 29 | -0.06159 | 0.09480 |
| 30 | -0.02892 | 0.07493 |
| 31 | 0.00449 | 0.05629 |
| 32 | 0.03876 | 0.03876 |

# CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

***Information is to be provided as per AIS-007***

# CHAPTER 3 : TYPE I TEST ON S.I. ENGINES, CNG, LPG AND DIESEL ENGINED VEHICLES (VERIFYING THE AVERAGE TAILPIPE EMISSION) OF GASEOUS AND PARTICULATE POLLUTANTS

1. This chapter describes the procedure for the Type I test defined in paragraph 5.2.2 of Chapter 1 of this Part. This chapter should be read in conjunction with the applicable Gazette notification for which the test is to be carried out.

2. Operating Cycle on the Chassis Dynamometer :

2.1 Description of the Cycle : The operating cycle on the chassis dynamometer shall be as given in 2.1.1and 2.1.2 as applicable.

2.1.1 The operating cycle on the chassis dynamometer for all two and three wheelers shall be that indicated in Table I and depicted in Figure 2 of this Chapter. The break down by operations is given in Table II of this Chapter

2.1.2 The operating cycle on the chassis dynamometer for vehicles other than two and three wheelers shall be as per modified Indian Driving Cycle i.e. Urban Driving Cycle (Table IV) and Extra Urban Driving Cycle (Table V) and as depicted in the Figure 3 and Figure 4 of this Chapter respectively. The break down by operations is given in Table IV-A for Urban Driving Cycle (Part One) and in Table V-A for Extra Urban Driving Cycle (Part Two) of this chapter.

2.2 General Conditions under which the cycle is carried out : preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximately to the theoretical cycle within the prescribed limits.

2.3 Use of the Gear Box : The use of the gear box in case of testing two and three wheeelers on chassis dynamometer shall be in accordance with Para 2.3.1 of this Chapter For the vehicles other than two and three wheeler vehicles, the use of gear box shall be in accordance with Para 2.3.2

2.3.1 Vehicles which do not attain the acceleration and maximum speed values required in the operating cycle shall be operated with the accelerator control fully depressed until they once again reach the required operating curve. Deviations from the operating cycle shall be recorded in the test report.

Use of the Gear Box for two and three wheelers : The use of the gear box shall be as specified by the manufacturer. However, in the absence of such instructions, the following points shall be taken into account.:

2.3.1.1 Manual Change Gear Box :

2.3.1.1.1 During each phase at constant speed, the rotating speed of the engine shall be, if possible, between 50 and 90% of the speed corresponding to the maximum power of the engine. When this speed can be reached in two or more gears, the vehicle shall be tested with the higher gear engaged.

2.3.1.1.2 During acceleration, the vehicle shall be tested in whichever gear is appropriate to the acceleration imposed by the cycle. A higher gear shall be engaged at the latest when the rotating speed is equal to 110% of the speed corresponding to the maximum power of the engine.

2.3.1.1.3 During deceleration, a lower gear shall be engaged before the engine starts to idle roughly, at the latest when the engine revolutions are equal to 30% of the speed corresponding to the maximum power of the engine. No change down to first gear shall be effected during deceleration.

2.3.1.1.4 Vehicles equipped with an overdrive which the driver can actuate shall be tested with the overdrive out of action.

2.3.1.1.5 When it is not possible to adhere to the cycle, the operating cycle will be modified for gear change points, allowing 2 seconds time interval at constant speed for each gear change keeping the total time constant. Figure 1 of this chapter shows the operating cycle with recommended gear positions.

2.3.1.2 Automatic Gear Box : Vehicles equipped with automatic shift gear boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order.

2.3.2 The use of gears shall be as shown in Table IV and Table for the elementary urban cycles (Part One) and the extra urban cycle (Part Two) respectively.

2.3.2.1 However, if the maximum speed which can be attained in first gear is below 15 km/h, the first gear need not be used and the second, the third and fourth gears are used for the elementary urban cycles (Part One) and the second, third, fourth and fifth gears for the extra urban cycle (Part Two). Similarly, the first gear need not be used and second, third and fourth gears may also be used for the urban cycles (Part One) and the second, third, fourth and fifth gears for the extra urban cycle (Part Two) when the driving instructions recommended starting in second gear on level ground, or when first gear is therein defined as a gear reserved for cross country driving, crawling or towing.

Vehicles which do not attain the acceleration and maximum speed values required in the operating cycle shall be operated with the accelerator control fully depressed until they once again reach the required operating curve. Deviations from the operating cycle shall be recorded in the test report.

2.3.2.2 Use of the Gear Box for two and three wheelers : The use of the gear box shall be as specified by the manufacturer. However, in the absence of such instructions, the following points shall be taken into account.:

2.3.2.3 Manual Change Gear Box :

2.3.2.4 During each phase at constant speed, the rotating speed of the engine shall be, if possible, between 50 and 90% of the speed corresponding to the maximum power of the engine. When this speed can be reached in two or more gears, the vehicle shall be tested with the higher gear engaged.

2.3.2.5 During acceleration, the vehicle shall be tested in whichever gear is appropriate to the acceleration imposed by the cycle. A higher gear shall be engaged at the latest when the rotating speed is equal to 110% of the speed corresponding to the maximum power of the engine.

2.3.2.6 During deceleration, a lower gear shall be engaged before the engine starts to idle roughly, at the latest when the engine revolutions are equal to 30% of the speed corresponding to the maximum power of the engine. No change down to first gear shall be effected during deceleration.

2.3.2.7 Vehicles equipped with an overdrive which the driver can actuate shall betested with the overdrive out of action.

2.3.2.8 When it is not possible to adhere to the cycle, the operating cycle will be modified for gear change points, allowing 2 seconds time interval at constant speed for each gear change keeping thetotal time constant. Figure 1 of this chapter shows the operating cycle with recommended gear positions.

2.3.2.9 Automatic Gear Box : Vehicles equipped with automatic shift gear boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order.

2.3.3 Vehicles equipped with automatic gear boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order. Furthermore the gear change points given in Table IV and Table V of this Chapter do not apply : accelerator must continue throughout the period represented by the straight line connecting the end of each period of idling with the beginning of the next following period of steady speed. The tolerance given in 2.4 shall apply.

2.3.4 Vehicles equipped with an overdrive which the driver can activate shall be tested with the overdrive out of action for the urban cycle (Part One) and with the overdrive in action for the extra urban cycle (Part Two).

2.4 Tolerances

2.4.1 A tolerance of ± 1 km/h shall be allowed between the indicated speed and the theoretical speed during acceleration, during steady speed and during deceleration, when the vehicle's brakes are used. If the vehicle decelerates more rapidly without the use of the brakes, then the timing of the theoretical cycle shall be restored by constant speed or idling period merging into the following operation. Speed tolerances greater than those prescribed shall be accepted, during phase changes provided that the tolerances are never exceeded for more than 0.5 second on any one occasion.

2.4.2 Time tolerances of ± 0.5 second shall be allowed. The above tolerances shall apply equally at the beginning and at the end of each gear changing period.

2.4.3 The speed and time tolerances shall be combined as indicated in Figure 5 of this chapter.

3. Vehicle and Fuel

3.1 Test Vehicle :

3.1.1 The vehicle presented shall be checked that it is the same model as specified as per format of chapter 2 of this Part. It shall have been run-in either as per manufacturer's specification or atleast 3000 kms before the test.

3.1.2 The exhaust device shall not exhibit any leak likely to reduce the quantity of gas collected, and this shall be the same emerging from the engine.

3.1.3 The air intake system should be leak proof.

3.1.4 The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer. This requirement also applies, in particular, to the settings for idling and for the cold start device, automatic choke, and exhaust gas cleaning systems, etc.

The vehicle to be tested, or an equivalent vehicle, shall be fitted, if necessary with a device to permit the measurement of characteristic parameters necessary for the chassis dynamometer setting.

3.1.5 The testing agency may verify that the vehicle conforms to the performance of power, acceleration, maximum speed etc., stated by the manufacturer and that it can be used for normal driving and more particularly that it is capable of starting when cold and when hot.

3.2 Fuel : The reference fuel as prescribed in the applicable Gazette notification shall be used. If the engine is lubricated by a fuel oil mixture, the oil added to reference fuel shall comply as to grade and quantity with the manufacturer's recommendation.

4. Test Equipment :

4.1 Chassis Dynamometer :

4.1.1 The dynamometer must be capable of simulating road load with adjustable load curve, i.e. a dynamometer with at least two road load parameters that can be adjusted to shape the load curve.

4.1.2 The chassis dynamometer may have one or two rollers. In the case of a single roller, the roller diameter shall not be less than 400 mm for 2-wheelers and 1200 mm for other vehicles.

4.1.3 The setting of the dynamometer shall not be affected by the lapse of time. It shall not produce any vibrations perceptible to the vehicle and likely to impair the vehicle's normal operations.

4.1.4 It shall be equipped with means to simulate inertia and load. These simulators shall be connected to the front roller, in the case of a two roller dynamometer.

4.1.5 The roller shall be fitted with a revolution counter with reset facility to measure the distance actually covered.

4.1.6 Accuracy :

4.1.6.1 It shall be possible to measure and read the indicated load to an accuracy of ± 5 per cent.

4.1.6.2 In the case of a dynamometer with an adjustable load curve, the accuracy of matching dynamometer load to road load shall be within 5 per cent at 80,60, 50, 40, 30 km/h and 10 per cent at 20 km/h. Below this, the dynamometer absorption must be positive.

4.1.6.3 The total equivalent inertia of the rotating parts (including the simulated inertia where applicable) must be known and within ± 20 kg of the inertia class for the test, in case of 4-wheeler vehicles; for 2-wheeler vehicles within ± 2 per cent.

4.1.6.4 The speed of the vehicle shall be measured by the speed of rotation of the roller (the front roller in the case of a two roller dynamometer). It shall be measured with an accuracy of ± 1 km/h at speeds above 10 km/h.

4.1.7 Load and Inertia Setting :

4.1.7.1 Dynamometer with adjustable load curve: the load simulator shall be adjusted in order to absorb the power exerted on the driving wheels at various steady speeds of 80, 60, 50, 40, 30 and 20 km/h for four-wheelers else, for two and three wheelers it is at the steady speed of 50, 40, 30 and 20 km/h.

4.1.7.2 The means by which these loads are determined and set are described in Chapter 4 of this Part.

4.1.7.3 Chassis Dynamometers with electrical inertia simulation must be demonstrated to be equivalent to mechanical inertia systems. The means by which equivalence is established is described in Chapter 5 of this Part.

4.1.8 Chassis Dynamometer Calibration :

4.1.8.1 The dynamometer should be calibrated periodically as recommended by the manufacturer of the chassis dynamometer and then calibrated as required. The calibration shall consist of the manufacturers' recommended procedure and a determination of the dynamometer frictional power absorption at 40 km/h when being used for testing of two and three wheelers and 80 km/h when being used for other vehicles. One method for determining this is given in Chapter 7. Other methods may be used if they are proven to yield equivalent results.

4.1.8.2 The performance check consists of conducting dynamometer coast down time at one or more inertia power setting and comparing the coast down time to that recorded during the last calibration. If the coast down time differs by more than 1 second, a new calibration is required.

4.2 Exhaust Gas-sampling System :

4.2.1 The exhaust gas-sampling shall be designed to enable the measurement of the true mass emissions of vehicle exhaust. A Constant Volume Sampler System (CVS) wherein the vehicle exhaust is continuously diluted with ambient air under controlled conditions should be used. In the constant volume sampler concept of measuring mass emissions, two conditions must be satisfied – the total volume of the mixture of exhaust and dilution air must be measured and a continuously proportional sample of the volume must be collected for analysis. Mass emissions are determined from the sample concentrations, corrected for the pollutant content of the ambient air and totalized flow, over the test period.

The particulate pollutant emission level is determined by using suitable filters to collect the particulates from a proportional part flow throughout the test and determining the quantity thereof gravimetrically in accordance with 4.3.2.

4.2.2 The flow through the system shall be sufficient to eliminate water condensation at all conditions which may occur during a test, as defined in Chapter 6 of this part.

4.2.3 Figure 9,10,11 of Chapter 6 of this Part gives a schematic diagram of the general concept. Examples of three types of Constant Volume Sampler systems which will meet the requirements are given in Chapter 6 of this part.

4.2.4 The gas and air mixture shall be homogenous at point S2 of the sampling probe.

4.2.5 The probe shall extract a true sample of the diluted exhaust gases.

4.2.6 The system should be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the diluted exhaust gas. Should any component (heat exchanger, blower, etc.) change the concentration of any pollutant gas in the diluted gas, then the sampling for that pollutant shall be carried out before that component, if the problem cannot be corrected.

4.2.7 If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connection tubes shall be connected as near as possible to the vehicle.

4.2.8 Static pressure variations at the tail pipe(s) of the vehicle shall remain within ± 1.25 kPa of the static pressure variations measured during the dynamometer driving cycle and with no connection to the tailpipe(s). Sampling systems capable of maintaining the static pressure to within ± 0.25 kPa will be used if a written request from a manufacturer to the authority granting the approval substantiates the need for the closer tolerance. The back-pressure shall be measured in the exhaust pipe as near as possible to its end or in an extension having the same diameter.

4.2.9 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

4.2.10 The gas samples shall be collected in sample bags of adequate capacity. These bags shall be made of such materials as will not change the pollutant gas by more than ± 2% after twenty minutes of storage.

4.3 Analytical Equipment :

4.3.1 Pollutant gases shall be analysed with the following instruments :

4.3.1.1 Carbon monoxide (CO) and carbon dioxide ($CO_2$) analysis. The carbon monoxide and carbon dioxide analysers shall be of the Non-Dispersive Infra Red (NDIR) absorption type.

4.3.1.2 Hydrocarbon (HC) analysis - Gasoline Vehicles. The hydrocarbons analyser shall be of the Flame Ionisation (FID) type calibrated with propane gas expressed equivalent to carbon atoms.

4.3.1.3 Hydrocarbons (HC) analysis - Diesel Vehicles. The hydrocarbon analyser shall be of the Flame Ionisation type Detector with valves , pipe work etc. heated to 463 K ± 10 K (HFID). It shall be calibrated with propane gas expressed equivalent to carbon atoms ($C_1$ ).

4.3.1.4 Nitrogen oxide ($NO_x$) analysis.

The nitrogen oxide analyser shall be of the Chemiluminescent (CLA) type with an $NO_x$-NO converter or by NDUVR (non-dispersive ultraviolet resonance absorption) type analyser.

4.3.1.5 Particulates :

Gravimetric determination of the particulates collected. These particulates are in each case collected by two series mounted filters in the sample gas flow. The quantity of particulates collected by each pair of filters shall be as follows :

$V_{ep}$ : Flow through filters.
$V_{mix}$ : Flow through tunnel.
M : Particulate mass (g/km)
$M_{limit}$ : Limit mass of particulates (limit mass in force, g/km)
m : Mass of particulates collected by filters (g)
d : Actual distance corresponding to the operating cycle (km)

$$M = \frac{(V_{mix} * m)}{(V_{ep} * d)} \quad \text{or}$$

$$m = \frac{(M * d * V_{ep})}{V_{mix}}$$

$$M = \frac{V_{mix}}{V_{ep}} * \frac{m}{d}$$

The particulate sample rate ($V_{ep}$ / $V_{mix}$) will be adjusted so that for $M = M_{limit}$ $1 \leq m \leq 5$ mg (when 47mm diameter filters are used).

The filter surface consist of a material that is hydrophobic and inert towards the components of exhaust gas (flurocarbon coated glass fibre filters or equivalent)

4.3.1.6 Accuracy

The analysers must have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants.

Measurements error must not exceed ± 2% (intrinsic error of analyser) disregarding the true value for the calibration gases.For concentration of less than 100 ppm the measurement error must not exceed ± 2 ppm.The ambient air sample must be measured on the same analyser with an appropriate range.

The microgram balance used to determine the weight of all filters must have an accuracy of 5 µg and readability of 1 µg.

4.3.1.7 Ice-trap

No gas drying device shall be used before the analysis unless it is shown that it has no effect on the pollutant content of the gas stream.

4.3.2 Particular requirements for compression ignition engines :

4.3.2.1 A heated sample line for a continuous HC-analysis with the heated flame ionisation detector (HFID), including recorder (R) is to be used.

4.3.2.2 The average concentration of the measured hydrocarbons shall be determined by integration. Throughout the test, the temperature of the heated sample line shall be controlled at 463 K (190°C) ±10 K. The heated sampling line shall be fitted with a heated filter ($F_h$) 99% efficient with particle ≥ 0.3 µm to extract any solid particles from the continuous flow of gas required for analysis.

4.3.2.3 The sampling system response time (from the probe to the analyser inlet) shall be no more than 4 s.

4.3.2.4 The HFID must be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.3.2.5 The particulate sampling unit consist of a dilution tunnel, a sampling probe, a filter unit, a partial flow pump, and a flow rate regulator and measuring unit. The particulate sampling part flow is drawn through two series mounted filters. The sampling probe for the test gas flow for particulates shall be so arranged within the dilution tract that a representative sample gas flow can be taken from the homogenous air / exhaust mixture and an air / exhaust gas mixture of 325 K (52°C) shall not exceed immediately before the particulate filter. The temperature of the gas flow in the flow meter shall not fluctuate more than ± 3K, nor the mass flow rate shall fluctuate more than ± 5%. If the volume of flow change unexpectedly as a result of excessive filter loading, the test should be stopped. When it is repeated, the rate of flow shall be decreased and / or larger filter shall be used. The filters shall be removed from the chamber not earlier than an hour before the test begins.

4.3.2.6 The necessary particulate filters should be conditioned (as regards temperature and humidity) in an open dish which shall be protected against dust ingress for at least 8 and not more than 56 hours before the test in an air conditioned chamber After this conditioning, the uncontaminated filters shall be read and stored until they are used.

4.3.2.7 If the filters are not used within 1 hour of their removal from the weighing chamber then they shall be re-weighed.
The one hour limit shall be replaced by an eight hour limit if one or both of the following conditions are met :

- A stabilised filter is placed and kept in a sealed filter holder assembly with the ends plugged, or
- A stabilised filter is placed in a sealed filter holder assembly which is then immediately placed in a sample line through which there is no flow.

4.3.3 Calibration :

4.3.3.1 Each analyser shall be calibrated as often as necessary and in any case in the month before type approval testing and at least once every six months for verifying conformity of production.

4.3.3.2 The calibration method that shall be used is described in Chapter 7 of this part for the analysers indicated in para 4.3.1 above.

4.4 Volume measurement :

4.4.1 The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to within ± 2 per cent.

4.4.2 Constant Volume Sampler Calibration :

4.4.2.1 The Constant Volume Sampler system volume measurement device shall be calibrated by a suitable method to ensure the prescribed accuracy and at a frequency sufficient to maintain such accuracy.

4.4.2.2 An example of a calibration procedure which will give the required accuracy is given in Chapter 7 of this part. The method shall utilise a flow metering device which is dynamic and suitable for the high flow rate encountered in Constant Volume Sampler testing. The devices shall be of certified accuracy traceable to an approved national or international standard.

4.5 Gases :

4.5.1 Pure Gases :

The following pure gases shall be available when necessary, for calibration and operation:

Purified nitrogen (purity ≤ 1 ppm C, ≤ 1ppm CO, ≤ 400 ppm $CO_2$, ≤0.1 ppm NO);

Purified synthetic air (purity ≤ 1 ppm C, ≤ 1ppm CO, ≤ 400 ppm$CO_2$, ≤ 0.1 ppm NO); oxygen content between 18% & 21% vol.;

Purified oxygen ( purity ≤ 99.5 per cent Vol $O_2$ );

Purified hydrogen (and mixture containing hydrogen)
( Purity ≤ 1ppm C, ≤ 400 ppm $CO_2$).

4.5.2 Calibration and span gases :

Gases having the following chemical compositions shall be available of:

- $C_3 H_8$ and purified synthetic air, as in para 4.5.1 above
- CO and purified nitrogen
- $CO_2$ and purified nitrogen
- NO and purified nitrogen

(The amount of $NO_2$ contained in this calibration gas must not exceed 5 percent of the NO content)

4.5.3 The true concentration of a calibration gas shall be within ± 2% of the stated figure.

4.5.4 The concentrations specified in Chapter 7 of this part may also be obtained by means of a gas divider, diluting with purified nitrogen or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined within ± 2%.

4.6 Additional equipment :

4.6.1 Temperatures : The temperature indicated in Chapter 8 of this part shall be measured with an accuracy of ± 1.5 K.

4.6.2 Pressure : The atmospheric pressure shall be measurable to within ± 0.1 kPa.

4.6.3 Absolute Humidity : The absolute humidity (H) shall be measurable to within ± 5 %.

4.7 The exhaust gas-sampling system shall be verified by the method described in para 3 of Chapter 7 of this part. The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured shall be 5 %.

5. Preparations for the test :

5.1 Adjustment of inertia simulators to the vehicle's translatory inertias : An inertia simulator shall be used enabling a total inertia of the rotating masses to be obtained proportional to the reference weight within the following limits given in Table III.

5.2 Setting of dynamometer :

5.2.1 The load shall be adjusted according to methods described in paragraph 4.1.7 above.

5.2.1 The method used and the values obtained (equivalent inertia, characteristic adjustment parameter) shall be recorded in the test report.

TABLE I

**OPERATING CYCLE ON THE CHASSIS DYNAMOMETER**

(Please ref. Para. 2.1.1 )

| No. of operation | | Acceleration $(m/sec^2)$ | Speed (Km/h) | Duration of each operation (S) | Cumulative time(s) |
|---|---|---|---|---|---|
| 01. | Idling | -- | --- | 16 | 16 |
| 02. | Acceleration | 0.65 | 0-14 | 6 | 22 |
| 03. | Acceleration | 0.56 | 14-22 | 4 | 26 |
| 04. | Deceleration | -0.63 | 22-13 | 4 | 30 |
| 05. | Steady speed | -- | 13 | 2 | 32 |
| 06. | Acceleration | 0.56 | 13-23 | 5 | 37 |
| 07. | Acceleration | 0.44 | 23-31 | 5 | 42 |
| 08. | Deceleration | -0.56 | 31-25 | 3 | 45 |
| 09. | Steady speed | -- | 25 | 4 | 49 |
| 10. | Deceleration | -0.56 | 25-21 | 2 | 51 |
| 11. | Acceleration | 0.45 | 21-34 | 8 | 59 |
| 12. | Acceleration | 0.32 | 34-42 | 7 | 66 |
| 13. | Deceleration | -0.46 | 42-37 | 3 | 69 |
| 14. | Steady speed | -- | 37 | 7 | 76 |
| 15. | Deceleration | - 0.42 | 37-34 | 2 | 78 |
| 16. | Acceleration | 0.32 | 34-42 | 7 | 85 |
| 17. | Deceleration | -0.46 | 42-27 | 9 | 94 |
| 18. | Deceleration | -0.52 | 27-14 | 7 | 101 |
| 19. | Deceleration | -0.56 | 14-00 | 7 | 108 |

## TABLE II

**BREAK DOWN OF THE OPERATING CYCLE USED FOR THE TYPE I TEST**

(Please ref. para. 2.1.1)

A: BREAK DOWN BY PHASES

| Sr. No. | Particulars | Time(s) | Percentage |
|---|---|---|---|
| 1 | Idling | 16 | 14.81 |
| 2 | Steady speed periods | 13 | 12.04 |
| 3 | Accelerations | 42 | 38.89 |
| 4 | Deceleration's | 37 | 34.26 |
| | | 108 | 100 |

B: AVERAGE SPEED DURING TEST : 21.93 Km/h

C: THEORETICAL DISTANCE COVERED PER CYCLE : 0.658 Km.

D: EQUIVALENT DISTANCE FOR THE TEST (6 cycles) : 3.948 Km.

**Table III**

| For 2 and 3 wheelers | | | | For vehicles other than 2 and 3 wheelers | | |
|---|---|---|---|---|---|---|
| Reference Mass of Vehicle RW (kg) | | Equivalent Inertia (kg.) | | Reference Mass of Vehicle RW (kg.) | | Equivalent Inertia (kg.) |
| Exceeding | Upto | | | Exceeding | Upto | |
| | 105 | 100 | | -- | 480 | 455 |
| 105 | 115 | 110 | | 480 | 540 | 510 |
| 115 | 125 | 120 | | 540 | 595 | 570 |
| 125 | 135 | 130 | | 595 | 650 | 625 |
| 135 | 150 | 140 | | 650 | 710 | 680 |
| 150 | 165 | 150 | | 710 | 765 | 740 |
| 165 | 185 | 170 | | 765 | 850 | 800 |
| 185 | 205 | 190 | | 850 | 965 | 910 |
| 205 | 225 | 210 | | 965 | 1080 | 1020 |
| 225 | 245 | 230 | | 1080 | 1190 | 1130 |
| 245 | 270 | 260 | | 1190 | 1305 | 1250 |
| 270 | 300 | 280 | | 1305 | 1420 | 1360 |
| 300 | 330 | 310 | | 1420 | 1530 | 1470 |
| 330 | 360 | 340 | | 1530 | 1640 | 1590 |
| 360 | 395 | 380 | | 1640 | 1760 | 1700 |
| 395 | 435 | 410 | | 1760 | 1870 | 1810 |
| 435 | 480 | 450 | | 1870 | 1980 | 1930 |
| 480 | 540 | 510 | | 1980 | 2100 | 2040 |
| 540 | 600 | 570 | | 2100 | 2210 | 2150 |
| 600 | 650 | 620 | | 2210 | 2380 | 2270 |
| 650 | 710 | 680 | | 2380 | 2610 | 2270 |
| 710 | 770 | 740 | | 2610 | -- | 2270 |
| 770 | 820 | 800 | | | | |
| 820 | 880 | 850 | | | | |
| 880 | 940 | 910 | | | | |
| 940 | 990 | 960 | | | | |
| 990 | 1050 | 1020 | | | | |
| 1050 | 1110 | 1080 | | | | |
| 1110 | 1160 | 1130 | | | | |
| 1160 | 1220 | 1190 | | | | |
| 1220 | 1280 | 1250 | | | | |
| 1280 | 1330 | 1300 | | | | |
| 1330 | 1390 | 1360 | | | | |
| 1390 | 1450 | 1420 | | | | |
| 1450 | 1500 | 1470 | | | | |
| 1500 | 1560 | 1530 | | | | |
| 1560 | 1620 | 1590 | | | | |
| 1620 | 1670 | 1640 | | | | |
| 1670 | 1730 | 1700 | | | | |
| 1730 | 1790 | 1760 | | | | |

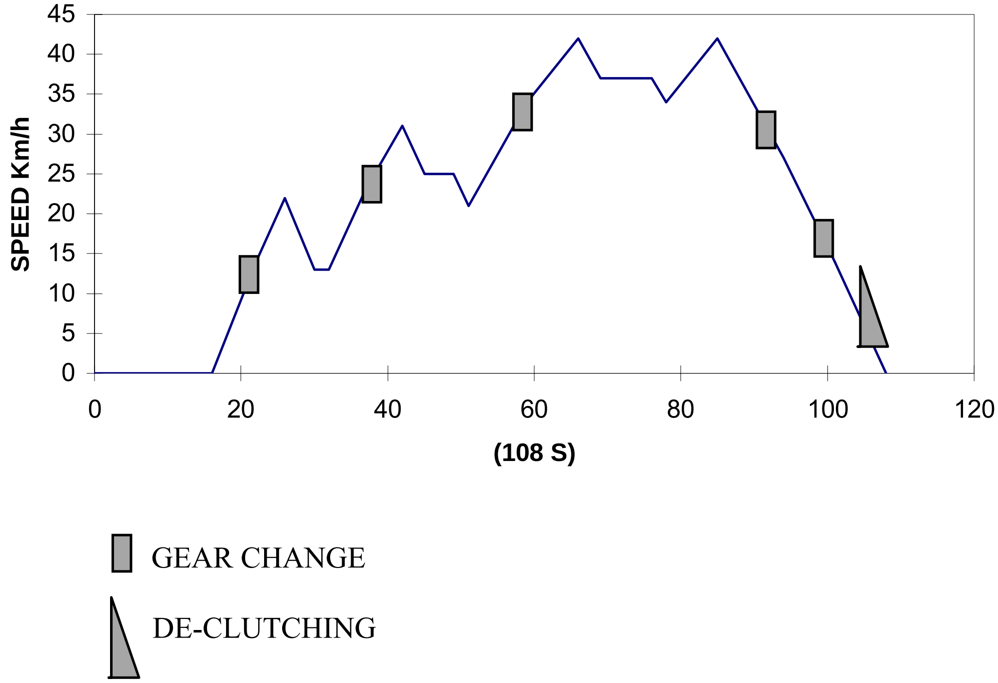
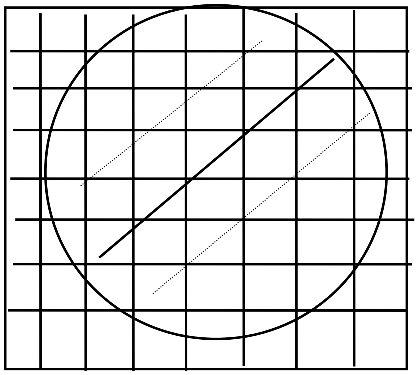



Fig 1 : OPERATING CYCLE WITH RECOMMENDED GEAR POSITION
(Pl. ref. para 2.3.1.1.5)



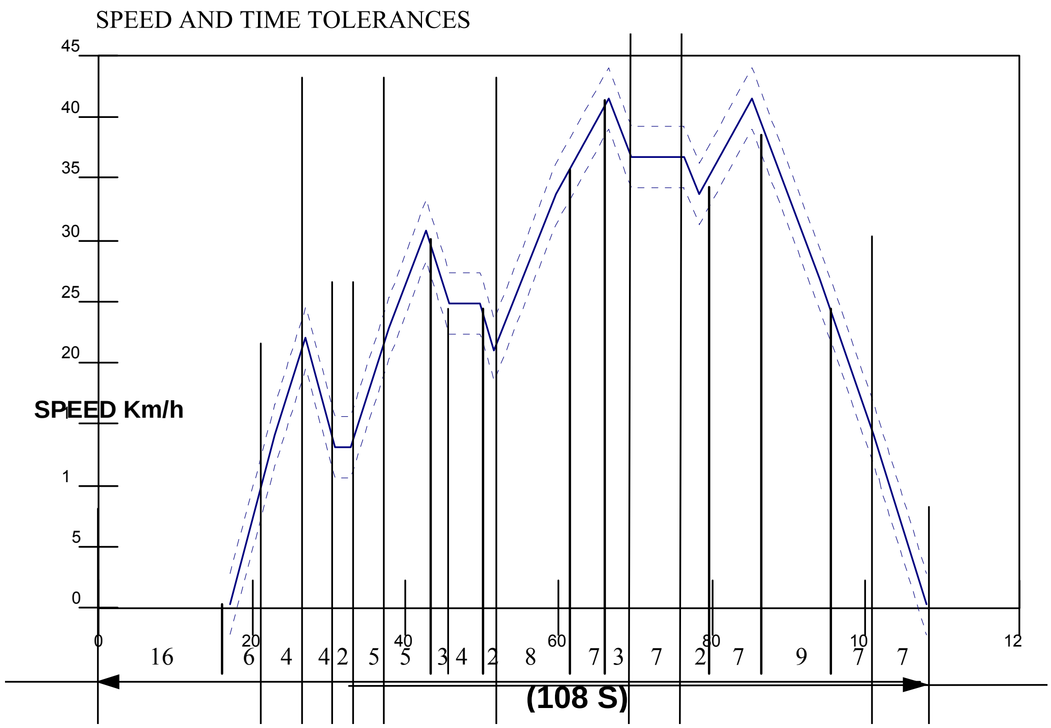



Fig 2: Operating cycle with speed and time tolerances
(Pl. ref. para 2.1.1)

5.2.3 Four wheel drive vehicles will be tested in a two-wheel drive mode of operation. Full time four-wheel drive vehicles will have one set of drive wheels temporarily disengaged by the vehicle manufacturers. Four-wheel drive vehicles which can be manually shifted to a two-wheel drive mode will be tested in the normal on highway two-wheel drive mode of operation.

5.3 Preconditioning of the vehicle :

5.3.1 For the compression ignition engine vehicles other than two and three wheelers, for the purpose of measuring particulates at most 36 hours and at least 6 hours before testing, the Part two cycle described in Table V of this chapter shall be used. Three consecutive cycles shall be driven. The dynamometer setting shall be as per 5.1 and 5.2 above

5.3.2 At the request of the manufacturers, vehicles with positive ignition engines may be pre-conditioned with one Part-I two Part-II driving cycles for four-wheeled vehicles.

5.3.3 After this preconditioning specific for compression ignition engines other than two and three wheelers and before testing, compression ignition and positive ignition engine vehicles shall be kept in a room in which a temperature remains relatively constant between 293 K and 303 K (20 and 30°C). The vehicle soaking shall be carried out for atleast 6 hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

5.3.4 If the manufacturer so requests, the test shall be carried out not later than 30 hours after the vehicle has been run at its normal temperature.

5.3.5 The tyre pressure shall be the same as that indicated by the manufacturer and used for the preliminary road test for data collection for adjustment of chassis Dynamometer. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting in the case of a two roll dynamometer. The actual pressure used shall be recorded in the test report.

6. Procedure for Chassis Dynamometer Test :

6.1 Special conditions for carrying out the cycle :

6.1.1 During the test, the test cell temperature shall be between 293 K and 303 K (20 and 30°C). The absolute humidity (H) of either the air in the test cell or the intake air of the engine shall be such that :

$$5.5 \leq H \leq 12.2 \text{ g } H_2O\text{/kg dry air}$$

6.1.2 The vehicle shall be approximately horizontal during the test so as to avoid any abnormal distribution of the fuel.

6.1.3 During the test, the speed can be recorded against time so that the correctness of the cycle performed can be assessed.

6.1.4 Cooling of the Vehicle :

6.1.4.1 For vehicles with liquid cooled engines the test shall be carried out with the bonnet raised unless this is technically impossible. An auxiliary ventilating device acting on the radiator (water cooling) or on the air intake (air cooling) may be used if necessary, to keep the engine temperature normal.

6.1.4.2 For vehicles with air cooled engines throughout the test, an auxiliary cooling blower shall be positioned in front of the vehicle, so as to direct cooling air to the engine. The blower speed shall be such that, within the operating range of 10 km/h to 50 km/h the linear velocity of the air at the blower outlet is within ± 5 km/h of the corresponding roller speed. At roller speeds of less than 10 km/h, air velocity may be zero, the blower outlet shall have a cross section area of at least 0.4 $m^2$ and the bottom of the blower outlet shall be between 15 and 20 cm above floor level. The blower outlet shall be perpendicular to the longitudinal axis of the vehicle between 30 and 45 cm in front of its front wheel.

6.1.4.3 The device used to measure the linear velocity of the air shall be located in the middle of the stream at 20 cm away from the air outlet. The air velocity shall be 25 km/h ± 5 km/h. This velocity shall be as nearly constant as possible across the whole of the blower outlet surface.

6.2 Starting up the engine :

6.2.1 The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions, as incorporated in the driver's handbook of production vehicles.

6.2.2 The cold start procedure for two and three wheeler diesel and all other vehicles to be followed shall be in accordance with 6.2.2.1 & 6.2.2.2

6.2.2.1 All two and three wheeler vehicles except diesel vehicles shall be run with 40 seconds idling and 4 cycles as per 2.1.1 of this Chapter as preparatory running before sampling on chassis dynamometer.

6.2.2.2 All other vehicles, i.e. 4 wheelers and diesel 2 & 3 wheelers shall be run with 40 seconds of idling as a preparatory running before sampling on chassis dynamometer.

6.2.3 If the maximum speed of the vehicle is less than the maximum speed of the driving cycle, that part of the driving cycle, where speed is exceeding the vehicle's maximum speed, the vehicle will be driven with the accelerator control fully actuated

6.3 Idling :

6.3.1 Manual-shift or semi-automatic gear-box :

6.3.1.1 During periods of idling, the clutch shall be engaged and gears in neutral.

6.3.1.2 To enable the accelerations to be performed according to normal cycle the vehicle shall be placed in first gear, with clutch disengaged, 5 seconds before the acceleration following the idling period considered of the elementary urban cycle (Part One).

6.3.1.3 The first idling period at the beginning of the urban cycle (Part One) shall consist of 6 seconds of idling in neutral with the clutch engaged and 5 seconds in first gear with the clutch disengaged.
The two idling periods referred to above shall be consecutive
The idling period at the beginning of extra-urban cycle (Part Two) consist of 20 seconds of idling in first gear with the clutch disengaged.

6.3.1.4 For the idling periods during each urban cycle (Part One) the corresponding times are 16 seconds in neutral and 5 seconds in first gear with the clutch disengaged.

6.3.1.5 The idle period between two successive elementary cycles (Part One) comprises 13 seconds in neutral with the clutch engaged.

6.3.1.6 At the end of the deceleration period that of the vehicle on the roller of the extra urban cycle (Part Two), the idling period consist of 20 seconds in neutral with the clutch engaged.
Note : Wherever first gear is mentioned above, second gear is to be used subject to 2.3.1 to 2.3.4

6.3.2 Automatic-shift gear-box : After initial engagement, the selector shall not be operated at any time during the test except in accordance with paragraph 6.4.3 below.

6.4 Accelerations :

6.4.1. Accelerations shall be so performed that the rate of acceleration shall be as constant as possible throughout the phase.

6.4.2. If an acceleration cannot be carried out in the prescribed time, the extra time required is, if possible, deducted from the time allowed for changing gear, but otherwise from the subsequent steady speed period.

6.4.3 Automatic-shift gear-boxes : If an acceleration cannot be carried out in the prescribed time the gear selector shall be operated in accordance with requirements for manual-shift gear-boxes.

6.5 Decelerations :

6.5.1 All decelerations of the elementary urban cycle (Part One) shall be effected by closing the throttle completely. The clutch shall be disengaged, at around a speed of 10 km/h.
All the deceleration of the extra urban cycle (Part Two) shall be effected by closing the throttle completely. The clutch shall be disengaged, at around a speed of 50 km/h for the last deceleration.

6.5.2 If the period of deceleration is longer than that prescribed for the corresponding phase, the vehicle's brakes shall be used to enable the timing of the cycle to be abided by.

6.5.3 If the period of deceleration is shorter than that prescribed for the corresponding phase, the timing of theoretical cycle shall be restored by constant speed or idling period merging into the following operation.

6.5.4 At the end of the deceleration period (halt of the vehicle on the rollers) of the elementary urban cycle (Part One) the gears shall be placed in neutral and the clutch engaged.

6.6 Steady Speeds :

6.6.1 "Pumping" or the closing of the throttle shall be avoided when passing from acceleration to the following steady speed.

6.6.2 Periods of constant speed shall be achieved by keeping the accelerator position fixed.

7. Procedure for Sampling and Analysis :

7.1 Sampling :

7.1.1 Sampling for all two and three wheelers except diesel vehicles shall begin at the end of fourth preparatory cycle and shall complete at the end of sixth cycle as defined in para 2.1.1 of this Chapter In the case of diesel two and three wheelers the sampling shall begin at the end of 40 seconds idling.

7.1.2 Sampling for all the vehicles other than mentioned at 7.1.1 shall begin at the end of 40 seconds idling and at the beginning of first elementary cycle (Part I) ends on conclusion of the final idling period in the extra urban cycle (Part Two).

7.2 Analysis :

7.2.1 The exhaust gases contained in the bag shall be analysed as soon as possible and in any event not later than 20 minutes after the end of the test cycle. The spent particulate filters must be taken to the chamber no later than 1 hour after conclusion of the test on the exhaust gases and must be conditioned for between 2 & 36 hours and then be weighed.

7.2.2 Prior to each sample analysis the analyser range to be used for each pollutant shall be set to zero with the appropriate zero gas.

7.2.3 The analysers shall then be set to the calibration curves by means of span gases of nominal concentrations of 70 to 100 percent of the range.

7.2.4 The analysers' zeros shall then be re-checked. If the reading differs by more than 2 percent of range from that set in paragraph 7.2.2 above, the procedure shall be repeated.

7.2.5 The samples shall then be analysed.

7.2.6 After the analysis zero and span points shall be re-checked using the same gases. If these re-checks are within 2 percent of those in paragraph 7.2.3, then the analysis shall be considered acceptable.

7.2.7 For all the points in this section, the flow rates and pressure of the various gases must be the same as those used during calibration of the analysers.

7.2.8 The figure adopted for the content of the gases in each of the pollutants measured shall be that read off after stabilisation of the measuring device. Diesel hydrocarbon mass emissions shall be calculated from the integrated HFID reading corrected for varying flow, if necessary as shown in Chapter 6 of this part.

8. Determination of the Quantity of Gaseous Pollutants Emitted :

8.1 The volume considered : The volume to be considered shall be corrected to conform to the conditions of 101.3 kPa and 293 K.

8.2 Total Mass of Gaseous Pollutants Emitted : The mass, M, of each pollutant emitted by the vehicle during the test shall be determined by obtaining the product of the voluminal concentration and the volume of the gas in question, with due regard for the following densities at the above mentioned reference condition.

- in the case of carbon monoxide (CO)d = 1.164 kg/m$^3$
- in the case of hydrocarbons ($CH_{1.85}$ )d = 0.5768 Kg/m$^3$
- in the case of nitrogen oxides ($NO_2$ )d = 1.913 kg/m$^3$.

The mass 'm' of particulate pollutant emissions from the vehicle during the test is defined by weighing the mass of particulates collected by two filters, '$m_1$' by the first filter, '$m_2$' by the second filter.

- if $0.95\ (m_1 + m_2) \leq m_1$, $m = m_1$,
- if $0.95\ (m_1 + m_2) > m_1$, $m = m_1 + m_2$,
- if $m_2 > m_1$, the test shall be cancelled.

8.3 Chapter 8 of this Part describes the calculations, followed by examples, used in determining the mass emissions of gaseous and particulates.

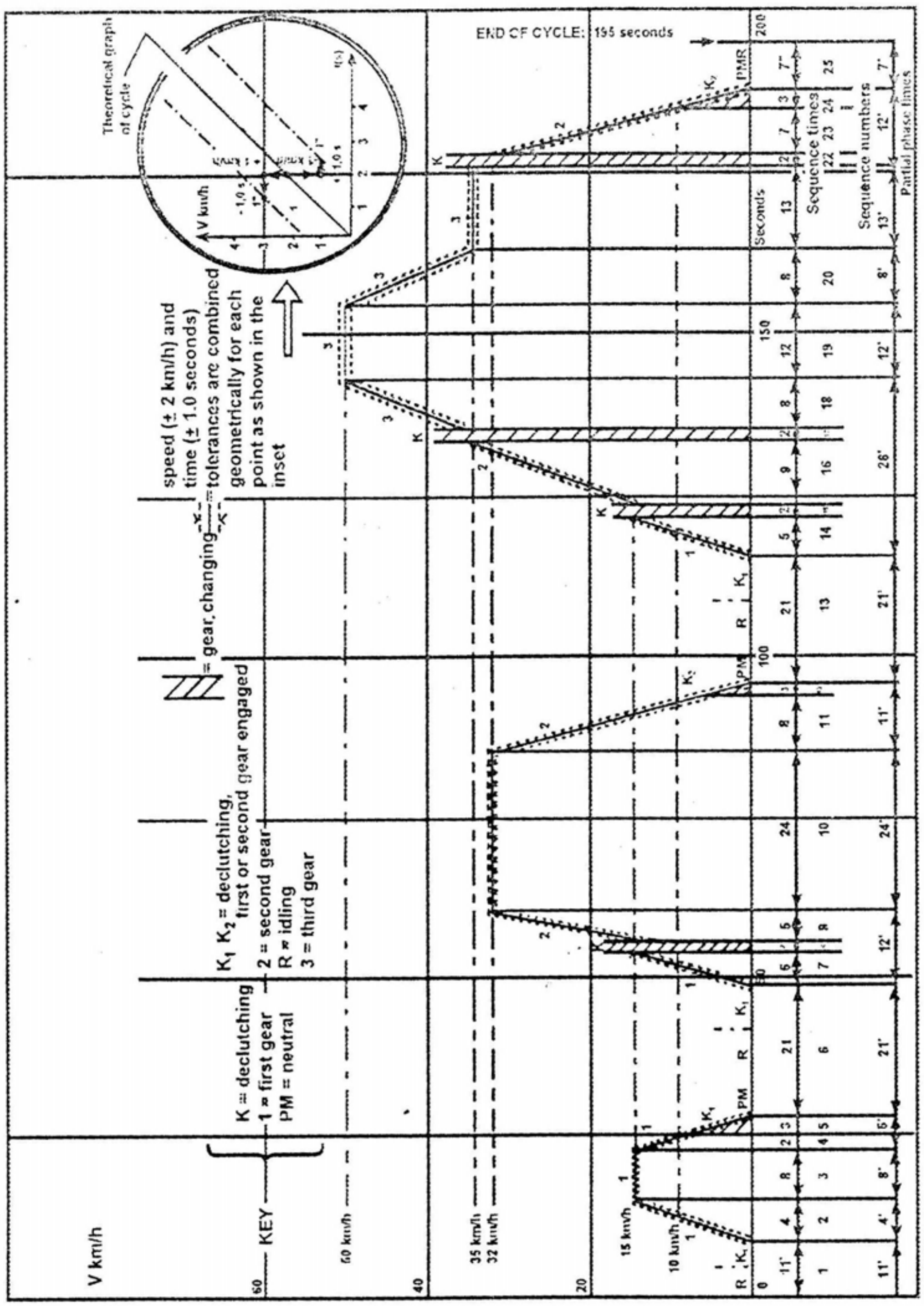



**Figure 3 : Elementary-Urban cycle for type I test**

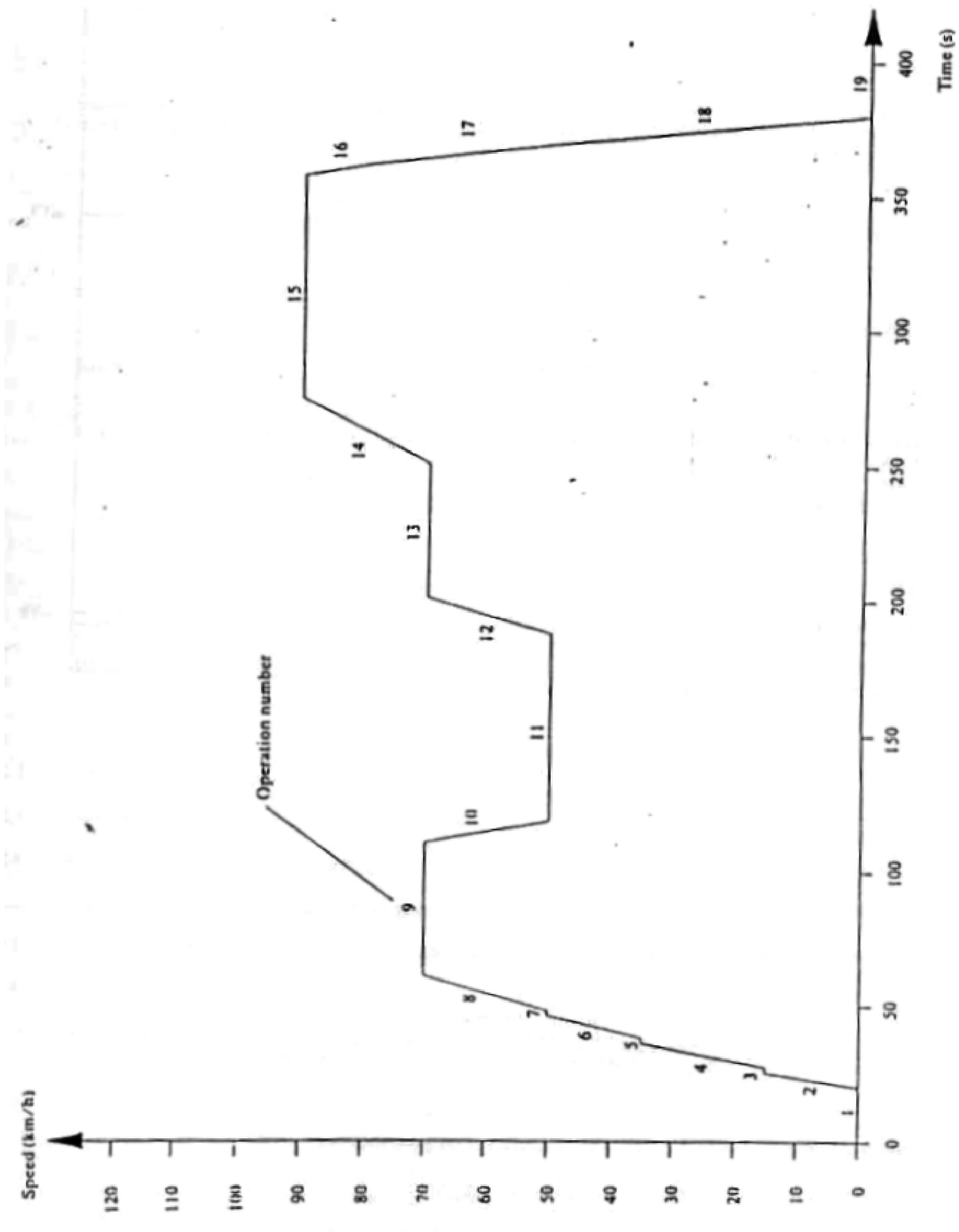



**Figure 4 : Extra-Urban cycle (Part two) for type I test**

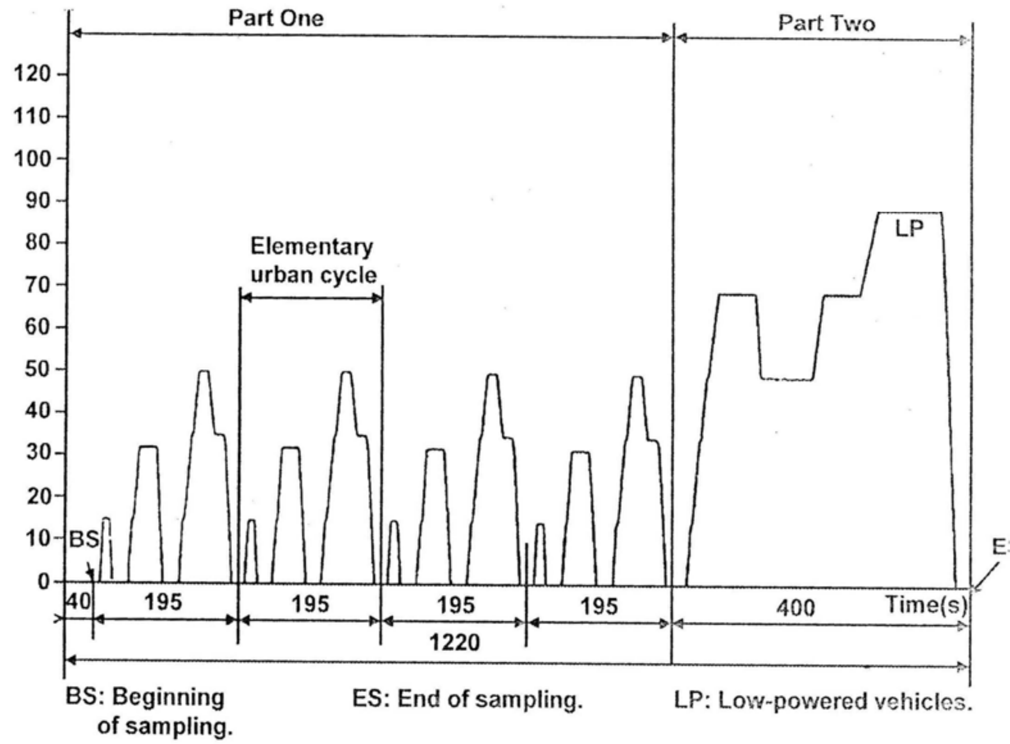



**Figure 5 : Operating cycle for the Type I Test**

**Table IV : Modified Indian Driving Cycle for the Year 2000**
**Operating Cycle on the Chassis Dynamometer (Part One)**

| No of Operation | Operation | Phase | Acceleration ($m/s^2$) | Speed (km/h) | Duration of each Operation (s) | Duration of each Phase (s) | Cumulative (s) | Gear to be used in case of manual gearbox |
|---|---|---|---|---|---|---|---|---|
| 1 | Idling | 1 | | | 11 | 11 | 11 | 6s PM + 5 s $K_1$(*) |
| 2 | Acceleration | 2 | 1.04 | 0-15 | 4 | 4 | 15 | 1 |
| 3 | Steady speed | 3 | | 15 | 9 | 8 | 23 | 1 |
| 4 | Deceleration | | -0.69 | 15-10 | 2 | | 25 | 1 |
| 5 | Deceleration, Clutch disengaged | 4 | -0.92 | 10-0 | 3 | 5 | 28 | $K_1$(*) |
| 6 | Idling | 5 | | | 21 | 21 | 49 | 16 s PM + 5 s $K_1$(*) |
| 7 | Acceleration | | 0.83 | 0-15 | 5 | | 54 | 1 |
| 8 | Gear change | 6 | | | 2 | 12 | 56 | |
| 9 | Acceleration | | 0.94 | 15-32 | 5 | | 61 | 2 |
| 10 | Steady speed | 7 | | 32 | 24 | 24 | 85 | 2 |
| 11 | Deceleration | | -0.75 | 32-10 | 8 | | 93 | 2 |
| 12 | Deceleration, Clutch disengaged | 8 | -0.92 | 10-0 | 3 | 11 | 96 | $K_2$(*) |
| 13 | Idling | 9 | | | 21 | 21 | 117 | 6 s PM + 5 s $K_1$(*) |
| 14 | Acceleration | | 1.04 | 0-15 | 5 | | 122 | 1 |
| 15 | Gear change | | | | 2 | | 124 | |
| 16 | Acceleration | 10 | 0.62 | 15-35 | 9 | | 133 | 2 |
| 17 | Gear change | | | | 2 | 26 | 135 | |
| 18 | Acceleration | | 0.52 | 35-50 | 8 | | 143 | 3 |
| 19 | Steady speed | 11 | | 50 | 12 | 12 | 155 | 3 |
| 20 | Deceleration | 12 | -0.52 | 50-35 | 8 | 8 | 163 | 3 |
| 21 | Steady speed | 13 | | 35 | 13 | 13 | 176 | 3 |
| 22 | Gear change | | | | 2 | | 178 | |
| 23 | Deceleration | 14 | -0.86 | 32-10 | 7 | | 185 | 2 |
| 24 | Deceleration Clutch disengaged | | -0.92 | 10-0 | 3 | 12 | 188 | $K_2$(*) |
| 25 | Idling | 15 | | | 7 | 7 | 195 | 7s PM(*) |

(*) PM = gearbox in neutral, clutch engaged
$K_1$, $K_2$ = first or second gear engaged, clutch disengaged.

**Table V : Modified Indian Driving Cycle for the Year 2000**

**Extra-urban cycle (Part Two) for the type I Test**

| No of Operation | Operation | Phase | Acceleration | Speed (km/h) | Duration of each | | Cumulative (s) | Gear to be used in case of a manual gearbox |
|---|---|---|---|---|---|---|---|---|
| | | | | | Operation (s) | Phase (s) | | |
| 1 | Idling | 1 | | | 20 | 20 | 20 | $K_1$(*) |
| 2 | Acceleration | 2 | 0.83 | 0-15 | 5 | 41 | 25 | 1 |
| 3 | Gear change | | | | 2 | | 27 | -- |
| 4 | Acceleration | | 0.62 | 15-35 | 9 | | 36 | 2 |
| 5 | Gear change | | | | 2 | | 38 | -- |
| 6 | Acceleration | | 0.52 | 35-50 | 8 | | 46 | 3 |
| 7 | Gear change | | | | 2 | | 48 | -- |
| 8 | Acceleration | | 0.43 | 50-70 | 13 | | 61 | 4 |
| 9 | Steady speed | 3 | | 70 | 50 | 50 | 111 | 5 |
| 10 | Deceleration | 4 | -0.69 | 70-50 | 8 | 8 | 119 | 4 s.5 + 4 s.4 |
| 11 | Steady speed | 5 | | 50 | 69 | 69 | 188 | 4 |
| 12 | Acceleration | 6 | 0.43 | 50-70 | 13 | 13 | 201 | 4 |
| 13 | Steady speed | 7 | | 70 | 50 | 50 | 251 | 5 |
| 14 | Acceleration | 8 | 0.24 | 70-90 | 24 | 24 | 275 | 5 |
| 15 | Steady speed | 9 | | 90 | 83 | 83 | 358 | 5 |
| 16 | Deceleration | 10 | -0.69 | 90-80 | 4 | 22 | 362 | 5 |
| 17 | Deceleration | | -1.04 | 80-50 | 8 | | 370 | 5 |
| 18 | Deceleration | | -1.39 | 50-00 | 10 | | 380 | $K_5$(*) |
| 19 | Idle | 11 | | | 20 | 20 | 400 | PM (*) |

(*) PM = gearbox in neutral, clutch engaged

$K_1$,$K_2$ = first or second gear engaged, clutch disengaged

**Table IV-A : Breakdown of the Part -One Of Modified Indian Driving Cycle**

**(ELEMENTARY URBAN CYCLE)**

**Breakdown by phases**

| | **Time (s)** | **%** |
|---|---|---|
| Idling | 60 | 30.8 } **35.4** |
| Idling, vehicle moving, clutch engaged on one combination | 9 | 4.6 } |
| Gear-changing | 8 | 4.1 |
| Accelerations | 36 | 18.5 |
| Steady-speed periods | 57 | 29.2 |
| Decelerations | 25 | 12.5 |
| | **195** | **100** |

**Breakdown by use of gears**

| | **Time (s)** | **%** |
|---|---|---|
| Idling | 60 | 30.8 } **35.4** |
| Idling, vehicle moving, clutch engaged on one combination | 9 | 4.6 } |
| Gear-changing | 8 | 4.1 |
| First gear | 24 | 12.3 |
| Second gear | 53 | 27.2 |
| Third gear | 41 | 21 |
| | **195** | **100** |

**General information**

Average speed during test : 19 km/h.
Effective running time : 195 seconds
Theoretical distance covered per cycle : 1.013 km
Equivalent distance for the four cycles : 4.053 km

**Table V-A : Breakdown of the Part Two of Modified Indian Driving Cycle**

**(Extra-Urban Cycle)**

**Breakdown by phases**

| | **Time (s)** | **%** |
|---|---|---|
| Idling | 20 | 5.0 |
| Idling, vehicle moving, clutch engaged on one combination | 20 | 5.0 |
| Gear-changing | 6 | 1.5 |
| Acceleration | 72 | 18.0 |
| Steady-speed periods | 252 | 63.0 |
| Deceleration | 30 | 7.5 |
| | **400** | **100** |

**Breakdown by use of gears**

| | **Time (s)** | **%** |
|---|---|---|
| Idling | 20 | 5.0 |
| Idling, vehicle moving, clutch engaged on one combination | 20 | 5.0 |
| Gear-changing | 6 | 1.5 |
| First gear | 5 | 1.3 |
| Second gear | 9 | 2.2 |
| Third gear | 8 | 2.0 |
| Fourth gear | 99 | 24.8 |
| Fifth gear | 233 | 58.2 |
| | **400** | **100** |

**General information**

Average speed during test : 59.3 km/h.
Effective running time : 400 seconds
Theoretical distance covered per cycle: 6.594 km
Maximal speed : 90 km/h
Maximal acceleration : 0.833 $m/s^2$
Maximal deceleration : -1.389 $m/s^2$

# CHAPTER 4 :RESISTANCE TO PROGRESS OF A VEHICLE-MEASUREMENT METHOD ON THE ROAD-SIMULATION ON A CHASSIS DYNAMOMETER

1. Scope :

This Chapter describes the methods to measure the resistance to the progress of a vehicle at stabilised speeds on the road and to simulate this resistance on a chassis dynamometer with adjustable load curves in accordance with paragraph 4.1.7.3 of Chapter 3 of this part.

2. Definition of the road :

2.1 The road shall be level and sufficiently long to enable the measurements specified below to be made. The longitudinal slope shall not exceed 1.5% and shall be constant within ± 0.1 % over the measuring strip.

3. Atmospheric Conditions :

3.1 Wind : Testing must be limited to wind speeds averaging less than 3 m/s with peak speeds less than 5 m/s. In addition, the vector component of the wind speed across the test road must be less than 2 m/s. Wind velocity should be measured 0.7 m above the road surface.

3.2 Humidity : The road shall be dry .

3.3 Pressure - Temperature : Air density at the time of the test shall not deviate by more than ±7.5 percent from the reference conditions:
P = 100 kPa & T = 293.2 K

4. Vehicle Preparation :

4.1 Running in : The vehicle shall be in normal running order and adjusted after having been run-in as per manufacturer's specifications. The tyres shall be run in at the same time as the vehicle or shall have a tread depth within 90 and 50 percent of the initial tread depth.

4.2 Verifications : The following verifications shall be made in accordance with the manufacturer's specifications for the use considered :

- wheel, wheel trims, tyres (make, type, pressure),
- front axle geometry,
- brake adjustment (elimination of parasitic drag)

- lubrication of front and rear axles,
- adjustment of the suspension and vehicle level, etc.

4.3 Preparation for the test :

The vehicle shall be loaded to its reference mass. The level of the vehicle shall be that obtained when the centre of gravity of the load is situated midway between the "R" points of the front outer seats and on a straight line passing through those points.

4.3.1 In case of road tests, the windows of the vehicle shall be closed. Any covers of air climatization systems, headlamps, etc., shall be in the non-operating position.

4.3.2 The vehicle shall be clean.

4.3.3 Immediately prior to the test the vehicle shall be brought to normal running temperature in an appropriate manner.

5. Methods for chassis dynamometer with adjustable load curve

5.1 Energy variation during coast-down method :

5.1.1 On the road

5.1.1.1 Accuracies of test equipment

Time shall be measured accurate to within 0.1 second. Speed shall be measured accurate to within 2 percent.

5.1.1.2 Test procedure

5.1.1.2.1 Accelerate the vehicle to a speed of 10 km/h greater than the chosen test speed, V.

5.1.1.2.2 Place the gear box in "neutral" position.

5.1.1.2.3 Measure the time taken ($t_1$)for the vehicle to decelerate from

$$V_2 = V + \Delta V \text{ km/h to } V_1 = V - \Delta V \text{ km/h : with } V \leq 5 \text{ km/h}$$

5.1.1.2.4 Perform the same test in the opposite direction : $t_2$

5.1.1.2.5 Take the average T, of the two times $t_1$ and $t_2$.

5.1.1.2.6 Repeat these tests several times such that the statistical accuracy (p) of the average

$$T = \frac{1}{n}\sum_{i=1}^{n} t_i$$ is not more than 2% (p ≤ 2%)

The statistical accuracy (p) is defined by :

$$p = \frac{t * s}{\sqrt{n}} * \frac{100}{T}$$

where,
t = coefficient given by the table below
s = standard deviation = $\sqrt{\sum \frac{(T_i - T)^2}{(n-1)}}$
n = number of tests

| N | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | 3.2 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| $\frac{t}{\sqrt{n}}$ | 1.6 | 1.25 | 1.06 | 0.94 | 0.85 | 0.77 | 0.73 | 0.66 | 0.64 | 0.61 | 0.59 | 0.57 |

5.1.1.2.7 Calculate the power by the formula :

$$P = \frac{m * V * \Delta V}{500 * T}$$

where,

P is expressed in kW
V = speed of the test in m/s
ΔV= speed deviation from speed V, in m/s
m = reference mass in kg
T = time in seconds

Alternatively, the coast down shall be carried out as per IS 14785-1999 to establish “a” and “b” coefficients for setting on chassis dynamometer.

5. 1.2 On the chassis dynamometer :

5.1.2.1 Measurement equipment and accuracy : The equipment shall be identical to that used on the road.

5.1.2.2 Test procedure :

5.1.2.2.1 Install the vehicle on the test dynamometer.

5.1.2.2.2 Adjust the tyre pressure (cold) of the driving wheels as required by the chassis dynamometer.

5.1.2.2.3 Adjust the equivalent inertia of the chassis dynamometer.

5.1.2.2.4 Bring the vehicle and chassis dynamometer to operating temperature in a suitable manner.

5.1.2.2.5 Carry out the following operations specified in paragraph 5.1.1.2 with the exception of paragraphs 5.1.1.2.4 and 5.1.1.2.5 and with changing m by I in the formula of paragraph 5.1.1.2.7 above.

5.1.2.2.6 Adjust the chassis dynamometer to meet the requirements of paragraphs of 4.1.6.1 of Chapter 3 of this Part.

5.2 Torque measurements method at constant speed :

5.2.1 On the road:

5.2.1.1 Measurement equipment and error :

Torque measurement shall be carried out with an appropriate measuring device, accurate to within 2 %. Speed measurement shall be accurate to within 2 %.

5.2.1.2 Test procedure

5.2.1.2.1 Bring the vehicle to the chosen stabilised speed, V.

5.2.1.2.2 Record the torque C(t) and speed over a period t(of at least 10 s) by means of class 1000 instrumentation meeting ISO standard No. 970, over small intervals of time t.

5.2.1.2.3 Differences in torque, and speed relative to time shall not exceed 5% for each second of the measurement period. The torque $C_{t_1}$ is the average torque derived from the following formula

$$C_{t_1} = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} C(t)dt$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. $C_{t_2}$.

5.2.1.2.5 Determine the average of these torques $C_{t_1}$ and $C_{t_2}$ i.e $C_t$.

5.2.2 On the chassis dynamometer

5.2.2.1 Measurement equipment and error

The equipment shall be identical to that used on the road.

5.2.2.2 Test procedure

5.2.2.2.1 Perform the operations specified in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

5.2.2.2.2 Adjust the chassis dynamometer setting to meet the requirements of paragraph 4.1.6.1. of Chapter 3 of this Part.

5.3 Integrated torque over vehicle driving pattern :

5.3.1 This method is a non-obligatory complement to the constant speed method described in paragraph 5.2 above.

5.3.2 In this dynamic procedure the mean torque value $\overline{M}$ is determined. This is accomplished by integrating the actual torque values,M(t) , with respect to time during operation of the test vehicle with a defined driving cycle. The integrated torque is then divided by the time difference $t_2$ - $t_1$,

The result is :

$$\overline{M} = \frac{1}{t_1 - t_2} \int_{t_1}^{t_2} M(t) * dt \text{ (with M(t) > 0)}$$

M is calculated from six sets of results.

It is recommended that the sampling rate of $\overline{M}$ be not less than two samples per second.

5.3.3 Dynamometer setting The dynamometer load is set by the method described in paragraph 5.2 above. If $\overline{M}$ (dynamometer) does not match $\overline{M}$ (road) then the inertia setting shall be adjusted until the values are equal within ± 5 percent.

Note : This method can only be used for dynamometers with electrical inertia simulation or fine adjustment.

5.3.3.1 Acceptance criteria :

Standard deviation of six measurements must be less than or equal to 2 % of the mean value.

5.4 Method by deceleration measurement by gyroscopic platform :

5.4.1 On the road :

5.4.1.1 Measurement equipment and accuracy:

- Speed shall be measured with an accuracy better than 2 %.
- Deceleration shall be measured with an accuracy better than 1 %.
- The slope of the road shall be measured with an accuracy better than 1%.
- Time shall be measured with an accuracy better than 0.1 s.
- The level of the vehicle is measured on a reference horizontal ground: as an alternative, it is possible to correct for the slope of the road ($\alpha_1$).

5.4.1.2 Test procedure :

5.4.1.2.1 Accelerate the vehicle to a speed 5 km/h greater than the chosen test speed V.

5.4.1.2.2 Record the deceleration between V + 0.5 km/h and V - 0.5 km/h.

5.4.1.2.3 Calculate the average deceleration attributed to the speed V by the formula:

$$\overline{\gamma}_1 = \frac{1}{t}\int_0^t \gamma_1(t)dt - (g.\sin \propto_1)$$

where:

$\overline{\gamma}_1$ = average deceleration value at the speed V in one direction of the road

t = time between V + 0.5 kmph and V - 0.5 kmph

$\gamma_1(t)$ = deceleration recorded with the time

g = 9.81 m/s².

5.4.1.2.4 Perform the same test in the other direction $\overline{\gamma}_2$

5.4.1.2.5 Calculate the average deceleration i.e.

$$\gamma_i = \frac{\gamma_1 + \gamma_2}{2} \text{ for test I.}$$

5.4.1.2.6 Perform a sufficient number of tests as specified in paragraph 5.1.1.2.6 above replacing T by $\gamma$ where

$$\gamma = \frac{1}{n}\sum_{i=1}^{n}\gamma_i$$

5.4.1.2.7 Calculate the average force absorbed F=m* $\gamma$ ,where m =vehicle reference mass in kg & $\gamma$ =average deceleration calculated as above.

5.4.2 On the chassis dynamometer :

5.4.2.1 Measuring equipment and accuracy
The measurement instrumentation of the chassis dynamometer itself shall be used as defined in para 5.1.2.1 of this Part.

5.4.2.2 Test procedure
Adjustment of the force on the rim under steady speed.
On chassis dynamometer, the total resistance is of the type:

$F_{total} = F_{indicated} + F_{driving\ axle\ rolling}$ with
$F_{total} = F_{road}$
$F_{indicated} = F_{road} - F_{driving\ axle\ rolling}$

where : $F_{indicated}$ is the force indicated on the force indicating device of the chassis dynamometer.
$F_{(road)}$ is known.
$F_{driving\ axle\ rolling}$ , can be measured on chassis dynamometer driving axle rolling able to work as generator.
The test vehicle, gear box in neutral position, is driven by the chassis dynamometer at the test speed; the rolling resistance, $R_R$, of the driving axle is then measured on the force indicating device of the chassis dynamometer.

Determination on chassis dynamometer unable to work as a generator.

For the two-roller chassis dynamometer, the $R_R$ value is the one which is determined before on the road.

For the single-roller chassis dynamometer, the $R_R$ value is the one which is determined on the road multiplied by a coefficient R which is equal to the ratio between the driving axle mass and the vehicle total mass.
Note : $R_R$ is obtained from the curve F = f(V).

5.4.2.2.1 Calibrate the force indicator for the chosen speed of the roller bench as defined in para 2 Chapter 5 of this Part.

5.4.2.2.2 Perform the same operation as in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

5.4.2.2.3 Set the force, $F_A = F - F_R$ on the indicator for the speed chosen.

5.4.2.2.4 Carry out a sufficient number of tests as indicated in paragraph 5.1.1.2.6 above, replacing T by $F_A$ .

5.5 Deceleration Method applying coastdown techniques :

5.5.1 On the Road

5.5.1.1 Accuracies of the test instrument shall be the same as specified in 5.1.1.1.

5.5.1.2 Drive the vehicle at a constant speed of about 10 km/h more than the chosen test speed, V km/h, along a straight line.

5.5.1.3 After this speed is held steady for a distance of at-least 100 m, disconnect the engine from the drive line by bringing the gear to neutral or by other means in the case of vehicle where manual shifting to neutral is not possible.

5.5.1.4 Measure the time taken ($t_1$ sec) for the speed to drop from V + ΔV km/h to V - ΔV km/h. The value of ΔV shall not be less than 1 km/h or more than 5 km/h. However, same value of Δ V shall be used for all the tests.

5.5.1.5 Repeat the test in the opposite direction and record the time ( $t_2$ sec.).

5.5.1.6 Repeat the test 10 times such that the statistical error of the time $t_i$ (arithmetic average of $t_1$ and $t_2$ ) is equal to or less than 2%.

5.5.1.7 The statistical error 'p' is calculated as -

$$p = \frac{24.24 * (t_i - t_m)^2}{t_m}$$

where t = average time for each consecutive set of reading, $\frac{t_1 + t_2}{2}$

$t_m$ = Arithmetic average of 10 such $t_i$ .

5.5.1.8 The basic equation of motion to calculate the road load resistance force, F, is

$$F = \frac{(W + W_2) * V}{(3.6 * t_m * g)}$$

where,

F - in N

W - the weight of the test vehicle in N

$W_2$ - equivalent inertia weight of rotating axle ( 0.035 x mass of the test vehicle for four-wheeled vehicles) in N

V - vehicle speed difference during the coast down, in km/h

$t_m$ - coast down time, in seconds

g - acceleration due to gravity, 9.81 m/s².

5.5.1.9 Using least square curve fitting method and values of F and V, the coefficient of aerodynamic and rolling resistance of the vehicle viz. a and b respectively are found from the following equation :

$F = a * V^2 + b$

5.5.2 Chassis Dynamometer Setting : The values of a and b are set on the dynamometer.

5.6 Alternate Method of Two-Wheelers

With the manufacturers` agreement for this method, the following values of a and b are set on the dynamometer as per the following equation :

$F = aV^2 + b$

where - F = the load, in N

a = 0.0225 for 2-wheeled vehicles with engines less than 50 cc capacity and 0.0250 for other 2-wheeled vehicles .

b = 0.18 x reference weight of vehicle, in kg

5.7 Alternative method for three wheelers : With the manufacturer's agreement, the following method may be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 50 km/h in accordance with the table I of this chapter.

5.8 Alternative method for vehicles other than two and three wheelers : With the manufacturer's agreement, the following method may be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 80 km/h in accordance with coefficients "a" and "b" of the table II of this chapter.

5.9 When the alternate method as per Para 5.7 or 5.8 is followed, the initial calibration of the chassis dynamometer shall be carried out without placing the vehicle on the chassis dynamometer.

**Table I of Chapter 4 of Part IX : Power setting for three wheelers.**

| Reference Mass of Vehicle RW(kg) | | Equivalent Inertia(kg) | Absorbed power at 50m/h (kW) |
|---|---|---|---|
| Exceeding | Upto | | |
| | 105 | 100 | 0.88 |
| 105 | 115 | 110 | 0.90 |
| 115 | 125 | 120 | 0.91 |
| 125 | 135 | 130 | 0.93 |
| 135 | 150 | 140 | 0.94 |
| 150 | 165 | 150 | 0.96 |
| 165 | 185 | 170 | 0.99 |
| 185 | 205 | 190 | 1.02 |
| 205 | 225 | 210 | 1.05 |
| 225 | 245 | 230 | 1.09 |
| 245 | 270 | 260 | 1.14 |
| 270 | 300 | 280 | 1.17 |
| 300 | 330 | 310 | 1.21 |
| 330 | 360 | 340 | 1.26 |
| 360 | 395 | 380 | 1.33 |
| 395 | 435 | 410 | 1.37 |
| 435 | 480 | 450 | 1.44 |
| 480 | 540 | 510 | 1.50 |
| 540 | 600 | 570 | 1.56 |
| 600 | 650 | 620 | 1.61 |
| 650 | 710 | 680 | 1.67 |
| 710 | 770 | 740 | 1.74 |
| 770 | 820 | 800 | 1.81 |
| 820 | 880 | 850 | 1.89 |
| 880 | 940 | 910 | 1.99 |
| 940 | 990 | 960 | 2.05 |
| 990 | 1050 | 1020 | 2.11 |
| 1050 | 1110 | 1080 | 2.18 |
| 1110 | 1160 | 1130 | 2.24 |
| 1160 | 1220 | 1190 | 2.30 |
| 1220 | 1280 | 1250 | 2.37 |
| 1280 | 1330 | 1300 | 2.42 |
| 1330 | 1390 | 1360 | 2.49 |
| 1390 | 1450 | 1420 | 2.54 |

| | | | |
|---|---|---|---|
| 1450 | 1500 | 1470 | 2.57 |
| 1500 | 1560 | 1530 | 2.62 |
| 1560 | 1620 | 1590 | 2.67 |
| 1620 | 1670 | 1640 | 2.72 |
| 1670 | 1730 | 1700 | 2.77 |
| 1730 | 1790 | 1760 | 2.83 |

**Table II of Chapter 4 of Part IX**

**Table II: Power setting for vehicles other than two and three wheelers.**

| Reference Mass of Vehicle | | Equivalent Inertia | Power & load absorbed by dynamometer at 80km/h | | Coefficients | |
|---|---|---|---|---|---|---|
| | | | | | a | B |
| RW(kg) | | Kg | kW | N | N | $N/(km/h)^2$ |
| Exceeding | Upto | | | | | |
| --- | 480 | 455 | 3.8 | 171 | 3.8 | 0.0261 |
| 480 | 540 | 510 | 4.1 | 185 | 4.2 | 0.0282 |
| 540 | 595 | 570 | 4.3 | 194 | 4.4 | 0.0296 |
| 595 | 650 | 625 | 4.5 | 203 | 4.6 | 0.0309 |
| 650 | 710 | 680 | 4.7 | 212 | 4.8 | 0.0323 |
| 710 | 765 | 740 | 4.9 | 221 | 5.0 | 0.0337 |
| 765 | 850 | 800 | 5.1 | 230 | 5.2 | 0.0351 |
| 850 | 965 | 910 | 5.6 | 252 | 5.7 | 0.0385 |
| 965 | 1080 | 1020 | 6.0 | 270 | 6.1 | 0.0412 |
| 1080 | 1190 | 1130 | 6.3 | 284 | 6.4 | 0.0433 |
| 1190 | 1305 | 1250 | 6.7 | 302 | 6.8 | 0.0460 |
| 1305 | 1420 | 1360 | 7.0 | 315 | 7.1 | 0.0481 |
| 1420 | 1530 | 1470 | 7.3 | 329 | 7.4 | 0.0502 |
| 1530 | 1640 | 1590 | 7.5 | 338 | 7.6 | 0.0515 |
| 1640 | 1760 | 1700 | 7.8 | 351 | 7.9 | 0.0536 |
| 1760 | 1870 | 1810 | 8.1 | 365 | 8.2 | 0.0557 |
| 1870 | 1980 | 1930 | 8.4 | 378 | 8.5 | 0.0577 |
| 1980 | 2100 | 2040 | 8.6 | 387 | 8.7 | 0.0591 |
| 2100 | 2210 | 2150 | 8.8 | 396 | 8.9 | 0.0605 |
| 2210 | 2380 | 2270 | 9.0 | 405 | 9.1 | 0.0619 |
| 2380 | 2610 | 2270 | 9.4 | 423 | 9.5 | 0.0646 |
| 2610 | -- | 2270 | 9.8 | 441 | 9.9 | 0.0674 |
| **In case of vehicles, other than passenger cars, with a reference mass of more than 1700 kg, or vehicles with a permanent all wheel drive, the power values given above are multiplied by the factor 1.3. However at the manufacturer's request, the factor of 1.3 need not be applied for measurement of fuel consumption.** | | | | | | |

# CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

1 Scope :

1.1 This Chapter describes the method to check that the simulated total inertia of the dynamometer is carried out satisfactorily in the running phases of the operating cycle.

2 Principle :

2.1 Drawing up working equations :

2.1.1 Since the chassis dynamometer is subjected to variations in the rotating speed of the roller(s), the force at the surface of the roller(s) can be expressed by the formula:

$F = I * \gamma = I_M * \gamma + F_I$

Where
F = force at the surface of the roller(s)

I = total inertia of the chassis dynamometer (equivalent inertia of the vehicle as in Table III of Chapter 3 of this Part).

$I_M$ = inertia of the mechanical masses of the chassis dynamometer

$\gamma$ = tangential acceleration at roller surface

$F_I$ = inertia force

2.1.2 The total inertia is expressed as follows :

$$I = I_M + \frac{F_I}{\gamma}$$

where
$I_M$ can be calculated or measured by traditional methods
$F_I$ can be measured on the bench
$\gamma$ can be calculated from the peripheral speed of the rollers

2.1.3 The total inertia "I" will be determined during an acceleration or deceleration test with values higher than or equal to those obtained on an operating cycle.

2.2 Specification for the calculation of total inertia :

The test and calculation methods must make it possible to determine total inertia I with a relative error ( ΔI / I) of less than 2 %.

3 Specification :

3.1 The mass of the simulated total inertia I must remain the same as the theoretical value of the equivalent inertia (paragraph 5.1 of Chapter 3 of this Part ) within the following limits:

3.1.1 ± 5 % of the theoretical value for each instantaneous value.

3.1.2 ± 2 % of the theoretical value for the average value calculated for each sequence of the cycle.

3.2 The limit given in paragraph 3.1.1 is brought to ± 50 percent for one second when starting and, for vehicles with manual transmission, for two seconds during gear changes.

4 Verification Procedure :

4.1 Verification is carried out during each test throughout the cycle defined in paragraph 2.1 of chapter 3 of this part.

4.2 However, if the provisions of paragraph 3 above are met, with instantaneous accelerations which are at least three times greater or smaller than the values obtained in the sequences of the theoretical cycle, the verification described above will not be necessary.

5 Technical Note :

Explanation of drawing up working equations:

5.1 Equilibrium of the forces on the road,

$$CR = k_1 Jr_1 \frac{d\theta_1}{dt} + k_2 Jr_2 \frac{d\theta_2}{dt} + k_3 M\gamma r_1 + k_3 F_s r_1$$

5.2 Equilibrium of the forces on dynamometer with mechanical simulated inertias

$$C_m = k_1 Jr_1 \frac{d\theta 1}{dt} + k_3 \frac{JR_m \frac{dW_m}{dt}}{R_m} r_1 + k_3 F_s r_1$$

$$= k_1 Jr_1 \frac{d\theta 1}{dt} + k_3 I\gamma r_1 + k_3 F_s r_1$$

5.3 Equilibrium of the forces of dynamometer with non-mechanically simulated inertias

$$C_e = k_1 Jr_1 \frac{d\theta_1}{dt} + \left( k_3 \frac{JR_e \frac{dW_e}{dt}}{R_e} r_1 + \frac{C_1}{R_e} r_1 \right) + k_3 F_s r_1$$

$$= k_1 Jr_1 \frac{d\theta_1}{dt} + k_3 (I_M \gamma + F_1) r_1 + k_3 F_s r_1$$

In these formulae :

CR = engine torque on the road

$C_m$ = engine torque on the chassis dynamometer with mechanically simulated inertias

$C_e$ = engine torque on the chassis dynamometer with electrically simulated inertias

$Jr_1$ = Moment of inertia of the vehicle transmission brought back to the driving wheels

$Jr_2$ = Moment of inertia of the non-driving wheels

$JR_m$ = Moment of inertia of the bench with mechanically simulated inertias

$JR_e$ = Moment of mechanical inertia of the chassis dynamometer with electrically simulated inertias

M = Mass of the vehicle on the road

I = Equivalent inertia of the chassis dynamometer with electrically simulated inertias

IM= Mechanical Inertia of the chassis dynamometer with electrically simulated inertia.

$F_s$ = Resultant force at stabilized speed.

$C_1$ = Resultant torque from electrically simulated inertias

$F_1$ = Resultant force from electrically simulated inertias

$\frac{d\theta_1}{dt}$ = Angular acceleration of the driving wheels

$\frac{d\theta_2}{dt}$ = Angular acceleration of the non-driving wheels

$\frac{dW_m}{dt}$ = Angular acceleration of the mechanical chassis dynamometer

$\frac{dW_e}{dt}$ = Angular acceleration of the electrical chassis dynamometer

$\gamma$ = Linear acceleration

$r_1$ = Radius under load of the driving wheels

$r_2$ = Radius under load of the non-driving wheels

$R_m$ = Radius of the rollers of the mechanical chassis dynamometer

$R_e$ = Radius of the rollers of the electrical chassis dynamometer

$k_1$ = Coefficient dependent on the gear reduction ratio and the various inertias of transmission and "efficiency"

$k_2$ = Ratio transmission * ($r_1/r_2$) * "efficiency"

$k_3$ = Ratio transmission * "efficiency"

5.4 Supposing the two types of bench (Paragraphs 5.2 and 5.3 above) are made equal and simplified, one obtains :

$k_3 * (I_M * \gamma + F_1) * r_1 = k_3 * I * \gamma * r_1$

where -

$I = I_M + (F_1 / \gamma)$

# CHAPTER 6 : GAS SAMPLING SYSTEMS

1 Scope :

1.1 This Chapter describes two types of gas sampling systems in paragraphs 2.1 and 2.2 meeting the requirements specified in para 4.2 of Chapter 3 of this Part. Another type described in paragraph 2.3, may be used if it meets these requirements.

1.2 The laboratory shall mention, in its communications, the system of sampling used when performing the test. Systems not described in this chapter could be used, if it is proven to give equivalent results.

2.0 Criteria relating to the variable-dilution system for measuring exhaust-Gas Emissions

2.1 Scope

This section specifies the operating characteristics of an exhaust-gas sampling system intended to be used for measuring the true mass emissions of a vehicle exhaust in accordance with the provisions of this Directive. The principle of variable-dilution sampling for measuring mass emissions requires three conditions to be satisfied:

2.1.1 The vehicle exhaust gases must be continuously diluted with ambient air under specified conditions;

2.1.2 The total volume of the exhaust gases and dilution air must be measured accurately;

2.1.3 A continuously proportional sample of the dilution exhaust gases and the dilution air must be collected for analysis.

The quantity of gaseous pollutants emitted is determined from the proportional sample concentrations and the total volume measured during the test. The sample concentrations are corrected to take account of the pollutant content of the ambient air. In addition, where vehicles are equipped with compression ignition engines, their particulate emissions are measured.

2.2 Technical summary :

Figure 7 gives a schematic diagram of the sampling system.

2.2.1 The vehicle exhaust gases must be diluted with a sufficient of ambient air to prevent any water condensation in the sampling and measuring system.

2.2.2 The exhaust-gas sampling system must be so designed as to make it possible to measure the average volume concentrations of the $CO_2$, CO, HC and $NO_x$, and in addition, in the case of vehicles equipped with compression-ignition engines, of the particulate emissions, contained in the exhaust gases emitted during the vehicle testing cycle.

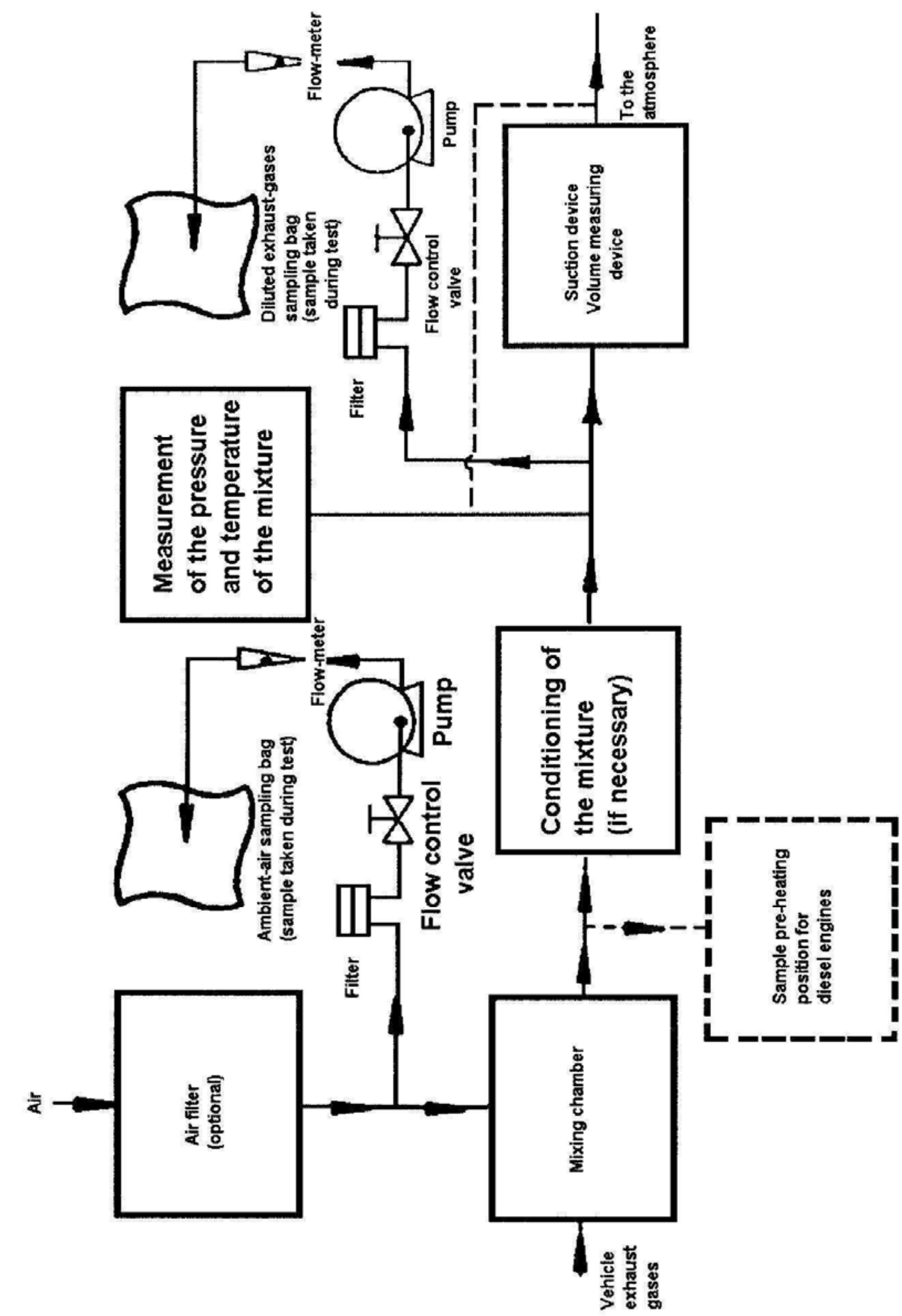



**Figure 7 :** **<u>Diagram of variable-dilution system for measuring exhaust-gas emissions</u>**

2.2.3 The mixture of air and exhaust gases must be homogeneous at the point where the sampling probe is located (see 2.3.1.2 below).

2.2.4 The probe must extract a representative sample of the diluted gases.

2.2.5 The system must make it possible to measure the total volume of the diluted exhaust gases from the vehicle being tested.

2.2.6 The sampling system must be gas-tight. The design of the variable-dilution sampling system and the material that go to make it up must be such that they do not affect the pollutant concentration in the diluted exhaust gases. Should any component in the system (heat exchanger, cyclone separator, blower etc) change the concentration of any of the pollutants in the diluted exhaust gases and the fault cannot be corrected, then sampling for that pollutant must be carried out before that component.

2.2.7 If the vehicle tested is equipped with an exhaust system comprising more than one tailpipe, the connecting tubes must be connected together by a manifold installed as near as possible to the vehicle.

2.2.8 The gas samples must be collected in sampling baggies of adequate capacity so as to hinder the gas flow during the sampling period. These baggies must be made of such materials as will not affect the concentration of pollutant gases (see 2.3.4.4 below).

2.2.9 The variable-dilution system must be so designed as to enable the exhaust gases to the sampled without appreciably changing the back-pressure at the exhaust pipe outlet (see 2.3.1.1 below).

2.3 Specific requirements :

2.3.1 Exhaust-gas collection and dilution device.

2.3.1.1 The connection tube between the vehicle exhaust tailpipe(s) and the mixing chamber must be as short as possible; it must in no case:

- cause the static pressure at he exhaust tailpipe(s) on the vehicle being tested to differ by more than ± 0.75 kPa at 50 km/h or more than ± 1.25 kPa for the whole duration of the test from the static pressures recorded when nothing is connected to the vehicle tailpipes. The pressure must be measured in the exhaust tailpipe or in an extension having the same diameter, as near as possible to the end of the pipe.

- Change the nature of the exhaust gas.

2.3.1.2 There must be a mixing chamber in which the vehicle exhaust gases and the dilution air are mixed so as to produce a homogeneous mixture at the chamber outlet.

The homogeneity of the mixture in any cross-section at the location of the sampling probe must not vary by more than ± 2 % from the average of the values obtained at least five points located at equal intervals on the diameter of the gas system. In order to minimize the effects on the conditions at the exhaust tailpipe and to limit the drop in pressure inside the dilution air-conditioning device, if any, the pressure inside the mixing chamber must not differ by more than 0.25 kPa from atmospheric pressure.

2.3.2 Suction device/volume measuring device

This device may have a range of fixed speeds so as to ensure sufficient flow to prevent any water condensation. This result is generally obtained by keeping the concentration of $CO_2$ in the dilute exhaust gas sampling bag lower than 3% by volume.

2.3.3 Volume measurement :

2.3.3.1 The volume-measuring device must retain its calibration accuracy to within ± 2% under all operating conditions. If the device cannot compensate for variations in the temperature of the mixture of exhaust gases and dilution air at the measuring point, a heat exchanger must be used to maintain the temperature to within ± 6 K of the specified operating temperature.

If necessary, a cyclone separator can be used to protect the volume-measuring device.

2.3.3.2 A temperature sensor must be installed immediately before the volume-measuring device. This temperature sensor must have an accuracy and a precision of ± 1 K and a response time of 0.1 second at 62% of a given temperature variation (value measured in silicone oil).

2.3.3.3 The pressure measurements must have a precision and an accuracy of ± 0.4 kPa during the test.

2.3.3.4 The measurement of the pressure difference from atmospheric pressure is taken before and, if necessary, after the volume-measuring device.

2.3.4 Gas sampling :

2.3.4.1 Dilute exhaust gases

2.3.4.1.1 The sample of dilute exhaust gases is taken before the suction devices but after the conditioning devices (if any).

2.3.4.1.2 The flow-rate must not deviate by more than ± 2% from the average.

2.3.4.1.3 The sampling rate must not fall below 5 litres per minute and must not exceed 0.2% of the flow-rate of the dilute exhaust gases.

2.3.4.1.4 An equivalent limit applies to constant-mass sampling systems.

2.3.4.2 Dilution air

2.3.4.2.1 A sample of the dilution air is taken at a constant flow-rate near the ambient air inlet (after the filter if one is fitted).

2.3.4.2.2 The air must not be contaminated by exhaust gases from the mixing area.

2.3.4.2.3 The sampling rate for the dilution air must be comparable to that used in the case of the dilute exhaust gases.

2.3.4.3 Sampling operations

2.3.4.3.1 The materials used for the sampling operations must be such that they do not change the pollutant concentration.

2.3.4.3.2 Filters may be used in order to extract the solid particles from the sample.

2.3.4.3.3 Pumps are required in order to convey the sample to the sampling bag(s).

2.3.4.3.4 Flow control valves and flow-meters are needed in order to obtain the flow-rates required for sampling.

2.3.4.3.5 Quick fastening gas-tight connections may be used between the three-way valves and the sampling bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyzer (three-way stop valves, for example).

2.3.4.3.6 The various valves used for directing the sampling gases must be of the quick-adjusting and quick-acting type.

2.3.4.4 Storage of the sample

The gas samples are collected in sampling bags of adequate capacity so as not to reduce the sampling rate. The bags must be made of such a material as will not change the concentration of synthetic pollutant gases by more than ± 2% after 20 minutes.

2.4 Additional sampling unit for the testing of vehicles equipped with a compression ignition engine

2.4.1 By way of a departure from the taking of gas samples from vehicles equipped with spark-ignition engines, the hydrocarbon and particulate sampling points are located in a dilution tunnel.

2.4.2 In order to reduce heat losses in the exhaust gases between the exhaust tail pipe and the dilution tunnel inlet, the pipe may not be more than 3.6 m long, or 6.1 m long if heat insulated. Its internal diameter may not exceed 105 mm.

2.4.3 Predominantly turbulent flow conditions (Reynolds number ≥ 4000) must apply in the dilution tunnel, which consist of a straight tube of electrically-conductive material, in order to guarantee that the diluted exhaust gas is homogeneous at the sampling points and that the samples consist of representative gases and particulate. The dilution tunnel must be at least 200 mm in diameter and the system must be earthed.

2.4.4 The particulate sampling system consist of a sampling probe in the dilution tunnel and two series-mounted filters. Quick-acting are located both up and downstream of the two filters in the direction of flow.
The configuration of the sample probe must be as indicated in Figure 8.

2.4.5 The particulate sampling probe must be arranged as follows :

It must be installed in the vicinity of the tunnel centerline, roughly 10 tunnel diameters downstream of the gas inlet, and have an internal diameter of at least 12 mm.

The distance form the sampling tip to the filter mount must be at least five probe diameters, but must not exceed 1020 mm.

2.4.6 The sample gas flow-measuring unit consists of pumps, gas flow regulators and flow measuring units.

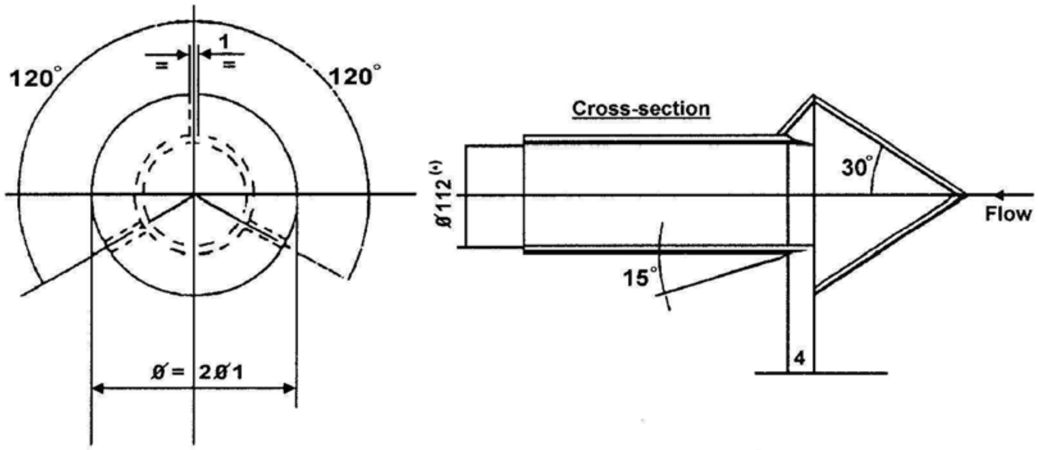



**Figure 8 : Particulate Sampling Probe Configuration**
(*) Minimum internal diameter
Wall thickness : ~1 mm; Material : Stainless Steel

2.4.7 The hydrocarbon sampling system consists of a heated sampling probe, line, filter and pump. The sampling probe must be installed in such a way, at the same distance from the exhaust gas inlet as the particulate sampling probe, that neither interferes with samples taken by the other. It must have a minimum internal diameter of 4 mm.

2.4.8 All heated parts must be maintained at a temperature of 463 K (190 °C) ± 10 K by heating system.

2.4.9 If it is not possible to compensate for variations in the flow rate there must be a heat exchanger and a temperature control device as specified in 2.3.3.1 above so as to ensure that the flow rate in the system is constant and the sampling rate is accordingly proportional.

3.0 Description of Devices :

3.1 Variable Dilution Device with Positive Displacement Pump (PDP-CVS) (Fig. 9).

3.1.1 The Positive Displacement Pump - Constant Volume Sampler (PDP-CVS) satisfies the requirements by metering at a constant temperature and pressure through the pump. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling with pump, flow meter and flow control valve at a constant flow rate.

3.1.2 Fig. 9 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawings is not essential. Additional components such as instruments, valves, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

3.1.3 The collecting equipment shall consist of :

3.1.3.1 A filter (B) for the dilution air, which can be preheated, if necessary. This filter shall consist of activated charcoal sandwiched between two layers of paper, and shall be used to reduce and stabilise the hydrocarbon concentrations of ambient emissions in the dilution air.

3.1.3.2 A mixing chamber (M) in which exhaust gas and air are mixed homogeneously.

3.1.3.3 A heat exchanger (H) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust gas mixture measured at a point immediately upstream of the positive displacement pump is within ± 6 K of the designed operating temperature. This device shall not affect the pollutant concentrations of diluted gases taken off for analysis.

3.1.3.4 A temperature control system (TC), used to preheat the heat exchanger before the test and to control its temperature during the test, so that deviations from the designed operating temperature are limited to ± 6 K.

3.1.3.5 The positive displacement pump (PDP), used to transport a constant volume flow of the air / exhaust gas mixture. The flow capacity of the pump shall be large enough to eliminate water condensation in the system under all operating conditions which may occur during a test, this can be generally ensured by using a positive displacement pump with an adequate flow capacity.

3.1.3.5.1 Twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle or

3.1.3.5.2 Sufficient to ensure that the $CO_2$ concentration in the dilute exhaust sample bag is less than 3 % by volume.

3.1.3.6 A temperature sensor ($T_1$) (accuracy and precision ± 1K) fitted at a point immediately upstream of the positive displacement pump. It shall be designed to monitor continuously the temperature of diluted exhaust gas mixture during the test.

3.1.3.7 A pressure gauge ($G_1$) (accuracy and precision ± 0.4 kPa) fitted immediately upstream of the volume meter and used to register the pressure gradient between the gas mixture and the ambient air.

3.1.3.8 Another pressure gauge ($G_2$) (accuracy and precision ± 0.4 kPa) fitted so that the differential pressure between pump inlet and pump outlet can be registered.

3.1.3.9 Two sampling outlets ($S_1$ and $S_2$ ) for taking constant samples of the dilution air and of the diluted exhaust gas/air mixture.

3.1.3.10A filter (F), to extract solid particles from the flow of gas collected for analysis.

3.1.3.11 Pumps (P), to collect a constant flow of the dilution air as well as of the diluted exhaust-gas/air mixture during the test.

3.1.3.12 Flow controllers (N), to ensure a constant uniform flow of the gas samples taken during the course of the test from sampling probes $S_1$ and $S_2$ , and flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (about 10 l/min.)

3.1.3.13 Flow meters (FL), for adjusting and monitoring the constant flow of gas samples during the test.

3.1.3.14 Quick-acting valves (V), to divert a constant flow of gas samples into the sampling bags or to the outside vent.

3.1.3.15 Gas-tight, quick-lock coupling elements (Q) between the quick-acting valves and the sampling bags; the coupling shall close automatically on the sampling-bag side; as an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).

3.1.3.16 Bags (B), for collecting samples of the diluted exhaust gas and of the dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

3.1.3.17 A digital counter (C), to register the number of revolutions performed by the positive displacement pump during the test.

3.1.4 Additional equipment required when testing diesel engined vehicles.

3.1.4.1 The additional components shown within the dotted lines of Fig.9 shall be used when testing Diesel Engined Vehicles.

$F_h$ is a heated filter

$S_3$ is a sample point close to the mixing chamber

$V_h$ is a heated multiway valve

Q is a quick connector to allow the ambient air sample BA to be analysed on the HFID

HFID is a heated flame, ionisation analyser.

R & I are means of integrating and recording the instantaneous hydrocarbon concentrations.

$L_h$ is a heated sample line

All heated components will be maintained at 463 K (190 °C) ± 10 K.
Particulate sampling system
S4 Sampling probe in the dilution tunnel
$F_P$ Filter unit consisting of two series mounted filters : Switching arrangement for further parallel mounted pairs of filters,
Sampling line,
Pumps, flow regulators, flow measuring units.

3.2 Critical-flow venturi dilution device/(CFV-CVS) (Fig.10).

3.2.1 Using a critical-flow venturi in connection with the CVS sampling procedure is based on the principles of flow mechanics for critical flow. The variable mixture flow rate of dilution and exhaust gas is maintained at sonic velocity which is directly proportional to the square root of the gas temperature. Flow is continually monitored, computed, and integrated over the test. If an additional critical-flow sampling venturi is used the proportionality of the gas samples taken is ensured. As both pressure and temperature are equal at the two venturi inlets, the volume of the gas flow diverted for sampling is proportional to the total volume of diluted exhaust gas mixture produced, and thus the requirements of this test are met.

3.2.2 Fig.10 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawing is not essential. Additional components such as instruments, valve, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

3.2.3 The collecting equipment shall consist of :

3.2.3.1 A filter (D), for the dilution air, which can be preheated if necessary; the filter shall consist of activated charcoal sandwiched between layers of paper, and shall be used to reduce and stabilize the hydrocarbon background emission of the dilution air.

3.2.3.2 A mixing chamber (M), in which exhaust gas and air are mixed homogeneously.

3.2.3.3 A cyclone separator (CS), to extract particles.

3.2.3.4 Two sampling probes ($S_1$ and $S_2$ ), for taking samples of the dilution air as well as of the diluted exhaust gas.

3.2.3.5 A sampling critical flow venturi (SV), to take proportional samples of the diluted exhaust gas at sampling probe, $S_2$.

3.2.3.6 A filter (F), to extract solid particles from the gas flows diverted for analysis.

3.2.3.7 Pumps (P), to collect part of the flow of air and diluted exhaust gas in bags during the test.

3.2.3.8 A flow controller (N), to ensure a constant flow of the gas samples taken in the course of the test from sampling probe $S_1$. The flow of the gas samples shall be such, that at the end of the test, the quantity of the samples is sufficient for analysis (about 10 l/min)

3.2.3.9 Flow meters (FL), for adjusting and monitoring the flow of gas samples during tests.

3.2.3.10 A scrubber (PS), in the sampling line.

3.2.3.11 Quick-acting solenoid valves (V), to divert a constant flow of gas samples into the sampling bags or to the vent.

3.2.3.12 Gas-tight, quick-lock coupling elements (Q), between the quick acting valves and the sampling bags; the couplings shall close automatically on the sampling bag side. As an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcock, for instance).

3.2.3.13 Bags (B), for collecting samples of the diluted exhaust gas and the dilution air during the test; they shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

3.2.3.14 A pressure gauge (G), which shall be precise and accurate to within ±0.4 kPa.

3.2.3.15 A temperature sensor (T), which shall be precise and accurate to within ±1 K and have a response time of 0.1 seconds to 62 % of a temperature change (as measured in silicon oil).

3.2.3.16 A measuring critical flow venturi tube (MV), to measure the flow volume of the diluted exhaust gas.

3.2.3.17 A blower (BL), of sufficient capacity to handle the total volume of diluted gas.

3.2.3.18 The capacity of the CFV-CVS system shall be such that under all operating conditions which may possibly occur during a test there will be no condensation of water. This is generally ensured by using a blower whose capacity is;

3.2.3.18.1 Twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle or

3.2.3.18.2 Sufficient to ensure that the $CO_2$ concentration in the dilute exhaust sample bag is less than 3 % by volume.

3.2.4 Additional equipment required when testing diesel engined vehicles.

3.2.4.1 The additional components shown within the dotted lines of Fig.10 shall be used when testing Diesel Engined Vehicles.

Fh : is a heated filter
$S_3$ : is a sample point close to the mixing chamber
$V_h$ : is a heated multiway valve
Q : is a quick connector to allow the ambient air sample BA to be analysed on the HFID
HFID : is a heated flame, ionisation analyser.
R & I : are means of integrating and recording the instantaneous hydrocarbon concentrations.
Lh : is a heated sample line

All heated components will be maintained at 463 K (190 °C) ± 10 K.

3.2.4.2 If compensation for varying flow is not possible then a heat exchanger (H) and temperature control system (TC) as described in Paragraph 2.2.3 of this Chapter will be required to ensure constant flow through the ventury (MV) and thus proportional flow through $S_3$.

Particulate sampling system :
$S_4$ Sampling probe in dilution tunnel
$F_P$ Filter series consisting of two series mounted filters : Switching

arrangement for further parallel mounted pairs of filters,
Sampling line,
Pumps, flow regulators, flow measuring units.

3.3 Variable dilution device with constant flow control by orifice (CFO-CVS) (Fig. 11).

3.3.1 The collection equipment shall consist of :

3.3.1.1 A sampling tube connecting the vehicle's exhaust pipe to the device itself;

3.3.1.2 A sampling device consisting of a pump for drawing in the diluted mixture of exhaust gas and air;

3.3.1.3 A mixing chamber (M) in which exhaust gas and air are mixed homogeneously.

3.3.1.4 A heat exchanger (H) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust gas mixture measured at a point immediately before the positive displacement of the flow rate measuring device is within ± 6 K. This device shall not alter the pollutant concentration of diluted gases taken off for analysis. Should this condition not be satisfied for certain pollutants, sampling will be effected before the cyclone for one or several considered pollutants.

If necessary, a device for temperature control (TC) is used to preheat the heat exchanger before testing and to keep up its temperature during the test within ± 6 K of the designed operating temperature.

3.3.1.5 Two probes ($S_1$ and $S_2$) for sampling by means of pumps (P), flowmeters (FL) and, if necessary, filters (F) allowing for the collection of solid particles from gases used for the analysis.

3.3.1.6 One pump for dilution air and another one for diluted mixture.

3.3.1.7 A volume-meter with an orifice.

3.3.1.8 A temperature sensor ($T_1$) (accuracy and precision ± 1 K) fitted at a point immediately before the volume measurement device. It shall be designed to monitor continuously the temperature of the diluted exhaust gas mixture during the test.

3.3.1.9 A pressure gauge ($G_1$) (capacity and precision ± 0.4 kPa) fitted immediately before the volume meter and used to register the pressure gradient between the gas mixture and the ambient air.

3.3.1.10 Another pressure gauge ($G_2$) (accuracy and precision ± 0.4 kPa) fitted so that the differential pressure between pump inlet and pump outlet can be registered.

3.3.1.11 Flow controllers (N) to ensure a constant uniform flow of gas samples taken during the course of the test from sampling outlets $S_1$ and $S_2$. The flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (about 10 l/min).

3.3.1.12 Flow meters (FL) for adjusting and monitoring the constant flow of gas samples during the test.

3.3.1.13 Three-way valves (V) to divert a constant flow of gas samples into the sampling bags or to the outside vent.

3.3.1.14 Gas-tight, quick lock sampling elements (Q) between the three-way valves and the sampling bags. The coupling shall close automatically on the sampling bag side. Other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).

3.3.1.15 Bags (B) for collecting samples of diluted exhaust gas and of dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

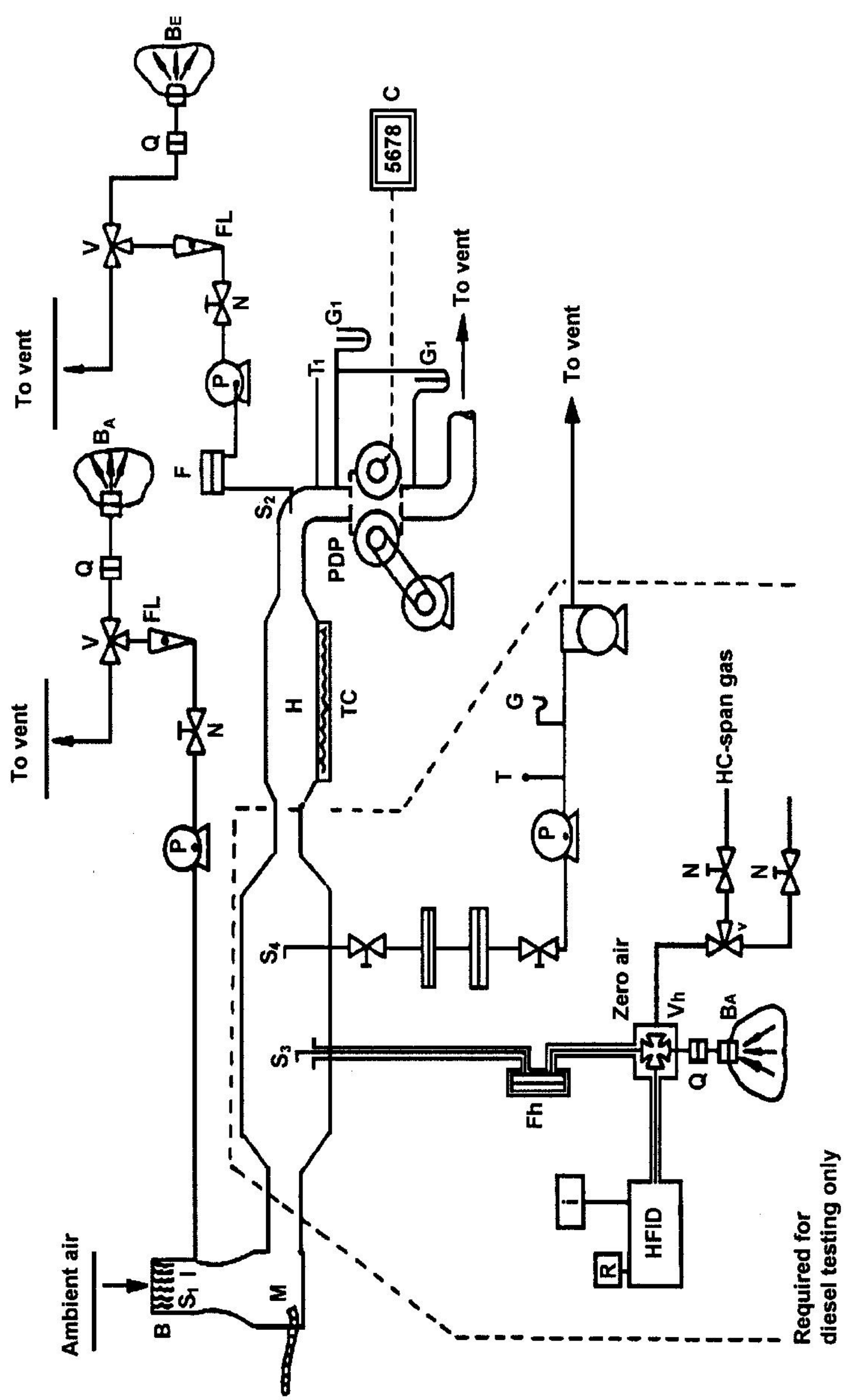



**Figure 9 : <u>Schematic Constant Volume Sampler with Positive Displacement Pump (PDP-CVS)</u>** (Pls. Ref. Para. 3.1 of this Chapter)

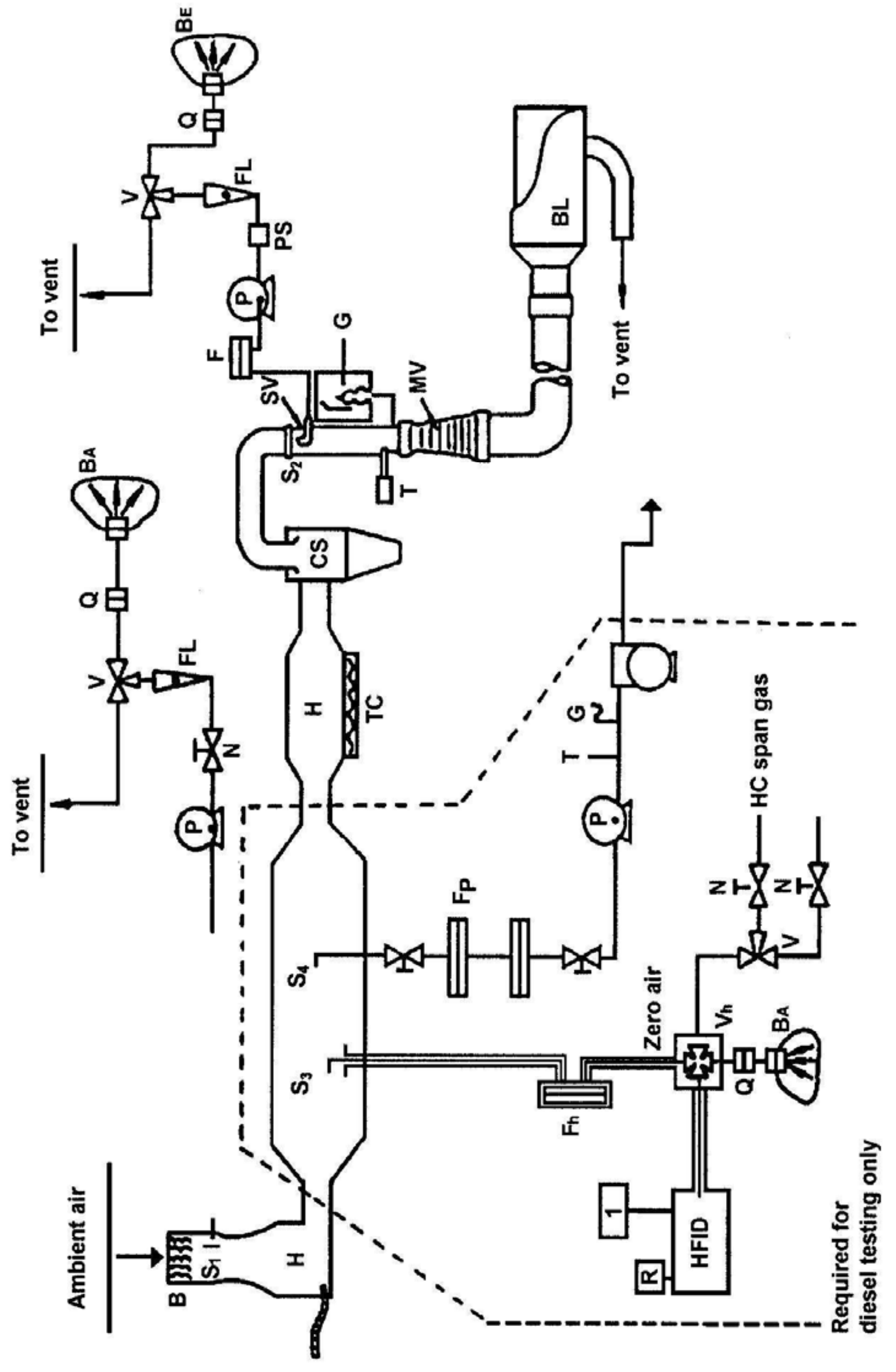



**Figure 10 : Schematic Constant Volume Sampler with Critical Flow Venturi (CFV-CVS)** (Pls.Ref.Para. 3.2 of this Chapter)

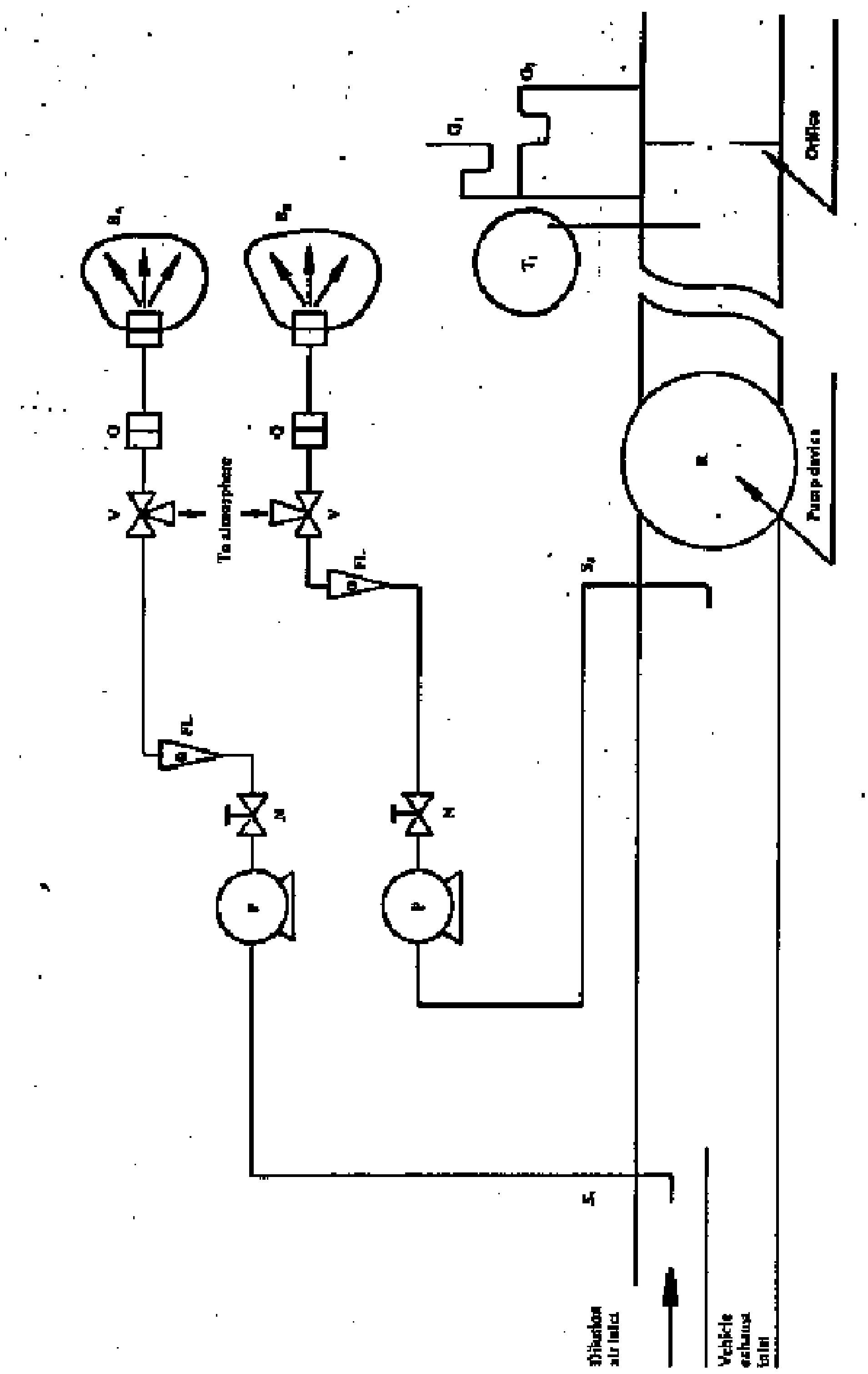



**Figure 11 : Schematic of Variable Dilution DeFFigure 11 : Schematic of Variable Dilution Device with Constant Flow Control by Orifice (CFO-CVS)**

(Pls. Ref. Para 3.3 of this Chapter)

# CHAPTER 7 : CALIBRATION OF CHASSIS DYNAMOMETERS, CVS SYSTEM AND GAS ANALYSIS SYSTEM AND TOTAL SYSTEM VERIFICATION

1. Scope :

1.1 This Chapter describes the methods used for calibrating, and verifying the Chassis Dynamometers, CVS System and Analysis System.

2. Methods of Calibration of Chassis Dynamometer :(The method to be used to determine the power absorbed by a dynamometric brake)

2.1 The power absorbed by chassis dynamometer comprises the power absorbed by frictional effects and the power absorbed by the power absorption device. The chassis dynamometer is brought into operation beyond the range of test speeds. The device used for starting up the chassis dynamometer is then disconnected; the rotational speed of the driven rollers decreases. The kinetic energy of rollers is dissipated by the power absorption unit and by the frictional effects. This method disregards variations in the roller's internal frictional effects caused by rollers with or without the vehicle. The frictional effects of the rear roller shall be disregarded when this is free.

2.2 Calibrating the power indicator to 80 km/h as a function the power absorbed The following procedure shall be used.(Fig.12)

2.2.1 Measure the rotational speed of the roller if this has not already been done. A fifth wheel, a revolution counter or some other method may be used.

2.2.2 Place the vehicle on the dynamometer or connect the device for starting up the dynamometer.

2.2.3 Use the fly-wheel or any other system of inertia simulation for the particular inertia class to be used.

2.2.4 Bring the dynamometer to a speed of 80 km/h.

2.2.5 Note the power indicated (Pi).

2.2.6 Bring the dynamometer to a speed of 90 km/h.

2.2.7 Disconnect the device used to start up the dynamometer.

2.2.8 Note the time taken by the dynamometer to pass from a speed of 85 km/h to a speed of 75 km/h.

2.2.9 Set the power absorption device at a different level.

2.2.10 The requirements of paragraphs 2.2.4 to 2.2.9 above shall be repeated sufficient number of times to cover the range of road power used.

2.2.11 Calculate the power absorbed, using the formula:

$$P_a = M_i * \frac{V_1^2 - V_2^2}{2000t}$$

Where

$P_a$ = power absorbed in kW

$M_i$ = equivalent inertia in kg (excluding the inertial effects of the free rear roller)

$V_1$ = initial speed in m/s (85 km/h = 23.61 m/s)

$V_2$ = final speed in m/s (75 km/h = 20.83 m/s)

t = time taken by the roller to pass from 85 km/h to 75 km/h in s.

2.2.11.1 The requirements of paragraphs 2.2.3 to 2.2.11 shall be repeated for all inertia classes to be used.

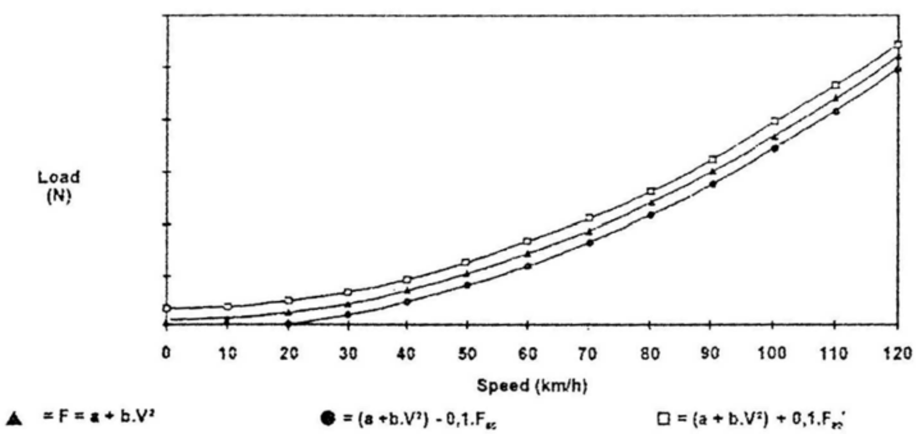



**Figure 12 : Diagram illustrating the load of the chassis dynamometer**

2.3 Calibration of the power indicator as a function of the absorbed power for other speeds :

The procedures of paragraph 2.2 shall be repeated sufficient number of times for the chosen speeds.

2.4 Verification of the power-absorption curve of the roller bench from a reference setting to a speed of 80 km/h :

2.4.1 Place the vehicle on the dynamometer or devise some other method of starting up the dynamometer.

2.4.2 Adjust the dynamometer to the absorbed power Pa, at 80 km/h.

2.4.3 Note the power absorbed at 100,80,60,40 and 20 km/h.

2.4.4 Draw the curve Pa versus V and verify that it meets the requirements of 6.1.1. of Chapter 4 of this part.

2..4.5 Repeat the procedure of para 2.4.1 to 2.4.4 for other values of power Pa at 80 km/h and for other values of inertia.

2.5 The same procedure will be used for force or torque calibration.

3. Calibration of the CVS System :

3.1 The CVS system shall be calibrated by using an accurate flow meter and a restricting device. The flow through the system shall be measured at various pressure readings and the control parameters of the system measured and related to the flows.

Various types of flow meter may be used, e.g. calibrated venturi, laminar flow meter, calibrated turbine meter provided that they are dynamic measurement systems and can meet the requirements of paragraphs 4.2.2 and 4.2.3 of Chapter 3 of this Part.

3.1.1 The following sections give details of methods of calibrating PDP and CFV units, using a laminar flow meter, which gives the required accuracy, together with a statistical check on the calibration validity.

3.2 Calibration of the Positive Displacement Pump (PDP) :

3.2.1 The following calibration procedure outlines the equipment the test configuration, and the various parameters which shall be measured to establish the flow rate of the CVS-pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow meter which is connected in series with pump. The calculated flow rate (given in $m^3$ /min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

3.2.2 This calibration procedure is based on the measurement of the absolute values of the pump and flow meter parameters that relate the flow rate at each point. Three conditions must be maintained to ensure the accuracy and integrity of the calibration curve as given below :

3.2.2.1 The pump pressures shall be measured at tappings on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top centre and bottom centre of the pump drive headplate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials.

3.2.2.2 Temperature stability shall be maintained during the calibration. The laminar flow meter is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes of ± 1K in temperature are acceptable as long as they occur over a period of several minutes.

3.2.2.3 All connections between the flow meter and the CVS pump shall be free of any leakage.

3.2.3 During an exhaust emission test, the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

3.2.3.1 Fig.13 in this chapter shows one possible test set-up. Variations are permissible, provided that they are approved by the Authority granting the approval as being of comparable accuracy. If the set-up shown in Fig.7 is used, the following data shall be found within the limits of precision given :

| | |
|---|---|
| Barometric pressure (corrected (PB) | ± 0.03 kPa |
| Ambient temperature (T) | ± 0.2 K |
| Air temperature at LFE (ETI) | ± 0.15 K |
| Pressure depression upstream of LFE(EPI) | ± 0.01 kPa |
| Pressure drop across the LFE matrix (EDP) | ± 0.0015 kPa |
| Air temperature at CVS pump inlet (PTI) | ± 0.2 K |
| Air temperature at CVS pump outlet (PTO) | ± 0.2 K |
| Pressure depression at CVS pump inlet (PPI) | ± 0.22 kPa |
| Pressure head at CVS-pump outlet (PPO) | ± 0.22 kPa |

Pump revolutions during test period (n) ± 1 rev.

Elapsed time for period (min 250 sec) (t) ± 0.1 sec

3.2.3.2 After the system has been connected, as shown in Fig.13, the variable restrictor is set in the wide-open position and the CVS pump run for 20 minutes before starting the calibration.

3.2.3.3 The restrictor valve is adjusted in steps to get an increment of pump inlet depression (about 1 kPa) that will yield a minimum of six data points for the total calibration. The system is allowed to stabilize for three minutes and the data acquisition repeated.

3.2.4 Data analysis :

3.2.4.1 The air flow rate, Qs, at each test point is calculated in standard $m^3$ /min from the flow meter data using the manufacturer's prescribed method.

3.2.4.2 The air flow rate is then converted to pump flow, Vo, in $m^3$ per revolution at absolute pump inlet temperature and pressure.

$$V_o = \frac{Q_s}{n} * \frac{T_p}{293} * \frac{101.33}{P_p}$$

Where,

$V_o$ = pump flow rate at Tp and $Pp_o$ given in $m^3$ /rev

$Q_s$ = air flow at 101.33 kPa and 293 K given in $m^3$ /min

$T_p$ = pump inlet temperature (K)

$P_p$ = absolute pump inlet pressure, in kPa

n = pump speed in revolutions per minute

To compensate the interaction of pump speed, pressure variations at the pump and the slip rate, the correlation function ($X_o$) between the pump speed (n), the pressure differential from the pump inlet to pump outlet and the absolute pump outlet Pressure is then calculated as follows :-

$$X_o = \frac{1}{n} * \sqrt{\frac{\Delta P_p}{P_e}}$$

Where,

Xo = correlation function

$\Delta P_p$ = pressure differential from pump inlet to pump outlet (kPa)

$P_e$ = absolute pump outlet pressure (PPO + PB) (kPa)

A linear least square fit is performed to generate the calibration equations which have the formula

$V_o = D_o - (M*X_o)$

$n = A-B(\Delta P_p)$

where -

$D_o$ , M, A and B are the slope-intercept constants describing the lines.

3.2.4.3 A CVS system that has multiple speeds shall be calibrated on each speed used. The calibration curves generated for the ranges should be approximately parallel and the intercept values, ($D_o$) should increase as the pump flow decreases.

3.2.4.4 If the calibration has been performed carefully, the calculated values from the equation should be within ± 0.5 % of the measured value of $V_o$. Values of M should vary from one pump to another. Calibration shall be performed at pump start-up and after major maintenance.

3.3 Calibration of the Critical-Flow Venturi (CFV) (Fig.14)

3.3.1 Calibration of the CFV is based upon the flow equation for a critical venturi

$$Q_s = K_v * \frac{P}{\sqrt{T}}$$

Where,
$Q_s$ = Flow rate in $m^3$ / min at 101.33 kPa and 293 K

$K_v$ = Calibration coefficient

P = Absolute pressure (kPa)

T = Absolute temperature ( K)

Gas flow is a function of inlet pressure and temperature. The calibration procedure described below establishes the value of the calibration coefficient at measured value of pressure, temperature and air flow.

3.3.2 The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

3.3.3 Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given :

| | |
|---|---|
| Barometric pressure (corrected) ($P_B$) | ± 0.03 kPa |
| LFE air temperature flowmeter (ETI) | ± 0.15 K |
| Pressure depression up-stream of LFE (EPI) | ± 0.01 kPa |
| Pressure drop across (EDP) LFE matrix | ± 0.0015 kPa |
| Air Flow ($Q_s$) | ± 0.5 % |
| CFV inlet depression (PPI) | ± 0.02 kPa |
| Temperature at venturi inlet ($T_v$) | ± 0.2 K |

3.3.4 The equipment shall be set up as shown in fig.14 and checked for leaks. Any leaks between the flow measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

3.3.5 The variable flow restrictor shall be set to the "open" position, the blower shall be started and the system shall be stabilised. Data from all instruments shall be recorded.

3.3.6 The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

3.3.7 The data recorded during the calibration shall be used in the following calculations. The air flow rate, Qs, at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

Values of the calibration coefficient Kv for each test point is calculated as below –

$$K_v = \frac{Q_s * \sqrt{T_v}}{P_v}$$

Where,

$Q_s$ = flow rate in $m^3$ /min at 293 K and 101.33 kPa

$T_v$ = temperature at the venturi inlet ( K)

$P_v$ = absolute pressure at the venturi inlet (kPa)

Plot $K_v$ as a function of venturi inlet pressure. For sonic flow $K_v$ will have a relatively constant value. As pressure decreases (vacuum increases) the venturi becomes unchoked and $K_v$ decreases.

The resultant $K_v$ changes are not permissible.

For a minimum of eight points in the critical region calculate the average $K_v$ and the standard deviation.

If the standard deviation exceeds 0.3 % of the average $K_v$, corrective action shall be taken.

4 Calibration of Gas Analysis System :

4.1 Establishment of Calibration Curve

4.1.1 The analyser calibration curve shall be established by at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 80% of the full scale.

4.1.2 The calibration curve is calculated by the least square method. If the degree of the polynomial resulting from the curve is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

4.1.3 The calibration curve shall not differ by more than 2% from the nominal value of calibration gas of each calibration point.

4.1.4 The different characteristic parameters of the analyser, particularly, the scale, the sensitivity, the zero point and the date of carrying out the calibration should be indicated on the calibration curve.

4.1.5 It can be shown to the satisfaction of the testing authority, that alternative technology e.g. computer, electronically controlled range switch etc., can give equivalent accuracy, then these alternatives may be used.

4.2 Verification of Calibration

4.2.1 The calibration procedure shall be carried out as often as necessary and in any case within one month preceding the type approval emission test and once in six months for verifying conformity of production.

4.2.1 The verification should be carried out using standard gases. The same gas flow rates shall be used as when sampling exhaust.

4.2.2 A minimum of two hours shall be allowed for warming up the analysers.

4.2.4 The NDIR analyser shall be tuned, where appropriate, and the flame combustion of the FID analyser optimised.

4.2.5 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser. Using appropriate calibrating gases mentioned in 4.5 of Chapter 3 of this part, the analysers shall be reset.

4.2.6 The zero setting shall be rechecked and the procedure described in Para 4.2.4 and 4.2.5 above repeated, if necessary.

4.2.7 The calibration curves of the analysers should be verified by checking at least at five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 80% of the full scale. It should meet the requirement of para 4.1.3 above.

4.2.8 If it does not meet, the system should be checked, fault, if any, corrected and a new calibration curve should be obtained.

4.3 Pre-test Checks

4.3.1 A minimum of two hours shall be allowed for warming up the infra-red NDIR analyser, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

4.3.2 Each normally used operating range shall be checked prior to each analysis.

4.3.3 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser.

4.3.4 Span gas having a concentration of the constituent that will give a 75-95% full-scale deflection shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure.

4.3.5 The nominal value of the span calibration gas used shall remain within ± 2% of the calibration curve.

4.3.6 If it does not, but it remains within ± 5% of the calibration curve, the system parameters such as gain of the amplifier, tuning of NDIR analysers, optimisation of FID analysers etc. may be adjusted to bring within ± 2%.

4.3.7 If the system does not meet the requirement of 4.3.5 and 4.3.6 above, the system should be checked, fault, if any corrected and a new calibration curve should be obtained.

4.3.8 Zero shall be checked and the procedures described in para 4.3.4 above repeated, if required.

4.4 Post test checks :

After testing zero gas and the span gas shall be used for re-checking. The analysis is considered acceptable if the difference between two measuring results is less than 2%.

4.5 Check for FID Hydrocarbon Response

4.5.1 Detector response optimization :

The FID shall be adjusted as specified by the instrument manufacturer. Propane in air shall be used to optimize the response, on the most common operating range.

4.5.2 Response factor of different hydrocarbons and recommended limits

4.5.2.1 The response factor ($R_f$ ) for a particular hydrocarbon species is the ratio of the FID $C_1$ reading to the gas cylinder concentration, expressed as ppm $C_1$.

4.5.2.2 The concentration of the test gas shall be at a level to give a response of approximately 80% of full scale deflection for the operating range. The concentration shall be known to an accuracy of ± 2% in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder shall be preconditioned for 24 hours at a temperature between 293 & 303 K (20°C and 30°C).

4.5.2.3 Response factors are to be determined when introducing an anlyser into service and thereafter at major service intervals. The test gases to be used and the recommended response factors are :

For methane and purified air $1.00 < R_f < 1.15$,
For propylene and purified air $0.90 < R_f < 1.00$,
For toluene and purified air $0.90 < R_f < 1.00$,

Relative to a response factor ($R_f$) of 1.00 for propane and purified air.

4.5.3 Oxygen interference check and recommended limits

The response factor shall be determined as described in 4.5.2. The test gas to be used and recommended response factor range are :

Propane and nitrogen $0.95 \leq R_f \leq 1.05$,

4.6 Efficiency Test of the NOx Converter :

4.6.1 The efficiency of the converter used for the conversion of $NO_2$ into NO is tested as follows :

4.6.1.1 Using the test set up shown in Fig.15 and the procedure described below, the efficiency of converters can be tested by means of an ozonator.

4.6.2 Calibrate the CLA analyser in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which should amount to about 80 % of the operating range and the $NO_2$ concentration of the gas mixture shall be less than 5 % of the NO concentration). The NOx analyser shall be in the NO mode so that span gas does not pass through the converter. Record the indicated concentration.

4.6.3 Via a T-fitting, oxygen or synthetic air is added continuously to the gas flow until the concentration indicated is about 10 % less than the indicated calibration concentration given in paragraph 4.5.2 above. Record the indicated concentration (c). The ozonator is kept deactivated throughout this process.

4.6.4 The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20 % (minimum 10 %) of the calibration concentration given in 4.6.2. Record the indicated concentration (d).

4.6.5 The NOx analyser is then switched to the NOx mode which means that the gas mixture (consisting of NO, $NO_2$, $O_2$ and $N_2$) now passes through the converter. Record the indicated concentration (a).

4.6.6 The ozonator is now deactivated. The mixture of gases described in paragraph 4.6.3 above passes through the converter into the detector. Record the indicated concentration (b).

4.6.7 With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NOx reading of the analyser shall then be no more than 5 % above the figure in paragraph 4.6.2

4.6.8 The efficiency of the NOx converter is calculated as follows :

$$\text{Efficiency (\%)} = 1 + \frac{(a - b)}{(c - d)} * 100$$

4.7.9 The efficiency of the converter shall not be less than 95%.

4.6.10 The efficiency of the converter shall be tested at least once a week.

4.7 System Leak Test :

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

5. Total System Verification :

5.1 To comply with the requirements of paragraph 4.7 of Chapter 3 of this Part, total accuracy of the CVS, sampling and analytical systems shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated as if during a normal test and then analysing and calculating the pollutant mass according to the formulae in chapter 8 except that the density of propane shall be taken as 1.833 $kg/m^3$ at standard conditions. The following two techniques are known to give sufficient accuracy :-

5.1.1 Metering a constant flow of pure gas (CO or $C_3H_8$ using a critical flow orifice device) is fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow rate (q), which is adjusted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceed by 5 %, the cause of the malfunction shall be located and determined. Then CVS system operated as in an exhaust emission test for about 5 to 10 minutes. The gas collected in the sampling bag is analysed by the usual equipment and the results compared to known quantity of pure gas.

5.2 Metering a limited quantity of pure gas ( CO or $C_3H_8$ ) by means of a gravimetric technique.

5.2.1 The following gravimetric procedure may be used to verify the CVS system. The mass of a small cylinder filled with either carbon monoxide or propane is determined with a precision of ± 0.01 gram. For about 5 to 10 minutes the CVS system is operated as in a normal exhaust emission test, while CO or propane is injected into the system. The quantity of pure gas involved is determined by means of differential weighing. The gas accumulated in the bag is then analysed by means of the equipment normally used for the exhaust gas analysis. The results are then compared to the concentration figures computed previously.

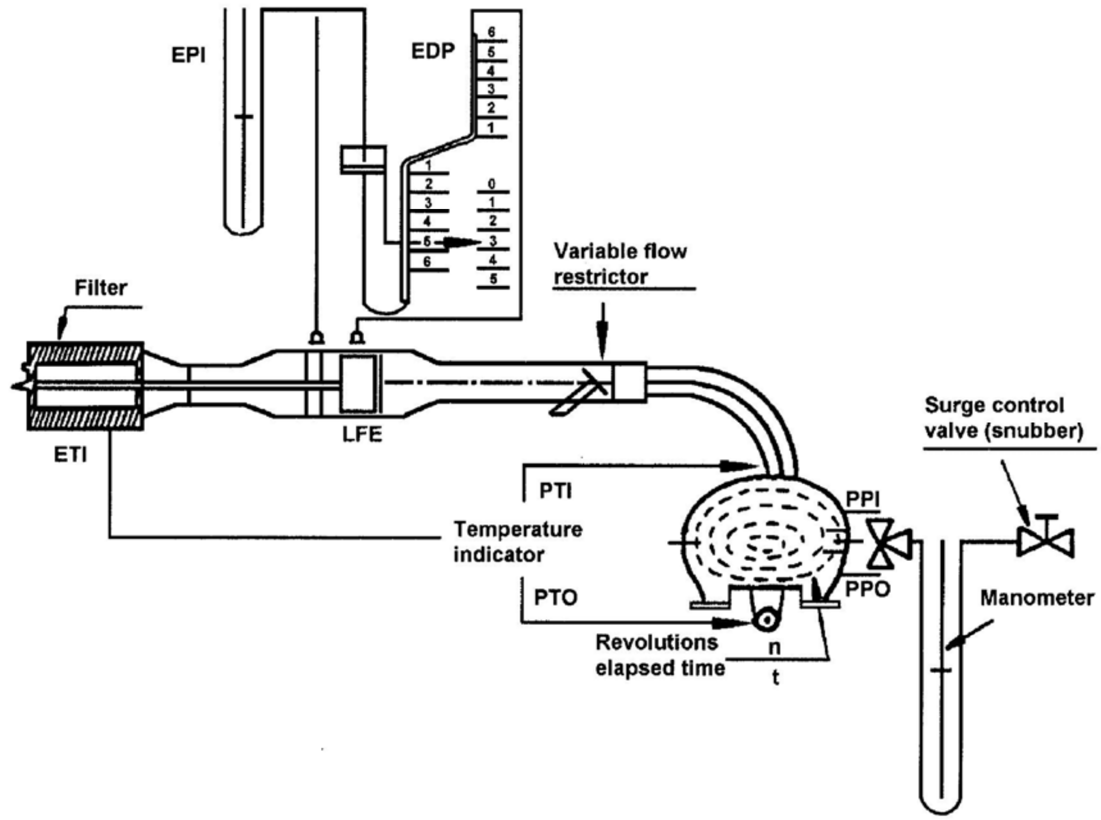



**Figure 13 : <u>Schematic of PDP-CVS Calibration Set-up</u>**
(Pls. Ref. Para. 3.2.3.1 of Chapter 7, Part IX)

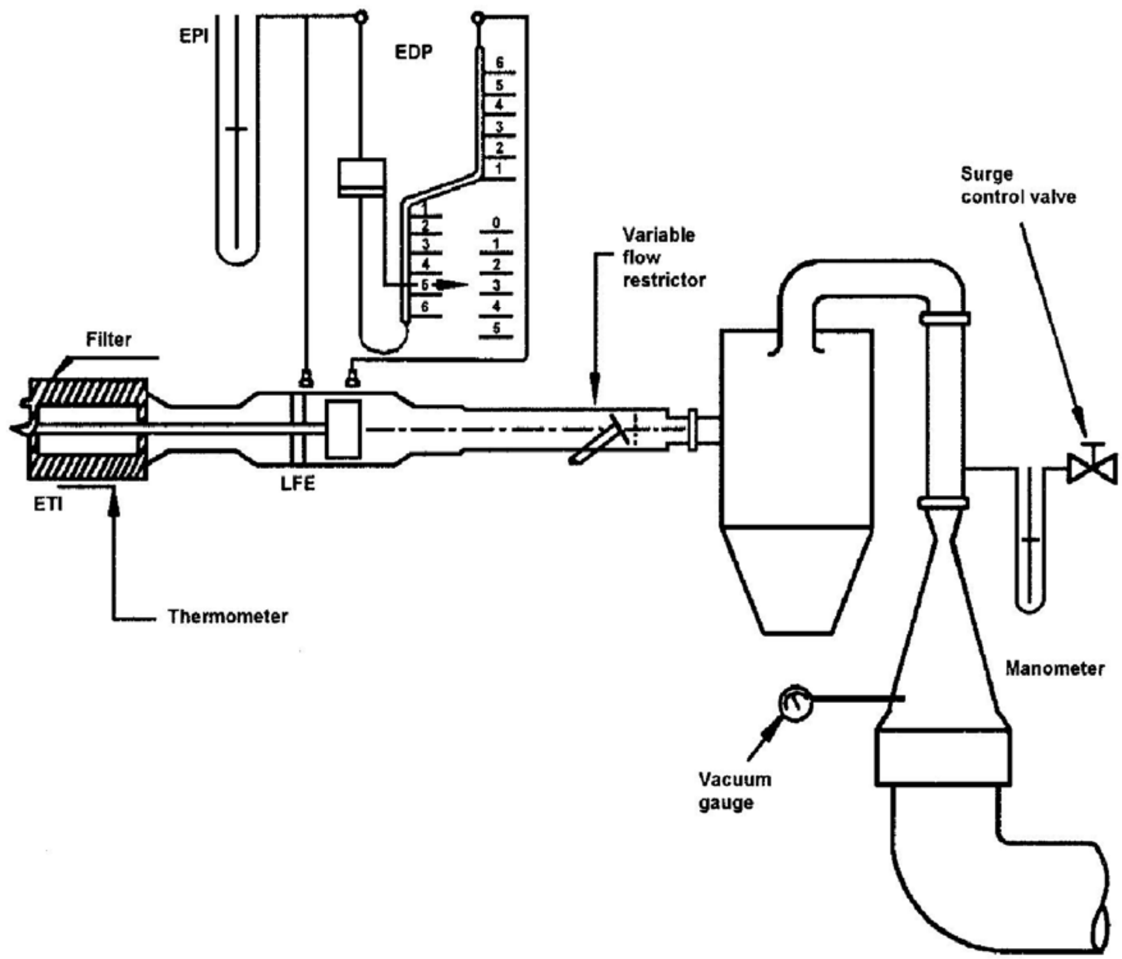



**Figure 14 : Schematic of CFV-CVS Calibration Set-up**
(Pls. Ref. Para. 3.3.4.of Chapter 7, Part IX)

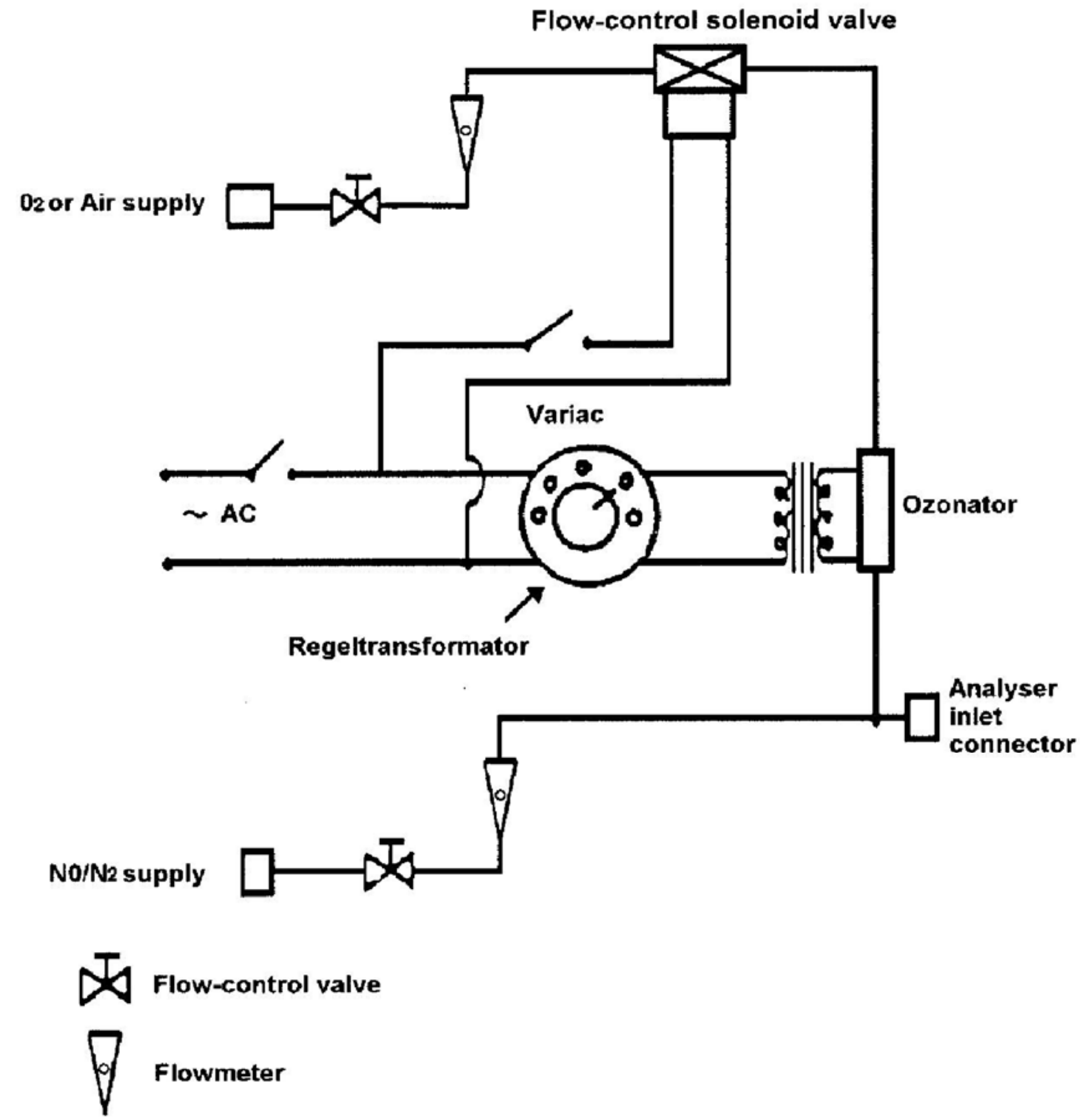



**Figure 15 : <u>Schematic of Set-up for checking the efficiency of NOx converter</u>**
(Pls. Ref. Para.4.6.1.1 of Chapter 7, Part IX)

# CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

1. Scope : This chapter describes the calculation procedures for the mass emission of pollutants and correction for humidity for oxides of nitrogen.

2. The mass emission of pollutants are calculated by means of the following equation :

$$M_i = \frac{V_{mix} * Q_i * k_H * C_i * 10^{-6}}{d} \qquad (1)$$

$M_i$ = Mass emission of the pollutant i in g/km

$V_{mix}$ = Volume of the diluted exhaust gas expressed in $m^3$/test and corrected to standard conditions 293 K and 101.33 kPa

$Q_i$ = Density of the pollutant i in kg/$m^3$ at normal temperature and pressure (293 K and 101.33 kPa)

$k_H$ = Humidity correction factor used for the calculation of the mass emissions of oxides of nitrogen. There is no humidity correction for HC and CO.

$C_i$ = Concentration of the pollutant i in the diluted exhaust gas expressed in ppm and corrected by the amount of the pollutant i contained in the dilution air.

d = distance covered in km

3. VOLUME DETERMINATION :

3.1 Calculation of the volume when a variable dilution device with constant flow control by orifice or venturi is used. Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

3.2 Calculation of volume when a positive displacement pump is used .

The volume of diluted exhaust gas in systems comprising a positive displacement pump is calculated with the following formula :

$$V = V_o * N$$

where,

V = Volume of diluted exhaust gas expressed in $m^3$/test (prior to correction)

$V_o$ = Volume of gas delivered by the positive displacement pump on testing conditions, in $m^3$/rev.

N = Number of revolutions per test.

3.3 Correction of the diluted exhaust gas volume to standard conditions . The diluted exhaust gas volume is corrected by means of the following formula :

$$V_{mix} = V * K_1 * \frac{P_B - P_1}{T_P} \qquad (2)$$

in which :

$$K_1 = \frac{293K\ (3)}{101.33kPa} = 2.8915(K * kPa^{-1})$$

where:

$P_B$ = Barometric pressure in the test room in kPa

$P_1$ = Vacuum at the inlet to the positive displacement pump in kPa relative to the ambient barometric pressure.

$T_P$ = Average temperature of the diluted exhaust gas entering the positive displacement pump during the test (K).

4. Calculation of the Corrected Concentration of Pollutants in the Sampling Bag

$$C_i = C_e - C_d (1 - \frac{1}{DF}) \qquad (4)$$

where:

$C_i$ = Concentration of the pollutant i in the diluted exhaust gas, expressed in ppm and corrected by the amount of i contained in the dilution air.

$C_e$ = Measured concentration of pollutant i in the diluted exhaust gas, expressed in ppm.

$C_d$ = Measured concentration of pollutant i in the air used for dilution, expressed in ppm.

DF = Dilution factor

The dilution factor is calculated as follows :

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}} \qquad (5)$$

where:

$C_{CO_2}$ = Concentration of $CO_2$ in the diluted exhaust gas contained in the sampling bag, expressed in % volume.

$C_{HC}$ = Concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent.

$C_{CO}$ = Concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm.

5. Determination of the NOx Humidity Correction Factor :

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

$$k_H = \frac{1}{1 - 0.0329(H - 10.71)} \qquad (6)$$

in which :

$$H = \frac{6.211 * R_a * P_d}{P_B - P_d * R_a * 10^{-2}}$$

where:
H = Absolute humidity expressed in grams of water per kg of dry air
$R_a$ = Relative humidity of the ambient air expressed in percentage
$P_d$ = Saturation vapour pressure at ambient temperature expressed in kPa
$P_B$ = Atmospheric pressure in the room, expressed in kPa

6. Special provision relating to vehicles equipped with compression-ignition engines

6.1 HC measurement for compression-ignition engines

The average HC concentration used in determining the HC mass emissions from compression-ignition engines is calculated with the aid of the following formula:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} \, .dt}{t_2 - t_1} \qquad (7)$$

where:

$\int_{t1}^{t2} C_{HC} .dt =$ Integral of the recording of the heated FID over the test $(t_2 - t_1)$

$C_e$ = concentration of HC measured in the diluted exhaust in ppm of $C_i$

$C_1$ is substituted directly for $C_{HC}$ in all relevant equations.

6.2 Determination of particulates

Particulate emission Mp (g/km) is calculated by means of the following equation:

$$M_P = \frac{(V_{mix} + V_{ep}) * P_e}{V_{ep} * d}$$

where exhaust gases are vented outside tunnel**.**

$$M = \frac{V_{mix} * P_e}{V_{ep} * d}$$

where exhaust gases are returned to the tunnel.

where:
Vmix : volume of diluted exhaust gases (see 2)under standard conditions .
Vep : volume of exhaust gas flowing through particulate filter under standard conditions.
Pe : particulate mass collected by filters.
d : actual distance corresponding to the operating cycle in km.
Mp : particulate emission in g/km

## *7. Calculation of fuel consumption*

1. The fuel consumptions are calculated by carbon balance method using measured emissions of carbon dioxide ($CO_2$) and other carbon related emissions (hydrocarbons - HC, carbon monoxide - CO)

2. The fuel consumption expressed in km per liter ( in the case of petrol, LPG or diesel) or in km per $m^3$ ( in the case of NG) is calculated by means of following formulae:

i) For vehicles with a positive ignition engine fuelled with petrol:

$FC = 100 * D / \{(0.1154)*[(0.866*HC)+(0.429*CO)+ (0.273*CO_2)]\}$

ii) For vehicles with a positive ignition engine fuelled with LPG

$Fc_{norm} = 100 * (0.538) / \{(0.1212)*[(0.825*HC)+(0.429*CO)+ (0.273*CO_2)]\}$

If the composition of the fuel used for the test differs from the composition that is assumed for the calculation of the normalised consumption, on the manufacturer's request a correction factor cf may be applied, as follows:

$Fc_{norm} = 100 * (0.538) / \{(0.1212) \cdot (cf) \cdot [(0.825 \cdot HC) + (0.429 \cdot CO) + (0.273 \cdot CO_2)]\}$

The correction factor cf, which may be applied, is determined as follows:

$cf = 0.825 + 0.0693 \cdot n_{actual}$

where:
$n_{actual}$ = the actual H/C ratio of the fuel used.

iii) For vehicles with a positive ignition engine fuelled with NG

$Fc_{norm} = 100 * (0.654) / \{(0.1336)*[(0.749*HC)+(0.429*CO)+ (0.273*CO_2)]\}$

iv) For vehicles with a compression ignition engine

$FC = 100 * D / \{(0.1155)*[(0.866*HC)+(0.429*CO)+(0.273*CO_2)]\}$

In these formulae:

FC = the fuel consumption in km per liter (in the case of petrol, LPG or diesel) or in km per $m^3$ (in the case of natural gas).

HC = the measured emission of hydrocarbons in g/km

CO = the measured emission of carbon monoxide in g/km

$CO_2$ = the measured emission of carbon dioxide in g/km

D = the density of the test fuel. In the case of gaseous fuels this is the density at 15° C.

For the purpose of these calculations, the fuel consumption shall be expressed in appropriate units and the following fuel characteristics shall be used,

(a) Density: measured on the test fuel according to ISO 3675 or an equivalent method. For petrol and diesel fuel density measured at 15° C will be used; for LPG and natural gas a reference density will be used, as follows:

0.538 kg/liter for LPG

0.654 kg/$m^3$ for NG*/

*/ Mean value of G20 and G23 reference fuels at 15°C.

(b) Hydrogen -carbon ratio: fixed values will be used which are:

1.85 for petrol

1.86 for diesel fuel

2.525 for LPG

4.00 for NG

## CHAPTER 9 : TYPE II TEST ON SI ENGINES (VERIFYING CARBON MONOXIDE EMISSION AT IDLING)

1 Scope :

This Chapter describes the procedure for the Type II test for verifying carbon monoxide emission at idling of spark ignition engined vehicles, as defined in para 5.2.3 of Chapter 1 of this Part.

2 Test Instrument

2.1 The instrument used for the measurement of CO should meet the requirements given in Para 5.0.

2.2 The instrument should be prepared, used and maintained following the directions given in the instrument manufacturer's operation manual, and it should be serviced at such intervals as to ensure accuracy.

2.3 Within a period of 4 hours before the instrument is first used, and each time the instrument is moved or transferred to a new environment, a "span and zero" calibration should be carried out using calibration gas. The calibration shall be performed well away from the exhaust of motor vehicles whose engines are running.

2.4 If the sample handling system is not integral with the analyser, the effectiveness of the condensate traps and all connections of the gas sampling system should be checked. It should be checked that filters are clean, that filter holders are fitted with their gaskets and that these are in good conditions.

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

2.6 It should be ensured that the sample handling line and probe are free from contaminants and condensates.

3 Vehicle and Fuel :

3.1 This test should be carried out immediately after the sixth operating cycle of the Type I test, or at after the Part II of the modified IDC, as applicable, with the engine at idling speed, the cold start device not being used. Immediately before each measurement of the carbon monoxide content, a TYPE I test operating cycle as described in Chapter 3 of this Part or Chapter 3 of Part IX as applicable shall be carried out.

3.1.1 In case the Type II test is carried out without Type I test, the following steps are to be taken for vehicle preparation :It should be checked that the road vehicle/engine in all its parts, components and systems conform to the declared particulars in the application for type approval.

3.1.2 It should be checked that the road vehicle exhaust system is leakproof and that the manual choke control has been returned to the rest position.

3.1.3 It should be checked that the gas sampling probe can be inserted into the exhaust pipe to a depth of at least 300 mm. If this proves impossible owing to the exhaust pipe configuration, a suitable extension to the exhaust pipe(s), making sure that the connection is leakproof, should be provided.
Alternatively, the sample may be taken from a fixed connection of the sample collecting system for the Type I test.

3.1.4 The vehicle shall have attained normal thermal conditions as defined in 2.3 of chapter 1 of this part immediately prior to the measurement, by running the vehicle on chassis dynamometer with specified number of warming up cycles declared by the manufacturer and six driving cycles.

3.1.5 The vehicle idling speed should be checked and set as per Para 2.2 Chapter 1 with all the accessories switched off.

3.2 Fuel :

The fuel shall be the reference fuel whose specifications are given in the relevant notification If the engine is lubricated by mixture, the oil added to the reference fuel shall comply with the manufacturer's recommendations.

4.0 Measurement :

4.1 Immediately preceding the measurement, the engine is to be accelerated to a moderate speed with no load, maintained for at least 15 seconds, then returned to idle speed.

4.2 While the engine idles, the sampling probe should be inserted into the exhaust pipe to a depth not less than 300 mm, if the probe prescribed in para 5.3.2.1 below is used.

4.3 After the engine speed stabilises the reading should be taken. In the case of 2 & 3 wheeled vehicles fitted with air cooled engines, this stabilised speed may be outside the range specified by the manufacturer.

4.4 The value of CO concentration reading should be recorded.

4.5 In cases where gadgets or devices are incorporated in the exhaust system, for dilution of the exhaust, both CO and $CO_2$ should be measured using an instrument having facility to measure both CO and $CO_2$ . If the total of the measured values of CO and $CO_2$ (T CO and T $CO_2$ ) concentrations exceed 15% for four stroke engines and 10% for two stroke engines, the measured value of CO should be taken as carbon mono-oxide emissions from the vehicle. If it does not, the corrected value (T corrected ) should be taken, as given below :-

$$T\ corrected = \frac{TCO_x * 15}{(TCO + TCO_2)} \quad \text{for 4 stroke engines.}$$

$$= \frac{TCO_x * 10}{(TCO + TCO_2)} \quad \text{for 2 stroke engines.}$$

4.6 Multiple exhaust outlets should be connected to a manifold arrangement terminating in a single outlet. If a suitable adapter is not available, the arithmetic average of the concentrations from the multiple pipes may be used.

4.7 If the measurement is to be repeated, the entire procedure of para 4 shall be repeated.

5 Technical Specifications of Carbon Monoxide Analyser/Equipment for Road Vehicles

5.1 The analyser shall be compatible with all types of motor vehicle operating environments and shall meet under the conditions and performance requirements as per Part I and Part VIII.

5.2 Instruments with facility for carbon-dioxide measurement, also for applications mentioned in 4.5 shall meet all the above performance criteria mentioned for CO, except that the instrument read-out shall have a range of 0 to 20% $CO_2$ or less (clause 5.3.3.1) above.

# PART X : DETAILS OF STANDARDS FOR EMISSION OF VISIBLE AND GASEOUS POLLUTANTS FROM COMPRESSION IGNITION (C.I.), NATURAL GAS (N.G.) AND LIQUEFIED PETROLEUM GAS (LPG) ENGINED VEHICLES AND TEST PROCEDURES EFFECTIVE FROM 1ST APRIL 2000


CHAPTER 1 : OVERALL REQUIREMENTS

CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

CHAPTER 3 : TEST PROCEDURE FOR MEASUREMENT OF GASEOUS POLLUTANTS AND THE PARTICULATE MATTERS FROM DIESEL, NG, LPG ENGINES.

CHAPTER 4 : CALCULATION OF GASEOUS AND PARTICULATE EMISSIONS

CHAPTER 5 : ANALYTICAL SYSTEMS

# CHAPTER 1 : OVERALL REQUIREMENTS

1 Scope :

This Part applies to the emission of gaseous pollutants and particulates from Compression Ignition (C.I.) engined vehicles, Natural Gas (NG) engined vehicles and Liquefied Petroleum Gas (LPG) vehicles. However, the vehicles whose GVW equal to or less than 3500 kg, may be approved on the basis of test procedure of Part IX as opted by the manufacturer.

The main Part X is applicable to automotive application heavy duty engines, however, the sub-part A of Part X for the applications other than automotive is as given below :

Sub-Part A : Details of standards of gaseous and particulate pollutants from diesel engined Agricultural Tractors and Construction Equipment Vehicles (CEV) .

2. Definitions :

2.1 Compression Ignition Engine : Means an internal combustion engine which operates on compression ignition principle (Diesel Engines).

2.2 CNG Engines : CNG Engine means an internal combustion engine which is fuelled with natural gas (NG).

2.3 Gaseous pollutants : Means carbon monoxide, hydro carbons (assuming a ratio of $C_1H_{1.85}$ for CI engines, $C_1H_{3.76}$ for NG engines and $C_1H_{2.61}$ for LPG engines) and oxides of nitrogen (expressed in nitrogen dioxide $NO_2$ equivalent).

2.4 Particulate pollutants : Means any material collected on a specified filter medium after diluting C.I. engine exhaust gas with clean filtered air so that the temperature of the diluted exhaust gas does not exceed 325K (52°C).

2.5 Maximum Rated Speed : Means the maximum speed permitted by governor at full load or if such governor is not present then the speed at which the maximum power is obtained from the engine.

2.6 Minimum Rated Speed : Means either the highest of the following three engine speeds -

45% of maximum net power speed,

1000 rev/min,

minimum speed permitted by the idling control or

such lower speed as the manufacturer may request.

2.7 Intermediate Speed :

2.7.1 Intermediate Speed for automotive engines : Means the speed corresponding to the maximum torque value if such speed is within the range of 60 to 75 % of rated speed; in other cases it means a speed equal to 60 % of rated speed.

2.7.2 Intermediate Speed for Agricultural Tractor Engines : Means the speed corresponding to the maximum torque value if such speed is within the range of 60 to 75 % of rated speed; in other cases if it is below 60% take intermediate speed as 60% of the rated speed; if it is above 75% take the intermediate speed as 75% of the rated speed.

2.8 Percent Load : Means the fraction of the maximum available torque at an engine speed.

2.9 Net Power : Means the power of a C.I. engine as defined in Chapter 6 of Part IV of this rule.

2.10 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90% full and the usual set of tools and spare wheel on board where applicable.

2.11 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer.

2.12 Cold Start Device : Means a device which enriches the airfuel mixture of the engine temporarily and thus to assist engine start up.

2.13 Starting Aid : Means a device which assists the engine start up without enrichment of the fuel mixture, e.g. glow plug, change of injection timing, etc.

2.14 Type Approval of a Vehicle : Means the type approval of a vehicle model with regard to the limitation of the emission of gaseous pollutants from the engine.

2.15 Vehicle Model : Means a category of power driven vehicles which do not differ in such essential respects of the vehicle characteristics which affects the vehicular emission and listed in Chapter 2 of this Part.

2.16 Vehicle for Type Approval Test : Means the fully built vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

2.17 Vehicle for Conformity of Production : Means a vehicle selected at random from a production series of vehicle model which has already been type approved.

2.18 Abbreviations and Units

| | | |
|---|---|---|
| P | kW | net power output non-corrected |
| CO | g/kWh | Carbon Monoxide emission |
| HC | g/kWh | Hydrocarbon emission |
| NOx | g/kWh | emission of oxides of nitrogen |
| PT | g/kWh | particulate emissions |
| conc | ppm | concentration (ppm by volume) |
| $conc_w$ | ppm | concentration (ppm by volume) wet |
| $conc_d$ | ppm | concentration (ppm by volume) dry |
| mass | g/h | pollutant mass flow rate |
| WF | | weighting factor |
| $WF_E$ | | Effective weighting factor |
| $G_{EXH}$ | kg/h | exhaust gas mass flow rate on wet basis |
| $V'_{EXH}$ | $m^3/h$ | exhaust gas volume flow rate on dry basis |
| $V''_{EXH}$ | $m^3/h$ | exhaust gas volume flow rate on wet basis |
| $G_{AIR}$ | kg/h | intake air mass flow rate |
| $V'_{AIR}$ | $m^3/h$ | intake air volume flow rate on dry basis |
| $V''_{AIR}$ | $m^3/h$ | intake air volume flow rate on wet basis |
| $G_{FUEL}$ | kg/h | fuel mass flow rate |
| FID | | flame ionization detector |
| $G_{DIL}$ | kg/h | dilution air mass flow rate |
| $V''_{DIL}$ | $m^3/h$ | dilution air volume flow rate on wet basis |
| $M_{SAM}$ | kg | mass of sample through particulate sampling filters. |
| $V_{SAM}$ | $m^3/h$ | volume of sample through particulate sampling filters on |

wet basis.

| | | |
|---|---|---|
| $G_{EDF}$ | kg/hr | equivalent diluted mass flow rate |
| $V"_{EDF}$ | $m^3/h$ | equivalent diluted volume flow rate on wet basis |
| i | | subscript denoting an individual mode |
| $P_f$ | mg | particulate sample mass |
| $G_{TOT}$ | kg/hr | Diluted exhaust gas mass flow rate. |
| $V"_{TOT}$ | $m^3/h$ | diluted exhaust gas volume flow rate on wet basis |
| q | | dilution ratio |
| r | | ratio of cross sectional area of sample probe and the exhaust pipe |
| $A_P$ | $m^2$ | cross sectional area of the isokinetic sample probe |
| $A_T$ | $m^2$ | cross sectional area of the exhaust pipe |
| HFID | | Heated Flame Ionisation Detector |
| NDUVR | | Non-dispersive ultra violet resonance absorption |
| NDIR | | Non-Dispersive Infra-Red |
| HCLA | | Heated Chemiluminescent Analyser |
| CLA | | Chemiluminescent Analyser |

3 Application for Type Approval :

3.1 The application for type approval of a vehicle model with regard to limitations of the emission of gaseous and particulate pollutants from its engine shall be submitted by the vehicle manufacturer with a description of the engine and vehicle model comprising all the particulars referred to in Chapter 2 of this Part.

3.2 A vehicle representative of the vehicle model to be type approved shall be submitted to the testing agency responsible for conducting tests referred in para 5 below.

4 Type Approval :

If the vehicle submitted for approval pursuant to these rules, meets the requirements of para 5.0 below, approval of vehicle model shall be granted. The approval of the vehicle model pursuant to this part shall be communicated to the Vehicle Manufacturer & Nodal Agency by the testing agency in the form of Certificate of Compliance to CMVR,as envisaged in Rule-126 of CMVR.

5 Specifications and Tests :

5.1 General : The components liable to affect the emission of gaseous and particulate pollutants shall be so designed, constructed and assembled as to enable the engine, in normal use, despite the vibration to which it may be subjected, to comply with the provisions of this Rule.

5.2 Specifications Concerning the Emission of Gaseous and Particulate Pollutants

5.2.1 The emission of gaseous and particulate pollutants by the engine submitted for testing shall be measured by the method described in Chapter 3 of this Part. Other methods may be approved if it is found that they yield equivalent results.

5.2.2 Testing of the engine for gaseous and particulate pollutants shall be done by recommended analytical and particulate sampling system. Other systems or analysers may be approved by the test agency if it is found that they yield equivalent results. For particulate emissions, only the full flow dilution system is recognised as the reference system. For introduction of a new system into this regulation, the determination of equivalency shall be based upon the calculation of repeatability and reproducibility by an inter laboratory test, as defined in ISO 5725.

5.2.2.1 Mass emission standards for the four wheeled diesel transport vehicles (other than passenger cars) manufactured on and after 1st April 2000 (India Stage-I) including two and three-wheelers shall be as per details given in Central Motor Vehicles Rule 1989, Rule No.115, Sub-Rule (10)(B) as amended from time to time. This has come into force for all parts of the country w.e.f. 1st April 2000. For CNG vehicles and LPG vehicles shall be as per details given in Central Motor Vehicles Rule 1989, Rule No.115-B and 115-C as amended from time to time.

5.2.2.2 Mass Emission Standards (Bharat Stage – II) for the four wheeled diesel transport vehicles (other than passenger cars) are as per details given in Central Motor Vehicle Rules 1989. Rule No.115, Sub-Rule (11)(C) as amended from time to time for various regions / cities. For CNG and LPG vehicles shall be as per details given inCentral Motor Vehicle Rule 1989, Rule No.115-B and 115-C as amended from time to time for various regions / cities.

6 Modifications of the vehicle Model :

6.1 Every modification in the essential characteristics of the Vehicle shall be intimated by the Vehicle Manufacturer to the test agency which Type approved the Vehicle model. The test agency may either :

6.1.1 Consider that the Vehicle with the modifications made may still comply with the requirement, or

6.1.2 Require a further test to ensure compliance.

6.2 In case of 6.1.1 above, the testing agency shall extend the type approval covering the modified specification.

In case of 6.1.2 above, the vehicle model shall be subjected to necessary test. In case the vehicle complies with the requirements, the test agency shall extend the type approval.

6.3 Any changes to the procedure of PDI and running in concerning emission shall also be intimated to the test agency by the vehicle manufacturer, whenever such changes are carried out.

7 Conformity of Production :

7.1 Every produced vehicle of the model approved under this rule shall conform, with regard to components affecting the emission of gaseous and particulate pollutants by the engine to the vehicle model type approved. The administrative procedure for carrying out conformity of production is given in Part VI of this Document.

7.2 For verifying the conformity of the engine in a test, the following procedure is adopted:-

7.2.1 For compliance of India Stage I norms :

An engine is taken from the series and subjected to the test described in Chapter 3 of this Part.

7.2.1.1 If the engine taken from the series does not satisfy the requirements of applicable limits, the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The Manufacturer shall specify the size n of the sample subject to n being minimum 2 and maximum 10, including the engine originally taken. The engines other than originally tested shall be subjected to a test. The arithmetical mean ( $\bar{x}$ ) of the results obtained from the sample shall be determined for each pollutant. The production of the series shall then be deemed to conform if the following condition is met :-

$\bar{x} + k.S \leq L$

where :-

$$S^2 = \frac{\sum (xi - \bar{x})^2}{(n-1)}$$

$x_i$ = the individual results obtained with the sample n.

L = the limit value laid down in Paragraph 5.2.2.1 or 5.2.2.2 for each pollutant considered; and

k = a statistical factor depending on 'n' and given in the following table:-

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| k | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

S = Standard Deviation ( rounded off to second decimal point).

7.2.1.2 The testing agency responsible for verifying the conformity of production shall carry out tests on engines which have been run-in partially or completely, according to the manufacturer's specifications.

7.2.2 Conformity of Production procedure for Bharat Stage-II engines (vehicles);

7.2.2.1 Minimum of three engines shall be selected randomly from the series with a sample lot size (Refer Part VI).

7.2.2.2 After selection by the authority, the manufacturer must not undertake any adjustments to the engines (vehicles) selected, except those permitted in Part VI.

7.2.2.3 First engine/vehicle out of three randomly selected engines/vehicles shall be tested for mass emission test as described in the. Part X.

7.2.2.4 If one or more than one of the pollutant exceeds limits prescribed in 5.2.2.2, the test shall be continued on samples 2 & 3

7.2.2.5 If the natural Logarithms of the value measured in the series are $X_1, X_2, X_3$...........$X_J$ and L is the natural logarithm of the limit value for the pollutant, then define :

$d_J = X_J - L$

$$\bar{d}_n = \frac{1}{n}\sum_{J=1}^{n} d_J$$

$$V_n^{\,2} = \frac{1}{n}\sum_{J=1}^{n}(d_J - \bar{d}_n)^2$$

Table I of Chapter 1 of this part shows values of the pass ($A_n$) and fail ($B_n$) decision numbers against current sample number. The test statistic result is the ratio $\bar{d}_n / V_n$ and shall be used to determine whether the series has passed or failed as follows :

For $m_0 \le n < m$

(Minimum sample size $m_0$=3 and maximum sample size m=32)

- pass the series if $\bar{d}_n/V_n \le A_n$
- fail the series if $\bar{d}_n/V_n \ge B_n$

take another measurement if $A_n < \bar{d}_n/V_n < B_n$

Remarks :

The following consecutive formulae are useful for calculating successive values of the test statistics:

$$\bar{d}_n = \left(1 - \frac{1}{n}\right)\bar{d}_{n-1} + \frac{1}{n} d_n$$

$$V_n^{\,2} = \left(1 - \frac{1}{n}\right)V^2_{n-1} + \frac{\left(\bar{d}_n - d_n\right)^2}{n-1}$$

($n = 2,3, \ldots;\ \bar{d}_1 = d_1;\ V_1 = 0$)

**Table I : Applicable for COP Procedure as per Bharat Stage II**

| Sample size (n) | Pass decision threshold ($A_n$) | Fail decision threshold ($B_n$) |
|---|---|---|
| 3 (including first sample) | -0.80381 | 16.64743 |
| 4 | -0.76339 | 7.68627 |
| 5 | -0.72982 | 4.67136 |
| 6 | -0.69962 | 3.25573 |
| 7 | -0.67129 | 2.45431 |
| 8 | -0.64406 | 1.94369 |
| 9 | -0.61750 | 1.59105 |
| 10 | -0.59135 | 1.33295 |
| 11 | -0.56542 | 1.13566 |
| 12 | -0.53960 | 0.97970 |
| 13 | -0.51379 | 0.85307 |
| 14 | -0.48791 | 0.74801 |
| 15 | -0.46191 | 0.65928 |
| 16 | -0.43573 | 0.58321 |
| 17 | -0.40933 | 0.51718 |
| 18 | -0.38266 | 0.45922 |
| 19 | -0.35570 | 0.40788 |
| 20 | -0.32840 | 0.36203 |
| 21 | -0.30072 | 0.32078 |
| 22 | -0.27263 | 0.28343 |
| 23 | -0.24410 | 0.24943 |
| 24 | -0.21509 | 0.21831 |
| 25 | -0.18557 | 0.18970 |
| 26 | -0.15550 | 0.16328 |
| 27 | -0.12483 | 0.13880 |
| 28 | -0.09354 | 0.11603 |
| 29 | -0.06159 | 0.09480 |
| 30 | -0.02892 | 0.07493 |
| 31 | 0.00449 | 0.05629 |
| 32 | 0.03876 | 0.03876 |

# CHAPTER 2 : ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

Information is to be provided as per AIS 007

# CHAPTER 3 : TEST PROCEDURE FOR MEASUREMENT OF GASEOUS & PARTICULATE POLLUTANTS FROM DIESEL ENGINES

1 Scope : This chapter describes the method of determining emissions of gaseous pollutants and the particulates from the engine to be tested, as defined in para 5.2 of Chapter 1 of this Part.

2 Measurement Principle : The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer. The gaseous & particulate emissions from the exhaust of the engine include hydrocarbons, carbon monoxide and oxides of nitrogen and particulates. During a prescribed sequence of warmed up engine operating conditions the amounts of the above pollutants in the exhaust shall be examined continuously. The prescribed sequence of operations consist of a number of speed and power modes which span the typical operating range of diesel engines. During each mode the concentration of each pollutant, exhaust flow and power output shall be determined and the measured values weighted and used to calculate the grammes of each pollutant emitted per kilowatt hour, as described in this part.

3 Equipment :

3.1 Dynamometer and Engine Equipment

The following equipment shall be used for emission tests of engines on engine dynamometers:

3.1.1 An engine dynamometer with adequate characteristics to perform the test cycle described in Paragraph 4.1 below.

3.1.2 Measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and section flow resistance, air inlet temperature, atmospheric pressure, fuel temperature and humidity. The accuracy of these instruments shall satisfy the method of measuring the power of the internal combustion engines of road vehicles, given in Chapter 6 of Part IV of this Rule. Other instruments shall have an accuracy which satisfies the following requirements.

3.1.2.1 Temperatures :
Exhaust gas temperature shall be measured with an accuracy of ± 5K (5°C), other temperatures with an accuracy of ± 1.5K (1.5°C).

3.1.2.2 Absolute humidity :
The absolute humidity (H) shall be determined to an accuracy of ± 5%.

3.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests;

Where there is a risk of an appreciable effect on the engine power, or when the manufacturer request so, the complete exhaust system shall be fitted as provided for the intended application, non insulated and uncooled, extending at least 0.5m past the point where the raw exhaust sample probes are located.

3.1.4 In other cases, an equivalent system may be installed provided the pressure measurement at the exit of the engine exhaust system does not differ by more than 1000 Pa from that specified by the manufacturer.
The exit from the engine exhaust system is defined as a point 150 mm down stream from the termination of the part of the exhaust system mounted on the engine.

Where there is a risk of an appreciable effect on the engine power, or where the manufacturer request so, the complete intake system shall be fitted as provided for the intended application.

3.1.5 In other cases, an equivalent system may be used and a check should be made to ascertain that the intake pressure does not differ by more than 100 Pa from the limit prescribed by the manufacturer for a clean air filter.

When an engine is tested for exhaust emissions, the complete engine shall be tested with all standard accessories which might reasonably be expected to influence emissions to the atmosphere installed and functioning as listed in Chapter 6 of Part IV of this regulation.

3.2 Exhaust Gas Sampling System :
Chapter 4 of this part describes the analytical system for gaseous and particulate pollutants in current use. Other systems or analysers which have proved to give equivalent results, may be used.

3.2.1 The exhaust gas sampling system shall be designed to enable the measurement of the true mass emissions of the exhaust.

3.2.2 The probe shall extract a true sample of the exhaust gases.

3.2.3 The system should be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the diluted exhaust gas. Should any component (heat exchanger, blower, etc.) change the concentration of any pollutant gas in the diluted gas, then the sampling for that pollutant shall be carried out before that component, if the problem cannot be corrected.

3.2.4 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

3.3 Analytical Equipment :

3.3.1 Pollutant gases shall be analysed with the following instruments

3.3.1.1 Carbon monoxide (CO) and carbon dioxide ($CO_2$) analysis.

The carbon monoxide and carbon dioxide analysers shall be of the NON-DISPERSIVE INFRA RED (NDIR) absorption type.

3.3.1.2 Hydrocarbon (HC) analysis

The Hydrocarbon analyser shall be of the Heated Flame Ionisation type (HFID) with the whole FID system maintained at a temperature between 453 K to 473 K (180°C to 200°C). It shall be calibrated with propane gas of equivalent to carbon atoms (C1 ).

3.3.1.3 Oxides of nitrogen (NOx) Analysis.

The nitrogen oxide analyser shall be of the heated Chemiluminescent (HCLA) type with an NOx-NO converter or equivalent .

3.3.1.4 Carbon dioxide (CO2) Analysis for checking dilution ratio.

The carbon dioxide analyser shall be of the non-dispersive infra red (NDIR) absorption type.

3.3.1.5 Accuracy

The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants. Measurement errors shall not exceed ±2.5 % of the full scale deflection or better disregarding the true value of the calibration gases. For concentrations of less than 100 ppm the measurement error shall not exceed ±3 ppm. The ambient air sample shall be measured on the same analyser and range as the corresponding diluted exhaust sample.

3.3.1.6 Gas Drying :

Optional gas drying devices shall have no effect on the pollutant content of the gas stream.

3.3.1.7 Sampling :

A heated sample line for continuous HC analysis with the flame ionisation detector (HFID), including recorder (R ) shall be used, through out the test, the temperature of complete sampling system shall be maintained at the temperature of 453 to 473 K (180°C to 200°C). The heated sampling line shall be fitted with a heated filter (F) (99% efficient with particles ≥ 0.3 μm) to extract any solid particles from the continuous flow of gas required for analysis. A second heated line for NOx analysis is to be used when appropriate. The temperature of this line shall be controlled at 368 to 473 K (95°C to 200°C). The sample line for CO and CO2 analysis may be heated or unheated.

3.3.1.8 Determination of the particulates :

The determination of the particulates requires a dilution system capable of maintaining the temperature of the diluted exhaust gas at or below 325 K (52°C) and preventing water condensation, a particulate sampling system, specified particulate sampling filters and a micro gram balance which shall be placed in an air conditioned weighing chamber. Dilution may be accomplished by a full flow dilution or a partial flow dilution system. Chapter 4 of this part describes the analytical system in current use. Other systems which have proved to give equivalent results may be used.

3.4 Gases

3.4.1 The following pure gases shall be available when necessary, for calibration and operation :

Purified nitrogen (purity ≤ 1ppm C, ≤ 1ppm CO, ≤ 400ppm $CO_2$, ≤ 0.1ppm NO);

Purified synthetic air (purity < 1ppm C, < 1ppm CO, < 400ppm $CO_2$,< 0.1ppm NO); Oxygen content between 18 and 21 percent vol.;

Purified oxygen (purity > 99.5 percent Vol. $0_2$) ;

Hydrogen mixture (40+/-2% hydrogen, balance helium )
(Purity ≤ 1ppm C, ≤ 400 ppm $CO_2$);

3.4.2 Calibration and span gases :

Gases having the following chemical compositions shall be available $C_3 H_8$ and purified synthetic air (see paragraph 3.4.1 above); CO and purified nitrogen; $CO_2$ and purified nitrogen; NO and purified nitrogen ( the amount of $NO_2$ contained in this calibration gas must not exceed 5 percent of the NO content)

The true concentration of a calibration and span gas shall be within ± 2% of the nominal value. All concentrations of calibration gases shall be given on volume basis (volume % or volume ppm)

The gases used for calibration and span must be obtained by means of a gas divider, diluting with purified nitrogen or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration and span gases may be determined within ± 2%.

4 Test Procedure :

4.1 Test Cycle :

The following 13-mode cycle in case of automotive engines for example, shall be followed in dynamometer operation on the test engine:-

| Mode No. | Engine Speed | % Load |
|---|---|---|
| 1 | Idle | ---- |
| 2 | Intermediate | 10 |
| 3 | ,,,, | 25 |
| 4 | ,,,, | 50 |
| 5 | ,,,, | 75 |
| 6 | ,,,, | 100 |
| 7 | Idle | ---- |
| 8 | Rated | 100 |
| 9 | ,,,, | 75 |
| 10 | ,,,, | 50 |
| 11 | ,,,, | 25 |
| 12 | ,,,, | 10 |
| 13 | Idle | ----- |

4.2 Measurement of Exhaust Gas Flow :

For calculation of the emission it is necessary to know the exhaust flow, as given in Para 4.3.1.1. below. For determination of exhaust flow either of the following methods may be used. The volumetric flow rates $V'_{EXH}$ and $V''_{EXH}$ are defined at T = 273 and P = 101.315 kPa

4.2.1 Direct measurement of the exhaust flow by flow nozzle or equivalent metering system.

4.2.2 Measurement of the air flow and the fuel flow by suitable metering systems and calculation of the exhaust flow by the following equations :

4.2.2.1 In the case of C.I. Engines

$$G_{EXH} = G_{AIR} + G_{FUEL}$$

or

$V'_{EXH} = V_{AIR} - 0.75\ G_{FUEL}$ (dry exhaust volume)

Or

$V''_{EXH} = V_{AIR} + 0.77\ G_{FUEL}$ (wet exhaust volume)

4.2.2.2 In the case of NG Engines

$$G_{EXH} = G_{AIR} + G_{FUEL}$$

or

$V'_{EXH} = V'_{AIR} - 1.35\ G_{FUEL}$ (dry exhaust volume)

or

$V''_{EXH} = V''_{AIR} + 1.36\ G_{FUEL}$ (wet exhaust volume)

The accuracy of exhaust flow determination shall be ± 2.5% or better.

4.2.2.3 In case of LPG fueled engines :

$$G_{EXH} = G_{AIR} + G_{FUEL}$$

or

$V'_{EXH} = V'_{AIR} - G_{FUEL}$ (dry exhaust volume)

or

$V''_{EXH} = V''_{AIR} + G_{FUEL}$ (wet exhaust volume)

4.2.3 The accuracy of exhaust flow determination shall be ±2.5% or better.

4.2.4 The concentration of carbon monoxide and nitric oxide are measured in the dry exhaust. For this reason the CO and NOx emissions shall be calculated using the dry exhaust gas volume $V'_{EXH.}$ If the exhaust mass flow rate ($G_{EXH}$) is used in the calculation the CO and NOx concentrations shall be related to the wet exhaust. Calculation of the HC emission shall include $G_{EXH}$ and $V''_{EXH}$ according to the measuring method used.

4.3 Operating and Calibrating Procedure for Analysers and Sampling System :

The operating procedure for analysers shall follow the startup and operating instructions of the instrument manufacturer. The following minimum requirements shall be included.

4.3.1 Calibration Procedure

4.3.1.1 The calibration procedure shall be carried out within one month preceeding the emission test. The instrument assembly shall be calibrated and calibration curves checked against standard gases. The same gas flow rates shall be used as when sampling exhaust.

4.3.1.1.1 A minimum of two hours shall be allowed for warming up the analysers.

4.3.1.1.2 A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyzer pump shall be switched on. After an initial stabilization period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.3.1.1.3 The NDIR analyzer shall be tuned, where appropriate, and the flame combustion of the HFID analyzer optimized.

4.3.1.1.4 Using purified dry air (or nitrogen), the CO ($CO_2$ if used) and $NO_x$ analysers shall be set at zero; dry air must be used for the HC analyzer. Using appropriate calibration gases, the analysers shall be reset.

4.1.1.1.5 The zero setting shall be rechecked and the procedure described in Paragraph 4.1.4 above repeated, if necessary.

4.3.1.1.6 Gas meters or flow instrumentation used to determine flow through the particulate filters and to calculate the dilution ratio are calibrated with a standard air flow measurement device upstream of the instrument. This device must conform to the regulations of the National Bureau of Standards of the respective country. The points on the calibration curves relative to the calibration device measurements must be within +/- 1.0% of the maximum operating range +/-2% of the point, whichever is smaller.

4.3.1.1.7 When using a partial-flow-dilution system with isokinetic probe, the dilution ratio is checked with the engine running using either the $CO_2$ or $NO_x$ concentrations in the raw and diluted exhaust.

4.3.1.1.8 When using a full-flow-dilution system, the total flow is verified by means of a propane check. The gravimeteric mass of propane injected into the system is subtracted from the mass measured with the full-flow-dilution system and then divided by the gravimetric mass. Any discrepancy greater than +/- 3% must be corrected.

4.3.2 Establishment of Calibration Curve

4.3.2.1 Each normally used operating range shall be calibrated in accordance with the following procedure :

4.3.2.2 The analyser calibration curve shall be established by at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90% of the full scale.

4.3.2.3 The calibration curve is calculated by the least square method. If the degree of the polynomial resulting from the curve is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

4.3.2.4 The calibration curve shall not differ by more than ±2% from the nominal value of calibration gas.

4.3.2.5 Trace of the Calibration curves.
From the trace of the calibration curve and the calibration points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyzer must be indicated, particulary:
the scale
the sensitivity
the zero point
the date of carrying out the calibration

4.3.2.6 It can be shown to the satisfaction of the technical service that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

4.3.3 Verification of Calibration

4.3.3.1 Each normally used operating range shall be checked prior to each analysis in accordance with the following:

4.3.3.2 The calibration is checked by using a zero gas and a span gas whose nominal value is near to the supposed value to be analysed.

4.3.3.3 If, for the two points considered, the value found does not differ by more than +/-5% of the full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with Paragraph 4.3.2 of this appendix.

4.3.3.4 After testing, zero gas and the same span gas will be used for rechecking. The analysis will be considered acceptable if the difference between the two measuring results is less than 2%.

4.3.4 Efficiency test of the $NO_x$ Converter

4.3.4.1 The efficiency of the converter used for the conversion of $NO_2$ into NO is tested as follows :

4.3.4.2 Using the test set up as shown at the end of this annex and the procedure below, the efficiency of conveters can be tested by means of an ozonator.

4.3.4.3 Calibrate the CLA in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80% of the operating range and the $NO_2$ concentration of the gas mixture to less than5% of the NO concentration). The $NO_x$ analyzer must be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

4.3.4.4 Via a T fitting, oxygen is added continuously to the span gas flow until the concentration indicated is about 10% less thanthe indicated calibration concentration given in Paragraph 4.3.4.3. Record the indicated concentration (c). The ozonator is kept deactivated throughout the process.

4.3.4.5 The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20% (minimum 10%) of the calibration concentration given in Paragraph 4.3.4.3. Record the indicated concentration (d).

4.3.4.6 The NO analyzer is then switched to the $NO_x$ mode which means that the gas mixture (consisting of NO, $NO_2$, $O_2$ and $N_2$) now passes through the converter. Record the indicated concentration (a).

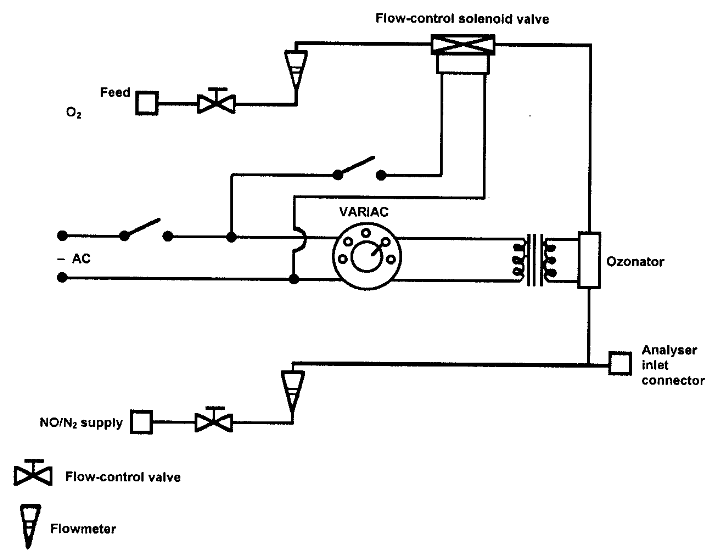
4.3.4.7 The ozonator is now deactivated. The mixture of gases described in Paragraph 4.4.4 passes through the converter into the detector. Record the indicated concentration (b).

4.3.4.8 With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO reading of the analyzer must then be no more than 5% above the figure given in Paragraph 4.3.4.3.

4.3.4.9 The efficiency of the $NO_x$ converter is calculated as follows :

$$Efficiency(\%) = 1 + \frac{a-b}{c-d}.100$$

4.3.4.10 The efficiency of the converter must be tested prior to each calibration of the $NO_x$ analyzer.




**<u>Figure 1 : Schematic of Nox Converter Efficiency Device</u>**

4.3.4.11 The efficiency of the converter must not be less than 95%.

NOTE : If the analyzer operating range is above the highest range that the $NO_x$ converter can operate to give a reduction from 80 to 20%, then the highest range the $NO_x$ converter will operate on will be used.

4.3.5 Pre-test Checks

4.3.5.1 A minimum of two hours shall be allowed for warming up the infra-red NDIR analyser, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

4.3.5.2 Each normally used operating range shall be checked prior to each analysis.

4.3.5.3 Using purified dry air ( or nitrogen ), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser.

4.3.5.4 Span gas having a concentration of the constituent that will give a 75-95% full-scale deflection or span gas where nominal value is near to the supposed value to be analysed shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure.

4.3.5.5 The nominal value of the span calibration gas used shall remain with ± 2% of the calibration curve.

4.3.5.6 If it does not, but it remains within ±5% of the calibration curve, the system parameters such as gain of the amplifier, tuning of NDIR analysers, optimisation of FID analysers etc. may be adjusted to bring within ±2%.

4.3.5.7 If the system does not meet the requirement of 4.3.5.5 and 4.3.5.6 above, the system should be checked, fault, if any corrected and a new calibration curve should be obtained.

4.3.5.8 Zero shall be checked and the procedures described in para 4.3.3.3 and 4.3.3.4 above repeated, if required.

4.4 System Leak Test :

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters and pressure gauges should read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.5 Checking for FID Hydrocarbon Response :

Detector response optimisation

The FID must be adjusted, as specified by the instrument manufacturer. Propane in air should be used, to optimise the response, on the most common operating range.

Calibration of the HC analyser.

The anlyser should be calibrated using propane ($C_3H_8$) in air and purified synthetic air. See paragraph 3.4.2 of this Appendix (calibration-and span gases).

Establish a calibration curve as described in Paragraphs 4.3.2 to 4.3.3 of this Appendix.

Response Factors of Different Hydrocarbons and Recommended Limits.

The response factor (Rf), for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas cylinder concentration, expressed as ppm C1.

The concentration of the test gas must be at a level to give a response of approximately 80% of full scale deflection, for the operating range. The concentration must be known, to an accuracy of ± 2% in reference to a gravimetric standard expressed in volume. In addition the gas cylinder must be pre-conditioned for 24 hours at a temperature between 20°C and 30°C.

Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The test gases to be used and the recommended response factors are, relative to a response factor (Rf) of 1.00 for propane and purified air:

| | |
|---|---|
| Methane and purified air | $1.00 \leq Rf \leq 1.15$ |
| Propylene and purified air | $0.90 \leq Rf \leq 1.00$ |
| Toluene and purified air | $0.90 \leq Rf \leq 1.00$ |

Oxygen Interference Check and Recommended Limits.

The response factor should be determined as described in above paragraph The test gas to be used and recommended response factor range are:

Propane and nitrogen $0.95 \leq Rf \leq 1.05$

4.6 Gas meters or flow instruments used to determine flow through the particulate filters and to calculate the dilution ratio shall be calibrated with a standard air flow measurement device upstream of the instrument. This device must conform to the regulations of the National Bureau of Standards of the respective country. The points on the calibration curve relative to the calibration device measurements must be within ± 1.0% of the maximum operating range or ± 2.0% of the point, whichever is smaller.

4.7 When using a partial flow dilution system with isokinetic probe, the dilution ratio is checked with the engine running using either the CO2 or Knox concentration in the raw and diluted exhaust.

4.8 When using a full flow dilution system, the total flow is verified by means of a propane check. The gravimetric mass of propane injected into the system is subtracted from the mass measured with the full flow dilution system and then divided by the gravimetric mass. Any discrepancy greater than ± 3% must be corrected.

4.9 Fuel :

4.9.1 The fuel shall be the reference fuel as specified in the applicable gazette notification.

4.10 Engine test conditions :

4.10.1 The absolute temperature (T) of the engine air at the inlet to the engine expressed in Kelvin, and the dry atmospheric pressure (PS), expressed in kilopascals, shall be measured and the parameter F shall be determined according to the following provisions :

4.10.2 Naturally Aspirated and Mechanically Supercharged Engines:

4.10.2.1 C.I. Engines

$$F=(99/PS) * (T/298) ^ {0.7}$$

4.10.2.2 Spark-ignition engines

$$F=(99/PS)^{1.2} * (T/298) ^ {0.6}$$

4.10.3 Turbo-Charged Engines With or Without Cooling of Inlet Air:

4.10.3.1 C.I. Engines

$$F=(99/PS)^{0.7} * (T/298) ^ {1.5}$$

4.10.3.2 Spark-ignition Engines

$$F=(99/PS)^{1.2} * (T/298) ^ {0.6}$$

4.10.4 For a test to be recognised as valid, the parameter F shall be between 0.98 and 1.02 for CI engines as per the notification issued by MOST from 1/4/96.

For a test to be recognised as valid, the parameter F shall be between 0.93 and 1.07 for SI engines as per IS-14599 - 1999.

4.11 Test Run

4.11.1 At least two hours before the test each filter for measurement of the emission of particulate pollutants shall be placed in a closed but unsealed petri dish and placed in the weighing chamber for stabilisation. At the end of the stabilisation period each filter is weighed and the tare weight recorded. The filter is then stored in the petri dish which must remain in the weighing chamber, or a sealed filter holder until needed for testing. If the filter is not used within one hour of its removal from the weighing chamber, it must be re-weighed before use.

4.11.2 During each mode of the test cycle, the specified speed shall be held to within ± 50 rpm and the specified torque shall be held to within ± 2% of the maximum torque at the test speed. The fuel temperature at the injection pump inlet shall be 311 ± 5K (33°C - 43°C). The governor and fuel system shall be adjusted as established by the manufacturer's sales and service literature. The following steps shall be taken for each test :-

4.11.3 In the case of NG engines, the fuel temperature and the pressure at pressure regulator final stage shall be within the range specified by the manufacturer; the speed limiting device and fuel system must be adjusted as established by the manufacturer's sales and service literature. The following steps are taken for each test :

4.11.4 Instrumentation and sample probes shall be installed as required. When using a full-flow-dilution system for exhaust gas dilution, the tailpipe is connected to the system, and the settings of inlet restriction and exhaust gas back pressure re-adjusted accordingly. The total flow must be set so as to keep the temperature of the diluted exhaust at or below 325 K (52° C) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/or temperatures;

4.11.5 The cooling system and the full flow dilution system, or partial flow dilution system, respectively, are started;

4.11.6 The engine shall be started and warmed up until all temperatures and pressures have reached equilibrium;

4.11.7 The torque curve at full load shall be determined by experimentation to calculate the torque values for the specified test modes and to check the conformity of the tested engine performance with manufacturer's specifications. The corrected performance shall not differ by more than ± 2% for maximum net power and ± 4% for maximum net torque from the values declared by the manufacturer. The maximum permissible power absorbed by engine-driven equipment, declared by the manufacturer to be applicable to the engine type, is taken into account. The dynamometer setting for each engine speed and load are calculated using the formula:

$$S = P_{\min} x \frac{L}{100} + P_{aux}$$

Where

S = dynamometer setting

$P_{\min}$ = minimum net engine power as indicated in Line (e) in the table of AIS 007

L = per cent load as indicated in Paragraph 4.1 of this Annex.

$P_{aux}$ = total permissible power absorbed by engine driven equipment minus the power of any such equipment actually driven by the engine: AIS 007

4.11.8 The emission analysers shall be set at zero and spanned. The particulate sampling system is started. When using a partial-flow-dilution-system, the dilution ratio must be set so as to keep the temperature of the diluted exhaust at or below 325 K (52°C) immediately before the particulate filters at the mode with the maximum heat flow as determined from exhaust flow and/or temperature;

The range of the exhaust gas velocity and the pressure oscillations is checked and adjusted according to the requirements of Annex 4, Appendix 4, if applicable.

4.11.9 The test sequence as given in para 4.1 above shall be started. The engine shall be operated for six minutes in each mode, completing engine speed and load changes in the first minute. The responses of the analysers shall be recorded on a strip chart recorder for the full six minutes with exhaust gas flowing through the analysers at least during the last three minutes for particulate sampling, one pair of filters (primary and back up filters, refer chapter … of this part) is used for the complete test procedure. With a partial flow dilution system, the product of dilution ratio and exhaust gas flow for each mode shall be within ± 7% of the average of all modes. With the full flow dilution system, the total mass flow rate shall be within ± 7% of the average of all modes. The sample mass drawn through the particulate filters ($M_{SAM}$) must be adjusted at each mode to take account of total modal weighing factor and the exhaust or fuel mass flow rate (Refer Chapter 4). A sampling time of at least 20 seconds is used. Sampling shall be conducted as late as possible within each mode. The engine speed and load, intake air temperature and vacuum exhaust back pressure, fuel flow and air or exhaust flow shall be recorded during the last five minutes of each mode, with the speed and load requirements being met during the time of particulate sampling, but in any case during the last minute of each mode.

4.11.10 Any additional data required for calculation shall be read and recorded. (See para 4.12 below)

4.11.11 The zero and span settings of the emission analysers shall be checked and reset, as required, at least at the end of the test. The test shall be considered satisfactory if the adjustment necessary after the test does not exceed the accuracy of the analysers prescribed in Paragraph 3.3.1.5 above.

4.12 Chart Reading and Data Evaluation

4.12.1 At the completion of testing, the total sample mass through the filters ($M_{SAM}$) shall be recorded. The filters shall be returned to the weighing chamber and conditioned for at least two hours, but not more than 36 hours, and then shall be weighed. The gross weight of the filters shall be recorded.The particulate mass (Pf) is the sum of the particulate mass collected on the primary and back up filters.

4.12.2 For the evaluation of the gaseous emissions chart recording, the last 60 seconds of each mode shall be located, and the average chart reading for HC, CO and NOx during each mode shall be determined from the average chart readings and the corresponding calibration data. However, a different type of registration can be used if it ensures as equivalent data acquisition.

# CHAPTER 4 : CALCULATION OF GASEOUS AND PARTICULATE EMISSIONS

1 Calculation :

1.1 The Final reported test results of the gaseous emissions are derived through the following steps

1.1.1 The exhaust gas mass flow rate $G_{EXH}$ or V' and $V''_{EXH}$ shall determined (see paragraph 4.2 of chapter 3) for each mode.

1.1.2 When applying $G_{EXH}$ the measured concentrations are converted to a wet basis according to paragraph 1.1.2.1 below, if not already measured on wet basis.

1.1.2.1 Exhaust gas concentration measured on a dry basis are converted to a wet basis, which represents the condition in the exhaust , according to following relationship:

1.1.2.1.1 In case of C.I. engines:

$$ppm(\text{wet basis}) = ppm(\text{dry basis}) * (1-1.85\ G_{FUEL}/G_{AIR})$$

where :

$G_{FUEL}$ is the fuel flow (kg/h)

$G_{AIR}$ is the air flow (kg/h) …..(dry air)

1.1.2.1.2 In the case of NG Engines:

$$ppm(\text{wet basis}) = ppm(\text{dry basis}) * (1-3.15G_{FUEL}/G_{AIR})$$

where:

$G_{FUEL}$ is the fuel flow (kg/h)

$G_{AIR}$ is the air flow (kg/h)

1.1.2.1.3 In the case of LPG fueled Engines:

$$ppm(\text{wet basis}) = ppm(\text{dry basis}) * (1-2.40G_{FUEL}/G_{AIR})$$

where:

$G_{FUEL}$ is the fuel flow (kg/h)

$G_{AIR}$ is the air flow (kg/h) ….. (dry air)

1.1.2.2 The NOx concentration shall be corrected for humidity according to paragraph below for C.I. engines, CNG engines and LPG engines

NOx Correction factor :

The value of the oxides of nitrogen shall be multiplied by the following humidity correction factor.

$$\frac{1}{1 + A(7H - 75) + B * 1.8(T - 302)}$$

where:

$$A = 0.044 \frac{G_{FUEL}}{G_{AIR}} - 0.0038$$

$$B = -0.116 \frac{G_{FUEL}}{G_{AIR}} + 0.0053$$

T= temperature of the air in K

$\frac{G_{FUEL}}{G_{AIR}}$ = Fuel air ratio (dry air basis)

H = humidity of the inlet air in grams of water per kilogram of dry air in which :

$H = (6.211 * R_a * P_d) / (P_a - (P_d * R_a * 10^{-2}))$

Where

$R_a$ = Relative humidity of the ambient air expressed in %

$P_d$=Saturation vapour pressure at ambient temperature expressed in kPa

$P_a$ = Atmospheric pressure expressed in kPa

1.1.2.3 The pollutant mass flow (gm/hr) for each mode shall be calculated as follows (Only C.I. engines )

(1) $NO_x$ mass = 0.001587 * $NO_x$conc * $G_{EXH}$
(2) COmass = 0.000966 * COconc * $G_{EXH}$
(3) HCmass = 0.000478 * HCconc * $G_{EXH}$

or:

(1) $NO_x$ mass = 0.00205 * $NO_x$ conc* $V'_{EXH}$
(2) $NO_x$ mass = 0.00205 * $NO_x$ conc * $V''_{EXH}$
(3) CO mass = 0.00125 * CO conc * $V'_{EXH}$
(4) HCmass = 0.000618 * HCconc * $V''_{EXH}$

1.1.2.4 The pollutant mass flow (gm/hr) for NG engine and for mode,assuming the density of exhaust gas equal to 1.249 kg/$m^3$, shall be calculated as follows:

(1) $NO_x$ mass = 0.001641 * $NO_x$ $conc_W$ * $G_{EXH}$
(2) CO mass = 0.001001 * CO $conc_W$ * $G_{EXH}$
(3) HC mass = 0.000563 * HC $conc_W$ * $G_{EXH}$

or

(1) $NO_x$ mass = 0.00205 * $NO_x$ $conc_D$* $V'_{EXH}$
(2) COx mass = 0.00125 * CO $conc_D$ * $V'_{EXH}$
(3) HC mass = 0.000703 * $Hcconc_D$ * $V'_{EXH}$

For HC ($CH_{3.76}$), the concentration shall be expressed in carbon equivalent (i.e. equivalent propane * 3).

1.1.2.5 The pollutant mass flow (gm/hr) for LPG- fuelled engine and for mode, shall be calculated as follows:

(1) $NO_x$ mass = 0.001587 * $NO_x$ conc * $G_{EXH}$
(2) CO mass = 0.000966 * CO conc * $G_{EXH}$
(3) HC mass = 0.000505 * HC conc * $G_{EXH}$

Or:

(1) $NO_x$ mass = 0.00205 * $NO_x$ conc* $V'_{EXH}$
(2) $NO_x$ mass = 0.00205 * $NO_x$ conc * $V''_{EXH}$
(3) CO mass = 0.00125 * CO conc * $V'_{EXH}$
(4) HC mass = 0.000653 * HCconc * $V''_{EXH}$

1.1.2.6 The emission shall be calculated in the following way :

$$\overline{NO_x} = \frac{\sum NOx_{mass.i} * WFi}{\sum (P_i - P_{aux,i}) * WFi}$$

$$\overline{CO} = \frac{\sum CO_{mass.i} * WFi}{\sum (P_i - P_{aux,i}) * WF_i}$$

$$\overline{HC} = \frac{\sum HC_{mass.i} * WFi}{\sum (P_i - P_{aux,i}) * WF_i}$$

where:
Pi are measured values.

1.1.2.7 The weighting factors used in the above calculation are according to the following table:

1.1.2.7.1 For Automotive Engines (13 – Mode Cycle)

| Mode Number | Weighting Factor(WF) |
|---|---|
| 1 | 0.25/3 |
| 2 | 0.08 |
| 3 | 0.08 |
| 4 | 0.08 |
| 5 | 0.08 |
| 6 | 0.25 |
| 7 | 0.25/3 |
| 8 | 0.10 |
| 9 | 0.02 |
| 10 | 0.02 |
| 11 | 0.02 |
| 12 | 0.02 |
| 13 | 0.25/3 |

1.1.2.7.2 For Agricultural Tractor Engines (8 – Mode Cycle) and construction equipment vehicles (variable speed).

| Mode Number | Engine Speed | Percent Load | Weighting Factor |
|---|---|---|---|
| 1 | Rated | 100 | 0.15 |
| 2 | Rated | 75 | 0.15 |
| 3 | Rated | 50 | 0.15 |
| 4 | Rated | 10 | 0.1 |
| 5 | Intermediate | 100 | 0.1 |
| 6 | Intermediate | 75 | 0.1 |
| 7 | Intermediate | 50 | 0.1 |
| 8 | Idle | --- | 0.15 |

1.1.2.7.3 For Construction Equipment Vehicle (Constant Speed) Engines (5 – Mode Cycle)

| Mode Number | Engine Speed | Percent Load | Weighting Factor |
|---|---|---|---|
| 1 | Rated | 100 | 0.05 |
| 2 | Rated | 75 | 0.25 |
| 3 | Rated | 50 | 0.30 |
| 4 | Rated | 25 | 0.30 |
| 5 | Rated | 10 | 0.10 |

1.1.3 The particulate emissions are calculated in the following way. The generalequations in this paragraph apply to both full-flow- dilution and partial-flow dilutionsystems:

$$\overline{PT} = \frac{PT_{mass}}{\sum\left(P_i - P_{aux,i}\right) * WF_i}$$

where :

WF = as in paragraph 1.1.2.5 above

1.1.3.1 The particulate mass flow rate (gm/hr) is calculated as follows :

$$PT_{mass} = \frac{P_f * \overline{G}_{EDF}}{M_{SAM} * 1000}$$

or:

$$PT_{mass} = \frac{P_f * \overline{V}_{EDF}}{V_{SAM} * 1000}$$

1.1.3.2 $G_{EDF}$, $V''_{EDF}$, $M_{SAM}$ and $V_{SAM}$ over the test cycle are determined by summation of the average values of the individual modes :

϶$_{EDF}$ = $\Sigma G_{EDF,i} * WF_i$

6"$_{EDF}$ = $\Sigma V''_{EDF,i} * WF_i$

$M_{SAM} = \Sigma M_{SAM,i}$

$V_{SAM} = \Sigma V_{SAM,i}$

1.1.3.3 The effective wieghting factor $WF_E$ for each mode is calculated in the following way:

$$WF_{E,i} = \frac{M_{SAM,i} * \overline{G}_{EDF}}{M_{SAM} * G_{EDF,i}}$$

$$WF_{E,i} = \frac{M_{SAM,i} * \overline{V''}_{EDF}}{V_{SAM_I} * V''_{EDFi}}$$

Or:

The value of the effective weighting factors must be within ± 0.003 of the weighting factors listed in paragraph 1.1.2.7.

1.1.3.4 The final reported test results of the particulate emission are derived through the following steps, when using the full-flow –dilution system (Chapter 5, system 2).

1.1.3.4.1 The diluted exhaust gas volume flow rate $V''_{TOT}$ over all modes is determined

$V''_{TOT,i}$ corresponds to $V''_{EDF,i}$ in the general equations in paragraph 1.1.3.2.

1.1.3.4.2 When using single –dilution system ,$M_{SAM}$ is the mass through the sampling filters(GF 1 in Chapter 5,system 2).

1.1.3.4.3 When using a double dilution system, $M_{SAM}$ is the mass through the sampling filters(GF 1 in Chapter 5, system 2) minus the mass of the secondary dilution air(GF 2 in Chapter 5,system 2)

1.1.4 The final reported test results of the particulate emission shall be derive through the following steps ,when using the partial-flow-dilution-system (Chapter 5, System 3).Since various types of dilution rate control may be used ,different calculation methods for $G_{EDF}$ or $V''_{EDF}$ apply.All calculations are based upon the average values of the individual modes during the sampling period.

1.1.4.1 Fractional Sampling Type with Isokinetic Probe

$G_{EDF,i} = G_{EXH,i} * q_i$

Or:

$V''_{EDF,i} = V''_{EXH,i} * q_i$

$$qi = \frac{G_{DIL,i} + (G_{EXH,i} * r)}{G_{EXH,i} * r}$$

Or:

$$qi = \frac{V''_{DIL,i} + (V''_{EXH,i} * r)}{V''_{EXH,i} * r}$$

where 'r' corresponds to the ratio of the cross sectional areas of the isokinetic probe and the exhaust pipe :

$$r = \frac{A_p}{A_T}$$

1.1.4.2 Fractional sampling type with $CO_2$ or NOx Measurement

$G_{EDF,i} = G_{EXH,i} * q_i$

Or:

$V''_{EDF,i} = V''_{EXH,i} * q_i$

$$qi = \frac{Conc_{E,i} - Conc_{A,i}}{Conc_{D,i} - Conc_{A,i}}$$

Where :

$Conc_E$ = concentration of the raw exhaust

$Conc_{\triangle}$ = Concentration of the diluted exhaust

$Conc_A$= concentration of the dilution air

Concentrations measured on dry basis are converted to a wet basis according to paragraph 1.1.2.1

1.1.4.3 Total Sampling type with $CO_2$ measurement and Carbon Balance Method

$$G_{EDF,i} = \frac{206 * G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

(C.I. engines)

Or:

$$G_{EDF,i} = \frac{195 * G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

(LPG Fuelled engines)

Or:

$$G_{EDF,i} = \frac{171 * G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

(NG Fuelled engines)

where :

$CO_{2D}$ = $CO_2$ concentration of the diluted exhaust gases
$CO_{2A}$ = $CO_2$ concentration of the dilution air

(Concentration is vol % on wet basis)

The equations are based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as $CO_2$) and derived through the following steps ;

$G_{EDF,i} = G_{EXH,i} * q_i$

$$qi = \frac{206 * G_{FUEL,i}}{G_{EXH,i} * (CO_{2D,i} - CO_{2A,i})}$$

1.1.4.4 Total Sampling Type with Mass Flow Control

$G_{EDF,i} = G_{EXH,i} * \quad q_i$

$$qi = \frac{G_{TOT,i}}{(G_{TOT,i} - G_{DIL,i})}$$

# CHAPTER 5 :ANALYTICAL AND SAMPLING SYSTEMS

1 SCOPE :

This chapter describes the analytical and sampling system mentioned in para 3.3 of Chapter 3 of this Part.

2 Analytical Systems for determination of gaseous emission.
System (HCLA or Equivalent System)

A schematic diagram of the analytical and gas sampling system using HCLA or equivalent systems for measuring NOx is shown in Figure 1 of this chapter.

SP - Stainless steel sample probe to obtain samples from exhaust system. A closed end, multi-hole straight probe extending at least 80% across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K ($70^{o}$ C).In the case of NG engine, the sample probe shall be installed at minimum 1.5m and maximum 2.5m from exhaust manifold or turbocharger.

HSL 1 - Heated sampling line, temperature shall be kept at 453 K - 473 K ($180^{o}$ C $200^{o}$ C): the line shall be made in stainless steel of PTFE.

F1 - Heated pre-filter, if used; temperature shall be the same as HSL 1.

T1 - Temperature readout of sample streams entering oven compartment.

V1 - Suitable valve for selecting sample, span gas or air or gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line HSL1.

V2,V3 - Needle valves to regulate calibration gas and zero gas.

F2 - Filter to remove particulates. A 70 mm diameter glass fibre type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.

PI - Heated sample pump

G1 - Pressure gauge to measure pressure in sample line HC-analyser.

R3 - Pressure regulator valve to control pressure in sample line and flow to detector.

HFID - Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept at 453 K - 473 K ($180^{o}$ C - $200^{o}$ C).

FL1,FL2,FL3 - Flow meter to measure sample bypass flow.

RI,R2 - Pressure regulators for air and fuel.

HSL2 - Heated sampling line, temperature shall be kept between 368 K - 473 K ($95^{o}$ C - $200^{o}$ C); the line shall be made in stainless steel or PTFE.

HCLA - Heated chemiluminescence analyser for oxides of nitrogen.

T2 - Temperature readout of sample stream entering HCLA analyser.

T3 - Temperature readout of $NO_2$ - NO converter.

V9, V10 - Three~way valve to by-pass $NO_2$ - NO converter.

V11 - Needle valve to balance flow through NO2 - NO converter and by-pass.

SL - Sample line. The line shall be made in PTFE or in stainless steel. It may be heated or unheated.

B - Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 K - 277 K (0°C – 4°C) by ice or refrigeration...

C - Cooling coil and trap sufficient to condense and collect water vapour (optional with water insensitive analyser).

T4 - Temperature readout of bath temperature.

V5,V6 - Toggle valves to drain condensate traps and bath.

R4,R5 - Pressure regulator to control sample flow.

V7,V8 - Bail valve or solenoid valves to direct sample, zero gas or calibrating gas streams to the analysers.

V12, V13 - Needle valves to regulate flows to the analysers.

CO - NDIR analyser for carbon monoxide.

NOx - HCLA analyser for oxides of nitrogen.

FL4,FL5 - By-pass flowmeter.

V4, V 14 - Three-way ball or solenoid valves. The valves shall be in an oven compartment or heated to the temperatures of the sampling line HSLI.

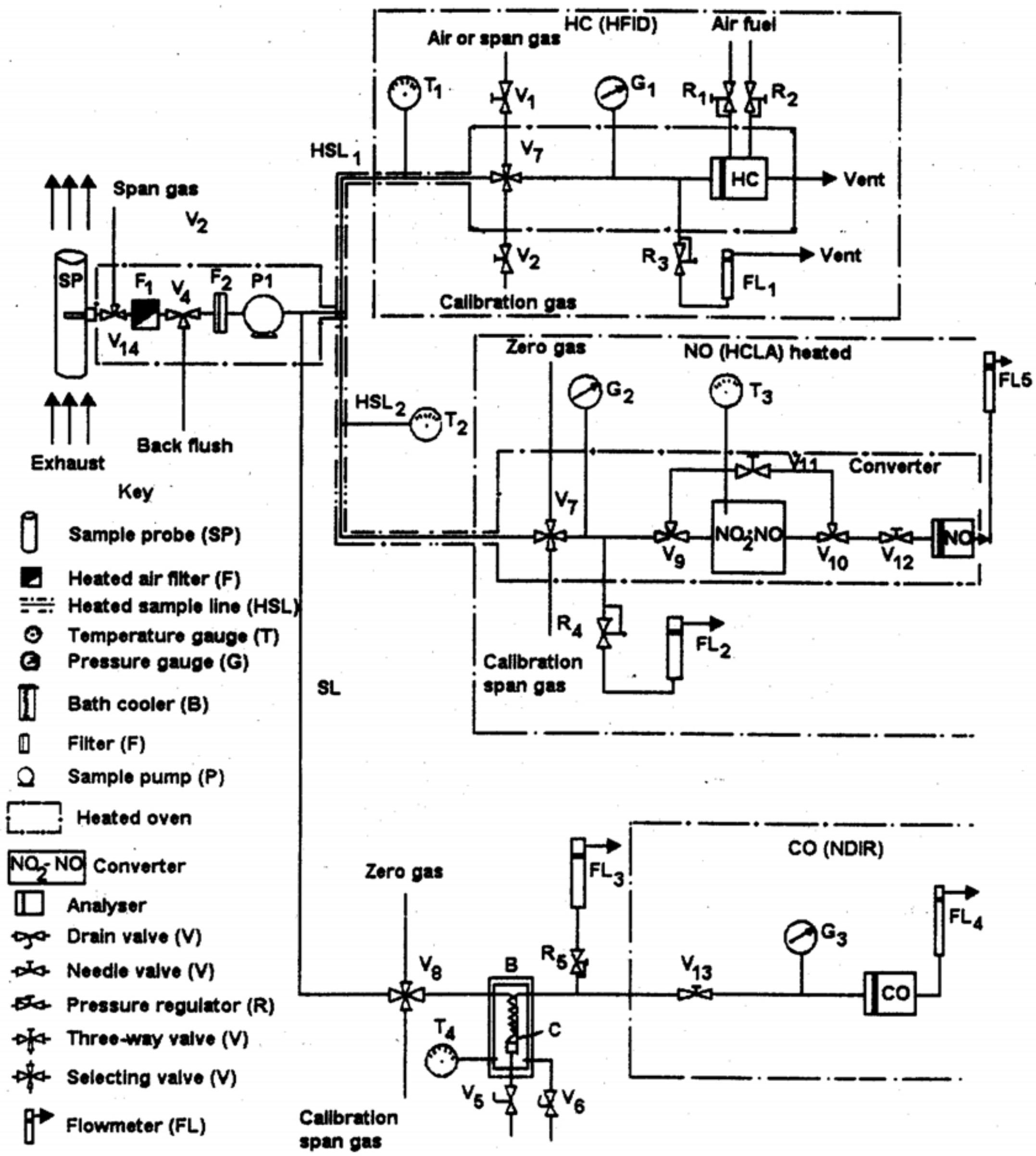



Figure 1

**Flow Diagram of Exhaust Gas Analysis System for CO, $NO_x$ and HC (Analysis by HCLA and Heated Sample Line).**

## 3 DETERMINATION OF THE PARTICULATE EMISSION

The determination of particulate emissions requires dilution system capable of maintaining the temperature of the diluted exhaust gas at or below 325K (52 deg. C), the particulate sampling system, specified sampling filters and microgram balance which shall be placed in an air conditioned weighing chamber. Two principally different dilution and sampling systems(full-flow-dilution system and partial-flow-dilution-system) are used The specification of filters, balance and the weighing chamber apply to both systems.

### 3.1 Particulate Sampling Filters

Fluorocarbon-coated glass fibre filters or fluorocarbon –based (membrane) filters are required.

Particulate filters shall have a minimum diameter of 47 mm(37 mm stain diameter ) Larger diameter filters are acceptable.

The diluted exhaust are sampled by pair of filters placed in series (one primary and one back-up filter )during the test sequence. The back-up filter shall be located no more than 100mm down stream of and shall not be in contact with primary filter .

The recommended minimum loading on primary 47 mm filter(37 mm stain diameter) is 0.5 milligrams , on primary 70 mm filter (60 mm stain diameter) 1.3 milligrams.

Equivalent minimum loading of 0.5 –mg/1075 mm2 (i.e mass/stain area) are recommended for other filters.

### 3.2 Weighing Chamber and Microbalance Specifications

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within ± 6K of set point between 293 and 303 K(20 $^{o}$ C and 30 $^{o}$ C) during all filter conditioning and weighing . The relative humidity shall be maintained to within ± 10% relative humidity of a set point between 35% and 55 %.

The chamber(or room) environment shall be free of any ambient contaminates (such as dust ) that could settle on particulate filtering during their stabilisation. At least two unused reference filters must be weighed within four hours of but preferably at the same time, as the sample filters weighing . If average weight of the reference filter changes between sample filter weighing by more than ± 6% of the recommended minimum filter loading ,then all sample filters discarded and the emission tests repeated.

In case of a weight change between –3.0 % and –6.0 % the manufacturer has the option of either repeating the test or adding the average amount of weight loss to the net weight sample .

In case of a weight change between +3.0 % and +6.0 % the manufacturer has the option of either repeating the test or accepting the measured sample filter weight values.

If the average weight changes by not more than ± 3% of minimum filter loading, the measured sample filter weights are used for calculations.The reference filters shall be of the same size and material as the sample filters and be changed at least once a month.

The microgram balance used to determine the weights of all the filters shall have a precision of 2% and readability of 1% of the recommended minimum filter loading.

**3.3 Additional Specifications**

All parts of the dilution system and the sampling from the exhaust pipe up to filter holder, which are in contact with raw and dilute exhaust gas shall be designed to minimise the deposition or alteration of the particulate matter. All parts shall be made of electrically conductive material, that does not react with exhaust gas components and shall be electrically grounded, to prevent electrostatic effects.

**3.4 System 2(Full-Flow-Dilution System)**

A particulate sampling system is described based upon the dilution of the total exhaust using the CVS (Constant Volume Sampling) concept.

Figure 2 is a schematic drawing of this system. The total flow of the mixture of exhaust and dilution air shall be measured , and a sample shall be collected for analysis.

The mass of particulate emissions is subsequently determined from the mass sample collected on a pair of filters ,the sample flow and the total flow of dilution air and exhaust over a test period. Either a PDP or a CFV and a single-dilution system may be used. Gaseous emissions shall not be determined with a CVS system. The components shall meet the following requirements

EP- The exhaust pipe length from the exit of the engine exhaust manifold or turbocharger outlet to the dilution tunnel is required to be not more than10m.If the system exceeds 4m in length then all tubing in excess of 4m shall be insulated. The radial thickness of the insulations must be at least 25 mm. The thermal conductivity of the insulating material shall have a value no greater than 0.1 W/mk measured at 673 k (300 $^{o}$ K).

PDP- The positive displacement pump meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system back pressure shall not artificially lowered by the PDP or dilution air intel system. Static pressure measured with the Operating CVS system shall remain within ± 1.5 kPa of the static pressure measured without connection to the CVS at identical engine speed and load. The gas mixture temperature immediately ahead of the PDP shall be within ± 6K of the average operating temperature observed during the test, when no flow compensation is used.

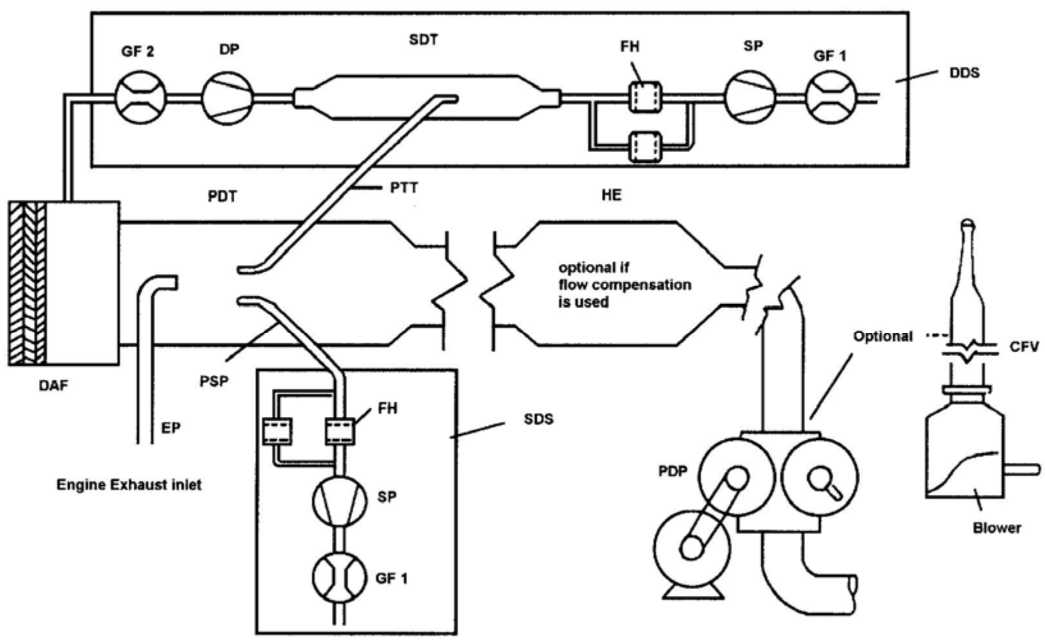



**Figure 2 : Full-Flow dilution system**

CFV- The critical flow venturi measures total diluted exhaust flow by maintaining the flow at choked conditions (critical flow). The static pressure variations in the raw exhaust shall conform to the specifications detailed for the PDP.

The gas mixture temperature immediately ahead of the CFV shall be within ± 11K of the average_operating temperature observed during the test, when flow compensation is used.

HE – The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above(optional if EEC is used)

EFC- If the temperature at the inlet to either PDP or CFV is not kept constant, an electronic flow computation system is required for continuous measurement of the flow rate (optional if HE is used)

PDT- The primary dilution tunnel shall be: Small enough in diameter to cause turbulent flow (Reynolds Number > 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air.

At least 460 mm in diameter with single – dilution system or at least 200 mm in diameter with a double –dilution system.

The engine exhaust shall be directed downstream at the point where it introduced into the primary dilution tunnel ,and thoroughly mixed.

SDS – The single-dilution system collects sample from the primary tunnel and then passes this sample through the collection filters. The flow capacity of the PDP or CFV shall be sufficient to maintain the diluted exhaust at a temperature of no more than 325 K(52 $^{o}$C) immediately before the primary particulate filter.

DDS- The double-dilution system collects sample form the primary tunnel and then transfers this sample to secondary dilution tunnel where the sample is further diluted. The double-diluted sample is then passed through the collection filters. The flow capacity of PDP or CFV shall be sufficient to maintain the diluted stream in the PDP at a temperature less than or equal to 464 K (191 $^{o}$ C) at the sampling zone.The secondary dilution system shall provide sufficient secondary dilution air to maintain the double diluted exhaust stream temperature of less than or equal to 325 K(52$^{o}$C) immediately before the primarily particulate filter.

PSP- The particulate sample probe (for SDS only) shall :

Be installed facing upstream at point where the dilution air exhaust gas are well mixed (i.e on the dilution tunnel centre – line, approximately
10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel)

Have an inside diameter at least 12 mm.

The distance from the probe tip to the filter holder shall not exceed 1020mm.
The sample probe shall not be heated.

PTT - The particulate transfer tube (for DDS only) shall be :

Installed facing upstream at a point where the dilution air and exhaust gas are well mixed (i.e on the dilution tunnel centre – line, approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel)
12mm minimum inside diameter.

Not more than 910 mm from the inlet plane to exit plane.

The particulate shall exit on the centre-line of the secondary dilution tunnel and point downstream. The sample shall not be heated.

SDT- The secondary dilution tunnel (for DDS only) shall have minimum diameter of 75 mm and be of sufficient length so as to provide a residence time of at least 0.25 seconds for the double diluted sample. The primary filter holder shall be located within 300 mm of the exit of the secondary dilution tunnel

DAF- The dilution air may be filtered at the dilution air inlet, shall have a temperature of 298 ($25^o$ C) $\pm$ 5K and may be sampled to determine background particulate levels , which can then be subtracted from the values measured in diluted exhaust.

FH – For primary and back-up filters housing the separate filter housing may be used. The requirements of paragraph 2.1.3 of this chapter have to be met. The filter holders shall not be heated

SP- The particulate sample pump shall be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant ( $\pm$ 3K) if flow compulation is not used. The sample pump(s) shall be running throughout the complete test procedure. A bypass system is used for passing the sample through the sampling filters.

DP- The dilution air pump (for DDS only) shall be located so that the secondary dilution air is supplied with a temperature of 298 ($25\ ^o$ C) $\pm$ 5K.

GF1- The gas meter or flow instrumentation (for particulate sample flow) shall be located sufficiently distant from the tunnel so that the inlet gas temperature remain constant ( $\pm$ 3K), if flow computation is not used.

GF2- The gas meter or flow instrumentation (dilution air, for DDS only) shall located so that the inlet gas temperature remains at 298 ($25\ ^o$ C) $\pm$ 5K.

### 3.5 System 3 (Partial – Flow –Dilution System )

A particulate sampling system is described based upon the dilution of part of the exhaust gas. Figure 3 is schematic drawing of this system. The mass of particulate emissions is determined from a mass sample collected on a pair of filter and from the dilution ratio sample flow and exhaust gas flow or fuel flow over the test period.

The calculation of the dilution ration depends upon type of system used . Only a fraction of diluted exhaust (fractional sampling type ) or all of the diluted exhaust ( total sampling type) may be sampled . All types described herein are equivalent as long as they comply with the requirements of chapter 4 paragraph 4.2.6 ,appendix 3,paragraph 1.1.6.3.The Components shall meet the following requirements:

EP - For types without , isokinetic probe it is necessary to have a straight pipe of length of 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe .

For a type with isokinetic probe, the exhaust pipe shall be free of elbows, bends and sudden diameter changes for at least 15 pipe diameters upstream and 4 pipe diameters downstream of the tip of the probe. The exhaust gas velocity at the sampling zone shall be higher than 10 m/s and lower than 200 m/s.

Pressure oscillations of the exhaust gas shall not exceed $\pm$ 500 Pa on average. Any steps to reduce pressure oscillations beyond using a chasis – type exhaust system (including muffler) shall not alter engine performance nor cause the deposition of particulate.

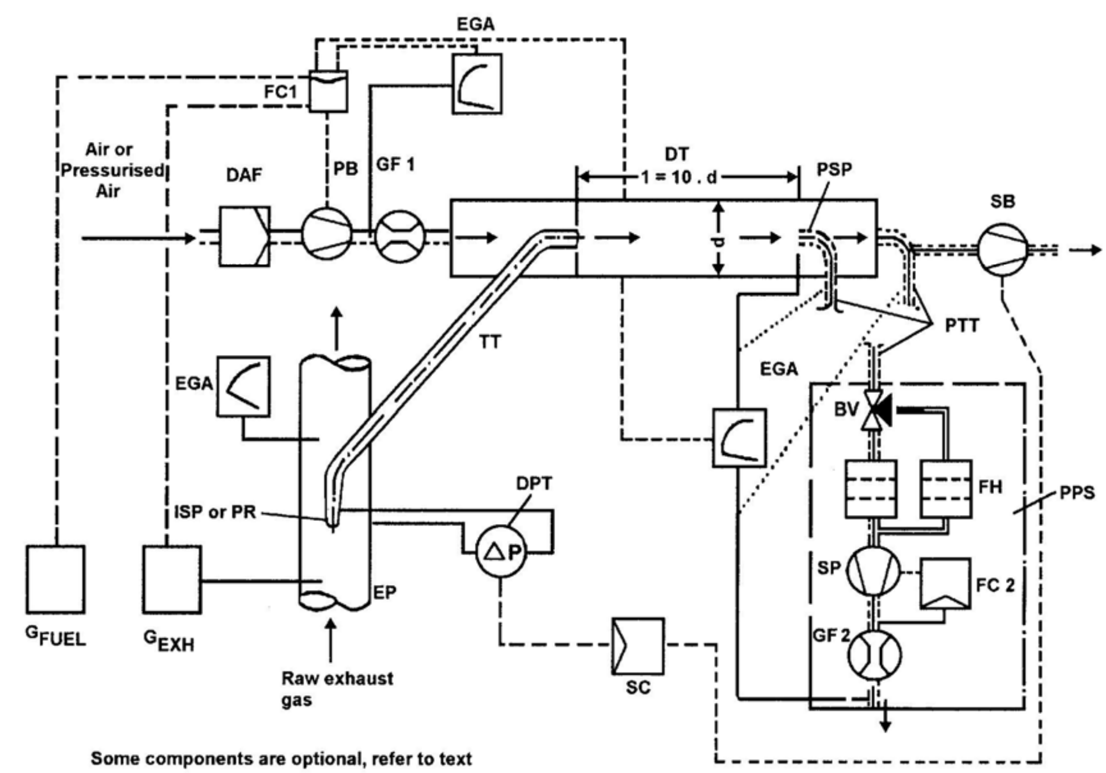



**Figure 3 : Partial-flow dilution system**

PR- The sampling probe shall be installed facing upstream on the exhaust pipe centre-line at apoint where the above flow conditions are met. the minimum inside diameter shall be 4 mm.

LSP- The isokinetic sampling probe(optional if EGA or mass flow control is used) shall be designed to provide a proportional sample of the raw exhaust gas. To that purpose, ISP replaces PR as described above and has to be connected to differential pressure transducer and a speed controller, to obtain isokinetic flow at the probe tip. The inside diameter shall be at least 12 mm.

EGA – Exhaust gas analysers (optional if EGA or a mass flow control is used) for $CO_2$ or NOx analysis may be used (with carbon balance method $CO_2$ only). The analysers shall be calibrated in the same way as the analysers for the measurement of the gaseous pollutant . One or more analysers may be used for the determination of the concentration differences.

TT- The particulate sample transfer tube shall be :

Heated or insulated so that the gas temperature in the transfer tube be not below 423K (150$^o$ C). If the exhaust gas temperature is below 425 K (150$^o$ C) it shall not be below the exhaust gas temperature.

Equal to or greater in diameter than probe diameter, but no more than 25 mm in diameter.

Not more than 100 mm from inlet plane to exit plane.

The particulate sample shall exit on the centre-line of the dilution tunnel and point downstream.

SC- (For ISP Only) A pressure control system is necessary for isokinetic exhaust splitting by maintaining a differential pressure of zero between EP and ISP. Under these conditions, exhaust gas velocities in EP and ISP are identical, and mass flow though ISP is a constant fraction of the total exhaust gas flow. The adjustment is done by controlling the speed of the suction blower (SB) and keeping the speed of the pressure blower (SP) constant during each mode. The remaining error in the pressure control loop shall not exceed $\pm$ 0.5% of the measuring range of the pressure transducer (DPT). The pressure oscillations in the dilution tunnel shall not exceed $\pm$ 250 Pa on average.

DPT- DPT - (for ISP only) the differential pressure transducer shall have a maximum range of $\pm$ 500 Pa.

FCI- A flow controller (dilution air) is necessary to control the dilution air mass flow. It may be connected to the exhaust flow or fuel flow and /or $CO_2$ differential signal.

When using pressurised air supply, FCI directly controls the air flow.

GF 1- The gas meter or flow instrumentation (particulate sample flow) shall be located so that the inlet gas temperature remains at 298 K(25$^o$ C) $\pm$ 5K.

SB – (For Fractional sampling type only)

PB – To control the dilution air mass flow rate, PB shall be connected to FCI. Exhaust flow or fuel flow and /or $CO_2$ differential signals may be used as command signals. PB is not required when using pressurised air supply.

DAF- The dilution air may be filtered at the dilution air inlet, shall have a temperature of 298 (25 $^o$C) $\pm$ 5K and may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

DT- The dilution tunnel shall be :

Small enough in diameter to cause turbulent flow (Reynolds Number >4000) and of sufficient length to cause complete mixing of the exhaust and dilution air.

At least 25 mm in diameter for the total sampling type.

At least 25 mm in diameter for the fractional sampling type.

The engine exhaust shall be directed downstream at the point where it is introduced into the dilution tunnel. And thoroughly mixed with in the dilution air means of mixing orifice. For the fractional sampling type, the mixing quality shall be checked after introduction into service by means of a $CO_2$ profile the tunnel with the engine running (at least six equally spaced measuring points.)

PSS- The particulate sampling system shall be configured so as to collect a sample from the dilution tunnel and to pass this sample through the sampling filters (fractional sampling type) or to pass all of the diluted exhaust through the sampling filters (total sampling type). In order to avoid any impact on the control loops, it is recommended that the sample pump be running through out the complete test procedure . A bypass system with a ball valve between the sample probe and filter holder shall be used for passing the sample through the sampling filters at the desired times. Interference of the switching procedure on the control loops shall be corrected within less than three seconds.

PSP- The particulate sample probe shall be:

Installed facing upstream at point where the dilution air and exhaust gas are well mixed (i.e on the dilution tunnel centre-line, approximately 10 tunnel diameter downstrem of the point where the exhaust enters the dilution tunnel ). Have inside diameter of at least 12 mm.

PTT- The particulate transfer tube shall not be heated and shall not exceed 1020 mm in length :

For fractional sampling type from the probe tip to the filter holder.

For the total sampling type from the end of the dilution tunnel to the filter holder.

FH- For primary and back–up filters one filter housings may be used. The requirements of paragraph 2.1.3 of this chapter shall be met. The filter holders shall not be heated.

SP- The particulate sample pump shall be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3K), if flow computation is not used.

FC2 – A flow controller (particulate sample flow, optional) may be used, in order to improve accuracy of the particulate sample flow rate.

GF2- The gas meter or flow instrumentation (particulate sample flow) shall be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (± 3K), if flow computation is not used.

BV- The ball value shall have a diameter no less than the sampling tube and a switching time less than 0.5 seconds.

## PART X – SUB PART (A) : DETAILS OF STANDARDS OF VISIBLE AND GASEOUS POLLUTANTS FROM DIESEL ENGINED AGRICULTURAL TRACTORS AND CONSTRUCTION EQUIPMENT VEHICLES

**1.** Scope

This part applies to the emission of visible pollutants and gaseous pollutants from compression ignition (C.I.) engined agricultural tractors effective from 1st October 1999 as per Central Motor Vehicle Rules 115 A and enforced as per the Government of India, Ministry of Road Transport and Highways, Notification no. GSR 83(E) dt. 05.02.2003.

2. Type Approval

Every manufacturer of an agricultural tractor shall meet the following requirements for the tractor model before granting the type approval.

2.1 An agricultural tractor shall comply with the standards for visible pollutants (smoke) emitted by it when tested as per the procedure described in Indian Standards IS : 12062-1987 and
shall not exceed the limit values of 3.25 $m^{-1}$ light absorption co-efficient (75 H.S.U.) when tested on engine dynamometer at 80% load at six equally spaced speeds between
55% of rated speed declared by the manufacturer or 1000 rpm whichever is higher.
**To**
Rated speed as declared by the manufacturer.

2.1.1 The gross power of the engine i.e. without fan when tested on engine dynamometer at steady speeds of the full load curve, may differ from the power declared by the manufacturer as follows :
For Type Approval :
For single cylinder engines, ±10% at maximum power point including all other measured speeds.
For all other engines, ±5% at rated speed and all other measured speeds.
For Conformity of Production :
At maximum power point by ±10% for single cylinder engines and –5%+8% for all other engines.

2.2 Every diesel driven agricultural tractor shall be so manufactured and produced by its manufacturer that it complies with the following standards mentioned below table of mass emission in addition to those of visible pollutants as mentioned above at clause 2.1 when tested as per the procedures described in ISO-8178-4 '$C_1$' 8 mode cycle.

**TABLE**

| **Notification and date of enforcement** | **Mass Emission Limits (g/kWh)** | | | | |
|---|---|---|---|---|---|
| | **CO** | **HC** | **NOx** | **HC+NOx** | **PM** |
| G.S.R. No. 627 (E) Dt. 8.9.1999 w.e.f. 1.10.1999 | 14.0 | 3.50 | 18.00 | --- | --- |
| G.S.R. No. 83 (E) Dt. 5.2.2003 w.e.f. 1.06.2003 [Bharat (Trem) Stage II] | 9.0 | --- | --- | 15.0 | 1.0 |
| G.S.R. No. 83 (E) Dt. 5.2.2003 w.e.f. 1.04.2005 [Bharat (Trem) Stage III] | 5.50 | --- | --- | 9.50 | 0.80 |

2.2.1 For mass emission test, procedure will be followed is as per Chapter X of MOST/CMVR/TAP-115/116 except the following clauses :

(1) Engine will be subjected to mass emission in gross condition i.e. w/o fan but inclusive of intake and exhaust system or equivalent in test cells.
(2) Cycle will be as per ISO 8178-4 '$C_1$' – 8 mode.
(3) Each mode duration will be 10 min.
(4) Particulate may be collected by single filter or by multi filter methods.
(5) For derated engines of same family, if the power at rated speed is within (-) 5% of declared power during type approval, a further test need not be carried out as per clause 2.2 of this document for derated engine of same specification. For all other cases a test is necessary as per clauses 2.1 and 2.2.
(6) Periodicity of COP :

| | | |
|---|---|---|
| A. | PRODUCTION ≤ 1000 per year | NO COP REQUIRED |
| B. | 1000 < PRODUCTION ≤ 7500 per year | ONE COP PER YEAR |
| C. | 7500 < PRODUCTION ≤ 25000 | ONE COP PER SIX MONTHS i.e. April to Sep. and Oct. to Mar. |
| D. | 25000 < PRODUCTION or six months whichever occurs earlier | ONE COP TEST IS REQUIRED |
| E. | For directly imported engines, one COP would be required for every 500 units. | |

(7) Test fuel shall be reference fuel as per Chapter 5, Part IV of this document (with sulphur content of less than 0.05% mass).

(8) Conformity of Production :

(8.1) Every produced vehicle of the model approved under this rule shall conform with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved. The procedure for carrying out conformity of production test is given in Part VI of this document.

(8.2) For verifying the conformity of the engine in a test, the following procedure is adopted :-

(8.2.1) An engine is taken from the series is subjected to the mass emission test.

(8.2.1.1) If the engine taken from the series does not satisfy the requirements of Paragraph 2.1 and 2.2 above, the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The Manufacturer shall specify the size n of the sample subject to n being minimum 2 and maximum 10, including the engine originally taken. The engines other than originally tested shall be subjected to a test. The arithmetical mean $(\bar{x})$ of the results obtained from the sample shall be determined for each pollutant .The production of the series shall then be deemed to conform if the following condition is met :-

$$\bar{x} + k.\ S \leq L$$

Where :-

$S^2 = \sum ( x_i - \bar{x} )^2 / (n-1)$

S = Standard Deviation

$X_i$ = any one of the individual results obtained with the sample n.
L = the limit value laid down in Paragraph 2.2 for each gaseous pollutant considered and
k = a statistical factor depending on 'n' and given in the following table :-

| n | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| K | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |
| | | | | | | | | | |

## PART X – SUB PART (A) : DETAILS OF STANDARDS OF VISIBLE AND GASEOUS POLLUTANTS FROM DIESEL ENGINES FOR AGRICULUTARAL TRACTORS MANUFACTURED ON AND FROM 1.4.2010.

1. Scope

This part applies to the emission of visible pollutants and gaseous pollutants from compression ignition (C.I.) engine agricultural tractor's effective from 1st April. 2010 & 1st April 2011 as per Central Motor Vehicle Rules 115 A and enforced as per applicable Gazette Notification under CMVR.

2. Type Approval

2.1 For the purpose of type approval and conformity of production certification, manufacturer's engine range shall be divided into model families, consisting of parent engine model and its variant and application for Type Approval shall be made in the proforma prescribed as amended by time to time.

2.2 The determination of an engine family and the decision regarding parent engine shall be based on Appendix - I to this Part. For the purpose of identification, the manufacturer shall designate the families as F1, F2, F3 ….. Fn.

2.3 The Testing agency shall decide the family, the parent model and its variants depending on the information provided by the manufacturer.

2.4 Testing of the parent model, shall, normally, be sufficient for type approval of the family. The Testing agency has the option to carry out the testing of more than one model in the family to satisfy itself, subject to parent engine-concept as per Annexure I.

2.5 At later stage if the manufacturer submits the application for type approval of a model, the Testing agency shall ascertain whether the model can be classified as belonging to a family of model(s) already certified.

If the model does not belong to a family already certified, the Testing agency shall proceed with the testing of the model for type approval.

If the model belongs to a family already certified, the Testing agency shall decide whether the specific testing of the model is required. In case the specific testing of the model is not required, the type approval certificate for the family may be extended to include the model.

2.6 The Testing agency shall intimate its decision to the applicant within a fortnight of receipt of the application, indicating need and plan (schedule) of testing for type approval.

2.7 MODIFICATIONS IN THE ENGINE MODEL

2.7.1 Every modification in the characteristics or parameters of the engine model, which has been declared by the manufacturer shall be intimated by the manufacturer to the Testing agency, which is responsible for carrying out TA & COP for that Model. The Testing agency may either Consider that the engine with the modifications made may still comply with the requirements. In this case, the Testing agency shall extend the type approval covering the modified specifications.

or

Consider that the engine with the modifications made require a further test to ensure compliance. In this case, if the engine with the modifications complies with the requirements on testing as per part X of this document, the Testing agency shall extend the type approval.

2.8 The manufacturer shall submit an engine for testing, as intimated by the Testing agency.

2.9 Every manufacturer of agricultural tractor's Engine shall meet the following requirements for the model before granting the type approval.

2.9.1 Agricultural tractor's Engine shall comply with the standards for visible pollutants (smoke) emitted by it when tested as per the procedure described in Indian Standards IS: 12062 – 1987 and shall not exceed the limit values of 3.25 m-1 light absorption co-efficient (75 H.S.U.) when tested on engine dynamometer at 80% load at six equally spaced speeds between

55% of maximum power speed as declared by the manufacturer or 1000 rpm whichever is higher

And

Maximum Power speed as declared by the manufacturer.

2.9.2 The gross power of the engine i.e. without fan shall be tested as per procedure given in Part IV of MoSRTH/CMVR/TAP-115/116 Issue No.3 on engine dynamometer.

When tested on engine dynamometer at steady speeds over the full load curve, may differ from the power declared by the manufacturer as follows:

For Type Approval:

For single cylinder engines, ±10% at maximum power speed including all other measured speeds.

For all other engines, ±5% at maximum power speed and all other measured speeds.

For Conformity of Production:

At maximum power speed by ±10% for single cylinder engines and –5%+8% for all other engines.

2.9.3 Every diesel driven Agricultural tractor's Engine (type or family) shall be so manufactured and produced by its manufacturer that it complies with the following mass emission standards mentioned in table below, in addition to those of visible pollutants as mentioned above at clause 2.9.1 when tested as per the procedures described in ISO-8178 Part-4(1996) 'C1' 8 mode cycle.

| Category Trem IIIA | Applicable with effect from | CO* | HC + NOx* | PM* |
|---|---|---|---|---|
| Category | | g/kWh | | |
| kW < 8 | 1-Apr-2010 | 5.5 | 8.5 | 0.80 |
| 8 ≤ kW < 19 | 1-Apr-2010 | 5.5 | 8.5 | 0.80 |
| 19 ≤ kW < 37 | 1-Apr-2010 | 5.5 | 7.5 | 0.60 |
| 37 ≤ kW < 56 | 1-Apr-2011 | 5.0 | 4.7 | 0.40 |
| 56 ≤ kW < 75 | 1-Apr-2011 | 5.0 | 4.7 | 0.40 |
| 75 ≤ kW < 130 | 1-Apr-2011 | 5.0 | 4.0 | 0.30 |
| 130≤ kW < 560 | 1-Apr-2011 | 3.5 | 4.0 | 0.20 |

** The limit values shall include deterioration-calculated in accordance with Annexure III.*

2.10 For mass emission test, procedure will be followed as per Part XV of MoSRTH/CMVR/TAP-115/116 except the following clauses for agricultural tractor & construction equipment vehicle:

(1) Engine will be subjected to mass emission in gross condition i.e. w/o fan but inclusive of intake and exhaust system or equivalent in test cells to simulate AID (Air Intake depression) & EBP (Exhaust Back Pressure) as specified by Engine manufacturer.

If the engine is equipped with an exhaust after-treatment device, the exhaust pipe shall have the same diameter as found in-use for at least four pipe diameters upstream to the inlet of the beginning of the expansion section containing the after-treatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust after-treatment device shall be the same as in the machine configuration or within the distance specifications of the manufacturer. The exhaust backpressure or restriction shall follow the same criteria as above, and may be set with a valve.

Agricultural tractor's Manufacturer & Engine Manufacturer shall declare Air Intake depression & Exhaust Back Pressure jointly for all vehicle models with same engine family. At the time of approval of vehicle model, AID & EBP shall be confirmed by Test Agency that they are within the declared specifications.

(2) Cycle will be as per ISO 8178 (1996) Part-4 'C1' – 8 modes cycle.

(3) Each mode-duration will be 10 min.

(4) Particulate may be collected by single filter or by multi filter methods.

(5) One Engine family covers more than one power band, the emission values of the parent engine (TA & COP) and of all engine types within the same family (TA & COP) must meet the more stringent requirements of the higher power band. The applicant has the free choice to restrict the definition of engine families to single power bands, and to correspondingly apply for certification.

(6) COP period for agricultural tractor & power tiller from April 2010.
For agricultural tractor & power tiller with annual production upto 200 nos., it shall be once in two years per family / Model.
For agricultural tractor & power tiller with annual production exceeding 200 nos., it shall be once in every year per family / Model.

(7) Test fuel shall be reference fuel as per enclosed as Annexure- II (a) (with sulphur content of less than 300 ppm).

## 3 Conformity of Production:

3.1 Every produced agricultural tractor Engine of the model approved under this rule shall conform with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved. The procedure for carrying out conformity of production test is given in Part VI of this document.

3.2 For verifying the conformity of the engine in a test, the following procedure is adopted: -

3.2.1 An engine is taken from the series is subjected to the mass emission test.

3.2.1.1 If the engine taken from the series does not satisfy the requirements of Paragraph 2.9.1 &2.9.2 above, two more engines are tested in the same way and if the Gross Power figure does not fulfill the requirements of 2.9.1 & 2.9.2, the production shall be considered not to conform the requirements of regulations.

3.2.1.2If the engine taken from the series does not satisfy the requirements of Paragraph 2.9.3 above, the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The Manufacturer shall specify the size n of the sample subject to n being minimum 2 and maximum 10, including the engine originally taken. The engines other than originally-tested shall be subjected to a test. The arithmetical mean ( $\bar{x}$ ) of the results obtained from the sample shall be determined for each pollutant .The production of the series shall then be deemed to conform if the following condition is met: -

$$\bar{x} + k*S \leq L$$

Where: -

$S^2 = \sum (x_i - x)^2 / (n-1)$

S = Standard Deviation

$x_i$ = any one of the individual results obtained with the sample n.

L = the limit value laid down in Paragraph 2.9.3 for each gaseous pollutant considered and

k = a statistical factor depending on ‘n’ and given in the following table :-

| N | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| K | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

# Appendix 1

## PARAMETERS DEFINING THE ENGINE FAMILY

The engine family may be defined by basic design parameters, which must be common to engines within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only engines with similar exhaust emission characteristics are included within an engine family.

In order that engines may be considered to belong to the same engine family, the following list of basic parameters must be common:

Combustion cycle:
- 2 cycle
- 4 cycle

Cooling medium:
- air
- water
- oil

Individual cylinder displacement:
- engines to be within a total spread of 15 %
- number of cylinders for engines with after-treatment device

Method of air aspiration:
- naturally aspirated
- pressure charged

Combustion chamber type/design:
- pre-chamber
- swirl chamber
- open chamber

Valve and porting - configuration, size and number:
- cylinder head
- cylinder wall
- crankcase

Fuel system:
- pump-line-injector
- in-line pump
- distributor pump
- single element
- unit injector
- common rail direct injection

Miscellaneous features:
- exhaust gas recirculation
- water injection/emulsion
- air injection
- charge cooling system

Exhaust after-treatment
- oxidation catalyst
- reduction catalyst
- thermal reactor
- particulates trap

**CHOICE OF THE PARENT ENGINE**

Gaseous & Particulate Emission test data of every engine type may be provided by manufacturer & based on the test results & also the following guidelines test agency shall decide parent engine.

The parent engine of the family shall be selected using the primary criteria of the highest fuel delivery per stroke at the declared maximum torque speed. In the event that two or more engines share this primary criterion, the parent engine shall be selected using the secondary criteria of highest fuel delivery per stroke at rated speed. Under certain circumstances, the approval authority may conclude that the worst-case emission rate of the family can best be characterized by testing a second engine. Thus, the approval authority may select an engine for test, based upon following additional features

a) An engine whose injection control is not dependent on speed;
b) An engine whose injection control is not dependent on load;
c) An engine with the lowest maximum injection pressure.
d) An engine with the highest charge air temperature at the inlet to the cylinder;
e) An engine with lowest charge air pressure at the inlet to the cylinder;
f) An engine with the least number of cylinders;
g) An engine with lowest rated power at rated speed;
h) An engine with lowest rated speed;
i) An engine with the lowest low idle speed;
j) An engine with the least number of injection points.

Which indicate that it may have the highest emission levels of the engines within that family.

If engines within the family incorporate other variable features, which could be considered to affect exhaust emissions, these features must also be identified and taken into account in the selection of the parent engine.

## Appendix 2

## DIESEL FUEL SPECIFICATIONS for Trem IIIA (Agricultural Tractor)

| | Minimum | Maximum | Test Method |
|---|---|---|---|
| Cetane Number | 52 | 54 | EN-ISO 5165 |
| Density at 15°C (kg/$m^3$) | 833 | 837 | EN-ISO 3675 |
| **Distillation : in °C** | | | |
| 50% point (°C) | 245 | --- | EN-ISO 3405 |
| 95% point (°C) | 345 | 350 | |
| Final boiling point (°C) | -- | 370 | |
| Flash point (°C) | 55 | --- | EN 22719 |
| CFPP (°C) | -- | (-) 5 | EN 116 |
| Viscosity at 40°C ($mm^2$/s) | 2.5 | 3.5 | EN-ISO 3104 |
| Polycyclic aromatic hydrocarbons (% m/m) | 3.0 | 6.0 | IP 391 |
| Sulphur Content (mg/kg) | --- | 300 | ASTM D 5453 |
| Copper Corrosion | --- | Class 1 | EN-ISO 2160 |
| Conradson carbon residue ( 10% DR ) (% m/m) | --- | 0.2 | EN-ISO 10370 |
| Ash Content (% m/m) | --- | 0.01 | EN-ISO 6245 |
| Water Content (% m/m) | --- | 0.05 | EN-ISO 12937 |
| Neutralisation (strong acid) No. (mg KOH/g) | --- | 0.02 | ASTM D 974 |
| Oxidation Stability (mg/ml) | --- | 0.025 | EN-ISO 12205 |

# Appendix 3

## DURABILITY REQUIREMENTS

1. **EMISSION DURABILITY PERIOD AND DETERIORATION FACTORS**.

This appendix shall apply to CI engines Trem IIIA (Agricultural tractor) only.

1.1. Manufacturers shall determine a Deterioration Factor (DF) value for each regulated pollutant for all Stage III engine families. Such DFs shall be used for type approval and Conformity Of Production Testing.

1.1.1. Test to establish DFs shall be conducted as follows:

1.1.1.1. The manufacturer shall conduct durability tests to accumulate engine operating hours according to a test schedule that is selected on the basis of good engineering judgement to be representative of in-use engine operation in respect to characterising emission performance deterioration. The durability test period should typically represent the equivalent of at least one quarter of the Emission Durability Period (EDP).

Service accumulation operating hours may be acquired through running engines on a dynamometer test bed or from actual in-field machine operation. Accelerated durability tests can be applied whereby the service accumulation test schedule is performed at a higher load factor than typically experienced in the field. The acceleration factor relating the number of engine durability test hours to the equivalent number of EDP hours shall be determined by the engine manufacturer based on good engineering judgement. During the period of the durability test, no emission sensitive components can be serviced or replaced other than to the routine service schedule recommended by the manufacturer.

The test engine, subsystems, or components to be used to determine exhaust emission DFs for an engine family, or for engine families of equivalent emission control system technology, shall be selected by the engine manufacturer on the basis of good engineering judgement. The criterion is that the test engine should represent the emission deterioration characteristic of the engine families that will apply the resulting DF values for certification approval. Engines of different bore and stroke, different configuration, different air management systems, different fuel systems can be considered as equivalent in respect to emissions deterioration characteristics if there is a reasonable technical basis for such determination.

DF values from another manufacturer can be applied if there is a reasonable basis for considering technology equivalence with respect to emissions deterioration, and evidence that the tests have been carried according to the specified requirements.

Emissions testing will be performed according to the procedures defined in this Document for the test engine after initial run-in but before any service accumulation, and at the completion of the durability. Emission tests can also be performed at intervals during the service accumulation test period, and applied in determining the deterioration trend.

1.1.1.2 The service accumulation tests or the emissions tests performed to determine deterioration must not be witnessed by the Test Agency.

1.1.1.3. Determination of DF values from durability tests An additive DF is defined as the value obtained by subtraction of the emission value determine at the beginning of the EDP, from the emissions value determined to represent the emission performance at the end of the EDP.

A multiplicative DF is defined as the emission level determined for the end of the EDP divided by the emission value recorded at the beginning of the EDP.

Separate DF values shall be established for each of the pollutants covered by the legislation. In the case of establishing a DF value relative to the NOx + HC standard, for an additive DF, this is determined based on the sum of the pollutants notwithstanding that a negative deterioration for one pollutant may not offset deterioration for the other. For a multiplicative NOx+HC DF, separate HC and NOx DFs shall be determined and applied separately when calculating the deteriorated emission levels from an emissions test result before combining the resultant deteriorated NOx and

HC values to establish compliance with the standard. In cases where the testing is not conducted for the full EDP, the emission values at the end of the EDP are determined by extrapolation of the emission deterioration trend established for the test period, to the full EDP.

When emissions test results have been recorded periodically during the service accumulation durability-testing, standard statistical processing techniques based on good practice shall be applied to determine the emission levels at the end of the EDP; statistical significance testing can be applied in the determination of the final emissions values.v If the calculation results in a value of less than 1,00 for a multiplicative DF, or less than 0,00 for an additive DF, then the DF shall be 1,0 or 0,00, respectively.

1.1.1.4 A manufacturer may, with the approval of the type Test Agency, use DF values established from results of durability tests conducted to obtain DF values for certification of on-road HD CI engines. This will be allowed if there is technological equivalency between the test on-road engine and the non-road engine families applying the DF values for certification. The DF values derived from on-road engine emission durability test results must be calculated on the basis of EDP values defined in clause 2.

1.1.1.5.In the case where an engine family uses established technology, an analysis based on good engineering practices may be used in lieu of testing to determine a deterioration factor for that engine family subject to approval of the type Test Agency.

1.2. DF information in approval applications

1.2.1. Additive DFs shall be specified for each pollutant in an engine family certification application for CI engines not using any after-treatment device.

1.2.2. Multiplicative DFs shall be specified for each pollutant in an engine family certification application for CI engines using an after-treatment device.

1.2.3. The manufacture shall furnish the type-approval agency on request with information to support the DF values.
This would typically include emission test results, service accumulation test schedule, and maintenance procedures together with information to support engineering judgments of technological equivalency, if applicable.

## 2.EMISSION DURABILITY PERIODS FOR Trem IIIA (Agricultural Tractor) ENGINES.

2.1. Manufacturers shall use the EDP in Table 1 of this section.

*Table 1: EDP categories for CI Trem IIIA (Agricultural Tractor) (hours)*

| Category (power band) | Useful life (hours)<br>(EDP) |
|---|---|
| <=19 kW | 3 000* |
| 19< kW <=37 (Constant speed) | 5 000 |

| | |
|---|---|
| > 37 kW | 8 000 |

*** In this case, if EDP declared by the manufacturer is less than 3000 hrs, whatever declared shall be considered for evaluation & the same shall be mentioned in the manufacturer's Sales & Service Manual.**

2.2 As an alternative to using a service accumulation schedule to determine deterioration factors, engine manufacturers may choose to use the following deterioration factors:

| CO | HC | NOx | PM |
|---|---|---|---|
| 1.1 | 1.05 | 1.05 | 1.1 |

## PART X – SUB PART (B): DETAILS OF STANDARDS OF VISIBLE AND GASEOUS POLLUTANTS FROM DIESEL ENGINES FOR CONSTRUCTION EQUIPMENT VEHICLES

Scope

This part applies to the emission of visible pollutants and gaseous pollutants from compression ignition (C.I.) engined construction equipment vehicle's Engines effective from 1st Oct. 2007, 1st Oct. 2008 & 1st April 2011 as per Central Motor Vehicle Rules 115 A and enforced as per the Government of India, Ministry of Shipping, Road Transport and Highways, Notification no. G.S.R 276 (E) dated 10th April 2007.

2. Type Approval

2.1 For the purpose of type approval and conformity of production certification, manufacturer's engine range shall be divided into model families, consisting of parent engine model and its variant and application for Type Approval shall be made in the proforma prescribed in AIS 007 Rev. 03 Table 15 & Annexure- I of Table 15, as amended by time to time.

2.2 The determination of an engine family and the decision regarding parent engine shall be based on Annexure - I to this Part. For the purpose of identification, the manufacturer shall designate the families as F1, F2, F3 ….. Fn.

2.3 The Testing agency shall decide the family, the parent model and its variants depending on the information provided by the manufacturer.

2.4 Testing of the parent model, shall, normally, be sufficient for type approval of the family. The Testing agency has the option to carry out the testing of more than one model in the family to satisfy itself, subject to parent engine-concept as per Annexure I.

2.5 At later stage if the manufacturer submits the application for type approval of a model, the Testing agency shall ascertain whether the model can be classified as belonging to a family of model(s) already certified.

If the model does not belong to a family already certified, the Testing agency shall proceed with the testing of the model for type approval.

If the model belongs to a family already certified, the Testing agency shall decide whether the specific testing of the model is required. In case the specific testing of the model is not required, the type approval certificate for the family may be extended to include the model.

2.6 The Testing agency shall intimate its decision to the applicant within a fortnight of receipt of the application, indicating need and plan (schedule) of testing for type approval.

2.7 MODIFICATIONS IN THE ENGINE MODEL

2.7.1 Every modification in the characteristics or parameters of the engine model, which has been declared by the manufacturer as per AIS 007 Rev. 03 Table 15 & Annexure I of Table 15, shall be intimated by the manufacturer to the Testing agency, which is responsible for carrying out TA & COP for that Model. The Testing agency may either

Consider that the engine with the modifications made may still comply with the requirements. In this case, the Testing agency shall extend the type approval covering the modified specifications.

or

Consider that the engine with the modifications made require a further test to ensure compliance. In this case, if the engine with the modifications complies with the requirements on testing as per part X of this document, the Testing agency shall extend the type approval.

2.8 The manufacturer shall submit an engine for testing, as intimated by the Testing agency.

2.9 Every manufacturer of construction equipment vehicle's Engine shall meet the following requirements for the model before granting the type approval.

2.9.3 Construction equipment vehicle's Engine shall comply with the standards for visible pollutants (smoke) emitted by it when tested as per the procedure described in Indian Standards IS: 12062 – 1987 and shall not exceed the limit values of 3.25 m-1 light absorption co-efficient (75 H.S.U.) when tested on engine dynamometer at 80% load at six equally spaced speeds between 55% of maximum power speed as declared by the manufacturer or 1000 rpm whichever is higher And Maximum Power speed as declared by the manufacturer.

2.9.4 The gross power of the engine i.e. without fan shall be tested as per procedure given in Part IV of MoRTH/CMVR/TAP-115/116 Issue No.3 on engine dynamometer.

When tested on engine dynamometer at steady speeds over the full load curve, may differ from the power declared by the manufacturer as follows:

For Type Approval:

For single cylinder engines, ±10% at maximum power speed including all other measured speeds.

For all other engines, ±5% at maximum power speed and all other measured speeds.

For Conformity of Production:

At maximum power speed by ±10% for single cylinder engines and +8% / -5% for all other engines.

2.9.3 Every diesel driven Construction equipment vehicle's Engine (type or family) shall be so manufactured and produced by its manufacturer that it complies with the following mass emission standards mentioned in table below, in addition to those of visible pollutants as mentioned above at clause 2.9.1 when tested as per the procedures described in ISO-8178 Part-4(1996) 'C1' 8 mode cycle for variable speed engines & ISO-8178 Part-4(1996) 'D2' 5-Mode cycle for constant speed engines.

| Bharat Stage II (CEV) | Applicable with effect from | CO | HC | NOx | PM |
|---|---|---|---|---|---|
| Category | | g/kWh | | | |
| KW < 8 | 1-Oct-2008 | 8.00 | 1.30 | 9.20 | 1.0 |
| 8 ≤ kW < 19 | 1-Oct-2008 | 6.60 | 1.30 | 9.20 | 0.85 |
| 19 ≤ kW < 37 | 1-Oct-2007 | 6.50 | 1.30 | 9.20 | 0.85 |

| | | | | | |
|---|---|---|---|---|---|
| 37 ≤ kW < 75 | 1-Oct-2007 | 6.50 | 1.30 | 9.20 | 0.85 |
| 75≤ kW < 130 | 1-Oct-2007 | 5.0 | 1.30 | 9.20 | 0.70 |
| 130≤ kW ≤ 560 | 1-Oct-2007 | 5.0 | 1.30 | 9.20 | 0.54 |

| Bharat Stage* III (CEV) | Applicable with effect from | CO | HC + NOx | PM |
|---|---|---|---|---|
| Category | | g/kWh | | |
| kW < 8 | 1-Apr-2011 | 8.0 | 7.5 | 0.80 |
| 8 ≤ kW < 19 | 1-Apr-2011 | 6.60 | 7.5 | 0.80 |
| 19 ≤ kW < 37 | 1-Apr-2011 | 5.50 | 7.50 | 0.60 |
| 37 ≤ kW < 75 | 1-Apr-2011 | 5.0 | 4.70 | 0.40 |
| 75 ≤ kW < 130 | 1-Apr-2011 | 5.0 | 4.0 | 0.30 |
| 130≤ kW ≤ 560 | 1-Apr-2011 | 3.50 | 4.0 | 0.20 |

** The limit values shall include deterioration-calculated in accordance with Annexure III.*

2.10 For mass emission test, procedure will be followed as per Part X of MoRTH/CMVR/TAP-115/116 except the following clauses:

(1) Engine will be subjected to mass emission in gross condition i.e. w/o fan but inclusive of intake and exhaust system or equivalent in test cells to simulate AID (Air Intake depression) & EBP (Exhaust Back Pressure) as specified by Engine manufacturer.

If the engine is equipped with an exhaust after-treatment device, the exhaust pipe shall have the same diameter as found in-use for at least four pipe diameters upstream to the inlet of the beginning of the expansion section containing the after-treatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust after-treatment device shall be the same as in the machine configuration or within the distance specifications of the manufacturer. The exhaust backpressure or restriction shall follow the same criteria as above, and may be set with a valve.

CEV Manufacturer & Engine Manufacturer shall declare Air Intake depression & Exhaust Back Pressure jointly for all vehicle models with same engine family. At the time of approval of vehicle model, AID & EBP shall be confirmed by Test Agency that they are within the declared specifications.

(2) Cycle will be as per ISO 8178 (1996) Part-4 ‘C1’ – 8 modes for variable speed engines & ISO-8178 (1996) Part-4 ‘D2’ 5 Modes for constant speed engines.

(3) Each mode-duration will be 10 min.

(4) Particulate may be collected by single filter or by multi filter methods.

(5) One Engine family covers more than one power band, the emission values of the parent engine (TA & COP) and of all engine types within the same family (TA & COP) must meet the more stringent requirements of the higher power band. The applicant has the free choice to restrict the definition of engine families to single power bands, and to correspondingly apply for certification.

(6) Periodicity of COP:
For equipment with annual production upto 200 nos., it shall be once in two years per family.
For equipment with annual production exceeding 200 nos., it shall be once in every year per family.

(7) Test fuel shall be reference fuel as per B.S.-II (enclosed as Annexure- II (a)) (with sulphur content of less than 500 ppm) for Bharat Stage II (CEV) and as per B.S. – III (enclosed as Annexure-II(b)) (with sulphur content of less than 300 ppm) for Bharat Stage III (CEV)

**3 Conformity of Production:**

3.3 Every produced vehicle's Engine of the model approved under this rule shall conform with regard to components affecting the emission of gaseous pollutants by the engine to the vehicle model type approved. The procedure for carrying out conformity of production test is given in Part VI of this document.

3.4 For verifying the conformity of the engine in a test, the following procedure is adopted: -

3.2.1 An engine is taken from the series is subjected to the mass emission test.

3.2.1.1 If the engine taken from the series does not satisfy the requirements of Paragraph 2.9.1 &2.9.2 above, two more engines are tested in the same way and if the Gross Power figure does not fulfill the requirements of 2.9.1 & 2.9.2, the production shall be considered not to conform the requirements of regulations.

3.2.1.2 If the engine taken from the series does not satisfy the requirements of Paragraph 2.9.3 above, the manufacturer may ask for measurements to be performed on a sample of engines taken from the series and including the engine originally taken. The Manufacturer shall specify the size n of the sample subject to n being minimum 2 and maximum 10, including the engine originally taken. The engines other than originally-tested shall be subjected to a test. The arithmetical mean ($\bar{x}$) of the results obtained from the sample shall be determined for each pollutant .The production of the series shall then be deemed to conform if the following condition is met: -

$$\bar{x} + k*S \leq L$$

Where: -

$S^2 = \sum (x_i - x)^2 / (n-1)$

S = Standard Deviation

$x_i$ = any one of the individual results obtained with the sample n.

L = the limit value laid down in Paragraph 2.9.3 for each gaseous pollutant considered and

k = a statistical factor depending on ‘n’ and given in the following table :-

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| N | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| K | 0.973 | 0.613 | 0.489 | 0.421 | 0.376 | 0.342 | 0.317 | 0.296 | 0.279 |

## ANNEXURE I

PARAMETERS DEFINING THE ENGINE FAMILY

The engine family may be defined by basic design parameters, which must be common to engines within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only engines with similar exhaust emission characteristics are included within an engine family.

In order that engines may be considered to belong to the same engine family, the following list of basic parameters must be common:

Combustion cycle:

- 2 cycle
- 4 cycle

Cooling medium:

- air
- water
- oil

Individual cylinder displacement:

- engines to be within a total spread of 15 %
- number of cylinders for engines with after-treatment device

Method of air aspiration:

- naturally aspirated
- pressure charged

Combustion chamber type/design:

- pre-chamber
- swirl chamber
- open chamber

Valve and porting - configuration, size and number:

- cylinder head
- cylinder wall
- crankcase

Fuel system:

- pump-line-injector
- in-line pump
- distributor pump
- single element
- unit injector
- common rail direct injection

Miscellaneous features:

- exhaust gas recirculation

- water injection/emulsion
- air injection
- charge cooling system

Exhaust after-treatment

- oxidation catalyst
- reduction catalyst
- thermal reactor
- particulates trap

**CHOICE OF THE PARENT ENGINE**

Gaseous & Particulate Emission test data of every engine type may be provided by manufacturer & based on the test results & also the following guidelines test agency shall decide parent engine.

The parent engine of the family shall be selected using the primary criteria of the highest fuel delivery per stroke at the declared maximum torque speed. In the event that two or more engines share this primary criterion, the parent engine shall be selected using the secondary criteria of highest fuel delivery per stroke at rated speed. Under certain circumstances, the approval authority may conclude that the worst-case emission rate of the family can best be characterized by testing a second engine. Thus, the approval authority may select an engine for test, based upon following additional features

k) An engine whose injection control is not dependent on speed;
l) An engine whose injection control is not dependent on load;
m) An engine with the lowest maximum injection pressure.
n) An engine with the highest charge air temperature at the inlet to the cylinder;
o) An engine with lowest charge air pressure at the inlet to the cylinder;
p) An engine with the least number of cylinders;
q) An engine with lowest rated power at rated speed;
r) An engine with lowest rated speed;
s) An engine with the lowest low idle speed;
t) An engine with the least number of injection points.

Which indicate that it may have the highest emission levels of the engines within that family.

If engines within the family incorporate other variable features, which could be considered to affect exhaust emissions, these features must also be identified and taken into account in the selection of the parent engine.

## ANNEXURE II(A)

## DIESEL FUEL SPECIFICATIONS for BSII (CEV)

| | Minimum | Maximum | Test Method |
|---|---|---|---|
| Cetane Number | 49 | 53 | ISO 5165 |
| Density at 15°C (kg/m$^3$) | 835 | 845 | ISO 3675<br>ASTM D 4052 |
| **Distillation : in °C** | | | |
| 50% point | 245 | | ISO 3405 |
| 90% point | 320 | 340 | |
| Final boiling point | -- | 370 | |
| Flash point (°C) | 55 | | ISO 2719 |
| CFPP (°C) | -- | (-) 5 | EN116(CEN) |
| Viscosity at 40°C | 2.5 mm²/s | 3.5 mm²/s | ISO 3104 |
| Sulphur Content (% mass) | to be reported | 0.05 | ISO 8754, EN24260 |
| Copper Corrosion at 50°C | | 1 | ISO 2160 |
| Conradson carbon residue<br>10% DR ) (% mass) | | 0.2 | ISO 10370 |
| Ash Content % mass | | 0.01 | ASTM D 482 |
| Water Content % mass | | 0.05 | ASTM D95 / D1744 |
| Neutralisation (strong acid) No. | | 0.2 mg/koh/g | --- |
| Oxidation Stability (mg/100 ml) | | 2.5 | ASTM D2274 |

## ANNEXURE II(B)

## DIESEL FUEL SPECIFICATIONS for BSIII (CEV)

| | Minimum | Maximum | Test Method |
|---|---|---|---|
| Cetane Number | 52 | 54 | EN-ISO 5165 |
| Density at 15°C (kg/m$^3$) | 833 | 837 | EN-ISO 3675 |
| **Distillation : in °C** | | | |
| 50% point (°C) | 245 | --- | |
| 95% point (°C) | 345 | 350 | EN-ISO 3405 |
| Final boiling point (°C) | -- | 370 | |
| Flash point (°C) | 55 | --- | EN 22719 |
| CFPP (°C) | -- | (-) 5 | EN 116 |
| Viscosity at 40°C (mm$^2$/s) | 2.5 | 3.5 | EN-ISO 3104 |
| Polycyclic aromatic hydrocarbons (% m/m) | 3.0 | 6.0 | IP 391 |
| Sulphur Content (mg/kg) | --- | 300 | ASTM D 5453 |
| Copper Corrosion | --- | Class 1 | EN-ISO 2160 |
| Conradson carbon residue ( 10% DR ) (% m/m) | --- | 0.2 | EN-ISO 10370 |
| Ash Content (% m/m) | --- | 0.01 | EN-ISO 6245 |
| Water Content (% m/m) | --- | 0.05 | EN-ISO 12937 |
| Neutralisation (strong acid) No. (mg KOH/g) | --- | 0.02 | ASTM D 974 |
| Oxidation Stability (mg/ml) | --- | 0.025 | EN-ISO 12205 |

## ANNEXURE III

DURABILITY REQUIREMENTS

1. **EMISSION DURABILITY PERIOD AND DETERIORATION FACTORS**.

This appendix shall apply to CI engines Bharat Stage III (CEV) only.

1.1. Manufacturers shall determine a Deterioration Factor (DF) value for each regulated pollutant for all Stage III engine families. Such DFs shall be used for type approval and Conformity Of Production Testing.

1.1.1. Test to establish DFs shall be conducted as follows:

1.1.1.1. The manufacturer shall conduct durability tests to accumulate engine operating hours according to a test schedule that is selected on the basis of good engineering judgement to be representative of in-use engine operation in respect to characterising emission performance deterioration. The durability test period should typically represent the equivalent of at least one quarter of the Emission Durability Period (EDP).

Service accumulation operating hours may be acquired through running engines on a dynamometer test bed or from actual in-field machine operation. Accelerated durability tests can be applied whereby the service accumulation test schedule is performed at a higher load factor than typically experienced in the field. The acceleration factor relating the number of engine durability test hours to the equivalent number of EDP hours shall be determined by the engine manufacturer based on good engineering judgement. During the period of the durability test, no emission sensitive components can be serviced or replaced other than to the routine service schedule recommended by the manufacturer.

The test engine, subsystems, or components to be used to determine exhaust emission DFs for an engine family, or for engine families of equivalent emission control system technology, shall be selected by the engine manufacturer on the basis of good engineering judgement. The criterion is that the test engine should represent the emission deterioration characteristic of the engine families that will apply the resulting DF values for certification approval. Engines of different bore and stroke, different configuration, different air management systems, different fuel systems can be considered as equivalent in respect to emissions deterioration characteristics if there is a reasonable technical basis for such determination.

DF values from another manufacturer can be applied if there is a reasonable basis for considering technology equivalence with respect to emissions deterioration, and evidence that the tests have been carried according to the specified requirements.

Emissions testing will be performed according to the procedures defined in this Document for the test engine after initial run-in but before any service accumulation, and at the completion of the durability. Emission tests can also be performed at intervals during the service accumulation test period, and applied in determining the deterioration trend.

1.1.1.2 The service accumulation tests or the emissions tests performed to determine deterioration must not be witnessed by the Test Agency.

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1.1.1.3. Determination of DF values from durability tests An additive DF is defined as the value obtained by subtraction of the emission value determine at the beginning of the EDP, from the emissions value determined to represent the emission performance at the end of the EDP.

A multiplicative DF is defined as the emission level determined for the end of the EDP divided by the emission value recorded at the beginning of the EDP.

Separate DF values shall be established for each of the pollutants covered by the legislation. In the case of establishing a DF value relative to the NOx + HC standard, for an additive DF, this is determined based on the sum of the pollutants notwithstanding that a negative deterioration for one pollutant may not offset deterioration for the other. For a multiplicative NOx+HC DF, separate HC and NOx DFs shall be determined and applied separately when calculating the deteriorated emission levels from an emissions test result before combining the resultant deteriorated NOx and HC values to establish compliance with the standard.

In cases where the testing is not conducted for the full EDP, the emission values at the end of the EDP are determined by extrapolation of the emission deterioration trend established for the test period, to the full EDP.

When emissions test results have been recorded periodically during the service accumulation durability-testing, standard statistical processing techniques based on good practice shall be applied to determine the emission levels at the end of the EDP; statistical significance testing can be applied in the determination of the final emissions values.

If the calculation results in a value of less than 1,00 for a multiplicative DF, or less than 0,00 for an additive DF, then the DF shall be 1,0 or 0,00, respectively.

1.1.1.4 A manufacturer may, with the approval of the type Test Agency, use DF values established from results of durability tests conducted to obtain DF values for certification of on-road HD CI engines. This will be allowed if there is technological equivalency between the test on-road engine and the non-road engine families applying the DF values for certification. The DF values derived from on-road engine emission durability test results must be calculated on the basis of EDP values defined in clause 2.

1.1.1.5. In the case where an engine family uses established technology, an analysis based on good engineering practices may be used in lieu of testing to determine a deterioration factor for that engine family subject to approval of the type Test Agency.

1.2. DF information in approval applications

1.2.1. Additive DFs shall be specified for each pollutant in an engine family certification application for CI engines not using any after-treatment device.

1.2.2. Multiplicative DFs shall be specified for each pollutant in an engine family certification application for CI engines using an after-treatment device.

1.2.3. The manufacture shall furnish the type-approval agency on request with information to support the DF values.

This would typically include emission test results, service accumulation test schedule, and maintenance procedures together with information to support engineering judgments of technological equivalency, if applicable.

2. EMISSION DURABILITY PERIODS FOR BHARAT STAGE III (CEV) ENGINES.

2.1. Manufacturers shall use the EDP in Table 1 of this section.

*Table 1: EDP categories for CI Bharat Stage III (CEV) (hours)*

| Category (power band) | Useful life (hours) |
|---|---|
| | (EDP) |
| <=19 kW | 3 000* |
| 19< kW <=37 (Constant speed) | 3 000 |
| 19< kW <=37 (Variable speed) | 5 000 |
| > 37 kW | 8 000 |

*** In this case, if EDP declared by the manufacturer is less than 3000 hrs, whatever declared shall be considered for evaluation & the same shall be mentioned in the manufacturer's Sales & Service Manual.**

2.2 As an alternative to using a service accumulation schedule to determine deterioration factors, engine manufacturers may choose to use the following deterioration factors:

| CO | HC | NOx | PM |
|---|---|---|---|
| 1.1 | 1.05 | 1.05 | 1.1 |