Chapter 5
Production and In-Service Conformity

5.1 Verification of Production Conformity

According to the new legislation the conformity of light-duty vehicles production with the approved type can be checked by means of the following tests: type I, type III, type IV, OBD test and smoke opacity test.

Testing principles discussed in [2] do not change significantly. In the case of heavy-duty vehicles, production conformity checks still include:

- testing for specific emission of pollutants,
- testing for OBD performance.

Also in this case the testing principles do not vary greatly from those in effect before [1]. The difference is that ESC and ETC tests have been replaced with WHSC and WHTC tests, respectively.

5.2 Verification of In-Service Conformity

The new legislation introduces the following key changes as regards verification of in-service conformity of light-duty vehicles, as compared to the previous legislation [2, 3]:

- more detailed rules of tests carried out by the manufacturer, requiring *inter alia* that a sample of vehicles should come from at least 2 EU member states and that tests should be carried out continuously and the beginnings of each series should not be more than 18 months apart,
- the number of samples tested in accordance with the above rules depends on the number of vehicles of a given family/type registered in the EU: up to 100,000 registrations – 1 sample, 100,001 to 200,000 registrations – 2 samples; above 200,000 registrations – 3 samples;
- it is now possible to admit information provided by competent type approval bodies other than the body inspecting in-service conformity.

For heavy-duty vehicles, the new legislation introduces significant changes in terms of verifying in-service conformity as compared to Euro V requirements.

J. Merkisz, J. Pielecha, and S. Radzimirski, *New Trends in Emission Control in the European Union*, Springer Tracts on Transportation and Traffic 4,
DOI: 10.1007/978-3-319-02705-0_5, © Springer International Publishing Switzerland 2014

The first in-service conformity check should be carried out by the manufacturer within 18 months after the registration of the first vehicle fitted with the engine in question. Such checks should be repeated at least once in two years within the vehicle's life (Tab. 4.8). The mileage of tested vehicles should be at least 25,000 km.

Tests are carried out on the vehicle, which is a significant difference against Euro V, whereby engines were removed from randomly selected vehicles and installed on test benches. Such tests are labor- and cost-intensive, which is why they are rarely carried out.

Table 5.1 Criteria for sample acceptance or rejection upon in-service conformity checks of heavy-duty vehicles

Sample size	Pass criterion	Fail criterion	Sample size	Pass criterion	Fail criterion
3	–	3	7	1	4
4	0	4	8	2	4
5	0	4	9	2	4
6	1	4	10	3	4

The assessment of in-service conformity is based on the rules presented in Table 5.1. The statistics corresponds to the number of non-conforming vehicles in the tested sample. The said rules have been compiled in such a way that the likelihood of sample acceptance is 65% if the percentage of non-conforming vehicles equals $u = 10\%$, and 20% if $u = 90\%$.

The inspection procedure is as follows:

- 3 in-service vehicles of the inspected type or family are sampled (the minimum sample size is $n_o = 3$, and the maximum size is $n_m = 10$);
- the selected vehicles undergo pollution emission tests presented below; for each of the 3 vehicles specific emission of each pollutant is measured (in g/km);
- on the basis of the said measurements, corresponding statistics (i.e. the number of non-conforming vehicles) are determined for each measured pollutant for $n = 3$ and then compared against pass / fail criteria;
- the sample is considered:
  - rejected, if the statistics is equal to or higher than the fail criterion,
  - accepted, if the statistics is equal to or lower than the pass criterion;
- if the rejection or acceptance conditions are not true for $n = 3$, an additional vehicle is sampled and pass/fail criteria are verified for $n = 4$;
- the procedure is continued until either pass or fail criterion is met.

The tests are carried out in normal road traffic, divided into three types:

- urban – driving speed from 0 to 50 km/h,
- extra-urban – driving speed from 50 to 75 km/h,
- highway – driving speed above 75 km/h.

The percentage of each traffic type in the driving cycle depends on vehicle category (Tab. 5.2).

The length of the driving cycle should be selected so that the total work or specific emission of carbon dioxide is five times greater than in the WHTC cycle. Measurement of the following engine and vehicle parameters is required:

- exhaust gas concentration of THC, CO, NO_X, CO_2, CH_4 (only for vehicles running on gaseous fuels); PM mass and particle number are excluded,

Table 5.2 Traffic types in the driving cycle for in-service conformity testing of heavy-duty vehicles

Vehicle category	Percentage of traffic types [%]		
	urban	extra-urban	highway
M1, N1	45	25	30
M2, M3 (classes I, II and A)	70	30	0
M2, M3 (remaining classes)	45	25	30
N2	45	25	30
N3	20	25	55

- exhaust gas mass flow rate,
- engine speed and torque,
- vehicle speed,
- vehicle location (latitude and longitude),
- fuel flow rate,
- ambient temperature and pressure,
- cooling agent temperature,
- air temperature at the engine intake.

Tests are carried out by means of a portable emission measurement system (PEMS, see chapter 6). In principle, the device should allow measuring all engine and vehicle parameters. However, information on engine speed and torque, vehicle speed, fuel flow rate and coolant temperature can be obtained from the vehicle's on-board computer. The legislation requires that such information is provided by the computer and then read and recorded by the PEMS.

The vehicle's in-service conformity as regards specific emission of pollutants is defined by the conformity factor. The method of its calculation is discussed below.

The PEMS is used to record emissions of each pollutant in the entire driving cycle (expressed in mg), as a function of engine work expressed in kWh. Those recording are divided into fragments referred to in the legislation as "windows", on the basis of either reference work or reference carbon dioxide mass.

5.3 Method for Determining Averaging Windows with the Use of Reference Work

The duration of the i^{th} averaging window ($t_{2,i} - t_{1,i}$) is determined using the following formula (Fig. 5.1):

$$W(t_{2,i}) - W(t_{1,i}) \geq W_{ref} \tag{5.1}$$

where: $W(t_{j,i})$ – engine work measured between the start and the time $t_{j,i}$ [kWh],
W_{ref} – engine work for the WHTC test [kWh],
$t_{2,i}$ – is selected so that:

$$W(t_{2,i} - \Delta t) - W(t_{1,i}) < W_{ref} \leq W(t_{2,i}) - W(t_{1,i}) \tag{5.2}$$

where Δt is the data sampling period (1s or less).

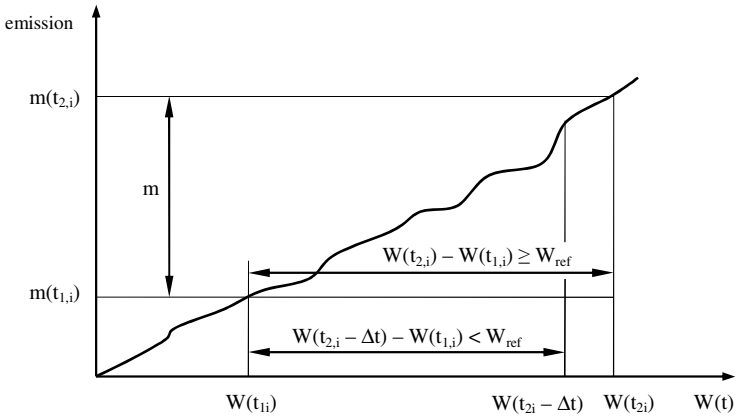

Fig. 5.1 Determination of "measurement window" based on work measurement

Specific emission e_j expressed in milligrams per kilowatt hour is calculated for each window i and for each pollutant j in the following way:

$$e_j = \frac{m}{W(t_{2,i}) - W(t_{1,i})} \tag{5.3}$$

where: m – component mass in the averaging window, $m = m(t_{2,i}) - m(t_{1,i})$ [mg],
$m(t_{2,i})$ – component mass corresponding to the work $W(t_{2,i})$ in the i^{th} averaging window [mg],
$m(t_{1,i})$ – component mass corresponding to the work $W(t_{1,i})$ in the i^{th} averaging window [mg],
$W(t_{2,i}) - W(t_{1,i})$ – engine work in the i^{th} averaging window [kWh].

Valid averaging windows are those where the power exceeds 20% of the maximum engine power. The percentage of valid averaging windows must be at least 50% for the entire test. If that percentage is below 50%, data assessment is repeated using lower power thresholds. Power thresholds are reduced in steps of 1% until the percentage of valid windows reaches at least 50% (the lowest value of the power threshold is 15% of the maximum engine power; if at a threshold of 15% the percentage of all valid windows is still below 50%, the test is void).

For each fragment of a single valid window the mass of individual pollutants and the performed work is measured. On that basis specific emission expressed in mg/kWh is calculated. Subsequently the conformity factor *CF* is calculated in accordance with the following formula:

$$CF = e_j / L_j \tag{5.4}$$

where: e_j – specific emission of the pollutant j [mg/kWh],
L_j – prescribed limit of specific pollution of the pollutant j in the WHTC test [mg/kWh].

5.4 Method for Determining Averaging Windows with the Use of Reference Carbon Dioxide Mass

The duration of the i^{th} averaging window $(t_{2,i} - t_{1,i})$ is determined using the following formula (Fig. 5.2):

$$m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i}) \geq m_{CO_2\,ref} \tag{5.5}$$

where: $m_{CO_2}(t_{j,i})$ – CO_2 mass measured between the test start and the time $t_{j,i}$ [kg],
$m_{CO_2\,ref}$ – CO_2 mass determined in the WHTC test [kg],
$t_{2,i}$ – is selected so that:

$$m_{CO_2}(t_{2,i} - \Delta t) - m_{CO_2}(t_{1,i}) < m_{CO_2\,ref} \leq m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i}) \tag{5.6}$$

where Δt is the data sampling period (1s or less).

Valid averaging windows are those whose duration does not exceed the maximum duration calculated using the following formula:

$$t_{\max} = 3600 \frac{W_{ref}}{0{,}2\, N_{e\max}} \tag{5.7}$$

where: $t_{\max}$ – maximum window duration [s],
$N_{e\,\max}$ – maximum engine power [kW].

Conformity factors are calculated for each window and each single pollutant in the following way:

$$CF = \frac{CF_i}{CF_c} \tag{5.8}$$

in-service ratio:
$$CF_i = \frac{m}{m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i})} \tag{5.9}$$

certification ratio:
$$CF_c = \frac{m_L}{m_{CO_2\ ref}} \tag{5.10}$$

where: m – pollutant mass in the averaging window [mg],
$m_{CO_2}(t_{2,i}) - m_{CO2}(t_{1,i})$ – CO_2 mass in the i^{th} averaging window [kg],
$m_{CO_2\ ref}$ – CO_2 mass from the engine determined for the WHTC test [kg],
m_L – component mass corresponding to the limit for the WHTC test [mg].

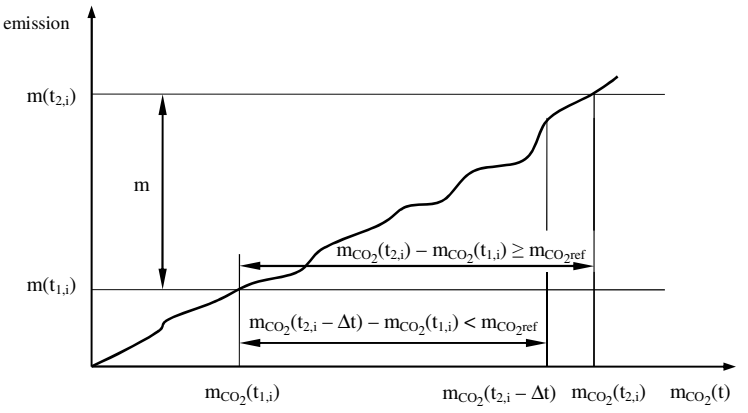

Fig. 5.2 Determination of "measurement window" based on carbon dioxide mass measurement

The vehicle is found conforming if 90% of CF values for each driving cycle fragment do not exceed 1.5.

In the new legislation the method for testing in-service conformity of heavy-duty vehicles varies from the method used for type approval. This is a significant difference as compared to the previous legislation for both light-duty and heavy-duty vehicles, whereby the methods used for in-service conformity and for type approval were expected to be identical.

References

[1] Engeljehringer, K.: Automotive Emission Testing and Certification: Past, Present and Future. Current and future trends in Automotive emissions, fuels, lubricants and test methods, Bielsko-Biała (May 25, 2011)

[2] Merkisz, J., Pielecha, J., Radzimirski, S.: Emisja zanieczyszczeń motoryzacyjnych w świetle nowych przepisów Unii Europejskiej. WKŁ, Warszawa (2012)

[3] Toshiaki, T.: Global Energy and Environmental Issues, Reflected in Toyota's Advanced Powertrain Development. Paper presented at the 34 Internationales Wiener Motorensymposium, Wiena (2013)