

Volume II

MoRTH/CMVR/ TAP- 115/116	STANDARDS FOR PETROL / DIESEL ENGINED VEHICLES	
ISSUE NO. 4		PART XI

**PART XI : DETAILS OF STANDARDS FOR TAILPIPE
EMISSIONS FROM PETROL, CNG, LPG AND DIESEL
ENGINED VEHICLES and Test Procedures Effective
from the 01-04-2005**

CHAPTER 1 : OVERALL REQUIREMENTS

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

CHAPTER 3 : TYPE I TEST ON S.I. ENGINED VEHICLES, CNG, LPG AND
DIESEL ENGINED VEHICLES (VERIFYING THE AVERAGE
EMISSIONS OF GASEOUS AND PARTICULATE POLLUTANTS)

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

CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

CHAPTER 6 : GAS SAMPLING SYSTEMS

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

CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

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

CHAPTER 10 : TYPE III TEST : VERIFYING EMISSION OF CRANK CASE GASES

CHAPTER 11 : TYPE IV TEST : THE DETERMINATION OF EVAPORATIVE
EMISSION FROM VEHICLES WITH SPARK IGNITION ENGINE

CHAPTER 12 : TYPE V TEST : DESCRIPTION OF THE AGEING TEST FOR
VERIFYING THE DURABILITY OF ANTI POLLUTION
DEVICES FROM 2/3 WHEELERS

CHAPTER 13 : TYPE V TEST : DESCRIPTION OF THE AGEING TEST FOR
VERIFYING THE DURABILITY OF ANTI POLLUTION
DEVICES FROM 4 WHEELERS

CHAPTER 1 : OVERALL REQUIREMENTS

1. Scope :
 - 1.1 This Part applies to the tailpipe emission of vehicles equipped with spark ignition engines (Petrol,CNG,LPG) and compression ignition engines(Diesel).
 - (i) 2/3 wheelers for Bharat Stage II with effect from 1st April 2005.
 - (ii) 4 wheelers for Bharat Stage III with effect from 1st April 2005
 - 1.1.1 Refer Part XIV , Chapter 16 for tailpipe emission of Hybrid Electrical 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 engined vehicles wherever applicable with Gross Vehicle Weight (GVW) not exceeding 3500 kg, instead of Part XII.
 - 1.3 This Part should be read in conjunction with the applicable Gazettee Notification for which the vehicle is subjected to test.
 - 1.4 For vehicles equipped with spark ignition engines and compression ignition engines
 - (i) 2/3 wheelers for Bharat Stage II with effect from 1st April 2005.
 - (ii) 4 wheelers for Bharat Stage III with effect from 1st April 2005

Definitions :

- 2.1 Spark Ignition Engine : Means an internal combustion engine in which the combustion of the air/fuel mixture is initiated at given instants by a hot spot, usually an electric spark.
- 2.2 Compression Ignition Engine : Means an engine which works on the compression-ignition principle (e.g. diesel engine).
- 2.3 Idle Speed : Means the engine rate, in revolution per minute, with fuel system controls (accelerator and choke) in the rest position, transmission in neutral and clutch engaged in the case of vehicles with manual or semi-automatic transmission, or with selector in park or neutral position when an automatic transmission is installed, as recommended by the manufacturer.
- 2.4 Normal Thermal Conditions : Means the thermal conditions attained by an engine and its drive line after a run of at least 15 minutes on a variable course, under normal traffic conditions.
- 2.5 Gaseous Pollutants : Means carbon monoxide, hydrocarbons (assuming a ratio of CH_{1.85}) and oxides of nitrogen, (being expressed in Nitrogen dioxide [NO₂] equivalent.)

- 2.6 Particulate Pollutants : Means components of exhaust gas which are removed from the diluted exhaust gas at a maximum temperature of 52°C (325 K) by means of filters described in Chapter 3 of this part.
- 2.7 Tailpipe emissions means
- For positive ignition engines, the emission of gaseous pollutants
 - For compression ignition engines, the emission of gaseous and particulate pollutants.
- 2.8 Unladen Mass : Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90% full and the usual set of tools and spare wheel on board where applicable. In the case of 3-wheeled tractors, designed for coupling to a semi-trailer, the unladen mass will be that of the drawing vehicle.
- 2.9 Reference Mass : Means the "Unladen Mass" of the vehicle increased by a uniform figure of 75 kg for 2 wheeled vehicles; and 150 kg for other vehicles.
- 2.10 Gross Vehicle Weight (GVW) : Means the technically permissible maximum weight declared by the vehicle manufacturer. In case of the 3 wheeled vehicles designed to be coupled to a semi-trailer, the mass GVW to be taken into consideration when classifying that vehicle, shall be the maximum weight of the tractor in running order, plus the weight transferred to the tractor by the laden semi-trailer in static condition.
- 2.11 Cold Start Device : Means a device which enriches the air fuel mixture of the engine temporarily and, thus, to, assist engine start up like choke.
- 2.12 Starting Aid : Means a device which assists engine start up without enrichment of the fuel mixture, e.g. glow plug, change of injection timing for fuel-injected spark ignition engine, etc.
- 2.13 Engine capacity means : For reciprocating piston engines, the nominal engine swept volume.
- 2.14 Anti pollution device : means those components of the vehicles that control and / or limit tail pipe and evaporative emissions
- 2.15 Type Approval of a vehicle : Means the type approval of a vehicle model with regard to the limitation of tailpipe emissions from the vehicles.
- 2.16 Vehicle Model : Means a category of power-driven vehicles which do not differ in such essential respects as the equivalent inertia determined in relation to the reference weight of engine and vehicle characteristics which effects the vehicular emission and listed in Chapter 2 of this Part.
- 2.17 Vehicle for Type Approval Test : Means the fully built vehicle incorporating all design features for the model submitted by the vehicle manufacturer.

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

Application for Type Approval :

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

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

4. Type Approval :

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

5. Specification and Tests :

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

5.2 Specifications concerning the emissions of pollutants

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

5.2.2 Type I Test: (Verifying the average tailpipe emissions)

- 5.2.2.1 The vehicle shall be placed on a Chassis dynamometer bench equipped with a means of load and inertia simulation.

- 5.2.2.2 For 2&3-wheel vehicles, a test lasting a total of 648 seconds and comprising of six cycles as described in Chapter 3 of Part XI shall be carried out, without interruption.

- 5.2.2.3 For all 4-wheel vehicles, a test lasting a total of 19 minutes and 40 seconds made up of two parts, One and Two, shall be performed without interruption. An unsampled period of not more 20 seconds may, with the agreement of the manufacturer, be introduced between the end of Part

One and the beginning of Part Two in order to facilitate adjustment of the test equipment.

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 3.2 of chapter 3. 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.

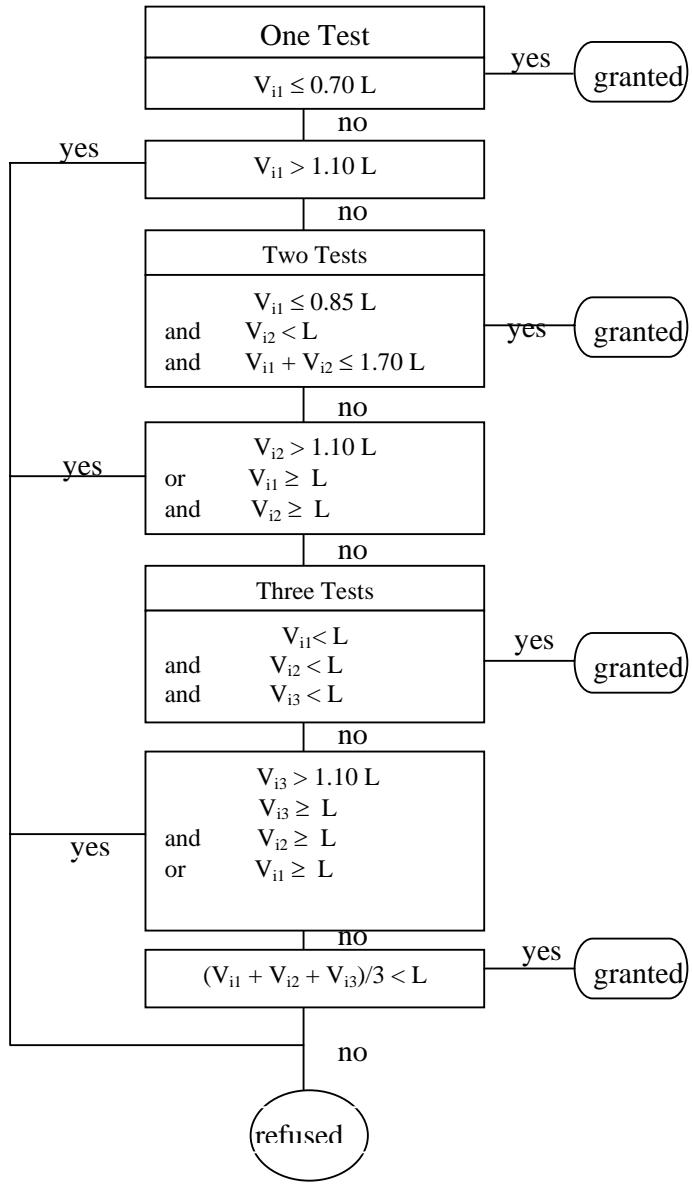
Until availability of reference LPG (fuel A & fuel B), CNG(G20,G25)) as per notification, CNG/LPG vehicles will be tested as per commercially available CNG/LPG fuels as per guidelines given by GOI.

- 5.2.2.3.1 Part One of the test cycle is made up of 4 elementary urban cycles.
Each elementary urban cycle comprises 15 phases (idling, acceleration, steady speed, deceleration).
- 5.2.2.3.2 Part Two of the test cycle is made up of one extra urban cycle. The extra urban cycle comprises 13 phases (idling, acceleration, steady speed, deceleration).
- 5.2.2.4 During the test the exhaust gases shall be diluted with air and a proportional sample collected in one or more bags. The contents of the bags will be analysed at the end of the test. The total volume of the diluted exhaust shall be measured. Carbon monoxide (CO), hydro carbon (HC) and nitrogen oxide emissions (NO_x), and in addition particulate matter (PM) the case of vehicles equipped with compression ignition engines shall be recorded. Carbon dioxide shall also be recorded for the purpose of calculation of fuel consumption.
- 5.2.2.5 The test shall be carried out by the procedure described in Chapter 3 of Part XI. 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*. 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 :
- 5.2.2.7.1 Mass emission standards for vehicles (2&3 wheelers) manufactured on and from 1st April 2005 (Bharat Stage II norms) shall be as per the details given in Rule no. 115(12) of CMVR, as amended from time to time for petrol and diesel vehicles. For CNG and LPG vehicles, this rule should be read in conjunction with Rule 115(B) and 115(C).

- 5.2.2.7.2 Mass emission standards for vehicles (4 wheelers) manufactured on and from 1st April 2005.(Bharat Stage III) shall be as per the details given in Rule No.115(14) 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.
- 5.2.2.9.1 Only one test shall be performed if the result obtained for each pollutant or the sum of values for pollutants in case of the limit is so specified (e.g. HC + NO_x) is less than or equal to 0.7 L i.e. $V_1 \leq 0.70$ L.
- 5.2.2.9.2 If the requirements of 5.2.2.9.1 is not satisfied, only two tests are performed if for each pollutant or 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 $V_2 \leq L$.

Fig.1 depicts the scheme.

Figure 1 : Flow Sheet for the Type Approval Test as per Bharat Stage II for 2/3 wheeler, Bharat Stage III 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 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 (verifying emission of crankcase gases)

5.2.4.1 This test must be carried out on all 4 wheeler vehicles referred to in Section 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 1.1 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, 80000 km for 4 wheelers driven in accordance with the programme described in chapter 12, on a test track, on the road or on a chassis dynamometer.

5.2.6.1 For all type of 2/3 & 4 wheelers 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 & 80000 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 technical service 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 (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 two steps higher or any lower equivalent inertia, for 4 wheelers and for 2&3 wheelers approval may be extended to vehicle model of a reference weight requiring merely the use of the next higher or lower equivalent inertia.
- 7.1.2 If the reference weight of the vehicle model for which extension of the type approval is requested requires the use of a flywheel of equivalent inertia lower than that used for the vehicle model already approved, extension of the type approval shall be granted if the masses of the pollutants obtained from the vehicle already approved are within the limits prescribed for the vehicle for which extension of the approval is requested.
- 7.1.3 If different body configurations are used with the same power plant and drive line and the change in the load equation due to changes in the coefficient of resistances that is within the limits that would be caused by the change of inertia as permitted by Clause 7.1.1 above the approval may be extended.

7.2 Vehicle models with Different Overall Gear Ratios :

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

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

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

where 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.

- 7.2.2 If for each gear ratio $E \leq 8\%$, the extension shall be granted without repeating the Type I Tests.
- 7.2.3 If for at least one gear ratio, $E > 8\%$ and if for each gear ratio $E \leq 13\%$ the Type I test must be repeated, but may be performed in laboratory chosen by the manufacturer subject to the approval of the test agency granting type approval. The report of the tests shall be submitted to the test agency by the manufacturer. .
- 7.3 Vehicle models of Different Reference Weights, coefficient of coast down and Different Overall Transmission Ratios Approval granted to a vehicle model may be extended to vehicle models differing from the approved type only in respect of their reference weight, coefficient of coast down and their overall transmission ratios, provided that all the conditions prescribed in Para 7.1 and 7.2 above are fulfilled.
- 7.4 Note : When a vehicle type has been approved in accordance with the provisions of Para 7.1 to 7.3 above, such approval may not be extended to other vehicle types.
- 7.5 Vehicle model with different makes of emission related components:
- 7.5.1 the names of suppliers of items such as ignition coil, magneto, CB point, air filter, silencer, etc. mentioned above, the manufacturers shall inform the test agency that In addition to carried out the type approval, the names of new alternate suppliers for these items as and when they are being introduced.
- 7.5.2 At the time of first type approval or for a subsequent addition of a make for a particular part, work out the combinations of tests in such a way that each make of such parts are tested at least once.
- 7.6 Evaporative emissions (type IV test)
- 7.6.1 Approval granted to a vehicle type equipped with a control system for evaporative emissions may be extended under the following conditions.
- 7.6.1.1 The basic principle of fuel/air metering (e.g. single point injection, carburettor) must be the same.
- 7.6.1.2 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 vapour/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 $\pm 10\%$. The setting of the tank relief valve must be identical.
- 7.6.1.3 The method of storage of the fuel vapour must be identical, i.e. trap form and volume, storage medium, air cleaner (if used for evaporative emission control), etc.

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

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

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

7.6.2 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.

7.7 Durability of anti-pollution devices (type V test)

7.7.1 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.

7.7.1.1 Engine:

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

7.7.1.2 Pollution control system:

- Catalytic Converters:
- Number of catalytic converters and elements
- Size and shape of catalytic convertors (volume of monolith $\pm 10\%$),
- 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, 42 km/h for 2& 3 wheelers and the load setting of type I test.

- Air injection:
- With or without
- Type (pulsair, air pumps....)
- EGR:
- With or without

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

7.7.1.4 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 is adopted :-

8.2.1. 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. The result masses of gaseous emissions and in addition in case of vehicles equipped with compression ignition engines, the mass of particulates obtained in the test shall not exceed the applicable limits.

8.2.2 Procedure for Conformity of Production as per Bharat Stage-II for 2/3 wheeler vehicles and BS III for 4 wheeler

8.2.2.1 Conformity of production shall be verified as per Bharat Stage-II emission norms for 2/3 wheeler vehicles and as per Bharat Stage III emission norms for 4 wheeler vehicles as given in para 5.2.2.7.1/5.2.2.7.2 and with the procedure given below.

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

8.2.2.3 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.

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

8.2.2.5 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.

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

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

$$d_j = X_j - L_i$$

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

$$V_n^2 = \frac{1}{n} \sum_{j=1}^n (d_j - \bar{d}_n)^2$$

8.2.2.8 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 \bar{d}_n / V_n and must be used to determine whether the series has passed or failed as follows :

- Pass the series, if $\bar{d}_n / V_n \leq A_n$ for all the pollutants
- Fail the series if $\bar{d}_n / V_n \geq B_n$ for any one of the pollutants.
- Increase the sample size by one, if $A_n < \bar{d}_n / V_n < B_n$ for any one of the pollutants. When a pass decision is reached for one pollutant, that decision will not be changed by any additional tests carried out to reach a decision for the other pollutants.
- If no pass decision is reached for all the pollutants and no fail decision is reached for one pollutant, a test shall be carried out on another randomly selected sample till a pass or fail decision is arrived at.

8.2.2.9 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.

8.2.2.10 Alternatively If the manufacturer wishes to run in the vehicles, ("x" km, where $x \leq 3000$ km for vehicles equipped with a positive ignition engine and $x \leq 15000$ 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:

$$\frac{\text{Emissions}'' x'' \text{km}}{\text{Emissions zero km}}$$

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.

8.2.2.11 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.

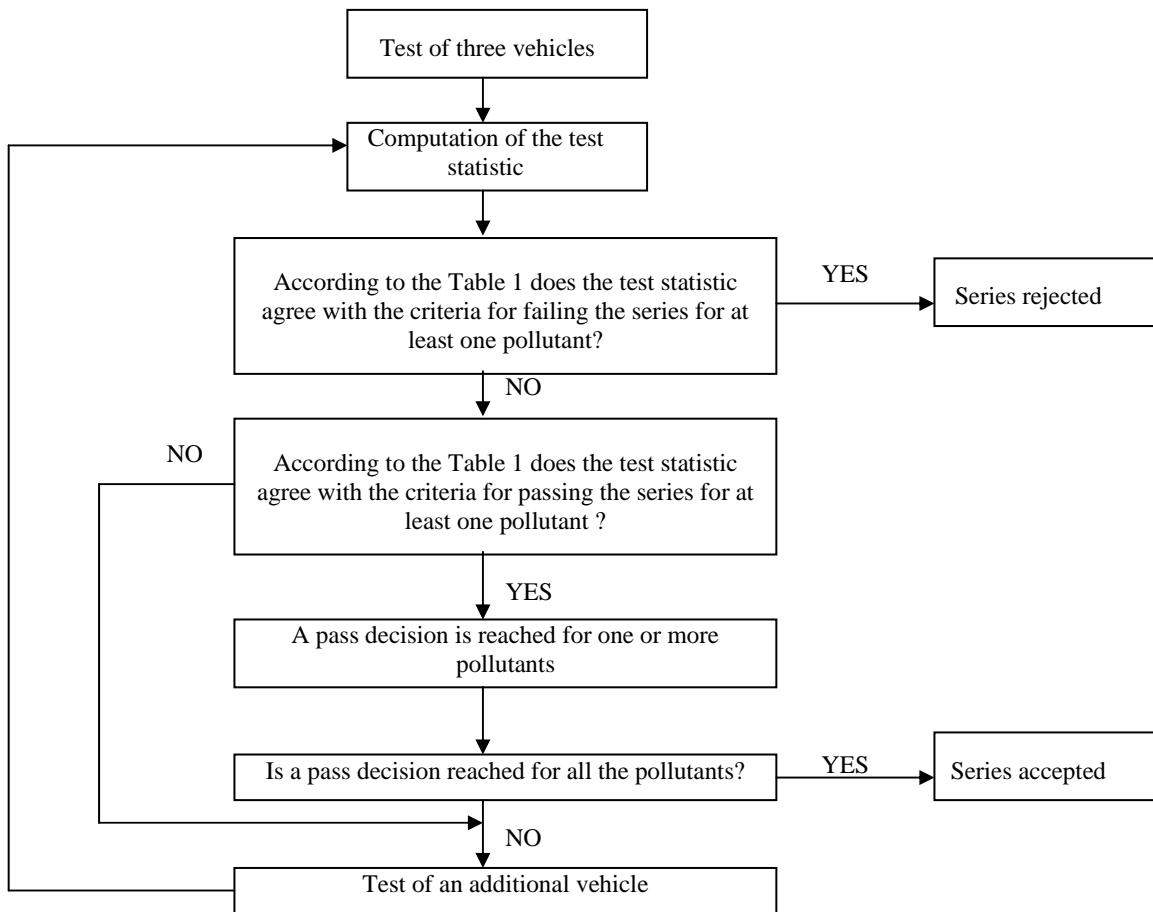


Figure 2 : COP Test Procedure as per Bharat Stage II for 2/3 wheeler & BS III for 4 wheelers

Table I : Applicable for COP Procedure as per Bharat Stage II for 2/3 wheelers & BS III for 4 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

- 8.3 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.
- 8.4 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.
- 8.5 For type IV test is to be carried out, it must be conducted in accordance with section 7 of chapter 11.

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 Revision 2

CHAPTER 3 : TYPE I TEST ON S.I. ENGINES, CNG, LPG AND DIESEL ENGINED VEHICLES (VERIFYING THE AVERAGE TAILPIPE EMISSION) OF GASEOUS AND PARTICULATE POLLUTANTS

1. This chapter describes the procedure for the Type I test defined in paragraph 5.2.2 of Chapter 1 of this Part. This chapter should be read in conjunction with the applicable Gazette notification for which the test is to be carried out.
2. Operating Cycle on the Chassis Dynamometer :
 - 2.1 Description of the Cycle : The operating cycle on the chassis dynamometer shall be as given in 2.1.1and 2.1.2 as applicable.
 - 2.1.1 The operating cycle on the chassis dynamometer for all two and three wheelers shall be that indicated in Table I and depicted in Figure 2 of this Chapter. The break down by operations is given in Table II of this Chapter
 - 2.1.2 The operating cycle on the chassis dynamometer for vehicles other than two and three wheelers shall be as per modified Indian Driving Cycle i.e. Urban Driving Cycle (Table IV) and Extra Urban Driving Cycle (Table V) and as depicted in the Figure 3 and Figure 4 of this Chapter respectively. The break down by operations is given in Table IV-A for Urban Driving Cycle (Part One) and in Table V-A for Extra Urban Driving Cycle (Part Two) of this chapter.
 - 2.2 General Conditions under which the cycle is carried out : preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximately to the theoretical cycle within the prescribed limits.
 - 2.3 Use of the Gear Box : The use of the gear box in case of testing two and three wheeler on chassis dynamometer shall be in accordance with Para 2.3.1 of this Chapter For the vehicles other than two and three wheeler vehicles, the use of gear box shall be in accordance with Para 2.3.2
 - 2.3.1 Vehicles which do not attain the acceleration and maximum speed values required in the operating cycle shall be operated with the accelerator control fully depressed until they once again reach the required operating curve. Deviations from the operating cycle shall be recorded in the test report.

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

2.3.1.1 Manual Change Gear Box :

- 2.3.1.1.1 During each phase at constant speed, the rotating speed of the engine shall be, if possible, between 50 and 90% of the speed corresponding to the

maximum power of the engine. When this speed can be reached in two or more gears, the vehicle shall be tested with the higher gear engaged.

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

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

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

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

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

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

2.3.2.1 However, if the maximum speed which can be attained in first gear is below 15 km/h, the first gear need not be used and the second, the third and fourth gears are used for the elementary urban cycles (Part One) and the second, third, fourth and fifth gears for the extra urban cycle (Part Two). Similarly, the first gear need not be used and second, third and fourth gears may also be used for the urban cycles (Part One) and the second, third, fourth and fifth gears for the extra urban cycle (Part Two) when the driving instructions recommended starting in second gear on level ground, or when first gear is therein defined as a gear reserved for cross country driving, crawling or towing.

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 in 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.

2.3.3 Vehicles equipped with automatic gear boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order. Furthermore the gear change points given in Table IV and Table V of this Chapter do not apply : accelerator must continue throughout the period represented by the straight line connecting the end of each period of idling with the beginning of the next following period of steady speed. The tolerance given in 2.4 shall apply.

2.3.4 Vehicles equipped with an overdrive which the driver can activate shall be tested with the overdrive out of action for the urban cycle (Part One) and with the overdrive in action for the extra urban cycle (Part Two).

2.4 Tolerances

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

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

2.4.3 The speed and time tolerances shall be combined as indicated in Figure 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 atleast 3000 kms before the test.

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

3.1.3 The air intake system should be leak proof.

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

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

- 3.1.4 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-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 \pm 5 per cent.
- 4.1.6.2 In the case of a dynamometer with an adjustable load curve, the accuracy of matching dynamometer load to road load shall be within 5 per cent at 80,60, 50, 40, 30 km/h and 10 per cent at 20 km/h. Below this, the dynamometer absorption must be positive.

4.1.6.3 The total equivalent inertia of the rotating parts (including the simulated inertia where applicable) must be known and within \pm 20 kg of the inertia class for the test, in case of 3 and 4-wheeler vehicles; for 2-wheeler vehicles within \pm 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 \pm 1 km/h at speeds above 10 km/h.

4.1.7 Load and Inertia Setting :

4.1.7.1 Dynamometer with adjustable load curve: the load simulator shall be adjusted in order to absorb the power exerted on the driving wheels at various steady speeds of 80, 60, 50, 40, 30 and 20 km/h for four-wheelers else, for two and three wheelers it is at the steady speed of 50, 40, 30 and 20 km/h.

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

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

4.1.8 Chassis Dynamometer Calibration :

4.1.8.1 The dynamometer should be calibrated periodically as recommended by the manufacturer of the chassis dynamometer and then calibrated as required. The calibration shall consist of the manufacturers' recommended procedure and a determination of the dynamometer frictional power absorption at 40 km/h when being used for testing of two and three wheelers and 80 km/h when being used for other vehicles. One method for determining this is given in Chapter 7. Other methods may be used if they are proven to yield equivalent results.

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

4.2 Exhaust Gas-sampling System :

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

The particulate pollutant emission level is determined by using suitable filters to collect the particulates from a proportional part flow throughout the test and determining the quantity thereof gravimetrically in accordance with 4.3.2.

- 4.2.2 The flow through the system shall be sufficient to eliminate water condensation at all conditions which may occur during a test, as defined in Chapter 6 of this part.
- 4.2.3 Figure 9,10,11 of Chapter 6 of this Part gives a schematic diagram of the general concept. Examples of three types of Constant Volume Sampler systems which will meet the requirements are given in Chapter 6 of this part.
- 4.2.4 The gas and air mixture shall be homogenous at point S2 of the sampling probe.
- 4.2.5 The probe shall extract a true sample of the diluted exhaust gases.
- 4.2.6 The system should be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the diluted exhaust gas. Should any component (heat exchanger, blower, etc.) change the concentration of any pollutant gas in the diluted gas, then the sampling for that pollutant shall be carried out before that component, if the problem cannot be corrected.
- 4.2.7 If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connection tubes shall be connected as near as possible to the vehicle.
- 4.2.8 Static pressure variations at the tail pipe(s) of the vehicle shall remain within ± 1.25 kPa of the static pressure variations measured during the dynamometer driving cycle and with no connection to the tailpipe(s). Sampling systems capable of maintaining the static pressure to within ± 0.25 kPa will be used if a written request from a manufacturer to the authority granting the approval substantiates the need for the closer tolerance. The back-pressure shall be measured in the exhaust pipe as near as possible to its end or in an extension having the same diameter.
- 4.2.9 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.
- 4.2.10 The gas samples shall be collected in sample bags of adequate capacity. These bags shall be made of such materials as will not change the pollutant gas by more than $\pm 2\%$ after twenty minutes of storage.

4.3 Analytical Equipment :

- 4.3.1 Pollutant gases shall be analysed with the following instruments :

4.3.1.1 Carbon monoxide (CO) and carbon dioxide (CO₂) analysis. The carbon monoxide and carbon dioxide analysers shall be of the Non-Dispersive Infra Red (NDIR) absorption type.

4.3.1.2 Hydrocarbon (HC) analysis - Gasoline Vehicles. The hydrocarbons analyser shall be of the Flame Ionisation (FID) type calibrated with propane gas expressed equivalent to carbon atoms.

4.3.1.3 Hydrocarbons (HC) analysis - Diesel Vehicles. The hydrocarbon analyser shall be of the Flame Ionisation type Detector with valves , pipe work etc. heated to 463 K ± 10 K (HFID). It shall be calibrated with propane gas expressed equivalent to carbon atoms (C₁).

4.3.1.4 Nitrogen oxide (NO_x) analysis.

The nitrogen oxide analyser shall be of the Chemiluminescent (CLA) type with an NO_x-NO converter or by NDUVR (non-dispersive ultraviolet resonance absorption) type analyser.

4.3.1.5 Particulates :

Gravimetric determination of the particulates collected. These particulates are in each case collected by two series mounted filters in the sample gas flow. The quantity of particulates collected by each pair of filters shall be as follows :

V_{ep} : Flow through filters.

V_{mix} : Flow through tunnel.

M : Particulate mass (g/km)

M_{limit} : Limit mass of particulates (limit mass in force, g/km)

m : Mass of particulates collected by filters (g)

d : Actual distance corresponding to the operating cycle (km)

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

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

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

The particulate sample rate (V_{ep} / V_{mix}) will be adjusted so that for M = M_{limit} 1 ≤ m ≤ 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 $\pm 2\%$ (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 $\geq 0.3 \mu\text{m}$ to extract any solid particles from the continuous flow of gas required for analysis.

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

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

4.3.2.5 The particulate sampling unit consist of a dilution tunnel, a sampling probe, a filter unit, a partial flow pump, and a flow rate regulator and measuring unit. The particulate sampling part flow is drawn through two series mounted filters. The sampling probe for the test gas flow for particulates shall be so arranged within the dilution tract that a representative sample gas flow can be taken from the homogenous air / exhaust mixture and an air / exhaust gas mixture 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 ± 3 K, nor the mass flow rate shall fluctuate more than $\pm 5\%$. If the volume of flow change unexpectedly as a result of excessive filter loading, the test should be stopped. When it is repeated, the rate of flow shall be decreased and / or larger filter shall be used. The filters shall be removed from the chamber not earlier than an hour before the test begins.

4.3.2.6 The necessary particulate filters should be conditioned (as regards temperature and humidity) in an open dish which shall be protected against dust ingress for at least 8 and not more than 56 hours before the test in an air conditioned chamber. After this conditioning, the uncontaminated filters shall be read and stored until they are used.

The temperature of the chamber (or room) in which particulate filters are conditioned and weighted shall be maintained to within $295 \pm 3^\circ\text{K}$ ($22^\circ\text{C} \pm 3^\circ\text{C}$) during all filter conditioning and weighing. The humidity shall be maintained to a dew point of $282.3^\circ\text{K} \pm 3^\circ\text{K}$ ($9.5^\circ\text{C} \pm 3^\circ\text{C}$) and a relative humidity of $45\% \pm 8\%$.

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 \leq 1 ppm C, \leq 1 ppm CO, \leq 400 ppm CO₂, \leq 0.1 ppm NO);

Purified synthetic air (purity \leq 1 ppm C, \leq 1 ppm CO, \leq 400 ppm CO₂, \leq 0.1 ppm NO); oxygen content between 18% & 21% vol.;

Purified oxygen (purity \leq 99.5 per cent Vol O₂);

Purified hydrogen (and mixture containing hydrogen)
(Purity \leq 1 ppm C, \leq 400 ppm CO₂).

4.5.2 Calibration and span gases :

Gases having the following chemical compositions shall be available of:

- C₃H₈ and purified synthetic air, as in para 4.5.1 above
- CO and purified nitrogen
- CO₂ and purified nitrogen
- NO and purified nitrogen

(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 \pm 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 \pm 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 \pm 1.5 K.

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

4.6.3 Absolute Humidity : The absolute humidity (H) shall be measurable to within \pm 5 %.

4.7 The exhaust gas-sampling system shall be verified by the method described in Para 5 of Chapter 7 of this part. The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured shall be 5 %.

5. Preparations for the test :

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

5.2 Setting of dynamometer :

- 5.2.1** The load shall be adjusted according to methods described in paragraph 4.1.7 above.
- 5.2.1** The method used and the values obtained (equivalent inertia, characteristic adjustment parameter) shall be recorded in the test report.

TABLE I
OPERATING CYCLE ON THE CHASSIS DYNAMOMETER
(Please ref. Para. 2.1.1)

No. of operation		Acceleration 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

TABLE II

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

A: BREAK DOWN BY PHASES

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

B: AVERAGE SPEED DURING TEST : 21.93 Km/h

C: THEORETICAL DISTANCE COVERED PER CYCLE : 0.658 Km.

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

Table III

For 2 and 3 wheelers			For vehicles other than 2 and 3 wheelers		
Reference Vehicle RW (kg)	Mass of	Equivalent Inertia (kg.)	Reference RW (kg.)	Mass of Vehicle	Equivalent Inertia (kg.)
Exceeding	Upto		Exceeding	Upto	
	105	100	--	480	455
105	115	110	480	540	510
115	125	120	540	595	570
125	135	130	595	650	625
135	150	140	650	710	680
150	165	150	710	765	740
165	185	170	765	850	800
185	205	190	850	965	910
205	225	210	965	1080	1020
225	245	230	1080	1190	1130
245	270	260	1190	1305	1250
270	300	280	1305	1420	1360
300	330	310	1420	1530	1470
330	360	340	1530	1640	1590
360	395	380	1640	1760	1700
395	435	410	1760	1870	1810
435	480	450	1870	1980	1930
480	540	510	1980	2100	2040
540	600	570	2100	2210	2150
600	650	620	2210	2380	2270
650	710	680	2380	2610	2270
710	770	740	2610	--	2270
770	820	800			
820	880	850			
880	940	910			
940	990	960			
990	1050	1020			
1050	1110	1080			
1110	1160	1130			
1160	1220	1190			
1220	1280	1250			
1280	1330	1300			
1330	1390	1360			
1390	1450	1420			
1450	1500	1470			
1500	1560	1530			
1560	1620	1590			
1620	1670	1640			
1670	1730	1700			
1730	1790	1760			

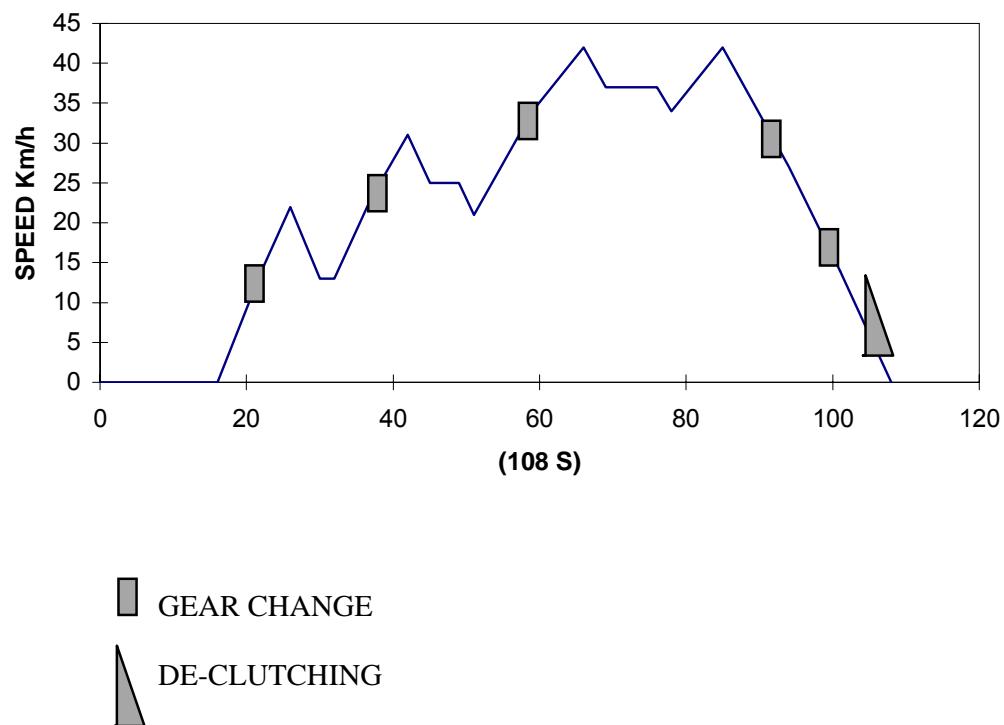
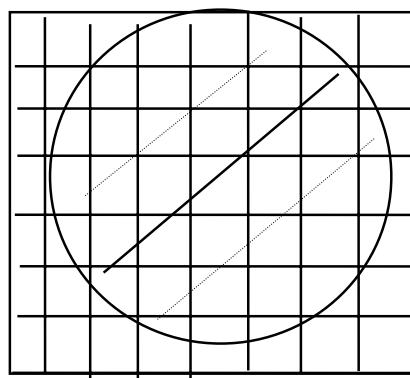


Fig 1 : OPERATING CYCLE WITH RECOMMENDED GEAR POSITION
 (Pl. ref. para 2.3.1.1.5)



SPEED AND TIME TOLERANCES

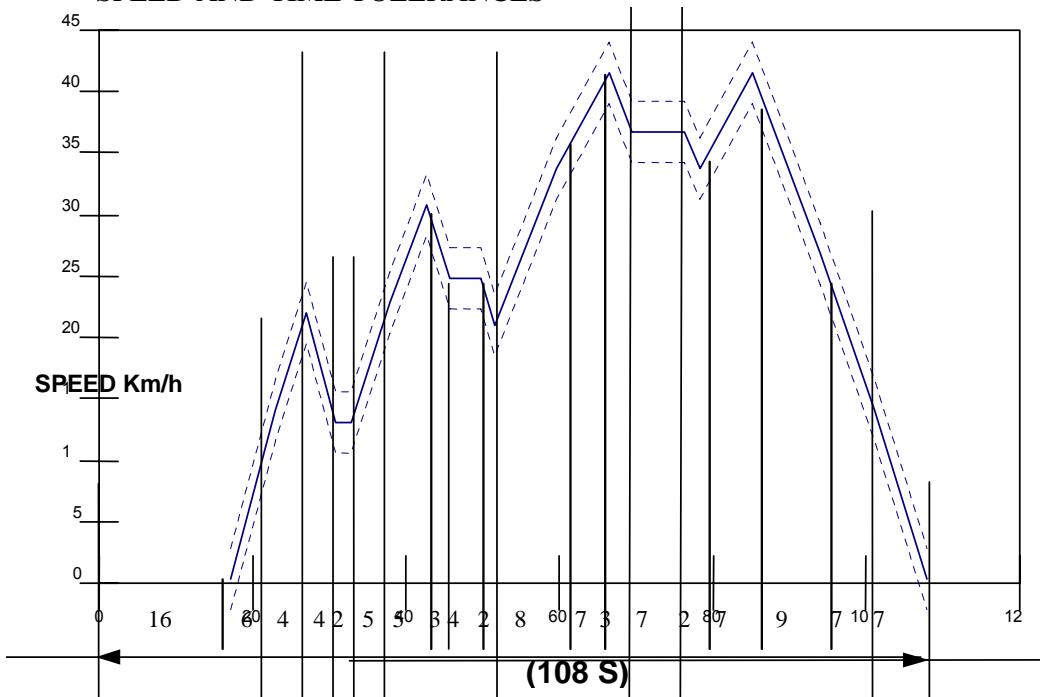


Fig 2: Operating cycle with speed and time tolerances
(Pl. ref. para 2.1.1)

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

5.3 Preconditioning of the vehicle :

- 5.3.1 For the compression ignition engine vehicles for the purpose of measuring particulates at most 36 hours and at least 6 hours before testing, the Part two cycle described in Table V for 4 wheelers and Table 1 for 3 wheeler vehicles shall be used. Three consecutive cycles for 4 wheelers & 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 At the request of the manufacturers, vehicles with positive ignition engines may be pre-conditioned with one Part-I two Part-II driving cycles for four-wheeled vehicles.
- 5.3.3 After this preconditioning specific for compression ignition engines 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, 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 for 4 wheelers and in case of 2 & 3 wheelers soaking period will be from 6 to 30 hours.
- 5.3.5 The tyre pressure shall be the same as that indicated by the manufacturer and used for the preliminary road test for data collection for adjustment of chassis Dynamometer. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting in the case of a two roll dynamometer. The actual pressure used shall be recorded in the test report.

6. Procedure for Chassis Dynamometer Test :

6.1 Special conditions for carrying out the cycle :

- 6.1.1 During the test, the test cell temperature shall be between 293 K and 303 K (20 and 30°C). The absolute humidity (H) of either the air in the test cell or the intake air of the engine shall be such that :

$$5.5 \leq H \leq 12.2 \text{ g H}_2\text{O/kg dry air}$$

- 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 m^2 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.

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 $25 \text{ km/h} \pm 5 \text{ km/h}$. 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 For all other vehicles Exhaust Gas Sampling should start at the initiation of engine start-up procedure.

6.2.2.3 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.

6.2.2.4 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.

- 6.2.2.5 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.
- 6.2.2.6 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.
- 6.2.2.7 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.
- 6.2.2.8 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).
- 6.2.2.9 The reason for the malfunction (if determined) and the corrective action taken shall be indicated in the test report.
- 6.2.2.10 During corrective action referred to the paragraphs 6.2.2.5, 6.2.2.6 and 6.2.2.9 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.
- 6.2.2.11 All other vehicles, i.e. 4 wheelers Exhaust Gas Sampling should start at the initiation of 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

6.3 Idling :

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

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

6.3.1.2 To enable the accelerations to be performed according to normal cycle the vehicle shall be placed in first gear, with clutch disengaged, 5 seconds before the acceleration following the idling period considered of the elementary urban cycle (Part One) for four wheelers and IDC for 2 & 3 wheelers.

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 for 4 wheelers.

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.

6.3.1.4 For the idling periods during each urban cycle (Part One) the corresponding times are 16 seconds in neutral and 5 seconds in first gear with the clutch disengaged.

6.3.1.5 The idle period between two successive elementary cycles (Part One) comprises 13 seconds in neutral with the clutch engaged.

6.3.1.6 At the end of the deceleration period that of the vehicle on the roller of the extra urban cycle (Part Two), the idling period consist of 20 seconds in neutral with the clutch engaged.

Note : Wherever first gear is mentioned above, second gear is to be used subject to 2.3.1 to 2.3.4

6.3.2 Automatic-shift gear-box : After initial engagement, the selector shall not be operated at any time during the test except in accordance with paragraph 6.4.3 below.

6.4 Accelerations :

6.4.1. Accelerations shall be so performed that the rate of acceleration shall be as constant as possible throughout the phase.

6.4.2. If an acceleration cannot be carried out in the prescribed time, the extra time required is, if possible, deducted from the time allowed for changing gear, but otherwise from the subsequent steady speed period.

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

6.5 Decelerations :

6.5.1 All decelerations of the elementary urban cycle (Part One) shall be effected by closing the throttle completely. The clutch shall be disengaged, at around a speed of 10 km/h.

All the deceleration of the extra urban cycle (Part Two) shall be effected by closing the throttle completely. The clutch shall be disengaged, at around a speed of 50 km/h for the last deceleration.

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

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

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

6.6 Steady Speeds :

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

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

7. Procedure for Sampling and Analysis :

7.1 Sampling :

7.1.1 Sampling for all two and three wheelers except diesel vehicles shall begin at the end of fourth preparatory cycle and shall complete at the end of 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.

7.1.2 Sampling for all the vehicles other than mentioned at 7.1.1 shall begin at the initiation of the engine start up 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) $d = 1.164 \text{ kg/m}^3$
- in the case of hydrocarbons ($\text{CH}_{1.85}$) $d = 0.5768 \text{ Kg/m}^3$
- in the case of nitrogen oxides (NO_x) $d = 1.913 \text{ kg/m}^3$.

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 $0.95(m_1 + m_2) \leq m_1$, $m = m_1$,
- if $0.95(m_1 + m_2) > m_1$, $m = m_1 + m_2$,
- if $m_2 > m_1$, the test shall be cancelled.

- 8.3 Chapter 8 of this Part describes the calculations, followed by examples, used in determining the mass emissions of gaseous and particulates.

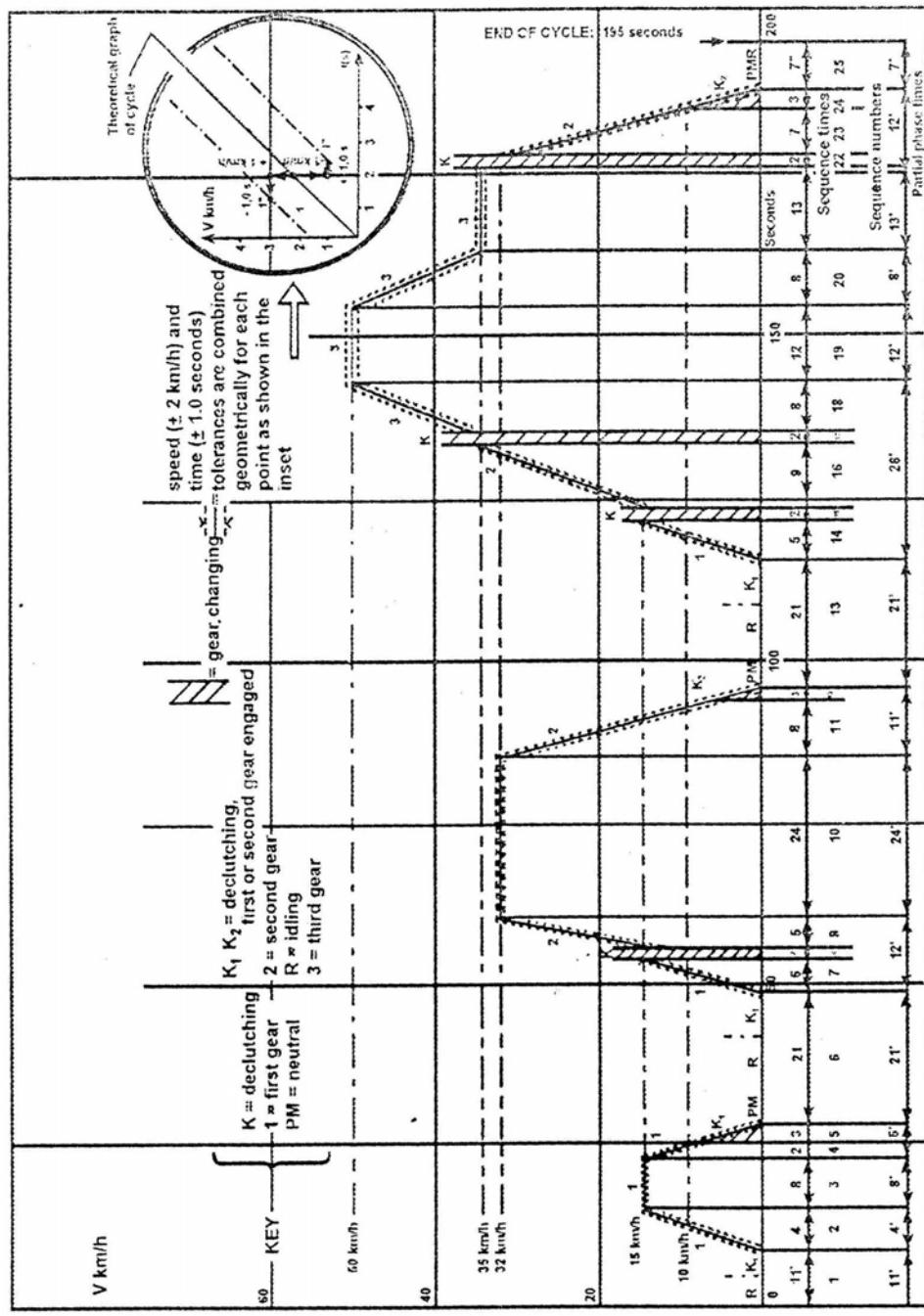


Figure 3 : Elementary-Urban cycle for type I test

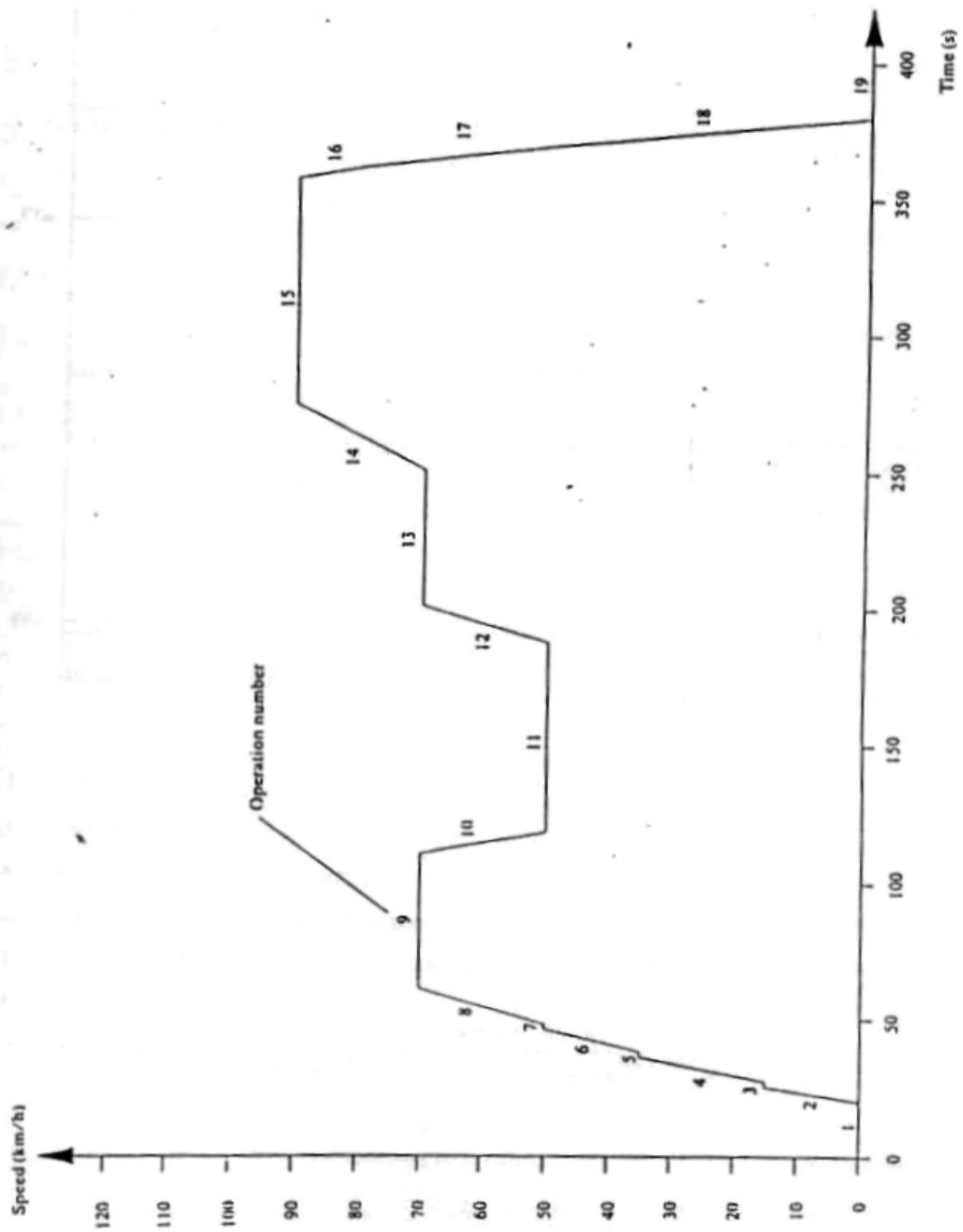


Figure 4 : Extra-Urban cycle (Part two) for type I test

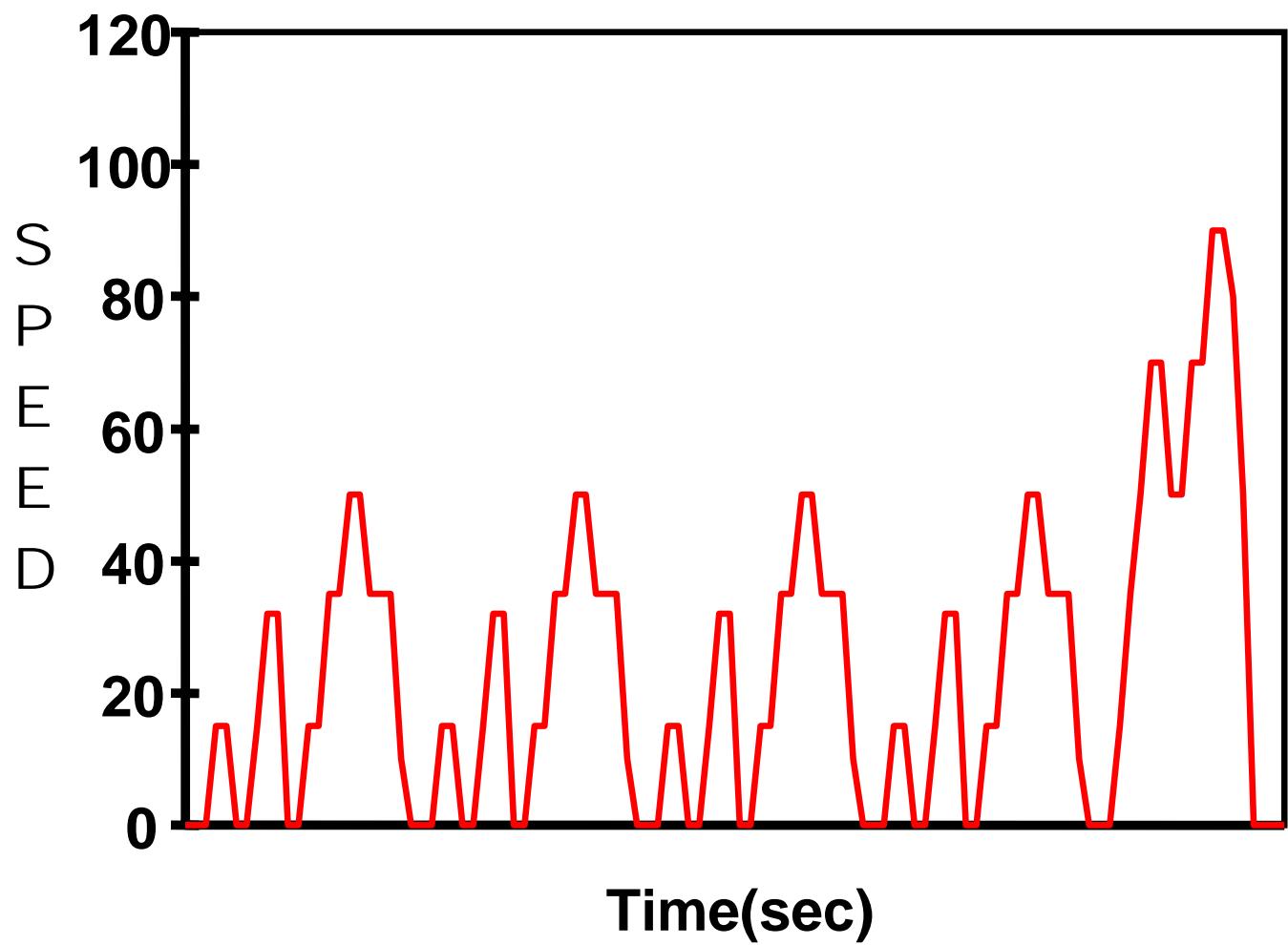


Figure 5 : OPERATING CYCLE FOR THE TYPE I TEST

Table IV : Modified Indian Driving Cycle for the Year 2000
Operating Cycle on the Chassis Dynamometer (Part One)

No of Operation	Operation	Phase	Acceleration (m/s ²)	Speed (km/h)	Duration of each		Cumulative (s)	Gear to be used in case of manual gearbox
					Operation (s)	Phase (s)		
1	Idling	1	1.04		11	11	11	6s 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	5	25	1
5	Deceleration, Clutch disengaged	4	-0.92	10-0	3		28	K ₁ (*)
6	Idling	5			21	21	49	16 s PM + 5 s K ₁ (*)
7	Acceleration	6	0.83	0-15	5	12	54	1
8	Gear change				2		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	11	93	2
12	Deceleration, Clutch disengaged	8	-0.92	10-0	3		96	K ₂ (*)
13	Idling	9			21		117	6 s PM + 5 s K ₁ (*)
14	Acceleration	10	1.04	0-15	5	26	122	1
15	Gear change				2		124	
16	Acceleration		0.62	15-35	9		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	14			2	12	178	
23	Deceleration		-0.86	32-10	7		185	2
24	Deceleration Clutch disengaged		-0.92	10-0	3		188	K ₂ (*)
25	Idling	15			7	7	195	7s PM(*)

(*) PM = gearbox in neutral, clutch engaged
 K_1, K_2 = first or second gear engaged, clutch disengaged.

Table V : Modified Indian Driving Cycle for the Year 2000

Extra-urban cycle (Part Two) for the type I Test

No of Operation	Operation	Phase	Acceleration	Speed (km/h)	Duration of each		Cumulative (s)	Gear to be used in case of a manual gearbox
					Operation(s)	Phase(s)		
1	Idling	1			20	20	20	$K_1(*)$
2	Acceleration		0.83	0-15	5			25
3	Gear change				2			--
4	Acceleration		0.62	15-35	9			36
5	Gear change				2			--
6	Acceleration		0.52	35-50	8			46
7	Gear change				2			--
8	Acceleration		0.43	50-70	13			61
9	Steady speed	3		70	50	50	111	5
10	Deceleration	4	-0.69	70-50	8	8	119	4 s.5 + 4 s.4
11	Steady speed	5		50	69	69	188	4
12	Acceleration	6	0.43	50-70	13	13	201	4
13	Steady speed	7		70	50	50	251	5
14	Acceleration	8	0.24	70-90	24	24	275	5
15	Steady speed	9		90	83	83	358	5
16	Deceleration	10	-0.69	90-80	4		362	5
17	Deceleration		-1.04	80-50	8		370	5
18	Deceleration		-1.39	50-00	10		380	$K_5(*)$
19	Idle	11			20	20	400	PM (*)

(*) PM = gearbox in neutral, clutch engaged

K_1, K_2 = first or second gear engaged, clutch disengaged

Table IV-A : Breakdown of the Part -One Of Modified Indian Driving Cycle

(ELEMENTARY URBAN CYCLE)

Breakdown by phases

	Time (s)	%
Idling	60	30.8
Idling, vehicle moving, clutch engaged on one combination	9	4.6
Gear-changing	8	4.1
Accelerations	36	18.5
Steady-speed periods	57	29.2
Decelerations	25	12.5
	195	100

Breakdown by use of gears

	Time (s)	%
Idling	60	30.8
Idling, vehicle moving, clutch engaged on one combination	9	4.6
Gear-changing	8	4.1
First gear	24	12.3
Second gear	53	27.2
Third gear	41	21
	195	100

General information

Average speed during test : 19 km/h.
 Effective running time : 195 seconds
 Theoretical distance covered per cycle : 1.013 km
 Equivalent distance for the four cycles : 4.053 km

Table V-A : Breakdown of the Part Two of Modified Indian Driving Cycle
(Extra-Urban Cycle)

Breakdown by phases

	Time (s)	%
Idling	20	5.0
Idling, vehicle moving, clutch engaged on one combination	20	5.0
Gear-changing	6	1.5
Acceleration	72	18.0
Steady-speed periods	252	63.0
Deceleration	30	7.5
	400	100

Breakdown by use of gears

	Time (s)	%
Idling	20	5.0
Idling, vehicle moving, clutch engaged on one combination	20	5.0
Gear-changing	6	1.5
First gear	5	1.3
Second gear	9	2.2
Third gear	8	2.0
Fourth gear	99	24.8
Fifth gear	233	58.2
	400	100

General information

Average speed during test : 59.3 km/h.
 Effective running time : 400 seconds
 Theoretical distance covered per cycle: 6.594 km
 Maximal speed : 90 km/h
 Maximal acceleration : 0.833 m/s²
 Maximal deceleration : -1.389 m/s²

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 $\pm 0.1\%$ 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:
 $P = 100 \text{ kPa}$ & $T = 293.2 \text{ K}$

4. Vehicle Preparation :

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

- 4.2 Verifications : The following verifications shall be made in accordance with the manufacturer's specifications for the use considered :
- wheel, wheel trims, tyres (make, type, pressure),
 - front axle geometry,
 - brake adjustment (elimination of parasitic drag)
 - lubrication of front and rear axles,
 - adjustment of the suspension and vehicle level, etc.

4.3 Preparation for the test :

The vehicle shall be loaded to its reference mass. The level of the vehicle shall be that obtained when the centre of gravity of the load is situated midway

between the “R” points of the front outer seats and on a straight line passing through those points.

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

4.3.2 The vehicle shall be clean.

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

5. Methods for chassis dynamometer with adjustable load curve

5.1 Energy variation during coast-down method :

5.1.1 On the road

5.1.1.1 Accuracies of test equipment

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

5.1.1.2 Test procedure

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

5.1.1.2.2 Place the gear box in “neutral” position.

5.1.1.2.3 Measure the time taken (t_1) for the vehicle to decelerate from

$$V_2 = V + \Delta V \text{ km/h} \text{ to } V_1 = V - \Delta V \text{ km/h} : \text{with } V \leq 5 \text{ km/h}$$

5.1.1.2.4 Perform the same test in the opposite direction : t_2

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

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

$$T = \frac{1}{n} \sum_{i=1}^n t_i \text{ is not more than } 2\% \text{ (} p \leq 2\% \text{)}$$

The statistical accuracy (p) is defined by :

$$p = \frac{t * s * 100}{\sqrt{n}} \frac{100}{T}$$

where,

t = coefficient given by the table below

$$s = \text{standard deviation} = \sqrt{\sum \frac{(T_i - T)^2}{(n-1)}}$$

n = number of tests

N	4	5	6	7	8	9	10	11	12	13	14	15
T	3.2	2.8	2.6	2.5	2.4	2.3	2.2	2.2	2.2	2.2	2.2	2.2
$\frac{t}{\sqrt{n}}$	1.6	1.25	1.06	0.94	0.85	0.77	0.73	0.66	0.64	0.61	0.59	0.57

5.1.1.2.7 Calculate the power by the formula :

$$P = \frac{m * V * \Delta V}{500 * T}$$

where,

P is expressed in kW

V = speed of the test in m/s

ΔV = speed deviation from speed V, in m/s

m = reference mass in kg

T = time in seconds

Alternatively, the coast down shall be carried out as per IS 14785-1999 to establish "a" and "b" coefficients for setting on chassis dynamometer.

5. 1.2 On the chassis dynamometer :

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

5.1.2.2 Test procedure :

5.1.2.2.1 Install the vehicle on the test dynamometer.

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

5.1.2.2.3 Adjust the equivalent inertia of the chassis dynamometer.

- 5.1.2.2.4 Bring the vehicle and chassis dynamometer to operating temperature in a suitable manner.
- 5.1.2.2.5 Carry out the following operations specified in paragraph 5.1.1.2 with the exception of paragraphs 5.1.1.2.4 and 5.1.1.2.5 and with changing m by I in the formula of paragraph 5.1.1.2.7 above.
- 5.1.2.2.6 Adjust the chassis dynamometer to meet the requirements of paragraphs of 4.1.6.1 of Chapter 3 of this Part.

5.2 Torque measurements method at constant speed :

5.2.1 On the road:

5.2.1.1 Measurement equipment and error :

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

5.2.1.2 Test procedure

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

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

5.2.1.2.3 Differences in torque, and speed relative to time shall not exceed 5% for each second of the measurement period. The torque C_{t_1} is the average torque derived from the following formula

$$C_{t_1} = \frac{1}{\Delta t} \int_t^{t+\Delta t} C(t) dt$$

5.2.1.2.4 Carry out the test in the opposite direction and find out the average torque i.e. C_{t_2} .

5.2.1.2.5 Determine the average of these torques C_{t_1} and C_{t_2} i.e. C_t .

5.2.2 On the chassis dynamometer

5.2.2.1 Measurement equipment and error

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

5.2.2.2 Test procedure

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

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

5.3 Integrated torque over vehicle driving pattern :

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

5.3.2 In this dynamic procedure the mean torque value \bar{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 :

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

M is calculated from six sets of results.

It is recommended that the sampling rate of \bar{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 \bar{M} (dynamometer) does not match \bar{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:

$$\bar{\gamma}_1 = \frac{1}{t} \int_0^t \gamma_1(t) dt - (g \cdot \sin \alpha_1)$$

where:

$\bar{\gamma}_1$ = 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 $\bar{\gamma}_2$

5.4.1.2.5 Calculate the average deceleration i.e.

$$\gamma_i = \frac{\bar{\gamma}_1 + \bar{\gamma}_2}{2} \text{ for test I.}$$

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 $F = m^* \gamma$, 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:

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

$F_{\text{total}} = F_{\text{road}}$

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

where : $F_{\text{indicated}}$ is the force indicated on the force indicating device of the chassis dynamometer.

$F_{(\text{road})}$ is known.

$F_{\text{driving axle rolling}}$, can be measured on chassis dynamometer driving axle rolling able to work as generator.

The test vehicle, gear box in neutral position, is driven by the chassis dynamometer at the test speed; the rolling resistance, R_R , of the driving axle is then measured on the force indicating device of the chassis dynamometer.

Determination on chassis dynamometer unable to work as a generator.

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

For the single-roller chassis dynamometer, the R_R value is the one which is determined on the road multiplied by a coefficient R which is equal to the ratio between the driving axle mass and the vehicle total mass.

Note : R_R is obtained from the curve $F = f(V)$.

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

5.4.2.2.2 Perform the same operation as in paragraphs 5.1.2.2.1 to 5.1.2.2.4 above.

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

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

5.5 Deceleration Method applying coastdown techniques :

5.5.1 On the Road

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

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

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

5.5.1.4 Measure the time taken (t_1 sec) for the speed to drop from $V + \Delta V$ km/h to $V - \Delta V$ 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/s².

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

$$F = a + b * V$$

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 vehicles other than two and three wheelers : With the manufacturer's agreement, the following method may be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 80 km/h in accordance with coefficients "a" and "b" of the table II of this chapter.

5.8 Alternate method for three wheelers: with the manufacturer's agreement, the following method can be used. The brake is adjusted so as to absorb the load exerted at the driving wheels at constant speed of 50 km/h in accordance with the table I of this chapter

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

Table I of Chapter 4 of Part XI
Table I: Power setting for three wheelers.

Reference RW(kg)	Mass of Vehicle upto	Equivalent Inertia(kg)	Absorbed power at 50m/h (kW)
Exceeding			
300	330	310	1.21
330	360	340	1.26
360	395	380	1.33
395	435	410	1.37
435	480	450	1.44
480	540	510	1.50
540	600	570	1.56
600	650	620	1.61
650	710	680	1.67
710	770	740	1.74
770	820	800	1.81
820	880	850	1.89
880	940	910	1.99
940	990	960	2.05
990	1050	1020	2.11
1050	1110	1080	2.18
1110	1160	1130	2.24
1160	1220	1190	2.30
1220	1280	1250	2.37
1280	1330	1300	2.42
1330	1390	1360	2.49
1390	1450	1420	2.54
1450	1500	1470	2.57
1500	1560	1530	2.62
1560	1620	1590	2.67
1620	1670	1640	2.72
1670	1730	1700	2.77
1730	1790	1760	2.83

Table II of Chapter 4 of Part XI**Table II: Power setting for vehicles other than two and three wheelers.**

Reference Mass of Vehicle		Equivalent Inertia	Power & load absorbed by dynamometer at 80km/h		Coefficients		
Exceeding	Upto		Kg	KW	N	a	b
RW(kg)							
---	480	455	3.8	171	3.8	0.0261	
480	540	510	4.1	185	4.2	0.0282	
540	595	570	4.3	194	4.4	0.0296	
595	650	625	4.5	203	4.6	0.0309	
650	710	680	4.7	212	4.8	0.0323	
710	765	740	4.9	221	5.0	0.0337	
765	850	800	5.1	230	5.2	0.0351	
850	965	910	5.6	252	5.7	0.0385	
965	1080	1020	6.0	270	6.1	0.0412	
1080	1190	1130	6.3	284	6.4	0.0433	
1190	1305	1250	6.7	302	6.8	0.0460	
1305	1420	1360	7.0	315	7.1	0.0481	
1420	1530	1470	7.3	329	7.4	0.0502	
1530	1640	1590	7.5	338	7.6	0.0515	
1640	1760	1700	7.8	351	7.9	0.0536	
1760	1870	1810	8.1	365	8.2	0.0557	
1870	1980	1930	8.4	378	8.5	0.0577	
1980	2100	2040	8.6	387	8.7	0.0591	
2100	2210	2150	8.8	396	8.9	0.0605	
2210	2380	2270	9.0	405	9.1	0.0619	
2380	2610	2270	9.4	423	9.5	0.0646	
2610	--	2270	9.8	441	9.9	0.0674	

In case of vehicles, other than passenger cars, with a reference mass of more than 1700 kg, or vehicles with a permanent all wheel drive, the power values given above are multiplied by the factor 1.3. However at the manufacturer's request, the factor of 1.3 need not be applied for measurement of fuel consumption.

CHAPTER 5 : VERIFICATION OF INERTIA OTHER THAN MECHANICAL

1 Scope :

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

2 Principle :

2.1 Drawing up working equations :

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

$$F = I * \gamma = I_M * \gamma + F_I$$

Where

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

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

I_M = inertia of the mechanical masses of the chassis dynamometer

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 $\pm 5\%$ of the theoretical value for each instantaneous value.

3.1.2 $\pm 2\%$ 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,

$$CR = k_1 J r_1 \frac{d\theta_1}{dt} + k_2 J r_2 \frac{d\theta_2}{dt} + k_3 M \gamma r_1 + k_3 F_s r_1$$

5.2 Equilibrium of the forces on dynamometer with mechanical simulated inertias

$$\begin{aligned} C_m &= k_1 J r_1 \frac{d\theta_1}{dt} + k_3 \frac{J R_m \frac{dW_m}{dt}}{R_m} r_1 + k_3 F_s r_1 \\ &= k_1 J r_1 \frac{d\theta_1}{dt} + k_3 I \gamma r_1 + k_3 F_s r_1 \end{aligned}$$

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

$$C_e = k_1 J r_1 \frac{d\theta_1}{dt} + \left(k_3 \frac{J R_e \frac{dW_e}{dt}}{R_e} r_1 + \frac{C_1}{R_e} r_1 \right) + k_3 F_s r_1 \\ = k_1 J r_1 \frac{d\theta_1}{dt} + k_3 (I_M \gamma + F_1) r_1 + k_3 F_s r_1$$

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.
- 2.0 Criteria relating to the variable-dilution system for measuring exhaust-Gas Emissions

2.1 Scope

This section specifies the operating characteristics of an exhaust-gas sampling system intended to be used for measuring the true mass emissions of a vehicle exhaust in accordance with the provisions of this Directive. The principle of variable-dilution sampling for measuring mass emissions requires three conditions to be satisfied:

- 2.1.1 The vehicle exhaust gases must be continuously diluted with ambient air under specified conditions;
- 2.1.2 The total volume of the exhaust gases and dilution air must be measured accurately;
- 2.1.3 A continuously proportional sample of the dilution exhaust gases and the dilution air must be collected for analysis.

The quantity of gaseous pollutants emitted is determined from the proportional sample concentrations and the total volume measured during the test. The sample concentrations are corrected to take account of the pollutant content of the ambient air. In addition, where vehicles are equipped with compression ignition engines, their particulate emissions are measured.

2.2 Technical summary :

Figure 7 gives a schematic diagram of the sampling system.

- 2.2.1 The vehicle exhaust gases must be diluted with a sufficient of ambient air to prevent any water condensation in the sampling and measuring system.
- 2.2.2 The exhaust-gas sampling system must be so designed as to make it possible to measure the average volume concentrations of the CO₂, 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.

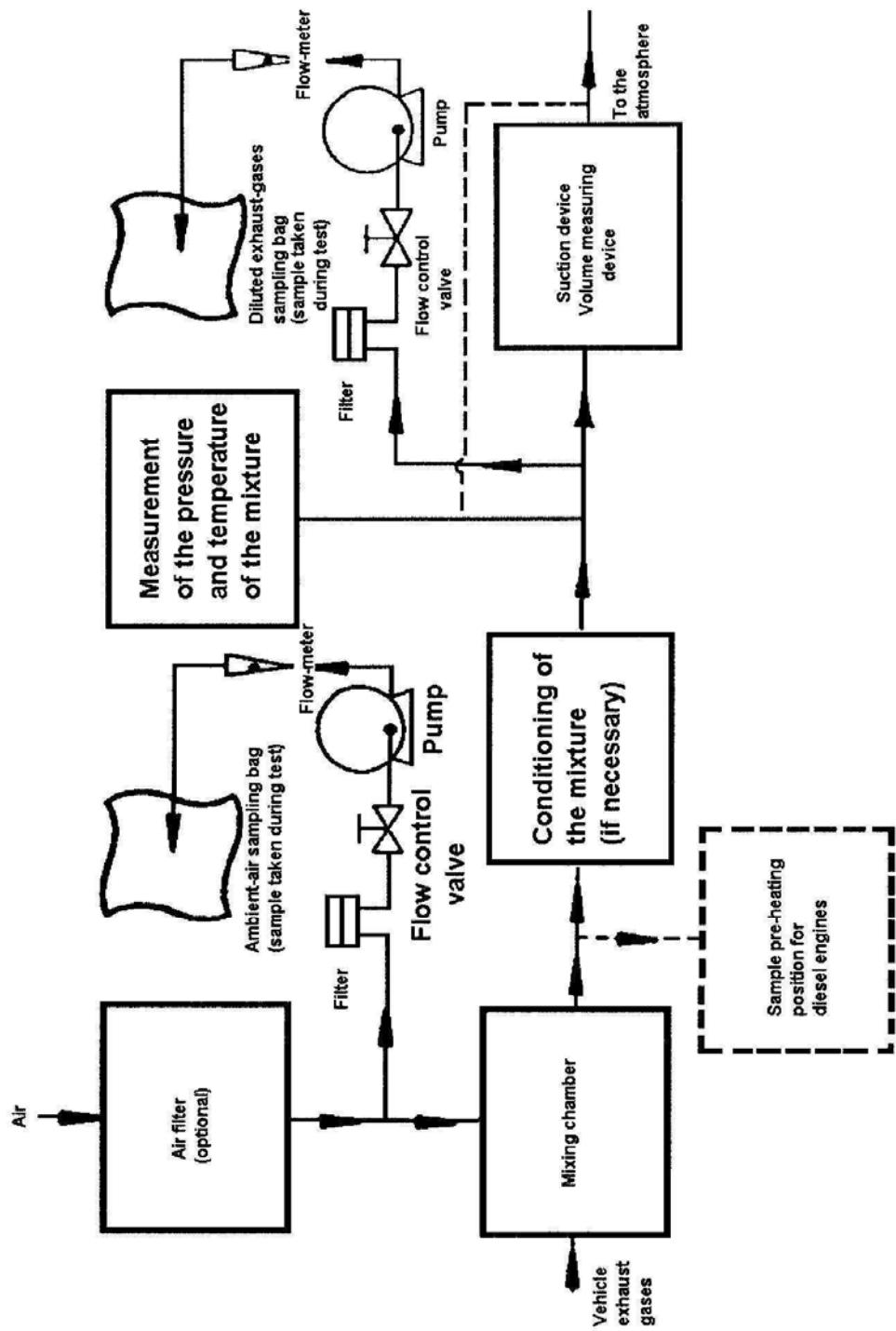


Figure 7 : Diagram of variable-dilution system for measuring exhaust-gas emissions

- 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 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 be 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 $\pm 2\%$ 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 CO₂ 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 $\pm 2\%$ 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 $\pm 6\text{ K}$ 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 $\pm 1\text{ K}$ 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 $\pm 0.4\text{ kPa}$ 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 $\pm 2\%$ from the average.

2.3.4.1.3 The sampling rate must not fall below 5 litres per minute and must not exceed 0.2% of the flow-rate of the dilute exhaust gases.

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

2.3.4.2 Dilution air

2.3.4.2.1 A sample of the dilution air is taken at a constant flow-rate near the ambient air inlet (after the filter if one is fitted).

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

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

2.3.4.3 Sampling operations

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

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

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

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

2.3.4.3.5 Quick fastening gas-tight connections may be used between the three-way valves and the sampling bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyzer (three-way stop valves, for example).

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

2.3.4.4 Storage of the sample

The gas samples are collected in sampling bags of adequate capacity so as not to reduce the sampling rate. The bags must be made of such a material as will not change the concentration of synthetic pollutant gases by more than $\pm 2\%$ after 20 minutes.

2.4 Additional sampling unit for the testing of vehicles equipped with a compression ignition engine

2.4.1 By way of a departure from the taking of gas samples from vehicles equipped with spark-ignition engines, the hydrocarbon and particulate sampling points are located in a dilution tunnel.

2.4.2 In order to reduce heat losses in the exhaust gases between the exhaust tail pipe and the dilution tunnel inlet, the pipe may not be more than 3.6 m long, or 6.1 m long if heat insulated. Its internal diameter may not exceed 105 mm.

2.4.3 Predominantly turbulent flow conditions (Reynolds number ≥ 4000) must apply in the dilution tunnel, which consist of a straight tube of electrically-conductive material, in order to guarantee that the diluted exhaust gas is homogeneous at the sampling points and that the samples consist of

representative gases and particulate. The dilution tunnel must be at least 200 mm in diameter and the system must be earthed.

- 2.4.4 The particulate sampling system consist of a sampling probe in the dilution tunnel and two series-mounted filters. Quick-acting are located both up and downstream of the two filters in the direction of flow.

The configuration of the sample probe must be as indicated in Figure 8.

- 2.4.5 The particulate sampling probe must be arranged as follows :

It must be installed in the vicinity of the tunnel centerline, roughly 10 tunnel diameters downstream of the gas inlet, and have an internal diameter of at least 12 mm.

The distance form the sampling tip to the filter mount must be at least five probe diameters, but must not exceed 1020 mm.

- 2.4.6 The sample gas flow-measuring unit consists of pumps, gas flow regulators and flow measuring units.

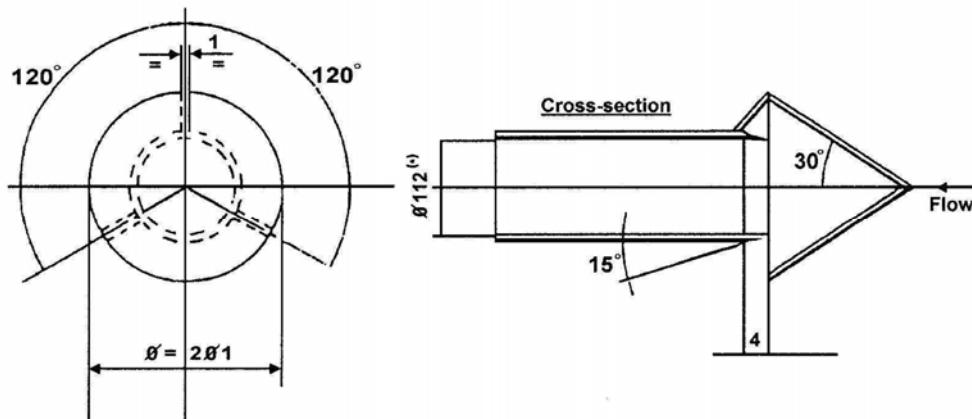


Figure 8 : Particulate Sampling Probe Configuration

(*) Minimum internal diameter

Wall thickness : ~1 mm; Material : Stainless Steel

- 2.4.7 The hydrocarbon sampling system consists of a heated sampling probe, line, filter and pump. The sampling probe must be installed in such a way, at the same distance from the exhaust gas inlet as the particulate sampling probe, that neither interferes with samples taken by the other. It must have a minimum internal diameter of 4 mm.

- 2.4.8 All heated parts must be maintained at a temperature of 463 K (190 °C) ± 10 K by heating system.

2.4.9 If it is not possible to compensate for variations in the flow rate there must be a heat exchanger and a temperature control device as specified in 2.3.3.1 above so as to ensure that the flow rate in the system is constant and the sampling rate is accordingly proportional.

3.0 Description of Devices :

3.1 Variable Dilution Device with Positive Displacement Pump (PDP-CVS) (Fig. 9).

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

3.1.2 Fig. 9 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawings is not essential. Additional components such as instruments, valves, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

3.1.3 The collecting equipment shall consist of :

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

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

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

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

3.1.3.5 The positive displacement pump (PDP), used to transport a constant volume flow of the air / exhaust gas mixture. The flow capacity of the pump shall be large enough to eliminate water condensation in the system under all operating conditions which may occur during a test, this can be generally ensured by using a positive displacement pump with an adequate flow capacity.

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

- 3.1.3.5.2 Sufficient to ensure that the CO₂ 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 (T₁) (accuracy and precision \pm 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 (G₁) (accuracy and precision \pm 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 (G₂) (accuracy and precision \pm 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 (S₁ and S₂) for taking constant samples of the dilution air and of the diluted exhaust gas/air mixture.
- 3.1.3.10A filter (F), to extract solid particles from the flow of gas collected for analysis.
- 3.1.3.11 Pumps (P), to collect a constant flow of the dilution air as well as of the diluted exhaust-gas/air mixture during the test.
- 3.1.3.12 Flow controllers (N), to ensure a constant uniform flow of the gas samples taken during the course of the test from sampling probes S₁ and S₂, and flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis (about 10 l/min.)
- 3.1.3.13 Flow meters (FL), for adjusting and monitoring the constant flow of gas samples during the test.
- 3.1.3.14 Quick-acting valves (V), to divert a constant flow of gas samples into the sampling bags or to the outside vent.
- 3.1.3.15 Gas-tight, quick-lock coupling elements (Q) between the quick-acting valves and the sampling bags; the coupling shall close automatically on the sampling-bag side; as an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).
- 3.1.3.16 Bags (B), for collecting samples of the diluted exhaust gas and of the dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

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

3.1.4 Additional equipment required when testing diesel engined vehicles.

3.1.4.1 The additional components shown within the dotted lines of Fig.9 shall be used when testing Diesel Engined Vehicles.

F_h is a heated filter

S_3 is a sample point close to the mixing chamber

V_h is a heated multiway valve

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

HFID is a heated flame, ionisation analyser.

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

L_h is a heated sample line

All heated components will be maintained at 463 K (190 °C) ± 10 K.

Particulate sampling system

S4 Sampling probe in the dilution tunnel

F_p Filter unit consisting of two series mounted filters : Switching arrangement for further parallel mounted pairs of filters,
Sampling line,
Pumps, flow regulators, flow measuring units.

3.2 Critical-flow venturi dilution device/(CFV-CVS) (Fig.10).

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

3.2.2 Fig.10 is a schematic drawing of such a sampling system. Since various configurations can produce accurate results, exact conformity with the drawing is not essential. Additional components such as instruments, valve, solenoids, and switches may be used to provide additional information and co-ordinate the functions of the component system.

3.2.3 The collecting equipment shall consist of :

- 3.2.3.1 A filter (D), for the dilution air, which can be preheated if necessary; the filter shall consist of activated charcoal sandwiched between layers of paper, and shall be used to reduce and stabilize the hydrocarbon background emission of the dilution air.
- 3.2.3.2 A mixing chamber (M), in which exhaust gas and air are mixed homogeneously.
- 3.2.3.3 A cyclone separator (CS), to extract particles.
- 3.2.3.4 Two sampling probes (S_1 and S_2), for taking samples of the dilution air as well as of the diluted exhaust gas.
- 3.2.3.5 A sampling critical flow venturi (SV), to take proportional samples of the diluted exhaust gas at sampling probe, S_2 .
- 3.2.3.6 A filter (F), to extract solid particles from the gas flows diverted for analysis.
- 3.2.3.7 Pumps (P), to collect part of the flow of air and diluted exhaust gas in bags during the test.
- 3.2.3.8 A flow controller (N), to ensure a constant flow of the gas samples taken in the course of the test from sampling probe S_1 . The flow of the gas samples shall be such, that at the end of the test, the quantity of the samples is sufficient for analysis (about 10 l/min)
- 3.2.3.9 Flow meters (FL), for adjusting and monitoring the flow of gas samples during tests.
- 3.2.3.10 A scrubber (PS), in the sampling line.
- 3.2.3.11 Quick-acting solenoid valves (V), to divert a constant flow of gas samples into the sampling bags or to the vent.
- 3.2.3.12 Gas-tight, quick-lock coupling elements (Q), between the quick acting valves and the sampling bags; the couplings shall close automatically on the sampling bag side. As an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcock, for instance).
- 3.2.3.13 Bags (B), for collecting samples of the diluted exhaust gas and the dilution air during the test; they shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples (for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).
- 3.2.3.14 A pressure gauge (G), which shall be precise and accurate to within ± 0.4 kPa.

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

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

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

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

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

3.2.3.18.2 Sufficient to ensure that the CO₂ 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.

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.

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 S₃.

Particulate sampling system :

S₄ Sampling probe in dilution tunnel
F_P Filter series consisting of two series mounted filters : Switching arrangement for further parallel mounted pairs of filters,
Sampling line,
Pumps, flow regulators, flow measuring units.

3.3 Variable dilution device with constant flow control by orifice (CFO-CVS) (Fig. 11).

3.3.1 The collection equipment shall consist of :

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

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

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

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

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

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

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

3.3.1.7 A volume-meter with an orifice.

3.3.1.8 A temperature sensor (T_1) (accuracy and precision ± 1 K) fitted at a point immediately before the volume measurement device. It shall be designed to monitor continuously the temperature of the diluted exhaust gas mixture during the test.

3.3.1.9 A pressure gauge (G_1) (capacity and precision ± 0.4 kPa) fitted immediately before the volume meter and used to register the pressure gradient between the gas mixture and the ambient air.

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

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

- 3.3.1.12 Flow meters (FL) for adjusting and monitoring the constant flow of gas samples during the test.
- 3.3.1.13 Three-way valves (V) to divert a constant flow of gas samples into the sampling bags or to the outside vent.
- 3.3.1.14 Gas-tight, quick lock sampling elements (Q) between the three-way valves and the sampling bags. The coupling shall close automatically on the sampling bag side. Other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance).
- 3.3.1.15 Bags (B) for collecting samples of diluted exhaust gas and of dilution air during the test. They shall be of sufficient capacity not to impede the sample flow. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples for instance, laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

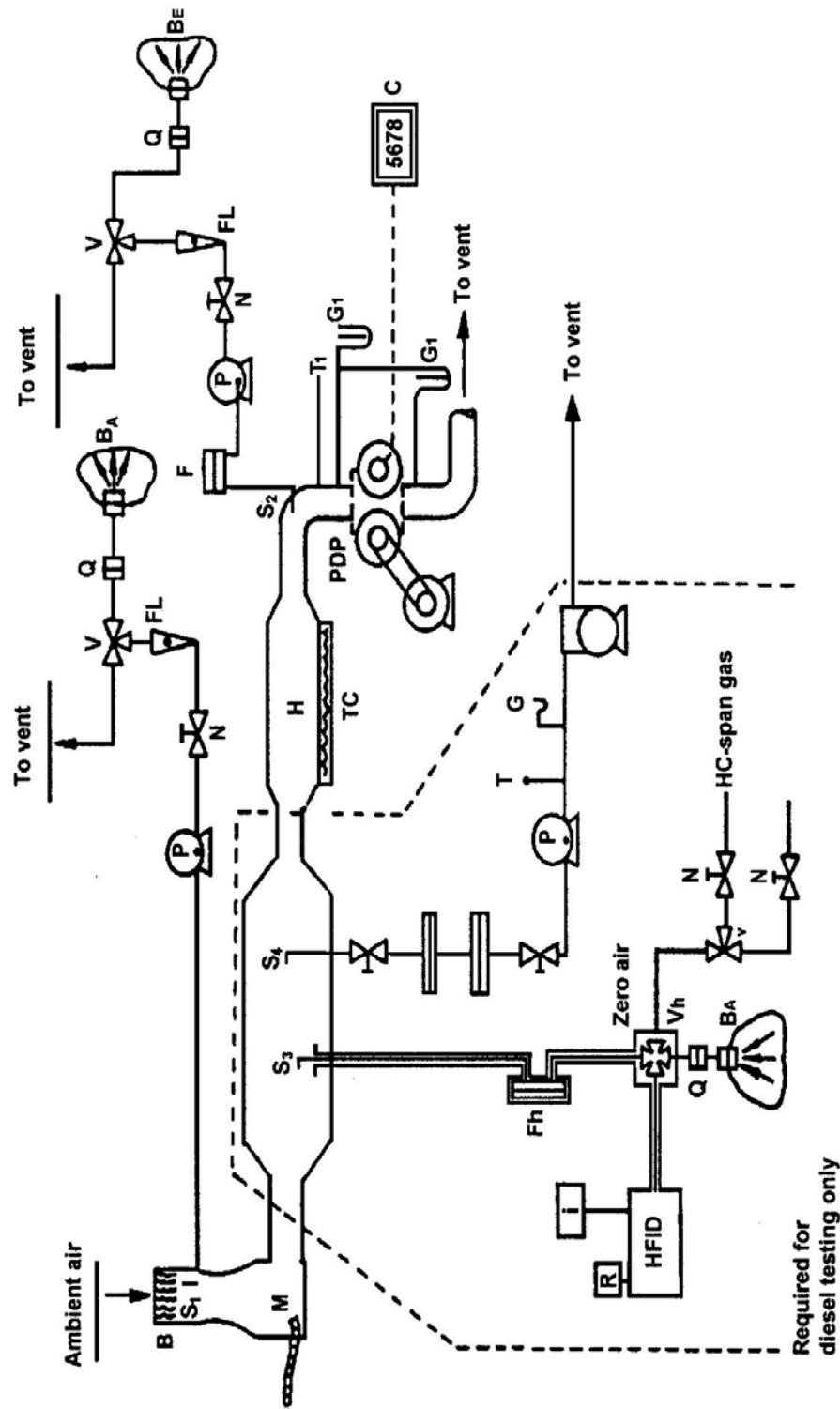


Figure 9 : Schematic Constant Volume Sampler with Positive Displacement Pump (PDP-CVS) (Pls. Ref. Para. 3.1 of this Chapter)

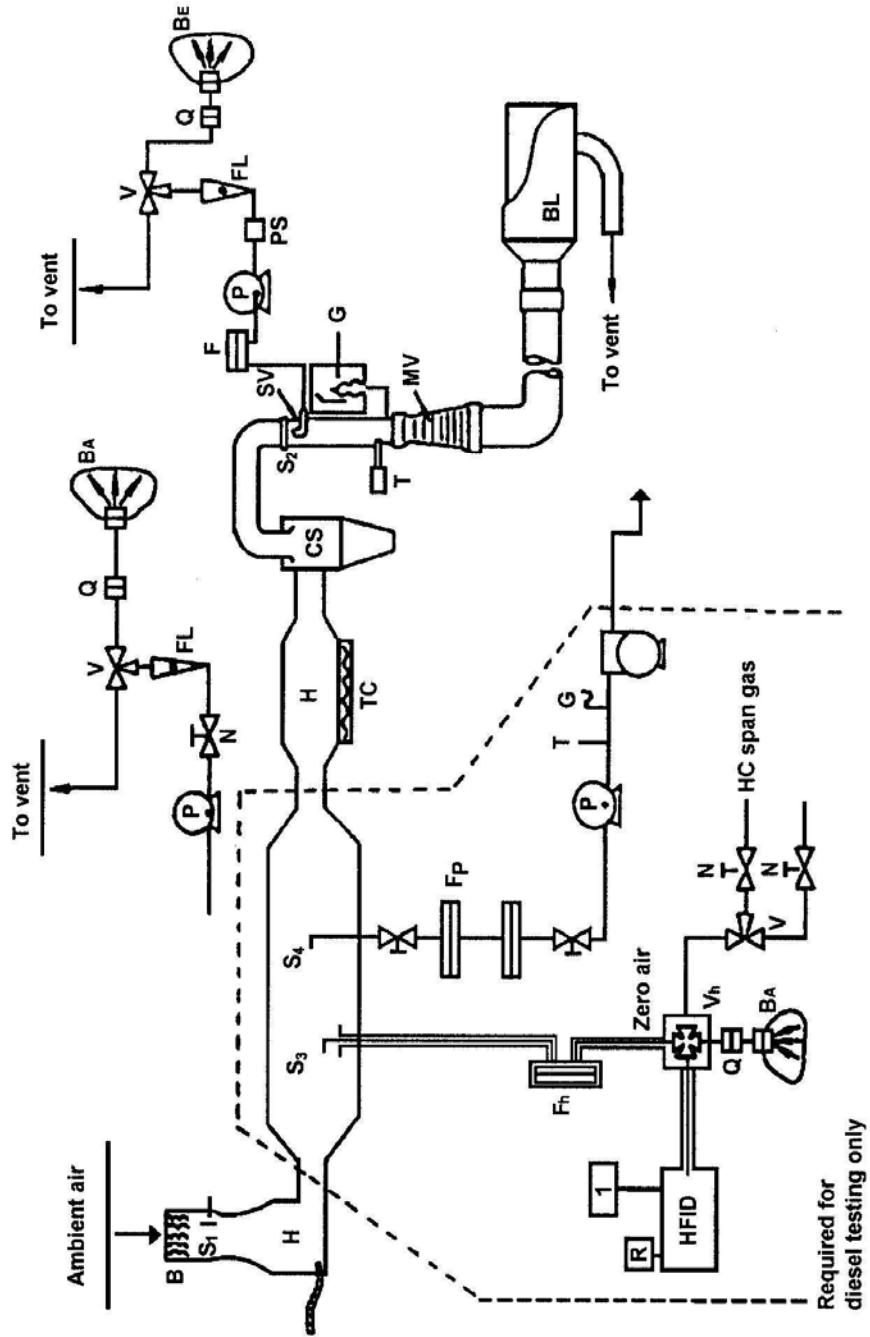


Figure 10 : Schematic Constant Volume Sampler with Critical Flow Venturi (CFV-CVS) (Pls.Ref.Para. 3.2 of this Chapter)

Required for
diesel testing only

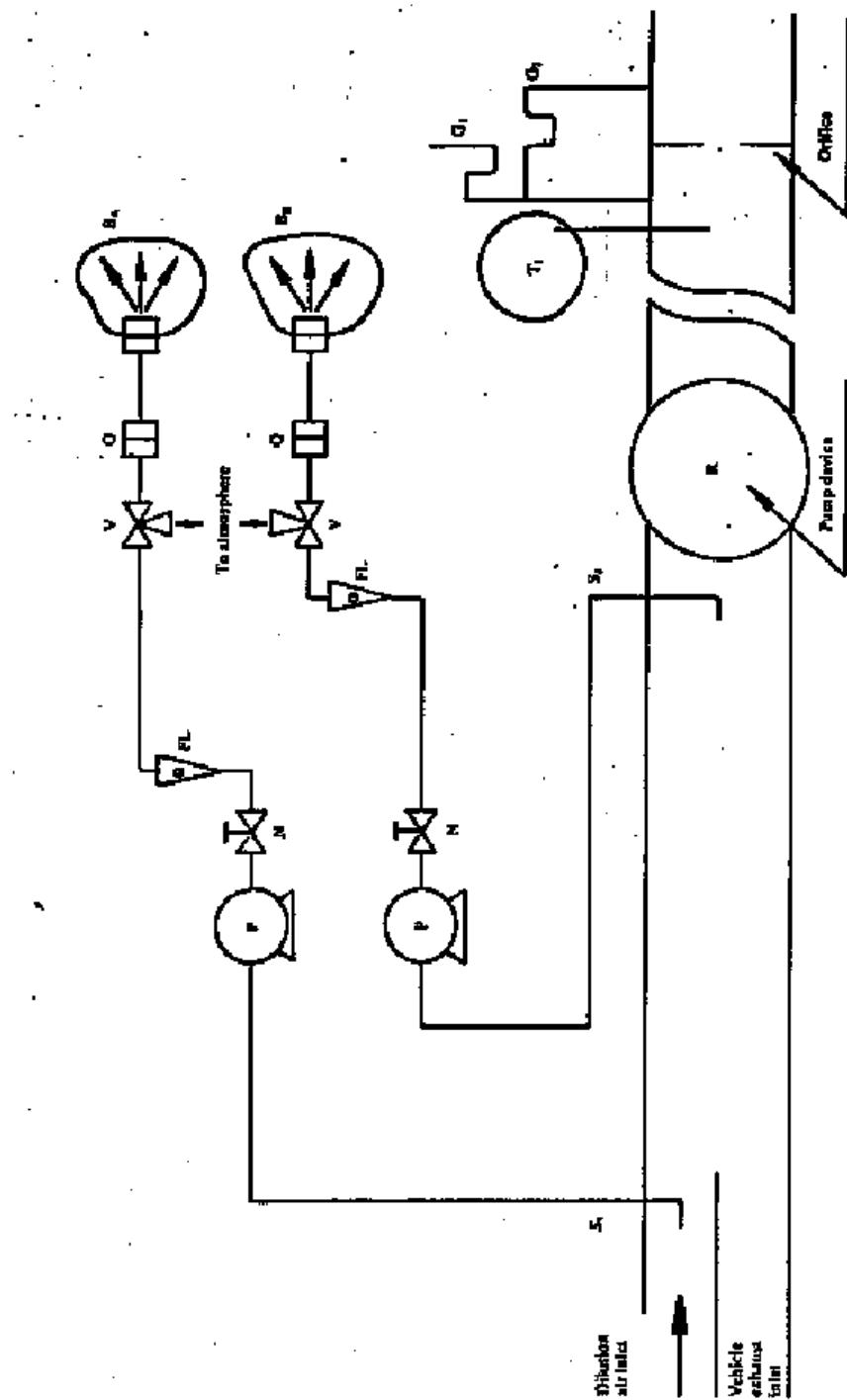


Figure 11 : Schematic of Variable Dilution Device with Constant Flow Control by Orifice (CFO-CVS)
 (Pls. Ref. Para 3.3 of this Chapter)

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

1. Scope :
- 1.1 This Chapter describes the methods used for calibrating, and verifying the Chassis Dynamometers, CVS System and Analysis System.
2. Methods of Calibration of Chassis Dynamometer :(The method to be used to determine the power absorbed by a dynamometric brake)
- 2.1 The power absorbed by chassis dynamometer comprises the power absorbed by frictional effects and the power absorbed by the power absorption device. The chassis dynamometer is brought into operation beyond the range of test speeds. The device used for starting up the chassis dynamometer is then disconnected; the rotational speed of the driven rollers decreases. The kinetic energy of rollers is dissipated by the power absorption unit and by the frictional effects. This method disregards variations in the roller's internal frictional effects caused by rollers with or without the vehicle. The frictional effects of the rear roller shall be disregarded when this is free.
- 2.2 Calibrating the power indicator to 80 km/h as a function the power absorbed
The following procedure shall be used.(Fig.12)
 - 2.2.1 Measure the rotational speed of the roller if this has not already been done. A fifth wheel, a revolution counter or some other method may be used.
 - 2.2.2 Place the vehicle on the dynamometer or connect the device for starting up the dynamometer.
 - 2.2.3 Use the fly-wheel or any other system of inertia simulation for the particular inertia class to be used.
 - 2.2.4 Bring the dynamometer to a speed of 80 km/h.
 - 2.2.5 Note the power indicated (P_i).
 - 2.2.6 Bring the dynamometer to a speed of 90 km/h.
 - 2.2.7 Disconnect the device used to start up the dynamometer.
 - 2.2.8 Note the time taken by the dynamometer to pass from a speed of 85 km/h to a speed of 75 km/h.
 - 2.2.9 Set the power absorption device at a different level.
 - 2.2.10 The requirements of paragraphs 2.2.4 to 2.2.9 above shall be repeated sufficient number of times to cover the range of road power used.

2.2.11 Calculate the power absorbed, using the formula:

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

Where

P_a = power absorbed in kW

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

V_1 = initial speed in m/s (85 km/h = 23.61 m/s)

V_2 = final speed in m/s (75 km/h = 20.83 m/s)

t = time taken by the roller to pass from 85 km/h to 75 km/h in s.

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

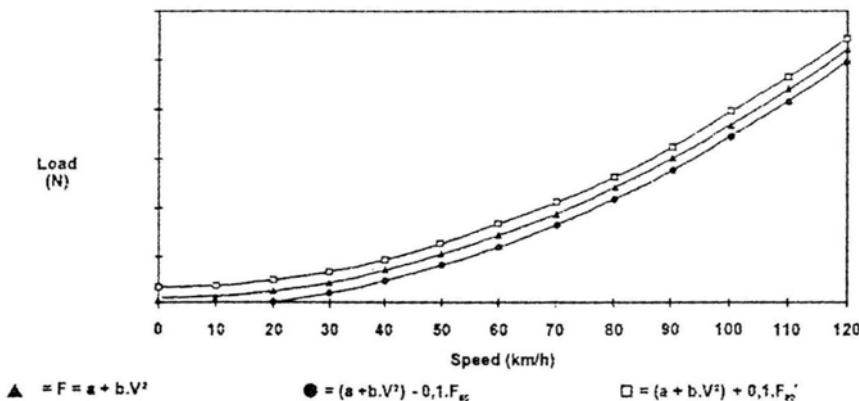


Figure 12 : Diagram illustrating the load of the chassis dynamometer

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

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

2.4 Verification of the power-absorption curve of the roller bench from a reference setting to a speed of 80 km/h :

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

2.4.2 Adjust the dynamometer to the absorbed power P_a , at 80 km/h.

- 2.4.3 Note the power absorbed at 100,80,60,40 and 20 km/h.
 - 2.4.4 Draw the curve P_a 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 P_a at 80 km/h and for other values of inertia.
- 2.5 The same procedure will be used for force or torque calibration.

3. Calibration of the CVS System :

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

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

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

3.2 Calibration of the Positive Displacement Pump (PDP) :

- 3.2.1 The following calibration procedure outlines the equipment the test configuration, and the various parameters which shall be measured to establish the flow rate of the CVS-pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow meter which is connected in series with pump. The calculated flow rate (given in m^3 /min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.
- 3.2.2 This calibration procedure is based on the measurement of the absolute values of the pump and flow meter parameters that relate the flow rate at each point. Three conditions must be maintained to ensure the accuracy and integrity of the calibration curve as given below :

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

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

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

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

3.2.3.1 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)) $\pm 0.03 \text{ kPa}$

Ambient temperature (T) $\pm 0.2 \text{ K}$

Air temperature at LFE (ETI) $\pm 0.15 \text{ K}$

Pressure depression upstream of LFE(EPI) $\pm 0.01 \text{ kPa}$

Pressure drop across the LFE matrix (EDP) $\pm 0.0015 \text{ kPa}$

Air temperature at CVS pump inlet (PTI) $\pm 0.2 \text{ K}$

Air temperature at CVS pump outlet (PTO) $\pm 0.2 \text{ K}$

Pressure depression at CVS pump inlet (PPI) $\pm 0.22 \text{ kPa}$

Pressure head at CVS-pump outlet (PPO) $\pm 0.22 \text{ kPa}$

Pump revolutions during test period (n) $\pm 1 \text{ rev.}$

Elapsed time for period (min 250 sec) (t) $\pm 0.1 \text{ sec}$

3.2.3.2 After the system has been connected, as shown in Fig.13, the variable restrictor is set in the wide-open position and the CVS pump run for 20 minutes before starting the calibration.

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

3.2.4 Data analysis :

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

3.2.4.2 The air flow rate is then converted to pump flow, V_o , 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 T_p and P_p 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,

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.

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

3.2.4.4 If the calibration has been performed carefully, the calculated values from the equation should be within $\pm 0.5\%$ of the measured value of V_o . Values of M

should vary from one pump to another. Calibration shall be performed at pump start-up and after major maintenance.

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

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

$$Q_s = K_v * \frac{P}{\sqrt{T}}$$

Where,

Q_s = Flow rate in m^3 / min at 101.33 kPa and 293 K

K_v = Calibration coefficient

P = Absolute pressure (kPa)

T = Absolute temperature (K)

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

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

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

Barometric pressure (corrected) (P_B) $\pm 0.03 \text{ kPa}$

LFE air temperature flowmeter (ETI) $\pm 0.15 \text{ K}$

Pressure depression up-stream of LFE (EPI) $\pm 0.01 \text{ kPa}$

Pressure drop across (EDP) LFE matrix $\pm 0.0015 \text{ kPa}$

Air Flow (Q_s) $\pm 0.5 \%$

CFV inlet depression (PPI) $\pm 0.02 \text{ kPa}$

Temperature at venturi inlet (T_v) $\pm 0.2 \text{ K}$

3.3.4 The equipment shall be set up as shown in fig.14 and checked for leaks. Any leaks between the flow measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

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

- 3.3.6 The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.
- 3.3.7 The data recorded during the calibration shall be used in the following calculations. The air flow rate, Q_s , at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

Values of the calibration coefficient K_v 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 \pm 2% of the calibration curve.
- 4.3.6 If it does not, but it remains within \pm 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 \pm 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 \pm 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 analyser 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 $1.00 \leq R_f < 1.05$ 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 NO₂ into NO is tested as follows :

4.6.1.1 Using the test set up shown in Fig.15 and the procedure described below, the efficiency of converters can be tested by means of an ozonator.

4.6.2 Calibrate the CLA analyser in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which should amount to about 80 % of the operating range and the NO₂ 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, NO₂, O₂ and N₂) 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.

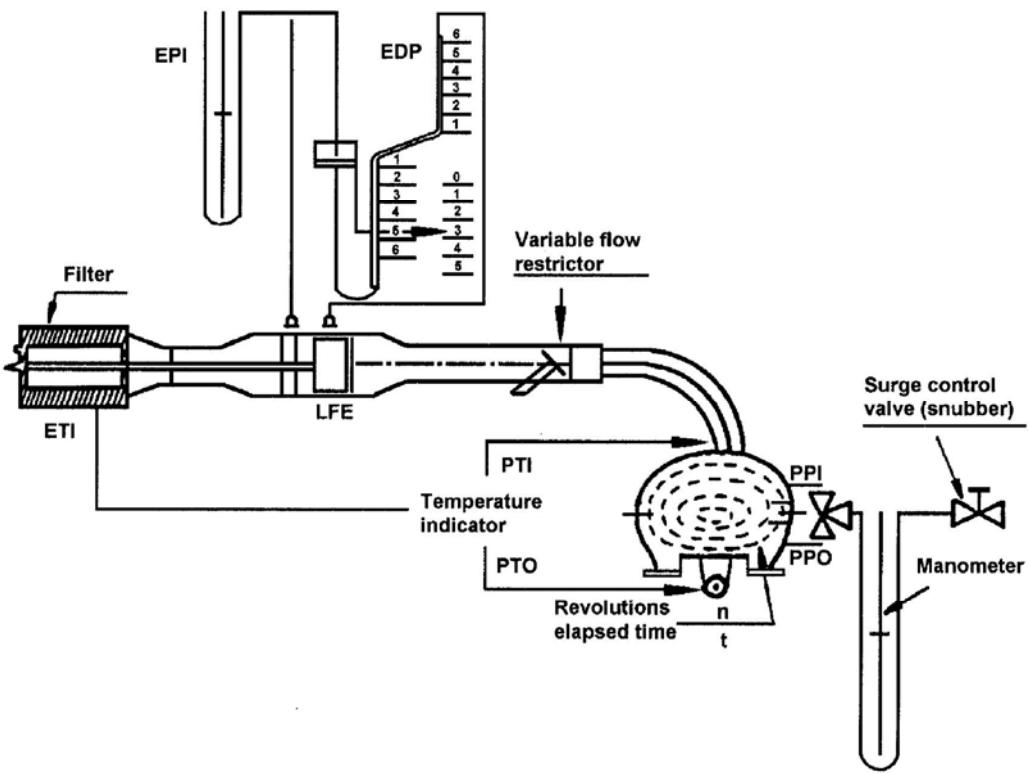


Figure 13 : Schematic of PDP-CVS Calibration Set-up
 (Pls. Ref. Para. 3.2.3.1 of Chapter 7, Part IX)

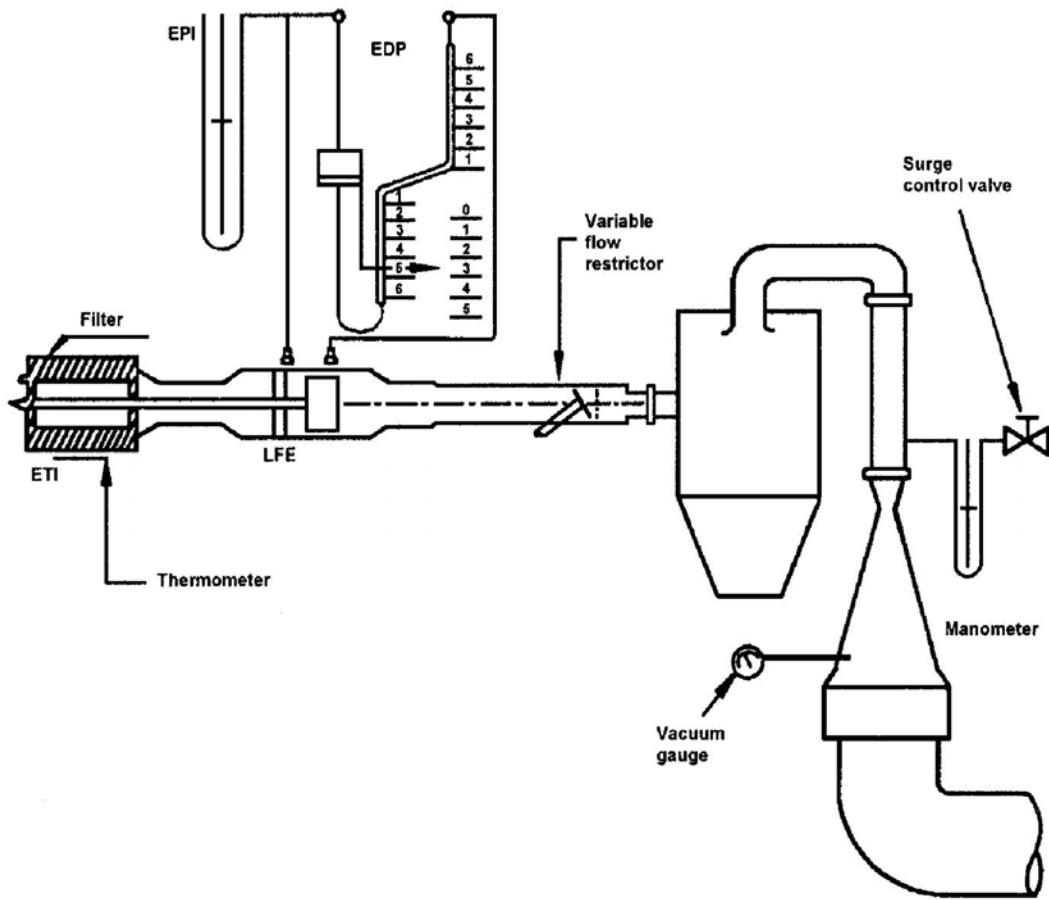


Figure 14 : Schematic of CFV-CVS Calibration Set-up
 (Pls. Ref. Para. 3.3.4.of Chapter 7, Part IX)

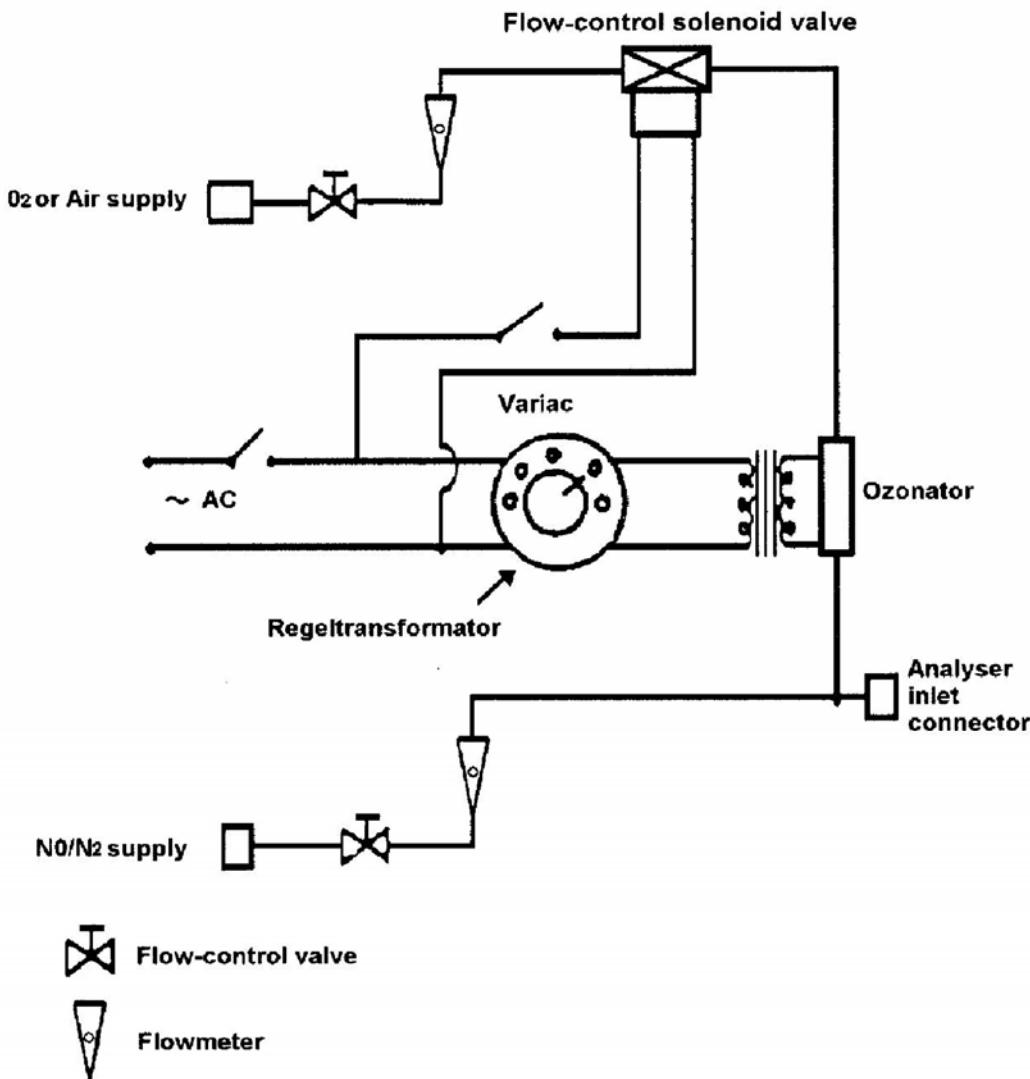


Figure 15 : Schematic of Set-up for checking the efficiency of NO_x converter
 (Pls. Ref. Para.4.6.1.1 of Chapter 7, Part IX)

CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

1. Scope : This chapter describes the calculation procedures for the mass emission of pollutants and correction for humidity for oxides of nitrogen.
2. The mass emission of pollutants are calculated by means of the following equation :

$$M_i = \frac{V_{mix} * Q_i * k_H * C_i * 10^{-6}}{d} \quad (1)$$

M_i = Mass emission of the pollutant i in g/km

V_{mix} = Volume of the diluted exhaust gas expressed in m³/test and corrected to standard conditions 293 K and 101.33 kPa

Q_i = Density of the pollutant i in kg/m³ 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 m³/test (prior to correction)

V_o = Volume of gas delivered by the positive displacement pump on testing conditions, in m³/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 :

$$V_{mix} = V * K_1 * \frac{P_B - P_1}{T_p} \quad (2)$$

in which :

$$K_1 = \frac{293K}{101.33kPa} = 2.8915(K * kPa^{-1}) \quad (3)$$

where:

P_B = Barometric pressure in the test room in kPa

P_1 = Vacuum at the inlet to the positive displacement pump in kPa relative to the ambient barometric pressure.

T_p = Average temperature of the diluted exhaust gas entering the positive displacement pump during the test (K).

4. Calculation of the Corrected Concentration of Pollutants in the Sampling Bag

$$C_i = C_e - C_d \left(1 - \frac{1}{DF}\right) \quad (4)$$

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 :

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

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

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

where:

C_{CO_2} = Concentration of CO₂ 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:

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

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:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} . dt}{t_2 - t_1} \quad (7)$$

where:

$\int_{t_1}^{t_2} C_{HC} . dt$ = 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_i is substituted directly for C_{HC} in all relevant equations.

6.2 Determination of particulates

Particulate emission M_p (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

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

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:

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

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

$$cf = 0.825 + 0.0693 * n_{actual}$$

where:

n_{actual} = the actual H/C ratio of the fuel used.

- iii) For vehicles with a positive ignition engine fuelled with NG

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

- 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 (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 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 Vehicle and Fuel :

- 3.1** This test should be carried out immediately after the tenth operating cycle of the Type I test, or at after the Part II of the modified IDC, as applicable, with the engine at idling speed, the cold start device not being used. Immediately before each measurement of the carbon monoxide content, a TYPE I test operating cycle as described in Chapter 3 of this Part shall be carried out.

- 3.1.1 In case the Type II test is carried out without Type I test, the following steps are to be taken for vehicle preparation :It should be checked that the road vehicle/engine in all its parts, components and systems conform to the declared particulars in the application for type approval.
- 3.1.2 It should be checked that the road vehicle exhaust system is leakproof and that the manual choke control has been returned to the rest position.
- 3.1.3 It should be checked that the gas sampling probe can be inserted into the exhaust pipe to a depth of at least 300 mm. If this proves impossible owing to the exhaust pipe configuration, a suitable extension to the exhaust pipe(s), making sure that the connection is leakproof, should be provided.
Alternatively, the sample may be taken from a fixed connection of the sample collecting system for the Type I test.
- 3.1.4 The vehicle shall have attained normal thermal conditions as defined in 2.3 of chapter 1 of this part immediately prior to the measurement, by running the vehicle on chassis dynamometer with specified number of warming up cycles declared by the manufacturer and six driving cycles.
- 3.1.5 The vehicle idling speed should be checked and set as per Para 2.2 Chapter 1 with all the accessories switched off.

3.2 Fuel :

The fuel shall be the reference fuel whose specifications are given in the relevant notification If the engine is lubricated by mixture, the oil added to the reference fuel shall comply with the manufacturer's recommendations.

4.0 Measurement :

- 4.1 Immediately preceding the measurement, the engine is to be accelerated to a moderate speed with no load, maintained for at least 15 seconds, then returned to idle speed.
- 4.2 While the engine idles, the sampling probe should be inserted into the exhaust pipe to a depth not less than 300 mm, if the probe prescribed in para 5.3.2.1 below is used.
- 4.3 After the engine speed stabilises the reading should be taken. In the case of 2 & 3 wheeled vehicles fitted with air cooled engines, this stabilised speed may be outside the range specified by the manufacturer.
- 4.4 The value of CO,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 CO₂ should be measured using an instrument having facility to measure both CO and CO₂ . If the total of the measured values of CO and CO₂ (T CO and T CO₂) concentrations exceed 15% for four stroke engines and 10% for two stroke engines, the measured

value of CO should be taken as carbon mono-oxide emissions from the vehicle. If it does not, the corrected value (T corrected) should be taken, as given below :-

$$\begin{aligned} T \text{ corrected} &= \frac{TCO_x * 15}{(TCO + TCO_2)} && \text{for 4 stroke engines.} \\ &= \frac{TCO_x * 10}{(TCO + TCO_2)} && \text{for 2 stroke engines.} \end{aligned}$$

- 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 : DETAILS FOR STANDARDS FOR EMISSIONS
OF CRANK-CASE EMISSIONS FROM PETROL ENGINES
EFFECTIVE FROM 1.4.2005**

CHAPTER 1 : TYPE III TEST
(VERIFYING EMISSIONS OF CRANKCASE GASES)

CHAPTER 1 : DETAILS FOR STANDARDS FOR EMISSIONS OF CRANK-CASE EMISSIONS FROM PETROL ENGINES EFFECTIVE FROM 1.4.2005

TYPE III TEST (Verifying Emissions of Crankcase Gases)

1 INTRODUCTION:

This chapter describes the procedure for the Type III test.

This is applicable for the passenger cars manufactured from 1.4.1996.

While preparing this standard considerable assistance has been taken from:

a) 91/441/EEC Air pollution by emission from motor vehicles.

2 GENERAL PROVISIONS:

2.1 Type III Test is carried out on the vehicle fitted with petrol engine subjected to the type I and the type II test.

2.2 The engines tested must include leak-proof engines other than those so designed that even a slight leak may cause unacceptable operating faults (such as flat-twin engines).

3 TEST CONDITIONS:

3.1 Idling must be regulated in conformity with the manufacturer's recommendations.

3.2 The measurement are performed in the following three sets of conditions of engine operation:

Condition No.	Vehicle Speed (km/h)
1	Idling
2	50 ± 2 (in 3rd gear or "drive")
3	50 ± 2 (in 3rd gear or "drive")
Condition No.	Power absorbed by brake
1	Nil
2	That corresponding to the settings for type I tests
3	That for conditions No.2 multiplied by a factor of 1.7

4 TEST METHOD:

4.1 For the operation conditions as listed in 3.2 reliable function of the crankcase ventilation system must be checked.

5 METHOD OF VERIFICATION OF THE CRANKCASE VENTILATION SYSTEM: (Refer also to Figure 1)

5.1 The engine's apertures must be left as found.

5.2 The pressure in the crankcase is measured at an appropriate location. It is measured at the dipstick hole with an inclined tube manometer.

5.3 The vehicle is deemed satisfactory if, in every condition of measurement defined in 3.2, the pressure measured in the crankcase does not exceed the atmospheric pressure prevailing at the time of measurement.

5.4 For the test by the method described above, the pressure in the intake manifold is measured to within $\pm 1\text{kPa}$.

5.5 The vehicle speed as indicated at the dynamometer is measured to within $\pm 2 \text{ km/h}$.

5.4 The pressure measured in the crankcase is measured to within $\pm 0.01 \text{ kPa}$.

5.7 If in one of the conditions of measurement defined in 3.2 the pressure measured in the crankcase exceeds the atmospheric pressure, an additional test as defined in para 6 is performed if so requested by the manufacturer.

6 ADDITIONAL TEST METHOD:

6.1 The engine's apertures must be left as found.

6.2 A flexible bag impervious to crankcase gases and having a capacity of approximately five litres is connected to the dip stick hole. The bag must be empty before each measurement.

6.3 The bag must be closed before each measurement. It must be opened to the crankcase for five minutes for each condition of measurement prescribed in 3.2

6.4 The vehicle is deemed satisfactory if in every condition of measurement defined in 3.2 no visible inflation of the bag occurs.

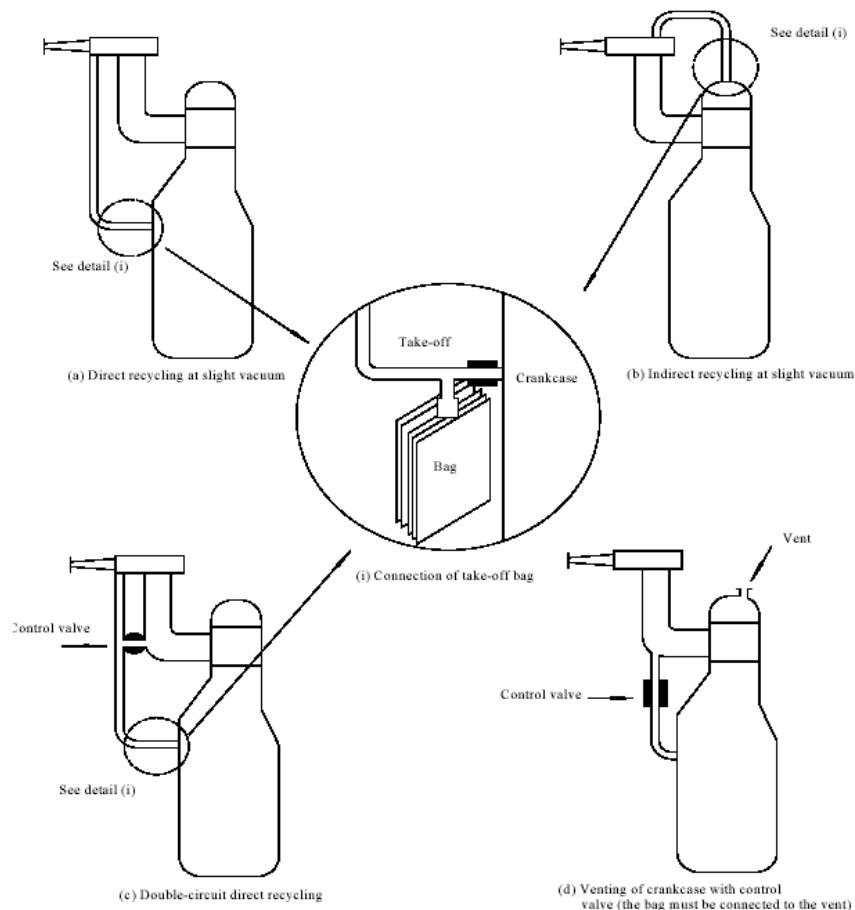
6.5 Remark:

6.5.1 If the structural layout of the engine is such that the test cannot be performed by the methods described in para 6.1 - the measurements must be effected by that method modified as follows:

- 6.5.2 Before the test, all apertures other than that required for the recovery of the gases are closed.

The bag is placed on a suitable take-off which does not introduce any additional loss of pressure and is installed on the recycling circuit of the device directly at the engine-connection aperture.

TYPE III TEST



TESTING ARRANGEMENT FOR VERIFICATION OF CRANKCASE GASES

CHAPTER 11 : DETAILS FOR STANDARDS FOR EVAPORATIVE EMISSION FROM VEHICLES WITH SPARK-IGNITION ENGINES EFFECTIVE FROM 1.4.2005

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 Annex 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 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 Appendix 1. 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 $\pm 1\text{K}$ 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 Appendix 1 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 $\pm 5\text{ hPa}$.

The enclosure must be capable of latching to a fixed volume. A variable volume enclosure must be capable of accommodating a $\pm 7\%$ change from its ‘nominal volume’ (see Appendix 1 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 $80\% \pm 20\%$ 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 $80\% \pm 20\%$ 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)

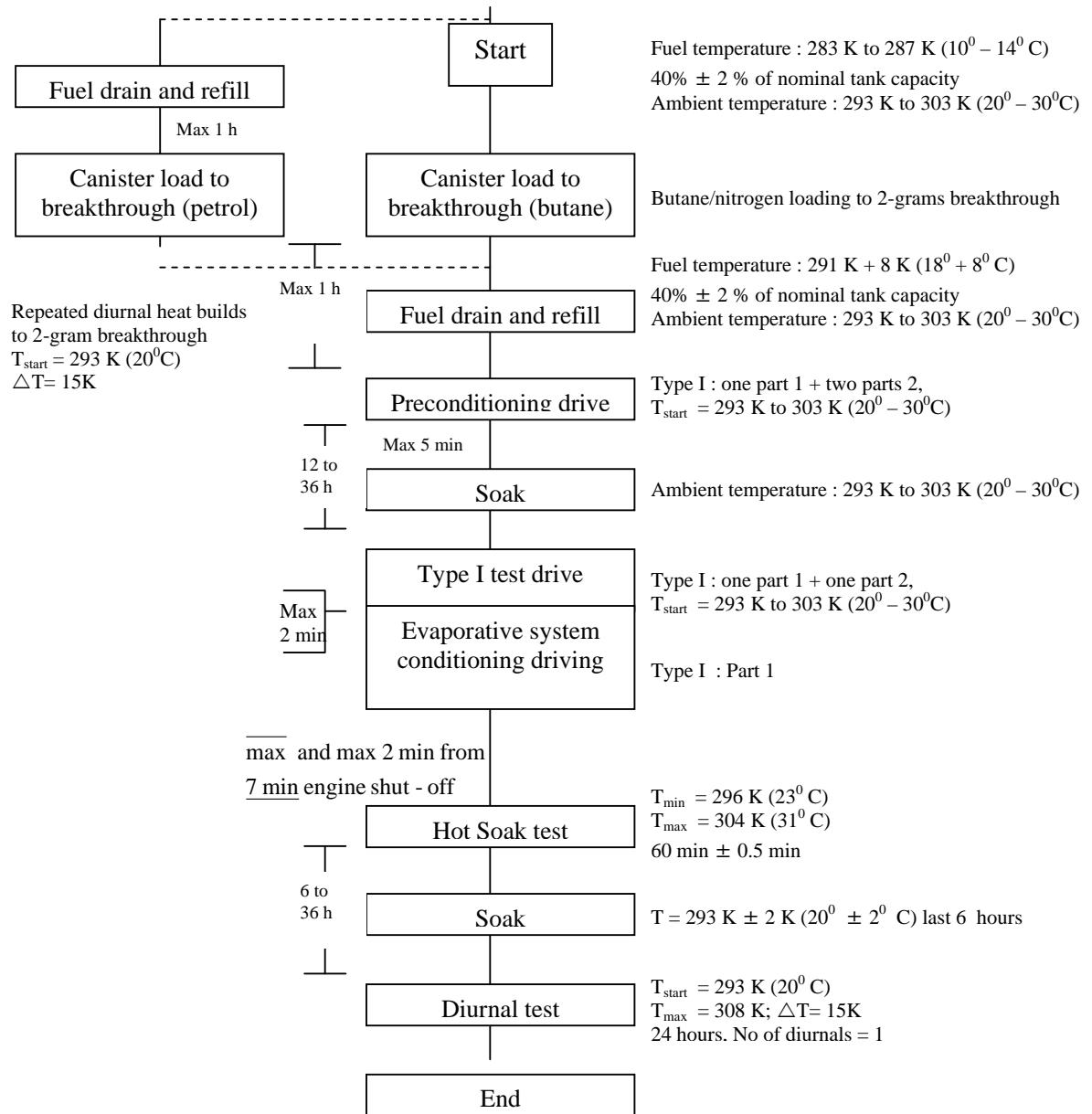


Figure VI.1
Evaporative Emission Determination

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 vapour 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 14^0K from 289^0K (16^0C) 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 $\pm 1.5^0\text{K}$ 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 \pm 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 C1 equivalent \pm 1 ppm CO, \pm 400 ppm CO₂, \pm 0.1 ppm NO); oxygen content between 18% and 21% by volume.
- Hydrocarbon analyzer fuel gas (40% \pm hydrocarbon, less than 400 ppm CO₂)
- Propane (C₃H₈), 99.5% minimum purity,
- Butane (C₄H₁₀), 98% minimum purity,
- Nitrogen (N₂), 98% minimum purity.

4.8.2 Calibration and span gases must be available containing mixtures of propane (C₃H₈) and purified synthetic air. The true concentrations of a calibration gas must be within \pm 2% of stated figures. The accuracy of the diluted gases obtained when using a gas divider must be to within \pm 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 \pm 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 or 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 Annex, 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 litres 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 14⁰ 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 (20⁰ C) ± 1 K.

5.1.5.5 When the fuel temperature reaches at least 292 K (19⁰ 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 (20⁰ C) a linear heat build of 15 K (15⁰ 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 ± 1.5⁰ K. The elapsed time of the heat build and temperature rise is recorded.

$$T_r = T_0 + 0.2333 \times t$$

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 308⁰ K (35⁰ 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 308⁰ K (35⁰ 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 vapour 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 $291^0\text{ K} \pm 8^0\text{ K}$ ($18 \pm 8^0\text{ C}$) to $40 \pm 2\%$ 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 Annex III. 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 $\pm 3^{\circ}$ 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 Annex III (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 be 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 $C_{HC,i}$, P_i and T_i for the hot soak test. These figures are used in the evaporative emission calculation, Section 6. The ambient SHED temperature T must not be less than $296^0 K$ and not more than $304^0 K$ 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 Section 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 $293^0 K \pm 2^0 K$ ($20^0 C \pm 2^0 C$)

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 Appendix 2 with a maximum deviation of $\pm 2^0 K$ at any time. The average temperature deviation from the profile, calculated using the absolute value of each measured deviation, must not exceed $1^0 K$. 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 $C_{HC,i}$, P_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 \pm 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 Section 6. This completes the evaporative emission test procedure.

6 CALCULATION

- 6.1 The evaporative emission tests described in Section 5 allow the hydrocarbon emissions from the 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 metres corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of 1,42 m³ 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 :

$$M_{\text{total}} = M_{\text{DI}} + M_{\text{HS}}$$

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 H₂O 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 H₂O 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 H₂O 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 H₂O 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 litres in one minutes must be attached to the purge inlet and a pressure vessel of sufficient size to have negligible effect on the purge system must be connected via a switching valve to the purge inlet, or alternatively.
 - 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 litres 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, litres 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 Annex. I.
- 7.5.3 If in pursuance of Section 7.1.5 of Annex. I the vehicle's test result falls outside the agreed limits of Section 5.3.4.2. of Annex I, the manufacturer may request that the approval procedure referred to in 7.1.4 of Annex I 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 Annex I 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 FO EQUIPEMTN FOR EVAPORATIVE EMISSION
TESTING**

1. CALIBRATION FREQUENCY AND METHODS

- 1.1 All equipment must be calibrated before its initial use and then calibrated as often as necessary and in any case in the month before type-approval testing. The calibration methods to be used are described in this Appendix.
- 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 303^0 K (30^0 C) [$(302^0$ K (29^0 C)]. This nominal volume must be repeatable within $\pm 0.5\%$ 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 $\pm 2\%$ 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 $308^0\text{ K} \pm 2^0\text{ K}$ ($35 \pm 2^0\text{ C}$) [$309^0\text{ K} \pm 2^0\text{ K}$ ($36 \pm 2^0\text{ C}$)], 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 $308^0\text{ K} \pm 2^0\text{ K}$ ($35 \pm 2^0\text{ C}$) [$309^0\text{ K} \pm 2^0\text{ K}$ ($36 \pm 2^0\text{ C}$) 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 $C_{HC,i}$, P_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° ± 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 Annex VI).
- 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 $C_{HC,f}$, T_f and P_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) C₁ equivalent)
- V = net enclosure volume in cubic metres corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of 1,42 m³ is subtracted.
- T = ambient chamber temperature, ⁰K,
- P = barometric pressure in kPa,
- H/C = hydrogen to carbon ratio,
- k = 17.6" for "k= 1.2 × (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.

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 Annex III (Calibration and span gases).

Establish a calibration curve as described in Sections 4.1 to 4.5 of this Appendix.

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 C_1 .

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 $\pm 2\%$ 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 (20^0 and 30^0 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 # R_f # 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 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			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)	Time (hours)	
Calibration	Test			
13	0/24	20	0	35,6
14	1	20,2	1	35,3
15	2	20,5	2	34,5
16	3	21,2	3	33,2
17	4	23,1	4	31,4
18	5	25,1	5	29,7
19	6	27,2	6	28,2
20	7	29,8	7	27,2
21	8	31,8	8	26,1
22	9	33,3	9	25,1
23	10	34,4	10	24,3
24/0	11	35	11	23,7
1	12	34,7	12	23,3
2	13	33,8	13	22,9
3	14	32	14	22,6
4	15	30	15	22,2
5	16	28,4	16	22,5
6	17	26,9	17	24,2
7	18	25,2	18	26,8
8	19	24	19	29,6
9	20	23	20	31,9
10	21	22	21	33,9
11	22	20,8	22	35,1
12	23	20,2	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 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.

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. A trip 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)

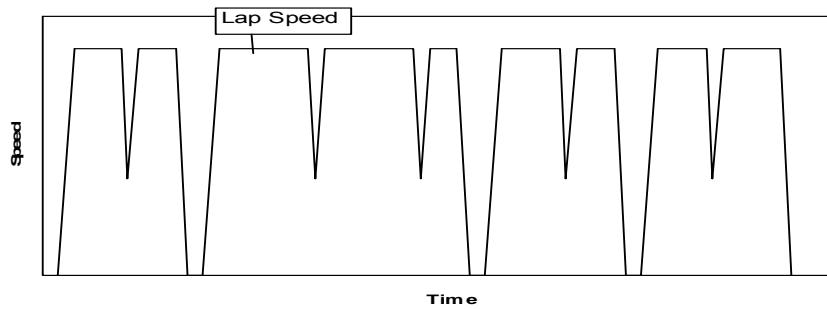


Figure 2 Pictorial representation of Lap 10(A,B & C)

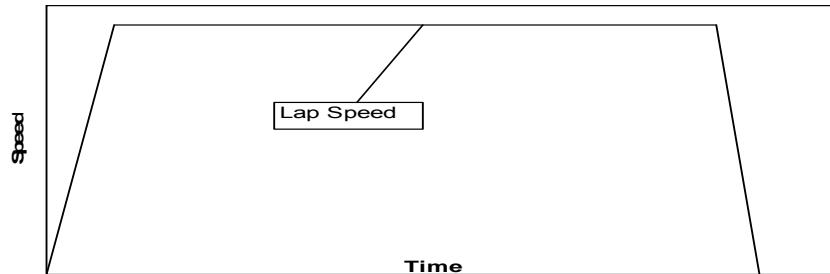


Figure 4 Pictorial representation of Lap 11 (A)

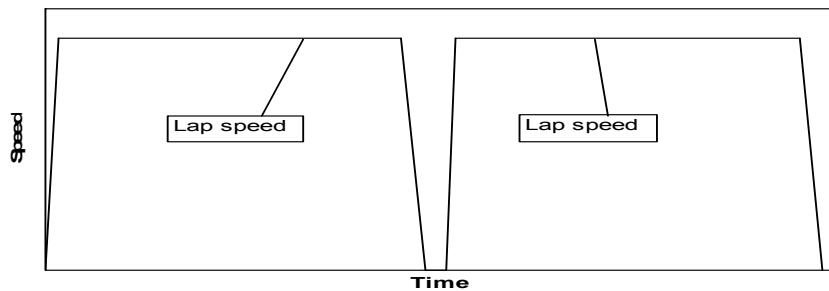
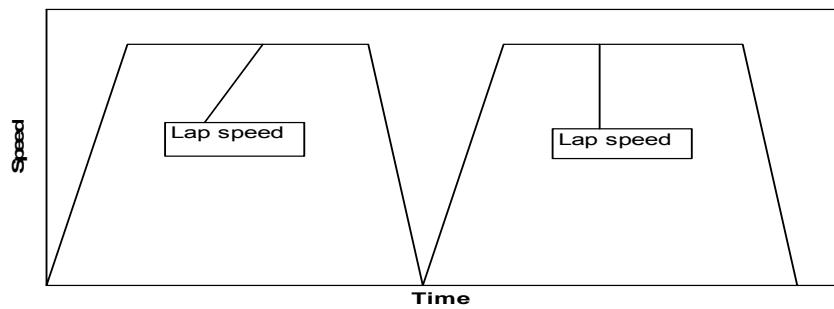


Figure 4 Pictorial representation of Lap 11 (B & C)



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. MoRTH/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 Lap speed--->	Time for each mode (second)	
		For Lap 10	For Lap 11
		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 Lap speed--->	Time for each mode (second)		
		For Lap 10		For Lap 11
		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			36
5	Steady state cruise	Not applicable		106
6	Deceleration: Lap speed - idle			24

CHAPTER 13 :

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 8000km.

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 Section 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 VII.5.1.) 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 10th 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.

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

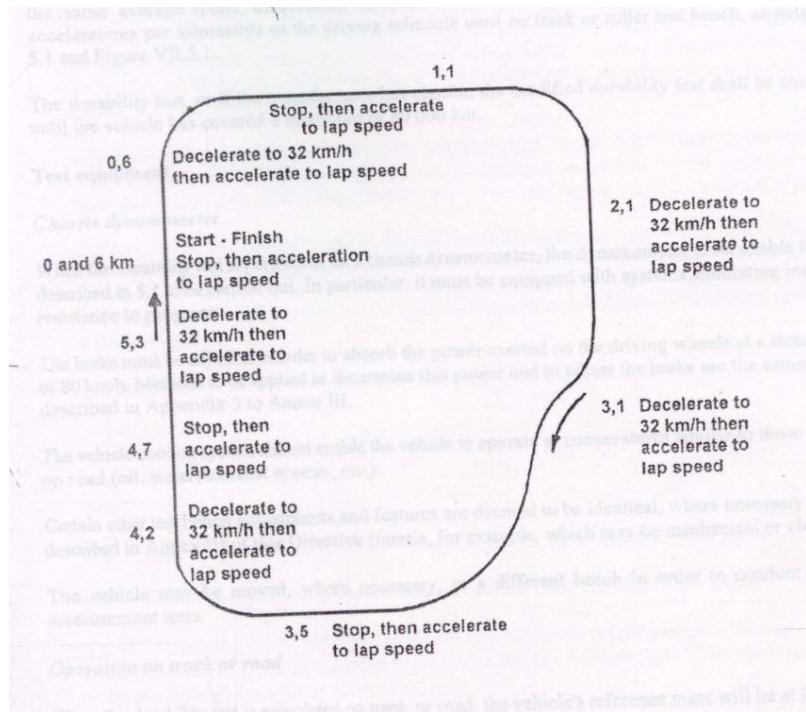


Figure VII.5.1

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 VII.5.1.
- 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 80000 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 Appendix 3 to Annexure III.
- 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 Annex III of this Directive (intertia, 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 10000km(+/- 400km) or more frequently, at regular intervals until having covered 80000 km, tailpipe emissions are measured in accordance with the type I test as defined in Annex. 1, Section 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 Annex. 1, Section 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 6400 km and 80000 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 6400 km interpolated point is higher than the 80000 km interpolated point) but the 80000 km actual data point is below the limit.

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

$$D. E. F. = \frac{M_{i_2}}{M_{i_1}}$$

Where,

M_{i_1} = Mass emission of the pollutant I in grams per km interpolated to 6400 km

M_{i_2} = mass emission of the pollutant in grams per km interpolated to 80000 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.

MoRTH/CMVR/ TAP-115/116	STANDARDS FOR PETROL / DIESEL ENGINED VEHICLES	
ISSUE NO. 4		PART XII

**PART XII : DETAILS OF STANDARDS FOR EMISSIONS OF
VISIBLE AND GASEOUS POLLUTANTS FROM
COMPRESSION IGNITION (CI), NATURAL GAS (NG)
& LIQUEFIED PETROLEUM GAS (LPG) ENGINED
VEHICLES AND TEST PROCEDURES EFFECTIVE
FROM 1ST APRIL 2005**

CHAPTER 1: OVERALL REQUIREMENT

APPENDIX 1 – PROCEDURE FOR PRODUCTION
CONFORMITY TESTING
APPENDIX 2 – PROCEDURE FOR PRODUCTION
CONFORMITY TESTING AT
MANUFACTURER'S REQUEST.

**CHAPTER 2: TECHNICAL SPECIFICATIONS FOR DIESEL/GAS
ENGINES (GREATER THAN 3500 Kg GVW)
(ONLY APPLICABLE TO BS III)
PART C**

CHAPTER 3: TEST PROCEDURE

APPENDIX 1 – ESC AND ELR TEST CYCLES
APPENDIX 2 – ETC TEST CYCLES
APPENDIX 3 – ETC ENGINE DYNAMOMETER
SCHEDULE
APPENDIX 4 – MEASUREMENT AND SAMPLING
PROCEDURE
APPENDIX 5 – CALIBRATION PROCEDURE

CHAPTER 4: TECHNICAL CHARACTERISTICS OF REFERENCE FUEL.

CHAPTER 5: ANALYTICAL AND SAMPLING SYSTEM.

CHAPTER 6: EXAMPLE OF CALCULATION PROCEDURE

CHAPTER I: OVERALL REQUIREMENTS

1. SCOPE

This part applies to the gaseous and particulate pollutant from all motor vehicles equipped with compression ignition engines and to the gaseous pollutant from 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 the vehicles of category N₁, N₂ and M₂ for which type-approval has been granted under Part XI – of MoRTH / CMVR / TAP 115-116 under CMVR Rules,115-14C.

2. DEFINITIONS AND ABBREVIATIONS

For the purposes of this Document:

- 2.1. **"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);
- 2.2. **"Approval of an engine"** means the approval of an engine type with regard to the level of the emission of gaseous and particulate pollutants;
- 2.3. **"Diesel engine"** means an engine which works on the compression-ignition principle;
- 2.4. **"Gas engine"** means an engine which is fuelled with natural gas (NG) or liquid petroleum gas (LPG);
- 2.5. **"Engine type"** means a category of engines which do not differ in such essential respects as engine characteristics as defined in Chapter 2 to this Document;
- 2.5. **"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)), methane (assuming a ratio of CH₄ for NG) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO₂) equivalent;
- 2.6. **"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);
- 2.6. **"Smoke"** means particles suspended in the exhaust stream of a diesel engine which absorb, reflect, or refract light;

- 2.7. "**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 MoRTH /CMVR/TAP-115/116;
- 2.8. "**Declared maximum power (P_{max})**" means the maximum power in kW (net power) as declared by the manufacturer in his application for type-approval;
- 2.9. "**Per cent load**" means the fraction of the maximum available torque at an engine speed;
- 2.10. "**ESC test**" means a test cycle consisting of 13 steady state modes to be applied in accordance with section 6.2 of this Chapter;
- 2.11 "**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
- 2.12. "**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.;
- 2.13. "**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 3 to this Document;
- 2.14. "**Low speed (n_{lo})**" means the lowest engine speed where 50 % of the declared maximum power occurs;
- 2.15. "**High speed (n_{hi})**" means the highest engine speed where 70 % of the declared maximum power occurs in case of diesel engines and in case of gas engines if the engine speed wherever highest 70% of the declared max. Power occurs, is not possible to measure then high speed is taken as rated speed as declared by the manufacturer or max. Power speed whichever is higher.
- 2.16. "**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 3, Appendix 1 to this Document;
- 2.17. "**Control area**" means the area between the engine speeds A and C and between 25 to 100 per cent load;
- 2.18. "**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 3, Appendix 2 to this Document;
- 2.19. "**Opacimeter**" means an instrument designed to measure the opacity of smoke particles by means of the light extinction principle;
- 2.20. "**NC gas range**" means one of the H or L range as defined in European Standard EN 437, dated November 1993;

- 2.21. "**Self adaptability**" means any engine device allowing the air/fuel ratio to be kept constant;
- 2.22. "**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;
- 2.23 "**Wobbe Index** (lower WI; or upper Wu)" 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:

$$W = H_{\text{Gas}} \times (\rho_{\text{air}} / \rho_{\text{Gas}})^{0.5}$$

- 2.24 " **λ shift factor** ($S\lambda$) means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio if the engine is fuelled with a gas composition different from pure methane (see Chapter VI for the calculation of $S\lambda$).
- 2.25. "**Defeat Device**" means any element of engine or vehicle design which measures or senses vehicle speed, engine speed, gear used, temperature, intake pressure or any other parameter, with a view to activating, modulating, delaying or deactivating the operation of any component of the emission control system so that the effectiveness of the emission control system is reduced under conditions encountered in normal vehicle use.

Such a device will not be regarded as a defeat device if:

- the need for the device is justified temporarily to protect the engine against intermittent operating conditions that could lead to damage or failure and no other measures are applicable for the same purpose which do not reduce the effectiveness of the emission control system;
- the device operates only when needed during engine starting and/or warming-up and no other measures are applicable for the same purpose which do not reduce the effectiveness of the emission control system.

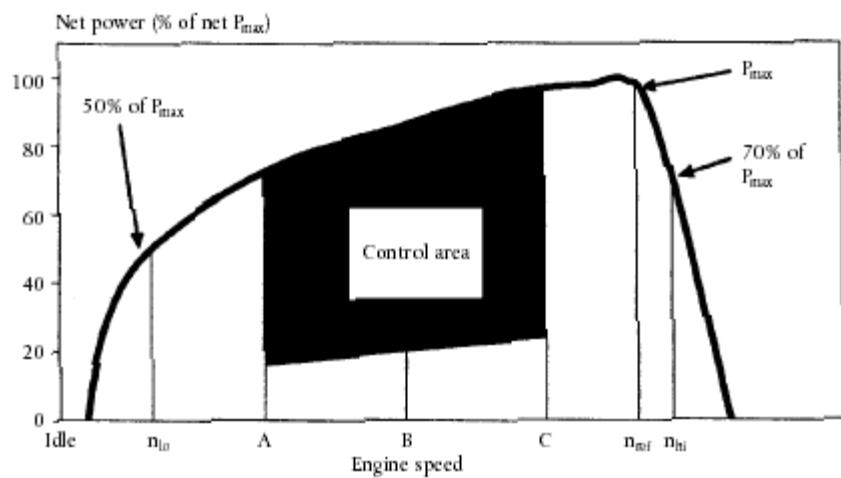


Figure 1
Specific definitions of the test cycles

2.29. Symbols and abbreviations

2.29.1. Symbols for test parameters

Symbol	Unit	Term
A_p	m^2	Cross-section area of the isokinetic sampling probe
A_T	m^2	Cross-section area of the exhaust pipe
CE_E	--	Ethane efficiency
CE_M	--	Methane efficiency
C_1	--	Carbon 1 equivalent hydrocarbon
conc	ppm/Vol%	Subscript denoting concentration
D_0	m^3/s	Intercept of PDP calibration function
DF	--	Dilution factor
D	--	Bessel function constant
E	--	Bessel function constant
E_z	g/kWh	Interpolated Nox emission of the control point
F_a	--	Laboratory atmospheric factor
F_c	s^{-1}	Bessel filter cut-off frequency
F_{FH}	--	Fuel specific factor for the calculation of wet concentration from dry concentration
F_s	--	Stoichiometric factor
G_{AIRW}	kg/h	Intake air mass flow rate on wet basis
G_{AIRD}	kg/h	Intake air mass flow rate on dry basis
G_{DILW}	kg/h	Dilution air mass flow rate on wet basis
G_{EDFW}	kg/h	Equivalent diluted exhaust gas mass flow rate on wet basis
G_{EXHW}	Kg/h	Exhaust gas mass flow rate on wet basis
G_{FUEL}	kg/h	Fuel mass flow rate
G_{TOTW}	kg/h	Diluted exhaust gas mass flow rate on wet basis
H	MJ/m^3	Calorific value
H_{REF}	g/kg	Reference value of absolute humidity (10.71 g/kg)
H_a	g/kg	Absolute humidity of the intake air
H_d	g/kg	Absolute humidity of the dilute air
HTCRAT	mol/mol	Hydrogen-to-carbon ratio
i	--	Subscript denoting an individual mode
K	--	Bessel constant
k	m^{-1}	Light absorption coefficient
$K_{H,D}$	--	Humidity correction factor for Nox, for diesel engines
$K_{H,G}$	--	Humidity correction factor of Nox, 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		Slope of PDP calibration function
mass	g/h or g	Subscript denoting emissions mass flow (rate)
M _{DIL}	kg	Mass of the dilution air sample passed through the particulates sampling filters
M _d	mg	Particulate sample mass of the dilution air collected
M _f	mg	Particulate sample mass collected
M _{f,p}	mg	Particulate sample mass collected on primary filter
M _{f,b}	mg	Particulate sample mass collected on back-up filter
M _{SAM}		Mass of the diluted exhaust sample passed through the particulate sampling filters
M _{SEC}	kg	Mass of secondary dilution air
M _{TOTW}	kg	Total CVS mass over the cycle on wet basis
M _{TOTW,i}	kg	Instantaneous CVS mass on wet basis
N	%	Opacity
N _{p,i}	--	Total revolutions of PDP over the cycle
N _{p,s}	--	Revolutions of PDP during a time interval
n	min ⁻¹	Engine 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 _A	kPa	Absolute pressure
p _B	kPa	Total atmospheric pressure
p _d	kPa	Saturation vapour pressure of the dilution air
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
Ω	--	Bessel constant
Q _s	m ³ /s	CVS volume flow rate
q	--	Dilution ratio
r	--	Ratio of cross sectional areas of isokinetic probe and exhaust pipe

Symbol	Unit	Term
R _a	%	Relative humidity of the intake air
R _d	%	Relative humidity of the dilution air
R _r	--	FID response factor
ρ	kg/m ³	Density
S	kW	Dynamometer setting
Si	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 CFV flow
ζ	%	Smoke transmittance
	M ³ /rev	PDP volume flow rate at actual conditions
V ₀	--	Wobbe index
W	kWh	Actual cycle work of ETC
W _{act}	kWh	Reference cycle work of ETC
W _{ref}	--	Weighting factor
WF	--	Effective weighting factor
WF _E	m ³ /rev	Calibration function of PDP volume flow rate
X ₀	m ⁻¹	1 s Bessel averaged smoke value
Y _i		

2.29.2 Symbols for the Chemical Components

CH ₄	Methane
C ₂ H ₆	Ethane
C ₃ H ₈	Propane
CO	Carbon monoxide
DOP	Di-octylphthalate
CO ₂	Carbon dioxide
HC	Hydrocarbons
NMHC	Non-methane hydrocarbons
NO _x	Oxides of nitrogen
NO	Nitric oxide
NO ₂	Nitrogen dioxide
PT	Particulates

2.29.3. Abbreviations

CFV	Critical Flow Venturi
CLD	Chemi-Luminescent detector
ELR	Engine Load Response Test

ESC	Engine Steady-state Cycle
ETC	Engine Transient Cycle
FID	Flame Ionization Detector
GC	Gas Chromatograph
HCLD	Heated Chemi-Luminescent Detector
HFID	Heated Flame-Ionization Detector
LPG	Liquified Petroleum Gas
NDIR	Non-Dispersive Infrared Analyser
NG	Natural Gas
NMC	Non-Methane Cutter

3. APPLICATION FOR TYPE-APPROVAL

- 3.1. As per AIS 007 Revision-02 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 part or the reference fuel specified in Annexure IV-F of CMVR rule.
- 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 ($S\lambda$). The composition of the reference fuels reflects the variations of those parameters

The parent engine shall meet the requirements of the part of the reference fuels G20 and G25 as specified in Annexure IV-I of CMVR rule, without any readjustment to the fuelling between the two tests.

- 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 Annex IV for each range, at each position of the switch. The fuels are G20 (fuel 1) and G23 (fuel 2) for the H-range of gases, G23 (fuel 1) and G25 (fuel 2) for the L-range of gases. The parent engine shall meet the requirements of this Directive 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 ESC cycle without measurement is permitted after the change of the fuel.

- 4.1.3.1. On the manufacturer's request the engine may be tested on a third fuel (fuel 3) if the shift factor ($S\lambda$) lies between those of the fuels G20 and G25, e.g. 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.

- 4.1.3.2. 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,

$$ra = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$rb = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

- 4.1.4. 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 C3/C4 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 Annex IV-H of CMVR rules without any readjustment to the fuelling between the two tests. However, one adaptation run over one ESC cycle without measurement is permitted after the change of the fuel.

- 4.1.4.1. The ratio of emission results "r" shall be determined for each pollutant as follows:

$$r = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 1}}$$

4.2. Granting of a fuel range restricted type-approval

At the present state of technology it is not yet possible to make leanburn natural gas engines self-adaptive. Yet these engines offer an advantage in efficiency and CO₂ emission. If a user has the guarantee of a supply of fuel of uniform composition, he may opt for a lean burn engine. Such an engine could be given a fuel restricted approval. In the interest of international harmonisation it is regarded desirable that a specimen of such an engine is granted international approval. Fuel restricted variants would then need to be identical except for the contents of the database of the ECU of the fuelling system, and such parts of the fuelling system (such as injector nozzles) that need to be adapted to the different fuel flow.

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 Annex IV-I of CMVR rules for the relevant range. The fuels are G20 (fuel 1) and G23 (fuel 2) for the H-range of gases, G23 (fuel 1) and G25 (fuel 2) 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 ESC cycle without measurement is permitted after the change of the fuel.

4.2.1.1. On the manufacturer's request it may be tested on a third fuel (fuel 3) of the ($S\lambda$) shift factor lies between those of the fuels G20 and G23, or G23 and G25 respectively, e.g. 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,

$$ra = \frac{\text{emission result on reference fuel 2}}{\text{emission result on reference fuel 3}}$$

and,

$$rb = \frac{\text{emission result on reference fuel 1}}{\text{emission result on reference fuel 3}}$$

4.2.1.3. Upon delivery to the customer the engine shall bear a label (see paragraph 5.1.5) 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 G20 and G25 in the case of natural gas, or the reference fuels A and B in the case of LPG, as specified in Annex IV-H of CMVR rules. 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 G20 and G23, or G23 and G25, 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 paragraph 5.1.5) stating for which fuel composition the engine has been calibrated.
- 4.2.3. **Until availability of reference LPG (fuel A & Fuel B), CNG (G20, G23, G25) as per notification, CNG/LPG engines will be tested as per commercially available CNG or LPG fuels as per guidelines given by GOI.**

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;
 - Ht 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;
 - Lt 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;
 - Hlt 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 paragraph 4.2.1.3, 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 CMVR rules 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

The components 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 and assembled as to enable the engine, in normal use, to comply with the provisions of this Document.

- 6.1.1. The use of a defeat device and/or irrational emissions control strategy is forbidden. If the type-approval authority suspects that a vehicle type utilises defeat device(s) and/or any irrational emission control strategy under certain operating conditions, upon request the manufacturer has to provide information on the operation and effect on emissions of the use of such devices and/or control strategy. Such information shall include a description of all emission control components, fuel control system logic including timing strategies and switch points during all modes of operation. These informations should remain strictly confidential and not be attached to the documentation required in Chapter I, section 3.

6.2. Specifications Concerning the Emission of Gaseous and Particulate Pollutants and Smoke

For type approval to B.S. III, the emission shall be determined on the ESC and ELR tests with conventional diesel engines including those fitted with electronic fuel injection equipment, exhaust gas re-circulation (EGR), and/or oxidation catalysts. Diesel engines fitted with advanced exhaust after treatment systems including the NOx catalysts and/or particulate traps, shall additionally be tested on the ETC test.

For gas engines, the gaseous emission shall be determined only on ESC test.

The ESC & ELR test procedures are described in Chapter III, Appendix 1. The ETC test procedure in Chapter III, Appendix 2 & 3.

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. Chapter V 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 Technical Service if it is found that they yield equivalent results on the respective test cycle. For particulate emissions only the full flow dilution system is recognised as the reference system. "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 criterion is defined as a $\pm 5\%$ agreement of the sample pair averages. For introduction of a new system into the Document the determination of equivalency shall be based upon the calculation of repeatability and reproducibility, as described in ISO 5725.

6.2.1. Limit Values

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 amounts shown in Notification 115 –14D.

Table 1

Limit values - ESC and ELR tests (TA = COP)

Year	Mass of carbon monoxide (CO) g/kWh	Mass of hydrocarbons (HC) g/kWh	Mass of oxides of Nitrogen (NO _x) g/kWh	Mass of Particulate (PT) ⁽²⁾ g/kWh	Smoke m ⁻¹ ⁽²⁾
1.4.2005	2,1	0,66	5,0	0,10 0,13 ⁽¹⁾	0,8

⁽¹⁾ For engines having swept volume of less than 0,75 dm³ per cylinder and a rated power speed of more than 3000 min⁻¹

⁽²⁾ Applicable to Diesel Engines only.

For diesel engines that are additionally tested on the ETC test, the specific masses of the carbon monoxide, of the non-methane hydrocarbons, of the oxides of nitrogen and of the particulates shall not exceed the amounts shown in Table 2.

Table 2**Limit values - ETC tests ⁽¹⁾ (TA = COP)**

Year	Mass of carbon monoxide (CO) g/kWh	Mass of hydrocarbons (HC) g/kWh	Mass of oxides of Nitrogen (NOx) g/kWh	Mass of Particulate (PT) ⁽³⁾ g/kWh
1.4.2005	5,45	0,78	5,0	0,16 0,21 ⁽²⁾

(1) The conditions for verifying the acceptability of the ETC tests (see Chapter III, Appendix 2, section 3.9)
(2) For engines having a swept volume of less than 0.75 dm^3 per cylinder and a rated power speed of more than 3000 min^{-1}
(3) Applicable to Diesel Engines only.

6.2.2. Hydrocarbon measurement for diesel fuelled engines

- 6.2.2.1. A manufacturer may choose to measure the mass of total hydrocarbons (THC) on the ETC test instead of measuring the mass of non-methane hydrocarbons. In this case, the limit for the mass of total hydrocarbons is the same as shown in table 2 for the mass of non-methane hydrocarbons.

6.2.3. Specific requirements for diesel engines

- 6.2.3.1. 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 Chapter III, Appendix 1 sections 4.6.2 and 4.6.3).
- 6.2.3.2. 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.

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. Power absorbed by the auxiliaries needed for operating the engine shall not exceed that specified for the type-approved engine.
- 7.1.4. Exhaust system value shall not differ by more than 40% of that specified for the type-approved engine

9. PRODUCTION CONFORMITY

- 9.1. Measures to ensure production conformity must be taken in accordance with the provisions as per Part VI of MoRTH /CMVR/TAP115/116.
- 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.

9.1.1.1. Conformity of the engine subjected to a pollutant test:

After submission of the engine to the authorities, 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. Engines that are subject to testing only on the ESC and ELR tests (for Diesel Engines) or only on the ESC test (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 to this Chapter.

OR

At the manufacturer's request, the tests may be carried out in accordance with Appendix 2 to 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 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.

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, 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:

$$\frac{\text{Emissions}'x'\text{hours}}{\text{Emissionszerohours}}$$

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;
- for L marked engines with a commercial fuel within the L range;
- for HL marked engines with a commercial fuel within the H or the L range.

However, at the manufacturer's request, the reference fuels described in Annexure IV-I of CMVR rules 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 paragraphs 4.1.3.1 and 4.2.1.1 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 paragraphs 4.1.3.2, 4.1.4.1 and 4.2.1.2. 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).

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.

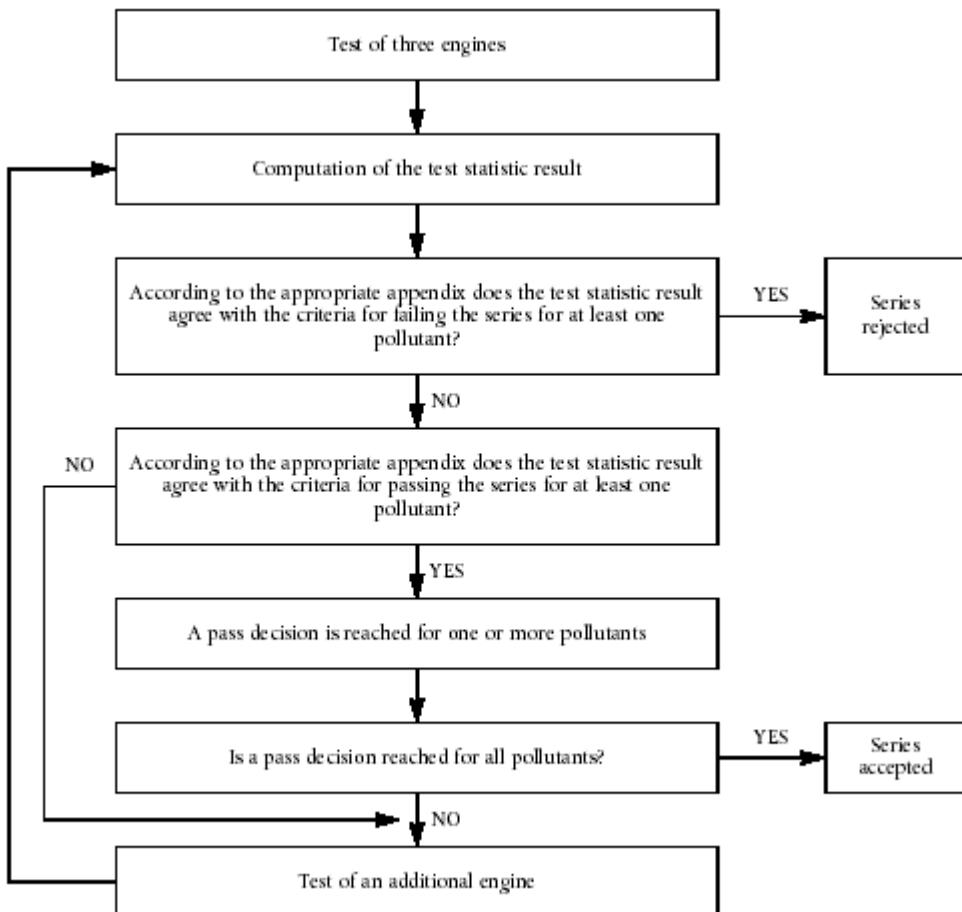


Figure 2
Schematic of production conformity testing

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 Chapter I 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 values measured in the series are $x_1, x_2 \dots x_n$, and L is the natural logarithm of the limit value for the pollutant, then, define

$$d_i = x_i - L$$

and,

$$\bar{d}_n = \frac{1}{n} \sum_{i=1}^n d_i$$

$$V_n^2 = \frac{1}{n} \sum_{i=1}^n (d_i - \bar{d}_n)^2$$

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 $\frac{\bar{d}_n}{V_n}$ and shall be used to determine whether the series has passed or failed as follows:

For $m_0 <= n <= m$:

- pass the series if $\frac{\bar{d}_n}{V_n} \leq A_n$

- fail the series if $\frac{\bar{d}_n}{V_n} \geq B_n$

- take another measurement if $A_n \leq \frac{\bar{d}_n}{V_n} \leq B_n$

6. Remarks

The following recursive formulae are useful for calculating successive values of the test statistic:

$$\overline{d}_n = \left(1 - \frac{1}{n}\right) \overline{d}_{n-1} + \frac{1}{n} d_n$$

$$V_n^2 = \left(1 - \frac{1}{n}\right) V_{n-1}^2 + \frac{(\overline{d}_n - d_n)^2}{n-1} \quad (n = 2, 3, \dots; \overline{d}_1 = d_1; V1 = 0)$$

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 Chapter I (see Figure 2):

Let:

L = the limit value for the pollutant,

x_i = the value of the measurement for the i -th engine of the sample,

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 Chapter I and the calculation procedure is applied to the sample increased by one more unit.

In Table 5 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

CHAPTER II

As per AIS 007 REVISION II

**TECHNICAL SPECIFICATIONS FOR DIESEL/GAS
ENGINES (GREATER THAN 3500 Kg GVW)**

PART C

CHAPTER III

TEST PROCEDURE

1. INTRODUCTION

- 1.1. This Chapter describes the methods of determining emissions of gaseous components, 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:
 - 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, oxides of nitrogen, particulates & Non-methane hydrocarbons (gas-engines only) for diesel & gas-engines on the ESC test 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 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. The particulate sample shall be diluted with conditioned ambient air. One sample over the complete test procedure shall be taken, and collected on suitable filters. The grams of each pollutant emitted per kilo-Watt hour shall be calculated as described in Appendix 1 to this Chapter.

Additionally, NOx shall be measured at three test points within the control area (Only for Diesel Engines) selected by the Technical Service ⁽¹⁾ and the measured values compared to the values calculated from those modes of the test cycle enveloping the selected test points. The NOx control check ensures the

⁽¹⁾ The test points shall be selected using approved statistical methods of randomization.

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 Technical Service⁽¹⁾ 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 to this Chapter.

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 after diluting the total exhaust gas with conditioned ambient air. 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. The concentration of NOx and HC shall be determined over the cycle by integration of the analyser signal. The concentration of CO, CO₂, and NMHC may be determined by integration of the analyser signal or by bag sampling. For particulates, a proportional sample shall be collected on suitable filters. The 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 to this Chapter.

2. TEST CONDITIONS

2.1. Engine Test Conditions

- 2.1.1. The absolute temperature (Ta) of the engine air at the inlet to the engine expressed in Kelvin, and the dry atmospheric pressure (ps), expressed in kPa shall be measured and the parameter F shall be determined according to the following provisions:

- (a) for diesel engines:

Naturally aspirated and mechanically supercharged engines:

⁽¹⁾ The test points shall be selected using approved statistical methods of randomisation.

$$F = \left(\frac{99}{Ps} \right) \times \left(\frac{T_a}{298} \right)^{0.7}$$

Turbocharged engines with or without cooling of the intake air:

$$F = \left(\frac{99}{Ps} \right)^{0.7} \times \left(\frac{T_a}{298} \right)^{1.5}$$

(b) for gas engines:

$$F = \left(\frac{99}{Ps} \right)^{1.2} \times \left(\frac{T_a}{298} \right)^{0.6}$$

2.1.2. Test Validity

For a test to be recognised as valid, the parameter F shall be such that:

$$0.96 \leq F \leq 1.06$$

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 and in Chapter V, section 2.2.1, EP and section 2.3.1, EP.

If the engine is equipped with an exhaust aftertreatment 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 aftertreatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust aftertreatment 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 aftertreatment 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 Annexure IV of the notification. 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 $311\text{ K} \pm 5\text{ K}$ ($38\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$) 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 Aftertreatment Systems

If the engine is equipped with an exhaust aftertreatment system, the emissions measured on the test cycle(s) shall be representative of the emissions in the field. If this cannot be achieved with one single test cycle (e.g. for particulate filters with periodic regeneration), several test cycles shall be conducted and the test results averaged and/or weighted. The exact procedure shall be agreed by the engine manufacturer and the Technical Service ⁽¹⁾ based upon good engineering judgement.

(1) The test points shall be selected using approved statistical methods of randomisation.

APPENDIX 1

ESC AND ELR TEST CYCLES

1. ENGINE AND DYNAMOMETER SETTINGS

1.1.1 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:

$$\text{Speed A} = n_{lo} + 25\% (n_{hi} - n_{lo})$$

$$\text{Speed B} = n_{lo} + 50\% (n_{hi} - n_{lo})$$

$$\text{Speed C} = n_{lo} + 75\% (n_{hi} - n_{lo})$$

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 n_{hi} and n_{lo} . The maximum power, n_{hi} and n_{lo} 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, n_{hi} and n_{lo} 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. 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:

$$s = P(n) \times \frac{L}{100} \quad \text{if tested under net conditions}$$
$$s = P(n) \times \frac{L}{100} + (P(a)-P(b)) \quad \text{if not tested under net conditions}$$

where:

- s = dynamometer setting, kW
- P(n) = net engine power as indicated in Chapter II, kW
- L = per cent load as indicated in Section 2.7.1, %
- P(a) = power absorbed by auxiliaries to be fitted as indicated in Chapter II.
- P(b) = power absorbed by auxiliaries to be removed as indicated in Chapter II.

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 Filters

At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed petri dish and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed petri dish or sealed filter holder until needed for testing. If the filter (pair) is not used within eight hours of its removal from the weighing chamber, it must be conditioned and reweighed before use.

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 CO₂ or NO_x concentration measurement for dilution ratio control, the CO₂ 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 CO₂ or NO_x concentration measurements of the dilution air must be within 100 ppm or 5 ppm 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 the mode numbers as set out in section 2.7.1.

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 $\pm 2\%$ 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 pair of filters (primary and back-up filters, see Chapter III, Appendix 4) 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 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) 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).

2.7.6 NOx Check within the Control Area

The NOx check within the control area (Only for Diesel Engine) 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 Technical Service⁽¹⁾. 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.

The calculation shall be carried out in accordance with section 4.

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 aftertreatment 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 L_A , as submitted by the opacimeter manufacturer, when the instrument is returned to the k readout mode for testing.

⁽¹⁾ The test points shall be selected using approved statistical methods of randomisation.

With no blockage of the opacimeter light beam, the readout shall be adjusted to $0,0\% \pm 1,0\%$ opacity. With the light being prevented from reaching the receiver, the readout shall be adjusted to $100,0\% \pm 1,0\%$ 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, followed by cycle 4 at a speed within the control area and a load between 10 % and 100 %, selected by the Technical Service⁽¹⁾. The following sequence shall be followed in dynamometer operation on the test engine, as shown in Figure 3.

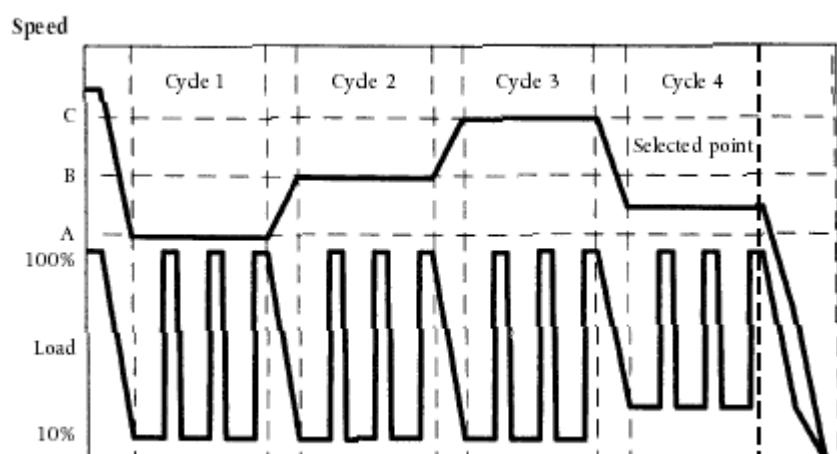


Figure 3
Sequence of ELR Test

⁽¹⁾ The test points shall be selected using approved statistical methods of randomisation.

(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 $\pm 2\%$ 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 (SV_A , SV_B , SV_C , 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 Table 1 of Chapter I,

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 $\pm 5,0\%$ of the limit value shown in Table 1 of Chapter I.

4. CALCULATION OF THE GASEOUS EMISSIONS

4.1. 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 chart 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 G_{EXHW} or the diluted exhaust gas flow G_{TOTW}, if used optionally, shall be determined in accordance with Chapter III, Appendix 4, section 2.3.

4.2. 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.

$$\text{Conc (wet)} = K_{w,r} \times \text{Conc (dry)}$$

For the raw exhaust gas:

For Diesel Engine:

Dry to Wet Correction Factor:

$$K_{w,r} = \left(1 - F_{FH} \times \frac{G_{FUEL}}{G_{AIRD}} \right) - K_{w,2}$$

$$F_{FH} = \frac{1.969}{1 + \frac{G_{FUEL}}{G_{AIRW}}}$$

For Gas-Engines:

$$K_{wr} = \left(\frac{V_{exhD}}{V_{exhW}} \right)$$

Where: -

$$V_{exhD} = V_{dry} - 1.35 * G_{fuel}$$

$$V_{exhW} = V_{dry} + 1.36 * G_{fuel}$$

Where: -

$$V_{dry} = \left(\frac{0.287 * G_{AirD} * (T_d + 273)}{P_{AirD}} \right)$$

Here,

V_{exhD} is Dry Exhaust volume.

V_{exhW} is Wet Exhaust volume.

T_d is Dry Bulb Temperature of Intake Air in Deg C.

P_{AirD} is Dry air Pressure of Intake Air in kPa. “

4.3. 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:

For Diesel Engine:

$$K_{HD} = \frac{1}{1 + A \times (Ha - 10.71) + B \times (T_a - 298)}$$

$$A = 0.309 G_{FUEL}/G_{AIRD} - 0.0266$$

$$B = -0.209 G_{FUEL}/G_{AIRD} + 0.00954$$

Where: -

T_a = temperature of the air, K

H_a = humidity of the intake air, g water per kg dry air

$$H_a = \frac{6.220 \times Ra \times Pa}{PB - Pa \times Ra \times 10^{-2}}$$

in which.

Ra = relative humidity of the intake air, %

Pa = saturation vapour pressure of the intake air, kPa

PB = total barometric pressure, kPa

For Gas-Engines:

$$K_{HD} = 0.6272 + 0.04403 * Ha - 0.0008625 * Ha^2$$

Where:

Ha is Humidity of Intake Air in g of water per kg of Dry Air.

4.4. Calculation of the Emission Mass Flow Rates

For Diesel Engines:

The emission mass flow rates (g/h) for each mode shall be calculated as follows, assuming the exhaust gas density to be 1.293 kg/m³ at 273 K (0 °C) and 101.3 kPa:

$$NO_x \text{ mass} = 0.001587 \times NO_{x\text{conc}} \times K_{H,D} \times G_{EXHW}$$

$$CO_x \text{ mass} = 0.000966 \times CO_{\text{conc}} \times G_{EXHW}$$

$$HC \text{ mass} = 0.000479 \times HC_{\text{conc}} \times G_{EXHW}$$

Where $NO_{x\text{conc}}$, CO_{conc} , HC_{conc} are the average concentrations (ppm) in the raw exhaust gas, as determined as in section 4.1.

For Gas-Engines:

The emission mass flow rates (g/h) for NG Engine and for each mode shall be calculated as follows, assuming the exhaust gas density to be 1.249 kg/m³ at 273 K (0 °C) and 101.3 kPa:

$$NO_x \text{ mass} = 0.001641 \times NO_{x\text{conc}} \times K_{H,D} \times G_{EXHW}$$

$$CO_x \text{ mass} = 0.001001 \times CO_{\text{conc}} \times G_{EXHW}$$

$$HC \text{ mass} = 0.000563 \times HC_{\text{conc}} \times G_{EXHW}$$

Where $NO_{x\text{conc}}$, CO_{conc} , HC_{conc} are the average concentrations (ppm) in the raw exhaust gas, as determined as in section 4.1.”

4.5. Calculation of the Specific Emissions

The emissions (g/kWh) shall be calculated for all individual components in the following way:

$$\overline{NO_x} = \frac{\sum NO_{x,mass} \times WF_i}{\sum P(n)_i \times WF_i}$$

$$\overline{CO} = \frac{\sum CO_{mass} \times WF_i}{\sum P(n)_i \times WF_i}$$

$$\overline{HC} = \frac{\sum HC_{mass} \times WF_i}{\sum P(n)_i \times WF_i}$$

The weighting factors (WF) used in the above calculation are according to section 2.7.1.

4.6. Calculation of the Area Control Values

For the three control points selected according to section 2.7.6, the NO_x emission shall be measured and calculated according to section 4.6.1 and also determined by interpolation from the modes of the test cycle closest to the respective control point according to section 4.6.2. The measured values are then compared to the interpolated values according to section 4.6.3.

4.6.1. Calculation of the Specific Emission

The NO_x emission for each of the control points (Z) shall be calculated as follows:

$$NO_{x,mass,z} = 0.001587 \times NO_{x,conc,Z} \times K_{H,D} \times G_{EXHW}$$

$$NO_{x,z} = NO_{x,mass,z} / P(n)_z$$

4.6.2. 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:

$$E_Z = E_{RS} + (E_{TU} - E_{RS}) \times (M_Z - M_{RS}) / (M_{TU} - M_{RS})$$

and:

$$E_{TU} = E_T + (E_U - E_T) \times (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$E_{RS} = E_R + (E_S - E_R) \times (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$M_{TU} = M_T + (M_U - M_T) \times (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

$$M_{RS} = M_R + (M_S - M_R) \times (n_Z - n_{RT}) / (n_{SU} - n_{RT})$$

where,

E_R, E_S, E_T, E_U = specific NO_x emission of the enveloping modes
Calculated in accordance with Section 4.6.1.

M_R, M_S, M_T, M_U = engine torque of the enveloping modes

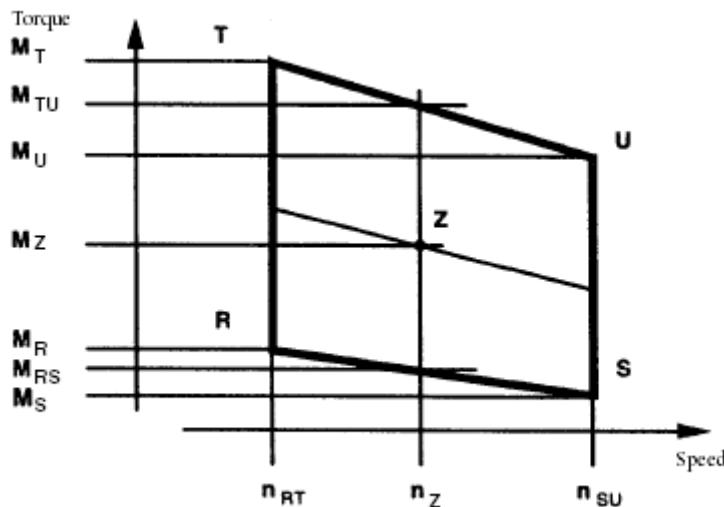


Figure 4
Interpolation of NOx Control Point

4.6.3. Comparison of NOx Emission Values

The measured specific NOx emission of the control point Z ($NO_{x,Z}$) is compared to the interpolated value (E_Z) as follows:

$$NO_{x,diff} = 100 \times (NO_{x,Z} - E_Z) / E_Z$$

5. CALCULATION OF THE PARTICULATE EMISSION

5.1. Data Evaluation

For the evaluation of the particulates, the total sample masses ($M_{SAM,i}$) 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. The particulate mass M_f is the sum of the particulate masses collected on the primary and back-up filters.

If background correction is to be applied, the dilution air mass (M_{DIL}) through the filters and the particulate mass (M_d) shall be recorded. If more than one measurement was made, the quotient M_d/M_{DIL} must be calculated for each single measurement and the values averaged.

5.2. 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 G_{EDFW} apply. All calculations shall be based upon the average values of the individual modes during the sampling period.

5.2.1. Isokinetic Systems

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{G_{DILW,i} + (G_{EXHW,i} \times r)}{(G_{EXHW,i} \times r)}$$

where r corresponds to the ratio of the cross sectional areas of the isokinetic probe and the exhaust pipe:

$$R = \frac{A_p}{A_T}$$

5.2.2. Systems with Measurement of CO₂ or NOx Concentration

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{conc_{E,i} - conc_{A,i}}{conc_{D,i} - conc_{A,i}}$$

where:

$conc_E$ = wet concentration of the tracer gas in the raw exhaust
 $conc_D$ = wet concentration of the tracer gas in the diluted exhaust
 $conc_A$ = 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 4.2 of this Appendix.

5.2.3. Systems with CO₂ Measurement and Carbon Balance Method

$$G_{EDFW,i} = \frac{206.5 - G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

where:

CO_{2D} = CO₂ concentration of the diluted exhaust
 CO_{2A} = CO₂ 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 CO₂) and determined through the following steps:

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

and

$$q_i = \frac{206.5 \times G_{FUEL,i}}{G_{EXHW,i} \times -(CO_{2D,i} - CO_{2A,i})}$$

5.2.4 Systems with Flow Measurement

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{G_{TOTW,i}}{(G_{TOTW,i} - G_{DILW,i})}$$

5.3. Full Flow Dilution System

The reported test results of the particulate emission shall be determined through the following steps. All calculations shall be based upon the average values of the individual modes during the sampling period.

$$G_{EDFW,i} = G_{TOTW,i}$$

5.4. Calculation of the Particulate Mass Flow Rate

The particulate mass flow rate shall be calculated as follows:

$$\text{PT mass} = \frac{M_f}{M_{SAM}} \times \overline{G_{EDFW}}$$

where

$$\overline{G_{EDFW}} = \sum_{i=1}^{i=n} G_{EDFW,i} \times WF_i$$

$$M_{SAM} = \sum_{i=1}^{i=n} M_{SAM,i}$$

$$i = 1, \dots n.$$

determined over the test cycle by summation of the average values of the individual modes during the sampling period.

The particulate mass flow rate may be background corrected as follows:

$$\text{PT mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} \times \left(\sum_{i=1}^{i=n} \left(1 - \frac{1}{DF_i} \right) \times WF_i \right) \right) \right] \times \overline{G_{EDFW}}$$

If more than one measurement is made, M_d / M_{DIL}
shall be replaced with $\overline{(M_d / M_{DIL})}$

$DF_i = 13,4 / (\text{concCO2} + (\text{concCO} + \text{concHC}) * 10^{-4})$ for the individual modes

or,

$DF_i = 13,4 / \text{concCO2}$ for the individual modes.

5.5. Calculation of the Specific Emission

The particulate emission shall be calculated in the following way:

$$\overline{PT} = \frac{PT_{\text{mass}}}{\sum P(n)i \times WF_i}$$

5.6. Effective Weighting Factor

The effective weighting factor $WF_{E,i}$ for each mode shall be calculated in the following way:

$$WF_{E,i} = \frac{M_{SAM}}{M_{SAM}} \times \frac{\overline{G}_{EDFW}}{G_{EDFW,i}}$$

The value of the effective weighting factors shall be within $\pm 0,003$ ($\pm 0,005$ for the idle mode) of the weighting factors listed in Section 2.7.1.

6. CALCULATION OF THE SMOKE VALUES

6.1. 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 6.3.1. 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 6.1.1 must be repeated whenever the system response time and/or sampling rate changes.

6.1.1. 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, 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 (f_c) are based on a step input 0 to 1 in $<= 0,01$ s (see Chapter VII). 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 f_c until $t_{90}-t_{10} \approx t_F$. The first iteration for f_c 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

Δt = 1/sampling rate

Ω = $1 / [\tan (\Pi \times \Delta t \times f_c)]$

6.1.2. Calculation of the Bessel Algorithm

Using the values of E and K, the 1 s Bessel averaged response to a step input S_i 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 t_{10} and t_{90} 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:

$$| (t_{90} - t_{10}) - t_F | \leq 0.01 \times t_F$$

6.2. Data Evaluation

The smoke measurement values shall be sampled with a minimum rate of 20 Hz.

6.3. Determination of Smoke

6.3.1. 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.

6.3.2. 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 6.1.1, 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 6.1.2:

$$Y_i = Y_{i-1} + E \times (S_i + 2 \times S_{i-1} + S_{i-2} - 4 \times Y_{i-2}) + K \times (Y_{i-1} - Y_{i-2})$$

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.

6.3.3. Final Result

The mean smoke values (SV) from each cycle (test speed) shall be calculated as follows:

For test speed A:

$$SV_A = (Y_{\max1,A} + Y_{\max2,A} + Y_{\max3,A}) / 3$$

For test speed B:

$$SV_B = (Y_{\max1,B} + Y_{\max2,B} + Y_{\max3,B}) / 3$$

For test speed C:

$$SV_C = (Y_{\max1,C} + Y_{\max2,C} + Y_{\max3,C}) / 3$$

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 $8 \pm 1 \text{ min}^{-1} / \text{s}$ from minimum to maximum mapping speed. Engine speed and torque points shall be recorded at a sample rate of at least one point per second.

1.3. Mapping Curve Generation

All data points recorded under section 1.2 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.

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 Technical Service 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 to 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:

$$\text{Actual speed} = \frac{\% \text{speed}(\text{reference_speed} - \text{idle_speed})}{100} + \text{idle_speed}$$

The reference speed (n_{ref}) corresponds to the 100 % speed values specified in the engine dynamometer schedule of Appendix 3. It is defined as follows (see Figure 1 of Chapter I):

$$n_{\text{ref}} = n_{\text{lo}} + 95\% \times (n_{\text{hi}} - n_{\text{lo}})$$

where n_{hi} and n_{lo} are either specified according to Chapter I, section 2 or determined according to Chapter III, Appendix 1, section 1.1.

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, as follows:

$$\text{Actual torque} = \frac{\% \text{torque} \times \text{max. torque}}{100}$$

for the respective actual speed as determined in Section 2.1. 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:

$$\% \text{ speed} = 43$$

$$\% \text{ torque} = 82$$

Given the following values:

$$\text{reference speed} = 2200 \text{ min}^{-1}$$

$$\text{idle speed} = 600 \text{ min}^{-1}$$

results in,

$$\text{actual speed} = \frac{43 \times (2200 - 600)}{100} + 600 = 1288 \text{ min}^{-1}$$

$$\text{actual torque} = \frac{82 \times 700}{100} 574 \text{ Nm}$$

where the maximum torque observed from the mapping curve at 1288 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 (Diesel Engines Only)

At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed petri dish and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed petri dish or sealed filter holder until needed for testing. If the filter (pair) is not used within eight hours of its removal from the weighing chamber, it must be conditioned and reweighed before use.

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.

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.

3.5. Adjustment of the Full Flow Dilution System

The total diluted exhaust gas 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 Chapter V, section 2.3.1, DT).

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. Analyser Response

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 NO_x shall be measured continuously in the dilution tunnel with a frequency of 2 Hz. The average concentrations shall be determined by integrating the analyser 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).

3.8.3. Particulate Sampling (Diesel Engines Only)

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 $\pm 5\%$ 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 $\pm 5\%$ 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 air flow 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 $\pm 5\%$) 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.

3.8.4. 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, 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.

For diesel engines only, the particulate filters shall be returned to the weighing chamber no later than one hour after completion of the test and shall be conditioned in a closed, but unsealed petri dish for at least one hour, but not more than 80 hours before weighing.

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 + 15 % 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% of power Map maximum engine torque	Max. 8% 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
Coefficient of determination, 12	Min. 0,9700	Min. 0,8800	Min. 0,9100
Y intercept of the regression line, b	± 50 min-1	± 20 Nm or ± 2% max. torque whichever is greater	± 4kW or ± 2% of max. power whichever is greater

Point deletions from the regression analyses are permitted where noted in Table 7.

Table 7**Permitted Point Deletions From Regression Analysis**

Conditions	Points to be deleted
Full load and torque feedback < torque reference	Torque and/or power
No load, not an idle point, and torque feedback > torque reference	Torque and/or power
No load/closed throttle, idle point and sped > reference idle speed	Speed and/or power

4. CALCULATION OF THE GASEOUS EMISSIONS

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 (V0 for PDP or KV for CFV, as determined in Chapter III, Appendix 5, section 2). 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, see Chapter V, section 2.3).

For the PDP-CVS system:

$$M_{TOTW} = 1,293 \times V_0 \times N_P \times (P_B - P_1) \times 273 / (101,3 \times T)$$

where:

M_{TOTW} = mass of the diluted exhaust gas on wet basis over the cycle, kg

V_0 = volume of gas pumped per revolution under test conditions, m³/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:

$$M_{TOTW} = 1.293 \times t \times K_v \times P_A / T^{0.5}$$

where:

M_{TOTW} = mass of the diluted exhaust gas on wet basis over the cycle, kg

t = cycle time, s

K_v = calibration coefficient of the critical flow venturi for standard conditions

P_A = absolute pressure at venturi inlet, kPa

T = absolute temperature at venturi inlet, K

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:

$$M_{TOTW,i} = 1.293 \times V_0 \times N_{P,i} \times (P_B - P_1) \times 273 / (101.3 \times T)$$

where,

$M_{TOTW,i}$ = instantaneous mass of the diluted exhaust gas on wet basis, kg

$N_{p,i}$ = total revolutions of pump per time interval

For the CFV-CVS system:

$$M_{TOTW,i} = 1,293 \times \Delta t_i \times K_v \times P_a/T^{0.5}$$

where:

$M_{TOTW,i}$ = instantaneous mass of the diluted exhaust gas on wet basis, kg

Δt_i = time interval, s

If the total sample mass of particulates (M_{SAM}) and gaseous pollutants exceeds 0,5 % of the total CVS flow (M_{TOTW}), the CVS flow shall be corrected for M_{SAM} or the particulate sample flow shall be returned to the CVS prior to the flow measuring device (PDP or CFV).

4.2. NOx Correction for Humidity

As the NOx emission depends on ambient air conditions, the NOx concentration shall be corrected for ambient air humidity with the factors given in the following formulae.

(a) for diesel engines:

$$K_{HD} = \frac{1}{1 - 0,0182 \times (H_a - 10,71)}$$

(b) for gas engines:

$$K_{HG} = \frac{1}{1 - 0,0329 \times (H_a - 10,71)}$$

where:

H_a = humidity of the intake air water per kg dry air in which:

$$H_a = \frac{6,220 \times R_a \times P_a}{P_B - P_a \times R_a \times 10^{-2}}$$

R_a = relative humidity of the intake air, %

P_a = saturation vapour pressure of the intake air, kPa

P_B = total barometric pressure, kPa

4.3. Calculation of the Emission Mass Flow

4.3.1. Systems with Constant Mass Flow

For systems with heat exchanger, the mass of the pollutants (g/test) shall be determined from the following equations:

$$(1) \text{ NO}_x \text{ mass} = 0,001587 \times \text{NO}_x \text{ conc} \times K_{H,D} \times M_{TOTW} \text{ (diesel engines)}$$

$$(2) \text{ NO}_x \text{ mass} = 0,001587 \times \text{NO}_x \text{ conc} \times K_{H,G} \times M_{TOTW} \text{ (gas engines)}$$

$$(3) \text{ CO mass} = 0,000966 \times \text{CO conc} \times M_{TOTW}$$

$$(4) \text{ HC mass} = 0,000479 \times \text{HC conc} \times M_{TOTW} \text{ (diesel engines)}$$

$$(5) \text{ HC mass} = 0,000502 \times \text{HC conc} \times M_{TOTW} \text{ (LPG fuelled engines)}$$

$$(6) \text{ NMHC mass} = 0,000516 \times \text{NMHC conc} \times M_{TOTW} \text{ (NG fuelled engines)}$$

$$(7) \text{ CH}_4 \text{ mass} = 0,000552 \times \text{CH}_4 \text{ mass} \times M_{TOTW} \text{ (NG fuelled engines)}$$

where:

$\text{NO}_x \text{ conc}$, CO conc , $\text{HC conc}^{(1)}$, NMHC conc = average background corrected concentrations over the cycle from integration (mandatory for NO_x and HC) or bag measurement, ppm

M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in Section 4.1, kg

$K_{H,D}$ = humidity correction factor for diesel engines as determined in Section 4.2

$K_{H,G}$ = humidity correction factor for gas engines as determined in Section 4.2

Concentrations measured on a dry basis shall be converted to a wet basis in accordance with Chapter III, Appendix 1, section 4.2.

The determination of NMHC conc depends on the method used (see Chapter III, Appendix 4, section 3.3.4). In both cases, the CH_4 concentration shall be determined and subtracted from the HC concentration as follows:

⁽¹⁾ Based on C1 equivalent.

$$\text{NMHC}_{\text{conc}} = \text{HC}_{\text{conc}} - \text{CH}_4_{\text{conc}}$$

(b) NMC method

$$\text{NMHC}_{\text{conc}} = \frac{\text{HC}(\text{w/oCutter}) \times (1 - \text{CE}_M) - \text{HC}(\text{wCutter})}{\text{CE}_E - \text{CE}_M}$$

where:

$\text{HC}(\text{wCutter})$ = HC concentration with the sample gas flowing through the NMC.

$\text{HC}(\text{w/oCutter})$ = HC concentration with the sample gas bypassing the NMC

CE_M = methane efficiency as determined per Chapter III, Appendix 5, Section 1.8.4.1

CE_E = ethane efficiency as determined per Chapter III, Appendix 5, Section 1.8.4.2

4.3.1.1. Determination of the Background Corrected Concentrations

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.

$$\text{Conc} = \text{conc}_e - \text{conc}_d \times (1 - (1/\text{DF}))$$

where:

conc = concentration of the respective pollutant in the diluted exhaust gas, corrected by the amount of the respective pollutant contained in the dilution air, ppm

conc_e = concentration of the respective pollutant measured in the diluted exhaust gas, ppm

conc_d = concentration of the respective pollutant measured in the dilution air, ppm

DF = dilution factor

The dilution factor shall be calculated as follows:

- (a) for diesel and LPG fuelled gas engines

$$DF = \frac{F_s}{CO_{2conce} + (HC_{conce} + CO_{conce}) \times 10^{-4}}$$

(b) for NG-fuelled gas engines

$$DF = \frac{F_s}{CO_{2conce} + (NMHC_{conce} + CO_{conce}) \times 10^{-4}}$$

where:

- $CO_{2, conce}$ = concentration of CO₂ in the diluted exhaust gas, % vol
- HC_{conce} = concentration of HC in the diluted exhaust gas, ppm C1
- $NMHC_{conce}$ = concentration of NMHC in the diluted exhaust gas, ppm C1
- CO_{conce} = 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 Chapter III, Appendix 1, Section 4.2.

The stoichiometric factor shall be calculated as follows:

$$F_s = 100 \times \frac{x}{x + \frac{y}{2} + 3.76 \times (x + \frac{y}{4})}$$

where:

- x, y = fuel composition C_xH_y

Alternatively, if the fuel composition is not known, the following stoichiometric factors may be used:

$$F_s (\text{diesel}) = 13.4$$

$$F_s (\text{LPG}) = 11.6$$

$$F_s (\text{NG}) = 9.5$$

4.3.2. Systems with Flow Compensation

For systems without heat exchanger, the mass of the pollutants (g/test) shall be determined by calculating the instantaneous mass emissions and integrating the instantaneous values over the cycle. Also, the background correction shall be applied directly to the instantaneous concentration value. The following formulae shall be applied:

$$(1) \text{ NO}_{\text{xmass}}$$

$$= \sum_{i=1}^n (M_{TOTW,i} \times NO_{xconce,i} \times 0.001587 \times K_{H,D}) - \\ (M_{TOTW} \times NO_{xconcd} \times (1 - 1/DF) \times 0.001587 \times K_{H,D}) (\text{diesel engines})$$

$$(2) \text{ NO}_{\text{xmass}} = \sum_{i=1}^n (M_{TOTW,i} \times NO_{xconce,i} \times 0.001587 \times K_{H,G}) -$$

$$(M_{TOTW} \times NO_{xconcd} \times (1 - 1/DF) \times 0.001587 \times K_{H,G}) (\text{gas engines})$$

$$(3) \text{ CO}_{\text{mass}} = \sum_{i=1}^n (M_{TOTW,i} \times CO_{xconce,i} \times 0.000966) -$$

$$(M_{TOTW} \times CO_{xconcd} \times (1 - 1/DF) \times 0.000966)$$

$$(4) \text{ HC}_{\text{mass}} = \sum_{i=1}^n (M_{TOTW,i} \times HC_{conce,i} \times 0.000479) -$$

$$(M_{TOTW} \times HC_{xconcd} \times (1 - 1/DF) \times 0.000479) (\text{diesel engines})$$

$$(5) \text{ HC}_{\text{mass}} = \sum_{i=1}^n (M_{TOTW,i} \times HC_{conce,i} \times 0.000502) -$$

$$(M_{TOTW} \times HC_{xconcd} \times (1 - 1/DF) \times 0.000502) (\text{LPG engines})$$

$$(6) \text{ NMHC}_{\text{mass}} = \sum_{i=1}^n (M_{TOTW,i} \times NMHC_{conce,i} \times 0.000516) -$$

$$(M_{TOTW} \times HC_{xconcd} \times (1 - 1/DF) \times 0.000516) (\text{NG engines})$$

$$(7) \text{ CH}_4\text{mass} = \sum_{i=1}^n (M_{TOTW,i} \times CH_4_{conce,i} \times 0.000552) -$$

$$(M_{TOTW} \times HC_{xconcd} \times (1 - 1/DF) \times 0.000552) (\text{NG engines})$$

where:

conc _e	=	concentration of the respective pollutant measured in the diluted exhaust gas, ppm
conc _d	=	concentration of the respective pollutant measured in the dilution air, ppm
M _{TOTW,i}	=	instantaneous mass of the diluted exhaust gas (see Section 4.1), Kg
M _{TOTW}	=	total mass of diluted exhaust gas over the cycle (see Section 4.1), kg
K _{H,D}	=	humidity correction factor for diesel engines as determined in Section 4.2
K _{H,G}	=	humidity correction factor for gas engines as determined in Section 4.2
DF	=	dilution factor as determined in Section 4.3.1.1

4.4. Calculation of the Specific Emissions

The emissions (g/kWh) shall be calculated for all individual components in the following way:

$$\overline{NO_x} = NO_{x\text{mass}} / W_{\text{act}} \text{ (diesel and gas engines)}$$

$$\overline{CO} = CO_{\text{mass}} / W_{\text{act}} \text{ (diesel and gas engines)}$$

$$\overline{HC} = HC_{\text{mass}} / W_{\text{act}} \text{ (diesel and LPG fuelled gas engines)}$$

$$\overline{NMHC} = HC_{\text{mass}} / W_{\text{act}} \text{ (NG fuelled gas engines)}$$

$$\overline{CH_4} = CH_4 / W_{\text{act}} \text{ (NG fuelled gas engines)}$$

where:

$$W_{\text{act}} = \text{actual cycle work as determined in Section 3.9.2, kWh}$$

5. CALCULATION OF THE PARTICULATE EMISSION (DIESEL ENGINES ONLY)

5.1. Calculation of the Mass Flow

The particulate mass (g/test) shall be calculated as follows:

$$PT_{mass} = \frac{M_f}{M_{SAM}} \times \frac{M_{TOTW}}{1000}$$

where:

M_f = particulate mass sampled over the cycle, mg

M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in section 4.1, kg

M_{SAM} = mass of diluted exhaust gas taken from the dilution tunnel for collecting particulates, kg

and:

M_f = $M_{f,p} + M_{f,b}$ if weighed separately, mg

$M_{f,p}$ = particulate mass collected on the primary filter, mg

$M_{f,b}$ = particulate mass collected on the back-up filter, mg

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.

$$M_{SAM} = M_{TOT} - M_{SEC}$$

where:

M_{TOT} = mass of double diluted exhaust gas through particulate filter, kg

M_{SEC} = mass of secondary dilution air, kg

If the particulate background level of the dilution air is determined in accordance with section 3.4, the particulate mass may be background corrected. In this case, the particulate mass (g/test) shall be calculated as follows:

$$PT_{mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} \times \left(1 - \frac{1}{DF} \right) \right) \right] \times \frac{M_{TOTW}}{1000}$$

where:

M_f, M_{SAM}, M_{TOTW} = see above

M_{DIL} = mass of primary dilution air sampled by background particulate sampler, kg

M_d= mass of the collected background particulates of the primary dilution air, mg

DF= dilution factor as determined in section 4.3.1.1

5.2. Calculation of the Specific Emission

The particulate emission (g/kWh) shall be calculated in the following way:

$$\overline{PT} = PT_{\text{mass}} / W_{\text{act}}$$

where:

W_{act} = actual cycle work as determined in Section 3.9.2, kWh.

APPENDIX 3
ETC DYNAMOMETER SCHEDULE

Time (s)	Normal Speed %	Normal Torque %	Time (s)	Normal Speed %	Normal Torque %	Time (s)	Normal Speed %	Normal Torque %
1	0	0	43	20,4	'm'	85	58,3	11,8
2	0	0	44	14,1	0	86	56,2	'm'
3	0	0	45	6,5	0	87	52	'm'
4	0	0	46	0	0	88	43,3	'm'
5	0	0	47	0	0	89	36,1	'm'
6	0	0	48	0	0	90	27,6	'm'
7	0	0	49	0	0	91	21,1	'm'
8	0	0	50	0	0	92	8	0
9	0	0	51	0	0	93	0	0
10	0	0	52	0	0	94	0	0
11	0	0	53	0	0	95	0	0
12	0	0	54	0	0	96	0	0
13	0	0	55	0	0	97	0	0
14	0	0	56	0	0	98	0	0
15	0	0	57	0	0	99	0	0
16	0,1	1,5	58	0	0	100	0	0
17	23,1	21,5	59	0	0	101	0	0
18	12,6	28,5	60	0	0	102	0	0
19	21,8	71	61	0	0	103	0	0
20	0	76,8	62	25,5	11,1	104	0	0
21	54,6	80,9	63	28,5	20,9	105	0	0
22	71,3	4,9	64	32	73,9	106	0	0
23	55,9	18,1	65	4	82,3	107	0	14,8
24	72	85,4	66	34,5	80,4	108	11,6	14,8
25	86,7	61,8	67	64,1	86	109	0	0
26	51,7	0	68	58	0	110	27,2	74,8
27	53,4	48,9	69	50,3	83,4	111	17	76,9
28	34,2	87,6	70	66,4	99,1	112	36	78
29	45,5	92,7	71	81,4	99,6	113	59,7	86
30	54,6	99,5	72	88,7	73,4	114	80,8	17,9
31	64,5	96,8	73	52,5	0	115	49,7	0
32	71,7	85,4	74	46,4	58,5	116	65,6	86
33	79,4	54,8	75	48,6	90,9	117	78,6	72,2
34	89,7	99,4	76	55,2	99,4	118	64,9	'm'
35	57,4	0	77	62,3	99	119	44,3	'm'
36	59,7	30,6	78	68,4	91,5	120	51,4	83,4
37	90,1	'm'	79	74,5	73,7	121	58,1	97
38	82,9	'm'	80	38	0	122	69,3	99,3
39	51,3	'm'	81	41,8	89,6	123	72	20,8
40	28,5	'm'	82	47,1	99,2	124	72,1	'm'
41	29,3	'm'	83	52,5	99,8	125	65,3	'm'
42	26,7	'm'	84	56,9	80,8	126	64	'm'

Time (s)	Normal Speed %	Normal Torque %	Time (s)	Normal Speed %	Normal Torque %	Time (s)	Normal Speed %	Normal Torque %
127	59,7	'm'	174	54,6	64,8	221	0	0
128	52,8	'm'	175	56,6	76,5	222	0	0
129	45,9	'm'	176	58	'm'	223	0	0
130	38,7	'm'	177	53,6	'm'	224	0	0
131	32,4	'm'	178	40,8	'm'	225	21,2	62,7
132	27	'm'	179	32,9	'm'	226	30,8	75,1
133	21,7	'm'	180	26,3	'm'	227	5,9	82,7
134	19,1	0,4	181	20,9	'm'	228	34,6	80,3
135	34,7	14	182	10	0	229	59,9	87
136	16,4	48,6	183	0	0	230	84,3	86,2
137	0	11,2	184	0	0	231	68,7	'm'
138	1,2	2,1	185	0	0	232	43,6	'm'
139	30,1	19,3	186	0	0	233	41,5	85,4
140	30	73,9	187	0	0	234	49,9	94,3
141	54,4	74,4	188	0	0	235	60,8	99
142	77,2	55,6	189	0	0	236	70,2	99,4
143	58,1	0	190	0	0	237	81,1	92,4
144	45	82,1	191	0	0	238	49,2	0
145	68,7	98,1	192	0	0	239	56	86,2
146	85,7	67,2	193	0	0	240	56,2	99,3
147	60,2	0	194	0	0	241	61,7	99
148	59,4	98	195	0	0	242	69,2	99,3
149	72,7	99,6	196	0	0	243	74,1	99,8
150	79,9	45	197	0	0	244	72,4	8,4
151	44,3	0	198	0	0	245	71,3	0
152	41,5	84,4	199	0	0	246	71,2	9,1
153	56,2	98,2	200	0	0	247	67,1	'm'
154	65,7	99,1	201	0	0	248	65,5	'm'
155	74,4	84,7	202	0	0	249	64,4	'm'
156	54,4	0	203	0	0	250	62,9	25,6
157	47,9	89,7	204	0	0	251	62,2	35,6
158	54,5	99,5	205	0	0	252	62,9	24,4
159	62,7	96,8	206	0	0	253	58,8	'm'
160	62,3	0	207	0	0	254	56,9	'm'
161	46,2	54,2	208	0	0	255	54,5	'm'
162	44,3	83,2	209	0	0	256	51,7	17
163	48,2	13,3	210	0	0	257	56,2	78,7
164	51	'm'	211	0	0	258	59,5	94,7
165	50	'm'	212	0	0	259	65,5	99,1
166	49,2	'm'	213	0	0	260	71,2	99,5
167	49,3	'm'	214	0	0	261	76,6	99,9
168	49,9	'm'	215	0	0	262	79	0
169	51,6	'm'	216	0	0	263	52,9	97,5
170	49,7	'm'	217	0	0	264	53,1	99,7
171	48,5	'm'	218	0	0	265	59	99,1
172	50,3	72,5	219	0	0	266	62,2	99
173	51,1	84,5	220	0	0	267	65	99,1

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
268	69	83,1	315	66,4	60,9	362	53,4	95,2
269	69,9	28,4	316	65,8	'm'	363	58,4	99,2
270	70,6	12,5	317	59	'm'	364	61,5	99
271	68,9	8,4	318	50,7	'm'	365	64,8	99
272	69,8	9,1	319	41,8	'm'	366	68,1	99,2
273	69,6	7	320	34,7	'm'	367	73,4	99,7
274	65,7	'm'	321	28,7	'm'	368	73,3	29,8
275	67,1	'm'	322	25,2	'm'	369	73,5	14,6
276	66,7	'm'	323	43	24,8	370	68,3	0
277	65,6*	'm'	324	38,7	0	371	45,4	49,9
278	64,5	'm'	325	48,1	31,9	372	47,2	75,7
279	62,9	'm'	326	40,3	61	373	44,5	9
280	59,3	'm'	327	42,4	52,1	374	47,8	10,3
281	54,1	'm'	328	46,4	47,7	375	46,8	15,9
282	51,3	'm'	329	46,9	30,7	376	46,9	12,7
283	47,9	'm'	330	46,1	23,1	377	46,8	8,9
284	43,6	'm'	331	45,7	23,2	378	46,1	6,2
285	39,4	'm'	332	45,5	31,9	379	46,1	'm'
286	34,7	'm'	333	46,4	73,6	380	45,5	'm'
287	29,8	'm'	334	51,3	60,7	381	44,7	'm'
288	20,9	73,4	335	51,3	51,1	382	43,8	'm'
289	36,9	'm'	336	53,2	46,8	383	41	'm'
290	35,5	'm'	337	53,9	50	384	41,1	6,4
291	20,9	'm'	338	53,4	52,1	385	38	6,3
292	49,7	11,9	339	53,8	45,7	386	35,9	0,3
293	42,5	'm'	340	50,6	22,1	387	33,5	0
294	32	'm'	341	47,8	26	388	53,1	48,9
295	23,6	'm'	342	41,6	17,8	389	48,3	'm'
296	19,1	0	343	38,7	29,8	390	49,9	'm'
297	15,7	73,5	344	35,9	71,6	391	48	'm'
298	25,1	76,8	345	34,6	47,3	392	45,3	'm'
299	34,5	81,4	346	34,8	80,3	393	41,6	3,1
300	44,1	87,4	347	35,9	87,2	394	44,3	79
301	52,8	98,6	348	38,8	90,8	395	44,3	89,5
302	63,6	99	349	41,5	94,7	396	43,4	98,8
303	73,6	99,7	350	47,1	99,2	397	44,3	98,9
304	62,2	'm'	351	53,1	99,7	398	43	98,8
305	29,2	'm'	352	46,4	0	399	42,2	98,8
306	46,4	22	353	42,5	0,7	400	42,7	98,8
307	47,3	13,8	354	43,6	58,6	401	45	99
308	47,2	12,5	355	47,1	87,5	402	43,6	98,9
309	47,9	11,5	356	54,1	99,5	403	42,2	98,8
310	47,8	35,5	357	62,9	99	404	44,8	99
311	49,2	83,3	358	72,6	99,6	405	43,4	98,8
312	52,7	96,4	359	82,4	99,5	406	45	99
313	57,4	99,2	360	88	99,4	407	42,2	54,3
314	61,8	99	361	46,4	0	408	61,2	31,9

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
409	56,3	72,3	456	44,1	92,6	503	21,9	'm'
410	59,7	99,1	457	46,8	99,2	504	12,8	0
411	62,3	99	458	47,2	99,3	505	0	0
412	67,9	99,2	459	51	100	506	0	0
413	69,5	99,3	460	53,2	99,7	507	0	0
414	73,1	99,7	461	53,1	99,7	508	0	0
415	77,7	99,8	462	55,9	53,1	509	0	0
416	79,7	99,7	463	53,9	13,9	510	0	0
417	82,5	99,5	464	52,5	'm'	511	0	0
418	85,3	99,4	465	51,7	'm'	512	0	0
419	86,6	99,4	466	51,5	52,2	513	0	0
420	89,4	99,4	467	52,8	80	514	30,5	25,6
421	62,2	0	468	54,9	95	515	19,7	56,9
422	52,7	96,4	469	57,3	99,2	516	16,3	45,1
423	50,2	99,8	470	60,7	99,1	517	27,2	4,6
424	49,3	99,6	471	62,4	'm'	518	21,7	1,3
425	52,2	99,8	472	60,1	'm'	519	29,7	28,6
426	51,3	100	473	53,2	'm'	520	36,6	73,7
427	51,3	100	474	44	'm'	521	61,3	59,5
428	51,1	100	475	35,2	'm'	522	40,8	0
429	51,1	100	476	30,5	'm'	523	36,6	27,8
430	51,8	99,9	477	26,5	'm'	524	39,4	80,4
431	51,3	100	478	22,5	'm'	525	51,3	88,9
432	51,1	100	479	20,4	'm'	526	58,5	11,1
433	51,3	100	480	19,1	'm'	527	60,7	'm'
434	52,3	99,8	481	19,1	'm'	528	54,5	'm'
435	52,9	99,7	482	13,4	'm'	529	51,3	'm'
436	53,8	99,6	483	6,7	'm'	530	45,5	'm'
437	51,7	99,9	484	3,2	63,8	531	40,8	'm'
438	53,5	99,6	485	14,3	0	532	38,9	'm'
439	52	99,8	486	34,1	75,7	533	36,6	'm'
440	51,7	99,9	487	23,9	79,2	534	36,1	72,7
441	53,2	99,7	488	31,7	19,4	535	44,8	78,9
442	54,2	99,5	489	32,1	5,8	536	51,6	91,1
443	55,2	99,4	490	35,9	0,8	537	59,1	99,1
444	53,8	99,6	491	36,6	'm'	538	66	99,1
445	53,1	99,7	492	38,7	'm'	539	75,1	99,9
446	55	99,4	493	38,4	'm'	540	81	8
447	57	99,2	494	39,4	'm'	541	39,1	0
448	61,5	99	495	39,7	'm'	542	53,8	89,7
449	59	5,7	496	40,5	'm'	543	59,7	99,1
450	59	0	497	40,8	'm'	544	64,8	99
451	57,3	59,8	498	39,7	'm'	545	70,6	96,1
452	64,1	99	499	39,2	'm'	546	72,6	19,6
453	70,9	90,5	500	38,7	'm'	547	72	6,3
454	58	0	501	32,7	'm'	548	68,9	0,1
455	41,5	59,8	502	30,1	'm'	549	67,7	'm'

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
550	66,8	'm'	597	32,9	70,2	644	48,6	'm'
551	64,3	16,97	598	43	79	645	47,5	'm'
552	64,9	12,5	599	57,4	98,9	646	46,5	'm'
553	63,6	7,7	600	72,1	73,8	647	46	11,3
554	63	38,2	601	53	0	648	45,6	42,8
555	64,4	11,8	602	48,1	86	649	47,1	83
556	63	0	603	56,2	99	650	46,2	99,3
557	63,6	5	604	65,4	98,9	651	47,9	99,7
558	63,3	9,1	605	72,9	99,7	652	49,5	99,9
559	60,1	8,4	606	67,5	'm'	653	50,6	99,7
560	61	0,9	607	39	'm'	654	51	99,6
561	59,7	'm'	608	41,9	38,1	655	53	99,3
562	58,7	'm'	609	44,1	80,4	656	54,9	99,1
563	56	'm'	610	46,8	99,4	657	55,7	99
564	53,9	'm'	611	48,7	99,9	658	56	99
565	52,1	'm'	612	50,5	99,7	659	56,1	9,3
566	49,9	'm'	613	52,5	90,3	660	55,6	'm'
567	46,4	'm'	614	51	1,8	661	55,4	'm'
568	43,6	'm'	615	50	'm'	662	54,9	51,3
569	40,8	'm'	616	49,1	'm'	663	54,9	59,8
570	37,5	'm'	617	47	'm'	664	54	39,3
571	27,8	'm'	618	43,1	'm'	665	53,8	'm'
572	17,1	0,6	619	39,2	'm'	666	52	'm'
573	12,2	0,9	620	40,6	0,5	667	50,4	'm'
574	11,5	1,1	621	41,8	53,4	668	50,6	0
575	8,7	0,5	622	44,4	65,1	669	49,3	41,7
576	8	0,9	623	48,1	67,8	670	50	73,2
577	5,3	0,2	624	53,8	99,2	671	50,4	99,7
578	4	0	625	58,6	98,9	672	51,9	99,5
579	3,9	0	626	63,6	98,8	673	53,6	99,3
580	0	0	627	68,5	99,2	674	54,6	99,1
581	0	0	628	72,2	89,4	675	56	99
582	0	0	629	77,1	0	676	55,8	99
583	0	0	630	57,8	79,1	677	58,4	98,9
584	0	0	631	60,3	98,8	678	59,9	98,8
585	0	0	632	61,9	98,8	679	60,9	98,8
586	0	0	633	63,8	98,8	680	63	98,8
587	8,7	22,8	634	64,7	98,9	681	64,3	98,9
588	16,2	49,4	635	65,4	46,5	682	64,8	64
589	23,6	56	636	65,7	44,5	683	65,9	46,5
590	21,1	56,1	637	65,6	3,5	684	66,2	28,7
591	23,6	56	638	49,1	0	685	65,2	1,8
592	46,2	68,8	639	50,4	73,1	686	65	6,8
593	68,4	61,2	640	50,5	'm'	687	63,6	53,6
594	58,7	'm'	641	51	'm'	688	62,4	82,5
595	31,6	'm'	642	49,4	'm'	689	61,8	98,8
596	19,9	8,8	643	49,2	'm'	690	59,8	98,8

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
691	59,2	98,8	738	39,9	89,8	785	56,6	52,4
692	59,7	98,8	739	42,3	98,6	786	58	50,3
693	61,2	98,8	740	43,7	98,8	787	58,6	20,6
694	62,2	49,4	741	45,5	99,1	788	58,7	'm'
695	62,8	37,2	742	45,6	99,2	789	59,3	'm'
696	63,5	46,3	743	48,1	99,7	790	58,6	'm'
697	64,7	72,3	744	49	100	791	60,5	9,7
698	64,7	72,3	745	49,8	99,9	792	59,2	9,6
699	65,4	77,4	746	49,8	99,9	793	59,9	9,6
700	66,1	69,3	747	51,9	99,5	794	59,6	9,6
701	64,3	'm'	748	52,3	99,4	795	59,9	6,2
702	64,3	'm'	749	53,3	99,3	796	59,9	9,6
703	63	'm'	750	52,9	99,3	797	60,5	13,1
704	62,2	'm'	751	54,3	99,2	798	60,3	20,7
705	61,6	'm'	752	55,5	99,1	799	59,9	31
706	62,4	'm'	753	56,7	99	800	60,5	42
707	62,2	'm'	754	61,7	98,8	801	61,5	52,5
708	61	'm'	755	64,3	47,4	802	60,9	51,4
709	58,7	'm'	756	64,7	1,8	803	61,2	57,7
710	55,5	'm'	757	66,2	'm'	804	62,8	98,8
711	51,7	'm'	758	49,1	'm'	805	63,4	96,1
712	49,2	'm'	759	52,1	46	806	64,6	45,4
713	48,8	40,4	760	52,6	61	807	64,1	5
714	47,9	'm'	761	52,9	0	808	63	3,2
715	46,2	'm'	762	52,3	20,4	809	62,7	14,9
716	45,6	9,8	763	54,2	56,7	810	63,5	35,8
717	45,6	34,5	764	55,4	59,8	811	64,1	73,3
718	45,5	37,1	765	56,1	49,2	812	64,3	37,4
719	43,8	'm'	766	56,8	33,7	813	64,1	21
720	41,9	'm'	767	57,2	96	814	63,7	21
721	41,3	'm'	768	58,6	98,9	815	62,9	18
722	41,4	'm'	769	59,5	98,8	816	62,4	32,7
723	41,2	'm'	770	61,2	98,8	817	61,7	46,2
724	41,8	'm'	771	62,1	98,8	818	59,8	45,1
725	41,8	'm'	772	62,7	98,8	819	57,4	43,9
726	43,2	17,4	773	62,8	98,8	820	54,8	42,8
727	45	29	774	64	98,9	821	54,3	65,2
728	44,2	'm'	775	63,2	46,3	822	52,9	62,1
729	43,9	'm'	776	62,4	'm'	823	52,4	30,6
730	36	'm'	777	60,3	'm'	824	50,4	'm'
731	56,8	10,7	778	58,7	'm'	825	48,6	'm'
732	57,1	'm'	779	57,2	'm'	826	47,9	'm'
733	52	'm'	780	56,1	'm'	827	46,8	'm'
734	44,4	'm'	781	56	9,3	828	46,9	9,4
735	40,2	'm'	782	55,2	26,3	829	49,5	41,7
736	39,2	16,5	783	54,8	42,8	830	50,5	37,8
737	38,9	73,2	784	55,7	47,1	831	52,3	20,4

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
832	54,1	30,7	879	60,3	1,2	926	56,4	38
833	56,3	41,8	880	60,5	2,9	927	56,4	11
834	58,7	26,5	881	61,2	34,1	928	56,4	35,1
835	57,3	'm'	882	61,6	13,2	929	54	7,3
836	59	'm'	883	61,5	16,4	930	53,4	5,4
837	59,8	'm'	884	61,2	16,4	931	52,3	27,6
838	60,3	'm'	885	61,3	'm'	932	52,1	32
839	61,2	'm'	886	63,1	'm'	933	52,3	33,4
840	61,8	'm'	887	63,2	4,8	934	52,2	34,9
841	62,5.	'm'	888	62,3	22,3	935	52,8	60,1
842	62,4	'm'	889	62	38,5	936	53,7	69,7
843	61,5	'm'	890	61,5	29,6	937	54	70,7
844	63,7	'm'	891	61,6	29,6	938	55,1	71,7
845	61,9	'm'	892	61,8	28,1	939	55,2	46
846	61,6	29,7	893	62	29,6	940	54,7	12,6
847	60,3	'm'	894	62	16,3	941	52,5	0
848	59,2	'm'	895	61,1	'm'	942	51,8	24,7
849	57,3	'm'	896	61,2	'm'	943	51,4	43,9
850	52,3	'm'	897	60,7	19,2	944	50,9	71,1
851	49,3	'm'	898	60,7	32,5	945	51,2	76,8
852	47,3	'm'	899	60,9	17,8	946	50,3	87,5
853	46,3	38,8	900	60,1	19,2	947	50,2	99,8
854	46,8	35,1	901	59,3	38,2	948	50,9	100
855	46,6	'm'	902	59,9	45	949	49,9	99,7
856	44,3	'm'	903	59,4	32,4	950	50,9	100
857	43,1	'm'	904	59,9	23,5	951	49,8	99,7
858	42,4	2,1	905	59,2	40,8	952	50,4	99,8
859	41,8	2,4	906	59,5	'm'	953	50,4	99,8
860	43,8	68,8	907	58,2	'm'	954	49,7	99,7
861	44,6	89,2	908	57,6	'm'	955	51	100
862	46	99,2	909	57,1	'm'	956	50,3	99,8
863	46,9	99,4	910	57	0,6	957	50,2	99,8
864	47,9	99,7	911	57	26,3	958	49,9	99,7
865	50,2	99,8	912	56,5	29,2	959	50,9	100
866	51,2	99,6	913	56,3	20,5	960	50	99,7
867	52,3	99,4	914	56,1	'm'	961	50,2	99,8
868	53	99,3	915	55,2	'm'	962	50,2	99,8
869	54,2	99,2	916	54,7	17,5	963	49,9	99,7
870	55,5	99,1	917	55,2	29,2	964	50,4	99,8
871	56,7	99	918	55,2	29,2	965	50,2	99,8
872	57,3	98,9	919	55,9	16	966	50,3	99,8
873	58	98,9	920	55,9	26,3	967	49,9	99,7
874	60,5	31,1	921	56,1	36,5	968	51,1	100
875	60,2	'm'	922	55,8	19	969	50,6	99,9
876	60,3	'm'	923	55,9	9,2	970	49,9	99,7
877	60,5	6,3	924	55,8	21,9	971	49,6	99,6
878	61,4	19,3	925	56,4	42,8	972	49,4	99,6

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
973	49	99,5	1020	49,1	'm'	1067	45,5	'm'
974	49,8	99,7	1021	49,4	'm'	1068	45,5	'm'
975	50,9	100	1022	48,3	'm'	1069	44,2	'm'
976	50,4	99,8	1023	49,4	'm'	1070	43	'm'
977	49,8	99,7	1024	48,5	'm'	1071	42,5	'm'
978	49,1	99,5	1025	48,7	'm'	1072	41	'm'
979	50,4	99,8	1026	48,7	'm'	1073	39,9	'm'
980	49,8	99,7	1027	49,1	'm'	1074	39,9	38,2
981	49,3	99,5	1028	49	'm'	1075	40,1	48,1
982	49,1	99,5	1029	49,8	'm'	1076	39,9	48
983	49,9	99,7	1030	48,7	'm'	1077	39,4	59,3
984	49,1	99,5	1031	48,5	'm'	1078	43,8	19,8
985	50,4	99,8	1032	49,3	31,3	1079	52,9	0
986	50,9	100	1033	49,7	45,3	1080	52,8	88,9
987	51,4	99,9	1034	48,3	44,5	1081	53,4	99,5
988	51,5	99,9	1035	49,8	61	1082	54,7	99,3
989	52,2	99,7	1036	49,4	64,3	1083	56,3	99,1
990	52,8	74,1	1037	49,8	64,4	1084	57,5	99
991	53,3	46	1038	50,5	65,6	1085	59	98,9
992	53,6	36,4	1039	50,3	64,5	1086	59,8	98,9
993	53,4	33,5	1040	51,2	82,9	1087	60,1	98,9
994	53,9	58,9	1041	50,5	86	1088	61,8	48,3
995	55,2	73,8	1042	50,6	89	1089	61,8	55,6
996	55,8	52,4	1043	50,4	81,4	1090	61,7	59,8
997	55,7	9,2	1044	49,9	49,9	1091	62	55,6
998	55,8	2,2	1045	49,1	20,1	1092	62,3	29,6
999	56,4	33,6	1046	47,9	24	1093	62	19,3
1000	55,4	'm'	1047	48,1	36,2	1094	61,3	7,9
1001	55,2	'm'	1048	47,5	34,5	1095	61,1	19,2
1002	55,8	26,3	1049	46,9	30,3	1096	61,2	43
1003	55,8	23,3	1050	47,7	53,5	1097	61,1	59,7
1004	56,4	50,2	1051	46,9	61,6	1098	61,1	98,8
1005	57,6	68,3	1052	46,5	73,6	1099	61,3	98,8
1006	58,8	90,2	1053	48	84,6	1100	61,3	26,6
1007	59,9	98,9	1054	47,2	87,7	1101	60,4	'm'
1008	62,3	98,8	1055	48,7	80	1102	58,8	'm'
1009	63,1	74,4	1056	48,7	50,4	1103	57,7	'm'
1010	63,7	49,4	1057	47,8	38,6	1104	56	'm'
1011	63,3	9,8	1058	48,8	63,1	1105	54,7	'm'
1012	48	0	1059	47,4	5	1106	53,3	'm'
1013	47,9	73,5	1060	47,3	47,4	1107	52,6	23,2
1014	49,9	99,7	1061	47,3	49,8	1108	53,4	84,2
1015	49,9	48,8	1062	46,9	23,9	1109	53,9	99,4
1016	49,6	2,3	1063	46,7	44,6	1110	54,9	99,3
1017	49,9	'm'	1064	46,8	65,2	1111	55,8	99,2
1018	49,3	'm'	1065	46,9	60,4	1112	57,1	99
1019	49,7	47,5	1066	46,7	61,5	1113	56,5	00 1

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
1114	58,9	98,9	1161	47,8	59,4	1208	57	70,1
1115	58,7	98,9	1162	48,1	77,1	1209	56,4	59,6
1116	59,8	98,9	1163	48,4	87,6	1210	56,7	39
1117	61	98,8	1164	49,6	87,5	1211	55,9	68,1
1118	60,7	19,2	1165	51	81,4	1212	56,3	79,1
1119	59,4	'm'	1166	51,6	66,7	1213	56,7	89,7
1120	57,9	'm'	1167	53,3	63,2	1214	56	89,4
1121	57,6	'm'	1168	55,2	62	1215	56	93,1
1122	56,3.	'm'	1169	55,7	43,9	1216	56,4	93,1
1123	55	'm'	1170	56,4	30,7	1217	56,7	94,4
1124	53,7	'm'	1171	56,8	23,4	1218	56,9	94,8
1125	52,1	'm'	1172	57	'm'	1219	57	94,1
1126	51,1	'm'	1173	57,6	'm'	1220	57,7	94,3
1127	49,7	25,8	1174	56,9	'm'	1221	57,5	93,7
1128	49,1	46,1	1175	56,4	4	1222	58,4	93,2
1129	48,7	46,9	1176	57	23,4	1223	58,7	93,2
1130	48,2	46,7	1177	56,4	41,7	1224	58,2	93,7
1131	48	70	1178	57	49,2	1225	58,5	93,1
1132	48	70	1179	57,7	56,6	1226	58,8	86,2
1133	47,2	67,6	1180	58,6	56,6	1227	59	72,9
1134	47,3	67,6	1181	58,9	64	1228	58,2	59,9
1135	46,6	74,7	1182	59,4	68,2	1229	57,6	8,5
1136	47,4	13	1183	58,8	71,4	1230	57,1	57,6
1137	46,3	'm'	1184	60,1	71,3	1231	57,2	74,4
1138	45,4	'm'	1185	60,6	79,1	1232	57	79,1
1139	45,5	24,8	1186	60,7	83,3	1233	56,7	67,2
1140	44,8	73,8	1187	60,7	77,1	1234	56,8	69,1
1141	46,6	99	1188	60	73,5	1235	56,9	71,3
1142	46,3	98,9	1189	60,2	55,5	1236	57	77,3
1143	48,5	99,4	1190	59,7	54,4	1237	57,4	78,2
1144	49,9	99,7	1191	59,8	73,3	1238	57,3	70,6
1145	49,1	99,5	1192	59,8	77,9	1239	57,7	64
1146	49,1	99,5	1193	59,8	73,9	1240	57,5	55,6
1147	51	100	1194	60	76,5	1241	58,6	49,6
1148	51,5	99,9	1195	59,5	82,3	1242	58,2	41,1
1149	50,9	100	1196	59,9	82,8	1243	58,8	40,6
1150	51,6	99,9	1197	59,8	65,8	1244	58,3	21,1
1151	52,1	99,7	1198	59	48,6	1245	58,7	24,9
1152	50,9	100	1199	58,9	62,2	1246	59,1	24,8
1153	52,2	99,7	1200	59,1	70,4	1247	58,6	'm'
1154	51,5	98,3	1201	58,9	62,1	1248	58,8	'm'
1155	51,5	47,2	1202	58,4	67,4	1249	58,8	'm'
1156	50,8	78,4	1203	58,7	58,9	1250	58,7	'm'
1157	50,3	83	1204	58,3	57,7	1251	59,1	'm'
1158	50,3	31,7	1205	57,5	57,8	1252	59,1	'm'
1159	49,3	31,3	1206	57,2	57,6	1253	59,4	'm'
1160	48,8	21,5	1207	57,1	42,6	1254	60,6	2,6

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
1255	59,6	'm'	1302	59,5	16,2	1349	60,7	59,1
1256	60,1	'm'	1303	59,7	50	1350	60,9	56,8
1257	60,6	'm'	1304	59,7	31,4	1351	60,7	58,1
1258	59,6	4,1	1305	60,1	43,1	1352	59,6	78,4
1259	60,7	7,1	1306	60,8	38,4	1353	59,6	84,6
1260	60,5	'm'	1307	60,9	40,2	1354	59,4	66,6
1261	59,7	'm'	1308	61,3	49,7	1355	59,3	75,5
1262	59,6	'm'	1309	61,6	45,9	1356	58,9	49,6
1263	59,8	'm'	1310	62	45,9	1357	59,1	75,8
1264	59,6•	4,9	1311	62,2	45,8	1358	59	77,6
1265	60,1	5,9	1312	62,6	46,8	1359	59	67,8
1266	59,9	6,1	1313	62,7	44,3	1360	59	56,7
1267	59,7	'm'	1314	62,9	44,4	1361	58,8	54,2
1268	59,6	'm'	1315	63,1	43,7	1362	58,9	59,6
1269	59,7	22	1316	63,5	46,1	1363	58,9	60,8
1270	59,6	10,3	1317	63,6	40,7	1364	59,3	56,1
1271	59,9	10	1318	64,3	49,5	1365	58,9	48,5
1272	60,6	6,2	1319	63,7	27	1366	59,3	42,9
1273	60,5	7,3	1320	63,8	15	1367	59,4	41,4
1274	60,2	14,8	1321	63,6	18,7	1368	59,6	38,9
1275	60,6	8,2	1322	63,4	8,4	1369	59,4	32,9
1276	60,6	5,5	1323	63,2	8,7	1370	59,3	30,6
1277	61	14,3	1324	63,3	21,6	1371	59,4	30
1278	61	12	1325	62,9	19,7	1372	59,4	25,3
1279	61,3	34,2	1326	63	22,1	1373	58,8	18,6
1280	61,2	17,1	1327	63,1	20,3	1374	59,1	18
1281	61,5	15,7	1328	61,8	19,1	1375	58,5	10,6
1282	61	9,5	1329	61,6	17,1	1376	58,8	10,5
1283	61,1	9,2	1330	61	0	1377	58,5	8,2
1284	60,5	4,3	1331	61,2	22	1378	58,7	13,7
1285	60,2	7,8	1332	60,8	40,3	1379	59,1	7,8
1286	60,2	5,9	1333	61,1	34,3	1380	59,1	6
1287	60,2	5,3	1334	60,7	16,1	1381	59,1	6
1288	59,9	4,6	1335	60,6	16,6	1382	59,4	13,1
1289	59,4	21,5	1336	60,5	18,5	1383	59,7	22,3
1290	59,6	15,8	1337	60,6	29,8	1384	60,7	10,5
1291	59,3	10,1	1338	60,9	19,5	1385	59,8	9,8
1292	58,9	9,4	1339	60,9	22,3	1386	60,2	8,8
1293	58,8	9	1340	61,4	35,8	1387	59,9	8,7
1294	58,9	35,4	1341	61,3	42,9	1388	61	9,1
1295	58,9	30,7	1342	61,5	31	1389	60,6	28,2
1296	58,9	25,9	1343	61,3	19,2	1390	60,6	22
1297	58,7	22,9	1344	61	9,3	1391	59,6	23,2
1298	58,7	24,4	1345	60,8	44,2	1392	59,6	19
1299	59,3	61	1346	60,9	55,3	1393	60,6	38,4
1300	60,1	56	1347	61,2	56	1394	59,8	41,6
1301	60,5	50,5	1348	60,9	60,1	1395	60	47,3

Time s	Initial Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
1396	60,5	55,4	1443	60,3	6,9	1490	58,7	'm'
1397	60,9	58,7	1444	60,8	7	1491	57,9	'm'
1398	61,3	37,9	1445	60,2	9,2	1492	58,2	'm'
1399	61,2	38,3	1446	60,5	21,7	1493	57,6	'm'
1400	61,4	58,7	1447	60,2	22,4	1494	58,3	9,5
1401	61,3	51,3	1448	60,7	31,6	1495	57,2	6
1402	61,4	71,1	1449	60,9	28,9	1496	57,4	27,3
1403	61,1	51	1450	59,6	21,7	1497	58,3	59,9
1404	61,5	56,6	1451	60,2	18	1498	58,3	7,3
1405	61 .	60,6	1452	59,5	16,7	1499	58,8	21,7
1406	61,1	75,4	1453	59,8	15,7	1500	58,8	38,9
1407	61,4	69,4	1454	59,6	15,7	1501	59,4	26,2
1408	61,6	69,9	4155	59,3	15,7	1502	59,1	25,5
1409	61,7	59,6	1456	59	7,5	1503	59,1	26
1410	61,8	54,8	1457	58,8	7,1	1504	59	39,1
1411	61,6	53,6	1458	58,7	16,5	1505	59,5	52,3
1412	61,3	53,5	1459	59,2	50,7	1506	59,4	31
1413	61,3	52,9	1460	59,7	60,2	1507	59,4	27
1414	61,2	54,1	1461	60,4	44	1508	59,4	29,8
1415	61,3	53,2	1462	60,2	35,3	1509	59,4	23,1
1416	61,2	52,2	1463	60,4	17,1	1510	58,9	16
1417	61,2	52,3	1464	59,9	13,5	1511	59	31,5
1418	61	48	1465	59,9	12,8	1512	58,8	25,9
1419	60,9	41,5	1466	59,6	14,8	1513	58,9	40,2
1420	61	32,2	1467	59,4	15,9	1514	58,8	28,4
1421	60,7	22	1468	59,4	22	1515	58,9	38,9
1422	60,7	23,3	1469	60,4	38,4	1516	59,1	35,3
1423	60,8	38,8	1470	59,5	38,8	1517	58,8	30,3
1424	61	40,7	1471	59,3	31,9	1518	59	19
1425	61	30,6	1472	60,9	40,8	1519	58,7	3
1426	61,3	62,6	1473	60,7	39	1520	57,9	0
1427	61,7	55,9	1474	60,9	30,1	1521	58	2,4
1428	62,3	43,4	1475	61	29,3	1522	57,1	'm'
1429	62,3	37,4	1476	60,6	28,4	1523	56,7	'm'
1430	62,3	35,7	1477	60,9	36,3	1524	56,7	5,3
1431	62,8	34,4	1478	60,8	30,5	1525	56,6	2,1
1432	62,8	31,5	1479	60,7	26,7	1526	56,8	'm'
1433	62,9	31,7	1480	60,1	4,7	1527	56,3	'm'
434	62,9	29,9	1481	59,9	0	1528	56,3	'm'
435	62,8	29,4	1482	60,4	36,2	1529	56	'm'
436	62,7	28,7	1483	60,7	32,5	1530	56,7	'm'
437	61,5	14,7	1484	59,9	3,1	1531	56,6	3,8
438	61,9	17,2	1485	59,7	'm'	1532	56,9	'm'
439	61,5	6,1	1486	59,5	'm'	1533	56,9	'm'
440	61	9,9	1487	59,2	'm'	1534	57,4	'm'
441	60,9	4,8	1488	58,8	0,6	1535	57,4	'm'
442	60,6	11,1	1489	58,7	'm'	1536	58,3	12 0

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
1537	58,5	'm'	1584	59,6	84,6	1631	62,8	21,9
1538	59,1	'm'	1585	59,4	76,1	1632	62,2	22,2
1539	59,4	'm'	1586	60,1	76,9	1633	62,5	31
1540	59,6	'm'	1587	59,5	84,6	1634	62,3	31,3
1541	59,5	'm'	1588	59,8	77,5	1635	62,6	31,7
1542	59,6	0,5	1589	60,6	67,9	1636	62,3	22,8
1543	59,3	9,2	1590	59,3	47,3	1637	62,7	12,6
1544	59,4	11,2	1591	59,3	43,1	1638	62,2	15,2
1545	59,1	26,8	1592	59,4	38,3	1639	61,9	32,6
1546	59 *	11,7	1593	58,7	38,2	1640	62,5	23,1
1547	58,8	6,4	1594	58,8	39,2	1641	61,7	19,4
1548	58,7	5	1595	59,1	67,9	1642	61,7	10,8
1549	57,5	'm'	1596	59,7	60,5	1643	61,6	10,2
1550	57,4	'm'	1597	59,5	32,9	1644	61,4	'm'
1551	57,1	1,1	1598	59,6	20	1645	60,8	'm'
1552	57,1	0	1599	59,6	34,4	1646	60,7	'm'
1553	57	4,5	1600	59,4	23,9	1647	61	12,4
1554	57,1	3,7	1601	59,6	15,7	1648	60,4	5,3
1555	57,3	3,3	1602	59,9	41	1649	61	13,1
1556	57,3	16,8	1603	60,5	26,3	1650	60,7	29,6
1557	58,2	29,3	1604	59,6	14	1651	60,5	28,9
1558	58,7	12,5	1605	59,7	21,2	1652	60,8	27,1
1559	58,3	12,2	1606	60,9	19,6	1653	61,2	27,3
1560	58,6	12,7	1607	60,1	34,3	1654	60,9	20,6
1561	59	13,6	1608	59,9	27	1655	61,1	13,9
1562	59,8	21,9	1609	60,8	25,6	1656	60,7	13,4
1563	59,3	20,9	1610	60,6	26,3	1657	61,3	26,1
1564	59,7	19,2	1611	60,9	26,1	1658	60,9	23,7
1565	60,1	15,9	1612	61,1	38	1659	61,4	32,1
1566	60,7	16,7	1613	61,2	31,6	1660	61,7	33,5
1567	60,7	18,1	1614	61,4	30,6	1661	61,8	34,1
1568	60,7	40,6	1615	61,7	29,6	1662	61,7	17
1569	60,7	59,7	1616	61,5	28,8	1663	61,7	2,5
1570	61,1	66,8	1617	61,7	27,8	1664	61,5	5,9
1571	61,1	58,8	1618	62,2	20,3	1665	61,3	14,9
1572	60,8	64,7	1619	61,4	19,6	1666	61,5	17,2
1573	60,1	63,6	1620	61,8	19,7	1667	61,1	'm'
1574	60,7	83,2	1621	61,8	18,7	1668	61,4	'm'
1575	60,4	82,2	1622	61,6	17,7	1669	61,4	8,8
1576	60	80,5	1623	61,7	8,7	1670	61,3	8,8
1577	59,9	78,7	1624	61,7	1,4	1671	61	18
1578	60,8	67,9	1625	61,7	5,9	1672	61,5	13
1579	60,4	57,7	1626	61,2	8,1	1673	61	3,7
1580	60,2	60,6	1627	61,9	45,8	1674	60,9	3,1
1581	59,6	72,7	1628	61,4	31,5	1675	60,9	4,7
1582	59,9	73,6	1629	61,7	22,3	1676	60,6	4,1
1583	59,8	74,1	1630	62,4	21,7	1677	60,6	6,7

Time s	Normal Speed %	Normal Torque %	Time s	Normal Speed %	Normal Torque %	Time s	Normal speed %	Normal torque %
1678	60,6	12,8	1725	60,2	18,6	1772	58,4	35,5
1679	60,7	11,9	1726	60,3	11,9	1773	58,4	29,3
1680	60,6	12,4	1727	60,4	11,6	1774	59	33,8
1681	60,1	12,4	1728	60,6	10,6	1775	59	18,7
1682	60,5	12	1729	60,8	16	1776	58,8	9,8
1683	60,4	11,8	1730	60,9	17	1777	58,8	23,9
1684	59,9	12,4	1731	60,9	16,1	1778	59,1	48,2
1685	59,6	12,4	1732	60,7	11,4	1779	59,4	37,2
1686	59,6	9,1	1733	60,9	11,3	1780	59,6	29,1
1687	59,9	0	1734	61,1	11,2	1781	50	25
1688	59,9	20,4	1735	61,1	25,6	1782	40	20
1689	59,8	4,4	1736	61	14,6	1783	30	15
1690	59,4	3,1	1737	61	10,4	1784	20	10
1691	59,5	26,3	1738	60,6	'm'	1785	10	5
1692	59,6	20,1	1739	60,9	'm'	1786	0	0
1693	59,4	35	1740	60,8	4,8	1787	0	0
1694	60,9	22,1	1741	59,9	'm'	1788	0	0
1695	60,5	12,2	1742	59,8	'm'	1789	0	0
1696	60,1	11	1743	59,1	'm'	1790	0	0
1697	60,1	8,2	1744	58,8	'm'	1791	0	0
1698	60,5	6,7	1745	58,8	'm'	1792	0	0
1699	60	5,1	1746	58,2	'm'	1793	0	0
1700	60	5,1	1747	58,5	14,3	1794	0	0
1701	60	9	1748	57,5	4,4	1795	0	0
1702	60,1	5,7	1749	57,9	0	1796	0	0
1703	59,9	8,5	1750	57,8	20,9	1797	0	0
1704	59,4	6	1751	58,3	9,2	1798	0	0
1705	59,5	5,5	1752	57,8	8,2	1799	0	0
1706	59,5	14,2	1753	57,5	15,3	1800	0	0
1707	59,5	6,2	1754	58,4	38			
1708	59,4	10,3	1755	58,1	15,4			
1709	59,6	13,8	1756	58,8	11,8			
1710	59,5	13,9	1757	58,3	8,1			
1711	60,1	18,9	1758	58,3	5,5			
1712	59,4	13,1	1759	59	4,1			
1713	59,8	5,4	1760	58,2	4,9			
1714	59,9	2,9	1761	57,9	10,1			
1715	60,1	7,1	1762	58,5	7,5			
1716	59,6	12	1763	57,4	7			
1717	59,6	4,9	1764	58,2	6,7			
1718	59,4	22,7	1765	58,2	6,6			
1719	59,6	22	1766	57,3	17,3			
1720	60,1	17,4	1767	58	11,4			
1721	60,2	16,6	1768	57,5	47,4			
1722	59,4	28,6	1769	57,4	28,8			
1723	60,3	22,4	1770	58,8	24,3			
1724	59,9	20	1771	57,7	25,5			

ETC ENGINE DYNAMOMETER SCHEDULE

"m"= motoring.

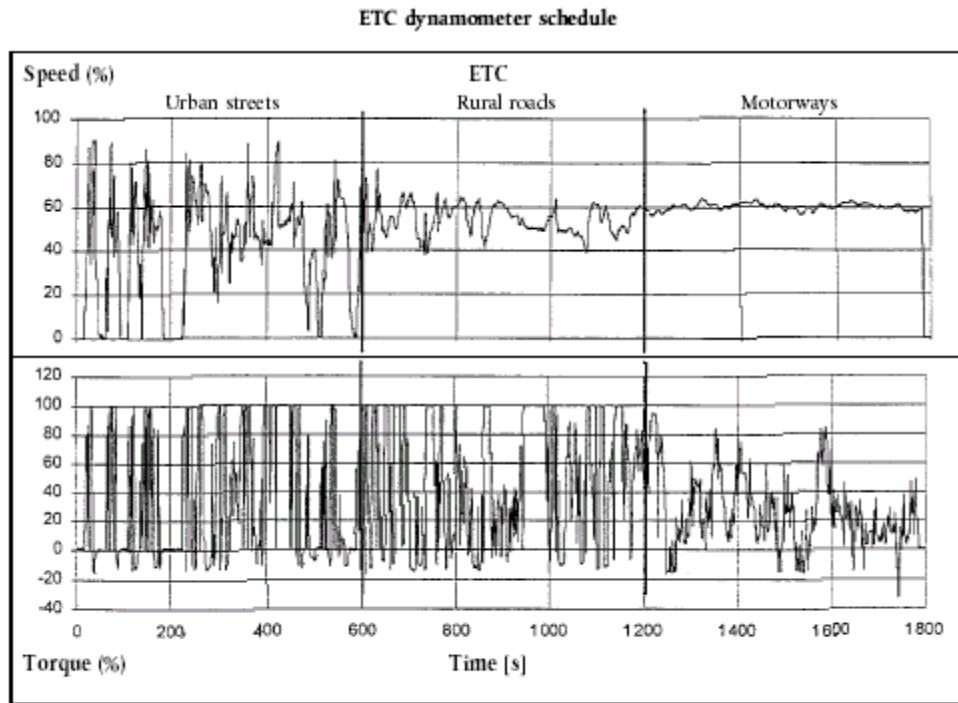


Figure 5 :- ETC dynamometer schedule

A Graphical display of the ETC dynamometer schedule is shown in figure 5

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. The respective sections of Chapter V 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, only a full flow dilution system shall be used for determining gaseous and particulate emissions, and is considered the reference system. However, partial flow dilution systems may be approved by the Technical Service, if their equivalency according to section 6.2 to Chapter I is proven, and if a detailed description of the data evaluation and calculation procedures is submitted to the Technical Service.

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 to this Chapter. The speed measuring system shall have an accuracy of $\pm 2\%$ of reading. The torque measuring system shall have an accuracy of $\pm 3\%$ of reading in the range $> 20\%$ of full scale, and an accuracy of $\pm 0,6\%$ of full scale in the range $\leq 20\%$ 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 engine's maximum value
Temperatures ≤ 600 K (327 °C)	± 2K 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	± 0,1kPa absolute
Relative humidity	± 3% absolute
Absolute humidity	± 5% of reading

2.3. Exhaust Gas Flow

For calculation of the emissions in the raw exhaust, it is necessary to know the exhaust gas flow (see section 4.4 of Appendix 1). For the determination of the exhaust flow either of the following methods may be used:

- a) Direct measurement of the exhaust flow by flow nozzle or equivalent metering system;
- b) Measurement of the air flow and the fuel flow by suitable metering systems and
calculation of the exhaust flow by the following equation:

$$G_{EXHW} = G_{AIRW} + G_{FUEL} \text{ (for wet exhaust mass)}$$

The accuracy of exhaust flow determination shall be ± 2,5 % of reading or better.

2.4. Diluted exhaust gas flow

For calculation of the emissions in the diluted exhaust using a full flow dilution system (mandatory for the ETC), it is necessary to know the diluted exhaust gas flow (see section 4.3 of Appendix 2). The total mass flow rate of the diluted exhaust (G_{TOTW}) or the total mass of the diluted exhaust gas over the cycle (M_{TOTW}) shall be measured with a PDP or CFV (Chapter V, section 2.3.1). The accuracy shall be ± 2 % of reading or better, and shall be determined according to the provisions of Chapter III, Appendix 5, section 2.4.

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). 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.

The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimise additional errors.

3.1.1. Measurement Error

The total measurement error, including the cross sensitivity to other gases (see Chapter III, Appendix 5, section 1.9), shall not exceed $\pm 5\%$ of the reading or $\pm 3,5\%$ of full scale, whichever is smaller. For concentrations of less than 100 ppm the measurement error shall not exceed $\pm 4\text{ ppm}$.

3.1.2. Repeatability

The repeatability, 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 $\pm 1\%$ of full scale concentration for each range used above 155 ppm (or ppmC) or $\pm 2\%$ 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 seconds period shall not exceed 2 % of full scale on all ranges used.

3.1.4. Zero Drift

The zero drift during a one hour period shall be less than 2 % of full scale on the lowest range used. The zero response is defined as the mean response, including noise, to a zero gas during a 30 seconds time interval.

3.1.5. Span Drift

The span drift during a one hour period shall be less than 2 % of full scale on the lowest range used. Span is defined as the difference between the span response and the zero response. The span response is defined as the mean response, including noise, to a span gas during a 30 seconds time interval.

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 describe the measurement principles to be used. A detailed description of the measurement systems is given in Chapter V. 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, pipework, etc. heated so as to maintain a gas temperature of $463K \pm 10K$ ($190 \pm 10 ^\circ C$). 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).

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 ($150 ^\circ C$) from the hydrocarbons measured according to section 3.3.3.

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 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 ChemiLuminescent Detector (CLD) or Heated ChemiLuminescent Detector (HCLD) type with a NO₂/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) is satisfied.

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 permissible to acquire a sample from each group individually and calculate an average exhaust 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 aftertreatment system, the exhaust sample shall be taken downstream of the exhaust aftertreatment system.

3.4.2. Diluted Exhaust Gas (mandatory for ETC, optional for ESC)

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.

For the ETC, 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 (ESC only) or a full flow dilution system (mandatory for ETC). The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas at or below 325K (52 °C) immediately upstream of the filter holders. Dehumidifying the dilution air before entering the dilution system is permitted, and especially useful if dilution air humidity is high. The temperature of the dilution air shall be $298\text{ K} \pm 5\text{ K}$ ($25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$). If the ambient temperature is below 293K (20 °C), dilution air pre-heating above the upper temperature limit of 303K (30 °C) is recommended. However, the dilution air temperature must not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel.

The partial flow dilution system has to be designed to split the exhaust stream into two fractions, the smaller one being diluted with air and subsequently used for particulate measurement. For this it is essential that the dilution ratio be determined very accurately. Different splitting methods can be applied, whereby the type of splitting used dictates to a significant degree the sampling hardware and procedures to be used (Chapter V, section 2.2). The particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, and the installation shall comply with the provisions of section 3.4.1.

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 pair of filters (see section 4.1.3) 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

4.1.1. Filter Specification

Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required. All filter types shall have a $0,3\text{ }\mu\text{m}$ DOP (di-octylphthalate) collection efficiency of at least 95 % at a gas face velocity between 35 and 80 cm/s.

4.1.2. Filter Size

Particulate filters must have a minimum diameter of 47 mm (37 mm stain diameter). Larger diameter filters are acceptable (section 4.1.5).

4.1.3. Primary and Back-up Filters

The diluted exhaust shall be sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter shall

be located no more than 100 mm downstream of, and shall not be in contact with the primary filter. The filters may be weighed separately or as a pair with the filters placed stain side to stain side.

4.1.4. Filter Face Velocity

A gas face velocity through the filter of 35 to 80 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.

4.1.5. Filter Loading

The recommended minimum filter loading shall be 0,5 mg/1075 mm² stain area. For the most common filter sizes the values are shown in Table 9.

Table 9

Recommended Filter Loadings

Filter Diameter (mm)	Recommended Stain (mm)	Recommended Minimum loading (mg)
47	37	0,5
70	60	1,3
90	80	2,3
110	100	3,6

4.2. Weighing Chamber and Analytical Balance Specifications

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 dewpoint 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 or reference filter pairs shall be weighed within 4 hours of, but preferably at the same time as the sample filter (pair) weighings. They shall be the same size and material as the sample filters.

If the average weight of the reference filters (reference filter pairs) changes between sample filter weighings by more than $\pm 5\%$ ($\pm 7,5\%$ for the filter pair respectively) of the recommended minimum filter loading (section 4.1.5.), 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 (pair) weighings 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 rerunning the test.

4.2.3. *Analytical Balance*

The analytical balance used to determine the weights of all filters shall have a precision (standard deviation) of $20\text{ }\mu\text{g}$ and a resolution of $10\text{ }\mu\text{g}$ (1 digit = $10\text{ }\mu\text{g}$). For filters less than 70 mm diameter, the precision and resolution shall be $2\text{ }\mu\text{g}$ and μg , respectively.

4.3. Additional Specifications for Particulate Measurement

All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, must be designed to minimise deposition or alteration of the particulates. All parts must be made of electrically conductive materials that do not react with exhaust gas components, and must be electrically grounded to prevent electrostatic effects.

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.

- A data processing unit capable of performing the functions described in Chapter III, Appendix 1, section 6.
- A printer and/or electronic storage medium to record and output the required smoke values specified in Chapter III, Appendix 1, section 6.3.

5.2. Specific Requirements

5.2.1. Linearity

The linearity shall be within $\pm 2\%$ opacity.

5.2.2. Zero Drift

The zero drift during a one hour period shall not exceed $\pm 1\%$ 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 fulfil the accuracy requirements of this Directive. 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.

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 \leq 1 ppm C1, \leq 1 ppm CO, \leq 400 ppm CO₂, \leq 0,1 ppm NO)

Purified oxygen

(Purity > 99,5 % vol O₂)

Hydrogen-helium mixture

(40 \pm 2 % hydrogen, balance helium)

(Contamination \leq 1 ppm C1, \leq 400 ppm CO₂)

Purified synthetic air

(Contamination \leq 1 ppm C1, \leq 1 ppm CO, \leq 400 ppm CO₂, \leq 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:

C₃H₈ and purified synthetic air (see section 1.2.1);

CO and purified nitrogen;

NOx and purified nitrogen (the amount of NO₂ contained in this calibration gas must not exceed 5 % of the NO content);

CO₂ and purified nitrogen

CH₄ and purified synthetic air

C₂H₆ 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).

The gases used for calibration and span may also be obtained by means of a gas divider, diluting with purified N₂ or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted calibration gases may be determined to within ± 2 %.

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 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 analyser 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.

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 shows a lower concentration compared to the introduced concentration, this points to calibration or leakage problems.

1.5. Calibration Procedure

1.5.1. *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.

1.5.2. *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.

1.5.3. *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).

1.5.4. *Calibration*

Each normally used operating range shall be calibrated.

Using purified synthetic air (or nitrogen), the CO, CO₂, 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 according to section 1.5.5.

The zero setting shall be rechecked and the calibration procedure repeated, if necessary.

1.5.5. *Establishment of the Calibration Curve*

1.5.5.1. General Guidelines

The analyser calibration curve shall be established by at least five calibration points (excluding zero) spaced as uniformly as possible. The highest nominal concentration must be equal to or higher than 90 % of full scale.

The calibration curve shall be calculated by the method of least squares. If the resulting polynomial degree is greater than 3, the number of calibration points (zero included) must be at least equal to this polynomial degree plus 2.

The calibration curve must not differ by more than $\pm 2\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero.

From the calibration curve and the calibration points, it is possible to verify that

the calibration has been carried out correctly. The different characteristic parameters of the analyser must be indicated, particularly:

- the measuring range;
- the sensitivity;
- the date of carrying out the calibration.

1.5.5.2. Calibration below 15 % of Full Scale

The analyser calibration curve shall be established by at least 4 additional calibration points (excluding zero) spaced nominally equally below 15 % of full scale.

The calibration curve is calculated by the method of least squares.

The calibration curve must not differ by more than $\pm 4\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero.

1.5.5.3. 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. 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 $\pm 4\%$ 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.

1.7. Efficiency test of the NOx Converter

The efficiency of the converter used for the conversion of NO₂ into NO shall be tested as given in sections 1.7.1 to 1.7.8 (Figure 6).

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) 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 NO₂ concentration of the gas mixture to less than 5 % of the NO concentration). The NOx 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 NOx 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 (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. The indicated concentration d shall be recorded (The analyser is in the NO mode).

1.7.6. NOx Mode

The NO analyser is then switched to the NO_x mode so that the gas mixture (consisting of NO, NO₂, O₂ and N₂) now passes through the converter. The indicated concentration a shall be recorded. (The analyser is in the NOx mode).

1.7.7. Deactivation of the Ozonator

The ozonator is now deactivated. The mixture of gases described in section 1.7.6 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 NO_x reading of the analyser shall not deviate by more than $\pm 5\%$ from the value measured according to section 1.7.2. (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, then the highest range which will give the reduction shall be used.

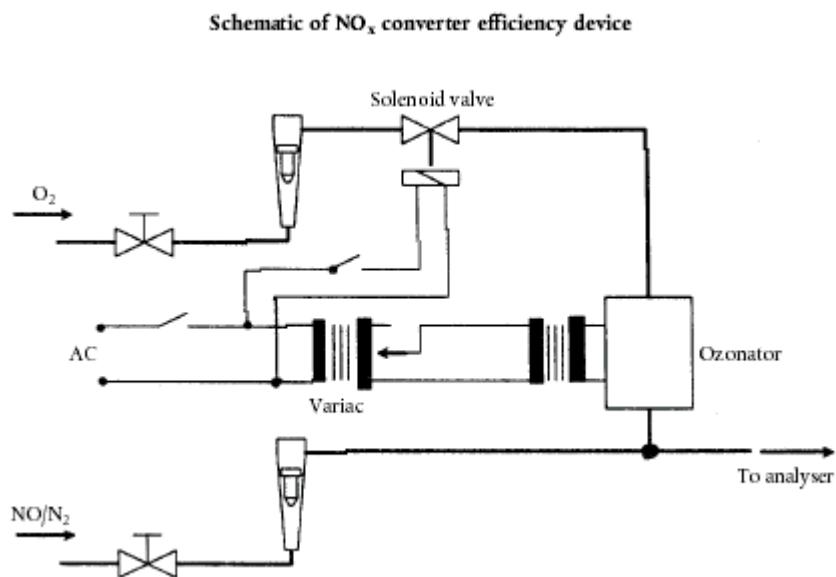


Figure 6

Schematic of NOx converter efficiency device

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.

Response factors shall be determined when introducing an analyser into service and after major service intervals. The response factor (Rf) 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 $298\text{ K} \pm 5\text{ K}$ ($25^\circ\text{C} \pm 5^\circ\text{C}$).

The test gases to be used and the recommended relative response factor ranges are as follows:

Methane and purified synthetic air $1,00 \leq Rf \leq 1,15$

Propylene and purified synthetic air $0,90 \leq Rf \leq 1,10$

Toluene and purified synthetic air $0,90 \leq Rf \leq 1,10$

These values are relative to the response factor (Rf) 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 analyser into service and after major service intervals.

The response factor is defined and shall be determined as described in section 1.8.2. The test gas to be used and the recommended relative response factor range are as follows:

$$\text{Propane and nitrogen } 0,95 \leq R_f \leq 1,05$$

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 analyser 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).

1.8.4.1. Methane Efficiency

Methane 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:

$$CE_M = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

$conc_w$ = HC concentration with CH_4 flowing through the NMC

$conc_{w/o}$ = 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:

$$CE_M = 1 - \frac{conc_w}{conc_{w/o}}$$

where,

$conc_w$ = HC concentration with C₂H₆ flowing through the NMC

$conc_{w/o}$ = HC concentration with C₂H₆ bypassing the NMC

1.9. Interference Effects with CO, CO₂, 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 shall be performed prior to an analyser's initial use and after major service intervals.

1.9.1. CO Analyser Interference Check

Water and CO₂ can interfere with the CO analyser performance. Therefore, a CO₂ 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 CO₂ 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. CO₂ Quench Check

A CO₂ 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 CO₂ 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 CO₂ and NO values recorded as B and C, respectively. The CO₂ 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 CO₂ concentration measured with NDIR in %
- B is the diluted CO₂ 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 CO₂ 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 (H_m, 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) as follows:

$$H_m = 0,9 \times A$$

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 m³/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 air flowrate (Q_s) at each restriction setting (minimum 6 settings) shall be calculated in standard m³/min from the flowmeter data using the manufacturer's prescribed method. The air flow rate shall then be converted to pump flow (V_0) in m³/rev at absolute pump inlet temperature and pressure as follows:

$$V_0 = \frac{Q_s}{n} \times \frac{T}{273} \times \frac{101.3}{P_A}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m³/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:

$$X_0 = \frac{1}{n} \times \sqrt{\frac{\Delta P_p}{P_A}}$$

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:

$$V_0 = D_0 - m \times (X_0)$$

D_0 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 $\pm 0,5\%$ 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) 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:

$$Q_s = \frac{K_v \times P_A}{\sqrt{T}}$$

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 m³/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:

$$K_v = \frac{Q_s \sqrt{T}}{P_A}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m³/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 K_V.

2.4. 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 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.

2.4.1. 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 ([equiv] 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 $\pm 3\%$ of the known mass of the gas injected.

2.4.2. 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 $\pm 0,01$ 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 $\pm 3\%$ of the known mass of the gas injected.

3. CALIBRATION OF THE PARTICULATE MEASURING SYSTEM

3.1. Introduction

Each component shall be calibrated as often as necessary to fulfil the accuracy requirements of this Directive. The calibration method to be used is described in this section for the components indicated in Chapter III, Appendix 4, section 4 and Chapter V, section 2.

3.2. Flow Measurement

The calibration of gas flow meters or flow measurement instrumentation shall be traceable to international and/or national standards. The maximum error of the measured value shall be within $\pm 2\%$ of reading. If the gas flow is determined by differential flow measurement, the maximum error of the difference shall be such that the accuracy of GEDF is within $\pm 4\%$ (see also

Chapter V, section 2.2.1, EGA). It can be calculated by taking the Root-Mean-Square of the errors of each instrument.

3.3. 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 Chapter V, section 2.2.1, EP, if applicable.

3.4. 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 fulfil the accuracy requirements of this Directive. The calibration method to be used is described in this section for the components indicated in Chapter III, Appendix 4, section 5 and Chapter V, section 3.

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, 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 at least every 3 months or whenever a system repair or change is made that could influence calibration.

CHAPTER IV

THE REFERENCE FUEL AS SPECIFIED IN THE APPLICABLE GAZZETE NOTIFICATION SHALL BE USED.

DIESEL FUEL: - AS PER ANNEXURE IV-F OF NOTIFICATION.

LPG (FUEL A AND FUEL B):- AS PER ANNEXURE IV-H OF NOTIFICATION.

CNG(G20, G23, G25):- AS PER ANNEXURE IV-I OF NOTIFICATION.

NOTE:- UNTIL AVAILABILITY OF REFERENCE FUEL LPG(FUEL A AND B), CNG (G20, G23, G25) AS PER ANNEX-IV-H AND IV-I, CNG OR LPG ENGINES WILL BE TESTED AS PER COMMERCIALY AVAILABLE CNG/LPG AS PER GUIDE-LINES GIVEN BY GOI.

CHAPTER V

ANALYTICAL AND SAMPLING SYSTEMS

1. DETERMINATION OF THE GASEOUS EMISSIONS

1.1. 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.

Flow diagram of raw exhaust gas analysis system for CO, CO₂, NO_x, HC ESC only

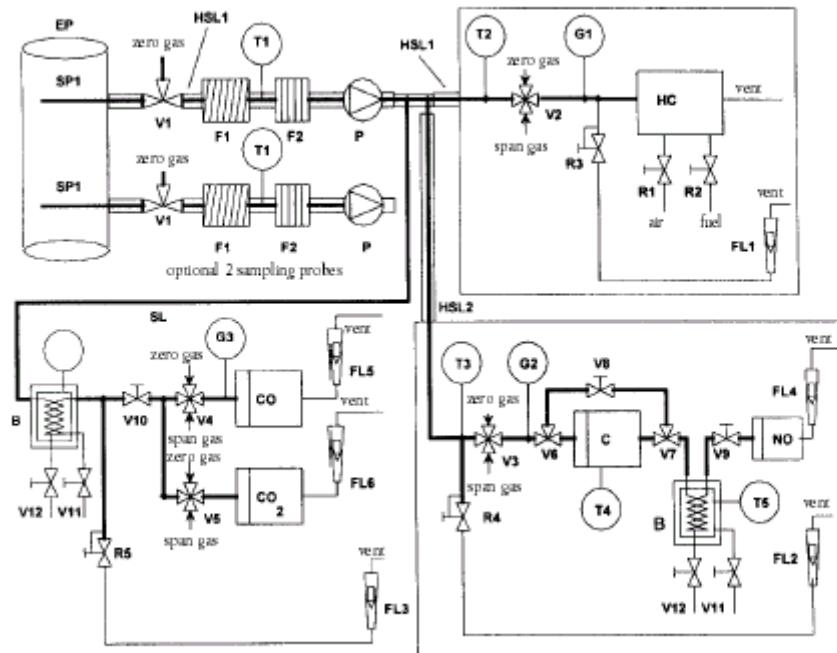


Figure 7

Flow diagram of raw exhaust gas analysis system
for CO, CO₂, NO_x, HC ESC only

1.2. 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.

Flow diagram of diluted exhaust gas analysis system for CO, CO₂, NO_x, HC ETC, optional for ESC

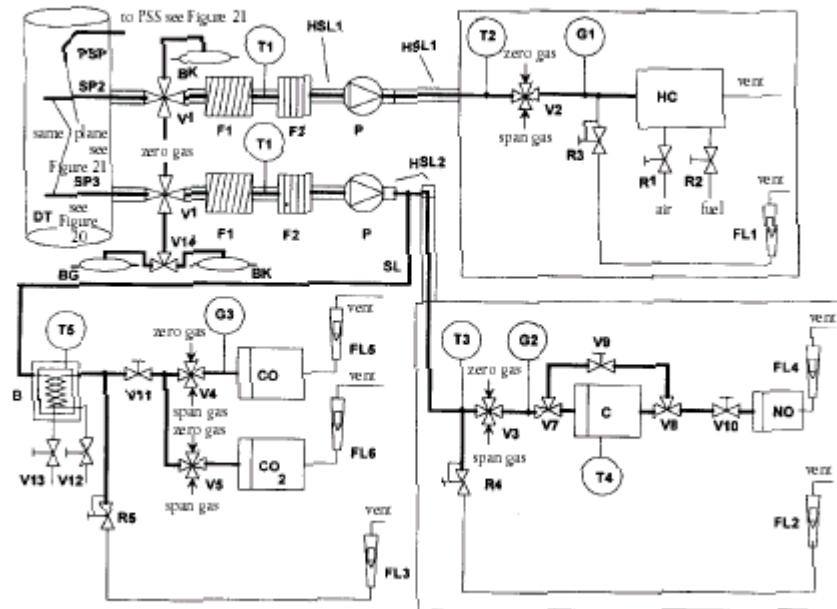


Figure 8

Flow diagram of diluted exhaust gas analysis system for CO, CO₂, NO_x, HC ETC, optional for ESC

1.2.1. 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 $463\text{ K} \pm 10\text{ K}$ ($190^\circ\text{C} \pm 10^\circ\text{C}$) 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 $463\text{ K} \pm 10\text{ K}$ ($190\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$) 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 ($190\text{ }^{\circ}\text{C}$);
- maintain a wall temperature greater than 453 K ($180\text{ }^{\circ}\text{C}$), if the temperature of the exhaust gas at the sampling probe is above 463 K ($190\text{ }^{\circ}\text{C}$);
- maintain a gas temperature of $463\text{ K} \pm 10\text{ K}$ ($190\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$) immediately before the heated filter F2 and the HFID;

HSL2 Heated NOx sampling line

The sampling line shall:

- maintain a wall temperature of 328 K to 473 K ($55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$), 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. 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 NO₂-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 NO₂-NO converter.

V8 Needle valve

To balance the flow through the NO₂-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.

1.3. NMHC Analysis (NG Fuelled Gas Engines Only)

1.3.1. 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

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).

Figure 9 shows a typical GC assembled to routinely determine CH₄. Other GC methods can also be used based on good engineering judgement.

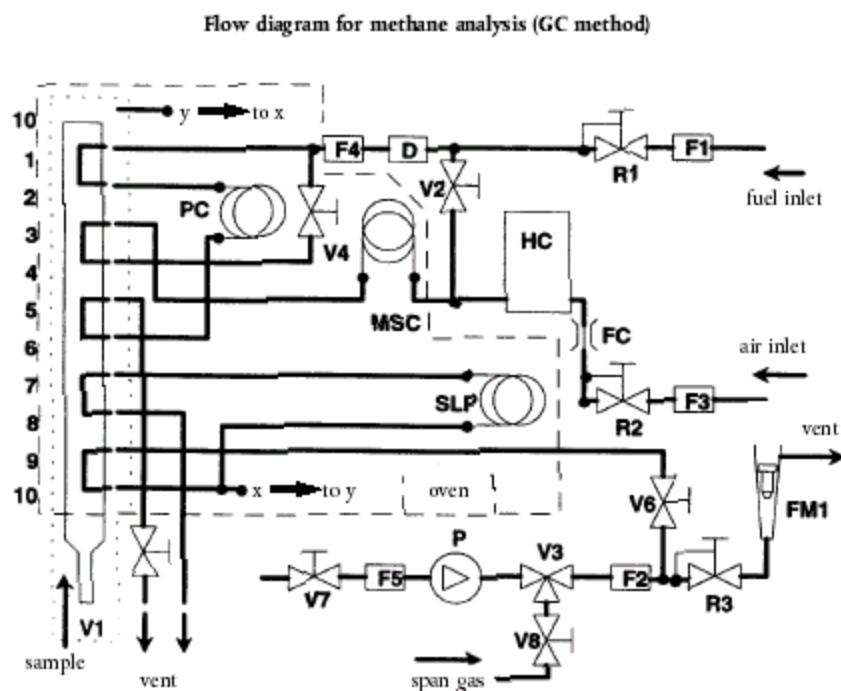


Figure 9

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 cm³ 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

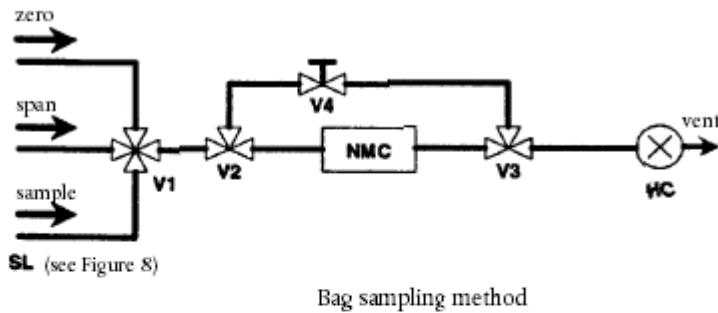
To measure the sample by-pass flow rate.

1.3.2. Non-Methane Cutter Method (NMC, Figure 10)

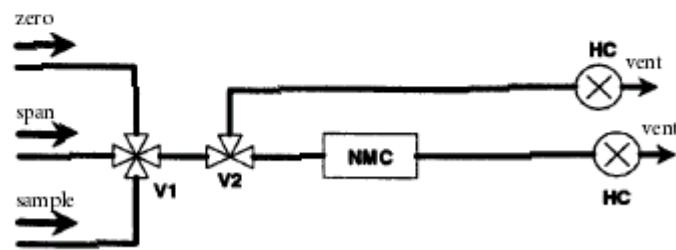
The cutter oxidises all hydrocarbons except CH₄ to CO₂ and H₂O, so that by passing the sample through the NMC only CH₄ is detected by the FID. If bag sampling is used, a flow diverter system shall be installed at SL (see section 1.2, Figure 8) with which the flow can be alternatively passed through or around the cutter according to the upper part of Figure 10. For NMHC measurement, both values (HC and CH₄) 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) according to the lower part of Figure 10. For NMHC measurement, the values of the two FID's (HC and CH₄) 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 CH₄ and C₂H₆ at H₂O values representative of exhaust stream conditions. The dewpoint and O₂ level of the sampled exhaust stream must be known. The relative response of the FID to CH₄ must be recorded (see Chapter III, Appendix 5, section 1.8.2).

Flow diagram for methane analysis with the non-methane cutter (NMC)



Bag sampling method



Integrating method

Figure 10

Flow diagram for methane analysis with the non-methane cutter (NMC)

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 CH₄ 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.

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.

FL1 Flowmeter

To measure the sample by-pass flow rate. FL1 is identical with FL1 of Figure 8.

2. EXHAUST GAS DILUTION AND DETERMINATION OF THE PARTICULATES

2.1. Introduction

Sections 2.2, 2.3 and 2.4 and figures 11 to 22 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 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). 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 CO₂ 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) or by the flow into the transfer tube (Figures 12, 13, 14).

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 air flow 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.

Partial flow dilution system with isokinetic probe and fractional sampling (SB control)

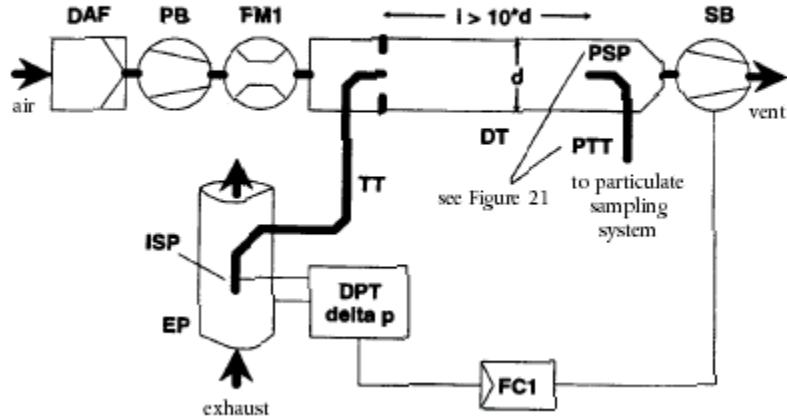


Figure 11

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 air flow rate is measured with the flow measurement device FM1. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

Partial flow dilution system with isokinetic probe and fractional sampling (PB control)

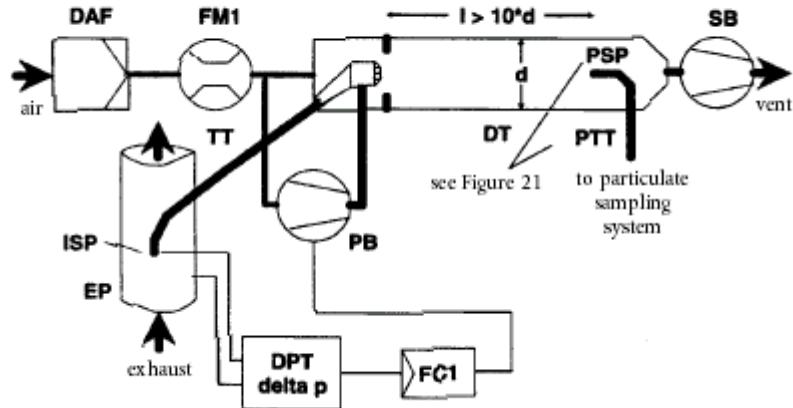


Figure 12
Partial flow dilution system with isokinetic probe and fractional sampling (PB control)

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.

Partial flow dilution system with CO₂ or NO_x concentration measurement and fractional sampling

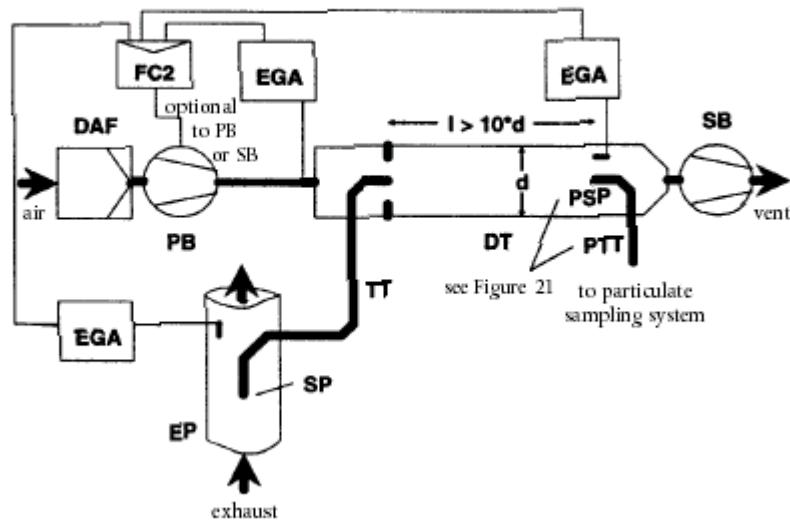


Figure 13
Partial flow dilution system with CO₂ or NO_x concentration measurement and fractional sampling

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 (CO₂ 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.

Partial flow dilution system with CO₂ concentration measurement, carbon balance and total sampling

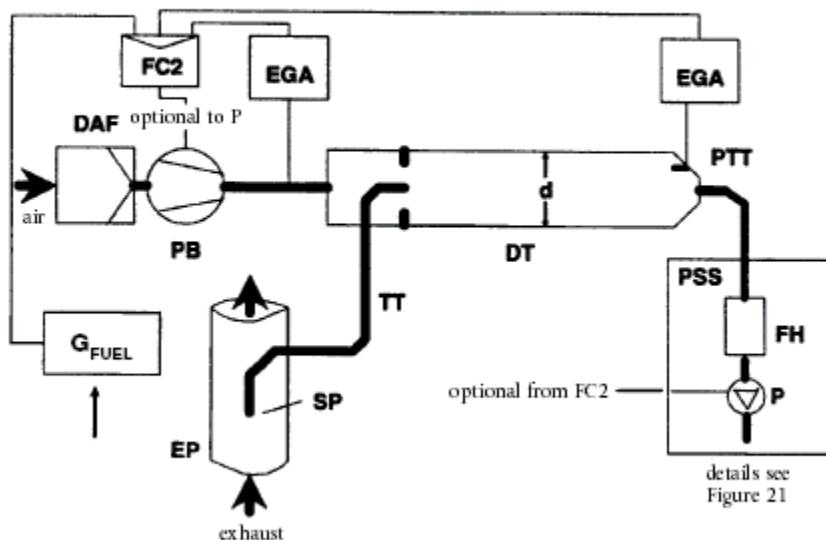


Figure 14

Partial flow dilution system with CO₂ 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 CO₂ concentrations are measured in the diluted exhaust gas and in the dilution air with the exhaust gas analyser(s) EGA. The CO₂ and fuel flow GFUEL signals are transmitted either to the flow controller FC2, or to the flow controller FC3 of the particulate sampling system (see Figure 21). FC2 controls the pressure blower PB, FC3 the sampling pump P (see Figure 21), 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 CO₂ concentrations and GFUEL using the carbon balance assumption.

Partial flow dilution system with single venturi, concentration measurement and fractional sampling

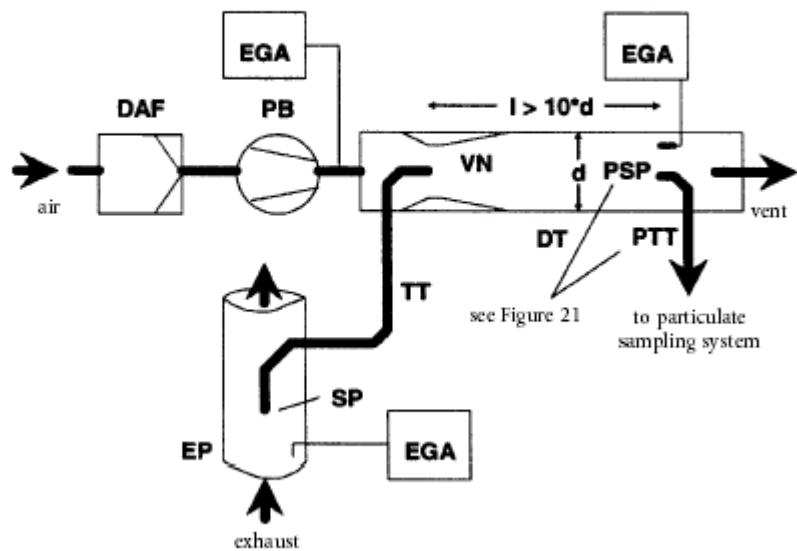


Figure 15
Partial flow dilution system with single venturi, concentration measurement and fractional sampling

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 (CO₂ 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.

Partial flow dilution system with twin venturi or twin orifice, concentration measurement and fractional sampling

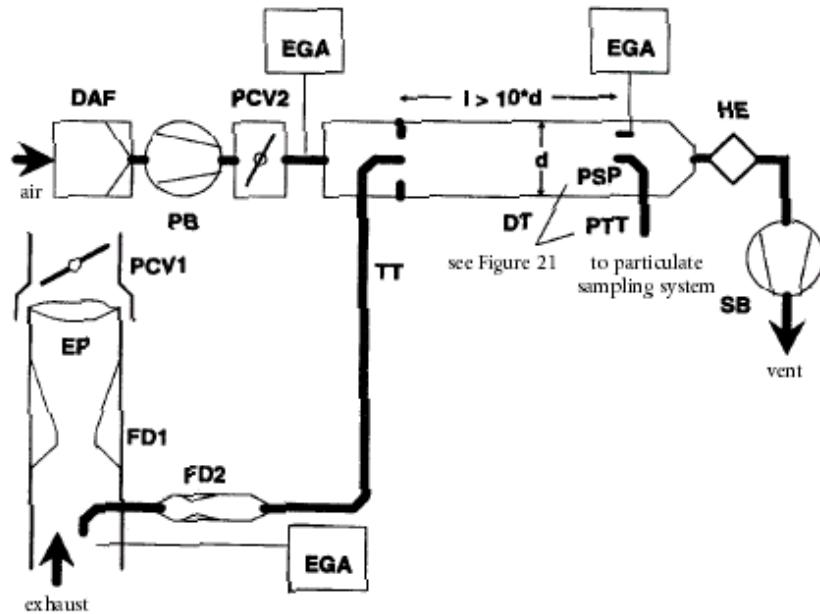


Figure 16
Partial flow dilution system with twin venturi or twin orifice, concentration measurement and fractional sampling

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 (CO₂ 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.

Partial flow dilution system with multiple tube splitting, concentration measurement and fractional sampling

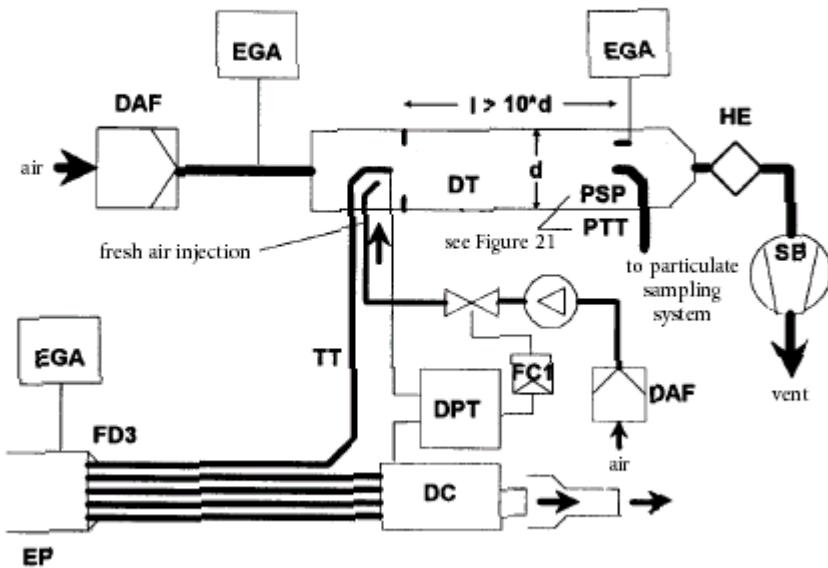


Figure 17

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 (CO₂ 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 air flow rate for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

Partial flow dilution system with flow control and total sampling

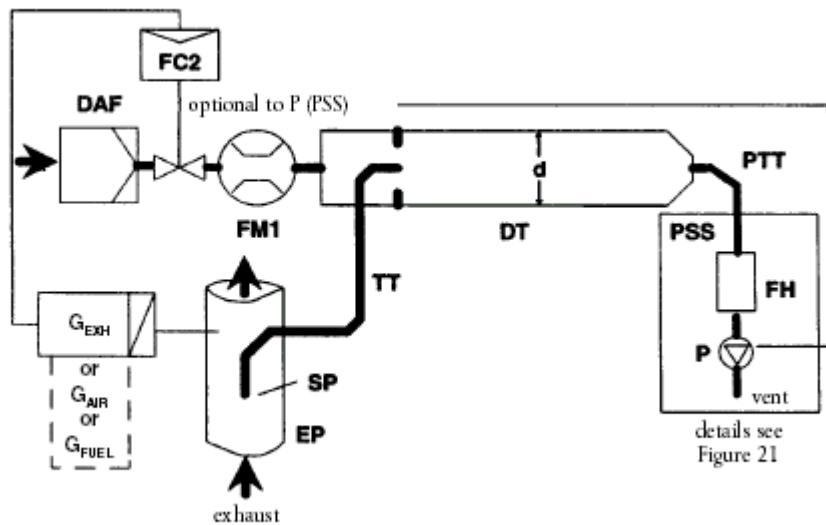


Figure 18
Partial flow dilution system with flow control and total sampling

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). The dilution air flow is controlled by the flow controller FC2, which may use GEXHW, GAIRW, or GFUEL 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). The dilution ratio is calculated from these two flow rates.

Partial flow dilution system with flow control and fractional sampling

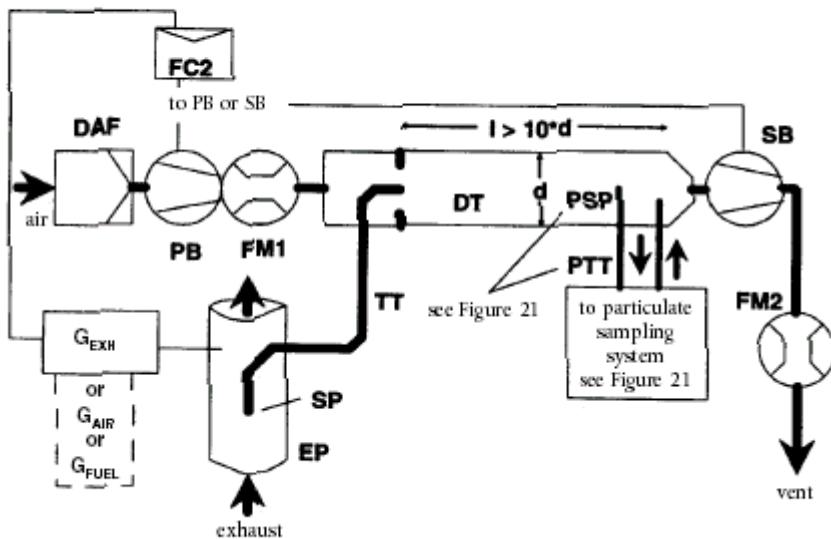


Figure 19

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. GEXHW, GAIRW, or GFUEL 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

aftertreatment 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 centreline, or a multiple hole probe as described under SP1 in section 1.2.1, Figure 5.

ISP Isokinetic sampling probe (Figures 11, 12)

The isokinetic sampling probe must be installed facing upstream on the exhaust pipe centreline 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)

CO₂ or NO_x analysers may be used (with carbon balance method CO₂ 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 GEDFW,i is within $\pm 4\%$.

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 centreline 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),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) 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).

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), 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 minimise 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 CO₂ or NO_x differential signals. When using a pressurised air supply (Figure 18), FC2 directly controls the air flow.

FM1 Flow measurement device (Figures 11, 12, 18, 19)

Gas meter or other flow instrumentation to measure the dilution air flow. 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 air flow 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 air flow, 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 than 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 CO₂ -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 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). 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, since it shares most of the parts with a typical particulate sampling system.

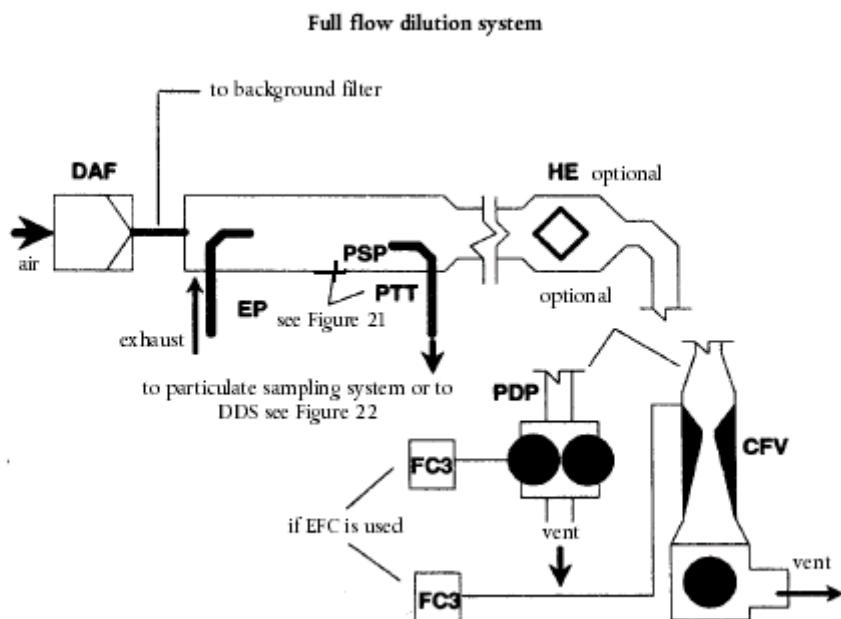


Figure 20
Full flow dilution system

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 aftertreatment device to the dilution tunnel shall not exceed

10 m. If the exhaust pipe downstream of the engine exhaust manifold, turbocharger outlet or aftertreatment device exceeds 4 m in length, then all tubing in excess of 4 m shall be insulated, except for an in-line smokemeter, 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/mK 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 $\pm 1,5$ 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 $\pm 1,5$ 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), 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). 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). 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) centreline 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) 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) and sampling systems usually form different units.

In this Directive, the double dilution system (Figure 22) of a full flow dilution system is considered as a specific modification of a typical particulate sampling system as shown in Figure 21. 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.

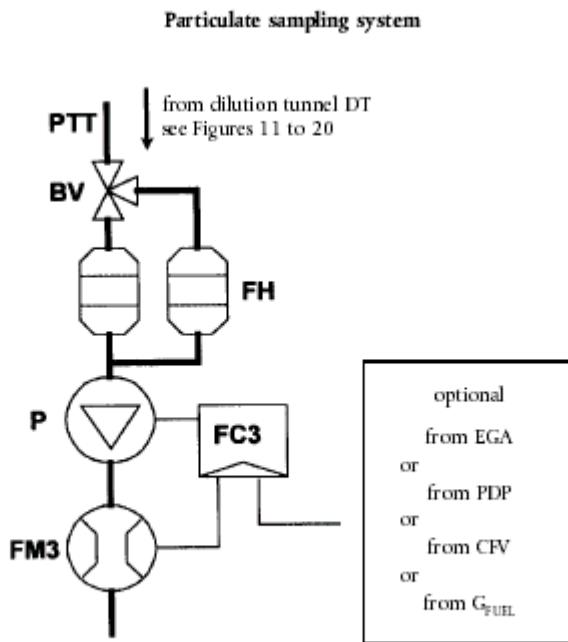


Figure 21
Particulate sampling system

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) is used, the diluted exhaust gas flow is used as command signal for FC3.

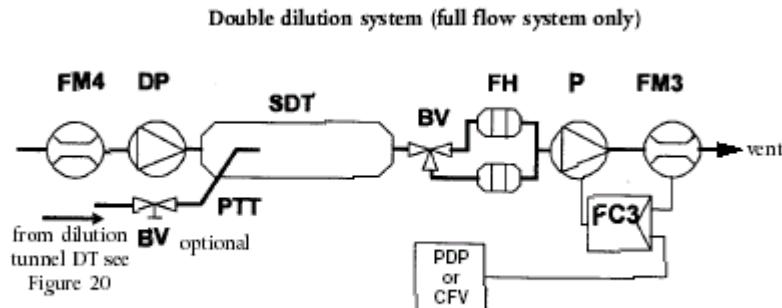


Figure 22

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) 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) 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 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 $298\text{ K} \pm 5\text{ K}$ ($25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$), 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) 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 air flow shall be located so that the inlet gas temperature remains at $298\text{ K} \pm 5\text{ K}$ ($25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$).

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 ($20\text{ }^{\circ}\text{C}$), 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 ($20\text{ }^{\circ}\text{C}$).

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 ($20\text{ }^{\circ}\text{C}$).

3. DETERMINATION OF SMOKE

3.1. Introduction

Sections 3.2 and 3.3 and figures 23 and 24 contain detailed descriptions of the recommended opacimeter systems. Since various configurations can produce

equivalent results, exact conformance with figures 23 and 24 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.

3.2. Full Flow Opacimeter

Two general types of full flow opacimeters may be used (Figure 23). With the in-line 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.

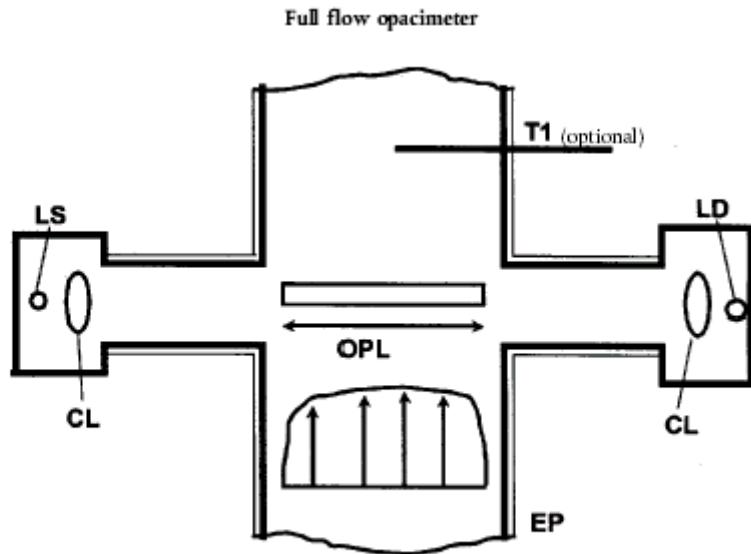


Figure 23

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 photopic 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.

3.3. Partial Flow Opacimeter

With the partial flow opacimeter (Figure 24), 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.

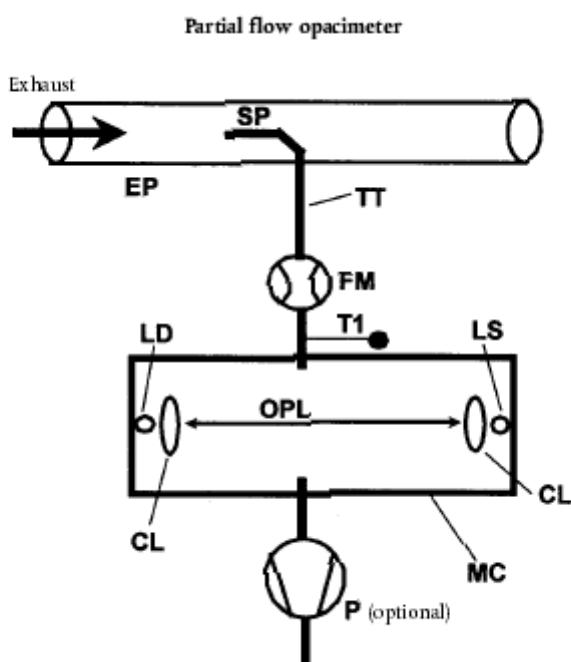


Figure 24

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 centreline. 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 ($100^\circ\text{C} \pm 30^\circ\text{C}$) 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.
- 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 photopic 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 soot 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 VI

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)	T _a (K)	H _a (g/kg)	G _{EXH} (kg)	G _{AIRW} (kg)	G _{HC} (kg)	HC (ppm)	CO (ppm)	NO _x (ppm)
82,9	294,8	7,81	563,38	545,29	18,09	6,3	41,2	495

Calculation of the dry to wet correction factor K_{W,F} (Annex III, Appendix 1, section 4.2):

$$F_{RH} = \frac{1,969}{\left(1 + \frac{18,09}{545,29}\right)} = 1,9058 \quad \text{and} \quad K_{W2} = \frac{1,608 * 7,81}{1\,000 + (1,608 * 7,81)} = 0,0124$$

$$K_{W,F} = \left(1 - 1,9058 * \frac{18,09}{541,06}\right) - 0,0124 = 0,9239$$

Calculation of the wet concentrations:

$$CO = 41,2 * 0,9239 = 38,1 \text{ ppm}$$

$$NO_x = 495 * 0,9239 = 457 \text{ ppm}$$

Calculation of the NO_x humidity correction factor K_{HD} (Annex III, Appendix 1, section 4.3):

$$A = 0,309 * 18,09 / 541,06 - 0,0266 = -0,0163$$

$$B = -0,209 * 18,09 / 541,06 + 0,00954 = 0,0026$$

$$K_{H,D} = \frac{1}{1 - 0,0163 * (7,81 - 10,71) + 0,0026 * (294,8 - 298)} = 0,9625$$

Calculation of the emission mass flow rates (Annex III, Appendix 1, section 4.4):

$$NO_x = 0,001587 * 457 * 0,9625 * 563,38 = 393,27 \text{ g/h}$$

$$CO = 0,000966 * 38,1 * 563,38 = 20,735 \text{ g/h}$$

$$HC = 0,000479 * 6,3 * 3 * 563,38 = 5,100 \text{ g/h}$$

Calculation of the specific emissions (Annex III, Appendix 1, section 4.5):

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 Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean emission mass flow rate over the cycle:

$$\begin{aligned}
CO &= (6,7 * 0,15) + (24,6 * 0,08) + (20,5 * 0,10) + (20,7 * 0,10) + (20,6 * 0,05) + (15,0 * 0,05) \\
&\quad + (19,7 * 0,05) + (74,5 * 0,09) + (31,5 * 0,10) + (81,9 * 0,08) + (34,8 * 0,05) + (30,8 * 0,05) \\
&\quad + (27,3 * 0,05) \\
&= 30,91 \text{ g/h}
\end{aligned}$$

The engine power of the individual modes is multiplied by the respective weighting factors, as indicated in Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean cycle power:

$$\begin{aligned}
P(n) &= (0,1 * 0,15) + (96,8 * 0,08) + (55,2 * 0,10) + (82,9 * 0,10) + (46,8 * 0,05) + (70,1 * 0,05) \\
&\quad + (23,0 * 0,05) + (114,3 * 0,09) + (27,0 * 0,10) + (122,0 * 0,08) + (28,6 * 0,05) + (87,4 * 0,05) \\
&\quad + (57,9 * 0,05) \\
&= 60,006 \text{ kW} \\
\overline{CO} &= \frac{30,91}{60,006} = 0,0515 \text{ g/kWh}
\end{aligned}$$

Calculation of the specific NO_x emission of the random point (Annex III, Appendix 1, section 4.6.1):

Assume the following values have been determined on the random point:

$$\begin{aligned}
n_Z &= 1\,600 \text{ min}^{-1} \\
M_Z &= 495 \text{ Nm} \\
NO_{x\text{max},Z} &= 487,9 \text{ g/h} \text{ (calculated according to the previous formulae)} \\
P(n)_Z &= 83 \text{ kW} \\
NO_{xz} &= 487,9 / 83 = 5,878 \text{ g/kWh}
\end{aligned}$$

Determination of the emission value from the test cycle (Annex III, Appendix 1, section 4.6.2):

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

$$E_{TU} = 5,889 + (4,973 - 5,889) * (1\,600 - 1\,368) / (1\,785 - 1\,368) = 5,377 \text{ g/kWh}$$

$$E_{RS} = 5,943 + (5,565 - 5,943) * (1\,600 - 1\,368) / (1\,785 - 1\,368) = 5,732 \text{ g/kWh}$$

$$M_{TU} = 681 + (601 - 681) * (1\,600 - 1\,368) / (1\,785 - 1\,368) = 641,3 \text{ Nm}$$

$$M_{RS} = 515 + (460 - 515) * (1\,600 - 1\,368) / (1\,785 - 1\,368) = 484,3 \text{ Nm}$$

$$E_Z = 5,732 + (5,377 - 5,732) * (495 - 484,3) / (641,3 - 484,3) = 5,708 \text{ g/kWh}$$

Comparison of the NO_x emission values (Annex III, Appendix 1, section 4.6.3):

$$NO_{x\text{diff}} = 100 * (5,878 - 5,708) / 5,708 = 2,98 \%$$

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_{SAM} and G_{EDF}) during the individual modes. The calculation of G_{EDF} 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, G_{EDF} is directly measured by the CVS equipment.

Calculation of G_{EDF} (Annex 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.

G _{EXH} (kg/h)	G _{UEH} (kg/h)	G _{DEWF} (kg/h)	G _{TOTW} (kg/h)	CO _{2D} (%)	CO _{2A} (%)
334,02	10,76	5,4435	6,0	0,657	0,040

(a) carbon balance method

$$G_{EDFW} = \frac{206,5 * 10,76}{0,657 - 0,040} = 3\,601,2 \text{ kg/h}$$

(b) flow measurement method

$$q = \frac{6,0}{(6,0 - 5,4435)} = 10,78$$

$$G_{EDFW} = 334,02 * 10,78 = 3\,600,7 \text{ kg/h}$$

Calculation of the mass flow rate (Annex III, Appendix 1, section 5.4):

The G_{EDFW} flow rates of the individual modes are multiplied by the respective weighting factors, as indicated in Annex III, Appendix 1, section 2.7.1, and summed up to result in the mean G_{EDF} over the cycle. The total sample rate M_{SAM} is summed up from the sample rates of the individual modes.

$$\begin{aligned} G_{EDFW} &= (3\,567 * 0,15) + (3\,592 * 0,08) + (3\,611 * 0,10) + (3\,600 * 0,10) + (3\,618 * 0,05) \\ &\quad + (3\,600 * 0,05) + (3\,640 * 0,05) + (3\,614 * 0,09) + (3\,620 * 0,10) + (3\,601 * 0,08) \\ &\quad + (3\,639 * 0,05) + (3\,582 * 0,05) + (3\,635 * 0,05) \\ &= 3\,604,6 \text{ kg/h} \end{aligned}$$

$$\begin{aligned} M_{SAM} &= 0,226 + 0,122 + 0,151 + 0,152 + 0,076 + 0,076 + 0,076 + 0,136 + 0,151 + 0,121 + 0,076 \\ &\quad + 0,076 + 0,075 \\ &= 1,515 \text{ kg} \end{aligned}$$

Assume the particulate mass on the filters to be 2,5 mg, then

$$PT_{mass} = \frac{2,5}{1,515} * \frac{3\,604,6}{1\,000} = 5,948 \text{ g/h}$$

Background correction (optional)

Assume one background measurement with the following values. The calculation of the dilution factor DF is identical to section 3.1 of this Annex and not shown here.

$$M_d = 0,1 \text{ mg}; M_{DEL} = 1,5 \text{ kg}$$

$$\begin{aligned} \text{Sum of DF} &= [(1-1/119,15) * 0,15] + [(1-1/8,89) * 0,08] + [(1-1/14,75) * 0,10] + [(1-1/10,10) \\ &\quad * 0,10] + [(1-1/18,02) * 0,05] + [(1-1/12,33) * 0,05] + [(1-1/32,18) * 0,05] \\ &\quad + [(1-1/6,94) * 0,09] + [(1-1/25,19) * 0,10] + [(1-1/6,12) * 0,08] + [(1-1/20,87) \\ &\quad * 0,05] + [(1-1/8,77) * 0,05] + [(1-1/12,59) * 0,05] \\ &= 0,923 \end{aligned}$$

$$PT_{mass} = \frac{2,5}{1,515} - \left(\frac{0,1}{1,5} * 0,923 \right) * \frac{3\,604,6}{1\,000} = 5,726 \text{ g/h}$$

Calculation of the specific emission (Annex III, Appendix 1, section 5.5):

$$\begin{aligned} P(n) &= (0,1 * 0,15) + (96,8 * 0,08) + (55,2 * 0,10) + (82,9 * 0,10) + (46,8 * 0,05) + (70,1 * 0,05) \\ &\quad + (23,0 * 0,05) + (114,3 * 0,09) + (27,0 * 0,10) + (122,0 * 0,08) + (28,6 * 0,05) + (87,4 * 0,05) \\ &\quad + (57,9 * 0,05) \\ &= 60,006 \text{ kW} \end{aligned}$$

$$\overline{PT} = \frac{5,948}{60,006} = 0,099 \text{ g/kWh}$$

$$\text{if background corrected } \overline{PT} = \frac{5,726}{60,006} = 0,095 \text{ g/kWh}$$

Calculation of the specific weighting factor (Annex III, Appendix 1, section 5.6):

Assume the values calculated for mode 4 above, then

$$WF_{E,i} = \frac{0,152 * 3\ 604,6}{1,515 * 3\ 600,7} = 0,1004$$

This value is within the required value of $0,10 \pm 0,003$.

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 characterise 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 (t_p)
- electrical response time of the opacimeter (t_e)
- filter response time of the applied Bessel filter (t_f)

The resulting overall response time of the system t_{Aver} is given by:

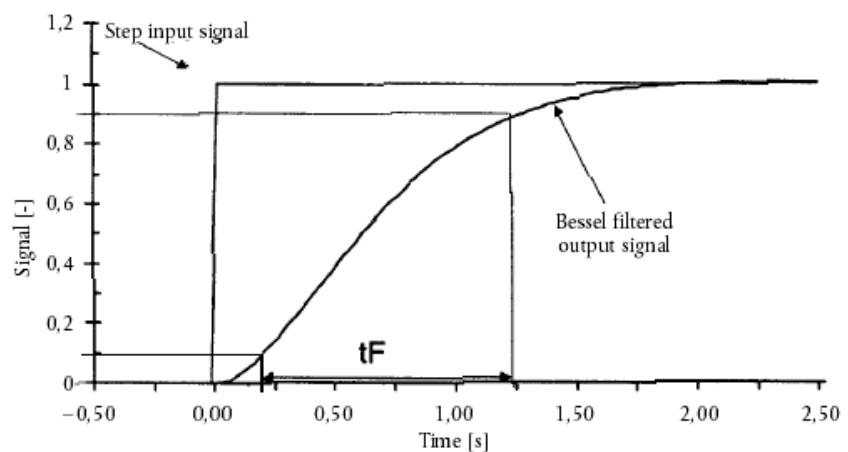
$$t_{Aver} = \sqrt{t_f^2 + t_p^2 + t_e^2}$$

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:

$$t_f = \sqrt{t_{Aver}^2 + t_p^2 + t_e^2}$$

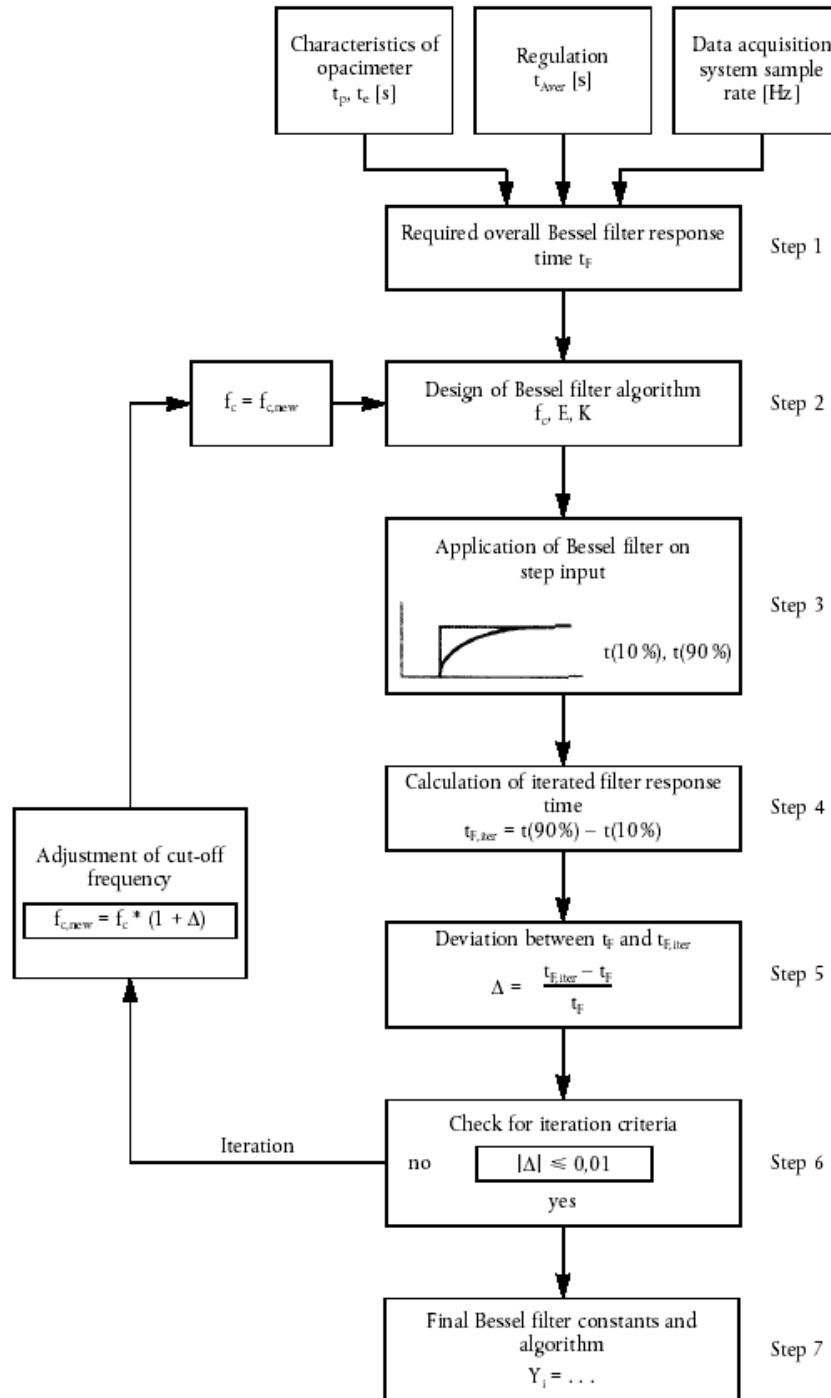
By definition, the filter response time t_f is the rise time of a filtered output signal between 10% and 90% on a step input signal. Therefore the cut-off frequency of the Bessel filter has to be iterated in such a way, that the response time of the Bessel filter fits into the required rise time.

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 Annex 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 Directive)
- 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:

$$f_c = 3,1415/(10 * 0,987421) = 0,318152 \text{ Hz}$$

$$\Delta t = 1/150 = 0,006667 \text{ s}$$

$$\Omega = 1/[\tan(3,1415 * 0,006667 * 0,318152)] = 150,076644$$

$$E = \frac{1}{1 + 150,076644 * \sqrt{3 * 0,618034 + 0,618034 * 150,076644^2}} = 7,07948 E - 5$$

$$K = 2 * 7,07948 E - 5 * (0,618034 * 150,076644^2 - 1) - 1 = 0,970783$$

This gives the Bessel algorithm:

$$Y_i = Y_{i-1} + 7,07948 E - 5 * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + 0,970783 * (Y_{i-1} - Y_{i-2})$$

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:

$$t_{10} = t_{lower} + \Delta t * (0,1 - out_{lower}) / (out_{upper} - out_{lower})$$

$$t_{90} = t_{lower} + \Delta t * (0,9 - out_{lower}) / (out_{upper} - out_{lower})$$

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.

$$t_{10} = 0,200000 + 0,006667 * (0,1 - 0,099208) / (0,104794 - 0,099208) = 0,200945 \text{ s}$$

$$t_{90} = 0,273333 + 0,006667 * (0,9 - 0,899147) / (0,901168 - 0,899147) = 1,276147 \text{ s}$$

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:

$$f_{c,new} = 0,318152 * (1 + 0,081641) = 0,344126 \text{ Hz}$$

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 ($\Delta=0,006657 \leq 0,01$). The final algorithm is then used for determining the averaged smoke values (see next section 2.3).

$$Y_i = Y_{i-1} + 8,272777 \text{ E-5} * (S_i + 2 * S_{i-1} + S_{i-2} - 4 * Y_{i-2}) + 0,968410 * (Y_{i-1} - Y_{i-2})$$

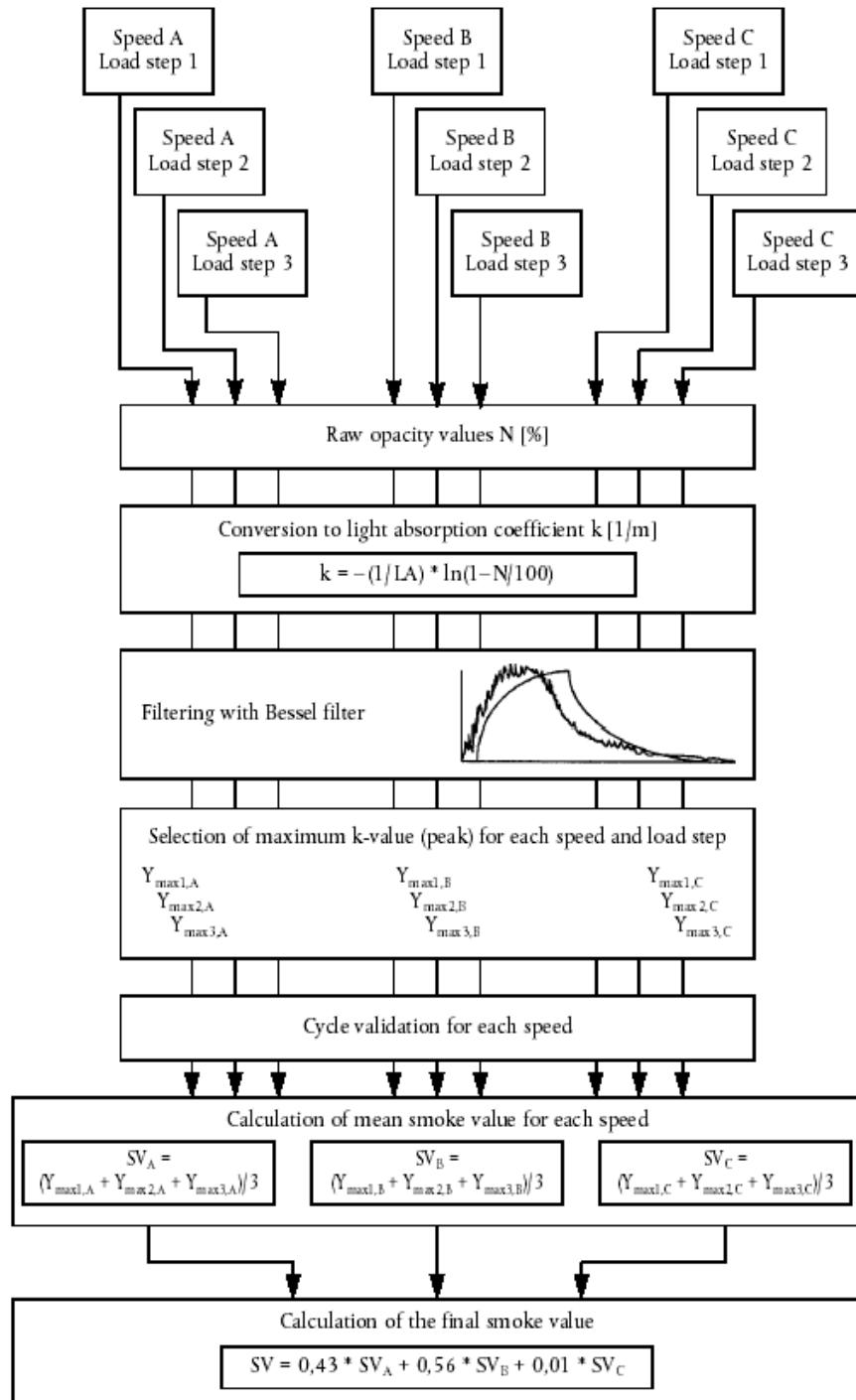
Table B
Values of step input signal and Bessel filtered output signal for the first and second iteration cycle

Index i [-]	Time [s]	Step Input Signal S _i [-]	Filtered Output Signal Y _i [-]	
			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

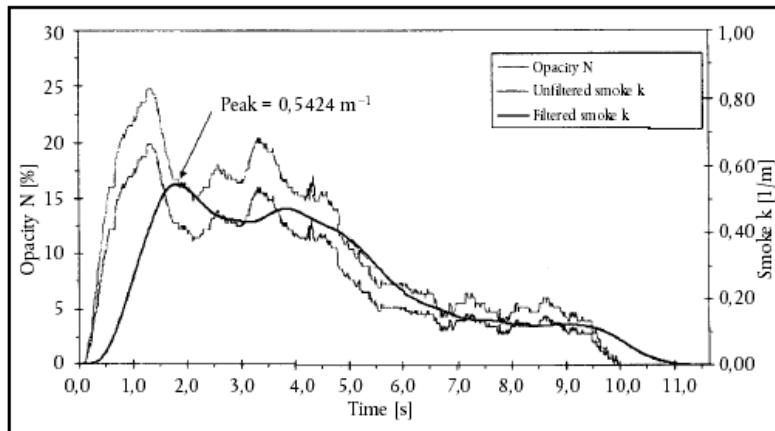
In the scheme below the general procedure of determining the final smoke value is presented.



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 $Y_{\max,A}$ (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 tabulated.

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 (Annex III, Appendix 1, section 6.3.1):

$$k = -\frac{1}{0,430} * \ln\left(1 - \frac{16,783}{100}\right) = 0,427252 \text{ m}^{-1}$$

This value corresponds to S_{272} in the following equation.

Calculation of Bessel averaged smoke (Annex 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_0). S_{271} (S_{+1}) and S_{270} (S_{+2}) are the two preceding unfiltered k -values, Y_{271} (Y_{-1}) and Y_{270} (Y_{-2}) are the two preceding filtered k -values.

$$\begin{aligned}
 Y_{272} &= 0,542383 + 8,272777 E - 5 * (0,427252 + 2 * 0,427392 + 0,427532 - 4 * 0,542337) \\
 &\quad + 0,968410 * (0,542383 - 0,542337) \\
 &= 0,542389 \text{ m}^{-1}
 \end{aligned}$$

This value corresponds to $Y_{\max 1,A}$ in the following equation.

Calculation of the final smoke value (Annex 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	$Y_{\max} (\text{m}^{-1})$		
	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 (Annex 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
H_a (g/kg)	12,8
NO_x conc (ppm)	53,7
NO_x concd (ppm)	0,4
CO conc (ppm)	38,9
CO concd (ppm)	1,0
HC conc (ppm)	9,00
HC concd (ppm)	3,02
CO_2 conc (%)	0,723
W_{act} (kWh)	62,72

Calculation of the diluted exhaust gas flow (Annex III, Appendix 2, section 4.1):

$$M_{TOTW} = 1,293 * 0,1776 * 23 073 * (98,0 - 2,3) * 273 / (101,3 * 322,5) \\ = 4 237,2 \text{ kg}$$

Calculation of the NO_x correction factor (Annex III, Appendix 2, section 4.2):

$$K_{H,D} = \frac{1}{1 - 0,0182 * (12,8 - 10,71)} = 1,039$$

Calculation of the background corrected concentrations (Annex III, Appendix 2, section 4.3.1.1):

Assuming a diesel fuel of the composition C₁H_{1,8},

$$F_S = 100 * \frac{1}{1 + (1,8/2) + [3,76 * (1 + (1,8/4))]} = 13,6$$

$$DF = \frac{13,6}{0,723 + (9,00 + 38,9) * 10^{-4}} = 18,69$$

$$NO_x \text{ conc} = 53,7 - 0,4 * (1 - (1/18,69)) = 53,3 \text{ ppm}$$

$$CO \text{ conc} = 38,9 - 1,0 * (1 - (1/18,69)) = 37,9 \text{ ppm}$$

$$HC \text{ conc} = 9,00 - 3,02 * (1 - (1/18,69)) = 6,14 \text{ ppm}$$

Calculation of the emissions mass flow (Annex III, Appendix 2, section 4.3.1):

$$NO_x \text{ mass} = 0,001587 * 53,3 * 1,039 * 4 237,2 = 372,391 \text{ g}$$

$$CO \text{ mass} = 0,000966 * 37,9 * 4 237,2 = 155,129 \text{ g}$$

$$HC \text{ mass} = 0,000479 * 6,14 * 4 237,2 = 12,462 \text{ g}$$

Calculation of the specific emissions (Annex III, Appendix 2, section 4.4):

$$\overline{NO_x} = 372,391 / 62,72 = 5,94 \text{ g/kWh}$$

$$\overline{CO} = 155,129 / 62,72 = 2,47 \text{ g/kWh}$$

$$\overline{HC} = 12,462 / 62,72 = 0,199 \text{ g/kWh}$$

3.2.

Particulate emissions (Diesel Engine)

Assume the following test results for a PDP-CVS system with double dilution

M _{TOTW} (kg)	4 237,2
M _{f,p} (mg)	3,030
M _{fb} (mg)	0,044
M _{TOT} (kg)	2,159
M _{SEC} (kg)	0,909
M _d (mg)	0,341
M _{DIL} (kg)	1,245
DF	18,69
W _{act} (kWh)	62,72

Calculation of the mass emission (Annex III, Appendix 2, section 5.1):

$$M_f = 3,030 + 0,044 = 3,074 \text{ mg}$$

$$M_{SAM} = 2,159 - 0,909 = 1,250 \text{ kg}$$

$$\overline{PT}_{\text{mass}} = \frac{3,074}{1,250} * \frac{4 237,2}{1 000} = 10,42 \text{ g}$$

Calculation of the background corrected mass emission (Annex III, Appendix 2, section 5.1):

$$\overline{PT}_{\text{mass}} = \left[\frac{3,074}{1,250} - \left(\frac{0,341}{1,245} * \left(1 - \frac{1}{18,69} \right) \right) \right] * \frac{4 237,2}{1 000} = 9,32 \text{ g}$$

Calculation of the specific emission (Annex III, Appendix 2, section 5.2):

$$\overline{PT} = 10,42 / 62,72 = 0,166 \text{ g/kWh}$$

$$\overline{PT} = 9,32 / 62,72 = 0,149 \text{ g/kWh, if background corrected}$$

3.3.

Gaseous Emissions (CNG Engine)

Assume the following test results for a PDP-CVS system with double dilution

M _{TOTW} (kg)	4 237,2
H _a (g/kg)	12,8
NO _x conc (ppm)	17,2
NO _x concd (ppm)	0,4
CO _{conce} (ppm)	44,3
CO _{concd} (ppm)	1,0
HC _{conce} (ppm)	27,0
HC _{concd} (ppm)	3,02
CH ₄ conc (ppm)	18,0
CH ₄ concd (ppm)	1,7
CO _{2,conce} (%)	0,723
W _{act} (kWh)	62,72

Calculation of the NO_x correction factor (Annex III, Appendix 2, section 4.2):

$$K_{H,G} = \frac{1}{1 - 0,0329 * (12,8 - 10,71)} = 1,074$$

Calculation of the NMHC concentration (Annex III, Appendix 2, section 4.3.1):

(a) GC method

$$\text{NMHC}_{\text{conc}} = 27.0 - 18.0 = 9.0 \text{ ppm}$$

(b) NMC method

Assuming a methane efficiency of 0,04 and an ethane efficiency of 0,98 (see Annex III, Appendix 5, section 1.8.4)

$$\text{NMHC}_{\text{conc}} = \frac{27.0 * (1 - 0.04) - 18.0}{0.98 - 0.04} = 8.4 \text{ ppm}$$

Calculation of the background corrected concentrations (Annex III, Appendix 2, section 4.3.1.1):

Assuming a G20 reference fuel (100% methane) of the composition C₁H₄:

$$F_S = 100 * \frac{1}{1 + (4/2) + [3.76 * (1 + (4/4))]} = 9.5$$

$$DF = \frac{9.5}{0.723 + (27.0 + 44.3) * 10^{-4}} = 13.01$$

For NMHC, the background concentration is the difference between HIC_{conc} and CH₄ conc

$$\text{NO}_x \text{ conc} = 17.2 - 0.4 * (1 - (1/13.01)) = 16.8 \text{ ppm}$$

$$\text{CO conc} = 44.3 - 1.0 * (1 - (1/13.01)) = 43.4 \text{ ppm}$$

$$\text{NMHC conc} = 8.4 - 1.32 * (1 - (1/13.01)) = 7.2 \text{ ppm}$$

$$\text{CH}_4 \text{ conc} = 18.0 - 1.7 * (1 - (1/13.01)) = 16.4 \text{ ppm}$$

Calculation of the emissions mass flow (Annex III, Appendix 2, section 4.3.1):

$$\text{NO}_x \text{ mass} = 0.001587 * 16.8 * 1.074 * 4 237.2 = 121,330 \text{ g}$$

$$\text{CO mass} = 0.000966 * 43.4 * 4 237.2 = 177,642 \text{ g}$$

$$\text{NMHC mass} = 0.000502 * 7.2 * 4 237.2 = 15,315 \text{ g}$$

$$\text{CH}_4 \text{ mass} = 0.000554 * 16.4 * 4 237.2 = 38,498 \text{ g}$$

Calculation of the specific emissions (Annex III, Appendix 2, section 4.4):

$$\overline{\text{NO}_x} = 121,330 / 62,72 = 1.93 \text{ g/kWh}$$

$$\overline{\text{CO}} = 177,642 / 62,72 = 2.83 \text{ g/kWh}$$

$$\overline{\text{NMHC}} = 15,315 / 62,72 = 0.244 \text{ g/kWh}$$

$$\overline{\text{CH}_4} = 38,498 / 62,72 = 0.614 \text{ g/kWh}$$

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. N₂, CO₂, 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:

$$n = \frac{1 \times \left[\frac{CH_4\%}{100} \right] + 2 \times \left[\frac{C_2\%}{100} \right] + 3 \times \left[\frac{C_3\%}{100} \right] + 4 \times \left[\frac{C_4\%}{100} \right] + 5 \times \left[\frac{C_5\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}}$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100} \right] + 4 \times \left[\frac{C_2H_4\%}{100} \right] + 6 \times \left[\frac{C_2H_6\%}{100} \right] + \dots + 8 \times \left[\frac{C_3H_8\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}}$$

where:

- CH_4 = % by volume of methane in the fuel;
- C_2 = % by volume of all C_2 hydrocarbons (e.g.: C_2H_6 , C_2H_4 , etc.) in the fuel;
- C_3 = % by volume of all C_3 hydrocarbons (e.g.: C_3H_8 , C_3H_6 , etc.) in the fuel;
- C_4 = % by volume of all C_4 hydrocarbons (e.g.: C_4H_{10} , C_4H_8 , etc.) in the fuel;
- C_5 = % by volume of all C_5 hydrocarbons (e.g.: C_5H_{12} , C_5H_{10} , etc.) in the fuel;
- diluent = % by volume of dilution gases in the fuel (i.e.: O_2^* , N_2 , CO_2 , 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)

$$n = \frac{1 \times \left[\frac{CH_4\%}{100} \right] + 2 \times \left[\frac{C_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{1 \times 0.86}{1 - \frac{14}{100}} = \frac{0.86}{0.86} = 1$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100} \right] + 4 \times \left[\frac{C_2H_4\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{4 \times 0.86}{0.86} = 4$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert \%}}{100} \right) \left(n + \frac{m}{4} \right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{14}{100} \right) \times \left(1 + \frac{4}{4} \right)} = 1,16$$

Example 2: G_{xy} : $CH_4 = 87\%$, $C_2H_6 = 13\%$ (by volume)

$$n = \frac{1 \times \left[\frac{CH_4\%}{100} \right] + 2 \times \left[\frac{C_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{1 \times 0.87 + 2 \times 0.13}{1 - \frac{0}{100}} = \frac{1.13}{1} = 1,13$$

$$m = \frac{4 \times \left[\frac{CH_4\%}{100} \right] + 6 \times \left[\frac{C_2H_6\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{4 \times 0.87 + 6 \times 0.13}{1} = 4,26$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert \%}}{100} \right) \left(n + \frac{m}{4} \right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{0}{100} \right) \times \left(1,13 + \frac{4,26}{4} \right)} = 0,911$$

Example 3: USA: CH₄ = 89 %, C₂H₆ = 4,5 %, C₃H₈ = 2,3 %, C₆H₁₄ = 0,2 %, O₂ = 0,6 %, N₂ = 4 %

$$n = \frac{1 \times \left[\frac{\text{CH}_4\%}{100} \right] + 2 \times \left[\frac{\text{C}_2\%}{100} \right] + \dots}{1 - \frac{\text{diluent \%}}{100}} = \frac{1 \times 0,89 + 2 \times 0,045 + 3 \times 0,023 + 4 \times 0,002}{1 - \frac{(0,64 + 4)}{100}} = 1,11$$

$$m = \frac{4 \times \left[\frac{\text{CH}_4\%}{100} \right] + 4 \times \left[\frac{\text{C}_2\text{H}_4\%}{100} \right] + 6 \times \left[\frac{\text{C}_2\text{H}_6\%}{100} \right] + \dots + 8 \times \left[\frac{\text{C}_3\text{H}_8\%}{100} \right]}{1 - \frac{\text{diluent \%}}{100}}$$

$$= \frac{4 \times 0,89 + 4 \times 0,045 + 8 \times 0,023 + 14 \times 0,002}{1 - \frac{0,6 + 4}{100}} = 4,24$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert \%}}{100}\right) \left(n + \frac{m}{4}\right) - \frac{\text{O}_2^*}{100}} = \frac{2}{\left(1 - \frac{4}{100}\right) \times \left(1,11 + \frac{4,24}{4}\right) - \frac{0,6}{100}} = 0,96$$
