CHAPTER 8 : CALCULATION OF THE MASS EMISSIONS OF POLLUTANTS

1. Scope : This chapter describes the calculation procedures for the mass emission of pollutants and correction for humidity for oxides of nitrogen.

2. The mass emission of pollutants are calculated by means of the following equation :

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

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

V_{mix} = Volume of the diluted exhaust gas expressed in m^3/test and corrected to standard conditions 293 K and 101.33 kPa

Q_i = Density of the pollutant i in kg/m^3 at normal temperature and pressure (293 K and 101.33 kPa)

k_H = Humidity correction factor used for the calculation of the mass emissions of oxides of nitrogen. There is no humidity correction for HC and CO.

C_i = Concentration of the pollutant i in the diluted exhaust gas expressed in ppm and corrected by the amount of the pollutant i contained in the dilution air.

d = distance covered in km

3. VOLUME DETERMINATION :

3.1 Calculation of the volume when a variable dilution device with constant flow control by orifice or venturi is used. Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

3.2 Calculation of volume when a positive displacement pump is used .

The volume of diluted exhaust gas in systems comprising a positive displacement pump is calculated with the following formula :

$$V = V_o * N$$

where,

V = Volume of diluted exhaust gas expressed in m^3/test (prior to correction)

V_o = Volume of gas delivered by the positive displacement pump on testing conditions, in m^3/rev.

N = Number of revolutions per test.

3.3 Correction of the diluted exhaust gas volume to standard conditions. The diluted exhaust gas volume is corrected by means of the following formula :

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

in which :

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

where:

P_B = Barometric pressure in the test room in kPa

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

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

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

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

where:

C_i = Concentration of the pollutant i in the diluted exhaust gas, expressed in ppm and corrected by the amount of i contained in the dilution air.

C_e = Measured concentration of pollutant i in the diluted exhaust gas, expressed in ppm.

C_d = Measured concentration of pollutant i in the air used for dilution, expressed in ppm.

DF = Dilution factor

The dilution factor is calculated as follows :

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

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

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

where:

C_{CO_2} = Concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, expressed in % volume.

C_{HC} = Concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent.

C_{CO} = Concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm.

5. Determination of the NOx Humidity Correction Factor :

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

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

in which :

$$H = \frac{6.211 * R_a * P_d}{P_B - P_d * R_a * 10^{-2}}$$

where:

H = Absolute humidity expressed in grams of water per kg of dry air

R_a = Relative humidity of the ambient air expressed in percentage

P_d = Saturation vapour pressure at ambient temperature expressed in kPa

P_B = Atmospheric pressure in the room, expressed in kPa

6. Special provision relating to vehicles equipped with compression-ignition engines

6.1 HC measurement for compression-ignition engines

The average HC concentration used in determining the HC mass emissions from compression-ignition engines is calculated with the aid of the following formula:

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

where:

$\int_{t1}^{t2} C_{HC} .dt =$ Integral of the recording of the heated FID over the test (t_2- t_1)

C_e = concentration of HC measured in the diluted exhaust in ppm of C_i

C_1 is substituted directly for C_{HC} in all relevant equations.

6.2 Determination of particulates

Particulate emission Mp (g/km) is calculated by means of the following equation:

$$M_P = \frac{(V_{mix} + V_{ep}) * P_e}{V_{ep} * d}$$

where exhaust gases are vented outside tunnel.

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

where exhaust gases are returned to the tunnel.

where:
Vmix : volume of diluted exhaust gases (see 2)under standard conditions .
Vep : volume of exhaust gas flowing through particulate filter under standard conditions.
Pe : particulate mass collected by filters.
d : actual distance corresponding to the operating cycle in km.
Mp : particulate emission in g/km

7. *Calculation of fuel consumption*

1. The fuel consumptions are calculated by carbon balance method using measured emissions of carbon dioxide (CO_2) and other carbon related emissions (hydrocarbons - HC, carbon monoxide - CO)

2. The fuel consumption expressed in km per liter (in the case of petrol, LPG or diesel) or in km per m^3 (in the case of NG) is calculated by means of following formulae:

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

$$FC= 100 * D /\{(0.1154)*[(0.866*HC)+(0.429*CO)+ (0.273*CO_2)]\}$$

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

$$Fc_{norm}= 100 * (0.538) /\{(0.1212)*[(0.825*HC)+(0.429*CO)+ (0.273*CO_2)]\}$$

If the composition of the fuel used for the test differs from the composition that is assumed for the calculation of the normalised consumption, on the manufacturer's request a correction factor cf may be applied, as follows:

$$Fc_{norm} = 100 * (0.538) / \{(0.1212) \cdot (cf) \cdot [(0.825 \cdot HC) + (0.429 \cdot CO) + (0.273 \cdot CO_2)]\}$$

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

$$cf = 0.825 + 0.0693 \cdot n_{actual}$$

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

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

$$Fc_{norm} = 100 * (0.654) /\{(0.1336)*[(0.749*HC)+(0.429*CO)+ (0.273*CO_2)]\}$$

iv) For vehicles with a compression ignition engine

$$FC= 100 * D /\{(0.1155)*[(0.866*HC)+(0.429*CO)+ (0.273*CO_2)]\}$$

In these formulae:

FC = the fuel consumption in km per liter (in the case of petrol, LPG or diesel) or in km per m^3 (in the case of natural gas).

HC = the measured emission of hydrocarbons in g/km

CO = the measured emission of carbon monoxide in g/km

CO_2 = the measured emission of carbon dioxide in g/km

D = the density of the test fuel. In the case of gaseous fuels this is the density at 15° C.

For the purpose of these calculations, the fuel consumption shall be expressed in appropriate units and the following fuel characteristics shall be used,

(a) Density: measured on the test fuel according to ISO 3675 or an equivalent method. For petrol and diesel fuel density measured at 15° C will be used; for LPG and natural gas a reference density will be used, as follows:

0.538 kg/liter for LPG

0.654 kg/m^3 for NG*/

*/ Mean value of G20 and G23 reference fuels at 15°C.

(b) Hydrogen -carbon ratio: fixed values will be used which are:

1.85 for petrol

1.86 for diesel fuel

2.525 for LPG

4.00 for NG ”