Chapter 1

Overall Requirements

1. SCOPE:

This Part applies to the control of gaseous and particulate pollutants, useful life of emission control devices and on-board diagnostic (OBD) systems of all motor vehicles equipped with compression-ignition engines and to the gaseous pollutants, useful life, and on-board diagnostic (OBD) systems of all motor vehicles equipped with positive-ignition engines fuelled with natural gas or LPG, with the exception of those vehicles of category M1, with a technically permissible maximum laden mass less than or equal to 3,500 kg and of compression-ignition engines of those vehicles of category N1, N2 and M2 and of positive-ignition engines fuelled with natural gas or LPG of those vehicles of category N1 for which type-approval has been granted under Part XIV – of MoSRTH/CMVR/TAP 115-116 under, sub-rule 15 of CMV-Rule 115.

2. DEFINITIONS AND ABBREVIATIONS :

For the purposes of this part the following definitions shall apply:

2.1 "**Approval of an engine (engine family)**" means the approval of an engine type (engine family) with regard to the level of the emission of gaseous and particulate pollutants.

2.2 **"Auxiliary emission control strategy (AECS**)" means an emission control strategy that becomes active or that modifies the base emission control strategy for a specific purpose or purposes and in response to a specific set of ambient and/or operating conditions, e.g. vehicle speed, engine speed, gear used, intake temperature, or intake pressure.

2.3 **"Base emission control strategy (BECS)"** means an emission control strategy that is active throughout the speed and load operating range of the engine unless an AECS is activated. Examples for BECS are, but are not limited to:

- Engine timing map
- EGR map
- SCR catalyst reagent dosing map

2.4 "**Combined de NO_X-particulate filter"** means an exhaust after treatment system designed to concurrently reduce emissions of oxides of nitrogen (NO_X) and particulate pollutants (PT).

2.5 **“Continuous regeneration”** means the regeneration process of an exhaust after treatment system that occurs either permanently or at least once per ETC test. Such a regeneration process will not require a special test procedure.

2.6 “**Control area**” means the area between the engine speeds A and C and between 25 to 100 per cent load.

2.7 "**Declared maximum power (P_{max})**" means the maximum power in kW (net power) as declared by the manufacturer in his application for type-approval.

2.8 **“Defeat strategy”** means:

- An AECS that reduces the effectiveness of the emission control relative to the BECS under conditions that may reasonably be expected to be encountered in normal vehicle operation and use

- A BECS that discriminates between operation on a standardized type-approval test and other operations and provides a lesser level of emission control under conditions not substantially included in the applicable type-approval test procedures or,

- An OBD or an emission control monitoring strategy that discriminates between operation on a standardised type-approval test and other operations and provides a lower level of monitoring capability (timely and accurately) under conditions not substantially included in the applicable type-approval test procedures.

2.9 **“De NO_X system”** means an exhaust after treatment system designed to reduce emissions of oxides of nitrogen (NO_X) (e.g. there are presently passive and active lean NO_X catalysts, NO_X adsorbers and Selective Catalytic Reduction (SCR) systems).

2.10 **“Delay time**” means the time between the change of the component to be measured at the reference point and a system response of 10 % of the final reading (t_{10}). For the gaseous components, this is basically the transport time of the measured component from the sampling probe to the detector. For the delay time, the sampling probe is defined as the reference point.

2.11 "**Diesel engine**" means an engine, which works on the compression-ignition principle.

2.12 "**ELR test**" means a test cycle consisting of a sequence of load steps at constant engine speeds to be applied in accordance with section 6.2 of this chapter.

2.13 "**ESC test**" means a test cycle consisting of 13 steady state modes to be applied in accordance with section 6.2 of this chapter.

2.14 "**ETC test**" means a test cycle consisting of 1800 second-by-second transient modes to be applied in accordance with section 6.2 of this chapter.

2.15 **“Element of design**” means in respect of a vehicle or engine,

- Any control system, including computer software, electronic control systems and computer logic,
- Any control system calibrations,
- The result of systems interaction,

or

- Any hardware items.

2.16 **“Emissions-related defect**” means a deficiency or deviation from normal production tolerances in design, materials or workmanship in a device, system or assembly that affects any parameter, specification or component belonging to the emission control system. A missing component may be considered to be an “emissions-related defect”.

2.17 **“Emission control strategy (ECS)”** means an element or set of elements of design that is incorporated into the overall design of an engine system or vehicle for the purposes of controlling exhaust emissions that includes one BECS and one set of AECS.

2.18 **”Emission control system”** means the exhaust after treatment system, the electronic management controller(s) of the engine system and any emission-related component of the engine system in the exhaust which supplies an input to or receives an output from this (these) controller(s), and when applicable the communication interface (hardware and messages) between the engine system electronic control unit(s) (EECU) and any other power train or vehicle control unit with respect to emissions management.

2.19 **“Emission control monitoring system”** means the system that ensures correct operation of the NO_X control measures implemented in the engine system according to the requirements of section 6.5 of this chapter.

2.20 **“Emission default mode”** means an AECS activated in the case of a malfunction of the ECS detected by the OBD system that results in the MI being activated and that does not require an input from the failed component or system.

2.21 **“Engine-after treatment system family”** means, for testing over a service accumulation schedule to establish deterioration factors according to chapter VII of this part relating to the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous pollutants from positive ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles, a manufacturer's grouping of engines that comply with the definition of engine family but which are further grouped into engines utilizing a similar exhaust after-treatment system.

2.22 **"Engine system"** means the engine, the emission control system and the communication interface (hardware and messages) between the engine system electronic control unit(s) (EECU) and any other power train or vehicle control unit.

2.23 **"Engine family"** means a manufacturers grouping of engine systems which, through their design as defined in Chapter II of this part, have similar exhaust emission characteristics; all members of the family must comply with the applicable emission limit values.

2.24 "**Engine operating speed range**" means the engine speed range, most frequently used during engine field operation, which lies between the low and high speeds, as set out in Chapter III to this Document.

2.25 "**Engine speeds A, B and C**" means the test speeds within the engine operating speed range to be used for the ESC test and the ELR test, as set out in chapter III, Appendix 1 of this part.

2.26 **"Engine setting"** means a specific engine/vehicle configuration that includes the emission control strategy (ECS), one single engine performance rating (the type-approved full-load curve) and, if used, one set of torque limiters.

2.27 "**Engine type**" means a category of engines, which do not differ in such essential respects as engine characteristics as defined in chapter II of this part.

2.28 **"Exhaust after treatment system**" means a catalyst (oxidation or 3-way), particulate filter, deNO_x system, combined deNO_x particulate filter or any other emission-reducing device that is installed downstream of the engine. This definition excludes exhaust gas recirculation, which, where fitted, is considered an integral part of the engine system.

2.29 **"Gas engine"** means a positive-ignition engine, which is fuelled with natural gas (NG) or liquefied petroleum gas (LPG).

2.30 **"Gaseous pollutants"** means carbon monoxide, hydrocarbons (assuming a ratio of $CH_{1,85}$ for diesel, $CH_{2,525}$ for LPG and $CH_{2,93}$ for NG (NMHC) and an assumed molecule $CH_3O_{0,5}$ for ethanol-fuelled diesel engines), methane (assuming a ratio of CH_4 for NG) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO_2) equivalent.

2.31 **"High speed (n_{hi})"** means the highest engine speed where 70 % of the declared maximum power occurs in case of diesel engines.

2.32 **“Low speed (n_{lo})”** means the lowest engine speed where 50 % of the declared maximum power occurs.

2.33 **“Major functional failure”** means a permanent or temporary malfunction of any exhaust after treatment system that is expected to result in an immediate or delayed increase of the gaseous or particulate emissions of the engine system and which cannot be properly estimated by the OBD system. Section 3.2.3.1 of chapter VIII provides for the monitoring for major functional failure instead of monitoring for the degradation or the loss of catalytic / filtering efficiency of an exhaust after treatment system. Examples of major functional failure are given in sections 3.2.3.2 and 3.2.3.3 of chapter VIII to this part.

2.34 **“malfunction”** means:

- Any deterioration or failure, including electrical failures, of the emission control system, that would result in emissions exceeding the OBD threshold limits or, when applicable, in failing to reach the range of functional performance of the exhaust after treatment system where the emission of any regulated pollutant would exceed the OBD threshold limits.

- Any case where the OBD system is not able to fulfill the monitoring requirements of this part.

A manufacturer may nevertheless consider a deterioration or failure that would result in emissions not exceeding the OBD threshold limits as a malfunction.

2.35 **“Malfunction indicator (MI)”** means a visual indicator that clearly informs the driver of the vehicle in the event of a malfunction in the sense of this part.

2.36 **“Multi-setting engine”** means an engine containing more than one engine setting.

2.37 "**NG gas range**" means one of the H or L range as defined in European Standard EN 437, dated November 1993.

2.38 "**Net power**" means the power in kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the method of measuring power as set out in part IV of MoSRTH/CMVR/TAP-115/116.

2.39 **“OBD”** means an on-board diagnostic system for emission control, which has the capability of detecting the occurrence of a malfunction and of identifying the likely area of malfunction by means of fault codes stored in computer memory.

2.40 **“OBD-engine family”** means, for type-approval of the OBD system according to the requirements of Chapter VIII this Part, a manufacturer’s grouping of engine systems having common OBD system design parameters according to section 8 of this chapter.

2.41 "**Opacimeter**" means an instrument designed to measure the opacity of smoke particles by means of the light extinction principle.

2.42 **“Parent engine”** means an engine selected from an engine family in such a way that its emissions characteristics will be representative for that engine family.

2.43 **“Particulate after treatment device”** means an exhaust after treatment system designed to reduce emissions of particulate pollutants (PT) through a mechanical, aerodynamic, diffusional or inertial separation.

2.44 "**Particulate pollutants**" means any material collected on a specified filter medium after diluting the exhaust with clean filtered air so that the temperature does not exceed 325°K (52 °C).

2.45 "**Percent load**" means the fraction of the maximum available torque at an engine speed.

2.46 **“Periodic regeneration”** means the regeneration process of an emission control device that occurs periodically in less than 100 hours of normal engine operation. During cycles where regeneration occurs, emission standards can be exceeded.

2.47 **“Power take-off unit”** means an engine-driven output device for the purposes of powering auxiliary, vehicle mounted equipment.

2.48 **“Reagent”** means any medium that is stored on-board the vehicle in a tank and provided to the exhaust after treatment system (if required) upon request of the emission control system.

2.49 "**Recalibration**" means a fine-tuning of an NG engine in order to provide the same performance (power, fuel consumption) in a different range of natural gas.

2.50 "**Reference speed (n_{ref})"** means the 100 per cent speed value to be used for denormalising the relative speed values of the ETC test, as set out in chapter III, Appendix 2 of this part.

2.51 **“Response time”** means the difference in time between a rapid change of the component to be measured at the reference point and the appropriate change in the response of the measuring system whereby the change of the measured component is at least 60 % FS and takes place in less than 0,1 second. The system response time (t_{90}) consists of the delay time to the system and of the rise time of the system (see also ISO 16183).

2.52 **“Rise time”** means the time between the 10 % and 90 % response of the final reading (t_{90} - t_{10}). This is the instrument response after the component to be measured has reached the instrument. For the rise time, the sampling probe is defined as the reference point.

2.53 "**Self adaptability**" means any engine device allowing the air/fuel ratio to be kept constant.

2.54 "**Smoke**" means particles suspended in the exhaust stream of a diesel engine, which absorb, reflect, or refract light.

2.55 "**Test Cycle**" means a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (ESC test) or transient operating conditions (ETC, ELR test).

2.56 **“Torque limiter”** means a device that temporarily limits the maximum torque of the engine.

2.57 **“Transformation time”** means the time between the change of the component to be measured at the sampling probe and a system response of 50 % of the final reading (t_{50}). The transformation time is used for the signal alignment of different measurement instruments.

2.58 “**useful life**” means, for vehicles and engines that are type-approved to BS4 emission norms, the relevant period of distance and/or time that is defined section 5 of Chapter VII of this Part over which compliance with the relevant gaseous, particulate and smoke emission limits has to be assured as part of the type-approval.

2.59 "**Wobbe Index** (lower $\mathbf{W_l}$; or upper $\mathbf{W_u}$)" means the ratio of the corresponding calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions.

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

2.60 **"λ shift factor (S_λ)”** means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio λ if the engine is fuelled with a gas composition different from pure methane (see section 4 of chapter 6 for the calculation of S_λ).

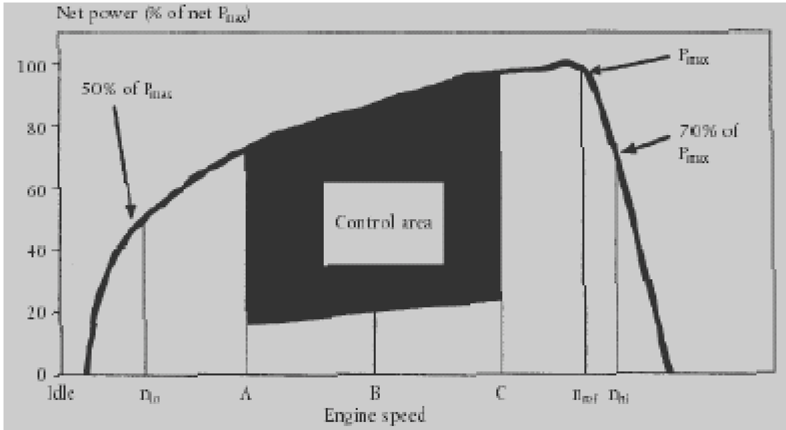


Figure 1
Specific definitions of the test cycles

2.2. Symbols, abbreviations and international standards

2.2.1. *Symbols for test parameters*

Symbol	Unit	Term
A_p	m^2	Cross sectional area of the isokinetic sampling probe
A_e	m^2	Cross sectional area of the exhaust pipe
c	ppm/vol. %	Concentration
C_d	—	Discharge coefficient of SSV-CVS
C1	—	Carbon 1 equivalent hydrocarbon
d	m	Diameter
D_0	m^3/s	Intercept of PDP calibration function
D	—	Dilution factor
D	—	Bessel function constant
E	—	Bessel function constant
E_E	—	Ethane efficiency
E_M	—	Methane efficiency
E_Z	g/kWh	Interpolated NO_x emission of the control point
f	1/s	Frequency
f_a	—	Laboratory atmospheric factor
f_c	s^{-1}	Bessel filter cut-off frequency
F_s	—	Stoichiometric factor
H	MJ/m^3	Calorific value
H_a	g/kg	Absolute humidity of the intake air
H_d	g/kg	Absolute humidity of the dilution air
i	—	Subscript denoting an individual mode or instantaneous measurement
K	—	Bessel constant
k	m^{-1}	Light absorption coefficient
k_f		Fuel specific factor for dry to wet correction
$k_{h,D}$	—	Humidity correction factor for NO_x for diesel engines
$k_{h,G}$	—	Humidity correction factor for NO_x for gas engines
K_V		CFV calibration function
$k_{W,a}$	—	Dry to wet correction factor for the intake air
$k_{W,d}$	—	Dry to wet correction factor for the dilution air
$k_{W,e}$	—	Dry to wet correction factor for the diluted exhaust gas

Symbol	Unit	Term
$k_{W,r}$	—	Dry to wet correction factor for the raw exhaust gas
L	%	Percent torque related to the maximum torque for the test engine
L_a	m	Effective optical path length
M_{ra}	g/mol	Molecular mass of the intake air
M_{re}	g/mol	Molecular mass of the exhaust
m_d	kg	Mass of the dilution air sample passed through the particulate sampling filters
m_{ed}	kg	Total diluted exhaust mass over the cycle
m_{edf}	kg	Mass of equivalent diluted exhaust over the cycle
m_{ew}	kg	Total exhaust mass over the cycle
m_f	mg	Particulate sample mass collected
$m_{f,d}$	mg	Particulate sample mass of the dilution air collected
m_{gas}	g/h or g	Gaseous emissions mass flow (rate)
m_{se}	kg	Sample mass over the cycle
m_{sep}	kg	Mass of the diluted exhaust sample passed through the particulate sampling filters
m_{set}	kg	Mass of the double diluted exhaust sample passed through the particulate sampling filters
m_{ssd}	kg	Mass of secondary dilution air
N	%	Opacity
N_P	—	Total revolutions of PDP over the cycle
$N_{P,i}$	—	Revolutions of PDP during a time interval
n	min^{-1}	Engine speed
n_p	s^{-1}	PDP speed
n_{hi}	min^{-1}	High engine speed
n_{lo}	min^{-1}	Low engine speed
n_{ref}	min^{-1}	Reference engine speed for ETC test
p_a	kPa	Saturation vapour pressure of the engine intake air
p_b	kPa	Total atmospheric pressure
p_d	kPa	Saturation vapour pressure of the dilution air
p_p	kPa	Absolute pressure
p_r	kPa	Water vapour pressure after cooling bath
p_s	kPa	Dry atmospheric pressure
p_1	kPa	Pressure depression at pump inlet
P(a)	kW	Power absorbed by auxiliaries to be fitted for test
P(b)	kW	Power absorbed by auxiliaries to be removed for test
P(n)	kW	Net power non-corrected
P(m)	kW	Power measured on test bed
q_{maw}	kg/h or kg/s	Intake air mass flow rate on wet basis
q_{mad}	kg/h or kg/s	Intake air mass flow rate on dry basis
q_{mdw}	kg/h or kg/s	Dilution air mass flow rate on wet basis
q_{mdew}	kg/h or kg/s	Diluted exhaust gas mass flow rate on wet basis
$q_{mdew,i}$	kg/s	Instantaneous CVS flow rate mass on wet basis
q_{medf}	kg/h or kg/s	Equivalent diluted exhaust gas mass flow rate on wet basis
q_{mew}	kg/h or kg/s	Exhaust gas mass flow rate on wet basis

Symbol	Unit	Term
q_{mf}	kg/h or kg/s	Fuel mass flow rate
q_{mp}	kg/h or kg/s	Particulate sample mass flow rate
q_{vs}	dm^3/min	Sample flow rate into analyser bench
q_{vt}	cm^3/min	Tracer gas flow rate
Ω	—	Bessel constant
Q_s	m^3/s	PDP/CFV-CVS volume flow rate
Q_{SSV}	m^3/s	SSV-CVS volume flow rate
r_a	—	Ratio of cross sectional areas of isokinetic probe and exhaust pipe
r_d	—	Dilution ratio
r_D	—	Diameter ratio of SSV-CVS
r_p	—	Pressure ratio of SSV-CVS
r_s	—	Sample ratio
R_f	—	FID response factor
ρ	kg/m^3	density
S	kW	Dynamometer setting
S_i	m^{-1}	Instantaneous smoke value
S_λ	—	λ-shift factor
T	K	Absolute temperature
T_a	K	Absolute temperature of the intake air
t	s	Measuring time
t_e	s	Electrical response time
t_f	s	Filter response time for Bessel function
t_p	s	Physical response time
Δt	s	Time interval between successive smoke data (= 1/sampling rate)
Δt_i	s	Time interval for instantaneous CVS flow
τ	%	Smoke transmittance
u	—	Ratio between densities of gas component and exhaust gas
V_0	m^3/rev	PDP gas volume pumped per revolution
V_s	l	System volume of analyser bench
W	—	Wobbe index
W_{act}	kWh	Actual cycle work of ETC
W_{ref}	kWh	Reference cycle work of ETC
W_F	—	Weighting factor
WF_E	—	Effective weighting factor
X_0	m^3/rev	Calibration function of PDP volume flow rate
Y_i	m^{-1}	1 s Bessel averaged smoke value

2.2.2 *Symbols for the Chemical Components*

CH_4	Methane
C_2H_6	Ethane
C_2H_5OH	Ethanol
C_3H_8	Propane
CO	Carbon monoxide
DOP	Di-octylphtalate
CO_2	Carbon dioxide
HC	Hydrocarbons
NMHC	Non-methane hydrocarbons
NO_X	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
PT	Particulates

2.2.3 Abbreviations

CFV	Critical flow venturi
CLD	Chemiluminescent detector
ELR	European load response test
ESC	European steady state cycle
ETC	European transient cycle
FID	Flame ionisation detector
GC	Gas chromatograph
HCLD	Heated chemiluminescent detector
HFID	Heated flame ionization detector
LPG	Liquefied petroleum gas
NDIR	Non-dispersive infrared analyser
NG	Natural gas
NMC	Non-methane cutter

2.2.4. Symbols for the fuel composition

W_{ALF}	hydrogen content of fuel, % mass
W_{BET}	carbon content of fuel, % mass
W_{GAM}	sulphur content of fuel, % mass
W_{DEL}	nitrogen content of fuel, % mass
W_{EPS}	oxygen content of fuel, % mass
α	molar hydrogen ratio (H/C)
β	molar carbon ratio (C/C)
γ	molar sulphur ratio (S/C)
δ	molar nitrogen ratio (N/C)
ε	molar oxygen ratio (O/C)

Referring to a fuel $C_\beta H_\alpha O_\varepsilon N_\delta S_\gamma$

β = 1 for carbon based fuels, β = 0 for hydrogen fuel.

3. APPLICATION FOR TYPE-APPROVAL

3.1 As per AIS 007 (as ammended from time to time) to be submitted to Test Agencies.

4. TYPE-APPROVAL:

4.1 Granting of a universal fuel type-approval:

A universal fuel type-approval is granted subject to the following requirements:

4.1.1 In the case of diesel fuel, the parent engine meets the requirements of this part on the reference fuel specified in chapter IV of this part.

4.1.2 In the case of natural gas, the parent engine demonstrates its capability to adapt to any fuel composition that may occur across the market. In the case of natural gas there are generally two types of fuel, high calorific fuel (H-gas) and low calorific fuel (L-gas), but with a significant spread within both ranges; they differ significantly in their energy content expressed by the Wobbe Index and in their shift factor (Sλ). The formulae for the calculation of the Wobbe index and S_{λ} are given in sections 2.58 and 2.59 of this chapter. Natural gases with a λ-shift factor between 0,89 and 1,08 ($0,89 \leq S_{\lambda} \leq 1,08$) are considered to belong to H-range, while natural gases with a λ-shift factor between 1,08 and 1,19 ($1,08 \leq S_{\lambda} \leq 1,19$) are considered to belong to L-range. The composition of the reference fuels reflects the extreme variations of Sλ.

The parent engine shall meet the requirements of this part on the reference fuels G_R and G_{25} as specified in chapter IV of this part, without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Chapter III.

4.1.2.1 On the manufacturer's request the engine may be tested on a third fuel (fuel 3) if the λ-shift factor (S_{λ}) lies between 0,89 (i.e. the lower range of G_R) and 1,19 (i.e. the upper range of G_{25}) for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.1.3 In the case of an engine fuelled with natural gas which is self-adaptive for the range of H-gases on the one hand and the range of L-gases on the other hand, and which switches between the H-range and the L-range by means of a switch, the parent engine shall be tested on the two relevant reference fuels as specified in chapter IV of this part for each range, at each position of the switch. The fuels are G_R (fuel 1) and G_{23} (fuel 3) for the H-range of gases, and G_{25} (fuel 2) and G_{23} (fuel 3) for the L-range of gases. The parent engine shall meet the requirements of this part at both positions of the switch without any readjustment to the fuelling between the two tests at each position of the switch. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing the parent engine shall be run-in using the procedure given in section 3 of appendix 2 to chapter III of this part.

4.1.3.1 On the manufacturer's request the engine may be tested on a third fuel instead of G_{23} (fuel 3) if the λ-shift factor (S_{λ}) lies between 0,89 (i.e. the lower range of G_R) and 1,19 (i.e. the Upper range of G_{25}), for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.1.4 In case of Natural Gas engines, the ratio of emission results "r" shall be determined for each pollutant as follows:

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

or,

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

and,

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

4.1.5 In the case of LPG the parent engine should demonstrate its capability to adapt to any fuel composition that may occur across the market. In the case of LPG there are variations in C_3/C_4 composition. These variations are reflected in the reference fuels. The parent engine should meet the emission requirements on the reference fuels A and B as specified in chapter IV of this part without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in section 3 of chapter III of this part.

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

$$r = \frac{\text{emission result on reference fuel B}}{\text{emission result on reference fuel A}}$$

4.2. Granting of a fuel range restricted type-approval:

Till the availability of reference fuel the engines will be tested with available commercial Fuel. However, if tested with commercial fuel section 4.2 of this Chapter is not applicable. Fuel range restricted type-approval is granted subject to the following requirements:

4.2.1 Exhaust emissions approval of an engine running on natural gas and laid out for operation on either the range of H-gases or on the range of L-gases.

The parent engine shall be tested on the two relevant reference fuels as specified in chapter IV of this part for the relevant range. The fuels are G_R (fuel 1) and G_{23} (fuel 3) for the H-range of gases and G_{25} (fuel 2) and G_{23} (fuel 3) for the L-range of gases. The parent engine shall meet the emission requirements without any readjustment to the fuelling between the two tests. However, one adaptation run over one ETC cycle without measurement is permitted after the change of the fuel. Before testing, the parent engine shall be run-in using the procedure given in paragraph 3 of Appendix 2 to Chapter III.

4.2.1.1 On the manufacturer's request it may be tested on a third fuel instead of G_{23} (fuel 3) if the λ-shift factor ($S\lambda$) lies between 0.89 (i.e. the lower range of G_R) and 1.19 (i.e. the upper range of G_{25}), for example when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

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

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

or,

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

and,

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

4.2.1.3 Upon delivery to the customer the engine shall bear a label (see section 5.1.5 of this chapter) stating for which range of gases the engine is approved.

4.2.2 Exhaust emissions approval of an engine running on natural gas or LPG and laid out for operation on one specific fuel composition.

4.2.2.1 The parent engine shall meet the emission requirements on the reference fuels G_R and G_{25} in the case of natural gas, or the reference fuels A and B in the case of LPG, as specified in chapter IV of this part. Between the tests fine-tuning of the fuelling system is allowed. This fine-tuning will consist of a recalibration of the fuelling database, without any alteration to either the basic control strategy or the basic structure of the database. If necessary the exchange of parts that are directly related to the amount of fuel flow (such as injector nozzles) is allowed.

4.2.2.2 If the manufacturer so desires the engine may be tested on the reference fuels G_R and G23, or on the reference fuel G_{25} and G_{23}, in which case the type approval is only valid for the H-range or the L-range of gases respectively.

4.2.2.3 Upon delivery to the customer the engine shall bear a label (see section of this chapter) stating for which fuel composition the engine has been calibrated.

4.3 Exhaust emissions approval of a member of a family

4.3.1 With the exception of the case mentioned in paragraph 4.3.2, the approval of a parent engine shall be extended to all family members without further testing, for any fuel composition within the range for which the parent engine has been approved (in the case of engines described in paragraph 4.2.2) or the same range of fuels (in the case of engines described in either paragraphs 4.1 or 4.2) for which the parent engine has been approved.

4.3.2 Secondary test engine
In case of an application for type-approval of an engine, or a vehicle in respect of its engine, that engine belonging to an engine family, if the technical service determines that, with regard to the selected parent engine the submitted application does not fully represent the engine family defined in this chapter, an alternative and if necessary an additional reference test engine may be selected by the technical service and tested.

<u>5. ENGINE MARKINGS:</u>

5.1. The engine approved as a technical unit must bear:

5.1.1 The trademark or trade name of the manufacturer of the engine.

5.1.2 The manufacturer's commercial description.

5.1.3. Declared maximum power.

5.1.4. In case of an NG engine one of the following markings to be placed after the type approval number:

- H in case of the engine being approved and calibrated for the H-range of gases.

- L in case of the engine being approved and calibrated for the L-range of gases.

- HL in case of the engine being approved and calibrated for both the H range and L-range of gases.

- H_t in case of the engine being approved and calibrated for a specific gas composition in the H-range of gases and transformable to another specific gas in the H-range of gases by fine tuning of the engine fuelling;

- L_t in case of the engine being approved and calibrated for a specific gas composition in the L-range of gases and transformable to another specific gas in the L-range of gases after fine-tuning of the engine fuelling;

- HL_t in the case of the engine being approved and calibrated for a specific gas composition in either the H-range or the L-range of gases and transformable to another specific gas in either the H-range or the L-range of gases by fine-tuning of the engine fuelling.

5.1.5. Labels

In the case of NG and LPG fuelled engines with a fuel range restricted type approval, the following labels are applicable:

5.1.5.1. Content

The following information must be given:

In the case of section 4.2.1.3 of this chapter, the label shall state "ONLY FOR USE WITH NATURAL GAS RANGE H". If applicable, "H" is replaced by "L".

In the case of paragraph 4.2.2.3, the label shall state "ONLY FOR USE WITH NATURAL GAS SPECIFICATION..." or "ONLY FOR USE WITH LIQUEFIED PETROLEUM GAS SPECIFICATION...", as applicable. All the information in the appropriate table(s) in chapter IV of this part shall be given with the individual constituents and limits specified by the engine manufacturer.

The letters and figures must be at least 4 mm in height.

Note:

If lack of space prevents such labelling, a simplified code may be used. In this event, explanatory notes containing all the above information must be easily accessible to any person filling the fuel tank or performing maintenance or repair on the engine and its accessories, as well as to the authorities concerned. The site and content of these explanatory notes will be determined by agreement between the manufacturer and the approval authority.

5.1.5.2. Properties

Labels must be durable for the useful life of the engine. Labels must be clearly legible and their letters and figures must be indelible. Additionally, labels must be attached in such a manner that their fixing is durable for the useful life of the engine, and the labels cannot be removed without destroying or defacing them.

5.1.5.3. Placing

Labels must be secured to an engine part necessary for normal engine operation and not normally requiring replacement during engine life. Additionally, these labels must be located so as to be readily visible to the average person after the engine has been completed with all the auxiliaries necessary for engine operation.

5.2. In case of an application for type-approval for a vehicle type in respect of its engine, the marking specified in section 5.1.5 shall also be placed close to fuel filling aperture.

5.3. In case of an application for type-approval for a vehicle type with an approved engine, the marking specified in section 5.1.5 shall also be placed close to the fuel-filling aperture.

6. SPECIFICATIONS AND TESTS

6.1 General:

6.1.1 Emission control equipment

6.1.1.1 The components liable to affect, where appropriate, the emission of gaseous and particulate pollutants from diesel and gas engines shall be so designed, constructed, assembled and installed as to enable the engine, in normal use, to comply with the provisions of this part.

6.1.2 The use of a defeat strategy is forbidden.

6.1.2.1 The use of a multi-setting engine is forbidden until appropriate and robust provisions for multi-setting engines are laid down in this part.

6.1.3 Emission control strategy

6.1.3.1 Any element of design and emission control strategy (ECS) liable to affect the emission of gaseous and particulate pollutants from diesel engines and the emission of gaseous pollutants from gas engines shall be so designed, constructed, assembled and installed as to enable the engine, in normal use, to comply with the provisions of this part. ECS consists of the base emission control strategy (BECS) and usually one or more auxiliary emission control strategies (AECS).

6.1.4 Requirements for base emission control strategy

6.1.4.1 The base emission control strategy (BECS) shall be so designed as to enable the engine, in normal use, to comply with the provisions of this part. Normal use is not restricted to the conditions of use as specified in section 6.1.5.4 of this chapter.

6.1.5 Requirements for auxiliary emission control strategy

6.1.5.1 An auxiliary emission control strategy (AECS) may be installed to an engine or on a vehicle provided that the AECS:

- Operates only outside the conditions of use specified in section 6.1.5.4 of this chapter for the purposes defined in section 6.1.5.5 of this chapter or

- Is activated only exceptionally within the conditions of use specified in section 6.1.5.4 of this chapter for the purposes defined in section 6.1.5.6 of this part and not longer than is needed for these purposes.

6.1.5.2 An auxiliary emission control strategy (AECS) that operates within the conditions of use specified in section 6.1.5.4 and which results in the use of a different or modified emission control strategy (ECS) to that normally employed during the applicable emission test cycles will be permitted if, in complying with the requirements of section 6.1.7 of this chapter, it is fully demonstrated that the measure does not permanently reduce the effectiveness of the emission control system. In all other cases, such strategy shall be considered to be a defeat strategy.

6.1.5.3 An auxiliary emission control strategy (AECS) that operates outside the conditions of use specified in section 6.1.5.4 of this chapter will be permitted if, in complying with the requirements of section 6.1.7 of this chapter, it is fully demonstrated that the measure is the minimum strategy necessary for the purposes of section 6.1.5.6 of this chapter with respect to environmental protection and other technical aspects. In all other cases, such a strategy shall be considered to be a defeat strategy.

6.1.5.4 As provided for in section 6.1.5.1, the following conditions of use apply under steady state and transient engine operations:

- An altitude not exceeding 1000 metres (or equivalent atmospheric pressure of 90 kPa), and

- An ambient temperature within the range 279°K to 303°K (6 °C to 30°C)*, and

- Engine coolant temperature within the range 343° K to 373° K (70 °C to 100 °C).

*Appropriateness of lower temperature may be reviewed as and when required.

6.1.5.5 An auxiliary emission control strategy (AECS) may be installed to an engine, or on a vehicle, provided that the operation of the AECS is included in the applicable type-approval test and is activated according to section 6.1.5.6 of this chapter.

6.1.5.6 The AECS is activated:

- Only by on-board signals for the purpose of protecting the engine system (including air-handling device protection) and/or vehicle from damage.

Or

- For purposes such as operational safety, emission default modes and limp-home strategies.

Or

- For such purposes as excessive emissions prevention, cold start or warming-up.

or

- If it is used to trade-off the control of one regulated pollutant under specific ambient or operating conditions in order to maintain control of all other regulated pollutants within the emission limit values that are appropriate for the engine in question. The overall effects of such an AECS is to compensate for naturally occurring phenomena and do so in a manner that provides acceptable control of all emission constituents.

6.1.6 Requirements for torque limiters

6.1.6.1 A torque limiter will be permitted if it complies with the requirements of section 6.1.6.2 or 6.5.5 of this chapter. In all other cases, a torque limiter shall be considered to be a defeat strategy.

6.1.6.2 A torque limiter may be installed to an engine, or on a vehicle, provided that:

- The torque limiter is activated only by on-board signals for the purpose of protecting the power train or vehicle construction from damage and/or for the purpose of vehicle safety, or for power take-off activation when the vehicle is stationary, or for measures to ensure the correct functioning of the deNO$_X$ system.

And

- The torque limiter is active only temporarily,

And

- The torque limiter does not modify the emission control strategy (ECS),

And

- In case of power take-off or power train protection the torque is limited to a constant value, independent from the engine speed, while never exceeding the full-load torque,

And

- Is activated in the same manner to limit the performance of a vehicle in order to encourage the driver to take the necessary measures in order to ensure the correct functioning of NO$_X$ control measures within the engine system.

6.1.7 Special requirements for electronic emission control systems

6.1.7.1 Documentation requirements

The manufacturer shall provide a documentation package that gives access to any element of design and emission control strategy (ECS), and torque limiter of the engine system and the means by which it controls its output variables, whether that control is direct or indirect. The documentation shall be made available in two parts:

(a) The formal documentation package, which shall be supplied to the technical service at the time of submission of the type-approval application, shall include a full description of the ECS and, if applicable, the torque limiter. This documentation may be brief, provided that it exhibits evidence that all outputs permitted by a matrix obtained from the range of control of the individual unit inputs have been identified. This information shall be attached to the documentation required in section 3 of this chapter;

(b) additional material that shows the parameters that are modified by any auxiliary emission control strategy (AECS) and the boundary conditions under which the AECS operates. The additional material shall include a description of the fuel system control logic, timing strategies and switch points during all modes of operation. It shall also include a description of the torque limiter described in section 6.5.5 of this chapter.

The additional material shall also contain a justification for the use of any AECS and include additional material and test data to demonstrate the effect on exhaust emissions of any AECS installed to the engine or on the vehicle. The justification for the use of an AECS may be based on test data and/or sound engineering analysis.

This additional material shall remain strictly confidential, and be made available to the type-approval authority on request. The type approval authority will keep this material confidential.

6.1.8 Provisions for electronic system security

6.1.8.1 Any vehicle with an Emission Control Unit must include features to deter modification, except as authorised by the manufacturer. The manufacturer shall authorise modifications if these modifications are necessary for the diagnosis, servicing, inspection, retrofitting or repair of the vehicle. Any reprogrammable computer codes or operating parameters must be resistant to tampering and afford a level of protection at least as good as the provisions in ISO 15031-7 (SAE J2186) provided that the security exchange is conducted using the protocols and diagnostic connector as prescribed in section 6 of Chapter VIII to this part. Any removable calibration memory chips must be potted, encased in a sealed container or protected by electronic algorithms and must not be changeable without the use of specialised tools and procedures.

6.1.8.2 Computer-coded engine operating parameters must not be changeable without the use of specialised tools and procedures (e.g. soldered or potted computer components or sealed (or soldered) computer enclosures).

6.1.8.3 Manufacturers must take adequate steps to protect the maximum fuel delivery setting from tampering while a vehicle is in-service.

6.1.8.4 Manufacturers may apply to the approval authority for an exemption from one of these requirements for those vehicles that are unlikely to require protection. The criteria that the approval authority will evaluate in considering an exemption will include, but are not limited to, the current availability of performance chips, the high-performance capability of the vehicle and the projected sales volume of the vehicle.

6.1.8.5 Manufacturers using programmable computer code systems (e.g. electrical erasable programmable read-only memory, EEPROM) must deter unauthorised reprogramming. Manufacturers must include enhanced tamper-protection strategies and write protect features requiring electronic access to an off-site computer maintained by the manufacturer. Alternative methods giving an equivalent level of tamper protection may be approved by the authority.

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

For type approval as per section 6.2.1 of this chapter, the emissions of diesel engines shall be determined on the ESC, ELR and ETC tests.

For gas engines, the gaseous emissions shall be determined on the ETC test.

The ESC and ELR test procedures are described in chapter III appendix 1 of this part, the ETC test procedure in chapter III appendices 2 and 3 of this chapter.

The emissions of gaseous pollutants and particulate pollutants, if applicable, and smoke, if applicable, by the engine submitted for testing shall be measured by the methods described in chapter III appendix 4 of this part. Chapter V of this part describes the recommended analytical systems for the gaseous pollutants, the recommended particulate sampling systems, and the recommended smoke measurement system.

Other systems or analysers may be approved by the test agency, if it is found that they yield equivalent results on the respective test cycle. The determination of system equivalency shall be based upon a 7 sample pair (or larger) correlation study between the system under consideration and one of the reference systems of this part. For particulate emissions, either the full flow dilution system or the partial flow dilution system meeting the requirements of ISO 16183 are recognised as equivalent reference systems. “Results” refer to the specific cycle emissions value. The correlation testing shall be performed at the same laboratory, test cell, and on the same engine, and is preferred to be run concurrently. The equivalency of the sample pair averages shall be determined by F-test and t-test statistics as described in appendix 4 of this chapter obtained under these laboratory, test cell and engine conditions. Outliers shall be determined in accordance with ISO 5725 and excluded from the database. For introduction of a new system into the part the determination of equivalency shall be based upon the calculation of repeatability and reproducibility, as described in ISO 5725.

6.2.1 Limit values for Type Approval (TA) as well as (COP)

(i) For Diesel engines

The specific mass of the carbon monoxide, of the total hydrocarbons, of the oxides of nitrogen and of the particulates, as determined on the ESC test, and of the smoke opacity, as determined on the ELR test, shall not exceed the values shown in following table:

Engine Steady State Cycle (ESC) test				Engine Load Response (ELR) test
CO (g/kWh)	HC (g/kWh)	NO_X (g/kWh)	PM (g/kWh)	Smoke (m^{-1})
1.5	0.46	3.5	0.02	0.5

ii) For Diesel engines, CNG Engines and LPG Engines

For diesel engines that are additionally tested on the ETC test, and specifically for the gas engines, the specific masses of the carbon monoxide, of the non-methane hydrocarbons, of the methane (where applicable), of the oxides of nitrogen and of the particulates (where applicable) shall not exceed the values shown in following table:

Engine Transient Cycle (ETC) test				
CO (g/kWh)	NMHC [(1)] (g/kWh)	CH_4 [(2)] g/kWh	NOx (g/kWh)	PM [(3)] (g/kWh)
4.0	0.55	1.1	3.5	0.03
[(1)] A manufacturer may choose to measure the mass of total hydrocarbons				

(THC) instead of measuring the mass of non-methane hydrocarbon (NMHC). In this case, the limit for mass of THC should be same as for the NMHC.

(2) For CNG engines only.

(3) For Diesel engines only.

6.2.2 Specific requirements for diesel engines:

6.2.2.1 The specific mass of the oxides of nitrogen measured at the random check points within the control area of the ESC test must not exceed by more than 10 per cent the values interpolated from the adjacent test modes (reference sections 4.6.2 and 4.6.3 of chapter III appendix 1 of this chapter).

6.2.2.2 The smoke value on the random test speed of the ELR must not exceed the highest smoke value of the two adjacent test speeds by more than 20 per cent, or by more than 5 per cent of the limit value, whichever is greater.

6.3. Durability and deterioration factors

6.3.1. For the purposes of this part, the manufacturer shall determine deterioration factors that will be used to demonstrate that the gaseous and particulate emissions of an engine family or engine-after treatment system family remain in conformity with the appropriate emission limits specified in the tables in section 6.2.1 of this chapter over the appropriate durability period laid down in chapter VII of this Part.

6.3.2 The procedures for demonstrating the compliance of an engine or engine-after treatment system family with the relevant emission limits over the appropriate durability period are given in chapter VII of this Part.

6.4 On-Board Diagnostic (OBD) system

6.4.1 Diesel engines or vehicles equipped with a diesel engine must be fitted with an on-board diagnostic (OBD) system for emission control in accordance with the requirements of chapter VIII of this part.

Gas engines or vehicles equipped with a gas engine must be fitted, with an on-board diagnostic (OBD) system for emission control in accordance with the requirements of chapter VIII of this part.

6.4.2. Small batch engine production

As an alternative to the requirements of this section, engine manufacturers whose annual production of a type of engine, belonging to an OBD engine family,

- is less than 250 units per year, may obtain type-approval on the basis of the requirements of this part where the engine is monitored only for circuit continuity and the after-treatment system is monitored for major functional failure.

- is less than 50 units per year, may obtain type-approval on the basis of the requirements of this part where the complete emission control system (i.e. the engine and after-treatment system) are monitored only for circuit continuity.

Type approval authority should inform any competent authority or Standing Committee on Implementation of Emission Legislation of each type approval granted under this provision.

6.4.3 For the vehicles with SCR technology and fitted with reagent tank the following requirement shall be applicable from 1st April 2010 till the time OBD is implemented.

6.4.3.1 For the vehicles with SCR technology and fitted with reagent tank , the driver shall be informed of the level of reagent in the on-vehicle reagent storage tank through a specific mechanical or electronic indication on the vehicle's dashboard. This shall include a warning when the level of reagent goes:

- Below 10 % of the tank or a higher percentage at the choice of the manufacturer.

Or

- Below the level corresponding to the driving distance possible with the fuel reserve level specified by the manufacturer

6.4.3.2 As soon as the reagent tank becomes empty - Torque limiter shall be activated when the vehicle becomes stationary for the first time after the aforementioned condition has occurred with engine torque shall not, in any case, exceed a constant value of:

- 60 % of engine maximum torque for vehicles of category N > 16 tons, M > 7.5 tons
- 75 % of engine maximum torque for vehicles of category N ≤ 16 tons, M ≤ 7.5 tons"

6.4.3.3 The torque limiter shall be deactivated when the engine speed is at idle if the condition for its activation have ceased to exist. The torque limiter shall not be automatically deactivated without the reason for its activation being remedied.

6.5 Requirements to ensure correct operation of NOx control measures

6.5.1 General

6.5.1.1 This section is applicable to compression-ignition engine systems irrespective of the technology used to comply with the emission limit values provided in the tables in section 6.2.1 of this chapter.

6.5.1.2 Any engine system covered by this section shall be designed, constructed and installed so as to be capable of meeting these requirements over the useful life of the engine.

6.5.1.3 Information that fully describes the functional operational characteristics of an engine system covered by this section shall be provided by the manufacturer in chapter II of this Part.

6.5.1.4 In its application for type-approval, if the engine system requires a reagent, the manufacturer shall specify the characteristics of all reagent(s) consumed by any exhaust after treatment system, e.g. type and concentrations, operational temperature conditions, reference to international standards etc.

6.5.1.5 Subject to requirements set out in section 6.1 of this chapter, any engine system covered by this section shall retain its emission control function during all conditions regularly.

6.5.1.6 For the purpose of type-approval, the manufacturer shall demonstrate to the test agency that for engine systems that require a reagent, any emission of ammonia does not exceed, over the applicable emissions test cycle, a mean value of 25 ppm.

6.5.1.7 For engine systems requiring a reagent, each separate reagent tank installed on a vehicle shall include a means for taking a sample of any fluid inside the tank. The sampling point shall be easily accessible without the use of any specialised tool or device.

6.5.2. Maintenance requirements

6.5.2.1 The manufacturer shall furnish or cause to be furnished to all owners of new heavy-duty vehicles or new heavy-duty engines written instructions that shall state that if the vehicle emission control system is not functioning correctly, the driver shall be informed of a problem by the malfunction indicator (MI) and the engine shall consequentially operate with a reduced performance.

6.5.2.2. The instructions will indicate requirements for the proper use and maintenance of vehicles, including where relevant the use of consumable reagents.

6.5.2.3 The instructions shall be written in clear and non-technical language.

6.5.2.4 The instructions shall specify if consumable reagents have to be refilled by the vehicle operator between normal maintenance intervals and shall indicate a likely rate of reagent consumption according to the type of new heavy-duty vehicle.

6.5.2.5 The instructions shall specify that use of and refilling of a required reagent of the correct specifications when indicated is mandatory for the vehicle to comply with the certificate of conformity issued for that vehicle or engine type.

6.5.2.6 The instructions shall state that it may be a criminal offence to use a vehicle that does not consume any reagent if it is required for the reduction of pollutant emissions and that, in consequence, any favorable conditions for the purchase or operation of the vehicle obtained in the country of registration or other country in which the vehicle is used may become invalid.

6.5.3. Engine system NOx control

6.5.3.1 Incorrect operation of the engine system with respect to NO_X emissions control (for example due to lack of any required reagent, incorrect EGR flow or deactivation of EGR) shall be determined through monitoring of the NO_X level by sensors positioned in the exhaust stream.

6.5.3.2 Any deviation in NO_X level more than 1,5 g/kwh above the applicable limit value given in table I of section 6.2.1 of this chapter, shall result in the driver being informed by activation of the MI as referred to in section 3.6.5 of chapter VIII of this part.

6.5.3.3 In addition, a non-erasable fault code identifying the reason why NO_X exceeds the levels specified in the section 6.5.3.2 shall be stored in accordance with section 3.9.2 of chapter VIII of this part for at least 400 days or 9600 hours of engine operation.

The reasons for the NO_X exceedance shall, at a minimum, and where applicable, be identified in the cases of empty reagent tank, interruption of reagent dosing activity, insufficient reagent quality, too low reagent consumption, incorrect EGR flow or deactivation of the EGR. In all other cases, the manufacturer is permitted to refer to a non-erasable fault code “high NO_X — root cause unknown”.

6.5.3.4 If the NO_X level exceeds the OBD threshold limit values given in section 7 of chapter VIII of this part, a torque limiter shall reduce the performance of the engine according to the requirements of section 6.5.5 of this chapter in a manner that is clearly perceived by the driver of the vehicle. When the torque limiter is activated the driver shall continue to be alerted according to the requirements of section 6.5.3.2 of this chapter and a non erasable fault code shall be stored in accordance with section 6.5.3.3 of this chapter.

6.5.3.5 In the case of engine systems that rely on the use of EGR and no other after treatment system for NOx emissions control, the manufacturer may utilise an alternative method to the requirements of section 6.5.3.1 of this chapter for the determination of the NO_X level. At the time of type approval the manufacturer shall demonstrate that the alternative method is equally timely and accurate in determining the NO_X level compared to the requirements of section 6.5.3.1 of this chapter and that it triggers the same consequences as those referred to in sections 6.5.3.2, 6.5.3.3 and 6.5.3.4 of this chapter.

6.5.4. Reagent control

6.5.4.1 For vehicles that require the use of a reagent to fulfill the requirements of this section 6.5 of this chapter, the driver shall be informed of the level of reagent in the on-vehicle reagent storage tank through a specific mechanical or electronic indication on the vehicle's dashboard. This shall include a warning when the level of reagent goes:

- Below 10 % of the tank or a higher percentage at the choice of the manufacturer.

Or

- Below the level corresponding to the driving distance possible with the fuel reserve level specified by the manufacturer.

The reagent indicator shall be placed in close proximity to the fuel level indicator.

6.5.4.2 The driver shall be informed, according to the requirements of section 3.6.5 of chapter VIII of this Part, if the reagent tank becomes empty.

6.5.4.3 As soon as the reagent tank becomes empty, the requirements of section 6.5.5 of this chapter shall apply in addition to the requirements of section 6.5.4.2.

6.5.4.4 A manufacturer may choose to comply with the sections 6.5.4.5 to 6.5.4.12 of this chapter as an alternative to complying with the requirements of section 6.5.3 of this chapter.

6.5.4.5 Engine systems shall include a means of determining that a fluid corresponding to the reagent characteristics declared by the manufacturer and recorded in Chapter II of this part is present on the vehicle.

6.5.4.6 If the fluid in the reagent tank does not correspond to the minimum requirements declared by the manufacturer as recorded in chapter II of this part the additional requirements of section 6.5.4.12 of this chapter shall apply.

6.5.4.7 Engine systems shall include a means for determining reagent consumption and providing off-board access to consumption information.

6.5.4.8 Average reagent consumption and average demanded reagent consumption by the engine system either over the previous complete 48 hour period of engine operation or the period needed for a demanded reagent consumption of at least 15 litres, whichever is longer, shall be available via the serial port of the standard diagnostic connector as referred in section 6.8.3 of chapter VIII of this part.

6.5.4.9 In order to monitor reagent consumption, at least the following parameters within the engine shall be monitored:

- Level of reagent in on-vehicle storage tank.

- Flow of reagent or injection of reagent as close as technically possible to the point of injection into an exhaust after treatment system.

6.5.4.10 Any deviation more than 50 % in average reagent consumption and average demanded reagent consumption by the engine system over the period defined in section 6.5.4.8 of this chapter shall result in application of the measures laid down in paragraph 6.5.4.12 of this chapter.

6.5.4.11 In the case of interruption in reagent dosing activity the measures laid down in section 6.5.4.12 of this chapter shall apply. This is not required where such interruption is demanded by the engine ECU because engine operating conditions are such that the engine's emission performance does not require reagent dosing, provided that the manufacturer has clearly informed the approval authority when such operating conditions apply.

6.5.4.12 Any failure detected with respect to sections 6.5.4.6, 6.5.4.10 or 6.5.4.11 of this chapter shall trigger the same consequences in the same order as those referred to in sections 6.5.3.2, 6.5.3.3 or 6.5.3.4 of this chapter.

6.5.5. Measures to discourage tampering of exhaust after treatment systems

6.5.5.1 Any engine system covered by this section 6.5 of this chapter shall include a torque limiter that will alert the driver that the engine system is operating incorrectly or the vehicle is being operated in an incorrect manner and thereby encourage the prompt rectification of any fault(s).

6.5.5.2 The torque limiter shall be activated when the vehicle becomes stationary for the first time after the conditions of either sections 6.5.3.4, 6.5.4.3, 6.5.4.6, 6.5.4.10, 6.5.4.11 of this chapter have occurred.

6.5.5.3 Where the torque limiter comes into effect, the engine torque shall not, in any case, exceed a constant value of:

- 60 % of engine maximum torque for vehicles of category N > 16 tons, M > 7.5 tons
- 75 % of engine maximum torque for vehicles of category N ≤ 16 tons, 3.5 < M ≤ 7.5 tons.

6.5.5.4 Requirements for documentation and the torque limiter are set out in sections 6.5.5.5 to 6.5.5.8.

6.5.5.5. Detailed written information fully describing the functional operation characteristics of the emission control monitoring system torque limiter shall be specified according to the documentation requirements of section 6.1.7.1 (b) of this chapter. Specifically, the manufacturer shall provide information on the algorithms used by the ECU for relating the NO_X concentration to the specific NO_X emission (in g/kWh) on the ETC in accordance with section 6.5.6.5 of this chapter.

6.5.5.6 The torque limiter shall be deactivated when the engine speed is at idle if the conditions for its activation have ceased to exist. The torque limiter shall not be automatically deactivated without the reason for its activation being remedied.

6.5.5.7 Deactivation of the torque limiter shall not be feasible by means of a switch or a maintenance tool.

6.5.5.8 The torque limiter shall not apply to engines or vehicles for use by the armed services, by rescue services and by fire-services and ambulances. Permanent deactivation shall only be done by the engine or vehicle manufacturer, and a special engine type within the engine family shall be designated for proper identification.

6.5.6 Operating conditions of the emission control monitoring system

6.5.6.1 The emission control monitoring system shall be operational,

— At all ambient temperatures between 266° K and 308° K (– 7 °C and 35 °C),

— At all altitudes below 1600 m,

— At engine coolant temperatures above 343° K (70 °C).

This section does not apply in the case of monitoring for reagent level in the storage tank where monitoring shall be conducted under all conditions of use.

6.5.6.2 The emission control monitoring system may be deactivated when a limp-home strategy is active and which results in a torque reduction greater than the levels indicated in section 6.5.5.3 of this chapter for the appropriate vehicle category.

6.5.6.3 If an emission default mode is active, the emission control monitoring system shall remain operational and comply with the provisions of section 6.5 of this chapter.

6.5.6.4 The incorrect operation of NO_X control measures shall be detected within four OBD test cycles as referred to in the definition given in section 6.1 of appendix 1 of chapter VIII of this Part.

6.5.6.5 Algorithms used by the ECU for relating the actual NO_X concentration to the specific NO_X emission (in g/kWh) on the ETC shall not be considered to be a defeat strategy.

6.5.6.6 If an AECS that has been approved by the type-approval authority in accordance with section 6.1.5 of this chapter becomes operational, any increase in NO_X due to the operation of the AECS may be applied to the appropriate NO_X level referred to in section 6.5.3.2 of this chapter. In all such cases, the influence of the AECS on the NO_X threshold shall be described in accordance with section 6.5.5.5 of this chapter.

6.5.7 Failure of the emission control monitoring system

6.5.7.1 The emission control monitoring system shall be monitored for electrical failures and for removal or deactivation of any sensor that prevents it from diagnosing an emission increase as required by sections 6.5.3.2 and 6.5.3.4 of this chapter.

Examples of sensors that affect the diagnostic capability are those directly measuring NO_X concentration, urea quality sensors, and sensors used for monitoring reagent dosing activity, reagent level, reagent consumption or EGR rate.

6.5.7.2 If a failure of the emission control monitoring system is confirmed, the driver shall be immediately alerted by the activation of the warning signal according to section 3.6.5 of chapter VIII of this part.

6.5.7.3 The torque limiter shall be activated in accordance with section 6.5.5 of this chapter if the failure is not remedied within 50 hours of engine operation.

6.5.7.4 When the emission control monitoring system has determined the failure has ceased to exist, the fault code(s) associated with that failure may be cleared from the system memory, except in the cases referred to in section 6.5.7.5 of this chapter and the torque limiter, if applicable, shall be deactivated according to section 6.5.5.6 of this chapter.

Fault code(s) associated with a failure of the emission control monitoring system shall not be capable of being cleared from the system memory by any scan tool.

6.5.7.5 In the case of the removal or deactivation of elements of the emission control monitoring system, in accordance with section 6.5.7.1of this chapter, a non-erasable fault code shall be stored in accordance with section 3.9.2 of chapter VIII of this part for a minimum of 400 days or 9600 hours of engine operation.

6.5.8 Demonstration of the emission control monitoring system

6.5.8.1 As part of the application for type-approval provided for in section 3 of this chapter, the manufacturer shall demonstrate the conformity of the provisions of this section by tests on an engine dynamometer in accordance with sections 6.5.8.2 to 6.5.8.7 of this chapter.

6.5.8.2 The compliance of an engine family or an OBD engine family to the requirements of this section may be demonstrated by testing the emission control monitoring system of one of the members of the family (the parent engine), provided the manufacturer demonstrates to the type approval authority that the emission control monitoring systems are similar within the family.

This demonstration may be performed by presenting to the type-approval authorities such elements as algorithms, functional analyses, etc.

The parent engine is selected by the manufacturer in agreement with the type approval authority.

6.5.8.3 The testing of the emission control monitoring system consists of the following three phases:

Selection :

An incorrect operation of the NO_X control measures or a failure of the emission control monitoring system is selected by the authority within a list of incorrect operations provided by the manufacturer.

Qualification :

The influence of the incorrect operation is validated by measuring the NO_X level over the ETC on an engine test bed.

Demonstration :

The reaction of the system (torque reduction, warning signal, etc.) shall be demonstrated by running the engine on four OBD test cycles.

6.5.8.3.1 For the selection phase, the manufacturer shall provide the type approval authority with a description of the monitoring strategies used to determine potential incorrect operation of any NO_X control measure and potential failures in the emission control monitoring system that would lead either to activation of the torque limiter or to activation of the warning signal only.

Typical examples of incorrect operations for this list are an empty reagent tank, an incorrect operation leading to an interruption of reagent dosing activity, an insufficient reagent quality, an incorrect operation leading to low reagent consumption, an incorrect EGR flow or a deactivation of the EGR.

A minimum of two and a maximum of three incorrect operations of the NO_X control system or failures of the emission control monitoring system shall be selected by the type approval authority from this list.

6.5.8.3.2 For the qualification phase, the NO_X emissions shall be measured over the ETC test cycle, according to the provisions of appendix 2 of Chapter III. The result of the ETC test shall be used to determine in which way the NO_X control monitoring system is expected to react during the demonstration process (torque reduction and/or warning signal). The failure shall be simulated in a way that the NO_X level does not exceed by more than 1 g/kWh any of the threshold levels given in sections 6.5.3.2 or 6.5.3.4 of this chapter.

Emissions qualification is not required in case of an empty reagent tank or for demonstrating a failure of the emission control monitoring system.

The torque limiter shall be deactivated during the qualification phase.

6.5.8.3.3 For the demonstration phase, the engine shall be run over a maximum of four OBD test cycles.

No failure other than the ones which are being considered for demonstration purposes shall be present.

6.5.8.3.4 Prior to starting the test sequence of section 6.5.8.3.3, the emission control monitoring system shall be set to a “no failure” status.

6.5.8.3.5 Depending on the NO_X level selected, the system shall activate a warning signal and in addition, if applicable, the torque limiter at any time before the end of the detection sequence. The detection sequence may be stopped once the NO_X control monitoring system has properly reacted.

6.5.8.4 In the case of an emission control monitoring system principally based on monitoring the NO_X level by sensors positioned in the exhaust stream, the manufacturer may choose to directly monitor certain system functionalities (e.g. interruption of dosing activity, closed EGR valve) for the determination of compliance. In that case, the selected system functionality shall be demonstrated.

6.5.8.5 The level of torque reduction required in section 6.5.5.3 of this chapter by the torque limiter shall be approved together with the general engine performance approval in accordance with this part. For the demonstration process, the manufacturer shall demonstrate to the type-approval authority the inclusion of the correct torque limiter into the engine ECU. Separate torque measurement during the demonstration is not required.

6.5.8.6 As an alternative to sections 6.5.8.3.3 to 6.5.8.3.5 of this chapter, the demonstration of the emission control monitoring system and the torque limiter may be performed by testing a vehicle. The vehicle shall be driven on the road or on a test track with the selected incorrect operations or failures of the emission control monitoring system to demonstrate that the warning signal and activation of the torque limiter will operate in accordance with the requirements of section 6.5 of this chapter, and in particular, those in sections 6.5.5.2 and 6.5.5.3 of this chapter.

6.5.8.7 If the storage in the computer memory of a non-erasable fault code is required for complying with the requirements of section 6.5 of this chapter, the following three conditions shall be met by the end of demonstration sequence:

— That it is possible to confirm via the OBD scan tool the presence in the OBD computer memory of the appropriate non-erasable fault code described in section 6.5.3.3 of this chapter and that it can be shown to the satisfaction of the type approval authority that the scan tool cannot erase it, and,

— That it is possible to confirm the time spent during the detection sequence with the warning signal activated by reading the non-erasable counter referred to in section 3.9.2 of chapter VIII of this part, and that it can be shown to the satisfaction of the type approval authority that the scan tool cannot erase it, and,

— That the type-approval authority has approved the elements of design showing that this non-erasable information is stored in accordance with section 3.9.2 of chapter VIII of this part for a minimum of 400 days or 9 600 hours of engine operation.

7. INSTALLATION ON THE VEHICLE:

7.1 The engine installation on the vehicle shall comply with the following characteristics in respect to the type-approval of the engine:

7.1.1 Intake depression shall not exceed that specified for the type-approved engine.

7.1.2 Exhaust back pressure shall not exceed that specified for the type-approved engine.

7.1.3 Exhaust system volume shall not differ by more than 40% of that specified for the type-approved engine

7.1.4 Power absorbed by the auxiliaries needed for operating the engine shall not exceed that specified for the type-approved engine.

8. ENGINE FAMILY

8.1. Parameters defining the engine family

The engine family, as determined by the engine manufacturer must comply with the provisions of ISO 16185.

In order that engines may be considered to belong to the same engine family, the following list of basic parameters must be common:

8.1.1. Combustion cycle:

— 2 cycle

— 4 cycle

8.1.2. Cooling medium:

— air

— water

— oil

8.1.3. For gas engines and engines with after treatment:

— number of cylinders

(other diesel engines with fewer cylinders than the parent engine may be considered to belong to the same engine family provided the fuelling system meters fuel for each individual cylinder)

8.1.4. Individual cylinder displacement:

— engines to be within a total spread of 15 %

8.1.5. Method of air aspiration:

— naturally aspirated

— pressure charged

— pressure charged with charge air cooler

8.1.6. Combustion chamber type/design:

— pre-chamber

— swirl chamber

— open chamber

8.1.7. Valve and porting — configuration, size and number:

— cylinder head

— cylinder wall

— crankcase

8.1.8. Fuel injection system (diesel engines):

— pump-line-injector

— in-line pump

— distributor pump

— single element

— unit injector

8.1.9. Fuelling system (gas engines):

— mixing unit

— gas induction/injection (single point, multi-point)

— liquid injection (single point, multi-point)

8.1.10. Ignition system (gas engines)

8.1.11. Miscellaneous features:

— exhaust gas recirculation

— water injection/emulsion

— secondary air injection

— charge cooling system

8.1.12. Exhaust after treatment:

— 3-way-catalyst

— oxidation catalyst

— reduction catalyst

— thermal reactor

— particulate trap

8.2 Choice of the parent engine

8.2.1 Diesel engines

The parent engine of the family shall be selected using the primary criteria of the highest fuel delivery per stroke at the declared maximum torque speed. In the event that two or more engines share this primary criteria, the parent engine shall be selected using the secondary criteria of highest fuel delivery per stroke at rated speed. Under certain circumstances, the approval authority may conclude that the worst case emission rate of the family can best be characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features, which indicate that it may have the highest emission level of the engines within that family.

If engines within the family incorporate other variable features, which could be considered to affect exhaust emissions, these features shall also be identified and taken into account in the selection of the parent engine.

8.2.2 Gas engines

The parent engine of the family shall be selected using the primary criteria of the largest displacement. In the event that two or more engines share this primary criteria, the parent engine shall be selected using the secondary criteria in the following order:

— the highest fuel delivery per stroke at the speed of declared rated power.

— The most advanced spark timing.

— The lowest EGR rate.

— No air pump or lowest actual airflow pump.

Under certain circumstances, the approval authority may conclude that the worst case emission rate of the family can best be characterised by testing a second engine. Thus, the approval authority may select an additional engine for test based upon features, which indicate that it may have the highest emission level of the engines within that family.

8.3 Parameters for defining an OBD-engine family

The OBD-engine family may be defined by basic design parameters that must be common to engine systems within the family.

In order that engine systems may be considered to belong to the same OBD-engine family, the following list of basic parameters must be common,

— The methods of OBD monitoring.

— The methods of malfunction detection.

Unless these methods have been shown as equivalent by the manufacturer by means of relevant engineering demonstration or other appropriate procedures.

Note: engines that do not belong to the same engine family may still belong to the same OBD-engine family provided the above-mentioned criteria are satisfied.

9. PRODUCTION CONFORMITY

9.1 Measures to ensure production conformity must be taken in accordance with the provisions as per Part VI of MoSRTH/CMVR/TAP115/116. However when the period between commencement of production of a new model and beginning of next rationalized COP period is less than two months, the same would be merged with the rationalized COP period.

For verifying the conformity of production the following procedure as per Option1 is adopted.

To verify the conformity of production for low volume vehicles model and its variants were less than 250 no. in any consecutive period of six months in a year, manufacture can choose from option 1 or option 2 as listed below.

9.1.1 If emissions of pollutants are to be measured and an engine type-approval has had one or several extensions, the tests will be carried out on the engine(s) described in the information package relating to the relevant extension.

Option 1

9.1.1.1 Conformity of the engine subjected to a pollutant test:

After submission of the engine to the test agencies, the manufacturer shall not carry out any adjustment to the engines selected.

9.1.1.1.1 Three engines are randomly taken in the series. With agreement of test agency, engines are subject to testing either on the ESC and ELR cycles or ETC cycle (for Diesel engines) or only on the ETC cycle (for Gaseous engines) for the checking of production conformity. The limit values are given in section 6.2.1 of this chapter.

9.1.1.1.2 The tests are carried out according to appendix 1 of this chapter.

or

At the manufacturer's request, the tests may be carried out in accordance with appendix 2 of this Chapter.

9.1.1.1.3 On the basis of a test of the engine by sampling, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a fail decision is reached for one pollutant, in accordance with the test criteria applied in the appropriate appendix.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see Figure 2).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

9.1.1.2 The tests will be carried out on newly manufactured engines. Gas fuelled engines shall be run-in using the procedure defined in section 3 of appendix 2 of Chapter III of this part.

9.1.1.2.1 However, at the request of the manufacturer, the tests may be carried out on diesel or gas engines, which have been run-in, up to a maximum of 100 hours. In this case, the running-in procedure will be conducted by the manufacturer who shall undertake not to make any adjustments to those engines.

9.1.1.2.2 When the manufacturer asks to conduct a running-in procedure in accordance with section 9.1.1.2.1 of this chapter, it may be carried out on:

- All the engines that are tested,

or

- The first engine tested, with the determination of an evolution coefficient as follows:

- The pollutant emissions will be measured at zero and at "x" hours on the first engine tested,

- The evolution coefficient of the emissions between zero and "x" hours will be calculated for each pollutant:

Emissions ' x' hours
Emissions zero hours

It may be less than one.

The subsequent test engines will not be subjected to the running-in procedure, but their zero hour emissions will be modified by the evolution coefficient.

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

- the values at "x" hours for the first engine,

- the values at zero hour multiplied by the evolution coefficient for the other engines.

9.1.1.2.3 For diesel and LPG fuelled engines, all these tests may be conducted with commercial fuel. However, at the manufacturer's request, the reference fuels described in Annexure IV(F&H) of CMVR rules respectively may be used. This implies tests, as described in section 4 of this Chapter, with at least two of the reference fuels for each gas engine.

9.1.1.2.4 For NG fuelled engines, all these tests may be conducted with commercial fuel in the following way:

- for H marked engines with a commercial fuel within the H range;
($0,89 \leq S\lambda \leq 1,00$),

- for L marked engines with a commercial fuel within the L range;
($1,00 \leq S\lambda \leq 1,19$),

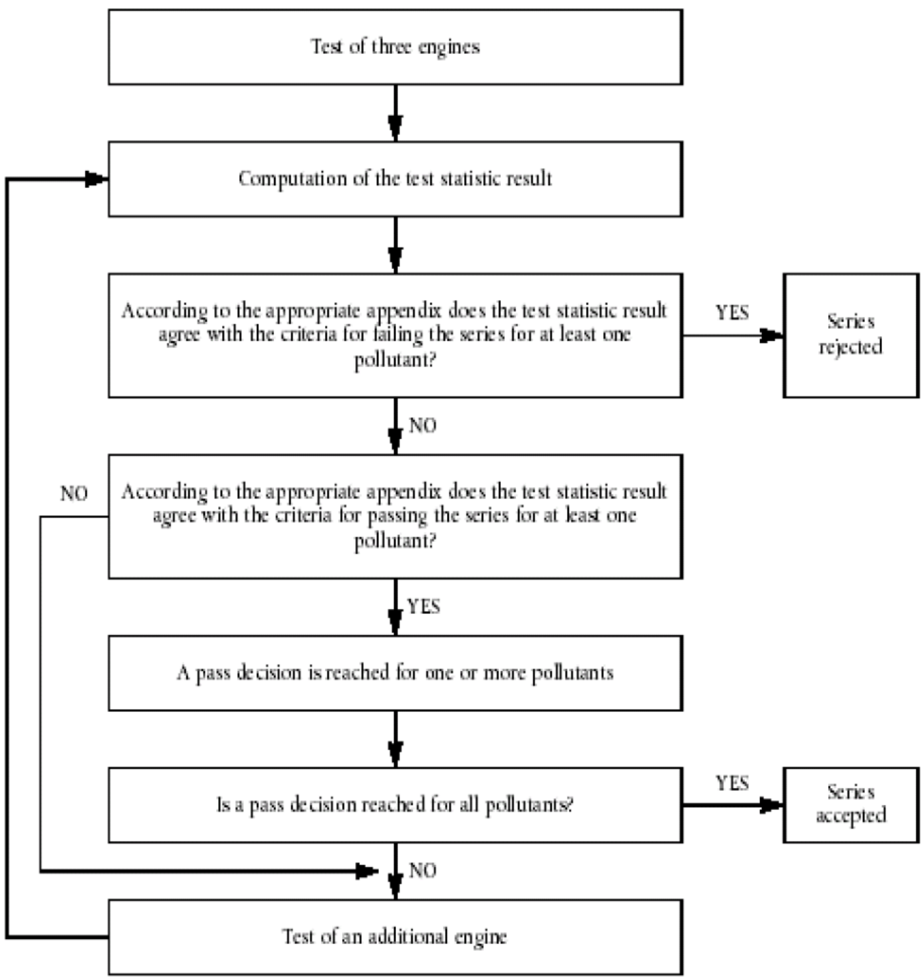
- for HL marked engines with a commercial fuel within the H or the L range.
($0,89 \leq S\lambda \leq 1,19$).

However, at the manufacturer's request, the reference fuels described in chapter IV of this part may be used. This implies tests, as described in section 4 of this Chapter, with at least two of the reference fuels for each gas engine.

9.1.1.2.5 In the case of dispute caused by the non-compliance of gas fuelled engines when using a commercial fuel, the tests shall be performed with a reference fuel on which the parent engine has been tested, or with the possible additional fuel 3 as referred to in sections 4.1.3.1 and 4.2.1.1 of this chapter on which the parent engine may have been tested. Then, the result has to be converted by a calculation applying the relevant factor(s) "r", "ra" or "rb" as described in sections 4.1.3.2, 4.1.4.1 and 4.2.1.2 of this chapter. If r, ra or rb are less than one no correction shall take place. The measured results and the calculated results must demonstrate that the engine meets the limit values with all relevant fuels (fuels 1, 2 and, if applicable, fuel 3 in the case of natural gas engines and fuels A and B in the case of LPG engines).

9.1.1.2.6 Tests for conformity of production of a gas fuelled engine laid out for operation on one specific fuel composition shall be performed on the fuel for which the engine has been calibrated.

Figure 2 (Option 1)
Schematic of production conformity testing



Option 2

9.1.1.3 Conformity of the engine subjected to a pollutant test:

After submission of the engine to the test agencies, the manufacturer shall not carry out any adjustment to the engines selected.

9.1.1.3.1 Three engines are randomly taken in the series. With agreement of test agency, only one engine are subject to testing either on the ESC and ELR cycles or ETC cycle (for Diesel engines) or only on the ETC cycle (for Gaseous engines) for the checking of production conformity. The limit values are given in section 6.2.1 of this chapter.

9.1.1.3.2 The tests are carried out according to appendix 1 of this chapter.

or

At the manufacturer's request, the tests may be carried out in accordance with appendix 2 of this Chapter.

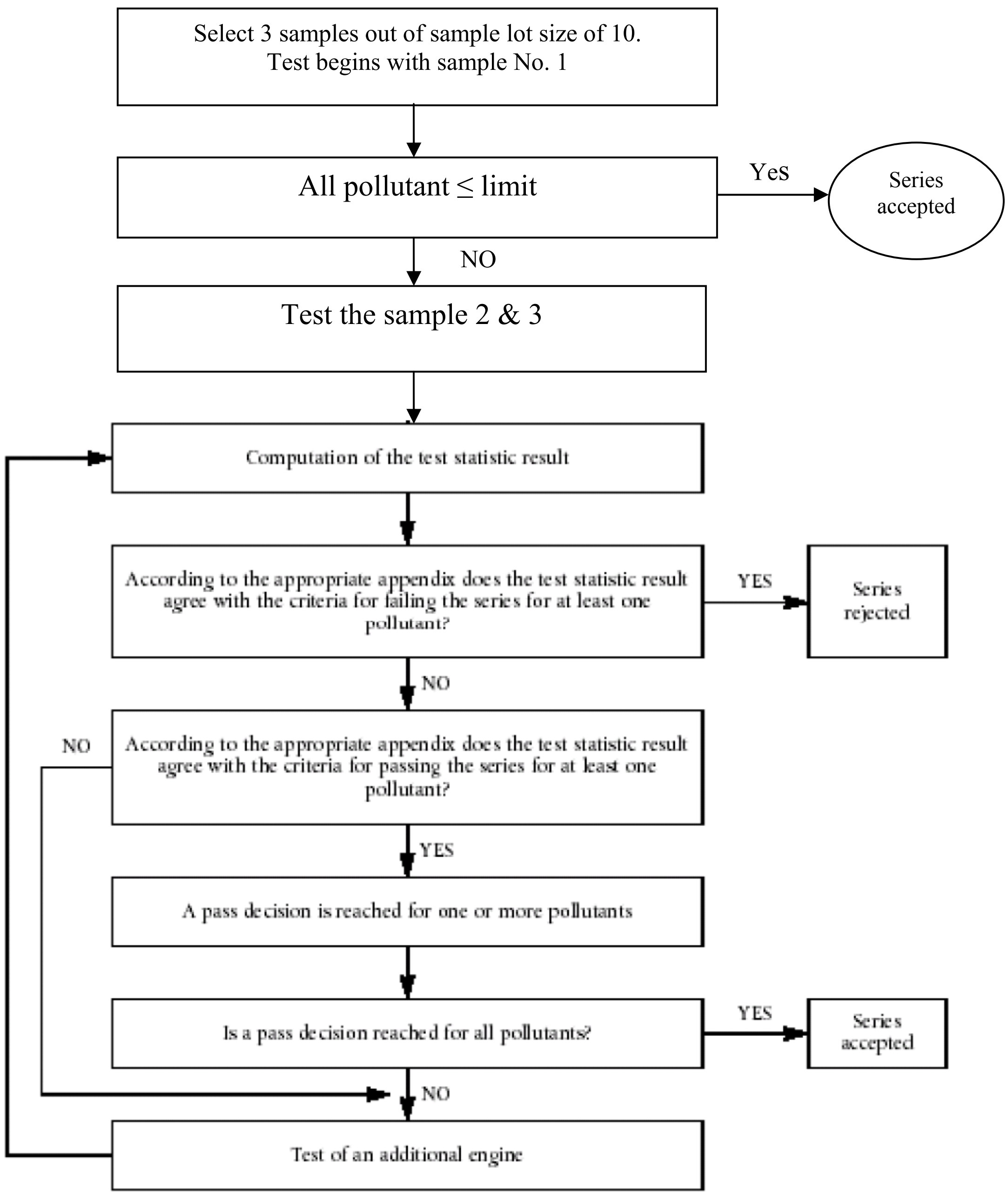
9.1.1.3.3 On the basis of a test of the engine, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a no pass decision is reached for one pollutant, in accordance with the limit values are given in section 6.2.1 of this chapter . When no pass decision has been reached for one pollutant saple 2 & 3 are subjected o test mentioned in 9.1.1.3.1 of this chapter.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see Figure 3).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

Figure 3 (option 2)
Schematic of production conformity testing



9.1.2. On-Board Diagnostics (OBD)

9.1.2.1 If a verification of the conformity of production of the OBD system is to be carried out, it must be conducted in accordance with the following:

9.1.2.2 When the test agency determines that the quality of production seems unsatisfactory an engine is randomly taken from the series and subjected to the tests described in appendix 1 to chapter VIII of this part. The tests may be carried out on an engine that has been run-in up to a maximum of 100 hours.

9.1.2.3 The production is deemed to conform if this engine meets the requirements of the tests described in appendix 1 to chapter VIII of this part.

9.1.2.4 If the engine taken from the series does not satisfy the requirements of section 9.1.2.2 of this chapter, a further random sample of four engines must be taken from the series and subjected to the tests described in appendix 1 to chapter VIII of this part. The tests may be carried out on engines that have been run-in up to a maximum of 100 hours.

9.1.2.5 The production is deemed to conform if at least three engines out of the further random sample of four engines meet the requirements of the tests described in appendix 1 to chapter VIII of this part.

Appendix 1

PROCEDURE FOR PRODUCTION CONFORMITY TESTING

1. This Appendix describes the procedure to be used to verify production conformity for the emissions of pollutants.

2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 40 % of the engines defective is 0,95 (producer's risk = 5 %) while the probability of a lot being accepted with 65 % of the engines defective is 0,10 (consumer's risk = 10 %).

3. The values of the pollutants given in section 6.2.1 of this chapter, after having applied the relevant DF, are considered to be log normally distributed and should be transformed by taking their natural logarithms. Let m_0 and m denote the minimum and maximum sample size respectively (m_0 = 3 and m = 32) and let n denote the current sample number.

4. If the natural logarithms of the measured values (after having applied the relevant DF) in the series are x_1, x_2, … x_i and L is the natural logarithm of the limit value for the pollutant, then, define:

$$d_i = x_i - L$$

and,

$$\overline{d_n} = \frac{1}{n}\sum_{i=1}^{n} d_i$$

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

5. Table 3 shows values of the pass (A_n) and fail (B_n) decision numbers against current sample number. The test statistic result is the ratio: d_n / V_n and shall be used to determine whether the series has passed or failed as follows:

for $m_0 \le n < m$:

— pass the series if $\overline{d_n}/v_n \le A_n$,

— fail the series if $\overline{d_n}/v_n \ge B_n$,

— take another measurement if $A_n < \overline{d_n}/v_n < B_n$.

6. Remarks

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

$$\overline{d_n} = (1-\frac{1}{n})\overline{d_n - 1} + \frac{1}{n}d_n$$

$$V_n^2 = (1-\frac{1}{n})V^2{}_{n-1} + \frac{(\overline{d_n} - d_n)^2}{n-1}$$ (n = 2, 3,.....; $\overline{d_1}$ = d_1; V1 = 0)

Table 3

Pass and Fail Decision Numbers of Appendix 1 Sampling Plan

Minimum Sample Size: 3

Cumulative number of engines tested (sample size)	Pass decision number A_n	Fail decision number B_n
3	-0,80381	16,64743
4	-0,76339	7,68627
5	-0,72982	4,67136
6	-0,69962	3,25573
7	-0,67129	2,45431
8	-0,64406	1,94369
9	-0,61750	1,59105
10	-0,59135	1,33295
11	-0,56542	1,13566
12	-0,53960	0,97970
13	-0,51379	0,85307
14	-0,48791	0,74801
15	-0,46191	0,65928
16	-0,43573	0,58321
17	-0,40933	0,51718
18	-0,38266	0,45922
19	-0,35570	0,40788
20	-0,32840	0,36203
21	-0,30072	0,32078
22	-0,27263	0,28343
23	-0,24410	0,24943
24	-0,21509	0,21831
25	-0,18557	0,18970
26	-0,15550	0,16328
27	-0,12483	0,13880
28	-0,09354	0,11603
29	-0,06159	0,09480
30	-0,02892	0,07493
31	-0,00449	0,05629
32	0,03876	0,03876

Appendix 2

PROCEDURE FOR PRODUCTION CONFORMITY TESTING AT MANUFACTURER'S REQUEST

1. This Appendix describes the procedure to be used to verify, at the manufacturer's request, production conformity for the emissions of pollutants.

2. With a minimum sample size of three engines the sampling procedure is set so that the probability of a lot passing a test with 30 % of the engines defective is 0,90 (producer's risk = 10 %) while the probability of a lot being accepted with 65 % of the engines defective is 0,10 (consumer's risk = 10 %).

3. The following procedure is used for each of the pollutants given in section 6.2.1 of this chapter (see Figure 2):

Let:

L = the natural logarithm of the limit value for the pollutant

x_i = the natural logarithm of the measurement (after having applied the relevant DF) for the i-th engine of the sample

s = an estimate of the production standard deviation (after taking the natural logarithm of the measurements)

n = the current sample number.'

4. Calculate for the sample the test statistic quantifying the number of non conforming engines, i.e. $x_i \geq L$:

5. Then:

- If the test statistic is less than or equal to the pass decision number for the sample size given in Table 4, a pass decision is reached for the pollutant;

- If the test statistic is greater than or equal to the fail decision number for the sample size given in Table 4, a fail decision is reached for the pollutant;

- Otherwise, an additional engine is tested according to section 9.1.1.1 of this chapter and the calculation procedure is applied to the sample increased by one more unit.

In Table 4 the pass and fail decision numbers are calculated by means of the International Standard ISO 8422/1991.

Table 4

Pass and Fail Decision Numbers of Appendix 2 Sampling Plan

Minimum sample Size : 3

Cumulative number of engines tested (sample size)	Pass decision number	Fail decision number
3	--	3
4	0	4
5	0	4
6	1	5
7	1	5
8	2	6
9	2	6
10	3	7
11	3	7
12	4	8
13	4	8
14	5	9
15	5	9
16	6	10
17	6	10
18	7	11
19	8	9

Appendix 3

DETERMINATION OF SYSTEM EQUIVALENCE

The determination of system equivalency according to section 6.2 of this chapter shall be based on a 7 sample pair (or larger) correlation study between the candidate system and one of the accepted reference systems of this part using the appropriate test cycle(s). The equivalency criteria to be applied shall be the F-test and the two-sided Student t-test.

This statistical method examines the hypothesis that the population standard deviation and mean value for an emission measured with the candidate system do not differ from the standard deviation and population mean value for that emission measured with the reference system. The hypothesis shall be tested on the basis of a 5 % significance level of the F and t values. The critical F and t values for 7 to 10 sample pairs are given in the table below. If the F and t values calculated according to the formulae below are greater than the critical F and t values, the candidate system is not equivalent.

The following procedure shall be followed. The subscripts R and C refer to the reference and candidate system, respectively:

(a) Conduct at least 7 tests with the candidate and reference systems preferably operated in parallel. The number of tests is referred to as n_R and n_C.

(b) Calculate the mean values x_R and x_C and the standard deviations s_R and s_C.

(c) Calculate the F value, as follows:

$$F = \frac{s_{\text{major}}^2}{s_{\text{minor}}^2}$$

(The greater of the two standard deviations S_R or S_C must be in the numerator)

(d) Calculate the t value, as follows:

$$t = \frac{|x_C - x_R|}{\sqrt{(n_C - 1) \times s_C^2 + (n_R - 1) \times s_R^2}} \times \sqrt{\frac{n_C \times n_R \times (n_C + n_R - 2)}{n_C + n_R}}$$

(e) Compare the calculated F and t values with the critical F and t values corresponding to the respective number of tests indicated in table below. If larger sample sizes are selected, consult statistical tables for 5 % significance (95 % confidence) level.

(f) Determine the degrees of freedom (df), as follows:

For the F-test: df = n_R - 1 / n_C – 1

For the t-test: df = n_C + n_R - 2

F and t values for selected sample sizes

Sample Size	F-test		t-test	
	df	F_{crit}	df	t_{crit}
7	6/6	4,284	12	2,179
8	7/7	3,787	14	2,145
9	8/8	3,438	16	2,120
10	9/9	3,179	18	2,101

(g) Determine the equivalency, as follows:

- if $F < F_{crit}$ **and** $t < t_{crit}$, then the candidate system is equivalent to the reference system of this Document,

- if $F \geq F_{crit}$ **and** $t \geq t_{crit}$, then the candidate system is different from the reference system of this Document.