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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 4:
Steady-state and transient test cycles for different engine applications

AMENDMENT 1: Update of data evaluation and calculation provisions, the molar based emission calculations and of the engine control area for E3 and E5 test cycle

AMENDEMENT 1

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CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
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This document was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust emission measurement*.

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AMENDMENT 1: Update of data evaluation and calculation provisions, the molar based emission calculations and of the engine control area for E3 and E5 test cycle

3.69

Add the following at the end of the existing definition of specific emission:

> ; particulate Number (PN) emissions expressed in #/kWh

5.5.1.2.1

Replace by the following:

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> For an exhaust aftertreatment system based on a continuous regeneration process the emissions shall be measured on an aftertreatment system that has been stabilized so as to result in repeatable emissions behaviour. The regeneration process shall occur at least once during the NRTC hot start test, LSI-NRTC or NRSC test, and the manufacturer shall declare the normal conditions under which regeneration occurs (soot load, temperature, exhaust back-pressure, etc.). In order to demonstrate that the regeneration process is continuous, at least three NRTC hot start tests, LSI-NRTC or NRSC tests shall be conducted. In case of NRTC hot start test, the engine shall be warmed up in accordance with 8.4.2, the engine shall be soaked according to 8.6.3 and the first NRTC hot start test run. The subsequent NRTC hot start tests shall be started after soaking according to 8.6.3. During the tests, exhaust temperatures and pressures shall be recorded (temperature before and after the after-treatment 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 and the emission results do not scatter by more than ±25 % from the mean value or 0,005 g/kWh, whichever is greater. **PN emissions do not need to meet the specified scatter requirement if gaseous and PM emissions meet this requirement.** If the exhaust aftertreatment has a security mode that shifts to an infrequent (periodic) regeneration mode, it shall be checked according to 5.5.1.2.2. For that specific case, the applicable emission limits could be exceeded and would not be weighted.

8.2.1.2

Replace the first paragraph by the following

> For the control of a partial flow dilution system to extract a proportional raw exhaust gas sample, a fast system response is required; this is identified by the promptness of the partial flow dilution system. The transformation time for the system shall be determined by the procedure in ISO 8178-1, 9.8.6.3.2 and the related Figure 1. The actual control of the partial flow dilution system shall be based on the current measured conditions. If the combined transformation time of the exhaust gas flow measurement and the partial flow system is ≤ 0,3 s, online control shall be used. If the transformation time exceeds 0,3 s, look-ahead control based on a pre-recorded test run shall be used. In this case, the combined rise time shall be ≤ 1 s and the combined delay time ≤ 10 s.

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Replace the second to last paragraph by the following

> Look-ahead control is required if the combined transformation times of the particulate system, $t_{50,\mathrm{P}}$ and of the exhaust gas mass flow signal, $t_{50,\mathrm{F}}$ are > 0,3 s. In this case, a pre-test shall be run and the exhaust gas mass flow signal of the pre-test be used for controlling the sample flow into the particulate system.

9.1.2.2

Add the following as first paragraph and before equation (18):

> This involves measurement of the concentration of a tracer gas in the exhaust. The calculation of the instantaneous exhaust gas flow $q_{\mathrm{mew},i}$ [kg/s] shall be as follows:

Add the following as last paragraph:

> The background concentration of the tracer gas c_b may be determined by averaging the background concentration measured immediately before the test run and after the test run. When the background concentration is less than 1 % of the concentration of the tracer gas after mixing $c_{\mathrm{mix},i}$ at maximum exhaust flow, the background concentration may be neglected.

9.1.4.2.1

Replace equation (22) with the following:

$$q_{\mathrm{mgas},i} = k_\mathrm{h} \times k \times u_\mathrm{gas} \times q_{\mathrm{mew},i} \times c_{\mathrm{gas},i} \times 3600$$

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9.1.4.2.2

Replace equation (23) with the following:

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$$m_\mathrm{gas} = \frac{1}{f} \times k_\mathrm{h} \times k \times u_\mathrm{gas} \times \sum_{i=1}^{i=n} \left(q_{\mathrm{mew},i} \times c_{\mathrm{gas},i} \right)$$

where

u_gas	component specific factor [-]
k_h	NO$_\mathrm{x}$ correction factor [-], only to be applied for the NOx emission calculation (see 9.1.5)
k	1 for $c_{\mathrm{gasr,w},i}$ in [µmol/mol] and k = 10 000 for $c_{\mathrm{gasr,w},i}$ in [% vol]
$c_{\mathrm{gas},i}$	instantaneous emission concentration in the raw exhaust gas, on a wet basis [µmol/mol] or [% vol]
$q_{\mathrm{mew},i}$	instantaneous exhaust gas mass flow rate on a wet basis [kg/s]
f	is the data sampling rate [Hz]
n	is the number of measurements

Replace Table 7 with the following

Table 1 — Values of *u* in the exhaust gas and density for various exhaust components

Gas		**NO_x**	**CO**	**HC**	**CO_2**	**O_2**	**CH_4**	**HCHO**	**CH_3OH**
ρ_{gas} [kg/m^3]		2,053	1,250	a	1,9636	1,4277	0,716	1,340	1,430
FUEL	ρ_e	**Coefficient u_{gas}** [b]							
Diesel (non-road gas-oil)	1,2943	0,001586	0,000966	0,000479	0,001517	0,001103	0,000553	0,001035	0,001104
RME	1,2950	0,001585	0,000965	0,000536	0,001516	0,001102	0,000553	0,001035	0,001104
Methanol	1,2610	0,001628	0,000991	0,001133	0,001557	0,001132	0,000568	0,001062	0,001134
Ethanol	1,2757	0,001609	0,000980	0,000805	0,001539	0,001119	0,000561	0,001050	0,001121
Ethanol for dedicated compression ignition engines (ED95)	1,2768	0,001609	0,000980	0,000780	0,001539	0,001119	0,000561	0,001050	0,001121
Ethanol (E85)	1,2797	0,001604	0,000977	0,000730	0,001534	0,001116	0,000559	0,001047	0,001117
Natural gas / bio-methane[c]	1,2661	0,001621	0,000987	0,000558[d]	0,001551	0,001128	0,000565	0,001058	0,001129
Propane	1,2805	0,001603	0,000976	0,000512	0,001533	0,001115	0,000559	0,001046	0,001116
Butane	1,2832	0,001600	0,000974	0,000505	0,001530	0,001113	0,000558	0,001044	0,001114
LPG [a]	1,2811	0,001602	0,000976	0,000510	0,001533	0,001115	0,000559	0,001046	0,001116
Gasoline	1,2977	0,001582	0,000963	0,000481	0,001513	0,001100	0,000552	0,001032	0,001102
Petrol (E10)	1,2931	0,001587	0,000966	0,000499	0,001518	0,001104	0,000553	0,001035	0,001105

[a] Depending on fuel.

[b] At $\lambda = 2$, wet air, 273 K, 101,3 kPa.

[c] u accurate within 0,2 % for mass composition of: C = 66 - 76 %; H = 22 - 25 %; N = 0 - 12 %.

[d] NMHC on the basis of $CH_{2,93}$ (for total HC the u_{gas} coefficient of CH_4 is used).

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9.1.4.4.

Replace equation (38) with the following:

$$c_{\mathrm{NMHC}} = \frac{c_{\mathrm{HC(w/oCutter)}} \times \left(1 - E_{\mathrm{CH4}}\right) - c_{\mathrm{HC(w/Cutter)}}}{\left(E_{\mathrm{C2H6}} - E_{\mathrm{CH4}}\right)}$$

Replace equation (39) with the following:

$$c_{\mathrm{CH4}} = \frac{c_{HC\mathrm{(w/Cutter)}} - c_{HC\mathrm{(w/oCutter)}} \times \left(1 - E_{\mathrm{C2H6}}\right)}{RF_{\mathrm{CH4[THC-FID]}} \times \left(E_{\mathrm{C2H6}} - E_{\mathrm{CH4}}\right)}$$

9.1.5.1.2

Replace equation (45) with the following:

$$k_{\mathrm{W}} = \frac{\dfrac{1}{1 + \alpha \times 0{,}005 \times \left(c_{\mathrm{CO2}} + c_{\mathrm{CO}}\right)} - k_{\mathrm{W1}}}{1 - \dfrac{p_{\mathrm{r}}}{p_{\mathrm{b}}}}$$

9.2.4.4

Replace equation (83) with the following:

$$q_{m\mathrm{PM}i} = \frac{m_{\mathrm{f}i}}{m_{\mathrm{sep}i}} \times \overline{q_{m\mathrm{edf}i}} \times \frac{3600}{1000}$$

Where:

$q_{m\mathrm{PM}i}$	particulate sample mass collected at mode *i* [mg]
$m_{\mathrm{f}i}$	$\mathrm{NO_x}$ correction factor [-], only to be applied for the NOx emission calculation (see 9.1.5)
$q_{m\mathrm{edf}i}$	equivalent diluted exhaust gas mass flow rate on wet basis at mode *i* [kg/s]
$m_{\mathrm{sep}i}$	mass of diluted exhaust sample passed through the particulate sampling filter at mode *i* [kg]

Replace equations (84) and (85) with the following:

$$q_{m\mathrm{PM}} = \left\{ \frac{m_{\mathrm{f}}}{m_{\mathrm{sep}}} - \left[\frac{m_{\mathrm{f,d}}}{m_{\mathrm{d}}} \times \sum_{i=1}^{n} \left(1 - \frac{1}{D_i} \right) \times WF_i \right] \right\} \times \overline{q_{m\mathrm{edf}}} \times \frac{3600}{1000} \quad (84)$$

$$q_{m\mathrm{PM}i} = \left\{ \frac{m_{\mathrm{f}i}}{m_{\mathrm{sep}i}} - \left[\frac{m_{\mathrm{f,d}}}{m_{\mathrm{d}}} \times \left(1 - \frac{1}{D} \right) \right] \right\} \times \overline{q_{m\mathrm{edf}i}} \times \frac{3600}{1000} \quad (85)$$

where

$q_{m\mathrm{PM}}$	particulate mass flow rate [g/h]
$q_{m\mathrm{PMi}}$	particulate mass flow rate at mode i [g/h]
m_{f}	particulate sample mass collected [mg]
$m_{\mathrm{f}i}$	particulate sample mass collected at mode *i* [mg]
m_{sep}	mass of diluted exhaust sample passed through the particulate sampling filter [kg]
$m_{\mathrm{sep}i}$	mass of diluted exhaust sample passed through the particulate sampling filter at mode *i* [kg]
$m_{\mathrm{f,d}}$	particulate sample mass of the dilution air collected [mg]
m_{d}	mass of the dilution air sample passed through the particulate sampling filters [kg]
D	dilution factor (see equation 50) [-]
D_i	dilution factor at mode i (see equation 50) [-]
WF_i	weighting factor for the mode *i* [-]
$\overline{\mathrm{q}_{\mathrm{medf}}}$	average equivalent diluted exhaust gas mass flow rate on wet basis [kg/s]
$q_{m\mathrm{edfi}}$	equivalent diluted exhaust gas mass flow rate on wet basis at mode *i* [kg/h]

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9.4.2.1

Add the following headline after the headline of 9.4.2 and before the first paragraph of 9.4.2:

9.4.2.1 Partial flow dilution sampling system

9.4.2.2

Add the following after 9.4.2.1

9.4.2.2 Raw gas sampling system

Where particle numbers are sampled using a raw gas sampling system according to the procedures set out in paragraph 8.4 of ISO 8178-1, the number of particles emitted over the test cycle shall be calculated by means of the following equation:

$$N = \frac{1}{f} \times \sum_{i=1}^{i=n} \left(\frac{q_{\mathrm{mew},i}}{\rho_{\mathrm{e},i}} \times c_{\mathrm{s},i} \right) \times k \times \overline{f_{\mathrm{r}}} \times 10^6 \qquad (91a)$$

where

N	is number of particles emitted over the test cycle [#/test]
$q_{\mathrm{mew},i}$	is instantaneous exhaust gas flow rate on a wet basis [kg/s]
$\rho_{\mathrm{e,i}}$	is instantaneous density of the exhaust gas in the standard conditions (273,15 K and 101,33 kPa) and on a wet basis [kg/m3] (refer to Eq.[35] and [36])
k	is calibration factor to correct the particle number counter measurements to the level of the reference instrument where this is not applied internally within the particle number counter. Where the calibration factor is applied internally within the particle number counter, a value of 1 shall be used for k in the above equation
$\overline{f_{\mathrm{r}}}$	is mean particle concentration reduction factor of the volatile particle remover specific to the dilution settings used for the test
$c_{\mathrm{s},i}$	is a discrete measurement of particle concentration in the raw exhaust gas from the particle counter, corrected for coincidence and to standard conditions (273,15 K and 101,33 kPa), particles per cubic centimetre
n	is number of particle concentration measurements taken over the duration of the test
F	is data sampling rate [Hz]

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9.4.4

Replace the text with the following:

9.4.4 Determination of particles numbers for discrete-mode cycles with partial flow dilution or raw gas sampling system

9.4.4.1 Partial flow dilution system

Where particle numbers are sampled using a raw gas sampling system according to the procedures set out in paragraph 8.4 of ISO 8178-1, the rate emission particles during each individual discrete mode shall be calculated by means of the following formula using average values for the mode:

9.4.4.2 Raw gas sampling system

Where particle numbers are sampled using a raw gas sampling system according to the procedures set out in paragraph 8.4 of ISO 8178-1, the rate emission particles during each individual discrete mode shall be calculated by means of the following formula using average values for the mode:

$$\dot{N} = \frac{q_{mew}}{\rho_e} \times k \times \overline{c_s} \times \overline{f_r} \times 10^6 \times 3600 \qquad (94)$$