

Commission Directive 2005/78/EC of 14 November 2005 implementing Directive 2005/55/EC of the European Parliament and of the Council on the approximation of the laws of the Member States 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petroleum gas for use in vehicles and amending Annexes I, II, III, IV and VI thereto (Text with EEA relevance) (repealed)

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## ANNEX I

### AMENDMENTS TO ANNEXES I, II, III, IV AND VI TO DIRECTIVE 2005/55/EC

Directive 2005/55/EC is amended as follows:

- (1) Annex I is amended as follows:
- (a) Section 1 is replaced by the following:
1. SCOPE
- This Directive applies to the control of gaseous and particulate pollutants, useful life of emission control devices, conformity of in-service vehicles/engines and on-board diagnostic (OBD) systems of all motor vehicles equipped with compression-ignition engines and to the gaseous pollutants, useful life, conformity of in-service vehicles/engines and on-board diagnostic (OBD) systems of all motor vehicles equipped with positive-ignition engines fuelled with natural gas or LPG, and to compression-ignition and positive-ignition engines as specified in Article 1 with the exception of compression-ignition engines of those vehicles of category N<sub>1</sub>, N<sub>2</sub> and M<sub>2</sub> and of positive-ignition engines fuelled with natural gas or LPG of those vehicles of category N<sub>1</sub> for which type-approval has been granted under Council Directive 70/220/EEC<sup>(1)</sup>.
- (b) In section 2, the title and sections 2.1 to 2.32.1 are replaced by the following:
2. DEFINITIONS
- 2.1. For the purposes of this Directive, the following definitions shall apply:
- “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;
- “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;
- “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;
- “combined deNO<sub>x</sub>-particulate filter” means an exhaust aftertreatment system designed to concurrently reduce emissions of oxides of nitrogen (NO<sub>x</sub>) and particulate pollutants (PT);
- “continuous regeneration” means the regeneration process of an exhaust aftertreatment system that occurs either permanently or at least once per ETC test. Such a regeneration process will not require a special test procedure;

“control area” means the area between the engine speeds A and C and between 25 to 100 per cent load;

“declared maximum power ( $P_{\max}$ )” means the maximum power in EC kW (net power) as declared by the manufacturer in his application for type-approval;

“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,
- or
- a BECS that discriminates between operation on a standardised 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,

“deNO<sub>x</sub> system” means an exhaust aftertreatment system designed to reduce emissions of oxides of nitrogen (NO<sub>x</sub>) (e.g. there are presently passive and active lean NO<sub>x</sub> catalysts, NO<sub>x</sub> adsorbers and Selective Catalytic Reduction (SCR) systems);

“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;

“diesel engine” means an engine which works on the compression-ignition principle;

“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 Annex;

“ESC test” means a test cycle consisting of 13 steady state modes to be applied in accordance with section 6.2 of this Annex;

“ETC test” means a test cycle consisting of 1 800 second-by-second transient modes to be applied in accordance with section 6.2 of this Annex;

“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,

“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

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belonging to the emission control system. A missing component may be considered to be an “emissions-related defect”;

“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;

“emission control system” means the exhaust aftertreatment 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;

“engine-aftertreatment system family” means, for testing over a service accumulation schedule to establish deterioration factors according to Annex II to Commission Directive 2005/78/EC implementing Directive 2005/55/EC of the European Parliament and of the Council on the approximation of the laws of the Member States 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 and amending Annexes I, II, III, IV and VI thereto<sup>(2)</sup> and for checking the conformity of in-service vehicles/engines according to Annex III to Directive 2005/78/EC, a manufacturer’s grouping of engines that comply with the definition of engine family but which are further grouped into engines utilising a similar exhaust after-treatment system;

“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 powertrain or vehicle control unit;

“engine family” means a manufacturers grouping of engine systems which, through their design as defined in Annex II, Appendix 2 to this Directive, have similar exhaust emission characteristics; all members of the family must comply with the applicable emission limit values;

“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 Annex III to this Directive;

“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 Annex III, Appendix 1 to this Directive;

“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;

“engine type” means a category of engines which do not differ in such essential respects as engine characteristics as defined in Annex II to this Directive;

“exhaust aftertreatment system” means a catalyst (oxidation or 3-way), particulate filter, deNO<sub>x</sub> system, combined deNO<sub>x</sub> 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;

“gas engine” means a positive-ignition engine which is fuelled with natural gas (NG) or liquefied petroleum gas (LPG);

“gaseous pollutants” means carbon monoxide, hydrocarbons (assuming a ratio of CH<sub>1,85</sub> for diesel, CH<sub>2,525</sub> for LPG and CH<sub>2,93</sub> for NG (NMHC) and an assumed molecule CH<sub>3</sub>O<sub>0,5</sub> for ethanol-fuelled diesel engines), methane (assuming a ratio of CH<sub>4</sub> for NG) and oxides of nitrogen, the last-named being expressed in nitrogen dioxide (NO<sub>2</sub>) equivalent;

“high speed (n<sub>hi</sub>)” means the highest engine speed where 70 % of the declared maximum power occurs;

“low speed (n<sub>lo</sub>)” means the lowest engine speed where 50 % of the declared maximum power occurs;

“major functional failure”<sup>(3)</sup> means a permanent or temporary malfunction of any exhaust aftertreatment 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;

“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 aftertreatment system where the emission of any regulated pollutant would exceed the OBD threshold limits,
- any case where the OBD system is not able to fulfil the monitoring requirements of this Directive.

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

“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 Directive;

“multi-setting engine” means an engine containing more than one engine setting;

“NG gas range” means one of the H or L range as defined in European Standard EN 437, dated November 1993;

“net power” means the power in EC kW obtained on the test bench at the end of the crankshaft, or its equivalent, measured in accordance with the EC method of measuring power as set out in Commission Directive 80/1269/EEC<sup>(4)</sup>;

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“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;

“OBD-engine family” means, for type-approval of the OBD system according to the requirements of Annex IV to Directive 2005/78/EC, a manufacturer's grouping of engine systems having common OBD system design parameters according to section 8 of this Annex;

“opacimeter” means an instrument designed to measure the opacity of smoke particles by means of the light extinction principle;

“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;

“particulate aftertreatment device” means an exhaust aftertreatment system designed to reduce emissions of particulate pollutants (PT) through a mechanical, aerodynamic, diffusional or inertial separation;

“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);

“per cent load” means the fraction of the maximum available torque at an engine speed;

“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.

“permanent 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;

“power take-off unit” means an engine-driven output device for the purposes of powering auxiliary, vehicle mounted, equipment;

“reagent” means any medium that is stored on-board the vehicle in a tank and provided to the exhaust aftertreatment system (if required) upon request of the emission control system;

“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;

“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 Annex III, Appendix 2 to this Directive;

“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);

“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;

“self adaptability” means any engine device allowing the air/fuel ratio to be kept constant;

“smoke” means particles suspended in the exhaust stream of a diesel engine which absorb, reflect, or refract light;

“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);

“torque limiter” means a device that temporarily limits the maximum torque of the engine;

“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;

“useful life” means, for vehicles and engines that are type-approved to either row B1, row B2 or row C of the table given in section 6.2.1 of this Annex, the relevant period of distance and/or time that is defined in Article 3 (durability of emission control systems) of this Directive over which compliance with the relevant gaseous, particulate and smoke emission limits has to be assured as part of the type-approval;

“Wobbe Index (lower Wl; or upper Wu)” means the ratio of the corresponding calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions:

$$W = H_{\text{gas}} \times \sqrt{\rho_{\text{air}} / \rho_{\text{gas}}}$$

“ $\lambda$ -shift factor ( $S_\lambda$ )” means an expression that describes the required flexibility of the engine management system regarding a change of the excess-air ratio  $\lambda$  if the engine is fuelled with a gas composition different from pure methane (see Annex VII for the calculation of  $S_\lambda$ ).

## 2.2. Symbols, abbreviations and international standards

### 2.2.1. Symbols for test parameters

Symbol	Unit	Term
$A_p$	$\text{m}^2$	Cross sectional area of the isokinetic sampling probe

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$A_e$	$m^2$	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 <sub>x</sub> 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 <sup>3</sup>	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



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$k_{h,D}$	—	Humidity correction factor for NO <sub>x</sub> for diesel engines
$k_{h,G}$	—	Humidity correction factor for NO <sub>x</sub> 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
$k_{W,r}$	—	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

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$m_{f,d}$	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
$n$	$\text{min}^{-1}$	Engine speed
$n_p$	$\text{s}^{-1}$	PDP speed
$n_{hi}$	$\text{min}^{-1}$	High engine speed
$n_{lo}$	$\text{min}^{-1}$	Low engine speed
$n_{ref}$	$\text{min}^{-1}$	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

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$p_s$	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
$q_{mf}$	kg/h or kg/s	Fuel mass flow rate
$q_{mp}$	kg/h or kg/s	Particulate sample mass flow rate
$q_{vs}$	dm <sup>3</sup> /min	Sample flow rate into analyser bench
$q_{vt}$	cm <sup>3</sup> /min	Tracer gas flow rate
$\Omega$	—	Bessel constant
$Q_s$	m <sup>3</sup> /s	PDP/CFV-CVS volume flow rate
$Q_{SSV}$	m <sup>3</sup> /s	SSV-CVS volume flow rate

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$r_a$	—	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
$\rho$	kg/m <sup>3</sup>	density
$S$	kW	Dynamometer setting
$S_i$	m <sup>-1</sup>	Instantaneous smoke value
$S_\lambda$	—	$\lambda$ -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
$\Delta t$	s	Time interval between successive smoke data (= 1/sampling rate)
$\Delta t_i$	s	Time interval for instantaneous CVS flow
$\tau$	%	Smoke transmittance
$u$	—	Ratio between densities of gas component and exhaust gas
$V_0$	m <sup>3</sup> /rev	PDP gas volume pumped per revolution
$V_s$	l	System volume of analyser bench
$W$	—	Wobbe index

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$W_{act}$	kWh	Actual cycle work of ETC
$W_{ref}$	kWh	Reference cycle work of ETC
$W_F$	—	Weighting factor
$W_{F_E}$	—	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

(c) Former sections 2.32.2 and 2.32.3 become sections 2.2.2 and 2.2.3 respectively.

(d) The following sections 2.2.4 and 2.2.5 are added:

#### 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
$\alpha$	molar hydrogen ratio (H/C)
$\beta$	molar carbon ratio (C/C)
$\gamma$	molar sulphur ratio (S/C)
$\delta$	molar nitrogen ratio (N/C)
$\epsilon$	molar oxygen ratio (O/C)

referring to a fuel  $C_\beta H_\alpha O_\epsilon N_\delta S_\gamma$   
 $\beta = 1$  for carbon based fuels,  $\beta = 0$  for hydrogen fuel.

#### 2.2.5. Standards referenced by this Directive

ISO 15031-1	ISO 15031-1: 2001 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 1: General information.
ISO 15031-2	ISO/PRF TR 15031-2: 2004 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part

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	2: Terms, definitions, abbreviations and acronyms.
ISO 15031-3	ISO 15031-3: 2004 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 3: Diagnostic connector and related electrical circuits, specification and use.
SAE J1939-13	SAE J1939-13: Off-Board Diagnostic Connector.
ISO 15031-4	ISO DIS 15031-4.3: 2004 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 4: External test equipment.
SAE J1939-73	SAE J1939-73: Application Layer – Diagnostics.
ISO 15031-5	ISO DIS 15031-5.4: 2004 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 5: Emissions-related diagnostic services.
ISO 15031-6	ISO DIS 15031-6.4: 2004 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 6: Diagnostic trouble code definitions.
SAE J2012	SAE J2012: Diagnostic Trouble Code Definitions Equivalent to ISO/DIS 15031-6, April 30, 2002.
ISO 15031-7	ISO 15031-7: 2001 Road vehicles – Communication between vehicle and external equipment for emissions related diagnostics – Part 7: Data link security.
SAE J2186	SAE J2186: E/E Data Link Security, dated October 1996.
ISO 15765-4	ISO 15765-4: 2001 Road vehicles – Diagnostics on Controller Area Network (CAN) – Part 4: Requirements for emissions-related systems.

SAE J1939	SAE J1939: Recommended Practice for a Serial Control and Communications Vehicle Network.
ISO 16185	ISO 16185: 2000 Road vehicles – Engine family for homologation.
ISO 2575	ISO 2575: 2000 Road vehicles – Symbols for controls, indicators and tell-tales.
ISO 16183	ISO 16183: 2002 Heavy duty engines – Measurement of gaseous emissions from raw exhaust gas and of particulate emissions using partial flow dilution systems under transient test conditions.

(e) Section 3.1.1 is replaced by the following:

3.1.1. The application for approval of an engine type or engine family with regard to the level of the emission of gaseous and particulate pollutants for diesel engines and with regard to the level of the emission of gaseous pollutants for gas engines as well as the useful life and on-board diagnostic (OBD) system shall be submitted by the engine manufacturer or by a duly accredited representative.

Should the application concern an engine equipped with an on-board diagnostic (OBD) system, the requirements of section 3.4 must be fulfilled.

(f) Section 3.2.1 is replaced by the following:

3.2.1. The application for approval of a vehicle with regard to emission of gaseous and particulate pollutants by its diesel engine or diesel engine family and with regard to the level of the emission of gaseous pollutants by its gas engine or gas engine family as well as the useful life and on-board diagnostic (OBD) system shall be submitted by the vehicle manufacturer or by a duly accredited representative.

Should the application concern an engine equipped with an on-board diagnostic (OBD) system, the requirements of section 3.4 must be fulfilled.

(g) The following section 3.2.3 is added:

3.2.3. The manufacturer shall provide a description of the malfunction indicator (MI) used by the OBD system to signal the presence of a fault to a driver of the vehicle.

The manufacturer shall provide a description of the indicator and warning mode used to signal the lack of required reagent to a driver of the vehicle.

(h) Section 3.3.1 is replaced by the following:

3.3.1. The application for approval of a vehicle with regard to emission of gaseous and particulate pollutants by its approved diesel engine

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or diesel engine family and with regard to the level of the emission of gaseous pollutants by its approved gas engine or gas engine family as well as the useful life and on-board diagnostic (OBD) system shall be submitted by the vehicle manufacturer or by a duly accredited representative.

(i) The following section 3.3.3 is added:

3.3.3. The manufacturer shall provide a description of the malfunction indicator (MI) used by the OBD system to signal the presence of a fault to a driver of the vehicle.

The manufacturer shall provide a description of the indicator and warning mode used to signal the lack of required reagent to a driver of the vehicle.

(j) The following section 3.4 is added:

3.4. On-board diagnostic systems

3.4.1. The application for approval of an engine equipped with an on-board diagnostic (OBD) system must be accompanied by the information required in section 9 of Appendix 1 to Annex II (description of the parent engine) and/or section 6 of Appendix 3 to Annex II (description of an engine type within the family) together with:

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

3.4.1.2. Where applicable, a declaration by the manufacturer of the parameters that are used as a basis for major functional failure monitoring and, in addition:

3.4.1.2.1. The manufacturer shall provide the technical service with a description of potential failures within the emission control system that will have an effect on emissions. This information shall be subject to discussion and agreement between the technical service and the vehicle manufacturer.

3.4.1.3. Where applicable, a description of the communication interface (hardware and messages) between the engine electronic control unit (EECU) and any other powertrain or vehicle control unit when the exchanged information has an influence on the correct functioning of the emission control system.

3.4.1.4. Where appropriate, copies of other type-approvals with the relevant data to enable extensions of approvals.

3.4.1.5. If applicable, the particulars of the engine family as referred to in section 8 of this Annex.

3.4.1.6. The manufacturer must describe provisions taken to prevent tampering with and modification of the EECU or any interface parameter considered in section 3.4.1.3.



- (k) In section 5.1.3 the footnote is deleted.
- (l) Section 6.1 is replaced by the following:
  - 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 Directive.
    - 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 Directive<sup>(5)</sup>.
    - 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 Directive. 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 Directive. Normal use is not restricted to the conditions of use as specified in paragraph 6.1.5.4.
    - 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 paragraph 6.1.5.4 for the purposes defined in paragraph 6.1.5.5,
        - or
        - is activated only exceptionally within the conditions of use specified in paragraph 6.1.5.4 for the purposes defined in paragraph 6.1.5.6. 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, it is fully demonstrated that the measure does

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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 will be permitted if, in complying with the requirements of section 6.1.7, it is fully demonstrated that the measure is the minimum strategy necessary for the purposes of paragraph 6.1.5.6 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 1 000 metres (or equivalent atmospheric pressure of 90 kPa),
  - and
  - an ambient temperature within the range 275 K to 303 K (2 °C to 30 °C)<sup>(6)(7)</sup>,
  - and
  - engine coolant temperature within the range 343 K to 373 K (70 °C to 100 °C).
- 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.
- 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, permanent 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. 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 powertrain 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<sub>x</sub> 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 powertrain 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<sub>x</sub> 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 Annex;

(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.

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It shall also include a description of the torque limiter described in section 6.5.5 of this Annex.

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. Specifically for the type-approval of engines according to row A of the tables in section 6.2.1 (engines not normally tested on ETC)

6.1.8.1. To verify whether any strategy or measure should be considered a defeat strategy according to the definitions given in section 2, the type-approval authority and/or the technical service may additionally request a NO<sub>x</sub> screening test using the ETC which may be carried out in combination with either the type-approval test or the procedures for checking the conformity of production.

6.1.8.2. In verifying whether any strategy or measure should be considered a defeat strategy according to the definitions given in section 2, an additional margin of 10 %, related to the appropriate NO<sub>x</sub> limit value, shall be accepted.

6.1.9. The transitional provisions for extension of type-approval are given in section 6.1.5 of Annex I to Directive 2001/27/EC.

Until the 8 November 2006, the existing approval certificate number will remain valid. In case of extension, only the sequential number to denote the extension base approval number will change as follows:

Example for the second extension of the fourth approval corresponding to application date A, issued by Germany:

e1\*88/77\*2001/27A\*0004\*02

6.1.10. Provisions for electronic system security

6.1.10.1. 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 Annex IV to Directive 2005/78/EC. 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.

- 6.1.10.2. 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).
- 6.1.10.3. Manufacturers must take adequate steps to protect the maximum fuel delivery setting from tampering while a vehicle is in-service.
- 6.1.10.4. 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.
- 6.1.10.5. 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.

(m) The introductory part of Section 6.2 is replaced by the following:

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

For type approval to row A of the tables in section 6.2.1, the emissions shall be determined on the ESC and ELR tests with conventional diesel engines including those fitted with electronic fuel injection equipment, exhaust gas recirculation (EGR), and/or oxidation catalysts. Diesel engines fitted with advanced exhaust aftertreatment systems including deNO<sub>x</sub> catalysts and/or particulate traps, shall additionally be tested on the ETC test.

For type approval testing to either row B1 or B2 or row C of the tables in section 6.2.1 the emissions 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 Annex III, Appendix 1, the ETC test procedure in Annex III, Appendices 2 and 3.

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

Other systems or analysers may be approved by the Technical Service if it is found that they yield equivalent results on the respective test cycle. The determination of system equivalency shall be based upon a 7 sample pair

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(or larger) correlation study between the system under consideration and one of the reference systems of this Directive. For particulate emissions, only 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 to this Annex 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 Directive the determination of equivalency shall be based upon the calculation of repeatability and reproducibility, as described in ISO 5725.

(n) The following sections 6.3, 6.4 and 6.5 are added:

### 6.3. Durability and deterioration factors

6.3.1. For the purposes of this Directive, the manufacturer shall determine deterioration factors that will be used to demonstrate that the gaseous and particulate emissions of an engine family or engine-aftertreatment system family remain in conformity with the appropriate emission limits specified in the tables in section 6.2.1 of this Annex over the appropriate durability period laid down in Article 3 to this Directive.

6.3.2. The procedures for demonstrating the compliance of an engine or engine-aftertreatment system family with the relevant emission limits over the appropriate durability period are given in Annex II to Directive 2005/78/EC.

### 6.4. On-Board Diagnostic (OBD) system

6.4.1. As laid down in Articles 4(1) and 4(2) of this Directive, 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 Annex IV to Directive 2005/78/EC.

As laid down in Article 4(2) of this Directive, 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 Annex IV to Directive 2005/78/EC.

### 6.4.2. Small batch engine production

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

- is less than 500 units per year, may obtain EC type-approval on the basis of the requirements of the present directive 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 EC type-approval on the basis of the requirements of the present directive where

the complete emission control system (i.e. the engine and after-treatment system) are monitored only for circuit continuity.

The type-approval authority must inform the Commission of the circumstances of each type-approval granted under this provision.

6.5. Requirements to ensure correct operation of NO<sub>x</sub> control measures<sup>(8)</sup>

6.5.1. General

6.5.1.1. This section is applicable to all engine systems irrespective of the technology used to comply with the emission limit values given in the tables in section 6.2.1 of this Annex.

6.5.1.2. Application dates

The Requirements of sections 6.5.3, 6.5.4 and 6.5.5 shall apply from 1 October 2006 for new type approvals and from 1 October 2007 for all registrations of new vehicles.

6.5.1.3. 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.

6.5.1.4. Information that fully describes the functional operational characteristics of an engine system covered by this section shall be provided by the manufacturer in Annex II to this Directive.

6.5.1.5. 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 aftertreatment system, e.g. type and concentrations, operational temperature conditions, reference to international standards etc.

6.5.1.6. With reference to section 6.1, any engine system covered by this section shall retain its emission control function during all conditions regularly pertaining in the territory of the European Union, especially at low ambient temperatures.

6.5.1.7. For the purpose of type-approval, the manufacturer shall demonstrate to the Technical Service 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.

6.5.1.8. 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

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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 and in the language of the country in which a new heavy-duty vehicle or new heavy-duty engine is sold or registered.
- 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 favourable 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 NO<sub>x</sub> control
  - 6.5.3.1. Incorrect operation of the engine system with respect to NO<sub>x</sub> 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<sub>x</sub> level by sensors positioned in the exhaust stream.
  - 6.5.3.2. Engine systems shall be equipped with a method for determining the NO<sub>x</sub> level in the exhaust stream. Any deviation in NO<sub>x</sub> level more than 1,5 g/kwh above the applicable limit value given in table I of section 6.2.1 of Annex I to this Directive, shall result in the driver being informed by activation of the MI (see section 3.6.5 of Annex IV to Directive 2005/78/EC).
  - 6.5.3.3. In addition, a non-erasable fault code identifying the reason why NO<sub>x</sub> exceeds the levels specified in the paragraph above shall be stored in accordance with paragraph 3.9.2 of Annex IV to Directive 2005/78/EC for at least 400 days or 9 600 hours of engine operation.
  - 6.5.3.4. If the NO<sub>x</sub> level exceeds the OBD threshold limit values given in the table in Article 4(3) of this Directive<sup>(9)</sup>, a torque limiter shall reduce the performance of the engine according to the requirements of section 6.5.5 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.

6.5.3.5. In the case of engine systems that rely on the use of EGR and no other aftertreatment system for NO<sub>x</sub> emissions control, the manufacturer may utilise an alternative method to the requirements of paragraph 6.5.3.1 for the determination of the NO<sub>x</sub> level. At the time of type approval the manufacturer shall demonstrate that the alternative method is equally timely and accurate in determining the NO<sub>x</sub> level compared to the requirements of paragraph 6.5.3.1 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.

6.5.4. Reagent control

6.5.4.1. For vehicles that require the use of a reagent to fulfil the requirements of this section, 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 Annex IV to Directive 2005/78/EC, 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 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 6.5.4.13 as an alternative to complying with the requirements of section 6.5.3.

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 Annex II to this Directive 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 Annex II to this Directive the additional requirements of section 6.5.4.13 shall apply.

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

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- 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 (see section 6.8.3 of Annex IV to Directive 2005/78/EC).
- 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 aftertreatment 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 shall result in application of the measures laid down in paragraph 6.5.4.13.
- 6.5.4.11. In the case of interruption in reagent dosing activity the measures laid down in paragraph 6.5.4.13 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. If the NO<sub>x</sub> level exceeds 7,0 g/kWh on the ETC test cycle the measures laid down in section 6.5.4.13 shall apply.
- 6.5.4.13. Where reference is made to this section, the driver shall be alerted by activation of the MI (see section 3.6.5 of Annex IV to Directive 2005/78/EC) and a torque limiter shall reduce the performance of the engine according to the requirements of section 6.5.5 in a manner that is clearly perceived by the driver of the vehicle.

A non-erasable fault code identifying the reason for torque limiter activation shall be stored in accordance with paragraph 3.9.2 of Annex IV to Directive 2005/78/EC for a minimum of 400 days or 9 600 hours of engine operation.

- 6.5.5. Measures to discourage tampering of exhaust aftertreatment systems
- 6.5.5.1. Any engine system covered by this section 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 or 6.5.4.12 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 full load torque, independent of engine speed, for vehicles of category N3 > 16 tons, M3/III and M3/B > 7,5 tons,
  - 75 % of full load torque, independent of engine speed, for vehicles of category N1, N2, N3 ≤ 16 tons, M2, M3/I, M3/II, M3/A and M3/B ≤ 7,5 tons.
- 6.5.5.4. The scheme of torque limitation is set out in sections 6.5.5.5 to 6.5.5.6.
- 6.5.5.5. Detailed written information fully describing the functional operation characteristics of the torque limiter shall be specified according to the documentation requirements of section 6.1.7.1 of this Annex.
- 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. Demonstration of torque limiter
- 6.5.5.7.1. As part of the application for type-approval provided for in section 3 of this Annex, the manufacturer shall demonstrate the operation of the torque limiter either by tests on an engine dynamometer or by a vehicle test.
- 6.5.5.7.2. If an engine dynamometer test is to be carried out the manufacturer shall run consecutive ETC test cycles in order to demonstrate that the torque limiter will operate, including its activation, in accordance with the requirements of section 6.5, and in particular with those of section 6.5.5.2 and 6.5.5.3.
- 6.5.5.7.3. If a vehicle test is to be carried out, the vehicle shall be driven over the road or test track to demonstrate that the torque limiter will operate, including its activation, in accordance with the requirements of section 6.5, and in particular with those of section 6.5.5.2 and 6.5.5.3.
- (o) Section 8.1 is replaced by the following:
- 8.1. Parameters defining the engine family
- The engine family, as determined by the engine manufacturer must comply with the provisions of ISO 16185.
- (p) The following section 8.3 is added:
- 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,

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- 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.

(q) Section 9.1 is replaced by the following:

9.1. Measures to ensure production conformity must be taken in accordance with the provisions of Article 10 of Directive 70/156/EEC. Production conformity is checked on the basis of the description in the type-approval certificates set out in Annex VI to this Directive. In applying Appendices 1, 2 or 3, the measured emission of the gaseous and particulate pollutants from engines subject to checking for conformity of production shall be adjusted by application of the appropriate deterioration factors (DF's) for that engine as recorded in section 1.5 of the Appendix to Annex VI.

Sections 2.4.2 and 2.4.3 of Annex X to Directive 70/156/EEC are applicable where the competent authorities are not satisfied with the auditing procedure of the manufacturer.

(r) The following section 9.1.2 is added:

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 approval authority 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 Annex IV to Directive 2005/78/EC. 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 Annex IV to Directive 2005/78/EC.

9.1.2.4. If the engine taken from the series does not satisfy the requirements of section 9.1.2.2, a further random sample of four engines must be taken from the series and subjected to the tests described in Appendix 1 to Annex IV to Directive 2005/78/EC. 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 Annex IV to Directive 2005/78/EC.

- (s) The following section 10 is added:
10. CONFORMITY OF IN-SERVICE VEHICLES/ENGINES
- 10.1. For the purpose of this Directive, the conformity of in-service vehicles/engines must be checked periodically over the useful life period of an engine installed in a vehicle.
- 10.2. With reference to type-approvals granted for emissions, additional measures are appropriate for confirming the functionality of the emission control devices during the useful life of an engine installed in a vehicle under normal conditions of use.
- 10.3. The procedures to be followed regarding the conformity of in-service vehicles/engines are given in Annex III to Directive 2005/78/EC.
- (t) Appendix 1, section 3 is replaced by the following:
3. The following procedure is used for each of the pollutants given in section 6.2.1 of Annex I (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.  |
- (u) In Appendix 2, section 3 and the introductory phrase of section 4 are replaced by the following:
3. The values of the pollutants given in section 6.2.1 of Annex I, 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  $x_1, x_2, \dots, x_i$  and  $L$  is the natural logarithm of the limit value for the pollutant, then, define:
- (v) In Appendix 3, section 3 is replaced by the following:
3. The following procedure is used for each of the pollutants given in section 6.2.1 of Annex I (see Figure 2):
- Let:

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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.

(w) A following Appendix 4 is added:

#### Appendix 4

##### DETERMINATION OF SYSTEM EQUIVALENCE

The determination of system equivalency according to section 6.2 of this Annex 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 Directive 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:  
  
(the greater of the two standard deviations  $s_R$  or  $s_C$  must be in the numerator)
- (d) Calculate the t value, as follows:
- (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 <sub>crit</sub>	df	t <sub>crit</sub>
7	6/6	4,284	12	2,179
8	7/7	3,787	14	2,145
9	8/8	3,438	16	2,12
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 Directive,
- if  $F \geq F_{crit}$  **and**  $t \geq t_{crit}$ , then the candidate system is different from the reference system of this Directive.

(2) Annex II is amended as follows:

(a) The following section 0.7 is inserted:

0.7. Name and address of the manufacturer's representative:

(b) Former section 0.7 and sections 0.8 and 0.9 become sections 0.8, 0.9 and 0.10 respectively.

(c) The following section 0.11 is added:

0.11 In the case of a vehicle equipped with an on-board diagnostic (OBD) system, written description and/or drawing of the MI:

(d) Appendix 1 is amended as follows:

(i) The following section 1.20 is added:

1.20. Engine Electronic Control Unit (EECU) (all engine types):

1.20.1. Make: ...

1.20.2. Type: ...

1.20.3. Software calibration number(s): ...

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- (ii) The following sections 2.2.1.12 and 2.2.1.13 are added:
  - 2.2.1.12. Normal operating temperature range (K): ...
  - 2.2.1.13. Consumable reagents (where appropriate):
  - 2.2.1.13.1 Type and concentration of reagent needed for catalytic action: ...
  - 2.2.1.13.2 Normal operational temperature range of reagent: ...
  - 2.2.1.13.3 International standard (where appropriate): ...
  - 2.2.1.13.4 Frequency of reagent refill: continuous/maintenance<sup>(10)</sup>
- (iii) Section 2.2.4.1 is replaced by the following:
  - 2.2.4.1. Characteristics (make, type, flow etc): ...
- (iv) The following sections 2.2.5.5 and 2.2.5.6 are added:
  - 2.2.5.5. Normal operating temperature (K) and pressure (kPa) range: ...
  - 2.2.5.6. In case of periodic regeneration:
    - Number of ETC test cycles between 2 regenerations (n1):
    - Number of ETC test cycles during regeneration (n2)
- (v) The following section 3.1.2.2.3 is added:
  - 3.1.2.2.3. Common rail, make and type: ...
- (vi) The following sections 9 and 10 are added:
  - 9. On-board diagnostic (OBD) system
    - 9.1. Written description and/or drawing of the MI<sup>(11)</sup>: ...
    - 9.2. List and purpose of all components monitored by the OBD system: ...
    - 9.3. Written description (general OBD working principles) for:
      - 9.3.1. Diesel/gas engines<sup>(11)</sup>: ...
        - 9.3.1.1. Catalyst monitoring<sup>(11)</sup>: ...
        - 9.3.1.2. deNO<sub>x</sub> system monitoring<sup>(11)</sup>: ...
        - 9.3.1.3. Diesel particulate filter monitoring<sup>(11)</sup>: ...
        - 9.3.1.4. Electronic fuelling system monitoring<sup>(11)</sup>: ...
        - 9.3.1.5. Other components monitored by the OBD system<sup>(11)</sup>: ...
      - 9.4. Criteria for MI activation (fixed number of driving cycles or statistical method): ...



- 9.5. List of all OBD output codes and formats used (with explanation of each): ...
- 10. Torque limiter
  - 10.1. Description of the torque limiter activation
  - 10.2. Description of the full load curve limitation
- (e) In Appendix 2, the fourth line of the first column of the table in section 2.1.1 is replaced by the following:
  - Fuel flow per stroke (mm<sup>3</sup>)
- (f) Appendix 3 is amended as follows:
  - (i) The following section 1.20 is added:
    - 1.20. Engine Electronic Control Unit (EECU) (all engine types):
      - 1.20.1. Make:
      - 1.20.2. Type:
      - 1.20.3. Software calibration number(s): ...
  - (ii) The following sections 2.2.1.12 and 2.2.1.13 are added:
    - 2.2.1.12. Normal operating temperature range (K): ...
    - 2.2.1.13. Consumable reagents (where appropriate):
      - 2.2.1.13.1 Type and concentration of reagent needed for catalytic action: ...
      - 2.2.1.13.2 Normal operational temperature range of reagent: ...
      - 2.2.1.13.3 International standard (where appropriate): ...
      - 2.2.1.13.4 Frequency of reagent refill: continuous/maintenance<sup>(12)</sup>:
  - (iii) Section 2.2.4.1 is replaced by the following:
    - 2.2.4.1. Characteristics (make, type, flow etc): ...
  - (iv) The following sections 2.2.5.5 and 2.2.5.6 are added:
    - 2.2.5.5. Normal operating temperature (K) and pressure (kPa) range: ...
    - 2.2.5.6. In case of periodic regeneration:
      - Number of ETC test cycles between 2 regenerations (n1)
      - Number of ETC test cycles during regeneration (n2)
  - (v) The following section 3.1.2.2.3 is added:
    - 3.1.2.2.3. Common rail, make and type: ...
  - (vi) The following sections 6 and 7 are added:

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6. On-board diagnostic (OBD) system
    - 6.1. Written description and/or drawing of the MI<sup>(13)</sup>:
    - 6.2. List and purpose of all components monitored by the OBD system: ...
    - 6.3. Written description (general OBD working principles) for:
      - 6.3.1. Diesel/gas engines<sup>(13)</sup>: ...
        - 6.3.1.1. Catalyst monitoring<sup>(13)</sup>: ...
        - 6.3.1.2. deNO<sub>x</sub> system monitoring<sup>(13)</sup>: ...
        - 6.3.1.3. Diesel particulate filter monitoring<sup>(13)</sup>: ...
        - 6.3.1.4. Electronic fuelling system monitoring<sup>(13)</sup>: ...
        - 6.3.1.5. Other components monitored by the OBD system<sup>(13)</sup>: ...
      - 6.4. Criteria for MI activation (fixed number of driving cycles or statistical method): ...
      - 6.5. List of all OBD output codes and formats used (with explanation of each): ...
    7. Torque limiter
      - 7.1. Description of the torque limiter activation
      - 7.2. Description of the full load curve limitation
- (g) The following Appendix 5 is added:

#### Appendix 5

##### OBD-RELATED INFORMATION

1. In accordance with the provisions of section 5 of Annex IV to Directive 2005/78/EC, the following additional information must be provided by the vehicle manufacturer for the purposes of enabling the manufacture of OBD-compatible replacement or service parts and diagnostic tools and test equipment, unless such information is covered by intellectual property rights or constitutes specific know-how of the manufacturer or the OEM supplier(s).

Where appropriate, the information given in this section shall be repeated in Appendix 2 to the EC type-approval certificate (Annex VI to this Directive):

- 1.1. A description of the type and number of the pre-conditioning cycles used for the original type approval of the vehicle.
- 1.2. A description of the type of the OBD demonstration cycle used for the original type-approval of the vehicle for the component monitored by the OBD system.

1.3. A comprehensive document describing all sensed components with the strategy for fault detection and MI activation (fixed number of driving cycles or statistical method), including a list of relevant secondary sensed parameters for each component monitored by the OBD system. A list of all OBD output codes and format used (with an explanation of each) associated with individual emission related powertrain components and individual non-emission related components, where monitoring of the component is used to determine MI activation.

1.3.1. The information required by this section may, for example, be defined by completing a table as follows, which shall be attached to this Annex:

Component	Fault code	Monitoring strategy	Fault detection criteria	MI activation criteria	Secondary parameters	Preconditioning	Demonstration test
SCR catalyst	Pxxxx	NO <sub>x</sub> sensor 1 and 2 signals	Difference between sensor 1 and sensor 2 signals	1 <sup>st</sup> cycle	Engine speed, engine load, catalyst temperature, reagent activity	Three OBD test cycles (3 short ESC cycles)	OBD test cycle (short ESC cycle)

1.3.2. The information required by this Appendix may be limited to the complete list of the fault codes recorded by the OBD system where section 5.1.2.1 of Annex IV to Directive 2005/78/EC is not applicable as in the case of replacement or service components. This information may, for example, be defined by completing the two first columns of the table of section 1.3.1 above.

The complete information package should be made available to the type-approval authority as part of the additional material requested in section 6.1.7.1 of Annex I to this Directive, “documentation requirements”.

1.3.3. The information required by this section shall be repeated in Appendix 2 to the EC type-approval certificate (Annex VI to this Directive).

Where section 5.1.2.1 of Annex IV to Directive 2005/78/EC is not applicable in the case of replacement or service components, the information provided in Appendix 2 to the EC type-approval certificate (Annex VI to this Directive) can be limited to the one mentioned in section 1.3.2.

(3) Annex III is amended as follows:

(a) Section 1.3.1 is replaced by the following:

1.3.1. ESC Test

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During a prescribed sequence of warmed-up engine operating conditions the amounts of the above exhaust emissions shall be examined continuously by taking a sample from the raw or diluted exhaust gas. The test cycle consists of a number of speed and power modes which cover the typical operating range of diesel engines. During each mode the concentration of each gaseous pollutant, exhaust flow and power output shall be determined, and the measured values weighted. For particulate measurement, the exhaust gas shall be diluted with conditioned ambient air using either a partial flow or full flow dilution system. The particulates shall be collected on a single suitable filter in proportion to the weighting factors of each mode. The grams of each pollutant emitted per kilowatt hour shall be calculated as described in Appendix 1 to this Annex. Additionally,  $\text{NO}_x$  shall be measured at three test points within the control area selected by the Technical Service and the measured values compared to the values calculated from those modes of the test cycle enveloping the selected test points. The  $\text{NO}_x$  control check ensures the effectiveness of the emission control of the engine within the typical engine operating range.

- (b) Section 1.3.3 is replaced by the following:

#### 1.3.3. ETC Test

During a prescribed transient cycle of warmed-up engine operating conditions, which is based closely on road-type-specific driving patterns of heavy-duty engines installed in trucks and buses, the above pollutants shall be examined either after diluting the total exhaust gas with conditioned ambient air (CVS system with double dilution for particulates) or by determining the gaseous components in the raw exhaust gas and the particulates with a partial flow dilution system. Using the engine torque and speed feedback signals of the engine dynamometer, the power shall be integrated with respect to time of the cycle resulting in the work produced by the engine over the cycle. For a CVS system, the concentration of  $\text{NO}_x$  and HC shall be determined over the cycle by integration of the analyser signal, whereas the concentration of CO,  $\text{CO}_2$ , and NMHC may be determined by integration of the analyser signal or by bag sampling. If measured in the raw exhaust gas, all gaseous components shall be determined over the cycle by integration of the analyser signal. For particulates, a proportional sample shall be collected on a suitable filter. The raw or diluted exhaust gas flow rate shall be determined over the cycle to calculate the mass emission values of the pollutants. The mass emission values shall be related to the engine work to get the grams of each pollutant emitted per kilowatt hour, as described in Appendix 2 to this Annex.

- (c) Section 2.1 is replaced by the following:

#### 2.1. Engine Test Conditions

- 2.1.1. The absolute temperature ( $T_a$ ) of the engine air at the inlet to the engine expressed in Kelvin, and the dry atmospheric pressure ( $p_s$ ), expressed in kPa shall be measured and the parameter  $f_a$  shall be determined according to the following provisions. In multi-cylinder engines having distinct groups of intake manifolds, for example, in a “V” engine configuration, the average temperature of the distinct groups shall be taken.

- (a) for compression-ignition engines:
  - Naturally aspirated and mechanically supercharged engines:
  - Turbocharged engines with or without cooling of the intake air:

- (b) for spark-ignition engines:

#### 2.1.2. Test Validity

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

$$0,96 \leq f_a \leq 1,06$$

- (d) Section 2.8 is replaced by the following:

2.8 If the engine is equipped with an exhaust aftertreatment system, the emissions measured on the test cycle shall be representative of the emissions in the field. In the case of an engine equipped with a exhaust aftertreatment system that requires the consumption of a reagent, the reagent used for all tests shall comply with section 2.2.1.13 of Appendix 1 to Annex II.

2.8.1. For an exhaust aftertreatment system based on a continuous regeneration process the emissions shall be measured on a stabilised aftertreatment system.

The regeneration process shall occur at least once during the ETC test and the manufacturer shall declare the normal conditions under which regeneration occurs (soot load, temperature, exhaust back-pressure, etc).

In order to verify the regeneration process at least 5 ETC tests shall be conducted. During the tests the exhaust temperature and pressure shall be recorded (temperature before and after the aftertreatment system, exhaust back pressure, etc).

The aftertreatment system is considered to be satisfactory if the conditions declared by the manufacturer occur during the test during a sufficient time.

The final test result shall be the arithmetic mean of the different ETC test results.

If the exhaust aftertreatment has a security mode that shifts to a periodic regeneration mode it should be checked following section 2.8.2. For that specific case the emission limits in table 2 of Annex I could be exceeded and would not be weighted.

2.8.2. For an exhaust aftertreatment based on a periodic regeneration process, the emissions shall be measured on at least two ETC tests, one during and one outside a regeneration event on a stabilised aftertreatment system, and the results be weighted.

The regeneration process shall occur at least once during the ETC test. The engine may be equipped with a switch capable of preventing or permitting

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the regeneration process provided this operation has no effect on the original engine calibration.

The manufacturer shall declare the normal parameter conditions under which the regeneration process occurs (soot load, temperature, exhaust back-pressure etc) and its duration time (n2). The manufacturer shall also provide all the data to determine the time between two regenerations (n1). The exact procedure to determine this time shall be agreed by the Technical Service based upon good engineering judgement.

The manufacturer shall provide an aftertreatment system that has been loaded in order to achieve regeneration during an ETC test. Regeneration shall not occur during this engine conditioning phase.

Average emissions between regeneration phases shall be determined from the arithmetic mean of several approximately equidistant ETC tests. It is recommended to run at least one ETC as close as possible prior to a regeneration test and one ETC immediately after a regeneration test. As an alternative, the manufacturer may provide data to show that the emissions remain constant ( $\pm 15\%$ ) between regeneration phases. In this case, the emissions of only one ETC test may be used.

During the regeneration test, all the data needed to detect regeneration shall be recorded (CO or NO<sub>x</sub> emissions, temperature before and after the aftertreatment system, exhaust back pressure etc).

During the regeneration process, the emission limits in table 2 of Annex I can be exceeded.

The measured emissions shall be weighted according to section 5.5 and 6.3 of Appendix 2 to this Annex and the final result shall not exceed the limits in table 2 of Annex I.

(e) Appendix 1 is amended as follows:

(i) Section 2.1 is replaced by the following:

#### 2.1. Preparation of the Sampling Filter

At least one hour before the test, each filter shall be placed in a partially covered petri dish which is protected against dust contamination, and placed in a weighing chamber for stabilisation. At the end of the stabilisation period each filter shall be weighed and the tare weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber. The tare weight shall be recorded.

(ii) Section 2.7.4. is replaced by the following:

#### 2.7.4. Particulate Sampling

One filter shall be used for the complete test procedure. The modal weighting factors specified in the test cycle procedure shall be taken into account by taking a sample proportional to the exhaust mass flow during each individual mode of the cycle. This can be achieved by adjusting sample flow rate, sampling time, and/

or dilution ratio, accordingly, so that the criterion for the effective weighting factors in section 5.6 is met.

The sampling time per mode must be at least 4 seconds per 0,01 weighting factor. Sampling must be conducted as late as possible within each mode. Particulate sampling shall be completed no earlier than 5 seconds before the end of each mode.

(iii) The following new section 4 is inserted:

#### 4. CALCULATION OF THE EXHAUST GAS FLOW

##### 4.1. Determination of Raw Exhaust Gas Mass Flow

For calculation of the emissions in the raw exhaust, it is necessary to know the exhaust gas flow. The exhaust gas mass flow rate shall be determined in accordance with section 4.1.1 or 4.1.2. The accuracy of exhaust flow determination shall be  $\pm 2,5$  % of reading or  $\pm 1,5$  % of the engine's maximum value whichever is the greater. Equivalent methods (e.g. those described in section 4.2 of Appendix 2 to this Annex) may be used.

###### 4.1.1. Direct measurement method

Direct measurement of the exhaust flow may be done by systems such as:

- pressure differential devices, like flow nozzle,
- ultrasonic flowmeter,
- vortex flowmeter.

Precautions shall be taken to avoid measurement errors which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Especially, engine performance and emissions shall not be affected by the installation of the device.

###### 4.1.2. Air and fuel measurement method

This involves measurement of the air flow and the fuel flow. Air flowmeters and fuel flowmeters shall be used that meet the total accuracy requirement of section 4.1. The calculation of the exhaust gas flow is as follows:

$$q_{mew} = q_{maw} + q_{mf}$$

##### 4.2. Determination of Diluted Exhaust Gas Mass Flow

For calculation of the emissions in the diluted exhaust using a full flow dilution system it is necessary to know the diluted exhaust gas flow. The flow rate of the diluted exhaust ( $q_{mdew}$ ) shall be measured over each mode with a PDP-CVS, CFV-CVS or SSV-CVS in line with the general formulae given in section 4.1 of Appendix 2 to this Annex. The accuracy shall be  $\pm 2$  % of reading or better, and shall be determined according to the provisions of section 2.4 of Appendix 5 to this Annex.

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(iv) Sections 4 and 5 are replaced by the following:

## 5. CALCULATION OF THE GASEOUS EMISSIONS

### 5.1. Data Evaluation

For the evaluation of the gaseous emissions, the chart reading of the last 30 seconds of each mode shall be averaged and the average concentrations (conc) of HC, CO and NO<sub>x</sub> during each mode shall be determined from the average chart readings and the corresponding calibration data. A different type of recording can be used if it ensures an equivalent data acquisition.

For the NO<sub>x</sub> check within the control area, the above requirements apply for NO<sub>x</sub> only.

The exhaust gas flow  $q_{mew}$  or the diluted exhaust gas flow  $q_{mdew}$ , if used optionally, shall be determined in accordance with section 2.3 of Appendix 4 to this Annex.

### 5.2. Dry/Wet Correction

The measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis. The conversion shall be done for each individual mode.

$$c_{wet} = k_w \times c_{dry}$$

For the raw exhaust gas:

$$k_{W,r} = \left( 1 - \frac{1,2442 \times H_a + 111,19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773,4 + 1,2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000} \right) \times 1$$

or

$$k_{W,r} = \left( 1 - \frac{1,2442 \times H_a + 111,19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773,4 + 1,2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000} \right) / \left( 1 - \frac{p_r}{p_r + p_{atm}} \right)$$

where:

$p_r$  = water vapour pressure after cooling bath, kPa,



$p_b$	=	total atmospheric pressure, kPa,
$H_a$	=	intake air humidity, g water per kg dry air,
$k_f$	=	$0,055584 \times W_{ALF} - 0,0001083 \times W_{BET} - 0,0001562 \times W_{GAM} + 0,0079936 \times W_{DEL} + 0,0069978 \times W_{EPS}$

For the diluted exhaust gas:

$$K_{We1} = \left( 1 - \frac{\alpha \times \% c_{wCO_2}}{200} \right) - K_{W1}$$

or,

$$K_{We2} = \left( \frac{(1 - K_{W1})}{1 + \frac{\alpha \times \% c_{dCO_2}}{200}} \right)$$

For the dilution air:

$$K_{Wd} = 1 - K_{W1}$$

$$K_{W1} = \frac{1,608 \times \left[ H_d \times \left( 1 - \frac{1}{D} \right) + H_a \times \left( \frac{1}{D} \right) \right]}{1000 + \left\{ 1,608 \times \left[ H_d \times \left( 1 - \frac{1}{D} \right) + H_a \times \left( \frac{1}{D} \right) \right] \right\}}$$

For the intake air:

$$K_{Wa} = 1 - K_{W2}$$

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$$K_{W2} = \frac{1,608 \times H_a}{1000 + (1,608 \times H_a)}$$

where:

$H_a$  = intake air humidity,  
g water per kg dry air  
 $H_d$  = dilution air  
humidity, g water  
per kg dry air

and may be derived from relative humidity measurement, dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

### 5.3. NO<sub>x</sub> correction for humidity and temperature

As the NO<sub>x</sub> emission depends on ambient air conditions, the NO<sub>x</sub> concentration shall be corrected for ambient air temperature and humidity with the factors given in the following formulae. The factors are valid in the range between 0 and 25 g/kg dry air.

(a) for compression ignition engines:

with:

$T_a$  = temperature  
of  
the  
intake  
air,  
K  
 $H_a$  = humidity  
of  
the  
intake  
air,  
g  
water  
per  
kg  
dry  
air

where:

$H_a$  may be derived from relative humidity measurement, dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

(b) for spark ignition engines

$$k_{h,G} = 0,6272 + 44,030 \times 10^{-3} \times H_a - 0,862 \times 10^{-3} \times H_a^2$$

where:

$H_a$  may be derived from relative humidity measurement, dew point measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

#### 5.4. Calculation of the emission mass flow rates

The emission mass flow rate (g/h) for each mode shall be calculated as follows. For the calculation of  $\text{NO}_x$ , the humidity correction factor  $k_{h,D}$ , or  $k_{h,G}$ , as applicable, as determined according to section 5.3, shall be used.

The measured concentration shall be converted to a wet basis according to section 5.2 if not already measured on a wet basis. Values for  $u_{\text{gas}}$  are given in Table 6 for selected components based on ideal gas properties and the fuels relevant for this Directive.

(a) for the raw exhaust gas

$$m_{\text{gas}} = u_{\text{gas}} \times c_{\text{gas}} \times q_{\text{mew}}$$

where:

$u_{\text{gas}}$	=	ratio between density of exhaust component and density of exhaust gas
$c_{\text{gas}}$	=	concentration of the respective component in the raw exhaust gas, ppm
$q_{\text{mew}}$	=	exhaust mass flow rate, kg/h

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(b) for the diluted gas

$$m_{\text{gas}} = u_{\text{gas}} \times c_{\text{gas,c}} \times q_{\text{mdew}}$$

where:

$u_{\text{gas}}$	=	ratio between density of exhaust component and density of air
$c_{\text{gas,c}}$	=	background corrected concentration of the respective component in the diluted exhaust gas, ppm
$q_{\text{mdew}}$	=	diluted exhaust mass flow rate, kg/h

where:

The dilution factor  $D$  shall be calculated according to section 5.4.1 of Appendix 2 to this Annex.

### 5.5. Calculation of the specific emissions

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

$$GAS_x = \frac{\sum_{i=1}^{i=n} (m_{GASi} \times W_{Fi})}{\sum_{i=1}^{i=n} (P(n)_i \times W_{Fi})}$$

where:

$m_{gas}$  is the mass of individual gas

$P_n$  is the net power determined according to section 8.2 in Annex II.

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

TABLE 6

Values of  $u_{gas}$  in the raw and dilute exhaust gas for various exhaust components

Fuel		NO <sub>x</sub>	CO	THC/ NMHC	CO <sub>2</sub>	CH <sub>4</sub>
Diesel	Exhaust raw	0,0015870	0,0009660	0,0004790	0,0015180	0,000553
	Exhaust dilute	0,0015880	0,0009670	0,00048	0,0015190	0,000553
Ethanol	Exhaust raw	0,0016090	0,00098	0,0008050	0,0015390	0,000561
	Exhaust dilute	0,0015880	0,0009670	0,0007950	0,0015190	0,000553
CNG	Exhaust raw	0,0016220	0,0009870	0,0005230	0,0015520	0,000565
	Exhaust dilute	0,0015880	0,0009670	0,0005840	0,0015190	0,000553

Notes:

- $u$  values of raw exhaust based on ideal gas properties at  $\lambda = 2$ , dry air, 273 K, 101,3 kPa
- $u$  values of dilute exhaust based on ideal gas properties and density of air
- $u$  values of CNG accurate within 0,2 % for mass composition of: C = 66 – 76 %; H = 22 – 25 %; N = 0 – 12 %
- $u$  value of CNG for HC corresponds to CH<sub>2,93</sub> (for total HC use  $u$  value of CH<sub>4</sub>).

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Propane	Exhaust raw	0,001603	0,000976	0,000511	0,001533	0,000559
	Exhaust dilute	0,001588	0,000967	0,000507	0,001519	0,000553
Butane	Exhaust raw	0,0016	0,000974	0,000505	0,00153	0,000558
	Exhaust dilute	0,001588	0,000967	0,000501	0,001519	0,000553

Notes:

- $u$  values of raw exhaust based on ideal gas properties at  $\lambda = 2$ , dry air, 273 K, 101,3 kPa
- $u$  values of dilute exhaust based on ideal gas properties and density of air
- $u$  values of CNG accurate within 0,2 % for mass composition of: C = 66 – 76 %; H = 22 – 25 %; N = 0 – 12 %
- $u$  value of CNG for HC corresponds to  $\text{CH}_{2,93}$  (for total HC use  $u$  value of  $\text{CH}_4$ ).

#### 5.6. Calculation of the area control values

For the three control points selected according to section 2.7.6, the  $\text{NO}_x$  emission shall be measured and calculated according to section 5.6.1 and also determined by interpolation from the modes of the test cycle closest to the respective control point according to section 5.6.2. The measured values are then compared to the interpolated values according to section 5.6.3.

##### 5.6.1. Calculation of the Specific Emission

The  $\text{NO}_x$  emission for each of the control points (Z) shall be calculated as follows:

$$m_{\text{NO}_x,Z} = 0,001587 \times c_{\text{NO}_x,Z} \times k_{h,D} \times q_{\text{mew}}$$

$$\text{NO}_x_Z = \frac{m_{\text{NO}_x,Z}}{P(n)_Z}$$

##### 5.6.2. Determination of the Emission Value from the Test Cycle

The  $\text{NO}_x$  emission for each of the control points shall be interpolated from the four closest modes of the test cycle that envelop the selected control point Z as shown in Figure 4. For these modes (R, S, T, U), the following definitions apply:

$$\text{Speed}(R) = \text{Speed}(T) = n_{RT}$$

$$\text{Speed}(S) = \text{Speed}(U) = n_{SU}$$

$$\text{Per cent load}(R) = \text{Per cent load}(S)$$

Per cent load(T) = Per cent load(U).

The NO<sub>x</sub> emission of the selected control point Z shall be calculated as follows:

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

and:

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

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

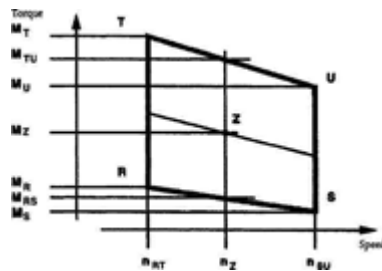
$$M_{TU} = \frac{M_T + (M_U - M_T) \times (n_Z - n_{RT})}{n_{SU} - n_{RT}}$$

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

where:

E<sub>R</sub>, E<sub>S</sub>, E<sub>T</sub>, E<sub>U</sub> = specific NO<sub>x</sub> emission of the enveloping modes calculated in accordance with section 5.6.1.

M<sub>R</sub>, M<sub>S</sub>, M<sub>T</sub>, M<sub>U</sub> = engine torque of the enveloping modes.



### 5.6.3. Comparison of NO<sub>x</sub> Emission Values

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The measured specific NO<sub>x</sub> emission of the control point Z (NO<sub>x,Z</sub>) is compared to the interpolated value (E<sub>Z</sub>) as follows:

$$NOx_{diff} = 100 \times \frac{NOx_Z - E_Z}{E_Z}$$

## 6. CALCULATION OF THE PARTICULATE EMISSIONS

### 6.1. Data Evaluation

For the evaluation of the particulates, the total sample masses ( $m_{sep}$ ) through the filter shall be recorded for each mode.

The filter shall be returned to the weighing chamber and conditioned for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight (see section 2.1) subtracted, which results in the particulate sample mass  $m_f$ .

If background correction is to be applied, the dilution air mass ( $m_d$ ) through the filter and the particulate mass ( $m_{f,d}$ ) shall be recorded. If more than one measurement was made, the quotient  $m_{f,d}/m_d$  shall be calculated for each single measurement and the values averaged.

### 6.2. Partial Flow Dilution System

The final reported test results of the particulate emission shall be determined through the following steps. Since various types of dilution rate control may be used, different calculation methods for  $q_{medf}$  apply. All calculations shall be based upon the average values of the individual modes during the sampling period.

#### 6.2.1. Isokinetic systems

$$q_{medf} = q_{mew} \times r_d$$

$$r_d = \frac{q_{mdw} + (q_{mew} \times r_a)}{q_{mew} \times r_a}$$

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

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



### 6.2.2. Systems with measurement of CO<sub>2</sub> or NO<sub>x</sub> concentration

$$q_{medf} = q_{mew} \times r_d$$

$$r_d = \frac{C_{wE} - C_{wA}}{C_{wD} - C_{wA}}$$

where:

- $c_{wE}$  = wet concentration of the tracer gas in the raw exhaust
- $c_{wD}$  = wet concentration of the tracer gas in the diluted exhaust
- $c_{wA}$  = wet concentration of the tracer gas in the dilution air

Concentrations measured on a dry basis shall be converted to a wet basis according to section 5.2 of this Appendix.

### 6.2.3. Systems with CO<sub>2</sub> measurement and carbon balance method<sup>(14)</sup>

$$q_{medf} = \frac{206,5 \times q_{mf}}{C_{(CO_2)D} - C_{(CO_2)A}}$$

where:

- $c_{(CO_2)D}$  = CO<sub>2</sub> concentration of the diluted exhaust
- $c_{(CO_2)A}$  = CO<sub>2</sub> concentration of the dilution air

(concentrations in vol % on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO<sub>2</sub>) and determined through the following steps:

$$q_{medf} = q_{mew} \times r_d$$

and

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$$r_d = \frac{206,5 \times q_{mf}}{q_{mew} \times [c_{(CO_2)D} - c_{(CO_2)A}]}$$

#### 6.2.4. Systems with flow measurement

$$q_{medf} = q_{mew} \times r_d$$

$$r_d = \frac{q_{mdew}}{q_{mdew} - q_{mdw}}$$

#### 6.3. Full Flow Dilution System

All calculations shall be based upon the average values of the individual modes during the sampling period. The diluted exhaust gas flow  $q_{mdew}$  shall be determined in accordance with section 4.1 of Appendix 2 to this Annex. The total sample mass  $m_{sep}$  shall be calculated in accordance with section 6.2.1 of Appendix 2 to this Annex.

#### 6.4. Calculation of the Particulate Mass Flow Rate

The particulate mass flow rate shall be calculated as follows. If a full flow dilution system is used,  $q_{medf}$  as determined according to section 6.2 shall be replaced with  $q_{mdew}$  as determined according to section 6.3.

$$PT_{mass} = \frac{m_f}{m_{sep}} \times \frac{q_{medf}}{1000}$$

$$q_{medf} = \sum_{i=1}^{i=n} q_{medfi} \times W_{fi}$$

$$m_{sep} = \sum_{i=1}^{i=n} m_{sepi}$$

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

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

$$PT_{mass} = \left\{ \frac{m_f}{m_{sep}} - \left[ \frac{m_{f,d}}{m_d} \times \sum_{i=1}^{i=n} \left( 1 - \frac{1}{Di} \right) \times W_{fi} \right] \right\} \times \frac{c}{1}$$

where  $D$  shall be calculated in accordance with section 5.4.1 of Appendix 2 to this Annex.

- (v) Former section 6 is renumbered as section 7.
- (f) Appendix 2 is amended as follows:
  - (i) Section 3 is replaced by the following:

### 3. EMISSIONS TEST RUN

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

NG and LPG fuelled engines shall be run-in using the ETC test. The engine shall be run over a minimum of two ETC cycles and until the CO emission measured over one ETC cycle does not exceed by more than 10 % the CO emission measured over the previous ETC cycle.

#### 3.1. Preparation of the sampling filters (if applicable)

At least one hour before the test, each filter shall be placed in a partially covered petri dish, which is protected against dust contamination, and placed in a weighing chamber for stabilisation. At the end of the stabilisation period, each filter shall be weighed and the tare weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber. The tare weight shall be recorded.

#### 3.2. Installation of the measuring equipment

The instrumentation and sample probes shall be installed as required. The tailpipe shall be connected to the full flow dilution system, if used.

#### 3.3. Starting the dilution system and the engine

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised at maximum power according to the recommendation of the manufacturer and good engineering practice.

#### 3.4. Starting the particulate sampling system (diesel engines only)

The particulate sampling system shall be started and running on by-pass. The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters.

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If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements at the beginning and at the end of the cycle may be done and the values averaged.

The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilised according to the recommendation of the manufacturer and good engineering practice.

In case of periodic regeneration aftertreatment, the regeneration shall not occur during the warm-up of the engine.

### 3.5. Adjustment of the dilution system

The flow rates of the dilution system (full flow or partial flow) shall be set to eliminate water condensation in the system, and to obtain a maximum filter face temperature of 325 K (52 °C) or less (see section 2.3.1 of Annex V, DT).

### 3.6. Checking the analysers

The emission analysers shall be set at zero and spanned. If sample bags are used, they shall be evacuated.

### 3.7. Engine starting procedure

The stabilised engine shall be started according to the manufacturer's recommended starting procedure in the owner's manual, using either a production starter motor or the dynamometer. Optionally, the test may start directly from the engine preconditioning phase without shutting the engine off, when the engine has reached the idle speed.

### 3.8. Test cycle

#### 3.8.1. Test sequence

The test sequence shall be started, if the engine has reached idle speed. The test shall be performed according to the reference cycle as set out in section 2 of this Appendix. Engine speed and torque command set points shall be issued at 5 Hz (10 Hz recommended) or greater. Feedback engine speed and torque shall be recorded at least once every second during the test cycle, and the signals may be electronically filtered.

#### 3.8.2. Gaseous emissions measurement

##### 3.8.2.1. Full flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the measuring equipment shall be started, simultaneously:

- start collecting or analysing dilution air,
- start collecting or analysing diluted exhaust gas,
- start measuring the amount of diluted exhaust gas (CVS) and the required temperatures and pressures,

- start recording the feedback data of speed and torque of the dynamometer.

HC and NO<sub>x</sub> shall be measured continuously in the dilution tunnel with a frequency of 2 Hz. The average concentrations shall be determined by integrating the analyzer signals over the test cycle. The system response time shall be no greater than 20 s, and shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary. CO, CO<sub>2</sub>, NMHC and CH<sub>4</sub> shall be determined by integration or by analysing the concentrations in the sample bag, collected over the cycle. The concentrations of the gaseous pollutants in the dilution air shall be determined by integration or by collecting into the background bag. All other values shall be recorded with a minimum of one measurement per second (1 Hz).

#### 3.8.2.2. Raw exhaust measurement

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the measuring equipment shall be started, simultaneously:

- start analysing the raw exhaust gas concentrations,
- start measuring the exhaust gas or intake air and fuel flow rate,
- start recording the feedback data of speed and torque of the dynamometer.

For the evaluation of the gaseous emissions, the emission concentrations (HC, CO and NO<sub>x</sub>) and the exhaust gas mass flow rate shall be recorded and stored with at least 2 Hz on a computer system. The system response time shall be no greater than 10 s. All other data may be recorded with a sample rate of at least 1 Hz. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

For calculation of the mass emission of the gaseous components the traces of the recorded concentrations and the trace of the exhaust gas mass flow rate shall be time aligned by the transformation time as defined in section 2 of Annex I. Therefore, the response time of each gaseous emissions analyser and of the exhaust gas mass flow system shall be determined according to the provisions of section 4.2.1 and section 1.5 of Appendix 5 to this Annex and recorded.

#### 3.8.3. Particulate sampling (if applicable)

##### 3.8.3.1. Full flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

If no flow compensation is used, the sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe

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or transfer tube is maintained at a value within  $\pm 5\%$  of the set flow rate. If flow compensation (i.e., proportional control of sample flow) is used, it must be demonstrated that the ratio of main tunnel flow to particulate sample flow does not change by more than  $\pm 5\%$  of its set value (except for the first 10 seconds of sampling).

*Note:* For double dilution operation, sample flow is the net difference between the flow rate through the sample filters and the secondary dilution air flow rate.

The average temperature and pressure at the gas meter(s) or flow instrumentation inlet shall be recorded. If the set flow rate cannot be maintained over the complete cycle (within  $\pm 5\%$ ) because of high particulate loading on the filter, the test shall be voided. The test shall be rerun using a lower flow rate and/or a larger diameter filter.

### 3.8.3.2. Partial flow dilution system

At the start of the engine or test sequence, if the cycle is started directly from the preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

For the control of a partial flow dilution system, a fast system response is required. The transformation time for the system shall be determined by the procedure in section 3.3 of Appendix 5 to Annex III. If the combined transformation time of the exhaust flow measurement (see section 4.2.1) and the partial flow system is less than 0,3 sec, online control may be used. If the transformation time exceeds 0,3 sec, look ahead control based on a pre-recorded test run must be used. In this case, the rise time shall be  $\leq 1$  sec and the delay time of the combination  $\leq 10$  sec.

The total system response shall be designed as to ensure a representative sample of the particulates,  $q_{mp,i}$ , proportional to the exhaust mass flow. To determine the proportionality, a regression analysis of  $q_{mp,i}$  versus  $q_{mew,i}$  shall be conducted on a minimum 1 Hz data acquisition rate, and the following criteria shall be met:

- The correlation coefficient  $R^2$  of the linear regression between  $q_{mp,i}$  and  $q_{mew,i}$  shall not be less than 0,95,
- The standard error of estimate of  $q_{mp,i}$  on  $q_{mew,i}$  shall not exceed 5 % of  $q_{mp}$  maximum,
- $q_{mp}$  intercept of the regression line shall not exceed  $\pm 2\%$  of  $q_{mp}$  maximum.

Optionally, a pretest may be run, and the exhaust mass flow signal of the pretest be used for controlling the sample flow into the particulate system (look-ahead control). Such a procedure is required if the transformation time of the particulate system,  $t_{50,P}$  or the transformation time of the exhaust mass flow signal,  $t_{50,F}$ , or both, are  $> 0,3$  sec. A correct control of the partial dilution system is obtained, if the time trace of  $q_{mew,pre}$  of the pretest, which controls  $q_{mp}$ , is shifted by a look-ahead time of  $t_{50,P} + t_{50,F}$ .

For establishing the correlation between  $q_{mp,i}$  and  $q_{mew,i}$  the data taken during the actual test shall be used, with  $q_{mew,i}$  time aligned by  $t_{50,F}$  relative to  $q_{mp,i}$  (no contribution from  $t_{50,P}$  to the time alignment). That is, the time shift between  $q_{mew}$  and  $q_{mp}$  is the difference in their transformation times that were determined in section 3.3 of Appendix 5 to Annex III.

#### 3.8.4. Engine stalling

If the engine stalls anywhere during the test cycle, the engine shall be preconditioned and restarted, and the test repeated. If a malfunction occurs in any of the required test equipment during the test cycle, the test shall be voided.

#### 3.8.5. Operations after test

At the completion of the test, the measurement of the diluted exhaust gas volume or raw exhaust gas flow rate, the gas flow into the collecting bags and the particulate sample pump shall be stopped. For an integrating analyser system, sampling shall continue until system response times have elapsed.

The concentrations of the collecting bags, if used, shall be analysed as soon as possible and in any case not later than 20 minutes after the end of the test cycle.

After the emission test, a zero gas and the same span gas shall be used for re-checking the analysers. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

### 3.9. Verification of the test run

#### 3.9.1. Data shift

To minimise the biasing effect of the time lag between the feedback and reference cycle values, the entire engine speed and torque feedback signal sequence may be advanced or delayed in time with respect to the reference speed and torque sequence. If the feedback signals are shifted, both speed and torque must be shifted the same amount in the same direction.

#### 3.9.2. Calculation of the cycle work

The actual cycle work  $W_{act}$  (kWh) shall be calculated using each pair of engine feedback speed and torque values recorded. This shall be done after any feedback data shift has occurred, if this option is selected. The actual cycle work  $W_{act}$  is used for comparison to the reference cycle work  $W_{ref}$  and for calculating the brake specific emissions (see sections 4.4 and 5.2). The same methodology shall be used for integrating both reference and actual engine power. If values are to be determined between adjacent reference or adjacent measured values, linear interpolation shall be used.

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In integrating the reference and actual cycle work, all negative torque values shall be set equal to zero and included. If integration is performed at a frequency of less than 5 Hertz, and if, during a given time segment, the torque value changes from positive to negative or negative to positive, the negative portion shall be computed and set equal to zero. The positive portion shall be included in the integrated value.

$W_{act}$  shall be between -15 % and +5 % of  $W_{ref}$

### 3.9.3. Validation statistics of the test cycle

Linear regressions of the feedback values on the reference values shall be performed for speed, torque and power. This shall be done after any feedback data shift has occurred, if this option is selected. The method of least squares shall be used, with the best fit equation having the form:

$$y = mx + b$$

where:

y	=	Feedback (actual) value of speed ( $\text{min}^{-1}$ ), torque (Nm), or power (kW)
m	=	slope of the regression line
x	=	reference value of speed ( $\text{min}^{-1}$ ), torque (Nm), or power (kW)
b	=	y intercept of the regression line

The standard error of estimate (SE) of y on x and the coefficient of determination ( $r^2$ ) shall be calculated for each regression line.

It is recommended that this analysis be performed at 1 Hertz. All negative reference torque values and the associated feedback values shall be deleted from the calculation of cycle torque and power validation statistics. For a test to be considered valid, the criteria of table 7 must be met.

TABLE 7

#### Regression line tolerances

	Speed	Torque	Power
<b>a</b>	Until 1 October 2005, the figures shown in brackets may be used for the type-approval testing of gas engines. (The Commission shall report on the development of gas engine technology to confirm or modify the regression line tolerances applicable to gas engines given in this table.)		



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Standard error of estimate (SE) of Y on X	Max 100 min <sup>-1</sup>	Max 13 % (15 %) <sup>a</sup> of power map maximum engine torque	Max 8 % (15 %) <sup>a</sup> of power map maximum engine power
Slope of the regression line, m	0,95 to 1,03	0,83–1,03	0,89–1,03 (0,83–1,03) <sup>a</sup>
Coefficient of determination, r <sup>2</sup>	min 0,97 (min 0,95) <sup>a</sup>	min 0,88 (min 0,75) <sup>a</sup>	min 0,91 (min 0,75) <sup>a</sup>
Y intercept of the regression line, b	±50 min <sup>-1</sup>	±20 Nm or ±2 % (±20 Nm or ±3 %) <sup>a</sup> of max torque whichever is greater	±4 kW or ±2 % (±4kW or ±3 %) <sup>a</sup> of max power whichever is greater

**a** Until 1 October 2005, the figures shown in brackets may be used for the type-approval testing of gas engines. (The Commission shall report on the development of gas engine technology to confirm or modify the regression line tolerances applicable to gas engines given in this table.)

Point deletions from the regression analyses are permitted where noted in Table 8.

TABLE 8

Permitted point deletions from regression analysis

Conditions	Points to be deleted
Full load demand and torque feedback < 95 % torque reference	Torque and/or power
Full load demand and speed feedback < 95 % speed reference	Speed and/or power
No load, not an idle point, and torque feedback > torque reference	Torque and/or power
No load, speed feedback ≤ idle speed +50 min <sup>-1</sup> and torque feedback = manufacturer defined/measured idle torque ±2 % of max. torque	Speed and/or power
No load, speed feedback > idle speed +50 min <sup>-1</sup> and torque	Torque and/or power

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feedback > 105 % torque reference	
No load and speed feedback > 105 % speed reference	Speed and/or power

(ii) The following section 4 is inserted:

#### 4. CALCULATION OF THE EXHAUST GAS FLOW

##### 4.1. Determination of the diluted exhaust gas flow

The total diluted exhaust gas flow over the cycle (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device ( $V_0$  for PDP,  $K_V$  for CFV,  $C_d$  for SSV), as determined in section 2 of Appendix 5 to Annex III). The following formulae shall be applied, if the temperature of the diluted exhaust is kept constant over the cycle by using a heat exchanger ( $\pm 6$  K for a PDP-CVS,  $\pm 11$  K for a CFV-CVS or  $\pm 11$  K for a SSV-CVS), see section 2.3 of Annex V).

*For the PDP-CVS system:*

$$m_{ed} = 1,293 \times V_0 \times N_P \times (p_b - p_1) \times 273 / (101,3 \times T)$$

where:

$V_0$	=	volume of gas pumped per revolution under test conditions, $m^3/rev$
$N_P$	=	total revolutions of pump per test
$p_b$	=	atmospheric pressure in the test cell, kPa
$p_1$	=	pressure depression below atmospheric at pump inlet, kPa
$T$	=	average temperature of the diluted exhaust gas at pump inlet over the cycle, K

*For the CFV-CVS system:*

$$m_{ed} = 1,293 \times t \times K_V \times p_p / T^{0,5}$$

where:

$t$	=	cycle time, s
$K_V$	=	calibration coefficient of the critical flow venturi for standard conditions,

- $p_p$  = absolute pressure at venturi inlet, kPa  
 $T$  = absolute temperature at venturi inlet, K

For the SSV-CVS system

$$m_{ed} = 1,293 \times Q_{SSV}$$

where:

$$Q_{SSV} = A_0 d^2 C_d p_p \sqrt{\left[ \frac{1}{T} \left( r_p^{1,4286} - r_p^{1,7143} \right) \right] \times \left( \frac{1}{1 - r_D^4 r_p^{1,4286}} \right)}$$

with:

- $A_0$  = collection of constants and units conversions  
 = 0,006111 in SI units of  
 $d$  = diameter of the SSV throat, m  
 $C_d$  = discharge coefficient of the SSV  
 $p_p$  = absolute pressure at venturi inlet, kPa  
 $T$  = temperature at the venturi inlet, K  
 $r_p$  = ratio of the SSV throat to inlet absolute, static pressure

$$r_D = \frac{1 - \frac{\Delta P}{P_A}}{\frac{d}{D}}$$

= ratio of the SSV throat diameter, d, to the inlet pipe inner diameter =  $\frac{d}{D}$

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated

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and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows.

*For the PDP-CVS system:*

$$m_{ed,i} = 1,293 \times V_0 \times N_{p,i} \times (p_b - p_1) \times 273 / (101,3 \times T)$$

where:

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

*For the CFV-CVS system:*

$$m_{ed,i} = 1,293 \times \Delta t_i \times K_V \times p_p / T^{0,5}$$

where:

$\Delta t_i$  = time interval, s

*For the SSV-CVS system:*

$$m_{ed} = 1,293 \times Q_{SSV} \times \Delta t_i$$

where:

$\Delta t_i$  = time interval, s

The real time calculation shall be initialised with either a reasonable value for  $C_d$ , such as 0,98, or a reasonable value of  $Q_{SSV}$ . If the calculation is initialised with  $Q_{SSV}$ , the initial value of  $Q_{SSV}$  shall be used to evaluate Re.

During all emissions tests, the Reynolds number at the SSV throat must be in the range of Reynolds numbers used to derive the calibration curve developed in section 2.4 of Appendix 5 to this Annex.

#### 4.2. Determination of raw exhaust gas mass flow

For calculation of the emissions in the raw exhaust gas and for controlling of a partial flow dilution system, it is necessary to know the exhaust gas mass flow rate. For the determination of the exhaust mass flow rate, either of the methods described in sections 4.2.2 to 4.2.5 may be used.

##### 4.2.1. Response time

For the purpose of emissions calculation, the response time of either method described below shall be equal to or less than the requirement for the analyzer response time, as defined in section 1.5 of Appendix 5 to this Annex.

For the purpose of controlling of a partial flow dilution system, a faster response is required. For partial flow dilution systems with online control, a response time of  $\leq 0,3$  seconds is required. For partial flow dilution systems with look ahead control based on a pre-recorded test run, a response time of the exhaust flow measurement system of  $\leq 5$  seconds with a rise time of  $\leq$

1 second is required. The system response time shall be specified by the instrument manufacturer. The combined response time requirements for exhaust gas flow and partial flow dilution system are indicated in section 3.8.3.2.

#### 4.2.2. Direct measurement method

Direct measurement of the instantaneous exhaust flow may be done by systems such as:

- pressure differential devices, like flow nozzle,
- ultrasonic flowmeter,
- vortex flowmeter.

Precautions shall be taken to avoid measurement errors which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Engine performance and emissions shall especially not be affected by the installation of the device.

The accuracy of exhaust flow determination shall be at least  $\pm 2,5\%$  of reading or  $\pm 1,5\%$  of engine's maximum value, whichever is the greater.

#### 4.2.3. Air and fuel measurement method

This involves measurement of the air flow and the fuel flow. Air flowmeters and fuel flowmeters shall be used that meet the total exhaust flow accuracy requirement of section 4.2.2. The calculation of the exhaust gas flow is as follows:

$$Q_{mew} = Q_{maw} + Q_{mf}$$

#### 4.2.4. Tracer measurement method

This involves measurement of the concentration of a tracer gas in the exhaust. A known amount of an inert gas (e.g. pure helium) shall be injected into the exhaust gas flow as a tracer. The gas is mixed and diluted by the exhaust gas, but shall not react in the exhaust pipe. The concentration of the gas shall then be measured in the exhaust gas sample.

In order to ensure complete mixing of the tracer gas, the exhaust gas sampling probe shall be located at least 1 m or 30 times the diameter of the exhaust pipe, whichever is larger, downstream of the tracer gas injection point. The sampling probe may be located closer to the injection point if complete mixing is verified by comparing the tracer gas concentration with the reference concentration when the tracer gas is injected upstream of the engine.

The tracer gas flow rate shall be set so that the tracer gas concentration at engine idle speed after mixing becomes lower than the full scale of the trace gas analyser.

The calculation of the exhaust gas flow is as follows:

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$$q_{mew,i} = \frac{q_{vt} \times \rho_e}{60 \times (c_{mix,i} - c_a)}$$

where:

$q_{mew,i}$	=	instantaneous exhaust mass flow, kg/s
$q_{vt}$	=	tracer gas flow, cm <sup>3</sup> /min
$c_{mix,i}$	=	instantaneous concentration of the tracer gas after mixing, ppm
$\rho_e$	=	density of the exhaust gas, kg/m <sup>3</sup> (cf. table 3)
$c_a$	=	background concentration of the tracer gas in the intake air, ppm

When the background concentration is less than 1 % of the concentration of the tracer gas after mixing ( $c_{mix,i}$ ) at maximum exhaust flow, the background concentration may be neglected.

The total system shall meet the accuracy specifications for the exhaust gas flow, and shall be calibrated according to section 1.7 of Appendix 5 to this Annex.

#### 4.2.5. Air flow and air-to-fuel ratio measurement method

This involves exhaust mass calculation from the air flow and the air to fuel ratio. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$q_{mew,i} = q_{maw,i} \times \left( 1 + \frac{1}{A/F_{st} \times \lambda_i} \right)$$

with:

$$A/F_{st} = \frac{138,0 \times \left( \beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right)}{12,011 \times \beta + 1,00794 \times \alpha + 15,9994 \times \varepsilon + 14,0067 \times \delta + 32,0}$$

$$\lambda_i = \frac{\beta \times \left( 100 - \frac{c_{CO} \times 10^{-4}}{2} - c_{HC} \times 10^{-4} \right) + \left( \frac{\alpha}{4} \times \frac{1 - \frac{2 \times c_{CO} \times 10^{-4}}{3,5 \times c_{CO_2}}}{1 + \frac{c_{CO} \times 10^{-4}}{3,5 \times c_{CO_2}}} - \frac{\varepsilon}{2} - \frac{\delta}{2} \right) \times (c_{CO_2} + c_{CO})}{4,764 \times \left( \beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right) \times (c_{CO_2} + c_{CO} \times 10^{-4} + c_{HC} \times 10^{-4})}$$

where:

$A/F_{st}$	=	stoichiometric air to fuel ratio, kg/kg
$\lambda$	=	excess air ratio
$c_{CO_2}$	=	dry $CO_2$ concentration, %
$c_{CO}$	=	dry CO concentration, ppm
$c_{HC}$	=	HC concentration, ppm

*Note:*  $\beta$  can be 1 for fuels containing carbon and 0 for hydrogen fuel.

The air flowmeter shall meet the accuracy specifications of section 2.2 of Appendix 4 to this Annex, the  $CO_2$  analyser used shall meet the specifications of section 3.3.2 of Appendix 4 to this Annex and the total system shall meet the accuracy specifications for the exhaust gas flow.

Optionally, air to fuel ratio measurement equipment such as a zirconia type sensor may be used for the measurement of the excess air ratio which meets the specifications of section 3.3.6 of Appendix 4 to this Annex.

(iii) Sections 4 and 5 are replaced by the following:

## 5. CALCULATION OF THE GASEOUS EMISSIONS

### 5.1. Data evaluation

For the evaluation of the gaseous emissions in the diluted exhaust gas, the emission concentrations (HC, CO and  $NO_x$ ) and the diluted exhaust gas mass flow rate shall be recorded according to section 3.8.2.1 and stored on a computer system. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

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For the evaluation of the gaseous emissions in the raw exhaust gas, the emission concentrations (HC, CO and NO<sub>x</sub>) and the exhaust gas mass flow rate shall be recorded according to section 3.8.2.2 and stored on a computer system. For analogue analysers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

#### 5.2. Dry/wet correction

If the concentration is measured on a dry basis, it shall be converted to a wet basis according to the following formula. For continuous measurement, the conversion shall be applied to each instantaneous measurement before any further calculation.

$$c_{\text{wet}} = k_{\text{W}} \times c_{\text{dry}}$$

The conversion equations of section 5.2 of Appendix 1 to this Annex shall apply.

#### 5.3. NO<sub>x</sub> correction for humidity and temperature

As the NO<sub>x</sub> emission depends on ambient air conditions, the NO<sub>x</sub> concentration shall be corrected for ambient air temperature and humidity with the factors given in section 5.3 of Appendix 1 to this Annex. The factors are valid in the range between 0 and 25 g/kg dry air.

#### 5.4. Calculation of the emission mass flow rates

The emission mass over the cycle (g/test) shall be calculated as follows depending on the measurement method applied. The measured concentration shall be converted to a wet basis according to section 5.2 of Appendix 1 to this Annex, if not already measured on a wet basis. The respective values for  $u_{\text{gas}}$  shall be applied that are given in Table 6 of Appendix 1 to this Annex for selected components based on ideal gas properties and the fuels relevant for this Directive.

(a) *for the raw exhaust gas:*

where:

$u_{\text{gas}}$  = ratio between density of exhaust component and density of exhaust gas from



$c_{\text{gas},i}$	=	table 6 instantaneous concentration of the respective component in the raw exhaust gas, ppm
$q_{\text{mew},i}$	=	instantaneous exhaust mass flow rate, kg/s
$f$	=	data sampling rate, Hz
$n$	=	number of measurements

(b) *for the diluted exhaust gas without flow compensation:*

$$m_{\text{gas}} = u_{\text{gas}} \times c_{\text{gas}} \times m_{\text{ed}}$$

where:

$u_{\text{gas}}$	=	ratio between density of exhaust component and density of air from table 6
$c_{\text{gas}}$	=	average background corrected concentration of the

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$m_{ed}$  = respective component, ppm total diluted exhaust mass over the cycle, kg

(c) *for the diluted exhaust gas with flow compensation:*

where:

$c_{e,i}$  = instantaneous concentration of the respective component measured in the diluted exhaust gas, ppm

$c_d$  = concentration of the respective component measured in the dilution air, ppm

$q_{mdew,i}$  = instantaneous diluted exhaust gas mass flow rate, kg/s

$m_{ed}$  = total mass of diluted

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$u_{\text{gas}}$  = exhaust gas over the cycle, kg ratio between density of exhaust component and density of air from table 6

$D$  = dilution factor (see section 5.4.1)

If applicable, the concentration of NMHC and CH<sub>4</sub> shall be calculated by either of the methods shown in section 3.3.4 of Appendix 4 to this Annex, as follows:

(a) *GC method (full flow dilution system, only):*

$$c_{\text{NMHC}} = c_{\text{HC}} - c_{\text{CH}_4}$$

(b) *NMC method:*

where:

$c_{\text{HC(w/Cutter)}}$  = HC concentration with the sample gas flowing through the NMC

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

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the  
NMC

#### 5.4.1. Determination of the background corrected concentrations (full flow dilution system, only)

The average background concentration of the gaseous pollutants in the dilution air shall be subtracted from measured concentrations to get the net concentrations of the pollutants. The average values of the background concentrations can be determined by the sample bag method or by continuous measurement with integration. The following formula shall be used.

$$c = c_e - c_d \times \left(1 - \frac{1}{D}\right)$$

where:

$c_e$	=	concentration of the respective pollutant measured in the diluted exhaust gas, ppm
$c_d$	=	concentration of the respective pollutant measured in the dilution air, ppm
$D$	=	dilution factor

The dilution factor shall be calculated as follows:

- (a) for diesel and LPG fueled gas engines
- (b) for NG fueled gas engines

where:

$c_{CO_2}$	=	concentration of $CO_2$ in the diluted exhaust gas, % vol
$c_{HC}$	=	concentration of HC in the

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$c_{\text{NMHC}}$	=	diluted exhaust gas, ppm C1 concentration of NMHC in the diluted exhaust gas, ppm C1
$c_{\text{CO}}$	=	concentration of CO in the diluted exhaust gas, ppm C1
$F_S$	=	stoichiometric factor

Concentrations measured on dry basis shall be converted to a wet basis in accordance with section 5.2 of Appendix 1 to this Annex.

The stoichiometric factor shall be calculated as follows:

where:

$\alpha$ ,  $\epsilon$  are the molar ratios referring to a fuel  $\text{CH}_\alpha\text{O}_\epsilon$

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

$F_S$	=	13,4
(diesel)		
$F_S$	=	11,6
(LPG)		
$F_S$	=	9,5
(NG)		

#### 5.5. Calculation of the specific emissions

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

- all components, except  $\text{NO}_x$ :
- $\text{NO}_x$ :

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where:

$W_{act}$  = actual cycle work as determined according to section 3.9.2.

- 5.5.1. In case of a periodic exhaust aftertreatment system, the emissions shall be weighted as follows:

$$\overline{M}_{Gas} = (n1 \times \overline{M}_{Gas, n1} + n2 \times \overline{M}_{Gas, n2}) / (n1 + n2)$$

where:

- |               |   |   |
|---------------|---|---|
| n1            | = | number of ETC tests between two regenerations                 |
| n2            | = | number of ETC during a regeneration (minimum of one ETC test) |
| $M_{gas, n2}$ | = | emissions during a regeneration                               |
| $M_{gas, n1}$ | = | emissions after a regeneration.                               |

## 6. CALCULATION OF THE PARTICULATE EMISSION (IF APPLICABLE)

### 6.1. Data evaluation

The particulate filter shall be returned to the weighing chamber no later than one hour after completion of the test. It shall be conditioned in a partially covered petri dish, which is protected against dust contamination, for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight subtracted, which results in the particulate sample mass  $m_f$ . For the evaluation of the particulate concentration, the total sample mass ( $m_{sep}$ ) through the filters over the test cycle shall be recorded.

If background correction is to be applied, the dilution air mass ( $m_d$ ) through the filter and the particulate mass ( $m_{f,d}$ ) shall be recorded.

### 6.2. Calculation of the mass flow

#### 6.2.1. Full flow dilution system

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

$$m_{PT} = \frac{m_f}{m_{sep}} \times \frac{m_{ed}}{1000}$$

where:

- $m_f$  = particulate mass sampled over the cycle, mg
- $m_{sep}$  = mass of diluted exhaust gas passing the particulate collection filters, kg
- $m_{ed}$  = mass of diluted exhaust gas over the cycle, kg

If a double dilution system is used, the mass of the secondary dilution air shall be subtracted from the total mass of the double diluted exhaust gas sampled through the particulate filters.

$$m_{sep} = m_{set} - m_{ssd}$$

where:

- $m_{set}$  = mass of double diluted exhaust gas through particulate filter, kg
- $m_{ssd}$  = mass of secondary dilution air, kg

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

$$m_{PT} = \left[ \frac{m_f}{m_{sep}} - \left( \frac{m_{f,d}}{m_d} \times \left( 1 - \frac{1}{D} \right) \right) \right] \times \frac{m}{10}$$

where:

- $m_{PT}$ ,  $m_{sep}$ ,  $m_{ed}$ ,  $m_d$  = see above
- $m_d$  = mass of primary dilution air sampled by background particulate sampler, kg
- $m_{f,d}$  = mass of the collected background particulates of the

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D = primary dilution air, mg dilution factor as determined in section 5.4.1.

### 6.2.2. Partial flow dilution system

The mass of particulates (g/test) shall be calculated by either of the following methods:

(a) where:

$m_f$  = particulate mass sampled over the cycle, mg

$m_{sep}$  = mass of diluted exhaust gas passing the particulate collection filters, kg

$m_{edf}$  = mass of equivalent diluted exhaust gas over the cycle, kg

The total mass of equivalent diluted exhaust gas mass over the cycle shall be determined as follows:

where:

$q_{medf,i}$  = instantaneous equivalent diluted exhaust mass flow



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		rate, kg/ s
$q_{mew,i}$	=	instantaneous exhaust mass flow rate, kg/ s
$r_{d,i}$	=	instantaneous dilution ratio
$q_{mdew,i}$	=	instantaneous diluted exhaust mass flow rate through dilution tunnel, kg/ s
$q_{mdw,i}$	=	instantaneous dilution air mass flow rate, kg/ s
$f$	=	data sampling rate, Hz
$n$	=	number of measurements

(b) where:

$m_f$	=	particulate mass sampled over the cycle, mg
$r_s$	=	average sample ratio over

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the  
test  
cycle

with:

where:

$m_{se}$  = sample  
mass  
over  
the  
cycle,  
kg

$m_{ew}$  = total  
exhaust  
mass  
flow  
over  
the  
cycle,  
kg

$m_{sep}$  = mass  
of  
diluted  
exhaust  
gas  
passing  
the  
particulate  
collection  
filters,  
kg

$m_{sed}$  = mass  
of  
diluted  
exhaust  
gas  
passing  
the  
dilution  
tunnel,  
kg.

*Note:* In case of the total sampling type system,  $m_{sep}$  and  
 $M_{sed}$  are identical.

### 6.3. Calculation of the Specific Emission

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

$$M_{PT} = \frac{m_{PT}}{W_{act}}$$

where:

$W_{act}$  = actual cycle work as determined according to section 3.9.2, kWh.

6.3.1. In case of a periodic regeneration aftertreatment system, the emissions shall be weighted as follows:

$$\overline{PT} = (n1 \times \overline{PT}_{n1} + n2 \times \overline{PT}_{n2}) / (n1 + n2)$$

where:

n1 = number of ETC tests between two regeneration events

n2 = number of ETC tests during a regeneration (minimum of one ETC)

$\overline{PT}_{n2}$  = emissions during a regeneration

$\overline{PT}_{n1}$  = emissions outside a regeneration.

(g) Appendix 4 is amended as follows:

(i) Section 1 is replaced by the following:

#### 1. INTRODUCTION

Gaseous components, particulates, and smoke emitted by the engine submitted for testing shall be measured by the methods described in Annex V. The respective sections of Annex V describe the recommended analytical systems for the gaseous emissions (section 1), the recommended particulate dilution and sampling systems (section 2), and the recommended opacimeters for smoke measurement (section 3).

For the ESC, the gaseous components shall be determined in the raw exhaust gas. Optionally, they may be determined in the diluted exhaust gas, if a full flow dilution system is used for particulate determination. Particulates shall be determined with either a partial flow or a full flow dilution system.

For the ETC, the following systems may be used

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- a CVS full flow dilution system for determining gaseous and particulate emissions (double dilution systems are permissible),
  - or
  - a combination of raw exhaust measurement for the gaseous emissions and a partial flow dilution system for particulate emissions,
  - or
  - any combination of the two principles (e.g. raw gaseous measurement and full flow particulate measurement).
- (ii) Section 2.2 is replaced by the following:

#### 2.2. Other instruments

Measuring instruments for fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and intake manifold depression, exhaust gas temperature, air intake temperature, atmospheric pressure, humidity and fuel temperature shall be used, as required. These instruments shall satisfy the requirements given in table 9:

TABLE 9

#### Accuracy of measuring instruments

Measuring Instrument	Accuracy
Fuel Consumption	±2 % of Engine's Maximum Value
Air Consumption	±2 % of reading or ±1 % of engine's maximum value whichever is greater
Exhaust Gas Flow	±2, % of reading or ±1,5 % of engine's maximum value whichever is greater
Temperatures ≤ 600 K (327 °C)	±2 K Absolute
Temperatures ≥ 600 K (327 °C)	±1 % of Reading
Atmospheric Pressure	± 0,1 kPa Absolute
Exhaust Gas Pressure	± 0,2 kPa Absolute
Intake Depression	± 0,05 kPa Absolute
Other Pressures	± 0,1 kPa Absolute
Relative Humidity	±3 % Absolute
Absolute Humidity	±5 % of Reading
Dilution Air Flow	±2 % of Reading

Diluted Exhaust Gas Flow	±2 % of Reading
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(iii) Sections 2.3 and 2.4 are deleted.

(iv) Sections 3 and 4 are replaced by the following:

### 3. DETERMINATION OF THE GASEOUS COMPONENTS

#### 3.1. General analyser specifications

The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (section 3.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If read-out systems (computers, data loggers) can provide sufficient accuracy and resolution below 15 % of full scale, measurements below 15 % of full scale are also acceptable. In this case, additional calibrations of at least 4 non-zero nominally equally spaced points are to be made to ensure the accuracy of the calibration curves according to section 1.6.4 of Appendix 5 to this Annex.

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

##### 3.1.1. Accuracy

The analyser shall not deviate from the nominal calibration point by more than ±2 % of the reading over the whole measurement range except zero, or ± 0,3 % of full scale whichever is larger. The accuracy shall be determined according to the calibration requirements laid down in section 1.6 of Appendix 5 to this Annex.

*Note:* For the purpose of this Directive, accuracy is defined as the deviation of the analyser reading from the nominal calibration values using a calibration gas (= true value).

##### 3.1.2. Precision

The precision, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, has to be not greater than ±1 % of full scale concentration for each range used above 155 ppm (or ppmC) or ±2 % of each range used below 155 ppm (or ppmC).

##### 3.1.3. Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10 second period shall not exceed 2 % of full scale on all ranges used.

##### 3.1.4. Zero drift

Zero response is defined as the mean response, including noise, to a zero gas during a 30 seconds time interval. The drift of the zero

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response during a one hour period shall be less than 2 % of full scale on the lowest range used.

#### 3.1.5. Span drift

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

#### 3.1.6. Rise time

The rise time of the analyser installed in the measurement system shall not exceed 3,5 s.

*Note:* Only evaluating the response time of the analyser alone will not clearly define the suitability of the total system for transient testing. Volumes and especially dead volumes through out the system will not only effect the transportation time from the probe to the analyser, but also effect the rise time. Also transport times inside of an analyser would be defined as analyser response time, like the converter or water traps inside NO<sub>x</sub> analysers. The determination of the total system response time is described in section 1.5 of Appendix 5 to this Annex.

### 3.2. Gas drying

The optional gas drying device must have a minimal effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

### 3.3. Analysers

Sections 3.3.1 to 3.3.4 describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex V. The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearising circuits is permitted.

#### 3.3.1. Carbon monoxide (CO) analysis

The carbon monoxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

#### 3.3.2. Carbon dioxide (CO<sub>2</sub>) analysis

The carbon dioxide analyser shall be of the Non-Dispersive InfraRed (NDIR) absorption type.

#### 3.3.3. Hydrocarbon (HC) analysis

For diesel and LPG fuelled gas engines, the hydrocarbon analyser shall be of the Heated Flame Ionisation Detector (HFID) type with detector, valves, pipework, etc. heated so as to maintain a gas temperature of 463 K ±10 K (190 ±10 °C). For NG fuelled gas engines, the hydrocarbon analyser may be of the non heated Flame Ionisation Detector (FID) type depending upon the method used (see section 1.3 of Annex V).

### 3.3.4. Non-Methane Hydrocarbon (NMHC) analysis (NG fuelled gas engines only)

Non-methane hydrocarbons shall be determined by either of the following methods:

#### 3.3.4.1. Gas chromatographic (GC) method

Non-methane hydrocarbons shall be determined by subtraction of the methane analysed with a Gas Chromatograph (GC) conditioned at 423 K (150 °C) from the hydrocarbons measured according to section 3.3.3.

#### 3.3.4.2. Non-Methane Cutter (NMC) method

The determination of the non-methane fraction shall be performed with a heated NMC operated in line with an FID as per section 3.3.3 by subtraction of the methane from the hydrocarbons.

### 3.3.5. Oxides of Nitrogen (NO<sub>x</sub>) analysis

The oxides of nitrogen analyser shall be of the ChemiLuminescent Detector (CLD) or Heated ChemiLuminescent Detector (HCLD) type with a NO<sub>2</sub>/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with converter maintained above 328 K (55 °C) shall be used, provided the water quench check (see section 1.9.2.2 of Appendix 5 to this Annex) is satisfied.

### 3.3.6. Air-to-fuel measurement

The air to fuel measurement equipment used to determine the exhaust gas flow as specified in section 4.2.5 of Appendix 2 to this Annex shall be a wide range air to fuel ratio sensor or lambda sensor of Zirconia type. The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.

The accuracy of the sensor with incorporated electronics shall be within:

%±3 of reading	$\lambda < 2$
%±5 of reading	$2 \leq \lambda < 5$
%±10 of reading	$5 \leq \lambda$

To fulfil the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.

## 3.4. Sampling of Gaseous Emissions

### 3.4.1. Raw exhaust gas

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The gaseous emissions sampling probes shall be fitted at least 0,5 m or 3 times the diameter of the exhaust pipe — whichever is the larger — upstream of the exit of the exhaust gas system but sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70 °C) at the probe.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a “Vee” engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from the group with the highest CO<sub>2</sub> emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation the total exhaust mass flow shall be used.

If the engine is equipped with an exhaust aftertreatment system, the exhaust sample shall be taken downstream of the exhaust aftertreatment system.

#### 3.4.2. Diluted exhaust gas

The exhaust pipe between the engine and the full flow dilution system shall conform to the requirements of section 2.3.1 of Annex V (EP).

The gaseous emissions sample probe(s) shall be installed in the dilution tunnel at a point where the dilution air and exhaust gas are well mixed, and in close proximity to the particulates sampling probe.

Sampling can generally be done in two ways:

- the pollutants are sampled into a sampling bag over the cycle and measured after completion of the test,
- the pollutants are sampled continuously and integrated over the cycle; this method is mandatory for HC and NO<sub>x</sub>.

#### 4. DETERMINATION OF THE PARTICULATES

The determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system or a full flow double dilution system. The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems. The temperature of the diluted exhaust gas shall be below 325 K (52 °C)<sup>(15)</sup> immediately upstream of the filter holders. Humidity control of the dilution air before entering the dilution system is permitted, and especially dehumidifying is useful if dilution air humidity is high. The temperature of the dilution air shall be higher than 288 K (15 °C) in close proximity to the entrance into the dilution tunnel.



The partial flow dilution system has to be designed to extract a proportional raw exhaust sample from the engine exhaust stream, thus responding to excursions in the exhaust stream flow rate, and introduce dilution air to this sample to achieve a temperature below 325 K (52 °C) at the test filter. For this it is essential that the dilution ratio or the sampling ratio  $r_{\text{dil}}$  or  $r_s$  be determined such that the accuracy limits of section 3.2.1 of Appendix 5 to this Annex are fulfilled. Different extraction methods can be applied, whereby the type of extraction used dictates to a significant degree the sampling hardware and procedures to be used (section 2.2 of Annex V).

In general, the particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, but sufficiently distant as to not cause interference. Therefore, the installation provisions of section 3.4.1 also apply to particulate sampling. The sampling line shall conform to the requirements of section 2 of Annex V.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a “Vee” engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from the group with the highest particulate emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emission calculation the total exhaust mass flow shall be used.

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, a microgram balance, and a temperature and humidity controlled weighing chamber, are required.

For particulate sampling, the single filter method shall be applied which uses one filter (see section 4.1.3) for the whole test cycle. For the ESC, considerable attention must be paid to sampling times and flows during the sampling phase of the test.

#### 4.1. Particulate sampling filters

The diluted exhaust shall be sampled by a filter that meets the requirements of sections 4.1.1 and 4.1.2 during the test sequence.

##### 4.1.1. Filter specification

Fluorocarbon coated glass fiber filters are required. All filter types shall have a 0,3 µm DOP (di-octylphthalate) collection efficiency of at least 99 % at a gas face velocity between 35 and 100 cm/s.

##### 4.1.2. Filter size

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Particulate filters with a diameter of 47 mm or 70 mm are recommended. Larger diameter filters are acceptable (section 4.1.4), but smaller diameter filters are not permitted.

#### 4.1.3. Filter face velocity

A gas face velocity through the filter of 35 to 100 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

#### 4.1.4. Filter loading

The required minimum filter loadings for the most common filter sizes are shown in table 10. For larger filter sizes, the minimum filter loading shall be 0,065 mg/1 000 mm<sup>2</sup> filter area.

TABLE 10

Minimum Filter Loadings

Filter Diameter (mm)	Minimum loading (mg)
47	0,11
70	0,25
90	0,41
110	0,62

If, based on previous testing, the required minimum filter loading is unlikely to be reached on a test cycle after optimisation of flow rates and dilution ratio, a lower filter loading may be acceptable, with the agreement of the parties involved, if it can be shown to meet the accuracy requirements of section 4.2, e.g. with a 0,1 µg balance.

#### 4.1.5. Filter holder

For the emissions test, the filters shall be placed in a filter holder assembly meeting the requirements of section 2.2 of Annex V. The filter holder assembly shall be of a design that provides an even flow distribution across the filter stain area. Quick acting valves shall be located either upstream or downstream of the filter holder. An inertial pre-classifier with a 50 % cut point between 2,5 µm and 10 µm may be installed immediately upstream of the filter holder. The use of the pre-classifier is strongly recommended if an open tube sampling probe facing upstream into the exhaust flow is used.

### 4.2. Weighing chamber and analytical balance specifications

#### 4.2.1. Weighing chamber conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295 K ±3 K (22 °C ±3 °C) during all filter conditioning and

weighing. The humidity shall be maintained to a dewpoint of 282,5 K  $\pm$  3 K (9,5 °C  $\pm$  3 °C) and a relative humidity of 45 %  $\pm$  8 %.

#### 4.2.2. Reference filter weighing

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in section 4.2.1 will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personal entrance into the weighing room. At least two unused reference filters shall be weighed within 4 hours of, but preferably at the same time as the sample filter weightings. They shall be the same size and material as the sample filters.

If the average weight of the reference filters changes between sample filter weightings by more than 10  $\mu$ g, then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in section 4.2.1 is not met, but the reference filter weightings meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

#### 4.2.3. Analytical balance

The analytical balance used to determine the filter weight shall have a precision (standard deviation) of at least 2  $\mu$ g and a resolution of at least 1  $\mu$ g (1 digit = 1  $\mu$ g) specified by the balance manufacturer.

#### 4.2.4. Elimination of static electricity effects

To eliminate the effects of static electricity, the filters shall be neutralized prior to weighing, e.g. by a Polonium neutralizer, a Faraday cage or a device of similar effect.

#### 4.2.5. Specifications for flow measurement

##### 4.2.5.1. General requirements

Absolute accuracies of flow meter or flow measurement instrumentation shall be as specified in section 2.2.

##### 4.2.5.2. Special provisions for partial flow dilution systems

For partial flow dilution systems, the accuracy of the sample flow  $q_{mp}$  is of special concern, if not measured directly, but determined by differential flow measurement:

$$q_{mp} = q_{mdew} - q_{mdw}$$

In this case an accuracy of  $\pm 2$  % for  $q_{mdew}$  and  $q_{mdw}$  is not sufficient to guarantee acceptable accuracies of  $q_{mp}$ . If the gas flow is determined by differential flow measurement, the maximum error

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of the difference shall be such that the accuracy of  $q_{mp}$  is within  $\pm 5\%$  when the dilution ratio is less than 15. It can be calculated by taking root-mean-square of the errors of each instrument.

Acceptable accuracies of  $q_{mp}$  can be obtained by either of the following methods:

The absolute accuracies of  $q_{mdew}$  and  $q_{mdw}$  are  $\pm 0,2\%$  which guarantees an accuracy of  $q_{mp}$  of  $\leq 5\%$  at a dilution ratio of 15. However, greater errors will occur at higher dilution ratios;

calibration of  $q_{mdw}$  relative to  $q_{mdew}$  is carried out such that the same accuracies for  $q_{mp}$  as in a) are obtained. For the details of such a calibration see section 3.2.1 of Appendix 5 to Annex III;

the accuracy of  $q_{mp}$  is determined indirectly from the accuracy of the dilution ratio as determined by a tracer gas, e.g.  $CO_2$ . Again, accuracies equivalent to method a) for  $q_{mp}$  are required;

the absolute accuracy of  $q_{mdew}$  and  $q_{mdw}$  is within  $\pm 2\%$  of full scale, the maximum error of the difference between  $q_{mdew}$  and  $q_{mdw}$  is within  $0,2\%$ , and the linearity error is within  $\pm 0,2\%$  of the highest  $q_{mdew}$  observed during the test.

(h) Appendix 5 is amended as follows:

(i) The following section 1.2.3 is added:

#### 1.2.3. Use of precision blending devices

The gases used for calibration and span may also be obtained by means of precision blending devices (gas dividers), diluting with purified  $N_2$  or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the blended calibration gases is accurate to within  $\pm 2\%$ . This accuracy implies that primary gases used for blending must be known to an accuracy of at least  $\pm 1\%$ , traceable to national or international gas standards. The verification shall be performed at between 15 and 50 % of full scale for each calibration incorporating a blending device.

Optionally, the blending device may be checked with an instrument which by nature is linear, e.g. using NO gas with a CLD. The span value of the instrument shall be adjusted with the span gas directly connected to the instrument. The blending device shall be checked at the used settings and the nominal value shall be compared to the measured concentration of the instrument. This difference shall in each point be within  $\pm 1\%$  of the nominal value.

(ii) Section 1.4 is replaced by the following:

#### 1.4. Leakage test

A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation

period all flow meters should read zero. If not, the sampling lines shall be checked and the fault corrected.

The maximum allowable leakage rate on the vacuum side shall be 0,5 % of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilisation period the pressure increase  $\Delta p$  (kPa/min) in the system should not exceed:

$$\Delta p = p / V_s \times 0,005 \times q_{vs}$$

where:

$V_s$	=	system volume, l
$q_{vs}$	=	system flow rate, l/ min

Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas. If after an adequate period of time the reading is about 1 % low compared to the introduced concentration, these points to calibration or leakage problems.

- (iii) The following section 1.5 is inserted:

#### 1.5. Response time check of analytical system

The system settings for the response time evaluation shall be exactly the same as during measurement of the test run (i.e. pressure, flow rates, filter settings on the analyzers and all other response time influences). The response time determination shall be done with gas switching directly at the inlet of the sample probe. The gas switching shall be done in less than 0,1 second. The gases used for the test shall cause a concentration change of at least 60 % FS.

The concentration trace of each single gas component shall be recorded. The response time is defined to be the difference in time between the gas switching and the appropriate change of the recorded concentration. The system response time ( $t_{90}$ ) consists of the delay time to the measuring detector and the rise time of the detector. The delay time is defined as the time from the change ( $t_0$ ) until the response is 10 % of the final reading ( $t_{10}$ ). The rise time is defined as the time between 10 % and 90 % response of the final reading ( $t_{90} - t_{10}$ ).

For time alignment of the analyzer and exhaust flow signals in the case of raw measurement, the transformation time is defined as the time from the change ( $t_0$ ) until the response is 50 % of the final reading ( $t_{50}$ ).

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The system response time shall be  $\leq 10$  seconds with a rise time  $\leq 3,5$  seconds for all limited components (CO, NO<sub>x</sub>, HC or NMHC) and all ranges used.

(iv) Former section 1.5 is replaced by the following:

#### 1.6. Calibration

##### 1.6.1. Instrument assembly

The instrument assembly shall be calibrated and calibration curves checked against standard gases. The same gas flow rates shall be used as when sampling exhaust.

##### 1.6.2. Warming-up time

The warming-up time should be according to the recommendations of the manufacturer. If not specified, a minimum of two hours is recommended for warming up the analysers.

##### 1.6.3. NDIR and HFID analyser

The NDIR analyser shall be tuned, as necessary, and the combustion flame of the HFID analyser shall be optimised (section 1.8.1).

##### 1.6.4. Establishment of the calibration curve

- Each normally used operating range shall be calibrated
- Using purified synthetic air (or nitrogen), the CO, CO<sub>2</sub>, NO<sub>x</sub> and HC analysers shall be set at zero
- The appropriate calibration gases shall be introduced to the analysers, the values recorded, and the calibration curve established
- The calibration curve shall be established by at least 6 calibration points (excluding zero) approximately equally spaced over the operating range. The highest nominal concentration shall be equal to or higher than 90 % of full scale
- The calibration curve shall be calculated by the method of least-squares. A best-fit linear or non-linear equation may be used
- The calibration points shall not differ from the least-squares best-fit line by more than  $\pm 2$  % of reading or  $\pm 0,3$  % of full scale whichever is larger
- The zero setting shall be rechecked and the calibration procedure repeated, if necessary.

##### 1.6.5. Alternative methods

If it can be shown that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

##### 1.6.6. Calibration of tracer gas analyser for exhaust flow measurement

The calibration curve shall be established by at least 6 calibration points (excluding zero) approximately equally spaced over the operating range. The highest nominal concentration shall be equal to or higher than 90 % of full scale. The calibration curve is calculated by the method of least squares.

The calibration points shall not differ from the least-squares best-fit line by more than  $\pm 2$  % of reading or  $\pm 0,3$  % of full scale whichever is larger.

The analyser shall be set at zero and spanned prior to the test run using a zero gas and a span gas whose nominal value is more than 80 % of the analyser full scale.

(v) Former section 1.6 becomes section 1.6.7.

(vi) The following section 2.4 is inserted:

#### 2.4. Calibration of the Subsonic Venturi (SSV)

Calibration of the SSV is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, pressure drop between the SSV inlet and throat.

##### 2.4.1. Data analysis

The air flowrate ( $Q_{SSV}$ ) at each restriction setting (minimum 16 settings) shall be calculated in standard  $m^3/min$  from the flowmeter data using the manufacturer's prescribed method. The discharge coefficient shall be calculated from the calibration data for each setting as follows:

$$Q_{SSV} = A_0 d^2 C_d p_p \sqrt{\left[ \frac{1}{T} \left( r_p^{1,4286} - r_p^{1,7143} \right) \times \left( \frac{1}{1 - r_D^4 r_p^{1,4286}} \right) \right]}$$

where:

$Q_{SSV}$	=	air flow rate at standard conditions (101,3 kPa, 273 K), $m^3/s$
$T$	=	temperature at the venturi inlet, K
$d$	=	diameter of the SSV throat, m
$r_p$	=	ratio of the SSV throat to inlet absolute, static

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$$r_D = \frac{1 - \frac{\Delta P}{P_A}}{\frac{d}{D}}$$

pressure

= ratio of the SSV throat diameter, d, to the inlet pipe inner diameter = D

To determine the range of subsonic flow,  $C_d$  shall be plotted as a function of Reynolds number at the SSV throat. The Re at the SSV throat is calculated with the following formula:

$$Re = A_1 \frac{Q_{SSV}}{d\mu}$$

where:

$A_1$  = a collection of constants and units conversions

$Q_{SSV}$  = air flow rate at standard conditions (101,3 kPa, 273 K),  $m^3/s$

$d$  = diameter of the SSV throat, m

$\mu$  = absolute or dynamic viscosity of the gas, calculated with the following formula:

$b$  = empirical constant

$$1,458 \times 10^6 \frac{kg}{msK^2}$$

$S$  = empirical constant = 110,4 K



Because  $Q_{SSV}$  is an input to the Re formula, the calculations must be started with an initial guess for  $Q_{SSV}$  or  $C_d$  of the calibration venturi, and repeated until  $Q_{SSV}$  converges. The convergence method must be accurate to 0,1 % of point or better.

For a minimum of sixteen points in the region of subsonic flow, the calculated values of  $C_d$  from the resulting calibration curve fit equation must be within  $\pm 0,5$  % of the measured  $C_d$  for each calibration point.

(vii) Former section 2.4 becomes Section 2.5.

(viii) Section 3 is replaced by the following:

### 3. CALIBRATION OF THE PARTICULATE MEASURING SYSTEM

#### 3.1. Introduction

The calibration of the particulate measurement is limited to the flow meters used to determine sample flow and dilution ratio. Each flow meter shall be calibrated as often as necessary to fulfil the accuracy requirements of this Directive. The calibration method that shall be used is described in section 3.2.

#### 3.2. Flow measurement

##### 3.2.1. Periodical calibration

— To fulfil the absolute accuracy of the flow measurements as specified in section 2.2 of Appendix 4 to this Annex, the flow meter or the flow measurement instrumentation shall be calibrated with an accurate flow meter traceable to international and/or national standards.

— If the sample gas flow is determined by differential flow measurement the flow meter or the flow measurement instrumentation shall be calibrated in one of the following procedures, such that the probe flow  $q_{mp}$  into the tunnel shall fulfil the accuracy requirements of section 4.2.5.2 of Appendix 4 to this Annex:

(a) The flow meter for  $q_{mdw}$  shall be connected in series to the flow meter for  $q_{mdew}$ , the difference between the two flow meters shall be calibrated for at least 5 set points with flow values equally spaced between the lowest  $q_{mdw}$  value used during the test and the value of  $q_{mdew}$  used during the test. The dilution tunnel may be bypassed.

(b) A calibrated mass flow device shall be connected in series to the flowmeter for  $q_{mdew}$  and the accuracy shall be checked for the value used for the test. Then the calibrated mass flow device shall be connected in series to the

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flow meter for  $q_{mdw}$ , and the accuracy shall be checked for at least 5 settings corresponding to dilution ratio between 3 and 50, relative to  $q_{mdew}$  used during the test.

- (c) The transfer tube TT shall be disconnected from the exhaust, and a calibrated flow measuring device with a suitable range to measure  $q_{mp}$  shall be connected to the transfer tube. Then  $q_{mdew}$  shall be set to the value used during the test, and  $q_{mdw}$  shall be sequentially set to at least 5 values corresponding to dilution ratios  $q$  between 3 and 50. Alternatively, a special calibration flow path, may be provided, in which the tunnel is bypassed, but the total and dilution air flow through the corresponding meters as in the actual test.
- (d) A tracer gas, shall be fed into the exhaust transfer tube TT. This tracer gas may be a component of the exhaust gas, like CO<sub>2</sub> or NO<sub>x</sub>. After dilution in the tunnel the tracer gas component shall be measured. This shall be carried out for 5 dilution ratios between 3 and 50. The accuracy of the sample flow shall be determined from the dilution ration  $r_d$ :

— The accuracies of the gas analysers shall be taken into account to guarantee the accuracy of  $q_{mp}$ .

### 3.2.2. Carbon flow check

— A carbon flow check using actual exhaust is recommended for detecting measurement and control problems and verifying the proper operation of the partial flow system. The carbon flow check should be run at least each time a new engine is installed, or something significant is changed in the test cell configuration.

— The engine shall be operated at peak torque load and speed or any other steady state mode that produces 5 % or more of CO<sub>2</sub>. The partial flow sampling system shall be operated with a dilution factor of about 15 to 1.

— If a carbon flow check is conducted, the procedure given in Appendix 6 to this Annex shall be applied. The carbon flow rates shall be calculated according to sections 2.1 to 2.3 of Appendix 6 to this Annex. All carbon flow rates should agree to within 6 % of each other.

### 3.2.3. Pre-test check

— A pre-test check shall be performed within 2 hours before the test run in the following way:

— The accuracy of the flow meters shall be checked by the same method as used for calibration (see section 3.2.1) for at least two points, including flow values of  $q_{mdw}$  that

- correspond to dilution ratios between 5 and 15 for the  $q_{mdew}$  value used during the test.
- If it can be demonstrated by records of the calibration procedure under section 3.2.1 that the flow meter calibration is stable over a longer period of time, the pre-test check may be omitted.
- 3.3. Determination of transformation time (for partial flow dilution systems on ETC only)
- The system settings for the transformation time evaluation shall be exactly the same as during measurement of the test run. The transformation time shall be determined by the following method:
  - An independent reference flowmeter with a measurement range appropriate for the probe flow shall be put in series with and closely coupled to the probe. This flowmeter shall have a transformation time of less than 100 ms for the flow step size used in the response time measurement, with flow restriction sufficiently low as to not affect the dynamic performance of the partial flow dilution system, and consistent with good engineering practice.
  - A step change shall be introduced to the exhaust flow (or air flow if exhaust flow is calculated) input of the partial flow dilution system, from a low flow to at least 90 % of full scale. The trigger for the step change should be the same one used to start the look-ahead control in actual testing. The exhaust flow step stimulus and the flowmeter response shall be recorded at a sample rate of at least 10 Hz.
  - From this data, the transformation time shall be determined for the partial flow dilution system, which is the time from the initiation of the step stimulus to the 50 % point of the flowmeter response. In a similar manner, the transformation times of the  $q_{mp}$  signal of the partial flow dilution system and of the  $q_{mew,i}$  signal of the exhaust flow meter shall be determined. These signals are used in the regression checks performed after each test (see section 3.8.3.2 of Appendix 2 to this Annex).
  - The calculation shall be repeated for at least 5 rise and fall stimuli, and the results shall be averaged. The internal transformation time (< 100 msec) of the reference flowmeter shall be subtracted from this value. This is the “look-ahead” value of the partial flow dilution system, which shall be applied in accordance with section 3.8.3.2 of Appendix 2 to this Annex.
- 3.4. Checking the partial flow conditions
- The range of the exhaust gas velocity and the pressure oscillations shall be checked and adjusted according to the requirements of section 2.2.1 of Annex V (EP), if applicable.
- 3.5. Calibration intervals

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The flow measurement instrumentation shall be calibrated at least every 3 months or whenever a system repair or change is made that could influence calibration.

- (i) The following Appendix 6 is added:

#### Appendix 6

### CARBON FLOW CHECK

#### 1. INTRODUCTION

All but a tiny part of the carbon in the exhaust comes from the fuel, and all but a minimal part of this is manifest in the exhaust gas as CO<sub>2</sub>. This is the basis for a system verification check based on CO<sub>2</sub> measurements.

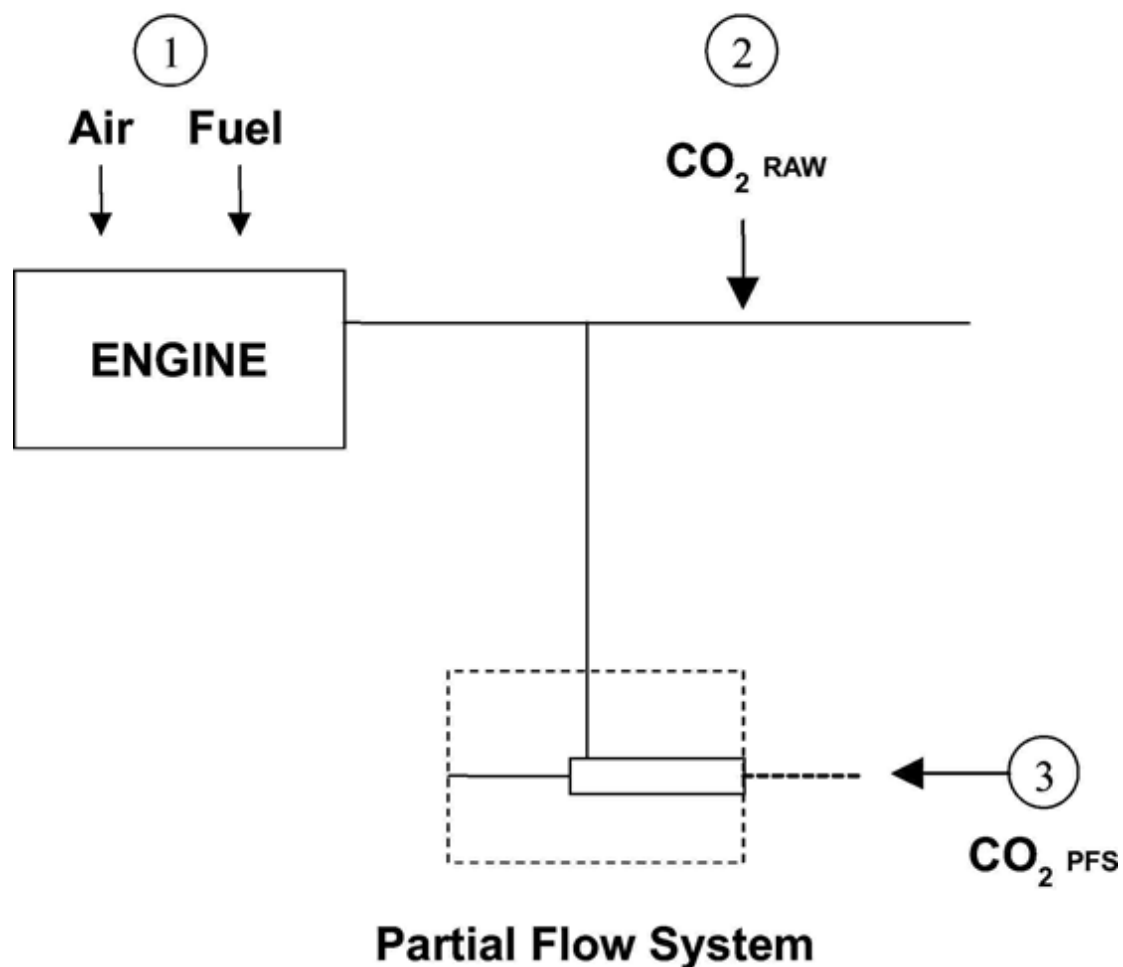
The flow of carbon into the exhaust measurement systems is determined from the fuel flow rate. The flow of carbon at various sampling points in the emissions and particulate sampling systems is determined from the CO<sub>2</sub> concentrations and gas flow rates at those points.

In this sense, the engine provides a known source of carbon flow, and observing the same carbon flow in the exhaust pipe and at the outlet of the partial flow PM sampling system verifies leak integrity and flow measurement accuracy. This check has the advantage that the components are operating under actual engine test conditions of temperature and flow.

The following diagram shows the sampling points at which the carbon flows shall be checked. The specific equations for the carbon flows at each of the sample points are given below.

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## Measuring points for carbon flow check



### 2. CALCULATIONS

#### 2.1. Carbon flow rate into the engine (location 1)

The carbon mass flow rate into the engine for a fuel CH<sub>α</sub>O<sub>ε</sub> is given by:

$$q_{mCf} = \frac{12,011}{12,011 + \alpha + 15,9994 \times \varepsilon} \times q_{mf}$$

where:

$q_{mf}$  = fuel mass flow rate, kg/s

#### 2.2. Carbon flow rate in the raw exhaust (location 2)

The carbon mass flow rate in the exhaust pipe of the engine shall be determined from the raw CO<sub>2</sub> concentration and the exhaust gas mass flow rate:

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$$q_{mCe} = \left( \frac{c_{CO_2,r} - c_{CO_2,a}}{100} \right) \times q_{mew} \times \frac{12,011}{M_{re}}$$

where:

$c_{CO_2,r}$	=	wet CO <sub>2</sub> concentration in the raw exhaust gas, %
$c_{CO_2,a}$	=	wet CO <sub>2</sub> concentration in the ambient air, % (around 0,04 %)
$q_{mew}$	=	exhaust gas mass flow rate on wet basis, kg/s
$M_{re}$	=	molecular mass of exhaust gas

If CO<sub>2</sub> is measured on a dry basis it shall be converted to a wet basis according to section 5.2 of Appendix 1 to this Annex.

### 2.3. Carbon flow rate in the dilution system (location 3)

The carbon flow rate shall be determined from the dilute CO<sub>2</sub> concentration, the exhaust gas mass flow rate and the sample flow rate:

$$q_{mCp} = \left( \frac{c_{CO_2,d} - c_{CO_2,a}}{100} \right) \times q_{mdew} \times \frac{12,011}{M_{re}} \times \frac{q_{mew}}{q_{mp}}$$

where:

$c_{CO_2,d}$	=	wet CO <sub>2</sub> concentration in the dilute exhaust gas at the outlet of the dilution tunnel, %
$c_{CO_2,a}$	=	wet CO <sub>2</sub> concentration in the ambient air, % (around 0,04 %)
$q_{mdew}$	=	diluted exhaust gas mass flow rate on wet basis, kg/s
$q_{mew}$	=	exhaust gas mass flow rate on wet basis, kg/s (partial flow system only)
$q_{mp}$	=	sample flow of exhaust gas into partial flow dilution system, kg/s (partial flow system only)
$M_{re}$	=	molecular mass of exhaust gas

If CO<sub>2</sub> is measured on a dry basis, it shall be converted to wet basis according to section 5.2 of Appendix 1 to this Annex.

### 2.4. The molecular mass ( $M_{re}$ ) of the exhaust gas shall be calculated as follows:

$$M_{re} = \frac{1 + \frac{q_{mf}}{q_{maw}}}{\frac{q_{mf}}{q_{maw}} \times \frac{\frac{\alpha}{4} + \frac{\varepsilon}{2} + \frac{\delta}{2}}{12,011 + 1,00794 \times \alpha + 15,9994 \times \varepsilon + 14,0067 \times \delta + 32,065 \times \gamma} + \frac{\frac{H_a \times 10^{-3}}{2 \times 1,00794 + 15,9994} + \frac{1}{M_{ra}}}{1 + H_a \times 10^{-3}}}$$

where:

$q_{mf}$	=	fuel mass flow rate, kg/s
$q_{maw}$	=	intake air mass flow rate on wet basis, kg/s
$H_a$	=	humidity of intake air, g water per kg dry air
$M_{ra}$	=	molecular mass of dry intake air (= 28,9 g/mol)
$\alpha,$ $\delta,$ $\varepsilon,$ $\gamma$	=	molar ratios referring to a fuel $CH_\alpha O_\delta N_\varepsilon S_\gamma$

Alternatively, the following molecular masses may be used:

$M_{re}$ (diesel)	=	28,9 g/mol
$M_{re}$ (LPG)	=	28,6 g/mol
$M_{re}$ (NG)	=	28,3 g/mol

(4) Annex IV is amended as follows:

(a) The title of section 1.1 is replaced by the following:

1.1. **Diesel reference fuel for testing engines to the emission limits given in row a of the Tables in Section 6.2.1 of Annex I <sup>(1)</sup>**

(b) The following section 1.2 is inserted:

1.2. **Diesel reference fuel for testing engines to the emission limits given in rows B1, B2 or C of the Tables in Section 6.2.1 of Annex I**

Parameter	Unit	Limits <sup>a</sup>		Test Method
		minimum	maximum	
Cetane number <sup>b</sup>		52,0	54,0	EN-ISO 5165
Density at 15 °C	kg/m <sup>3</sup>	833	837	EN-ISO 3675
Distillation:				
— 50 % point	°C	245	—	EN-ISO 3405

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— 95 % point	°C	345	350	EN-ISO 3405
— Final boiling point	°C	—	370	EN-ISO 3405
Flash point	°C	55	—	EN 22719
CFPP	°C	—	−5	EN 116
Viscosity at 40 °C	mm <sup>2</sup> /s	2,3	3,3	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	2,0	6,0	IP 391
Sulphur content <sup>c</sup>	mg/kg	—	10	ASTM D 5453
Copper corrosion		—	class 1	EN-ISO 2160
Conradson carbon residue (10 % DR)	% m/m	—	0,2	EN-ISO 10370
Ash content	% m/m	—	0,01	EN-ISO 6245
Water content	% m/m	—	0,02	EN-ISO 12937
Neutralisation (strong acid) number	mg KOH/g	—	0,02	ASTM D 974
Oxidation stability <sup>d</sup>	mg/ml	—	0,025	EN-ISO 12205
Lubricity (HFRR wear scan diameter at 60 °C)	µm	—	400	CEC F-06-A-96
FAME	prohibited			

**a** The values quoted in the specifications are “true values”. In establishment of their limit values the terms of ISO 4259 “Petroleum products – Determination and application of precision data in relation to methods of test” have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).  
Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the questions as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

**b** The range for cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of



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ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

- c The actual sulphur content of the fuel used for the Type I test shall be reported.
- d Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life.

(c) Former Section 1.2 becomes section 1.3.

(d) Section 3 is replaced by the following:

3. TECHNICAL DATA OF THE LPG REFERENCE FUELS

A. Technical data of the LPG reference fuels used for testing vehicles to the emission limits given in row A of the tables in Section 6.2.1 of Annex I

Parameter	Unit	Fuel A	Fuel B	Test method
Composition:				ISO 7941
C <sub>3</sub> -content	% vol	50 ±2	85 ±2	
C <sub>4</sub> -content	% vol	balance	balance	
< C <sub>3</sub> , >C <sub>4</sub>	% vol	max. 2	max. 2	
Olefins	% vol	max. 12	max. 14	
Evaporation residue	mg/kg	max. 50	max. 50	ISO 13757
Water at 0 °C		free	Free	visual inspection
Total sulphur content	mg/kg	max. 50	max. 50	EN 24260
Hydrogen sulphide		none	none	ISO 8819
Copper strip corrosion	rating	class 1	class 1	ISO 6251 <sup>a</sup>
Odour		characteristic	characteristic	
Motor octane number		min. 92,5	min. 92,5	EN 589 Annex B

**a** This method may not accurately determine the presence of corrosive materials if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test method is prohibited.

B. Technical data of the LPG reference fuels used for testing vehicles to the emission limits given in row B1, B2 or C of the tables in section 6.2.1 of Annex I

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Parameter	Unit	Fuel A	Fuel B	Test method
Composition:				ISO 7941
C <sub>3</sub> -content	% vol	50 ±2	85 ±2	
C <sub>4</sub> -content	% vol	balance	balance	
< C <sub>3</sub> , > C <sub>4</sub>	% vol	max. 2	max. 2	
Olefins	% vol	max. 12	max. 14	
Evaporation residue	mg/kg	max. 50	max. 50	ISO 13757
Water at 0 °C		free	free	Visual inspection
Total sulphur content	mg/kg	max. 10	max. 10	EN 24260
Hydrogen sulphide		none	none	ISO 8819
Copper strip corrosion	rating	class 1	class 1	ISO 6251 <sup>a</sup>
Odour		characteristic	characteristic	
Motor octane number		min. 92,5	min. 92,5	EN 589 Annex B

**a** This method may not accurately determine the presence of corrosive materials if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test method is prohibited.

(5) Annex VI is amended as follows:

(a) The Appendix becomes 'Appendix 1'.

(b) Appendix 1 is amended as follows:

(i) The following section 1.2.2 is added:

1.2.2. Engine Control Unit (ECU) software calibration number:

(ii) Section 1.4 is replaced by the following:

1.4. Emission levels of the engine/parent engine<sup>(16)</sup>:

1.4.1. ESC test:

Deterioration factor (DF): calculated/fixed<sup>(16)</sup>

Specify the DF values and the emissions on the ESC test in the table below:

ESC test
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DF:	CO	THC	NO <sub>x</sub>	PT
Emissions	CO (g/kWh)	THC (g/kWh)	NO <sub>x</sub> (g/kWh)	PT (g/kWh)
Measured:				
Calculated with DF:				

1.4.2. ELR test:

smoke value: ... m<sup>-1</sup>

1.4.3. ETC test:

Deterioration factor (DF): calculated/fixed<sup>(16)</sup>

<b>ETC test</b>					
DF:	CO	NMHC	CH <sub>4</sub>	NO <sub>x</sub>	PT
Emissions	CO (g/kWh)	NMHC (g/kWh) <sup>a</sup>	CH <sub>4</sub> (g/kWh) <sup>a</sup>	NO <sub>x</sub> (g/kWh)	PT (g/kWh) <sup>a</sup>
Measured with regeneration:					
Measured without regeneration:					
Measured/weighted:					
Calculated with DF:					

**a** Delete what is not applicable.

(c) The following Appendix 2 is added:

### Appendix 2

#### OBD RELATED INFORMATION

As noted in Appendix 5 of Annex II to this Directive, the information in this appendix is provided by the vehicle manufacturer for the purposes of enabling the manufacture of OBD-compatible replacement or service parts and diagnostic tools and test equipment. Such information need not be supplied by the vehicle manufacturer if it is covered by intellectual property rights or constitutes specific know-how of the manufacturer or the OEM supplier(s).

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Upon request, this appendix will be made available to any interested component, diagnostic tools or test equipment manufacturer, on a non-discriminatory basis.

In compliance with the provisions of section 1.3.3 of Appendix 5 to Annex II, the information required by this section shall be identical to that provided in that Appendix.

1. A description of the type and number of the pre-conditioning cycles used for the original type approval of the vehicle.
2. A description of the type of the OBD demonstration cycle used for the original type approval of the vehicle for the component monitored by the OBD system.
3. A comprehensive document describing all sensed components with the strategy for fault detection and MI activation (fixed number of driving cycles or statistical method), including a list of relevant secondary sensed parameters for each component monitored by the OBD system. A list of all OBD output codes and format used (with an explanation of each) associated with individual emission related powertrain components and individual non-emission related components, where monitoring of the component is used to determine MI activation.

## ANNEX II

### PROCEDURES FOR CONDUCTING THE TEST FOR DURABILITY OF EMISSION CONTROL SYSTEMS

#### 1. INTRODUCTION

This Annex details the procedures for selecting a family of engines to be tested over a service accumulation schedule for the purpose of determining deterioration factors. Such deterioration factors will be applied to the measured emissions from engines undergoing a periodical audit to ensure that in-service engine emissions remain in conformity with the applicable emission limits, as given in the tables in section 6.2.1 of Annex I to Directive 2005/55/EC, over the durability period applicable to the vehicle in which the engine is installed.

This Annex also details the emission and non-emission-related maintenance that will be carried out on engines undergoing a service accumulation schedule. Such maintenance will be performed on in-service engines and communicated to owners of new heavy-duty engines.

#### 2. SELECTION OF ENGINES FOR ESTABLISHING USEFUL LIFE DETERIORATION FACTORS

- 2.1. Engines will be selected from the engine family defined in section 8.1 of Annex I to Directive 2005/55/EC for emission testing to establish useful life deterioration factors.
- 2.2. Engines from different engine families may be further combined into families based on the type of exhaust aftertreatment system utilised. In order to place engines with different numbers of cylinders and different cylinder configuration but having the same technical specifications and installation for the exhaust aftertreatment systems

into the same engine-aftertreatment system family, the manufacturer shall provide data to the approval authority that demonstrates that the emissions of such engines are similar.

2.3. One engine representing the engine-aftertreatment system family shall be selected by the engine manufacturer for testing over the service accumulation schedule defined in section 3.2 of this Annex, according to the criteria for selecting engines given in section 8.2 of Annex I to Directive 2005/55/EC and shall be reported to the type-approval authority before any testing commences.

2.3.1. If the type-approval authority decides that the worst case emission rate of the engine-aftertreatment system family can be characterised better by another engine then the test engine shall be selected jointly by the type-approval authority and the engine manufacturer.

### 3. ESTABLISHING USEFUL LIFE DETERIORATION FACTORS

#### 3.1. General

Deterioration factors applicable to an engine-aftertreatment system family are developed from the selected engines based on a distance and service accumulation procedure that includes periodic testing for gaseous and particulate emissions over the ESC and ETC tests.

#### 3.2. Service accumulation schedule

Service accumulation schedules may be carried out at the choice of the manufacturer by running a vehicle equipped with the selected parent engine over an 'in-service accumulation' schedule or by running the selected parent engine over a 'dynamometer service accumulation' schedule.

##### 3.2.1. In-service and dynamometer service accumulation

3.2.1.1. The manufacturer shall determine the form and extent of the distance and service accumulation for engines, consistent with good engineering practice.

3.2.1.2. The manufacturer will determine when the engine will be tested for gaseous and particulate emissions over the ESC and ETC tests.

3.2.1.3. A single engine-operating schedule shall be used for all engines in an engine-aftertreatment system family.

3.2.1.4. At the request of the manufacturer and with the agreement of the type-approval authority, only one test cycle (either the ESC or ETC test) need be run at each test point with the other test cycle run only at the beginning and at the end of the service accumulation schedule.

3.2.1.5. Operating schedules may be different for different engine-aftertreatment system families.

3.2.1.6. Operating schedules may be shorter than the useful life period provided that the number of test points allows for a proper extrapolation of the test results, according to section 3.5.2. In any case, the service accumulation shall not be shorter than shown in the table in section 3.2.1.8.

3.2.1.7. The manufacturer has to provide the applicable correlation between minimum service accumulation period (driving distance) and engine dynamometer hours, for example, fuel consumption correlation, vehicle speed versus engine revolutions correlation etc.

##### 3.2.1.8. Minimum service accumulation

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<b>Category of vehicle in which engine will be installed</b>	<b>Minimum service accumulation period</b>	<b>Useful life(Article of this Directive)</b>
Category N1 vehicles	100 000 km	Article 3(1)(a)
Category N2 vehicles	125 000 km	Article 3(1)(b)
Category N3 vehicles with a maximum technically permissible mass not exceeding 16 tonnes	125 000 km	Article 3(1)(b)
Category N3 vehicles with a maximum technically permissible mass exceeding 16 tonnes	167 000 km	Article 3(1)(c)
Category M2 vehicles	100 000 km	Article 3(1)(a)
Category M3 vehicles of classes I, II, A and B, with a maximum technically permissible mass not exceeding 7,5 tonnes	125 000 km	Article 3(1)(b)
Category M3 vehicles of classes III and B, with a maximum technically permissible mass exceeding 7,5 tonnes	167 000 km	Article 3(1)(c)

3.2.1.9. The in-service accumulation schedule shall be fully described in the application for type-approval and reported to the type-approval authority before the start of any testing.

3.2.2. If the type-approval authority decides that additional measurements need to be carried out on the ESC and ETC tests between the points selected by the manufacturer it shall notify the manufacturer. The revised in-service accumulation schedule or dynamometer service accumulation schedule shall be prepared by the manufacturer and agreed by the type-approval authority.

3.3. Engine testing

3.3.1. Start of the service accumulation schedule

3.3.1.1. For each engine-aftertreatment system family, the manufacturer shall determine the number of hours of engine running after which the operation of the engine-after-treatment system has stabilised. If requested by the approval authority the manufacturer shall make available the data and analysis used to make this determination. As an alternative, the manufacturer may elect to run the engine for 125 hours to stabilise the engine-aftertreatment system.

3.3.1.2. The stabilisation period determined in section 3.3.1.1 will be deemed to be the start of the service accumulation schedule.

3.3.2. Service accumulation testing

- 3.3.2.1. After stabilisation, the engine will be run over the service accumulation schedule selected by the manufacturer, as described in section 3.2 above. At the periodic intervals in the service accumulation schedule determined by the manufacturer, and, where appropriate, also stipulated by the type-approval authority according to section 3.2.2, the engine shall be tested for gaseous and particulate emissions over the ESC and ETC tests. In accordance with section 3.2, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point, the other test cycle (ESC or ETC) must be run at the beginning and end of the service accumulation schedule.
- 3.3.2.2. During the service accumulation schedule, maintenance will be carried out on the engine according to section 4.
- 3.3.2.3. During the service accumulation schedule, unscheduled maintenance on the engine or vehicle may be performed, for example if the OBD system has specifically detected a problem that has resulted in the malfunction indicator (MI) being activated.
- 3.4. Reporting
  - 3.4.1. The results of all emission tests (ESC and ETC) conducted during the service accumulation schedule shall be made available to the type-approval authority. If any emission test is declared to be void, the manufacturer shall provide an explanation of why the test has been declared void. In such a case, another series of emission tests over the ESC and ETC tests shall be carried out within a further 100 hours of service accumulation.
  - 3.4.2. Whenever a manufacturer tests an engine over a service accumulation schedule for the establishment of deterioration factors, the manufacturer shall retain in its records all information concerning all the emission tests and maintenance carried out on the engine during the service accumulation schedule. This information shall be submitted to the approval authority along with the results of the emission tests conducted over the service accumulation schedule.
- 3.5. Determination of deterioration factors
  - 3.5.1. For each pollutant measured on the ESC and ETC tests and at each test point during the service accumulation schedule, a “best fit” regression analysis shall be made on the basis of all test results. The results of each test for each pollutant shall be expressed to the same number of decimal places as the limit value for that pollutant, as shown in the Tables in section 6.2.1 of Annex I to Directive 2005/55/EC, plus one additional decimal place. In accordance with section 3.2, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point and the other test cycle (ESC or ETC) run only at the beginning and end of the service accumulation schedule, the regression analysis shall be made only on the basis of the test results from the test cycle run at each test point.
  - 3.5.2. On the basis of the regression analysis, the manufacturer shall calculate the projected emission values for each pollutant at the start of the service accumulation schedule and at the useful life that is applicable for the engine under test by extrapolation of the regression equation as determined in section 3.5.1.
  - 3.5.3. For engines not equipped with an exhaust aftertreatment system, the deterioration factor for each pollutant is the difference between the projected emission values at the useful life period and at the start of the service accumulation schedule.

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For engines equipped with an exhaust aftertreatment system, the deterioration factor for each pollutant is the ratio of the projected emission values at the useful life period and at the start of the service accumulation schedule.

In accordance with section 3.2, if it has been agreed that only one test cycle (ESC or ETC) be run at each test point and the other test cycle (ESC or ETC) run only at the beginning and end of the service accumulation schedule, the deterioration factor calculated for the test cycle that has been run at each test point shall be applicable also for the other test cycle, provided that for both test cycles, the relationship between the measured values run at the beginning and at the end of the service accumulation schedule are similar.

- 3.5.4. The deterioration factors for each pollutant on the appropriate test cycles shall be recorded in section 1.5 of Appendix 1 to Annex VI to Directive 2005/55/EC.
- 3.6. As an alternative to using a service accumulation schedule to determine deterioration factors, engine manufacturers may choose to use the following deterioration factors:

Engine type	Test cycle	CO	HC	NMHC	CH <sub>4</sub>	NO <sub>x</sub>	PM
Diesel engine <sup>a</sup>	ESC	1,1	1,05	—	—	1,05	1,1
	ETC	1,1	1,05	—	—	1,05	1,1
Gas engine <sup>a</sup>	ETC	1,1	1,05	1,05	1,2	1,05	—

<sup>a</sup> Where appropriate and on the basis of information to be supplied by the Member States, the Commission may propose a revision of the DF's shown in this table in accordance with the procedure laid down in Article 13 of Directive 70/156/EEC.

- 3.6.1. The manufacturer may select to carry across the DF's determined for an engine or engine/aftertreatment combination to engines or engine/aftertreatment combinations that do not fall into the same engine family category as determined according to section 2.1. In such cases, the manufacturer must demonstrate to the approval authority that the base engine or engine/aftertreatment combination and the engine or engine/aftertreatment combination for which the DF's are being carried over have the same technical specifications and installation requirements on the vehicle and that the emissions of such engine or engine/aftertreatment combinations are similar.
- 3.7. Checking of conformity of production
- 3.7.1. Conformity of production for emissions compliance is checked on the basis of section 9 of Annex I to Directive 2005/55/EC.
- 3.7.2. At the time of type-approval, the manufacturer may choose to measure at the same time the pollutant emissions before any exhaust aftertreatment system. In so doing, the manufacturer may develop an informal deterioration factor separately for the engine and the aftertreatment system that may be used by the manufacturer as an aid to end of production line auditing.
- 3.7.3. For the purposes of type-approval, only the deterioration factors adopted by the manufacturer from section 3.6.1 or the deterioration factors developed according to section 3.5 shall be recorded in section 1.4 of Appendix 1 to Annex VI to Directive 2005/55/EC.
4. MAINTENANCE



During the service accumulation schedule, maintenance performed on engines and proper consumption of any required reagent used to determine deterioration factors are classified as either emission-related or non-emission-related and each of these can be classified as scheduled and unscheduled. Some emission-related maintenance is also classified as critical emission-related maintenance.

#### 4.1. Emission-related scheduled maintenance

- 4.1.1. This section specifies emission-related scheduled maintenance for the purpose of conducting a service accumulation schedule and for inclusion in the maintenance instructions furnished to owners of new heavy-duty vehicles and heavy-duty engines.
- 4.1.2. All emission-related scheduled maintenance for purposes of conducting a service accumulation schedule must occur at the same or equivalent distance intervals that will be specified in the manufacturer's maintenance instructions to the owner of the heavy-duty vehicle or heavy-duty engine. This maintenance schedule may be updated as necessary throughout the service accumulation schedule provided that no maintenance operation is deleted from the maintenance schedule after the operation has been performed on the test engine.
- 4.1.3. Any emission-related maintenance performed on engines must be necessary to assure in-use conformity with the relevant emission standards. The manufacturer shall submit data to the type-approval authority to demonstrate that all of the emission-related scheduled maintenance is technically necessary.
- 4.1.4. The engine manufacturer shall specify the adjustment, cleaning and maintenance (where necessary) of the following items:
  - Filters and coolers in the exhaust gas re-circulation system
  - Positive crankcase ventilation valve
  - Fuel injector tips (cleaning only)
  - Fuel injectors
  - Turbocharger
  - Electronic engine control unit and its associated sensors and actuators
  - Particulate filter system (including related components)
  - Exhaust gas re-circulation system, including all related control valves and tubing
  - Any exhaust aftertreatment system.
- 4.1.5. For the purposes of maintenance, the following components are defined as critical emission-related items:
  - Any exhaust aftertreatment system
  - Electronic engine control unit and its associated sensors and actuators
  - Exhaust gas re-circulation system including all related filters, coolers, control valves and tubing
  - Positive crankcase ventilation valve.
- 4.1.6. All critical emission-related scheduled maintenance must have a reasonable likelihood of being performed in-use. The manufacturer shall demonstrate to the approval authority the reasonable likelihood of such maintenance being performed in-use and such demonstration shall be made prior to the performance of the maintenance during the service accumulation schedule.

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- 4.1.7. Critical emission-related scheduled maintenance items that satisfy any of the conditions defined in sections 4.1.7.1 to 4.1.7.4 will be accepted as having a reasonable likelihood of the maintenance item being performed in-use.
  - 4.1.7.1. Data is submitted which establishes a connection between emissions and vehicle performance such that as emissions increase due to lack of maintenance, vehicle performance will simultaneously deteriorate to a point unacceptable for typical driving.
  - 4.1.7.2. Survey data is submitted which demonstrates that, at an 80 % confidence level, 80 % of such engines already have this critical maintenance item performed in-use at the recommended interval(s).
  - 4.1.7.3. In association with the requirements of section 4.7 of Annex IV to this Directive, a clearly visible indicator shall be installed on the dashboard of the vehicle to alert the driver that maintenance is due. The indicator shall be actuated at the appropriate distance or by component failure. The indicator must remain activated while the engine is in operation and shall not be erased without the required maintenance being carried out. Re-setting of the signal shall be a required step in the maintenance schedule. The system must not be designed to deactivate upon the end of the appropriate useful life period of the engine or thereafter.
  - 4.1.7.4. Any other method which the approval authority determines as establishing a reasonable likelihood that the critical maintenance will be performed in-use.
- 4.2. Changes to scheduled maintenance
  - 4.2.1. The manufacturer must submit a request to the type-approval authority for approval of any new scheduled maintenance that it wishes to perform during the service accumulation schedule and thereby recommend to owners of heavy-duty vehicles and engines. The manufacturer shall also include its recommendation as to the category (i.e. emission-related, non-emission-related, critical or non-critical) of the new scheduled maintenance being proposed and, for emission-related maintenance, the maximum feasible maintenance interval. The request must be accompanied by data supporting the need for the new scheduled maintenance and the maintenance interval.
- 4.3. Non-emission-related scheduled maintenance
  - 4.3.1. Non-emission-related scheduled maintenance which is reasonable and technically necessary (e.g. oil change, oil filter change, fuel filter change, air filter change, cooling system maintenance, idle speed adjustment, governor, engine bolt torque, valve lash, injector lash, timing, adjustment of the tension of any drive-belt, etc) may be performed on engines or vehicles selected for the service accumulation schedule at the least frequent intervals recommended by the manufacturer to the owner (e.g. not at the intervals recommended for severe service).
- 4.4. Maintenance on engines selected for testing over a service accumulation schedule
  - 4.4.1. Repairs to the components of an engine selected for testing over a service accumulation schedule other than the engine, emission control system or fuel system shall be performed only as a result of part failure or engine system malfunction.
  - 4.4.2. Equipment, instruments or tools may not be used to identify malfunctioning, maladjusted or defective engine components unless the same or equivalent equipment, instruments or tools will be available to dealerships and other service outlets and,
    - Are used in conjunction with scheduled maintenance on such components,

- and
- Are used subsequent to the identification of an engine malfunction.
- 4.5. Critical emission-related unscheduled maintenance
- 4.5.1. The consumption of a required reagent is defined as critical emission-related unscheduled maintenance for the purpose of conducting a service accumulation schedule and for inclusion in the maintenance instructions furnished by manufacturers to owners of new heavy-duty vehicles or heavy-duty engines.

## ANNEX III

### CONFORMITY OF IN-SERVICE VEHICLES/ENGINES

1. GENERAL
- 1.1. With reference to type-approvals granted for emissions, measures are appropriate for confirming the functionality of the emission control devices during the useful life of an engine installed in a vehicle under normal conditions of use (conformity of in-service vehicles/engines properly maintained and used).
- 1.2. For the purpose of this Directive these measures must be checked over a period corresponding to the appropriate useful life period defined in Article 3 of this Directive for vehicles or engines which are type-approved to either row B1, row B2 or row C of the tables in section 6.2.1 of Annex I to Directive 2005/55/EC.
- 1.3. The checking of conformity of in-service vehicles/engines is done on the basis of information provided by the manufacturer to the type-approval authority conducting an audit of the emissions-performance of a range of representative vehicles or engines of which the manufacturer holds the type-approval.

Figure 1 in this Annex illustrates the procedure for in-service conformity checking.

2. PROCEDURES FOR AUDIT
- 2.1. Audit of in-service conformity by the type-approval authority is conducted on the basis of any relevant information that the manufacturer has, under procedures similar to those defined in Article 10(1) and (2), and in sections 1 and 2 of Annex X to Directive 70/156/EEC.

Alternatives are in-service monitoring reports supplied by the manufacturer, type approval authority surveillance testing and/or information on surveillance testing performed by a Member State. The procedures to be used are given in section 3.

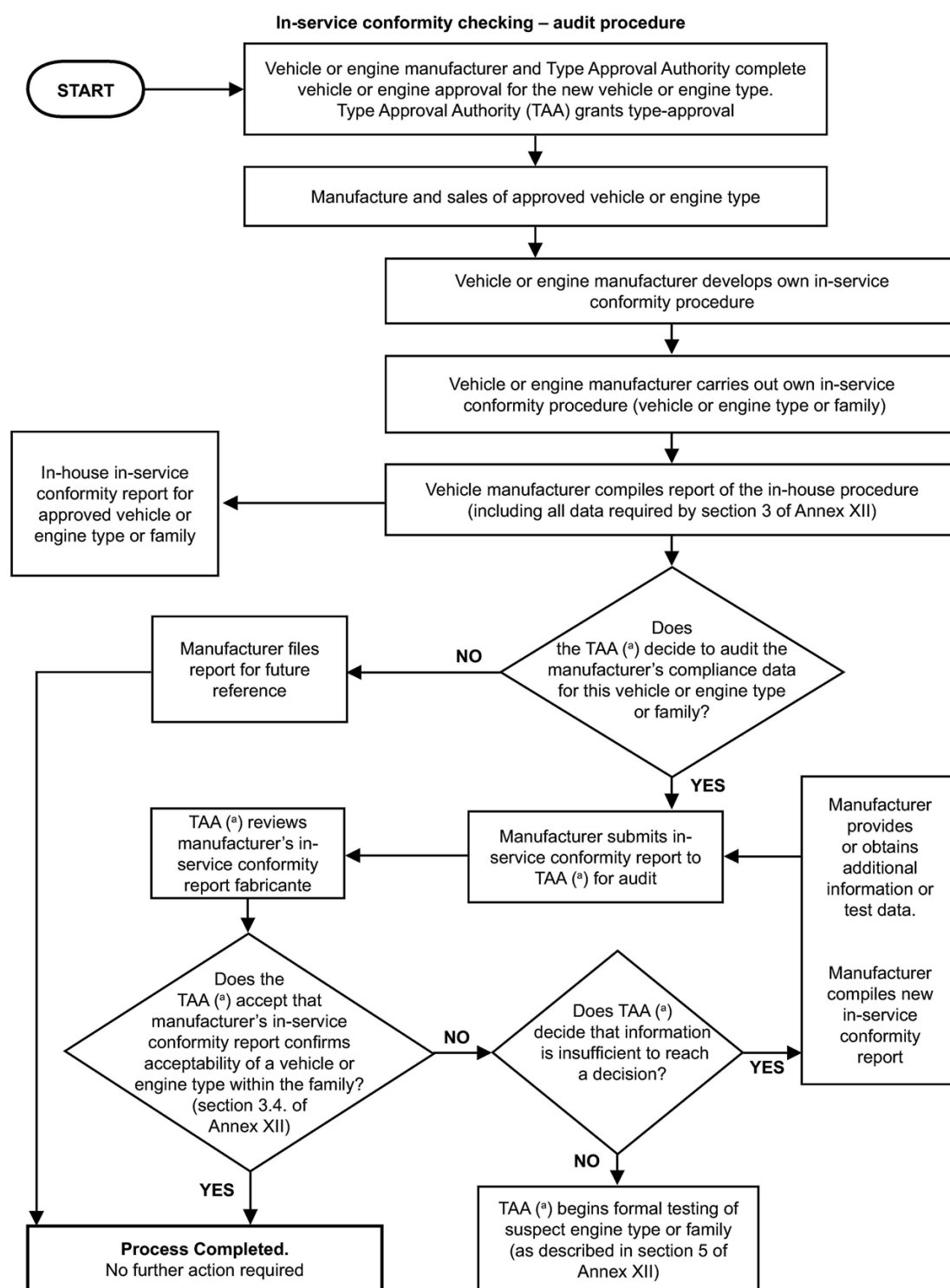
3. AUDIT PROCEDURES
- 3.1. An audit of in-service conformity will be conducted by the type-approval authority on the basis of information supplied by the manufacturer. The manufacturers' in-service monitoring (ISM) report should be based on in-use testing of engines or vehicles using proven and relevant testing protocols. Such information (the ISM report) must include, but is not limited to, the following (see sections 3.1.1 to 3.1.13):
- 3.1.1. The name and address of the manufacturer.

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- 3.1.2. The name, address, telephone and fax numbers and e-mail address of his authorised representative within the areas covered by the manufacturer's information.
- 3.1.3. The model name(s) of the engines included in the manufacturer's information.
- 3.1.4. Where appropriate, the list of engine types covered within the manufacturer's information, i.e. the engine-after-treatment system family.
- 3.1.5. The vehicle identification number (VIN) codes applicable to the vehicles equipped with an engine that is part of the audit.



(a) In this case, TAA means the Type-Approval Authority that granted the type-approval.

3.1.6. The numbers of the type approvals applicable to the engine types within the in-service family, including, where applicable, the numbers of all extensions and field fixes/recalls (re-works):

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- 3.1.7. Details of extensions, field fixes/recalls to those type approvals for the engines covered within the manufacturer's information (if requested by the type-approval authority).
- 3.1.8. The period of time over which the manufacturer's information was collected.
- 3.1.9. The engine build period covered within the manufacturer's information (e.g. 'vehicles or engines manufactured during the 2005 calendar year').
- 3.1.10. The manufacturer's in-service conformity checking procedure, including:
  - 3.1.10.1. Vehicle or engine location method
  - 3.1.10.2. Selection and rejection criteria for vehicle or engine
  - 3.1.10.3. Test types and procedures used for the programme
  - 3.1.10.4. The manufacturer's acceptance/rejection criteria for the in-service family group
  - 3.1.10.5. Geographical area(s) within which the manufacturer has collected information
  - 3.1.10.6. Sample size and sampling plan used.
- 3.1.11. The results from the manufacturer's in-service conformity procedure, including:
  - 3.1.11.1. Identification of the engines included in the programme (whether tested or not). The identification will include:
    - model name
    - vehicle identification number (VIN)
    - engine identification number
    - vehicle registration number equipped with an engine that is part of the audit
    - date of manufacture
    - region of use (where known)
    - type of use of the vehicle (where known), i.e. urban delivery, long haul etc.
  - 3.1.11.2. The reason(s) for rejecting a vehicle or engine from a sample (e.g., vehicle being in-use for less than one year, improper emission-related maintenance, evidence of using a fuel having a higher sulphur content than required for normal vehicle use, emission control equipment not in conformity with type-approval). The reason for rejection shall be substantiated (e.g., the nature of non-fulfilment of maintenance instructions, etc.). A vehicle should not be excluded solely on the ground that the AECS may have been excessively in operation.
  - 3.1.11.3. Emission-related servicing and maintenance history for each engine in the sample (including any re-works).
  - 3.1.11.4. Repair history for each engine in the sample (where known).
  - 3.1.11.5. Test data, including:
    - (a) date of test
    - (b) location of test
    - (c) where applicable, distance indicated odometer of vehicle equipped with an engine that is covered by the audit
    - (d) test fuel specifications (e.g. test reference fuel or market fuel)

- (e) test conditions (temperature, humidity, dynamometer inertia weight)
  - (f) dynamometer settings (e.g. power setting)
  - (g) emission test results conducted on the ESC, ETC and ELR tests according to section 4 of this Annex. A minimum of five engines shall be tested
  - (h) alternative to item (g) above, tests may be conducted using another protocol. The relevance for monitoring in-service functionality with such a test shall be stated and substantiated by manufacturer in conjunction with the type-approval process (sections 3 and 4 in Annex I to Directive 2005/55/EC).
- 3.1.12. Records of indication from the OBD system.
- 3.1.13. Record of experiences of the use of consumable reagent. Reports should detail, but not be limited to, operator experiences with the handling of filling, refilling and consumption of the reagent, and the conduct of the filling installations, and, specifically, the frequency of activation in-use of the temporary performance limiter and events of other defect instances, activation of the MI and the registering of a fault code relating to a lack of the consumable reagent.
- 3.1.13.1. The manufacturer shall supply in-use and defect reports. The manufacturer shall report on warranty claims and their nature, and in-field indications of activation/deactivation of the MI and the registering of a fault code relating to a lack of the consumable reagent and the activation/deactivation of the engine performance limiter (see section 6.5.5 of Annex I to Directive 2005/55/EC).
- 3.2. The information gathered by the manufacturer must be sufficiently comprehensive to ensure that in-service performance can be assessed for normal conditions over the appropriate durability/useful life period defined in Article 3 of this Directive and in a way representative of the manufacturer's geographic penetration.
- 3.3. The manufacturer may wish to run in-service monitoring comprising fewer engines/vehicles than the number given in section 3.1.11.5, item (g), and using a procedure defined under section 3.1.11.5, item (h). The reason could be that the engines in the engine family(-ies) covered by the report are in a small number. The conditions should have been agreed on beforehand by the type-approval authority.
- 3.4. On the basis of the monitoring report referred to in this section, the type-approval authority must either:
- decide that the in-service conformity of an engine type or an engine family is satisfactory and not to take any further action
  - decide that the data provided by the manufacturer is insufficient to reach a decision and request additional information and/or test data from the manufacturer. Where requested, and depending on the type-approval of the engine, such additional test data shall include ESC, ELR, and ETC test results, or from other proven procedures according to section 3.1.11.5, item (h)
  - decide that the in-service conformity of an engine family is unsatisfactory and proceed to have confirmatory testing carried out on a sample of engines from the engine family, according to section 5 of this Annex.
- 3.5. A Member State may conduct and report its' surveillance testing, based on the audit procedure spelled out in this section. Information on the procurement, maintenance, and manufacturer's participation in the activities may be recorded. Likewise, the Member State may use alternative emission test protocols, according to section 3.1.11.5, item (h).

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- 3.6. The type-approval authority may take up surveillance testing conducted and reported by a Member State as a basis for the decisions according to section 3.4.
- 3.7. The manufacturer should report to the type-approval authority and the Member State(s) where the subject engines/vehicles are kept in service when planning to conduct a voluntary remedial action. The reporting shall be supplied by the manufacturer in conjunction with taking the decision to take action, specifying the particulars of the action, describe the groups of engines/vehicles to be included in the action, and regularly thereafter on the commencement of the campaign. The applicable particulars of section 7 to this Annex may be used.

#### 4. EMISSION TESTS

- 4.1. An engine selected from the engine family shall be tested over the ESC and ETC test cycles for gaseous and particulate emissions and over the ELR test cycle for smoke emission. The engine shall be representative of the type of use expected for this type of engine, and come from a vehicle in normal use. The procurement, inspection, and restorative maintenance of the engine/vehicle shall be conducted using a protocol such as is specified in section 3, and shall be documented.

The appropriate maintenance schedule, referred to in section 4 of Annex II, shall have been carried out on the engine.

- 4.2. The emission values determined from the ESC, ETC and ELR tests shall be expressed to the same number of decimal places as the limit value for that pollutant, as shown in the tables in section 6.2.1 of Annex I to Directive 2005/55/EC, plus one additional decimal place.

#### 5. CONFIRMATORY TESTING

- 5.1. Confirmatory testing is done for the purpose of confirmation of the in-service emission functionality of an engine family.
  - 5.1.1. If the type-approval authority is not satisfied with the manufacturers' ISM according to section 3.4 or on a reported evidence of unsatisfactory in-service conformity, e.g., according to section 3.5, may order the manufacturer to run test for confirmatory purposes. The type-approval authority will examine the confirmatory test report supplied by the manufacturer.
  - 5.1.2. The type-approval authority may conduct confirmatory testing.
- 5.2. The confirmatory test should be applicable engine ESC, ETC and ELR tests, as specified in Section 4. Representative engines to be tested should be dismantled from vehicles used under normal conditions and be tested. Alternatively, after prior agreement with the type-approval authority, the manufacturer may test emission control components from vehicles in use, after being dismantled, transferred and mounted on properly used and representative engine(s). For each series of tests, the same package of emission control components shall be selected. The reason for the selection shall be stated.
- 5.3. A test result may be regarded as non-satisfactory when, from tests of two or more engines representing the same engine family, for any regulated pollutant component, the limit value as shown in section 6.2.1 of Annex I to Directive 2005/55/EC is exceeded significantly.

#### 6. ACTIONS TO BE TAKEN



- 6.1. Where the type-approval authority is not satisfied with the information or test data supplied by the manufacturer, and, having carried out confirmatory engine testing according to section 5, or based on confirmatory testing conducted by a Member State (section 6.3), and it is certain that an engine type is not in conformity with the requirements of these provisions, the type-approval authority must request the manufacturer to submit a plan of remedial measure to remedy the non-conformity.
- 6.2. In this case, the remedial measures referred to in Article 11(2) and in Annex X to Directive 70/156/EEC [or the refont of the framework Directive] are extended to engines in service belonging to the same vehicle type which are likely to be affected with the same defects, in accordance with section 8.

To be valid the plan of remedial measures presented by the manufacturer must be approved by the type-approval authority. The manufacturer is responsible for the execution of the remedial plan as approved.

The type-approval authority must notify its decision to all Member States within 30 days. The Member States may require that the same plan of remedial measures be applied to all engines of the same type registered in their territory.

- 6.3. If a Member State has established that an engine type does not conform to the applicable requirements of this Annex, it must notify without delay the Member State which granted the original type-approval in accordance with the requirements of Article 11(3) of Directive 70/156/EEC.

Then, subject to the provision of Article 11(6) of Directive 70/156/EEC, the competent authority of the Member State which granted the original type-approval shall inform the manufacturer that an engine type fails to satisfy the requirements of these provisions and that certain measures are expected of the manufacturer. The manufacturer shall submit to the authority, within two months after this notification, a plan of measures to overcome the defects, the substance of which should correspond with the requirements of section 7. The competent authority which granted the original type-approval shall, within two months, consult the manufacturer in order to secure agreement on a plan of measures and on carrying out the plan. If the competent authority which granted the original type-approval establishes that no agreement can be reached, the procedure pursuant to Article 11(3) and (4) of Directive 70/156/EEC shall be initiated.

## 7. PLAN OF REMEDIAL MEASURES

- 7.1. The plan of remedial measures, requested according to section 6.1, must be filed with the type-approval authority not later than 60 working days from the date of the notification referred to in section 6.1. The type-approval authority must within 30 working days declare its approval or disapproval of the plan of remedial measures. However, where the manufacturer can demonstrate to the satisfaction of the competent type-approval authority, that further time is required to investigate the non-compliance in order to submit a plan of remedial measures, an extension is granted.
- 7.2. The remedial measures must apply to all engines likely to be affected by the same defect. The need to amend the type-approval documents must be assessed.
- 7.3. The manufacturer must provide a copy of all communications related to the plan of remedial measures, must also maintain a record of the recall campaign, and supply regular status reports to the type-approval authority.

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- 7.4. The plan of remedial measures must include the requirements specified in 7.4.1 to 7.4.11. The manufacturer must assign a unique identifying name or number to the plan of remedial measures.
  - 7.4.1. A description of each engine type included in the plan of remedial measures.
  - 7.4.2. A description of the specific modifications, alterations, repairs, corrections, adjustments, or other changes to be made to bring the engines into conformity including a brief summary of the data and technical studies which support the manufacturer's decision as to the particular measures to be taken to correct the non-conformity.
  - 7.4.3. A description of the method by which the manufacturer informs the engine or vehicle owners about the remedial measures.
  - 7.4.4. A description of the proper maintenance or use, if any, which the manufacturer stipulates as a conditions of eligibility for repair under the plan of remedial measures, and an explanation of the manufacturer's reasons for imposing any such condition. No maintenance or use conditions may be imposed unless it is demonstrably related to the non-conformity and the remedial measures.
  - 7.4.5. A description of the procedure to be followed by engine owners to obtain correction of the non-conformity. This must include a date after which the remedial measures may be taken, the estimated time for the workshop to perform the repairs and where they can be done. The repair must be done expediently, within a reasonable time after delivery of the vehicle.
  - 7.4.6. A copy of the information transmitted to the vehicle owner.
  - 7.4.7. A brief description of the system which the manufacturer uses to assure an adequate supply of component or systems for fulfilling the remedial action. It must be indicated when there will be an adequate supply of components or systems to initiate the campaign.
  - 7.4.8. A copy of all instructions to be sent to those persons who are to perform the repair.
  - 7.4.9. A description of the impact of the proposed remedial measures on the emissions, fuel consumption, driveability, and safety of each engine type, covered by the plan of remedial measures with data, technical studies, etc. which support these conclusions.
  - 7.4.10. Any other information, reports or data the type-approval authority may reasonably determine is necessary to evaluate the plan of remedial measures.
  - 7.4.11. Where the plan of remedial measures includes a recall, a description of the method for recording the repair must be submitted to the type-approval authority. If a label is used, an example of it must be submitted.
- 7.5. The manufacturer may be required to conduct reasonably designed and necessary tests on components and engines incorporating a proposed change, repair, or modification to demonstrate the effectiveness of the change, repair, or modification.
- 7.6. The manufacturer is responsible for keeping a record of every engine or vehicle recalled and repaired and the workshop which performed the repair. The type-approval authority must have access to the record on request for a period of 5 years from the implementation of the plan of remedial measures.

- 7.7. The repair and/or modification or addition of new equipment shall be recorded in a certificate supplied by the manufacturer to the owner of the engine.

## ANNEX IV

### ON-BOARD DIAGNOSTIC SYSTEMS (OBD)

#### 1. INTRODUCTION

This Annex describes the provisions specific to the on-board diagnostic (OBD) system for the emission control systems of motor vehicles.

#### 2. DEFINITIONS

For the purposes of this Annex, the following definitions, in addition to the definitions contained in section 2 of Annex I to Directive 2005/55/EC, apply:

‘arm-up cycle’ means sufficient engine operation such that the coolant temperature has risen by at least 22 K from engine starting and reaches a minimum temperature of 343 K (70 °C);

‘access’ means the availability of all emission-related OBD data including all fault codes required for the inspection, diagnosis, servicing or repair of emissions related parts of the vehicle, via the serial interface of the standard diagnostic connector;

‘deficiency’ means, in respect of engine OBD systems, that up to two separate components or systems that are monitored contain temporary or permanent operating characteristics that impair the otherwise efficient OBD monitoring of those components or systems or do not meet all the other detailed requirements for OBD. Engines or vehicles in respect of their engine may be type-approved, registered and sold with such deficiencies according to the requirements of section 4.3 of this Annex;

‘deteriorated component/system’ means an engine or exhaust aftertreatment component/system that has been intentionally deteriorated in a controlled manner by the manufacturer for the purpose of conducting a type-approval test on the OBD system;

‘OBD test cycle’ means a driving cycle which is a version of the ESC test cycle having the same running-order of the 13 individual modes as described in section 2.7.1 of Appendix 1 to Annex III to Directive 2005/55/EC but where the length of each mode is reduced to 60 seconds;

‘operating sequence’ means the sequence used for determining the conditions for extinguishing the MI. It consists of an engine start-up, an operating period, an engine shut-off, and the time until the next start-up, where the OBD monitoring is running and a malfunction would be detected if present;

‘preconditioning cycle’ means the running of at least three consecutive OBD test cycles or emission test cycles for the purpose of achieving stability of the engine operation, the emission control system and OBD monitoring readiness;

‘repair information’ means all information required for diagnosis, servicing, inspection, periodic monitoring or repair of the engine and which the manufacturers provide for their authorised dealers/repair shops. Where necessary, such information shall include service handbooks, technical manuals, diagnosis information (e.g. minimum and maximum theoretical values for measurements), wiring diagrams, the software calibration identification number applicable to an engine type, information enabling the update of the software of the electronic systems in

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accordance with the specifications of the vehicle manufacturer, instructions for individual and special cases, information provided concerning tools and equipment, data record information and two-directional monitoring and test data. The manufacturer shall not be obliged to make available that information which is covered by intellectual property rights or constitutes specific know-how of manufacturers and/or OEM suppliers; in this case the necessary technical information shall not be improperly withheld;

‘standardised’ means that all emission related OBD data (i.e. stream information in the case a scanning tool is used), including all fault codes used, shall be produced only in accordance with industry standards which, by virtue of the fact that their format and the permitted options are clearly defined, provide for a maximum level of harmonisation in the motor vehicle industry, and whose use is expressly permitted in this Directive;

‘unrestricted’ means:

- access not dependent on an access code obtainable only from the manufacturer, or a similar device,
- or
- access allowing evaluation of the data produced without the need for any unique decoding information, unless that information itself is standardised.

### 3. REQUIREMENTS AND TESTS

#### 3.1. General requirements

3.1.1. OBD systems must be designed, constructed and installed in a vehicle so as to enable it to identify types of malfunction over the entire life of the engine. In achieving this objective the approval authority must accept that engines which have been used in excess of the appropriate durability period defined in Article 3 of this Directive may show some deterioration in OBD system performance such that the OBD thresholds given in the table in Article 4(3) of this Directive may be exceeded before the OBD system signals a failure to the driver of the vehicle.

3.1.2. A sequence of diagnostic checks must be initiated at each engine start and completed at least once provided that the correct test conditions are met. The test conditions must be selected in such a way that they all occur under the driving conditions as represented by the test defined in section 2 of Appendix 1 to this Annex.

3.1.2.1. Manufacturers are not required to activate a component/system exclusively for the purpose of OBD functional monitoring under vehicle operating conditions when it would not normally be active (e.g. activation of a reagent tank heater of a deNO<sub>x</sub> system or combined deNO<sub>x</sub>-particulate filter when such a system would not normally be active).

3.1.3. OBD may involve devices, which measure, senses or responds to operating variables (e.g. vehicle speed, engine speed, gear used, temperature, intake pressure or any other parameter) for the purpose of detecting malfunctions and of minimising the risk of indicating false malfunction. These devices are not defeat devices.

3.1.4. Access to the OBD system required for the inspection, diagnosis, servicing or repair of the engine must be unrestricted and standardised. All emission related fault codes must be consistent with those described in section 6.8.5 of this Annex.

#### 3.2. OBD Stage 1 requirements

- 3.2.1. From the dates given in Article 4(1) of this Directive, the OBD system of all diesel engines and of vehicles equipped with a diesel engine must indicate the failure of an emission-related component or system when that failure results in an increase in emissions above the appropriate OBD thresholds given in the table in Article 4(3) of this Directive.
- 3.2.2. In satisfying the Stage 1 requirements, the OBD system must monitor for:
- 3.2.2.1. complete removal of a catalyst, where fitted in a separate housing, that may or may not be part of a deNO<sub>x</sub> system or particulate filter.
- 3.2.2.2. reduction in the efficiency of the deNO<sub>x</sub> system, where fitted, with respect to the emissions of NO<sub>x</sub> only.
- 3.2.2.3. reduction in the efficiency of the particulate filter, where fitted, with respect to the emissions of particulate only.
- 3.2.2.4. reduction in the efficiency of a combined deNO<sub>x</sub>-particulate filter system, where fitted, with respect to both the emissions of NO<sub>x</sub> and particulate.
- 3.2.3. Major functional failure
- 3.2.3.1. As an alternative to monitoring against the appropriate OBD threshold limits with respect to sections 3.2.2.1 to 3.2.2.4, OBD systems of diesel engines may in accordance with Article 4(1) of this Directive monitor for major functional failure of the following components:
- a catalyst, where fitted as a separate unit, that may or may not be part of a deNO<sub>x</sub> system or particulate filter
  - a deNO<sub>x</sub> system, where fitted
  - a particulate filter, where fitted
  - a combined deNO<sub>x</sub>-particulate filter system.
- 3.2.3.2. In the case of an engine equipped with a deNO<sub>x</sub> system, examples of monitoring for major functional failure are for complete removal of the system or replacement of the system by a bogus system (both intentional major functional failure), lack of required reagent for a deNO<sub>x</sub> system, failure of any SCR electrical component, any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a deNO<sub>x</sub> system including, when applicable, the reagent heating system, failure of the reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure).
- 3.2.3.3. In the case of an engine equipped with a particulate filter, examples of monitoring for major functional failure are for major melting of the trap substrate or a clogged trap resulting in a differential pressure out of the range declared by the manufacturer, any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a particulate filter, any failure, when applicable, of a reagent dosing system (e.g. clogged nozzle, dosing pump failure).
- 3.2.4. Manufacturers may demonstrate to the approval authority that certain components or systems need not be monitored if, in the event of their total failure or removal, emissions do not exceed the applicable thresholds limits for OBD Stage 1 given in the table in Article 4(3) of this Directive when measured over the cycles shown in section 1.1 of Appendix 1 to this Annex. This provision shall not apply to an exhaust gas recirculation (EGR) device, a deNO<sub>x</sub> system, a particulate filter or a combined

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deNO<sub>x</sub>-particulate filter system nor shall it apply to a component or system that is monitored for major functional failure.

### 3.3. OBD Stage 2 requirements

- 3.3.1. From the dates given in Article 4(2) of this Directive the OBD system of all diesel or gas engines and of vehicles equipped with a diesel or a gas engine must indicate the failure of an emission-related component or system of the engine system when that failure results in an increase in emissions above the appropriate OBD thresholds given in the table in Article 4(3) of this Directive.

The OBD system must consider the communication interface (hardware and messages) between the engine system electronic control unit(s) (EECU) and any other power train or vehicle control unit when the exchanged information has an influence on the correct functioning of the emission control. The OBD system must diagnose the integrity of the connection between the EECU and the medium that provides the link with these other vehicle components (e.g. the communication bus).

- 3.3.2. In satisfying the Stage 2 requirements, the OBD system must monitor for:

- 3.3.2.1 reduction in the efficiency of the catalyst, where fitted in a separate housing, that may or may not be part of a deNO<sub>x</sub> system or particulate filter.
- 3.3.2.2 reduction in the efficiency of the deNO<sub>x</sub> system, where fitted, with respect to the emissions of NO<sub>x</sub> only.
- 3.3.2.3 reduction in the efficiency of the particulate filter, where fitted, with respect to the emissions of particulate only.
- 3.3.2.4 reduction in the efficiency of a combined deNO<sub>x</sub>-particulate filter system, where fitted, with respect to both the emissions of NO<sub>x</sub> and particulate.
- 3.3.2.5 the interface between the engine electronic control unit (EECU) and any other powertrain or vehicle electrical or electronic system (e.g. the transmission control unit (TECU)) for electrical disconnection.
- 3.3.3 Manufacturers may demonstrate to the approval authority that certain components or systems need not be monitored if, in the event of their total failure or removal, emissions do not exceed the applicable thresholds limits for OBD Stage 2 given in the table in Article 4(3) of this Directive when measured over the cycles shown in section 1.1 of Appendix 1 to this Annex. This provision shall not apply to an exhaust gas recirculation (EGR) device, a deNO<sub>x</sub> system, a particulate filter or a combined deNO<sub>x</sub>-particulate filter system.

### 3.4. Stage 1 and Stage 2 requirements

- 3.4.1. In satisfying both the Stage 1 or Stage 2 requirements the OBD system must monitor:
- 3.4.1.1. the fuel-injection system electronic, fuel quantity and timing actuator(s) for circuit continuity (i.e. open circuit or short circuit) and total functional failure.
- 3.4.1.2. all other engine or exhaust aftertreatment emission-related components or systems, which are connected to a computer, the failure of which would result in tailpipe emissions exceeding the OBD threshold limits given in the table in Article 4(3) of this Directive. At a minimum, examples include the exhaust gas recirculation (EGR) system, systems or components for monitoring and control of air mass-flow, air volumetric flow (and temperature), boost pressure and inlet manifold pressure (and

relevant sensors to enable these functions to be carried out), sensors and actuators of a deNO<sub>x</sub> system, sensors and actuators of an electronically activated active particulate filter.

3.4.1.3. any other emission-related engine or exhaust aftertreatment component or system connected to an electronic control unit must be monitored for electrical disconnection unless otherwise monitored.

3.4.1.4. In the case of engines equipped with an aftertreatment system using a consumable reagent, the OBD system must monitor for:

- lack of any required reagent
- the quality of the required reagent being within the specifications declared by the manufacturer in Annex II to Directive 2005/55/EC
- reagent consumption and dosing activity

according to section 6.5.4 of Annex I to Directive 2005/55/EC.

3.5. OBD operation and temporary disablement of certain OBD monitoring capabilities

3.5.1. The OBD system must be so designed, constructed and installed in a vehicle as to enable it to comply with the requirements of this Annex during the conditions of use defined in section 6.1.5.4 of Annex I to Directive 2005/55/EC.

Outside these normal operating conditions the emission control system may show some degradation in OBD system performance such that the thresholds given in the table in Article 4(3) of this Directive may be exceeded before the OBD system signals a failure to the driver of the vehicle.

The OBD system must not be disabled unless one or more of the following conditions for disablement are met:

3.5.1.1. The affected OBD monitoring systems may be disabled if its ability to monitor is affected by low fuel levels. For this reason, disablement is permitted when the fuel tank level falls below 20 % of the nominal capacity of the fuel tank.

3.5.1.2. The affected OBD monitoring systems may be temporarily disabled during the operation of an auxiliary emission control strategy as described in section 6.1.5.1 of Annex I to Directive 2005/55/EC.

3.5.1.3. The affected OBD monitoring systems may be temporarily disabled when operational safety or limp-home strategies are activated.

3.5.1.4. For vehicles designed to accommodate the installation of power take-off units, disablement of affected OBD monitoring systems is permitted provided disablement takes place only when the power take-off unit is active and the vehicle is not being driven.

3.5.1.5. The affected OBD monitoring systems may be disabled temporarily during the periodic regeneration of an emission control system downstream of the engine (i.e. a particulate filter, deNO<sub>x</sub> system or combined deNO<sub>x</sub>-particulate filter).

3.5.1.6. The affected OBD monitoring systems may be disabled temporarily outside the conditions of use defined in section 6.1.5.4 of Annex I to Directive 2005/55/EC when this disablement can be justified by a limitation of the OBD monitoring (including modelling) capability.

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- 3.5.2. The OBD monitoring system is not required to evaluate components during malfunction if such evaluation would result in a risk to safety or component failure.
- 3.6. Activation of malfunction indicator (MI)
- 3.6.1. The OBD system must incorporate a malfunction indicator readily visible to the vehicle operator. Except in the case of section 3.6.2 of this Annex, the MI (e.g. symbol or lamp) must not be used for any purpose other than emission related malfunction except to indicate emergency start-up or limp-home routines to the driver. Safety related messages can be given the highest priority. The MI must be visible in all reasonable lighting conditions. When activated, it must display a symbol in conformity with ISO 2575<sup>(17)</sup> (as a dashboard telltale lamp or a symbol on a dashboard display). A vehicle must not be equipped with more than one general purpose MI for emission-related problems. Displaying separate specific information is permitted (e.g. such as information dealing with brake system, fasten seat belt, oil pressure, servicing requirements, or indicating the lack of necessary reagent for the deNO<sub>x</sub> system). The use of red for the MI is prohibited.
- 3.6.2. The MI may be used to indicate to the driver that an urgent service task needs to be carried out. Such an indication may also be accompanied by an appropriate message on a dashboard display that an urgent servicing requirement needs to be carried out.
- 3.6.3. For strategies requiring more than a preconditioning cycle for MI activation, the manufacturer must provide data and/or an engineering evaluation which adequately demonstrates that the monitoring system is equally effective and timely in detecting component deterioration. Strategies requiring on average more than ten OBD or emission test cycles for MI activation are not accepted.
- 3.6.4. The MI must also activate whenever the engine control enters [<sup>F1</sup>an][<sup>F1</sup>emission default mode] of operation. The MI must also activate if the OBD system is unable to fulfil the basic monitoring requirements specified in this Directive.

**Textual Amendments**

**F1** Substituted by [Commission Directive 2006/51/EC of 6 June 2006 amending for the purposes of adapting to technical progress Annex I to Directive 2005/55/EC of the European Parliament and of the Council and Annexes IV and V to Directive 2005/78/EC as regards requirements for the emission control monitoring system for use in vehicles and exemptions for gas engines \(Text with EEA relevance\).](#)

- 3.6.5. Where reference is made to this section, the MI must be activated and, in addition, a distinct warning mode should also be activated, e.g. flashing MI or activation of a symbol in conformity with ISO 2575<sup>(18)</sup> in addition to MI activation.
- 3.6.6. The MI must activate when the vehicle's ignition is in the 'key-on' position before engine starting or cranking and de-activate within 10 seconds after engine starting if no malfunction has previously been detected.
- 3.7. Fault code storage

The OBD system must record fault code(s) indicating the status of the emission-control system. A fault code must be stored for any detected and verified malfunction causing MI activation and must identify the malfunctioning system or component as uniquely as possible. A separate



code should be stored indicating the expected MI activation status (e.g. MI commanded ‘ON’, MI commanded ‘OFF’).

Separate status codes must be used to identify correctly functioning emission control systems and those emission control systems that need further engine operation to be fully evaluated. If the MI is activated due to malfunction or [<sup>F1</sup>emission default mode] of operation, a fault code must be stored that identifies the likely area of malfunction. A fault code must also be stored in the cases referred to in sections 3.4.1.1 and 3.4.1.3 of this Annex.

3.7.1. If monitoring has been disabled for 10 driving cycles due to the continued operation of the vehicle under conditions conforming to those specified in section 3.5.1.2 of this Annex, readiness for the subject monitoring system may be set to ‘ready’ status without monitoring having been completed.

3.7.2. The hours run by the engine while the MI is activated must be available upon request at any instant through the serial port on the standard link connector, according to the specifications given in section 6.8 of this Annex.

3.8. Extinguishing the MI

3.8.1. The MI may be de-activated after three subsequent sequential operating sequences or 24 engine running hours during which the monitoring system responsible for activating the MI ceases to detect the malfunction and if no other malfunction has been identified that would independently activate the MI.

3.8.2. In the case of MI activation due to lack of reagent for the deNO<sub>x</sub> system, or combined deNO<sub>x</sub>-particulate after-treatment device or use of a reagent outside the specifications declared by the manufacturer, the MI may be switched back to the previous state of activation after filling or replacement of the storage medium with a reagent having the correct specifications.

[<sup>F1</sup>3.8.3. In the case of MI activation due to incorrect operation of the engine system with respect to NO<sub>x</sub> control measures, or incorrect reagent consumption and dosing activity, the MI may be switched back to the previous state of activation if the conditions given in section 6.5.3., 6.5.4 and 6.5.7. of Annex I to Directive 2005/55/EC no longer apply.]

3.9. Erasing a fault code

3.9.1. The OBD system may erase a fault code and the hours run by the engine and freeze-frame information if the same fault is not re-registered in at least 40 engine warm-up cycles or 100 engine running hours, whichever occurs first, with the exception of the cases referred to in section 3.9.2.

[<sup>F1</sup>3.9.2. From 9 November 2006 for new type approvals and from 1 October 2007 for all registrations, in the case of a non-erasable fault code being generated according to sections 6.5.3 or 6.5.4 of Annex I to Directive 2005/55/EC, the OBD system shall retain a record of the fault code and the hours run by the engine during the MI activation for at least 400 days or 9 600 hours of engine operation.

Any such fault code and the corresponding hours run by the engine during MI activation shall not be erased through use of any external diagnostic or other tool as referred to in section 6.8.3 of this Annex.]

4. REQUIREMENTS RELATING TO THE TYPE-APPROVAL OF OBD SYSTEMS

4.1. For the purpose of type-approval, the OBD system shall be tested according to the procedures given in Appendix 1 to this Annex.

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An engine representative of its engine family (see section 8 of Annex I to Directive 2005/55/EC) shall be used for the OBD demonstration tests or the test report of the parent OBD system of the OBD engine family will be provided to the type-approval authority as an alternative to carrying out the OBD demonstration test.

- 4.1.1. In the case of OBD stage 1 referred to in section 3.2, the OBD system must:
- 4.1.1.1. indicate the failure of an emission-related component or system when that failure results in an increase in emissions above the OBD thresholds given in the table in Article 4(3) of this Directive, or;
- 4.1.1.2. where appropriate, indicate any major functional failure of an exhaust aftertreatment system.
- 4.1.2. In the case of OBD stage 2 referred to in section 3.3, the OBD system must indicate the failure of an emission-related component or system when that failure results in an increase in emissions above the OBD thresholds given in the table in Article 4(3) of this Directive.
- 4.1.3. In the case of both OBD 1 and OBD 2, the OBD system must indicate the lack of any required reagent necessary for the operation of an exhaust aftertreatment system.
- 4.2. Installation requirements
- 4.2.1. The installation on the vehicle of an engine equipped with an OBD system shall comply with the following provisions of this Annex with respect to the vehicle equipment:
- the provisions of sections 3.6.1, 3.6.2 and 3.6.5 concerning the MI and, where appropriate, additional warning modes;
  - when applicable, the provisions of section 6.8.3.1 concerning the use of an on-board diagnostic facility;
  - the provisions of section 6.8.6 concerning the connection interface.
- 4.3. Type-approval of an OBD system containing deficiencies
- 4.3.1. A manufacturer may request to the authority that an OBD system be accepted for type-approval even though the system contains one or more deficiencies such that the specific requirements of this Annex are not fully met.
- 4.3.2. In considering the request, the authority shall determine whether compliance with the requirements of this Annex is feasible or unreasonable.

The authority shall take into consideration data from the manufacturer that details such factors as, but not limited to, technical feasibility, lead time and production cycles including phase-in or phase-out of engines designs and programmed upgrades of computers, the extent to which the resultant OBD system will be effective in complying with the requirements of this directive and that the manufacturer has demonstrated an acceptable level of effort toward the requirements of the Directive.

- 4.3.3. The authority will not accept any deficiency request that includes the complete lack of a required diagnostic monitor.
- 4.3.4. The authority shall not accept any deficiency request that does not respect the OBD threshold limits given in the table in Article 4(3) of this Directive.
- 4.3.5. In determining the identified order of deficiencies, deficiencies relating to OBD Stage 1 in respect of sections 3.2.2.1, 3.2.2.2, 3.2.2.3, 3.2.2.4 and 3.4.1.1 and OBD Stage 2

in respect of sections 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.2.4 and 3.4.1.1 of this Annex shall be identified first.

4.3.6. Prior to or at the time of type-approval, no deficiency shall be granted in respect of the requirements of section 3.2.3 and section 6, except sub-section 6.8.5 of this Annex.

4.3.7. Deficiency period

4.3.7.1. A deficiency may be carried-over for a period of two years after the date of type-approval of the engine type or vehicle in respect of its engine type, unless it can be adequately demonstrated that substantial engine modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-out for a period not exceeding three years.

4.3.7.2. A manufacturer may request that the original type-approval authority grant a deficiency retrospectively when such a deficiency is discovered after the original type-approval. In this case, the deficiency may be carried-over for a period of two years after the date of notification to the type-approval authority unless it can be adequately demonstrated that substantial engine modifications and additional lead-time beyond two years would be necessary to correct the deficiency. In such a case, the deficiency may be carried-out for a period not exceeding three years.

4.3.7.3. The authority shall notify its decision in granting a deficiency request to all authorities in other Member States according to the requirements of Article 4 to Directive 70/156/EEC.

5. ACCESS TO OBD INFORMATION

5.1. Replacement parts, diagnostic tools and test equipment

5.1.1. Applications for type-approval or amendment of a type-approval according to either Article 3 or Article 5 of Directive 70/156/EEC shall be accompanied by the relevant information concerning the OBD system. This relevant information shall enable manufacturers of replacement or retrofit components to make the parts they manufacture compatible with the OBD system with a view to fault-free operation assuring the vehicle user against malfunctions. Similarly, such relevant information shall enable the manufacturers of diagnostic tools and test equipment to make tools and equipment that provide for effective and accurate diagnosis of emission control systems.

5.1.2. Upon request, the type-approval authorities shall make Appendix 2 to the EC type approval certificate containing the relevant information on the OBD system available to any interested components, diagnostic tools or test equipment manufacturer on a non-discriminatory basis.

5.1.2.1. In the case of replacement or service components, information can only be requested for such components that are subject to EC type-approval, or for components that form part of a system that is subject to EC type-approval.

5.1.2.2. The request for information must identify the exact specification of the engine model type/engine model type within an engine family for which the information is required. It must confirm that the information is required for the development of replacement or retrofit parts or components or diagnostic tools or test equipment.

5.2. Repair information

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- 5.2.1. No later than three months after the manufacturer has provided any authorised dealer or repair shop within the Community with repair information, the manufacturer shall make that information (including all subsequent amendments and supplements) available upon reasonable and non-discriminatory payment.
- 5.2.2. The manufacturer must also make accessible, where appropriate upon payment the technical information required for the repair or maintenance of motor vehicles unless that information is covered by an intellectual property right or constitutes essential, secret know-how which is identified in an appropriate form; in such case, the necessary technical information must not be withheld improperly.

Entitled to such information is any person engaged in commercially servicing or repairing, road-side rescuing, inspecting or testing of vehicles or in manufacturing or selling replacement or retro-fit components, diagnostic tools and test equipment.

- 5.2.3. In the event of failure to comply with these provisions the approval authority shall take appropriate measures to ensure that repair information is available, in accordance with the procedures laid down for type-approval and in-service surveys.

## 6. DIAGNOSTIC SIGNALS

- 6.1. Upon determination of the first malfunction of any component or system, 'freeze-frame' engine conditions present at the time must be stored in computer memory. Stored engine conditions must include, but are not limited to calculated load value, engine speed, coolant temperature, intake manifold pressure (if available), and the fault code which caused the data to be stored. For freeze-frame storage, the manufacturer must choose the most appropriate set of conditions facilitating effective repairs.
- 6.2. Only one frame of data is required. Manufacturers may choose to store additional frames provided that at least the required frame can be read by a generic scan tool meeting the specifications of sections 6.8.3 and 6.8.4. If the fault code causing the conditions to be stored is erased in accordance with section 3.9 of this Annex, the stored engine conditions may also be erased.
- 6.3. If available, the following signals in addition to the required freeze-frame information must be made available on demand through the serial port on the standardised data link connector, if the information is available to the on-board computer or can be determined using information available to the on-board computer: diagnostic trouble codes, engine coolant temperature, injection timing, intake air temperature, manifold air pressure, air flow rate, engine speed, pedal position sensor output value, calculated load value, vehicle speed and fuel pressure.

The signals must be provided in standard units based on the specifications given in section 6.8. Actual signals must be clearly identified separately from default value or limp-home signals.

- 6.4. For all emission control systems for which specific on-board evaluation tests are conducted, separate status codes, or readiness codes, must be stored in computer memory to identify correctly functioning emission control systems and those emission control systems which require further vehicle operation to complete a proper diagnostic evaluation. A readiness code need not be stored for those monitors that can be considered continuously operating monitors. Readiness codes should never be set to 'not ready' status upon 'key-on' or 'key-off'. The intentional setting of readiness codes to 'not ready' status via service procedures must apply to all such codes, rather than applying to individual codes.

- 6.5. The OBD requirements to which the vehicle is certified (i.e. stage 1 OBD or stage 2 OBD) and the major emission control systems monitored by the OBD system consistent with section 6.8.4 must be available through the serial data port on the standardised data link connector according to the specifications given in section 6.8.
- 6.6. The software calibration identification number as declared in Annexes II and VI to Directive 2005/55/EC shall be made available through the serial port of the standardised diagnostic connector. The software calibration identification number shall be provided in a standardised format.
- 6.7. The vehicle identification number (VIN) number shall be made available through the serial port of the standardised diagnostic connector. The VIN number shall be provided in a standardised format.
- 6.8. The emission control diagnostic system must provide for standardised or unrestricted access and conform to either ISO 15765 or SAE J1939, as specified in the following sections<sup>(19)</sup>.
  - 6.8.1. The use of either ISO 15765 or SAE J1939 shall be consistent throughout sections 6.8.2 to 6.8.5.
  - 6.8.2. The on-board to off-board communications link must conform to ISO 15765-4 or to the similar clauses within the SAE J1939 series of standards.
  - 6.8.3. Test equipment and diagnostic tools needed to communicate with OBD systems must meet or exceed the functional specification given in ISO 15031-4 or SAE J1939-73 section 5.2.2.1.
    - 6.8.3.1. The use of an on-board diagnostic facility such as a dashboard mounted video display device for enabling access to OBD information is permitted but this is in addition to enabling access to OBD information by means of the standard diagnostic connector.
  - 6.8.4. Diagnostic data, (as specified in this section) and bi-directional control information must be provided using the format and units described in ISO 15031-5 or SAE J1939-73 section 5.2.2.1 and must be available using a diagnostic tool meeting the requirements of ISO 15031-4 or SAE J1939-73 section 5.2.2.1.

The manufacturer shall provide a national standardisation body with emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO 15031-5 but related to this Directive.

- 6.8.5. When a fault is registered, the manufacturer must identify the fault using the most appropriate fault code consistent with those given in Section 6.3 of ISO 15031-6 relating to emission-related system diagnostic trouble codes. If such identification is not possible, the manufacturer may use diagnostic trouble codes according to Sections 5.3 and 5.6 of ISO 15031-6. The fault codes must be fully accessible by standardised diagnostic equipment complying with the provisions of section 6.8.3 of this Annex.

The manufacturer shall provide a national standardisation body with emission-related diagnostic data, e.g. PID's, OBD monitor Id's, Test Id's not specified in ISO 15031-5 but related to this Directive.

As an alternative, the manufacturer may identify the fault using the most appropriate fault code consistent with those given in SAE J2012 or in SAE J1939-73.

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- 6.8.6. The connection interface between the vehicle and the diagnostic tester must be standardised and must meet all the requirements of ISO 15031-3 or SAE J1939-13.

In the case of category N2, N3, M2, and M3 vehicles, as an alternative to the connector location described in the above standards and provided all other requirements of ISO 15031-3 are met, the connector may be located in a suitable position by the side of the driver's seat, including on the floor of the cabin. In this case the connector should be accessible by a person standing outside the vehicle and not restrict access to the driver's seat.

The installation position must be subject to agreement of the approval authority such that it is readily accessible by service personnel but protected from accidental damage during normal conditions of use.

## Appendix 1

### ON-BOARD DIAGNOSTIC (OBD) SYSTEM APPROVAL TESTS

#### 1. INTRODUCTION

This Appendix describes the procedure for checking the function of the on board diagnostic (OBD) system installed on the engine by failure simulation of relevant emission-related systems in the engine management or emission control system. It also sets procedures for determining the durability of OBD systems.

##### 1.1. Deteriorated components/systems

In order to demonstrate the efficient monitoring of an emission control system or component, the failure of which may result in tailpipe emissions exceeding the appropriate OBD threshold limits, the manufacturer must make available the deteriorated components and/or electrical devices which would be used to simulate failures.

Such deteriorated components or devices must not cause emissions to exceed the OBD threshold limits referred to in the table in Article 4(3) of this Directive by more than 20 %.

In the case of type-approval of an OBD system according to Article 4(1) of this Directive, the emissions shall be measured over the ESC test cycle (see Appendix 1 to Annex III to Directive 2005/55/EC). In the case of type-approval of an OBD system according to Article 4(2) of this Directive, the emissions shall be measured over the ETC test cycle (see Appendix 2 to Annex III to Directive 2005/55/EC).

- 1.1.1. If it is determined that the installation of a deteriorated component or device on an engine means that a comparison with the OBD threshold limits is not possible (e.g. because the statistical conditions for validating the ETC test cycle are not met), the failure of that component or device may be considered as qualified upon the agreement of the type-approval authority based on technical argumentation provided by the manufacturer.
- 1.1.2. In the case that the installation of a deteriorated component or device on an engine means that the full load curve (as determined with a correctly operating engine) cannot (even partially) be attained during the test, the deteriorated component or device is considered as qualified upon the agreement of the type-approval authority based on technical argumentation provided by the manufacturer.
- 1.1.3. The use of deteriorated components or devices that cause engine emissions to exceed the OBD threshold limits referred to in the table in Article 4(3) of this Directive by no more than 20 % may not be required in some very specific cases (for example, if a limp home strategy is activated, if the engine cannot run any test, or in case of EGR sticking valves, etc). This exception shall be documented by the manufacturer. It is subject to the agreement of the technical service.

##### 1.2. Test principle

When the engine is tested with the deteriorated component or device fitted, the OBD system is approved if the MI is activated. The OBD system is also approved if the MI is activated below the OBD threshold limits.

The use of deteriorated components or devices that cause the engine emissions to exceed the OBD threshold limits referred to in the table in Article 4(3) of this Directive by no more than

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20 % are not required in the specific case of the failure modes described in sections 6.3.1.6 and 6.3.1.7 of this Appendix and also with respect to monitoring for major functional failure.

1.2.1. The use of deteriorated components or devices that cause engine emissions to exceed the OBD threshold limits referred to in the table in Article 4(3) of this Directive by no more than 20 % may not be required in some very specific cases (for example, if a limp home strategy is activated, if the engine cannot run any test, or in case of EGR sticking valves, etc). This exception shall be documented by the manufacturer. It is subject to the agreement of the technical service.

## 2. DESCRIPTION OF TEST

2.1. The testing of OBD systems consists of the following phases:

- simulating the malfunction of a component of the engine management or emission control system as described in section 1.1 of this Appendix
- preconditioning of the OBD system with a simulated malfunction over the preconditioning cycle specified in section 6.2
- operating the engine with a simulated malfunction over the OBD test cycle referred to in section 6.1
- determining whether the OBD system reacts to the simulated malfunction and indicates malfunction in an appropriate manner.

2.1.1. Should the performance (e.g. power curve) of the engine be affected by the malfunction, the OBD test-cycle remains the shortened version of the ESC test-cycle used for the assessing the exhaust emissions of the engine without that malfunction.

2.2. Alternatively, at the request of the manufacturer, malfunction of one or more components may be electronically simulated according to the requirements of section 6.

2.3. Manufacturers may request that monitoring take place outside the OBD test cycle referred to in section 6.1 if it can be demonstrated to the authority that monitoring during conditions encountered during this OBD test cycle would impose restrictive monitoring conditions when the vehicle is used in service.

## 3. TEST ENGINE AND FUEL

### 3.1. Engine

The test engine shall comply with the specifications laid down in Appendix 1 of Annex II to Directive 2005/55/EC.

### 3.2. Fuel

The appropriate reference fuel as described in Annex IV to Directive 2005/55/EC must be used for testing.

## 4. TEST CONDITIONS

The test conditions must satisfy the requirements of the emission test described in the present directive.

## 5. TEST EQUIPMENT

The engine dynamometer must meet the requirements of Annex III to Directive 2005/55/EC.

## 6. OBD TEST CYCLE



- 6.1. The OBD test cycle is a single shortened ESC test cycle. The individual modes shall be performed in the same order as the ESC test cycle, as defined in section 2.7.1 of Appendix 1 to Annex III to Directive 2005/55/EC.

The engine must be operated for a maximum of 60 seconds in each mode, completing engine speed and load changes in the first 20 seconds. The specified speed shall be held to within  $\pm 50$  rpm and the specified torque shall be held to within  $\pm 2$  % of the maximum torque at each speed.

Exhaust emissions are not required to be measured during the OBD test cycle.

- 6.2. Preconditioning cycle

6.2.1. After introduction of one of the failure modes given in section 6.3, the engine and its OBD system shall be preconditioned by performing a preconditioning cycle.

6.2.2. At the request of the manufacturer and with the agreement of the type-approval authority, an alternative number of a maximum of nine consecutive OBD test cycles may be used.

- 6.3. OBD system test

- 6.3.1. Diesel engines and vehicles equipped with a diesel engine

6.3.1.1. After preconditioning according to section 6.2, the test engine is operated over the OBD test cycle described in section 6.1 of this Appendix. The MI must activate before the end of this test under any of the conditions given in 6.3.1.2 to 6.3.1.7. The technical service may substitute those conditions by others in accordance with section 6.3.1.7. For the purposes of type-approval, the total number of failures subject to testing, in the case of different systems or components, must not exceed four.

If the test is being carried out to type-approve an OBD-engine family consisting of engines that do not belong to the same engine family, the type approval authority will increase the number of failures subject to testing up to a maximum of four times the number of engine families present in the OBD-engine family. The type-approval authority may decide to curtail the test at any time before this maximum number of failure tests has been reached.

6.3.1.2. Where fitted in a separate housing that may or may not be part of a deNO<sub>x</sub> system or diesel particulate filter, replacement of any catalyst with a deteriorated or defective catalyst or electronic simulation of such a failure.

6.3.1.3. Where fitted, replacement of a deNO<sub>x</sub> system (including any sensors that are an integral part of the system) with a deteriorated or defective deNO<sub>x</sub> system or electronic simulation of a deteriorated or defective deNO<sub>x</sub> system that results in emissions exceeding the OBD NO<sub>x</sub> threshold limit referred to in the table given in Article 4(3) of this Directive.

In the case that the engine is being type-approved according to Article 4(1) of this Directive in relation to monitoring for major functional failure, the test of the deNO<sub>x</sub> system shall determine that the MI illuminates under any of the following conditions:

- complete removal of the system or replacement of the system by a bogus system
- lack of any required reagent for a deNO<sub>x</sub> system
- any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a deNO<sub>x</sub> system, including, when applicable, the reagent heating system
- failure of a reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure) of a deNO<sub>x</sub> system

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— major breakdown of the system.

6.3.1.4. Where fitted, total removal of the particulate filter or replacement of the particulate filter with a defective particulate filter that results in emissions exceeding the OBD particulate threshold limit given in the table in Article 4(3) of this Directive.

In the case that the engine is being type-approved according to Article 4(1) of this Directive in relation to monitoring for major functional failure, the test of the particulate filter shall determine that the MI illuminates under any of the following conditions:

- complete removal of the particulate filter or replacement of the system by a bogus system
- major melting of the particulate filter substrate
- major cracking of the particulate filter substrate
- any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a particulate filter
- failure, when applicable, of the reagent dosing system (e.g. clogged nozzle, dosing pump failure) of a particulate filter
- a clogged particulate filter resulting in a differential pressure out of the range declared by the manufacturer.

6.3.1.5. Where fitted, replacement of a combined deNO<sub>x</sub>-particulate filter system (including any sensors that are an integral part of the device) with a deteriorated or defective system or electronic simulation of a deteriorated or defective system that results in emissions exceeding the OBD NO<sub>x</sub> and particulate threshold limits given in the table in Article 4(3) of this Directive.

In the case that the engine is being type-approved according to Article 4(1) of this Directive in relation to monitoring for major functional failure, the test of the combined deNO<sub>x</sub>-particulate filter system shall determine that the MI illuminates under any of the following conditions:

- complete removal of the system or replacement of the system by a bogus system
- lack of any required reagent for a combined deNO<sub>x</sub>-particulate filter system
- any electrical failure of a component (e.g. sensors and actuators, dosing control unit) of a combined deNO<sub>x</sub>-particulate filter system, including, when applicable, the reagent heating system
- failure of a reagent dosing system (e.g. missing air supply, clogged nozzle, dosing pump failure) of a combined deNO<sub>x</sub>-particulate filter system
- major breakdown of a NO<sub>x</sub> trap system
- major melting of the particulate filter substrate
- major cracking of the particulate filter substrate
- a clogged particulate filter resulting in a differential pressure out of the range declared by the manufacturer.

6.3.1.6. Disconnection of any fuelling system electronic fuel quantity and timing actuator that results in emissions exceeding any of the OBD thresholds referred to in the table given in Article 4(3) of this Directive.

6.3.1.7. Disconnection of any other emission-related engine component connected to a computer that results in emissions exceeding any of the thresholds referred to in the table given in Article 4(3) of this Directive.

- 6.3.1.8. In demonstrating compliance with the requirements of 6.3.1.6 and 6.3.1.7 and with the agreement of the approval authority, the manufacturer may take appropriate steps to demonstrate that the OBD system will indicate a fault when disconnection occurs.

## ANNEX V

### APPROVAL CERTIFICATE NUMBERING SYSTEM

1. The number shall consist of five sections separated by the ‘\*’ character. the lower case letter ‘e’ followed by the distinguishing number of the Member State issuing the approval:

1	for Germany
2	for France
3	for Italy
4	for the Netherlands
5	for Sweden
6	for Belgium
7	for Hungary
8	for the Czech Republic
9	for Spain
11	for the United Kingdom
12	for Austria
13	for Luxembourg
17	for Finland
18	for Denmark
20	for Poland
21	for Portugal
23	for Greece
24	for Ireland
26	for Slovenia
27	for Slovakia
29	for Estonia
32	for Latvia
36	for Lithuania

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49 for Cyprus

50 for Malta

the number of this Directive.

the number of the latest amending Directive applicable to the approval. As it contains different implementation dates and different technical standards, an alphabetical character shall be added in accordance with the table in section 4 below. This character refers to the different application dates for the stages of severity on the basis of which type-approval was granted.

a four-digit sequential number (with leading zeros as applicable) to denote the base approval number. The sequence shall start from 0001.

a two-digit sequential number (with a leading zero as applicable) to denote the extension. The sequence shall start from 01 for each base approval number.

2. <sup>[F1]</sup>Example of applying requirements set out in this Directive and Directive 2005/55/EC for the third approval (with, as yet, no extension) corresponding to application date B1 with OBD stage I, issued by the United Kingdom:

e11\*2005/55\*2005/78B\*0003\*00]

3. <sup>[F1]</sup>Example of applying requirements set out in Directives 2005/55/EC and amending Directive 2006/51/EC for the second extension to the fourth approval corresponding to application date B2, with OBD stage II, issued by Germany:

e1\*2005/55\*2006/51F\*0004\*02]

4. <sup>[F2]</sup>Table showing the characters to be used in accordance with the different implementation dates set out in Directive 2005/55/EC:

Character	Row <sup>a</sup>	OBD Stage I <sup>b</sup>	OBD Stage II	Durability and in-use	NO <sub>x</sub> control <sup>c</sup>
A	A	—	—	—	—
B	B1(2005)	YES	—	YES	—
C	B1(2005)	YES	—	YES	YES
D	B2(2008)	YES	—	YES	—
E	B2(2008)	YES	—	YES	YES
F	B2(2008)	—	YES	YES	—
G	B2(2008)	—	YES	YES	YES
H	C	YES	—	YES	—
I	C	YES	—	YES	YES
J	C	—	YES	YES	—
K	C	—	YES	YES	YES

**a** In accordance with table I, section 6 of Annex I to Directive 2005/55/EC.

**b** In accordance with Article 4 of Directive 2005/55/EC, gas engines are excluded from OBD stage I.

**c** In accordance with section 6.5 of Annex I to Directive 2005/55/EC.]

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### Textual Amendments

- F2** Inserted by [Commission Directive 2006/51/EC](#) of 6 June 2006 amending for the purposes of adapting to technical progress Annex I to Directive 2005/55/EC of the European Parliament and of the Council and Annexes IV and V to Directive 2005/78/EC as regards requirements for the emission control monitoring system for use in vehicles and exemptions for gas engines (Text with EEA relevance).

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- (1) [OJ L 76, 6.4.1970, p. 1](#). Directive as last amended by Commission Directive 2003/76/EC ([OJ L 206, 15.8.2003, p. 29](#)).’
- (2) [OJ L 313, 29.11.2005, p. 1](#).
- (3) Article 4(1) of this Directive provides for the monitoring for major functional failure instead of monitoring for the degradation or the loss of catalytic/filtering efficiency of an exhaust aftertreatment system. Examples of major functional failure are given in sections 3.2.3.2 and 3.2.3.3 of Annex IV to Directive 2005/78/EC.
- (4) [OJ L 375, 31.12.1980, p. 46](#). Directive as last amended by Directive 1999/99/EC ([OJ L 334, 28.12.1999, p. 32](#)).’
- (5) The Commission will determine whether specific measures regarding multi-setting engines need to be laid down in this Directive at the same time as a proposal addressing the requirements of Article 10 of this Directive.
- (6) Up to 1 October 2008, the following applies: “an ambient temperature within the range 279 K to 303 K (6 °C to 30 °C)”.
- (7) This temperature range will be reconsidered as part of the review of this Directive with special emphasis on the appropriateness of the lower temperature boundary.’
- (8) The Commission intends to review this section by 31 December 2006.
- (9) The Commission intends to review those values by 31 December 2005.’
- (10) Delete where inapplicable.’
- (11) Delete where inapplicable.’
- (12) Delete where inapplicable.’
- (13) Delete where inapplicable.’
- (14) The value is only valid for the reference fuel specified in Annex IV.’
- (15) The Commission shall review the temperature upstream of the filter holder, 325 K (52 °C), and, if necessary propose an alternative temperature to be applicable for type-approval of new types from 1 October 2008.’
- (16) Delete what is not applicable.’
- (17) Symbol numbers F01 or F22.
- (18) Symbol number F24.
- (19) The use of the future ISO single protocol standard developed in the framework of the UN/ECE for a world-wide global technical regulation on heavy-duty OBD will be considered by the Commission in a proposal to replace the use of the SAE J1939 and ISO 15765 series of standards to satisfy the appropriate requirements of section 6 as soon as the ISO single protocol standard has reached the DIS stage.