Part XIII : 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

Chapter 1

OVERALL REQUIREMENTS

1. Scope

1.1 This Part applies to the tailpipe emission of **2/3 wheelers** vehicles equipped with spark ignition engines (Petrol, CNG, LPG) and compression ignition engines (Diesel) **for Bharat Stage III with effect from 1st April 2010.**

1.1.1 Refer Part XIV, Chapter 16 for tailpipe emission of Hybrid Electric Vehicles.

1.2 This Part should be read in conjunction with the applicable Gazette Notification under CMVR 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 semiautomatic 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 the exhaust gas emissions of carbon monoxide, oxides of nitrogen, expressed in nitrogen dioxide (NO2) equivalent, and hydrocarbons assuming a ratio of:

- $C_1H_{1.85}$ for petrol,
- $C_1H_{1.86}$ for diesel,
- $C_1H_{2.525}$ for LPG,
- CH_4 for NG.

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 Two wheeled vehicles and by a uniform figure of 150 kg for Three Wheeled vehicle.

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 tail pipe 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 this Part shall be carried out, without interruption. Vehicles that are fuelled with LPG or NG shall be tested in the type I test for variations in the composition of LPG or NG, as set out in notification, vehicles that can be fuelled either with LPG or NG to be tested for Fuel A & Fuel B in case of LPG and G20 & G25 in case of NG.
Until availability of reference LPG (fuel A & fuel B), CNG(G20,G25)) as per notification, CNG/LPG vehicles will be tested as per commercially available CNG/LPG fuels as per guidelines given by GOI.

5.2.2.3 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 (NOX), 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.

5.2.2.4 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 and to remove and weigh the particulates shall be as prescribed.

5.2.2.5 Subject to the provisions of the paragraphs 5.2.2.7 & 5.2.2.8, the test shall be repeated three times, the test results shall be multiplied by appropriate deterioration factors as *notified in CMVR.* 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.

5.2.2.6 Type Approval Mass Emission Standards for Type I test:

5.2.2.6.1 Mass emission standards for vehicles (2&3 wheelers) manufactured on and from 1st April 2010 (Bharat Stage III norms) shall be as per the details given in Rule no. 115(Sub Rule 14) (F) 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).

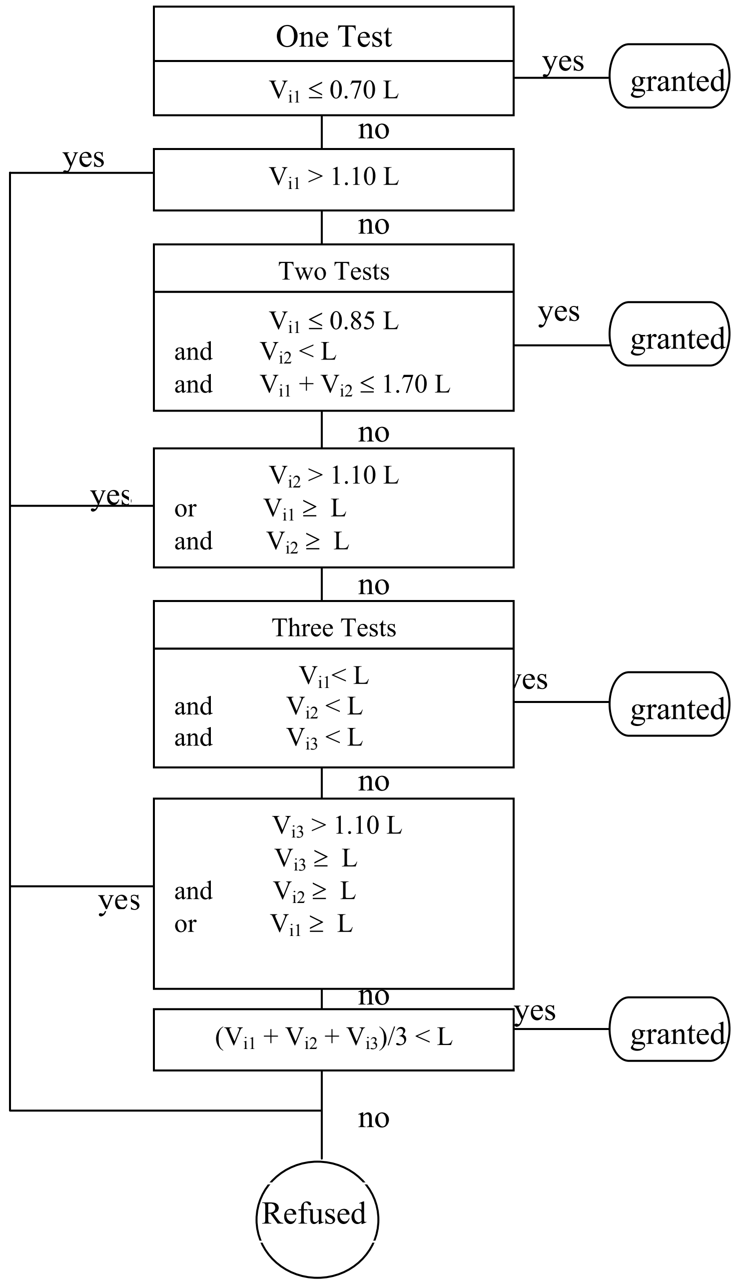
5.2.2.7 Nevertheless, for each of the pollutants or combination of pollutants one of the three results obtained may exceed by not more than 10% of the applicable limits prescribed for the vehicle concerned, provided the arithmetical mean of the three results is not exceeding the prescribed limit. Where the prescribed limits are exceeded for more than one pollutant or combination of pollutants, it shall be immaterial whether this occurs in the same test or in different tests.

5.2.2.8 The number of tests prescribed in Para 5.2.2.7 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 5.2.2.5 above.

5.2.2.8.1 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 + NOx) is less than or equal to 0.7 L i.e. $V_1 \leq 0.70$ L.

5.2.2.8.2 If the requirements of 5.2.2.8.1 is not satisfied, only two tests are performed if for each pollutant 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 $V_1 + V_2 \leq 1.7$ L and $V_2 < L$.

Fig.1 **Depicts the scheme. Figure 1 : Flow Sheet for the Type Approval Test as per Bharat Stage III for 2/3 wheeler.**



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

5.2.3.1 This is applicable only for spark ignition engined vehicles

5.2.3.2 The carbon monoxide and Hydrocarbons content by volume of the exhaust gases emitted with the engine idling must not exceed as per the limits mentioned in 4.1 of Part I of this document.

5.2.4 Type III test (durability of anti-pollution devices)

The requirement of durability must be compiled on all vehicles referred to in para 1.1 of this Chapter. This may be established by using the deterioration factor notified in CMVR or by carrying out the durability test. The test represents an ageing test of 30000 km for 2& 3 wheelers, driven in accordance with the program described in chapter 10, on a test track, on the road or on a chassis dynamometer.

5.2.4.1 For all type of 2/3 Wheeler a deterioration factor as notified in Notification is applicable. OR
The vehicle manufacturer may opt for an ageing test of 30000 km for 2/3 wheelers for evaluation deterioration factor as described in chapter **10**.

5.2.4.2 At the request of the manufacturer, the testing agency may carry out the Type I test before Type **III** test has been completed using the deterioration factors given in Notification. On completion of Type **III** test, the testing agency may then amend the type-approval results recorded in the Notification with those measured in type **III** test.

5.2.4.3 Deterioration factor are determined using either procedure in chapter **10** or using the values in the notifications at the option of manufacturer. The factors are used to establish compliance with the requirements of 5.2.2.5 and 8.2

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 (Type I & Type II test) :

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 one higher or any lower equivalent inertia, for 2&3 wheelers.

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**

7.3.1 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.

7.6 Durability of anti-pollution devices (Type III test)

7.6.1 Approval granted to a vehicle type may be extended to different vehicle types, provided that the engine/pollution control system combination is identical to that of the vehicle already approved. To this end, those vehicle types whose parameters described below are identical or remain within the limit values prescribed are considered to belong to the same engine/pollution control system combination.

7.6.1.1 Engine:

- number of cylinders,
- engine capacity (± 15%)
- configuration of the cylinder block,
- number of valves,
- fuel system
- type of cooling system
- combustion process
- cylinder bore center to center dimensions

7.6.1.2 Pollution control system :

- Catalytic Converters:
    - o Number of catalytic converters and elements
    - o Size and shape of catalytic converters (volume of monolith ± 10%),
    - o Type of catalytic activity (oxidizing, three-way)
    - o Precious metal load (identical or higher),
    - o Precious metal ratio (+/-15%)
    - o Substrate (structure and material),
    - o Cell density,
    - o Type of casing for the catalytic converter(s),
    - o Location of catalytic converters (position and dimension in the exhaust system, that does not produce a temperature variation of more than 50 K at the inlet of the catalytic converter). This temperature variation shall be checked under stabilized conditions at a speed 42 km/h for 2 & 3 wheelers and the load setting of type I test.
- Air injection :
    - o With or without
    - o Type (pulsair, air pumps....)
- EGR:
    - o With or without
-

7.6.1.3 Inertia category : The two inertia categories immediately above and any inertia category below.

7.6.1.4 The durability test may be achieved by using a vehicle, the body style, gear box (automatic or manual) and size of the wheels or tyres of which are different from those of the vehicle type for which the type approval is sought.

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 as per Option1 is adopted.

8.2.1 To verify the average tailpipe emissions of gaseous pollutants of low volume vehicles with Annual production less than 250 per 6 months, manufacture can choose from the Option 1 or Option 2 as listed below:

8.3 Option 1

8.3.1 The vehicle samples taken from the series, as described in 8.1 is subjected to the single test described in para 5.2.2 above. The results shall be multiplied by the deterioration factors used at the time of type approval. 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.

8.3.2 Procedure for Conformity of Production as per Bharat Stage-III for 2/3 wheeler vehicles

8.3.2.1 Conformity of production shall be verified as per Bharat Stage-III emission norms for 2/3 wheeler vehicles as given in para 5.2.2.6.1 and with the procedure given below.

8.3.2.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted

8.3.2.3 Minimum of three vehicles shall be selected randomly from the series with a sample lot size as defined in part VI of MoSRTH/CMVR^TAP-115/116.

8.3.2.4 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in Part VI.

8.3.2.5 All three randomly selected vehicles shall be tested for a Type -1 test as per Para 5.2.2 of chapter 1 of this part.

8.3.2.6 Let XM, X i2 &X i3 are the test results for the Sample No.1, 2 & 3.

8.3.2.7 If the natural Logarithms of the measurements in the series are X1,X2,X3...........Xj and Li is the natural logarithm of the limit value for the pollutant, then define :

$$d_j = X_j - L_i$$

$$\overline{d}_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n}(d_j - \overline{d_n})^2$$

8.3.2.8 Table I of Chapter 1 of this part shows values of the pass (An) and fail (Bn) decision numbers against current sample number. The test statistic is the ratio *dn I* Vn and must be used to determine whether the series has passed or failed as follows :

- Pass the series, if *dn* /Vn < An for all the pollutants
- Fail the series if *dn* /Vn > Bn for any one of the pollutants.
- Increase the sample size by one, if An < *dn* /Vn < Bn 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.

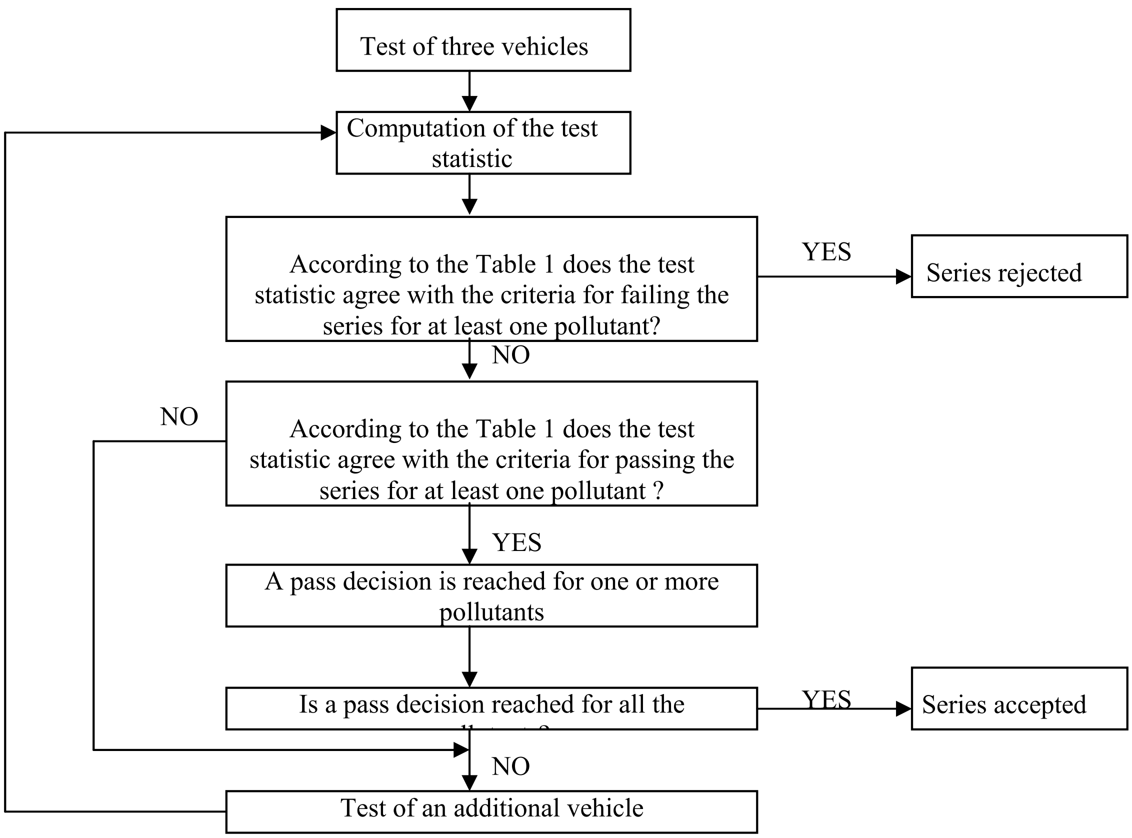


Figure 2 :

Option I : COP Test Procedure as per Bharat Stage III for 2/3 wheeler

Table I : Applicable for COP Procedure as per Bharat Stage III for 2/3 wheelers

Sample size (n)	Pass decision threshold (A_n)	Fail decision threshold (B_n)
3	-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

8.4 Option 2

8.4.1 Minimum of three vehicles shall be selected randomly from the series with a sample lot size.

8.4.2 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in Part VI. MoRTH/CMVR/TAP-115/116

8.4.3 First vehicle out of three randomly selected vehicles shall be tested for Type - I test as per MoRTH/CMVR/TAP-115/116 Para 5.2.2 of chapter 1.

8.4.4 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)

8.4.5 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.

8.4.6 Third Type - I (V_3) test shall be performed if the para 4.11 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. $(V_1 + V_2 + V_3)/3 \leq L$)

8.4.7 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

8.4.8 These randomly selected sample No.2 & 3 shall be tested for only one Type - I test as per para 5.2.2. of Part 09, Chapter 1 of MoRTH/CMVR/TAP-115/116.

8.4.9 Let X i2 & X i3 are the test results for the Sample No.2 & 3 and Xi1 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

8.4.10 If the natural Logarithms of the measurements in the series are X1,X2,X3...........Xj and Li is the natural logarithm of the limit value for the pollutant, then define :

$$dj = Xj - Li$$

$$d_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^{\,2} = \frac{1}{n}\sum_{j=1}^{n}(d_j - \overline{d_n})^2$$

8.4.11 Table I of this part shows values of the pass (An) and fail (Bn) 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, $\overline{d}_n / V_n \geq A_n$ for all the pollutants-
- Fail the series $\overline{d}_n / V_n \geq B_n$ 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.

8.4.12 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.-

8.4.13 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.

8.5 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.

8.6 Type II Test : Carbon-monoxide and Hydrocarbons emission at idling speed When the vehicle taken from the series for the first 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 and hydrocarbon 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. These vehicles can be same as those selected for carrying out Type I test. Additional vehicles if required, shall be selected for carrying out for Type II test. At least 9 vehicles should meet the limit values specified in para 5.2.3.2 above. Then the series is deemed to conform.

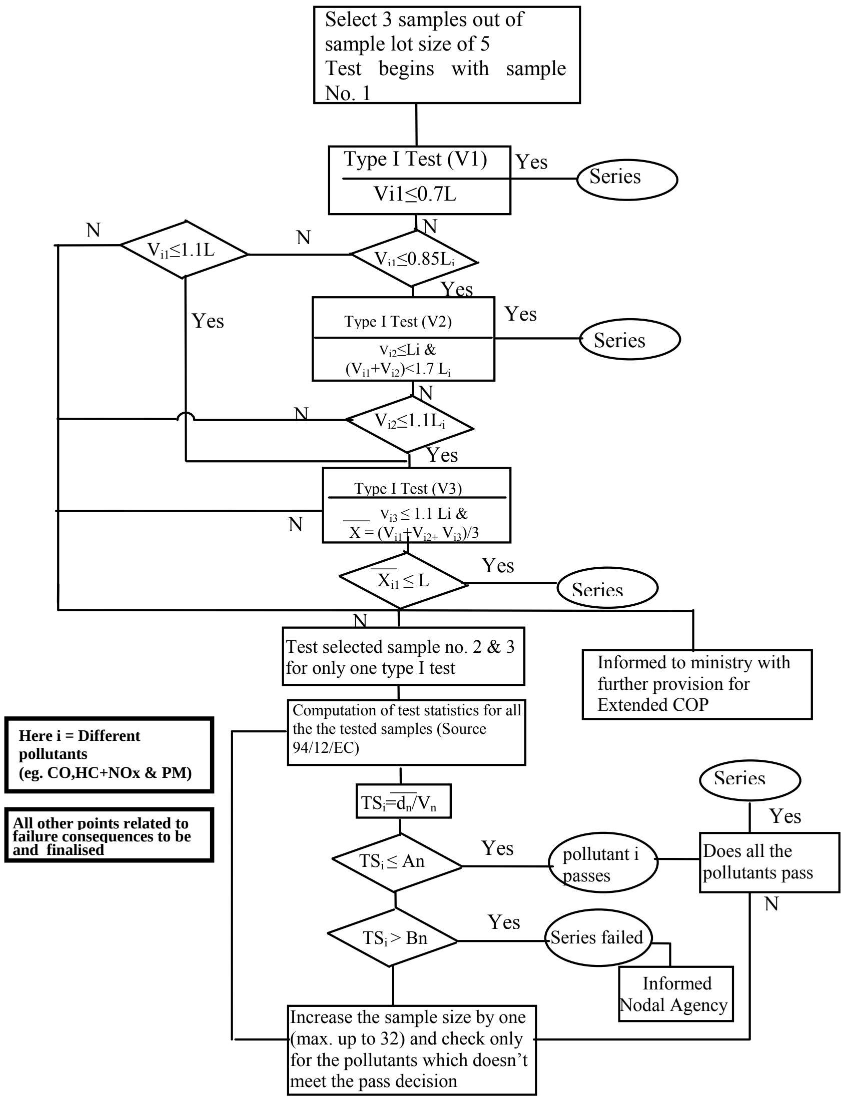


Figure 3
OPTION II : COP Test Procedure as per Bharat Stage III for 2& 3 Wheelers

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 as amended from time to time

Chapter 3

TYPE I TEST ON S.I. ENGINES, CNG, LPG AND DIESEL ENGINED VEHICLE (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 applicable Gazette Notification under CMVR 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 2.1.1 and 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 breakdown by operations is given in Table II 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.

2.2.1 Use of the Gear Box : The use of the gearbox in case of testing two and three wheelers on chassis dynamometer shall be in accordance with Para 2.2.2 of this Chapter.

2.2.2 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.:

2.2.2.1 Manual Change Gear Box :

2.2.2.1.1 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.

2.2.2.1.2 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.

2.2.2.1.3 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.

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

2.2.2.1.5 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.

2.2.2.2 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 **Tolerances**

2.3.1 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.

2.3.2 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.

2.3.3 The speed and time tolerances shall be combined as indicated in Figure 2 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 at least 250 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. Until availability of reference LPG (Fuel A & Fuel B), CNG (G20, G25) as per Notification, CNG, LPG vehicles will be tested as per commercially available CNG/LPG fuels as per guidelines given GOI.

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 & 3 wheelers.

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 percent.

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 50, 40, 30 km/h and 10 percent 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 3 -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 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. 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 5, 6, and 7 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 carton 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 (C1).

4.3.1.4 Nitrogen oxide (NOx) analysis. The nitrogen oxide analyser shall be of the Chemiluminescent (CLA) type with an NOx-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 ug and readability of 1 ug.

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 byintegration. 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 (Fh) 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 4s.

4.3.2.3.1 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.

4.3.2.4 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 temperature 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.

4.3.2.5 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.

The temperature of the chamber (or room) in which particulate filters are conditioned and weighted shall be maintained to within 295 +/-3°K(22°C +/-3°C) during all filter conditioning and weighing. The humidity shall be maintained to a dew point of 282-3 °K +/-3°K (9.5°C +/- 3°C) and a relative humidity of 45%+/-8%.

4.3.2.6 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 stabilized filter is placed and kept in a sealed filter holder assembly with the ends plugged, or

A stabilized 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 analyzer 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 analyzers 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 utilize 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_3H_8 and purified synthetic air, as in para 4.5.1 above

-CO and purified nitrogen, as in para 4.5.1 above
-CO_2 and purified nitrogen, as in para 4.5.1 above
-NO and purified nitrogen, as in para 4.5.1 above (The amount of NO2 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.

5.2.2 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 2 (m/sec)	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

BREAK DOWN OF THE OPERATING CYCLE USED FOR THE TYPE I TEST (Please ref. para. 2.1.1)

TABLE II

A: BREAK DOWN BY PHASES

Sr. No.	Particulars	Time(s)	Percentage
1	Idling	1-6	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		
Reference Mass of Vehicle RW (kg)		Equivalent Inertia (kg.)
Exceeding	Upto	
	105	100
105	115	110
115	125	120
125	135	130
135	150	140
150	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	480	450

480	540	510
540	600	570
600	650	620
650	710	680
710	770	740
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

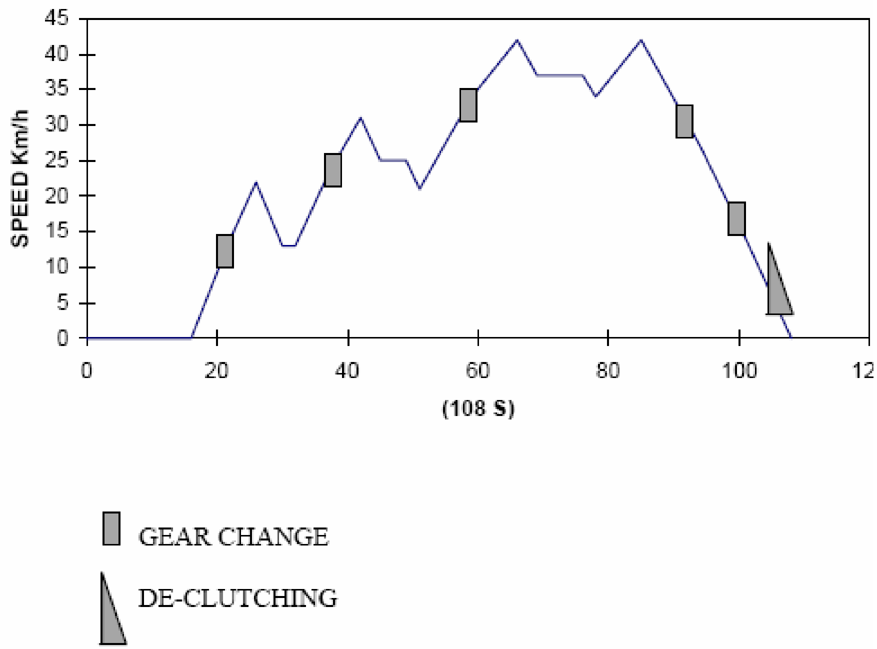
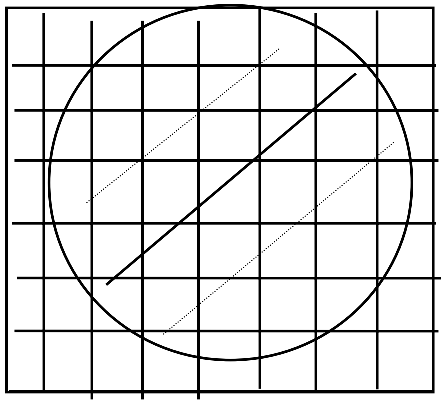


Fig 1 : OPERATING CYCLE WITH RECOMMENDED GEAR POSITION
(Pl. ref. para 2.3.1.1.5)



SPEED AND TIME TOLERANCES

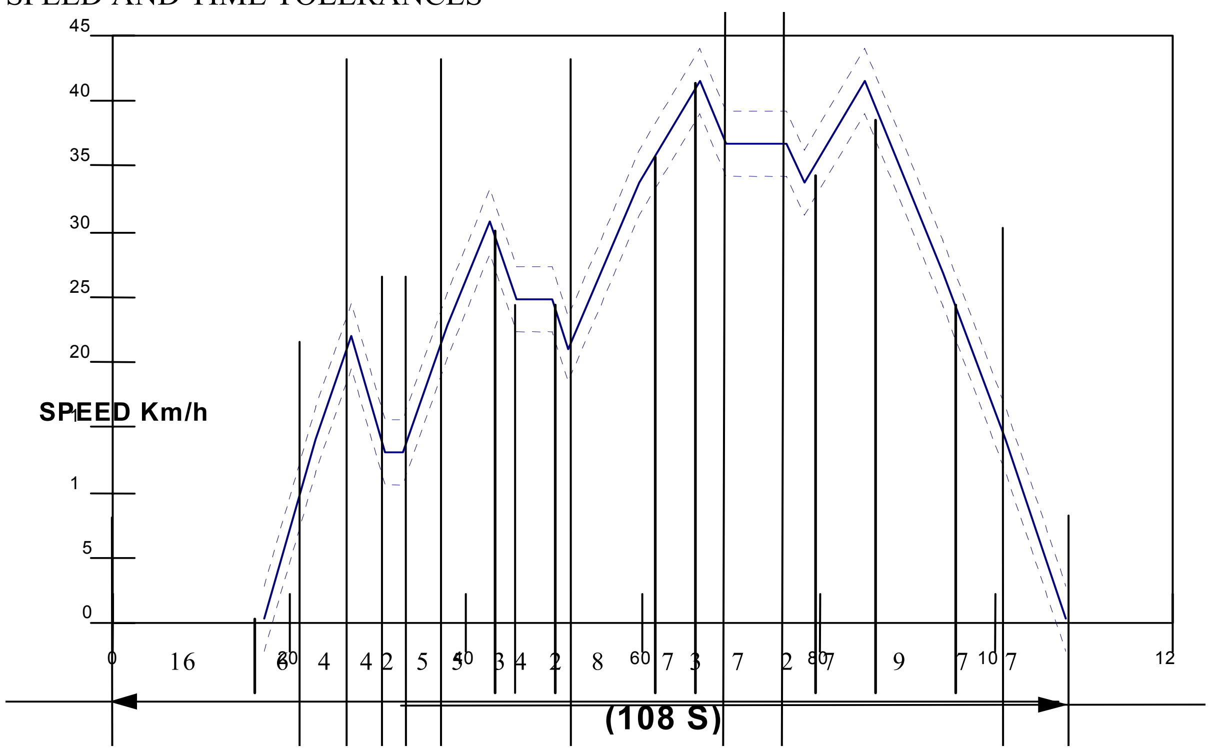


Fig 2: Operating cycle with speed and time tolerances
(Pl. ref. para 2.1.1)

5.3 Preconditioning of the vehicle :

5.3.1 For the compression ignition engine vehicles for the purpose of measuring particulates at most 36 hours and at least 6 hours before testing, Table 1 for 3 wheeler vehicles shall be used. 6 consecutive cycles for 3 wheelers shall be driven. The dynamometer setting shall be as per 5.1 and 5.2 above

5.3.2 After this preconditioning specific for compression ignition engines 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 at least 6 hours and continue until the engine oil temperature, or coolant temp, or in case or in case of air cooled engines spark plug/gasket temp, equal to the +/- 2K of the air temp, of soak area room.

5.3.3 Soaking period will be from 6 to 30 hours.

5.3.4 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: $5.5 \leq H \leq 12.2$ gH_2O/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 The blower speed shall be such that, within the operating range of 10 km/h to at least up 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 m2 and the bottom of the blower outlet shall be between 15 and 20 cm above floor level. The distance from front end of the vehicle is appox. 30 cm to 45 cm.

6.1.4.2 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. At the request of the manufacturer for special vehicles (e.g Van, Off road) the height of the cooling fan can be modified.

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 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. Diesel two and three wheelers shall be run with 40 seconds idling before sampling on chassis dynamometer.

6.2.2.2 The engine shall be kept idling for 40 seconds, in the case of two and three wheelers. During the idling phase, the operator may use choke, throttling etc., where necessary to keep the engine running. In the case of two and three wheelers with spark ignition engine, immediately after the end of the 40 seconds of idling period the number of complete preparatory cycles specified in para 6.2.2.1 are affected without collecting exhaust gases. The test cycle shall begin immediately after this.

6.2.2.3 If during the start, the vehicle does not start after 10 seconds of cranking, or ten operations of manual starting mechanism, cranking shall cease and the reason for failure to start shall be determined.

6.2.2.4 The corrective action for this, including those caused by the vehicle malfunction, if it is of less than 30 minutes duration, may be taken and test continued. If the failure to start is caused by vehicle malfunction and the vehicle can not be started, the test shall be cancelled, the vehicle removed from the dynamometer, corrective action taken and the vehicle rescheduled for test (Refer para 5.3.3 above). The reason for malfunction (if determined) and the corrective action taken shall be reported.

6.2.2.5 If the engine stalls during 40 seconds of idling and where applicable during the preparatory cycles, the engine shall be restarted immediately and test continued. If the vehicle does not restart within a minute, the test shall be cancelled, the vehicle rescheduled for the test (refer para 5.3.3 above). The reason for malfunction, (if determined) and the corrective action taken shall be reported.

6.2.2.6 If the engine stalls during some operating mode other than idle/preparatory cycles, the driving schedule indicator and gas sampling shall be stopped, the vehicle shall then be restarted and accelerated to the speed required at the point in driving schedule and the test and the gas sampling continued. During the acceleration upto this point, gear shifting shall be performed as per para 2.3 of this chapter.

6.2.2.7 If the vehicle does not restart within one minute, the test shall be canceled, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for test (refer para 5.3.3 above).

6.2.2.8 The reason for the malfunction (if determined) and the corrective action taken shall be indicated in the test report.

6.2.2.9 During corrective action referred to the paragraphs 6.2.2.4, 6.2.2.5 and 6.2.2.8 above, adjustments and setting only within the limits specified by the manufacturer shall be permitted. Changes outside the limits specified shall be governed by the applicable procedure given in Part VI.

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 IDC for 2&3 wheelers.

6.3.1.3 For 2 & 3 wheelers 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 6.4.3 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 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.

6.5.2 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

6.6 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 tenth cycle as defined in para

2.1.1 of this Chapter In the case of diesel three wheelers the sampling shall begin at the end of 40 seconds of idling after initiation of the engine start up.

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 ($CH_{1.85}$):
    - for petrol ($CH_{1.85}$) d = 0.5768 Kg/ m^3
    - for diesel ($CH_{1.86}$) d = 0.5768 Kg/ m^3
    - for LPG ($CH_{2.525}$) d = 0.6047 Kg/ m^3
    - for CNG (CH_4) d = 0.665 Kg/ m^3
- in the case of nitrogen oxides (NO_x): d = 1.913 kg/ m^3.
- in the case of Carbon Dioxides (CO_2): d = 1.830 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, 'm1' by the first filter, 'm2' by the second filter.

- if $0.95 (m1 + m2) \leq m1$, $m = m1$,
- if $0.95 (m1 + m2) > m1$, $m = m1 + m2$,
- if $m2 > m1$, 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.

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 4.1.7.1 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.

5.1.1.3 Measure the time taken (t1)for the vehicle to decelerate from $V_2 = V + \Delta V$ km/h to $V_1 = V - \Delta V$ km/h : with $V \leq 5$ km/h

5.1.1.4 Perform the same test in the opposite direction : t_2

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

5.1.1.6 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% ($p \leq 2\%$)

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 Chapters 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 is the average

$$C_{t1} = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} C(t) dt$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. Ct.

5.2.1.2.5 Determine the average of these torques Ct and Ct2 i.e Ct.

5.2.2 On the chassis dynamometer

5.2.2.1 Measurement equipment and errorThe 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 :

$$\bar{M} = \frac{1}{t_1 - t_2} \int_{t_1}^{t_2} M(t) * dt \quad \text{(with M(t) > 0)}$$

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 M (dynamometer) does not match 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 (a1).

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 -y2

5.4.1.2.5 Calculate the average deceleration i.e.

$$\gamma_i = \frac{\gamma_1 + \gamma_2}{2} \text{ for test I.}$$

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

5.4.1.1.1 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

$F_{total} = F_{road}$

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

where : F indicated is the force indicated on the force indicating device of the chassis dynamometer. F(road) is known.

33F 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 dynamometer at the test speed; the rolling resistance, RR, 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 RR value is the one which is determined before on the road.

For the single-roller chassis dynamometer, the RR 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 : RR 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.

5.4.1.3.6 perform the same operation as in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.
5.4.1.3.7 Set the force, FA = F - FR 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 FA.

5.7 Deceleration Method applying coast-down 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, Vkm/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 (11 sec) for the speed to drop from V + AV km/h to V - AV km/h. The value of AV shall not be less than 1 km/h or more than 5 km/h. However, same value of A V shall be used for all the tests.

5.5.1.5 Repeat the test in the opposite direction and record the time (12 sec.).

5.5.1.6 Repeat the test 10 times such that the statistical error of the time ti (arithmetic average oftl and 12) 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.

5.5.1.8 Using least square curve fitting method and values of F and V, the coefficient of rolling and aerodynamic resistance of the vehicle viz. a and b respectively are found from the following equation : $F = a + b * V^2$

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:

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

Where: F = the load, in N

a = 0.18 x Reference weight of vehicle, in kg

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

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 table I of this chapter.

5.8 When the alternate method as per Para 5.7 is followed, the initial calibration of the chassis dynamometer shall be carried out without placing the vehicle on the chassis dynamometer.

Table I: Power setting for three wheelers.

Reference Mass of Vehicle RW(kg)		Equivalent Inertia(kg)	Absorbed power at 50 km/h (kW)
Exceeding	Upto		
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

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

γ = 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
γ 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 ($\Delta I / I$) 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

γ = 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 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 3 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 compress ion-ignition engines, of the particulate emissions, contained in the exhaust gases emitted during the vehicle testing cycle.

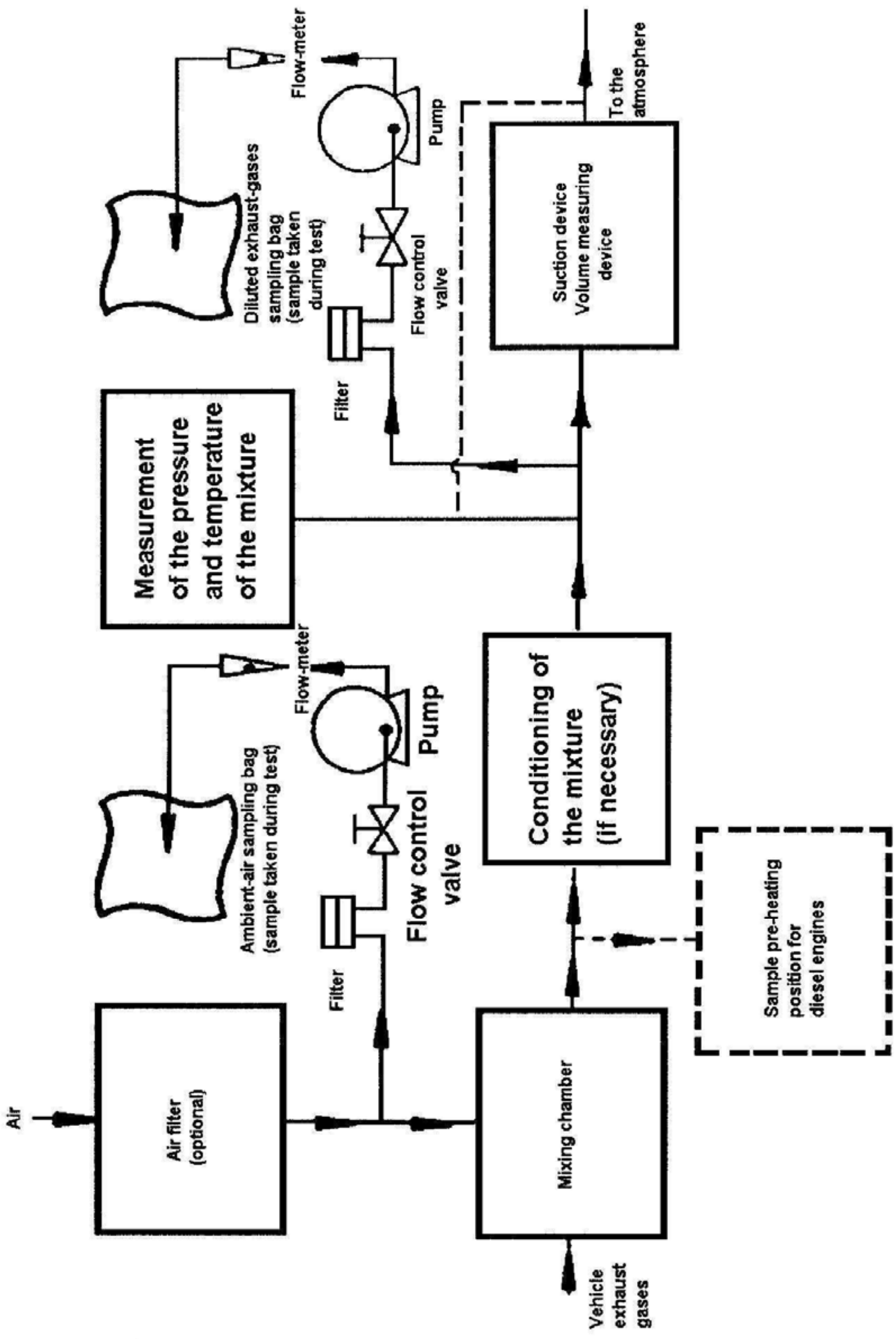


Fig 3. Diagram of Variable –Dilution System for Measuring Exhaust Gas Emission

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 COi in the dilute exhaust gas sampling bag lower than 3% by volume.

2.3.2 Volume measurement :

2.3.2.1 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.

2.3.2.2 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.

2.3.3 Gas sampling :

2.3.3.1 Dilute exhaust gases

2.3.3.1.1 The sample of dilute exhaust gases is taken before the suction devices but after the conditioning devices (if any).

2.3.3.1.2 The flow-rate must not deviate by more than ± 2% from the average.

2.3.3.1.3 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.

2.3.3.1.4 An equivalent limit applies to constant-mass sampling systems.

2.3.3.2 Dilution air

2.3.3.2.1 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).

2.3.3.2.2 The air must not be contaminated by exhaust gases from the mixing area.

2.3.3.2.3 The sampling rate for the dilution air must be comparable to that used in the case of the dilute exhaust gases.

2.3.3.3 Sampling operations

2.3.3.3.1 The materials used for the sampling operations must be such that they do not change the pollutant concentration.

2.3.3.3.2 Filters may be used in order to extract the solid particles from the sample.

2.3.3.3.3 Pumps are required in order to convey the sample to the sampling bag(s).

2.3.3.3.4 Flow control valves and flow-meters are needed in order to obtain the flow-rates required for sampling.

2.3.3.3.5 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).

2.3.3.3.6 The various valves used for directing the sampling gases must be of the quick-adjusting and quick-acting type.

2.3.3.4 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 4.

2.4.5 The participate 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.

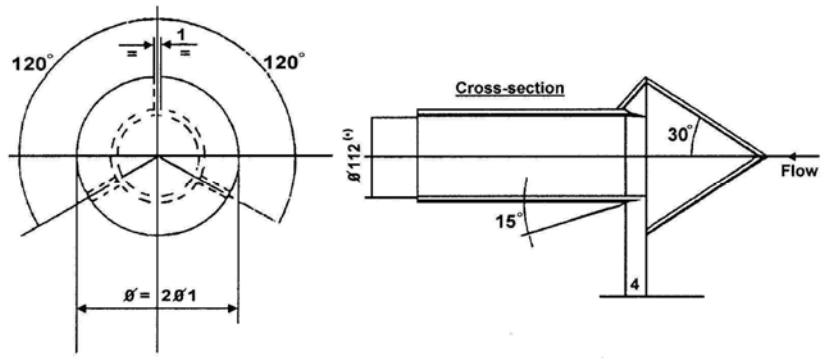


Figure 4 : Particulate Sampling Probe Configuration
(*) Minimum internal diameter
Wall thickness : ~1 mm; Material: Stainless Steel

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. 5).

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. 5 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 COi concentration in the dilute exhaust sample bag is less than 3 % by volume for reference diesel, less than 2.2%, cylinder for LPG and less than 1.5% cylinder for NG.

3.1.3.6 A temperature sensor (Ti) (accuracy and precision ± IK) 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 (Gi) (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 (Gi) (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 (Si and 82) for taking constant samples of the dilution air and of the diluted exhaust gas/air mixture.

3.1.3.10 A 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 Si 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 1/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/poly amide 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.5 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. 6).

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. 6 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 (Si and 82), 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, 82.

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 Si. 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 1/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 83.

Particulate sampling system :
84 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. 7).

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 (Si and 82) 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 (Ti) (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 (Gi) (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 Si and 82 . 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 1/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/poly amide films, or fluorinated polyhydro carbons).

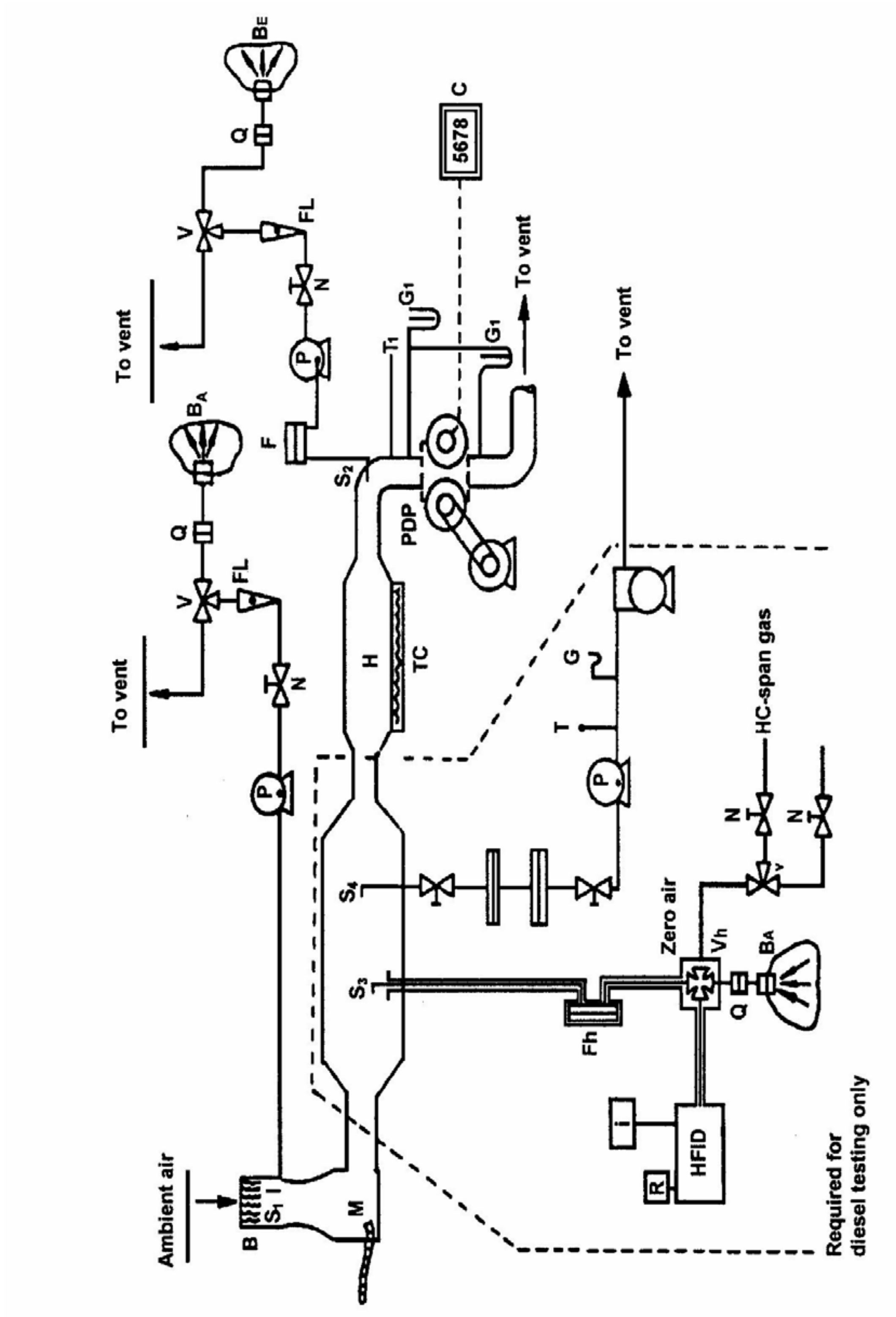


Figure 5 : Schematic Constant Volume Sampler with Positive Displacement Pump (PDP-CVS) (Pis. Ref Para. 3.1 of this Chapter)

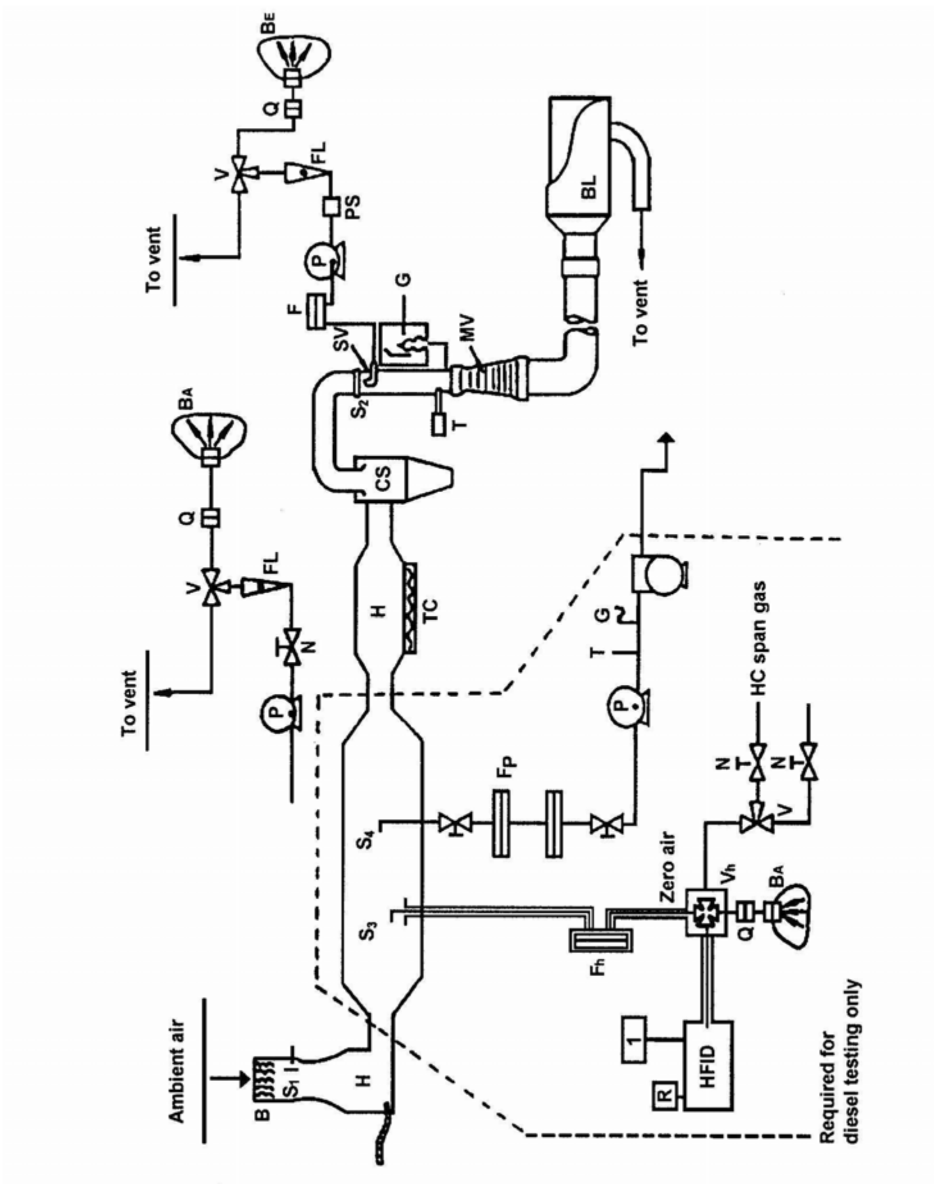


Fig. 6. Schematic constant Volume Sampler with Critical Flow Venturi
(CFV-CVS) (pls Ref para 3.2 of this Chapter)

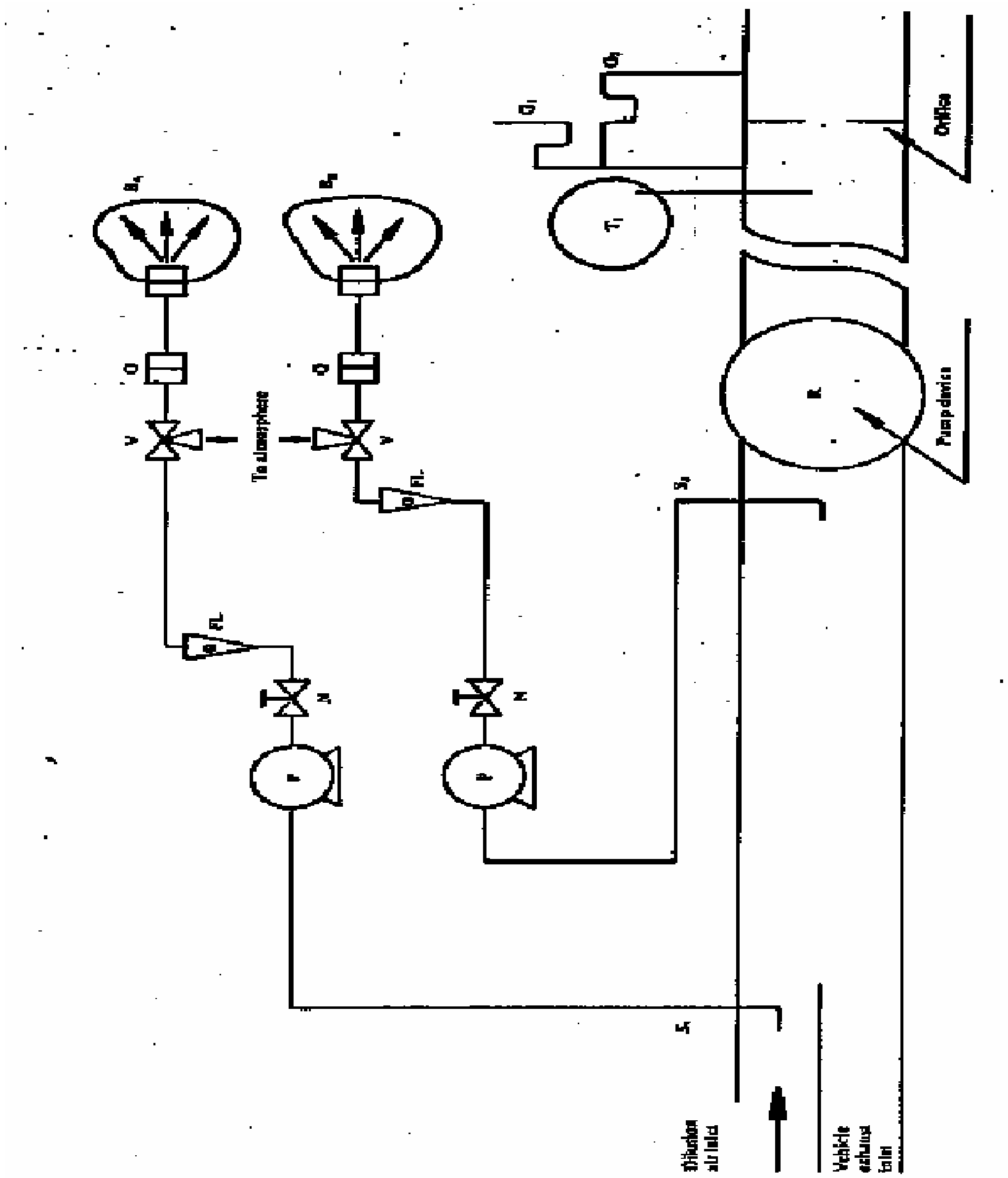


Figure 7 : Schematic of Variable Dilution DeFFigure 11 : Schematic of Variable Dilution Device with Constant Flow Control by Orifice (CFO-CVS)

(Pis. 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 **50** km/h as a function the power absorbed The following procedure shall be used.(Fig. 8)

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 **50** km/h.

2.2.5 Note the power indicated (Pi).

2.2.6 Bring the dynamometer to a speed of **60** 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 55 km/h to 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:

$$P_a = M_i * \frac{V_1^2 - V_2^2}{2000t}$$

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 (**55 km/h = 15.28 m/s**)

V2 = final speed in m/s (**45** km/**h = 12.50 m/s**)

t = time taken by the roller to pass from **55 km/h to 45 km/h** in s.

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

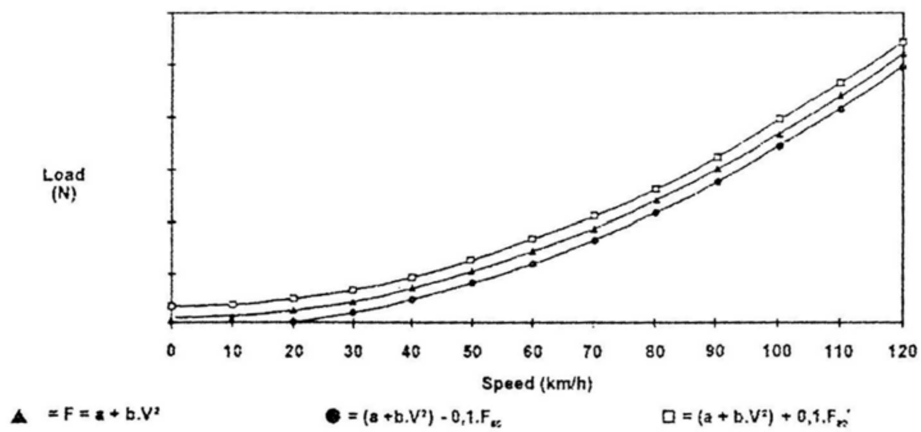


Figure 8 : Diagram illustrating the load of the chassis dynamometer

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 50** 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 **50 km/h**.

2.4.3 Note the power absorbed at **50,40,30 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 **50** 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 /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 ± IK 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. 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.3 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 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.

3.2.4 Data analysis :

3.2.4. 1 The air flow rate, Qs, at each test point is calculated in standard m /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

ΔP_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 = Vo = Do - M(Xo)
n = A-B(ΔP_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_0) 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_0. 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. 10)

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. 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 –

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

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 $1.00 < R_f < 1.15$, or 1.00 $R_f < 1.05$ for NG fuelled vehicles
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. 11 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 :

$$\text{Efficiency (\%)} = \left(1 + \frac{(a - b)}{(c - d)}\right) * 100$$

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.

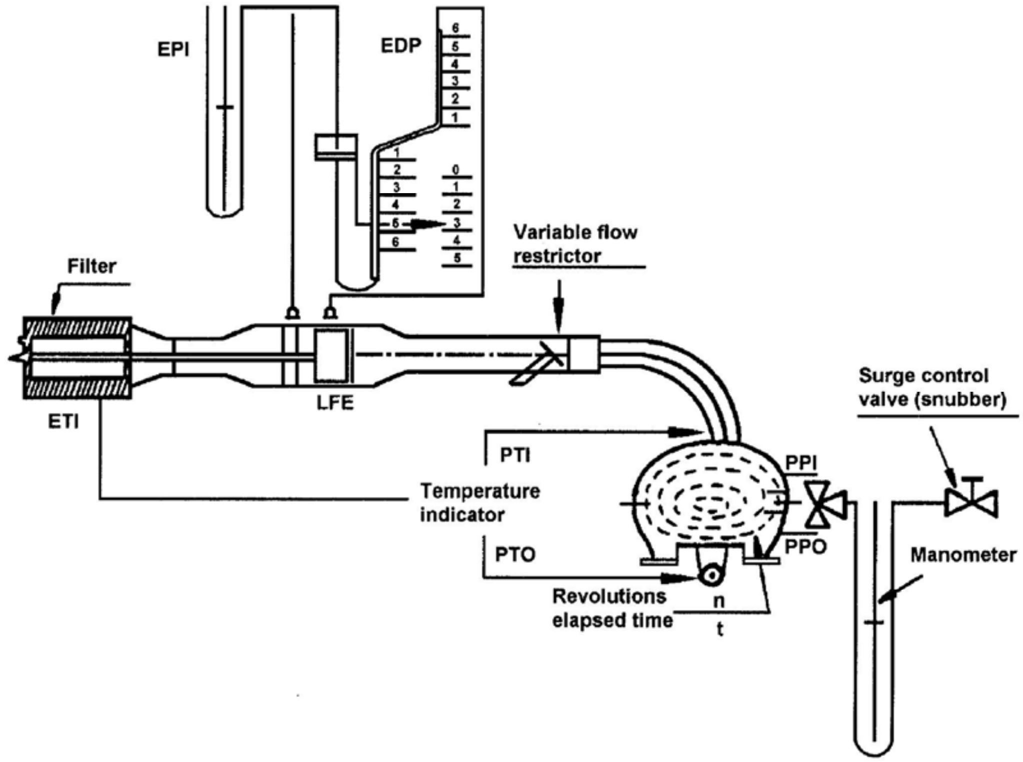


Figure 9: Schematic of PDP-CVS Calibration Set-un
(Pis. Ref. Para. 3.2.3.1 of Chapter 7, Part IX)

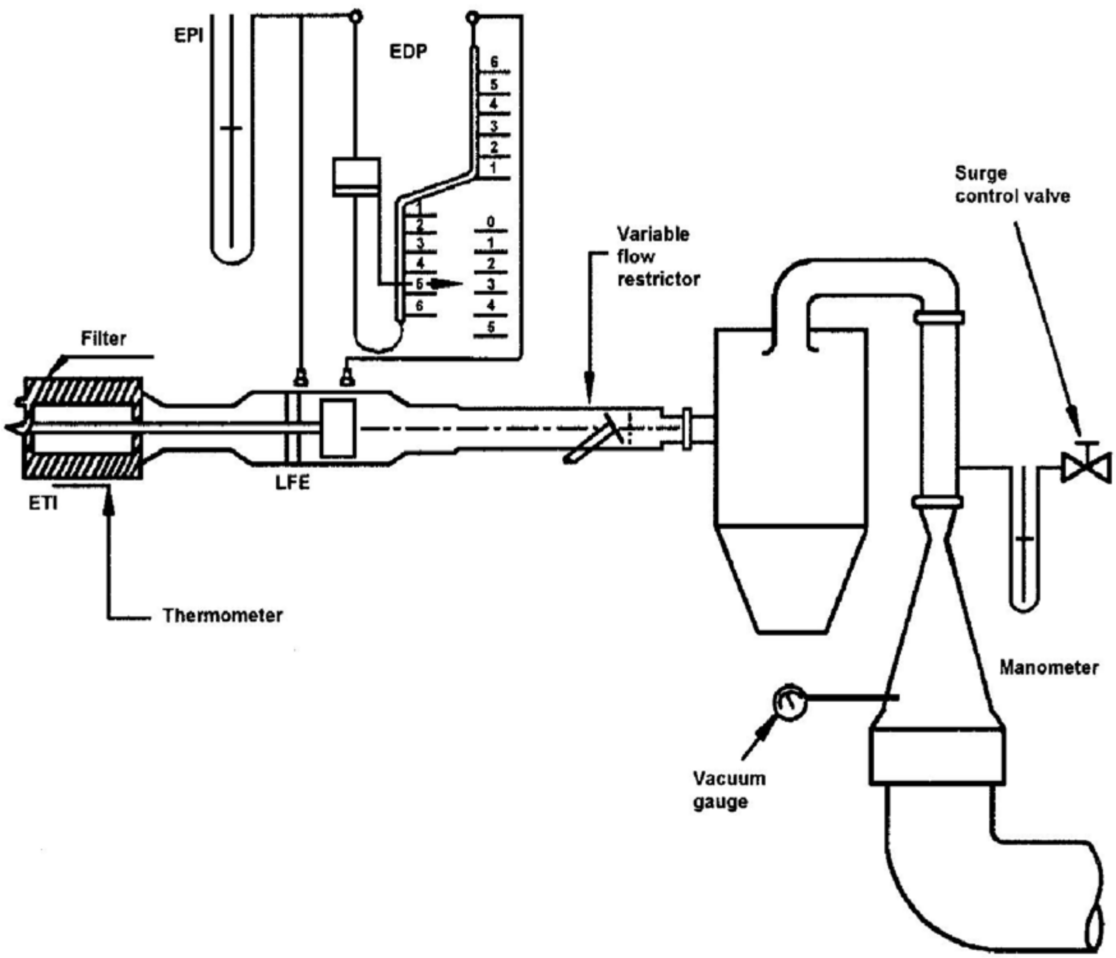


Figure 10 : Schematic of CFV-CVS Calibration Set-un
(Pis. Ref. Para. 3.3.4.of Chapter 7, Part IX)

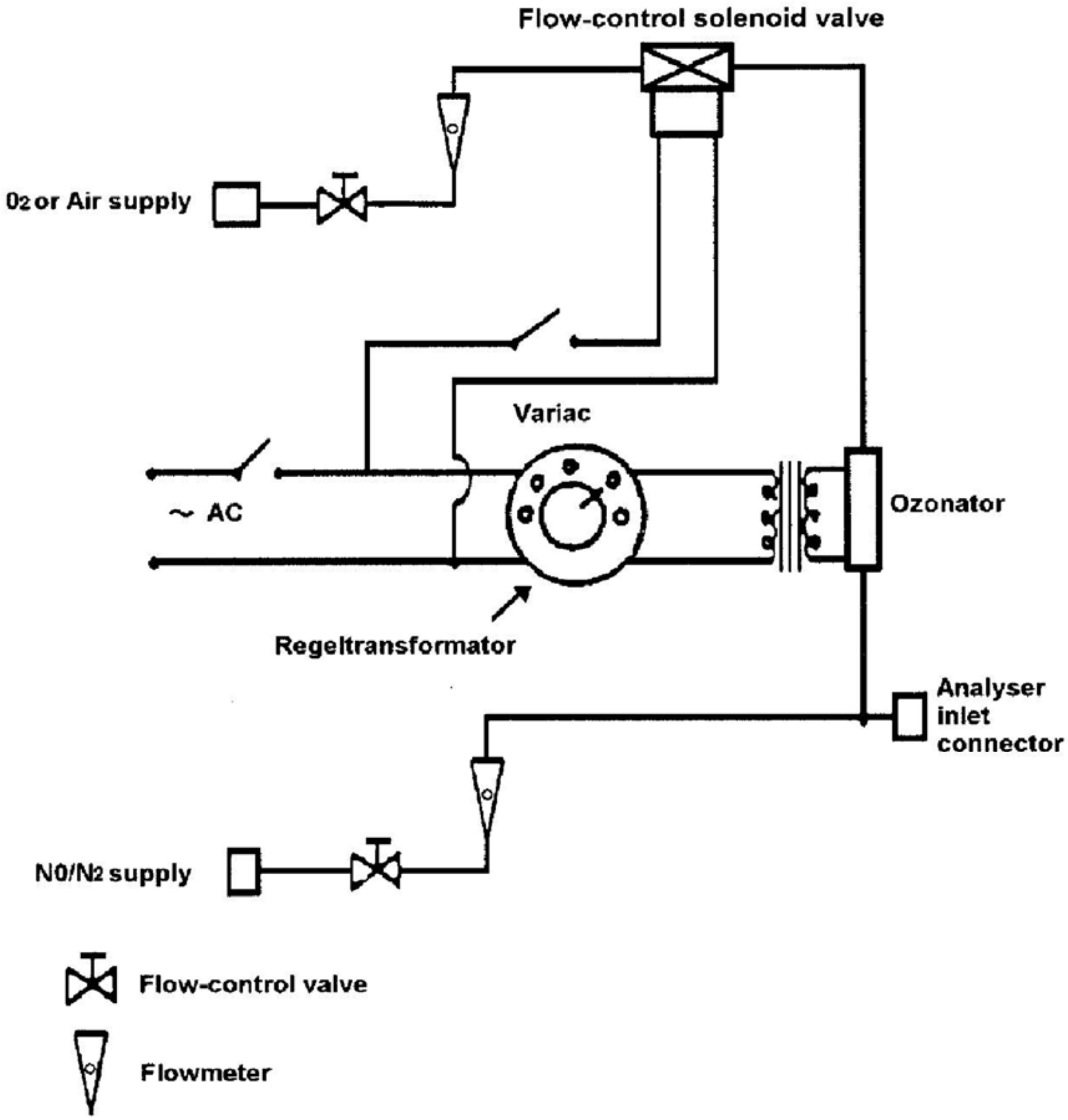


Figure 11 : Schematic of Set-up for checking the efficiency of NOx converter
(Pis. Ref. Para.4.6.1.1 of Chapter 7, Part IX)

Chapter 8

CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS AND FUEL CONSUMPTION

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 :

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}}$$ (5a) for petrol and diesel fuels

$$DF = \frac{11.9}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}}$$ (5b) for LPG

$$DF = \frac{9.5}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}}$$ (5c) for Natural Gas (NG)

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 (CO2) 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 m3 (in the case of NG) is calculated by means of following formulae:

i. For vehicles with a positive ignition engine fuelled with petrol:

$$FC = 100 * D / \{(0.1154) * [(0.866 * HC) + (0.429 * CO) + (0.273 * CO2)]\}$$

ii. For vehicles with a positive ignition engine fuelled with LPG

$$Fcnorm = 100 * (0.538) / \{(0.1212) * [(0.825 * HC) + (0.429 * CO) + (0.273 * CO2)]\}$$

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:

$$Fcnorm = 100 * (0.538) / \{(0.1212) \cdot (cf) \cdot [(0.825 \cdot HC) + (0.429 \cdot CO) + (0.273 \cdot CO2)]\}$$

The correction factor cf, which may be applied, is determined as follows:

$$cf = 0.825 + 0.0693 \cdot nactual$$

where:
nactual = the actual H/C ratio of the fuel used.

iii For vehicles with a positive ignition engine fuelled with NG

$$Fcnorm = 100 * (0.654) / \{(0.1336) * [(0.749 * HC) + (0.429 * CO) + (0.273 * CO2)]\}$$

iv For vehicles with a compression ignition engine

$$FC = 100 * D / \{(0.1155) * [(0.866 * HC) + (0.429 * CO) + (0.273 * CO2)]\}$$

In these formulae:

FC = the fuel consumption in km per liter (in the case of petrol, LPG or diesel) or in km per m3 (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
CO2 = 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/m3 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 (VERIFYINGCARBON MONOXIDE, HYDROCARBONS EMISSION AT IDLING)

1 Scope :

This Chapter describes the procedure for the Type II test for verifying carbon monoxide, Hydrocarbons 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, HC should meet the requirements given in Part VIII of this document.

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.

3.0 Vehicle and Fuel :

3.1 This test should be carried out immediately after the tenth 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 leak proof 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 leak proof, 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, HC 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 :-

$$\text{T corrected} = \frac{TCO_x * 15}{(TCO + TCO_2)} \qquad \text{for 4 stroke engines.}$$

$$= \frac{TCO_x * 10}{(TCO + TCO_2)} \qquad \text{for 2 stroke engines.}$$

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 and Hydrocarbons 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.

Chapter 10

TYPE III TEST: DESCRIPTION OF THE AGEING TEST FOR VERIFYING THE DURABILITY OF ANTI POLLUTION DEVICES FROM 2/3 WHEELERS

Procedure For Durability Testing Of 2 & 3 Wheelers.

1 Scope: This standard covers the procedure for establishing the deterioration factor for two and three wheelers.

2

This procedure shall be followed in case the manufacturer does not desire to use the fixed deterioration factors specified in the corresponding emission notification.

2. Mileage accumulation:

2.1 Mileage accumulation may be done on road/ test track or on chassis dynamometer, at the option of the vehicle manufacturer.

2.2 If the mileage accumulation is carried out on roads, the traffic on the selected road shall be such that the lap speeds can be maintained. The details of routes followed and the trends of the traffic pattern shall be recorded.

2.3 If the mileage accumulation is done on a chassis dynamometer, the chassis dynamometer shall comply with the requirements given in Para 4.1.1.1 (Fixed load type dynamometer or given in Para 4.1.1.2 (Variable load chassis dynamometer) of chapter 3, Part III of the document No. MOST/CMVR/TAP115/116. Suitable robotic controls may be used when the mileage accumulation is being carried out on a chassis dynamometer.

2.4 Mileage accumulation shall be exclusive of the running in period.

3.0 Speeds for mileage accumulation:

3.1 Mileage accumulation shall be done in laps of 6km. Atrip consisting of eleven laps is counted as one test cycle.

The following test cycles shall be followed for different categories of two and three wheelers:

Vehicle type	Engine cc		Test Cycle classification
	Exceeding	Upto and lower than	
Two wheelers	—	75	A
	75	250	B
	250	—	C
Three wheelers	All		A

The different Lap speeds for each test cycle classification is given in table 1.

Table 1 Lap speeds for different Test cycle classification (See 3.1)

Test cycle classification	Lap speed, km/hr										
	1	2	3	4	5	6	7	8	9	10	11
A	35	30	35	35	30	30	30	40	30	40	40
B	55	35	55	55	45	35	45	60	50	65	70/65*
C	65	45	65	65	55	45	55	70	55	70	70

*Speed of 65km/hr for engine cc below 100.

3.2 The break down of time vs. speed for each lap is given in Annex 1. The time versus speed is pictorially shown in Figures 1,2 and 3 for laps 1 to 9, 10 and 11 respectively.

3.3 If the lap speed is not achievable because of the speed capability of the vehicle, the vehicle shall be driven at 90% of the actual maximum speed of the vehicle. In such cases, the actual lap speed followed shall be reported.

Figure 1 Pictorial representation of Laps 1 to 9 (A,B & C)

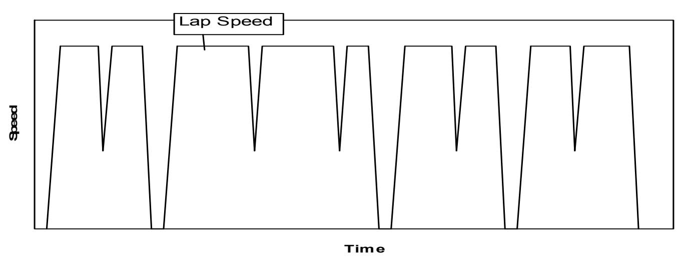


Figure 2 Pictorial representation of Lap 10(A,B & C)

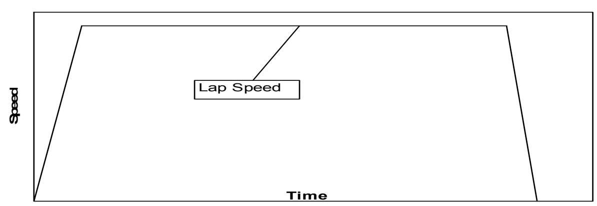


Figure 3 Pictorial representation of Lap 11 (A)

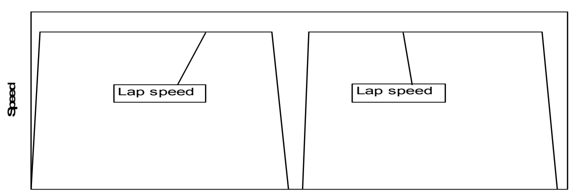
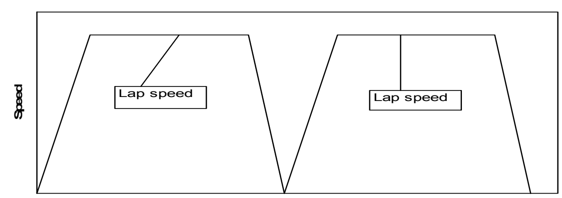


Figure 4 Pictorial representation of Lap 11 (B & C)



4. Gear shifting:

During lap 1 to 10 gear shifting shall be as recommended by the manufacturer. In acceleration phase of lap 11, gearshift shall be done at the maximum safe speed of engine recommended by the manufacturer. The gear shifting pattern actually followed shall be reported for a test cycle.

5. Fuel:

The fuel used shall comply with the requirements for the commercial fuel specified in the applicable emission regulation.

In case the lubricating oil is premixed with petrol, the quantity and quality of the oil shall be as specified by the vehicle manufacturer. The actual quality and quantity used shall be reported.

6. General:

6.1 If the mileage accumulation is done on a road or test track, the vehicle shall be loaded to the reference mass condition, specified in document No. MOST/CMVR/TAP115/116.

6.2 If the mileage accumulation is done on a chassis dynamometer, the load and inertia setting shall be as prescribed for the mass emission test as per document MOST/CMVR/TAP115/116 for the type approval test for specific model.

6.3 Operation of fuel enrichening devices such as choke, lights etc shall be restricted as is required for the actual running of the vehicle.

6.4 The typical test cycle followed during mileage accumulation shall be reported.

7.0 Maintenance of vehicle during mileage accumulation:

7.1 Scheduled maintenance:

A scheduled major engine tune up shall be conducted in a manner consistent with owners manual / service instructions and specifications provided by the manufacturer for use by costumer service personnel. Typical servicing items are listed below:

a) Contact Breaker points & setting

b) Ignition timing and setting

c) Idle speed and Idle air/fuel mixture setting

d) Tappet clearance

e) Engine bolt tightening

f) Spark plugs (Clean, gap setting, replace)

g) Change of engine and transmission oil, change of elements for oil, air and fuel filters

h) De-carbonization of engine including silencer in case of two stroke engines.

j) Adjustment of chains (transmission, valve train)

k) Adjustment of control cables, clutch etc.

l) The catalytic converter may be serviced only once during the mileage accumulation, if the failure of the catalytic converter system activates an audible and/ or visual signal which alerts the vehicle operator to the need for catalytic converter system maintenance or if the need for the periodic maintenance of the catalytic converter system is overly signalled to the vehicle operator by appropriate means, e.g., An indicator light or significantly reduced drivability performance.

The catalytic converter may be serviced as recommended by the vehicle manufacturer.

7.2 Other maintenance:

Certain engine components may require maintenance/replacement, which, by its nature can not be scheduled for periodic interval, but which the manufacturer believes will be necessary, shall be permitted. For example, piston and cylinder replacement caused by piston seizure, excessive wear, which results in the vehicle being inoperative.

7.2.1 Any unscheduled engine, emission control system, or fuel system adjustment, repair, removal, disassembly, cleaning or replacement on vehicle shall be performed only in case of significantly reduced driving performance, subject to the following:

a) part failure or system malfunction or the repairs of such failure or malfunction does not render the vehicle unrepresentative of vehicles in use, and

b) does not require direct access to the combustion chamber except for:

- spark plug, fuel injection component, or
- removal or replacement of the removable pre-chamber, or
- decarbonising.

7.2.2 Equipment, instruments or tools shall not be used to identify the malfunctioning, mal-adjustment or defective engine components unless the same or equivalent equipment, instrument or tools will be available at the dealerships and other service outlets and are used in conjunction with scheduled maintenance on such components.

7.2.3 Emission measurements shall not be used as a means of determining the need for an unscheduled maintenance.

7.2.4 Repairs/replacement to vehicle components of test vehicle, other than engine, emission control system or fuel system, shall be performed only as a result of part failure, vehicle system malfunction

7.4 Records of maintenance activities:

All the maintenance work carried out shall be recorded in the test report.

8. Mass emission testing during the mileage accumulation:

8.1 During the mileage accumulation the vehicle shall be tested for mass emission. Emission of CO, HC and NOx shall be measured. The measurements shall be done at the following spots:

8.1.1 The first exhaust emission test shall be carried out when the mileage accumulation reaches 1500km.

8.1.2 The final exhaust emission test shall be carried out when the mileage accumulation reaches the end.

8.1.3 Between the first exhaust emission test and final exhaust emission test regular maintenance shall be done as recommended by the manufacturer. The gap between the maintenance shall not be less than 2000km. At least one maintenance shall be carried out during the durability test. Tests shall be carried out before and after each regular maintenance.

8.1.4 Besides the tests specified above, additional tests may be carried out at certain mileage gaps. Such gaps between the tests shall be approximately uniform.

8.1.5 The total number of tests carried out, including the first and final test shall be at least 5.

8.1.6 If the final test coincides with a scheduled maintenance, only the final test shall be carried out before the maintenance. In this case test after maintenance shall not be carried out.

8.2 The difference between the actual mileage accumulation at each test spot and the planned mileage accumulation shall not exceed 200km.

8.3 Emission tests shall be carried out as per the procedure used for type approval testing as per document No. MoSRTH/CMVR/TAP115/116

8.4 During the emission test, if the test is affected by abnormal behavior of the vehicle, test shall be discarded. In any other case, the test result shall be deemed effective.

The results which are discarded and the reasons thereof shall be recorded in the test report.

8.5 If more than one test is carried out at each spot, the number of effective tests (see 9.1) at each spot shall be same. If so each spot result can be used for regression.

If the number of effective tests at each spot is not the same, the average of results for each spot shall be used for final calculation.

The number of effective tests for each spot shall not be more than three.

8.6 If two vehicles of one model are selected to take durability test at the same time, the number of tests and mileage accumulation at each test spot shall be same for each vehicle.

9. Calculation of deterioration factor:

9.1 The results of tests at all spots as per 8.1.1, 8.1.2, 8.1.3 and 8.1.4, excluding those discarded, as per para 8.4, are the effective test results and shall be considered for calculation of deterioration factor.

9.2 Emission test result of any pollutant less than 0.01g/km, shall be deemed to be 0.01g/km.

9.3 The emission data before and after maintenance shall not be averaged.

9.4 The actual mileage number shall be rounded upto the last digit before decimal point, when expressed in kilometer.

9.5 The test result of each pollutant shall be corresponded to the mileage number. Using the least square method, regress out linear function, for each pollutant separately.

9.6 Use the linear function to calculate the pollutant value at 2500km and 30,000 kilometer. The value of the pollutant shall be calculated to the fourth digit after the decimal point, when expressed in g/km.

9.7 Divide the number at L km by the number at 2500km to work out the D.F. The D.F. shall be calculated to the third digit after the decimal point.

9.8 If D.F. is less than 1, it shall be deemed as 1.

9.9 D.F. for each applicable pollutant shall be calculated separately.

10.0 Extrapolation of the test results:

10.1 After accumulating at least half the specified kilometer 30,000 km, given in para 9.6, carry out regression of the results between 2500km and actual kilometre as per para 9.5.

11.0 The D.F. established as per this procedure (para 9 and 10) shall be applicable for all models of the same engine family.

Annex 1

Table A1. Mode-wise break up for Laps 1 to 9 of Test cycle classification A

Mode	**Driving Mode** **Lap speed--->**	**Time for each mode (second)**		
		30	**35**	**40**
1	Acceleration: Idle - Lap speed	13	15	18
2	Steady state cruise	68	68	52
3	Deceleration: Lap speed - 15km/h	10	11	10
4	Acceleration: 15km/h - Lap speed	10	11	10
5	Steady state cruise	45	45	37
6	Deceleration: Lap speed - idle	10	11	10
7	Idle	15	15	15
8	Acceleration: Idle - Lap speed	13	15	18
9	Steady state cruise	100	100	85
10	Deceleration: Lap speed - 15km/h	10	11	10
11	Acceleration: 15km/h - Lap speed	10	11	10
12	Steady state cruise	100	100	85
13	Deceleration: Lap speed - 15km/h	10	11	10
14	Acceleration: 15km/h - Lap speed	10	11	10
15	Steady state cruise	52	33	29
16	Deceleration: Lap speed - idle	10	11	10
17	Idle	15	15	15
18	Acceleration: Idle - Lap speed	13	15	18
19	Steady state cruise	63	63	52
20	Deceleration: Lap speed - 15km/h	10	11	10
21	Acceleration: 15km/h - Lap speed	10	11	10
22	Steady state cruise	52	11	30
23	Deceleration: Lap speed - idle	10	11	10
24	Idle	15	15	15
25	Acceleration: Idle - Lap speed	13	15	18
26	Steady state cruise	52	52	30
27	Deceleration: Lap speed - 15km/h	10	11	10
28	Acceleration: 15km/h - Lap speed	10	11	10
29	Steady state cruise	59	50	44
30	Deceleration: Lap speed - idle	10	11	10

Table A2. Mode-wise break up for Lap 10 & 11 of Test cycle classification A

Mode	Driving Mode	Time for each mode (second)	
		For Lap 10	**For Lap 11**
	Lap speed--->	**40**	**40**
1	Acceleration: Idle - Lap speed	18	10
2	Steady state cruise	515	260
3	Deceleration: Lap speed - idle	18	18
4	Idle	Not applicable	15
5	Acceleration: Idle - Lap speed		10
6	Steady state cruise		260
7	Deceleration: Lap speed - idle		18

Table A3. Mode-wise break up for Laps 1 to 9 of Test cycle classification B &C

Mode	Driving Mode Lap speed--->	Time for each mode (second) 35	45	50	55	60	65	70
1	Idle	15	15	15	15	15	15	15
2	Acceleration: Idle - Lap speed	18	23	26	29	31	33	34
3	Steady state cruise	46	29	22	16	11	11	7
4	Deceleration: Lap speed - 15km/h	7	10	12	14	15	16	17
5	Acceleration: 15km/h - Lap speed	10	16	18	21	23	24	25
6	Steady state cruise	38	22	16	10	5	5	5
7	Deceleration: Lap speed - idle	12	15	17	19	20	22	23
8	Idle	15	15	15	15	15	15	15
9	Accelerate from idle to lap speed	18	23	28	29	31	33	34
10	Steady state cruise	89	61	51	42	35	20	11
11	Deceleration: Lap speed - 15km/h	7	10	12	14	15	16	17
12	Acceleration: 15km/h - Lap speed	10	16	18	21	23	24	25
13	Steady state cruise	89	61	51	42	35	20	12
14	Deceleration: Lap speed - 15km/h	7	10	12	14	15	16	17
15	Acceleration: 15km/h - Lap speed	10	16	18	21	23	24	25
16	Steady state cruise	28	14	8	4	1	1	1
17	Deceleration: Lap speed - idle	12	15	17	19	21	22	23
18	Idle	15	15	15	15	15	15	15
19	Accelerate from idle to lap speed	18	23	26	29	31	33	34
20	Steady state cruise	58	37	30	23	17	14	12
21	Deceleration: Lap speed - 15km/h	7	10	12	14	15	16	17
22	Acceleration: 15km/h - Lap speed	10	16	16	21	23	24	25
23	Steady state cruise	38	22	16	10	5	5	5
24	Deceleration: Lap speed - idle	12	15	17	19	21	22	23
25	Idle	15	15	15	15	15	15	15
26	Acceleration: Idle - Lap speed	18	23	26	29	31	33	34
27	Steady state cruise	48	29	22	18	11	7	7
28	Deceleration: Lap speed - 15km/h	7	10	12	14	15	16	17
29	Acceleration: 15km/h - Lap speed	10	16	18	21	23	24	25
30	Steady state cruise	58	37	30	23	17	15	7
31	Deceleration: Lap speed - idle	12	15	17	19	21	22	23
	Total time	757	654	628	615	594	578	565

Table A4. Mode-wise break up for Lap 10 & 11 of Test cycle classification B &C

Mode	Driving Mode	Time for each mode (second)		
		For Lap 10		For Lap 11
	Lap speed--->	65	70	70
1	Acceleration: Idle - Lap speed	34	36	36
2	Steady state cruise	304	278	106
3	Deceleration: Lap speed - idle	22	24	24
4	Acceleration: Idle - Lap speed	Not applicable		36
5	Steady state cruise			106
6	Deceleration: Lap speed - idle			24

Part XIV : 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

12.	Type V Test: Description of the Ageing Test for Verifying the Durability of Anti Pollution Devices from Four-Wheelers
13.	Test Procedure for On-Board Diagnostics I (OBD - I)
14.	Test Procedure for On-Board Diagnostics II (OBD - II)
15.	Emissions Test Procedure for a Vehicle Equipped with a Periodically Regenerating System
16.	Emission Tests And Measurement Of Fuel Consumption For Hybrid Electric Vehicles

Chapter 1

OVERALL REQUIREMENTS

1. Scope

1.1. This Part applies to the tailpipe emission of vehicles equipped with spark ignition engines (Petrol, CNG and LPG) and compression ignition engines (Diesel) for all M & N Category vehicles with GVW upto 3.5 tons for Bharat Stage IV.

At the request of the manufacturers, type-approval pursuant to TAP 115/116 issue 4 may be extended from M1 or N1 vehicles equipped with compression ignition engines which have already been type-approved, to M2 and N2 vehicles having a reference mass not exceeding 2,840 kg and meeting the conditions of Para 6 & 7 of this chapter.

1.1.1 Refer Chapter 16 of this part for tailpipe emission of Hybrid Electric vehicles.

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 engine vehicles wherever applicable with Gross Vehicle Weight (GVW) not exceeding 3500 kg, instead of Part XV.

1.3. This Part should be read in conjunction with applicable Gazette Notification under CMVR 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 semiautomatic 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 the exhaust gas emissions of carbon monoxide, oxides of nitrogen, expressed in nitrogen dioxide (NO_2) equivalent, and hydrocarbons assuming a ratio of:

- $C_1H_{1.85}$ for petrol,
- $C_1H_{1.86}$ for diesel,
- $C_1H_{2.525}$ for LPG,
- CH_4 for NG.

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. Evaporative emissions means the hydrocarbon vapors lost from the fuel system of a motor vehicle other than those from tailpipe emissions.

2.8.1. Tank breathing losses are hydrocarbon emissions caused by temperature changes in the fuel tank (assuming a ratio of $C_1H_{2.33}$).

2.8.2. Hot soak losses are hydrocarbon emissions arising from the fuel system of a stationary vehicle after a period of driving (assuming a ratio of $C_1 H_{2.20}$).

2.9. **Engine crankcase :** means the spaces in, or external to, an engine which are connected to the oil sump by internal or external ducts through which gases and vapors can escape.

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. **Reference Mass**: Means the "Unladen Mass" of the vehicle increased by a uniform figure of 150 kgs.

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

2.13. **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.

2.14. **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.

2.15. **Engine capacity means:** For reciprocating piston engines, the nominal engine swept volume.

2.16. **Anti pollution device**: means those components of the vehicles that control and / or limit tail pipe and evaporative emissions.

2.17. **OBD an on-board diagnostic system** for emission control which has the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.18. **Type Approval of a vehicle:** Means the type approval of a vehicle model with regard to the limitation of tailpipe emissions from the vehicles.

2.19. **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.

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

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

2.22. **Hybrid Vehicle (HV)** means a vehicle with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion.

2.23. **Hybrid Electric Vehicle (HEV)** means a vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power

- a consumable fuel
- an electrical energy/power storage device (e.g.: battery, capacitor, flywheel/ generator etc.)

2.24 **Bi Fuel** means a vehicle that can run part-time on petrol and also part-time on either LPG or NG

2.25 **Mono-fuel vehicle** means a vehicle that is designed primarily for permanent running on LPG or NG, but may also have a petrol system for emergency purposes for starting only, where the petrol tank does not contain more than 15 litres of petrol.

2.26 **Periodically regenerating system** " means an anti-pollution device (e.g. catalytic converter, particulate trap) that requires a periodical regeneration process in less than 4,000 km of normal vehicle operation. During cycles where regeneration occurs, emission standards can be exceeded. If a regeneration of an anti-pollution device occurs at least once per Type I test and that has already regenerated at least once during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure.

At the request of the manufacturer, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data to the type approval authority that, during cycles where regeneration occurs, emissions remain below the standards given in applicable Gazette Notification applied for the concerned vehicle category after agreement of the test agency.

2.27 **Defeat Device** means any element of design which senses temperature, vehicle speed, engine rotational speed, transmission gear, manifold vaccum or any other parameter for the purpose of activating, modeling, delaying or deactivating the operation of any part of the emission control system, that reduces the effectiveness of the emission control stsem under conditions which may reasonably be expected to be encountered in normal vehicle operation and use. Such an element of design may not be considered a defeat device if

2.27.1 The need of the device is justified in terms of protecting the engine against damage or accident and for safe operation of the vehicle, or

2.27.2 The device does not function beyond the requirements of engine starting or,

2.27.3 Conditions are substantially included in the Type I or Type VI test procedure.

2.28 **Fuel Requirement by the Engine** means the type of fuel normally used by the engine.

- Petrol
- LPG (liquid petroleum gas)
- NG (Natural Gas)
- Either petrol or LPG
- Either petrol or NG
- Diesel fuel

3. Application for Type Approval

3.1. The application for type approval of a vehicle model with regard to limitation of its tailpipe emissions, evaporative emissions, durability of anti-pollution devices as well as to its on-board diagnostic (OBD) system 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. Should the application concern an on-board diagnostic (OBD) system the procedure described in Chapter 13, Para 3 for OBD I & Chapter 14, Para 3 for OBD II as applicable must be followed.

3.1.1. Should the application concern an on-board diagnostic (OBD) system, it must be accompanied by the additional information required in chapter 2 of this part.

3.1.1.1.Declaration by the manufacturer for OBD II:

i. In the case of vehicles equipped with positive-ignition engines, the percentage of misfires out of a total number of firing events that would result in emissions exceeding the limits given in Para 3.3.2 of Chapter 14 if that percentage of misfire had been present from the start of a Type I test as described in Para 5.3.1 of Chapter 3**;**

ii. In the case of vehicles equipped with positive-ignition engines, the percentage of misfires out of a total number of firing events that could lead to an exhaust catalyst, or catalysts, overheating prior to causing irreversible damage;

3.1.1.2.Detailed written information fully describing the functional operation characteristics of the OBD system, including a listing of all relevant parts of the vehicle's emission control system, i.e. sensors, actuators and components, that are monitored by the OBD system;

3.1.1.3.a description of the malfunction indicator (MI) used by the OBD system to signal the presence of a fault to a driver of the vehicle;

3.1.1.4.the manufacturer must describe provisions taken to prevent tampering with and modification of the emission control computer;

3.1.1.5.when appropriate, copies of other type-approvals with the relevant data to enable extensions of approvals;

3.1.1.6. if applicable, the particulars of the vehicle family as referred to in Chapter 13, Annex 3 or Chapter 14, Annex 2 as applicable.

3.1.2. For the tests described in Para 5 & 6 of Chapter 13 or Para 3 of Chapter 14 as applicable, a vehicle representative of the vehicle type or vehicle family fitted with the OBD system to be approved must be submitted to the test agency responsible for the type-approval test. If the test agency determines that the submitted vehicle does not fully represent the vehicle type or vehicle family described in Chapter 13, Annex 3 or Chapter 14, Annex 2 as applicable, an alternative and if necessary an additional vehicle must be submitted for test in accordance with Para 5 of Chapter 13 or Para 3 of Chapter 14.

3.2. A model of the information document relating to tailpipe emissions, evaporative emissions, durability and the on-board diagnostic (OBD) system is given in Chapter 2.

3.2.1. Where appropriate, copies of other type-approvals with the relevant data to enable extension of approvals and establishment of deterioration factors must be submitted.

3.3. For the tests described in Para 5 of this Chapter a vehicle representative of vehicle type to be approved must be submitted to the / testing agency responsible for the type-approval test.

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 and evaporative 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. 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 than 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.

If reference fuel is available, vehicles that are fuelled with LPG or CNG shall be tested in the type I test for variations in the composition of LPG or CNG, as set out in 3.2 of chapter 3 of this part. Vehicles that can be fuelled either with LPG or CNG to be tested for Fuel A & Fuel B in case of LPG and G20 & G25 in case of CNG.

Reference Fuel shall be used for Type Approval and Conformity of Production one year after the same is available to the test agencies. Till then, Commercial CNG/LPG fuel shall be used as per applicable Gazette Notification under CMVR.

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, and 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, and 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 XIV. 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 as notified in CMVR and, in the case of periodically regenerating systems also must be multiplied by the K_i factors obtained from Chapter 15 of Part XIV of this document. 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 Mass Emission Standards for Type I test:
Mass emission standards (Bharat Stage IV) for vehicles (4 wheelers) shall be as per the details given in Rule No. 115 [15 (b) (i)] 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).

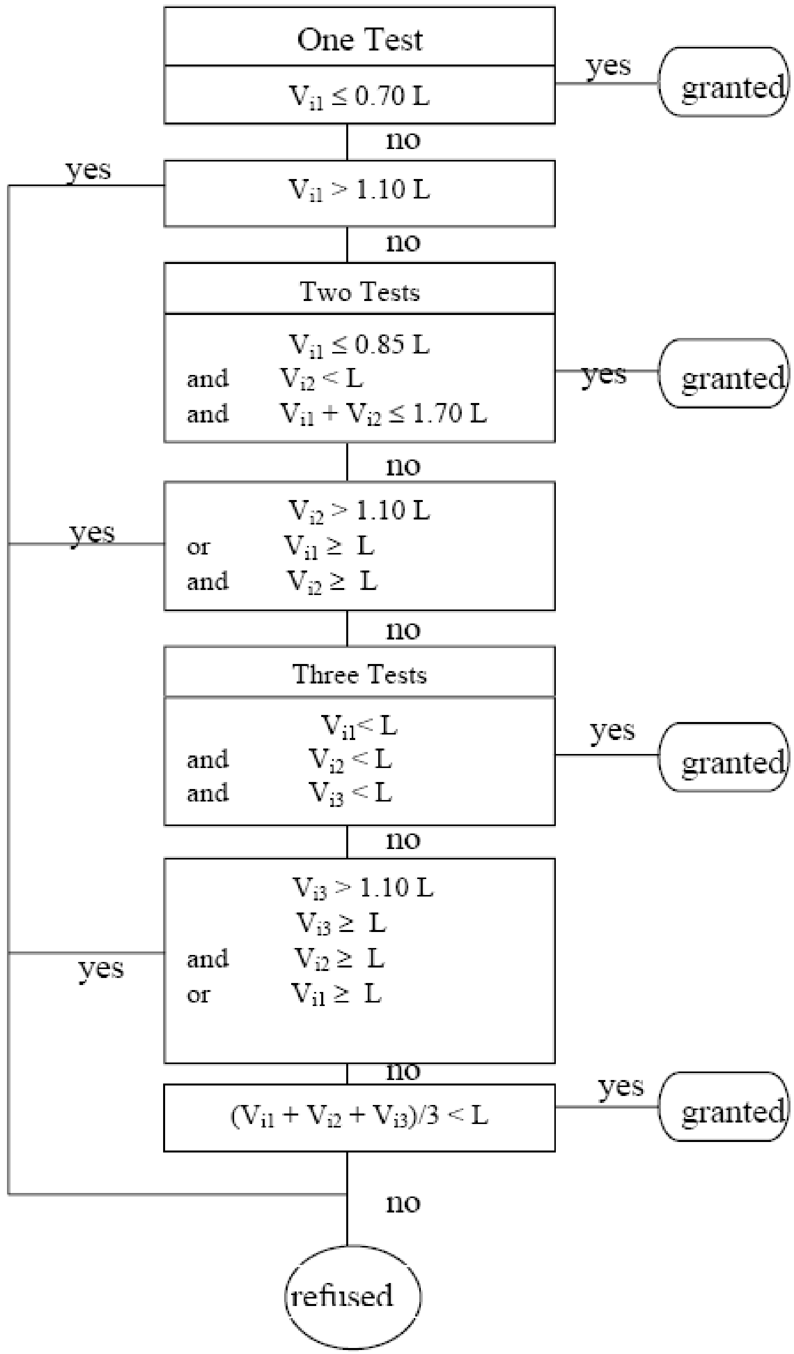
5.2.2.8. Nevertheless, for each of the pollutants or combination of pollutants one of the three results obtained may exceed by not more than 10% of the applicable limits prescribed for the vehicle concerned, provided the arithmetical mean of the three results is not exceeding the prescribed limit. Where the prescribed limits are exceeded for more than one pollutant or combination of pollutants, 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.

i. 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.

ii. If the requirements of 5.2.2.9.1 are not satisfied, only two tests are performed, if for each pollutant 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 $V_1 + V_2 \leq 1.7$ L and $V_2 \leqq <$ L. Fig.1 depicts the scheme.

Figure 1: Flow Sheet for the Type Approval Test as per Bharat Stage IV for 4 wheelers



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

5.2.3.1. This is applicable only for spark ignition engine vehicles.

5.2.3.2. The carbon monoxide and Hydrocarbons content by volume of the exhaust gases emitted with the engine idling must not exceed as per the limits mentioned in 4.1 of Part I of this document.

5.2.4. Type III test (verifying emission of crankcase gases).

5.2.4.1. This test must be carried out on all 4 wheeler vehicles referred to in Para 1 except those having compression ignition engines.

5.2.4.2. When tested in accordance with Chapter 10, the engine's crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

5.2.5. Type IV test (determination of evaporative emission).

5.2.5.1. This test must be carried out on all 4 wheeler gasoline vehicles.

5.2.5.2. When tested in accordance with Chapter 11, evaporative emission shall be less than 2 g/test.

5.2.6. Type V test (durability of anti-pollution devices): The requirement of durability must be compiled on all vehicles referred to in Para 1 of this Chapter. This may be established by using the deterioration factor notified in CMVR or by carrying out the durability test. The test represents an ageing test of 80,000 km for four wheelers driven in accordance with the program described in chapter 12, on a test track, on the road or on a chassis dynamometer.

5.2.6.1 For all type of 4 wheelers a deterioration factor as notified in Notification is applicable.

OR

The vehicle manufacturer may opt for an ageing test of 80,000 km for 4 wheeler vehicles for evaluation deterioration factor as described in chapter 12.

5.2.6.2 At the request of the manufacturer, the testing agency may carry out the Type I test before Type V test has been completed using the deterioration factors given in Notification. On completion of Type V test, the test agency may then amend the type-approval results recorded in the Notification with those measured in type V test.

5.2.6.3 Deterioration factor are determined using either procedure in chapter 12 or using the values in the notifications at the option of manufacturer. The factors are used to establish compliance with the requirements of 5.2.2.6 and 8.2.

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 Type I & Type II test

7.1.1 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.

7.1.1.1 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.

7.1.1.2 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.

7.1.1.3 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.

7.1.2 Vehicle models with Different Overall Gear Ratios:

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

7.1.2.2 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 at engine speed of 1000 rev/min, V1 is the speed of the vehicle model type approved and V2 is the speed of the vehicle model for which extension of the approval is requested.

7.1.2.3 If for each gear ratio $E \leq 8\%$, the extension shall be granted without repeating the Type I Tests.

7.1.2.4 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.

7.1.3 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.

7.1.4 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.

7.1.5 Vehicle model with different makes of emission related components:

7.1.5.1 the manufacturers shall inform the test agency The names of suppliers of items such as ignition coil, magneto, CB point, air filter, silencer, etc. mentioned above, 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.

7.1.5.2 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,

7.2 Evaporative Emissions (type IV test)

7.2.1.1 Approval granted to a vehicle type equipped with a control system for evaporative emissions may be extended under the following conditions.

7.2.1.2 The basic principle of fuel/air metering (e.g. single point injection, carburetor) must be the same.

7.2.1.3 The shape of the fuel tank and the material of the fuel tank and liquid fuel hoses must be identical. The worst-case of family with regards to the cross-section and approximate hose length must be tested. Whether non-identical vapor/liquid separators are acceptable is decided by the technical service 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.

7.2.1.4 The method of storage of the fuel vapor must be identical, i.e. trap form and volume, storage medium, air cleaner (if used for evaporative emission control), etc.

7.2.1.5 The carburetor bowl fuel volume must be within a 10 milliliter range.

7.2.1.6 The method of purging of the stored vapor must be identical (e.g., air flow, start point or purge volume over driving cycle).

7.2.1.7 The method of sealing and venting of the fuel metering system must be identical.]

7.2.2 Further notes:

i. different engine sizes are allowed;
ii. different engine powers are allowed;
iii. automatic and manual gearboxes, two and four wheel transmissions are allowed;
iv. different body styles are allowed;
v. different wheel and tyre sizes are allowed.

7.3 Durability of anti-pollution devices (Type V Test)

7.3.1 Approval granted to a vehicle type may be extended to different vehicle types, provided that the engine/pollution control system combination is identical to that of the vehicle already approved. To this end, those vehicle types whose parameters described below are identical or remain within the limit values prescribed are considered to belong to the same engine/pollution control system combination.

7.3.2 Engine:

- number of cylinders,
- engine capacity (± 15%),
- configuration of the cylinder block,
- number of valves,
- fuel system,
- type of cooling system,
- combustion process,
- cylinder bore center to center dimensions

7.3.3 Pollution control system:

- Catalytic Converters:
  - Number of catalytic converters and elements
  - Size and shape of catalytic converters (volume of monolith ± 10%),
  - Type of catalytic activity (oxidizing, three-way),
  - Precious metal load (identical or higher),
  - Precious metal ratio (+/- 15%)
  - Substrate (structure and material),
  - Cell density,
  - Type of casing for the catalytic converter(s),
  - Location of catalytic converters (position and dimension in the exhaust system that does not produce a temperature variation of more than 50 K at the inlet of the catalytic converter). This temperature variation shall be checked under stabilized conditions at a speed of 90 km/h for Four Wheelers, and the load setting of type I test.
- Air injection:

- With or without
- Type (pulsair, air pumps….)

- EGR:
  - With or without

7.3.4 Inertia category: the two inertia categories immediately above and any inertia category below.

7.3.5 The durability test may be achieved by using a vehicle, the body style, gear box (automatic or manual) and size of the wheels or tyres of which are different from those of the vehicle type for which the type approval is sought.

7.4 On-board diagnostics

Approval granted to a vehicle type with respect to the OBD system may be extended to different vehicle types belonging to the same vehicle-OBD family as described in Chapter 13, Annex 3 or Chapter 14, Annex 2 as applicable. The engine emission control system must be identical to that of the vehicle already approved and comply with the description of the OBD engine family given in Chapter 13, Annex 3 or Chapter 14, Annex 2 as applicable, regardless of the following vehicle characteristics:

- engine accessories,
- tyres,
- equivalent inertia,
- cooling system,
- overall gear ratio,
- transmission type,
- type of bodywork.

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. However, when the period between commencement of production of a new model and beginning of next rationalized COP period is less than two months, the same would be merged with the rationalized COP period.

8.2 If a type I test is to be carried out and a vehicle type-approval has one or several extensions, the tests will be carried out either on the vehicle described in the initial information package or on the vehicle described in the information package relating to the relevant extension.

8.3 Three vehicles are selected at random in the series and are tested as described in para 5.2.2 above. However, in case of vehicle model and its variants produced less than 250 in the half yearly period as mentioned in clause 11.1 of Part VI of this document sample size shall be one. The deterioration factors are used in the same way. The limit values are as specified in applicable notification.

8.4 Type I Test: Verifying the average emission of gaseous pollutants: For verifying the conformity of production in a Type I Test, the following procedure as per Option1 is adopted.

8.5 To verify the average tailpipe emissions of gaseous pollutants of low volume vehicles with Annual production less than 250 per 6 months, manufacture can choose from the Option 1 OR Option 2 as listed below:

8.6 Option 1

8.6.1 The vehicle samples 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 deterioration factors used at the time of type approval and in the case of periodically regenerating systems the results shall also be multiplied by the K_i factors obtained by the procedure specified in Chapter 15 of Part XIV of this document at the time when type approval was granted. 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.

8.6.2 Procedure for Conformity of Production as per Bharat Stage IV for all M and N Category vehicles upto 3.5 tons GVW.

8.6.2.1 Conformity of production shall be verified as per Bharat Stage IV emission norms for 4 wheeler vehicles as given in Para 5.2.2.7 and with the procedure given below.

8.6.2.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted:

8.6.2.3 Minimum of three vehicles shall be selected randomly from the series with a sample lot size as defined in part VI of MoRTH/CMVR/TAP-115/116.

8.6.2.4 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in Part VI.

8.6.2.5 All three randomly selected vehicles shall be tested for a Type - I test as per Para 5.2.2 of chapter 1 of this part.

8.6.2.6 Let X_{i1}, X_{i2} & X_{i3} are the test results for the Sample No.1, 2 & 3.

8.6.2.7 If the natural Logarithms of the measurements in the series are X_1, X_2, X_3 .... X_j and L_i is the natural logarithm of the limit value for the pollutant, then define:

$d_j = X_j - L_i$

$$\overline{d}_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^2 = \frac{1}{n}\sum_{j=1}^{n}(d_j - \overline{d_n})^2$$

8.6.2.8 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 d_n / V_n and must be used to determine whether the series has passed or failed as follows:

- Pass the series, if $\overline{d}_n / V_n \leq A_n$ 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 $An < \overline{d}_n / V_n < Bn$ 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.

8.6.2.9 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.

8.6.2.10 Alternatively if the manufacturer wishes to run in the vehicles, ("x" km, where x ≤ 3000 km for vehicles equipped with a positive ignition engine and x ≤ 15000 km for vehicles equipped with a compression ignition engine), the procedure will be as follows:

- the pollutant emissions (type I) will be measured at zero and at "x" km on the first tested vehicle,
- the evolution coefficient of the emissions between zero and "x" km will be calculated for each of the pollutants:

$$\frac{Emissions\ "x"\ km}{Emissions\ zero\ km}$$

This may be less than 1,

- the other vehicles will not be run in, but their zero km emissions will be multiplied by the evolution coefficient.

In this case, the values to be taken will be:

- the values at "x" km for the first vehicle,
- the values at zero km multiplied by the evolution coefficient for the other vehicles.

8.6.2.11 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.

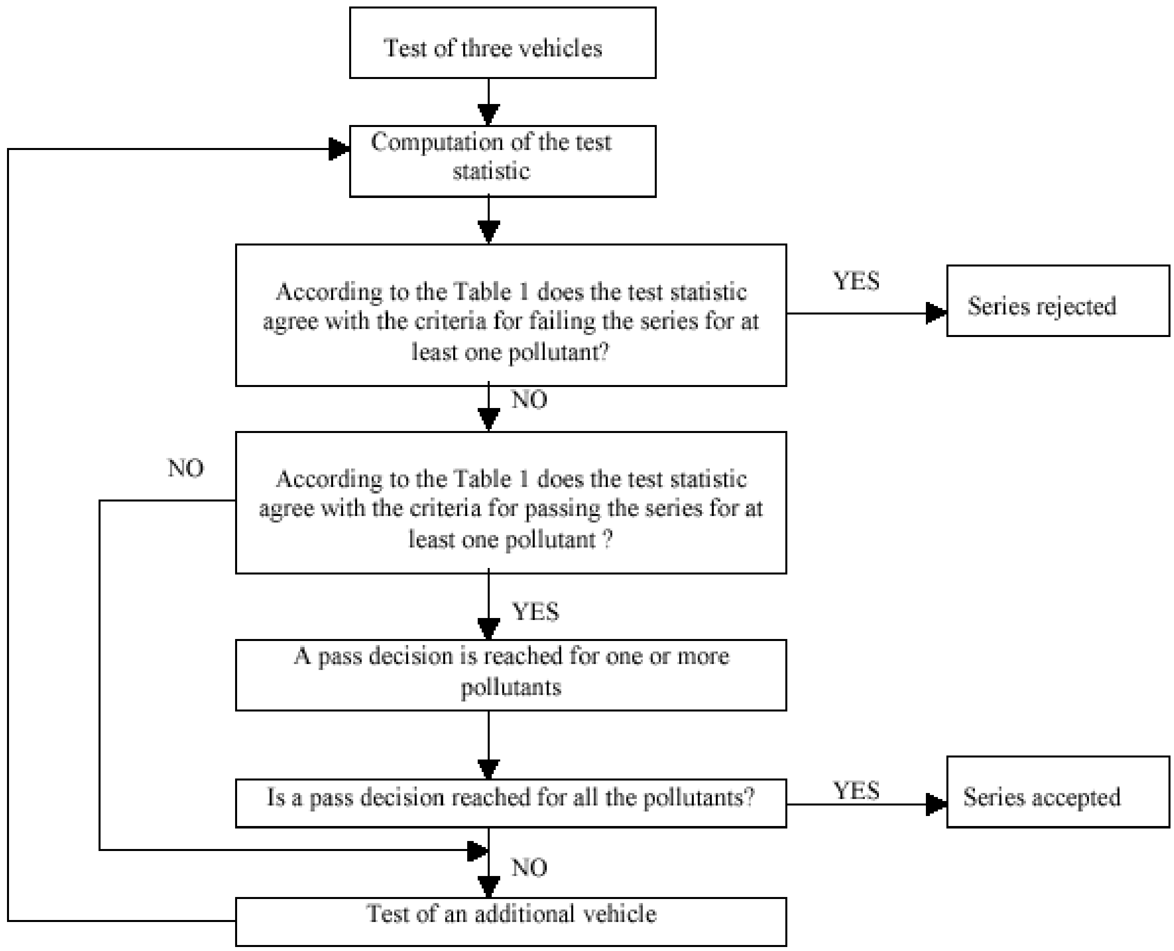


Figure 2: Option 1 CoP Test Procedure as per Bharat Stage IV for 4 wheelers.

Table I: <u>Applicable for CoP Procedure as per Bharat Stage IV for 4 wheelers.</u>

Sample size (n)	Pass decision threshold (A_n)	Fail decision threshold (B_n)
3	-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

8.7 Option 2

8.7.1 The vehicle samples 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 deterioration factors used at the time of type approval and in the case of periodically regenerating systems the results shall also be multiplied by the K_i factors obtained by the procedure specified in Chapter 15 of Part XIV of this document at the time when type approval was granted. 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.

8.7.2 Procedure for Conformity of Production as per Bharat Stage IV for all M and N Category vehicles upto 3.5 tons GVW.

8.7.2.1 Conformity of production shall be verified as per Bharat Stage IV emission norms for 4 wheeler vehicles as given in Para 5.2.2.7 and with the procedure given below.

8.7.2.2 To verify the average tailpipe emissions of gaseous pollutants following procedure shall be adopted:

8.7.2.3 Minimum of three vehicles shall be selected randomly from the series with a sample lot size.

8.7.2.4 After selection by the authority, the manufacturer must not undertake any adjustments to the vehicles selected, except those permitted in Part VI. MoRTH/CMVR/TAP-115/116

8.7.2.5 First vehicle out of three randomly selected vehicles shall be tested for Type - I test as per MoRTH/CMVR/TAP-115/116 Para 5.2.2 of chapter 1.

8.7.2.6 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)

8.7.2.7 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.

8.7.2.8 Third Type - I (V_3) test shall be performed if the para 4.11 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. $(V_1 + V_2 + V_3)/3 \leq L$)

8.7.2.9 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

8.7.2.10 These randomly selected sample No.2 & 3 shall be tested for only one Type - I test as per para 5.2.2. of Part 09, Chapter 1 of MoRTH/CMVR/TAP-115/116.

8.7.2.11 Let X i2 & X i3 are the test results for the Sample No.2 & 3 and Xi1 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

8.7.2.12 If the natural Logarithms of the measurements in the series are X1,X2,X3...........Xj and Li is the natural logarithm of the limit value for the pollutant, then define :

dj = Xj – Li

$$d_n = \frac{1}{n}\sum_{j=1}^{n} d_j$$

$$V_n^{\ 2} = \frac{1}{n}\sum_{j=1}^{n}(d_j - \overline{d_n})^2$$

8.7.2.13 Table I of this part shows values of the pass (An) and fail (Bn) 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, $\overline{d}_n / V_n \geq A_n$ for all the pollutants-
- Fail the series $\overline{d}_n / V_n \geq B_n$ 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.

8.7.2.14 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.-

8.7.2.15 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.

8.8 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.

8.9 Type II Test: Carbon monoxide and Hydrocarbons emission at idling speed. When the vehicle taken from the series for the first 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 and hydrocarbon 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. These vehicles can be same as those selected for carrying out Type I test. Additional vehicles if required, shall be selected for carrying out for Type II test. At least 9 vehicles should meet the limit values specified in Para 5.2.3.2 above. Then the series is deemed to conform.

8.10 For type III test is to be carried out, it must be conducted on all vehicles selected for type I CoP test. (8.2.2.3). The conditions laid down in 5.2.4.2 must be complied with.

8.11 For type IV test is to be carried out, it must be conducted in accordance with section 7 of chapter 11.

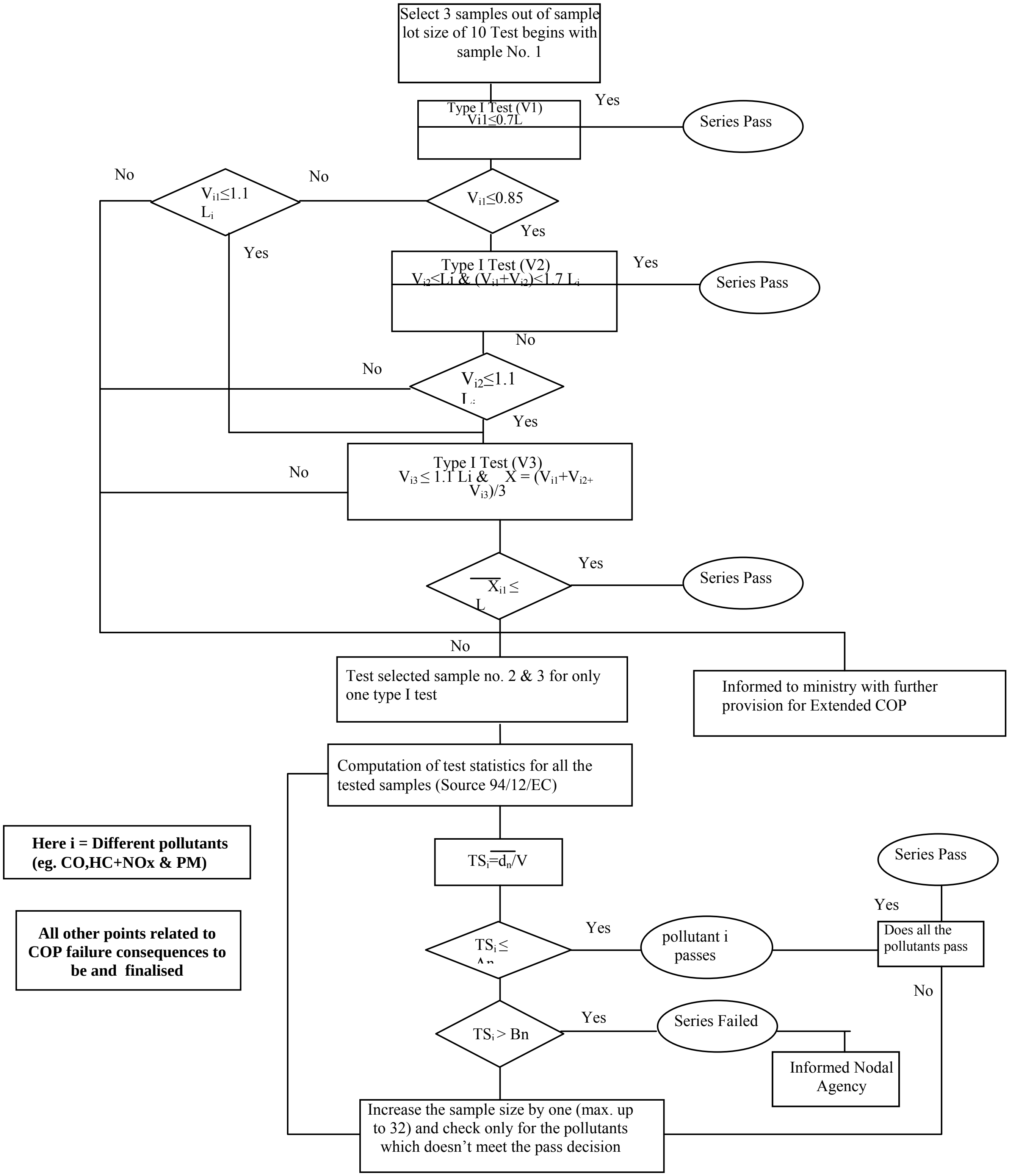


Figure 3

OPTION II : COP Test Procedure as per Bharat Stage IV for 4-Wheelers

Chapter 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE AND ENGINE AND INFORMATION CONCERNING THE CONDUCT OF TESTS

1. Information is to be provided as per AIS-007 Revision 3

2. Additionally for On-board Diagnostic (OBD) system, the following information shall be provided:

2.1. Written description and/or drawing of the Malfunction Indicator (MI).

2.2. List and purpose of all components monitored by the OBD system.

2.3. Written description (general working principles).

2.4. For Positive-ignition engines.
2.4.1. Catalyst monitoring.
2.4.2. Misfire detection.
2.4.3. Oxygen sensor monitoring.
2.4.4. Other components monitored by the OBD system.

2.5. Compression-ignition engines.
2.5.1. Catalyst monitoring.
2.5.2. Particulate trap monitoring
2.5.3. Electronic fuelling system monitoring.
2.5.4. Other components monitored by the OBD system.

2.6. Criteria for MI activation (fixed number of driving cycles or statistical method).

2.7. List of all OBD output codes and formats used (with explanation of each).

2.8. The following additional information shall be provided by the vehicle manufacturer for the purposes of enabling the manufacture of OBD-compatible replacement or service parts and diagnostic tools and test equipment, unless such information is covered by intellectual property rights or constitutes specific know-how of the manufacturer or the OEM supplier(s).

2.8.1. A description of the type and number of the pre-conditioning cycles used for the original type approval of the vehicle.

2.8.2. A description of the type of the OBD demonstration cycle used for the original type-approval of the vehicle for the component monitored by the OBD system.
2.8.3. A comprehensive document describing all sensed components with the strategy for fault detection and MI activation (fixed number of driving cycles

or statistical method), including a list of relevant secondary sensed parameters for each component monitored by the OBD system. A list of all OBD output codes and format used (with an explanation of each) associated with individual emission related power-train components and individual non-emission related components, where monitoring of the component is used to determine MI activation. In particular, a comprehensive explanation for the data given in service $05 Test ID $21 to FF and the data given in service $06 must be provided. In the case of vehicle types that use a communication link in accordance with ISO 15765-4 "Road vehicles, diagnostics on controller area network (CAN) – part 4: requirements for emissions-related systems", a comprehensive explanation for the data given in service $06 Test ID $00 to FF, for each OBD monitor ID supported, must be provided. This information may be defined in the form of a table, as follows:

Component	Fault code	Monitoring strategy	Fault detection criteria	MI activation criteria	Secondary parameters	Preconditioning	Demonstration test
Catalyst	P0420	Oxygen sensor 1 and 2 signals	Difference between sensor 1 and sensor 2 signals	3rd cycle	Engine speed, engine load, A/F mode, catalyst temperature	Two type l cycles	Type l'

Note: For OBD – I the sections 2.4.1, 2.4.2, 2.4.3, 2.5.1, 2.5.2 and 2.5.3, are not required

2.9. Additionally for vehicle equipped with a periodically regenerating system, the following information shall be provided

2.9.1. Regeneration systems / method of exhaust after-treatment systems, description

2.9.1.1. The number of Type I operating cycles, or equivalent engine test bench cycles, between two cycles where regenerative phases occur under the conditions equivalent to Type I test (Distance "D" in figure 1 in Chapter 15).

2.9.1.2. Description of method employed to determine the number of cycles between two cycles where regenerative phases occur.

2.9.1.3. Parameters to determine the level of loading required before regeneration occurs (i.e. temperature, pressure etc.)

2.9.1.4. Description of method used to load system in the test procedure described in paragraph 3.1., Chapter 15

2.9.2. Particulate trap: yes/no

2.9.2.1. Dimensions and shape of the particulate trap (capacity)

2.9.2.2. Type of particulate trap and design

2.9.2.3. Location of the particulate trap (reference distances in the exhaust system)

2.9.2.4. Regeneration system/method. Description and drawing

2.9.2.5. The number of Type I operating cycles, or equivalent engine test bench cycle, between two cycles where regeneration phases occur under the conditions equivalent to Type I test (Distance 'D' in figure 1 in Chapter 15)

2.9.2.6. Description of method employed to determine the number of cycles between two cycles where regenerative phases occur

2.9.2.7. Parameters to determine the level of loading required before regeneration occurs (i.e. temperature, pressure, etc.)

2.9.2.8. Description of method used to load system in the test procedure described in paragraph 3.1 Chapter 15

Chapter 3

TYPE I TEST ON S.I. ENGINES, CNG, LPG AND DIESEL ENGINE 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 2.1.1.

2.1.1. The operating cycle on the chassis dynamometer for four wheelers shall be as per modified Indian Driving Cycle i.e. Urban Driving Cycle (Table II) and Extra Urban Driving Cycle (Table III) and as depicted in the Figure 1 and Figure 2 of this Chapter respectively. The break down by operations is given in Table II-A for Urban Driving Cycle (Part One) and in Table III-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:

2.3.1. The use of gears shall be as shown in Table II and Table III for the elementary urban cycles (Part One) and the extra urban cycle (Part Two) respectively.

2.3.1.1. However, if the maximum speed which can be attained in first gear is below 15 km/h, 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). 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.

Alternatively, if technical justification given by vehicle manufacturer is acceptable to the certifying agency to use first gear for elementary urban cycles (Part One) and extra urban cycle (Part Two) based on vehicle driving characteristics then such cases the first gear can be used.

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. Vehicles equipped with semi-automatic-shift gearboxes shall be tested by using the gears normally employed for driving, and the gear shift is used in accordance with the manufacturer's instructions.

2.3.3. Vehicles equipped with automatic gearboxes 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 II and Table III of this Chapter do not apply: acceleration 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 are 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).

2.3.5. At the request of the manufacturer, for a vehicle type where the idle speed of the engine is higher than the engine speed that would occur during operations 5, 12 and 24 of the elementary urban cycle (Part One), the clutch may be disengaged during the previous operation

2.4. Tolerances

2.4.1. A tolerance of ± 2 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, only the requirements of 6.5.3 apply. Speed tolerances greater than those prescribed shall be accepted, during phase changes provided that the tolerances are never exceeded for more than 0.5 on any one occasion.

2.4.2. Time tolerances of ± 1 second shall be allowed. The above tolerances shall apply equally at the beginning and at the end of each gear changing period for the urban cycle (Part One) and for the operations Nos 3, 5 and 7 of the extra-urban cycle (Part Two).

2.4.3. The speed and time tolerances shall be combined as indicated in Figure 1 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 at least 3000 km 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, 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.

3.1.6. The testing agency may verify that the vehicle performance conforms to that 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.

3.2.1. Reference Fuel shall be used for Type Approval and Conformity of Production one year after the same is available to the test agencies. Till then, Commercial CNG/LPG fuel shall be used as per applicable Gazette Notification under CMVR.

4. **Test Equipment:**

4.1. Chassis Dynamometer:

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

- dynamometer with fixed load curve, i.e. a dynamometer whose physical characteristics provide a fixed load curve shape.

- 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.

4.1.2. The chassis dynamometer may have one or two rollers.

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. Accuracy:

4.1.5.1. It shall be possible to measure and read the indicated load to an accuracy of ± 5 percent.

4.1.5.2. In the case of a dynamometer with a fixed load curve the accuracy of the load setting at 80 km/h shall be ± 5 percent. 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 90, 80, 60, 50, 40, 30 km/h and 10 per cent at 20 km/h. Below this, the dynamometer absorption must be positive.

4.1.5.3. The total inertia of the rotating parts (including the simulated inertia where applicable) shall be known and shall be within ± 20 kg of the inertia class for the test.

4.1.5.4. 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.

4.1.6. Load and Inertia Setting:

4.1.6.1. 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 80 km/h and the absorbed power at 50 km/h shall be noted. The means by which this load is determined and set are described in Chapter 4 of this part.

4.1.6.2. 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 90, 80, 60, 50, 40, 30 and 20 km/h. The means by which these loads are determined and set are described in Chapter 4 of this Part.

4.1.6.3. Chassis Dynamometers with electrical inertia simulation shall be demonstrated to be equivalent to mechanical inertia systems. The means by which equivalence is established is described in Chapter 5 of this Part.

4.1.7. Chassis Dynamometer Calibration:

4.1.7.1. 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 80 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.

4.1.7.2. 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 shall be measured and a continuously proportional sample of the volume shall 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 S_2 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 but in such a manner so as not to effect the functioning of 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 backpressure 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 - Spark ignition Vehicles. The hydrocarbons analyzer shall be of the Flame Ionisation (FID) type calibrated with propane gas expressed equivalent to carbon atoms (C_1).

4.3.1.3.Hydrocarbons (HC) analysis - Compression Ignition Vehicles. The hydrocarbon analyzer 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 (NOx) analysis. The nitrogen oxide analyser shall be of the Chemiluminescent (CLA) type or by NDUVR (non-dispersive ultraviolet resonance absorption) type analyzer, both with an NO_X – NO converter.

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)

$$M = \frac{(V_{mix} * m)}{(V_{ep} * d)} \quad \text{or}$$

$$m = \frac{(M * d * V_{ep})}{V_{mix}}$$

- 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 consists of a material that is hydrophobic and inert towards the components of exhaust gas (fluorocarbon 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 consists 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 temperature 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 changes 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 weighed and stored until they are used. The temperature of the chamber (or room) in which particulate filters are conditioned and weighed shall be maintained to within 295 +/- 3 K (22°C +/-3°C) during all filters conditioning and weighing. The humidity shall be maintained to a dew point of 282.5 K +/- 3 K (9.5°C +/- 3°C) and a relative humidity of 45% +/- 8%.

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, as in para 4.5.1 above
- CO_2 and purified nitrogen, as in para 4.5.1 above.
- NO and purified nitrogen, as in para 4.5.1 above (The amount of NO_2 contained in this calibration gas shall 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 4 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 I. If the corresponding equivalent inertia is not available on the dynamometer, the large value closest to the vehicle reference mass will be used.

5.2. Setting of dynamometer:

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

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

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.

TABLE I

For 4 Wheeler vehicles		
Reference Mass of Vehicle RW (kg)		Equivalent Inertia (kg)
Exceeding	Upto	
----	480	455
480	540	510
540	595	570
595	650	625
650	710	680
710	765	740
765	850	800
850	965	910
965	1080	1020
1080	1190	1130
1190	1305	1250
1305	1420	1360
1420	1530	1470
1530	1640	1590
1640	1760	1700
1760	1870	1810
1870	1980	1930
1980	2100	2040
2100	2210	2150
2210	2380	2270
2380	2610	2270
2610	----	2270

5.3. Preconditioning of the vehicle:

5.3.1. For the compression ignition engine vehicles for the purpose of measuring particulates at most 36 hours and at least 6 hours before testing, the Part II cycle described in Table III 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 and two Part-II driving cycles.

5.3.3. After this preconditioning specific for compression ignition engines 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 at least 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. For positive-ignition engine vehicles fuelled with LPG or CNG or so equipped that they can be fuelled with either petrol or LPG or CNG, between the tests on the first gaseous reference fuel and the second gaseous reference fuel, the vehicle shall be preconditioned before the test on the second reference fuel. This preconditioning is done on the second reference fuel by driving a preconditioning cycle consisting of one part one (urban part) and two times part two (extra urban part) of the test cycle, if reference fuel is available. On the manufacturer's request and with the agreement of the test agency this preconditioning cycle may be extended. The dynamometer setting shall be the one indicated in points 5.1 and 5.2 of this Chapter.

5.3.6. The tyre pressure shall be the same as that indicated by the manufacturer and used for the preliminary road test for brake adjustment. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting in the case of a two-roller 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: $5.5 \leq H \leq 12.2$ g H_2O/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. The blower speed shall be such that, within the operating range of 10 km/h to at least up to 50 km/h the linear velocity of the air at the blower outlet is within ± 5 km/h of the corresponding roller speed., the blower outlet shall have a cross section area of at least 0.2 m^2, height of the lower edge above ground approximately 20 cm. The distance from front end of the vehicle is approx. 30 cm.

6.1.4.2. As an alternative the blower speed shall be at least 6 m/s (21.6 km/h). At the request of the manufacturer for special vehicles (e.g. vans, off-road) the height of the cooling fan can be modified.

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 first cycle starts on the initiation of the engine start-up procedure.

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.

6.2.4. In the case of the use of LPG or CNG as a fuel, it is permissible that the engine is started on petrol and switched to LPG or CNG after a predetermined period of time which cannot be changed by the driver.

6.3. Idling:

6.3.1. Manual-shift or semi-automatic gearbox:

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 gearbox: After initial engagement, the selector shall not be operated at any time during the test except in accordance with paragraph 6.4.3 below or if the selector can actuate the overdrive, if any.

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 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 begins (BS) before or at the initiation of the engine start up procedure and 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 ($CH_{1.85}$):

  - for petrol ($CH_{1.85}$) d = 0.5768 kg/ m^3
  - for diesel ($CH_{1.86}$) d = 0.5768 kg/ m^3
  - for LPG ($CH_{2.525}$) d = 0.6047 kg/ m^3
  - for CNG (CH_4) d = 0.665 kg/ m^3

- In the case of nitrogen oxides (NO_x): d = 1.913 kg/ m^3.
- In case of carbon dioxide(CO_2): d=1.830 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.
  - o 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 1: Elementary – Urban cycle for type I test

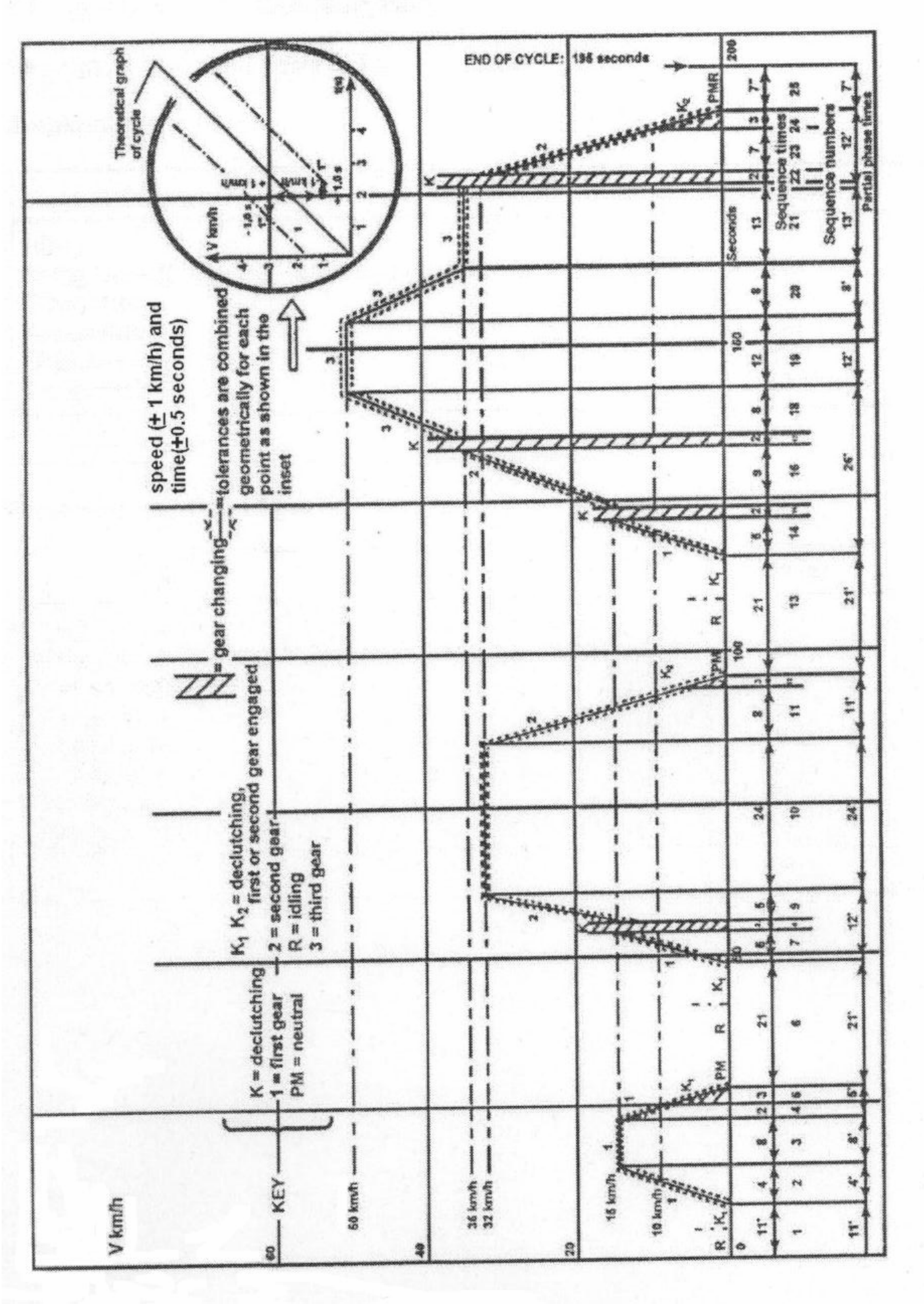


Figure 2: <u>Extra – Urban cycle (Part two) for type I test</u>

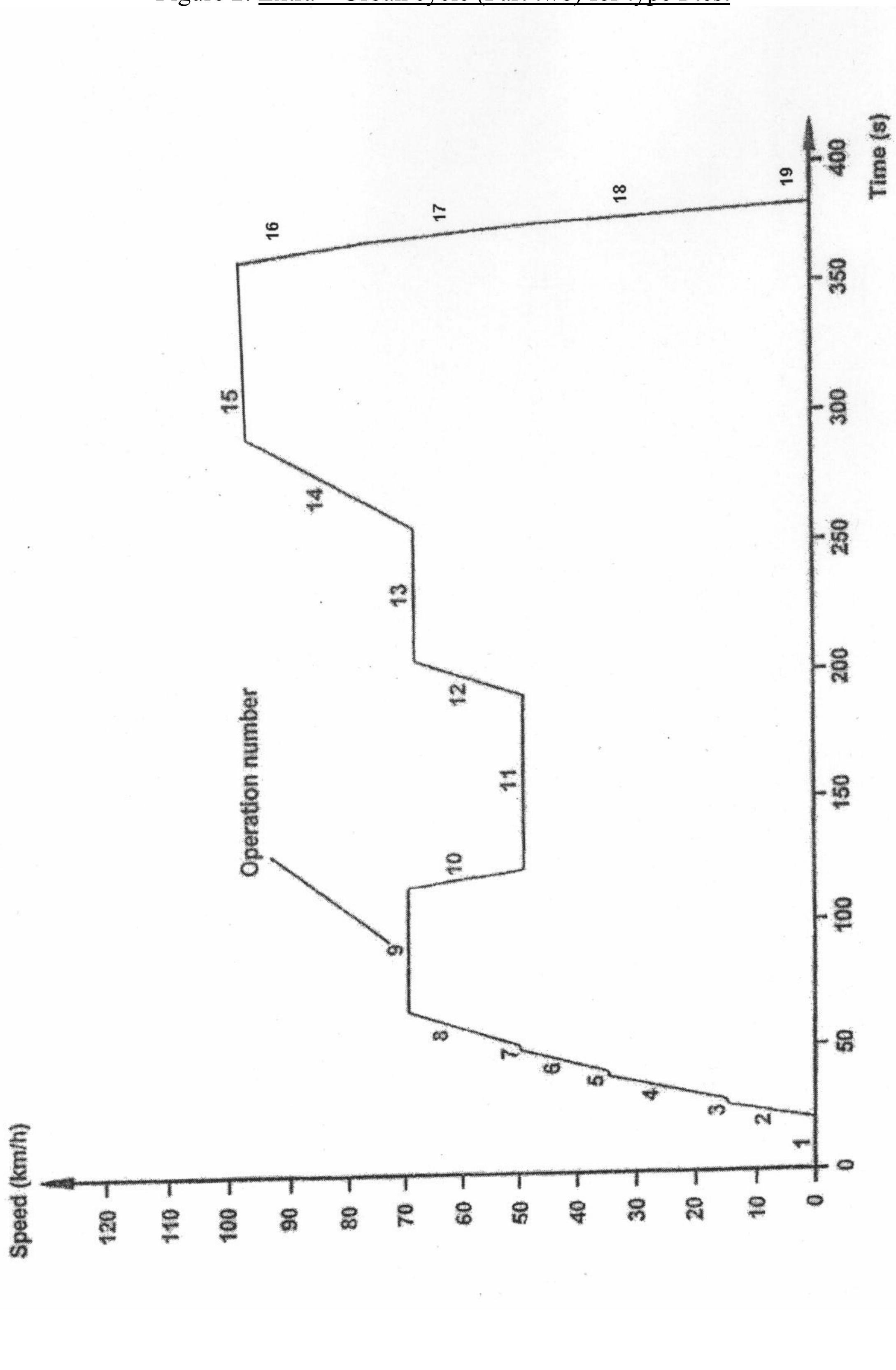


Figure 3: Operating Cycle for the type I Test

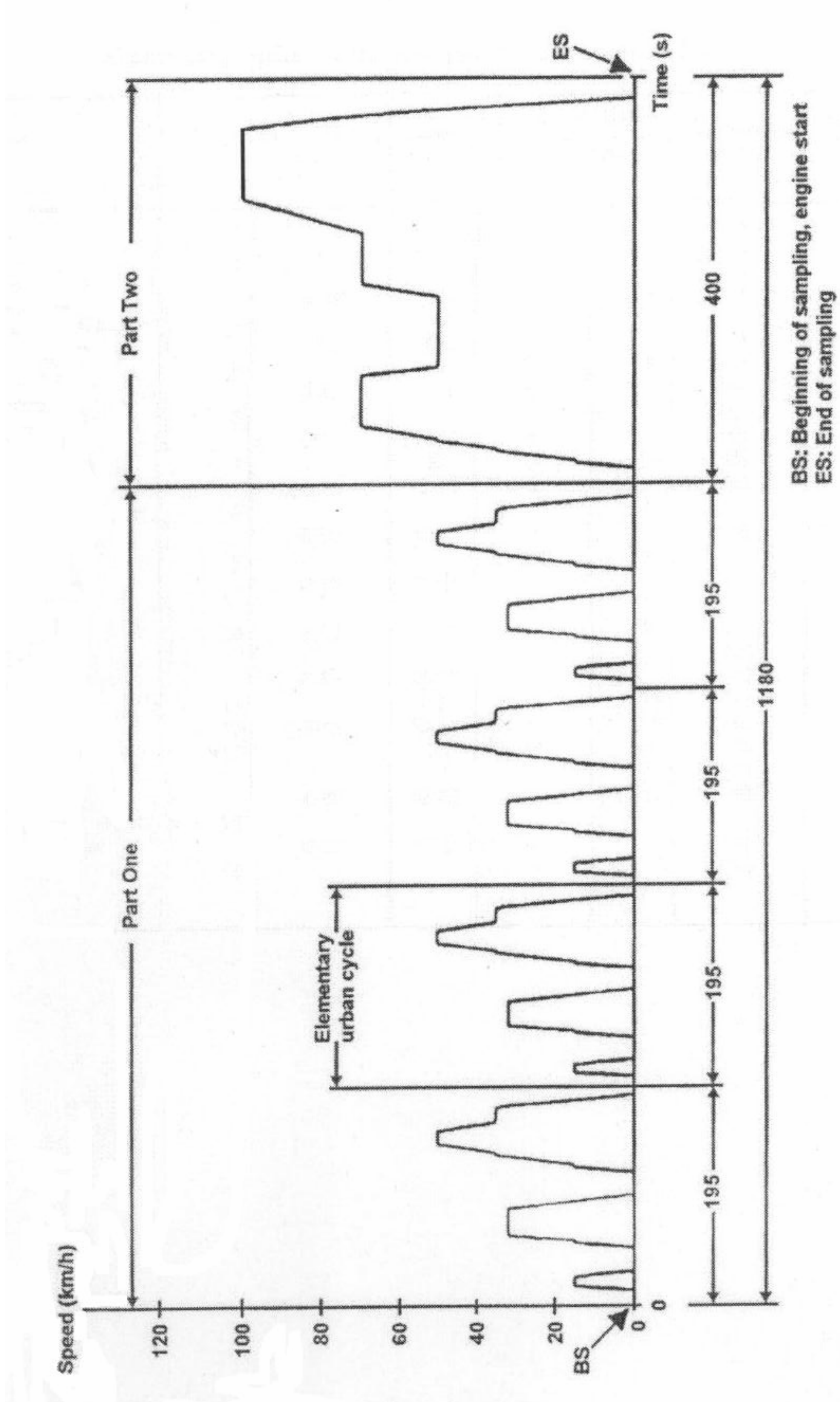


Table II: Modified Indian Driving Cycle Operating Cycle on the Chassis Dynamometer (Part One)

No of Operation	Operation	Phase	Acceleration time ( )	Speed (km)	Duration of each		Cumulative ( )	Gear to be used in case of manual gearbox
					Operation	Phase		
1.	Idling	1	1.04		11	11	11	6 s PM + 5 s K_1 (*)
2.	Acceleration	2		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	26	133	2
17.	Gear change				2		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	12	185	2
24.	Deceleration Clutch disengaged		-0.92	10-0	3		188	K_2 (*)
25.	Idling	15			7	7	195	7 s PM (*)

(*) [ ] - gearbox in neutral, clutch engaged
K_1 K_2 - first or second gear engaged , clutch disengaged

Table II 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	12.8	
	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 III: Modified Indian Driving Cycle Extra-urban cycle (Part Two) for the type I Test

No of Operation	Operation	Phase	Acceleration time ( )	Speed (km)	Duration of each: Operation	Duration of each: Phase	Cumulative ( )	Gear to be used in case of manual gearbox
1	Idling	1			20	20	20	K_1 (*)
2	Acceleration		0.83	0-15	5		25	1
3	Gear change				2		27	----
4	Acceleration	2	0.62	15-35	9		36	2
5	Gear change				2	41	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		-0.69	90-80	4		362	5
17	Deceleration	10	-1.04	80-50	8	22	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 III 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
Accelerations	72	18.0
Steady-speed periods	252	63.0
Decelerations	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
Maximum Speed	:	90 km/h
Maximal Acceleration	:	0.833 m/s^2
Maximal Deceleration	:	-1.389 m/s^2

Chapter 4
CHASSIS DYNAMOMETER

Section I

1. Definition of a Chassis Dynamometer with Fixed Load Curve

1.1. Introduction : In the event that total resistance to progress on the road is not reproduced on the chassis dynamometer between speeds of 10 and 120 km/h, it is recommended to use a chassis dynamometer having the characteristics defined below.

1.2. Definition

1.2.1. The chassis dynamometer may have one or two rollers. The front roller drives, directly or indirectly, the inertia masses and the power absorption device.

1.2.2. The load absorbed by the brake and the chassis dynamometer internal frictional effects from the speed of 0 to 120 km/h is as follows:

$F = (a + b * V^2) +/- 0.1 * F_{80}$ (without being negative)

where:

F = total load absorbed by the chassis dynamometer (N)

a = value equivalent to rolling resistance (N)

b = value equivalent to coefficient of air resistance ($N/(km/h)^2$)

V = speed (km/h)

F_{80} = load at the speed of 80 km/h (N)

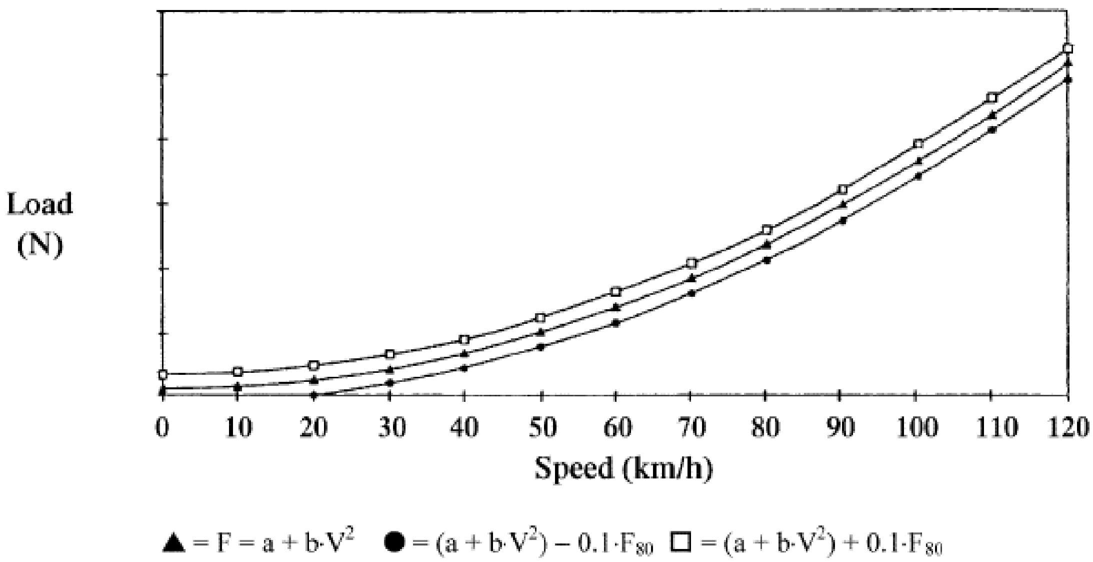
2. Method of Calibrating the Dynamometer

2.1. Introduction: This section describes the method to be used to determine the load absorbed by a dynamometer brake. The load absorbed comprises the load absorbed by frictional effects and the load absorbed by the power-absorption device. The dynamometer is brought into operation beyond the range of test speeds. The device used for starting up the dynamometer is then disconnected: the rotational speed of the driven roller 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 load indicator to 80 km/h as a function of the load absorbed. The following procedure is used (see also Figure 4).

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.

Figure 4. Diagram illustrating the load of the chassis dynamometer



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

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

2.2.4. Bring the dynamometer to a speed of 80 km/h.

2.2.5. Note the load indicated F_i (N).

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 2.2.4 to 2.2.9 must be repeated sufficiently often to cover the range of load used.

2.2.11. Calculate the power absorbed, using the formula:

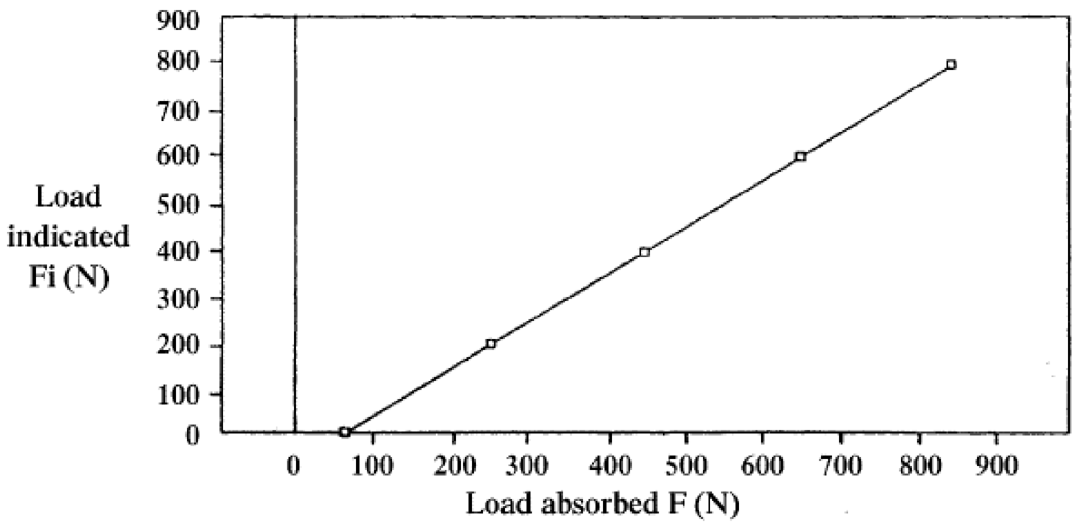
$$F = \frac{M_i \cdot \Delta V}{t}$$

where:

- F = load absorbed in N
- Mi = equivalent inertia in kg (excluding the inertial effects of free rear roller)
- ΔV = speed deviation in m/s (10 km/h = 2.775 m/s)
- t = time taken by the roller to pass from 85 to 75 km/h.

2.2.12. Figure 5 shows the load indicated at 80 km/h in terms of the load absorbed at 80 km/h.

Figure 5. Load indicated at 80 km/h in terms of load absorbed at 80 km/h



2.2.13. The operation described in 2.2.3 to 2.2.12 must be repeated for all inertia classes to be used.

2.3. Calibration of the load indicator as a function of the absorbed load for other speeds. The procedures described in 2.2 must be repeated as often as necessary for the chosen speeds.

2.4. Verification of the load-absorption curve of the dynamometer from a reference setting at 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 load at 80 km/h.

2.4.3. Note the load absorbed at 100, 80, 60, 40 and 20 km/h.

2.4.4. Draw the curve F(v) and verify that it corresponds to the requirements of 1.2.2.

2.4.5. Repeat the procedure set out in 2.4.1 to 2.4.4 for other values of load F at 80 km/h and for other values of inertia.

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

3. Setting of the Dynamometer

3.1. Setting methods: The dynamometer setting may be carried out at a constant speed of 80 km/h in accordance with the requirements of Annexure II of this chapter.

3.1.1. Introduction: This method is not a preferred method and must be used only with fixed load curve shape dynamometers for determination of load setting at 80 km/h and cannot be used for vehicles with compression-ignition engines.

3.1.2. Test instrumentation: The vacuum (or absolute pressure) in the intake manifold vehicle is measured to an accuracy of +/- 0.25 kPa. It must be possible to record this reading continuously or at intervals of no more than one second. The speed must be recorded continuously with a precision of +/- 0.4 km/h.

3.1.3. Road test

3.1.3.1. Ensure that the requirements of clause 4 of Annexure II of this chapter are met.

3.1.3.2. Drive the vehicle at steady speed of 80 km/h recording speed and vacuum (or absolute pressure) in accordance with the requirements of 3.1.2.

3.1.3.3. Repeat procedure set out in 3.1.3.2 three times in each direction. All six runs must be completed within four hours.

3.1.4. Data reduction and acceptance criteria

3.1.4.1. Review results obtained in accordance with 3.1.3.2 and 3.1.3.3 (speed must not be lower than 79.5 km/h or greater than 80.5 km/h for more than one second). For each run, read vacuum level at one-second intervals, calculate mean vacuum ($\bar{v}$) and standard deviation(s). This calculation must consist of no less than 10 readings of vacuum.

3.1.4.2. The standard deviation must not exceed 10% of mean ($\bar{v}$) for each run.

3.1.4.3. Calculate the mean value ($\bar{\bar{v}}$) for the six runs (three runs in each direction).

3.1.5. Dynamometer setting

3.1.5.1. Preparation: Perform the operations specified in 5.1.2.2.1 to 5.1.2.2.4 of Section II of this chapter.

3.1.5.2. Setting: After warm-up, drive the vehicle at a steady speed of 80 km/h and adjust dynamometer load to reproduce the vacuum reading (v) obtained in accordance with 3.1.4.3. Deviation from this reading must be no greater than 0.25 kPa. The same instruments are used for this exercise as were used during the road test.

3.2. Alternative method: With the manufacturer's agreement the following method may be used:

3.2.1. The brake is adjusted so as to absorb the load exerted at the driving wheels at a constant speed of 80 km/h in accordance with the following table:

TABLE: Setting of the Dynamometer (Alternative Method)

Reference Mass of Vehicles		**Equivalent Inertia**	**Power and load absorbed by dynamometer at 80 km/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

3.2.2. 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 as per table given below. However at the manufacturer's request, the factor of 1.3 need not be applied for measurement of fuel consumption.

Sr.No.	Vehicle Type	4 Wheel Drive Mode	Reference Mass	Use of 1.3 factor
1	M1, Passenger Vehicle	Selectable	< 1700 Kg	No
2	M1, Passenger Vehicle	Selectable	> 1700 Kg	No
3	M1, Passenger Vehicle	Permanent	> 1700 Kg	Yes
4	N1, Other than passenger veh	Selectable	> 1700 Kg	Yes
5	N1, Other than passenger veh	Selectable	< 1700 Kg	No

Chapter 4

Section II

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

1. Scope: This section 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 in accordance with paragraph 4.1.7 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. Selection of the vehicle: If not all variants of a vehicle type are measured the following criteria for the selection of the test vehicle shall be used.

4.1.1. Body: If there are different types of body, the worst one in terms of aerodynamics shall be chosen. The manufacturer shall provide data for the selection.

4.1.2. Tyres: The widest tyres shall be chosen. If there are more than three tyres sizes, the widest minus one shall be chosen.

4.1.3. Testing mass: The testing mass shall be the reference mass of the vehicle with the highest inertia range.

4.1.4. Engine: The test vehicle shall have the largest heat exchanger(s).

4.1.5. Transmission: A test shall be carried out with each type of the following transmissions:

- front wheel drive
- rear wheel drive
- full time 4 x 4
- part time 4 x 4
- automatic gear box
- manual gear box

4.2. 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.

4.3. 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.

4.4. 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.

4.4.1. 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.

4.4.2. The vehicle shall be clean.

4.4.3. 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 $V_2 = V + \Delta V$ km/h to $V1 = V - \Delta V$ km/h: with $\Delta V \leq 5$ 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 % ($p \leq 2$ %)

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,

$$s = \sqrt{\sum_{i=1}^{n} \frac{(T_i - \overline{T})^2}{n-1}}$$

n = number of tests,

TABLE : Method of Energy Variation during coast-down

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	2.3	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 14785-2000 to establish “a” and “b” coefficients for setting on chassis dynamometer.

The power (P) determined on the track shall be corrected to the reference ambient conditions as follows:

P corrected = K . P measured

$$K=\frac{R_R}{R_T}\left[I+K_R\left(t-t_\Theta\right)\right]+\frac{R_{AERO}}{R_T}.\frac{\left(p_\Theta\right)}{p}$$

Where

R_R = rolling resistance at speed V

R_{AERO} = aerodynamic drag at speed V

R_T = total driving resistance = $R_R + R_{AERO}$

K_R = temperature correction factor of rolling resistance, taken to be equal to: 8.64 x 10^{-3} / degrees C or the manufacturer’s correction factor that is approved by the authority.

t = road test ambient temperature in degrees C

t_0 = reference ambient temperature = 20 degrees C

rho = air density at the test conditions

rho_0 = air density at the reference conditions (20 degrees C, 100 kPa)

The ratios R_R / R_T and R_{AERO}/ R_T shall be specified by the vehicle manufacturer on the basis of the data normally available to the company.

If these values are not available, subject to the agreement of the manufacturer and the technical service concerned, the figures for the rolling/ total resistance ratio given by the following formula may be used:

Where:

M= vehicle mass in kg

And for each speed the coefficients a and b are shown in the following table:

V (km /h)	a	b
20	7.24 x 10^{-5}	0.82
40	1.59 x 10^{-4}	0.54
60	1.96 x 10^{-4}	0.33
80	1.85 x 10^{-4}	0.23
100	1.63 x 10^{-4}	0.18
120	1.57 x 10^{-4}	0.14

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 brake to reproduce the corrected power (Section 5.1.1.2.8) and to take into account the difference between the vehicle mass (M) on the track and the equivalent inertia test mass (I) to be used. This may be done by calculating the mean corrected road coast down time from V2 to V1 and reproducing the same time on the dynamometer by the following relationship:

$$T_{corrected} = \frac{T_{measured}}{K} \cdot \frac{I}{M}$$

K = specified in 5.1.1.2.8.

5.1.2.2.7. The power Pa to be absorbed by the bench should be determined in order to enable the same power (clause 5.1.1.2.8) to be reproduced for the same vehicle on different days.

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 of at least 20 s. The accuracy of the data recording system shall be at least ± 1 Nm for the torque and ± 0.2 km/h for the speed.

5.2.1.2.3 Differences in torque $C_{(t)}$, and speed relative to time shall not exceed 5% for each second of the measurement period.

5.2.1.2.4 The torque C is the average torque derived from the following formula

$$C_{t1} = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} C(t) dt$$

5.2.1.2.5 The test shall be carried out three times in each direction. Determine the average torque from these six measurements for the reference speed. If the average speed deviates by more than 1 km/h from the reference speed, a linear regression shall be used for calculating the average torque.

5.2.1.2.6 Determine the average of these torques C_{t1} and C_{t2} i.e C_t.

5.2.1.2.7 The average torque $C_{(t)}$ determined on the track shall be corrected to the reference ambient conditions as follows:

$C_{T\ corrected} = K * C_{T\ measured}$

Where K is defined in 5.1.1.2.8 of this annexure.

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 Perform the operations specified in paragraphs 5.2.1.2.1 to 5.2.1.2.4 above.

5.2.2.2.3 Adjust the power absorption unit to reproduce the corrected total track torque of 5.2.1.2.7.

5.2.2.2.4 Proceed with the same operations as in 5.1.2.2.7 for the same purpose.

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:

$$\overline{M} = \frac{1}{t_1 - t_2} \int_{t_1}^{t_2} M(t) * dt \quad \text{(with M(t) > 0)}$$

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 (α 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/s^2.

5.4.1.2.4 Perform the same test in the other direction γ_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 γ where

$$\gamma = \frac{1}{n}\sum_{i=1}^{n}\gamma_i$$

5.4.1.2.7 Calculate the average force absorbed F = m * γ, where m = vehicle reference mass in kg & γ = 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, gearbox 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 coast down 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 driveline 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 ΔV 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/s^2.

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.

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 I of Chapter 3 of this Part).
I_M = inertia of the mechanical masses of the chassis dynamometer
γ = tangential acceleration at roller surface
F_I = inertia force

2.1.2 The total inertia is expressed as follows:

$$I = I_M + \frac{F_1}{\gamma}$$

where
I_M can be calculated or measured by traditional methods
F_I can be measured on the dynamometer, but also can be calculated from the peripheral speed of the rollers.
γ 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 ($\Delta I / I$) 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

Cm = 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

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

γ = 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:

$k_3 * (I_M * ã + F_1) * r_1 = k_3 * I * \gamma * r_1$

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 TAP 115/116. 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 mixture of 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.

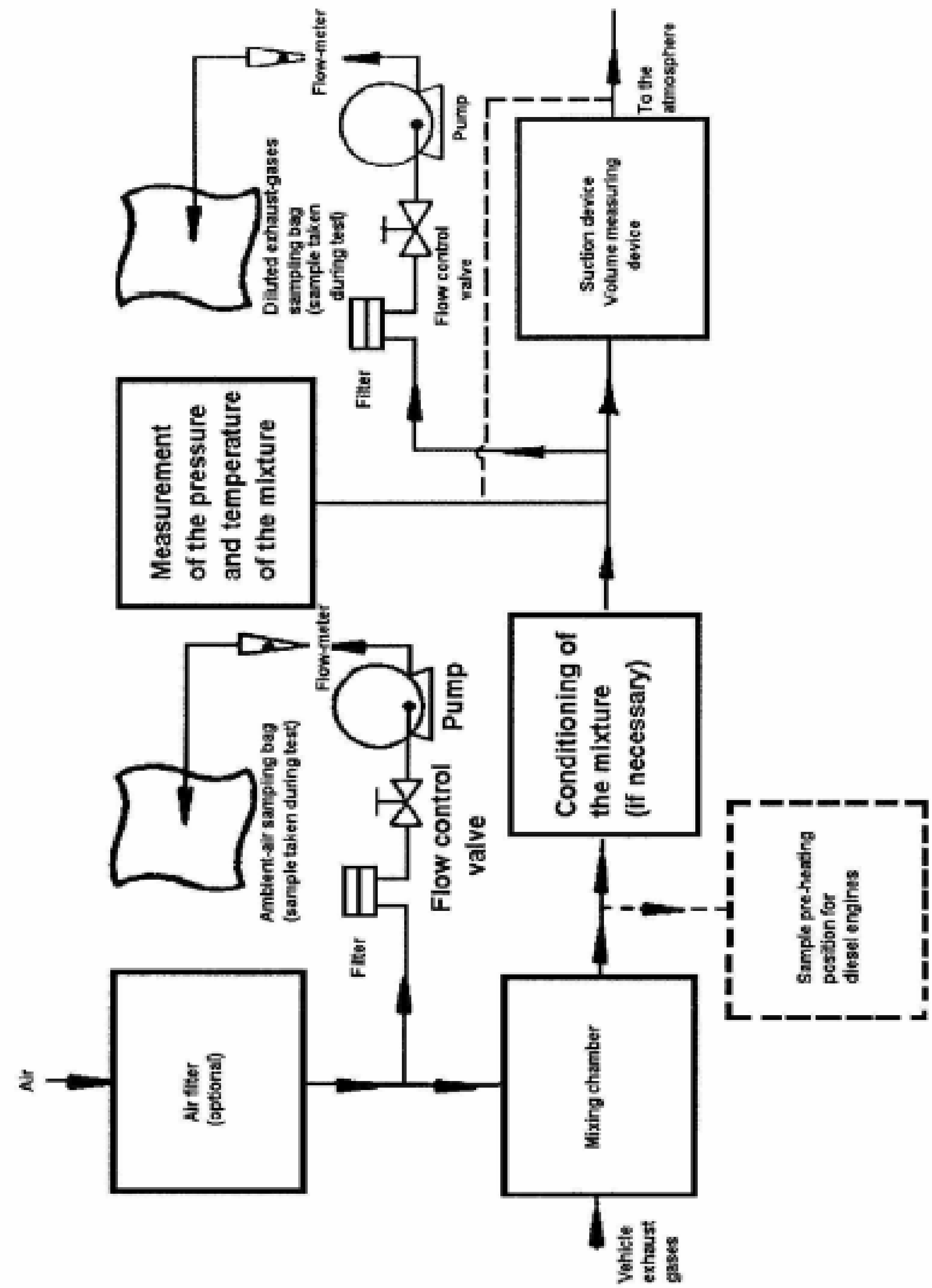


Figure 7 : Diagram of variable-dilution system for measuring exhaust-gas emissions

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 bags of adequate capacity so as to hinder the gas flow during the sampling period. These bags 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 the 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 liters 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 shall 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 ≥ 4,000) shall 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 shall be at least 200 mm in diameter and the system shall be earthed.

2.4.4 The particulate sampling system consists 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 shall be as indicated in Figure 8.

2.4.5 The particulate sampling probe shall 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.

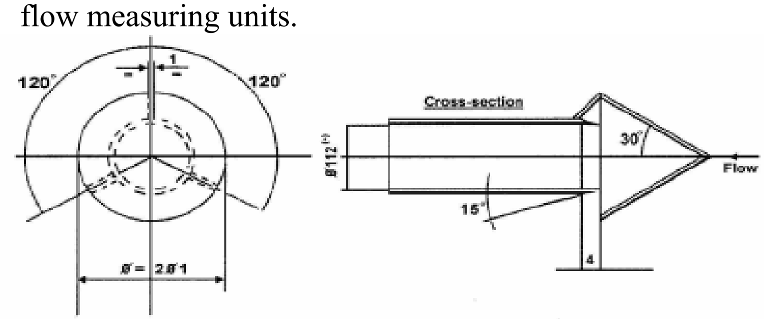


Figure 8 : Particulate Sampling Probe Configuration
(*) Minimum internal diameter
Wall thickness : ~1 mm; Material : Stainless Steel

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 CO2 concentration in the dilute exhaust sample bag is less than 3 % by volume for petrol and diesel, less than 2.2% by volume for LPG and less than 1.5% by volume for NG.

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.

3.1.3.10 A 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-engine vehicles.

3.1.4.1 The additional components shown within the dotted lines of Fig.9 shall be used when testing Diesel Engine 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
S_4 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, s2.

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-engine vehicles.

3.2.4.1 The additional components shown within the dotted lines of Fig.10 shall be used when testing Diesel Engine 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.

L_h: 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 venturi (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), flow meters (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).

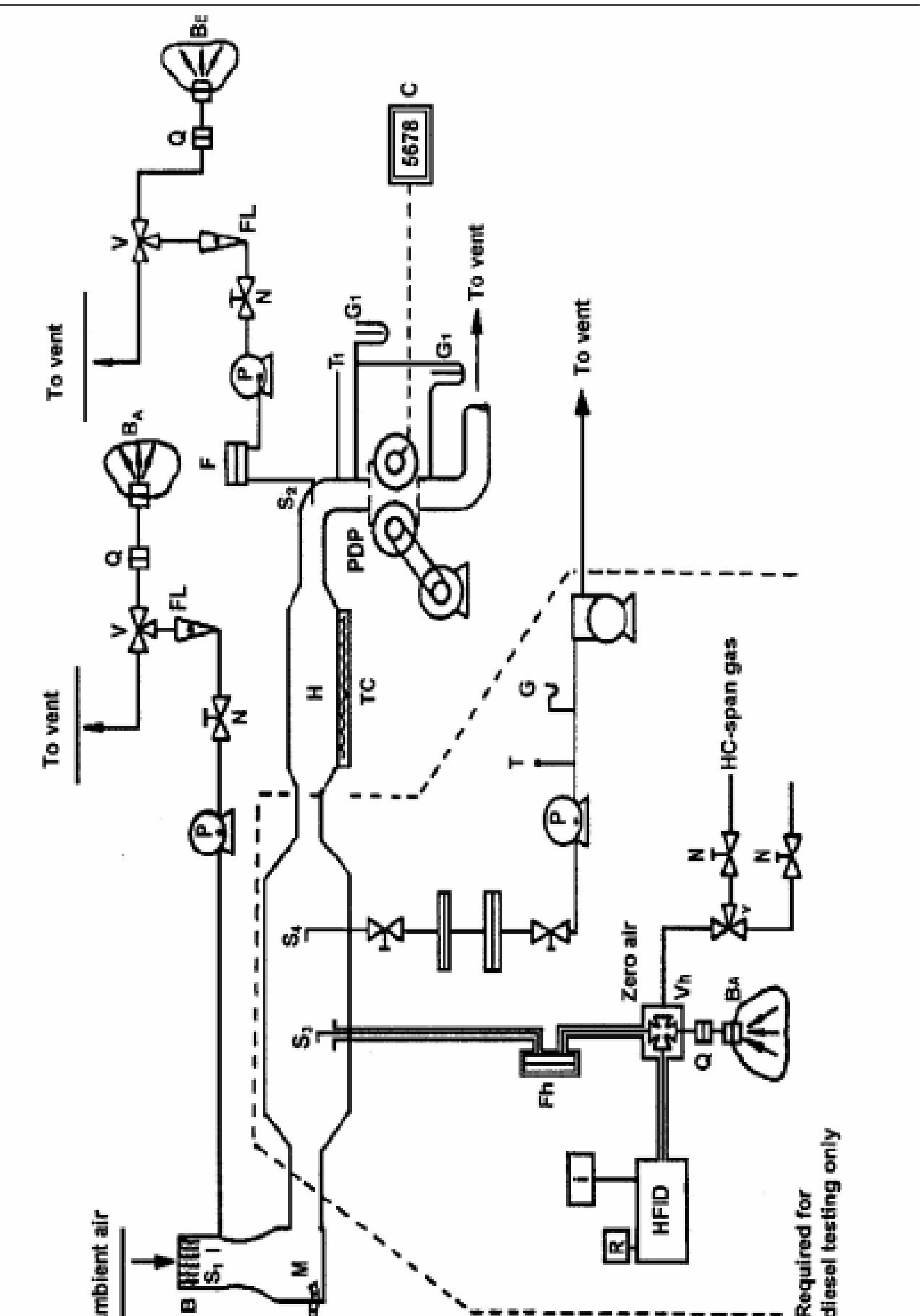


Figure 9 : Schematic Constant Volume Sampler with Positive Displacement Pump (PDP-CVS) (Pls. Ref. Para. 3.1 of this Chapter)

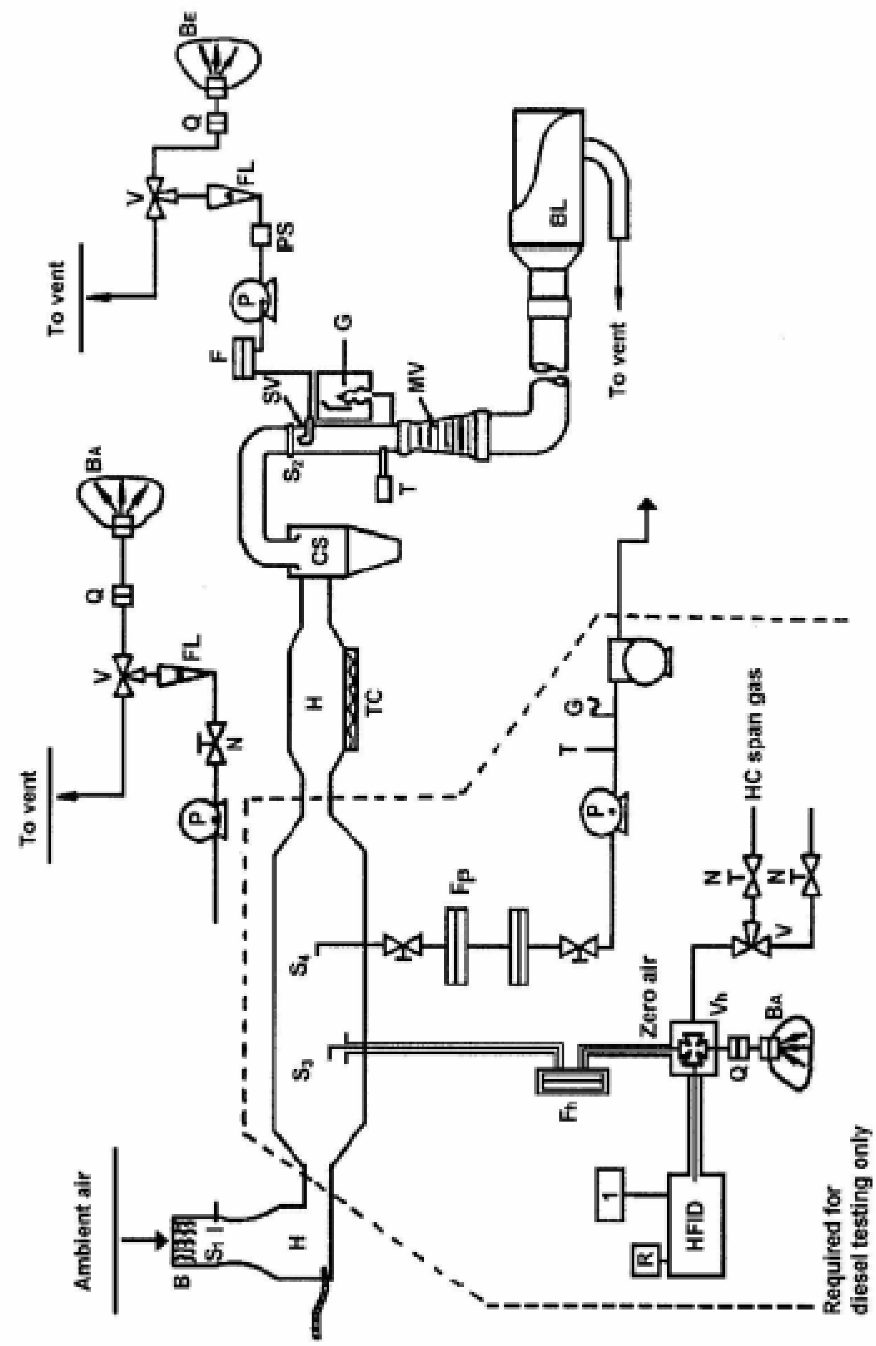


Figure 10 : Schematic Constant Volume Sampler with Critical Flow Venturi (CFV-CVS) (Pls.Ref.Para. 3.2 of this Chapter)

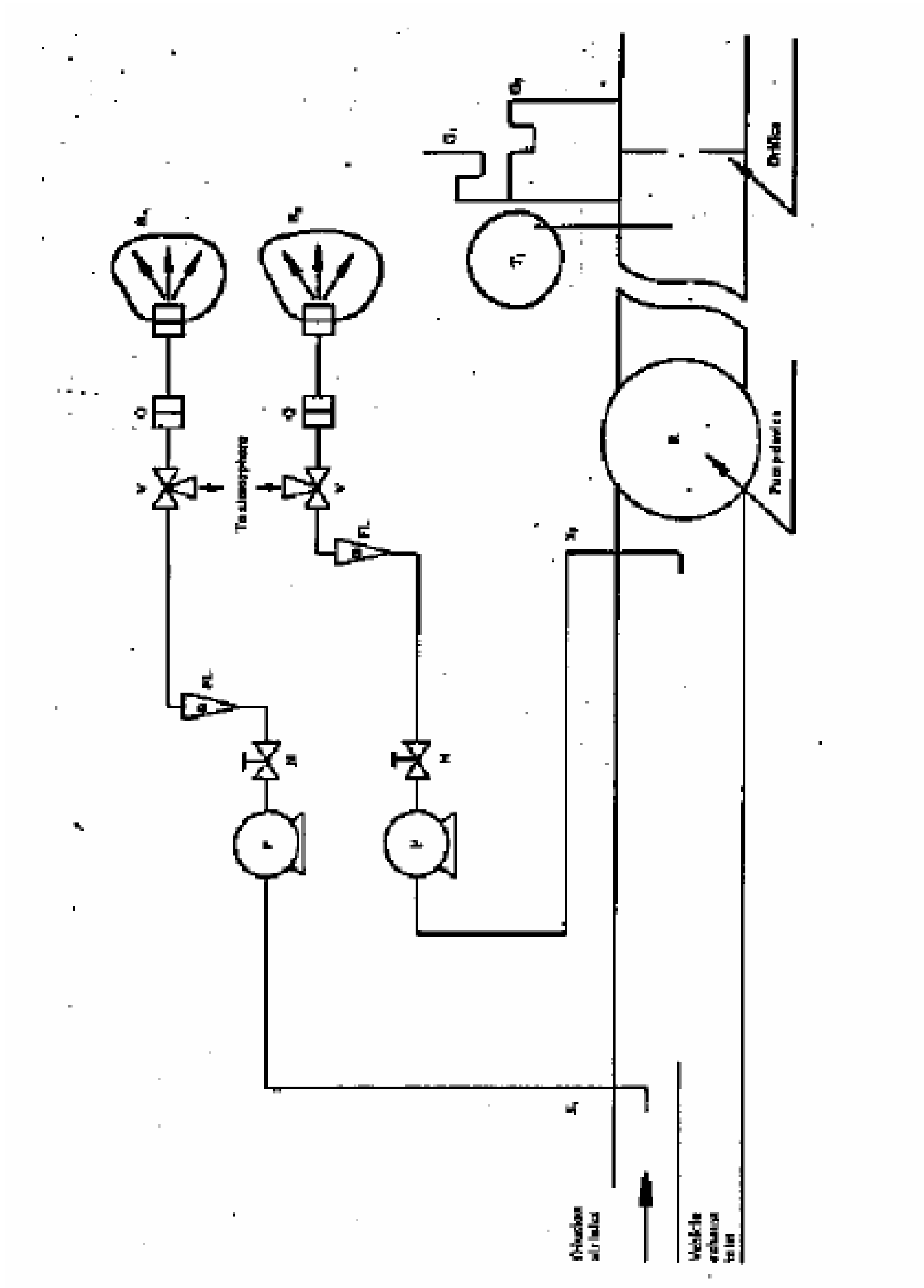


Figure 11 : Schematic of Variable Dilution DeFFigure 11 : Schematic of Variable Dilution Device with Constant Flow Control by Orifice (CFO-CVS)

(Pls. Ref. Para 3.3 of this Chapter)

Chapter 7

CALIBRATION OF CVS SYSTEM AND GAS ANALYSIS SYSTEM AND TOTAL SYSTEM VERIFICATION

1. Scope:

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

2. Calibration of the CVS System:

2.1 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.

2.1.1 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.

2.2 Calibration of the Positive Displacement Pump (PDP):

2.2.1 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.

2.2.2 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:

2.2.2.1 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 head plate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials.

2.2.2.2 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.

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

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

2.2.3.1 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

2.2.3.2 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.

2.2.3.3 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.

2.2.4 Data analysis:

2.2.4.1 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.

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

$$V_o = \frac{Q_s}{n} \cdot \frac{T_p}{273.2} \cdot \frac{101.33}{P_p}$$

Where,

V_o = pump flow rate at T_p and P_p given in m^3 /rev

Q_s = air flow at 101.33 kPa and 273.2 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,

X_o = correlation function

ΔP_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.

2.2.4.3 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.

2.2.4.4 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.

2.3 Calibration of the Critical-Flow Venturi (CFV) (Fig.14)

2.3.1 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 273.2 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 airflow.

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

2.3.3 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 flow meter (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

2.3.4 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.

2.3.5 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.

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

2.3.7 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 273.2 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.

3 Calibration of Gas Analysis System:

3.1 Establishment of Calibration Curve

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 80% of the full scale.

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.

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

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.

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.

3.2 Verification of Calibration

3.2.1 Each normally used operating range must be checked prior to each analysis in accordance with the following:

3.2.2 The calibration is checked by using a zero gas and a span gas whose nominal value is within 80 to 95% of the supposed value to be analyzed.

3.2.3 If, for the two points considered, the value found does not differ by more than ± 5% of full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve must be established in accordance with clause 4.1.

3.2.4 After testing, zero gas and the same span gas used for re-checking. The analysis is considered acceptable if the difference between the two measuring results is less than 2 %.

3.2.5 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.

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

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

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

3.2.9 Using purified dry air (or nitrogen), the CO and NO_x 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.

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

3.2.11 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 3.1.3 above.

3.2.12 If it does not meet, the system should be checked, fault, if any, corrected and a new calibration curve should be obtained.

3.3 Pre-test Checks

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.

3.3.2 Each normally used operating range shall be checked prior to each analysis.

3.3.3 Using purified dry air (or nitrogen), the CO and NO_x analysers shall be set at zero; dry air shall be purified for the HC analyser.

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.

3.3.5 The nominal value of the span calibration gas used shall remain within ± 2% of the calibration curve.

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, tuning of NDIR analysers, optimisation of FID analysers etc. may be adjusted to bring within ± 2%.

3.3.7 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.

3.3.8 Zero shall be checked and the procedures described in Para 4.3.4 above repeated, if required.

3.4 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%.

3.5 Check for FID Hydrocarbon Response

3.5.1 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.

3.5.2 Response factor of different hydrocarbons and recommended limits

3.5.2.1 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.

3.5.2.2 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).

3.5.2.3 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 $1.00 < R_f < 1.15$, or $1.00\ R_f < 1.05$ for NG fuelled vehicles
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.

3.5.3 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 is:
Propane and nitrogen $0.95 \leq R_f \leq 1.05$,

3.6 Efficiency Test of the NO_x Converter:

3.6.1 The efficiency of the converter used for the conversion of NO_2 into NO is tested as follows:

3.6.1.1 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.

3.6.2 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 NO_x analyser shall be in the NO mode so that span gas does not pass through the converter. Record the indicated concentration.

3.6.3 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.

3.6.4 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).

3.6.5 The NO_x analyser 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).

3.6.6 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).

3.6.7 With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_x reading of the analyser shall then be no more than 5 % above the figure in paragraph 4.6.2

3.6.8 The efficiency of the NO_x converter is calculated as follows:

$$\text{Efficiency (\%)} = \left(1 + \frac{(a - b)}{(c - d)}\right) * 100$$

3.6.9 The efficiency of the converter shall not be less than 95%.

3.6.10 The efficiency of the converter shall be tested at least once a week.

3.7 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.

4. Total System Verification:

4.1 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: -

4.1.1 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.

4.2 Metering a limited quantity of pure gas (CO or C_3H_8) by means of a gravimetric technique.

4.2.1 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.

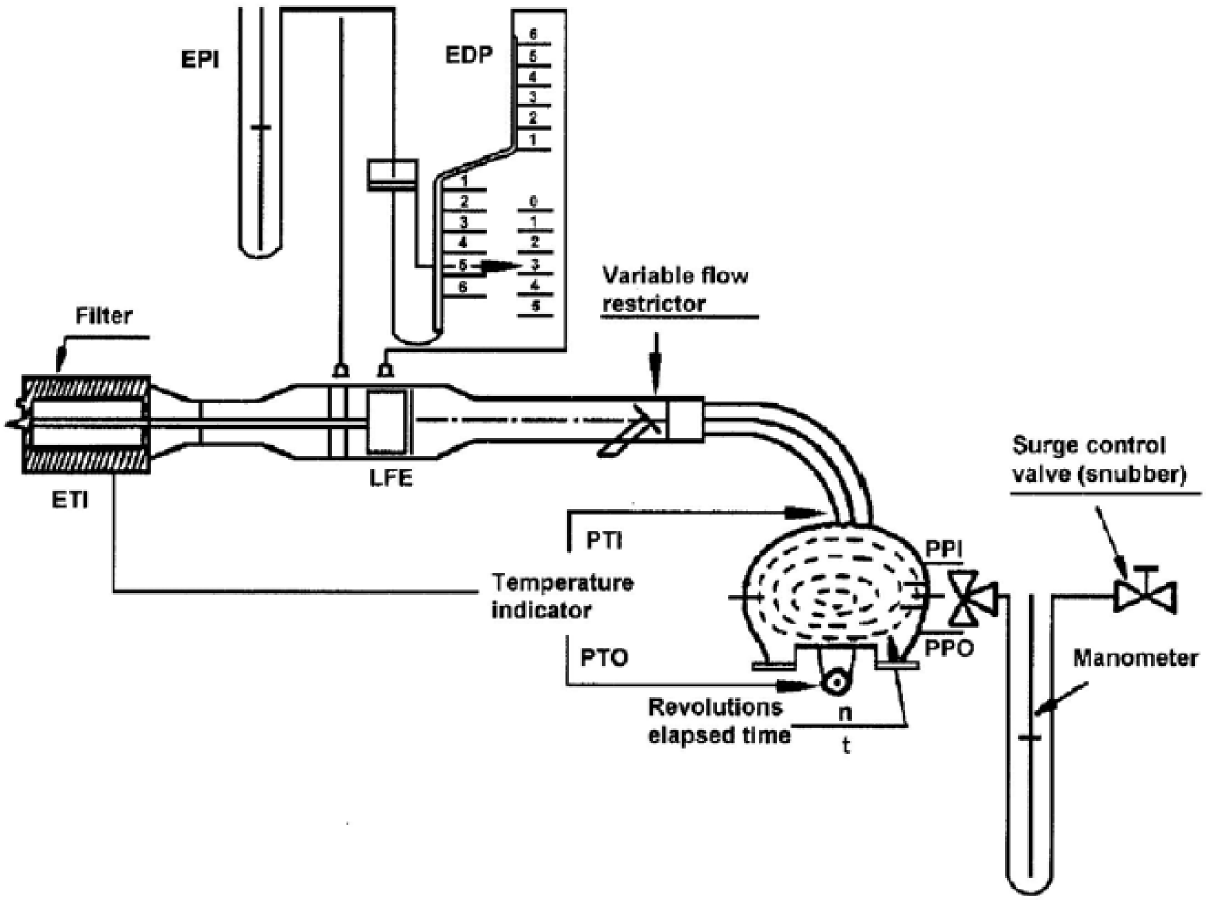


Figure 13: Schematic of PDP-CVS Calibration Set-up
(Pls. Ref. Para 2.2.3.1 of this Chapter)

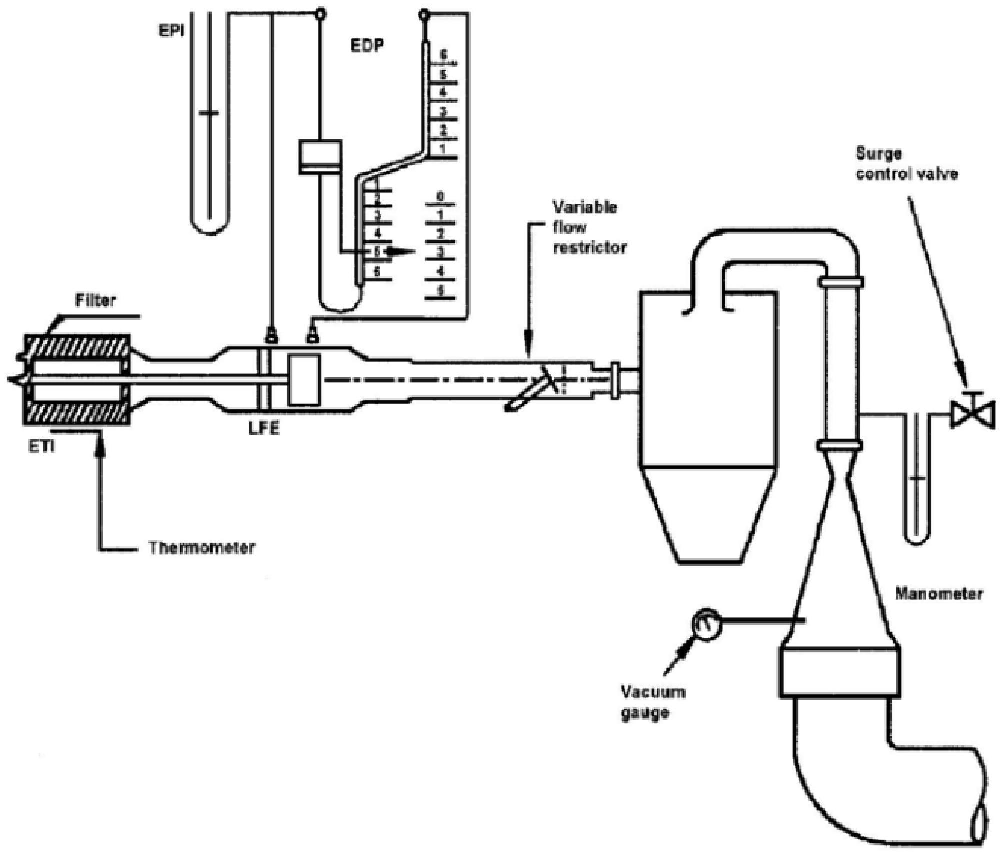


Figure 14: Schematic of CFV-CVS Calibration Set-up
(Pls. Ref. Para 2.3.4 of this Chapter)

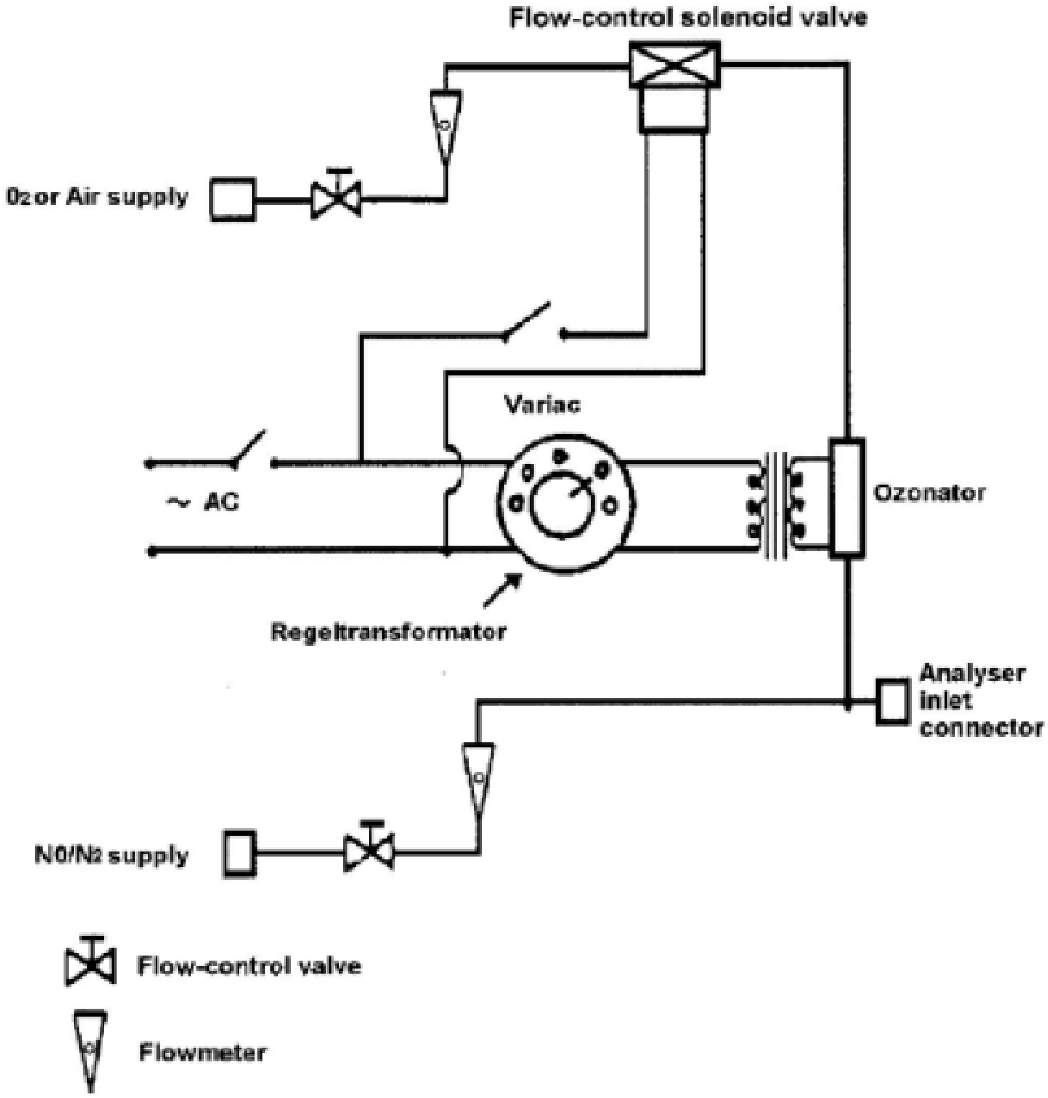


Figure 15: Schematic of Set-up for checking the efficiency of NO_x converter
(Pls. Ref. Para 3.6.1.1 of this Chapter)

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 293K 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:

$$K_1 = \frac{293K}{101.33kPa} = 2.8915(K * kPa^{-1})$$

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:

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}} \qquad \text{(5a) for petrol and diesel fuels}$$

$$DF = \frac{11.9}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}} \qquad \text{(5b) for LPG}$$

$$DF = \frac{9.5}{C_{CO_2} + (C_{HC} + C_{CO})10^{-4}} \qquad \text{(5c) for Natural Gas (NG)}$$

where:

C_{co2} = 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 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:

$$k_H = \frac{1}{1 - 0.0329(H - 10.71)} \qquad (6)$$

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 vapor 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:

V_{mix}: volume of diluted exhaust gases (see 2) under standard conditions.

V_{ep}: volume of exhaust gas flowing through particulate filter under standard conditions.
P_e: 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

7.1 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).

7.2 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, HYDROCARBONS EMISSION AT IDLING)

1 Scope:

This Chapter describes the procedure for the Type II test for verifying carbon monoxide, Hydrocarbons emission at idling of spark ignition engine vehicles, as defined in Para 5.2.3 of Chapter 1 of this Part.

2 Condition of Measurement

2.1 The fuel shall be the reference fuel, specifications for which are given applicable Gazette Notification under CMVR for which vehicle is subjected to test.

2.2 During the test, the environmental temperature must be between 293 and 303 K (20 and 30 degrees C).
The engine shall be warmed up until all temperatures of cooling and lubrication means and the pressure of lubrication means have reached equilibrium.

2.2.1 Vehicles that are fuelled either with petrol or with LPG or NG shall be tested with the reference fuel(s) used for the type I test.

2.3 In the case of vehicle with manually operated or semi-automatic-shift gearboxes the test must be carried out with the gear lever in the 'neutral' position and with the engaged.

2.4 In the case of vehicle with automatic gear-boxes the test is carried out with the gear selector in either the 'neutral' of the 'parking' position.

2.5 Components for adjusting the idling speed.

2.5.1 Definition
For the purposes of this Part, 'components for adjusting the idling speed' means controls for changing the idling conditions of the engine which may be easily by a mechanic using only the tools described in 2.5.1.1. In particular, devices for calibrating fuel and air flows are not considered as adjustment components if their setting requires the removal of the set-stops, an operation which cannot normally be performed except by a professional mechanic.

2.5.1.1 Tools which may be used to control components for adjusting the idling speed: screwdrivers (ordinary or cross-headed), spanners (ring, open-end of adjustable), pliers, Allen keys.

2.5.2 Determination of measurement points

2.5.2.1 A measurement at the setting in accordance with the conditions fixed by the manufacturer is performed first.

2.5.2.2 For each adjustment component with a continuous variation, a sufficient number of characteristic positions are determined.

2.5.2.3 The measurement of the carbon-monoxide content of exhaust gases must be carried out for all the possible position of the adjustment components, but for components with a continuous variation only the positions defined in 2.5.2.2 are adopted.

2.5.2.4 The Type II test is considered satisfactory if at least one of the two following conditions is met:

2.5.2.4.1 none of the values measured in accordance with 2.5.2.3 exceeds the limit values;

2.5.2.4.2 the maximum content obtained by continuously varying one of the adjustment components while the other components are kept stable does not exceed the limit value, this condition being met for the various combinations of adjustment components other than the one which was varied continuously.

2.5.2.5 The possible positions of the adjustment components are limited:

2.5.2.5.1 on the one hand, by the larger of the following two values: the lowest idling speed which the engine can reach; the speed recommended by the manufacturer, minus 100 revolutions per minute;

2.5.2.5.2 on the other hand, by the smallest of the following three values: the highest speed the engine can attain by activation of the idling speed components; the speed recommended by the manufacturer, plus 250 revolutions per minute; the cut-in speed of automatic clutches.

2.5.2.6 In addition, settings incompatible with correct running of the engine must not be adopted as measurement settings. In particular, when the engine is equipped with several carburetors all carburetors must have the same setting.

3 Sampling of Gases

3.1 The value of CO, HC concentration reading shall be recorded.

3.2 The sampling probe is placed in the pipe connecting the exhaust with the sampling bag and as close as possible to exhaust.

3.3 The concentration in CO (Cco) and CO2 (Cco_2) is determined from the measuring instrument readings or recordings, by use of appropriate calibration curves.

3.4 The corrected concentration for carbon monoxide regarding four-stroke engine is:

$$C_{CO}corr = C_{CO} \frac{15}{C_{CO} + C_{CO_2}} \quad (vol.\%)$$

3.5 The concentration in Cco (see 3.2) measured according to the formulae contained in 3.3 need not be corrected if the total of the concentrations measured (Cco + Cco_2) is at least 15 for four stroke engines.

Chapter 10

TYPE III TEST - DETAILS FOR STANDARDS FOR EMISSIONS OF CRANK-CASE EMISSIONS FROM PETROL ENGINES

1 INTRODUCTION:

This Annexure describes the procedure for the Type III test.

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.

5.6 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 liters 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.

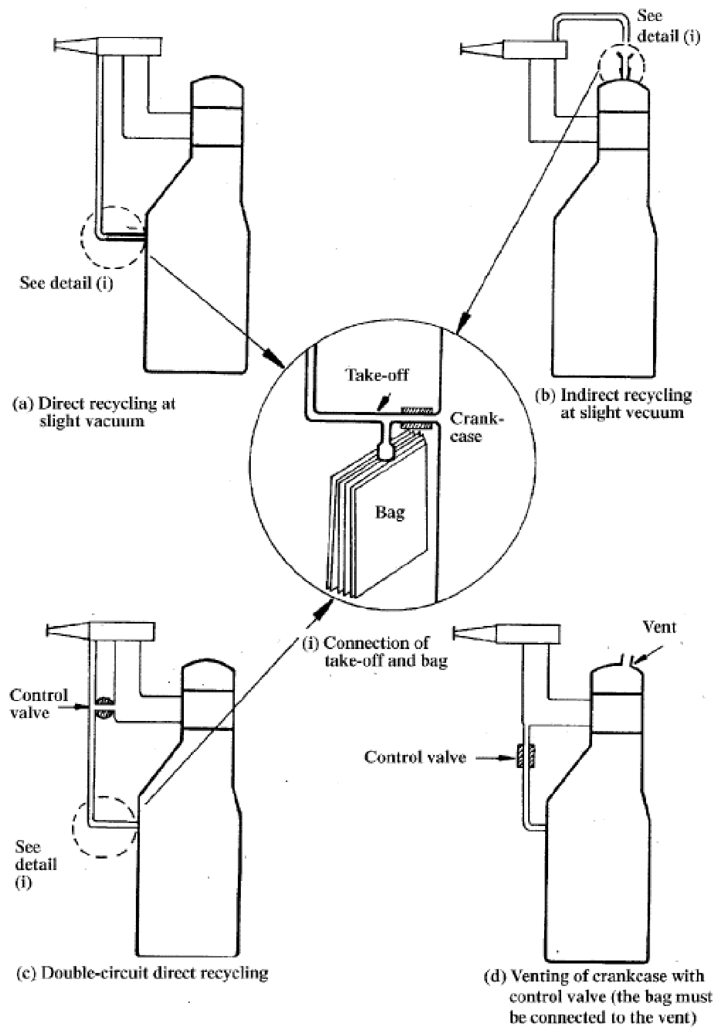
6.5 Remark:

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.

6.5.3 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.

Figure 1.



See detail (i)
(a) Direct recycling at slight vacuum
See detail (i)
(b) Indirect recycling at slight vecuum
Take-off
Crank-case
Bag
(i) Connection of take-off and bag
Control valve
See detail (i)
(c) Double-circuit direct recycling
Vent
Control valve
(d) Venting of crankcase with control valve (the bag must be connected to the vent)

Chapter 11

DETAILS FOR STANDARDS FOR EVAPORATIVE EMISSION FROM VEHICLES WITH SPARK-IGNITION ENGINES

Annexure 1: TYPE-IV TEST
(THE DETERMINATION OF EVAPORATIVE EMISSIONS FROM VEHICLES WITH SPARK-IGNITION ENGINES)

Annexure 2: CALIBRATION OF EQUIPMENT FOR EVAPORATIVE EMISSION TESTING.

ANNEXURE 1:

1. INTRODUCTION

This Annexure describes the procedure of the Type IV test.
This procedure describes a method for a determination of the loss of hydrocarbons by evaporation from the fuel systems of vehicles with positive-ignition engines.

2. DESCRIPTION OF TEST

The evaporative emission test (Figure VI.1) is designed to determine hydrocarbon evaporative emissions as a consequence of diurnal temperatures fluctuation, hot soaks during parking, and urban driving.
The test consists of these phases:

- test preparation including an urban (Part One) and extra-urban (Part Two) driving cycle,
- hot soak loss determination,
- diurnal loss determination.

Mass emissions of hydrocarbons from the hot soak and the diurnal loss phases are added up to provide an overall result for the test.

3. VEHICLE AND FUEL

3.1 Vehicle

The vehicle must be in good mechanical condition and have been run in and driven at least 3000 km before the test. The evaporative emission control system must be connected and have been functioning correctly over this period and the carbon canister(s) must have been subject to normal use, neither undergoing abnormal purging nor abnormal loading.

3.2 Fuel

The reference fuel as prescribed in the applicable Gazette Notification under CMVR shall be used.

4. TEST EQUIPMENT FOR EVAPORATIVE TEST

4.1 Chassis Dynamometer

The chassis dynamometer must meet the requirements of Chapter 3.

4.2 Evaporative Emission Measurement Enclosure

The evaporative emission measurement enclosure must be a gas-tight 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 Annexure 2. The inner surface of the enclosure must be impermeable and non-reactive to hydrocarbons. The temperature conditioning system must be capable of controlling the internal enclosure air temperature to follow the prescribed temperature versus time profile throughout the test, and an average tolerance of ± 1K over the duration of the test.

The control system must be tuned to provide a smooth temperature pattern that has a minimum of overshoot, hunting and instability about the desired long-term ambient temperature profile. Interior surface temperatures must not be less than 278 K (5 °C) nor more than 320 K (55 °C) at any time during the diurnal emission test. Wall design must be such as to promote good dissipation of heat. Interior surface temperatures must not be below 293 K (20 °C), nor above 325 K (52 °C) for the duration of the hot soak test.

To accommodate the volume changes due to enclosure temperature changes, either a variable-volume or fixed-volume enclosure may be used.

4.2.1 Variable-volume Enclosure

The variable-volume enclosure expands and contracts in response to the temperature change of the air mass in the enclosure. Two potential means of accommodating the internal volume changes are movable panel(s), or a bellows design, in which an impermeable bag or bag(s) inside the enclosure expand(s) and contract(s) in response to internal pressure changes by exchanging air from outside the enclosure. Any design for volume accommodation must maintain the integrity of the enclosure as specified in Annexure 2 over the specified temperature range.

Any method of volume accommodation must limit the differential between the enclosure internal pressure and the barometric pressure to a maximum value of ± 5 hPa.

The enclosure must be capable of latching to a fixed volume. A variable volume enclosure must be capable of accommodating a ± 7% change from its ‘nominal volume’ (see Annexure 2 section 2.1.1), taking into account temperature and barometric pressure variation during testing.

4.2.2 Fixed-volume Enclosure

The fixed-volume enclosure must be constructed with rigid panels that maintain a fixed enclosure volume, and meet the requirements below:

4.2.2.1 The enclosure must be equipped with an outlet flow stream that withdraws air at a low, constant rate from the enclosure throughout the test. An inlet flow stream may provide make-up air to balance the outgoing flow with incoming ambient air. Inter air must be filtered with activated carbon to provide a relatively constant hydrocarbon level. Any method of volume accommodation must maintain the differential between the enclosure internal pressure and the barometric pressure between 0 and -5 hPa.

4.2.2.2 The equipment must be capable of measuring the mass of hydrocarbon in the inlet and outlet flow streams with a resolution of 0.01 gram. A bag sampling system may be used to collect a proportional sample of the air withdrawn from and admitted to the enclosure. Alternatively, the inlet and outlet flow streams may be continuously analysed using an on-line FID analyzer and integrated with the flow measurements to provide a continuous record of the mass hydrocarbon removal.

4.3 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 ionization detector (FID) type. Sample gas must be drawn from the mid-point 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 analyzer must have a response time to 90% of final reading of less than 1.5 seconds. Its stability must 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 for the analyzer expressed as one standard deviation must 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 analyzer 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 analyzer 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 at least equivalent to the signal being recorded and must provide a permanent record of results. The record must show a positive indication of the beginning and end of the hot soak or diurnal emission test (including beginning and end of sampling periods along with the time elapsed between start and completion of each test).

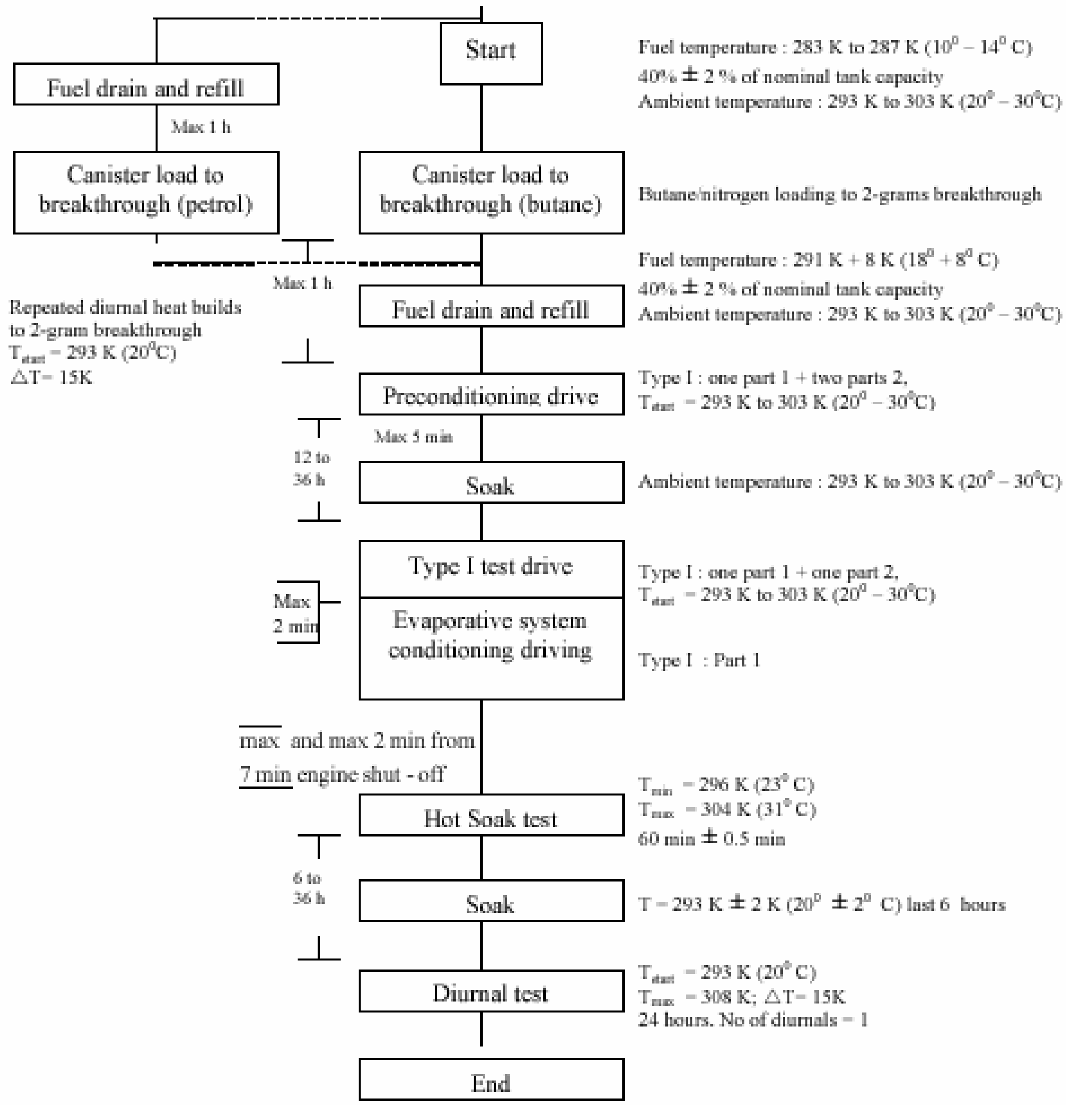


Figure VI.1

Evaporative Emission Determination

3000 km run-in period (no excessive purge/load)

Ageing of canister(s) verified

Steam clean of vehicle (if necessary)

Note : 1) Evaporative emission control families – details clarified.

2) Tailpipe emissions may be measured during Type I test drive, but these are not used for legislative purposes. Exhaust emission legislative test remains separate

4.4 Fuel Tank Heating (only applicable for gasoline canister load option)

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 vapor in the tank above the fuel.

4.4.2 The tank heating device must make it possible to heat the fuel in the tank evenly by 14 °K from 289 °K (16 °C) within 60 minutes, with the temperature sensor position as in 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 0,1 m into the enclosure from the vertical center line of each side wall at a height of 0.9 ± 0.2 m.

4.5.2 The temperature of the fuel tank(s) are recorded by means of the sensor positioned in the fuel tank as in 5.1.1 in the case of use of the gasoline canister load option (5.1.5)

4.5.3 Temperatures must, throughout the evaporative emission measurements, be recorded or entered into 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 Pressure Recording

4.6.1 The difference Δ_p between barometric pressure within the test area and the enclosure internal pressure must, throughout the evaporative emission measurements, be recorded or entered into a data processing system at a frequency of at least once per minute.

4.6.2 The accuracy of the pressure recording system must be within ± 2 hPa and the pressure must be capable of being resolved to ± 0.2 hPa.

4.6.3 The recording or data processing system must be capable of resolving time to ± 15 seconds.

4.7 Fans

4.7.1 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.

4.7.2 The chamber must have one or more fans or blowers of likely capacity 0.1 to 0.5 $m^3 s^{-1}$ 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.

4.8 Gases

4.8.1 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 analyzer fuel gas (40% ± 2% hydrogen and balance helium with less than 1 ppm C1 equivalent hydrocarbon, less than 400 ppm CO_2)
- Propane (C_3H_8), 99.5% minimum purity,
- Butane (C_4H_{10}), 98% minimum purity,
- Nitrogen (N_2), 98% minimum purity.

4.8.2 Calibration and span gases must 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 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 Appendix 1 may also be obtained by the use of a gas divider using synthetic air as the diluent gas.

4.9 Additional Equipment

4.9.1 The absolute humidity in the tests area must be measurable to within ± 5%.

5 TEST PROCEDURE

5.1 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,

- In the case of use of the gasoline canister load option (5.1.5) the fuel tank of the vehicle must be equipped with a temperature sensor to enable the temperature to be measured at the mid-point of the fuel in the fuel tank when filled to 40% of its capacity,
- Additional fittings, adapters of devices may be fitted to the fuel system in order to allow a complete draining of the fuel tank. For this purpose it is not necessary to modify the shell of the tank.
- The manufacturer may propose a test method in order to take into account the loss of hydrocarbons by evaporation coming only from the fuel system of the vehicle.

5.1.2 The vehicle is taken into the test area where the ambient temperature is between 293 K and 303 K (20 and 30 °C)

5.1.3 The ageing of the canister(s) has to be verified. This may be done by demonstrating that it has accumulated a minimum of 3000 km. If this demonstration is not given, the following procedure is used. In the case of a multiple canister system each canister must undergo the procedure separately.

5.1.3.1 The canister is removed from the vehicle. Special care must be taken during this step to avoid damage to components and the integrity of the fuel system.

5.1.3.2 The weight of the canister must be checked.

5.1.3.3 The canister is connected to a fuel tank, possibly an external one, filled with reference fuel, to 40% volume of the fuel tank(s).

5.1.3.4 The fuel temperature in the fuel tank must be between 283 K (10 °C) and 287 K (14 °C)

5.1.3.5 The (external) fuel tank is heated from 288 K to 318 K (15 °C to 45 °C) (1 °C increase every 9 minutes)

5.1.3.6 If the canister reaches breakthrough before the temperature reaches 318 K (45 °C), the heat source must be turned off. Then the canister is weighed. If the canister did not reach breakthrough during the heating to 318 K (45 °C), the procedure from 5.1.3.3 must be repeated until breakthrough occurs.

5.1.3.7 Breakthrough may be checked as is described in 5.1.5 and 5.1.6 of this Chapter, or with the use of another sampling and analytical arrangement capable of detecting the emission of hydrocarbons from the canister at breakthrough.

5.1.3.8 The canister must be purged with 25 ± 5 liters per minute with the emission laboratory air until 300 bed volume exchanges are reached

5.1.3.9 The weight of the canister must be checked.

5.1.3.10 The steps of the procedure in 5.1.3.4 and 5.1.3.9 must be repeated nine times. The test may be terminated prior to that, after not less than three ageing cycles, if the weight of the canister after the last cycles has stabilized.

5.1.3.11 The evaporative emission canister is reconnected and the vehicle restored to its normal operating condition.

5.1.4 One of the methods specified in 5.1.5 and 5.1.6 must be used to precondition the evaporative canister. For vehicles with multiple canisters, each canister must be preconditioned separately.

5.1.4.1 Canister emissions are measured to determine breakthrough.
Breakthrough is here defined as the point at which the cumulative quantity of hydrocarbons emitted is equal to 2 grams.

5.1.4.2 Breakthrough may be verified using the evaporative emission enclosure as described in 5.1.5 and 5.1.6 respectively. Alternatively, breakthrough may be determined using an auxiliary evaporative canister connected downstream of the vehicle's canister. The auxiliary canister must be well purged with dry air prior to loading.

5.1.4.3 The measuring chamber must be purged for several minutes immediately before the test until a stable background is obtained. The chamber air mixing fan(s) must be switched on at this time. The hydrocarbon analyzer must be zeroed and spanned immediately before the test.

5.1.5 Canister Loading with Repeated Heat Builds to Breakthrough

5.1.5.1 The fuel tank(s) of the vehicle(s) is (are) emptied using the fuel tank drain(s). This must be done so as not to abnormally purge or abnormally load the evaporative control devices fitted to the vehicle. Removal of the fuel cap is normally sufficient to achieve this.

5.1.5.2 The fuel tank(s) is (are) refilled with test fuel at a temperature of between 283 K to 287 K (10 to 14 °C) to 40% ± 2 % of the tank's normal volumetric capacity. The fuel cap(s) of the vehicle must be fitted at this point.

5.1.5.3 Within one hour of being refueled the vehicle must be placed, with the engine shut off, in the evaporative emission enclosure. The fuel tank temperature sensor is connected to the temperature recording system. A heat source must be properly positioned with respect to the fuel tank(s) and connected to the temperature controller. The heat source is specified in 4.4 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 ± 1.5 °K.

5.1.5.4 The fuel may be artificially heated to the starting diurnal temperature of 293 K (20 °C) ± 1 K.

5.1.5.5 When the fuel temperature reaches at least 292 K (19 °C), the following steps must be taken immediately; the purge blower must be turned off; enclosure doors closed and sealed; and measurement initiated of the hydrocarbon level in the enclosure.

5.1.5.6 When the fuel temperature of the fuel tank reaches 293 K (20 °C) a linear heat build of 15 K (15 °C) begins. The fuel must be heated in such a way that the temperature of the fuel during the heating conforms to the function below to within ± 1.5 °K. The elapsed time of the heat build and temperature rise is recorded.

$$T_r = T_0 + 0.2333 \text{ x } t$$

Where:
T_r = required temperature (K);
T_0 = initial temperature (K);
T = time from start of the tank heat build in minutes.

5.1.5.7 As soon as breakthrough occurs or when the fuel temperature reaches 308 °K (35 °C), whichever occurs first, the heat source is turned off, the enclosure doors unsealed and opened, the vehicle fuel tank cap(s) removed. If breakthrough has not occurred by the time the fuel temperature reaches 308 °K (35 °C), the heat source is removed from the vehicle, the vehicle removed from the evaporative emission enclosure and the entire procedure outlined in 5.1.7 repeated until breakthrough occurs.

5.1.6 Butane Loading to Breakthrough

5.1.6.1 If the enclosure is used for the determination of the breakthrough (see 5.1.4.2) the vehicle must be placed, with the engine shut off, in the evaporative emission enclosure.

5.1.6.2 The evaporative emission canister must be prepared for the canister loading operation. The canister must not be removed from the vehicle, unless access to it in its normal location is so restricted that loading can only reasonably be accomplished by removing the canister from the vehicle. Special care must be taken during this step to avoid damage to the components and the integrity of the fuel system.

5.1.6.3 The canister is loaded with a mixture composed of 50% butane and 50% nitrogen by volume at a rate of 40 grams butane per hour.

5.1.6.4 As soon as the canister reaches breakthrough, the vapor source must be shut off, 5.1.6.5 The evaporative emission canister must then be reconnected and the vehicle restored to its normal operating condition.

5.1.7 Fuel Drain and Refill

5.1.7.1 The fuel tank(s) of the vehicle(s) is (are) emptied using the fuel tank drain(s). This must be done so as not to abnormally purge or abnormally load the evaporative control devices fitted to the vehicle. Removal of the fuel cap is normally sufficient to achieve this.

5.1.7.2 The fuel tank(s) is (are) refilled with test fuel at a temperature of between 291 K ± 8 K (18 ± 8 °C) to 40 ± 2% of the tank's normal volumetric capacity. The fuel cap(s) of the vehicle must be fitted at this point.

5.2 Preconditioning Drive

5.2.1 Within one hour from the completing of canister loading in accordance with 5.1.5 or 5.1.6 the vehicle is placed on the chassis dynamometer and is driven through one Part One and two Part Two driving cycles of Type I test as specified in Chapter 3. Exhaust emissions are not sampled during this operation.

5.3 Soak

5.3.1 Within five minutes of completing the preconditioning operation specified in 5.2.1 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 12 hours and a maximum of 36 hours. The engine oil and coolant temperatures must have reached the temperature of the area of within ± 3 K of it at the end of the period.

5.4 Dynamometer Test

5.4.1 After conclusion of the soak period the vehicle is driven through a complete Type I test drive as described in Chapter 3 (cold start urban and extra urban test). Then the engine is shut off. Exhaust emissions may be sampled during this operation and the results must not used for the purpose of exhaust emission type-approval.

5.4.2 Within two minutes of completing the Type I test drive specified in 5.4.1 the vehicle is driven a further conditioning drive consisting of one urban test cycle (hot start) of a Type I test. Then the engine is shut off again. Exhaust emissions need not be sampled during this operation.

5.5 Hot Soak Evaporative Emission Test

5.5.1 Before the completion of the conditioning drive 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.

5.5.2 The hydrocarbon analyzer must be zeroed and spanned immediately prior to the test.

5.5.3 At the end of the conditioning drive 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.

5.5.4 The vehicle must be pushed or otherwise moved into the measuring chamber with the engine switched off.

5.5.5 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 conditioning drive.

5.5.6 The start of a 60 ± 0.5 minutes hot soak period begins when the chamber is sealed. The hydrocarbon concentration, temperature and barometric pressure are measured to give the initial readings C_{HC}, $_iP_i$ and T_i for the hot soak test. These figures are used in the evaporative emission calculation, clause 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.

5.5.7 The hydrocarbon analyzer must be zeroed and spanned immediately before the end of the 60 ± 0.5 minute test period.

5.5.8 At the end of the 60 ± 0.5 minute test period the hydrocarbon concentration in the chamber must be measured. The temperature and the barometric pressure are also measured. These are the final readings C_{HC}, f, P_f and T_f for the hot soak test used for the calculation in clause 6.

5.6 Soak

5.6.1 The test vehicle must be pushed or otherwise moved to the soak area without use of the engine and soaked for not less than 6 hours and not more than 36 hours between the end of the hot soak test and the start of the diurnal emission test. For at least 6 hours of this period the vehicle must be soaked at 293 K ± 2 K (20 °C ± 2 °C).

5.7 Diurnal Test

5.7.1 The test vehicle must be exposed to one cycle of ambient temperature according to the profile specified in Table 1 with a maximum deviation of ± 2 K at any time. The average temperature deviation from the profile, calculated using the absolute value of each measured deviation, must not exceed 1 K. Ambient temperature must be measured at least every minute. Temperature cycling begins when time $t_{start} = 0$, as specified in 5.7.6.

5.7.2 The measuring chamber must be purged for several minutes immediately before the test until a stable background is obtainable. The chamber mixing fan(s) must also be switched on at this time.

5.7.3 The test vehicle, with the engine shut off and the test vehicle windows and luggage compartment(s) opened must be moved into the measuring chamber. The mixing fan(s) must be adjusted in such a way as to maintain a minimum air circulation of 8 km/h under the fuel tank of the test vehicle.

5.7.4 The hydrocarbon analyzer must be zeroed and spanned immediately before the test.

5.7.5 The enclosure doors must be closed and gas-tight sealed.

5.7.6 Within 10 minutes of closing and sealing the doors, the hydrocarbon concentration, temperature and barometric pressure are measured to give the initial readings C_{HC}, $_iP_i$ and T_i for the diurnal test. This is the point where time $t_{start} = 0$.

5.7.7 The hydrocarbon analyzer must be zeroed and spanned immediately before the end of the test.

5.7.8 The end of the emission sampling period occurs 24 hours ± 6 minutes after the beginning of the initial sampling, as specified in 5.7.6. The time elapsed is recorded. The hydrocarbon concentration, temperature and barometric pressure are measured to give the final readings C_{HC}, f, P_f and T_f for the diurnal test used for the calculation in clause 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 diurnal 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:

$$M_{HC} = k \cdot V \cdot 10^{-4} \cdot \left(\frac{C_{HC,f} \cdot P_f}{T_f} - \frac{C_{HC,i} \cdot P_i}{T_i}\right) + M_{HC,out} - M_{HC,i}$$

where:
M_{HC} = hydrocarbon mass in grams
$M_{HC, out}$ = mass of hydrocarbon exiting the enclosure, in the case of fixed-volume enclosures for diurnal emission testing (grams)
$M_{HC, i}$ = mass of hydrocarbon entering the enclosure, in the case of fixed-volume enclosures for diurnal emission testing (grams)
C_{HC} = measured hydrocarbon concentration in the enclosure (ppm (volume) C_1 equivalent)
V = net enclosure volume in cubic meters 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 x (12 + H/C);

where:
i is the initial reading,
f is the final reading,
H/C is taken to be 2.33 for diurnal test 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 :
$M_{total} = M_{DI} + M_{HS}$

where:
M_{total} = overall mass emissions of the vehicle (grams),
M_{DI} = hydrocarbon mass emission for diurnal test (grams),
M_{HS} = hydrocarbon mass emission for the hot soak (grams).

7 CONFORMITY OF PRODUCTION

7.1 For routine end-of-production-line testing, the holder of the approval may demonstrate compliance by sampling vehicles, which shall meet the following requirements.

7.2 Test for leakage

7.2.1 Vents to the atmosphere from the emission control system shall be isolated.

7.2.2 A pressure of 370 ± 10 mm of H_2O must be applied to the fuel system.

7.2.3 The pressure must be allowed to stabilize prior to isolating the fuel system from the pressure source.

7.2.4 Following isolation of the fuel system, the pressure must not drop by more than 50 mm of H_2O in five minutes.

7.3 Test for venting

7.3.1 Vents to the atmosphere from the emission control must be isolated.

7.3.2 A pressure of 370 ± 10 mm of H_2O must be applied to the fuel system.

7.3.3 The pressure must be allowed to stabilize prior to isolating the fuel system from the pressure source.

7.3.4 The venting outlets from the emission control system to the atmosphere must be reinstated to the production condition.

7.3.5 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.

7.3.6 At the request of the manufacturer 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.

7.4 Purge test

7.4.1 Equipment capable of detecting an airflow rate of 1.0 liters 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.

7.4.2 The manufacturer may use a flow meter of his own choice, if acceptable to the competent authority.

7.4.3 The vehicle must be operated in such a manner that any design feature of the purge system that could restrict purge operation is detected and the circumstances noted.

7.4.4 Whilst the engine is operating within the bounds noted in 7.4.3, the air flow must be determined by either:

7.4.4.1 the device indicated in 7.4.1. being switched in. A pressure drop from atmospheric to a level indicating that a volume of 1.0 liters of air has flowed into the evaporative emission control system within one minutes must be observed; or

7.4.4.2 if an alternative flow-measuring device is used, a reading of no less than 1.0, liters per minutes must be detectable.

7.4.4.3 At the request of the manufacturer an alternative purge test procedure can be used, if the procedure has been presented to and has been accepted by the technical service during the type approval procedure.

7.5 The competent authority, which has granted type-approval, may at any time verify the conformity control methods applicable to each production unit.

7.5.1 The inspector must take a sufficiently large sample from the series.

7.5.2 The inspector may test these vehicles by application of either 7.1.4. or 7.1.5 of Chapter 1.

7.5.3 If in pursuance of Section 7.1.5 of Chapter 1 the vehicle's test result falls outside the agreed limits of Section 5.3.4.2. of Chapter 1, the manufacturer may request that the approval procedure referred to in 7.1.4 of Chapter 1 be applied.

7.5.3.1 The manufacturer must not be allowed to adjust, repair or modify any of the vehicles, unless they failed to comply with the requirements of Section 7.1.4 of Chapter 1 and unless such work is documented in the manufacturer's vehicle assembly and inspection procedures.

7.5.3.2 The manufacturer may request a single re-test for a vehicle whose evaporative emission characteristics are likely to have changed due to his actions under 7.5.3.1.

7.6 If the requirements of 7.5 are not met, the competent authority must ensure that all necessary steps are taken to re-establish conformity of production as rapidly as possible.

Annexure 2:

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 Annexure.

1.2 Normally the series of temperatures, which are mentioned, firstly must be used. The series of temperatures within square brackets may alternatively be used.

2. CALIBRATION OF 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.
For variable-volume enclosures, the enclosure must be latched to a fixed volume when the enclosure is held at an ambient temperature of 303 K (30 °C) [(302 K (29 °C)]. This nominal volume must be repeatable within ± 0.5 % of the reported value.

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 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 operations in the enclosure, which may affect background emissions, and at a frequency of at least once per year.

2.2.1 Variable-volume enclosures may be operated in either latched or unlatched volume configuration, as described in 2.1.1. Ambient temperatures must be maintained at 308 K ± 2 K (35 ± 2 °C) [309 K ± 2 K (36 ± 2 °C)], throughout the 4 - hour period mentioned below.

2.2.2 Fixed volume enclosures must be operated with inlet and outlet flow streams closed. Ambient temperatures must be maintained at 308 K ± 2 K (35 ° ± 2 °C) [309 K ± 2 K (36 ° ± 2 °C) throughout the four-hour period mentioned below.

2.2.3 The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the four-hour background sampling period begins.

2.2.4 The analyzer (if required) must be calibrated, then zeroed and spanned.

2.2.5 The enclosure must be purged until a stable hydrocarbon reading is obtained, and the mixing fan turned on if not already on.

2.2.6 The Chamber is then sealed and the background hydrocarbon concentration, temperature and barometric pressure are measured. These are the initial readings C_{HC}, $_iP_i$ and T_i used in the enclosure background calculation.

2.2.7 The enclosure is allowed to stand undisturbed with the mixing fan on for a period of four hours.

2.2.8 At the end of this time the same analyzer is used to measure the hydrocarbon concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings C_{HC}, f, P_f and T_f.

2.2.9 The change in mass of hydrocarbons in the enclosure must be calculated over the time of the test in accordance with 2.4 and must not exceed 0.05 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. The enclosure leak rate must be determined at the enclosure’s introduction to service, after any operations in the enclosure which may affect the integrity of the enclosure, and at least monthly thereafter. If six consecutive monthly retention checks are successfully completed without corrective action, the enclosure leak rate may be determined quarterly thereafter as long as no corrective action is required.

2.3.1. The enclosure must be purged until a stable hydrocarbon concentration is reached. The mixing fan is turned on, if not already switched on. The hydrocarbon analyser is zeroed, calibrated if required, and spanned.

2.3.2. On variable-volume enclosures the enclosure must be latched to the nominal volume position. On fixed-volume enclosures the outlet and inlet flow streams must be closed.

2.3.3. The ambient temperature control system is then turned on (if not already on) and adjusted for an initial temperature of 308 K (35°C) [309 K (36°C)].

2.3.4. When the enclosure stabilizes at 308 K ± 2 K (35°C ± 2°C) [309 K ± 2 K (36° ± 2°C)], the enclosure is sealed and the background concentration, temperature and barometric pressure measured. These are the initial readings $C_{HC, i}$, P_i and T_i used in the enclosure calibration.

2.3.5. A quantity of approximately 4 grams of propane is injected into the enclosure. The mass of propane must be measured to an accuracy and precision of ± 0.2 % of the measured value.

2.3.6. The contents of the chamber must be allowed to mix for five minutes and then the hydrocarbon concentration, temperature and barometric pressure are measured. These are the final readings $C_{HC, f}$, P_f and T_f for the calibration of the enclosure as well as the initial readings $C_{HC, i}$, P_i and T_i for the retention check.

2.3.7. On the basis of the readings taken in 2.3.4 and 2.3.6 and the formula in 2.4, the mass of propane in the enclosure is calculated. This must be within ± 2 % of the mass of propane measured in 2.3.5.

2.3.8. For variable-volume enclosures the enclosure must be unlatched from the nominal volume configuration. For fixed-volume enclosures, the outlet and inlet flow streams must be opened.

2.3.9. The process is then begun of cycling the ambient temperature from 308°K (35°C) to 293°K (20°C) and back to 308°K (35°C) [308.6°K (35.6°C) to 295.2°K (22.2°C) and back to 308.6°K (35.6°C)] over a 24-hour period according to the profile [alternative profile] specified in Table 1 within 15 minutes of sealing the enclosure. (Tolerances as specified in section 5.7.1 of Chapter 6).

2.3.10. At the completion of the 24-hour cycling period, the final hydrocarbon concentration, temperature and barometric pressure are measured and recorded. These are the final readings $C_{HC, f}$, P_f and T_f for the hydrocarbon retention check.

2.3.11. Using the formula in 2.4, the hydrocarbon mass is then calculated from the readings taken in 2.3.10 and 2.3.6. The mass may not differ by more than 3 % from the hydrocarbon mass given by 2.3.7.

2.4 Calculations

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 hydrocarbon concentration, temperature and barometric pressure are used in the following formula to calculate the mass change.

$$M_{HC} = k \cdot V \cdot 10^{-4} \cdot \left(\frac{C_{HC,f} \cdot P_f}{T_f} - \frac{C_{HC,i} \cdot P_i}{T_i}\right) + M_{HC,out} - M_{HC,i}$$

where:

M_{HC} = hydrocarbon mass in grams
$M_{HC,out}$ = mass of hydrocarbon exiting the enclosure, in the case of fixed-volume enclosures for diurnal emission testing (grams)
$M_{HC,i}$ = mass of hydrocarbon entering the enclosure, in the case of fixed-volume enclosures for diurnal emission testing (grams)
C_{HC} = measured hydrocarbon concentration in the enclosure (ppm (volume) C_1 equivalent)
V =. Enclosure volume in cub.m. as measured in section 2.1.1
T = ambient chamber temperature, K,
P = barometric pressure in kPa,
k = 17.6;

where:

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 analyzer

The analyzer should be calibrated using propane in air and purified synthetic air. See Section 4.5.2 of Chapter 3 (Calibration and span gases). Establish a calibration curve as described in Sections 4.1 to 4.5 of this Annexure.

3.3 Oxygen interference check and recommended limits

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 c1. The concentration of the test must be 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 analyzer 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 $0.95 \leq R_f \leq 1.05$.

4 CALIBRATION OF THE HYDROCARBON ANALYZER

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 as evenly as possible over the operating range. The nominal concentration of the calibration gas with the highest concentrations to be at least 80% of the full scale.

4.2 Calculate the calibration curve by the method of least squares. If the resulting polynomial degree is greater than 3, 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 polynomial derived from 3.2, a table of indicated reading against true concentration shall be drawn up in steps of no greater than 1% of full scale. This is to be carried out for each analyzer range calibrated. The table shall also contain other relevant data such as:
Date of calibration,
Span and zero potentiometer reading (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 alternatives may be used.

Table 1

Diurnal ambient temperature profile for the calibration of the enclosure and the diurnal emission test		
Time (hours)		Temperature ($°C_i$)
Calibration	Test	
13	0/24	20
14	1	20,2
15	2	20,5
16	3	21,2
17	4	23,1
18	5	25,1
19	6	27,2
20	7	29,8
21	8	31,8
22	9	33,3
23	10	34,4
24/0	11	35
1	12	34,7
2	13	33,8
3	14	32
4	15	30
5	16	28,4
6	17	26,9
7	18	25,2
8	19	24
9	20	23
10	21	22
11	22	20,8
12	23	20,2

Alternative diurnal ambient temperature profile for the calibration of the enclosure in accordance with Chapter 3, sections 1.2 and 2.3.9	
Time (hours)	Temperature ($°C_i$)
0	35,6
1	35,3
2	34,5
3	33,2
4	31,4
5	29,7
6	28,2
7	27,2
8	26,1
9	25,1
10	24,3
11	23,7
12	23,3
13	22,9
14	22,6
15	22,2
16	22,5
17	24,2
18	26,8
19	29,6
20	31,9
21	33,9
22	35,1
23	35,4
24	35,6

CHAPTER 12

TYPE V TEST: DESCRIPTION OF THE AGEING TEST FOR VERIFYING THE DURABILITY OF ANTI POLLUTION DEVICES FROM 4 WHEELERS

1. INTRODUCTION

This Section described the test for verifying the durability of anti-pollution devices equipping vehicles with positive-ignition or compression-ignition engines during an ageing test of 80,000 km.

2 TEST VEHICLE

2.1 The vehicle must be in good mechanical order, the engines and the anti-pollution devices must be new. The vehicle may be the same as that presented for type I test; this type I test has to be done after the vehicle has run at least 3000 km of the ageing cycle of clause 5.1.

3 FUEL

The durability test is conducted with commercially available unleaded petrol or diesel fuel.

4 VEHICLE MAINTENANCE AND ADJUSTMENTS

Maintenance, adjustments as well as the use of the test vehicle's controls shall be those recommended by the manufacturer.

5 VEHICLE OPERATION ON TRACK, ROAD OR ON CHASSIS DYNAMOMETER

5.1 Operating cycle

During operation on track, road or on roller test bench, the distance must be covered according to the driving schedule (Figure 1 below) described below:

- the durability test schedule is composed of 11 cycles covering 6 kilometers each,
- during the first nine cycles, the vehicle is stopped four times in the middle of the cycle, with the engine idling each time for 15 seconds,
- normal acceleration and deceleration,
- five decelerations in the middle of each cycle, dropping from cycle speed to 32 km/h and the vehicle is gradually accelerated again until cycle speed is attained,
- the 10^{th} cycle is carried out at a steady speed of 72 km/h,

- the 11th cycle begins with maximum acceleration from top point up to 90 km/h. at half-way, braking is employed normally until the vehicle comes to a stop. This is followed by an idle period of 15 seconds and a second maximum acceleration.

The schedule is then restarted from the beginning. The maximum speed of each cycle is given in the following Table.

Figure 1: a. Maximum speed of each cycle

Cycle	Cycle speed in km/h
1	64
2	48
3	64
4	64
5	56
6	48
7	56
8	72
9	56
10	72
11	90

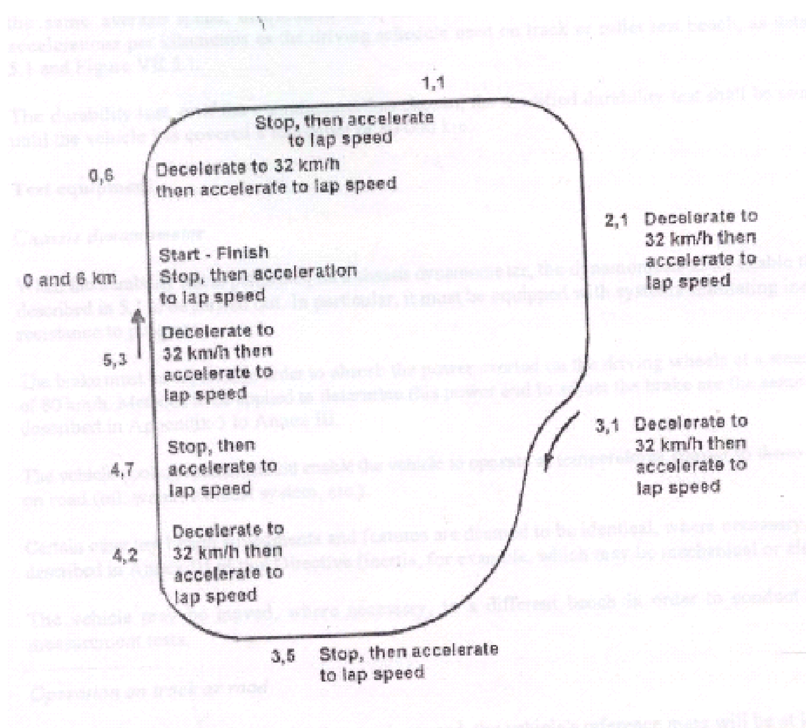


Figure 1: b. Driving Schedule

5.1.1 At the request of the manufacturer, an alternative road test schedule may be used. Such alternative schedules shall be approved by the technical service in advance of the test and must have substantially the same average speed, distribution of speeds, number of stops per kilometers and number of accelerations per kilometers as the driving schedules used on track or roller test bench, as detailed in 5.1 and Figure 1 above.

5.1.2 The durability test, or if the manufacturer has chosen, the modified durability test shall be conducted until the vehicle has covered a minimum of 80,000 km.

5.2 Test equipment

5.2.1 Chassis dynamometer

5.2.1.1 When the durability test is performed on a chassis dynamometer, the dynamometer must enable the cycle described in 5.1 to be carried out. In particular, it must be equipped with systems simulating inertia and resistance to progress.

5.2.1.2 The brake must be adjusted in order to absorb the power exerted on the driving wheels at a steady speed of 80 km/h. Methods to be applied to determine this power and to adjust the brake are the same as those described in Chapter 4.

5.2.1.3 The vehicle cooling system should enable the vehicle to operate at temperatures similar to those obtained on road (oil, water, exhaust system, etc.)

5.2.1.4 Certain other test branch adjustments and features are deemed to be identical, where necessary, to those described in Chapter 3 of this part (inertia, for example, which may be mechanical or electronic).

5.2.1.5 The vehicle may be moved, where necessary, to a different bench in order to conduct emission measurement tests.

5.2.2 Operation on track or road

When the durability test is completed on track or road, the vehicle's reference mass will be at least equal to that retained for tests conducted on a chassis dynamometer.

6 MEASURING EMISSION OF POLLUTANTS

At the start of the test (0 km), and every 10,000 km (+/- 400 km) or more frequently, at regular intervals until having covered 80,000 km, tailpipe emissions are measured in accordance with the type I test as defined in Chapter 1, clause 5.3.1. The limit values to be complied with are those laid down in applicable

Notification. However, the tailpipe emissions may also be measured in accordance with the provisions of Chapter 1, Clause 8.2.

All exhaust emissions results must be plotted as a function of the running distance on the system rounded to the nearest kilometer and the best fit straight line fitted by the method of least squares shall be drawn through all these data points. This calculation shall not take into account the test results at 0 km.

The data will be acceptable for use in the calculation of the deterioration factor only if the interpolated 6,400 km and 80,000 km points on this line are within the above mentioned limits. The data are still acceptable when a best-fit straight line crosses an applicable limit with a negative slope (the 6,400 km interpolated point is higher than the 80,000 km interpolated point) but the 80,000 km actual data point is below the limit.

A multiplicative exhaust emission deterioration factor shall be calculated for each pollutant as follows:

$$D.\,E.\,F. = \frac{Mi_2}{Mi_1}$$

Where,

Mi_1 = Mass emission of the pollutant I in grams per km interpolated to 6,400 km
Mi_2 = mass emission of the pollutant in grams per km interpolated to 80,000 km

These interpolated values must be carried out to a minimum of four places to the right of the decimal point before dividing one by the other to determine the deterioration factor. The result must be rounded to three places to the right of the decimal point.

If a deterioration factor is less than one, it is deemed to be equal to one.

Chapter 13

TEST PROCEDURE FOR ON BOARD DIAGNOSTICS – I (OBD-I)

1. INTRODUCTION

This chapter applies to the Type Approval procedure for on-board diagnostic I (OBD I) system for the motor vehicles.

2. DEFINITIONS

2.1 **'OBD I'** means an on-board diagnostic system for emission control, which shall have the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory as specified in section 5.1 below of this chapter. For all subsequent references in this chapter OBD implies OBD I.

2.2 **'Vehicle type'** means a category of power-driven vehicles, which do not differ in such essential engine and OBD system characteristics.

2.3 **'Vehicle family'** means a manufacturer's grouping of vehicles, which through their design, are expected to have similar exhaust emission and OBD system characteristics. Each vehicle of family shall have complied with the requirement of this document as defined in Annexure III to this Chapter.

2.4 **'Emission control system'** means the electronic engine management controller and any emission-related component in the exhaust system, which supplies an input to or receives an output from this controller.

2.5 **'Malfunction indicator (MI)'** means a visible or audible indicator that clearly informs the driver of the vehicle in the event of a malfunction of any emission-related component connected to the OBD system, or the OBD system itself.

2.6 **‘Circuit discontinuity’ (CD)** means disconnection of only those components (sensors/actuators) which are monitored by EMS/ECU/Computer, by physically removing corresponding connector or cutting / separating wire(s) of corresponding sensor or actuator.

2.7 **'A driving cycle'** consists of engine start-up, driving mode where a malfunction would be detected if present, and engine shut-off.

3. APPLICATION FOR TYPE APPROVAL

3.1 The application for type approval of a vehicle model with regard to OBD of the vehicles shall be submitted by the vehicle manufacturer along with duly filled OBD specification sheet (refer annexure 1 for format) for components monitored by EMS/ECU/Computer & OBD flow chart application table (refer annexure 2 for format).

3.2 A vehicle representative of the vehicle model to be type approved shall be submitted to the test agency responsible for conducting tests for compliance to the requirements referred in Para 5 of this chapter.

4. TYPE APPROVAL

For the purpose of type approval, manufacturer can choose one of the below mentioned options (4.1 or 4.2)

4.1 The vehicle submitted for type approval shall be tested for maximum four discontinuity demonstration tests selected by the test agency out of the OBD parameters as declared by the vehicle manufacturer, subject to condition mentioned in clause 4.3.

4.2 Alternatively, the vehicle can be tested for all OBD parameters for discontinuity demonstration tests, subject to condition mentioned in clause 4.3.

4.3 If discontinuity demonstration test is conducted on any vehicle model for a particular OBD parameter, demonstration test for such OBD parameter need not be conducted once again in the new vehicle model of same vehicle family submitted for type approval. In this case the vehicle manufacturer has to fill the vehicle model in which the demonstration test was carried out and date of testing (in DEMO column of annex 2).

4.4 If the submitted vehicle meets the requirements of Para 5 below when tested as per the procedure described in Para 6 below for circuit discontinuity of parameters in Table in 5.1, approval of that vehicle model shall be granted.

5. REQUIREMENTS

5.1 Vehicle submitted for type approval shall contain the OBD monitoring system. Please refer Table – II for Positive Ignition Engine vehicles & Table – III (for Compression ignition Engine Vehicles) of GSR 84 (E) dated 9th Feb-2009 for OBD – I monitoring system.

5.2 The vehicle manufacturer shall submit a test vehicle along with necessary equipments, which can simulate the discontinuity of OBD parameters as declared by the manufacturer for testing.

5.3 Activation of malfunction indicator (MI).

5.3.4 Distance traveled since MIL is ‘ON’ shall be recorded.

5.3.5 The OBD system shall incorporate a malfunction indicator readily perceivable to the vehicle operator. The MI must not be used for any other purpose except to indicate emergency start-up or limp-home routines to the driver. The MI shall be visible in all reasonable lighting conditions. When activated, it shall display a symbol in conformity with ISO 2575. A vehicle shall not be equipped with more than one general purpose MI for emission-related problems. Separate specific purpose telltales (e.g. brake system, fasten seat belt, oil pressure, etc.) are permitted. The use of red color for an MI is prohibited.

5.3.6 The MI shall activate when the vehicle's ignition is in the "key-on" position before engine starting or cranking and de-activate before engine starting after few seconds (or 'on' till engine is started) if no malfunction has previously been detected.

5.3.7 For meeting the requirements of 5.1, the manufacturer shall take appropriate steps to demonstrate that the OBD system will indicate a fault when discontinuity occurs.

5.4 The OBD system shall be capable of recording the fault code(s) indicating the status of the emission control system.

5.4.1 The distance traveled by the vehicle while the MI is activated must be available at any instant through the serial port on the standard link connector.

6. TEST PROCEDURE

6.1 The test Vehicle shall be mounted on the chassis dynamometer along with necessary equipments of test agency for carrying out test (OBD Scan tool and related accessories need to be provided by manufacturer)

6.2 Initial check

6.2.1 Switch "ON" the ignition and check for MIL "ON". MIL shall be "ON" for few seconds and then may turn "OFF" (in case of vehicle models with such design of MIL operation) or may continue to glow.

6.2.2 Start the engine and check for MIL "OFF".

6.2.3 Switch "OFF" the engine and ignition key to "OFF" position.

6.3 Circuit Discontinuity check

6.3.1 Vehicle soaking for 6 hours, if necessary for certain OBD parameters as specified by vehicle manufacturer.

6.3.2 Open or disconnect the circuit for the OBD parameter to be checked for circuit discontinuity.

6.3.3 Switch "ON" the ignition. Check for MIL "ON".

6.3.4 Start the engine and check for MIL "ON".

6.3.4.1 If the OBD parameter requires engine to be driven for MIL activation, vehicle shall be driven as per driving cycle (modified Indian Driving Cycle); including key `ON` `OFF` cycles, vehicle can be considered meeting circuit discontinuity when the MIL activates within maximum of 10 driving cycles.

6.3.4.2 If the OBD parameter does not require vehicle to be driven for MIL activation, vehicle can be considered meeting circuit discontinuity for the tested OBD parameter.

6.3.4.3 The DTC code shall be retrieved by the OBD Scan tool or any other method as mutually agreed between test agency and vehicle manufacturer.

6.3.5 Procedure from 6.3.1 to 6.3.4 shall be repeated for other OBD parameters to be checked for circuit discontinuity.

6.4 The requirement of distance traveled since MIL "ON" shall be checked along with one of the circuit discontinuity tests for OBD parameters as specified by vehicle manufacturer by running the vehicle on chassis dynamometer or on road as per driving cycle preferred by the vehicle manufacturer.

6.5 The process flow is shown in the figure 1 of this chapter.

7. Modifications of the vehicle model

7.1 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,

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

7.3 In case of 7.2 above, the testing agency shall extend the type approval covering the modified specification or the vehicle model shall be subjected to necessary tests as per the guidelines for extension of approval (clause 8). In case, the vehicle complies with the requirements, the test agency shall extend the type approval.

8. Guidelines for Extension of Approval of the vehicle for OBD.

8.1 Approval granted to a vehicle type with respect to the OBD system may be extended to different vehicle types belonging to the same vehicle-OBD family as described in Annex III. The engine emission control system must be identical to that of the vehicle already approved and comply with the description of the OBD engine family given in Annex III, regardless of the following vehicle characteristics:

- engine accessories,
- tyres,
- equivalent inertia,
- cooling system,
- overall gear ratio,
- transmission type,
- type of bodywork.

8.2 In a vehicle model, which is previously approved for OBD parameter, if there is any change in OBD parameter, then the discontinuity testing for the changed OBD parameter only needs to be conducted as mutually agreed between the test agency and vehicle manufacturer if manufacturer can prove that changed OBD parameter don't have any interaction with other OBD parameters.

OBD - 1 TEST PROCEDURE FLOW CHART

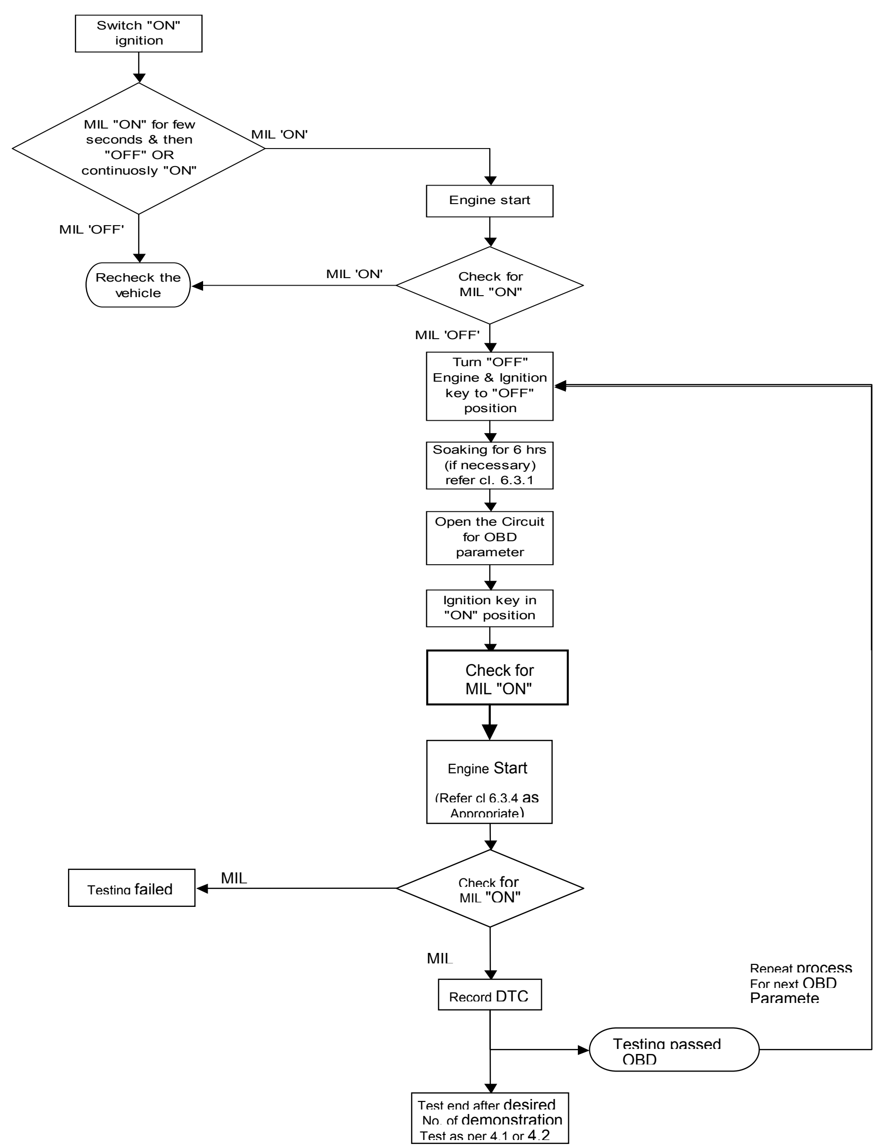


Figure 1

Annexure 1 - OBD Specification table format					
Component / system	Fault Code	Monitor Strategy Description	Malfunction criteria	Secondary Parameters	MIL Illumination

Annexure 2 - OBD Flow Chart Application Table Format

Function	DEMO	DTC	TYPE	CONFIGURATION

DEMO: **The monitoring system simulated for the purpose of the type-approval is marked with the tested vehicle & date.**

Annexure 3

ESSENTIAL CHARACTERISTICS OF THE VEHICLE FAMILY

1. PARAMETERS DEFINING THE OBD FAMILY

The OBD family may be defined by basic design parameters, which must be common to vehicles within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only vehicles with similar exhaust emission characteristics are included within an OBD family.

2. To this end, those vehicle types whose parameters described below are identical are considered to belong to the same engine-emission control/OBD system combination.

Engine:
- combustion process (i.e. positive-ignition, compression-ignition, two-stroke, four-stroke),
- method of engine fuelling (i.e. carburetor or fuel injection).
- fuel type (i.e petrol, diesel, NG, LPG, bi-fuel petrol/NG, bi-fuel petrol/LPG

Emission control system:
- type of catalytic converter (i.e. oxidation, three-way, heated catalyst, other),
- type of particulate trap,
- secondary air injection (i.e. with or without),
- exhaust gas recirculation (i.e. with or without)

OBD parts and functioning:
- the methods of OBD functional monitoring, malfunction detection and malfunction indication to the vehicle driver.

Chapter 14

TEST PROCEDURE FOR ON-BOARD DIAGNOSTICS – II (OBD - II)

1. INTRODUCTION

This Chapter applies to the functional aspects of on-board diagnostic (OBD - II) system for the emission control of motor vehicles.

2. DEFINITIONS

For the purposes of this Chapter:

2.1. 'OBD' means an on-board diagnostic system for emission control, which must have the capability of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.2. 'Vehicle type' means a category of power-driven vehicles, which do not differ in such essential engine and OBD system characteristics as defined in Annexure 2.

2.3. 'Vehicle family' means a manufacturer's grouping of vehicles, which through their design, are expected to have similar exhaust emission and OBD system characteristics. Each engine of this family must have complied with the requirements of TAP 115/116 (Issue 4).

2.4. 'Emission control system' means the electronic engine management controller and any emission-related component in the exhaust or evaporative system, which supplies an input to or receives an output from this controller.

2.5. 'Malfunction indicator (MI)' means a visible or audible indicator that clearly informs the driver of the vehicle in the event of a malfunction of any emission-related component connected to the OBD system, or the OBD system itself.

2.6. "Malfunction" means the failure of an emission-related component or system that would result in emissions exceeding the limits in the applicable Gazette Notification under CMVR or if the OBD system is unable to fulfill the basic monitoring requirements of this Chapter.

2.7. 'Secondary air' refers to air introduced into the exhaust system by means of a pump or aspirator valve or other means that is intended to aid in the oxidation of HC and CO contained in the exhaust gas stream.

2.8. 'Engine misfire' means lack of combustion in the cylinder of a positive-ignition engine due to absence of spark, poor fuel metering, poor compression or any other cause. In terms of OBD monitoring it is that percentage of misfires out of a total number of firing events (as declared by the manufacturer) that would result in emissions exceeding the limits given in the applicable Gazette Notification under CMVR or that percentage that could lead to an exhaust catalyst, or catalysts, overheating causing irreversible damage.

2.9. 'Type I test' means the driving cycle (Parts One and Two) used for emission approvals, as detailed in Chapter 3.

2.10. 'A driving cycle' consists of engine start-up, driving mode where a malfunction would be detected if present, and engine shut-off.

2.11. 'A warm-up cycle' means sufficient vehicle operation such that the coolant temperature has risen by a least 22 degrees K from engine starting and reaches a minimum temperature of 343 degrees K (70 degrees C).

2.12. 'Fuel trim' refers to feedback adjustments to the base fuel schedule. Short-term fuel trim refers to dynamic or instantaneous adjustments. Long-term fuel trim refers to much more gradual adjustments to the fuel calibration schedule than short-term trim adjustments. These long-term adjustments compensate for vehicle differences and gradual changes that occur over time.

2.13. 'Calculated load value' refers to an indication of the current airflow divided by peak airflow, where peak airflow is corrected for altitude, if available. This definition provides a dimensionless number that is not engine specific and provides the service technician with an indication of the proportion of engine capacity that is being used (with wide open throttle as 100 %);

$$CLV = \frac{\text{Current airflow}}{\text{Peak airflow (at sea level)}} \times \frac{\text{Atmospheric pressure (at sea level)}}{\text{Barometric pressure}}$$

2.14. 'Permanent emission default mode' refers to a case where the engine management controller permanently switches to a setting that does not require an input from a failed component or system where such a failed component or system would result in an increase in emissions from the vehicle to a level above the limits given in the applicable Gazette Notification under CMVR.

2.15. 'Power take-off unit' means an engine-driven output provision for the purposes of powering auxiliary, vehicle mounted, and equipment.

2.16 Access' means the availability of all emission-related OBD data including all fault codes required for the inspection, diagnosis, servicing or repair of emissions-related parts of the vehicle, via the serial interface for the standard diagnostic connection (pursuant to Annexure 1, Para 6.5.3.5 of this Chapter).

2.17. 'Unrestricted' means

- access not dependent on an access code obtainable only from the manufacturer, or a similar device, or
- access allowing evaluation of the data produced without the need for any unique decoding information, unless that information itself is standardised.

2.18. 'Standardised' means that all data stream information, including all fault codes used, shall be produced only in accordance with industry standards which, by virtue of the fact that their format and their permitted options are clearly defined, provide for a maximum level of harmonisation in the motor vehicle industry, and whose use is expressly permitted in TAP 115/116.

2.19. "*Repair information*" means all information required for diagnosis, servicing, inspection, periodic monitoring or repair of the vehicle and which the manufacturers provide for their authorised dealers/repair shops. Where necessary, such information shall include service handbooks, technical manuals, diagnosis information (e.g. minimum and maximum theoretical values for measurements), wiring diagrams, the software calibration identification number applicable to a vehicle type, instructions for individual and special cases, information provided concerning tools and equipment, data record information and two-directional monitoring and test data. The manufacturer shall not be obliged to make available that information which is covered by intellectual property rights or constitutes specific know-how of manufacturers and/or OEM suppliers; in this case the necessary technical information shall not be improperly withheld.

2.20 "*Deficiency*" means, in respect of vehicle OBD systems, that up to two separate components or systems that are monitored contain temporary or permanent operating characteristics that impair the otherwise efficient OBD monitoring of those components or systems or do not meet all of the other detailed requirements for OBD. Vehicles may be type-approved, registered and sold with such deficiencies according to the requirements of Para 4 of this Chapter.

3. REQUIREMENTS AND TESTS

3.1. All vehicles shall be equipped with an OBD system so designed, constructed and installed in a vehicle as to enable it to identify types of deterioration or malfunction over the entire life of the vehicle. In achieving this objective the test agency shall accept that vehicles which have traveled distances in excess of the Type V durability distance, referred to in Para 3.3.1, may show some deterioration in OBD system performance such that the emission limits given in the applicable Gazette Notification under CMVR may be exceeded before the OBD system signals a failure to the driver of the vehicle.

3.1.1. Access to the OBD system required for the inspection, diagnosis, servicing or repair of the vehicle shall be unrestricted and standardised. All emission-related fault codes must be consistent with Para 6.5.3.4 of Annex 1 to this Chapter.

3.1.2. No later than three months after the manufacturer has provided any authorised dealer or repair shop with repair information, the manufacturer shall make that information (including all subsequent amendments and supplements) available upon reasonable and non-discriminatory payment and shall notify the approval authority accordingly.
In the event of failure to comply with these provisions the approval authority shall take appropriate measures to ensure that repair information is available, in accordance with the procedures laid down for type-approval.

3.2. The OBD system must be so designed, constructed and installed in a vehicle as to enable it to comply with the requirements of this Chapter during conditions of normal use.

3.2.1. Temporary disablement of the OBD system

3.2.1.1 A manufacturer may disable the OBD system if its ability to monitor is affected by low fuel levels. Disablement shall not occur when the fuel tank level is above 20 % of the nominal capacity of the fuel tank.

3.2.1.2 A manufacturer may disable the OBD system at ambient engine starting temperatures below 266 degrees K (-7 degrees C) or at elevations over 2,500 m above sea level provided the manufacturer submits data and/or an engineering evaluation which adequately demonstrate that monitoring would be unreliable when such conditions exist. A manufacturer may also request disablement of the OBD system at other ambient engine starting temperatures if he demonstrates to the test agency with data and/or an engineering evaluation that misdiagnosis would occur under such conditions.

3.2.1.3 For vehicles designed to accommodate the installation of power take-off units, disablement of affected monitoring systems is permitted provided disablement occurs only when the power take-off unit is active.

3.2.2. Engine misfire - vehicles equipped with positive-ignition engines

3.2.2.1 Manufacturers may adopt higher misfire percentage malfunction criteria than those declared to the authority, under specific engine speed and load conditions where it can be demonstrated to the authority that the detection of lower levels of misfire would be unreliable.

3.2.2.2 When a manufacturer can demonstrate to the authority that the detection of higher levels of misfire percentages is still not feasible, or that misfire cannot be distinguished from other effects (e.g. rough roads, transmission shifts, after engine starting; etc.) the misfire monitoring system may be disabled when such conditions exist.

3.3. Description of tests

3.3.1. The OBD II tests are carried out on the vehicle used for the Type V durability test, given in Chapter 12, and using the test procedure in Annexure I to this Chapter. OBD II tests are carried out at the conclusion of the Type V durability testing. When no Type V durability testing is carried out, or at the request of the manufacturer, a suitably aged and representative vehicle may be used for these OBD II demonstration tests.

3.3.2. The OBD II system must indicate the failure of an emission-related component or system when that failure results in emissions exceeding the threshold limits given in the applicable Gazette Notification under CMVR.

3.3.3. Monitoring requirements for vehicles equipped with positive-ignition engines

In satisfying the requirements of Para 3.3.2 the OBD system must, at a minimum, monitor for:

3.3.3.1 Reduction in the efficiency of the catalytic converter with respect to the emissions of HC only. Manufactures may monitor the front catalyst alone or in combination with the next catalyst(s) downstream. Each monitored catalyst or catalyst combination shall be considered malfunctioning when the emissions exceed the HC threshold given in the applicable Gazette Notification under CMVR.

3.3.3.2 The presence of engine misfire in the engine operating region bounded by the following lines:

(a) a maximum speed of 4,500 min^{-1} or 1,000 min^{-1} greater than the highest speed occurring during a Type I test cycle, whichever is the lower;

(b) the positive torque line (i.e. engine load with the transmission in neutral);

(c) a line joining the following engine operating points: the positive torque line at 3,000 min^{-1} and a point on the maximum speed line defined in (a) above with the engine's manifold vacuum at 13.33 kPa lower than that at the positive torque line.

3.3.3.3 Oxygen sensor deterioration

3.3.3.4 If active on the selected fuel, other emission control system components or systems, or emission-related power train components or systems which are connected to a computer, the failure of which may result in tailpipe emissions exceeding the limits given in the applicable Gazette Notification under CMVR.

3.3.3.5 Unless otherwise monitored, any other emission-related power train component connected to a computer, including any relevant sensors to enable monitoring functions to be carried out, must be monitored for circuit continuity.

3.3.3.6 the electronic evaporative emission purge control, Fuel tank leakage, and fuel system must, at a minimum, be monitored for circuit continuity.

3.3.4. Monitoring requirements for vehicles equipped with compression-ignition engines In satisfying the requirements of Para 3.3.2 the OBD II system must monitor:

3.3.4.1 Where fitted, reduction in the efficiency of the catalytic converter;

3.3.4.2 Where fitted, the functionality and integrity of the particulate trap;

3.3.4.3 The fuel-injection system electronic fuel quantity and timing actuator(s) is/are monitored for circuit continuity and total functional failure;

3.3.4.4 Other emission control system components or systems, or emission-related power train components or systems, which are connected to a computer, the failure of which may result in tailpipe emissions exceeding the limits given in the applicable Gazette Notification under CMVR. Examples of such systems or components are those for monitoring and control of air mass-flow, air volumetric flow (and temperature), boost pressure and inlet manifold pressure (and relevant sensors to enable these functions to be carried out).

3.3.4.5 Unless otherwise monitored, any other emission-related powertrain component connected to a computer must be monitored for circuit continuity.

3.3.5 Manufacturers may demonstrate to the approval authority that certain components or systems need not be monitored if, in the event of their total failure or removal, emissions do not exceed the emission limits given in the official applicable Gazette Notification under CMVR.

3.4. A sequence of diagnostic checks for OBD II must be initiated at each engine start and completed at least once provided that the correct test conditions are met. The test conditions must be selected in such a way that they all occur under normal driving as represented by the Type I test.

3.5. Activation of malfunction indicator (MI)

3.5.1. The OBD system must incorporate a malfunction indicator readily perceivable to the vehicle operator. The MI must not be used for any other purpose except to indicate emergency start-up or limp-home routines to the driver. The MI must be visible in all reasonable lighting conditions. When activated, it must display a symbol in conformity with ISO 2575[1]. A vehicle must not be equipped with more than one general purpose MI for emission-related problems. Separate specific purpose telltales (e.g. brake system, fasten seat belt, oil pressure, etc.) are permitted. The use of red for an MI is prohibited.

(1) International Standard ISO 2575-1982 (E), entitled 'Road vehicles – Symbols for controls indicators and tell tales', Symbol Number 4.36.

3.5.2. For strategies requiring more than two preconditioning cycles for MI activation, the manufacturer must provide data and/or an engineering evaluation, which adequately demonstrates that the monitoring system is equally effective and timely in detecting component deterioration. Strategies requiring on average more than 10 driving cycles for MI activation are not accepted. The MI must also activate whenever the engine control enters a permanent emission default mode of operation if the emission limits given in the applicable Gazette Notification under CMVR are exceeded or if the OBD system is unable to fulfill the basic monitoring requirements specified in Para 3.3.3 or Para 3.3.4 of this Chapter. The MI must operate in a distinct warning mode, e.g. a flashing light, under any period during which engine misfire occurs at a level likely to cause catalyst damage, as specified by the manufacturer. The MI shall activate when the vehicle's ignition is in the "key-on" position before engine starting or cranking and de-activate before engine starting after few seconds (or 'on' till engine is started) if no malfunction has previously been detected.

3.6. The OBD system must record fault code(s) indicating the status of the emission control system. Separate status codes must be used to identify correctly functioning emission control systems and those emission control systems, which need further vehicle operation to be fully evaluated.
If the MI is activated due to deterioration or malfunction or permanent emission default modes of operation, a fault code must be stored that identifies the type of malfunction. A fault code must also be stored in the cases referred to in Para 3.3.3.5 and Para 3.3.4.5 of this Chapter.

3.6.1. The distance traveled by the vehicle while the MI is activated must be available at any instant through the serial port on the standard link connector.

3.6.2. In the case of vehicles equipped with positive-ignition engines, misfiring cylinders need not be uniquely identified if a distinct single or multiple cylinder misfire fault code is stored.

3.7. Extinguishing the MI

3.7.1. If misfire at levels likely to cause catalyst damage (as specified by the manufacturer) is not present any more, or if the engine is operated after changes to speed and load conditions where the level of misfire will not cause catalyst damage, the MI may be switched back to the previous state of activation during the first driving cycle on which the misfire level was detected and may be switched to the normal activated mode on subsequent driving cycles. If the MI is switched back to the previous state of activation, the corresponding fault codes and stored freeze-frame conditions may be erased.

3.7.2. For all other malfunctions, the MI may be de-activated after three subsequent sequential driving cycles during which the monitoring system responsible for activating the MI ceases to detect the malfunction and if no other malfunction has been identified that would independently activate the MI.

3.8. Erasing a fault code

3.8.1. The OBD system may erase a fault code and the distance traveled and freeze-frame information if the same fault is not re-registered in at least 40 engine warm-up cycles.

3.9. Bi-fuelled gas vehicles

In general, for bi-fuelled gas vehicles for each of the fuel types (petrol and NG/LPG) all the OBD requirements as for a mono-fuelled vehicle are applicable. To this end one of the following two options in paragraphs 3.9.1. or 3.9.2. or any combination thereof shall be used.

3.9.1. One OBD system for both fuel types.

3.9.1.1. The following procedures shall be executed for each diagnostic in a single OBD system for operation on petrol and on NG/LPG, either independent of the fuel currently in use or fuel type specific:

(a) activation of malfunction indicator (MI) (see paragraph 3.5. of this annex),
(b) fault code storage (see paragraph 3.6. of this annex),
(c) extinguishing the MI (see paragraph 3.7. of this annex),
(d) erasing a fault code (see paragraph 3.8. of this annex).

For components or systems to be monitored, either separate diagnostics for each fuel type can be used or a common diagnostic.

3.9.1.2. The OBD system can reside in either one or more computers.

Notwithstanding this requirement, the status code (described in Para 3.6 of this Chapter) shall indicate fully evaluated control systems for both fuel types (petrol and gas) when the control systems are fully evaluated for one of the fuel types

3.9.2. Two separate OBD systems, one for each fuel type.

3.9.2.1. The following procedures shall be executed independently of each other when the vehicle is operated on petrol or on NG/LPG:

(a) activation of malfunction indicator (MI) (see paragraph 3.5. of this annex),
(b) fault code storage (see paragraph 3.6. of this annex),
(c) extinguishing the MI (see paragraph 3.7. of this annex),
(d) erasing a fault code (see paragraph 3.8. of this annex).

3.9.2.2. The separate OBD systems can reside in either one or more computers.

3.9.3. Specific requirements regarding the transmission of diagnostic signals from bi-fuelled gas vehicles.

3.9.3.1. On a request from a diagnostic scan tool, the diagnostic signals shall be transmitted on one or more source addresses. The use of source addresses is described in ISO DIS 15031-5 "Road vehicles - communication between vehicles and external test equipment for emissions-related diagnostics - Part 5: Emissions-related diagnostic services", dated 1 November 2001.

3.9.3.2. Identification of fuel specific information can be realized:

(a) by use of source addresses and/or
(b) by use of a fuel select switch and/or
(c) by use of fuel specific fault codes.

The following procedures shall be executed for each diagnostic in a single OBD system for operation on petrol and on NG/LPG, either independent of the fuel currently in use or fuel type specific:

(a) activation of malfunction indicator (MI) (see paragraph 3.5. of this annex),
(b) fault code storage (see paragraph 3.6. of this annex),
(c) extinguishing the MI (see paragraph 3.7. of this annex),
(d) erasing a fault code (see paragraph 3.8. of this annex).

For components or systems to be monitored, either separate diagnostics for each fuel type can be used or a common diagnostic.

3.9.4. Regarding the status code (as described in paragraph 3.6. of this annex), one of the following two options has to be used:

(a) the status code is fuel specific, i.e. use of two status codes, one for each fuel type;
(b) the status code shall indicate fully evaluated control systems for both fuel types (petrol and NG/LPG) when the control systems are fully evaluated for one of the fuel types.

If none of the diagnostics reporting readiness is fuel type specific, then only one status code has to be supported.

4. Requirements relating to the type-approval of on-board diagnostic systems

4.1. A manufacturer may request to the authority that an OBD system be accepted for type-approval even though the system contains one or more deficiencies such that the specific requirements of this Chapter are not fully met.

4.2. In considering the request, the authority shall determine whether compliance with the requirements of this Chapter is infeasible or unreasonable. The authority shall take into consideration data from the manufacturer that details such factors as, but not limited to, technical feasibility, lead time and production cycles including phase-in or phase-out of engines or vehicle designs and programmed upgrades of computers, the extent to which the resultant OBD system will be effective in complying with the requirements of TAP 115 / 116 and that the manufacturer has demonstrated an acceptable level of effort toward compliance with the requirements of TAP 115 / 116.

4.2.1. The authority will not accept any deficiency request that includes the complete lack of a required diagnostic monitor.

4.2.2. The authority will not accept any deficiency request that does not respect the OBD threshold limits in the applicable Gazette Notification under CMVR.

4.3. In determining the identified order of deficiencies, deficiencies relating to Para 3.3.3.1, 3.3.3.2 and 3.3.3.3 of this Chapter for positive-ignition engines and Para 3.3.4.1, 3.3.4.2 and 3.3.4.3 of this Chapter for compression-ignition engines shall be identified first.

4.4. Prior to or at the time of type-approval, no deficiency shall be granted in respect of the requirements of Para 6.5, except Para 6.5.3.4 of Annexure 1 to this Chapter.

4.5. Deficiency period

4.5.1. A deficiency may be carried-over for a period of two years after the date of type-approval of the vehicle type unless it can be adequately demonstrated that substantial vehicle hardware modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-over for a period not exceeding three years.

4.5.2. A manufacturer may request that the type-approval authority grant a deficiency retrospectively when such a deficiency is discovered after the original type-approval. In this case, the deficiency may be carried-over for a period of two years after the date of notification to the type-approval authority unless it can be adequately demonstrated that substantial vehicle hardware modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-over for a period not exceeding three years.

5. ACCESS TO OBD INFORMATION

5.1. Applications for type-approval or amendment of a type-approval shall be accompanied by the relevant information concerning the vehicle OBD system. This relevant information shall enable manufacturers of replacement or retrofit components to make the parts they manufacture compatible with the vehicle OBD system with a view to fault-free operation assuring the vehicle user against malfunctions. Similarly, such relevant information shall enable the manufacturers of diagnostic tools and test equipment to make tools and equipment that provide for effective and accurate diagnosis of vehicle emission control systems.

5.2. Upon request, the type-approval authorities shall make Annexure to the type-approval certificate containing the relevant information on the OBD system available to any interested components, diagnostic tools or test equipment manufacturer on a non-discriminatory basis.

5.2.1. If a type-approval authority receives a request from any interested components, diagnostic tools or test equipment manufacturer for information on the OBD system of a vehicle that has been type-approved as per TAP 115/116,

- the type-approval authority shall, within 30 days, request the manufacturer of the vehicle in question to make available the information required.
- the manufacturer shall submit this information to the type-approval authority within two months of the request,
- the type-approval authority shall transmit this information to the test agencies, which granted the original type-approval, shall attach this information to Annexure II to the vehicle type-approval information.

This requirement shall not invalidate any approval previously granted pursuant to TAP 115 / 116 nor prevent extensions to such approvals under the terms of the regulation under which they were originally granted.

5.2.2. Information can only be requested for replacement or service components that are subject to type-approval, or for components that form part of a system that is subject to type approval.

5.2.3. The request for information must identify the exact specification of the vehicle model for which the information is required. It must confirm that the information is required for the development of replacement or retrofit parts or components or diagnostic tools or test equipment.

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,

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

6.3 In case of 6.2 above, the testing agency shall extend the type approval covering the modified specification or the vehicle model shall be subjected to necessary tests as per the guidelines for extension of approval (clause 7). In case, the vehicle complies with the requirements, the test agency shall extend the type approval.

7. Guidelines for Extension of Approval of the vehicle for OBD.

7.1 Approval granted to a vehicle type with respect to the OBD system may be extended to different vehicle types belonging to the same vehicle-OBD family as described in Annex 2. The engine emission control system must be identical to that of the vehicle already approved and comply with the description of the OBD engine family given in Annex 2, regardless of the following vehicle characteristics:

- engine accessories,
- tyres,
- equivalent inertia,
- cooling system,
- overall gear ratio,
- transmission type,
- type of bodywork.

7.2 In a vehicle model, which is previously approved for OBD parameter, if there is any change in OBD parameter, then the testing for the changed OBD parameter only needs to be conducted as mutually agreed between the test agency and vehicle manufacturer if manufacturer can prove that changed OBD parameter don't have any interaction with other OBD parameters.

Annexure 1:

FUNCTIONAL ASPECTS OF ON-BOARD DIAGNOSTIC (OBD) SYSTEMS

1. INTRODUCTION

This Annexure describes the procedure of the test according to Para 5 of this Chapter. The procedure describes a method for checking the function of the on-board diagnostic (OBD) system installed on the vehicle by failure simulation of relevant systems in the engine management or emission control system. It also sets procedures for determining the durability of OBD systems.

The manufacturer must make available the defective components and/or electrical devices which would be used to simulate failures. When measured over the Type I test cycle, such defective components or devices must not cause the vehicle emissions to exceed the limits given in the applicable Gazette Notification under CMVR by more than 20 %.

When the vehicle is tested with the defective component or device fitted, the OBD system is approved if the MI is activated. The OBD system is also approved if the MI is activated below the OBD threshold limits given in the applicable Gazette Notification under CMVR.

2. DESCRIPTION OF TEST

2.1. The testing of OBD – II systems consists of the following phases:

- simulation of malfunction of a component of the engine management or emission control system,
- preconditioning of the vehicle with a simulated malfunction over preconditioning specified in Para 6.2.1 or Para 6.2.2.
- driving the vehicle with a simulated malfunction over the Type I test cycle and measuring the emissions of the vehicle,
- determining whether the OBD system reacts to the simulated malfunction and indicates malfunction in an appropriate manner to the vehicle driver.

2.2. Alternatively, at the request of the manufacturer, malfunction of one or more components may be electronically simulated according to the requirements of Para 6.

2.3. Manufacturers may request that monitoring take place outside the Type I test cycle if it can be demonstrated to the authority that monitoring during conditions encountered during the Type I test cycle would impose restrictive monitoring conditions when the vehicle is used in service.

3. TEST VEHICLE AND FUEL

3.1. Vehicle

The test vehicle shall meet the requirements of Para 3.1 of Chapter 3.

3.2. Fuel

The reference fuel shall be as described in the applicable Gazette Notification under CMVR shall be used.

4. TEST TEMPERATURE AND PRESSURE

4.1. The test temperature and pressure must meet the requirements of the Type I test as described in Chapter 3.

5. TEST EQUIPMENT

5.1. Chassis dynamometer

The chassis dynamometer must meet the requirements of Chapter 3.

6. OBD – II TEST PROCEDURE

6.1. The operating cycle on the chassis dynamometer must meet the requirements of Chapter 3.

6.2. Vehicle preconditioning

6.2.1. According to the engine type and after introduction of one of the failure modes given in Para 6.3, the vehicle must be preconditioned by driving at least two consecutive Type I tests (Parts One and Two). For compression-ignition engine vehicles an additional preconditioning of two Part Two cycles is permitted.

6.2.2. At the request of the manufacturer, alternative preconditioning methods may be used.

6.3. Failure modes to be tested

6.3.1. Positive-ignition engine vehicles:

6.3.1.1 Replacement of the catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.1.2 Engine misfire conditions according to the conditions for misfire monitoring given in Para 3.3.3.2 of this chapter.

6.3.1.3 Replacement of the oxygen sensor with a deteriorated or defective oxygen sensor or electronic simulation of such a failure.

6.3.1.4 Electrical disconnection of any other emission-related component connected to a power-train management computer (if active on the selected fuel type).

6.3.1.5 Electrical disconnection of the electronic evaporative purge control device, (if equipped and if active on the selected fuel type) Fuel tank leakage, and fuel system. For this specific failure mode, the Type I test need not be performed.

6.3.2. Compression-ignition engine vehicles:

6.3.2.1 Where fitted, replacement of the catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.2.2 Where fitted, total removal of the particulate trap or, where sensors are an integral part of the trap, a defective trap assembly.

6.3.2.3 Electrical disconnection of any fuelling system electronic fuel quantity and timing actuator.

6.3.2.4 Electrical disconnection of any other emission-related component connected to a power train management computer.

6.3.2.5 In meeting the requirements of 6.3.2.3 and 6.3.2.4, and with the agreement between the test agency, the manufacturer must take appropriate steps to demonstrate that the OBD system will indicate a fault when disconnection occurs.

6.4. OBD system test

6.4.1. Vehicles fitted with positive-ignition engines:

6.4.1.1 After vehicle preconditioning according to 6.2, the test vehicle is driven over a Type I test (Parts One and Two). The MI must activate before the end of this test under any of the conditions given in 6.4.1.2 to 6.4.1.5. The technical service may substitute those conditions by others in accordance with 6.4.1.6. However, the total number of failures simulated must not exceed 4 for the purpose of type-approval.

In the case of testing a bi-fuel gas vehicle, both fuel types shall be used within the maximum of four (4) simulated failures at the discretion of the test agency.

6.4.1.2 Replacement of a catalyst with a deteriorated or defective catalyst or electronic simulation of a deteriorated or defective catalyst that results in emissions exceeding the HC limit given in the applicable Gazette Notification under CMVR.

6.4.1.3 An induced misfire condition according to the conditions for misfire monitoring given in Para 3.3.3.2 of this chapter that results in emissions exceeding any of the limits given in the applicable Gazette Notification under CMVR.

6.4.1.4 Replacement of an oxygen sensor with a deteriorated or defective oxygen sensor or electronic simulation of a deteriorated or defective oxygen sensor that results in emissions exceeding any of the limits given in the applicable Gazette Notification under CMVR.

6.4.1.5 Electrical disconnection of the electronic evaporative purge control device (if equipped and if active on the selected fuel type).

6.4.1.6 Electrical disconnection of any other emission-related power train component connected to a computer that results in emissions exceeding any of the limits given in the applicable Gazette Notification under CMVR (if active on the selected fuel type).

6.4.2. Vehicles fitted with compression-ignition engines:

6.4.2.1 After vehicle preconditioning according to 6.2, the test vehicle is driven over a Type I test (Parts One and Two). The MI must activate before the end of this test under any of the conditions given in 6.4.2.2 to 6.4.2.5. The technical service may substitute those conditions by others in accordance with 6.4.2.5. However, the total number of failures simulated must not exceed four for the purposes of type approval.

6.4.2.2 Where fitted, replacement of a catalyst with a deteriorated or defective catalyst or electronic simulation of a deteriorated or defective catalyst that results in emissions exceeding limits given in the applicable Gazette Notification under CMVR.

6.4.2.3 Where fitted, total removal of the particulate trap or replacement of the particulate trap with a defective particulate trap meeting the conditions of 6.3.2.2 that results in emissions exceeding the limits given in the applicable Gazette Notification under CMVR.

6.4.2.4 With reference to 6.3.2.5, disconnection of any fuelling system electronic fuel quantity and timing actuator that results in emissions exceeding any of the limits given in the applicable Gazette Notification under CMVR.

6.4.2.5 With reference to 6.3.2.5, disconnection of any other emission-related power train component connected to a computer that results in emissions exceeding any of the limits given in the applicable Gazette Notification under CMVR.

6.5. Diagnostic signals

6.5.1.1 Upon determination of the first malfunction of any component or system, 'freeze-frame' engine conditions present at the time must be stored in computer memory.

Should a subsequent fuel system or misfire malfunction occur, any previously stored freeze-frame conditions must be replaced by the fuel system or misfire conditions (whichever occurs first). Stored engine conditions must include, but are not limited to calculated load value, engine speed, fuel trim value(s) (if available), fuel pressure (if available), vehicle speed (if available), coolant temperature, intake manifold pressure (if available), closed - or open - loop operation (if available) and the fault code which caused the data to be stored. The manufacturer must choose the most appropriate set of conditions facilitating effective repairs for freeze-frame storage.

Only one frame of data is required. Manufacturers may choose to store additional frames provided that at least the required frame can be read by a generic scan tool meeting the specifications of 6.5.3.2 and 6.5.3.3. If the fault code causing the conditions to be stored is erased in accordance with Para 3.7 of this Chapter, the stored engine conditions may also be erased.

6.5.1.2 If available, the following signals in addition to the required freeze-frame information must be made available on demand through the serial port on the standardized data link connector, if the information is available to the on-board computer or can be determined using information available to the on-board computer: diagnostic trouble codes, engine coolant temperature, fuel control system status (closed-loop, open-loop, other), fuel trim, ignition timing advance, intake air temperature, manifold air pressure, air flow rate, engine speed, throttle position sensor output value, secondary air status (upstream, downstream or atmosphere), calculated load value, vehicle speed and fuel pressure.

The signals must be provided in standard units based on the specifications given in 6.5.3. Actual signals must be clearly identified separately from default value or limp-home signals.

6.5.1.3 For all emission control systems for which specific on-board evaluation tests are conducted (catalyst, oxygen sensor, etc.), except misfire detection, fuel system monitoring and comprehensive component monitoring, the results of the most recent test performed by the vehicle and the limits to which the system is compared must be made available through the serial data port on the standardized data link connector according to the specifications given in 6.5.3. For the monitored components and systems excepted above, a pass/fail indication for the most recent test results must be available through the data link connector.

6.5.1.4 The OBD requirements to which the vehicle is certified (i.e. this Chapter or the alternative requirements specified in Para 5 of Chapter I) and the major emission control systems monitored by the OBD system consistent with 6.5.3.3 must be available through the serial data port on the standardized data link connector according to the specifications given in 6.5.3.

6.5.1.5 Vehicles entering into service, the software calibration identification number shall be made available through the serial port on the standardised data link connector.

The software calibration identification number shall be provided in a standardised format.

6.5.2. The emission control diagnostic system is not required to evaluate components during malfunction if such evaluation would result in a risk to safety or component failure.

6.5.3. The emission control diagnostic system must provide for standardised and unrestricted access and conform with the following ISO standards and/or SAE specification.

6.5.3.1 One of the following standards with the restrictions as described must be used as the on-board to off-board communications link:
ISO 9141 - 2: 1994 (amended 1996) "Road Vehicles - Diagnostic Systems - Part 2: CARB requirements for interchange of digital information";
SAE J1850: March 1998 "Class B Data Communication Network Interface". Emission-related messages must use the cyclic redundancy check and the three-byte header and not use interbyte separation or checksums;
ISO 14230 - Part 4 "Road Vehicles - Keyword protocol 2000 for diagnostic systems - Part 4: Requirements for emissions-related systems";
ISO DIS 15765-4 "Road vehicles - Diagnostics on Controller Area Network (CAN) - Part 4: Requirements for emissions-related systems", dated 1 November 2001.

6.5.3.2 Test equipment and diagnostic tools needed to communicate with OBD systems must meet or exceed the functional specification given in ISO DIS 15031-4 "Road vehicles Communication between vehicle and external test equipment for emissions-related diagnostics - Part 4: External test equipment", dated 1 November 2001.

6.5.3.3 Basic diagnostic data, (as specified in 6.5.1) and bi-directional control information must be provided using the format and units described in ISO DIS 15031-5 "Road vehicles - Communication between vehicle and external test equipment for emissions-related diagnostics - Part 5: Emissions-related diagnostic services", dated 1 November 2001, and must be available using a diagnostic tool meeting the requirements of ISO DIS 15031-4.
The vehicle manufacturer shall provide to a national standardisation body the details of any emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO DIS 15031-5 but related to TAP 115 / 116.

6.5.3.4 When a fault is registered, the manufacturer must identify the fault using an appropriate fault code consistent with those given in Section 6.3. of ISO DIS 15031-6 "Road vehicles - Communication between vehicle and external test equipment for emissions-related diagnostics - Part 6: Diagnostic trouble code definitions", relating to "emission related system diagnostic trouble codes". If such identification is not possible, the manufacturer may use diagnostic trouble codes according to Sections 5.3 and 5.6 of ISO DIS 15031-6. The fault codes must be fully accessible by standardised diagnostic equipment complying with the provisions of section 6.5.3.2.

The vehicle manufacturer shall provide to a national standardisation body the details of any emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO DIS 15031-5 but related to TAP 115 / 116.

6.5.3.5 The connection interface between the vehicle and the diagnostic tester must be standardized and must meet all the requirements of ISO DIS 15031-3 "Road vehicles – Communication between vehicle and external test equipment for emissions-related diagnostics - Part 3: Diagnostic connector and related electrical circuits: specification and use", dated 1 November 2001. The installation position must be subject to agreement of the approval authority such that it is readily accessible by service personnel but protected from accidental damage during normal conditions of use.

6.5.3.6 The manufacturer shall also make accessible, where appropriate on payment, the technical information required for the repair or maintenance of motor vehicles unless that information is covered by an intellectual property right or constitutes essential, secret know how which is identified in an appropriate form; in such case, the necessary technical information shall not be withheld improperly.

Entitled to such information is any person engaged in commercially servicing or repairing, road side rescuing, inspecting or testing of vehicles or in the manufacturing or selling replacement or retro-fit components, diagnostic tools and test equipment.

Annexure 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE FAMILY

1. PARAMETERS DEFINING THE OBD FAMILY

The OBD family may be defined by basic design parameters, which must be common to vehicles within the family. In some cases there may be interaction of parameters. These effects must also be taken into consideration to ensure that only vehicles with similar exhaust emission characteristics are included within an OBD family.

2. To this end, those vehicle types whose parameters described below are identical are considered to belong to the same engine-emission control/OBD system combination.

Engine:

- combustion process (i.e. positive-ignition, compression-ignition, two-stroke, four-stroke),
- method of engine fuelling (i.e. carburetor or fuel injection).
- fuel type (i.e petrol, diesel, NG, LPG, bi-fuel petrol/NG, bi-fuel petrol/LPG

Emission control system:

- type of catalytic converter (i.e. oxidation, three-way, heated catalyst, other),
- type of particulate trap,
- secondary air injection (i.e. with or without),
- exhaust gas recirculation (i.e. with or without)

OBD parts and functioning:

- the methods of OBD functional monitoring, malfunction detection and malfunction indication to the vehicle driver.

Chapter 15

EMISSIONS TEST PROCEDURE FOR A VEHICLE EQUIPPED WITH A PERIODICALLY REGENERATING SYSTEM

1. INTRODUCTION

This chapter defines the specific provisions regarding type-approval of a vehicle equipped with a periodically regenerating system as defined in paragraph 1.1.1

1.1 DEFINITIONS

1.1.1 "Periodically regenerating system" means an anti-pollution device (e.g. catalytic converter, particulate trap) that requires a periodical regeneration process in less than 4,000 km of normal vehicle operation. During cycles where regeneration occurs, emission standards can be exceeded. If a regeneration of an anti-pollution device occurs at least once per Type I test and that has already regenerated at least once during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure. This chapter does not apply to continuously regenerating systems.

At the request of the manufacturer, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data to the type approval authority that, during cycles where regeneration occurs, emissions remain below the standards given in applicable Gazette Notification applied for the concerned vehicle category after agreement of the test agency.

2. SCOPE AND EXTENSION OF THE TYPE APPROVAL

2.1. Vehicle family groups equipped with periodically regenerating system

The procedure applies to vehicles equipped with a periodically regenerating system as defined in paragraph 1.1.1. For the purpose of this annex vehicle family groups may be established. Accordingly, those vehicle types with regenerative systems, whose parameters described below are identical, or within the stated tolerances, shall be considered to belong to the same family with respect to measurements specific to the defined periodically regenerating systems.

2.1.1. Identical parameters are:

Engine:

(a) Combustion process.

Periodically regenerating system (i.e. catalyst, particulate trap):

(a) Construction (i.e. type of enclosure, type of precious metal, type of substrate, cell density),
(b) Type and working principle,
(c) Dosage and additive system,
(d) Volume ±10 per cent,
(e) Location (temperature ±50 °C at 90 km/h or 5 per cent difference of max. temperature / pressure).

2.2. <u>Vehicle types of different reference masses</u>

The K_i factors developed by the procedures in this chapter for type approval of a vehicle type with a periodically regenerating system as defined in paragraph 1.1.1, may be extended to other vehicles in the family group with a reference mass within the next two higher equivalent inertia classes or any lower equivalent inertia.

3. TEST PROCEDURE

The vehicle may be equipped with a switch capable of preventing or permitting the regeneration process provided that this operation has no effect on original engine calibration. This switch shall be permitted only for the purpose of preventing regeneration during loading of the regeneration system and during the pre-conditioning cycles. However, it shall not be used during the measurement of emissions during the regeneration phase; rather the emission test shall be carried out with the unchanged Original Equipment Manufacturer's (OEM) control unit.

3.1. <u>Exhaust emission measurement between two cycles where regenerative phases occur</u>

Average emissions between regeneration phases and during loading of the regenerative device shall be determined from the arithmetic mean of several approximately equidistant (if more than 2) Type I operating cycles or equivalent engine test bench cycles. As an alternative the manufacturer may provide data to show that the emissions remain constant (+/-15 per cent) between regeneration phases. In this case, the emissions measured during the regular Type I test may be used. In any other case emissions measurement for at least two Type I operating cycles or equivalent engine test bench cycles must be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions measurements and calculations shall be carried out according to Chapter 3 paragraph 5, 6, 7 and 8.

3.1.2. The loading process and K_i determination shall be made during the Type I operating cycle, on a chassis dynamometer or on an engine test bench using an equivalent test cycle. These cycles may be run continuously (i.e. without the need to switch the engine off between cycles). After any number of completed cycles, the vehicle may be removed from the chassis dynamometer, and the test continued at a later time.

3.1.3. The number of cycles (D) between two cycles where regeneration phases occur, the number of cycles over which emissions measurements are made (n), and each emissions measurement (M'_{sij}) shall be reported in Chapter 2 , items 7.1 to 7.4 or 8.4.1 to 8.4.4 as applicable.

3.2. <u>Measurement of emissions during regeneration</u>

3.2.1. Preparation of the vehicle, if required, for the emissions test during a regeneration phase, may be completed using the preparation cycles in paragraph 5.3. of chapter 3 or equivalent engine test bench cycles, depending on the loading procedure chosen in paragraph 3.1.2. above.

3.2.2. The test and vehicle conditions for the Type I test described in chapter 3 apply before the first valid emission test is carried out.

3.2.3. Regeneration must not occur during the preparation of the vehicle. This may be ensured by one of the following methods:

3.2.3.1. A "dummy" regenerating system or partial system may be fitted for the pre-conditioning cycles.

3.2.3.2. Any other method agreed between the manufacturer and the test agency.

3.2.4. A cold-start exhaust emission test including a regeneration process shall be performed according to the Type I operating cycle, or equivalent engine test bench cycle. If the emissions tests between two cycles where regeneration phases occur are carried out on an engine test bench, the emissions test including a regeneration phase shall also be carried out on an engine test bench.

3.2.5. If the regeneration process requires more than one operating cycle, subsequent test cycle(s) shall be driven immediately, without switching the engine off, until complete regeneration has been achieved (each cycle shall be completed). The time necessary to set up a new test should be as short as possible (e.g. particular matter filter change). The engine must be switched off during this period.

3.2.6. The emission values during regeneration (M_{ri}) shall be calculated according to chapter 8. The number of operating cycles (d) measured for complete regeneration shall be recorded.

3.3. Calculation of the combined exhaust emissions

$$M_{si} = \frac{\sum_{j=1}^{n} M'_{sij}}{n} \qquad n \geq 2; \qquad M_{ri} = \frac{\sum_{j=1}^{d} M'_{rij}}{d}$$

$$M_{pi} = \left\{ \frac{M_{si} * D + M_{ri} * d}{D + d} \right\}$$

where for each pollutant (i) considered:

M'_{sij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) without regeneration

M'_{rij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) during regeneration. (when n > 1, the first Type I test is run cold, and subsequent cycles are hot)

M_{si} = mean mass emission of pollutant (i) in g/km without regeneration

M_{ri} = mean mass emission of pollutant (i) in g/km during regeneration

M_{pi} = mean mass emission of pollutant (i) in g/km

n = number of test points at which emissions measurements (Type I operating cycles or equivalent engine test bench cycles) are made between two cycles where regenerative phases occur, ≥ 2

d = number of operating cycles required for regeneration

D = number of operating cycles between two cycles where regenerative phases occur

For exemplary illustration of measurement parameters see Figure 8/1.

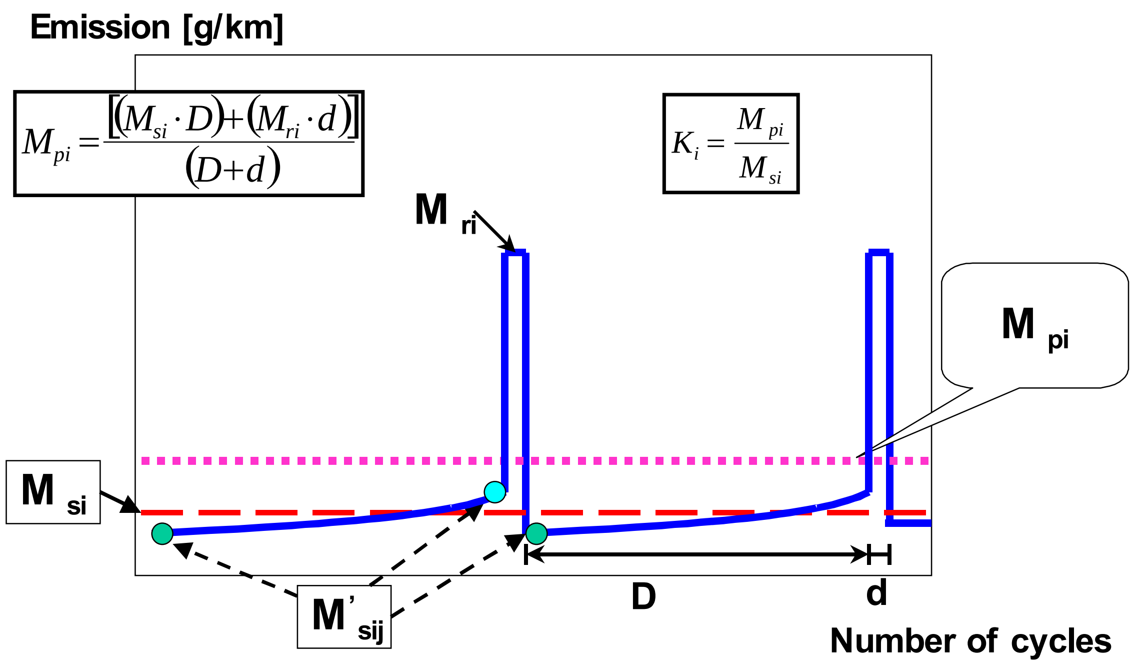


Figure 8/1: Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example, the emissions during 'D' may increase or decrease)

3.4. Calculation of the regeneration factor K for each pollutant (i) considered

$K_i = M_{pi} / M_{si}$

M_{si}, M_{pi} and K_i results shall be recorded in the test report delivered by the Testing Agency.

K_i may be determined following the completion of a single sequence.

Chapter 16

EMISSION TESTS AND MEASUREMENT OF FUEL CONSUMPTION FOR HYBRID ELECTRIC VEHICLES

1. INTRODUCTION

This chapter defines the specific provisions regarding type-approval of hybrid electric vehicles.

2. Categories of Hybrid Electric Vehicles

HEV's are categorized as below.

Vehicle charging	**Off Vehicle Charging (OVC)** [1/]		**Not Off Vehicle Charging (NOVC)** [2/]	
Operating mode switch	without	with	without	with
[1/] also known as "externally chargeable" [2/] also known as "not externally chargeable"				

3. **Type I test method for Externally Chargeable (OVC HEV) without an Operating Mode Switch**

Two tests shall be performed under the following conditions

(a) **Condition A**: test shall be carried out with a fully charged electrical energy / power storage device.

(b) **Condition B**: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

(c) The profile of the state of charge (SOC) of the electrical energy/power storage device during different stages of the Type I test for condition A and B are given in Annex II**.**

3.1. Condition A

3.1.1. Discharge of Battery

The procedure shall start with the discharge of the electrical energy / power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.) :

a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up

b) or, if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine or for other reasons, the speed shall be reduced until the vehicle can run at a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between testing agency and manufacturer).

c) or with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.1.2 **Conditioning of Vehicle**

3.1.2.1 **M and N Category fitted with Compression Ignition Engine**

Vehicle shall be driven according to paragraph 3.1.4.2. for three consecutive Part II cycles of the modified Indian driving cycle defined in Table II of Annex IV B of CMVR 1989.

3.1.2.2 **M and N Category fitted with Positive Ignition Engine**

Vehicle shall be driven according to paragraph 3.1.4.2**.** for one Part One and two Part Two driving cycles of the modified Indian driving cycle defined in Table I and Table II of Annex IV B respectively of CMVR 1989.

3.1.2.3 **L Category**

Vehicle shall be driven according to paragraph 3.1.4.2 for three consecutive cycles of IDC defined in Annexure II of CMVR 1989.

3.1.3 **Soak**

3.1.3.1 After this preconditioning, and before testing, the vehicle shall be soaked as prescribed for IC engined vehicles as per MORTH/CMVR/TAP-115/116 and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 3.1.3.2.

3.1.3.2 During soak, the electrical energy/power storage device shall be charged:

(a) with the on board charger if fitted, or

(b) with an external charger recommended by the manufacturer, using the normal overnight charging procedure (see 4.1.2. of Annexure I)

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalization charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred

(c) For details of end of charge, see 4.1.3 of Annexure I.

3.1.4 **Mass Emission Test**

3.1.4.1 Mass emission test shall be carried out, as prescribed for corresponding IC engined vehicle

3.1.4.2 However, in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information) shall be followed. For these vehicles the gear shifting points prescribed in MORTH/CMVR/TAP-115/116 are not applied.

3.1.4.3 In the case of L category vehicle, the weight of traction battery shall be ignored for the purpose of calculating the reference mass and inertia mass.

3.1.4.4 **Measurement of Energy**

Within the 30 minutes after the conclusion of the cycle, of the v_1 test, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_1 [Wh] delivered from the mains.

The electric energy consumption for condition A is e_1 [Wh].

3.1.4.5 Number of tests to be carried and averaging shall be as prescribed in MORTH/CMVR/TAP-115/116 for IC engined vehicles.

3.2 **Condition B**

3.2.1 Conditioning of vehicle: shall be as per paragraph 3.1.2

3.2.2 Discharge of battery shall be as per paragraph 3.1.1

3.2.3 After this discharge of the battery and before testing, the vehicle shall be soaked as prescribed for IC engined vehicles as per

MORTH/CMVR/TAP-115/116.

3.2.4 Mass emission test shall be as per 3.1.4

3.2.5 **Measurement of Energy**

3.2.5.1 Within the 30 minutes after the conclusion of the cycle, of the v_1 test, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_2 [Wh] delivered from the mains.

3.2.5.2 The electrical energy/power storage device of the vehicle shall be discharged in accordance with paragraph 3.1.1**.**

3.2.5.3 Within the 30 minutes after discharge, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_3 [Wh] delivered from the mains.

3.2.5.4 The electric energy consumption e_4 [Wh] for condition B is:

$e_4 = e_2 - e_3$

3.3.0 **Final Test Results**

3.3.1 The final results of pollutants for deciding on compliance and for CO_2 shall be:

$$Mi = (De \times M1i + Dav \times M2i) / (De + Dav)$$

where

Mi = mass emission of the pollutant i in grams per kilometer

M1i = average mass emission of the pollutant i in grams per kilometre with a fully charged electrical energy/power storage device, determined as per paragraph 3.1.4

M2i = average mass emission of the pollutant i in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) determined as per paragraph 3.2.4

De = vehicle electric range, according to the procedure described in Annex I.

D_{av} = 25 km (average distance between two battery recharges)

3.3.2 Fuel Consumption

Reported fuel consumption shall be calculated by carbon balance method, as per procedure prescribed in MORTH/CMVR/TAP-115/116, except that the values of HC, CO and CO_2 for calculation of fuel consumption shall be based on figures arrived at, as per paragraph 3.3.1.

3.3.3 Electric Energy Consumption

3.3.3.1 The values of electric energy consumption shall be

$E_1 = e_1/D_{test1}$ [Wh/km] for condition A, and

$E_4 = e_4/D_{test2}$ [Wh/km] for condition B

with D_{test1} and D_{test2} are the actual driven distances in the tests performed under conditions A (3.1.4.) and B (3.2.4) respectively, and e_1 and e_4 determined in paragraphs 3.1.4.4. and 3.2.5.4 respectively.

3.3.3.2 The weighted values of electric energy consumption shall be calculated as below:

$$E = (D_e * E_1 + D_{av} * E_4) / (D_e + D_{av})$$

Where:

E = electric consumption Wh/km

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated as per 3.3.3.1**.**

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) 3.3.3.1.

D_e = vehicle electric range, according to the procedure described in Annex I.

D_{av} = 25 km (assumed average distance between two battery recharges)

3.4 If the tests are carried out only for measurement of CO_2, fuel consumption and electrical energy:

3.4.1 Only one test need be carried out and the conditions of paragraph 3.1.4.5 are not applicable.

3.4.2 The preconditioning as per paragraph 3.2.1 need to be carried out only on manufacturer's request.

If measurement of electric energy consumption is not part of the test, it is not necessary to carry out the measurement as per paragraphs 3.1.4.4 and 3.2.5.

4.0 **Type I Test for Externally Chargeable (OVC HEV) with an Operating Mode Switch**

4.1 The operating mode switch shall be positioned according the table below

Hybrid-modes / Battery State of charge	- Pure electric - Hybrid Switch in position	- Pure fuel consuming - Hybrid Switch in position	- Pure electric - Pure fuel consuming - Hybrid Switch in position	- Hybrid mode n [1/] - Hybrid mode m [1/] Switch in position
Condition A Fully charged	Hybrid	Hybrid	Hybrid	Most electric hybrid mode [2/]
Condition B Min. state of charge	Hybrid	Fuel consuming	Fuel consuming	Most fuel consuming mode [3/]

1/ For instance: sport, economic, urban, extra urban position

2/ Most electric hybrid mode:

The hybrid mode which can be proven to have the highest electricity consumption of all selectable hybrid modes when tested in accordance with Condition A of this chapter, to be established based on information/test reports provided by the manufacturer and in agreement with the testing agency.

3/ Most fuel consuming mode:

The hybrid mode which can be proven to have the highest fuel consumption of all selectable hybrid modes when tested in accordance with Condition B of this chapter, to be established based on information/test reports provided by the manufacturer and in agreement with the testing agency.

4.2 Two tests shall be performed one under Condition A and the other under Condition as defined in 3.0. The test procedures for Condition A and Condition B shall be same as those given in 3.1 and 3.2 respectively, except that the switching modes shall be as given in 4.1, 4.2.1 and 4.3.

4.2.1 However, if the pure electric range of the vehicle measured in accordance with Annex-I is higher than one full emission test cycle, on the request of the manufacturer, the Type I test for condition A may not be carried out.

In such cases, the value of M1i shall be taken as zero for calculation of final results. (3.3.1 and 3.3.2).

In this case, engine preconditioning prescribed in paragraph 3.1.2 can be omitted at the request of manufacturer.

4.3 Discharge of Battery

4.3.1 In the case of OVC HEV's equipped with a pure electric mode, the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent ± 5 per cent of the maximum thirty minutes speed of the vehicle (determined according to clause 6.0 of AIS-041).

Stopping the discharge occurs when any of the following conditions happens, earliest :

- when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed; or
- when an indication to stop the vehicle is given to the driver by the standard onboard instrumentation, or
- after covering the distance of 100 km.

4.3.2 In case of HEV's not equipped with "pure electric" mode, the discharge procedure shall be as per 3.1.1.

4.4 Final test results shall be obtained using procedure given in 3.3.

5.0 Type I Tests for Not Externally Chargeable (NOT OVC HEV) without an Operating Mode Switch

5.1 These vehicles shall be tested according to MORTH/CMVR/ TAP-115/116

5.2 In the case of M and N category vehicles, for preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) are carried out without soak.

In the case of L category vehicles, preconditioning as per 3.1.2.3 are carried out without soak.

5.3 The vehicle shall be driven according to driving cycles prescribed, taking into account requirements given in paragraph 3.1.4.2 in case of special gear shifting strategy.

5.4 Special requirements for measurement and correction of the test results for CO_2 and fuel consumption are given in Annex III.

6.0 Type I Tests for Not Externally Chargeable (NOT OVC HEV) with an Operating Mode Switch

6.1 These vehicles shall be tested in Hybrid mode, according to MORTH/CMVR/TAP-115/116. If several hybrid modes are available, the test shall be carried out in the mode that is automatically set after turn on of the ignition key (normal mode). On the basis of information provided by the manufacturer, the testing agency will make sure that the limit values are met in all hybrid modes.

6.2 Preconditioning of vehicle shall be as per 5.2.

6.3 The vehicle shall be driven according to driving cycles prescribed, taking into account requirements given in paragraph 3.1.4.2 in case of special gear shifting strategy.

6.4 Special requirements for measurement and correction of the test results for CO_2 and fuel consumption are given in Annex III.

7.0 **Type II Test Methods (Idling Emissions) for SI Engines**

7.1 The vehicles shall be tested according to MoRTH/CMVR/TAP-115/116 with the fuel consuming engine running.

7.2 The manufacturer shall provide a “service mode” that makes execution of this test possible, However for HEV’s using constant speed engine for charging of batteries, above test shall be exempted.

7.3 If necessary, the special procedure provided for in paragraph 7.4. shall be used

7.4 It shall be possible to inspect the vehicle for roadworthiness test in order to determine its performance in relation to the data collected in accordance with the procedure prescribed in MORTH/CMVR/ TAP-115/116. If this inspection requires a special procedure, this shall be detailed in the service manual (or equivalent media). This special procedure shall not require the use of special equipment other than that provided with the vehicle

8.0 **Type III Test Method: (Crank Case Emission)**

8.1 In the case of M and N categories, the vehicles shall be tested according to conditions (1) and (2) of testing for crankcase emissions as mentioned in MoRTH/CMVR/TAP-115/116 with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.

9.0 Type IV Test Method (Evaporative Emission)

9.1 In the case of petrol engined M and N categories, the vehicles shall be tested according to MoRTH/CMVR/TAP-115/116

9.2 Before starting the test procedure (MoRTH/CMVR/TAP-115/116), the vehicles shall be preconditioned as follows:

9.2.1 **For Externally Chargeable (OVC HEV) Vehicles**

9.2.1.1 **For Externally Chargeable (OVC HEV) Vehicles without an Operating Mode Switch:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle as per paragraph 3.1.1

9.2.1.2 **For Externally Chargeable (OVC HEV) Vehicles with an Operating Mode Switch with a "Pure Electric" mode:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position as per 4.3.1.

9.2.1.3 **For Externally Chargeable (OVC HEV) Vehicles with Operating mode switch but without an Operating Mode for a "Pure Electric" mode:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle as per paragraph 3.1.1.

9.2.2 **For Not Externally Chargeable (NOVC HEV) Vehicles**

9.2.2.1 **NOVC Vehicles without an Operating Mode Switch:** The procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak.

9.2.2.2 **NOVC Vehicles with an Operating Mode Switch:** The procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak, performed with the vehicle in "hybrid" mode. If several hybrid modes are available, the test shall be carried out in the mode which is automatically set after turn on of the ignition key (normal mode).

9.3 The preconditioning drive and the dynamometer test shall be carried out according to cycles and procedure given in MORTH/CMVR/ TAP-115/116.

9.3.1 In the case of externally chargeable (OVC) HEV: Under the same conditions, as specified by condition B of the Type I test (paragraphs 3.2 and 4.2)

9.3.2 In the case of not externally chargeable (NOVC) HEV:: Under the same conditions of Type I test as specified in 5.2 and 6.2.

10.0 Type V Test Methods (Durability)

In case the mileage accumulation for durability tests is opted by the vehicle manufacturer, vehicles shall be tested according to MoRTH/CMVR/TAP-115/116 with the following additional requirements.

10.1 **For External Chargeable Vehicles (OVC)**

10.1.1 It is allowed to charge the electrical energy/power storage device twice a day during mileage accumulation.

10.1.2 For External Chargeable vehicles (OVC) with an operating mode switch, mileage accumulation should be driven in the mode which is automatically set after turn on of the ignition key (normal mode). During the mileage accumulation a change into another hybrid mode is allowed if necessary in order to continue the mileage accumulation after agreement of the testing agency.

10.1.3 The measurements of emissions of pollutants shall be carried out under the same conditions as specified by condition B of the Type I test (paragraphs 3.2 and 4.2).

10.2 **For Not Externally Chargeable (NOVC HEV) Vehicles**

For not externally chargeable (NOVC HEV) vehicles with an operating mode switch, mileage accumulation shall be driven in the mode which is automatically set after turn on of the ignition key (normal mode). The measurements of emissions of pollutants shall be carried out in the same conditions as in the Type I test.(Refer 6.0 and 5.0).

11. ON BOARD DIAGNOSTICS (OBD) TEST METHODS

11.1. The vehicles shall be tested according to Chapter 13 & 14.

11.2. For OVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as specified for condition B of the Type I test.

11.3. For NOVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as in the Type I test.

12. For the measurement of Net Power AIS 041 as amended time to time is applicable.

Annexure I

METHOD OF MEASURING THE ELECTRIC RANGE OF VEHICLES POWERED BY A HYBRID ELECTRIC POWER TRAIN

1.0 The test method described hereafter permits to measure the electric range, expressed in km, of externally chargeable HEV's (OVC-HEV) as defined in paragraph 2 of Chapter 16.

2.0 **Parameters, Units and Accuracy of Measurements**

Parameters, units and accuracy of measurements shall be as given in Table -1:

Table 1
Parameters, Units and Accuracy of Measurements

Parameter	Unit	Accuracy	Resolution
Time	s	± 0.1 s	0.1 s
Distance	m	± 0.1 per cent	1 m
Temperature	°C	± 1°C	1°C
Speed	km/h	± 1 per cent	0.2 km/h
Mass	kg	± 0.5 per cent	1 kg

3.0 **Test Conditions**

3.1 **Condition of the Vehicle**

3.1.1. The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer when the tyres are at the ambient temperature.

3.1.2. The viscosity of the oils for the mechanical moving parts shall conform to the specifications of the vehicle manufacturer.

3.1.3. The lighting and light-signaling and auxiliary devices shall be off, except those required for testing and usual daytime operation of the vehicle.

3.1.4. All energy storage systems available for other than traction purposes (electric, hydraulic, pneumatic, etc.) shall be charged up to their maximum level specified by the manufacturer.

3.1.5. If the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the vehicle manufacturer in order to keep the temperature of the battery in the normal operating range.

The manufacturer's agent shall be in a position to attest that the thermal management system of the battery is neither disabled nor reduced.

3.1.6. The vehicle must have run at least 300 km during the seven days before the test with those batteries that are installed in the test vehicle. This condition can be waived on request of the vehicle manufacturer

3.2 **Climatic Conditions**

3.2.1 For testing performed outdoors, the ambient temperature shall be between 5 °C and 32 °C.

3.2.2 The indoors testing shall be performed at a temperature between 20 °C and 30 °C.

3.2.3 The test may be carried out at temperatures different from those specified above, at the request of manufacturer.

4.0 Operation Modes

The test method includes the following steps:

(a) Initial charge of the battery.

(b) Application of the cycle and measurement of the electric range. Between the steps, if the vehicle shall move, it is pushed to the following test area (without regenerative recharging).

4.1. **Initial Charge of the Battery**

Charging the battery consists of the following procedures:

Note: "Initial charge of the battery" applies to the first charge of the battery, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal overnight charge" procedure.

4.1.1. **Discharge of the Battery**

4.1.1.2. For externally chargeable hybrid electric vehicle (OVC HEV) without an operating mode switch:

4.1.1.2.1. The manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state.

4.1.1.2.2. The procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 3.1.1 of Chapter 16.

4.1.1.3. For externally chargeable hybrid electric vehicle (OVC HEV) with an operating mode switch.

4.1.1.3.1. If there is not a pure electric position, the manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state. The procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 3.1.1 of Chapter 16.

4.1.1.3.2. If there is a pure electric position, the procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 4.3.1 of Chapter 16.

4.1.2. **Application of a Normal Overnight Charge**

The electrical energy/power storage device shall be charged according to the normal overnight charge procedure given below.

4.1.2.1 Normal Overnight Charge Procedure

The charging is carried out:

(a) with the on board charger if fitted, or

(b) with an external charger recommended by the manufacturer using the charging pattern prescribed for normal charging;

(c) in an ambient temperature comprised between 20 ºC and 30 ºC.

Charging may be carried out at temperatures different from those specified above, at the request of manufacturer.

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

4.1.3 End of Charge Criteria

The end of charge criteria corresponds to a charging time of 12 hours, except if a clear indication is given to the driver by the standard instrumentation that the electrical energy/power storage device is not yet fully charged.

In this case,

$$\text{The maximum time is} = \frac{3 \text{ x claimed battery capacity (Wh)}}{\text{Mains power supply (W)}}$$

4.2. Application of the Cycle and Measurement of the Range

4.2.1. The applicable test sequence as per the driving cycle used for mass emission testing is applied on a chassis dynamometer until the end of the test criteria is reached. Gear shifting pattern shall be as prescribed in paragraph 3.1.4.2 of Chapter 16.

4.2.2. The end of the test criteria is reached earliest:

4.2.2.1 When the vehicle is not able to meet the target curve up to 30 km/h,

4.2.2.2 or when an indication from the standard on-board instrumentation is given to the driver to stop the vehicle

4.2.2.3 or when the fuel consuming engine starts up.

Then the vehicle shall be slowed down to 5 km/h by releasing the accelerator pedal, without touching the brake pedal and then stopped by braking.

4.2.2.4 At a speed over speeds specified in paragraph 4.2.2.1 when the vehicle does not reach the required acceleration or speed of the test cycle, the accelerator pedal shall remain fully depressed until the reference curve has been reached again.

4.2.2.5 To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.

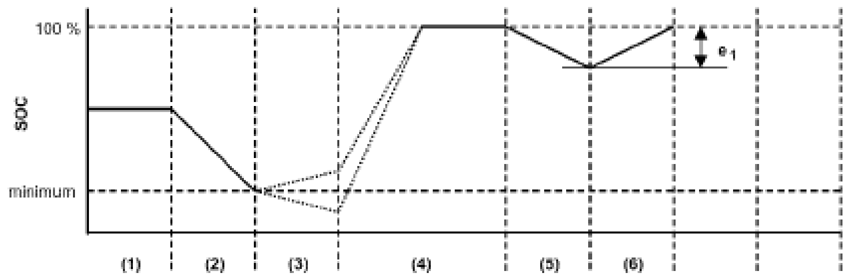
4.2.2.6 At the end, the measure D_e of the covered distance in km is the electric range of the hybrid electric vehicle. It shall be rounded to the nearest whole number as per IS 2.

Annexure II

ELECTRICAL ENERGY/POWER STORAGE DEVICE STATE OF CHARGE (SOC) PROFILE FOR OVC-HEV'S.

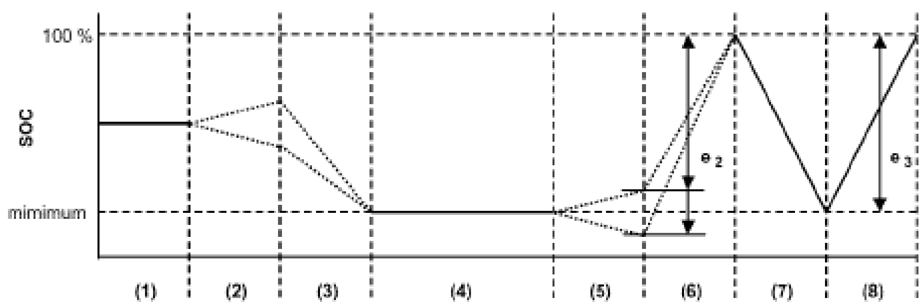
The SOC profiles for OVC-HEV's tested under conditions A and B are:

Condition A:



(1) initial state of charge of the electrical energy/power storage device
(2) discharge according to paragraph 3.1.1 or 4.3 of Chapter 16
(3) vehicle conditioning according to paragraph 3.1.2 of Chapter 16
(4) charge during soak according to paragraph 3.1.3.2 of Chapter 16
(5) test according to paragraph 3.1.4 of Chapter 16
(6) charging (3.1.4.4 of Chapter 16)

Condition B:



(1) initial state of charge
(2) vehicle conditioning according to paragraph 3.2.1 of Chapter 16
(3) discharge according to paragraph 3.2.2 of Chapter 16
(4) soak according to paragraph 3.2.3 of Chapter 16
(5) test according to paragraph 3.2.4 of Chapter 16
(6) charging according to paragraph 3.2.5.1 of Chapter 16
(7) discharging according to paragraph 3.2.5.2 of Chapter 16.
(8) charging according to paragraph 3.2.5.3 of Chapter 16.

ANNEX III

SPECIAL REQUIREMENTS FOR MEASUREMENT AND CORRECTION OF THE TEST RESULTS FOR CO_2 AND FUEL CONSUMPTION FOR NOT EXTERNALLY CHARGEABLE (NOVC) HEV'S.

1 In the case of M and N category vehicles, emissions of carbon dioxide (CO_2) and fuel consumption shall be determined separately for the Part One (urban driving) and the Part Two (extra-urban driving) of the specified driving cycle.

2 **Test Results**

2.1 The test results (fuel consumption C [l/100 km] and CO_2-emission M [g/km]) of the test are corrected in function of the energy balance ΔE_{batt} of the vehicle's battery. The corrected values (C_0 [l/100 km] and M_0 [g/km]) should correspond to a zero energy balance ($\Delta E_{batt} = 0$), and are calculated using a correction coefficient determined by the manufacturer as defined below. In case of other storage systems than an electric battery, ΔE_{batt} is representing $\Delta E_{storage}$, the energy balance of the electric energy storage device.

2.2 The electricity balance Q [Ah], measured using the procedure specified in Clause 6.0, is used as a measure of the difference in the vehicle battery's energy content at the end of the cycle compared to the beginning of the cycle. In the case of M and N category vehicles, the electricity balance is to be determined separately for the Part One cycle and the Part Two cycle.

2.3 Under the conditions below, it is allowed to take the uncorrected measured values C and M as the test results:

a) in case the manufacturer can prove that there is no relation between the energy balance and fuel consumption,

b) in case that ΔE_{batt} always corresponds to a battery charging,

c) in case that ΔE_{batt} always corresponds to a battery decharging and ΔE_{batt} is within 1 per cent of the energy content of the consumed fuel (consumed fuel meaning the total fuel consumption over one cycle):

Energy content of the consumed fuel can be calculated from the following equation :
Total Fuel Energy = $NHV_{fuel} * m_{fuel}$
Where,
NHV_{fuel} = Net heating value of consumable fuel in J/kg
mf_{uel} = Total mass of fuel consumed over one test cycle
The change in battery energy content ΔE_{batt} can be calculated from the

measured electricity balance Q as follows:

$$\Delta E_{batt} = \Delta SOC(\%) \cdot E_{TEbatt} \cong 0.0036 \cdot |\Delta Ah| \cdot V_{batt} = 0.0036 \cdot Q \cdot V_{batt} \quad (MJ)$$

with E_{TEbatt} [MJ] the total energy storage capacity of the battery and V_{batt} [V] the nominal battery voltage.

3 **Fuel Consumption Correction Coefficient (K_{fuel}) Defined by the Manufacturer**

3.1 The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$.

3.2 If the latter condition can not be realised on the driving cycle (Part One or Part Two of modified Indian Driving Cycle in the case of M and N category or IDC in the case of L category as applicable) used in this test, then it is up to the testing agency to judge the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{batt} = 0$

The fuel consumption correction coefficient (K_{fuel}) is defined as

$$K_{fuel} = (n \cdot \Sigma Q_i C_i - \Sigma Q_i \cdot \Sigma C_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2) \qquad (l/100\ km/Ah)$$

where:

C_i **:** fuel consumption measured during i-th manufacturer's test (l/100 km)

Q_i **:** electricity balance measured during i-th manufacturer's test (Ah)

n **:** number of data

The fuel consumption correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the fuel consumption correction coefficient is to be judged by the testing agency.

3.3 In the case of M and N category, separate fuel consumption correction coefficients shall be determined for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

4 Fuel consumption at zero battery energy balance (C_0)

4.1 The fuel consumption C_0 at $\Delta E_{batt} = 0$ is determined by the following equation

$C_0 = C - K_{fuel} * Q$ (l/100 km)
where:

C **:** fuel consumption measured during test (l/100 km)

Q **:** electricity balance measured during test (Ah)

4.2 In the case of M and N category, fuel consumption at zero battery energy balance shall be determined separately for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

5.0 CO_2-emission correction coefficient (K_{CO2}) defined by the manufacturer

5.1 The CO_2-emission correction coefficient (K_{CO2}) shall be determined as follows from a set of n measurements performed by the manufacturer. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$. If the latter condition can not be realised on the driving cycle (Part One or Part Two in the case of M and N category or IDC as applicable) used in this test, then it is up to the testing agency to judge the statistical significance of the extrapolation necessary to determine the CO_2- emission value at $\Delta E_{batt} = 0$.

5.2 The CO_2-emission correction coefficient (K_{CO2}) is defined as:

$$K_{CO2} = (n \cdot \Sigma Q_i M_i - \Sigma Q_i \cdot \Sigma M_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2) \qquad \text{(g/km/Ah)}$$

where

M_i **:** CO_2-emission measured during i-th manufacturer's test (g/km)

Q_i **:** electricity balance during i-th manufacturer's test (Ah)

n **:** number of data

The CO_2-emission correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the CO_2-emission correction coefficient is to be judged by the testing agency.

5.3 In the case of M and N category, separate CO_2-emission correction coefficients shall be determined for the CO_2 emission values measured over the Part One cycle and the Part Two cycle respectively.

5.4 CO_2-emission at zero battery energy balance (M_0).

5.5 The CO_2-emission M_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$M_0 = M - K_{CO2} * Q$ (g/km)

where:

C : CO_2 emission measured during test (g/km)

Q : electricity balance measured during test (Ah)

5.6 In the case of M and N category, CO_2 - emission at zero battery energy balance shall be determined separately for the CO_2 - emission values measured over the Part One cycle and the Part Two cycle respectively

6.0 Electricity Balance

6.1 General

6.1.1. The purpose of this paragraph is to define the method and required instrumentation for measuring the electricity balance of Not externally chargeable Hybrid Electric Vehicles (NOVC HEVs). Measurement of the electricity balance is necessary to correct the measured fuel consumption and CO_2-emissions for the change in battery energy content occurring during the Type I test, using the method defined in paragraphs 4 and 5.

6.1.2. The method described in this paragraph shall be used by the manufacturer for the measurements that are performed to determine the correction factors K_{fuel} and K_{CO2}, as defined in paragraphs 3.2 and 5.2 The testing agency shall check whether these measurements have been performed in accordance with the procedure described in this annex.

6.1.3. The method described in this paragraph shall be used by the testing agency for the measurement of the electricity balance Q, as defined in paragraphs 4.1 and 5.5.

6.2 Measurement Equipment and Instrumentation

6.2.1 During the Type I tests as described in paragraphs 5.0. and 5.0 of Chapter 16, the battery current shall be measured using a current transducer of the clamp-on type or the closed type. The current transducer (i.e. the current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value or 0.1 per cent of the maximum value of the scale. OEM diagnostic testers are not to be used for the purpose of this test.

6.2.1.1 The current transducer shall be fitted on one of the wires directly connected to the battery. In order to easily measure battery current using external measuring equipment, manufacturers should preferably integrate appropriate, safe and accessible connection points in the vehicle. If that is not feasible, the manufacturer is obliged to support the testing agency by providing the means to connect a current transducer to the wires connected to the battery in the above described manner.

6.2.1.2 The output of the current transducer shall be sampled with a minimum sample frequency of 5 Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in Ampere hours (Ah).

6.2.1.3 The temperature at the location of the sensor shall be measured and sampled with the same sample frequency as the current, so that this value can be used for possible compensation of the drift of current transducers and, if applicable, the voltage transducer used to convert the output of the current transducer. Measurement of temperature can be skipped if accuracy of current measurement is guaranteed through the test term.

6.2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer for determining the correction factors K_{fuel} and K_{CO2} (as defined in paragraphs 3.2 and 5.2) and the last calibration dates of the instruments (where applicable) should be provided to the testing agency.

6.3 Measurement Procedure

6.3.1. Measurement of the battery current shall start at the same time as the test starts . and shall end immediately after the vehicle has driven the complete driving cycle.

6.3.2. In the case of M and N category, separate values of Q shall be logged over the Part One and Part Two of the cycle.

Part XV: 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

Chapter 1

Overall Requirements

1. SCOPE:

This Part applies to the control of gaseous and particulate pollutants, useful life of emission control devices and on-board diagnostic (OBD) systems of all motor vehicles equipped with compression-ignition engines and to the gaseous pollutants, useful life, and on-board diagnostic (OBD) systems of all motor vehicles equipped with positive-ignition engines fuelled with natural gas or LPG, with the exception of those vehicles of category M1, with a technically permissible maximum laden mass less than or equal to 3,500 kg and of compression-ignition engines of those vehicles of category N1, N2 and M2 and of positive-ignition engines fuelled with natural gas or LPG of those vehicles of category N1 for which type-approval has been granted under Part XIV – of MoSRTH/CMVR/TAP 115-116 under, sub-rule 15 of CMV-Rule 115.

2. DEFINITIONS AND ABBREVIATIONS :

For the purposes of this part the following definitions shall apply:

2.1 "**Approval of an engine (engine family)**" means the approval of an engine type (engine family) with regard to the level of the emission of gaseous and particulate pollutants.

2.2 **"Auxiliary emission control strategy (AECS**)" means an emission control strategy that becomes active or that modifies the base emission control strategy for a specific purpose or purposes and in response to a specific set of ambient and/or operating conditions, e.g. vehicle speed, engine speed, gear used, intake temperature, or intake pressure.

2.3 **"Base emission control strategy (BECS)"** means an emission control strategy that is active throughout the speed and load operating range of the engine unless an AECS is activated. Examples for BECS are, but are not limited to:

- Engine timing map
- EGR map
- SCR catalyst reagent dosing map

2.4 "**Combined de NO_X-particulate filter"** means an exhaust after treatment system designed to concurrently reduce emissions of oxides of nitrogen (NO_X) and particulate pollutants (PT).

2.5 **“Continuous regeneration”** means the regeneration process of an exhaust after treatment system that occurs either permanently or at least once per ETC test. Such a regeneration process will not require a special test procedure.

2.6 “**Control area**” means the area between the engine speeds A and C and between 25 to 100 per cent load.

2.7 "**Declared maximum power (P_{max})**" means the maximum power in kW (net power) as declared by the manufacturer in his application for type-approval.

2.8 **“Defeat strategy”** means:

- An AECS that reduces the effectiveness of the emission control relative to the BECS under conditions that may reasonably be expected to be encountered in normal vehicle operation and use

- A BECS that discriminates between operation on a standardized type-approval test and other operations and provides a lesser level of emission control under conditions not substantially included in the applicable type-approval test procedures or,

- An OBD or an emission control monitoring strategy that discriminates between operation on a standardised type-approval test and other operations and provides a lower level of monitoring capability (timely and accurately) under conditions not substantially included in the applicable type-approval test procedures.

2.9 **“De NO_X system”** means an exhaust after treatment system designed to reduce emissions of oxides of nitrogen (NO_X) (e.g. there are presently passive and active lean NO_X catalysts, NO_X adsorbers and Selective Catalytic Reduction (SCR) systems).

2.10 **“Delay time**” means the time between the change of the component to be measured at the reference point and a system response of 10 % of the final reading (t_{10}). For the gaseous components, this is basically the transport time of the measured component from the sampling probe to the detector. For the delay time, the sampling probe is defined as the reference point.

2.11 "**Diesel engine**" means an engine, which works on the compression-ignition principle.

2.12 "**ELR test**" means a test cycle consisting of a sequence of load steps at constant engine speeds to be applied in accordance with section 6.2 of this chapter.

2.13 "**ESC test**" means a test cycle consisting of 13 steady state modes to be applied in accordance with section 6.2 of this chapter.

2.14 "**ETC test**" means a test cycle consisting of 1800 second-by-second transient modes to be applied in accordance with section 6.2 of this chapter.

2.15 **“Element of design**” means in respect of a vehicle or engine,

- Any control system, including computer software, electronic control systems and computer logic,
- Any control system calibrations,
- The result of systems interaction,

or

- Any hardware items.

2.16 **“Emissions-related defect**” means a deficiency or deviation from normal production tolerances in design, materials or workmanship in a device, system or assembly that affects any parameter, specification or component belonging to the emission control system. A missing component may be considered to be an “emissions-related defect”.

2.17 **“Emission control strategy (ECS)”** means an element or set of elements of design that is incorporated into the overall design of an engine system or vehicle for the purposes of controlling exhaust emissions that includes one BECS and one set of AECS.

2.18 **”Emission control system”** means the exhaust after treatment system, the electronic management controller(s) of the engine system and any emission-related component of the engine system in the exhaust which supplies an input to or receives an output from this (these) controller(s), and when applicable the communication interface (hardware and messages) between the engine system electronic control unit(s) (EECU) and any other power train or vehicle control unit with respect to emissions management.

2.19 **“Emission control monitoring system”** means the system that ensures correct operation of the NO_X control measures implemented in the engine system according to the requirements of section 6.5 of this chapter.

2.20 **“Emission default mode”** means an AECS activated in the case of a malfunction of the ECS detected by the OBD system that results in the MI being activated and that does not require an input from the failed component or system.

2.21 **“Engine-after treatment system family”** means, for testing over a service accumulation schedule to establish deterioration factors according to chapter VII of this part relating to the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles, a manufacturer's grouping of engines that comply with the definition of engine family but which are further grouped into engines utilizing a similar exhaust after-treatment system.

2.22 **"Engine system"** means the engine, the emission control system and the communication interface (hardware and messages) between the engine system electronic control unit(s) (EECU) and any other power train or vehicle control unit.

2.23 **"Engine family"** means a manufacturers grouping of engine systems which, through their design as defined in Chapter II of this part, have similar exhaust emission characteristics; all members of the family must comply with the applicable emission limit values.

2.24 "**Engine operating speed range**" means the engine speed range, most frequently used during engine field operation, which lies between the low and high speeds, as set out in Chapter III to this Document.

2.25 "**Engine speeds A, B and C**" means the test speeds within the engine operating speed range to be used for the ESC test and the ELR test, as set out in chapter III, Appendix 1 of this part.

2.26 **"Engine setting"** means a specific engine/vehicle configuration that includes the emission control strategy (ECS), one single engine performance rating (the type-approved full-load curve) and, if used, one set of torque limiters.

2.27 "**Engine type**" means a category of engines, which do not differ in such essential respects as engine characteristics as defined in chapter II of this part.

2.28 **"Exhaust after treatment system**" means a catalyst (oxidation or 3-way), particulate filter, deNO_x system, combined deNO_x particulate filter or any other emission-reducing device that is installed downstream of the engine. This definition excludes exhaust gas recirculation, which, where fitted, is considered an integral part of the engine system.

2.29 **"Gas engine"** means a positive-ignition engine, which is fuelled with natural gas (NG) or liquefied petroleum gas (LPG).

2.30 **"Gaseous pollutants"** means carbon monoxide, hydrocarbons (assuming a ratio of $CH_{1,85}$ for diesel, $CH_{2,525}$ for LPG and $CH_{2,93}$ for NG (NMHC) and an assumed molecule $CH_3O_{0,5}$ for ethanol-fuelled diesel engines), methane (assuming a ratio of CH_4 for NG) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO_2) equivalent.

2.31 **"High speed (n_{hi})"** means the highest engine speed where 70 % of the declared maximum power occurs in case of diesel engines.

2.32 **“Low speed (n_{lo})”** means the lowest engine speed where 50 % of the declared maximum power occurs.

2.33 **“Major functional failure”** means a permanent or temporary malfunction of any exhaust after treatment system that is expected to result in an immediate or delayed increase of the gaseous or particulate emissions of the engine system and which cannot be properly estimated by the OBD system. Section 3.2.3.1 of chapter VIII provides for the monitoring for major functional failure instead of monitoring for the degradation or the loss of catalytic / filtering efficiency of an exhaust after treatment system. Examples of major functional failure are given in sections 3.2.3.2 and 3.2.3.3 of chapter VIII to this part.

2.34 **“malfunction”** means:

- Any deterioration or failure, including electrical failures, of the emission control system, that would result in emissions exceeding the OBD threshold limits or, when applicable, in failing to reach the range of functional performance of the exhaust after treatment system where the emission of any regulated pollutant would exceed the OBD threshold limits.

- Any case where the OBD system is not able to fulfill the monitoring requirements of this part.

A manufacturer may nevertheless consider a deterioration or failure that would result in emissions not exceeding the OBD threshold limits as a malfunction.

2.35 **“Malfunction indicator (MI)”** means a visual indicator that clearly informs the driver of the vehicle in the event of a malfunction in the sense of this part.

2.36 **“Multi-setting engine”** means an engine containing more than one engine setting.

2.37 "**NG gas range**" means one of the H or L range as defined in European Standard EN 437, dated November 1993.

2.38 "**Net power**" means the power in kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the method of measuring power as set out in part IV of MoSRTH/CMVR/TAP-115/116.

2.39 **“OBD”** means an on-board diagnostic system for emission control, which has the capability of detecting the occurrence of a malfunction and of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.40 **“OBD-engine family”** means, for type-approval of the OBD system according to the requirements of Chapter VIII this Part, a manufacturer’s grouping of engine systems having common OBD system design parameters according to section 8 of this chapter.

2.41 "**Opacimeter**" means an instrument designed to measure the opacity of smoke particles by means of the light extinction principle.

2.42 **“Parent engine”** means an engine selected from an engine family in such a way that its emissions characteristics will be representative for that engine family.

2.43 **“Particulate after treatment device”** means an exhaust after treatment system designed to reduce emissions of particulate pollutants (PT) through a mechanical, aerodynamic, diffusional or inertial separation.

2.44 "**Particulate pollutants**" means any material collected on a specified filter medium after diluting the exhaust with clean filtered air so that the temperature does not exceed 325°K (52 °C).

2.45 "**Percent load**" means the fraction of the maximum available torque at an engine speed.

2.46 **“Periodic regeneration”** means the regeneration process of an emission control device that occurs periodically in less than 100 hours of normal engine operation. During cycles where regeneration occurs, emission standards can be exceeded.

2.47 **“Power take-off unit”** means an engine-driven output device for the purposes of powering auxiliary, vehicle mounted equipment.

2.48 **“Reagent”** means any medium that is stored on-board the vehicle in a tank and provided to the exhaust after treatment system (if required) upon request of the emission control system.

2.49 "**Recalibration**" means a fine-tuning of an NG engine in order to provide the same performance (power, fuel consumption) in a different range of natural gas.

2.50 "**Reference speed (n_{ref})"** means the 100 per cent speed value to be used for denormalising the relative speed values of the ETC test, as set out in chapter III, Appendix 2 of this part.

2.51 **“Response time”** means the difference in time between a rapid change of the component to be measured at the reference point and the appropriate change in the response of the measuring system whereby the change of the measured component is at least 60 % FS and takes place in less than 0,1 second. The system response time (t_{90}) consists of the delay time to the system and of the rise time of the system (see also ISO 16183).

2.52 **"Rise time"** means the time between the 10 % and 90 % response of the final reading (t_{90} - t_{10}). This is the instrument response after the component to be measured has reached the instrument. For the rise time, the sampling probe is defined as the reference point.

2.53 "**Self adaptability**" means any engine device allowing the air/fuel ratio to be kept constant.

2.54 "**Smoke**" means particles suspended in the exhaust stream of a diesel engine, which absorb, reflect, or refract light.

2.55 "**Test Cycle**" means a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (ESC test) or transient operating conditions (ETC, ELR test).

2.56 **"Torque limiter"** means a device that temporarily limits the maximum torque of the engine.

2.57 **"Transformation time"** means the time between the change of the component to be measured at the sampling probe and a system response of 50 % of the final reading (t_{50}). The transformation time is used for the signal alignment of different measurement instruments.

2.58 "**useful life**" means, for vehicles and engines that are type-approved to BS4 emission norms, the relevant period of distance and/or time that is defined section 5 of Chapter VII of this Part over which compliance with the relevant gaseous, particulate and smoke emission limits has to be assured as part of the type-approval.

2.59 "**Wobbe Index** (lower $\mathbf{W_l}$; or upper $\mathbf{W_u}$)" means the ratio of the corresponding calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions.

$$W = H_{gas} \times (\rho_{air}/\rho_{gas})^{0.5}$$

2.60 **"λ shift factor (S_λ)"** means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio λ if the engine is fuelled with a gas composition different from pure methane (see section 4 of chapter 6 for the calculation of S_λ).

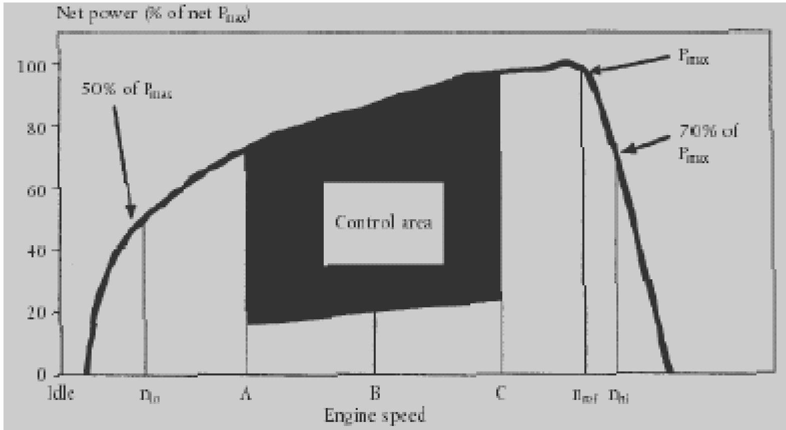


Figure 1
Specific definitions of the test cycles

2.2. Symbols, abbreviations and international standards

2.2.1. *Symbols for test parameters*

Symbol	Unit	Term
A_p	m^2	Cross sectional area of the isokinetic sampling probe
A_e	m^2	Cross sectional area of the exhaust pipe
c	ppm/vol. %	Concentration
C_d	—	Discharge coefficient of SSV-CVS
C1	—	Carbon 1 equivalent hydrocarbon
d	m	Diameter
D_0	m^3/s	Intercept of PDP calibration function
D	—	Dilution factor
D	—	Bessel function constant
E	—	Bessel function constant
E_E	—	Ethane efficiency
E_M	—	Methane efficiency
E_Z	g/kWh	Interpolated NO_x emission of the control point
f	1/s	Frequency
f_a	—	Laboratory atmospheric factor
f_c	s^{-1}	Bessel filter cut-off frequency
F_s	—	Stoichiometric factor
H	MJ/m^3	Calorific value
H_a	g/kg	Absolute humidity of the intake air
H_d	g/kg	Absolute humidity of the dilution air
i	—	Subscript denoting an individual mode or instantaneous measurement
K	—	Bessel constant
k	m^{-1}	Light absorption coefficient
k_f		Fuel specific factor for dry to wet correction
$k_{h,D}$	—	Humidity correction factor for NO_x for diesel engines
$k_{h,G}$	—	Humidity correction factor for NO_x for gas engines
K_V		CFV calibration function
$k_{W,a}$	—	Dry to wet correction factor for the intake air
$k_{W,d}$	—	Dry to wet correction factor for the dilution air
$k_{W,e}$	—	Dry to wet correction factor for the diluted exhaust gas

Symbol	Unit	Term
$k_{W,r}$	—	Dry to wet correction factor for the raw exhaust gas
L	%	Percent torque related to the maximum torque for the test engine
L_a	m	Effective optical path length
M_{ra}	g/mol	Molecular mass of the intake air
M_{re}	g/mol	Molecular mass of the exhaust
m_d	kg	Mass of the dilution air sample passed through the particulate sampling filters
m_{ed}	kg	Total diluted exhaust mass over the cycle
m_{edf}	kg	Mass of equivalent diluted exhaust over the cycle
m_{ew}	kg	Total exhaust mass over the cycle
m_f	mg	Particulate sample mass collected
$m_{f,d}$	mg	Particulate sample mass of the dilution air collected
m_{gas}	g/h or g	Gaseous emissions mass flow (rate)
m_{se}	kg	Sample mass over the cycle
m_{sep}	kg	Mass of the diluted exhaust sample passed through the particulate sampling filters
m_{set}	kg	Mass of the double diluted exhaust sample passed through the particulate sampling filters
m_{ssd}	kg	Mass of secondary dilution air
N	%	Opacity
N_P	—	Total revolutions of PDP over the cycle
$N_{P,i}$	—	Revolutions of PDP during a time interval
n	min^{-1}	Engine speed
n_p	s^{-1}	PDP speed
n_{hi}	min^{-1}	High engine speed
n_{lo}	min^{-1}	Low engine speed
n_{ref}	min^{-1}	Reference engine speed for ETC test
p_a	kPa	Saturation vapour pressure of the engine intake air
p_b	kPa	Total atmospheric pressure
p_d	kPa	Saturation vapour pressure of the dilution air
p_p	kPa	Absolute pressure
p_r	kPa	Water vapour pressure after cooling bath
p_s	kPa	Dry atmospheric pressure
p_1	kPa	Pressure depression at pump inlet
P(a)	kW	Power absorbed by auxiliaries to be fitted for test
P(b)	kW	Power absorbed by auxiliaries to be removed for test
P(n)	kW	Net power non-corrected
P(m)	kW	Power measured on test bed
q_{maw}	kg/h or kg/s	Intake air mass flow rate on wet basis
q_{mad}	kg/h or kg/s	Intake air mass flow rate on dry basis
q_{mdw}	kg/h or kg/s	Dilution air mass flow rate on wet basis
q_{mdew}	kg/h or kg/s	Diluted exhaust gas mass flow rate on wet basis
$q_{mdew,i}$	kg/s	Instantaneous CVS flow rate mass on wet basis
q_{medf}	kg/h or kg/s	Equivalent diluted exhaust gas mass flow rate on wet basis
q_{mew}	kg/h or kg/s	Exhaust gas mass flow rate on wet basis

Symbol	Unit	Term
q_{mf}	kg/h or kg/s	Fuel mass flow rate
q_{mp}	kg/h or kg/s	Particulate sample mass flow rate
q_{vs}	dm^3/min	Sample flow rate into analyser bench
q_{vt}	cm^3/min	Tracer gas flow rate
Ω	—	Bessel constant
Q_s	m^3/s	PDP/CFV-CVS volume flow rate
Q_{SSV}	m^3/s	SSV-CVS volume flow rate
r_a	—	Ratio of cross sectional areas of isokinetic probe and exhaust pipe
r_d	—	Dilution ratio
r_D	—	Diameter ratio of SSV-CVS
r_p	—	Pressure ratio of SSV-CVS
r_s	—	Sample ratio
R_f	—	FID response factor
ρ	kg/m^3	density
S	kW	Dynamometer setting
S_i	m^{-1}	Instantaneous smoke value
S_λ	—	λ-shift factor
T	K	Absolute temperature
T_a	K	Absolute temperature of the intake air
t	s	Measuring time
t_e	s	Electrical response time
t_f	s	Filter response time for Bessel function
t_p	s	Physical response time
Δt	s	Time interval between successive smoke data (= 1/sampling rate)
Δt_i	s	Time interval for instantaneous CVS flow
τ	%	Smoke transmittance
u	—	Ratio between densities of gas component and exhaust gas
V_0	m^3/rev	PDP gas volume pumped per revolution
V_s	l	System volume of analyser bench
W	—	Wobbe index
W_{act}	kWh	Actual cycle work of ETC
W_{ref}	kWh	Reference cycle work of ETC
W_F	—	Weighting factor
WF_E	—	Effective weighting factor
X_0	m^3/rev	Calibration function of PDP volume flow rate
Y_i	m^{-1}	1 s Bessel averaged smoke value

2.2.2 *Symbols for the Chemical Components*

CH_4	Methane
C_2H_6	Ethane
C_2H_5OH	Ethanol
C_3H_8	Propane
CO	Carbon monoxide
DOP	Di-octylphtalate
CO_2	Carbon dioxide
HC	Hydrocarbons
NMHC	Non-methane hydrocarbons
NO_X	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
PT	Particulates

2.2.3 Abbreviations

CFV	Critical flow venturi
CLD	Chemiluminescent detector
ELR	European load response test
ESC	European steady state cycle
ETC	European transient cycle
FID	Flame ionisation detector
GC	Gas chromatograph
HCLD	Heated chemiluminescent detector
HFID	Heated flame ionization detector
LPG	Liquefied petroleum gas
NDIR	Non-dispersive infrared analyser
NG	Natural gas
NMC	Non-methane cutter

2.2.4. Symbols for the fuel composition

W_{ALF}	hydrogen content of fuel, % mass
W_{BET}	carbon content of fuel, % mass
W_{GAM}	sulphur content of fuel, % mass
W_{DEL}	nitrogen content of fuel, % mass
W_{EPS}	oxygen content of fuel, % mass
α	molar hydrogen ratio (H/C)
β	molar carbon ratio (C/C)
γ	molar sulphur ratio (S/C)
δ	molar nitrogen ratio (N/C)
ε	molar oxygen ratio (O/C)

Referring to a fuel $C_\beta H_\alpha O_\varepsilon N_\delta S_\gamma$

β = 1 for carbon based fuels, β = 0 for hydrogen fuel.

3. APPLICATION FOR TYPE-APPROVAL

3.1 As per AIS 007 (as ammended from time to time) to be submitted to Test Agencies.

4. TYPE-APPROVAL:

4.1 Granting of a universal fuel type-approval:

A universal fuel type-approval is granted subject to the following requirements:

4.1.1 In the case of diesel fuel, the parent engine meets the requirements of this part on the reference fuel specified in chapter IV of this part.

4.1.2 In the case of natural gas, the parent engine demonstrates its capability to adapt to any fuel composition that may occur across the market. In the case of natural gas there are generally two types of fuel, high calorific fuel (H-gas) and low calorific fuel (L-gas), but with a significant spread within both ranges; they differ significantly in their energy content expressed by the Wobbe Index and in their shift factor (Sλ). The formulae for the calculation of the Wobbe index and S_λ are given in sections 2.58 and 2.59 of this chapter. Natural gases with a λ-shift factor between 0,89 and 1,08 ($0,89 \leq S_\lambda \leq 1,08$) are considered to belong to H-range, while natural gases with a λ-shift factor between 1,08 and 1,19 ($1,08 \leq S_\lambda \leq 1,19$) are considered to belong to L-range. The composition of the reference fuels reflects the extreme variations of Sλ.

The parent engine shall meet the requirements of this part on the reference fuels G_R and G_{25} as specified in chapter IV of this part, without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Chapter III.

4.1.2.1 On the manufacturer's request the engine may be tested on a third fuel (fuel 3) if the λ-shift factor (S_λ) lies between 0,89 (i.e. the lower range of G_R) and 1,19 (i.e. the upper range of G_{25}) for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.1.3 In the case of an engine fuelled with natural gas which is self-adaptive for the range of H-gases on the one hand and the range of L-gases on the other hand, and which switches between the H-range and the L-range by means of a switch, the parent engine shall be tested on the two relevant reference fuels as specified in chapter IV of this part for each range, at each position of the switch. The fuels are G_R (fuel 1) and G_{23} (fuel 3) for the H-range of gases, and G_{25} (fuel 2) and G_{23} (fuel 3) for the L-range of gases. The parent engine shall meet the requirements of this part at both positions of the switch without any readjustment to the fuelling between the two tests at each position of the switch. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing the parent engine shall be run-in using the procedure given in section 3 of appendix 2 to chapter III of this part.

4.1.3.1 On the manufacturer's request the engine may be tested on a third fuel instead of G_{23} (fuel 3) if the λ-shift factor (S_{λ}) lies between 0,89 (i.e. the lower range of G_R) and 1,19 (i.e. the Upper range of G_{25}), for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.1.4 In case of Natural Gas engines, the ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

or,

$$r_a = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$r_b = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

4.1.5 In the case of LPG the parent engine should demonstrate its capability to adapt to any fuel composition that may occur across the market. In the case of LPG there are variations in C_3/C_4 composition. These variations are reflected in the reference fuels. The parent engine should meet the emission requirements on the reference fuels A and B as specified in chapter IV of this part without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in section 3 of chapter III of this part.

4.1.4.1.The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel B}}{\text{emission result on reference fuel A}}$$

4.2. Granting of a fuel range restricted type-approval:

Till the availability of reference fuel the engines will be tested with available commercial Fuel. However, if tested with commercial fuel section 4.2 of this Chapter is not applicable. Fuel range restricted type-approval is granted subject to the following requirements:

4.2.1 Exhaust emissions approval of an engine running on natural gas and laid out for operation on either the range of H-gases or on the range of L-gases.

The parent engine shall be tested on the two relevant reference fuels as specified in chapter IV of this part for the relevant range. The fuels are G_R (fuel 1) and G_{23} (fuel 3) for the H-range of gases and G_{25} (fuel 2) and G_{23} (fuel 3) for the L-range of gases. The parent engine shall meet the emission requirements without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Chapter III.

4.2.1.1 On the manufacturer's request it may be tested on a third fuel instead of G_{23} (fuel 3) if the λ-shift factor ($S\lambda$) lies between 0.89 (i.e. the lower range of G_R) and 1.19 (i.e. the upper range of G_{25}), for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.2.1.2 The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

or,

$$r_a = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$r_b = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

4.2.1.3 Upon delivery to the customer the engine shall bear a label (see section 5.1.5 of this chapter) stating for which range of gases the engine is approved.

4.2.2 Exhaust emissions approval of an engine running on natural gas or LPG and laid out for operation on one specific fuel composition.

4.2.2.1 The parent engine shall meet the emission requirements on the reference fuels G_R and G_{25} in the case of natural gas, or the reference fuels A and B in the case of LPG, as specified in chapter IV of this part. Between the tests fine-tuning of the fuelling system is allowed. This fine-tuning will consist of a recalibration of the fuelling database, without any alteration to either the basic control strategy or the basic structure of the database. If necessary the exchange of parts that are directly related to the amount of fuel flow (such as injector nozzles) is allowed.

4.2.2.2 If the manufacturer so desires the engine may be tested on the reference fuels G_R and G23, or on the reference fuel G_{25} and G_{23}, in which case the type approval is only valid for the H-range or the L-range of gases respectively.

4.2.2.3 Upon delivery to the customer the engine shall bear a label (see section of this chapter) stating for which fuel composition the engine has been calibrated.

4.3 Exhaust emissions approval of a member of a family

4.3.1 With the exception of the case mentioned in paragraph 4.3.2, the approval of a parent engine shall be extended to all family members without further testing, for any fuel composition within the range for which the parent engine has been approved (in the case of engines described in paragraph 4.2.2) or the same range of fuels (in the case of engines described in either paragraphs 4.1 or 4.2) for which the parent engine has been approved.

4.3.2 Secondary test engine
In case of an application for type-approval of an engine, or a vehicle in respect of its engine, that engine belonging to an engine family, if the technical service determines that, with regard to the selected parent engine the submitted application does not fully represent the engine family defined in this chapter, an alternative and if necessary an additional reference test engine may be selected by the technical service and tested.

5. ENGINE MARKINGS:

5.1. The engine approved as a technical unit must bear:

5.1.1 The trademark or trade name of the manufacturer of the engine.

5.1.2 The manufacturer's commercial description.

5.1.3. Declared maximum power.

5.1.4. In case of an NG engine one of the following markings to be placed after the type approval number:

- H in case of the engine being approved and calibrated for the H-range of gases.

- L in case of the engine being approved and calibrated for the L-range of gases.

- HL in case of the engine being approved and calibrated for both the H range and L-range of gases.

- H_t in case of the engine being approved and calibrated for a specific gas composition in the H-range of gases and transformable to another specific gas in the H-range of gases by fine tuning of the engine fuelling;

- L_t in case of the engine being approved and calibrated for a specific gas composition in the L-range of gases and transformable to another specific gas in the L-range of gases after fine-tuning of the engine fuelling;

- HL_t in the case of the engine being approved and calibrated for a specific gas composition in either the H-range or the L-range of gases and transformable to another specific gas in either the H-range or the L-range of gases by fine-tuning of the engine fuelling.

5.1.5. Labels

In the case of NG and LPG fuelled engines with a fuel range restricted type approval, the following labels are applicable:

5.1.5.1. Content

The following information must be given:

In the case of section 4.2.1.3 of this chapter, the label shall state "ONLY FOR USE WITH NATURAL GAS RANGE H". If applicable, "H" is replaced by "L".

In the case of paragraph 4.2.2.3, the label shall state "ONLY FOR USE WITH NATURAL GAS SPECIFICATION..." or "ONLY FOR USE WITH LIQUEFIED PETROLEUM GAS SPECIFICATION...", as applicable. All the information in the appropriate table(s) in chapter IV of this part shall be given with the individual constituents and limits specified by the engine manufacturer.

The letters and figures must be at least 4 mm in height.

Note:

If lack of space prevents such labelling, a simplified code may be used. In this event, explanatory notes containing all the above information must be easily accessible to any person filling the fuel tank or performing maintenance or repair on the engine and its accessories, as well as to the authorities concerned. The site and content of these explanatory notes will be determined by agreement between the manufacturer and the approval authority.

5.1.5.2. Properties

Labels must be durable for the useful life of the engine. Labels must be clearly legible and their letters and figures must be indelible. Additionally, labels must be attached in such a manner that their fixing is durable for the useful life of the engine, and the labels cannot be removed without destroying or defacing them.

5.1.5.3. Placing

Labels must be secured to an engine part necessary for normal engine operation and not normally requiring replacement during engine life. Additionally, these labels must be located so as to be readily visible to the average person after the engine has been completed with all the auxiliaries necessary for engine operation.

5.2. In case of an application for type-approval for a vehicle type in respect of its engine, the marking specified in section 5.1.5 shall also be placed close to fuel filling aperture.

5.3. In case of an application for type-approval for a vehicle type with an approved engine, the marking specified in section 5.1.5 shall also be placed close to the fuel-filling aperture.

6. SPECIFICATIONS AND TESTS

6.1 General:

6.1.1 Emission control equipment

6.1.1.1 The components liable to affect, where appropriate, the emission of gaseous and particulate pollutants from diesel and gas engines shall be so designed, constructed, assembled and installed as to enable the engine, in normal use, to comply with the provisions of this part.

6.1.2 The use of a defeat strategy is forbidden.

6.1.2.1 The use of a multi-setting engine is forbidden until appropriate and robust provisions for multi-setting engines are laid down in this part.

6.1.3 Emission control strategy

6.1.3.1 Any element of design and emission control strategy (ECS) liable to affect the emission of gaseous and particulate pollutants from diesel engines and the emission of gaseous pollutants from gas engines shall be so designed, constructed, assembled and installed as to enable the engine, in normal use, to comply with the provisions of this part. ECS consists of the base emission control strategy (BECS) and usually one or more auxiliary emission control strategies (AECS).

6.1.4 Requirements for base emission control strategy

6.1.4.1 The base emission control strategy (BECS) shall be so designed as to enable the engine, in normal use, to comply with the provisions of this part. Normal use is not restricted to the conditions of use as specified in section 6.1.5.4 of this chapter.

6.1.5 Requirements for auxiliary emission control strategy

6.1.5.1 An auxiliary emission control strategy (AECS) may be installed to an engine or on a vehicle provided that the AECS:

- Operates only outside the conditions of use specified in section 6.1.5.4 of this chapter for the purposes defined in section 6.1.5.5 of this chapter or

- Is activated only exceptionally within the conditions of use specified in section 6.1.5.4 of this chapter for the purposes defined in section 6.1.5.6 of this part and not longer than is needed for these purposes.

6.1.5.2 An auxiliary emission control strategy (AECS) that operates within the conditions of use specified in section 6.1.5.4 and which results in the use of a different or modified emission control strategy (ECS) to that normally employed during the applicable emission test cycles will be permitted if, in complying with the requirements of section 6.1.7 of this chapter, it is fully demonstrated that the measure does not permanently reduce the effectiveness of the emission control system. In all other cases, such strategy shall be considered to be a defeat strategy.

6.1.5.3 An auxiliary emission control strategy (AECS) that operates outside the conditions of use specified in section 6.1.5.4 of this chapter will be permitted if, in complying with the requirements of section 6.1.7 of this chapter, it is fully demonstrated that the measure is the minimum strategy necessary for the purposes of section 6.1.5.6 of this chapter with respect to environmental protection and other technical aspects. In all other cases, such a strategy shall be considered to be a defeat strategy.

6.1.5.4 As provided for in section 6.1.5.1, the following conditions of use apply under steady state and transient engine operations:

- An altitude not exceeding 1000 metres (or equivalent atmospheric pressure of 90 kPa), and

- An ambient temperature within the range 279°K to 303°K (6 °C to 30°C)*, and

- Engine coolant temperature within the range 343° K to 373° K (70 °C to 100 °C).

*Appropriateness of lower temperature may be reviewed as and when required.

6.1.5.5 An auxiliary emission control strategy (AECS) may be installed to an engine, or on a vehicle, provided that the operation of the AECS is included in the applicable type-approval test and is activated according to section 6.1.5.6 of this chapter.

6.1.5.6 The AECS is activated:

- Only by on-board signals for the purpose of protecting the engine system (including air-handling device protection) and/or vehicle from damage.

Or

- For purposes such as operational safety, emission default modes and limp-home strategies.

Or

- For such purposes as excessive emissions prevention, cold start or warming-up.

or

- If it is used to trade-off the control of one regulated pollutant under specific ambient or operating conditions in order to maintain control of all other regulated pollutants within the emission limit values that are appropriate for the engine in question. The overall effects of such an AECS is to compensate for naturally occurring phenomena and do so in a manner that provides acceptable control of all emission constituents.

6.1.6 Requirements for torque limiters

6.1.6.1 A torque limiter will be permitted if it complies with the requirements of section 6.1.6.2 or 6.5.5 of this chapter. In all other cases, a torque limiter shall be considered to be a defeat strategy.

6.1.6.2 A torque limiter may be installed to an engine, or on a vehicle, provided that:

- The torque limiter is activated only by on-board signals for the purpose of protecting the power train or vehicle construction from damage and/or for the purpose of vehicle safety, or for power take-off activation when the vehicle is stationary, or for measures to ensure the correct functioning of the deNO$_X$ system.

And

- The torque limiter is active only temporarily,

And

- The torque limiter does not modify the emission control strategy (ECS),

And

- In case of power take-off or power train protection the torque is limited to a constant value, independent from the engine speed, while never exceeding the full-load torque,

And

- Is activated in the same manner to limit the performance of a vehicle in order to encourage the driver to take the necessary measures in order to ensure the correct functioning of NO$_X$ control measures within the engine system.

6.1.7 Special requirements for electronic emission control systems

6.1.7.1 Documentation requirements

The manufacturer shall provide a documentation package that gives access to any element of design and emission control strategy (ECS), and torque limiter of the engine system and the means by which it controls its output variables, whether that control is direct or indirect. The documentation shall be made available in two parts:

(a) The formal documentation package, which shall be supplied to the technical service at the time of submission of the type-approval application, shall include a full description of the ECS and, if applicable, the torque limiter. This documentation may be brief, provided that it exhibits evidence that all outputs permitted by a matrix obtained from the range of control of the individual unit inputs have been identified. This information shall be attached to the documentation required in section 3 of this chapter;

(b) additional material that shows the parameters that are modified by any auxiliary emission control strategy (AECS) and the boundary conditions under which the AECS operates. The additional material shall include a description of the fuel system control logic, timing strategies and switch points during all modes of operation. It shall also include a description of the torque limiter described in section 6.5.5 of this chapter.

The additional material shall also contain a justification for the use of any AECS and include additional material and test data to demonstrate the effect on exhaust emissions of any AECS installed to the engine or on the vehicle. The justification for the use of an AECS may be based on test data and/or sound engineering analysis.

This additional material shall remain strictly confidential, and be made available to the type-approval authority on request. The type approval authority will keep this material confidential.

6.1.8 Provisions for electronic system security

6.1.8.1 Any vehicle with an Emission Control Unit must include features to deter modification, except as authorised by the manufacturer. The manufacturer shall authorise modifications if these modifications are necessary for the diagnosis, servicing, inspection, retrofitting or repair of the vehicle. Any reprogrammable computer codes or operating parameters must be resistant to tampering and afford a level of protection at least as good as the provisions in ISO 15031-7 (SAE J2186) provided that the security exchange is conducted using the protocols and diagnostic connector as prescribed in section 6 of Chapter VIII to this part. Any removable calibration memory chips must be potted, encased in a sealed container or protected by electronic algorithms and must not be changeable without the use of specialised tools and procedures.

6.1.8.2 Computer-coded engine operating parameters must not be changeable without the use of specialised tools and procedures (e.g. soldered or potted computer components or sealed (or soldered) computer enclosures).

6.1.8.3 Manufacturers must take adequate steps to protect the maximum fuel delivery setting from tampering while a vehicle is in-service.

6.1.8.4 Manufacturers may apply to the approval authority for an exemption from one of these requirements for those vehicles that are unlikely to require protection. The criteria that the approval authority will evaluate in considering an exemption will include, but are not limited to, the current availability of performance chips, the high-performance capability of the vehicle and the projected sales volume of the vehicle.

6.1.8.5 Manufacturers using programmable computer code systems (e.g. electrical erasable programmable read-only memory, EEPROM) must deter unauthorised reprogramming. Manufacturers must include enhanced tamper-protection strategies and write protect features requiring electronic access to an off-site computer maintained by the manufacturer. Alternative methods giving an equivalent level of tamper protection may be approved by the authority.

6.2. Specifications Concerning the Emission of Gaseous and Particulate Pollutants and Smoke:

For type approval as per section 6.2.1 of this chapter, the emissions of diesel engines shall be determined on the ESC, ELR and ETC tests.

For gas engines, the gaseous emissions shall be determined on the ETC test.

The ESC and ELR test procedures are described in chapter III appendix 1 of this part, the ETC test procedure in chapter III appendices 2 and 3 of this chapter.

The emissions of gaseous pollutants and particulate pollutants, if applicable, and smoke, if applicable, by the engine submitted for testing shall be measured by the methods described in chapter III appendix 4 of this part. Chapter V of this part describes the recommended analytical systems for the gaseous pollutants, the recommended particulate sampling systems, and the recommended smoke measurement system.

Other systems or analysers may be approved by the test agency, if it is found that they yield equivalent results on the respective test cycle. The determination of system equivalency shall be based upon a 7 sample pair (or larger) correlation study between the system under consideration and one of the reference systems of this part. For particulate emissions, either the full flow dilution system or the partial flow dilution system meeting the requirements of ISO 16183 are recognised as equivalent reference systems. “Results” refer to the specific cycle emissions value. The correlation testing shall be performed at the same laboratory, test cell, and on the same engine, and is preferred to be run concurrently. The equivalency of the sample pair averages shall be determined by F-test and t-test statistics as described in appendix 4 of this chapter obtained under these laboratory, test cell and engine conditions. Outliers shall be determined in accordance with ISO 5725 and excluded from the database. For introduction of a new system into the part the determination of equivalency shall be based upon the calculation of repeatability and reproducibility, as described in ISO 5725.

6.2.1 Limit values for Type Approval (TA) as well as (COP)

(i) For Diesel engines

The specific mass of the carbon monoxide, of the total hydrocarbons, of the oxides of nitrogen and of the particulates, as determined on the ESC test, and of the smoke opacity, as determined on the ELR test, shall not exceed the values shown in following table:

Engine Steady State Cycle (ESC) test				Engine Load Response (ELR) test
CO (g/kWh)	HC (g/kWh)	NO_X (g/kWh)	PM (g/kWh)	Smoke (m^{-1})
1.5	0.46	3.5	0.02	0.5

ii) For Diesel engines, CNG Engines and LPG Engines

For diesel engines that are additionally tested on the ETC test, and specifically for the gas engines, the specific masses of the carbon monoxide, of the non-methane hydrocarbons, of the methane (where applicable), of the oxides of nitrogen and of the particulates (where applicable) shall not exceed the values shown in following table:

Engine Transient Cycle (ETC) test				
CO (g/kWh)	NMHC (1) (g/kWh)	CH_4 (2) g/kWh	NOx (g/kWh)	PM (3) (g/kWh)
4.0	0.55	1.1	3.5	0.03
(1) A manufacturer may choose to measure the mass of total hydrocarbons				

(THC) instead of measuring the mass of non-methane hydrocarbon (NMHC). In this case, the limit for mass of THC should be same as for the NMHC. (2) For CNG engines only. (3) For Diesel engines only.

6.2.2 Specific requirements for diesel engines:

6.2.2.1 The specific mass of the oxides of nitrogen measured at the random check points within the control area of the ESC test must not exceed by more than 10 per cent the values interpolated from the adjacent test modes (reference sections 4.6.2 and 4.6.3 of chapter III appendix 1 of this chapter).

6.2.2.2 The smoke value on the random test speed of the ELR must not exceed the highest smoke value of the two adjacent test speeds by more than 20 per cent, or by more than 5 per cent of the limit value, whichever is greater.

6.3. Durability and deterioration factors

6.3.1. For the purposes of this part, the manufacturer shall determine deterioration factors that will be used to demonstrate that the gaseous and particulate emissions of an engine family or engine-after treatment system family remain in conformity with the appropriate emission limits specified in the tables in section 6.2.1 of this chapter over the appropriate durability period laid down in chapter VII of this Part.

6.3.2 The procedures for demonstrating the compliance of an engine or engine-after treatment system family with the relevant emission limits over the appropriate durability period are given in chapter VII of this Part.

6.4 On-Board Diagnostic (OBD) system

6.4.1 Diesel engines or vehicles equipped with a diesel engine must be fitted with an on-board diagnostic (OBD) system for emission control in accordance with the requirements of chapter VIII of this part.

Gas engines or vehicles equipped with a gas engine must be fitted, with an on-board diagnostic (OBD) system for emission control in accordance with the requirements of chapter VIII of this part.

6.4.2. Small batch engine production

As an alternative to the requirements of this section, engine manufacturers whose annual production of a type of engine, belonging to an OBD engine family,

- is less than 250 units per year, may obtain type-approval on the basis of the requirements of this part where the engine is monitored only for circuit continuity and the after-treatment system is monitored for major functional failure.

- is less than 50 units per year, may obtain type-approval on the basis of the requirements of this part where the complete emission control system (i.e. the engine and after-treatment system) are monitored only for circuit continuity.

Type approval authority should inform any competent authority or Standing Committee on Implementation of Emission Legislation of each type approval granted under this provision.

6.4.3 For the vehicles with SCR technology and fitted with reagent tank the following requirement shall be applicable from 1st April 2010 till the time OBD is implemented.

6.4.3.1 For the vehicles with SCR technology and fitted with reagent tank , the driver shall be informed of the level of reagent in the on-vehicle reagent storage tank through a specific mechanical or electronic indication on the vehicle's dashboard. This shall include a warning when the level of reagent goes:

- Below 10 % of the tank or a higher percentage at the choice of the manufacturer.

Or

- Below the level corresponding to the driving distance possible with the fuel reserve level specified by the manufacturer

6.4.3.2 As soon as the reagent tank becomes empty - Torque limiter shall be activated when the vehicle becomes stationary for the first time after the aforementioned condition has occurred with engine torque shall not, in any case, exceed a constant value of:

- 60 % of engine maximum torque for vehicles of category N > 16 tons, M > 7.5 tons
- 75 % of engine maximum torque for vehicles of category N ≤ 16 tons, M ≤ 7.5 tons"

6.4.3.3 The torque limiter shall be deactivated when the engine speed is at idle if the condition for its activation have ceased to exist. The torque limiter shall not be automatically deactivated without the reason for its activation being remedied.

6.5 Requirements to ensure correct operation of NOx control measures

6.5.1 General

6.5.1.1 This section is applicable to compression-ignition engine systems irrespective of the technology used to comply with the emission limit values provided in the tables in section 6.2.1 of this chapter.

6.5.1.2 Any engine system covered by this section shall be designed, constructed and installed so as to be capable of meeting these requirements over the useful life of the engine.

6.5.1.3 Information that fully describes the functional operational characteristics of an engine system covered by this section shall be provided by the manufacturer in chapter II of this Part.

6.5.1.4 In its application for type-approval, if the engine system requires a reagent, the manufacturer shall specify the characteristics of all reagent(s) consumed by any exhaust after treatment system, e.g. type and concentrations, operational temperature conditions, reference to international standards etc.

6.5.1.5 Subject to requirements set out in section 6.1 of this chapter, any engine system covered by this section shall retain its emission control function during all conditions regularly.

6.5.1.6 For the purpose of type-approval, the manufacturer shall demonstrate to the test agency that for engine systems that require a reagent, any emission of ammonia does not exceed, over the applicable emissions test cycle, a mean value of 25 ppm.

6.5.1.7 For engine systems requiring a reagent, each separate reagent tank installed on a vehicle shall include a means for taking a sample of any fluid inside the tank. The sampling point shall be easily accessible without the use of any specialised tool or device.

6.5.2. Maintenance requirements

6.5.2.1 The manufacturer shall furnish or cause to be furnished to all owners of new heavy-duty vehicles or new heavy-duty engines written instructions that shall state that if the vehicle emission control system is not functioning correctly, the driver shall be informed of a problem by the malfunction indicator (MI) and the engine shall consequentially operate with a reduced performance.

6.5.2.2. The instructions will indicate requirements for the proper use and maintenance of vehicles, including where relevant the use of consumable reagents.

6.5.2.3 The instructions shall be written in clear and non-technical language.

6.5.2.4 The instructions shall specify if consumable reagents have to be refilled by the vehicle operator between normal maintenance intervals and shall indicate a likely rate of reagent consumption according to the type of new heavy-duty vehicle.

6.5.2.5 The instructions shall specify that use of and refilling of a required reagent of the correct specifications when indicated is mandatory for the vehicle to comply with the certificate of conformity issued for that vehicle or engine type.

6.5.2.6 The instructions shall state that it may be a criminal offence to use a vehicle that does not consume any reagent if it is required for the reduction of pollutant emissions and that, in consequence, any favorable conditions for the purchase or operation of the vehicle obtained in the country of registration or other country in which the vehicle is used may become invalid.

6.5.3. Engine system NOx control

6.5.3.1 Incorrect operation of the engine system with respect to NO_X emissions control (for example due to lack of any required reagent, incorrect EGR flow or deactivation of EGR) shall be determined through monitoring of the NO_X level by sensors positioned in the exhaust stream.

6.5.3.2 Any deviation in NO_X level more than 1,5 g/kwh above the applicable limit value given in table I of section 6.2.1 of this chapter, shall result in the driver being informed by activation of the MI as referred to in section 3.6.5 of chapter VIII of this part.

6.5.3.3 In addition, a non-erasable fault code identifying the reason why NO_X exceeds the levels specified in the section 6.5.3.2 shall be stored in accordance with section 3.9.2 of chapter VIII of this part for at least 400 days or 9600 hours of engine operation.

The reasons for the NO_X exceedance shall, at a minimum, and where applicable, be identified in the cases of empty reagent tank, interruption of reagent dosing activity, insufficient reagent quality, too low reagent consumption, incorrect EGR flow or deactivation of the EGR. In all other cases, the manufacturer is permitted to refer to a non-erasable fault code “high NO_X — root cause unknown”.

6.5.3.4 If the NO_X level exceeds the OBD threshold limit values given in section 7 of chapter VIII of this part, a torque limiter shall reduce the performance of the engine according to the requirements of section 6.5.5 of this chapter in a manner that is clearly perceived by the driver of the vehicle. When the torque limiter is activated the driver shall continue to be alerted according to the requirements of section 6.5.3.2 of this chapter and a non erasable fault code shall be stored in accordance with section 6.5.3.3 of this chapter.

6.5.3.5 In the case of engine systems that rely on the use of EGR and no other after treatment system for NOx emissions control, the manufacturer may utilise an alternative method to the requirements of section 6.5.3.1 of this chapter for the determination of the NO_X level. At the time of type approval the manufacturer shall demonstrate that the alternative method is equally timely and accurate in determining the NO_X level compared to the requirements of section 6.5.3.1 of this chapter and that it triggers the same consequences as those referred to in sections 6.5.3.2, 6.5.3.3 and 6.5.3.4 of this chapter.

6.5.4. Reagent control

6.5.4.1 For vehicles that require the use of a reagent to fulfill the requirements of this section 6.5 of this chapter, the driver shall be informed of the level of reagent in the on-vehicle reagent storage tank through a specific mechanical or electronic indication on the vehicle's dashboard. This shall include a warning when the level of reagent goes:

- Below 10 % of the tank or a higher percentage at the choice of the manufacturer.

Or

- Below the level corresponding to the driving distance possible with the fuel reserve level specified by the manufacturer.

The reagent indicator shall be placed in close proximity to the fuel level indicator.

6.5.4.2 The driver shall be informed, according to the requirements of section 3.6.5 of chapter VIII of this Part, if the reagent tank becomes empty.

6.5.4.3 As soon as the reagent tank becomes empty, the requirements of section 6.5.5 of this chapter shall apply in addition to the requirements of section 6.5.4.2.

6.5.4.4 A manufacturer may choose to comply with the sections 6.5.4.5 to 6.5.4.12 of this chapter as an alternative to complying with the requirements of section 6.5.3 of this chapter.

6.5.4.5 Engine systems shall include a means of determining that a fluid corresponding to the reagent characteristics declared by the manufacturer and recorded in Chapter II of this part is present on the vehicle.

6.5.4.6 If the fluid in the reagent tank does not correspond to the minimum requirements declared by the manufacturer as recorded in chapter II of this part the additional requirements of section 6.5.4.12 of this chapter shall apply.

6.5.4.7 Engine systems shall include a means for determining reagent consumption and providing off-board access to consumption information.

6.5.4.8 Average reagent consumption and average demanded reagent consumption by the engine system either over the previous complete 48 hour period of engine operation or the period needed for a demanded reagent consumption of at least 15 litres, whichever is longer, shall be available via the serial port of the standard diagnostic connector as referred in section 6.8.3 of chapter VIII of this part.

6.5.4.9 In order to monitor reagent consumption, at least the following parameters within the engine shall be monitored:

- Level of reagent in on-vehicle storage tank.

- Flow of reagent or injection of reagent as close as technically possible to the point of injection into an exhaust after treatment system.

6.5.4.10 Any deviation more than 50 % in average reagent consumption and average demanded reagent consumption by the engine system over the period defined in section 6.5.4.8 of this chapter shall result in application of the measures laid down in paragraph 6.5.4.12 of this chapter.

6.5.4.11 In the case of interruption in reagent dosing activity the measures laid down in section 6.5.4.12 of this chapter shall apply. This is not required where such interruption is demanded by the engine ECU because engine operating conditions are such that the engine's emission performance does not require reagent dosing, provided that the manufacturer has clearly informed the approval authority when such operating conditions apply.

6.5.4.12 Any failure detected with respect to sections 6.5.4.6, 6.5.4.10 or 6.5.4.11 of this chapter shall trigger the same consequences in the same order as those referred to in sections 6.5.3.2, 6.5.3.3 or 6.5.3.4 of this chapter.

6.5.5. Measures to discourage tampering of exhaust after treatment systems

6.5.5.1 Any engine system covered by this section 6.5 of this chapter shall include a torque limiter that will alert the driver that the engine system is operating incorrectly or the vehicle is being operated in an incorrect manner and thereby encourage the prompt rectification of any fault(s).

6.5.5.2 The torque limiter shall be activated when the vehicle becomes stationary for the first time after the conditions of either sections 6.5.3.4, 6.5.4.3, 6.5.4.6, 6.5.4.10, 6.5.4.11 of this chapter have occurred.

6.5.5.3 Where the torque limiter comes into effect, the engine torque shall not, in any case, exceed a constant value of:

- o 60 % of engine maximum torque for vehicles of category N > 16 tons, M > 7.5 tons
- o 75 % of engine maximum torque for vehicles of category N ≤ 16 tons, 3.5 < M ≤ 7.5 tons.

6.5.5.4 Requirements for documentation and the torque limiter are set out in sections 6.5.5.5 to 6.5.5.8.

6.5.5.5. Detailed written information fully describing the functional operation characteristics of the emission control monitoring system torque limiter shall be specified according to the documentation requirements of section 6.1.7.1 (b) of this chapter. Specifically, the manufacturer shall provide information on the algorithms used by the ECU for relating the NO_X concentration to the specific NO_X emission (in g/kWh) on the ETC in accordance with section 6.5.6.5 of this chapter.

6.5.5.6 The torque limiter shall be deactivated when the engine speed is at idle if the conditions for its activation have ceased to exist. The torque limiter shall not be automatically deactivated without the reason for its activation being remedied.

6.5.5.7 Deactivation of the torque limiter shall not be feasible by means of a switch or a maintenance tool.

6.5.5.8 The torque limiter shall not apply to engines or vehicles for use by the armed services, by rescue services and by fire-services and ambulances. Permanent deactivation shall only be done by the engine or vehicle manufacturer, and a special engine type within the engine family shall be designated for proper identification.

6.5.6 Operating conditions of the emission control monitoring system

6.5.6.1 The emission control monitoring system shall be operational,

— At all ambient temperatures between 266° K and 308° K (– 7 °C and 35 °C),

— At all altitudes below 1600 m,

— At engine coolant temperatures above 343° K (70 °C).

This section does not apply in the case of monitoring for reagent level in the storage tank where monitoring shall be conducted under all conditions of use.

6.5.6.2 The emission control monitoring system may be deactivated when a limp-home strategy is active and which results in a torque reduction greater than the levels indicated in section 6.5.5.3 of this chapter for the appropriate vehicle category.

6.5.6.3 If an emission default mode is active, the emission control monitoring system shall remain operational and comply with the provisions of section 6.5 of this chapter.

6.5.6.4 The incorrect operation of NO_X control measures shall be detected within four OBD test cycles as referred to in the definition given in section 6.1 of appendix 1 of chapter VIII of this Part.

6.5.6.5 Algorithms used by the ECU for relating the actual NO_X concentration to the specific NO_X emission (in g/kWh) on the ETC shall not be considered to be a defeat strategy.

6.5.6.6 If an AECS that has been approved by the type-approval authority in accordance with section 6.1.5 of this chapter becomes operational, any increase in NO_X due to the operation of the AECS may be applied to the appropriate NO_X level referred to in section 6.5.3.2 of this chapter. In all such cases, the influence of the AECS on the NO_X threshold shall be described in accordance with section 6.5.5.5 of this chapter.

6.5.7 Failure of the emission control monitoring system

6.5.7.1 The emission control monitoring system shall be monitored for electrical failures and for removal or deactivation of any sensor that prevents it from diagnosing an emission increase as required by sections 6.5.3.2 and 6.5.3.4 of this chapter.

Examples of sensors that affect the diagnostic capability are those directly measuring NO_X concentration, urea quality sensors, and sensors used for monitoring reagent dosing activity, reagent level, reagent consumption or EGR rate.

6.5.7.2 If a failure of the emission control monitoring system is confirmed, the driver shall be immediately alerted by the activation of the warning signal according to section 3.6.5 of chapter VIII of this part.

6.5.7.3 The torque limiter shall be activated in accordance with section 6.5.5 of this chapter if the failure is not remedied within 50 hours of engine operation.

6.5.7.4 When the emission control monitoring system has determined the failure has ceased to exist, the fault code(s) associated with that failure may be cleared from the system memory, except in the cases referred to in section 6.5.7.5 of this chapter and the torque limiter, if applicable, shall be deactivated according to section 6.5.5.6 of this chapter.

Fault code(s) associated with a failure of the emission control monitoring system shall not be capable of being cleared from the system memory by any scan tool.

6.5.7.5 In the case of the removal or deactivation of elements of the emission control monitoring system, in accordance with section 6.5.7.1of this chapter, a non-erasable fault code shall be stored in accordance with section 3.9.2 of chapter VIII of this part for a minimum of 400 days or 9600 hours of engine operation.

6.5.8 Demonstration of the emission control monitoring system

6.5.8.1 As part of the application for type-approval provided for in section 3 of this chapter, the manufacturer shall demonstrate the conformity of the provisions of this section by tests on an engine dynamometer in accordance with sections 6.5.8.2 to 6.5.8.7 of this chapter.

6.5.8.2 The compliance of an engine family or an OBD engine family to the requirements of this section may be demonstrated by testing the emission control monitoring system of one of the members of the family (the parent engine), provided the manufacturer demonstrates to the type approval authority that the emission control monitoring systems are similar within the family.

This demonstration may be performed by presenting to the type-approval authorities such elements as algorithms, functional analyses, etc.

The parent engine is selected by the manufacturer in agreement with the type approval authority.

6.5.8.3 The testing of the emission control monitoring system consists of the following three phases:

Selection :

An incorrect operation of the NO_X control measures or a failure of the emission control monitoring system is selected by the authority within a list of incorrect operations provided by the manufacturer.

Qualification :

The influence of the incorrect operation is validated by measuring the NO_X level over the ETC on an engine test bed.

Demonstration :

The reaction of the system (torque reduction, warning signal, etc.) shall be demonstrated by running the engine on four OBD test cycles.

6.5.8.3.1 For the selection phase, the manufacturer shall provide the type approval authority with a description of the monitoring strategies used to determine potential incorrect operation of any NO_X control measure and potential failures in the emission control monitoring system that would lead either to activation of the torque limiter or to activation of the warning signal only.

Typical examples of incorrect operations for this list are an empty reagent tank, an incorrect operation leading to an interruption of reagent dosing activity, an insufficient reagent quality, an incorrect operation leading to low reagent consumption, an incorrect EGR flow or a deactivation of the EGR.

A minimum of two and a maximum of three incorrect operations of the NO_X control system or failures of the emission control monitoring system shall be selected by the type approval authority from this list.

6.5.8.3.2 For the qualification phase, the NO_X emissions shall be measured over the ETC test cycle, according to the provisions of appendix 2 of Chapter III. The result of the ETC test shall be used to determine in which way the NO_X control monitoring system is expected to react during the demonstration process (torque reduction and/or warning signal). The failure shall be simulated in a way that the NO_X level does not exceed by more than 1 g/kWh any of the threshold levels given in sections 6.5.3.2 or 6.5.3.4 of this chapter.

Emissions qualification is not required in case of an empty reagent tank or for demonstrating a failure of the emission control monitoring system.

The torque limiter shall be deactivated during the qualification phase.

6.5.8.3.3 For the demonstration phase, the engine shall be run over a maximum of four OBD test cycles.

No failure other than the ones which are being considered for demonstration purposes shall be present.

6.5.8.3.4 Prior to starting the test sequence of section 6.5.8.3.3, the emission control monitoring system shall be set to a “no failure” status.

6.5.8.3.5 Depending on the NO_X level selected, the system shall activate a warning signal and in addition, if applicable, the torque limiter at any time before the end of the detection sequence. The detection sequence may be stopped once the NO_X control monitoring system has properly reacted.

6.5.8.4 In the case of an emission control monitoring system principally based on monitoring the NO_X level by sensors positioned in the exhaust stream, the manufacturer may choose to directly monitor certain system functionalities (e.g. interruption of dosing activity, closed EGR valve) for the determination of compliance. In that case, the selected system functionality shall be demonstrated.

6.5.8.5 The level of torque reduction required in section 6.5.5.3 of this chapter by the torque limiter shall be approved together with the general engine performance approval in accordance with this part. For the demonstration process, the manufacturer shall demonstrate to the type-approval authority the inclusion of the correct torque limiter into the engine ECU. Separate torque measurement during the demonstration is not required.

6.5.8.6 As an alternative to sections 6.5.8.3.3 to 6.5.8.3.5 of this chapter, the demonstration of the emission control monitoring system and the torque limiter may be performed by testing a vehicle. The vehicle shall be driven on the road or on a test track with the selected incorrect operations or failures of the emission control monitoring system to demonstrate that the warning signal and activation of the torque limiter will operate in accordance with the requirements of section 6.5 of this chapter, and in particular, those in sections 6.5.5.2 and 6.5.5.3 of this chapter.

6.5.8.7 If the storage in the computer memory of a non-erasable fault code is required for complying with the requirements of section 6.5 of this chapter, the following three conditions shall be met by the end of demonstration sequence:

— That it is possible to confirm via the OBD scan tool the presence in the OBD computer memory of the appropriate non-erasable fault code described in section 6.5.3.3 of this chapter and that it can be shown to the satisfaction of the type approval authority that the scan tool cannot erase it, and,

— That it is possible to confirm the time spent during the detection sequence with the warning signal activated by reading the non-erasable counter referred to in section 3.9.2 of chapter VIII of this part, and that it can be shown to the satisfaction of the type approval authority that the scan tool cannot erase it, and,

— That the type-approval authority has approved the elements of design showing that this non-erasable information is stored in accordance with section 3.9.2 of chapter VIII of this part for a minimum of 400 days or 9 600 hours of engine operation.

7. INSTALLATION ON THE VEHICLE:

7.1 The engine installation on the vehicle shall comply with the following characteristics in respect to the type-approval of the engine:

7.1.1 Intake depression shall not exceed that specified for the type-approved engine.

7.1.2 Exhaust back pressure shall not exceed that specified for the type-approved engine.

7.1.3 Exhaust system volume shall not differ by more than 40% of that specified for the type-approved engine

7.1.4 Power absorbed by the auxiliaries needed for operating the engine shall not exceed that specified for the type-approved engine.

8. ENGINE FAMILY

8.1. Parameters defining the engine family

The engine family, as determined by the engine manufacturer must comply with the provisions of ISO 16185.

In order that engines may be considered to belong to the same engine family, the following list of basic parameters must be common:

8.1.1. Combustion cycle:

— 2 cycle

— 4 cycle

8.1.2. Cooling medium:

— air

— water

— oil

8.1.3. For gas engines and engines with after treatment:

— number of cylinders

(other diesel engines with fewer cylinders than the parent engine may be considered to belong to the same engine family provided the fuelling system meters fuel for each individual cylinder)

8.1.4. Individual cylinder displacement:

— engines to be within a total spread of 15 %

8.1.5. Method of air aspiration:

— naturally aspirated

— pressure charged

— pressure charged with charge air cooler

8.1.6. Combustion chamber type/design:

— pre-chamber

— swirl chamber

— open chamber

8.1.7. Valve and porting — configuration, size and number:

— cylinder head

— cylinder wall

— crankcase

8.1.8. Fuel injection system (diesel engines):

— pump-line-injector

— in-line pump

— distributor pump

— single element

— unit injector

8.1.9. Fuelling system (gas engines):

— mixing unit

— gas induction/injection (single point, multi-point)

— liquid injection (single point, multi-point)

8.1.10. Ignition system (gas engines)

8.1.11. Miscellaneous features:

— exhaust gas recirculation

— water injection/emulsion

— secondary air injection

— charge cooling system

8.1.12. Exhaust after treatment:

— 3-way-catalyst

— oxidation catalyst

— reduction catalyst

— thermal reactor

— particulate trap

8.2 Choice of the parent engine

8.2.1 Diesel engines

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 criteria, 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 characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features, which indicate that it may have the highest emission level 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 shall also be identified and taken into account in the selection of the parent engine.

8.2.2 Gas engines

The parent engine of the family shall be selected using the primary criteria of the largest displacement. In the event that two or more engines share this primary criteria, the parent engine shall be selected using the secondary criteria in the following order:

— the highest fuel delivery per stroke at the speed of declared rated power.

— The most advanced spark timing.

— The lowest EGR rate.

— No air pump or lowest actual airflow pump.

Under certain circumstances, the approval authority may conclude that the worst case emission rate of the family can best be characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features, which indicate that it may have the highest emission level of the engines within that family.

8.3 Parameters for defining an OBD-engine family

The OBD-engine family may be defined by basic design parameters that must be common to engine systems within the family.

In order that engine systems may be considered to belong to the same OBD-engine family, the following list of basic parameters must be common,

— The methods of OBD monitoring.

— The methods of malfunction detection.

Unless these methods have been shown as equivalent by the manufacturer by means of relevant engineering demonstration or other appropriate procedures.

Note: engines that do not belong to the same engine family may still belong to the same OBD-engine family provided the above-mentioned criteria are satisfied.

9. PRODUCTION CONFORMITY

9.1 Measures to ensure production conformity must be taken in accordance with the provisions as per Part VI of MoSRTH/CMVR/TAP115/116. However when the period between commencement of production of a new model and beginning of next rationalized COP period is less than two months, the same would be merged with the rationalized COP period.

For verifying the conformity of production the following procedure as per Option1 is adopted.

To verify the conformity of production for low volume vehicles model and its variants were less than 250 no. in any consecutive period of six months in a year, manufacture can choose from option 1 or option 2 as listed below.

9.1.1 If emissions of pollutants are to be measured and an engine type-approval has had one or several extensions, the tests will be carried out on the engine(s) described in the information package relating to the relevant extension.

Option 1

9.1.1.1 Conformity of the engine subjected to a pollutant test:

After submission of the engine to the test agencies, the manufacturer shall not carry out any adjustment to the engines selected.

9.1.1.1.1 Three engines are randomly taken in the series. With agreement of test agency, engines are subject to testing either on the ESC and ELR cycles or ETC cycle (for Diesel engines) or only on the ETC cycle (for Gaseous engines) for the checking of production conformity. The limit values are given in section 6.2.1 of this chapter.

9.1.1.1.2 The tests are carried out according to appendix 1 of this chapter.

or

At the manufacturer's request, the tests may be carried out in accordance with appendix 2 of this Chapter.

9.1.1.1.3 On the basis of a test of the engine by sampling, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a fail decision is reached for one pollutant, in accordance with the test criteria applied in the appropriate appendix.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see Figure 2).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

9.1.1.2 The tests will be carried out on newly manufactured engines. Gas fuelled engines shall be run-in using the procedure defined in section 3 of appendix 2 of Chapter III of this part.

9.1.1.2.1 However, at the request of the manufacturer, the tests may be carried out on diesel or gas engines, which have been run-in, up to a maximum of 100 hours. In this case, the running-in procedure will be conducted by the manufacturer who shall undertake not to make any adjustments to those engines.

9.1.1.2.2 When the manufacturer asks to conduct a running-in procedure in accordance with section 9.1.1.2.1 of this chapter, it may be carried out on:

- All the engines that are tested,

or

- The first engine tested, with the determination of an evolution coefficient as follows:

- The pollutant emissions will be measured at zero and at "x" hours on the first engine tested,

- The evolution coefficient of the emissions between zero and "x" hours will be calculated for each pollutant:

Emissions ' x' hours
Emissions zero hours

It may be less than one.

The subsequent test engines will not be subjected to the running-in procedure, but their zero hour emissions will be modified by the evolution coefficient.

In this case, the values to be taken will be:

- the values at "x" hours for the first engine,

- the values at zero hour multiplied by the evolution coefficient for the other engines.

9.1.1.2.3 For diesel and LPG fuelled engines, all these tests may be conducted with commercial fuel. However, at the manufacturer's request, the reference fuels described in Annexure IV(F&H) of CMVR rules respectively may be used. This implies tests, as described in section 4 of this Chapter, with at least two of the reference fuels for each gas engine.

9.1.1.2.4 For NG fuelled engines, all these tests may be conducted with commercial fuel in the following way:

- for H marked engines with a commercial fuel within the H range;
($0,89 \leq S\lambda \leq 1,00$),

- for L marked engines with a commercial fuel within the L range;
($1,00 \leq S\lambda \leq 1,19$),

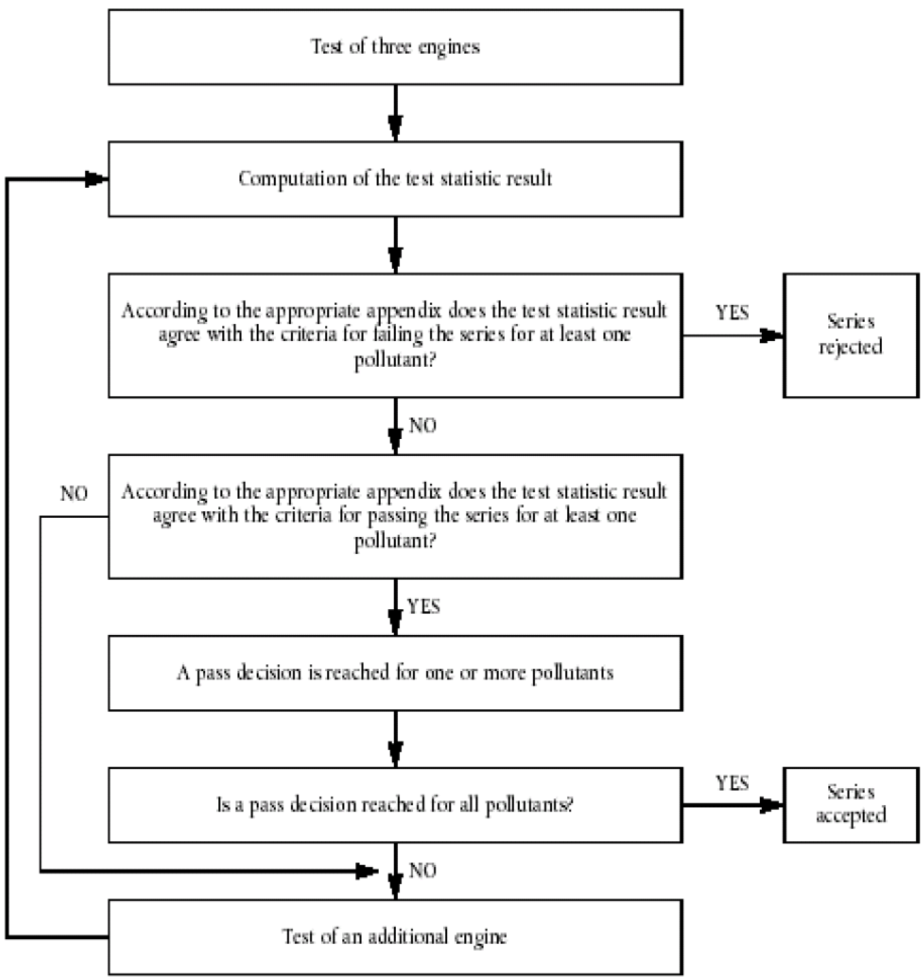
- for HL marked engines with a commercial fuel within the H or the L range.
($0,89 \leq S\lambda \leq 1,19$).

However, at the manufacturer's request, the reference fuels described in chapter IV of this part may be used. This implies tests, as described in section 4 of this Chapter, with at least two of the reference fuels for each gas engine.

9.1.1.2.5 In the case of dispute caused by the non-compliance of gas fuelled engines when using a commercial fuel, the tests shall be performed with a reference fuel on which the parent engine has been tested, or with the possible additional fuel 3 as referred to in sections 4.1.3.1 and 4.2.1.1 of this chapter on which the parent engine may have been tested. Then, the result has to be converted by a calculation applying the relevant factor(s) "r", "ra" or "rb" as described in sections 4.1.3.2, 4.1.4.1 and 4.2.1.2 of this chapter. If r, ra or rb are less than one no correction shall take place. The measured results and the calculated results must demonstrate that the engine meets the limit values with all relevant fuels (fuels 1, 2 and, if applicable, fuel 3 in the case of natural gas engines and fuels A and B in the case of LPG engines).

9.1.1.2.6 Tests for conformity of production of a gas fuelled engine laid out for operation on one specific fuel composition shall be performed on the fuel for which the engine has been calibrated.

Figure 2 (Option 1)
Schematic of production conformity testing



Option 2

9.1.1.3 Conformity of the engine subjected to a pollutant test:

After submission of the engine to the test agencies, the manufacturer shall not carry out any adjustment to the engines selected.

9.1.1.3.1 Three engines are randomly taken in the series. With agreement of test agency, only one engine are subject to testing either on the ESC and ELR cycles or ETC cycle (for Diesel engines) or only on the ETC cycle (for Gaseous engines) for the checking of production conformity. The limit values are given in section 6.2.1 of this chapter.

9.1.1.3.2 The tests are carried out according to appendix 1 of this chapter.

or

At the manufacturer's request, the tests may be carried out in accordance with appendix 2 of this Chapter.

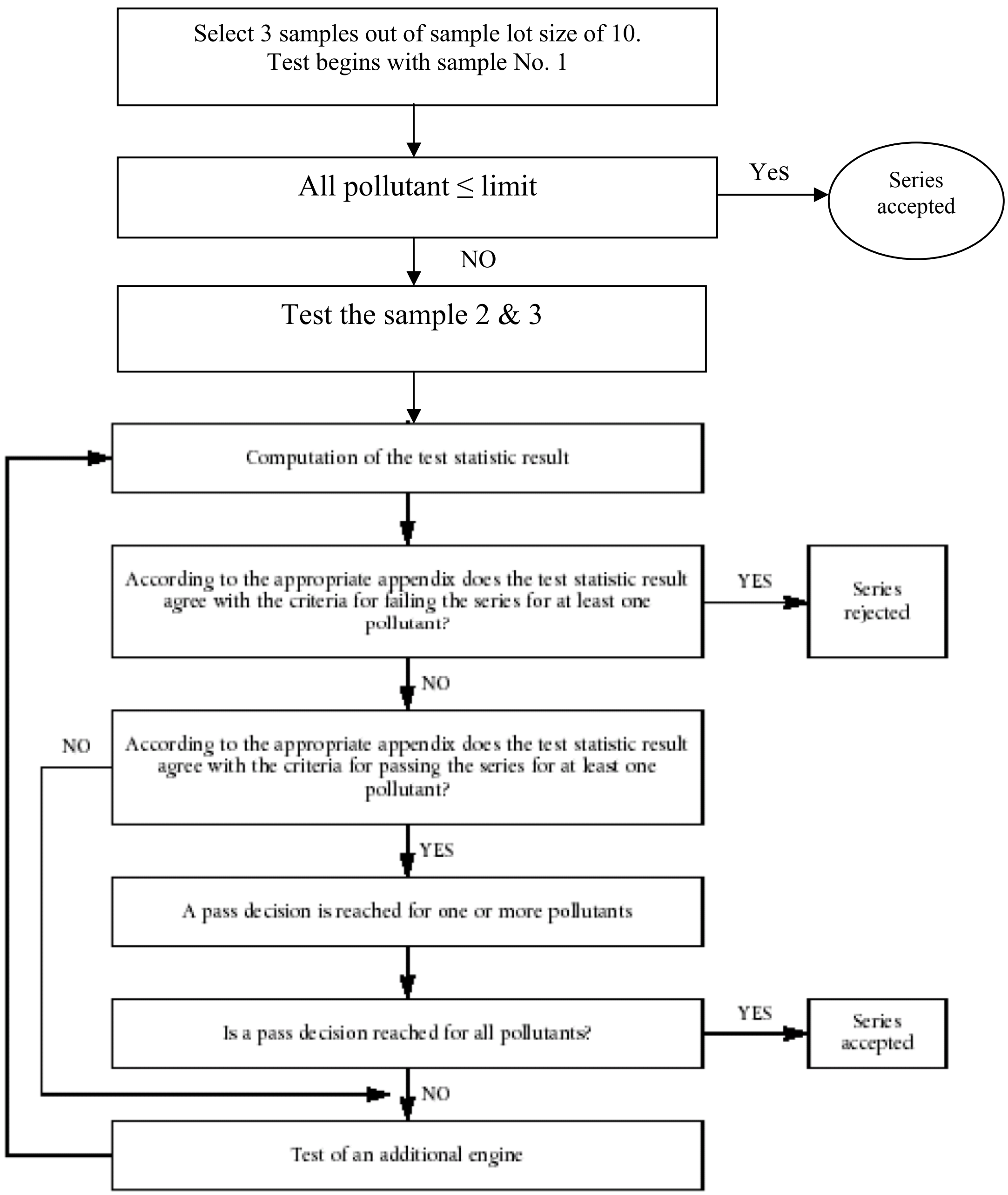
9.1.1.3.3 On the basis of a test of the engine, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a no pass decision is reached for one pollutant, in accordance with the limit values are given in section 6.2.1 of this chapter . When no pass decision has been reached for one pollutant saple 2 & 3 are subjected o test mentioned in 9.1.1.3.1 of this chapter.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see Figure 3).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

Figure 3 (option 2)
Schematic of production conformity testing



9.1.2. On-Board Diagnostics (OBD)

9.1.2.1 If a verification of the conformity of production of the OBD system is to be carried out, it must be conducted in accordance with the following:

9.1.2.2 When the test agency determines that the quality of production seems unsatisfactory an engine is randomly taken from the series and subjected to the tests described in appendix 1 to chapter VIII of this part. The tests may be carried out on an engine that has been run-in up to a maximum of 100 hours.

9.1.2.3 The production is deemed to conform if this engine meets the requirements of the tests described in appendix 1 to chapter VIII of this part.

9.1.2.4 If the engine taken from the series does not satisfy the requirements of section 9.1.2.2 of this chapter, a further random sample of four engines must be taken from the series and subjected to the tests described in appendix 1 to chapter VIII of this part. The tests may be carried out on engines that have been run-in up to a maximum of 100 hours.

9.1.2.5 The production is deemed to conform if at least three engines out of the further random sample of four engines meet the requirements of the tests described in appendix 1 to chapter VIII of this part.

Appendix 1

PROCEDURE FOR PRODUCTION CONFORMITY TESTING

1. This Appendix describes the procedure to be used to verify production conformity for the emissions of pollutants.

2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 40 % of the engines defective is 0,95 (producer's risk = 5 %) while the probability of a lot being accepted with 65 % of the engines defective is 0,10 (consumer's risk = 10 %).

3. The values of the pollutants given in section 6.2.1 of this chapter, after having applied the relevant DF, are considered to be log normally distributed and should be transformed by taking their natural logarithms. Let m_0 and m denote the minimum and maximum sample size respectively (m_0 = 3 and m = 32) and let n denote the current sample number.

4. If the natural logarithms of the measured values (after having applied the relevant DF) in the series are x_1, x_2, … x_i and L is the natural logarithm of the limit value for the pollutant, then, define:

$$d_i = x_i - L$$

and,

$$\overline{d_n} = \frac{1}{n}\sum_{i=1}^{n} d_i$$

$$V_n^2 = \frac{1}{n}\sum_{i=1}^{n}(d_i - \overline{d_n})^2$$

5. Table 3 shows values of the pass (A_n) and fail (B_n) decision numbers against current sample number. The test statistic result is the ratio: d_n / V_n and shall be used to determine whether the series has passed or failed as follows:

for $m_0 \leq n < m$:

— pass the series if $\overline{d_n}/v_n \leq A_n$,

— fail the series if $\overline{d_n}/v_n \geq B_n$,

— take another measurement if $A_n < \overline{d_n}/v_n < B_n$.

6. Remarks

The following recursive formulae are useful for calculating successive values of the test statistic:

$$\overline{d_n} = (1-\frac{1}{n})\overline{d_n - 1} + \frac{1}{n}d_n$$

$$V_n^2 = (1-\frac{1}{n})V^2{}_{n-1} + \frac{(\overline{d_n} - d_n)^2}{n-1}$$ (n = 2, 3,…..; $\overline{d_1}$ = d_1; V1 = 0)

Table 3

Pass and Fail Decision Numbers of Appendix 1 Sampling Plan

Minimum Sample Size: 3

Cumulative number of engines tested (sample size)	Pass decision number A_n	Fail decision number B_n
3	-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

Appendix 2

PROCEDURE FOR PRODUCTION CONFORMITY TESTING AT MANUFACTURER'S REQUEST

1. This Appendix describes the procedure to be used to verify, at the manufacturer's request, production conformity for the emissions of pollutants.

2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 30 % of the engines defective is 0,90 (producer's risk = 10 %) while the probability of a lot being accepted with 65 % of the engines defective is 0,10 (consumer's risk = 10 %).

3. The following procedure is used for each of the pollutants given in section 6.2.1 of this chapter (see Figure 2):

Let:

L = the natural logarithm of the limit value for the pollutant

x_i = the natural logarithm of the measurement (after having applied the relevant DF) for the i-th engine of the sample

s = an estimate of the production standard deviation (after taking the natural logarithm of the measurements)

n = the current sample number.'

4. Calculate for the sample the test statistic quantifying the number of non conforming engines, i.e. $x_i \geq L$:

5. Then:

- If the test statistic is less than or equal to the pass decision number for the sample size given in Table 4, a pass decision is reached for the pollutant;

- If the test statistic is greater than or equal to the fail decision number for the sample size given in Table 4, a fail decision is reached for the pollutant;

- Otherwise, an additional engine is tested according to section 9.1.1.1 of this chapter and the calculation procedure is applied to the sample increased by one more unit.

In Table 4 the pass and fail decision numbers are calculated by means of the International Standard ISO 8422/1991.

Table 4

Pass and Fail Decision Numbers of Appendix 2 Sampling Plan

Minimum sample Size : 3

Cumulative number of engines tested (sample size)	Pass decision number	Fail decision number
3	--	3
4	0	4
5	0	4
6	1	5
7	1	5
8	2	6
9	2	6
10	3	7
11	3	7
12	4	8
13	4	8
14	5	9
15	5	9
16	6	10
17	6	10
18	7	11
19	8	9

Appendix 3

DETERMINATION OF SYSTEM EQUIVALENCE

The determination of system equivalency according to section 6.2 of this chapter shall be based on a 7 sample pair (or larger) correlation study between the candidate system and one of the accepted reference systems of this part using the appropriate test cycle(s). The equivalency criteria to be applied shall be the F-test and the two-sided Student t-test.

This statistical method examines the hypothesis that the population standard deviation and mean value for an emission measured with the candidate system do not differ from the standard deviation and population mean value for that emission measured with the reference system. The hypothesis shall be tested on the basis of a 5 % significance level of the F and t values. The critical F and t values for 7 to 10 sample pairs are given in the table below. If the F and t values calculated according to the formulae below are greater than the critical F and t values, the candidate system is not equivalent.

The following procedure shall be followed. The subscripts R and C refer to the reference and candidate system, respectively:

(a) Conduct at least 7 tests with the candidate and reference systems preferably operated in parallel. The number of tests is referred to as n_R and n_C.

(b) Calculate the mean values x_R and x_C and the standard deviations s_R and s_C.

(c) Calculate the F value, as follows:

$$F = \frac{s^2_{major}}{s^2_{minor}}$$

(The greater of the two standard deviations S_R or S_C must be in the numerator)

(d) Calculate the t value, as follows:

$$t = \frac{|x_C - x_R|}{\sqrt{(n_C - 1) \times s_C^2 + (n_R - 1) \times s_R^2}} \times \sqrt{\frac{n_C \times n_R \times (n_C + n_R - 2)}{n_C + n_R}}$$

(e) Compare the calculated F and t values with the critical F and t values corresponding to the respective number of tests indicated in table below. If larger sample sizes are selected, consult statistical tables for 5 % significance (95 % confidence) level.

(f) Determine the degrees of freedom (df), as follows:

For the F-test: df = n_R - 1 / n_C – 1

For the t-test: df = n_C + n_R - 2

F and t values for selected sample sizes

Sample Size	F-test		t-test	
	df	F_{crit}	df	t_{crit}
7	6/6	4,284	12	2,179
8	7/7	3,787	14	2,145
9	8/8	3,438	16	2,120
10	9/9	3,179	18	2,101

(g) Determine the equivalency, as follows:

- if $F < F_{crit}$ **and** $t < t_{crit}$, then the candidate system is equivalent to the reference system of this Document,

- if $F \geq F_{crit}$ **and** $t \geq t_{crit}$, then the candidate system is different from the reference system of this Document.

CHAPTER 2

TECHNICAL SPECIFICATIONS FOR DIESEL/GAS ENGINES (GREATER THAN 3500 Kg GVW) PART C

As per applicable AIS 007, as amended from time to time

Chapter 3

Test Procedure

1. INTRODUCTION

1.1 This Chapter describes the methods of determining emissions of, particulates and smoke from the engines to be tested. Three test cycles are described that shall be applied according to the provisions of chapter-I, section 6.2 of this part:

- The ESC which consists of a steady state 13-mode cycle,

- The ELR which consists of transient load steps at different speeds, which are integral parts of one test procedure, and are run concurrently,

- The ETC which consists of a second-by-second sequence of transient modes.

1.2 The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer.

1.3 Measurement principle

The emissions to be measured from the exhaust of the engine include the gaseous components (carbon monoxide, total hydrocarbons for diesel engines on the ESC test only; non-methane hydrocarbons for diesel and gas engines on the ETC test only; methane for gas engines on the ETC test only and oxides of nitrogen), the particulates (diesel engines only) and smoke (diesel engines on the ELR test only). Additionally, carbon dioxide is often used as a tracer gas for determining the dilution ratio of partial and full flow dilution systems. Good engineering practice recommends the general measurement of carbon dioxide as an excellent tool for the detection of measurement problems during the test run.

1.3.1 ESC Test

During a prescribed sequence of warmed-up engine operating conditions the amounts of the above exhaust emissions shall be examined continuously by taking a sample from the raw or diluted exhaust gas. The test cycle consists of a number of speed and power modes, which cover the typical operating, range of diesel engines. During each mode the concentration of each gaseous pollutant, exhaust flow and power output shall be determined, and the measured values weighted. For particulate measurement, the exhaust gas shall be diluted with conditioned ambient air using either a partial flow or full flow dilution system. The particulates shall be collected on a single suitable filter in proportion to the weighting factors of each mode. The grams of each pollutant emitted per kilowatt-hour shall be calculated as described in appendix 1 of this chapter. Additionally, NO_X shall be measured at three test points within the control area (only for diesel engines) selected by the test agency and the measured values compared to the values calculated from those modes of the test cycle enveloping the selected test points. The NO_X control check ensures the effectiveness of the emission control of the engine within the typical engine operating range.

1.3.2 ELR Test

During a prescribed load response test, the smoke of a warmed-up engine shall be determined by means of an opacimeter. The test consists of loading the engine at constant speed from 10 % to 100 % load at three different engine speeds. Additionally, a fourth load step selected by the test agency shall be run, and the value compared to the values of the previous load steps. The smoke peak shall be determined using an averaging algorithm, as described in appendix 1 of this chapter.

(1) The test points shall be selected using approved statistical methods of randomisation.

1.3.3 ETC Test

During a prescribed transient cycle of warmed-up engine operating conditions, which is based closely on road-type-specific driving patterns of heavy-duty engines installed in trucks and buses, the above pollutants shall be examined either after diluting the total exhaust gas with conditioned ambient air (CVS system with double dilution for particulates) or by determining the gaseous components in the raw exhaust gas and the particulates with a partial flow dilution system. Using the engine torque and speed feedback signals of the engine dynamometer, the power shall be integrated with respect to time of the cycle resulting in the work produced by the engine over the cycle. For a CVS system, the concentration of NO_X and HC shall be determined over the cycle by integration of the analyzer signal, whereas the concentration of CO, CO_2, and NMHC may be determined by integration of the analyzer signal or by bag sampling. If measured in the raw exhaust gas, all gaseous components shall be determined over the cycle by integration of the analyzer signal or bag sample. For particulates, a proportional sample shall be collected on a suitable filter. The raw or diluted exhaust gas flow rate shall be determined over the cycle to calculate the mass emission values of the pollutants. The mass emission values shall be related to the engine work to get the grams of each pollutant emitted per kilowatt hour, as described in appendix 2 of this chapter.

2.1 Engine Test Conditions

2.1.1 The absolute temperature (T_a) of the engine air at the inlet to the engine expressed in Kelvin, and the dry atmospheric pressure (p_s), expressed in kPa shall be measured and the parameter f_a shall be determined according to the following provisions. In multi-cylinder engines having distinct groups of intake manifolds, for example, in a "V" engine configuration, the average temperature of the distinct groups shall be taken.

(a) For diesel engines:

Naturally aspirated and mechanically supercharged engines:

$$fa = \left(\frac{99}{p_s}\right) \times \left(\frac{Ta}{298}\right)^{0.7}$$

(b)Turbocharged engines with or without cooling of the intake air:

$$fa = \left(\frac{99}{p_s}\right)^{0,7} \times \left(\frac{Ta}{298}\right)^{1,5}$$

(c) For gas engines:

$$fa = \left(\frac{99}{p_s}\right)^{1,2} \times \left(\frac{Ta}{298}\right)^{0,6}$$

2.1.2 Test Validity:

For a test to be recognised as valid, the parameter f_a shall be such that:

$$0,96 \le f_a \le 1,06$$

2.2 Engines with Charge Air Cooling

The charge air temperature shall be recorded and shall be, at the speed of the declared maximum power and full load, within ± 5 K of the maximum charge air temperature specified by the manufacturer in the application. The temperature of the cooling medium shall be at least 293 K (20 °C).

If a test shop system or external blower is used, the charge air temperature shall be within ± 5 K of the maximum charge air temperature specified by the manufacturer at the speed of the declared maximum power and full load. The setting of the charge air cooler for meeting the above conditions shall be used for the whole test cycle.

2.3 Engine Air Intake System

An engine air intake system shall be used presenting an air intake restriction within ± 100 Pa of the upper limit of the engine operating at the speed at the declared maximum power and full load.

2.4 Engine Exhaust System

An exhaust system shall be used presenting an exhaust back pressure within ± 1000 Pa of the upper limit of the engine operating at the speed of declared maximum power and full load and a volume within ± 40 % of that specified by the manufacturer. A test shop system may be used, provided it represents actual engine operating conditions. The exhaust system shall conform to the requirements for exhaust gas sampling, as set out in chapter III, appendix 4, section 3.4 of this part and in chapter V, section 2.2.1, EP and section 2.3.1, EP.

If the engine is equipped with an exhaust after treatment device, the exhaust pipe must have the same diameter as found in-use for at least 4 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 vehicle 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. The after treatment container may be removed during dummy tests and during engine mapping, and replaced with an equivalent container having an inactive catalyst support.

2.5 Cooling System

An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer shall be used.

2.6 Lubricating Oil

Specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test, as specified in the application.

2.7 Fuel

The fuel shall be the reference fuel specified in chapter IV of this part.

The fuel temperature and measuring point shall be specified by the manufacturer within the limits given in the application. The fuel temperature shall not be lower than 306 K (33 °C). If not specified, it shall be 311 K ± 5 K (38 °C ± 5 °C) at the inlet to the fuel supply.

For NG and LPG fuelled engines, the fuel temperature and measuring point shall be within the limits given in application.

2.8 Testing of exhaust after treatment systems

If the engine is equipped with an exhaust after treatment system, the emissions measured on the test cycle shall be representative of the emissions in the field. In the case of an engine equipped with a exhaust after treatment system that requires the consumption of a reagent, the reagent used for all tests shall comply with Part 1 and Part 2 of ISO 22241-2006.

2.8.1. For an exhaust after treatment system based on a continuous regeneration process the emissions shall be measured on a stabilized after treatment system.

The regeneration process shall occur at least once during the ETC test and the manufacturer shall declare the normal conditions under which regeneration occurs (soot load, temperature, exhaust back-pressure, etc).

In order to verify the regeneration process at least 5 ETC tests shall be conducted. During the tests the exhaust temperature and pressure shall be recorded (temperature before and after the after treatment system, exhaust back pressure, etc).

The after treatment system is considered to be satisfactory if the conditions declared by the manufacturer occur during the test during a sufficient time.

The final test result shall be the arithmetic mean of the different ETC test results.

If the exhaust after treatment has a security mode that shifts to a periodic regeneration mode it should be checked following section 2.8.2 of this chapter. For that specific case the emission limits in 6.2.1 (ii) of chapter I of this part could be exceeded and would not be weighted.

2.8.2. For an exhaust after treatment based on a periodic regeneration process, the emissions shall be measured on at least two ETC tests, one during and one outside a regeneration event on a stabilized after treatment system, and the results be weighted.

The regeneration process shall occur at least once during the ETC test. The engine may be equipped with a switch capable of preventing or permitting the regeneration process provided this operation has no effect on the original engine calibration.

The manufacturer shall declare the normal parameter conditions under which the regeneration process occurs (soot load, temperature, exhaust back-pressure etc) and its duration time (n2). The manufacturer shall also provide all the data to determine the time between two regenerations (n1). The exact procedure to determine this time shall be agreed by the Technical Service based upon good engineering judgment.

The manufacturer shall provide an after treatment system that has been loaded in order to achieve regeneration during an ETC test. Regeneration shall not occur during this engine-conditioning phase.

Average emissions between regeneration phases shall be determined from the arithmetic mean of several approximately equidistant ETC tests. It is recommended to run at least one ETC as close as possible prior to a regeneration test and one ETC immediately after a regeneration test. As an alternative, the manufacturer may provide data to show that the emissions remain constant (± 15 %) between regeneration phases. In this case, the emissions of only one ETC test may be used.

During the regeneration test, all the data needed to detect regeneration shall be recorded (CO or NO_X emissions, temperature before and after the after treatment system, exhaust back pressure etc).

During the regeneration process, the emission limits in 6.2.1 (ii) of chapter I of this part can be exceeded. The measured emissions shall be weighted according to section 5.5 and 6.3 of appendix 2 to this chapter and the final result shall not exceed the limits in 6.2.1 (ii) of chapter I of this part.

Appendix 1
ESC & ELR Test cycles

1. ENGINE AND DYNAMOMETER SETTINGS

1.1 Determination of Engine Speeds A, B and C

The engine speeds A, B and C shall be declared by the manufacturer in accordance with the following provisions:

The high speed n_{hi} shall be determined by calculating 70 % of the declared maximum net power P(n), as determined in Chapter II. The highest engine speed where this power value occurs on the power curve is defined as n_{hi}.

The low speed n_{lo} shall be determined by calculating 50 % of the declared maximum net power P(n), as determined in Chapter II. The lowest engine speed where this power value occurs on the power curve is defined as n_{lo}.

The engine speeds A, B and C shall be calculated as follows:

Speed A = n_{lo} + 25% (n_{hi} – n_{lo})

Speed B = n_{lo} + 50% (n_{hi} – n_{lo})

Speed C = n_{lo} + 75% (n_{hi} – n_{lo})

The engine speeds A, B and C may be verified by either of the following methods

a) Additional test points shall be measured during engine power approval according to MORTH/CMVR/TAP-115 / 116 for an accurate determination of nhi and n_{lo}. The maximum power, nhi and nlo shall be determined from the power curve, and engine speeds A, B and C shall be calculated according to the above provisions.

b) The engine shall be mapped along the full load curve, from maximum no load speed to idle speed, using at least 5 measurement points per 1000 rpm intervals and measurement points within ± 50 rpm of the speed at declared maximum power. The maximum power, nhi and nlo shall be determined from this mapping curve, and engine speeds A, B and C shall be calculated according to the above provisions.

If the measured engine speeds A, B and C are within ± 3 % of the engine speeds as declared by the manufacturer, the declared engine speeds shall be used for the emissions test. If the tolerance is exceeded for any of the engine speeds, the measured engine speeds shall be used for the emissions test.

1.2 Determination of Dynamometer Settings

The torque curve at full load shall be determined by experimentation to calculate the torque values for the specified test modes under net conditions, as specified in Chapter II of this part. The power absorbed by engine-driven equipment, if applicable, shall be taken into account. The dynamometer setting for each test mode shall be calculated using the formula:

s = P (n) x L / 100 if tested under net conditions

s = P (n) x L / 100 + (P(a)-P(b)) if not tested under net conditions

where:

s = dynamometer setting, kW

P(n) = net engine power as indicated in chapter II of this part, kW

L = per cent load as indicated in Section 2.7.1, of this chapter %

P(a) = power absorbed by auxiliaries to be fitted as indicated in chapter II of this part.

P(b) = power absorbed by auxiliaries to be removed as indicated in chapter II of this part.

2 ESC Test run

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

2.1 Preparation of the Sampling Filter

At least one hour before the test, each filter shall be placed in a partially covered petri dish, which is protected against dust contamination, and placed in a weighing chamber for stabilisation. At the end of the stabilisation period each filter shall be weighed and the tare weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber. The tare weight shall be recorded.

2.2 Installation of the Measuring Equipment

The instrumentation and sample probes shall be installed as required. When using a full flow dilution system for exhaust gas dilution, the tailpipe shall be connected to the system.

2.3 Starting the Dilution System and the Engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at maximum power according to the recommendation of the manufacturer and good engineering practice.

2.4 Starting the Particulate Sampling System

The particulate sampling system shall be started and running on by-pass. The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements at the beginning and at the end of the cycle, may be done, and the values averaged.

2.5 Adjustment of the Dilution Ratio

The dilution air shall be set such that the temperature of the diluted exhaust gas measured immediately prior to the primary filter shall not exceed 325 K (52 °C) at any mode. The dilution ratio (q) shall not be less than 4.

For systems that use CO_2 or NO_X concentration measurement for dilution ratio control, the CO_2 or NO_X content of the dilution air must be measured at the beginning and at the end of each test. The pre- and post test background CO_2 or NO_X concentration measurements of the dilution air must be within 100 ppm or 5ppm of each other, respectively.

2.6 Checking the Analysers

The emission analysers shall be set at zero and spanned.

2.7 Test Cycle

2.7.1 The following 13-mode cycle shall be followed in dynamometer operation on the test engine

Mode Number	Engine speed	Percent load	Weighting factor	Mode length
1	Idle	--	0.15	4 minutes
2	A	100	0.08	2 minutes
3	B	50	0.10	2 minutes
4	B	75	0.10	2 minutes
5	A	50	0.05	2 minutes
6	A	75	0.05	2 minutes
7	A	25	0.05	2 minutes
8	B	100	0.09	2 minutes
9	B	25	0.10	2 minutes
10	C	100	0.08	2 minutes
11	C	25	0.05	2 minutes
12	C	75	0.05	2 minutes
13	C	50	0.05	2 minutes

2.7.2 Test Sequence

The test sequence shall be started. The test shall be performed in the order of he mode numbers as set out in section 2.7.1 of this chapter.

The engine must be operated for the prescribed time in each mode, completing engine speed and load changes in the first 20 seconds. 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.

At the manufacturers request, the test sequence may be repeated a sufficient number of times for sampling more particulate mass on the filter. The manufacturer shall supply a detailed description of the data evaluation and calculation procedures. The gaseous emissions shall only be determined on the first cycle.

2.7.3 Analyser Response

The output of the analysers shall be recorded on a strip chart recorder or measured with an equivalent data acquisition system with the exhaust gas flowing through the analysers throughout the test cycle.

2.7.4 Particulate Sampling

One filter shall be used for the complete test procedure. The modal weighting factors specified in the test cycle procedure shall be taken into account by taking a sample proportional to the exhaust mass flow during each individual mode of the cycle. This can be achieved by adjusting sample flow rate, sampling time, and/or dilution ratio, accordingly, so that the criterion for the effective weighting factors in section 5.6 of this chapter is met.

The sampling time per mode must be at least 4 seconds per 0,01 weighting factor. Sampling must be conducted as late as possible within each mode. Particulate sampling shall be completed no earlier than 5 seconds before the end of each mode.'

2.7.5 Engine Conditions

The engine speed and load, intake air temperature and depression, exhaust temperature and backpressure, fuel flow and air or exhaust flow, charge air temperature, fuel temperature and humidity shall be recorded during each mode, with the speed and load requirements (see section 2.7.2 of this chapter) being met during the time of particulate sampling, but in any case during the last minute of each mode.

Any additional data required for calculation shall be recorded (see sections 4 and 5 of this chapter).

2.7.6 NO_X Check within the Control Area (only for Diesel engines)

The NO_X check within the control area shall be performed immediately upon completion of mode 13.

The engine shall be conditioned at mode 13 for a period of three minutes before the start of the measurements. Three measurements shall be made at different locations within the control area, selected by the test agency. The time for each measurement shall be 2 minutes.

The measurement procedure is identical to the NOx measurement on the 13-mode cycle, and shall be carried out in accordance with sections 2.7.3, 2.7.5, and 4.1 of this appendix, and chapter III, appendix 4, section 3 of this part.

The calculation shall be carried out in accordance with section 4 of this chapter.

(1) The test points shall be selected using approved statistical methods of randomisation.

2.7.7 Rechecking the Analysers

After the emission test a zero gas and the same span gas shall be used for rechecking. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

3 ELR TEST RUN

3.1 Installation of the Measuring Equipment

The opacimeter and sample probes, if applicable, shall be installed after the exhaust silencer or any after treatment device, if fitted, according to the general installation procedures specified by the instrument manufacturer. Additionally, the requirements of section 10 of ISO IDS 11614 shall be observed, where appropriate.

Prior to any zero and full scale checks, the opacimeter shall be warmed up and stabilised according to the instrument manufacturer's recommendations. If the opacimeter is equipped with a purge air system to prevent sooting of the meter optics, this system shall also be activated and adjusted according to the manufacturer's recommendations.

3.2 Checking of the Opacimeter

The zero and full-scale checks shall be made in the opacity readout mode, since the opacity scale offers two truly definable calibration points, namely 0 % opacity and 100 % opacity. The light absorption coefficient is then correctly calculated based upon the measured opacity and the La, as submitted by the opacimeter manufacturer, when the instrument is returned to the k readout mode for testing.

With no blockage of the opacimeter light beam, the readout shall be adjusted to 0,0 % ± 1,0 % opacity. With the light being prevented from reaching the receiver, the readout shall be adjusted to 100,0 % ± 1,0 % opacity.

3.3 Test Cycle

3.3.1 Conditioning of the Engine

Warming up of the engine and the system shall be at maximum power in order to stabilise the engine parameters according to the recommendation of the manufacturer. The preconditioning phase should also protect the actual measurement against the influence of deposits in the exhaust system from a former test.

When the engine is stabilised, the cycle shall be started within 20 ± 2 s after the preconditioning phase. At the manufacturers request, a dummy test may be run for additional conditioning before the measurement cycle.

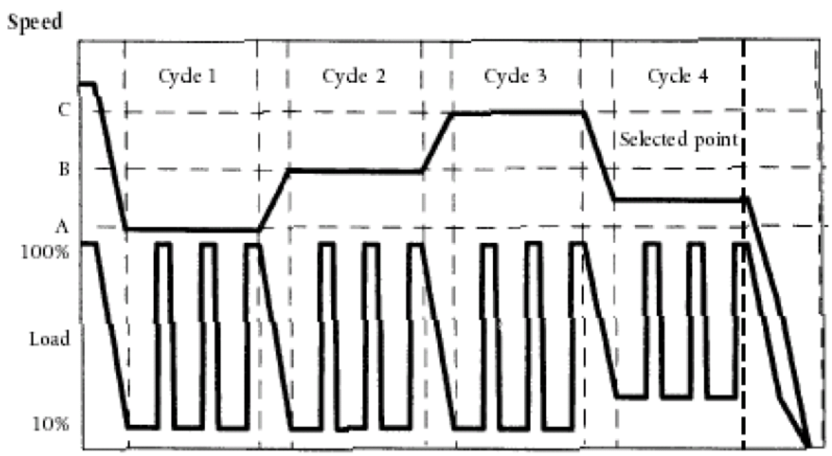
3.3.2 Test Sequence

The test consists of a sequence of three load steps at each of the three engine speeds A (cycle 1), B (cycle 2) and C (cycle 3) determined in accordance with chapter III, section 1.1 of this part, followed by cycle 4 at a speed within the control area and a load between 10 % and 100 %, selected by the test agency. The following sequence shall be followed in dynamometer operation on the test engine, as shown in Figure 3.

(1) The test points shall be selected using approved statistical methods of randomisation.

Figure 3

Sequence of ELR Test



(a) The engine shall be operated at engine speed A and 10 per cent load for 20 ± 2 s. The specified speed shall be held to within ± 20 rpm and the specified torque shall be held to within ± 2 % of the maximum torque at the test speed.

(b) At the end of the previous segment, the speed control lever shall be moved rapidly to, and held in, the wide open position for 10 ± 1 s. The necessary dynamometer load shall be applied to keep the engine speed within ± 150 rpm during the first 3 s, and within ± 20 rpm during the rest of the segment.

(c) The sequence described in (a) and (b) shall be repeated two times.

(d) Upon completion of the third load step, the engine shall be adjusted to engine speed B and 10 per cent load within 20 ± 2 s.

(e) The sequence (a) to (c) shall be run with the engine operating at engine speed B.

(f) Upon completion of the third load step, the engine shall be adjusted to engine speed C and 10 per cent load within 20 ± 2 s.

(g) The sequence (a) to (c) shall be run with the engine operating at engine speed C.

(h) Upon completion of the third load step, the engine shall be adjusted to the selected engine speed and any load above 10 per cent within 20 ± 2 s.

(i) The sequence (a) to (c) shall be run with the engine operating at the selected engine speed.

3.4 Cycle Validation

The relative standard deviations of the mean smoke values at each test speed (SVA, SVB, SVC, as calculated in accordance with section 6.3.3 of this appendix from the three successive load steps at each test speed) shall be lower than 15% of the mean value, or 10 % of the limit value shown in 6.2.1 (i) of chapter I of this part, whichever is greater. If the difference is greater, the sequence shall be repeated until 3 successive load steps meet the validation criteria.

3.5 Rechecking of the Opacimeter

The post-test opacimeter zero drift value shall not exceed ± 5,0 % of the limit value shown in 6.2.1 (i) of chapter I of this part.

4 CALCULATION OF THE EXHAUST GAS FLOW

4.1 Determination of Raw Exhaust Gas Mass Flow

For calculation of the emissions in the raw exhaust, it is necessary to know the exhaust gas flow. The exhaust gas mass flow rate shall be determined in accordance with section 4.1.1 or 4.1.2 of this chapter. The accuracy of exhaust flow determination shall be ± 2,5 % of reading or ± 1,5 % of the engine's maximum value whichever is the greater. Equivalent methods (e.g. those described in section 4.2 of appendix 2 of this chapter may be used.

4.1.1 Direct measurement method

Direct measurement of the exhaust flow may be done by systems such as:

— pressure differential devices, like flow nozzle,

— ultrasonic flow meter,

— vortex flow meter.

Precautions shall be taken to avoid measurement errors, which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Especially, engine performance and emissions shall not be affected by the installation of the device.

4.1.2 Air and fuel measurement method

This involves measurement of the airflow and the fuel flow. Air flow meters and fuel flow meters shall be used that meet the total accuracy requirement of section 4.1 of this chapter. The calculation of the exhaust gas flow is as follows:

$$q_{mew} = q_{maw} + q_{mf}$$

4.2 Determination of Diluted Exhaust Gas Mass Flow

For calculation of the emissions in the diluted exhaust using a full flow dilution system it is necessary to know the diluted exhaust gas flow. The flow rate of the diluted exhaust (q_{mdew}) shall be measured over each mode with a PDP-CVS, CFV-CVS or SSV-CVS in line with the general formulae given in section 4.1 of appendix 2 of this Chapter. The accuracy shall be ± 2 % of reading or better, and shall be determined according to the provisions of section 2.4 of appendix 5 of this Chapter.

5 CALCULATION OF THE GASEOUS EMISSIONS

5.1 Data Evaluation

For the evaluation of the gaseous emissions, the chart reading of the last 30 seconds of each mode shall be averaged, and the average concentrations (conc) of HC, CO and NO_X during each mode shall be determined from the average hart readings and the corresponding calibration data. A different type of recording can be used if it ensures an equivalent data acquisition.

For the NO_X check within the control area, the above requirements apply for NO_X, only.

The exhaust gas flow q_{mew} or the diluted exhaust gas flow q_{mdew}, if used optionally, shall be determined in accordance with appendix 4, section 2.3 of this chapter.

5.2. Dry/Wet Correction

The measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis. The conversion shall be done for each individual mode.

$$c_{wet} = k_w \times c_{dry}$$

For the raw exhaust gas:

$$k_{W,r} = \left(1 - \frac{1{,}2442 \times H_a + 111{,}19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773{,}4 + 1{,}2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000} \right) \times 1{,}008$$

or

$$k_{W,r} = \left(1 - \frac{1{,}2442 \times H_a + 111{,}19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773{,}4 + 1{,}2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000} \right) \Bigg/ \left(1 - \frac{p_r}{p_b} \right)$$

where:

p_r = water vapour pressure after cooling bath, kPa,

p_b = total atmospheric pressure, kPa,

H_a = intake air humidity, g water per kg dry air,

$k_f = 0{,}055584 \times w_{ALF} - 0{,}0001083 \times w_{BET} - 0{,}0001562 \times w_{GAM} + 0{,}0079936 \times w_{DEL} + 0{,}0069978 \times w_{EPS}$

For the diluted exhaust gas:

$$K_{We1} = \left(1 - \frac{\alpha \times \% \, c_{wCO_2}}{200}\right) - K_{W1}$$

or,

$$K_{We2} = \left(\frac{(1 - K_{W1})}{1 + \frac{\alpha \times \% \, c_{dCO_2}}{200}}\right)$$

For the dilution air:

$$K_{Wd} = 1 - K_{W1}$$

$$K_{W1} = \frac{1{,}608 \times \left[H_d \times \left(1 - \frac{1}{D}\right) + H_a \times \left(\frac{1}{D}\right)\right]}{1000 + \left\{1{,}608 \times \left[H_d \times \left(1 - \frac{1}{D}\right) + H_a \times \left(\frac{1}{D}\right)\right]\right\}}$$

For the intake air:

$$K_{Wa} = 1 - K_{W2}$$

$$K_{W2} = \frac{1{,}608 \times H_a}{1000 + (1{,}608 \times H_a)}$$

where:

H_a = intake air humidity, g water per kg dry air
H_d = dilution air humidity, g water per kg dry air

and may be derived from relative humidity measurement, dew point measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

5.3 NOx correction for humidity and temperature

As the NOx emission depends on ambient air conditions, the NOx concentration shall be corrected for ambient air temperature and humidity with the factors given in the following formulae. The factors are valid in the range between 0 and 25 g/kg dry air.

(a) For compression ignition engines

$$k_{h,D} = \frac{1}{1 - 0{,}0182 \times (H_a - 10{,}71) + 0{,}0045 \times (T_a - 298)}$$

with:

T_a = temperature of the intake air, K

H_a = humidity of the intake air, g water per kg dry air

Where:

H_a may be derived from relative humidity measurement, dew point measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

(b) For Spark- ignition Engines:

$$k_{h,G} = 0{,}6272 + 44{,}030 \times 10^{-3} \times H_a - 0{,}862 \times 10^{-3} \times H_a^2$$

Where:

Ha is Humidity of Intake Air in g of water per kg of Dry Air.

5.4. Calculation of the emission mass flow rates

The emission mass flow rate (g/h) for each mode shall be calculated as follows. For the calculation of NOx, the humidity correction factor $k_{h,D}$, or $k_{h,G}$, as applicable, as determined according to section 5.3 of this chapter, shall be used.

The measured concentration shall be converted to a wet basis according to section 5.2 of this chapter if not already measured on a wet basis. Values for u_{gas} are given in Table 5 of this chapter for selected components based on ideal gas properties and the fuels relevant for this part.

(a) for the raw exhaust gas4

$$m_{gas} = u_{gas} \times c_{gas} \times q_{mew}$$

where:

u_{gas} = ratio between density of exhaust component and density of exhaust gas

c_{gas} = concentration of the respective component in the raw exhaust gas, ppm

q_{mew} = exhaust mass flow rate, kg/h

(b) for diluted gas

$$m_{gas} = u_{gas} \times c_{gas,c} \times q_{mdew}$$

where

u_{gas} = ratio between density of exhaust component and density of air

$c_{gas,c}$ = background corrected concentration of the respective component in the diluted exhaust gas, ppm

q_{mdew} = diluted exhaust mass flow rate, kg/h

where:

$$c_{gas,c} = c - c_d \times \left[1 - \frac{1}{D}\right]$$

The dilution factor D shall be calculated according to section 5.4.1 of appendix 2 of this chapter.

5.5 Calculation of the specific emissions

The emissions (g/kWh) shall be calculated for all individual components in the following way: where:

$$GAS_x = \frac{\sum_{i=1}^{i=n}\left(m_{GASi} \times W_{Fi}\right)}{\sum_{i=1}^{i=n}\left(P(n)_i \times W_{Fi}\right)}$$

m_{gas} is the mass of individual gas

P_n is the net power determined according to chapter II of this part.

The weighting factors used in the above calculation are according to section 2.7.1.of this chapter

Table 5

Values of u_{gas} in the raw and dilute exhaust gas for various exhaust components

Fuel		NO_x	CO	THC/NMHC	CO_2	CH_4
Diesel	Exhaust raw	0,001587	0,000966	0,000479	0,001518	0,000553
	Exhaust dilute	0,001588	0,000967	0,000480	0,001519	0,000553
Ethanol	Exhaust raw	0,001609	0,000980	0,000805	0,001539	0,000561
	Exhaust dilute	0,001588	0,000967	0,000795	0,001519	0,000553
CNG	Exhaust raw	0,001622	0,000987	0,000523	0,001552	0,000565
	Exhaust dilute	0,001588	0,000967	0,000584	0,001519	0,000553
Propane	Exhaust raw	0,001603	0,000976	0,000511	0,001533	0,000559
	Exhaust dilute	0,001588	0,000967	0,000507	0,001519	0,000553
Butane	Exhaust raw	0,001600	0,000974	0,000505	0,001530	0,000558
	Exhaust dilute	0,001588	0,000967	0,000501	0,001519	0,000553

Notes:

— u values of raw exhaust based on ideal gas properties at $\lambda = 2$, dry air, 273 K, 101,3 kPa

— u values of dilute exhaust based on ideal gas properties and density of air

— u values of CNG accurate within 0,2 % for mass composition of: C = 66 − 76 %; H = 22 − 25 %; N = 0 − 12 %

— u value of CNG for HC corresponds to $CH_{2,93}$ (for total HC use u value of CH_4).

5.6 Calculation of Area control values:

For the three control points selected according to section 2.7.6 of this chapter, the NO_X emission shall be measured and calculated according to section 5.6.1 of this chapter and also determined by interpolation from the modes of the test cycle closest to the respective control point according to section 5.6.2 of this chapter. The measured values are then compared to the interpolated values according to section 5.6.3 of this chapter.

5.6.1. Calculation of the Specific Emission

The NO_X emission for each of the control points (Z) shall be calculated as follows:

$$m_{NO_x},Z = 0,001587 \times c_{NO_x},Z \times k_{h,D} \times q_{mew}$$

$$NOx_Z = \frac{m_{NOx,Z}}{P(n)_Z}$$

5.6.2. Determination of the Emission Value from the Test Cycle

The NO_X emission for each of the control points shall be interpolated from the four closest modes of the test cycle that envelop the selected control point Z as shown in Figure 4. For these modes (R, S, T, U), the following definitions apply:

Speed(R) = Speed (T) = n_{RT}
Speed (S) = Speed (U) = n_{SU}
Per cent load(R) = Per cent load (S)
Per cent load (T) = Per cent load (U).

The NOx emission of the selected control point Z shall be calculated as follows:

$$Ez = \frac{E_{RS} + (E_{TU} - E_{RS}) \times (M_Z - M_{RS})}{M_{TU} - M_{RS}}$$

and:

$$E_{TU} = \frac{E_T + (E_{TU} - E_T) \times (n_Z - n_{RT})}{n_{SU} - n_{RT}}$$

$$E_{RS} = \frac{E_R + (E_S - E_R) \times (n_Z - n_{RT})}{n_{SU} - n_{RT}}$$

$$M_{TU} = \frac{M_T + (M_U - M_T) \times (n_Z - n_{RT})}{n_{SU} - n_{RT}}$$

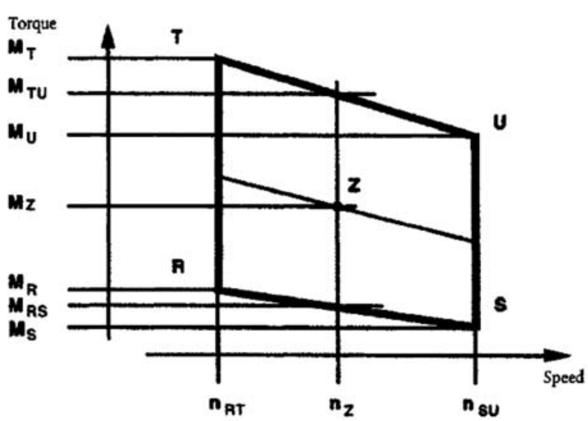
$$M_{RS} = \frac{M_R + (M_S - M_R) \times (n_Z - n_{RT})}{n_{SU} - n_{RT}}$$

where:

ER, ES, ET, EU = specific NOx emission of the enveloping modes calculated in accordance with section 5.6.1 of this chapter.

MR, MS, MT, MU = engine torque of the enveloping modes.

Figure 4
Interpolation of NO_X Control Point



5.6.3. Comparison of NOx Emission Values

The measured specific NOx emission of the control point Z (NOx,Z) is compared to the interpolated value (EZ) as follows:

$$NOx_{diff} = 100 \times \frac{NOx_Z - E_Z}{E_Z}$$

6 CALCULATION OF THE PARTICULATE EMISSIONS

6.1 Data evaluation

For the evaluation of the particulates, the total sample masses (m_{sep}) through the filters shall be recorded for each mode.

The filters shall be returned to the weighing chamber and conditioned for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight (see section 1 of this appendix) subtracted, which results in the particulate sample mass m_f.

If background correction is to be applied, the dilution air mass (m_d) through the filters and the particulate mass ($m_{f,d}$) shall be recorded. If more than one measurement was made, the quotient $m_{f,d}/m_d$ must be calculated for each single measurement and the values averaged.

6.2 Partial flow Dilution system

The final reported test results of the particulate emission shall be determined through the following steps. Since various types of dilution rate control may be used, different calculation methods for q_{medf} apply. All calculations shall be based upon the average values of the individual modes during the sampling period.

6.2.1. Isokinetic Systems

$$q_{medf} = q_{mew} \times r_d$$

$$r_d = \frac{q_{mdw} + (q_{mew} \times r_a)}{q_{mew} \times r_a}$$

where r_a corresponds to the ratio of the cross sectional areas of the isokinetic probe and the exhaust pipe:

$$r_a = \frac{A_p}{A_T}$$

6.2.2. Systems with Measurement of CO_2 or NO_X Concentration

$$q_{medf} = q_{mew} \times r_d$$

$$r_d = \frac{c_{wE} - c_{wA}}{c_{wD} - c_{wA}}$$

where:

c_{wE} = wet concentration of the tracer gas in the raw exhaust

c_{wD} = wet concentration of the tracer gas in the diluted exhaust

c_{wA} = wet concentration of the tracer gas in the dilution air

Concentrations measured on a dry basis shall be converted to a wet basis according to section 5.2 of this appendix.

6.2.3. Systems with CO_2 Measurement and Carbon Balance Method (*):

$$q_{medf} = \frac{206{,}5 \times q_{mf}}{c_{(CO_2)D} - c_{(CO_2)A}}$$

where:

$c_{(CO2)D}$ = CO_2 concentration of the diluted exhaust

$c_{(CO2)A}$ = CO_2 concentration of the dilution air

(concentrations in vol % on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO_2) and determined through the following steps:

$q_{medf} = q_{mew} \times r_d$

(*) – The value is only valid for the reference fuel specified in chapter IV of this part

and

$$r_d = \frac{206{,}5 \times q_{mf}}{q_{mew} \times \left[c_{(CO_2)D} - c_{(CO_2)A}\right]}$$

6.2.4 Systems with Flow Measurement:

$q_{medf} = q_{mew} \times r_d$

$$r_d = \frac{q_{mdew}}{q_{mdew} - q_{mdw}}$$

6.3 Full Flow Dilution System

All calculations shall be based upon the average values of the individual modes during the sampling period. The diluted exhaust gas flow q_{mdew} shall be determined in accordance with section 4.1 of appendix 2 of this chapter. The total sample mass m_{sep} shall be calculated in accordance with section 6.2.1 of appendix 2 of this chapter.

6.4. Calculation of the Particulate Mass Flow Rate

The particulate mass flow rate shall be calculated as follows. If a full flow dilution system is used, q_{medf} as determined according to section 6.2 of this appendix shall be replaced with q_{mdew} as determined according to section 6.3 of this appendix.

$$PT_{mass} = \frac{m_f}{m_{sep}} \times \frac{q_{medf}}{1000}$$

$$\overline{q_{medf}} = \sum_{i=1}^{i=n} q_{medfi} \times W_{fi}$$

$$m_{sep} = \sum_{i=1}^{i=n} m_{sepi}$$

i = 1, … n

The particulate mass flow rate may be background corrected as follows:

$$PT_{mass} = \left\{ \frac{m_f}{m_{sep}} - \left[\frac{m_{f,d}}{m_d} \times \sum_{i=1}^{i=n} \left(1 - \frac{1}{Di} \right) \times W_{f_i} \right] \right\} \times \frac{\overline{q_{medf}}}{1000}$$

where D shall be calculated in accordance with section 5.4.1 of appendix 2 of this chapter.

6.5 Calculation of the Specific Emission

The particulate emission shall be calculated in the following way:

$$\overline{PT} = \frac{PT_{mass}}{\sum P(n)i \times WF_i}$$

6.6 Effective Weighting Factor

The effective weighting factor WFE,i for each mode shall be calculated in the following way:

$$WFE,I = \frac{m_{sep,i} \times \overline{q_{medf}}}{m_{sep} \times q_{medf,I}}$$

The value of the effective weighting factors shall be within ± 0,003 (± 0,005 for the idle mode) of the weighting factors listed in section 2.7.1 of this appendix.

7 Calculation of Smoke values

7.1 Bessel Algorithm

The Bessel algorithm shall be used to compute the 1 s average values from the instantaneous smoke readings, converted in accordance with section 7.3.1 of this appendix. The algorithm emulates a low pass second order filter, and its use requires iterative calculations to determine the coefficients. These coefficients are a function of the response time of the opacimeter system and the sampling rate. Therefore, section 7.1.1 of this appendix must be repeated whenever the system response time and/or sampling rate changes.

7.1.1. Calculation of Filter Response Time and Bessel Constants

The required Bessel response time (t_F) is a function of the physical and electrical response times of the opacimeter system, as specified in chapter III, appendix 4, section 5.2.4 of this part, and shall be calculated by the following equation:

$$t_F = \sqrt{1 - (t_p^{\,2} + t_e^{\,2})}$$

where:

t_p = physical response time, s

t_e = electrical response time, s

The calculations for estimating the filter cut-off frequency (fc) are based on a step input 0 to 1 in < = 0,01 s (see chapter VI of this part). The response time is defined as the time between when the Bessel output reaches 10 % (t_{10}) and when it reaches 90 % (t_{90}) of this step function. This must be obtained by iterating on fc until t_{90}-t_{10} ≈ t_F. The first iteration for fc is given by the following formula:

$f_c = \Pi / (10 \times t_F)$

The Bessel constants E and K shall be calculated by the following equations:

$$E = \frac{1}{1 + \Omega \times \sqrt{3 \times D} + D \times \Omega^2}$$

$K = 2 \times E \times (D \times \Omega^2 - 1) - 1$

where:

D = 0,618034

Δ t = 1/sampling rate

$\Omega = 1/[\tan(\Pi \times \Delta t * fc)]$

7.1.2 Calculation of the Bessel Algorithm

Using the values of E and K, the 1 s Bessel averaged response to a step input Si shall be calculated as follows:

$Y_i = Y_{i-1} + E \times (S_{i+2} \times S_{i-1} + S_{i-2} - 4 \times Y_{i-2}) + K \times (Y_{i-1} - Y_{i-2})$
where:
$S_{i-2} = S_{i-1} = 0$
$S_i = 1$
$Y_{i-2} = Y_{i-1} = 0$

The times t10 and t90 shall be interpolated. The difference in time between t_{90} and t_{10} defines the response time t_F for that value of f_c. If this response time is not close enough to the required response time, iteration shall be continued until the actual response time is within 1 % of the required response as follows:

$$\left| (t_{90} - t_{10}) - t_F \right| \leq 0.01 \times t_F$$

7.2 Data Evaluation

The smoke measurement values shall be sampled with a minimum rate of 20 Hz.

7.3 Determination of Smoke

7.3.1 Data Conversion

Since the basic measurement unit of all opacimeters is transmittance, the smoke values shall be converted from transmittance (τ) to the light absorption coefficient (k) as follows:

$$k = -\frac{1}{L_A} \times \ln\left(1 - \frac{N}{100}\right)$$

and

$$N = 100 - \tau$$

where:

k = light absorption coefficient, m^{-1}
L_A = effective optical path length, as submitted by instrument manufacturer, m
N = opacity, %
τ = transmittance, %

The conversion shall be applied, before any further data processing is made.

7.3.2 Calculation of Bessel Averaged Smoke

The proper cut-off frequency f_c is the one that produces the required filter response time t_F. Once this frequency has been determined through the iterative process of section 7.1.1 of this appendix, the proper Bessel algorithm constants E and K shall be calculated. The Bessel algorithm shall then be applied to the instantaneous smoke trace (k-value), as described in section 7.1.2 of this appendix:

$$Y_i = Y_{i-1} + E \times (S_{i+2} \times S_{i-1} + S_{i-2} - 4 \times Y_{i-2}) + K \times (Y_{i-1} - Y_{i-2})$$

The Bessel algorithm is recursive in nature. Thus, it needs some initial input values of S_{i-1} and S_{i-2} and initial output values Y_{i-1} and Y_{i-2} to get the algorithm started. These may be assumed to be 0.

For each load step of the three speeds A, B and C, the maximum 1s value Y_{max} shall be selected from the individual Y_i values of each smoke trace.

7.3.3 Final Result

The mean smoke values (SV) from each cycle (test speed) shall be calculated as follows:

For test speed A: $SVA = (Y_{max1,A} + Y_{max2,A} + Y_{max3,A}) / 3$

For test speed B: $SVB = (Y_{max1,B} + Y_{max2,B} + Y_{max3,B}) / 3$

For test speed C: $SVC = (Y_{max1,C} + Y_{max2,C} + Y_{max3,C}) / 3$

where:

Y_{max1}, Y_{max2}, Y_{max3} = highest 1 s Bessel averaged smoke value at each of the three load steps

The final value shall be calculated as follows:

$$SV = (0{,}43 * SV_A) + (0{,}56 * SV_B) + (0{,}01 * SV_C)$$

Appendix 2:

ETC TEST CYCLE

1 ENGINE MAPPING PROCEDURE:

1.1 Determination of the Mapping Speed Range

For generating the ETC on the test cell, the engine needs to be mapped prior to the test cycle for determining the speed vs. torque curve. The minimum and maximum mapping speeds are defined as follows:

Minimum mapping speed = idle speed

Maximum mapping speed = n_{hi} * 1,02 or speed where full load torque drops off to zero, whichever is lower

1.2 Performing the Engine Power Map

The engine shall be warmed up at maximum power in order to stabilise the engine parameters according to the recommendation of the manufacturer and good engineering practice. When the engine is stabilised, the engine map shall be performed as follows:

(a) the engine shall be unloaded and operated at idle speed;

(b) the engine shall be operated at full load setting of the injection pump at minimum mapping speed;

(c) the engine speed shall be increased at an average rate of 8 ± 1 min^{-1} /s from minimum to maximum mapping speed. Engine speed and torque points shall be recorded at a sample rate of a least one point per second.

1.3 Mapping Curve Generation

All data points recorded under section 1.2 of this appendix shall be connected using linear interpolation between points. The resulting torque curve is the mapping curve and shall be used to convert the normalised torque values of the engine cycle into actual torque values for the test cycle, as described in section 2 of this appendix.

1.4 Alternate Mapping

If a manufacturer believes that the above mapping techniques are unsafe or unrepresentative for any given engine, alternate mapping techniques may be used. These alternate techniques must satisfy the intent of the specified mapping procedures to determine the maximum available torque at all engine speeds achieved during the test cycles. Deviations from the mapping techniques specified in this section for reasons of safety or representativeness shall be approved by the test agency along with the justification for their use. In no case, however, shall descending continual sweeps of engine speed be used for governed or turbocharged engines.

1.5 Replicate Tests

An engine need not be mapped before each and every test cycle. An engine shall be remapped prior to a test cycle if:

- an unreasonable amount of time has transpired since the last map, as determined by engineering judgments,

or,

- physical changes or recalibrations have been made to the engine which may potentially affect engine performance.

2 Generation of the Reference Test cycle

The transient test cycle is described in appendix 3 of this chapter. The normalised values for torque and speed shall be changed to the actual values, as follows, resulting in the reference cycle.

2.1 Actual Speed

The speed shall be unnormalised using the following equation:

$$\text{Actual speed} = \frac{\%speed(reference\_speed - idle\_speed)}{100} + idle\_speed$$

The reference speed (nref) corresponds to the 100 % speed values specified in the engine dynamometer schedule of appendix 3 of this chapter. It is defined as follows (see Figure 1 of chapter I of this part):

$$n_{ref} = n_{lo} + 95\% \times (n_{hi} - n_{lo})$$

where n_{hi} and n_{lo} are either specified according to chapter I, section 2 of this part or determined according to chapter III, appendix 1, section 1.1 of this part.

2.2 Actual torque

The torque is normalised to the maximum torque at the respective speed. The torque values of the reference cycle shall be unnormalised, using the mapping curve determined according to section 1.3 of this appendix, as follows:

$$\text{Actual torque} = \frac{\%\ torque \times \max.\ torque}{100}$$

for the respective actual speed as determined in Section 2.1 of this appendix.

The negative torque values of the motoring points ("m") shall take on, for purposes of reference cycle generation, unnormalised values determined in either of the following ways:

- negative 40 % of the positive torque available at the associated speed point,

- mapping of the negative torque required to motor the engine from minimum to maximum mapping speed,

- determination of the negative torque required to motor the engine at idle and reference speeds and linear interpolation between these two points.

2.3 Example of the Unnormalisation Procedure

As an example, the following test point shall be unnormalised:

% speed = 43
% torque = 82

Given the following values:

reference speed = 2200 min-1
idle speed = 600 min-1
results in,

actual speed = (43 × (2 200 − 600)/100) + 600 = 1 288 min−1
actual torque = (82 × 700/100) = 574 Nm

where the maximum torque observed from the mapping curve at 1 288 min−1 is 700 Nm.

3 EMISSIONS TEST RUN:

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

NG and LPG fuelled engines shall be run-in using the ETC test. The engine shall be run over a minimum of two ETC cycles and until the CO emission measured over one ETC cycle does not exceed by more than 10 % the CO emission measured over the previous ETC cycle.

3.1 Preparation of the sampling filters (if applicable)

At least one hour before the test, each filter shall be placed in a partially covered petri dish, which is protected against dust contamination, and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter shall be weighed and the tare weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber. The tare weight shall be recorded.

3.2 Installation of the measuring equipment

The instrumentation and sample probes shall be installed as required. The tailpipe shall be connected to the full flow dilution system, if used.

3.3 Starting the dilution system and the engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at maximum power according to the recommendation of the manufacturer and good engineering practice.

3.4 Starting the particulate sampling system (diesel engines only)

The particulate sampling system shall be started and running on by-pass. The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements at the beginning and at the end of the cycle may be done and the values averaged.

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised according to the recommendation of the manufacturer and good engineering practice.

In case of periodic regeneration after treatment, the regeneration shall not occur during the warm-up of the engine.

3.5 Adjustment of the dilution system

The flow rates of the dilution system (full flow or partial flow) shall be set to eliminate water condensation in the system, and to obtain a maximum filter face temperature of 325 K (52 °C) or less (see section 2.3.1 of chapter V, DT of this part).

3.6 Checking the analysers

The emission analysers shall be set at zero and spanned. If sample bags are used, they shall be evacuated.

3.7 Engine starting procedure

The stabilised engine shall be started according to the manufacturer's recommended starting procedure in the owner's manual, using either a production starter motor or the dynamometer. Optionally, the test may start directly from the engine preconditioning phase without shutting the engine off, when the engine has reached the idle speed.

3.8 Test cycle

3.8.1 Test sequence

The test sequence shall be started, if the engine has reached idle speed. The test shall be performed according to the reference cycle as set out in section 2 of this appendix. Engine speed and torque command set points shall be issued at 5

Hz (10 Hz recommended) or greater. Feedback engine speed and torque shall be recorded at least once every second during the test cycle, and the signals may be electronically filtered.

3.8.2 Gaseous emissions measurement

3.8.2.1 Full flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the measuring equipment shall be started, simultaneously:

- start collecting or analysing dilution air,
- start collecting or analysing diluted exhaust gas,
- start measuring the amount of diluted exhaust gas (CVS) and the required temperatures and pressures,
- start recording the feedback data of speed and torque of the dynamometer.

HC and NOx shall be measured continuously in the dilution tunnel with a frequency of 2 Hz. The average concentrations shall be determined by integrating the analyzer signals over the test cycle. The system response time shall be no greater than 20 s, and shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary. CO, CO2, NMHC and CH4 shall be determined by integration or by analysing the concentrations in the sample bag, collected over the cycle. The concentrations of the gaseous pollutants in the dilution air shall be determined by integration or by collecting into the background bag. All other values shall be recorded with a minimum of one measurement per second (1 Hz).

3.8.2.2 Raw exhaust measurement

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the measuring equipment shall be started, simultaneously:

- start analysing the raw exhaust gas concentrations,
- start measuring the exhaust gas or intake air and fuel flow rate,

- start recording the feedback data of speed and torque of the dynamometer.

For the evaluation of the gaseous emissions, the emission concentrations (HC, CO and NOx) and the exhaust gas mass flow rate shall be recorded and stored with at least 2 Hz on a computer system. The system response time shall be no greater than 10 s. All other data may be recorded with a sample rate of at least 1 Hz. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

For calculation of the mass emission of the gaseous components the traces of the recorded concentrations and the trace of the exhaust gas mass flow rate shall be time aligned by the transformation time as defined in section 2 of chapter I of this part. Therefore, the response time of each gaseous emissions analyser and of the exhaust gas mass flow system shall be determined according to the provisions of section 4.2.1 and section 1.5 of appendix 5 to this chapter and recorded.

3.8.3 Particulate sampling (if applicable)

3.8.3.1 Full flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

If no flow compensation is used, the sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe or transfer tube is maintained at a value within ± 5 % of the set flow rate. If flow compensation (i.e., proportional control of sample flow) is used, it must be demonstrated that the ratio of main tunnel flow to particulate sample flow does not change by more than ± 5 % of its set value (except for the first 10 seconds of sampling).

Note: For double dilution operation, sample flow is the net difference between the flow rate through the sample filters and the secondary dilution airflow rate.

The average temperature and pressure at the gas meter(s) or flow instrumentation inlet shall be recorded. If the set flow rate cannot be maintained over the complete cycle (within ± 5 %) because of high particulate loading on the filter, the test shall be voided. The test shall be rerun using a lower flow rate and/or a larger diameter filter.

3.8.3.2 Partial flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

For the control of a partial flow dilution system, a fast system response is required. The transformation time for the system shall be determined by the procedure in section 3.3 of appendix 5 to chapter III of this part. If the combined transformation time of the exhaust flow measurement (see section 4.2.1 of this appendix) and the partial flow system is less than 0,3 sec, online control may be used. If the transformation time exceeds 0,3 sec, look ahead control based on a pre- recorded test run must be used. In this case, the rise time shall be $\leq$ 1 sec and the delay time of the combination $\leq$ 10 sec.

The total system response shall be designed as to ensure a representative sample of the particulates, $q_{mp,i}$, proportional to the exhaust mass flow. To determine the proportionality, a regression analysis of $q_{mp,}$i versus $q_{mew,i}$ shall be conducted on a minimum 1 Hz data acquisition rate, and the following criteria shall be met:

- The correlation coefficient R^2 of the linear regression between $q_{mp,i}$ and $q_{mew,i}$ shall not be less than 0,95,

- The standard error of estimate of $q_{mp,i}$ on $q_{mew,i}$ shall not exceed 5 % of q_{mp} maximum,

- q_{mp} intercept of the regression line shall not exceed ± 2 % of q_{mp} maximum.

Optionally, a pretest may be run, and the exhaust mass flow signal of the pretest be used for controlling the sample flow into the particulate system (look-ahead control). Such a procedure is required if the transformation time of the particulate system, $t_{50,P}$ or the transformation time of the exhaust mass flow signal, $t_{50,F}$, or both, are > 0,3 sec. A correct control of the partial dilution system is obtained, if the time trace of $q_{mew,pre}$ of the pretest, which controls q_{mp}, is shifted by a look-ahead time of $t_{50,P} + t_{50,F}$.

For establishing the correlation between $q_{mp,i}$ and $q_{mew,i}$ the data taken during the actual test shall be used, with $q_{mew,i}$ time aligned by $t_{50,F}$ relative to $q_{mp,i}$ (no contribution from $t_{50,P}$ to the time alignment). That is, the time shift between q_{mew} and q_{mp} is the difference in their transformation times that were determined in section 3.3 of appendix 5 to chapter III of this part.

3.8.4 Engine stalling

If the engine stalls anywhere during the test cycle, the engine shall be preconditioned and restarted, and the test repeated. If a malfunction occurs in any of the required test equipment during the test cycle, the test shall be voided.

3.8.5 Operations after test

At the completion of the test, the measurement of the diluted exhaust gas volume or raw exhaust gas flow rate, the gas flow into the collecting bags and the particulate sample pump shall be stopped. For an integrating analyser system, sampling shall continue until system response times have elapsed.

The concentrations of the collecting bags, if used, shall be analysed as soon as possible and in any case not later than 20 minutes after the end of the test cycle.

After the emission test, a zero gas and the same span gas shall be used for re-checking the analysers. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

3.9 Verification of the test run

3.9.1 Data shift

To minimise the biasing effect of the time lag between the feedback and reference cycle values, the entire engine speed and torque feedback signal sequence may be advanced or delayed in time with respect to the reference speed and torque sequence. If the feedback signals are shifted, both speed and torque must be shifted the same amount in the same direction.

3.9.2 Calculation of the cycle work

The actual cycle work W_{act} (kWh) shall be calculated using each pair of engine feedback speed and torque values recorded. This shall be done after any feedback data shift has occurred, if this option is selected. The actual cycle work W_{act} is used for comparison to the reference cycle work W_{ref} and for calculating the brake specific emissions (see sections 4.4 and 5.2). The same methodology shall be used for integrating both reference and actual engine power. If values are to be determined between adjacent reference or adjacent measured values, linear interpolation shall be used.

In integrating the reference and actual cycle work, all negative torque values shall be set equal to zero and included. If integration is performed at a frequency of less than 5 Hertz, and if, during a given time segment, the torque value changes from positive to negative or negative to positive, the negative portion shall be computed and set equal to zero. The positive portion shall be included in the integrated value.

W_{act} shall be between - 15 % and + 5 % of W_{ref}

3.9.3. Validation statistics of the test cycle

Linear regressions of the feedback values on the reference values shall be performed for speed, torque and power. This shall be done after any feedback data shift has occurred, if this option is selected. The method of least squares shall be used, with the best fit equation having the form:

$$y = mx + b$$

where:

y = Feedback (actual) value of speed (min-1), torque (Nm), or power (kW)

m = slope of the regression line

x = reference value of speed (min-1), torque (Nm), or power (kW)

b = y intercept of the regression line

The standard error of estimate (SE) of y on x and the coefficient of determination (r^2) shall be calculated for each regression line.

It is recommended that this analysis be performed at 1 Hertz. All negative reference torque values and the associated feedback values shall be deleted from the calculation of cycle torque and power validation statistics. For a test to be considered valid, the criteria of table 6 must be met.

Table 6

Regression line tolerances

	Speed	Torque	Power
Standard error of estimate (SE) of Y on X	Max 100 min^{-1}	Max 13 % (15 %) (*) of power map maximum engine torque	Max 8 % (15 %) (*) of power map maximum engine power
Slope of the regression line, m	0,95 to 1,03	0,83–1,03	0,89–1,03 (0,83–1,03) (*)
Coefficient of determination, r^2	min 0,9700 (min 0,9500) (*)	min 0,8800 (min 0,7500) (*)	min 0,9100 (min 0,7500) (*)
Y intercept of the regression line, b	± 50 min^{-1}	± 20 Nm or ± 2 % (± 20 Nm or ± 3 %) (*) of max torque whichever is greater	± 4 kW or ± 2 % (± 4 kW or ± 3 %) (*) of max power whichever is greater

(*) Until 31st March, 2011 the figure shown in brackets may be used for the type-approval testing of gas engines.

Point deletions from the regression analyses are permitted where noted in Table 7.

Permitted point deletions from regression analysis

Conditions	Points to be deleted
Full load demand and torque feedback < 95 % torque reference	Torque and/or power
Full load demand and speed feedback < 95 % speed reference	Speed and/or power
No load, not an idle point, and torque feedback > torque reference	Torque and/or power
No load, speed feedback ≤ idle speed + 50 min^{-1} and torque feedback = manufacturer defined/measured idle torque ± 2 % of max. torque	Speed and/or power
No load, speed feedback > idle speed + 50 min^{-1} and torque feedback > 105 % torque reference	Torque and/or power
No load and speed feedback > 105 % speed reference	Speed and/or power

Table 7

4 CALCULATION OF THE EXHAUST GAS FLOW

4.1 Determination of the diluted exhaust gas flow

The total diluted exhaust gas flow over the cycle (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device (V_0 for PDP, K_V for CFV, C_d for SSV), as determined in section 2 of appendix 5 to chapter III of this part. The following formulae shall be applied, if the temperature of the diluted exhaust is kept constant over the cycle by using a heat exchanger (± 6 K for a PDP-CVS, ± 11 K for a CFV-CVS or ± 11 K for a SSV-CVS), see section 2.3 of chapter V of this part.

For the PDP-CVS system:

$$m_{ed} = 1,293 \times V_0 \times N_P \times (p_b - p_1) \times 273 / (101,3 \times T)$$

where:

V_0 = volume of gas pumped per revolution under test conditions, m^3/rev
N_P = total revolutions of pump per test
p_b = atmospheric pressure in the test cell, kPa
p_1 = pressure depression below atmospheric at pump inlet, kPa
T = average temperature of the diluted exhaust gas at pump inlet over the cycle, K

For the CFV-CVS system:

$$m_{ed} = 1,293 \times t \times K_v \times p_p / T^{0.5}$$

where:
t = cycle time, s

K_v = calibration coefficient of the critical flow venturi for standard conditions,
p_p = absolute pressure at venturi inlet, kPa
T = absolute temperature at venturi inlet, K

For the SSV-CVS system

m_{ed} = 1,293 × Q_{SSV}
where,

$$Q_{SSV} = A_0 d^2 C_d p_p \sqrt{\left[\frac{1}{T}\left(r_p^{1,4286} - r_p^{1,7143}\right) \times \left(\frac{1}{1 - r_D^4 r_p^{1,4286}}\right)\right]}$$

with:
A_0 = collection of constants and units conversions

$$\left(\frac{m^3}{\min}\right)\left(\frac{K^{\frac{1}{2}}}{kPa}\right)\left(\frac{1}{mm^2}\right)$$

= 0,006111 in SI units of

d = diameter of the SSV throat, m
C_d = discharge coefficient of the SSV
p_p = absolute pressure at venturi inlet, kPa
T = temperature at the venturi inlet, K
r_p = ratio of the SSV throat to inlet absolute, static pressure $= 1 - \frac{\Delta P}{P_A}$
r_D = ratio of the SSV throat diameter, d, to the inlet pipe inner diameter = d/ D

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows.

For the PDP-CVS system:

$m_{ed,i}$ = 1,293 × V_0 × $N_{P,i}$ × (p_b - p_1) × 273 / (101,3 × T),
where
$N_{P,i}$ = total revolutions of pump per time interval

For the CFV-CVS system:

$m_{ed,i}$ = 1,293 × Δ_{ti} × K_V × p_p / $T^{0,5}$

where:

Δ_{ti} = time interval, s

For the SSV-CVS system:

$$m_{ed} = 1{,}293 \times Q_{SSV} \times \Delta_{ti}$$

where:

Δ_{ti} = time interval, s

The real time calculation shall be initialised with either a reasonable value for C_d, such as 0,98, or a reasonable value of Q_{ssv}. If the calculation is initialised with Q_{ssv}, the initial value of Q_{ssv} shall be used to evaluate Re.

During all emissions tests, the Reynolds number at the SSV throat must be in the range of Reynolds numbers used to derive the calibration curve developed in section 2.4 of appendix 5 of this Chapter.

4.2 Determination of raw exhaust gas mass flow

For calculation of the emissions in the raw exhaust gas and for controlling of a partial flow dilution system, it is necessary to know the exhaust gas mass flow rate. For the determination of the exhaust mass flow rate, either of the methods described in sections 4.2.2 to 4.2.5 of this appendix may be used.

4.2.1 Response time

For the purpose of emissions calculation, the response time of either method described below shall be equal to or less than the requirement for the analyzer response time, as defined in section 1.5 of appendix 5 of this Chapter.

For the purpose of controlling of a partial flow dilution system, a faster response is required. For partial flow dilution systems with online control, a response time of ≤ 0,3 seconds is required. For partial flow dilution systems with look ahead control based on a pre-recorded test run, a response time of the exhaust flow measurement system of ≤ 5 seconds with a rise time of ≤ 1 second is required. The system response time shall be specified by the instrument manufacturer. The combined response time requirements for exhaust gas flow and partial flow dilution system are indicated in section 3.8.3.2. of this appendix.

4.2.2 Direct measurement method

Direct measurement of the instantaneous exhaust flow may be done by systems such as:

- pressure differential devices, like flow nozzle,
- ultrasonic flowmeter,
- vortex flowmeter.

Precautions shall be taken to avoid measurement errors which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Engine performance and emissions shall especially not be affected by the installation of the device.

The accuracy of exhaust flow determination shall be at least ± 2,5 % of reading or ± 1,5 % of engine's maximum value, whichever is the greater.

4.2.3 Air and fuel measurement method

This involves measurement of the air flow and the fuel flow. Air flow meters and fuel flow meters shall be used that meet the total exhaust flow accuracy requirement of section 4.2.2 of this appendix. The calculation of the exhaust gas flow is as follows:

$$q_{mew} = q_{maw} + q_{mf}$$

4.2.4 Tracer measurement method

This involves measurement of the concentration of a tracer gas in the exhaust. A known amount of an inert gas (e.g. pure helium) shall be injected into the exhaust gas flow as a tracer. The gas is mixed and diluted by the exhaust gas, but shall not react in the exhaust pipe. The concentration of the gas shall then be measured in the exhaust gas sample.

In order to ensure complete mixing of the tracer gas, the exhaust gas sampling probe shall be located at least 1 m or 30 times the diameter of the exhaust pipe, whichever is larger, downstream of the tracer gas injection point. The sampling probe may be located closer to the injection point if complete mixing is verified by comparing the tracer gas concentration with the reference concentration when the tracer gas is injected upstream of the engine.

The tracer gas flow rate shall be set so that the tracer gas concentration at engine idle speed after mixing becomes lower than the full scale of the trace gas analyser.

The calculation of the exhaust gas flow is as follows:

$$q_{mew,i} = \frac{q_{vt} \times \rho_e}{60 \times (c_{mix,i} - c_a)}$$

where:

$q_{mew,i}$ = instantaneous exhaust mass flow, kg/s

q_{vt} = tracer gas flow, cm^3/min

$c_{mix.i}$ = instantaneous concentration of the tracer gas after mixing, ppm

ρ_e = density of the exhaust gas, kg/m^3 (Refer Table 6, Page 98 of 2005/55/EC)

c_a = background concentration of the tracer gas in the intake air, ppm

When the background concentration is less than 1 % of the concentration of the tracer gas after mixing ($c_{mix.i}$) at maximum exhaust flow, the background concentration may be neglected.

The total system shall meet the accuracy specifications for the exhaust gas flow, and shall be calibrated according to section 1.7 of appendix 5 of this Chapter.

4.2.5 Air flow and air-to-fuel ratio measurement method

This involves exhaust mass calculation from the airflow and the air to fuel ratio. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$q_{mew,i} = q_{maw,i} \times \left(1 + \frac{1}{A/F_{st} \times \lambda_i}\right)$$

with:

$$A/F_{st} = \frac{138,0 \times \left(\beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right)}{12,011 \times \beta + 1,00794 \times \alpha + 15,9994 \times \varepsilon + 14,0067 \times \delta + 32,065 \times \gamma}$$

$$\lambda_i = \frac{\beta \times \left(100 - \frac{c_{CO} \times 10^{-4}}{2} - c_{HC} \times 10^{-4}\right) + \left(\frac{\alpha}{4} \times \frac{1 - \frac{2 \times c_{CO} \times 10^{-4}}{3,5 \times c_{CO2}}}{1 + \frac{c_{CO} \times 10^{-4}}{3,5 \times c_{CO2}}} - \frac{\varepsilon}{2} - \frac{\delta}{2}\right) \times \left(c_{CO2} + c_{CO} \times 10^{-4}\right)}{4,764 \times \left(\beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right) \times \left(c_{CO2} + c_{CO} \times 10^{-4} + c_{HC} \times 10^{-4}\right)}$$

where:

A/F_{st} = stoichiometric air to fuel ratio, kg/kg

λ = excess air ratio

c_{CO2} = dry CO_2 concentration, %

c_{CO} = dry CO concentration, ppm

c_{HC} = HC concentration, ppm

Note: β can be 1 for fuels containing carbon and 0 for hydrogen fuel.

The air flowmeter shall meet the accuracy specifications of section 2.2 of appendix 4 of this chapter, the CO_2 analyser used shall meet the specifications of section 3.3.2 of appendix 4 of this chapter and the total system shall meet the accuracy specifications for the exhaust gas flow.

Optionally, air to fuel ratio measurement equipment such as a zirconia type sensor may be used for the measurement of the excess air ratio which meets the specifications of section 3.3.6 of appendix 4 of this chapter.

5 CALCULATION OF THE GASEOUS EMISSIONS:

5.1 Data evaluation

For the evaluation of the gaseous emissions in the diluted exhaust gas, the emission concentrations (HC, CO and NO_X) and the diluted exhaust gas mass flow rate shall be recorded according to section 3.8.2.1 of this appendix and stored on a computer system. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

For the evaluation of the gaseous emissions in the raw exhaust gas, the emission concentrations (HC, CO and NO_X) and the exhaust gas mass flow rate shall be recorded according to section 3.8.2.2 of this appendix and stored on a computer system. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

5.2 Dry/wet correction

If the concentration is measured on a dry basis, it shall be converted to a wet basis according to the following formula. For continuous measurement, the conversion shall be applied to each instantaneous measurement before any further calculation.

$$c_{wet} = k_W \times c_{dry}$$

The conversion equations of section 5.2 of appendix 1 of this Chapter shall apply.

5.3 NO_X correction for humidity and temperature

As the NO_X emission depends on ambient air conditions, the NOx concentration shall be corrected for ambient air temperature and humidity with the factors given in section 5.3 of appendix 1 of this chapter. The factors are valid in the range between 0 and 25 g/kg dry air.

5.4 Calculation of the emission mass flow rates

The emission mass over the cycle (g/test) shall be calculated as follows depending on the measurement method applied. The measured concentration shall be converted to a wet basis according to section 5.2 of appendix 1 of this chapter, if not already measured on a wet basis. The respective values for u_{gas} shall be applied that are given in Table 5 of appendix 1 of this chapter for selected components based on ideal gas properties and the fuels relevant for this part.

(a) for the raw exhaust gas:

$$m_{gas} = u_{gas} \times \sum_{i=1}^{i=n} c_{gas,i} \times q_{mew,i} \times \frac{1}{f}$$

where:

u_{gas} = ratio between density of exhaust component and density of exhaust gas from table5 of this part.

$c_{gas,i}$ = instantaneous concentration of the respective component in the raw exhaust gas, ppm

$q_{mew,i}$ = instantaneous exhaust mass flow rate, kg/s

f = data sampling rate, Hz

n = number of measurements

(b) for the diluted exhaust gas without flow compensation:

$$m_{gas} = u_{gas} \times c_{gas} \times m_{ed}$$

where:

u_{gas} = ratio between density of exhaust component and density of air from table 5 of this part

c_{gas} = average background corrected concentration of the respective component, ppm

m_{ed} = total diluted exhaust mass over the cycle, kg

(c) for the diluted exhaust gas with flow compensation*:*

$$m_{gas} = \left[u_{gas} \times \sum_{i=1}^{i=n}\left(c_{e,i} \times q_{mdew,i} \times \frac{1}{f}\right)\right] - \left[\left(m_{ed} \times c_d \times (1 - 1/D) \times u_{gas}\right)\right]$$

where:

$c_{e,i}$ = instantaneous concentration of the respective component measured in the diluted exhaust gas, ppm

c_d = concentration of the respective component measured in the dilution air, ppm

$q_{mdew,i}$ = instantaneous diluted exhaust gas mass flow rate, kg/s

m_{ed} = total mass of diluted exhaust gas over the cycle, kg

u_{gas} = ratio between density of exhaust component and density of air from table 5 of this part

D = dilution factor (see section 5.4.1 of this appendix)

If applicable, the concentration of NMHC and CH4 shall be calculated by either of the methods shown in section 3.3.4 of appendix 4 of this chapter, as follows:

(a) GC method (full flow dilution system, only):

$$c_{NMHC} = c_{HC} - c_{CH4}$$

(b) NMC method:

$$c_{NMHC} = \frac{c_{HC(w/oCutter)} \times (1 - E_M) - c_{HC(w/Cutter)}}{E_E - E_M}$$

$$c_{CH_4} = \frac{c_{HC(w/Cutter)} - c_{HC(w/oCutter)} \times (1 - E_E)}{E_E - E_M}$$

c_{HC}(w/Cutter) = HC concentration with the sample gas flowing through the NMC

c_{HC}(w/o Cutter) = HC concentration with the sample gas bypassing the NMC

5.4.1 Determination of the background corrected concentrations (full flow dilution system, only)

The average background concentration of the gaseous pollutants in the dilution air shall be subtracted from measured concentrations to get the net concentrations of the pollutants. The average values of the background concentrations can be determined by the sample bag method or by continuous measurement with integration. The following formula shall be used.

$$c = c_e - c_d \times \left(1 - \frac{1}{D}\right)$$

where:

c_e = concentration of the respective pollutant measured in the diluted exhaust gas, ppm

c_d = concentration of the respective pollutant measured in the dilution air, ppm

D = dilution factor

The dilution factor shall be calculated as follows:

(a) for diesel and LPG fueled gas engines

$$D = \frac{F_s}{c_{CO_2} + (c_{HC} + c_{CO}) \times 10^{-4}}$$

(b) for NG fueled gas engines

$$D = \frac{F_S}{c_{CO_2} + (c_{NMHC} + c_{CO}) \times 10^{-4}}$$

where:

c_{CO2} = concentration of CO_2 in the diluted exhaust gas, % vol

c_{HC} = concentration of HC in the diluted exhaust gas, ppm C1

c_{NMHC} = concentration of NMHC in the diluted exhaust gas, ppm C1

c_{CO} = concentration of CO in the diluted exhaust gas, ppm

F_S = stoichiometric factor

Concentrations measured on dry basis shall be converted to a wet basis in accordance with section 5.2 of appendix 1 of this chapter.

The stoichiometric factor shall be calculated as follows:

$$F_S = 100 \times \frac{1}{1 + \frac{\alpha}{2} + 3{,}76 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2}\right)}$$

where:

α, ε are the molar ratios referring to a fuel $CH_\alpha O_\varepsilon$

Alternatively, if the fuel composition is not known, the following stoichiometric factors may be used:

F_S (diesel) = 13,4

F_S (LPG) = 11,6

F_S (NG) = 9,5

5.5 Calculation of the specific emissions

The emissions (g/kWh) shall be calculated in the following way:

(a) all components, except NOx:

$$M_{gas} = \frac{m_{gas}}{W_{act}}$$

(b) NOx:

$$M_{gas} = m_{gas} \times \frac{k_h}{W_{act}}$$

where:

W_{act} = actual cycle work as determined according to section 3.9.2 of this appendix.

5.5.1. In case of a periodic exhaust after treatment system, the emissions shall be weighted as follows:

$$\overline{M_{Gas}} = (n1 \times \overline{M_{Gas,n1}} + n2 \times \overline{M_{Gas,n2}}) / (n1 + n2)$$

where:

n1 = number of ETC tests between two regenerations

n2 = number of ETC during a regeneration (minimum of one ETC test)

$M_{gas,n2}$ = emissions during a regeneration

$M_{gas,n1}$ = emissions after a regeneration.

6 CALCULATION OF THE PARTICULATE EMISSION (IF APPLICABLE)

6.1 Data evaluation

The particulate filter shall be returned to the weighing chamber no later than one hour after completion of the test. It shall be conditioned in a partially covered petri dish, which is protected against dust contamination, for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight subtracted, which results in the particulate sample mass m_f. For the evaluation of the particulate concentration, the total sample mass (m_{sep}) through the filters over the test cycle shall be recorded.

If background correction is to be applied, the dilution air mass (m_d) through the filter and the particulate mass ($m_{f,d}$) shall be recorded.

6.2 Calculation of the mass flow

6.2.1 Full flow dilution system

The particulate mass (g/test) shall be calculated as follows:

$$m_{PT} = \frac{m_f}{m_{sep}} \times \frac{m_{ed}}{1000}$$

where:

m_f = particulate mass sampled over the cycle, mg

m_{sep} = mass of diluted exhaust gas passing the particulate collection filters, kg

m_{ed} = mass of diluted exhaust gas over the cycle, kg

If a double dilution system is used, the mass of the secondary dilution air shall be subtracted from the total mass of the double diluted exhaust gas sampled through the particulate filters.

$$m_{sep} = m_{set} - m_{ssd}$$

where:

m_{set} = mass of double diluted exhaust gas through particulate filter, kg

m_{ssd} = mass of secondary dilution air, kg

If the particulate background level of the dilution air is determined in accordance with section 3.4 of this appendix, the particulate mass may be background corrected. In this case, the particulate mass (g/test) shall be calculated as follows:

$$m_{PT} = \left[\frac{m_f}{m_{sep}} - \left(\frac{m_{f,d}}{m_d} \times \left(1 - \frac{1}{D} \right) \right) \right] \times \frac{m_{ed}}{1000}$$

where,

m_{PT}, m_{sep}, m_{ed} = see above

m_d = mass of primary dilution air sampled by background particulate sampler, kg

$m_{f,d}$ = mass of the collected background particulates of the primary dilution air, mg

D = dilution factor as determined in section 5.4.1 of this appendix.

6.2.2. Partial flow dilution system

The mass of particulates (g/test) shall be calculated by either of the following methods:

(a) $$m_{PT} = \frac{m_f}{m_{sep}} \times \frac{m_{edf}}{1000}$$

where,

m_f = particulate mass sampled over the cycle, mg

m_{sep} = mass of diluted exhaust gas passing the particulate collection filters, kg

m_{edf} = mass of equivalent diluted exhaust gas over the cycle, kg

The total mass of equivalent diluted exhaust gas mass over the cycle shall be determined as follows:

The total mass of equivalent diluted exhaust gas mass over the cycle shall be determined as follows:

$$m_{edf} = \sum_{i=1}^{i=n} q_{medf,i} \times \frac{1}{f}$$

$$q_{medf,i} = q_{mew,i} \times r_{d,i}$$

$$r_{d,i} = \frac{q_{mdew,,i}}{\left(q_{mdew,,i} - q_{mdw,,i}\right)}$$

where:

$q_{medf,i}$ = instantaneous equivalent diluted exhaust mass flow rate, kg/s

$q_{mew,i}$ = instantaneous exhaust mass flow rate, kg/s

$r_{d,i}$ = instantaneous dilution ratio

$q_{mdew,i}$ = instantaneous diluted exhaust mass flow rate through dilution tunnel, kg/s

$q_{mdw,i}$ = instantaneous dilution air mass flow rate, kg/s f = data sampling rate, Hz

n = number of measurements

(b)

$$m_{PT} = \frac{m_f}{r_s \times 1000}$$

where,

m_f = particulate mass sampled over the cycle, mg

r_s = average sample ratio over the test cycle

with:

$$r_s = \frac{m_{se}}{m_{ew}} \times \frac{m_{sep}}{m_{sed}}$$

where:

m_{se} = sample mass over the cycle, kg

m_{ew} = total exhaust mass flow over the cycle, kg

m_{sep} = mass of diluted exhaust gas passing the particulate collection filters, kg

m_{sed} = mass of diluted exhaust gas passing the dilution tunnel, kg.

Note: In case of the total sampling type system, msep and Msed are identical.

6.3 Calculation of the Specific Emission

The particulate emission (g/kWh) shall be calculated in the following way:

$$M_{PT} = \frac{m_{PT}}{W_{act}}$$

where:

W_{act} = actual cycle work as determined according to section 3.9.2 of this appendix, kWh.

6.3.1. In case of a periodic regeneration after treatment system, the emissions shall be weighted as follows:

$$\overline{PT} = (n1 \times \overline{PT}_{n1} + n2 \times \overline{PT}_{n2}) / (n1 + n2)$$

where:

n1 = number of ETC tests between two regeneration events

n2 = number of ETC tests during a regeneration (minimum of one ETC)

$\overline{PT_{n2}}$ = emissions during a regeneration

$\overline{PT_{n1}}$ = emissions outside a regeneration.'

Appendix 3

ETC ENGINE DYNAMOMETER SCHEDULE

ETC ENGINE DYNAMOMETER SCHEDULE

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
1	0	0	63	28,5	20,9	125	65,3	'm'
2	0	0	64	32	73,9	126	64	'm'
3	0	0	65	4	82,3	127	59,7	'm'
4	0	0	66	34,5	80,4	128	52,8	'm'
5	0	0	67	64,1	86	129	45,9	'm'
6	0	0	68	58	0	130	38,7	'm'
7	0	0	69	50,3	83,4	131	32,4	'm'
8	0	0	70	66,4	99,1	132	27	'm'
9	0	0	71	81,4	99,6	133	21,7	'm'
10	0	0	72	88,7	73,4	134	19,1	0,4
11	0	0	73	52,5	0	135	34,7	14
12	0	0	74	46,4	58,5	136	16,4	48,6
13	0	0	75	48,6	90,9	137	0	11,2
14	0	0	76	55,2	99,4	138	1,2	2,1
15	0	0	77	62,3	99	139	30,1	19,3
16	0,1	1,5	78	68,4	91,5	140	30	73,9
17	23,1	21,5	79	74,5	73,7	141	54,4	74,4
18	12,6	28,5	80	38	0	142	77,2	55,6
19	21,8	71	81	41,8	89,6	143	58,1	0
20	19,7	76,8	82	47,1	99,2	144	45	82,1
21	54,6	80,9	83	52,5	99,8	145	68,7	98,1
22	71,3	4,9	84	56,9	80,8	146	85,7	67,2
23	55,9	18,1	85	58,3	11,8	147	60,2	0
24	72	85,4	86	56,2	'm'	148	59,4	98
25	86,7	61,8	87	52	'm'	149	72,7	99,6
26	51,7	0	88	43,3	'm'	150	79,9	45
27	53,4	48,9	89	36,1	'm'	151	44,3	0
28	34,2	87,6	90	27,6	'm'	152	41,5	84,4
29	45,5	92,7	91	21,1	'm'	153	56,2	98,2
30	54,6	99,5	92	8	0	154	65,7	99,1
31	64,5	96,8	93	0	0	155	74,4	84,7
32	71,7	85,4	94	0	0	156	54,4	0
33	79,4	54,8	95	0	0	157	47,9	89,7
34	89,7	99,4	96	0	0	158	54,5	99,5
35	57,4	0	97	0	0	159	62,7	96,8
36	59,7	30,6	98	0	0	160	62,3	0
37	90,1	'm'	99	0	0	161	46,2	54,2
38	82,9	'm'	100	0	0	162	44,3	83,2
39	51,3	'm'	101	0	0	163	48,2	13,3
40	28,5	'm'	102	0	0	164	51	'm'
41	29,3	'm'	103	0	0	165	50	'm'
42	26,7	'm'	104	0	0	166	49,2	'm'
43	20,4	'm'	105	0	0	167	49,3	'm'
44	14,1	0	106	0	0	168	49,9	'm'
45	6,5	0	107	0	0	169	51,6	'm'
46	0	0	108	11,6	14,8	170	49,7	'm'
47	0	0	109	0	0	171	48,5	'm'
48	0	0	110	27,2	74,8	172	50,3	72,5
49	0	0	111	17	76,9	173	51,1	84,5
50	0	0	112	36	78	174	54,6	64,8
51	0	0	113	59,7	86	175	56,6	76,5
52	0	0	114	80,8	17,9	176	58	'm'
53	0	0	115	49,7	0	177	53,6	'm'
54	0	0	116	65,6	86	178	40,8	'm'
55	0	0	117	78,6	72,2	179	32,9	'm'
56	0	0	118	64,9	'm'	180	26,3	'm'
57	0	0	119	44,3	'm'	181	20,9	'm'
58	0	0	120	51,4	83,4	182	10	0
59	0	0	121	58,1	97	183	0	0
60	0	0	122	69,3	99,3	184	0	0
61	0	0	123	72	20,8	185	0	0
62	25,5	11,1	124	72,1	'm'	186	0	0

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
187	0	0	255	54,5	'm'	323	43	24,8
188	0	0	256	51,7	17	324	38,7	0
189	0	0	257	56,2	78,7	325	48,1	31,9
190	0	0	258	59,5	94,7	326	40,3	61
191	0	0	259	65,5	99,1	327	42,4	52,1
192	0	0	260	71,2	99,5	328	46,4	47,7
193	0	0	261	76,6	99,9	329	46,9	30,7
194	0	0	262	79	0	330	46,1	23,1
195	0	0	263	52,9	97,5	331	45,7	23,2
196	0	0	264	53,1	99,7	332	45,5	31,9
197	0	0	265	59	99,1	333	46,4	73,6
198	0	0	266	62,2	99	334	51,3	60,7
199	0	0	267	65	99,1	335	51,3	51,1
200	0	0	268	69	83,1	336	53,2	46,8
201	0	0	269	69,9	28,4	337	53,9	50
202	0	0	270	70,6	12,5	338	53,4	52,1
203	0	0	271	68,9	8,4	339	53,8	45,7
204	0	0	272	69,8	9,1	340	50,6	22,1
205	0	0	273	69,6	7	341	47,8	26
206	0	0	274	65,7	'm'	342	41,6	17,8
207	0	0	275	67,1	'm'	343	38,7	29,8
208	0	0	276	66,7	'm'	344	35,9	71,6
209	0	0	277	65,6	'm'	345	34,6	47,3
210	0	0	278	64,5	'm'	346	34,8	80,3
211	0	0	279	62,9	'm'	347	35,9	87,2
212	0	0	280	59,3	'm'	348	38,8	90,8
213	0	0	281	54,1	'm'	349	41,5	94,7
214	0	0	282	51,3	'm'	350	47,1	99,2
215	0	0	283	47,9	'm'	351	53,1	99,7
216	0	0	284	43,6	'm'	352	46,4	0
217	0	0	285	39,4	'm'	353	42,5	0,7
218	0	0	286	34,7	'm'	354	43,6	58,6
219	0	0	287	29,8	'm'	355	47,1	87,5
220	0	0	288	20,9	73,4	356	54,1	99,5
221	0	0	289	36,9	'm'	357	62,9	99
222	0	0	290	35,5	'm'	358	72,6	99,6
223	0	0	291	20,9	'm'	359	82,4	99,5
224	0	0	292	49,7	11,9	360	88	99,4
225	21,2	62,7	293	42,5	'm'	361	46,4	0
226	30,8	75,1	294	32	'm'	362	53,4	95,2
227	5,9	82,7	295	23,6	'm'	363	58,4	99,2
228	34,6	80,3	296	19,1	0	364	61,5	99
229	59,9	87	297	15,7	73,5	365	64,8	99
230	84,3	86,2	298	25,1	76,8	366	68,1	99,2
231	68,7	'm'	299	34,5	81,4	367	73,4	99,7
232	43,6	'm'	300	44,1	87,4	368	73,3	29,8
233	41,5	85,4	301	52,8	98,6	369	73,5	14,6
234	49,9	94,3	302	63,6	99	370	68,3	0
235	60,8	99	303	73,6	99,7	371	45,4	49,9
236	70,2	99,4	304	62,2	'm'	372	47,2	75,7
237	81,1	92,4	305	29,2	'm'	373	44,5	9
238	49,2	0	306	46,4	22	374	47,8	10,3
239	56	86,2	307	47,3	13,8	375	46,8	15,9
240	56,2	99,3	308	47,2	12,5	376	46,9	12,7
241	61,7	99	309	47,9	11,5	377	46,8	8,9
242	69,2	99,3	310	47,8	35,5	378	46,1	6,2
243	74,1	99,8	311	49,2	83,3	379	46,1	'm'
244	72,4	8,4	312	52,7	96,4	380	45,5	'm'
245	71,3	0	313	57,4	99,2	381	44,7	'm'
246	71,2	9,1	314	61,8	99	382	43,8	'm'
247	67,1	'm'	315	66,4	60,9	383	41	'm'
248	65,5	'm'	316	65,8	'm'	384	41,1	6,4
249	64,4	'm'	317	59	'm'	385	38	6,3
250	62,9	25,6	318	50,7	'm'	386	35,9	0,3
251	62,2	35,6	319	41,8	'm'	387	33,5	0
252	62,9	24,4	320	34,7	'm'	388	53,1	48,9
253	58,8	'm'	321	28,7	'm'	389	48,3	'm'
254	56,9	'm'	322	25,2	'm'	390	49,9	'm'

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
391	48	'm'	459	51	100	527	60,7	'm'
392	45,3	'm'	460	53,2	99,7	528	54,5	'm'
393	41,6	3,1	461	53,1	99,7	529	51,3	'm'
394	44,3	79	462	55,9	53,1	530	45,5	'm'
395	44,3	89,5	463	53,9	13,9	531	40,8	'm'
396	43,4	98,8	464	52,5	'm'	532	38,9	'm'
397	44,3	98,9	465	51,7	'm'	533	36,6	'm'
398	43	98,8	466	51,5	52,2	534	36,1	72,7
399	42,2	98,8	467	52,8	80	535	44,8	78,9
400	42,7	98,8	468	54,9	95	536	51,6	91,1
401	45	99	469	57,3	99,2	537	59,1	99,1
402	43,6	98,9	470	60,7	99,1	538	66	99,1
403	42,2	98,8	471	62,4	'm'	539	75,1	99,9
404	44,8	99	472	60,1	'm'	540	81	8
405	43,4	98,8	473	53,2	'm'	541	39,1	0
406	45	99	474	44	'm'	542	53,8	89,7
407	42,2	54,3	475	35,2	'm'	543	59,7	99,1
408	61,2	31,9	476	30,5	'm'	544	64,8	99
409	56,3	72,3	477	26,5	'm'	545	70,6	96,1
410	59,7	99,1	478	22,5	'm'	546	72,6	19,6
411	62,3	99	479	20,4	'm'	547	72	6,3
412	67,9	99,2	480	19,1	'm'	548	68,9	0,1
413	69,5	99,3	481	19,1	'm'	549	67,7	'm'
414	73,1	99,7	482	13,4	'm'	550	66,8	'm'
415	77,7	99,8	483	6,7	'm'	551	64,3	16,9
416	79,7	99,7	484	3,2	'm'	552	64,9	7
417	82,5	99,5	485	14,3	63,8	553	63,6	12,5
418	85,3	99,4	486	34,1	0	554	63	7,7
419	86,6	99,4	487	23,9	75,7	555	64,4	38,2
420	89,4	99,4	488	31,7	79,2	556	63	11,8
421	62,2	0	489	32,1	19,4	557	63,6	0
422	52,7	96,4	490	35,9	5,8	558	63,3	5
423	50,2	99,8	491	36,6	0,8	559	60,1	9,1
424	49,3	99,6	492	38,7	'm'	560	61	8,4
425	52,2	99,8	493	38,4	'm'	561	59,7	0,9
426	51,3	100	494	39,4	'm'	562	58,7	'm'
427	51,3	100	495	39,7	'm'	563	56	'm'
428	51,1	100	496	40,5	'm'	564	53,9	'm'
429	51,1	100	497	40,8	'm'	565	52,1	'm'
430	51,8	99,9	498	39,7	'm'	566	49,9	'm'
431	51,3	100	499	39,2	'm'	567	46,4	'm'
432	51,1	100	500	38,7	'm'	568	43,6	'm'
433	51,3	100	501	32,7	'm'	569	40,8	'm'
434	52,3	99,8	502	30,1	'm'	570	37,5	'm'
435	52,9	99,7	503	21,9	'm'	571	27,8	'm'
436	53,8	99,6	504	12,8	0	572	17,1	0,6
437	51,7	99,9	505	0	0	573	12,2	0,9
438	53,5	99,6	506	0	0	574	11,5	1,1
439	52	99,8	507	0	0	575	8,7	0,5
440	51,7	99,9	508	0	0	576	8	0,9
441	53,2	99,7	509	0	0	577	5,3	0,2
442	54,2	99,5	510	0	0	578	4	0
443	55,2	99,4	511	0	0	579	3,9	0
444	53,8	99,6	512	0	0	580	0	0
445	53,1	99,7	513	0	0	581	0	0
446	55	99,4	514	30,5	25,6	582	0	0
447	57	99,2	515	19,7	56,9	583	0	0
448	61,5	99	516	16,3	45,1	584	0	0
449	59,4	5,7	517	27,2	4,6	585	0	0
450	59	0	518	21,7	1,3	586	0	0
451	57,3	59,8	519	29,7	28,6	587	8,7	22,8
452	64,1	99	520	36,6	73,7	588	16,2	49,4
453	70,9	90,5	521	61,3	59,5	589	23,6	56
454	58	0	522	40,8	0	590	21,1	56,1
455	41,5	59,8	523	36,6	27,8	591	23,6	56
456	44,1	92,6	524	39,4	80,4	592	46,2	68,8
457	46,8	99,2	525	51,3	88,9	593	68,4	61,2
458	47,2	99,3	526	58,5	11,1	594	58,7	'm'

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
595	31,6	‘m’	663	54,9	59,8	731	56,8	‘m’
596	19,9	8,8	664	54	39,3	732	57,1	‘m’
597	32,9	70,2	665	53,8	‘m’	733	52	‘m’
598	43	79	666	52	‘m’	734	44,4	‘m’
599	57,4	98,9	667	50,4	‘m’	735	40,2	‘m’
600	72,1	73,8	668	50,6	0	736	39,2	16,5
601	53	0	669	49,3	41,7	737	38,9	73,2
602	48,1	86	670	50	73,2	738	39,9	89,8
603	56,2	99	671	50,4	99,7	739	42,3	98,6
604	65,4	98,9	672	51,9	99,5	740	43,7	98,8
605	72,9	99,7	673	53,6	99,3	741	45,5	99,1
606	67,5	‘m’	674	54,6	99,1	742	45,6	99,2
607	39	‘m’	675	56	99	743	48,1	99,7
608	41,9	38,1	676	55,8	99	744	49	100
609	44,1	80,4	677	58,4	98,9	745	49,8	99,9
610	46,8	99,4	678	59,9	98,8	746	49,8	99,9
611	48,7	99,9	679	60,9	98,8	747	51,9	99,5
612	50,5	99,7	680	63	98,8	748	52,3	99,4
613	52,5	90,3	681	64,3	98,9	749	53,3	99,3
614	51	1,8	682	64,8	64	750	52,9	99,3
615	50	‘m’	683	65,9	46,5	751	54,3	99,2
616	49,1	‘m’	684	66,2	28,7	752	55,5	99,1
617	47	‘m’	685	65,2	1,8	753	56,7	99
618	43,1	‘m’	686	65	6,8	754	61,7	98,8
619	39,2	‘m’	687	63,6	53,6	755	64,3	47,4
620	40,6	0,5	688	62,4	82,5	756	64,7	1,8
621	41,8	53,4	689	61,8	98,8	757	66,2	‘m’
622	44,4	65,1	690	59,8	98,8	758	49,1	‘m’
623	48,1	67,8	691	59,2	98,8	759	52,1	46
624	53,8	99,2	692	59,7	98,8	760	52,6	61
625	58,6	98,9	693	61,2	98,8	761	52,9	0
626	63,6	98,8	694	62,2	49,4	762	52,3	20,4
627	68,5	99,2	695	62,8	37,2	763	54,2	56,7
628	72,2	89,4	696	63,5	46,3	764	55,4	59,8
629	77,1	0	697	64,7	72,3	765	56,1	49,2
630	57,8	79,1	698	64,7	72,3	766	56,8	33,7
631	60,3	98,8	699	65,4	77,4	767	57,2	96
632	61,9	98,8	700	66,1	69,3	768	58,6	98,9
633	63,8	98,8	701	64,3	‘m’	769	59,5	98,8
634	64,7	98,9	702	64,3	‘m’	770	61,2	98,8
635	65,4	46,5	703	63	‘m’	771	62,1	98,8
636	65,7	44,5	704	62,2	‘m’	772	62,7	98,8
637	65,6	3,5	705	61,6	‘m’	773	62,8	98,8
638	49,1	0	706	62,4	‘m’	774	64	98,9
639	50,4	73,1	707	62,2	‘m’	775	63,2	46,3
640	50,5	‘m’	708	61	‘m’	776	62,4	‘m’
641	51	‘m’	709	58,7	‘m’	777	60,3	‘m’
642	49,4	‘m’	710	55,5	‘m’	778	58,7	‘m’
643	49,2	‘m’	711	51,7	‘m’	779	57,2	‘m’
644	48,6	‘m’	712	49,2	‘m’	780	56,1	‘m’
645	47,5	‘m’	713	48,8	40,4	781	56	9,3
646	46,5	‘m’	714	47,9	‘m’	782	55,2	26,3
647	46	11,3	715	46,2	‘m’	783	54,8	42,8
648	45,6	42,8	716	45,6	9,8	784	55,7	47,1
649	47,1	83	717	45,6	34,5	785	56,6	52,4
650	46,2	99,3	718	45,5	37,1	786	58	50,3
651	47,9	99,7	719	43,8	‘m’	787	58,6	20,6
652	49,5	99,9	720	41,9	‘m’	788	58,7	‘m’
653	50,6	99,7	721	41,3	‘m’	789	59,3	‘m’
654	51	99,6	722	41,4	‘m’	790	58,6	‘m’
655	53	99,3	723	41,2	‘m’	791	60,5	9,7
656	54,9	99,1	724	41,8	‘m’	792	59,2	9,6
657	55,7	99	725	41,8	‘m’	793	59,9	9,6
658	56	99	726	43,2	17,4	794	59,6	9,6
659	56,1	9,3	727	45	29	795	59,9	6,2
660	55,6	‘m’	728	44,2	‘m’	796	59,9	9,6
661	55,4	‘m’	729	43,9	‘m’	797	60,5	13,1
662	54,9	51,3	730	38	10,7	798	60,3	20,7

Time s	Normal speed %	Normal torque %
799	59,9	31
800	60,5	42
801	61,5	52,5
802	60,9	51,4
803	61,2	57,7
804	62,8	98,8
805	63,4	96,1
806	64,6	45,4
807	64,1	5
808	63	3,2
809	62,7	14,9
810	63,5	35,8
811	64,1	73,3
812	64,3	37,4
813	64,1	21
814	63,7	21
815	62,9	18
816	62,4	32,7
817	61,7	46,2
818	59,8	45,1
819	57,4	43,9
820	54,8	42,8
821	54,3	65,2
822	52,9	62,1
823	52,4	30,6
824	50,4	‘m’
825	48,6	‘m’
826	47,9	‘m’
827	46,8	‘m’
828	46,9	9,4
829	49,5	41,7
830	50,5	37,8
831	52,3	20,4
832	54,1	30,7
833	56,3	41,8
834	58,7	26,5
835	57,3	‘m’
836	59	‘m’
837	59,8	‘m’
838	60,3	‘m’
839	61,2	‘m’
840	61,8	‘m’
841	62,5	‘m’
842	62,4	‘m’
843	61,5	‘m’
844	63,7	‘m’
845	61,9	‘m’
846	61,6	29,7
847	60,3	‘m’
848	59,2	‘m’
849	57,3	‘m’
850	52,3	‘m’
851	49,3	‘m’
852	47,3	‘m’
853	46,3	38,8
854	46,8	35,1
855	46,6	‘m’
856	44,3	‘m’
857	43,1	‘m’
858	42,4	2,1
859	41,8	2,4
860	43,8	68,8
861	44,6	89,2
862	46	99,2
863	46,9	99,4
864	47,9	99,7
865	50,2	99,8
866	51,2	99,6

Time s	Normal speed %	Normal torque %
867	52,3	99,4
868	53	99,3
869	54,2	99,2
870	55,5	99,1
871	56,7	99
872	57,3	98,9
873	58	98,9
874	60,5	31,1
875	60,2	‘m’
876	60,3	‘m’
877	60,5	6,3
878	61,4	19,3
879	60,3	1,2
880	60,5	2,9
881	61,2	34,1
882	61,6	13,2
883	61,5	16,4
884	61,2	16,4
885	61,3	‘m’
886	63,1	‘m’
887	63,2	4,8
888	62,3	22,3
889	62	38,5
890	61,6	29,6
891	61,6	26,6
892	61,8	28,1
893	62	29,6
894	62	16,3
895	61,1	‘m’
896	61,2	‘m’
897	60,7	19,2
898	60,7	32,5
899	60,9	17,8
900	60,1	19,2
901	59,3	38,2
902	59,9	45
903	59,4	32,4
904	59,2	23,5
905	59,5	40,8
906	58,3	‘m’
907	58,2	‘m’
908	57,6	‘m’
909	57,1	‘m’
910	57	0,6
911	57	26,3
912	56,5	29,2
913	56,3	20,5
914	56,1	‘m’
915	55,2	‘m’
916	54,7	17,5
917	55,2	29,2
918	55,2	29,2
919	55,9	16
920	55,9	26,3
921	56,1	36,5
922	55,8	19
923	55,9	9,2
924	55,8	21,9
925	56,4	42,8
926	56,4	38
927	56,4	11
928	56,4	35,1
929	54	7,3
930	53,4	5,4
931	52,3	27,6
932	52,1	32
933	52,3	33,4
934	52,2	34,9

Time s	Normal speed %	Normal torque %
935	52,8	60,1
936	53,7	69,7
937	54	70,7
938	55,1	71,7
939	55,2	46
940	54,7	12,6
941	52,5	0
942	51,8	24,7
943	51,4	43,9
944	50,9	71,1
945	51,2	76,8
946	50,3	87,5
947	50,2	99,8
948	50,9	100
949	49,9	99,7
950	50,9	100
951	49,8	99,7
952	50,4	99,8
953	50,4	99,8
954	49,7	99,7
955	51	100
956	50,3	99,8
957	50,2	99,8
958	49,9	99,7
959	50,9	100
960	50	99,7
961	50,2	99,8
962	50,2	99,8
963	49,9	99,7
964	50,4	99,8
965	50,2	99,8
966	50,3	99,8
967	49,9	99,7
968	51,1	100
969	50,6	99,9
970	49,9	99,7
971	49,6	99,6
972	49,4	99,6
973	49	99,5
974	49,8	99,7
975	50,9	100
976	50,4	99,8
977	49,8	99,7
978	49,1	99,5
979	50,4	99,8
980	49,8	99,7
981	49,3	99,5
982	49,1	99,5
983	49,9	99,7
984	49,1	99,5
985	50,4	99,8
986	50,9	100
987	51,4	99,9
988	51,5	99,9
989	52,2	99,7
990	52,8	74,1
991	53,3	46
992	53,6	36,4
993	53,4	33,5
994	53,9	58,9
995	55,2	73,8
996	55,8	52,4
997	55,7	9,2
998	55,8	2,2
999	56,4	33,6
1000	55,4	‘m’
1001	55,2	‘m’
1002	55,8	26,3

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
1003	55,8	23,3	1071	42,5	'm'	1139	45,5	24,8
1004	56,4	50,2	1072	41	'm'	1140	44,8	73,8
1005	57,6	68,3	1073	39,9	'm'	1141	46,6	99
1006	58,8	90,2	1074	39,9	38,2	1142	46,3	98,9
1007	59,9	98,9	1075	40,1	48,1	1143	48,5	99,4
1008	62,3	98,8	1076	39,9	48	1144	49,9	99,7
1009	63,1	74,4	1077	39,4	59,3	1145	49,1	99,5
1010	63,7	49,4	1078	43,8	19,8	1146	49,1	99,5
1011	63,3	9,8	1079	52,9	0	1147	51	100
1012	48	0	1080	52,8	88,9	1148	51,5	99,9
1013	47,9	73,5	1081	53,4	99,5	1149	50,9	100
1014	49,9	99,7	1082	54,7	99,3	1150	51,6	99,9
1015	49,9	48,8	1083	56,3	99,1	1151	52,1	99,7
1016	49,6	2,3	1084	57,5	99	1152	50,9	100
1017	49,9	'm'	1085	59	98,9	1153	52,2	99,7
1018	49,3	'm'	1086	59,8	98,9	1154	51,5	98,3
1019	49,7	47,5	1087	60,1	98,9	1155	51,5	47,2
1020	49,1	'm'	1088	61,8	48,3	1156	50,8	78,4
1021	49,4	'm'	1089	61,8	55,6	1157	50,3	83
1022	48,3	'm'	1090	61,7	59,8	1158	50,3	31,7
1023	49,4	'm'	1091	62	55,6	1159	49,3	31,3
1024	48,5	'm'	1092	62,3	29,6	1160	48,8	21,5
1025	48,7	'm'	1093	62	19,3	1161	47,8	59,4
1026	48,7	'm'	1094	61,3	7,9	1162	48,1	77,1
1027	49,1	'm'	1095	61,1	19,2	1163	48,4	87,6
1028	49	'm'	1096	61,2	43	1164	49,6	87,5
1029	49,8	'm'	1097	61,1	59,7	1165	51	81,4
1030	48,7	'm'	1098	61,1	98,8	1166	51,6	66,7
1031	48,5	'm'	1099	61,3	98,8	1167	53,3	63,2
1032	49,3	31,3	1100	61,3	26,6	1168	55,2	62
1033	49,7	45,3	1101	60,4	'm'	1169	55,7	43,9
1034	48,3	44,5	1102	58,8	'm'	1170	56,4	30,7
1035	49,8	61	1103	57,7	'm'	1171	56,8	23,4
1036	49,4	64,3	1104	56	'm'	1172	57	'm'
1037	49,8	64,4	1105	54,7	'm'	1173	57,6	'm'
1038	50,5	65,6	1106	53,3	'm'	1174	56,9	'm'
1039	50,3	64,5	1107	52,6	23,2	1175	56,4	4
1040	51,2	82,9	1108	53,4	84,2	1176	57	23,4
1041	50,5	86	1109	53,9	99,4	1177	56,4	41,7
1042	50,6	89	1110	54,9	99,3	1178	57	49,2
1043	50,4	81,4	1111	55,8	99,2	1179	57,7	56,6
1044	49,9	49,9	1112	57,1	99	1180	58,6	56,6
1045	49,1	20,1	1113	56,5	99,1	1181	58,9	64
1046	47,9	24	1114	58,9	98,9	1182	59,4	68,2
1047	48,1	36,2	1115	58,7	98,9	1183	58,8	71,4
1048	47,5	34,5	1116	59,8	98,9	1184	60,1	71,3
1049	46,9	30,3	1117	61	98,8	1185	60,6	79,1
1050	47,7	53,5	1118	60,7	19,2	1186	60,7	83,3
1051	46,9	61,6	1119	59,4	'm'	1187	60,7	77,1
1052	46,5	73,6	1120	57,9	'm'	1188	60	73,5
1053	48	84,6	1121	57,6	'm'	1189	60,2	55,5
1054	47,2	87,7	1122	56,3	'm'	1190	59,7	54,4
1055	48,7	80	1123	55	'm'	1191	59,8	73,3
1056	48,7	50,4	1124	53,7	'm'	1192	59,8	77,9
1057	47,8	38,6	1125	52,1	'm'	1193	59,8	73,9
1058	48,8	63,1	1126	51,1	'm'	1194	60	76,5
1059	47,4	5	1127	49,7	25,8	1195	59,5	82,3
1060	47,3	47,4	1128	49,1	46,1	1196	59,9	82,8
1061	47,3	49,8	1129	48,7	46,9	1197	59,8	65,8
1062	46,9	23,9	1130	48,2	46,7	1198	59	48,6
1063	46,7	44,6	1131	48	70	1199	58,9	62,2
1064	46,8	65,2	1132	48	70	1200	59,1	70,4
1065	46,9	60,4	1133	47,2	67,6	1201	58,9	62,1
1066	46,7	61,5	1134	47,3	67,6	1202	58,4	67,4
1067	45,5	'm'	1135	46,6	74,7	1203	58,7	58,9
1068	45,5	'm'	1136	47,4	13	1204	58,3	57,7
1069	44,2	'm'	1137	46,3	'm'	1205	57,5	57,8
1070	43	'm'	1138	45,4	'm'	1206	57,2	57,6

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
1207	57,1	42,6	1275	60,6	8,2	1343	61,3	19,2
1208	57	70,1	1276	60,6	5,5	1344	61	9,3
1209	56,4	59,6	1277	61	14,3	1345	60,8	44,2
1210	56,7	39	1278	61	12	1346	60,9	55,3
1211	55,9	68,1	1279	61,3	34,2	1347	61,2	56
1212	56,3	79,1	1280	61,2	17,1	1348	60,9	60,1
1213	56,7	89,7	1281	61,5	15,7	1349	60,7	59,1
1214	56	89,4	1282	61	9,5	1350	60,9	56,8
1215	56	93,1	1283	61,1	9,2	1351	60,7	58,1
1216	56,4	93,1	1284	60,5	4,3	1352	59,6	78,4
1217	56,7	94,4	1285	60,2	7,8	1353	59,6	84,6
1218	56,9	94,8	1286	60,2	5,9	1354	59,4	66,6
1219	57	94,1	1287	60,2	5,3	1355	59,3	75,5
1220	57,7	94,3	1288	59,9	4,6	1356	58,9	49,6
1221	57,5	93,7	1289	59,4	21,5	1357	59,1	75,8
1222	58,4	93,2	1290	59,6	15,8	1358	59	77,6
1223	58,7	93,2	1291	59,3	10,1	1359	59	67,8
1224	58,2	93,7	1292	58,9	9,4	1360	59	56,7
1225	58,5	93,1	1293	58,8	9	1361	58,8	54,2
1226	58,8	86,2	1294	58,9	35,4	1362	58,9	59,6
1227	59	72,9	1295	58,9	30,7	1363	58,9	60,8
1228	58,2	59,9	1296	58,9	25,9	1364	59,3	56,1
1229	57,6	8,5	1297	58,7	22,9	1365	58,9	48,5
1230	57,1	47,6	1298	58,7	24,4	1366	59,3	42,9
1231	57,2	74,4	1299	59,3	61	1367	59,4	41,4
1232	57	79,1	1300	60,1	56	1368	59,6	38,9
1233	56,7	67,2	1301	60,5	50,6	1369	59,4	32,9
1234	56,8	69,1	1302	59,5	16,2	1370	59,3	30,6
1235	56,9	71,3	1303	59,7	50	1371	59,4	30
1236	57	77,3	1304	59,7	31,4	1372	59,4	25,3
1237	57,4	78,2	1305	60,1	43,1	1373	58,8	18,6
1238	57,3	70,6	1306	60,8	38,4	1374	59,1	18
1239	57,7	64	1307	60,9	40,2	1375	58,5	10,6
1240	57,5	55,6	1308	61,3	49,7	1376	58,8	10,5
1241	58,6	49,6	1309	61,8	45,9	1377	58,5	8,2
1242	58,2	41,1	1310	62	45,9	1378	58,7	13,7
1243	58,8	40,6	1311	62,2	45,8	1379	59,1	7,8
1244	58,3	21,1	1312	62,6	46,8	1380	59,1	6
1245	58,7	24,9	1313	62,7	44,3	1381	59,1	6
1246	59,1	24,8	1314	62,9	44,4	1382	59,4	13,1
1247	58,6	‘m’	1315	63,1	43,7	1383	59,7	22,3
1248	58,8	‘m’	1316	63,5	46,1	1384	60,7	10,5
1249	58,8	‘m’	1317	63,6	40,7	1385	59,8	9,8
1250	58,7	‘m’	1318	64,3	49,5	1386	60,2	8,8
1251	59,1	‘m’	1319	63,7	27	1387	59,9	8,7
1252	59,1	‘m’	1320	63,8	15	1388	61	9,1
1253	59,4	‘m’	1321	63,6	18,7	1389	60,6	28,2
1254	60,6	2,6	1322	63,4	8,4	1390	60,6	22
1255	59,6	‘m’	1323	63,2	8,7	1391	59,6	23,2
1256	60,1	‘m’	1324	63,3	21,6	1392	59,6	19
1257	60,6	‘m’	1325	62,9	19,7	1393	60,6	38,4
1258	59,6	4,1	1326	63	22,1	1394	59,8	41,6
1259	60,7	7,1	1327	63,1	20,3	1395	60	47,3
1260	60,5	‘m’	1328	61,8	19,1	1396	60,5	55,4
1261	59,7	‘m’	1329	61,6	17,1	1397	60,9	58,7
1262	59,6	‘m’	1330	61	0	1398	61,3	37,9
1263	59,8	‘m’	1331	61,2	22	1399	61,2	38,3
1264	59,6	4,9	1332	60,8	40,3	1400	61,4	58,7
1265	60,1	5,9	1333	61,1	34,3	1401	61,3	51,3
1266	59,9	6,1	1334	60,7	16,1	1402	61,4	71,1
1267	59,7	‘m’	1335	60,6	16,6	1403	61,1	51
1268	59,6	‘m’	1336	60,5	18,5	1404	61,5	56,6
1269	59,7	22	1337	60,6	29,8	1405	61	60,6
1270	59,8	10,3	1338	60,9	19,5	1406	61,1	75,4
1271	59,9	10	1339	60,9	22,3	1407	61,4	69,4
1272	60,6	6,2	1340	61,4	35,8	1408	61,6	69,9
1273	60,5	7,3	1341	61,3	42,9	1409	61,7	59,6
1274	60,2	14,8	1342	61,5	31	1410	61,8	54,8

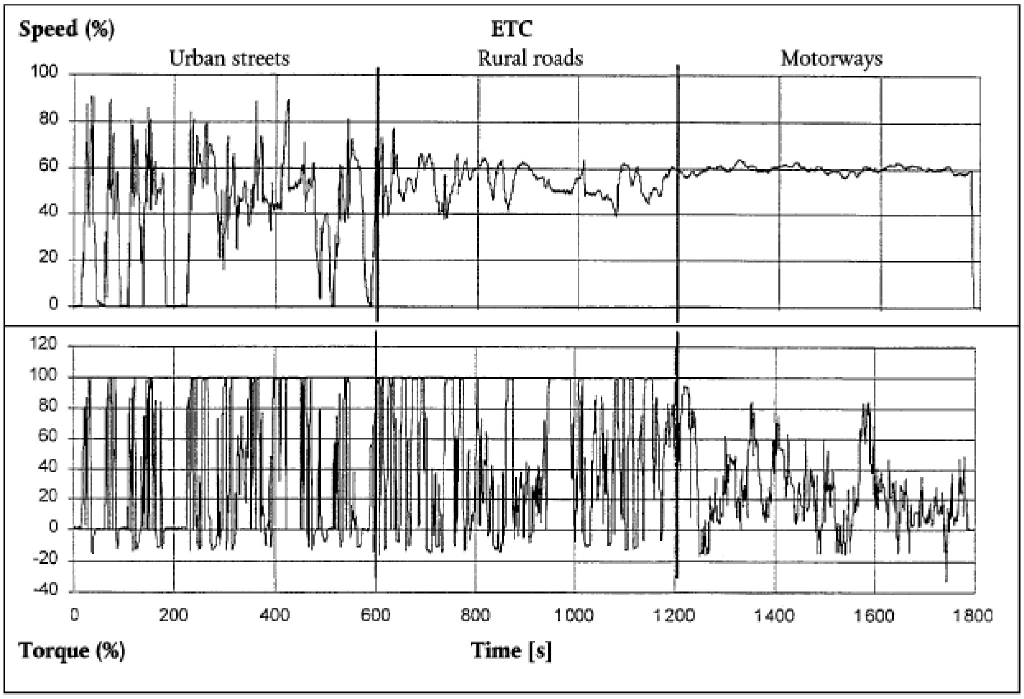
Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
1411	61,6	53,6	1479	60,7	26,7	1547	58,8	6,4
1412	61,3	53,5	1480	60,1	4,7	1548	58,7	5
1413	61,3	52,9	1481	59,9	0	1549	57,5	'm'
1414	61,2	54,1	1482	60,4	36,2	1550	57,4	'm'
1415	61,3	53,2	1483	60,7	32,5	1551	57,1	1,1
1416	61,2	52,2	1484	59,9	3,1	1552	57,1	0
1417	61,2	52,3	1485	59,7	'm'	1553	57	4,5
1418	61	48	1486	59,5	'm'	1554	57,1	3,7
1419	60,9	41,5	1487	59,2	'm'	1555	57,3	3,3
1420	61	32,2	1488	58,8	0,6	1556	57,3	16,8
1421	60,7	22	1489	58,7	'm'	1557	58,2	29,3
1422	60,7	23,3	1490	58,7	'm'	1558	58,7	12,5
1423	60,8	38,8	1491	57,9	'm'	1559	58,3	12,2
1424	61	40,7	1492	58,2	'm'	1560	58,6	12,7
1425	61	30,6	1493	57,6	'm'	1561	59	13,6
1426	61,3	62,6	1494	58,3	9,5	1562	59,8	21,9
1427	61,7	55,9	1495	57,2	6	1563	59,3	20,9
1428	62,3	43,4	1496	57,4	27,3	1564	59,7	19,2
1429	62,3	37,4	1497	58,3	59,9	1565	60,1	15,9
1430	62,3	35,7	1498	58,3	7,3	1566	60,7	16,7
1431	62,8	34,4	1499	58,8	21,7	1567	60,7	18,1
1432	62,8	31,5	1500	58,8	38,9	1568	60,7	40,6
1433	62,9	31,7	1501	59,4	26,2	1569	60,7	59,7
1434	62,9	29,9	1502	59,1	25,5	1570	61,1	66,8
1435	62,8	29,4	1503	59,1	26	1571	61,1	58,8
1436	62,7	28,7	1504	59	39,1	1572	60,8	64,7
1437	61,5	14,7	1505	59,5	52,3	1573	60,1	63,6
1438	61,9	17,2	1506	59,4	31	1574	60,7	83,2
1439	61,5	6,1	1507	59,4	27	1575	60,4	82,2
1440	61	9,9	1508	59,4	29,8	1576	60	80,5
1441	60,9	4,8	1509	59,4	23,1	1577	59,9	78,7
1442	60,6	11,1	1510	58,9	16	1578	60,8	67,9
1443	60,3	6,9	1511	59	31,5	1579	60,4	57,7
1444	60,8	7	1512	58,8	25,9	1580	60,2	60,6
1445	60,2	9,2	1513	58,9	40,2	1581	59,6	72,7
1446	60,5	21,7	1514	58,8	28,4	1582	59,9	73,6
1447	60,2	22,4	1515	58,9	38,9	1583	59,8	74,1
1448	60,7	31,6	1516	59,1	35,3	1584	59,6	84,6
1449	60,9	28,9	1517	58,8	30,3	1585	59,4	76,1
1450	59,6	21,7	1518	59	19	1586	60,1	76,9
1451	60,2	18	1519	58,7	3	1587	59,5	84,6
1452	59,5	16,7	1520	57,9	0	1588	59,8	77,5
1453	59,8	15,7	1521	58	2,4	1589	60,6	67,9
1454	59,6	15,7	1522	57,1	'm'	1590	59,3	47,3
1455	59,3	15,7	1523	56,7	'm'	1591	59,3	43,1
1456	59	7,5	1524	56,7	5,3	1592	59,4	38,3
1457	58,8	7,1	1525	56,6	2,1	1593	58,7	38,2
1458	58,7	16,5	1526	56,8	'm'	1594	58,8	39,2
1459	59,2	50,7	1527	56,3	'm'	1595	59,1	67,9
1460	59,7	60,2	1528	56,3	'm'	1596	59,7	60,5
1461	60,4	44	1529	56	'm'	1597	59,5	32,9
1462	60,2	35,3	1530	56,7	'm'	1598	59,6	20
1463	60,4	17,1	1531	56,6	3,8	1599	59,6	34,4
1464	59,9	13,5	1532	56,9	'm'	1600	59,4	23,9
1465	59,9	12,8	1533	56,9	'm'	1601	59,6	15,7
1466	59,6	14,8	1534	57,4	'm'	1602	59,9	41
1467	59,4	15,9	1535	57,4	'm'	1603	60,5	26,3
1468	59,4	22	1536	58,3	13,9	1604	59,6	14
1469	60,4	38,4	1537	58,5	'm'	1605	59,7	21,2
1470	59,5	38,8	1538	59,1	'm'	1606	60,9	19,6
1471	59,3	31,9	1539	59,4	'm'	1607	60,1	34,3
1472	60,9	40,8	1540	59,6	'm'	1608	59,9	27
1473	60,7	39	1541	59,5	'm'	1609	60,8	25,6
1474	60,9	30,1	1542	59,6	0,5	1610	60,6	26,3
1475	61	29,3	1543	59,3	9,2	1611	60,9	26,1
1476	60,6	28,4	1544	59,4	11,2	1612	61,1	38
1477	60,9	36,3	1545	59,1	26,8	1613	61,2	31,6
1478	60,8	30,5	1546	59	11,7	1614	61,4	30,6

Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %	Time s	Normal speed %	Normal torque %
1615	61,7	29,6	1677	60,6	6,7	1739	60,9	'm'
1616	61,5	28,8	1678	60,6	12,8	1740	60,8	4,8
1617	61,7	27,8	1679	60,7	11,9	1741	59,9	'm'
1618	62,2	20,3	1680	60,6	12,4	1742	59,8	'm'
1619	61,4	19,6	1681	60,1	12,4	1743	59,1	'm'
1620	61,8	19,7	1682	60,5	12	1744	58,8	'm'
1621	61,8	18,7	1683	60,4	11,8	1745	58,8	'm'
1622	61,6	17,7	1684	59,9	12,4	1746	58,2	'm'
1623	61,7	8,7	1685	59,6	12,4	1747	58,5	14,3
1624	61,7	1,4	1686	59,6	9,1	1748	57,5	4,4
1625	61,7	5,9	1687	59,9	0	1749	57,9	0
1626	61,2	8,1	1688	59,9	20,4	1750	57,8	20,9
1627	61,9	45,8	1689	59,8	4,4	1751	58,3	9,2
1628	61,4	31,5	1690	59,4	3,1	1752	57,8	8,2
1629	61,7	22,3	1691	59,5	26,3	1753	57,5	15,3
1630	62,4	21,7	1692	59,6	20,1	1754	58,4	38
1631	62,8	21,9	1693	59,4	35	1755	58,1	15,4
1632	62,2	22,2	1694	60,9	22,1	1756	58,8	11,8
1633	62,5	31	1695	60,5	12,2	1757	58,3	8,1
1634	62,3	31,3	1696	60,1	11	1758	58,3	5,5
1635	62,6	31,7	1697	60,1	8,2	1759	59	4,1
1636	62,3	22,8	1698	60,5	6,7	1760	58,2	4,9
1637	62,7	12,6	1699	60	5,1	1761	57,9	10,1
1638	62,2	15,2	1700	60	5,1	1762	58,5	7,5
1639	61,9	32,6	1701	60	9	1763	57,4	7
1640	62,5	23,1	1702	60,1	5,7	1764	58,2	6,7
1641	61,7	19,4	1703	59,9	8,5	1765	58,2	6,6
1642	61,7	10,8	1704	59,4	6	1766	57,3	17,3
1643	61,6	10,2	1705	59,5	5,5	1767	58	11,4
1644	61,4	'm'	1706	59,5	14,2	1768	57,5	47,4
1645	60,8	'm'	1707	59,5	6,2	1769	57,4	28,8
1646	60,7	'm'	1708	59,4	10,3	1770	58,8	24,3
1647	61	12,4	1709	59,6	13,8	1771	57,7	25,5
1648	60,4	5,3	1710	59,5	13,9	1772	58,4	35,5
1649	61	13,1	1711	60,1	18,9	1773	58,4	29,3
1650	60,7	29,6	1712	59,4	13,1	1774	59	33,8
1651	60,5	28,9	1713	59,8	5,4	1775	59	18,7
1652	60,8	27,1	1714	59,9	2,9	1776	58,8	9,8
1653	61,2	27,3	1715	60,1	7,1	1777	58,8	23,9
1654	60,9	20,6	1716	59,6	12	1778	59,1	48,2
1655	61,1	13,9	1717	59,6	4,9	1779	59,4	37,2
1656	60,7	13,4	1718	59,4	22,7	1780	59,6	29,1
1657	61,3	26,1	1719	59,6	22	1781	50	25
1658	60,9	23,7	1720	60,1	17,4	1782	40	20
1659	61,4	32,1	1721	60,2	16,6	1783	30	15
1660	61,7	33,5	1722	59,4	28,6	1784	20	10
1661	61,8	34,1	1723	60,3	22,4	1785	10	5
1662	61,7	17	1724	59,9	20	1786	0	0
1663	61,7	2,5	1725	60,2	18,6	1787	0	0
1664	61,5	5,9	1726	60,3	11,9	1788	0	0
1665	61,3	14,9	1727	60,4	11,6	1789	0	0
1666	61,5	17,2	1728	60,6	10,6	1790	0	0
1667	61,1	'm'	1729	60,8	16	1791	0	0
1668	61,4	'm'	1730	60,9	17	1792	0	0
1669	61,4	8,8	1731	60,9	16,1	1793	0	0
1670	61,3	8,8	1732	60,7	11,4	1794	0	0
1671	61	18	1733	60,9	11,3	1795	0	0
1672	61,5	13	1734	61,1	11,2	1796	0	0
1673	61	3,7	1735	61,1	25,6	1797	0	0
1674	60,9	3,1	1736	61	14,6	1798	0	0
1675	60,9	4,7	1737	61	10,4	1799	0	0
1676	60,6	4,1	1738	60,6	'm'	1800	0	0

'm' = motoring.

Figure 5

ETC dynamometer schedule



Appendix 4:

MEASUREMENT AND SAMPLING PROCEDURES

1 INTRODUCTION

Gaseous components, particulates, and smoke emitted by the engine submitted for testing shall be measured by the methods described in chapter V of this part. The respective sections of chapter V of this part describe the recommended analytical systems for the gaseous emissions (section 1), the recommended particulate dilution and sampling systems (section 2), and the recommended opacimeters for smoke measurement (section 3).

For the ESC, the gaseous components shall be determined in the raw exhaust gas. Optionally, they may be determined in the diluted exhaust gas, if a full flow dilution system is used for particulate determination. Particulates shall be determined with either a partial flow or a full flow dilution system.

For the ETC, the following systems may be used

- a CVS full flow dilution system for determining gaseous and particulate emissions (double dilution systems are permissible),

or

- a combination of raw exhaust measurement for the gaseous emissions and a partial flow dilution system for particulate emissions,

or

- any combination of the two principles (e.g. raw gaseous measurement and full flow particulate measurement).'

2 DYNAMOMETER AND TEST CELL EQUIPMENT

The following equipment shall be used for emission tests of engines on engine dynamometers.

2.1 Engine dynamometer

An engine dynamometer shall be used with adequate characteristics to perform the test cycles described in appendices 1 and 2 of this chapter. The speed measuring system shall have an accuracy of ± 2 % of reading. The torque measuring system shall have an accuracy of ± 3 % of reading in the range > 20 % of full scale, and an accuracy of ± 0,6 % of full scale in the range < = 20 % of full scale.

2.2 Other instruments

Measuring instruments for fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and intake manifold depression, exhaust gas temperature, air intake temperature, atmospheric pressure, humidity and fuel temperature shall be used, as required. These instruments shall satisfy the requirements given in table 8:

TABLE 8
Accuracy of measuring instruments

Measuring Instrument	Accuracy
Fuel Consumption	± 2 % of Engine's Maximum Value
Air Consumption	± 2 % of reading or ± 1 % of engine's maximum value whichever is greater
Exhaust Gas Flow	± 2,5 % of reading or ± 1,5 % of engine's maximum value whichever is greater
Temperatures ≤ 600 K (327 °C)	± 2 K Absolute
Temperatures ≥ 600 K (327 °C)	± 1 % of Reading
Atmospheric Pressure	± 0,1 kPa Absolute
Exhaust Gas Pressure	± 0,2 kPa Absolute
Intake Depression	± 0,05 kPa Absolute
Other Pressures	± 0,1 kPa Absolute

Relative Humidity	± 3 % Absolute
Absolute Humidity	± 5 % of Reading
Dilution Air Flow	± 2 % of Reading
Diluted Exhaust Gas Flow	± 2 % of Reading

3 DETERMINATION OF THE GASEOUS COMPONENTS:

3.1 General analyser specifications

The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (section 3.1.1 of this appendix). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If read-out systems (computers, data loggers) can provide sufficient accuracy and resolution below 15 % of full scale, measurements below 15 % of full scale are also acceptable. In this case, additional calibrations of at least 4 non-zero nominally equally spaced points are to be made to ensure the accuracy of the calibration curves according to chapter III, appendix 5, section 1.5.5.2 of this part

The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimise additional errors.

3.1.1 Accuracy

The analyser shall not deviate from the nominal calibration point by more than ± 2 % of the reading over the whole measurement range except zero, or ± 0,3 % of full scale whichever is larger. The accuracy shall be determined according to the calibration requirements laid down in section 1.6 of appendix 5 of this chapter.

Note: For the purpose of this part, accuracy is defined as the deviation of the analyser reading from the nominal calibration values using a calibration gas (= true value).

3.1.2 Precision

The precision, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, has to be not greater than ± 1 % of full scale concentration for each range used above 155 ppm (or ppmC) or ± 2 % of each range used below 155 ppm (or ppmC).

3.1.3 Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10 second period shall not exceed 2 % of full scale on all ranges used.

3.1.4 Zero Drift

Zero response is defined as the mean response, including noise, to a zero gas during a 30 seconds time interval. The drift of the zero response during a one hour period shall be less than 2 % of full scale on the lowest range used.

3.1.5 Span Drift

Span response is defined as the mean response, including noise, to a span gas during a 30 seconds time interval. The drift of the span response during a one hour period shall be less than 2 % of full scale on the lowest range used.

3.1.6 Rise time

The rise time of the analyser installed in the measurement system shall not exceed 3,5s.

Note: Only evaluating the response time of the analyser alone will not clearly define the suitability of the total system for transient testing. Volumes and especially dead volumes through out the system will not only effect the transportation time from the probe to the analyser, but also effect the rise time. Also transport times inside of an analyser would be defined as analyser response time, like the converter or water traps inside NO_X analysers. The determination of the total system response time is described in section 1.5 of appendix 5 of this chapter.

3.2 Gas Drying

The optional gas drying device must have a minimal effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

3.3 Analysers

Sections 3.3.1 to 3.3.4 of this appendix describe the measurement principles to be used. A detailed description of the measurement systems is given in chapter

V of this part. The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearising circuits is permitted.

3.3.1 Carbon Monoxide (CO) Analysis

The carbon monoxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

3.3.2 Carbon Dioxide (CO2) Analysis

The carbon dioxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

3.3.3 Hydrocarbon (HC) analysis

For diesel and LPG fuelled gas engines, the hydrocarbon analyser shall be of the Heated Flame Ionisation Detector (HFID) type with detector, valves, pipe work, etc. heated so as to maintain a gas temperature of 463K ± 10K (190 ± 10 °C). For NG fuelled gas engines, the hydrocarbon analyser may be of the non-heated Flame Ionisation Detector (FID) type depending upon the method used (see chapter V, section 1.3 of this part).

3.3.4 Non-Methane Hydrocarbon (NMHC) Analysis (NG Fuelled Gas Engines Only)

Non-methane hydrocarbons shall be determined by either of the following methods:

3.3.4.1 Gas Chromatographic (GC) Method

Non-methane hydrocarbons shall be determined by subtraction of the methane analysed with a Gas Chromatograph (GC) conditioned at 423 K (150 °C) from the hydrocarbons measured according to section 3.3.3 of this appendix.

3.3.4.2 Non-Methane Cutter (NMC) Method

The determination of the non-methane fraction shall be performed with a heated NMC operated in line with an FID as per section 3.3.3 of this appendix by subtraction of the methane from the hydrocarbons.

3.3.5 Oxides of Nitrogen (NOx) Analysis

The oxides of nitrogen analyser shall be of the Chemi Luminescent Detector (CLD) or Heated ChemiLuminescent Detector (HCLD) type with a NO_2/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with converter maintained above 328 K (55 °C) shall be used, provided the water quench check (see chapter III, appendix 5, section 1.9.2.2 of this part) is satisfied.

3.3.6. Air-to-fuel measurement

The air to fuel measurement equipment used to determine the exhaust gas flow as specified in section 4.2.5 of appendix 2 of this Chapter shall be a wide range air to fuel ratio sensor or lambda sensor of Zirconia type. The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.

The accuracy of the sensor with incorporated electronics shall be within:

$\pm$ 3 % of reading $\lambda < 2$

$\pm$ 5 % of reading $2 \leq \lambda < 5$

$\pm$10 % of reading $5 \leq \lambda$

To fulfil the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.

3.4 Sampling of Gaseous Emissions

3.4.1 Raw Exhaust Gas (ESC only)

The gaseous emissions sampling probes must be fitted at least 0,5 m or 3 times the diameter of the exhaust pipe-whichever is the larger-upstream of the exit of the exhaust gas system as far as applicable and sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70 °C) at the probe.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a "Vee" engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from each group with the highest CO_2 emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation the total exhaust mass flow must be used.

If the engine is equipped with an exhaust after treatment system, the exhaust sample shall be taken downstream of the exhaust after treatment system.

3.4.2 Diluted Exhaust Gas

The exhaust pipe between the engine and the full flow dilution system shall conform to the requirements of chapter V, section 2.3.1, EP.

The gaseous emissions sample probe(s) shall be installed in the dilution tunnel at a point where the dilution air and exhaust gas are well mixed, and in close proximity to the particulates sampling probe.

Sampling can generally be done in two ways:

- the pollutants are sampled into a sampling bag over the cycle and measured after completion of the test;

- the pollutants are sampled continuously and integrated over the cycle; this method is mandatory for HC and NOx.

4. DETERMINATION OF THE PARTICULATES:

The determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system or a full flow double dilution system. The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems. The temperature of the diluted exhaust gas shall be below 325 K (52 °C) immediately upstream of the filter holders. Humidity control of the dilution air before entering the dilution system is permitted, and especially dehumidifying is useful if dilution air humidity is high. The temperature of the dilution air shall be higher than 288 K (15 °C) in close proximity to the entrance into the dilution tunnel.

The partial flow dilution system has to be designed to extract a proportional raw exhaust sample from the engine exhaust stream, thus responding to excursions in the exhaust stream flow rate, and introduce dilution air to this sample to achieve a temperature below 325 K (52 °C) at the test filter. For this it is essential that the dilution ratio or the sampling ratio r_{dil} or r_s be determined such that the accuracy limits of section 3.2.1 of appendix 5 of this chapter are fulfilled. Different extraction methods can be applied, whereby the type of extraction used dictates to a significant degree the sampling hardware and procedures to be used (section 2.2 of chapter V of this part).

In general, the particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, but sufficiently distant as to not cause interference. Therefore, the installation provisions of section 3.4.1 of this appendix also apply to particulate sampling. The sampling line shall conform to the requirements of section 2 of chapter V of this part.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a “Vee” engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from the group with the highest particulate emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation the total exhaust mass flow shall be used.

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, a microgram balance, and a temperature and humidity controlled weighing chamber, are required. For particulate sampling, the single filter method shall be applied which uses one filter (see section 4.1.3 of this appendix) for the whole test cycle. For the ESC, considerable attention must be paid to sampling times and flows during the sampling phase of the test.

4.1 Particulate Sampling Filters

The diluted exhaust shall be sampled by a filter that meets the requirements of sections 4.1.1 and 4.1.2 of this appendix during the test sequence.

4.1.1 Filter Specification

Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required. All filter types shall have a 0,3 μ DOP (di-octylphthalate) collection efficiency of at least 99 % at a gas face velocity between 35 and 100 cm/s.

4.1.2 Filter Size

Particulate filters must have a minimum diameter of 47 mm or 70 mm are recommended. Larger diameter filters are acceptable (section 4.1.4 of this appendix) but smaller diameter filters are not permitted.

4.1.3 Filter Face Velocity

A gas face velocity through the filter of 35 to 100 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

4.1.4 Filter Loading

The required minimum filter loadings for the most common filter sizes are shown in table 10. For larger filter sizes, the minimum filter loading shall be 0,065 mg/1 000 mm2 filter area.

Table 9
Minimum Filter Loadings

Filter Diameter (mm)	Minimum loading (mg)
47	0,11
70	0,25
90	0,41
110	0,62

If, based on previous testing, the required minimum filter loading is unlikely to be reached on a test cycle after optimisation of flow rates and dilution ratio, a lower filter loading may be acceptable, with the agreement of the parties involved, if it can be shown to meet the accuracy requirements of section 4.2, e.g. with a 0,1 μg balance.

4.1.5 Filter holder

For the emissions test, the filters shall be placed in a filter holder assembly meeting the requirements of section 2.2 of chapter V of this part. The filter holder assembly shall be of a design that provides an even flow distribution across the filter stain area. Quick acting valves shall be located either upstream or downstream of the filter holder. An inertial pre-classifier with a 50 % cut point between 2,5 μm and 10 μm may be installed immediately upstream of the filter holder. The use of the pre-classifier is strongly recommended if an open tube sampling probe facing upstream into the exhaust flow is used.

4.2 Weighing Chamber and Analytical Balance Specifications

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilization.

Disturbance to weighing room specification as outlined in section 4.2.1 will be allowed if the duration of disturbance does not exceed 30 minutes. The weighing room should meet the required specification prior to personal entrance into the weighing room. At least two unused reference filter shall be weigh within 4 hours of, but preferably at the same time as sample filter weightings. They shall be the same size & material as the sample filter.
If the average weight of the reference filter changes between sample filter weightings by more than 10μg, then all sample filter shall be discarded & the emission test repeated.
If the weighing room stability criteria outlined in section 4.2.1 is not met, but the reference filter weightings meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system & re-running the test.

4.2.1 Weighing Chamber Conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295K ± 3 K (22 °C ± 3 °C) during all filter conditioning and weighing. The humidity shall be maintained to a dew point of 282,5K ± 3 K (9,5 °C ± 3 °C) and a relative humidity of 45 % ± 8 %.

4.2.2 Reference Filter Weighing

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in section 4.2.1 will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personal entrance into the weighing room. At least two unused reference filters shall be weighed within 4 hours of, but preferably at the same time as the sample filter weightings. They shall be the same size and material as the sample filters.

If the average weight of the reference filters changes between sample filter weightings by more than 10 μg, then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in section 4.2.1 is not met, but the reference filter weightings meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

4.2.3 Analytical Balance

The analytical balance used to determine the filter weight shall have a precision (standard deviation) of at least 2 μg and a resolution of at least 1 μg (1 digit = 1 μg) specified by the balance manufacturer.

4.2.4 Elimination of static electricity effects

To eliminate the effects of static electricity, the filters shall be neutralized prior to weighing, e.g. by a Polonium neutralizer, a Faraday cage or a device of similar effect.

4.2.5 Specifications for flow measurement

4.2.5.1 General requirements

Absolute accuracies of flow meter or flow measurement instrumentation shall be as specified in section 2.2 of this appendix.

4.2.5.2 Special provision for partial flow dilution system

For partial flow dilution systems, the accuracy of the sample flow q_{mp} is of special concern, if not measured directly, but determined by differential flow measurement:

$$q_{mp} = q_{mdew} - q_{mdw}$$

In this case an accuracy of ± 2 % for q_{mdew} and q_{mdw} is not sufficient to guarantee acceptable accuracies of q_{mp}. If the gas flow is determined by differential flow measurement, the maximum error of the difference shall be such that the accuracy of q_{mp} is within ± 5 % when the dilution ratio is less than 15. It can be calculated by taking root-mean-square of the errors of each instrument.

Acceptable accuracies of q_{mp} can be obtained by either of the following methods:

The absolute accuracies of q_{mdew} and q_{mdw} are ± 0,2 % which guarantees an accuracy of q_{mp} of $\leq$ 5 % at a dilution ratio of 15. However, greater errors will occur at higher dilution ratios;

calibration of q_{mdw} relative to q_{mdew} is carried out such that the same accuracies

for q_{mp} as in a) are obtained. For the details of such a calibration see section

3.2.1 of appendix 5 of chapter III of this part;

the accuracy of q_{mp} is determined indirectly from the accuracy of the dilution ratio as determined by a tracer gas, e.g. CO_2. Again, accuracies equivalent to method a) for q_{mp} are required;

the absolute accuracy of q_{mdew} and q_{mdw} is within ± 2 % of full scale, the maximum error of the difference between q_{mdew} and q_{mdw} is within 0,2 %, and the linearity error is within ± 0,2 % of the highest q_{mdew} observed during the test.

5 DETERMINATION OF SMOKE

This section provides specifications for the required and optional test equipment to be used for the ELR test. The smoke shall be measured with an opacimeter having an opacity and a light absorption coefficient readout mode. The opacity readout mode shall only be used for calibration and checking of the opacimeter. The smoke values of the test cycle shall be measured in the light absorption coefficient readout mode.

5.1 General Requirements:

The ELR requires the use of a smoke measurement and data processing system which includes three functional units. These units may be integrated into a single component or provided as a system of interconnected components. The three functional units are:

- an opacimeter meeting the specifications of chapter V, section 3 of this part.

- a data processing unit capable of performing the functions described in chapter III, appendix 1, section 6 of this part.

- a printer and/or electronic storage medium to record and output the required smoke values specified in chapter III, appendix 1, section 6.3 of this part.

5.2 Specific Requirements

5.2.1. Linearity

The linearity shall be within ± 2 % opacity.

5.2.2. Zero Drift

The zero drift during a one-hour period shall not exceed ± 1 % opacity.

5.2.3. Opacimeter Display and Range

For display in opacity, the range shall be 0-100 % opacity, and the readability 0,1 % opacity. For display in light absorption coefficient, the range shall be 0-30 m-1 light absorption coefficient, and the readability 0,01 m-1 light absorption coefficient.

5.2.4. Instrument Response Time

The physical response time of the opacimeter shall not exceed 0,2 s. The physical response time is the difference between the times when the output of a rapid response receiver reaches 10 and 90 % of the full deviation when the opacity of the gas being measured is changed in less than 0,1 s.

The electrical response time of the opacimeter shall not exceed 0,05 s. The electrical response time is the difference between the times when the opacimeter output reaches 10 and 90 % of the full scale when the light source is interrupted or completely extinguished in less than 0,01 s.

5.2.5. Neutral Density Filters

Any neutral density filter used in conjunction with opacimeter calibration, linearity measurements, or setting span shall have its value known to within 1,0 % opacity. The filter's nominal value must be checked for accuracy at least yearly using a reference traceable to a national or international standard.

Neutral density filters are precision devices and can easily be damaged during use. Handling should be minimised and, when required, should be done with care to avoid scratching or soiling of the filter.

APPENDIX 5

CALIBRATION PROCEDURE

1 Calibration of the analytical instruments:

1.1 Introduction

Each analyser shall be calibrated as often as necessary to fulfill the accuracy requirements of this part. The calibration method that shall be used is described in this section for the analysers indicated in chapter III, appendix 4, section 3 and chapter V, section 1 of this part.

1.2 Calibration gases

The shelf life of all calibration gases must be respected.

The expiration date of the calibration gases stated by the manufacturer shall be recorded.

1.2.1 Pure gases:

The required purity of the gases is defined by the contamination limits given below. The following gases must be available for operation:

Purified nitrogen

(Contamination ≤ 1 ppm C1, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO)

Purified oxygen

(Purity > 99,5 % vol O_2)

Hydrogen-helium mixture

(40 ± 2 % hydrogen, balance helium)
(Contamination ≤ 1 ppm C1, ≤ 400 ppm CO_2)

Purified synthetic air

(Contamination ≤ 1 ppm C1, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0,1 ppm NO)
(Oxygen content between 18-21 % vol.)
Purified propane or CO for the CVS verification

1.2.2 Calibration and span gases:

Mixtures of gases having the following chemical compositions shall be available:

C_3H_8 and purified synthetic air (see section 1.2.1 of this appendix);

CO and purified nitrogen;

NO_X and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed 5 % of the NO content);

CO_2 and purified nitrogen

CH_4 and purified synthetic air

C_2H_6 and purified synthetic air

Note: Other gas combinations are allowed provided the gases do not react with one another.

The true concentration of a calibration and span gas must be within ± 2 % of the nominal value. All concentrations of calibration gas shall be given on a volume basis (volume percent or volume ppm).

1.2.3 Use of precision blending devices

The gases used for calibration and span may also be obtained by means of precision blending devices (gas dividers), diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the blended calibration gases is accurate to within ± 2 %. This accuracy implies that primary gases used for blending must be known to an accuracy of at least ± 1 %, traceable to national or international gas standards. The verification shall be performed at between 15 and 50 % of full scale for each calibration incorporating a blending device.

Optionally, the blending device may be checked with an instrument, which by nature is linear, e.g. using NO gas with a CLD. The span value of the instrument shall be adjusted with the span gas directly connected to the instrument. The blending device shall be checked at the used settings and the nominal value shall be compared to the measured concentration of the instrument. This difference shall in each point be within ± 1 % of the nominal value.

1.3 Operating Procedure for Analysers and Sampling System

The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The minimum requirements given in sections 1.4 to 1.9 of this appendix shall be included.

1.4 Leakage test

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 stabilisation period all flow meters should read zero. If not, the sampling lines shall be checked and the fault corrected.

The maximum allowable leakage rate on the vacuum side shall be 0,5 % of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilization period the pressure increase Δp (kPa/min) in the system should not exceed:

$$\Delta p = p / V_s \times 0{,}005 \times q_{vs}$$

Where,

V_s = system volume, l

q_{vs} = system flow rate, l/min

Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas. If after an adequate period of time the reading is about 1 % low compared to the introduced concentration, these points to calibration or leakage problems.

1.5 Response time check of analytical system :

The system settings for the response time evaluation shall be exactly the same as during measurement of the test run (i.e. pressure, flow rates, filter settings on the analyzers and all other response time influences). The response time determination shall be done with gas switching directly at the inlet of the sample probe. The gas switching shall be done in less than 0,1 second. The gases used for the test shall cause a concentration change of at least 60 % FS.

The concentration trace of each single gas component shall be recorded. The response time is defined to be the difference in time between the gas switching and the appropriate change of the recorded concentration. The system response time (t_{90}) consists of the delay time to the measuring detector and the rise time of the detector. The delay time is defined as the time from the change (t_0) until the response is 10 % of the final reading (t_{10}). The rise time is defined as the time between 10 % and 90 % response of the final reading (t_{90} - t_{10}).

For time alignment of the analyzer and exhaust flow signals in the case of raw measurement, the transformation time is defined as the time from the change (t_0) until the response is 50 % of the final reading (t_{50}).

The system response time shall be ≤ 10 seconds with a rise time ≤ 3,5 seconds for all limited components (CO, NO_x, HC or NMHC) and all ranges used.

1.6 Calibration Procedure:

1.6.1 Instrument Assembly

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.

1.6.2 Warming-up Time

The warming-up time should be according to the recommendations of the manufacturer. If not specified, a minimum of two hours is recommended for warming up the analysers.

1.6.3 NDIR and HFID Analyser

The NDIR analyser shall be tuned, as necessary, and the combustion flame of the HFID analyser shall be optimised (section 1.8.1 of this appendix).

1.6.4 Establishment of the calibration curve

- Each normally used operating range shall be calibrated
- Using purified synthetic air (or nitrogen), the CO, CO_2, NO_X and HC analysers shall be set at zero
- The appropriate calibration gases shall be introduced to the analysers, the values recorded, and the calibration curve established
- The calibration curve shall be established by at least 6 calibration points (excluding zero) approximately equally spaced over the operating range.

The highest nominal concentration shall be equal to or higher than 90 % of full scale.

- The calibration curve shall be calculated by the method of least squares. A best-fit linear or non-linear equation may be used
- The calibration points shall not differ from the least-squares best-fit line by more than ± 2 % of reading or ± 0,3 % of full scale whichever is larger
- The zero setting shall be rechecked and the calibration procedure repeated, if necessary.

1.6.5 Alternative methods

If it can be shown that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

1.6.6 Calibration of tracer gas analyser for exhaust flow measurement

The calibration curve shall be established by at least 6 calibration points (excluding zero) approximately equally spaced over the operating range. The highest nominal concentration shall be equal to or higher than 90 % of full scale. The calibration curve is calculated by the method of least squares.

The calibration points shall not differ from the least-squares best-fit line by more than ± 2 % of reading or ± 0,3 % of full scale whichever is larger.

The analyser shall be set at zero and spanned prior to the test run using a zero gas and a span gas whose nominal value is more than 80 % of the analyser full scale.

1.6.7 Verification of the Calibration

Each normally used operating range shall be checked prior to each analysis in accordance with the following procedure.

The calibration shall be checked by using a zero gas and a span gas whose nominal value is more than 80 % of full scale of the measuring range.

If, for the two points considered, the value found does not differ by more than ± 4 % of full scale from the declared reference value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with section 1.5.5 of this appendix.

1.7 Efficiency test of the NOx Converter

The efficiency of the converter used for the conversion of NO_2 into NO shall be tested as given in sections 1.7.1 to 1.7.8 (Figure 6) of this appendix.

1.7.1 Test Set-up

Using the test set-up as shown in Figure 6 (see also chapter III, appendix 4, section 3.3.5 of this part) and the procedure below, the efficiency of converters can be tested by means of an ozonator.

1.7.2 Calibration

The CLD and the HCLD shall be calibrated 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 than 5 % of the NO concentration). The NO_X analyser must be in the NO mode so that the span gas does not pass through the converter. The indicated concentration has to be recorded.

1.7.3 Calculation

The efficiency of the NO_x converter is calculated as follows:

$$\text{Efficiency (\%)} = \left(1 + \frac{a-b}{c-d}\right) \times 100$$

where,

a is the NOx concentration according to section 1.7.6

b is the NOx concentration according to section 1.7.7

c is the NO concentration according to section 1.7.4

d is the NO concentration according to section 1.7.5

1.7.4 Adding of Oxygen

Via a T-fitting, oxygen or zero air is added continuously to the gas flow until the concentration indicated is about 20 % less than the indicated calibration concentration given in section 1.7.2 of this appendix (The analyser is in the NO mode). The indicated concentration c shall be recorded. The ozonator is kept deactivated throughout the process.

1.7.5 Activation of the Ozonator

The ozonator is now activated to generate enough ozone to bring the NO concentration down to about 20 % (minimum 10 %) of the calibration concentration given in section 1.7.2 of this appendix. The indicated concentration d shall be recorded (The analyser is in the NO mode).

1.7.6 NO_X Mode

The NO analyser is then switched to the NOx mode so that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. The indicated concentration a shall be recorded. (The analyser is in the NO_X mode).

1.7.7 Deactivation of the Ozonator

The ozonator is now deactivated. The mixture of gases described in section 1.7.6 of this appendix passes through the converter into the detector. The indicated concentration b shall be recorded. (The analyser is in the NO_X mode).

1.7.8 NO Mode

Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NOx reading of the analyser shall not deviate by more than ± 5 % from the value measured according to section 1.7.2. of this appendix (The analyser is in the NO mode).

1.7.9 Test Interval

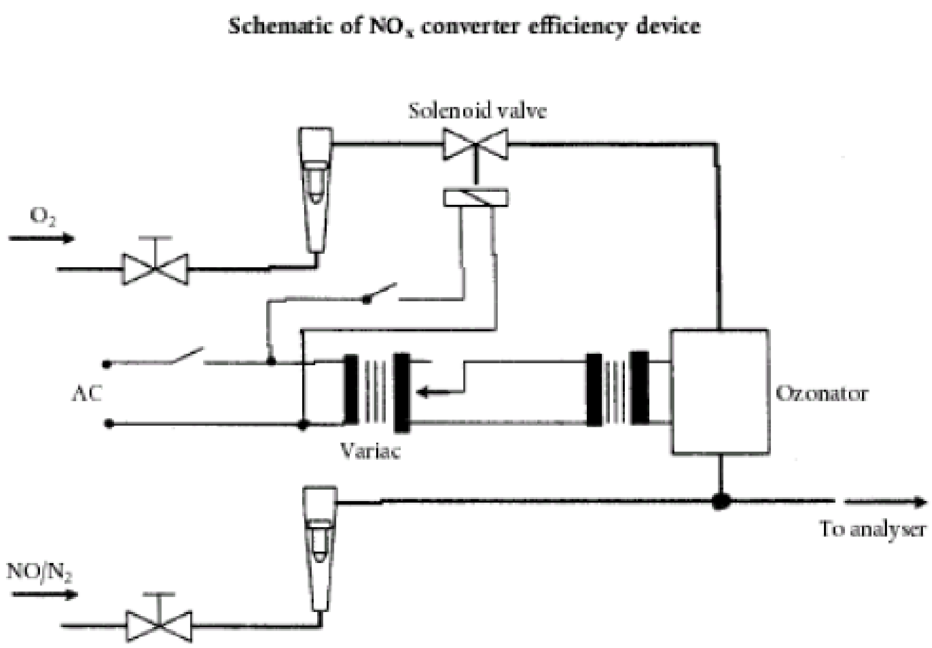
The efficiency of the converter must be tested prior to each calibration of the NO_X analyser.

1.7.10 Efficiency Requirement

The efficiency of the converter shall not be less than 90 %, but a higher efficiency of 95 % is strongly recommended.

Note: If, with the analyser in the most common range, the ozonator cannot give a reduction from 80 % to 20 % according to section 1.7.5 of this appendix, then the highest range which will give the reduction shall be used.

Figure 6



1.8 Adjustment of the FID

1.8.1 Optimisation of the Detector Response

The FID must be adjusted as specified by the instrument manufacturer. A propane in air span gas should be used to optimise the response on the most common operating range.

With the fuel and air flow rates set at the manufacturer's recommendations, a 350 ± 75 ppm C span gas shall be introduced to the analyser. The response at a given fuel flow shall be determined from the difference between the span gas response and the zero gas response. The fuel flow shall be incrementally adjusted above and below the manufacturer's specification. The span and zero response at these fuel flows shall be recorded. The difference between the span and zero response shall be plotted and the fuel flow adjusted to the rich side of the curve.

1.8.2 Hydrocarbon Response Factors

The analyser shall be calibrated using propane in air and purified synthetic air, according to section 1.5 of this appendix.

Response factors shall be determined when introducing an analyser into service and after major service intervals. The response factor (R_f) for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas concentration in the cylinder expressed by ppm C1.

The concentration of the test gas must be at a level to give a response of approximately 80 % of full scale. 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 of 298 K ± 5 K (25 °C ± 5 °C).

The test gases to be used and the recommended relative response factor ranges are as follows:

Methane and purified synthetic air 1,00 < = R_f < = 1,15

Propylene and purified synthetic air 0,90 < = R_f < = 1,10

Toluene and purified synthetic air 0,90 < = R_f < = 1,10

These values are relative to the response factor (R_f) of 1,00 for propane and purified synthetic air.

1.8.3 Oxygen Interference Check

The oxygen interference check shall be determined when introducing an analyzer into service and after major service intervals.

The response factor is defined and shall be determined as described in section 1.8.2 of this appendix. The test gas to be used and the recommended relative response factor range are as follows:

Propane and nitrogen $0,95 \leq R_f \leq 1,05$

This value is relative to the response factor (R_f) of 1,00 for propane and purified synthetic air.

The FID burner air oxygen concentration must be within ± 1 mole% of the oxygen concentration of the burner air used in the latest oxygen interference check. If the difference is greater, the oxygen interference must be checked and the analyzer adjusted, if necessary.

1.8.4 Efficiency of the Non-Methane Cutter (NMC, For NG Fuelled Gas Engines Only)

The NMC is used for the removal of the non-methane hydrocarbons from the sample gas by oxidising all hydrocarbons except methane. Ideally, the conversion for methane is 0 %, and for the other hydrocarbons represented by ethane is 100 %. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emission mass flow rate (see chapter III, appendix 2, section 4.3 of this part).

1.8.4.1 Methane Efficiency

Methane calibration gas shall be flown through the FID with and without by passing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$CE_M = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

concw = HC concentration with CH_4 flowing through the NMC

concw/o = HC concentration with CH_4 bypassing the NMC

1.8.4.2 Ethane Efficiency

Ethane calibration gas shall be flown through the FID with and without bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$CE_E = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

concw = HC concentration with C_2H_6 flowing through the NMC

concw/o = HC concentration with C_2H_6 bypassing the NMC

1.9 Interference Effects with CO, CO_2, and NO_X Analysers

Gases present in the exhaust other than the one being analysed can interfere with the reading in several ways. Positive interference occurs in NDIR instruments where the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks in sections 1.9.1 and 1.9.2 of this appendix shall be performed prior to an analyser's initial use and after major service intervals.

1.9.1 CO Analyser Interference Check

Water and CO_2 can interfere with the CO analyser performance. Therefore, a CO_2 span gas having a concentration of 80 to 100 % of full scale of the maximum operating range used during testing shall be bubbled through water at room temperature and the analyser response recorded. The analyser response must not be more than 1 % of full scale for ranges equal to or above 300 ppm or more than 3 ppm for ranges below 300 ppm.

1.9.2 NO_X Analyser Quench Checks

The two gases of concern for CLD (and HCLD) analysers are CO_2 and water vapour. Quench responses to these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.

1.9.2.1 CO_2 Quench Check

A CO_2 span gas having a concentration of 80 to 100 % of full scale of the maximum operating range shall be passed through the NDIR analyser and the CO_2 value recorded as A. It shall then be diluted approximately 50 % with NO span gas and passed through the NDIR and (H)CLD, with the CO_2 and NO values recorded as B and C, respectively. The CO_2 shall then be shut off and only the NO span gas be passed through the (H)CLD and the NO value recorded as D.

The quench, which must not be greater than 3 % of full scale, shall be calculated as follows:

$$\% \text{ quench} = \left[1 - \left(\frac{C \times A}{(D \times A) - (D \times B)}\right)\right] \times 100$$

where,

A is the undiluted CO_2 concentration measured with NDIR in %

B is the diluted CO_2 concentration measured with NDIR in %

C is the diluted NO concentration measured with (H)CLD in ppm

D is the undiluted NO concentration measured with (H)CLD in ppm

Alternative methods of diluting and quantifying of CO_2 and NO span gas values such as dynamic mixing/blending can be used.

1.9.2.2 Water Quench Check

This check applies to wet gas concentration measurements only. Calculation of water quench must consider dilution of the NO span gas with water vapour and scaling of water vapour concentration of the mixture to that expected during testing.

A NO span gas having a concentration of 80 to 100 % of full scale of the normal operating range shall be passed through the (H)CLD and the NO value recorded as D. The NO span gas shall then be bubbled through water at room temperature and passed through the (H)CLD and the NO value recorded as C. The analyser's absolute operating pressure and the water temperature shall be determined and recorded as E and F, respectively. The mixture's saturation vapour pressure that corresponds to the bubbler water temperature F shall be determined and recorded as G. The water vapour concentration (H, in %) of the mixture shall be calculated as follows:

$$H = 100 \times (G/E)$$

The expected diluted NO span gas (in water vapour) concentration (D_e) shall be calculated as follows:

$$D_e = D \times (1 – H/100)$$

For diesel exhaust, the maximum exhaust water vapour concentration (Hm, in %) expected during testing shall be estimated, under the assumption of a fuel atom H/C ratio of 1,8:1, from the undiluted CO2 span gas concentration (A, as measured in section 1.9.2.1 of this appendix) as follows:

$$Hm = 0{,}9 \times A$$

The water quench, which must not be greater than 3 %, shall be calculated as follows:

$$\% \text{ Quench} = 100 \times ((D_e – C) / D_e) \times H_m / H)$$

where,

D_e= is the expected diluted NO concentration in ppm

C= is the diluted NO concentration in ppm

H_m= is the maximum water vapour concentration in %

H= is the actual water vapour concentration in %

Note: It is important that the NO span gas contains minimal NO_2 concentration for this check, since absorption of NO_2 in water has not been accounted for in the quench calculations.

1.10 Calibration Intervals

The analysers shall be calibrated according to section 1.5 at least every 3 months or whenever a system repair or change is made that could influence calibration.

2 CALIBRATION OF THE CVS-SYSTEM

2.1 General

The CVS system shall be calibrated by using an accurate flow meter traceable to national or international standards and a restricting device. The flow through the system shall be measured at different restriction settings, and the control parameters of the system shall be measured and related to the flow.

Various types of flow meters may be used, e.g. calibrated venturi, calibrated laminar flow meter, calibrated turbine meter.

2.2 Calibration of the Positive Displacement Pump (PDP)

All parameters related to the pump shall be simultaneously measured with the parameters related to the flow meter, which is connected in series with the pump. The calculated flow rate (in m^3/min at pump inlet, absolute pressure and temperature) shall be plotted versus a correlation function, which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function shall then be determined. If a CVS has a multiple speed drive, the calibration shall be performed for each range used. Temperature stability shall be maintained during calibration.

2.2.1 Data Analysis

The airflow rate (Q_s) at each restriction setting (minimum 6 settings) shall be calculated in standard m^3/min from the flow meter data using the manufacturer's prescribed method. The airflow rate shall then be converted to pump flow (V_0) in m^3/rev at absolute pump inlet temperature and pressure as follows:

$$V_o = \frac{Q_s}{n} \times \frac{T}{273} \times \frac{101.3}{PA}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at pump inlet, K

p_A = absolute pressure at pump inlet (p_B-p_1), kPa

n = pump speed, rev/s

To account for the interaction of pressure variations at the pump and the pump slip rate, the correlation function (X_0) between pump speed, pressure differential from pump inlet to pump outlet and absolute pump outlet pressure shall be calculated as follows:

$$Xo = \frac{1}{n} \times \sqrt{\frac{\Delta Pp}{P_A}}$$

where,

Δp_p = pressure differential from pump inlet to pump outlet, kPa

p_A = absolute outlet pressure at pump outlet, kPa

A linear least-square fit shall be performed to generate the calibration equation as follows:

$$V_o = D_o - m \times (X_o)$$

D_o and m are the intercept and slope constants, respectively, describing the regression lines.

For a CVS system with multiple speeds, the calibration curves generated for the different pump flow ranges shall be approximately parallel, and the intercept values (D_0) shall increase as the pump flow range decreases.

The calculated values from the equation shall be within ± 0,5 % of the measured value of V_0. Values of m will vary from one pump to another. Particulate influx over time will cause the pump slip to decrease, as reflected by lower values for m. Therefore, calibration shall be performed at pump start-up, after major maintenance, and if the total system verification (section 2.4 of this appendix) indicates a change of the slip rate.

2.3 Calibration of the Critical Flow Venturi (CFV)

Calibration of the CFV is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature, as shown below:

$$Qs = \frac{K_V \times P_A}{\sqrt{T}}$$

where,

K_v = calibration coefficient

P_A = absolute pressure at venturi inlet, kPa

T= temperature at venturi inlet, K

2.3.1 Data Analysis

The air flowrate (Q_s) at each restriction setting (minimum 8 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The calibration coefficient shall be calculated from the calibration data for each setting as follows:

$$K_V = \frac{Q_s \sqrt{T}}{PA}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at the venturi inlet, K

p_A = absolute pressure at venturi inlet, kPa

To determine the range of critical flow, K_v shall be plotted as a function of venturi inlet pressure. For critical (choked) flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases, which indicates that the CFV is operated outside the permissible range.

For a minimum of eight points in the region of critical flow, the average K_v and the standard deviation shall be calculated. The standard deviation shall not exceed ± 0,3 % of the average Kv.

2.4 Calibration of the Subsonic Venturi (SSV)

Calibration of the SSV is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, pressure drop between the SSV inlet and throat.

2.4.1 Data analysis

The air flowrate (Q_{SSV}) at each restriction setting (minimum 16 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The discharge coefficient shall be calculated from the calibration data for each setting as follows:

$$Q_{SSV} = A_0 d^2 C_d p_p \sqrt{\left[\frac{1}{T}\left(r_p^{1,4286} - r_p^{1,7143}\right) \times \left(\frac{1}{1 - r_D^4 r_p^{1,4286}}\right)\right]}$$

where:

Q_{SSV} = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at the venturi inlet, K

d = diameter of the SSV throat, m

r_p = ratio of the SSV throat to inlet absolute, static pressure = $1 - \frac{\Delta P}{P_A}$

r_D = ratio of the SSV throat diameter, d, to the inlet pipe inner diameter = d / D

To determine the range of subsonic flow, C_d shall be plotted as a function of Reynolds number at the SSV throat. The Re at the SSV throat is calculated with the following formula:

$$\mathrm{Re} = A_1 \frac{Q_{SSV}}{d\mu}$$

where:

A_1 = a collection of constants and units conversions

$$= 25{,}55152 \left(\frac{1}{m^3}\right)\left(\frac{\min}{s}\right)\left(\frac{mm}{m}\right)$$

Q_{SSV} = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

d = diameter of the SSV throat, m

μ = absolute or dynamic viscosity of the gas, calculated with the following formula:

$$\mu = \frac{bT^{3/2}}{S+T} = \frac{bT^{1/2}}{1+\frac{S}{T}} \text{ kg/m-s}$$

b = empirical constant = $1{,}458 \times 10^{6} \frac{kg}{msK^{\frac{1}{2}}}$

S = empirical constant = 110,4 K

Because Q_{SSV} is an input to the Re formula, the calculations must be started with an initial guess for Q_{SSV} or C_d of the calibration venturi, and repeated until Q_{SSV} converges. The convergence method must be accurate to 0,1 % of point or better.

For a minimum of sixteen points in the region of subsonic flow, the calculated values of C_d from the resulting calibration curve fit equation must be within ±0,5% of the measured C_d for each calibration point.

2.5 Total System Verification:

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analysed, and the mass calculated according to chapter III, appendix 2, section 4.3 of this part except in the case of propane where a factor of 0,000472 is used in place of 0,000479 for HC. Either of the following two techniques shall be used.

2.5.1 Metering with a Critical Flow Orifice

A known quantity of pure gas (carbon monoxide or propane) shall be fed into the CVS system through a calibrated critical orifice. If the inlet pressure is high enough, the flow rate, which is adjusted by means of the critical flow orifice, is independent of the orifice outlet pressure (≡ critical flow). The CVS system shall be operated as in a normal exhaust emission test for about 5 to 10 minutes. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within ± 3 % of the known mass of the gas injected.

2.5.2 Metering by Means of a Gravimetric Technique

The weight of a small cylinder filled with carbon monoxide or propane shall be determined with a precision of ± 0,01 gram. For about 5 to 10 minutes, the CVS system shall be operated as in a normal exhaust emission test, while carbon monoxide or propane is injected into the system. The quantity of pure gas discharged shall be determined by means of differential weighing. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within ± 3 % of the known mass of the gas injected.

3 CALIBRATION OF THE PARTICULATE MEASURING SYSTEM

3.1 Introduction

The calibration of the particulate measurement is limited to the flow meters used to determine sample flow and dilution ratio. Each flow meter shall be calibrated as often as necessary to fulfill the accuracy requirements of this Document. The calibration method that shall be used is described in section 3.2 of this appendix.

3.2 Flow measurement

3.2.1 Periodical calibration

- To fulfill the absolute accuracy of the flow measurements as specified in section 2.2 of appendix 4 of this Chapter, the flow meter or the flow measurement instrumentation shall be calibrated with an accurate flow meter traceable to international and/or national standards.

- If the sample gas flow is determined by differential flow measurement the flow meter or the flow measurement instrumentation shall be calibrated in one of the following procedures, such that the probe flow q_{mp} into the tunnel shall fulfill the accuracy requirements of section 4.2.5.2 of appendix 4 of this Chapter:

a) The flow meter for q_{mdw} shall be connected in series to the flow meter for q_{mdew}, the difference between the two flow meters shall be calibrated for at least 5 set points with flow values equally spaced between the lowest q_{mdw} value used during the test and the value of q_{mdew} used during the test. The dilution tunnel may be bypassed.

b) A calibrated mass flow device shall be connected in series to the flow meter for q_{mdew} and the accuracy shall be checked for the value used for the test. Then the calibrated mass flow device shall be connected in series to the flow meter for q_{mdw}, and the accuracy shall be checked for at least 5 settings corresponding to dilution ratio between 3 and 50, relative to q_{mdew} used during the test.

c) The transfer tube TT shall be disconnected from the exhaust, and a calibrated flow measuring device with a suitable range to measure q_{mp} shall be connected to the transfer tube. Then q_{mdew} shall be set to the value used during the test, and q_{mdw} shall be sequentially set to at least 5 values corresponding to dilution ratios q between 3 and 50. Alternatively, a special calibration flow path, may be provided, in which the tunnel is bypassed, but the total and dilution air flow through the corresponding meters as in the actual test.

d) A tracer gas, shall be fed into the exhaust transfer tube TT. This tracer gas may be a component of the exhaust gas, like CO_2 or NO_x. After dilution in the tunnel the tracer gas component shall be measured. This shall be carried out for 5 dilution ratios between 3 and 50. The accuracy of the sample flow shall be determined from the dilution ration r_d:

$$q_{mp} = \frac{q_{mdew}}{r_d}$$

- The accuracies of the gas analysers shall be taken into account to guarantee the accuracy of $q_{mp.}$

3.2.2 Carbon flow check

- 1A carbon flow check using actual exhaust is recommended for detecting measurement and control problems and verifying the proper operation of the partial flow system. The carbon flow check should be run at least each time a new engine is installed, or something significant is changed in the test cell configuration.

- The engine shall be operated at peak torque load and speed or any other steady state mode that produces 5 % or more of CO_2. The partial flow sampling system shall be operated with a dilution factor of about 15 to 1.

- If a carbon flow check is conducted, the procedure given in appendix 6 of this Chapter shall be applied. The carbon flow rates shall be calculated according to sections 2.1 to 2.3 of appendix 6 of this Chapter. All carbon flow rates should agree to within 6 % of each other.

3.2.3 Pre-test check

- A pre-test check shall be performed within 2 hours before the test run in the following way:

- The accuracy of the flow meters shall be checked by the same method as used for calibration (see section 3.2.1 of this appendix) for at least two points, including flow values of q_{mdw} that correspond to dilution ratios between 5 and 15 for the q_{mdew} value used during the test.
- If it can be demonstrated by records of the calibration procedure under section 3.2.1 of this appendix that the flow meter calibration is stable over a longer period of time, the pre-test check may be omitted.

3.3 Determination of transformation time (for partial flow dilution systems on ETC only)

- The system settings for the transformation time evaluation shall be exactly the same as during measurement of the test run. The transformation time shall be determined by the following method:

- An independent reference flowmeter with a measurement range appropriate for the probe flow shall be put in series with and closely coupled to the probe. This flowmeter shall have a transformation time of less than 100 ms for the flow step size used in the response time measurement, with flow restriction sufficiently low as to not affect the dynamic performance of the partial flow dilution system, and consistent with good engineering practice.

- A step change shall be introduced to the exhaust flow (or air flow if exhaust flow is calculated) input of the partial flow dilution system, from a low flow to at least 90 % of full scale. The trigger for the step change should be the same one used to start the look-ahead control in actual testing. The exhaust flow step stimulus and the flowmeter response shall be recorded at a sample rate of at least 10 Hz.

- From this data, the transformation time shall be determined for the partial flow dilution system, which is the time from the initiation of the step stimulus to the 50% point of the flow meter response. In a similar manner, the transformation times of the q_{mp} signal of the partial flow dilution system and of the $q_{mew,i}$ signal of the exhaust flow meter shall be determined. These signals are used in the regression checks performed after each test (see section 3.8.3.2 of appendix 2 of this chapter).

- The calculation shall be repeated for at least 5 rise and fall stimuli, and the results shall be averaged. The internal transformation time (< 100 msec) of the reference flowmeter shall be subtracted from this value. This is the "look-ahead" value of the partial flow dilution system, which shall be applied in accordance with section 3.8.3.2 of appendix 2 of this chapter.

3.4 Checking the partial flow conditions

The range of the exhaust gas velocity and the pressure oscillations shall be checked and adjusted according to the requirements of section 2.2.1 of chapter V (EP), if applicable.

3.5 Calibration intervals

The flow measurement instrumentation shall be calibrated at least every 3 months or whenever a system repair or change is made that could influence calibration.

4 CALIBRATION OF THE SMOKE MEASUREMENT EQUIPMENT

4.1 Introduction

The opacimeter shall be calibrated as often as necessary to fulfill the accuracy requirements of this part. The calibration method to be used is described in this section for the components indicated in chapter III, appendix 4, section 5 of this part and chapter V, section 3 of this part.

4.2 Calibration Procedure

4.2.1 Warming-up Time

The opacimeter shall be warmed up and stabilised according to the manufacturer's recommendations. If the opacimeter is equipped with a purge air system to prevent sooting of the instrument optics, this system should also be activated and adjusted according to the manufacturer's recommendations.

4.2.2 Establishment of the Linearity Response

The linearity of the opacimeter shall be checked in the opacity readout mode as per the manufacturer's recommendations. Three neutral density filters of known transmittance, which shall meet the requirements of chapter III, appendix 4,section 5.2.5 of this part, shall be introduced to the opacimeter and the value recorded. The neutral density filters shall have nominal opacities of approximately 10 %, 20 and 40 %.

The linearity must not differ by more than ± 2 % opacity from the nominal value of the neutral density filter. Any non-linearity exceeding the above value must be corrected prior to the test.

4.3 Calibration Intervals
The opacimeter shall be calibrated according to section 4.2.2 of this appendix at least every 3 months or whenever a system repair or change is made that could influence calibration.

Appendix 6

CARBON FLOW CHECK

1. INTRODUCTION

All but a tiny part of the carbon in the exhaust comes from the fuel, and all but a minimal part of this is manifest in the exhaust gas as CO_2. This is the basis for a system verification check based on CO_2 measurements.

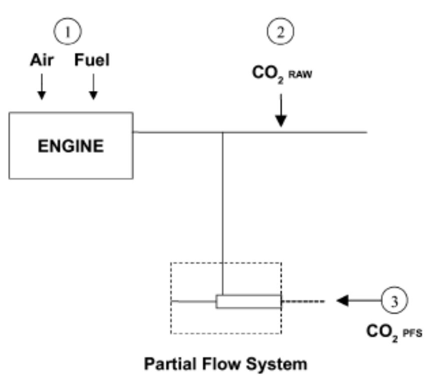
The flow of carbon into the exhaust measurement systems is determined from the fuel flow rate. The flow of carbon at various sampling points in the emissions and particulate sampling systems is determined from the CO_2 concentrations and gas flow rates at those points.

In this sense, the engine provides a known source of carbon flow, and observing the same carbon flow in the exhaust pipe and at the outlet of the partial flow PM sampling system verifies leak integrity and flow measurement accuracy. This check has the advantage that the components are operating under actual engine test conditions of temperature and flow.

The following diagram shows the sampling points at which the carbon flows shall be checked. The specific equations for the carbon flows at each of the sample points are given below.

Figure 7

Measuring points for carbon flow check



2 CALCULATIONS

2.1 Carbon flow rate into the engine (location 1)

The carbon mass flow rate into the engine for a fuel $CH_\alpha O_\varepsilon$ is given by:

$$q_{mCf} = \frac{12{,}011}{12{,}011 + \alpha + 15{,}9994 \times \varepsilon} \times q_{mf}$$

where:

q_{mf} = fuel mass flow rate, kg/s

2.2 Carbon flow rate in the raw exhaust (location 2)

The carbon mass flow rate in the exhaust pipe of the engine shall be determined from the raw CO_2 concentration and the exhaust gas mass flow rate:

$$q_{mCe} = \left(\frac{c_{CO2,r} - c_{CO2,a}}{100} \right) \times q_{mew} \times \frac{12{,}011}{M_{re}}$$

where:

$c_{CO2,r}$ = wet CO_2 concentration in the raw exhaust gas, %

$c_{CO2,a}$ = wet CO_2 concentration in the ambient air, % (around 0,04 %)

q_{mew} = exhaust gas mass flow rate on wet basis, kg/s

M_{re} = molecular mass of exhaust gas

If CO_2 is measured on a dry basis it shall be converted to a wet basis according to section 5.2 of appendix 1 of this chapter.

2.3 Carbon flow rate in the dilution system (location 3)

The carbon flow rate shall be determined from the dilute CO_2 concentration, the exhaust gas mass flow rate and the sample flow rate:

$$q_{mCp} = \left(\frac{c_{CO2,d} - c_{CO2,a}}{100}\right) \times q_{mdew} \times \frac{12{,}011}{M_{re}} \times \frac{q_{mew}}{q_{mp}}$$

where:

$c_{CO2,d}$ = wet CO_2 concentration in the dilute exhaust gas at the outlet of the dilution tunnel, %

$c_{CO2,a}$ = wet CO_2 concentration in the ambient air, % (around 0,04 %)

q_{mdew} = diluted exhaust gas mass flow rate on wet basis, kg/s

q_{mew} = exhaust gas mass flow rate on wet basis, kg/s (partial flow system only)

q_{mp} = sample flow of exhaust gas into partial flow dilution system, kg/s (partial flow system only)

M_{re} = molecular mass of exhaust gas

If CO_2 is measured on a dry basis, it shall be converted to wet basis according to section 5.2 of appendix 1 of this chapter.

2.4 The molecular mass (M_{re}) of the exhaust gas shall be calculated as follows:

$$M_{re} = \frac{1 + \frac{q_{mf}}{q_{maw}}}{\frac{q_{mf}}{q_{maw}} \times \frac{\frac{\alpha}{4} + \frac{\varepsilon}{2} + \frac{\delta}{2}}{12{,}011 + 1{,}00794 \times \alpha + 15{,}9994 \times \varepsilon + 14{,}0067 \times \delta + 32{,}065 \times \gamma} + \frac{\frac{H_a \times 10^{-3}}{2 \times 1{,}00794 + 15{,}9994} + \frac{1}{M_{ra}}}{1 + H_a \times 10^{-3}}}$$

where:

q_{mf} = fuel mass flow rate, kg/s

q_{maw} = intake air mass flow rate on wet basis, kg/s

H_a = humidity of intake air, g water per kg dry air

M_{ra} = molecular mass of dry intake air (= 28,9 g/mol)

$\alpha, \delta, \varepsilon, \gamma$ = molar ratios referring to a fuel $CH_\alpha O_\delta N_\varepsilon S_\gamma$

Alternatively, the following molecular masses may be used:

M_{re} (diesel) = 28,9 g/mol

M_{re} (LPG) = 28,6 g/mol

M_{re} (NG) = 28,3 g/mol

Chapter 4

Technical Characteristics of Reference Fuel

As per applicable Gazette Notification under CMVR

Chapter 5

Analytical and Sampling Systems

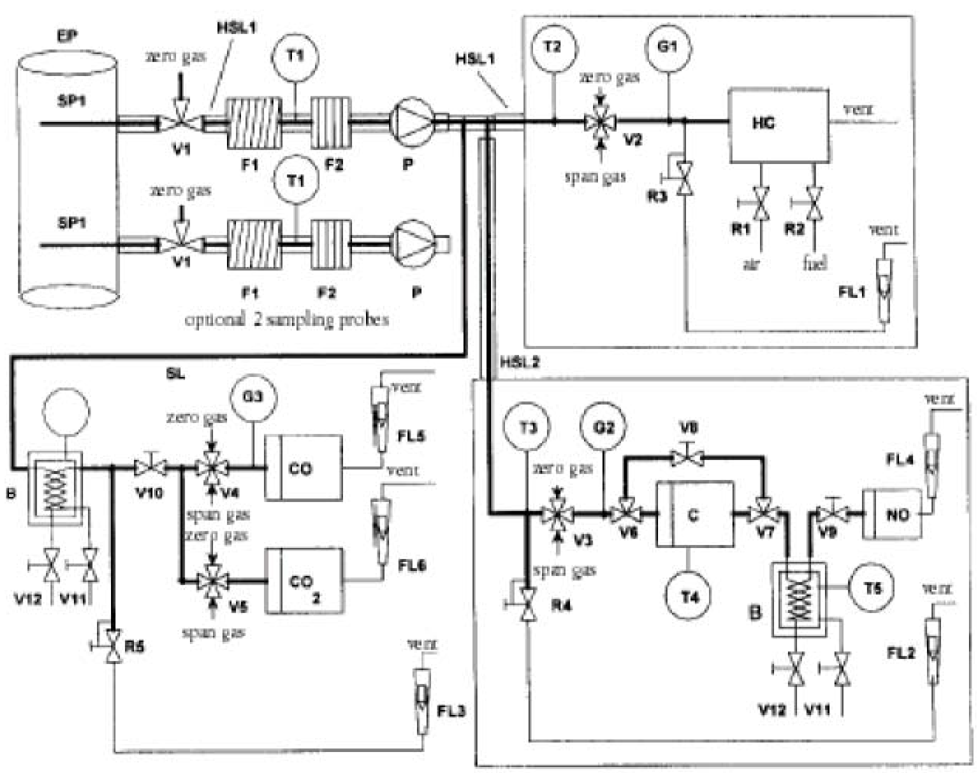
1. DETERMINATION OF THE GASEOUS EMISSIONS

Introduction

Section 1.2 and figures 7 and 8 contain detailed descriptions of the recommended sampling and analysing systems. Since various configurations can produce equivalent results, exact conformance with figures 7 and 8 is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components, which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

Figure 7

Flow diagram of raw exhaust gas analysis system for CO, CO_2, NO_x, HC ESC only



Description of the Analytical System

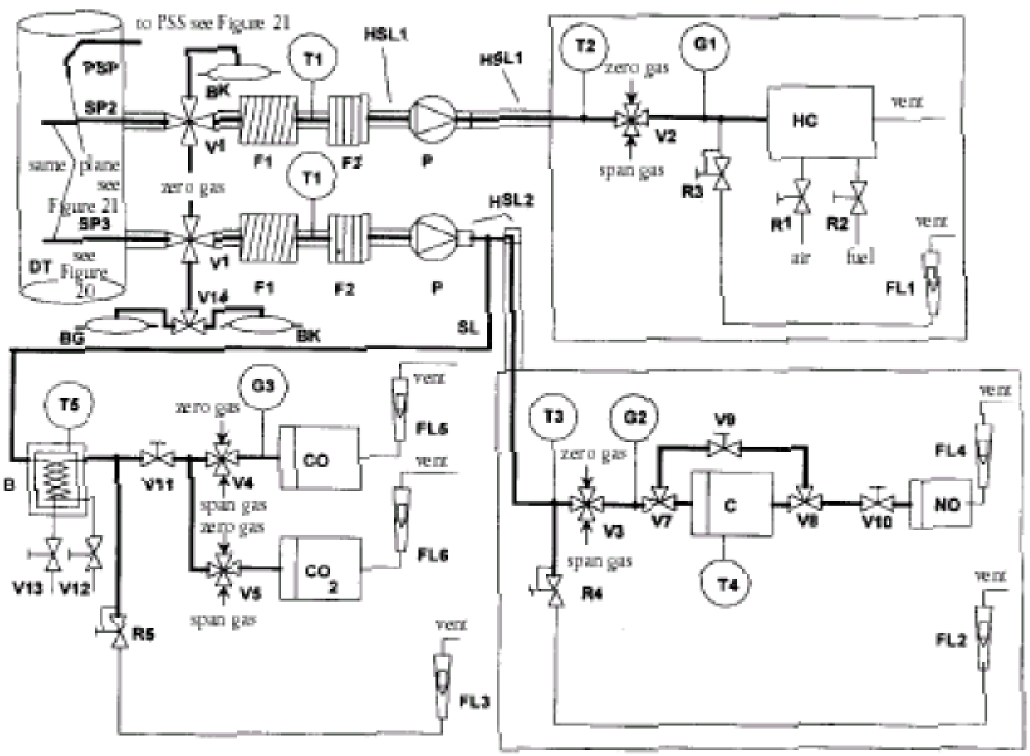
An analytical system for the determination of the gaseous emissions in the raw (Figure 7, ESC only) or diluted (Figure 8, ETC and ESC) exhaust gas is described based on the use of

- HFID analyser for the measurement of hydrocarbons.
- NDIR analysers for the measurement of carbon monoxide and carbon dioxide.
- HCLD or equivalent analyser for the measurement of the oxides of nitrogen

The sample for all components may be taken with one sampling probe or with two sampling probes located in close proximity and internally split to the different analysers. Care must be taken that no condensation of exhaust components (including water and sulphuric acid) occurs at any point of the analytical system.

Figure 8

Flow diagram of diluted exhaust gas analysis system for CO, CO_2, NO_x, HC ETC, optional for ESC



Components of figures 7 and 8

EP Exhaust pipe

Exhaust gas sampling probe (Figure 7 only)

A stainless steel straight closed end multi-hole probe is recommended. The inside diameter shall not be greater than the inside diameter of the sampling line. The wall thickness of the probe shall not be greater than 1 mm. There shall be a minimum of 3 holes in 3 different radial planes sized to sample approximately the same flow. The probe must extend across at least 80 % of the diameter of the exhaust pipe. One or two sampling probes may be used.

SP2 Diluted exhaust gas HC sampling probe (Figure 8 only)

The probe shall:

- Be defined as the first 254 mm to 762 mm of the heated sampling line HSL1

- Have a 5 mm minimum inside diameter

- Be installed in the dilution tunnel DT (see section 2.3, Figure 20) at a point where the dilution air and exhaust gas are well mixed (i.e. approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel)

- Be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies

- Be heated so as to increase the gas stream temperature to 463 K ± 10 K (190 °C ± 10 °C) at the exit of the probe.

SP3 Diluted exhaust gas CO, CO2, NOx sampling probe (Figure 8 only)

The probe shall:

- Be in the same plane as SP 2

- Be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies

- Be heated and insulated over its entire length to a minimum temperature of 328 K (55 °C) to prevent water condensation.

HSL1 Heated sampling line

The sampling line provides a gas sample from a single probe to the split point(s) and the HC analyser.

The sampling line shall:

- Have a 5 mm minimum and a 13,5 mm maximum inside diameter.

- Be made of stainless steel or PTFE.

- Maintain a wall temperature of 463 K ± 10 K (190 °C ± 10 °C) as measured at every separately controlled heated section, if the temperature of the exhaust gas at the sampling probe is equal to or below 463 K (190 °C).

- Maintain a wall temperature greater than 453 K (180 °C), if the temperature of the exhaust gas at the sampling probe is above 463 K (190 °C).

- Maintain a gas temperature of 463 K ± 10 K (190 °C ± 10 °C) immediately before the heated filter F2 and the HFID.

HSL2 Heated NO_x sampling line

The sampling line shall:

- Maintain a wall temperature of 328 K to 473 K (55 °C to 200 °C), up to the converter C when using a cooling bath B, and up to the analyser when a cooling bath B is not used.

- Be made of stainless steel or PTFE.

SL Sampling line for CO and CO2

The line shall be made of PTFE or stainless steel. It may be heated or unheated.

BK Background bag (optional; Figure 8 only)

For the sampling of the background concentrations.

BG Sample bag (optional; Figure 8 CO and CO2 only)

For the sampling of the sample concentrations.

F1 Heated pre-filter (optional)

The temperature shall be the same as HSL1.

F2 Heated filter

The filter shall extract any solid particles from the gas sample prior to the analyser. The temperature shall be the same as HSL1. The filter shall be changed as needed.

P Heated sampling pump

The pump shall be heated to the temperature of HSL1.

HC

Heated flame ionisation detector (HFID) for the determination of the hydrocarbons. The temperature shall be kept at 453 K to 473 K (180 °C to 200 °C).

CO, CO2

NDIR analysers for the determination of carbon monoxide and carbon dioxide (optional for the determination of the dilution ratio for PT measurement).

NO

CLD or HCLD analyser for the determination of the oxides of nitrogen. If a HCLD is used it shall be kept at a temperature of 328 K to 473 K (55 °C to 200 °C).

C Converter

A converter shall be used for the catalytic reduction of NO2 to NO prior to analysis in the CLD or HCLD.

B Cooling bath (optional)

To cool and condense water from the exhaust sample. The bath shall be maintained at a temperature of 273 K to 277 K (0 °C to 4 °C) by ice or refrigeration. It is optional if the analyser is free from water vapour interference as determined in chapter III, appendix 5, sections 1.9.1 and 1.9.2 of this part. If water is removed by condensation, the sample gas temperature or dew point shall be monitored either within the water trap or downstream. The sample gas temperature or dew point must not exceed 280 K (7 °C). Chemical dryers are not allowed for removing water from the sample.

T1, T2, T3 Temperature sensor

To monitor the temperature of the gas stream.

T4 Temperature sensor

To monitor the temperature of the NO_2-NO converter.

T5 Temperature sensor

To monitor the temperature of the cooling bath

G1, G2, G3 Pressure gauge

To measure the pressure in the sampling lines.

R1, R2 Pressure regulator

To control the pressure of the air and the fuel, respectively, for the HFID.

R3, R4, R5 Pressure regulator

To control the pressure in the sampling lines and the flow to the analysers.

FL1, FL2, FL3 Flowmeter

To monitor the sample by-pass flow rate.

FL4 to FL6 Flowmeter (optional)

To monitor the flow rate through the analysers.

V1 to V5 Selector valve

Suitable valving for selecting sample, span gas or zero gas flow to the analysers.

V6, V7 Solenoid valve

To by-pass the NO_2-NO converter.

V8 Needle valve

To balance the flow through the NO_2-NO converter C and the by-pass.

V9, V10 Needle valve

To regulate the flows to the analysers.

V11, V12 Toggle valve (optional)

To drain the condensate from the bath B.

NMHC Analysis (NG Fuelled Gas Engines Only)

Gas Chromatographic Method (GC, Figure 9)

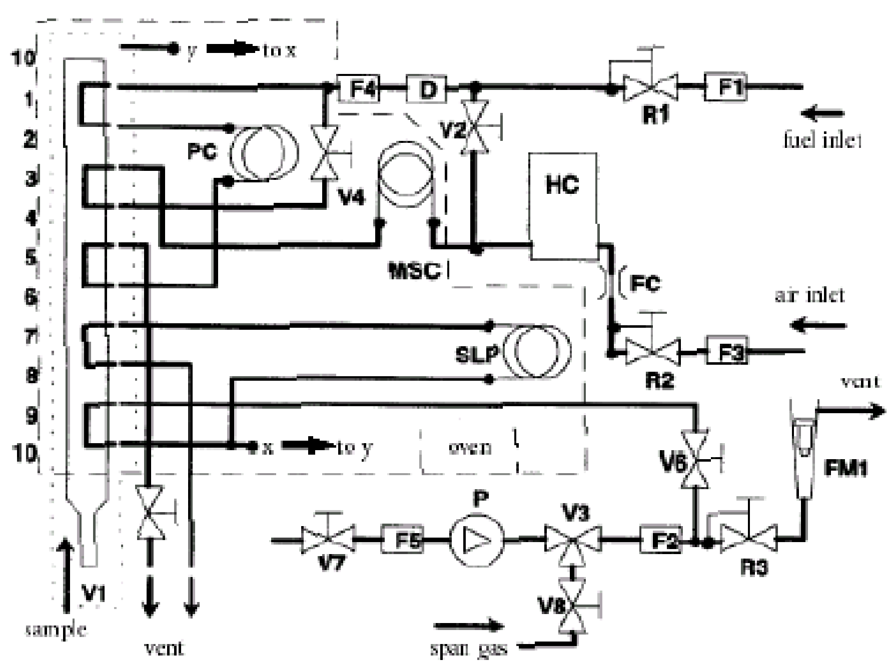
When using the GC method, a small measured volume of a sample is injected onto an analytical column through which it is swept by an inert carrier gas. The column separates various components according to their boiling points so that they elute from the column at different times. They then pass through a detector, which gives an electrical signal that depends on their concentration. Since it is not a continuous analysis technique, it can only be used in conjunction with the bag sampling method as described in chapter III, appendix 4, section 3.4.2 of this part.

For NMHC an automated GC with a FID shall be used. The exhaust gas shall be sampled into a sampling bag from which a part shall be taken and injected into the GC. The sample is separated into two parts (CH4/Air/CO and NMHC/CO2/H2O) on the Porapak column. The molecular sieve column separates CH4 from the air and CO before passing it to the FID where its concentration is measured. A complete cycle from injection of one sample to injection of a second can be made in 30 s. To determine NMHC, the CH4 concentration shall be subtracted from the total HC concentration (see chapter III, appendix 2, section 4.3.1 of this part).

Figure 9 shows a typical GC assembled to routinely determine CH4. Other GC methods can also be used based on good engineering judgement.

Figure 9

Flow diagram for methane analysis (GC method)



Components of Figure 9

PC Porapak column

Porapak N, 180/300 µm (50/80 mesh), 610 mm length × 2,16 mm ID shall be used and conditioned at least 12 h at 423 K (150 °C) with carrier gas prior to initial use.

MSC Molecular sieve column

Type 13X, 250/350 µm (45/60 mesh), 1220 mm length × 2,16 mm ID shall be used and conditioned at least 12 h at 423 K (150 °C) with carrier gas prior to initial use.

OV Oven

To maintain columns and valves at stable temperature for analyser operation, and to condition the columns at 423 K (150 °C).

SLP Sample loop

A sufficient length of stainless steel tubing to obtain approximately 1 cm^3 volume.

P Pump

To bring the sample to the gas chromatograph.

D Dryer

A dryer containing a molecular sieve shall be used to remove water and other contaminants, which might be present in the carrier gas.

HC

Flame ionisation detector (FID) to measure the concentration of methane.

V1 Sample injection valve

To inject the sample taken from the sampling bag via SL of Figure 8. It shall be low dead volume, gas tight, and heatable to 423 K (150 °C).

V3 Selector valve

To select span gas, sample, or no flow.

V2, V4, V5, V6, V7, V8 Needle valve

To set the flows in the system.

R1, R2, R3 Pressure regulator

To control the flows of the fuel (= carrier gas), the sample, and the air, respectively.

FC Flow capillary

To control the rate of air flow to the FID

G1, G2, G3 Pressure gauge

To control the flows of the fuel (= carrier gas), the sample, and the air, respectively.

F1, F2, F3, F4, F5 Filter

Sintered metal filters to prevent grit from entering the pump or the instrument.

FL1

To measure the sample by-pass flow rate.

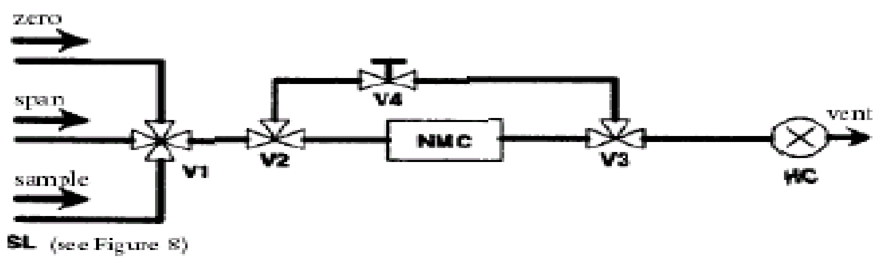
Non-Methane Cutter Method (NMC, Figure 10)

The cutter oxidises all hydrocarbons except CH_4 to CO_2 and H_2O, so that by passing the sample through the NMC only CH_4 is detected by the FID. If bag sampling is used, a flow diverter system shall be installed at SL (see section 1.2, Figure 8 of this chapter) with which the flow can be alternatively passed through or around the cutter according to the upper part of Figure 10. For NMHC measurement, both values (HC and CH_4) shall be observed on the FID and recorded. If the integration method is used, an NMC in line with a second FID shall be installed parallel to the regular FID into HSL1 (see section 1.2, Figure 8 of this chapter) according to the lower part of Figure 10 of this chapter. For NMHC measurement, the values of the two FID's (HC and CH_4) shall be observed and recorded.

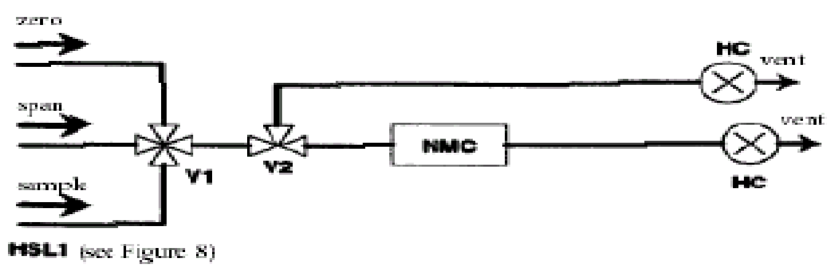
The cutter shall be characterised at or above 600 K (327 °C) prior to test work with respect to its catalytic effect on CH_4 and C_2H_6 at H_2O values representative of exhaust stream conditions. The dew point and O_2 level of the sampled exhaust stream must be known. The relative response of the FID to CH_4 must be recorded (see chapter III, appendix 5, section 1.8.2 of this part).

Figure 10

Flow diagram for methane analysis with the non-methane cutter (NMC)



Bag sampling method



Integrating method

Components of Figure 10

NMC Non-methane cutter

To oxidise all hydrocarbons except methane.

HC

Heated flame ionisation detector (HFID) to measure the HC and CH_4 concentrations. The temperature shall be kept at 453 K to 473 K (180 °C to 200 °C).

V1 Selector valve

To select sample, zero and span gas. V1 is identical with V2 of Figure 8 of this chapter.

V2, V3 Solenoid valve

To by-pass the NMC.

V4 Needle valve

To balance the flow through the NMC and the by-pass.

R1 Pressure regulator

To control the pressure in the sampling line and the flow to the HFID. R1 is identical with R3 of Figure 8 of this chapter.

FL1 Flowmeter

To measure the sample by-pass flow rate. FL1 is identical with FL1 of Figure 8 of this chapter.

2. EXHAUST GAS DILUTION AND DETERMINATION OF THE PARTICULATES

Introduction

Sections 2.2, 2.3 and 2.4 and figures 11 to 22 of this chapter contain detailed descriptions of the recommended dilution and sampling systems. Since various configurations can produce equivalent results, exact conformance with these figures is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components, which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

2.2. Partial Flow Dilution System

A dilution system is described in figures 11 to 19 of this chapter based upon the dilution of a part of the exhaust stream. Splitting of the exhaust stream and the following dilution process may be done by different dilution system types. For subsequent collection of the particulates, the entire dilute exhaust gas or only a portion of the dilute exhaust gas is passed to the particulate sampling system (section 2.4, Figure 21 of this chapter). The first method is referred to as total sampling type, the second method as fractional sampling type.

The calculation of the dilution ratio depends upon the type of system used. The following types are recommended:

Isokinetic systems (Figures 11, 12)

With these systems, the flow into the transfer tube is matched to the bulk exhaust flow in terms of gas velocity and/or pressure, thus requiring an undisturbed and uniform exhaust flow at the sampling probe. This is usually achieved by using a resonator and a straight approach tube upstream of the sampling point. The split ratio is then calculated from easily measurable values like tube diameters. It should be noted that isokinesis is only used for matching the flow conditions and not for matching the size distribution. The latter is typically not necessary, as the particles are sufficiently small as to follow the fluid streamlines.

Flow controlled systems with concentration measurement (Figures 13 to 17)

With these systems, a sample is taken from the bulk exhaust stream by adjusting the dilution air flow and the total dilute exhaust flow. The dilution ratio is determined from the concentrations of tracer gases, such as CO_2 or NO_X naturally occurring in the engine exhaust. The concentrations in the dilute exhaust gas and in the dilution air are measured, whereas the concentration in the raw exhaust gas can be either measured directly or determined from fuel flow and the carbon balance equation, if the fuel composition is known. The systems may be controlled by the calculated dilution ratio (Figures 13, 14 of this chapter) or by the flow into the transfer tube (Figures 12, 13,14 of this chapter).

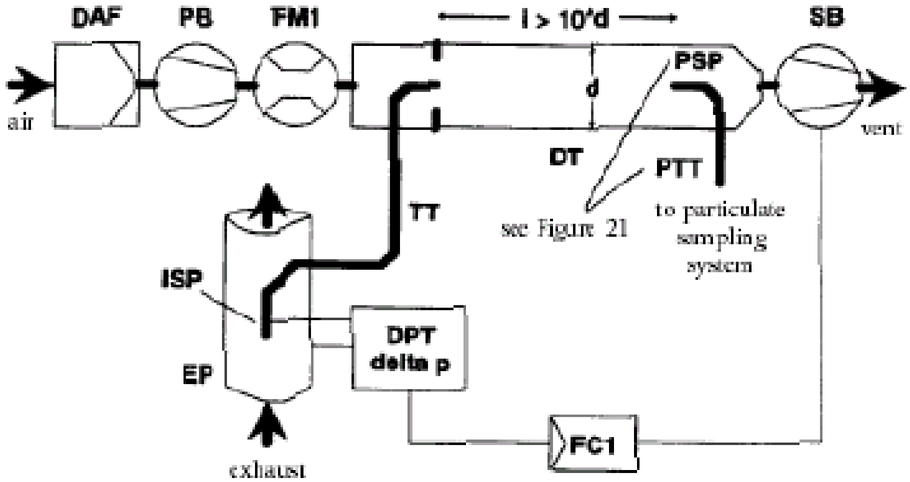
Flow controlled systems with flow measurement (Figures 18, 19)

With these systems, a sample is taken from the bulk exhaust stream by setting the dilution airflow and the total dilute exhaust flow. The dilution ratio is determined from the difference of the two flows rates. Accurate calibration of the flow meters relative to one another is required, since the relative magnitude of the two flow rates can lead to significant errors at higher dilution ratios (of 15 and above). Flow control is very straight forward by keeping the dilute exhaust flow rate constant and varying the dilution air flow rate, if needed.

When using partial flow dilution systems, attention must be paid to avoiding the potential problems of loss of particulates in the transfer tube, ensuring that a representative sample is taken from the engine exhaust, and determination of the split ratio. The systems described pay attention to these critical areas.

Figure 11

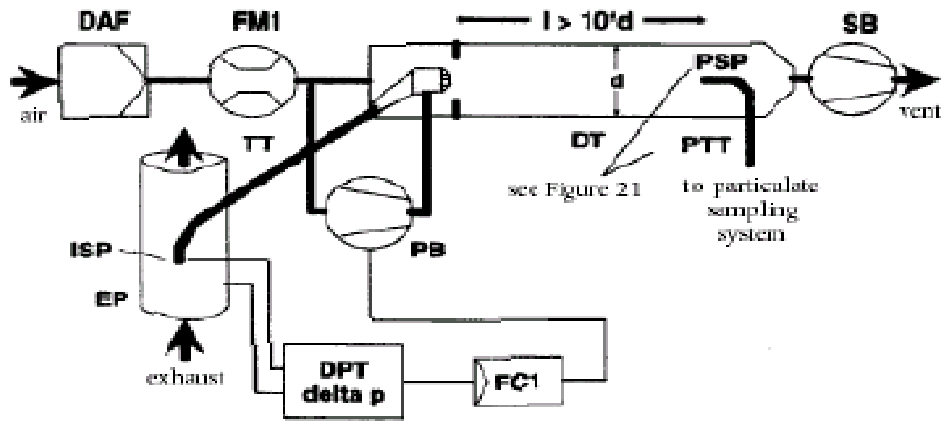
Partial flow dilution system with isokinetic probe and fractional sampling (SB control)



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the suction blower SB to maintain a differential pressure of zero at the tip of the probe. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution airflow rate is measured with the flow measurement device FM1. The dilution ratio is calculated from the dilution airflow rate and the split ratio.

Figure 12

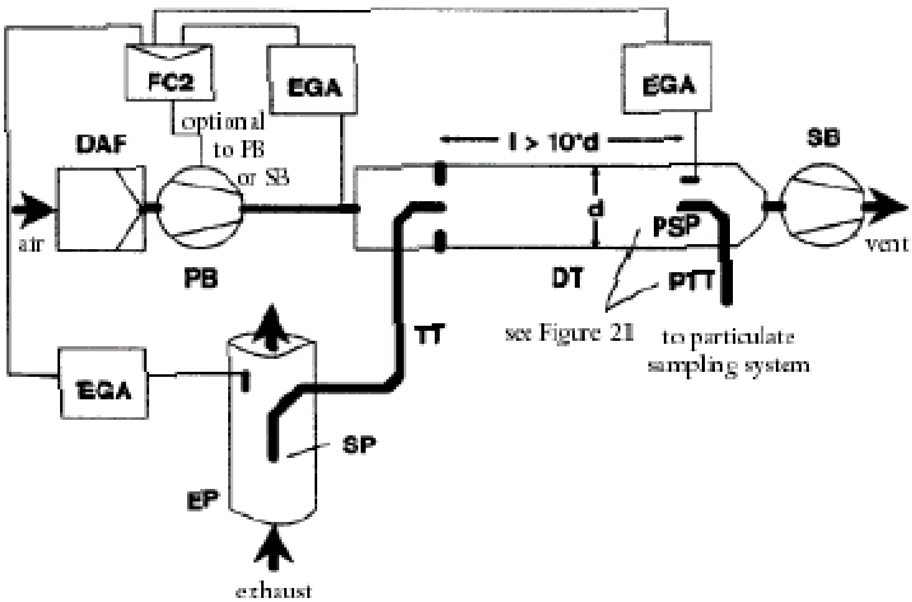
Partial flow dilution system with isokinetic probe and fractional sampling (PB control)



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the pressure blower PB to maintain a differential pressure of zero at the tip of the probe. This is done by taking a small fraction of the dilution air whose flow rate has already been measured with the flow measurement device FM1, and feeding it to TT by means of a pneumatic orifice. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution air is sucked through DT by the suction blower SB, and the flow rate is measured with FM1 at the inlet to DT. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

Figure 13

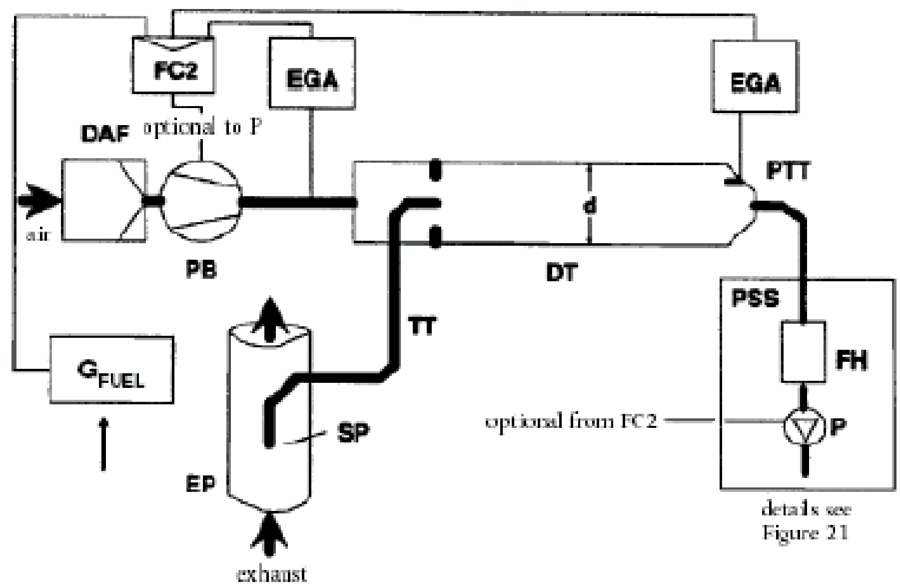
Partial flow dilution system with CO_2 or NO_x concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The concentrations of a tracer gas (CO_2 or NO_X) are measured in the raw and diluted exhaust gas as well as in the dilution air with the exhaust gas analyser(s) EGA. These signals are transmitted to the flow controller FC2 that controls either the pressure blower PB or the suction blower SB to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the tracer gas concentrations in the raw exhaust gas, the diluted exhaust gas, and the dilution air.

Figure 14

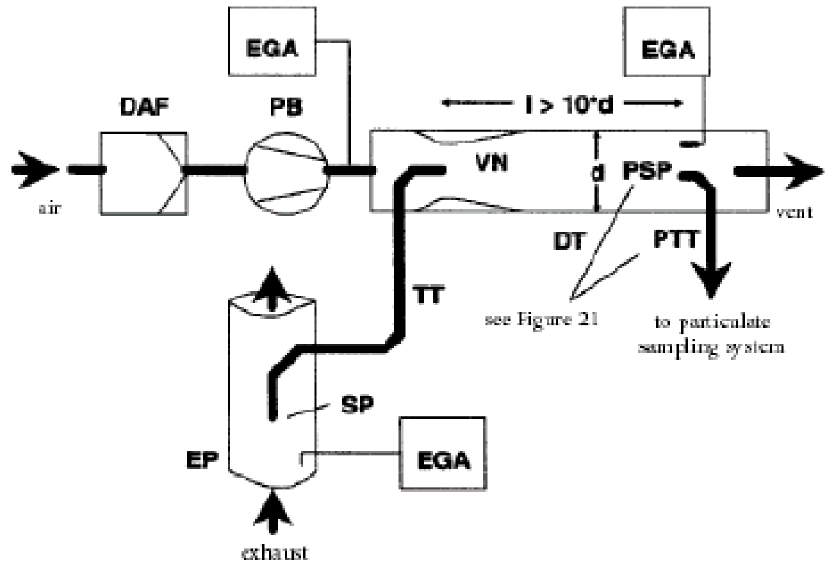
Partial flow dilution system with CO_2 concentration measurement, carbon balance and total sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The CO_2 concentrations are measured in the diluted exhaust gas and in the dilution air with the exhaust gas analyser(s) EGA. The CO_2 and fuel flow q_{mf} signals are transmitted either to the flow controller FC2, or to the flow controller FC3 of the particulate sampling system (see Figure 21 of this chapter). FC2 controls the pressure blower PB, FC3 the sampling pump P (see Figure 21 of this chapter), thereby adjusting the flows into and out of the system so as to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the CO_2 concentrations and q_{mf} using the carbon balance assumption.

Figure 15

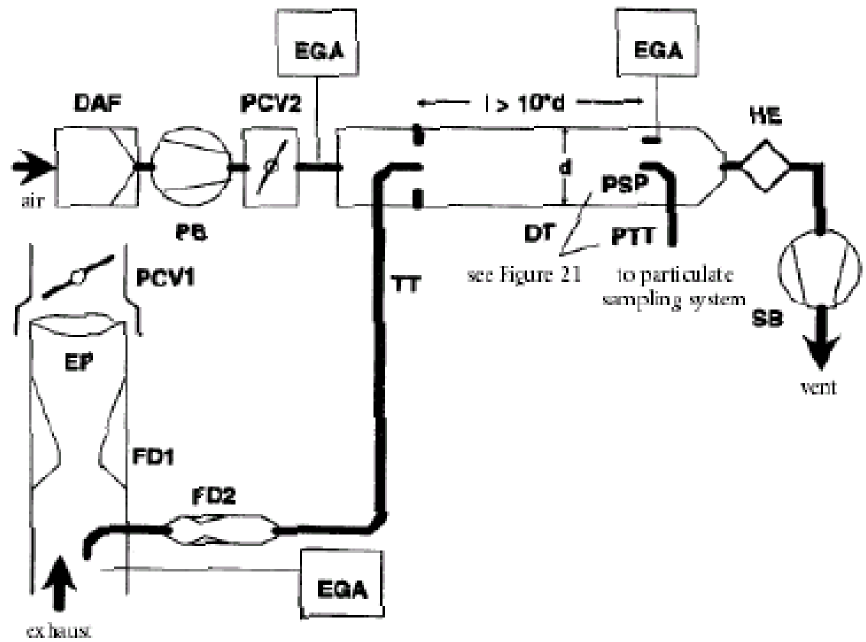
Partial flow dilution system with single venturi, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT due to the negative pressure created by the venturi VN in DT. The gas flow rate through TT depends on the momentum exchange at the venturi zone, and is therefore affected by the absolute temperature of the gas at the exit of TT. Consequently, the exhaust split for a given tunnel flow rate is not constant, and the dilution ratio at low load is slightly lower than at high load. The tracer gas concentrations (CO_2 or NO_X) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA, and the dilution ratio is calculated from the values so measured.

Figure 16

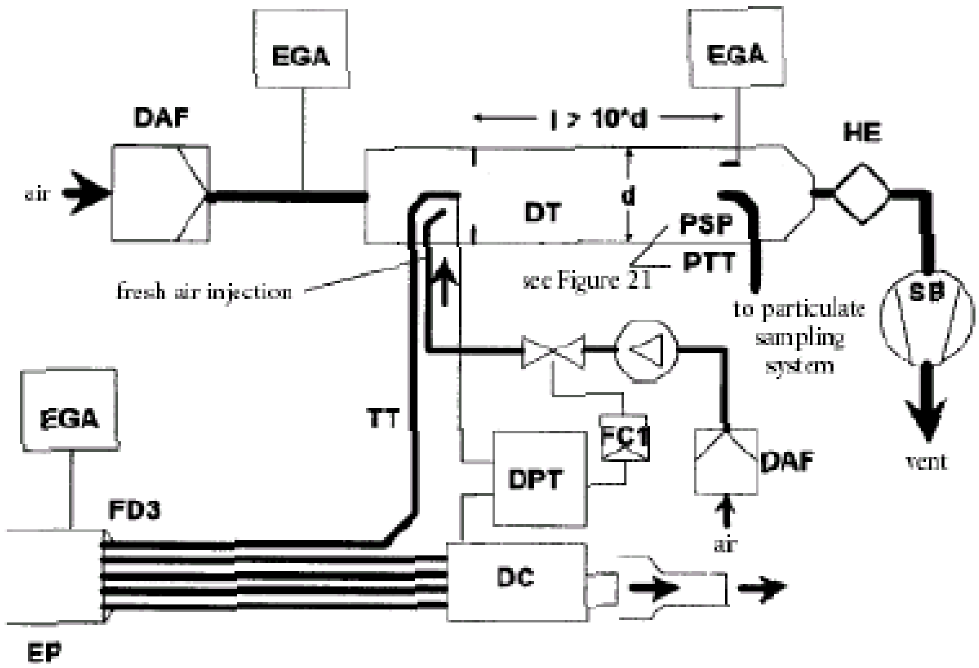
Partial flow dilution system with twin venturi or twin orifice, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT by a flow divider that contains a set of orifices or venturis. The first one (FD1) is located in EP, the second one (FD2) in TT. Additionally, two pressure control valves (PCV1 and PCV2) are necessary to maintain a constant exhaust split by controlling the backpressure in EP and the pressure in DT. PCV1 is located downstream of SP in EP, PCV2 between the pressure blower PB and DT. The tracer gas concentrations (CO_2 or NO_X) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split, and may be used to adjust PCV1 and PCV2 for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

Figure 17

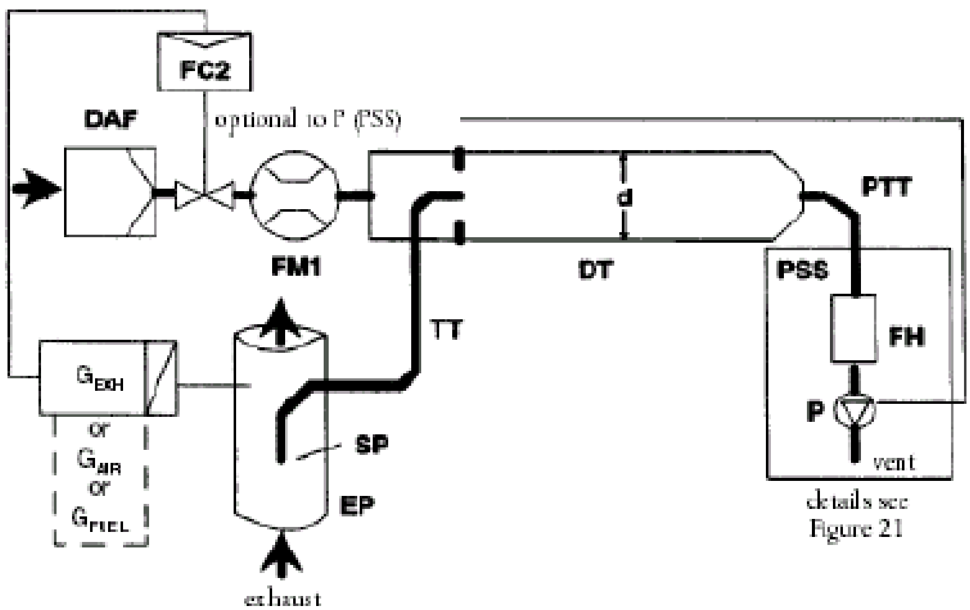
Partial flow dilution system with multiple tube splitting, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the flow divider FD3 that consists of a number of tubes of the same dimensions (same diameter, length and bend radius) installed in EP. The exhaust gas through one of these tubes is lead to DT, and the exhaust gas through the rest of the tubes is passed through the damping chamber DC. Thus, the exhaust split is determined by the total number of tubes. A constant split control requires a differential pressure of zero between DC and the outlet of TT, which is measured with the differential pressure transducer DPT. A differential pressure of zero is achieved by injecting fresh air into DT at the outlet of TT. The tracer gas concentrations (CO_2 or NO_X) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split and may be used to control the injection airflow rate for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

Figure 18

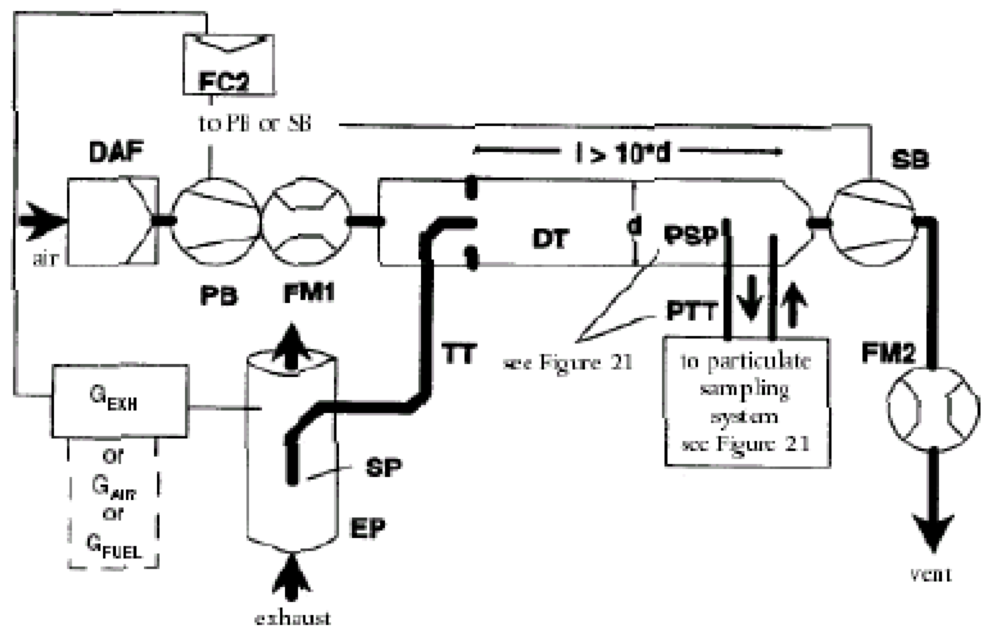
Partial flow dilution system with flow control and total sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The total flow through the tunnel is adjusted with the flow controller FC3 and the sampling pump P of the particulate sampling system (see Figure 18 of this chapter). The dilution air flow is controlled by the flow controller FC2, which may use q_{mew}, q_{maw}, or q_{mf} as command signals, for the desired exhaust split. The sample flow into DT is the difference of the total flow and the dilution air flow. The dilution air flow rate is measured with the flow measurement device FM1, the total flow rate with the flow measurement device FM3 of the particulate sampling system (see Figure 21 of this chapter). The dilution ratio is calculated from these two flow rates.

Figure 19

Partial flow dilution system with flow control and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The exhaust split and the flow into DT is controlled by the flow controller FC2 that adjusts the flows (or speeds) of the pressure blower PB and the suction blower SB, accordingly. This is possible since the sample taken with the particulate sampling system is returned into DT. q_{mew}, q_{maw}, or q_{mf} may be used as command signals for FC2. The dilution air flow rate is measured with the flow measurement device FM1, the total flow with the flow measurement device FM2. The dilution ratio is calculated from these two flow rates.

2.2.1. Components of Figures 11 to 19

EP Exhaust pipe

The exhaust pipe may be insulated. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less. Bends shall be minimised to reduce inertial deposition. If the system includes a test bed silencer the silencer may also be insulated.

For an isokinetic system, the exhaust pipe must be free of elbows, bends and sudden diameter changes for at least 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe. The gas velocity at the sampling zone must be higher than 10 m/s except at idle mode. Pressure oscillations of the exhaust gas must not exceed ± 500 Pa on the average. Any steps to reduce pressure oscillations beyond using a chassis-type exhaust system (including silencer and after treatment devices) must not alter engine performance nor cause the deposition of particulates.

For systems without isokinetic probe, it is recommended to have a straight pipe of 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

SP Sampling probe (Figures 10, 14, 15, 16, 18, 19)

The minimum inside diameter shall be 4 mm. The minimum diameter ratio between exhaust pipe and probe shall be 4. The probe shall be an open tube facing upstream on the exhaust pipe centerline, or a multiple hole probe as described under SP1 in section 1.2.1, Figure 5 of this chapter.

ISP Isokinetic sampling probe (Figures 11, 12)

The isokinetic sampling probe must be installed facing upstream on the exhaust pipe centerline where the flow conditions in section EP are met, and designed to provide a proportional sample of the raw exhaust gas. The minimum inside diameter shall be 12 mm.

A 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 the mass flow through ISP is a constant fraction of the exhaust gas flow. ISP has to be connected to a differential pressure transducer DPT. The control to provide a differential pressure of zero between EP and ISP is done with the flow controller FC1.

FD1, FD2 Flow divider (Figure 16)

A set of venturis or orifices is installed in the exhaust pipe EP and in the transfer tube TT, respectively, to provide a proportional sample of the raw exhaust gas. A control system consisting of two pressure control valves PCV1 and PCV2 is necessary for proportional splitting by controlling the pressures in EP and DT.

FD3 Flow divider (Figure 17)

A set of tubes (multiple tube unit) is installed in the exhaust pipe EP to provide a proportional sample of the raw exhaust gas. One of the tubes feeds exhaust gas to the dilution tunnel DT, whereas the other tubes exit exhaust gas to a damping chamber DC. The tubes must have the same dimensions (same diameter, length, bend radius), so that the exhaust split depends on the total number of tubes. A control system is necessary for proportional splitting by maintaining a differential pressure of zero between the exit of the multiple tube unit into DC and the exit of TT. Under these conditions, exhaust gas velocities in EP and FD3 are proportional, and the flow TT is a constant fraction of the exhaust gas flow. The two points have to be connected to a differential pressure transducer DPT. The control to provide a differential pressure of zero is done with the flow controller FC1.

EGA Exhaust gas analyser (Figures 13, 14, 15, 16, 17)

CO_2 or NO_X analysers may be used (with carbon balance method CO_2 only). The analysers shall be calibrated like the analysers for the measurement of the gaseous emissions. One or several analysers may be used to determine the concentration differences. The accuracy of the measuring systems has to be such that the accuracy of $q_{medf,i}$ is within ± 4 %.

TT Transfer tube (Figures 11 to 19)

The transfer tube shall be:

- As short as possible, but not more than 5 m in length.

- Equal to or greater than the probe diameter, but not more than 25 mm in diameter.

- Exiting on the centerline of the dilution tunnel and pointing downstream.

If the tube is 1 meter or less in length, it shall be insulated with material with a maximum thermal conductivity of 0,05 W/m*K with a radial insulation thickness corresponding to the diameter of the probe. If the tube is longer than 1 meter, it must be insulated and heated to a minimum wall temperature of 523 K (250 °C).

DPT Differential pressure transducer (Figures 11, 12, 17)

The differential pressure transducer shall have a range of ± 500 Pa or less.

FC1 Flow controller (Figures 11, 12, 17)

For isokinetic systems (Figures 11,12 of this chapter), a flow controller is necessary to maintain a differential pressure of zero between EP and ISP. The adjustment can be done by:

a) controlling the speed or flow of the suction blower SB and keeping the speed or flow of the pressure blower PB constant during each mode (Figure 11 of this chapter) or

b) adjusting the suction blower SB to a constant mass flow of the diluted exhaust gas and controlling the flow of the pressure blower PB, and therefore the exhaust sample flow in a region at the end of the transfer tube TT (Figure 12 of this chapter).

In the case of a pressure controlled system the remaining error in the control loop must not exceed ± 3 Pa. The pressure oscillations in the dilution tunnel must not exceed ± 250 Pa on the average.

For a multi tube system (Figure 17 of this chapter), a flow controller is necessary for proportional exhaust splitting to maintain a differential pressure of zero between the exit of the multi tube unit and the exit of TT. The adjustment is done by controlling the injection air flow rate into DT at the exit of TT.

PCV1, PCV2 Pressure control valve (Figure 16)

Two pressure control valves are necessary for the twin venturi/twin orifice system for proportional flow splitting by controlling the backpressure of EP and the pressure in DT. The valves shall be located downstream of SP in EP and between PB and DT.

DC Damping chamber (Figure 17)

A damping chamber shall be installed at the exit of the multiple tube unit to minimize the pressure oscillations in the exhaust pipe EP.

VN Venturi (Figure 15)

A venturi is installed in the dilution tunnel DT to create a negative pressure in the region of the exit of the transfer tube TT. The gas flow rate through TT is determined by the momentum exchange at the venturi zone, and is basically proportional to the flow rate of the pressure blower PB leading to a constant dilution ratio. Since the momentum exchange is affected by the temperature at the exit of TT and the pressure difference between EP and DT, the actual dilution ratio is slightly lower at low load than at high load.

FC2 Flow controller (Figures 13, 14, 18, 19, optional)

A flow controller may be used to control the flow of the pressure blower PB and/or the suction blower SB. It may be connected to the exhaust, intake air, or fuel flow signals and/or to the CO_2 or NO_X differential signals. When using a pressurised air supply (Figure 18 of this chapter), FC2 directly controls the airflow.

FM1 Flow measurement device (Figures 11, 12, 18, 19)

Gas meter or other flow instrumentation to measure the dilution airflow. FM1 is optional if the pressure blower PB is calibrated to measure the flow.

FM2 Flow measurement device (Figure 19)

Gas meter or other flow instrumentation to measure the diluted exhaust gas flow. FM2 is optional if the suction blower SB is calibrated to measure the flow.

PB Pressures blower (Figures 11, 12, 13, 14, 15, 16, 19)

To control the dilution airflow rate, PB may be connected to the flow controllers FC1 or FC2. PB is not required when using a butterfly valve. PB may be used to measure the dilution airflow, if calibrated.

SB Suction blower (Figures 11, 12, 13, 16, 17, 19)

For fractional sampling systems only. SB may be used to measure the diluted exhaust gas flow, if calibrated.

DAF Dilution air filter (Figures 11 to 19)

It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. At the engine manufacturers request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

DT Dilution tunnel (Figures 11 to 19)

The dilution tunnel:

- shall be of a sufficient length to cause complete mixing of the exhaust and dilution air under turbulent flow conditions;

- shall be constructed of stainless steel with:

- thickness/diameter ratio of 0,025 or less for dilution tunnels with inside diameters greater than 75 mm;

- a nominal thickness of no less then 1,5 mm for dilution tunnels with inside diameters of equal to or less than 75 mm;

- shall be at least 75 mm in diameter for the fractional sampling type;

- is recommended to be at least 25 mm in diameter for the total sampling type;

- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;

- may be insulated.

The engine exhaust shall be thoroughly mixed with the dilution air. For fractional sampling systems, the mixing quality shall be checked after introduction into service by means of a CO_2 - profile of the tunnel with the engine running (at least four equally spaced measuring points). If necessary, a mixing orifice may be used.

Note: If the ambient temperature in the vicinity of the dilution tunnel (DT) is below 293K (20 °C), precautions should be taken to avoid particle losses onto the cool walls of the dilution tunnel. Therefore, heating and/or insulating the tunnel within the limits given above is recommended.

At high engine loads, the tunnel may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293K (20 °C).

HE Heat exchanger (Figures 16, 17)

The heat exchanger shall be of sufficient capacity to maintain the temperature at the inlet to the suction blower SB within ± 11K of the average operating temperature observed during the test.

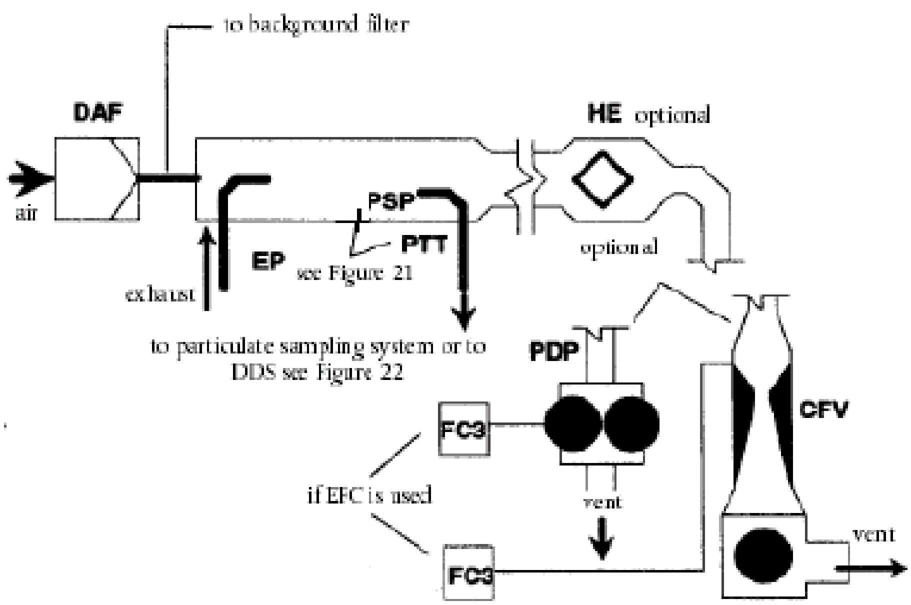
2.3 Full flow dilution system

A dilution system is described in Figure 20 of this chapter based upon the dilution of the total exhaust using the CVS (Constant Volume Sampling) concept. The total volume of the mixture of exhaust and dilution air must be measured. Either a PDP or a CFV system may be used.

For subsequent collection of the particulates, a sample of the dilute exhaust gas is passed to the particulate sampling system (section 2.4, figures 21 and 22 of this chapter). If this is done directly, it is referred to as single dilution. If the sample is diluted once more in the secondary dilution tunnel, it is referred to as double dilution. This is useful, if the filter face temperature requirement cannot be met with single dilution. Although partly a dilution system, the double dilution system is described as a modification of a particulate sampling system in section 2.4, Figure 22, of this chapter since it shares most of the parts with a typical particulate sampling system.

Figure 20

Full flow dilution system



The total amount of raw exhaust gas is mixed in the dilution tunnel DT with the dilution air. The diluted exhaust gas flow rate is measured either with a Positive Displacement Pump PDP or with a Critical Flow Venturi CFV. A heat exchanger HE or electronic flow compensation EFC may be used for proportional particulate sampling and for flow determination. Since particulate mass determination is based on the total diluted exhaust gas flow, the dilution ratio is not required to be calculated.

2.3.1. Components of Figure 20

EP Exhaust pipe

The exhaust pipe length from the exit of the engine exhaust manifold, turbocharger outlet or after treatment device to the dilution tunnel shall not exceed10 m. If the exhaust pipe downstream of the engine exhaust manifold, turbocharger outlet or after treatment device exceeds 4 m in length, then all tubing in excess of 4 m shall be insulated, except for an in-line smoke meter, if used. The radial thickness of the insulation must be at least 25 mm. The thermal conductivity of the insulating material must have a value no greater than 0,1 W/m*K measured at 673 K. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less.

PDP Positive displacement pump

The PDP meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system backpressure must not be artificially lowered by the PDP or dilution air inlet system. Static exhaust backpressure measured with the PDP system operating shall remain within ± 1,5 kPa of the static pressure measured without connection to the PDP at identical engine speed and load. The gas mixture temperature immediately ahead of the PDP shall be within ± 6 K of the average operating temperature observed during the test, when no flow compensation is used. Flow compensation may only be used if the temperature at the inlet to the PDP does not exceed 323K (50 °C)

CFV Critical Flow Venturi

CFV measures total diluted exhaust flow by maintaining the flow at choked conditions (critical flow). Static exhaust backpressure measured with the CFV system operating shall remain within ± 1,5 kPa of the static pressure measured without connection to the CFV at identical engine speed and load. The gas mixture temperature immediately ahead of the CFV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation is used.

HE Heat exchanger (optional, if EFC is used)

The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above.

EFC Electronic flow compensation (optional, if HE is used)

If the temperature at the inlet to either the PDP or CFV is not kept within the limits stated above, a flow compensation system is required for continuous measurement of the flow rate and control of the proportional sampling in the particulate system. To that purpose, the continuously measured flow rate signals are used to correct the sample flow rate through the particulate filters of the particulate sampling system (see section 2.4, figures 21, 22 of this chapter), accordingly.

DT Dilution tunnel

The dilution tunnel:

- shall be small enough in diameter to cause turbulent flow (Reynolds Number greater than 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air; a mixing orifice may be used;

- shall be at least 460 mm in diameter with a single dilution system;

- shall be at least 210 mm in diameter with a double dilution system;

- may be insulated.

The engine exhaust shall be directed downstream at the point where it is introduced into the dilution tunnel, and thoroughly mixed.

When using single dilution, a sample from the dilution tunnel is transferred to the particulate sampling system (section 2.4, Figure 21 of this chapter). The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust at a temperature of less than or equal to 325 K (52 °C) immediately before the primary particulate filter.

When using double dilution, a sample from the dilution tunnel is transferred to the secondary dilution tunnel where it is further diluted, and then passed through the sampling filters (section 2.4, Figure 22 of this chapter). The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust stream in the DT at a temperature of less than or equal to 464 K (191 °C) at the sampling zone. The secondary dilution system must provide sufficient secondary dilution air to maintain the doubly diluted exhaust stream at a temperature of less than or equal to 325 K (52 °C) immediately before the primary particulate filter.

DAF Dilution air filter

It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. At the engine manufacturers request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

PSP Particulate sampling probe

The probe is the leading section of PTT and:

- shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel (DT) centerline approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel;

- shall be of 12 mm minimum inside diameter;

- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;

- may be insulated.

2.4. **Particulate Sampling System**

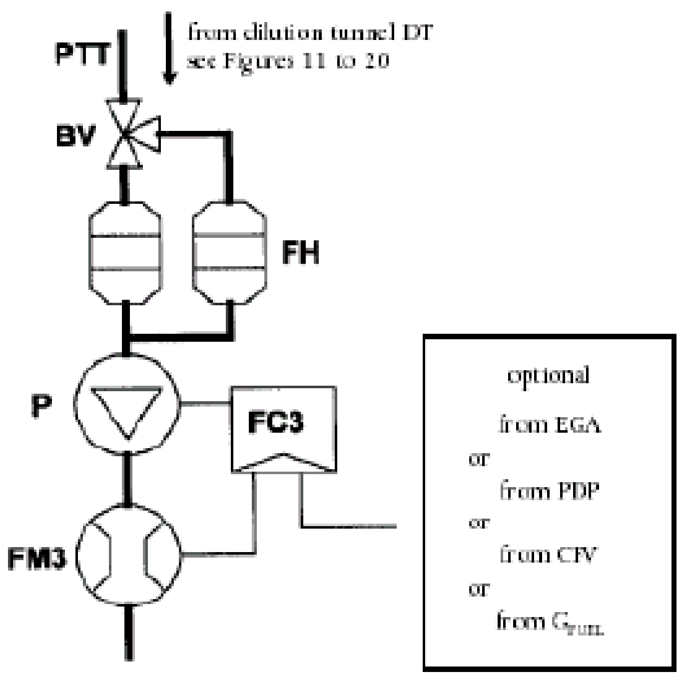
The particulate sampling system is required for collecting the particulates on the particulate filter. In the case of total sampling partial flow dilution, which consists of passing the entire diluted exhaust sample through the filters, dilution (section 2.2, figures 14, 18 of this chapter) and sampling system usually form an integral unit. In the case of fractional sampling partial flow dilution or full flow dilution, which consists of passing through the filters only a portion of the diluted exhaust, the dilution (section 2.2, figures 11,12,13,15,16,17,19; section 2.3, Figure 20 of this chapter) and sampling systems usually form different units.

In this part, the double dilution system (Figure 22 of this chapter) of a full flow dilution system is considered as a specific modification of a typical particulate sampling system as shown in Figure 21 of this chapter. The double dilution system includes all important parts of the particulate sampling system, like filter holders and sampling pump, and additionally some dilution features, like a dilution air supply and a secondary dilution tunnel.

In order to avoid any impact on the control loops, it is recommended that the sample pump be running throughout the complete test procedure. For the single filter method, a bypass system shall be used for passing the sample through the sampling filters at the desired times. Interference of the switching procedure on the control loops must be minimised.

Figure 21

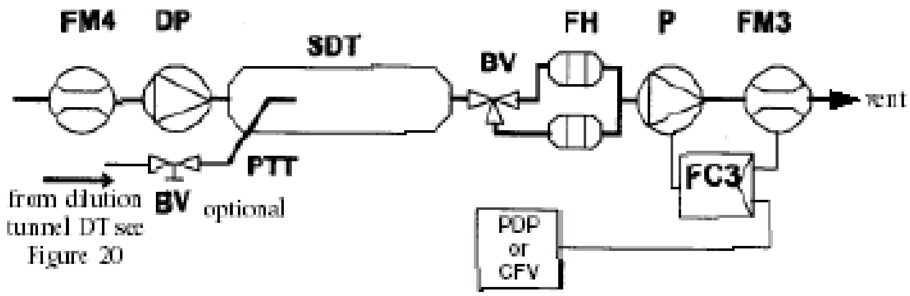
Particulate sampling system



A sample of the diluted exhaust gas is taken from the dilution tunnel DT of a partial flow or full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT by means of the sampling pump P. The sample is passed through the filter holder(s) FH that contain the particulate sampling filters. The sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 20 of this chapter) is used, the diluted exhaust gas flow is used as command signal for FC3.

Figure 22

Double dilution system (full flow system only)



A sample of the diluted exhaust gas is transferred from the dilution tunnel DT of a full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT to the secondary dilution tunnel SDT, where it is diluted once more. The sample is then passed through the filter holder(s) FH that contain the particulate sampling filters. The dilution air flow rate is usually constant whereas the sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 20 of this chapter) is used, the total diluted exhaust gas flow is used as command signal for FC3.

2.4.1. Components of figures 21 and 22

PTT Particulate transfer tube (Figures 21, 22)

The particulate transfer tube must not exceed 1020 mm in length, and must be minimised in length whenever possible. Where applicable (i.e. for partial flow dilution fractional sampling systems and for full flow dilution systems), the length of the sampling probes (SP, ISP, PSP, respectively, see sections 2.2 and 2.3 of this chapter) shall be included.

The dimensions are valid for:

- the partial flow dilution fractional sampling type and the full flow single dilution system from the tip of the probe (SP, ISP, PSP, respectively) to the filter holder;

- the partial flow dilution total sampling type from the end of the dilution tunnel to the filter holder;

- the full flow double dilution system from the tip of the probe (PSP) to the secondary dilution tunnel.

The transfer tube:

- may be heated to no greater than 325K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;

- may be insulated.

SDT Secondary dilution tunnel (Figure 22)

The secondary dilution tunnel should have a minimum diameter of 75 mm, and should be of sufficient length so as to provide a residence time of at least 0,25 seconds for the doubly diluted sample. The primary filter holder FH shall be located within 300 mm of the exit of the SDT.

The secondary dilution tunnel:

- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;

- may be insulated.

FH Filter holder(s) (Figures 21, 22)

For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of chapter III, appendix 4, section 4.1.3 of this part shall be met.

The filter holder(s):

- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;

- may be insulated.

P Sampling pump (Figures 21, 22)

The particulate sampling pump shall be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow correction by FC3 is not used.

DP Dilution air pump (Figure 22)

The dilution air pump shall be located so that the secondary dilution air is supplied at a temperature of 298 K ± 5 K (25 °C ± 5 °C), if the dilution air is not preheated.

FC3 Flow controller (Figures 21, 22)

A flow controller shall be used to compensate the particulate sample flow rate for temperature and backpressure variations in the sample path, if no other means are available. The flow controller is required if electronic flow compensation EFC (see Figure 20 of this chapter) is used.

FM3 Flow measurement device (Figures 21, 22)

The gas meter or flow instrumentation for the particulate sample flow shall be located sufficiently distant from the sampling pump P so that the inlet gas temperature remains constant (± 3 K), if flow correction by FC3 is not used.

FM4 Flow measurement device (Figure 22)

The gas meter or flow instrumentation for the dilution airflow shall be located so that the inlet gas temperature remains at 298 K ± 5 K (25 °C ± 5 °C).

BV Ball valve (optional)

The ball valve shall have an inside diameter not less than the inside diameter of the particulate transfer tube PTT, and a switching time of less than 0,5 seconds.

> **Note:** If the ambient temperature in the vicinity of PSP, PTT, SDT, and FH is below 293K (20 °C), precautions should be taken to avoid particle losses onto the cool wall of these parts. Therefore, heating and/or insulating these parts within the limits given in the respective descriptions is recommended. It is also recommended that the filter face temperature during sampling be not below 293K (20 °C).
>
> At high engine loads, the above parts may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293K (20 °C).

3. DETERMINATION OF SMOKE

Introduction

Sections 3.2 and 3.3 and figures 23 and 24 of this chapter contain detailed descriptions of the recommended opacimeter systems. Since various configurations can produce equivalent results, exact conformance with figures 23 and 24 of this chapter is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

The principle of measurement is that light is transmitted through a specific length of the smoke to be measured and that proportion of the incident light which reaches a receiver is used to assess the light obscuration properties of the medium. The smoke measurement depends upon the design of the apparatus, and may be done in the exhaust pipe (full flow in-line opacimeter), at the end of the exhaust pipe (full flow end-of-line opacimeter) or by taking a sample from the exhaust pipe (partial flow opacimeter). For the determination of the light absorption coefficient from the opacity signal, the optical path length of the instrument shall be supplied by the instrument manufacturer.

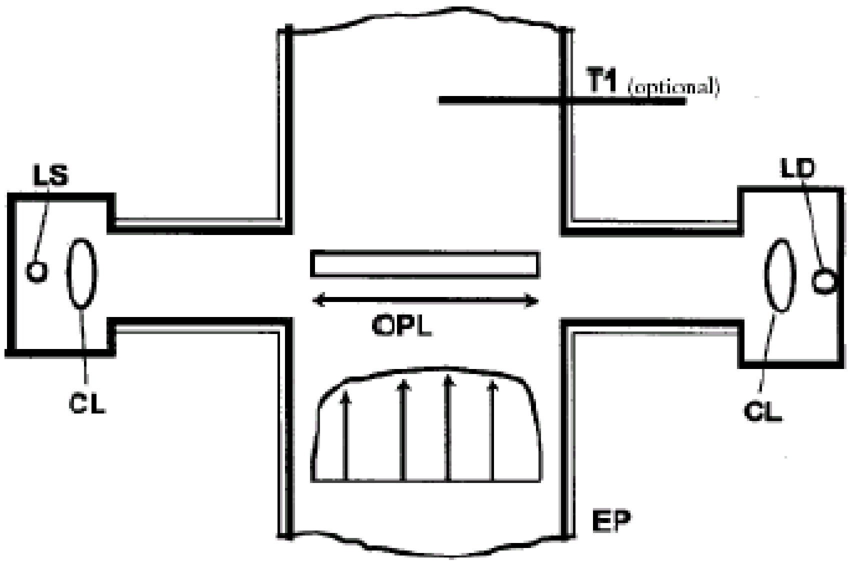
Full Flow Opacimeter

Two general types of full flow opacimeters may be used (Figure 23 of this chapter). With the inline opacimeter, the opacity of the full exhaust plume within the exhaust pipe is measured. With this type of opacimeter, the effective optical path length is a function of the opacimeter design.

With the end-of-line opacimeter, the opacity of the full exhaust plume is measured as it exits the exhaust pipe. With this type of opacimeter, the effective optical path length is a function of the exhaust pipe design and the distance between the end of the exhaust pipe and the opacimeter.

Figure 23

Full flow opacimeter



3.2.1. Components of Figure 23

EP Exhaust Pipe

With an in-line opacimeter, there shall be no change in the exhaust pipe diameter within 3 exhaust pipe diameters before or after the measuring zone. If the diameter of the measuring zone is greater than the diameter of the exhaust pipe, a pipe gradually convergent before the measuring zone is recommended.

With an end-of-line opacimeter, the terminal 0,6 m of the exhaust pipe shall be of circular cross section and be free from elbows and bends. The end of the exhaust pipe shall be cut off squarely. The opacimeter shall be mounted centrally to the plume within 25 ± 5 mm of the end of the exhaust pipe.

OPL Optical Path Length

The length of the smoke obscured optical path between the opacimeter light source and the receiver, corrected as necessary for non-uniformity due to density gradients and fringe effect. The optical path length shall be submitted by the instrument manufacturer taking into account any measures against sooting (e.g. purge air). If the optical path length is not available, it shall be determined in accordance with ISO IDS 11614, section 11.6.5. For the correct determination of the optical path length, a minimum exhaust gas velocity of 20 m/s is required.

LS Light source

The light source shall be an incandescent lamp with a colour temperature in the range of 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The light source shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

LD Light detector

The detector shall be a photocell or a photodiode (with a filter, if necessary). In the case of an incandescent light source, the receiver shall have a peak spectral response similar to the phototopic curve of the human eye (maximum response) in the range of 550 to 570 nm, to less than 4 % of that maximum response below 430 nm and above 680 nm. The light detector shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

CL Collimating lens

The light output shall be collimated to a beam with a maximum diameter of 30 mm. The rays of the light beam shall be parallel within a tolerance of 3° of the optical axis.

T1 Temperature sensor (optional)

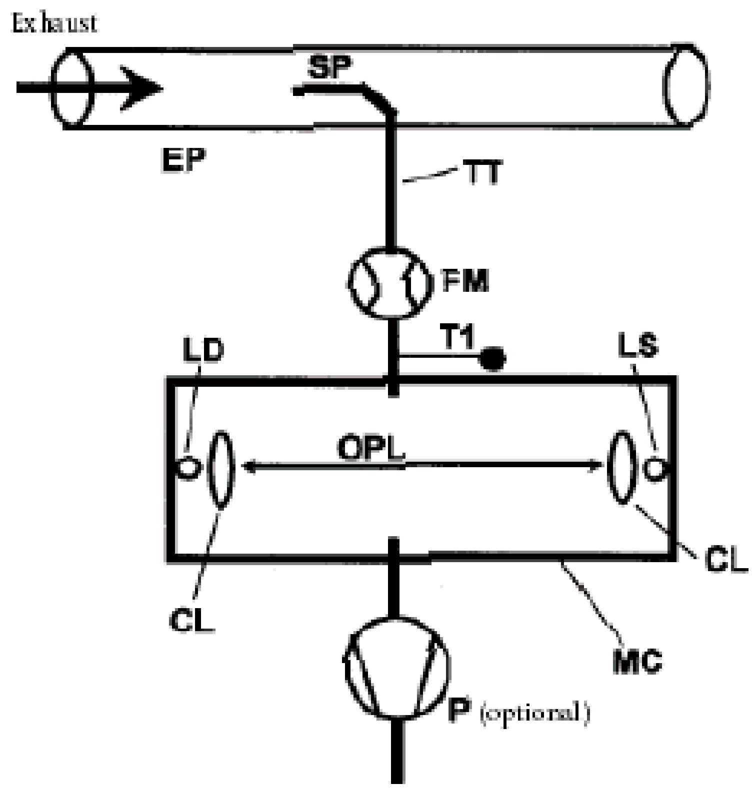
The exhaust gas temperature may be monitored over the test.

Partial Flow Opacimeter

With the partial flow opacimeter (Figure 24 of this chapter), a representative exhaust sample is taken from the exhaust pipe and passed through a transfer line to the measuring chamber. With this type of opacimeter, the effective optical path length is a function of the opacimeter design. The response times referred to in the following section apply to the minimum flow rate of the opacimeter, as specified by the instrument manufacturer.

Figure 24

Partial flow opacimeter



3.3.1. Components of Figure 24

EP Exhaust Pipe

The exhaust pipe shall be a straight pipe of at least 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

SP Sampling probe

The sampling probe shall be an open tube facing upstream on or about the exhaust pipe centerline. The clearance with the wall of the tailpipe shall be at least 5 mm. The probe diameter shall ensure a representative sampling and a sufficient flow through the opacimeter.

TT Transfer tube

The transfer tube shall:

- Be as short as possible and ensure an exhaust gas temperature of 373 ± 30 K (100 °C ± 30 °C) at the entrance to the measuring chamber.

- Have a wall temperature sufficiently above the dew point of the exhaust gas to prevent condensation.

- Be equal to the diameter of the sampling probe over the entire length.

- Have a response time of less than 0,05 s at minimum instrument flow, as determined according to chapter III, appendix 4, section 5.2.4 of this part.

- Have no significant effect on the smoke peak.

FM Flow measurement device

Flow instrumentation to detect the correct flow into the measuring chamber. The minimum and maximum flow rates shall be specified by the instrument manufacturer, and shall be such that the response time requirement of TT and the optical path length specifications are met. The flow measurement device may be close to the sampling pump, P, if used.

MC Measuring chamber

The measuring chamber shall have a non-reflective internal surface, or equivalent optical environment. The impingement of stray light on the detector due to internal reflections of diffusion effects shall be reduced to a minimum.

The pressure of the gas in the measuring chamber shall not differ from the atmospheric pressure by more than 0,75 kPa. Where this is not possible by design, the opacimeter reading shall be converted to atmospheric pressure.

The wall temperature of the measuring chamber shall be set to within ± 5 K between 343 K (70 °C) and 373 K (100 °C), but in any case sufficiently above the dew point of the exhaust gas to prevent condensation. The measuring chamber shall be equipped with appropriate devices for measuring the temperature.

OPL Optical Path Length

The length of the smoke obscured optical path between the opacimeter light source and the receiver, corrected as necessary for non-uniformity due to density gradients and fringe effect. The optical path length shall be submitted by the instrument manufacturer taking into account any measures against sooting (e.g.

purge air). If the optical path length is not available, it shall be determined in accordance with ISO IDS 11614, section 11.6.5.

LS Light source

The light source shall be an incandescent lamp with a colour temperature in the range of 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The light source shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

LD Light detector

The detector shall be a photocell or a photodiode (with a filter, if necessary). In the case of an incandescent light source, the receiver shall have a peak spectral response similar to the phototopic curve of the human eye (maximum response) in the range of 550 to 570 nm, to less than 4 % of that maximum response below 430 nm and above 680 nm. The light detector shall be protected against sooting by means that do not influence the optical path length beyond the manufacturers specifications.

CL Collimating lens

The light output shall be collimated to a beam with a maximum diameter of 30 mm. The rays of the light beam shall be parallel within a tolerance of 3° of the optical axis.

T1 Temperature sensor

To monitor the exhaust gas temperature at the entrance to the measuring chamber.

P Sampling pump (optional)

A sampling pump downstream of the measuring chamber may be used to transfer the sample gas through the measuring chamber.

Chapter 6

Example of Calculation Procedure

1. ESC TEST

1.1. Gaseous emissions

The measurement data for the calculation of the individual mode results are shown below. In this example, CO and NO_X are measured on a dry basis, HC on a wet basis. The HC concentration is given in propane equivalent (C3) and has to be multiplied by 3 to result in the C1 equivalent. The calculation procedure is identical for the other modes.

P(kW)	82.9
T_a (K)	294.8
H_a (g/Kg)	7.81
q_{mew} (Kg/h)	563.38
q_{maw} (Kg/h)	545.29
q_{mf} (Kg/h)	18.09
HC (ppm)	6.3
CO (ppm)	41.2
NO_X (ppm)	495
W_{ALF} , % mass	15.38
W_{BET} , % mass	84.60
W_{GAM} , % mass	0.005
W_{DEL} , % mass	0.011
W_{EPS} , % mass	0.004

Calculation of the dry to wet correction factor $K_{W,r}$ (Chapter III, Appendix 1, Section 5.2)

$$k_{W,r} = \left(1 - \frac{1{,}2442 \times H_a + 111{,}19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773{,}4 + 1{,}2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000} \right) \times 1{,}008$$

$q_{mad} = q_{maw} / k_{w,a}$

$$k_{w,a} = 1 - \frac{(1.608 \times 7.81)}{1000 + (1.608 \times 7.81)} = 0.9876$$

$q_{mad} = 545.29 / 0.9876 = 552.138$

$k_f = 0{,}055584 \times 15.38 – 0{,}0001083 \times 84.60 – 0{,}0001562 \times 0.005 + 0{,}0079936 \times 0.011 + 0{,}0069978 \times 0.004 = 0.8458$

$k_{w,r}$ = 0.9263

Calculation of the wet concentrations:

CO = 41,2 × 0,9263 = 38,16 ppm

NOx = 495 × 0,9263 = 458.5 ppm

Calculation of the NO_X humidity correction factor $K_{h,D}$ (Chapter III, appendix 1, section 5.3):

$$k_{h,D} = \frac{1}{1 - 0,0182 \times (H_a - 10,71) + 0,0045 \times (T_a - 298)}$$

= 0.9630

Calculation of the emission mass flow rates (Chapter III, appendix 1, section 5.4):

NOx = 0,001587 × 458.5 × 0,9630 × 563,38 = 394.78 g/h

CO = 0,000966 × 38,16 × 563,38 = 20,767 g/h

HC = 0,000479 × 6,3 × 3 × 563,38 = 5,100 g/h

Calculation of the specific emissions (Chapter III, appendix 1, section 5.5):

The following example calculation is given for CO; the calculation procedure is identical for the other components.

The emission mass flow rates of the individual modes are multiplied by the respective weighting factors, as indicated in Chapter III, appendix 1, section 2.7.1, and summed up to result in the mean emission mass flow rate over the cycle:

CO = (6,7 × 0,15) + (24,6 × 0,08) + (20,5 × 0,10) + (20,7 × 0,10) + (20,6 × 0,05) + (15,0 × 0,05) + (19,7 × 0,05) + (74,5 × 0,09) + (31,5 × 0,10) + (81,9 × 0,08) + (34,8 × 0,05) + (30,8 × 0,05) + (27,3 × 0,05)

= 30,91 g/h

The engine power of the individual modes is multiplied by the respective weighting factors, as indicated in Chapter III, appendix 1, section 2.7.1, and summed up to result in the mean cycle power:

P(n) = (0,1 × 0,15) + (96,8 × 0,08) + (55,2 ×0,10) + (82,9 × 0,10) + (46,8 × 0,05) + (70,1 × 0,05) + (23,0 × 0,05) + (114,3 × 0,09) + (27,0 × 0,10) + (122,0 ×

0,08) + (28,6 × 0,05) + (87,4 × 0,05) + (57,9 × 0,05)

= 60,006 kW

CO = 30,91 / 60,006 = 0,0515 g / kWh

Calculation of the specific NO_X emission of the random point (Chapter III, appendix 1, Section 5.6.1):

Assume the following values have been determined on the random point:

n_Z = 1 600 min-1

M_Z = 495 Nm

$NO_{X\ mass,Z}$ = 487,9 g/h (calculated according to the previous formulae)

$P(n)_Z$ = 83 kW

$NO_{X,Z}$ = 487,9/83 = 5,878 g/kWh

Determination of the emission value from the test cycle (Chapter III, appendix 1, section 5.6.2):

Assume the values of the four enveloping modes on the ESC to be as follows:

n_{RT}	n_{SU}	E_R	E_S	E_T	E_U	M_R	M_S	M_T	M_U
1 368	1 785	5,943	5,565	5,889	4,973	515	460	681	610

E_{TU} = 5,889 + (4,973_5,889) × (1 600_1 368) / (1 785_1 368) = 5,377 g/kWh

E_{RS} = 5,943 + (5,565_5,943) × (1 600_1 368) / (1 785_1 368) = 5,732 g/kWh

M_{TU} = 681 + (601_681) × (1 600_1 368) / (1 785_1 368) = 641,3 Nm

M_{RS} = 515 + (460_515) × (1 600_1 368) / (1 785_1 368) = 484,3 Nm

E_Z = 5,732 + (5,377_5,732) × (495_484,3) / (641,3_484,3) = 5,708 g/kWh

Comparison of the NOx emission values (Chapter III, appendix 1, Section 5.6.3):

$NO_{X\ diff}$ = 100 × (5,878 - 5,708) / 5,708 = 2,98 %

1.2. Particulate emissions

Particulate measurement is based on the principle of sampling the particulates over the complete cycle, but determining the sample and flow rates (m_{sep} and q_{medf}) during the individual modes. The calculation of q_{medf} depends on the system used. In the following examples, a system with CO2 measurement and carbon balance method and a system with flow measurement are used. When using a full flow dilution system, q_{medf} is directly measured by the CVS equipment.

Calculation of q_{medf} (Chapter III, Appendix 1, Sections 5.2.3 and 5.2.4):

Assume the following measurement data of mode 4. The calculation procedure is identical for the other modes.

q_{mew} (Kg/h)	q_{mf} (Kg/h)	q_{mdw} (Kg/h)	q_{mdew} (Kg/h)	CO_{2D} (%)	CO_{2A} (%)
334.02	10.76	5.4435	6.0	0.657	0.040

(a) carbon balance method

$$q_{medf} = \frac{206,5 \times 10,76}{0,657 - 0,040} = 3\,601,2 \text{ kg/h}$$

(b) flow measurement method

$$q = 6.0 / (6.0 - 5.4435) = 10.78$$

$$q_{medf} = 334.02 \text{ X } 10.78 = 3600.7 \text{ Kg/h}$$

Calculation of the mass flow rate (Chapter III, Appendix 1, Section 5.4):

The q_{medf} flow rates of the individual modes are multiplied by the respective weighting factors, as indicated in chapter III, Appendix 1, Section 2.7.1, and summed up to result in the mean q_{medf} over the cycle. The total sample rate m_{sep} is summed up from the sample rates of the individual modes.

$$\overline{q_{medf}} = (3\,567 \times 0,15) + (3\,592 \times 0,08) + (3\,611 \times 0,10) + (3\,600 \times 0,10) + (3\,618 \times 0,05) + (3\,600 \times 0,05) + (3\,640 \times 0,05) + (3\,614 \times 0,09) + (3\,620 \times 0,10) + (3\,601 \times 0,08) + (3\,639 \times 0,05) + (3\,582 \times 0,05) + (3\,635 \times 0,05)$$

$$= 3\,604,6 \text{ kg/h}$$

m_{sep} = 0,226 + 0,122 + 0,151 + 0,152 + 0,076 + 0,076 + 0,076 + 0,136 + 0,151 + 0,121 + 0,076 + 0,076 + 0,075

= 1,515 kg

Assume the particulate mass on the filters to be 2,5 mg, then

PT_{mass} = (2.5 X 360.4) / (1.515 X 1000) = 5.948 g/h

Background correction (optional)

Assume one background measurement with the following values. The calculation of the dilution factor D is identical to Section 3.1 of this chapter and not shown here.

$m_{f,d}$ = 0,1 mg; m_d = 1,5 kg

Sum of D = [(1-1/119,15) × 0,15] + [(1-1/8,89) × 0,08] + [(1-1/14,75) × 0,10] + [(1-1/10,10) × 0,10] + [(1-1/18,02) × 0,05] + [(1-1/12,33) × 0,05) + [(1-1/32,18) × 0,05]+ [(1-1/6,94) × 0,09] + [(1-1/25,19) × 0,10] + [(1-1/6,12) × 0,08] + [(1-1/20,87) × 0,05] + [(1-1/8,77) × 0,05] + [(1-1/12,59) × 0,05]

= 0,923

PT_{mass} = 2.5 / 1.515 – (0.1 / 1.5 X 0.923) X 3604.6 /1000 = 5.726 g/h.

Calculation of the specific emission (Chapter III, Appendix 1, Section 5.5):

P(n) = (0,1 × 0,15) + (96,8 × 0,08) + (55,2 × 0,10) + (82,9 × 0,10) + (46,8 × 0,05) + (70,1 × 0,05)+ (23,0 × 0,05) + (114,3 × 0,09) + (27,0 × 0,10) + (122,0 × 0,08) + (28,6 × 0,05) +(87,4 × 0,05) + (57,9 × 0,05)

= 60,006 kW

$\overline{PT}$ = 5.948 / 60.006 = 0,099 g/kWh

$\overline{PT}$ = (5.726/60.006) = 0,095 g/kWh, if background corrected

Calculation of the specific weighting factor (Chapter III, Appendix 1, Section 5.6):

Assume the values calculated for mode 4 above, then

$WF_{E,i}$ = (0,152 × 3 604,6/1,515 × 3 600,7) = 0,1004

This value is within the required value of 0,10 ± 0,003.

2. ELR TEST

Since Bessel filtering is a completely new averaging procedure in European exhaust legislation, an explanation of the Bessel filter, an example of the design of a Bessel algorithm, and an example of the calculation of the final smoke value is given below. The constants of the Bessel algorithm only depend on the design of the opacimeter and the sampling rate of the data acquisition system. It is recommended that the opacimeter manufacturer provide the final Bessel filter constants for different sampling rates and that the customer use these constants for designing the Bessel algorithm and for calculating the smoke values.

2.1. General remarks on the Bessel filter

Due to high frequency distortions, the raw opacity signal usually shows a highly scattered trace. To remove these high frequency distortions a Bessel filter is required for the ELR-test. The Bessel filter itself is a recursive, second-order low-pass filter which guarantees the fastest signal rise without overshoot.

Assuming a real time raw exhaust plume in the exhaust tube, each opacimeter shows a delayed and differently measured opacity trace. The delay and the magnitude of the measured opacity trace is primarily dependent on the geometry of the measuring chamber of the opacimeter, including the exhaust sample lines, and on the time needed for processing the signal in the electronics of the opacimeter. The values that characterize these two effects are called the physical and the electrical response time, which represent an individual filter for each type of opacimeter.

The goal of applying a Bessel filter is to guarantee a uniform overall filter characteristic of the whole opacimeter system, consisting of:

— physical response time of the opacimeter (tp),

— electrical response time of the opacimeter (te),

— filter response time of the applied Bessel filter (tF).

The resulting overall response time of the system tAver is given by:

$$t_{Aver} = \sqrt{t_F^2 + t_p^2 + t_e^2}$$

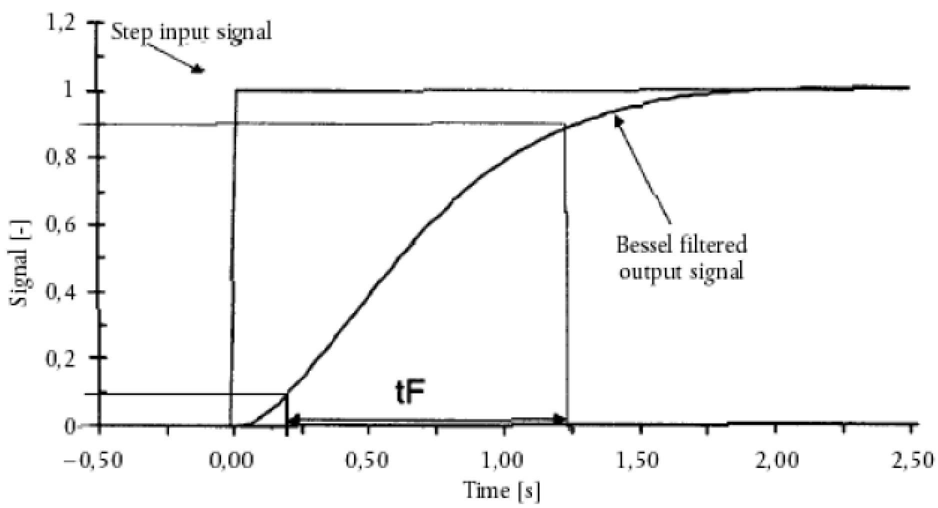
and must be equal for all kinds of opacimeters in order to give the same smoke value. Therefore, a Bessel filter has to be created in such a way, that the filter response time (t_F) together with the physical (t_p) and electrical response time (t_e) of the individual opacimeter must result in the required overall response time (t_{Aver}). Since t_p and t_e are given values for each individual opacimeter, and t_{Aver} is defined to be 1,0 s in this Directive, t_F can be calculated as follows:

$$t_F = \sqrt{t_{Aver}^2 + t_p^2 + t_e^2}$$

By definition, the filter response time tF is the rise time of a filtered output signal between 10 % and 90 % on a step input signal. Therefore the cut-off frequency of the Bessel filter has to be iterated in such a way, that the response time of the Bessel filter fits into the required rise time.

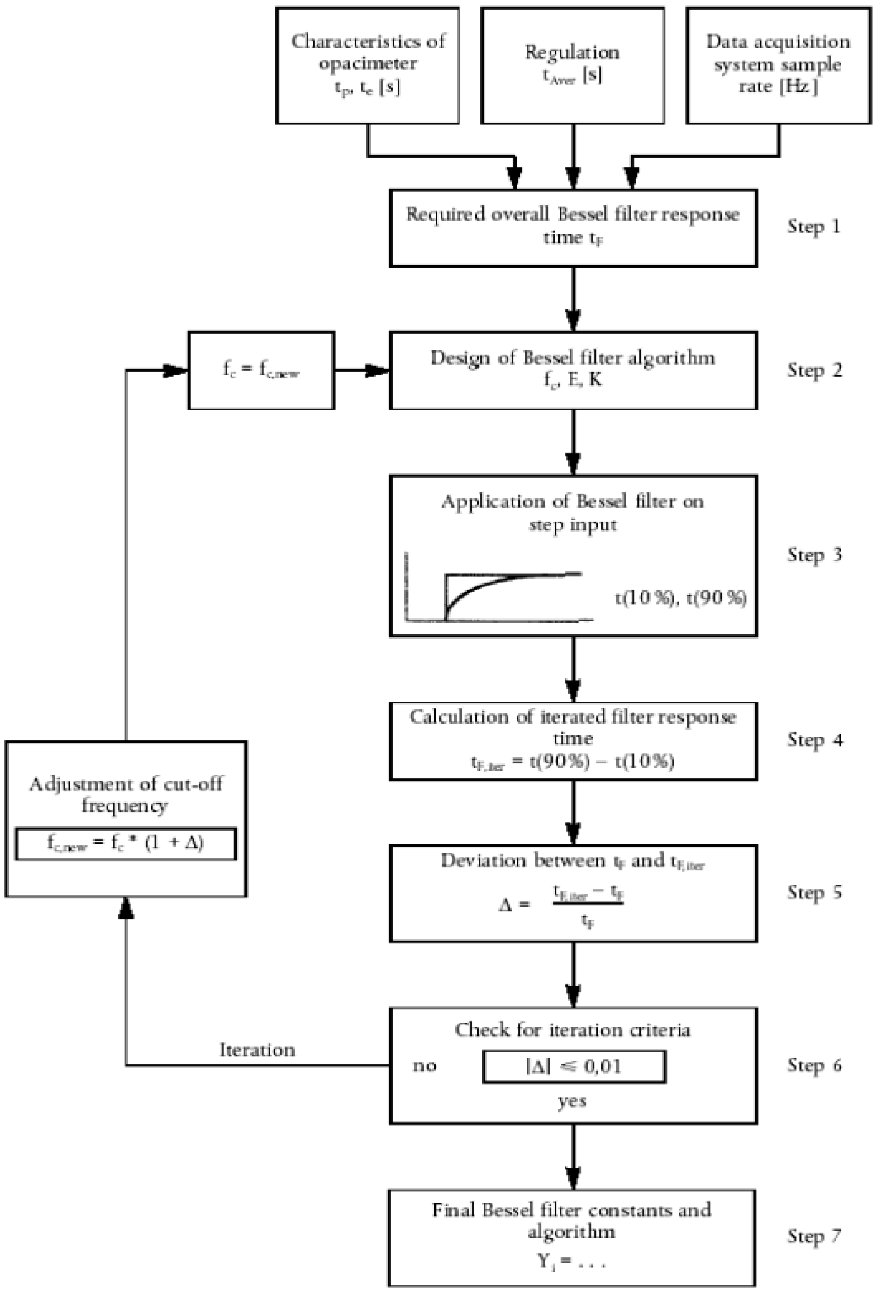
Figure a

Traces of a step input signal and the filtered output signal



In Figure a, the traces of a step input signal and Bessel filtered output signal as well as the response time of the Bessel filter (t_F) are shown.

Designing the final Bessel filter algorithm is a multi step process which requires several iteration cycles. The scheme of the iteration procedure is presented below.



2.2. Calculation of the Bessel algorithm

In this example a Bessel algorithm is designed in several steps according to the above iteration procedure which is based upon Chapter III, Appendix 1, Section 6.1.

For the opacimeter and the data acquisition system, the following characteristics are assumed:

— physical response time t_p 0,15 s

— electrical response time t_e 0,05 s

— overall response time t_{Aver} 1,00 s (by definition in this Part)

— sampling rate 150 Hz

Step 1 Required Bessel filter response time t_F:

$$t_F = \sqrt{1^2 - (0{,}15^2 + 0{,}05^2)} = 0{,}987421 \text{ s}$$

Step 2 Estimation of cut-off frequency and calculation of Bessel constants E, K for first iteration:

$$f_c = \frac{3{,}1415}{10 \times 0{,}987421} = 0{,}318152 \text{ Hz}$$

$$\Delta t = 1/150 = 0{,}006667 \text{ s}$$

$$\Omega = \frac{1}{\tan[3{,}1415 \times 0{,}006667 \times 0{,}318152]} = 150{,}07664$$

$$E = \frac{1}{1 + 150{,}076644 \times \sqrt{3 \times 0{,}618034} + 0{,}618034 + 150{,}076644^2} = 7{,}07948 \times 10^{-5}$$

$$K = 2 \times 7{,}07948 \times 10^{-5} \times (0{,}618034 \times 150{,}076644^2 - 1) - 1 = 0{,}970783$$

This gives the Bessel algorithm:

$Y_i = Y_{i-1} + 7{,}07948 \text{ E} - 5 \times (S_i + 2 \times S_{i-1} + S_{i-2} - 4 \times Y_{i-2}) + 0{,}970783 \times (Y_{i-1} - Y_{i-2})$

where S_i represents the values of the step input signal (either '0' or '1') and Y_i represents the filtered values of the output signal.

Step 3 Application of Bessel filter on step input:

The Bessel filter response time t_F is defined as the rise time of the filtered output signal between 10 % and 90 % on a step input signal. For determining the times of 10 % (t_{10}) and 90 % (t_{90}) of the output signal, a Bessel filter has to be applied to a step input using the above values of f_c, E and K.

The index numbers, the time and the values of a step input signal and the resulting values of the filtered output signal for the first and the second iteration are shown in Table B. The points adjacent to t_{10} and t_{90} are marked in bold numbers.

In Table B, first iteration, the 10 % value occurs between index number 30 and 31 and the 90 % value occurs between index number 191 and 192. For the calculation of $t_{F,iter}$ the exact t_{10} and t_{90} values are determined by linear interpolation between the adjacent measuring points, as follows:

$$t_{10} = t_{lower} + \Delta t \times (0,1 - out_{lower})/(out_{upper} - out_{lower})$$

$$t_{90} = t_{lower} + \Delta t \times (0,9 - out_{lower})/(out_{upper} - out_{lower})$$

where out_{upper} and out_{lower}, respectively, are the adjacent points of the Bessel filtered output signal, and t_{lower} is the time of the adjacent time point, as indicated in Table B.

t_{10} = 0,200000 + 0,006667 × (0,1 - 0,099208)/(0,104794 - 0,099208) = 0,200945 s

t_{90} = 0,273333 + 0,006667 × (0,9 - 0,899147)/(0,901168 - 0,899147) = 1,276147 s

Step 4 Filter response time of first iteration cycle:

$$t_{F,iter} = 1,276147 - 0,200945 = 1,075202 \text{ s}$$

Step 5 Deviation between required and obtained filter response time of first iteration cycle:

$$\Delta = (1,075202 - 0,987421)/0,987421 = 0,081641$$

Step 6 Checking the iteration criteria:

$|\Delta| \leq 0,01$ is required. Since 0,081641 > 0,01, the iteration criteria is not met and a further iteration cycle has to be started. For this iteration cycle, a new cut-off frequency is calculated from f_c and Δ as follows:

$$f_{c,new} = 0,318152 \times (1 + 0,081641) = 0,344126 \text{ Hz}$$

This new cut-off frequency is used in the second iteration cycle, starting at step 2 again. The iteration has to be repeated until the iteration criteria is met. The resulting values of the first and second iteration are summarised in Table A

Table A

Values of the first and second iteration

Parameter		1. Iteration	2. Iteration
f_c	(Hz)	0,318152	0,344126
E	(-)	7,07948 E-5	8,272777 E-5
K	(-)	0,970783	0,968410
t_{10}	(s)	0,200945	0,185523
t_{90}	(s)	1,276147	1,179562
$t_{F,iter}$	(s)	1,075202	0,994039
Δ	(-)	0,081641	0,006657
$f_{c,new}$	(Hz)	0,344126	0,346417

Step 7 Final Bessel algorithm:

As soon as the iteration criteria has been met, the final Bessel filter constants and the final Bessel algorithm are calculated according to step 2. In this example, the iteration criteria has been met after the second iteration (Δ = 0,006657 ≤ 0,01). The final algorithm is then used for determining the averaged smoke values (see next Section 2.3).

$$Y_i = Y_{i-1} + 8,272777 \times 10^{-5} \times (S_i + 2 \times S_{i-1} + S_{i-2} - 4 \times Y_{i-2}) + 0,968410 \times (Y_{i-1} - Y_{i-2})$$

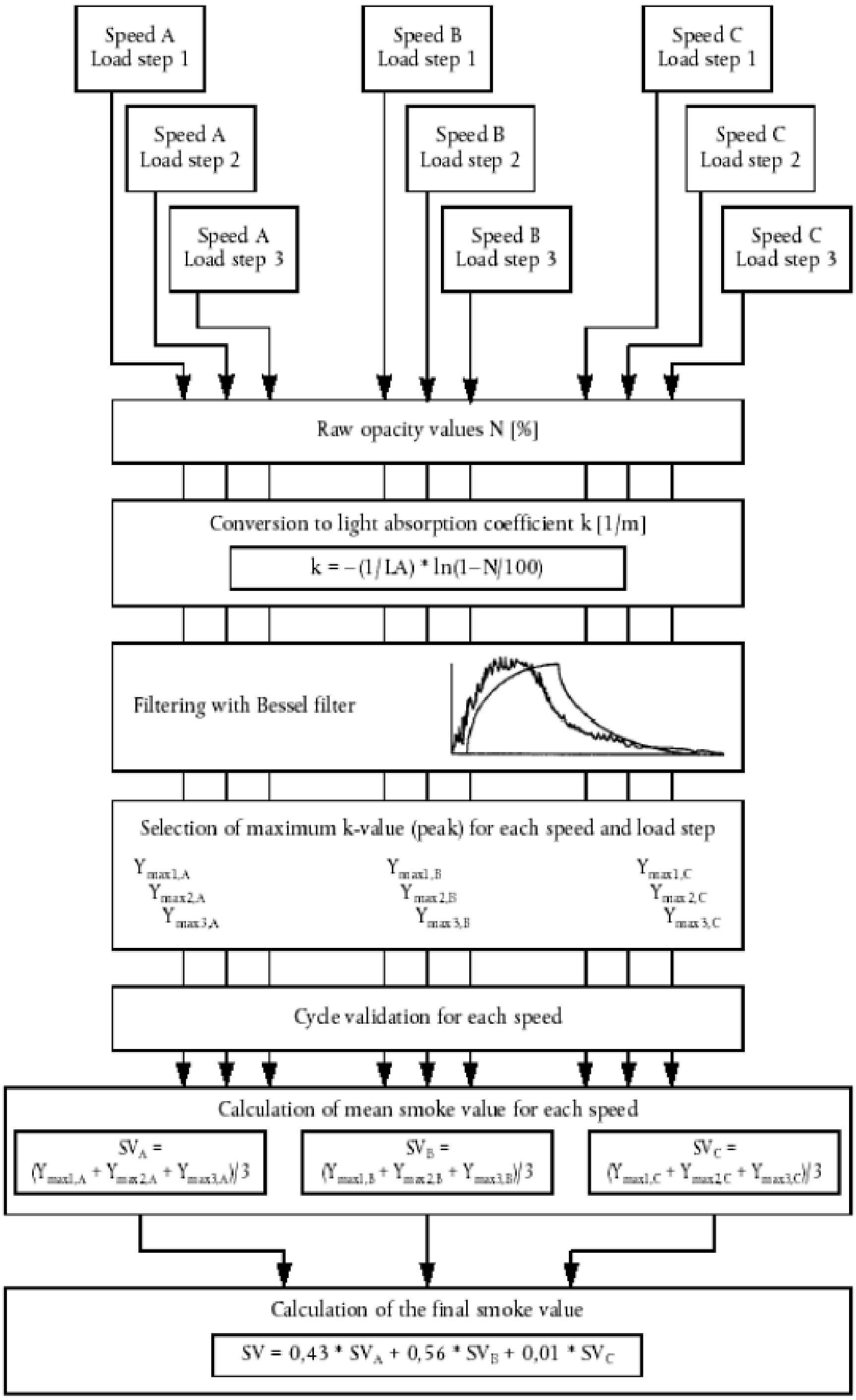
Table B

Values of step input signal and Bessel filtered output signal for the first and second iteration cycle

Index i	Time	Step Input Signal S_i	Filtered Output Signal Y_i	
			[−]	
[−]	[s]	[−]	1. Iteration	2. Iteration
−2	−0,013333	0	0,000000	0,000000
−1	−0,006667	0	0,000000	0,000000
0	0,000000	1	0,000071	0,000083
1	0,006667	1	0,000352	0,000411
2	0,013333	1	0,000908	0,001060
3	0,020000	1	0,001731	0,002019
4	0,026667	1	0,002813	0,003278
5	0,033333	1	0,004145	0,004828
~	~	~	~	~
24	0,160000	1	0,067877	0,077876
25	0,166667	1	0,072816	0,083476
26	0,173333	1	0,077874	0,089205
27	0,180000	1	0,083047	0,095056
28	0,186667	1	0,088331	0,101024
29	0,193333	1	0,093719	0,107102
30	0,200000	1	0,099208	0,113286
31	0,206667	1	0,104794	0,119570
32	0,213333	1	0,110471	0,125949
33	0,220000	1	0,116236	0,132418
34	0,226667	1	0,122085	0,138972
35	0,233333	1	0,128013	0,145605
36	0,240000	1	0,134016	0,152314
37	0,246667	1	0,140091	0,159094
~	~	~	~	~
175	1,166667	1	0,862416	0,895701
176	1,173333	1	0,864968	0,897941
177	1,180000	1	0,867484	0,900145
178	1,186667	1	0,869964	0,902312
179	1,193333	1	0,872410	0,904445
180	1,200000	1	0,874821	0,906542
181	1,206667	1	0,877197	0,908605
182	1,213333	1	0,879540	0,910633
183	1,220000	1	0,881849	0,912628
184	1,226667	1	0,884125	0,914589
185	1,233333	1	0,886367	0,916517
186	1,240000	1	0,888577	0,918412
187	1,246667	1	0,890755	0,920276
188	1,253333	1	0,892900	0,922107
189	1,260000	1	0,895014	0,923907
190	1,266667	1	0,897096	0,925676
191	1,273333	1	0,899147	0,927414
192	1,280000	1	0,901168	0,929121
193	1,286667	1	0,903158	0,930799
194	1,293333	1	0,905117	0,932448
195	1,300000	1	0,907047	0,934067
~	~	~	~	~

2.3. **Calculation of the smoke Values**

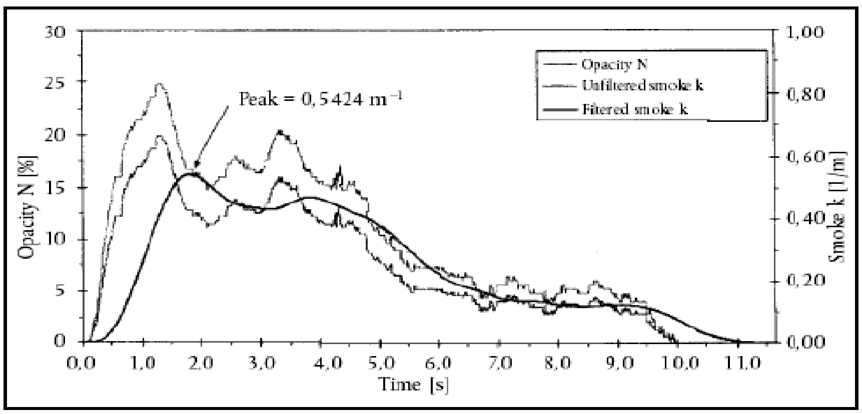
In the scheme below the general procedure of determining the final smoke value is presented.



In Figure b, the traces of the measured raw opacity signal, and of the unfiltered and filtered light absorption coefficients (k-value) of the first load step of an ELR-Test are shown, and the maximum value Ymax1,A (peak) of the filtered k trace is indicated. Correspondingly, Table C contains the numerical values of index i, time (sampling rate of 150 Hz), raw opacity, unfiltered k and filtered k. Filtering was conducted using the constants of the Bessel algorithm designed in Section 2.2 of this Annex. Due to the large amount of data, only those sections of the smoke trace around the beginning and the peak are tabled.

Figure b

Traces of measured opacity N, of unfiltered smoke k and of filtered smoke k



The peak value (i = 272) is calculated assuming the following data of Table C. All other individual smoke values are calculated in the same way. For starting the algorithm, S_{-1}, S_{-2}, Y_{-1} and Y_{-2} are set to zero.

L_A (m)	0,430
Index i	272
N (%)	16,783
S_{271} (m^{-1})	0,427392
S_{270} (m^{-1})	0,427532
Y_{271} (m^{-1})	0,542383
Y_{270} (m^{-1})	0,542337

Calculation of the k-value (Chapter III, Appendix 1, Section 6.3.1):

$$k = -(1/0{,}430) \times \ln(1 - (16{,}783/100)) = 0{,}427252 \text{ m}^{-1}$$

This value corresponds to S_{272} in the following equation.

Calculation of Bessel averaged smoke (Chapter III, Appendix 1, Section 6.3.2):

In the following equation, the Bessel constants of the previous Section 2.2 are used. The actual unfiltered k-value, as calculated above, corresponds to S_{272} (S_i). S_{271} (S_{i-1}) and S_{270} (S_{i-2}) are the two preceding unfiltered k-values, Y_{271} (Y_{i-1}) and Y_{270} (Y_{i-2}) are the two preceding filtered k-values.

$$Y272 = 0,542383 + 8,272777 \times 10^{-5} \times (0,427252 + 2 \times 0,427392 + 0,427532 - 4 \times 0,542337) + 0,968410 \times (0,542383 - 0,542337)$$

$$= 0,542389 \text{ m}^{-1}$$

This value corresponds to $Y_{max1,A}$ in the following equation.

Calculation of the final smoke value (Chapter III, Appendix 1, Section 6.3.3):

From each smoke trace, the maximum filtered k-value is taken for the further calculation.

Assume the following values

Speed	Y_{max} (m^{-1})		
	Cycle 1	Cycle 2	Cycle 3
A	0,5424	0,5435	0,5587
B	0,5596	0,5400	0,5389
C	0,4912	0,5207	0,5177

$SV_A = (0,5424 + 0,5435 + 0,5587) / 3 = 0,5482 \text{ m}^{-1}$

$SV_B = (0,5596 + 0,5400 + 0,5389) / 3 = 0,5462 \text{ m}^{-1}$

$SV_C = (0,4912 + 0,5207 + 0,5177) / 3 = 0,5099 \text{ m}^{-1}$

$SV = (0,43 * 0,5482) + (0,56 * 0,5462) + (0,01 * 0,5099) = 0,5467 \text{ m}^{-1}$

Cycle validation (Chapter III, Appendix 1, Section 3.4)

Before calculating SV, the cycle must be validated by calculating the relative standard deviations of the smoke of the three cycles for each speed.

Speed	Mean SV (m^{-1})	Absolute standard deviation (m^{-1})	Relative standard deviation (%)
A	0,5482	0,0091	1,7
B	0,5462	0,0116	2,1
C	0,5099	0,0162	3,2

In this example, the validation criteria of 15 % are met for each speed.

Table C

Values of opacity N, unfiltered and filtered k-value at beginning of load step

Index i [–]	Time [s]	Opacity N [%]	unfiltered k-value [m^{-1}]	filtered k-value [m^{-1}]
−2	0,000000	0,000000	0,000000	0,000000
−1	0,000000	0,000000	0,000000	0,000000
0	0,000000	0,000000	0,000000	0,000000
1	0,006667	0,020000	0,000465	0,000000
2	0,013333	0,020000	0,000465	0,000000
3	0,020000	0,020000	0,000465	0,000000
4	0,026667	0,020000	0,000465	0,000001
5	0,033333	0,020000	0,000465	0,000002
6	0,040000	0,020000	0,000465	0,000002
7	0,046667	0,020000	0,000465	0,000003
8	0,053333	0,020000	0,000465	0,000004
9	0,060000	0,020000	0,000465	0,000005
10	0,066667	0,020000	0,000465	0,000006
11	0,073333	0,020000	0,000465	0,000008
12	0,080000	0,020000	0,000465	0,000009
13	0,086667	0,020000	0,000465	0,000011
14	0,093333	0,020000	0,000465	0,000012
15	0,100000	0,192000	0,004469	0,000014
16	0,106667	0,212000	0,004935	0,000018
17	0,113333	0,212000	0,004935	0,000022
18	0,120000	0,212000	0,004935	0,000028
19	0,126667	0,343000	0,007990	0,000036
20	0,133333	0,566000	0,013200	0,000047
21	0,140000	0,889000	0,020767	0,000061
22	0,146667	0,929000	0,021706	0,000082
23	0,153333	0,929000	0,021706	0,000109
24	0,160000	1,263000	0,029559	0,000143
25	0,166667	1,455000	0,034086	0,000185
26	0,173333	1,697000	0,039804	0,000237
27	0,180000	2,030000	0,047695	0,000301
28	0,186667	2,081000	0,048906	0,000378
29	0,193333	2,081000	0,048906	0,000469
30	0,200000	2,424000	0,057067	0,000573
31	0,206667	2,475000	0,058282	0,000693
32	0,213333	2,475000	0,058282	0,000827
33	0,220000	2,808000	0,066237	0,000977
34	0,226667	3,010000	0,071075	0,001144
35	0,233333	3,253000	0,076909	0,001328
36	0,240000	3,606000	0,085410	0,001533
37	0,246667	3,960000	0,093966	0,001758
38	0,253333	4,455000	0,105983	0,002007
39	0,260000	4,818000	0,114836	0,002283
40	0,266667	5,020000	0,119776	0,002587
~	~	~	~	~

Values of opacity N, unfiltered and filtered k-value around $Y_{max1,A}$ (≡ peak value, indicated in bold number)

Index i [–]	Time [s]	Opacity N [%]	unfiltered k-value [m^{-1}]	filtered k-value [m^{-1}]
~	~	~	~	~
259	1,726667	17,182000	0,438429	0,538856
260	1,733333	16,949000	0,431896	0,539423
261	1,740000	16,788000	0,427392	0,539936
262	1,746667	16,798000	0,427671	0,540396
263	1,753333	16,788000	0,427392	0,540805
264	1,760000	16,798000	0,427671	0,541163
265	1,766667	16,798000	0,427671	0,541473
266	1,773333	16,788000	0,427392	0,541735
267	1,780000	16,788000	0,427392	0,541951
268	1,786667	16,798000	0,427671	0,542123
269	1,793333	16,798000	0,427671	0,542251
270	1,800000	16,793000	0,427532	0,542337
271	1,806667	16,788000	0,427392	0,542383
272	1,813333	16,783000	0,427252	**0,542389**
273	1,820000	16,780000	0,427168	0,542357
274	1,826667	16,798000	0,427671	0,542288
275	1,833333	16,778000	0,427112	0,542183
276	1,840000	16,808000	0,427951	0,542043
277	1,846667	16,768000	0,426833	0,541870
278	1,853333	16,010000	0,405750	0,541662
279	1,860000	16,010000	0,405750	0,541418
280	1,866667	16,000000	0,405473	0,541136
281	1,873333	16,010000	0,405750	0,540819
282	1,880000	16,000000	0,405473	0,540466
283	1,886667	16,010000	0,405750	0,540080
284	1,893333	16,394000	0,416406	0,539663
285	1,900000	16,394000	0,416406	0,539216
286	1,906667	16,404000	0,416685	0,538744
287	1,913333	16,394000	0,416406	0,538245
288	1,920000	16,394000	0,416406	0,537722
289	1,926667	16,384000	0,416128	0,537175
290	1,933333	16,010000	0,405750	0,536604
291	1,940000	16,010000	0,405750	0,536009
292	1,946667	16,000000	0,405473	0,535389
293	1,953333	16,010000	0,405750	0,534745
294	1,960000	16,212000	0,411349	0,534079
295	1,966667	16,394000	0,416406	0,533394
296	1,973333	16,394000	0,416406	0,532691
297	1,980000	16,192000	0,410794	0,531971
298	1,986667	16,000000	0,405473	0,531233
299	1,993333	16,000000	0,405473	0,530477
300	2,000000	16,000000	0,405473	0,529704

3. ETC TEST

3.1. Gaseous emissions (diesel engine)

Assume the following test results for a PDP-CVS system

V_0 (m^3/rev)	0,1776
n_p (rev)	23 073
p_b (kPa)	98,0
p_1 (kPa)	2,3
T (K)	322,5
T_a (K)	298
H_a (g/kg)	12,8
C_{NOxe} (ppm)	53,7
C_{NOxd} (ppm)	0,4
C_{COe} (ppm)	38,9
C_{COd} (ppm)	1,0
C_{HCe} (ppm)	9,00
C_{HCd} (ppm)	3,02
C_{CO2e} (%)	0,723
W_{act} (kWh)	62,72

Calculation of the diluted exhaust gas flow (Chapter III, Appendix 2, Section 4.1):

m_{ed} = 1,293 × 0,1776 × 23 073 × (98,0 - 2,3) × 273 / (101,3 × 322,5) = 4 237,2 kg

Calculation of the NOx correction factor (Chapter III, Appendix 1, Section 5.3):

$$K_{h,D} = \frac{1}{1 - 0.0182 \times (12.8 - 10.71) + 0.0045 \times (298 - 298)} = 1.039$$

Calculation of the background corrected concentrations
(chapter III, Appendix 2, Section 5.4.1):

Assuming a diesel fuel of the composition $C_1H_{1,8}O_{0.01}$

$$F_s = 100 \times \frac{1}{1 + 1.8 / 2 + 3.76 \times (1 + 1.8 / 4 - 0.01 / 2)} = 13.6$$

DF = 13,6 . = 18,69

$$0{,}723 + (9{,}00 + 38{,}9) \times 10^{-4}$$

C_{NOx} = 53,7 - 0,4 × (1 - (1/18,69)) = 53,3 ppm

C_{CO} = 38,9 - 1,0 × (1 - (1/18,69)) = 37,9 ppm

C_{HC} = 9,00 - 3,02 × (1 - (1/18,69)) = 6,14 ppm

Calculation of the emissions mass flow (Chapter III, Appendix 2, Section 5.4):

m_{NOx} = 0,001587 × 53,3 × 1,039 × 4 237,2 = 372,391 g

m_{CO} = 0,000966 × 37,9 × 4 237,2 = 155,129 g

m_{HC} = 0,000479 × 6,14 × 4 237,2 = 12,462 g

Calculation of the specific emissions (Chapter III, Appendix 2, Section 5.5):

NOx = 372,391 / 62,72 = 5,94 g/kWh

CO = 155,129 / 62,72 = 2,47 g/kWh

HC = 12,462 / 62,72 = 0,199 g/kWh

3.2. Particulate emissions (diesel engine)

Assume the following test results for a PDP-CVS system with double dilution

m_{ed} (kg)	4 237,2
m_f (mg)	3,074
m_{set} (kg)	2,159
m_{ssd} (kg)	0,909
$m_{f,d}$ (mg)	0,341
m_d (kg)	1,245
D	18,69
Wact (kWh)	62,72

Calculation of the mass emission (Chapter III, Appendix 2, Section 6.2.1):

m_{sep} = 2,159 – 0,909 = 1,250 kg

m_{PT} = (3.074 / 1.250) x (4237.2 / 1000) = 10.42g

Calculation of the background corrected mass emission

(Chapter III, Appendix 2, Section 6.2.1):

m_{PT} = [(3.074 / 1.250) – ((0.341 / 1.245) x (1 - (1/18.69)))] x (4237.2 / 1000)

= 9.32g

Calculation of the specific emission (Chapter III, Appendix 2, Section 5.2):

M_{PT} = 10,42 / 62,72 = 0,166 g / kWh

M_{PT} = 9,32 / 62,72 = 0,149 g / kWh, if background corrected.

3.3. Gaseous emissions (CNG engine)

Assume the following test results for a PDP-CVS system with double dilution

m_{ed} (kg)	4 237,2
H_a (g/kg)	12,8
C_{NOxe} (ppm)	17,2
C_{NOxd} (ppm)	0,4
C_{COe} (ppm)	44,3
C_{COd} (ppm)	1,0
C_{HCe} (ppm)	27,0
C_{HCd} (ppm)	3,02
C_{CH4e} (ppm)	18,0

C_{CH4d} (ppm)	1,7
C_{CO2e} (%)	0,723
W_{act} (kWh)	62,72

Calculation of the NOx, correction factor (Chapter III, Appendix 1, Section 5.3):

$$k_{h,G} = 0.6272 + (44.030 \times 10^{-3} \times 12.8) – (0.862 \times 10^{-3} \times (12.8)^2) = 1.049$$

Calculation of the NMHC concentration (Annex III, Appendix 2, Section 4.3.1):

(a) GC method

$$C_{NMHC} = 27,0 - 18,0 = 9,0 \text{ ppm}$$

(b) NMC method
Assuming a methane efficiency of 0,04 and an ethane efficiency of 0,98 (see Chapter III, Appendix 5, Section 1.8.4)

$$C_{HC(w/cutter)} = 18 \times (0.98 – 0.04) + 27 \times (1-0.98) = 17.46$$

$$C_{NMHC} = \frac{27 \times (1 – 0.04) – 17.46.}{(0.98 – 0.04)} = 9.0 \text{ ppm}$$

Calculation of the background corrected concentrations (Chapter III, Appendix 2, Section 5.4.1):

Assuming a G_{20} reference fuel (100 % methane) of the composition $C_1H_4O_{0.01}$:

$$Fs = 100 \times \frac{1}{1 + 4 / 2 + 3.76 \times (1 + 4 / 4 – 0.01 / 2)} = 9.5$$

$$DF = \frac{9,5}{0,723 + (27,0 + 44,3) \times 10^{-4}} = 13,01$$

For NMHC, the background concentration is the difference between C_{HCd} and C_{CH4d}

$$C_{NOx} = 17,2 - 0,4 \times (1 - (1/13,01)) = 16,8 \text{ ppm}$$

$$C_{CO} = 44,3 -1,0 \times (1 - (1/13,01)) = 43,4 \text{ ppm}$$

$$C_{NMHC} = 9.0 - 1,32 \times (1 - (1/13,01)) = 7,8 \text{ ppm}$$

$$C_{CH4} = 18,0 - 1,7 \times (1 - (1/13,01)) = 16,4 \text{ ppm}$$

Calculation of the emissions mass flow (Chapter III, Appendix 2, Section 5.4):

m_{NOx} = 0,001588 × 16,8 × 1,049 × 4 237,2 = 118,581 g

m_{CO} = 0,000967 × 43,4 × 4 237,2 = 177,826 g

m_{NMHC} = 0,000584 × 7,8 × 4 237,2 = 19.301g

m_{CH4} = 0,000553 × 16,4 × 4 237,2 = 38,428 g

Calculation of the specific emissions (Annex III, Appendix 2, Section 4.4):

NOx = 118.581 / 62,72 = 1,89 g/kWh

CO = 177.826 / 62,72 = 2,84 g/kWh

NMHC = 19.301 / 62,72 = 0,308 g/kWh

CH4 = 38.428 / 62,72 = 0,613 g/kWh

4. λ-SHIFT FACTOR (S_λ)

4.1. Calculation of the λ-shift factor (S_λ) (1)

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert }\%}{100}\right)\left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}}$$

where:

S_λ = λ-shift factor;

inert % = % by volume of inert gases in the fuel (i.e. N_2, CO_2, He, etc.);

O2* = % by volume of original oxygen in the fuel;

(1) Stoichiometric Air/Fuel ratios of automotive fuels - SAE J1829, June 1987. John B. Heywood, Internal combustion engine fundamentals, McGraw-Hill, 1988, Chapter 3.4 'Combustion stoichiometry' (pp. 68 to 72).

n and m = refer to average C_nH_m representing the fuel hydrocarbons, i.e:

$$n = \frac{1 \times \left[\frac{CH_4\ \%}{100}\right] + 2 \times \left[\frac{C_2\ \%}{100}\right] + 3 \times \left[\frac{C_3\ \%}{100}\right] + 4 \times \left[\frac{C_4\ \%}{100}\right] + 5 \times \left[\frac{C_5\ \%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}}$$

$$m = \frac{4 \times \left[\frac{CH_4\ \%}{100}\right] + 4 \times \left[\frac{C_2H_4\ \%}{100}\right] + 6 \times \left[\frac{C_2H_6\ \%}{100}\right] + \ldots 8 \times \left[\frac{C_3H_8\ \%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}}$$

where:

CH4 = % by volume of methane in the fuel;

C2 = % by volume of all C2 hydrocarbons (e.g. C2H6, C2H4, etc.) in the fuel;

C3 = % by volume of all C3 hydrocarbons (e.g. C3H8, C3H6, etc.) in the fuel;

C4 = % by volume of all C4 hydrocarbons (e.g. C4H10, C4H8, etc.) in the fuel

C5 = % by volume of all C5 hydrocarbons (e.g. C5H12, C5H10, etc.) in the fuel;

diluent = % by volume of dilution gases in the fuel (i.e. O2*, N2, CO2, He etc.).

4.2. Examples for the calculation of the λ-shift factor S_λ

Example 1: G_{25}: CH_4 = 86 %, N_2 = 14 % (by volume)

$$n = \frac{1 \times \left[\frac{CH_4\ \%}{100}\right] + 2 \times \left[\frac{C_2\ \%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}} = \frac{1 \times 0{,}86}{1 - \frac{14}{100}} = \frac{0{,}86}{0{,}86} = 1$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100}\right] + 4 \times \left[\frac{C_2H_4\%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}} = \frac{4 \times 0{,}86}{0{,}86} = 4$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert}\ \%}{100}\right)\left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{14}{100}\right) \times \left(1 + \frac{4}{4}\right)} = 1{,}16$$

Example 2: GR: CH_4 = 87 %, C_2H_6 = 13 % (by vol)

$$n = \frac{1 \times \left[\frac{CH_4\%}{100}\right] + 2 \times \left[\frac{C_2\%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}} = \frac{1 \times 0{,}87 + 2 \times 0{,}13}{1 - \frac{0}{100}} = \frac{1{,}13}{1} = 1{,}13$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100}\right] + 4 \times \left[\frac{C_2H_4\%}{100}\right] + ..}{\frac{1 - \text{diluent}\ \%}{100}} = \frac{4 \times 0{,}87 + 6 \times 0{,}13}{1} = 4{,}26$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert}\ \%}{100}\right)\left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{0}{100}\right) \times \left(1{,}13 + \frac{4{,}26}{4}\right)} = 0{,}911$$

Example 3: USA: CH_4 = 89 %, C_2H_6 = 4,5 %, C_3H_8 = 2,3 %, C_6H_{14} = 0,2 %, O_2 = 0,6 %, N_2 = 4 %

$$n = \frac{1 \times \left[\frac{CH_4\%}{100}\right] + 2 \times \left[\frac{C_2\%}{100}\right] + ..}{\frac{1 - \text{diluent } \%}{100}} = \frac{1 \times 0,89 + 2 \times 0,045 + 3 \times 0,023 + 4 \times 0,002}{1 - \frac{(0,64 + 4)}{100}} = 1,11$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100}\right] + 4 \times \left[\frac{C_2H_4\%}{100}\right] + 6 \times \left[\frac{C_2H_6}{100}\right] + .. + 8 \times \left[\frac{C_3H_8}{100}\right]}{\frac{1 - \text{diluent } \%}{100}}$$

$$= \frac{4 \times 0,89 + 4 \times 0,045 + 8 \times 0,023 + 14 \times 0,002}{1 - \frac{0,6 + 4}{100}} = 4,24$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert } \%}{100}\right)\left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{4}{100}\right) \times \left(1,11 + \frac{4,24}{4}\right) - \frac{0,6}{100}} = 0,96$$

Chapter 7

Procedure for Conducting The Test for Durability of Emission Control Systems

1. INTRODUCTION:

This Chapter details the procedures for selecting a family of engines to be tested over a service accumulation schedule for the purpose of determining deterioration factors. Such deterioration factors will be applied to the measured emissions from engines.

This Chapter also details the emission and non-emission-related maintenance that will be carried out on engines undergoing a service accumulation schedule.

2. SELECTION OF ENGINES FOR ESTABLISHING USEFUL LIFE DETERIORATION FACTORS:

2.1. Engines will be selected from the engine family defined in section 8.1 of chapter I to this Part for emission testing to establish useful life deterioration factors.

2.2 Engines from different engine families may be further combined into families based on the type of exhaust after treatment system utilised. In order to place engines with different numbers of cylinders and different cylinder configuration but having the same technical specifications and installation for the exhaust after treatment systems into the same engine-after treatment system family, the manufacturer shall provide data to the approval authority that demonstrates that the emissions of such engines are similar.

2.3 One engine representing the engine-after treatment system family shall be selected by the engine manufacturer for testing over the service accumulation schedule defined in section 3.2 of this chapter, according to the criteria for selecting engines given in section 8.2 of chapter I to this part and shall be reported to the type-approval authority before any testing commences.

2.3.1 If the type-approval authority decides that the worst case emission rate of the engine-after treatment system family can be characterised better by another engine then the test engine shall be selected jointly by the type-approval authority and the engine manufacturer.

3. ESTABLISHING USEFUL LIFE DETERIORATION FACTORS

3.1 General

Deterioration factors applicable to an engine-after treatment system family are developed from the selected engines based on a distance and service accumulation procedure that includes periodic testing for gaseous and particulate emissions over the ESC and ETC tests.

3.2 Service accumulation schedule

Service accumulation schedules may be carried out at the choice of the manufacturer by running a vehicle equipped with the selected parent engine over an "in-service accumulation" schedule or by running the selected parent engine over a "dynamometer service accumulation" schedule.

3.2.1 In-service and dynamometer service accumulation

3.2.1.1 The manufacturer shall determine the form and extent of the distance and service accumulation for engines, consistent with good engineering practice.

3.2.1.2 The manufacturer will determine when the engine will be tested for gaseous and particulate emissions over the ESC and ETC tests.

3.2.1.3 A single engine-operating schedule shall be used for all engines in an engine-after treatment system family.

3.2.1.4 At the request of the manufacturer and with the agreement of the type-approval authority, only one test cycle (either the ESC or ETC test) need be run at each test point with the other test cycle run only at the beginning and at the end of the service accumulation schedule.

3.2.1.5 Operating schedules may be different for different engine-after treatment system families.

3.2.1.6. Operating schedules may be shorter than the useful life period provided that the number of test points allows for a proper extrapolation of the test results, according to section 3.5.2 in this chapter. In any case, the service accumulation shall not be shorter than shown in the table in section 3.2.1.8 of this chapter.

3.2.1.7 The manufacturer has to provide the applicable correlation between

minimum service accumulation period (driving distance) and engine

dynamometer hours, for example, fuel consumption correlation, vehicle speed

versus engine revolutions correlation etc.

3.2.1.8 Minimum service accumulation

Category of Vehicle in which engine will be installed	**Minimum Service accumulation period**
Category N1 Vehicles	100,000 km
Category N2 Vehicles	125,000 km
Category N3 Vehicles with GVW equal to or less than 16,000 kg	125,000 km
Category N3 Vehicles with GVW above 16,000 kg	167,000 km
Category M2 Vehicles	100,000 km
Category M3 Vehicles with GVW equal to or less than 7,500 kg	125,000 km
Category M3 Vehicles with GVW above 7,500 kg	167,000 km

3.2.1.9 The in-service accumulation schedule shall be fully described in the application for type-approval and reported to the type-approval authority before the start of any testing.

3.2.2 If the type-approval authority decides that additional measurements need to be carried out on the ESC and ETC tests between the points selected by the manufacturer it shall notify the manufacturer. The revised in-service accumulation schedule or dynamometer service accumulation schedule shall be prepared by the manufacturer and agreed by the type-approval authority.

3.3 Engine testing

3.3.1 Start of the service accumulation schedule

3.3.1.1 For each engine-after treatment system family, the manufacturer shall determine the number of hours of engine running after which the operation of the engine-after treatment system has stabilised. If requested by the approval authority the manufacturer shall make available the data and analysis used to make this determination. As an alternative, the manufacturer may elect to run the engine for 125 hours to stabilise the engine after treatment system.

3.3.1.2 The stabilisation period determined in section 3.3.1.1 will be deemed to be the start of the service accumulation schedule.

3.3.2. Service accumulation testing

3.3.2.1. After stabilisation, the engine will be run over the service accumulation schedule selected by the manufacturer, as described in section 3.2 of this chapter. At the periodic intervals in the service accumulation schedule determined by the manufacturer, and, where appropriate, also stipulated by the type-approval authority according to section 3.2.2 of this chapter, the engine shall be tested for gaseous and particulate emissions over the ESC and ETC tests. In accordance with section 3.2 of this chapter, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point, the other test cycle (ESC or ETC) must be run at the beginning and end of the service accumulation schedule.

3.3.2.2 During the service accumulation schedule, maintenance will be carried out on the engine according to section 4 of this chapter.

3.3.2.3 During the service accumulation schedule, unscheduled maintenance on the engine or vehicle may be performed, for example if the OBD system has specifically detected a problem that has resulted in the malfunction indicator (MI) being activated.

3.4 Reporting

3.4.1 The results of all emission tests (ESC and ETC) conducted during the service accumulation schedule shall be made available to the type-approval authority. If any emission test is declared to be void, the manufacturer shall provide an explanation of why the test has been declared void. In such a case, another series of emission tests over the ESC and ETC tests shall be carried out within a further 100 hours of service accumulation.

3.4.2 Whenever a manufacturer tests an engine over a service accumulation schedule for the establishment of deterioration factors, the manufacturer shall retain in its records all information concerning all the emission tests and maintenance carried out on the engine during the service accumulation schedule. This information shall be submitted to the approval authority along with the results of the emission tests conducted over the service accumulation schedule.

3.5 Determination of deterioration factors

3.5.1 For each pollutant measured on the ESC and ETC tests and at each test point during the service accumulation schedule, a “best fit” regression analysis shall be made on the basis of all test results. The results of each test for each pollutant shall be expressed to the same number of decimal places as the limit value for that pollutant, as shown in the tables in section 6.2.1 of chapter I to this part, plus one additional decimal place. In accordance with section 3.2 of this chapter, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point and the other test cycle (ESC or ETC) run only at the beginning and end of the service accumulation schedule, the regression analysis shall be made only on the basis of the test results from the test cycle run at each test point.

3.5.2 On the basis of the regression analysis, the manufacturer shall calculate the projected emission values for each pollutant at the start of the service accumulation schedule and at the useful life that is applicable for the engine under test by extrapolation of the regression equation as determined in section 3.5.1 of this chapter.

3.5.3 For engines not equipped with an exhaust after treatment system, the deterioration factor for each pollutant is the difference between the projected emission values at the useful life period and at the start of the service accumulation schedule.

For engines equipped with an exhaust after treatment system, the deterioration factor for each pollutant is the ratio of the projected emission values at the useful life period and at the start of the service accumulation schedule.

In accordance with section 3.2 of this chapter, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point and the other test cycle (ESC or ETC) run only at the beginning and end of the service accumulation schedule, the deterioration factor calculated for the test cycle that has been run at each test point shall be applicable also for the other test cycle, provided that for both test cycles, the relationship between the measured values run at the beginning and at the end of the service accumulation schedule are similar.

3.5.4 The deterioration factors for each pollutant on the appropriate test cycles shall be recorded in Type Approval Certificate.

3.6 As an alternative to using a service accumulation schedule to determine deterioration factors, engine manufacturers may choose to use the following deterioration factors:

Engine type	Test cycle	CO	HC	NMHC	CH_4	NOx	PM
Diesel engine	ESC	1.1	1.05	-	-	1.05	1.1
	ETC	1.1	1.05	-	-	1.05	1.1
CNG, LPG or Gaseous fuelled engine	ETC	1.1	1.05	1.05	1.2	1.05	-

3.6.1 The manufacturer may select to carry across the DF's determined for an engine or engine/after treatment combination to engines or engine/after treatment combinations that do not fall into the same engine family category as determined according to section 2.1 of this chapter. In such cases, the manufacturer must demonstrate to the approval authority that the base engine or engine/after treatment combination and the engine or engine/after treatment combination for which the DF's are being carried over have the same technical specifications and installation requirements on the vehicle and that the emissions of such engine or engine/after treatment combinations are similar.

3.7 Checking of conformity of production

3.7.1 Conformity of production for emissions compliance is checked on the basis of section 9 of chapter I to this part.

3.7.2 At the time of type-approval, the manufacturer may choose to measure at the same time the pollutant emissions before any exhaust after treatment system. In so doing, the manufacturer may develop an informal deterioration factor separately for the engine and the after treatment system that may be used by the manufacturer as an aid to end of production line auditing.

3.7.3 For the purposes of type-approval, only the deterioration factors adopted by the manufacturer from section 3.6.1 of this chapter or the deterioration factors developed according to section 3.5 shall be recorded in Type approval certificate.

4. MAINTENANCE

During the service accumulation schedule, maintenance performed on engines and proper consumption of any required reagent used to determine deterioration factors are classified as either emission-related or non-emission-related and each of these can be classified as scheduled and unscheduled. Some emission-related maintenance is also classified as critical emission-related maintenance.

4.1 Emission-related scheduled maintenance

4.1.1 This section specifies emission-related scheduled maintenance for the purpose of conducting a service accumulation schedule and for inclusion in the maintenance instructions furnished to owners of new heavy-duty vehicles and heavy-duty engines.

4.1.2 All emission-related scheduled maintenance for purposes of conducting a service accumulation schedule must occur at the same or equivalent distance intervals that will be specified in the manufacturer's maintenance instructions to the owner of the heavy-duty vehicle or heavy-duty engine. This maintenance schedule may be updated as necessary throughout the service accumulation schedule provided that no maintenance operation is deleted from the maintenance schedule after the operation has been performed on the test engine.

4.1.3 Any emission-related maintenance performed on engines must be necessary to assure in-service conformity with the relevant emission standards. The manufacturer shall submit data to the type-approval authority to demonstrate that all of the emission-related scheduled maintenance is technically necessary.

4.1.4 The engine manufacturer shall specify the adjustment, cleaning and maintenance (where necessary) of the following items:

— Filters and coolers in the exhaust gas re-circulation system

— Positive crankcase ventilation valve

— Fuel injector tips (cleaning only)

— Fuel injectors

— Turbocharger

— Electronic engine control unit and its associated sensors and actuators

— Particulate filter system (including related components)

— Exhaust gas re-circulation system, including all related control valves and tubing

— Any exhaust after treatment system.

4.1.5 For the purposes of maintenance, the following components are defined as critical emission-related items:

— Any exhaust after treatment system

— Electronic engine control unit and its associated sensors and actuators

— Exhaust gas re-circulation system including all related filters, coolers, control valves and tubing

— Positive crankcase ventilation valve.

4.1.6 All critical emission-related scheduled maintenance must have a reasonable likelihood of being performed in-service. The manufacturer shall demonstrate to the approval authority the reasonable likelihood of such maintenance being performed in-service and such demonstration shall be made prior to the performance of the maintenance during the service accumulation schedule.

4.1.7 Critical emission-related scheduled maintenance items that satisfy any of the conditions defined in sections 4.1.7.1 to 4.1.7.4 of this chapter will be accepted as having a reasonable likelihood of the maintenance item being performed in-service.

4.1.7.1 Data is submitted which establishes a connection between emissions and vehicle performance such that as emissions increase due to lack of maintenance, vehicle performance will simultaneously deteriorate to a point unacceptable for typical driving.

4.1.7.2 Survey data is submitted which demonstrates that, at an 80 % confidence level, 80 % of such engines already have this critical maintenance item performed in-service at the recommended interval(s).

4.1.7.3 In association with the requirements of section 4.2 of chapter VIII to this part, a clearly visible indicator shall be installed on the dashboard of the vehicle to alert the driver that maintenance is due. The indicator shall be actuated at the appropriate distance or by component failure. The indicator must remain activated while the engine is in operation and shall not be erased without the required maintenance being carried out. Re-setting of the signal shall be a required step in the maintenance schedule. The system must not be designed to deactivate upon the end of the appropriate useful life period of the engine or thereafter.

4.1.7.4 Any other method which the approval authority determines as establishing a reasonable likelihood that the critical maintenance will be performed in-service.

4.2. Changes to scheduled maintenance

4.2.1 The manufacturer must submit a request to the type-approval authority for approval of any new scheduled maintenance that it wishes to perform during the service accumulation schedule and thereby recommend to owners of heavy-duty vehicles and engines. The manufacturer shall also include its recommendation as to the category (i.e. emission-related, non-emission-related, critical or non-critical) of the new scheduled maintenance being proposed and, for emission-related maintenance, the maximum feasible maintenance interval. The request must be accompanied by data supporting the need for the new scheduled maintenance and the maintenance interval.

4.3 Non-emission-related scheduled maintenance

4.3.1 Non-emission-related scheduled maintenance which is reasonable and technically necessary (e.g. oil change, oil filter change, fuel filter change, air filter change, cooling system maintenance, idle speed adjustment, governor, engine bolt torque, valve lash, injector lash, timing, adjustment of the tension of any drive-belt, etc) may be performed on engines or vehicles selected for the service accumulation schedule at the least frequent intervals recommended by the manufacturer to the owner (e.g. not at the intervals recommended for severe service).

4.4 Maintenance on engines selected for testing over a service accumulation schedule

4.4.1 Repairs to the components of an engine selected for testing over a service accumulation schedule other than the engine, emission control system or fuel system shall be performed only as a result of part failure or engine system malfunction.

4.4.2 Equipment, instruments or tools may not be used to identify malfunctioning, maladjusted or defective engine components unless the same or equivalent equipment, instruments or tools will be available to dealerships and other service outlets and,

__ Are used in conjunction with scheduled maintenance on such components,

and

— Are used subsequent to the identification of an engine malfunction.

4.5 Critical emission-related unscheduled maintenance

4.5.1 The consumption of a required reagent is defined as critical emission-related unscheduled maintenance for the purpose of conducting a service accumulation schedule and for inclusion in the maintenance instructions furnished by manufacturers to owners of new heavy-duty vehicles or heavy-duty engines.

5. Useful Life period

(a) 100 000 km or five years, whichever is the sooner, in the case of engines to be fitted to vehicles of category N1 and M2;

(b) 200 000 km or six years, whichever is the sooner, in the case of engines to be fitted to vehicles of category N2, N3 with a maximum technically permissible mass not exceeding 16 tonnes and M3 Class I, Class II and Class A, and Class B with a maximum technically permissible mass not exceeding 7,5 tonnes;

(c) 500 000 km or seven years, whichever is the sooner, in the case of engines to be fitted to vehicles of category N3 with a maximum technically permissible mass exceeding 16 tonnes and M3, Class III and Class B with a maximum technically permissible mass exceeding 7,5 tonnes.

Chapter 8
On Board Diagnostic Systems (OBD)

1. INTRODUCTION

This chapter describes the provisions specific to the on board diagnostic (OBD) system for the emission control systems of motor vehicles.

2. DEFINITIONS

For the purposes of this chapter, the following definitions, in addition to the definitions contained in section 2 of chapter I of this part, apply:

'**access**' means the availability of all emission-related OBD data including all fault codes required for the inspection, diagnosis, servicing or repair of emissions related parts of the vehicle, via the serial interface of the standard diagnostic connector.

'**deficiency**' means, in respect of engine OBD systems, that up to two separate components or systems that are monitored contain temporary or permanent operating characteristics that impair the otherwise efficient OBD monitoring of those components or systems or do not meet all the other detailed requirements for OBD. Engines or vehicles in respect of their engine may be type-approved, registered and sold with such deficiencies according to the requirements of section 4.3 of this chapter.

'**deteriorated component / system**' means an engine or exhaust after treatment component/system that has been intentionally deteriorated in a controlled manner by the manufacturer for the purpose of conducting a type-approval test on the OBD system.

'**OBD test cycle**' means a driving cycle, which is a version of the ESC test cycle having the same running-order of the 13 individual modes as described in section 2.7.1 of appendix 1 to chapter III of this part but where the length of each mode is reduced to 60 seconds.

'**operating sequence**' means the sequence used for determining the conditions for extinguishing the MI. It consists of an engine start-up, an operating period, an engine shut-off, and the time until the next start-up, where the OBD monitoring is running and a malfunction would be detected if present.

'**pre conditioning cycle**' means the running of at least three consecutive OBD test cycles or emission test cycles for the purpose of achieving stability of the engine operation, the emission control system and OBD monitoring readiness.

‘**repair information**’ means all information required for diagnosis, servicing, inspection, periodic monitoring or repair of the engine and which the manufacturers provide for their authorised dealers/repair shops. Where necessary, such information shall include service handbooks, technical manuals, diagnosis information (e.g. minimum and maximum theoretical values for measurements), wiring diagrams, the software calibration identification number applicable to an engine type, information enabling the update of the software of the electronic systems in accordance with the specifications of the vehicle manufacturer, instructions for individual and special cases, information provided concerning tools and equipment, data record information and two-directional monitoring and test data. The manufacturer shall not be obliged to make available that information which is covered by intellectual property rights or constitutes specific know-how of manufacturers and/or OEM suppliers; in this case the necessary technical information shall not be improperly withheld.

‘**standardised**’ means that all emission related OBD data (i.e. stream information in the case a scanning tool is used), including all fault codes used, shall be produced only in accordance with industry standards which, by virtue of the fact that their format and the permitted options are clearly defined, provide for a maximum level of harmonisation in the motor vehicle industry, and whose use is expressly permitted in this part.

‘**unrestricted**’ means:

— access not dependent on an access code obtainable only from the manufacturer, or a similar device,

or

— access allowing evaluation of the data produced without the need for any unique decoding information, unless that information itself is standardised.

‘**warm-up cycle**’ means sufficient engine operation such that the coolant temperature has risen by at least 22° K from engine starting and reaches a minimum temperature of 343° K (70 °C).

3. REQUIREMENTS AND TESTS

3.1 General requirements

3.1.1 OBD systems must be designed, constructed and installed in a vehicle so as to enable it to identify types of malfunction over the entire life of the engine. In achieving this objective the approval authority must accept that engines which have been used in excess of the appropriate durability period defined in section 3.2.1.8 of chapter VII of this part may show some deterioration in OBD system performance such that the OBD thresholds given in section 7 of this chapter may be exceeded before the OBD system signals a failure to the driver of the vehicle.

3.1.2 A sequence of diagnostic checks must be initiated at each engine start and completed at least once provided that the correct test conditions are met. The test conditions must be selected in such a way that they all occur under the driving conditions as represented by the test defined in section 2 of appendix 1 to this chapter.

3.1.2.1 Manufacturers are not required to activate a component / system exclusively for the purpose of OBD functional monitoring under vehicle operating conditions when it would not normally be active (e.g. activation of a reagent tank heater of a deNOx system or combined deNOx-particulate filter when such a system would not normally be active).

3.1.3 OBD may involve devices, which measure, senses or responds to operating variables (e.g. vehicle speed, engine speed, gear used, temperature, intake pressure or any other parameter) for the purpose of detecting malfunctions and of minimising the risk of indicating false malfunction. These devices are not defeat devices.

3.1.4 Access to the OBD system required for the inspection, diagnosis, servicing or repair of the engine must be unrestricted and standardised. All emission related fault codes must be consistent with those described in section 6.8.5 of this chapter.

3.2 OBD requirements

3.2.1 From 1st April 2013 the OBD system of all diesel engines and of vehicles equipped with a diesel engine must indicate the failure of an emission-related component or system of the engine system when that failure results in an increase in emissions above the OBD thresholds given in section 7 of this chapter.

3.2.2 In satisfying the requirements, the OBD system must monitor for:

3.2.2.1 Complete removal of a catalyst, where fitted in a separate housing, that may or may not be part of a $deNO_X$ system or particulate filter.

3.2.2.2 reduction in the efficiency of the $deNO_X$ system, where fitted, with respect to the emissions of NO_X only.

3.2.2.3 reduction in the efficiency of the particulate filter, where fitted, with respect to the emissions of particulate only.

3.2.2.4 reduction in the efficiency of a combined $deNO_X$-particulate filter system, where fitted, with respect to both the emissions of NO_X and particulate.

3.2.3 Major Functional Failure

3.2.3.1 As an alternative to monitoring against the OBD threshold limits with respect to sections 3.2.2.1 to 3.2.2.4 of this chapter, OBD systems of diesel engines may monitor for major functional failure of the following components:

- a catalyst, where fitted as a separate unit, that may or may not be part of a $deNO_X$ system or particulate filter

— a $deNO_X$ system, where fitted

- a particulate filter, where fitted

— a combined $deNO_X$-particulate filter system.

3.2.3.2. In the case of an engine equipped with a $deNO_X$ system, examples of monitoring for major functional failure are for complete removal of the system or replacement of the system by a bogus system (both intentional major functional failure), lack of required reagent for a $deNO_X$ system, failure of any SCR electrical component, any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a $deNO_X$ system including, when applicable, the reagent heating system, failure of the reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure).

3.2.3.3 In the case of an engine equipped with a particulate filter, examples of monitoring for major functional failure are for major melting of the trap substrate or a clogged trap resulting in a differential pressure out of the range declared by the manufacturer, any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a particulate filter, any failure, when applicable, of a reagent dosing system (e.g. clogged nozzle, dosing pump failure).

3.2.4 Manufacturers may demonstrate to the approval authority that certain components or systems need not be monitored if, in the event of their total failure or removal, emissions do not exceed the thresholds limits for OBD given in section 7 of this chapter when measured over the cycles shown in section 1.1 of Appendix 1 to this Chapter. This provision shall not apply to an exhaust gas recirculation (EGR) device, a $deNO_X$ system, a particulate filter or a combined deNOx-particulate filter system nor shall it apply to a component or system that is monitored for major functional failure.

3.3 In satisfying the above requirements, the OBD system must also monitor for:

3.3.1 The fuel-injection system electronic, fuel quantity and timing actuator(s) for circuit continuity (i.e. open circuit or short circuit) and total functional failure.

3.3.2 All other engine or exhaust after treatment emission-related components or systems, which are connected to a computer, the failure of which would result in tailpipe emissions exceeding the OBD threshold limits given in section 7 of this chapter. At a minimum, examples include the exhaust gas recirculation (EGR) system, systems or components for monitoring and control of air mass-flow, air volumetric flow (and temperature), boost pressure and inlet manifold pressure (and relevant sensors to enable these functions to be carried out), sensors and actuators of a $deNO_X$ system, sensors and actuators of an electronically activated active particulate filter.

3.3.3 Any other emission-related engine or exhaust after treatment component or system connected to an electronic control unit must be monitored for electrical disconnection unless otherwise monitored.

3.3.4 In the case of engines equipped with an after treatment system using a consumable reagent, the OBD system must monitor for:

— lack of any required reagent

— the quality of the required reagent being within the specifications declared by the manufacturer in chapter II to this Part.

— reagent consumption and dosing activity

according to section 6.5.4 of chapter I to this part.

3.4 OBD operation and temporary disablement of certain OBD monitoring capabilities

3.4.1. The OBD system must be so designed, constructed and installed in a vehicle as to enable it to comply with the requirements of this chapter during the conditions of use defined in section 6.1.5.4 of chapter I of this part.

Outside these normal operating conditions the emission control system may show some degradation in OBD system performance such that the thresholds given in section 7 of this chapter may be exceeded before the OBD system signals a failure to the driver of the vehicle.

The OBD system must not be disabled unless one or more of the following conditions for disablement are met:

3.4.1.1 The affected OBD monitoring systems may be disabled if its ability to monitor is affected by low fuel levels. For this reason, disablement is permitted when the fuel tank level falls below 20 % of the nominal capacity of the fuel tank.
3.4.1.2 The affected OBD monitoring systems may be temporarily disabled during the operation of an auxiliary emission control strategy as described in section 6.1.5.1 of Chapter I to this Part.

3.4.1.3 The affected OBD monitoring systems may be temporarily disabled when operational safety or limp-home strategies are activated.

3.4.1.4 For vehicles designed to accommodate the installation of power take-off units, disablement of affected OBD monitoring systems is permitted provided disablement takes place only when the power take-off unit is active and the vehicle is not being driven.

3.4.1.5 The affected OBD monitoring systems may be disabled temporarily during the periodic regeneration of an emission control system downstream of the engine (i.e. a particulate filter, deNO_X system or combined deNO_X-particulate filter).

3.4.1.6 The affected OBD monitoring systems may be disabled temporarily outside the conditions of use defined in section 6.1.5.4 of chapter I of this part when this disablement can be justified by a limitation of the OBD monitoring (including modelling) capability.

3.4.2 The OBD monitoring system is not required to evaluate components during malfunction if such evaluation would result in a risk to safety or component failure.

3.5 Activation of malfunction indicator (MI)

3.5.1 The OBD system must incorporate a malfunction indicator readily visible to the vehicle operator. Except in the case of section 3.5.2 of this chapter, the MI (e.g. symbol or lamp) must not be used for any purpose other than emission related malfunction except to indicate emergency start-up or limp-home routines to the driver. Safety related messages can be given the highest priority. The MI must be visible in all reasonable lighting conditions. When activated, it must display a symbol in conformity with ISO 2575 (1) (as a dashboard telltale lamp or a symbol on a dashboard display).A vehicle must not be equipped with more than one general purpose MI for emission-related problems. Displaying separate specific information is permitted (e.g. such as information dealing with brake system, fasten seat belt, oil pressure, servicing requirements, or indicating the lack of necessary reagent for the deNOx system). The use of red for the MI is prohibited.

[(1)] Symbol numbers F01 or F22.

3.5.2 The MI may be used to indicate to the driver that an urgent service task needs to be carried out. Such an indication may also be accompanied by an appropriate message on a dashboard display that an urgent servicing requirement needs to be carried out.

3.5.3 For strategies requiring more than a preconditioning cycle for MI activation, the manufacturer must provide data and/or an engineering evaluation which adequately demonstrates that the monitoring system is equally effective and timely in detecting component deterioration. Strategies requiring on average more than ten OBD or emission test cycles for MI activation are not accepted.

3.5.4 The MI must also activate whenever the engine control enters a emission default mode of operation. The MI must also activate if the OBD system is unable to fulfill the basic monitoring requirements specified in this Document.

3.5.5 Where reference is made to this section, the MI must be activated and, in addition, a distinct warning mode should also be activated, e.g. flashing MI or activation of a symbol in conformity with ISO 2575 [(1)] in addition to MI activation.

[(1)] Symbol number F24.

3.5.6 The MI must activate when the vehicle's ignition is in the 'key-on' position before engine starting or cranking and de-activate within 10 seconds after engine starting if no malfunction has previously been detected.

3.6 Fault code storage

The OBD system must record fault code(s) indicating the status of the emission-control system. A fault code must be stored for any detected and verified malfunction causing MI activation and must identify the malfunctioning system or component as uniquely as possible. A separate code should be stored indicating the expected MI activation status (e.g. MI commanded 'ON', MI commanded 'OFF').

Separate status codes must be used to identify correctly functioning emission control systems and those emission control systems that need further engine operation to be fully evaluated. If the MI is activated due to malfunction or emission default modes of operation, a fault code must be stored that identifies the likely area of malfunction. A fault code must also be stored in the cases referred to in sections 3.3.1 and 3.3.3 of this chapter.

3.6.1 If monitoring has been disabled for 10 driving cycles due to the continued operation of the vehicle under conditions conforming to those specified in section

3.4.1.2 of this Annex, readiness for the subject monitoring system may be set to 'ready' status without monitoring having been completed.

3.6.2 The hours run by the engine while the MI is activated must be available upon request at any instant through the serial port on the standard link connector, according to the specifications given in section 6.8 of this Chapter.

3.7 Extinguishing the MI

3.7.1 The MI may be de-activated after three subsequent sequential operating sequences or 24 engine running hours during which the monitoring system responsible for activating the MI ceases to detect the malfunction and if no other malfunction has been identified that would independently activate the MI.

3.7.2 In the case of MI activation due to lack of reagent for the $deNO_X$ system, or combined $deNO_X$ particulate after-treatment device or use of a reagent outside the specifications declared by the manufacturer, the MI may be switched back to the previous state of activation after filling or replacement of the storage medium with a reagent having the correct specifications.

3.7.3 In the case of MI activation due to incorrect operation of the engine system with respect to NO_X control measures, or incorrect reagent consumption and dosing activity, the MI may be switched back to the previous state of activation if the conditions given in section 6.5.3, 6.5.4 and 6.5.7 of chapter I to this part no longer apply.

3.8 Erasing a fault code

3.8.1 The OBD system may erase a fault code and the hours run by the engine and freeze-frame information if the same fault is not re-registered in at least 40 engine warm-up cycles or 100 engine running hours, whichever occurs first, with the exception of the cases referred to in section 3.8.2 of this chapter.

3.8.2 In the case of a non erasable fault code being generated according to sections 6.5.3 or 6.5.4 of chapter I of this part, the OBD system shall retain a record of the fault code and the hours run by the engine during MI activation for at least 400 days or 9600 hours of engine operation.

Any such fault code and the corresponding hours run by the engine during MI activation shall not be erased through use of any external diagnostic or other tool as referred to in section 6.8.3 of this chapter

4. REQUIREMENTS RELATING TO THE TYPE-APPROVAL OF OBD SYSTEMS

4.1 For the purpose of type-approval, the OBD system shall be tested according to the procedures given in appendix 1 to this chapter.

An engine representative of its engine family (see section 8 of chapter I to this part) shall be used for the OBD demonstration tests or the test report of the parent OBD system of the OBD engine family will be provided to the type-approval authority as an alternative to carrying out the OBD demonstration test.

4.1.1 In the case of OBD referred to in section 3.2 of this chapter, the OBD system must:

4.1.1.1 Indicate the failure of an emission-related component or system when that failure results in an increase in emissions above the OBD thresholds given in section 7 of this chapter, or

4.1.1.2 Where appropriate, indicate any major functional failure of an exhaust after treatment system.

4.1.1.3 Indicate the lack of any required reagent necessary for the operation of an exhaust after treatment system.

4.2 Installation requirements

4.2.1 The installation on the vehicle of an engine equipped with an OBD system shall comply with the following provisions of this chapter with respect to the vehicle equipment:

— the provisions of sections 3.5.1, 3.5.2 and 3.5.5 of this chapter concerning the MI and, where appropriate, additional warning modes

— when applicable, the provisions of section 6.8.3.1 of this chapter concerning the use of an on-board diagnostic facility

— the provisions of section 6.8.6 of this chapter concerning the connection interface.

4.3 Type-approval of an OBD system containing deficiencies

4.3.1 A manufacturer may request to the authority that an OBD system be accepted for type-approval even though the system contains one or more deficiencies such that the specific requirements of this chapter are not fully met.

4.3.2 In considering the request, the authority shall determine whether compliance with the requirements of this chapter is feasible or unreasonable.

The authority shall take into consideration data from the manufacturer that details such factors as, but not limited to, technical feasibility, lead time and production cycles including phase-in or phase-out of engines designs and programmed upgrades of computers, the extend to which the resultant OBD system will be effective in complying with the requirements of this directive and that the manufacturer has demonstrated an acceptable level of effort toward the requirements of this part.

4.3.3 The authority will not accept any deficiency request that includes the complete lack of a required diagnostic monitor.

4.3.4 The authority shall not accept any deficiency request that does not respect the OBD threshold limits given in section 7 of this chapter.

4.3.5 In determining the identified order of deficiencies, deficiencies relating to OBD in respect of sections 3.2.2.1, 3.2.2.2, 3.2.2.3, 3.2.2.4 and 3.3.1 of this chapter shall be identified first.

4.3.6 Prior to or at the time of type-approval, no deficiency shall be granted in respect of the requirements of section 3.2.3 and section 6, except subsection 6.8.5 of this chapter.

4.3.7 Deficiency period

4.3.7.1 A deficiency may be carried-over for a period of two years after the date of type-approval of the engine type or vehicle in respect of its engine type, unless it can be adequately demonstrated that substantial engine modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-out for a period not exceeding three years.

4.3.7.2 A manufacturer may request that the original type-approval authority grant a deficiency retrospectively when such a deficiency is discovered after the original type-approval. In this case, the deficiency may be carried-over for a period of two years after the date of notification to the type approval authority unless it can be adequately demonstrated that substantial engine modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-out for a period not exceeding three years.

5. ACCESS TO OBD INFORMATION

5.1 Replacement parts, diagnostic tools and test equipment

5.1.1 Applications for type-approval or amendment of a type-approval according to this part shall be accompanied by the relevant information concerning the OBD system. This relevant information shall enable manufacturers of replacement or retrofit components to make the parts they manufacture compatible with the OBD system with a view to fault-free operation assuring the vehicle user against malfunctions. Similarly, such relevant information shall enable the manufacturers of diagnostic tools and test equipment to make tools and equipment that provide for effective and accurate diagnosis of emission control systems.

5.1.2 Upon request, the type-approval authorities shall make changes in the type approval certificate containing the relevant information on the OBD system available to any interested components, diagnostic tools or test equipment manufacturer on a non-discriminatory basis.

5.1.2.1 In the case of replacement or service components, information can only be requested for such components that are subject to type approval, or for components that form part of a system that is subject to type approval.

5.1.2.2 The request for information must identify the exact specification of the engine model type/engine model type within an engine family for which the information is required. It must confirm that the information is required for the development of replacement or retrofit parts or components or diagnostic tools or test equipment.

5.2 Repair information

5.2.1. No later than three months after the manufacturer has provided any authorised dealer or repair shop with repair information, the manufacturer shall make that information (including all subsequent amendments and supplements) available upon reasonable and non-discriminatory payment.

5.2.2. The manufacturer must also make accessible, where appropriate upon payment the technical information required for the repair or maintenance of motor vehicles unless that information is covered by an intellectual property right or constitutes essential, secret know-how which is identified in an appropriate form; in such case, the necessary technical information must not be withheld improperly.

Entitled to such information is any person engaged in commercially servicing or repairing, road-side rescuing, inspecting or testing of vehicles or in manufacturing or selling replacement or retro-fit components, diagnostic tools and test equipment.

5.2.3. In the event of failure to comply with these provisions the approval authority shall take appropriate measures to ensure that repair information is available, in accordance with the procedures laid down for type-approval and in-service surveys.

6. DIAGNOSTIC SIGNALS

6.1 Upon determination of the first malfunction of any component or system, ‘freeze-frame’ engine conditions present at the time must be stored in computer memory. Stored engine conditions must include, but are not limited to calculated load value, engine speed, coolant temperature, intake manifold pressure (if available), and the fault code which caused the data to be stored. For freeze-frame storage, the manufacturer must choose the most appropriate set of conditions facilitating effective repairs.

6.2 Only one frame of data is required. Manufacturers may choose to store additional frames provided that at least the required frame can be read by a generic scan tool meeting the specifications of sections 6.8.3 and 6.8.4 of this chapter. If the fault code causing the conditions to be stored is erased in accordance with section 3.8 of this chapter, the stored engine conditions may also be erased.

6.3 If available, the following signals in addition to the required freeze-frame information must be made available on demand through the serial port on the standardised data link connector, if the information is available to the on-board computer or can be determined using information available to the on-board computer: diagnostic trouble codes, engine coolant temperature, injection timing, intake air temperature, manifold air pressure, air flow rate, engine speed, pedal position sensor output value, calculated load value, vehicle speed and fuel pressure.

The signals must be provided in standard units based on the specifications given in section 6.8. Actual signals must be clearly identified separately from default value or limp-home signals.

6.4 For all emission control systems for which specific on-board evaluation tests are conducted, separate status codes, or readiness codes, must be stored in computer memory to identify correctly functioning emission control systems and those emission control systems which require further vehicle operation to complete a proper diagnostic evaluation. A readiness code need not be stored for those monitors that can be considered continuously operating monitors. Readiness codes should never be set to ‘not ready’ status upon ‘key-on’ or ‘key-off’. The intentional setting of readiness codes to ‘not ready’ status via service procedures must apply to all such codes, rather than applying to individual codes.

6.5 The OBD requirements and the major emission control systems monitored by the OBD system consistent with section 6.8.4 must be available through the serial data port on the standardised data link connector according to the specifications given in section 6.8.

6.6 The software calibration identification number as declared in chapters II and VI of this part shall be made available through the serial port of the standardised diagnostic connector. The software calibration identification number shall be provided in a standardised format.

6.7 The vehicle identification number (VIN) number shall be made available through the serial port of the standardised diagnostic connector. The VIN number shall be provided in a standardised format.

6.8 The emission control diagnostic system must provide for standardised or unrestricted access and conform to either ISO 15765 or SAE J1939, as specified in the following sections (1):

(1) The use of the future ISO single protocol standard developed in the framework of the UN/ECE for a world-wide global technical regulation on heavy-duty OBD will be considered by the Commission in a proposal to replace the use of the SAE J1939 and ISO 15765 series of standards to satisfy the appropriate requirements of section 6 as soon as the ISO single protocol standard has reached the DIS stage.

6.8.1 The use of either ISO 15765 or SAE J1939 shall be consistent throughout sections 6.8.2 to 6.8.5.

6.8.2 The on-board to off-board communications link must conform to ISO 15765-4 or to the similar clauses within the SAE J1939 series of standards.

6.8.3 Test equipment and diagnostic tools needed to communicate with OBD systems must meet or exceed the functional specification given in ISO 15031-4 or SAE J1939-73 section 5.2.2.1.

6.8.3.1 The use of an on-board diagnostic facility such as a dashboard mounted video display device for enabling access to OBD information is permitted but this is in addition to enabling access to OBD information by means of the standard diagnostic connector.

6.8.4 Diagnostic data, (as specified in this section) and bi-directional control information must be provided using the format and units described in ISO 15031-5 or SAE J1939-73 section 5.2.2.1 and must be available using a diagnostic tool meeting the requirements of ISO 15031-4 or SAE J1939-73 section 5.2.2.1.

The manufacturer shall provide a national standardisation body with emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO 15031-5 but related to this part.

6.8.5 When a fault is registered, the manufacturer must identify the fault using the most appropriate fault code consistent with those given in Section 6.3 of ISO 15031-6 relating to emission-related system diagnostic trouble codes. If such identification is not possible, the manufacturer may use diagnostic trouble codes according to Sections 5.3 and 5.6 of ISO 15031-6. The fault codes must be fully accessible by standardised diagnostic equipment complying with the provisions of section 6.8.3 of this Chapter.

The manufacturer shall provide a national standardisation body with emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO 15031-5 but related to this part.

As an alternative, the manufacturer may identify the fault using the most appropriate fault code consistent with those given in SAE J2012 or in SAE J1939-73.

6.8.6 The connection interface between the vehicle and the diagnostic tester

must be standardised and must meet all the requirements of ISO 15031-3 or

SAE J1939-13.

In the case of category N2, N3, M2, and M3 vehicles, as an alternative to the connector location described in the above standards and provided all other requirements of ISO 15031-3 are met, the connector may be located in a suitable position by the side of the driver's seat, including on the floor of the cabin. In this case the connector should be accessible by a person standing outside the vehicle and not restrict access to the driver's seat.

The installation position must be subject to agreement of the approval authority such that it is readily accessible by service personnel but protected from accidental damage during normal conditions of use.

7. THRESHOLD LIMITS FOR OBD

The OBD threshold limits shall be as follows:
Mass of Oxides of Nitrogen (NO_X) = 7.0 g/kWh
Mass of Particulate (PT) = 0.10 g/kWh

Appendix 1

ON-BOARD DIAGNOSTIC (OBD) SYSTEM APPROVAL TESTS

1. INTRODUCTION

This Appendix describes the procedure for checking the function of the on board diagnostic (OBD) system installed on the engine by failure simulation of relevant emission-related systems in the engine management or emission control system. It also sets procedures for determining the durability of OBD systems.

1.1 Deteriorated components / systems

In order to demonstrate the efficient monitoring of an emission control system or component, the failure of which may result in tailpipe emissions exceeding the OBD threshold limits, the manufacturer must make available the deteriorated components and/or electrical devices which would be used to simulate failures.

Such deteriorated components or devices must not cause emissions to exceed the OBD threshold limits given in section 7 of this chapter by more than 20 %.

In the case of type-approval of an OBD system according to this part, the emissions shall be measured over the ESC test cycle (see Appendix 1 to chapter III to this Part)

1.1.1 If it is determined that the installation of a deteriorated component or device on an engine means that a comparison with the OBD threshold limits is not possible (e.g. because the statistical conditions for validating the ETC test cycle are not met), the failure of that component or device may be considered as qualified upon the agreement of the type-approval authority based on technical argumentation provided by the manufacturer.

1.1.2 In the case that the installation of a deteriorated component or device on an engine means that the full load curve (as determined with a correctly operating engine) cannot (even partially) be attained during the test, the deteriorated component or device is considered as qualified upon the agreement of the type-approval authority based on technical argumentation provided by the manufacturer.

1.1.3 The use of deteriorated components or devices that cause engine emissions to exceed the OBD threshold limits given in section 7 of this chapter by no more than 20 % may not be required in some very specific cases (for example, if a limp home strategy is activated, if the engine cannot run any test, or in case of EGR sticking valves, etc). This exception shall be documented by the manufacturer. It is subject to the agreement of the test agency.

1.2 Test principle

When the engine is tested with the deteriorated component or device fitted, the OBD system is approved if the MI is activated. The OBD system is also approved if the MI is activated below the OBD threshold limits.

The use of deteriorated components or devices that cause the engine emissions to exceed the OBD threshold limits given in section 7 of this chapter by no more than 20 % are not required in the specific case of the failure modes described in sections 6.3.1.6 and 6.3.1.7 of this Appendix and also with respect to monitoring for major functional failure.

1.2.1 The use of deteriorated components or devices that cause engine emissions to exceed the OBD threshold limits given in section 7 of this chapter by no more than 20 % may not be required in some very specific cases (for example, if a limp home strategy is activated, if the engine cannot run any test, or in case of EGR sticking valves, etc). This exception shall be documented by the manufacturer. It is subject to the agreement of the test agency.

2. DESCRIPTION OF TEST

2.1 The testing of OBD systems consists of the following phases:

— simulating the malfunction of a component of the engine management or emission control system as described in section 1.1 of this appendix

— preconditioning of the OBD system with a simulated malfunction over the preconditioning cycle specified in section 6.2 of this appendix.

— operating the engine with a simulated malfunction over the OBD test cycle referred to in section 6.1 of this appendix.

— determining whether the OBD system reacts to the simulated malfunction and indicates malfunction in an appropriate manner.

2.1.1 Should the performance (e.g. power curve) of the engine be affected by the malfunction, the OBD test-cycle remains the shortened version of the ESC test-cycle used for the assessing the exhaust emissions of the engine without that malfunction.

2.2 Alternatively, at the request of the manufacturer, malfunction of one or more components may be electronically simulated according to the requirements of section 6 of this appendix.

2.3 Manufacturers may request that monitoring take place outside the OBD test cycle referred to in section 6.1 of this appendix, if it can be demonstrated to the authority that monitoring during conditions encountered during this OBD test cycle would impose restrictive monitoring conditions when the vehicle is used in service.

3. TEST ENGINE AND FUEL

3.1 Engine

The test engine shall comply with the specifications laid down in chapter II of this part.

3.2. Fuel

The appropriate reference fuel as described in chapter IV of this part must be used for testing.

4. TEST CONDITIONS

The test conditions must satisfy the requirements of the emission test described in this part.

5. TEST EQUIPMENT

The engine dynamometer must meet the requirements of chapter III of this part.

6. OBD TEST CYCLE

6.1 The OBD test cycle is a single shortened ESC test cycle. The individual modes shall be performed in the same order as the ESC test cycle, as defined in section 2.7.1 of appendix 1 to chapter III of this part.

The engine must be operated for a maximum of 60 seconds in each mode, completing engine speed and load changes in the first 20 seconds. 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 each speed.

Exhaust emissions are not required to be measured during the OBD test cycle.

6.2 Preconditioning cycle

6.2.1 After introduction of one of the failure modes given in section 6.3 of this appendix, the engine and its OBD system shall be preconditioned by performing a preconditioning cycle.

6.2.2. At the request of the manufacturer and with the agreement of the type-approval authority, an alternative number of a maximum of nine consecutive OBD test cycles may be used.

6.3 OBD system test

6.3.1 Diesel engines and vehicles equipped with a diesel engine

6.3.1.1 After preconditioning according to section 6.2 of this appendix, the test engine is operated over the OBD test cycle described in section 6.1 of this appendix. The MI must activate before the end of this test under any of the conditions given in 6.3.1.2 to 6.3.1.7 of this appendix. The technical service may substitute those conditions by others in accordance with section 6.3.1.7 of this appendix. For the purposes of type-approval, the total number of failures subject to testing, in the case of different systems or components, must not exceed four.

If the test is being carried out to type-approve an OBD-engine family consisting of engines that do not belong to the same engine family, the type approval authority will increase the number of failures subject to testing up to a maximum of four times the number of engine families present in the OBD-engine family. The type-approval authority may decide to curtail the test at any time before this maximum number of failure tests has been reached.

6.3.1.2 Where fitted in a separate housing that may or may not be part of a $deNO_X$ system or diesel particulate filter, replacement of any catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.1.3 Where fitted, replacement of a $deNO_X$ system (including any sensors that are an integral part of the system) with a deteriorated or defective $deNO_X$ system or electronic simulation of a deteriorated or defective deNOx system that results in emissions exceeding the OBD NO_X threshold limit given in section 7 of this chapter.

In the case that the engine is being type-approved according to this part in relation to monitoring for major functional failure, the test of the $deNO_X$ system shall determine that the MI illuminates under any of the following conditions:

— complete removal of the system or replacement of the system by a bogus system

— lack of any required reagent for a $deNO_X$ system

— any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a $deNO_X$ system, including, when applicable, the reagent heating system

— failure of a reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure) of a $deNO_x$ system

— major breakdown of the system.

6.3.1.4 Where fitted, total removal of the particulate filter or replacement of the particulate filter with a defective particulate filter that results in emissions exceeding the OBD particulate threshold limit given in section 7 of this chapter.

In the case that the engine is being type-approved according to this part in relation to monitoring for major functional failure, the test of the particulate filter shall determine that the MI illuminates under any of the following conditions:

— complete removal of the particulate filter or replacement of the system by a bogus system

— major melting of the particulate filter substrate

— major cracking of the particulate filter substrate

— any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a particulate filter

— failure, when applicable, of the reagent dosing system (e.g. clogged nozzle, dosing pump failure) of a particulate filter

— a clogged particulate filter resulting in a differential pressure out of the range declared by the manufacturer.

6.3.1.5 Where fitted, replacement of a combined deNOx-particulate filter system (including any sensors that are an integral part of the device) with a deteriorated or defective system or electronic simulation of a deteriorated or defective system that results in emissions exceeding the OBD NOx and particulate threshold limits given in section 7 of this chapter.

In the case that the engine is being type-approved according to this part in relation to monitoring for major functional failure, the test of the combined deNOx-particulate filter system shall determine that the MI illuminates under any of the following conditions:

— complete removal of the system or replacement of the system by a bogus system

— lack of any required reagent for a combined $deNO_X$-particulate filter system

— any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a combined deNO_X-particulate filter system, including, when applicable, the reagent heating system

— failure of a reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure) of a combined deNO_X-particulate filter system

— major breakdown of a NO_X trap system

— major melting of the particulate filter substrate

— major cracking of the particulate filter substrate

— a clogged particulate filter resulting in a differential pressure out of the range declared by the manufacturer.

6.3.1.6 Disconnection of any fuelling system electronic fuel quantity and timing actuator that results in emissions exceeding any of the OBD thresholds given in section 7 of this chapter.

6.3.1.7 Disconnection of any other emission-related engine component connected to a computer that results in emissions exceeding any of the thresholds given in section 7 of this chapter.

6.3.1.8 In demonstrating compliance with the requirements of 6.3.1.6 and 6.3.1.7 of this appendix and with the agreement of the approval authority, the manufacturer may take appropriate steps to demonstrate that the OBD system will indicate a fault when disconnection occurs.

PART XV– SUB PART (A): DETAILS OF STANDARDS OF VISIBLE AND GASEOUS POLLUTANTS FROM DIESEL ENGINES FOR AGRICULUTARAL TRACTORS

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) (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