

## EXHAUST EMISSION FROM VEHICLES UNDER REAL ROAD TRAFFIC CONDITIONS - A NEW CHANCE FOR PTI?

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### **Abstract**

*The paper presents regulations and methods of testing emissions of exhaust toxic components from vehicles, particularly with respect to research methods under real road traffic conditions. In Europe, legal regulations determine emission values of the exhaust toxic components: carbon monoxide CO, unburned hydrocarbons HC and hydrocarbons released by evaporation (VOC – Volatile Organic Compound), nitrogen oxides NO<sub>x</sub>, and also PM emitted with the exhaust gasses. Emission of the harmful substances from the vehicles is tested on the chassis dynamometer, and the combustion engines themselves, on engine test bench. Due to a high cost of the test equipment and complexity of the tests it is possible to use one measuring system, for both types of stands. Basic EU Directives and UN-ECE Regulations contain rules on conducting the aforementioned tests together with the regulations for the measuring equipment. In the beginning of 2005 in Europe the introduction of a new set of regulations began be introduced, concerning emissions from the M1 and N1 category vehicles. They are called Euro IV (currently obligatory) and Euro V (introduced in 2008). New regulations introduced not only more stringent requirements for the vehicles they refer to, but also for the research laboratories as far as the equipment level and research methods are concerned. Compliance with these requirements is being verified during: type approval of vehicles, conformity of production (COP), in-service conformity.*

**Keywords:** exhaust emission, road transport, combustion engines, air pollution, environment protection

### **1. European regulations and research methods**

In Europe, legal regulations determine emission values of the exhaust toxic components: carbon monoxide CO, unburned hydrocarbons HC and hydrocarbons released by evaporation (VOC - Volatile Organic Compound), nitrogen oxides NO<sub>x</sub>, and also PM emitted with the exhaust gasses. Emission of the harmful substances from the vehicles is tested on the chassis dynamometer, and the combustion engines themselves, on engine test bench. Due to a high cost of the test equipment and complexity of the tests it is possible to use one measuring system, for both types of stands. Basic EU Directives and UN-ECE Regulations contain rules on conducting the aforementioned tests together with the regulations for the measuring equipment.

In the beginning of 2005 in Europe the introduction of a new set of regulations began be introduced, concerning emissions from the M1 and N1 category vehicles. They are called Euro IV (currently obligatory, Fig. 1) and Euro V (introduced in 2008 - Fig. 2) [1, 3, 5].

New regulations introduced not only more stringent requirements for the vehicles they refer to, but also for the research laboratories as far as the equipment level and research methods are concerned. Compliance with these requirements is being verified during:

- type approval of vehicles (Tab. 1),
- conformity of production (COP),
- in-service conformity.

Amendment 05 the Regulation 83 refers to:

- all motor vehicles equipped with positive - ignition (P.I.) engines which have at least four wheels,

- motor vehicles which have at least four wheels and maximum mass not exceeding 3.500 kg, equipped with positive - ignition engines fuelled with NG or LPG,
- motor vehicles of categories M1, N1 equipped with compression - ignition (C.I.), having at least four wheels and maximum mass not exceeding 3.500 kg.

Determining the emission data (CO concentration at the idle run as well as CO concentration and value of the lambda parameter at high idle run) necessary to on the road technical vehicles tests is regarded as a new research. According to the 96/96/EC Directive relating to roadworthiness tests, admissible values of CO for the low emission vehicles equipped with PI engines, at idle speed, should be the same as stated by the manufacturer. Only when these values are not available, the fixed values established in the Directive, equal 0.3% vol. CO at high idle speed, are obligatory.

Value of the absorption coefficient can be compared with the emission limits of the particulate matter, and this was done for the passenger cars with the CI engines for the successive Euro standards. Fig. 3 shows admissible limits for the absorption coefficient, whose value for the Euro I - Euro III standards is  $3.0 \text{ m}^{-1}$ , and for the Euro IV is  $1.5 \text{ m}^{-1}$  and for Euro V expected limit is  $0.05 \text{ m}^{-1}$  [3].

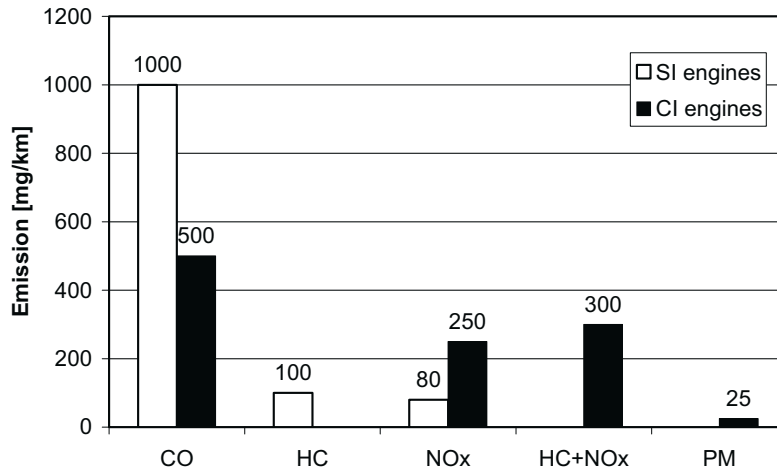


Fig. 1. Limits proposal of exhaust pollutants for motor vehicles - standard Euro IV, test NEDC [1]

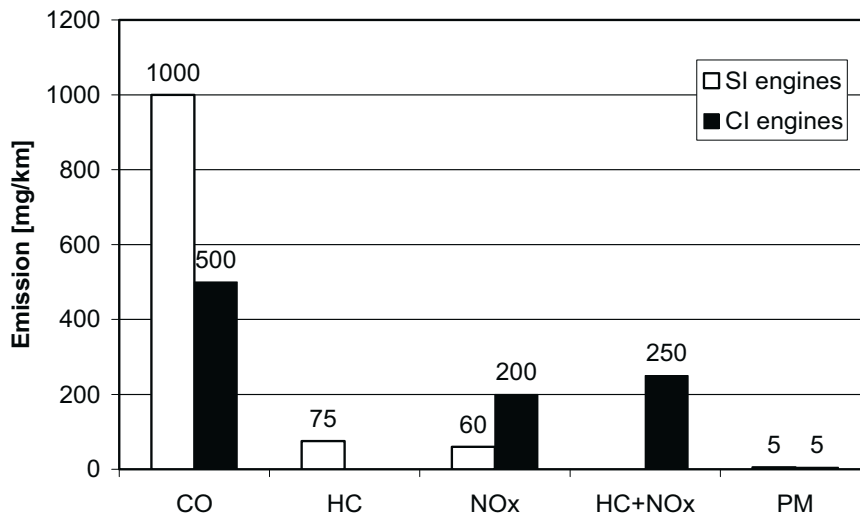


Fig. 2. Limits proposal of exhaust pollutants for motor vehicles - standard Euro V, test NEDC [1]

Tab. 1. Different routes for type approval and extensions [1]

Type approval test	Positive - ignition engines	Compression - ignition engines
I test NEDC - simulating the average exhaust emissions after a cold start	According to Euro standards	
II carbon monoxide emission test at idling speed	0.5% CO (content by volume) at normal idling speed	smokiness of exhaust gases during free acceleration: 2.5 m <sup>-1</sup> - naturally aspirated diesel engines 3.0 m <sup>-1</sup> - turbo-charged diesel engines
III verifying emissions of crankcase gases	zero	–
IV determination of evaporative emissions	evaporative test 2 g HC	–
V durability of anti - pollution devices	100 000 km/5 years	
VI test UDC in - 7°C	CO = 15, HC = 1.8 g/km	–
VII on-board diagnostic	from 2001 r.	from 2003 r.

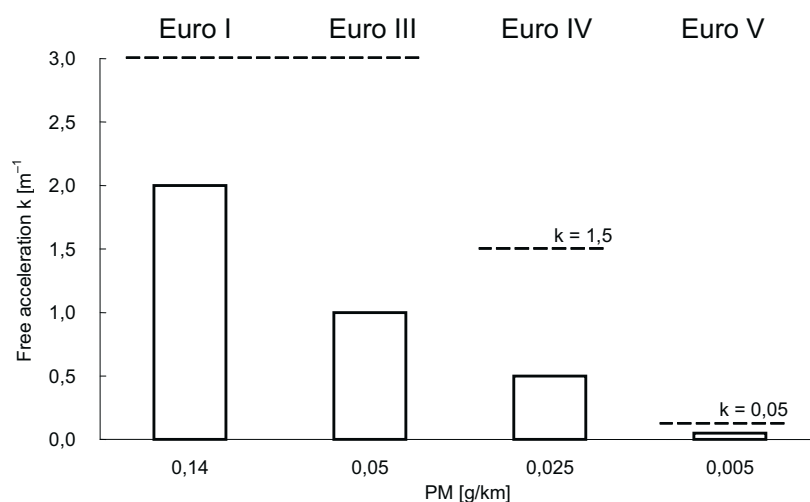


Fig. 3. Limits of absorption coefficient for LDV type vehicles [1]

In the amendment 05 there is a new type VI test introduced concerning emission of the pollutant in the ambient temperature of -7°C following a cold engine start. This test is applicable only to the M1 category vehicles and part of a N1 category, equipped with PI engines. In this case the emission of CO and HC gets restricted. Admissible values are however relatively high and meeting these requirements will not cause significant technical difficulties. For the investigation in type VI test, it is necessary to use low temperature chamber equipped with the chassis dynamometer and adequate exhaust collection system. The requirements have been introduced on conducting this type of tests for the remaining N1 category vehicles (from 1.01.2003 for class I - CO = 5 g/km, HC = 1.8 g/km, for class II - CO = 24 g/km, HC = 2.7 g/km, for class III - CO = 30 g/km, HC = 3.2 g/km) (Fig. 4).

European Commission for the Innovation Policies (DG Enterprise) proposes temporary package of EURO V standards for the PC and LDV category vehicles [6]:

- limiting mass of a PM emitted from the CI and PI engines with a direct fuel injection,
- restricting the HC limit with a separation into substances contained in the alternative fuels i.e. LPG, NG and bio - fuels,
- increasing requirements on durability of the exhaust aftertreatment components (over 160.000 km),

- change of the type approval test, with a consideration given to the influence of toxic substances from the air conditioning system,
- introduction of a low - sulphur fuels (10 ppm) for all countries of the extended European Union by 2010.

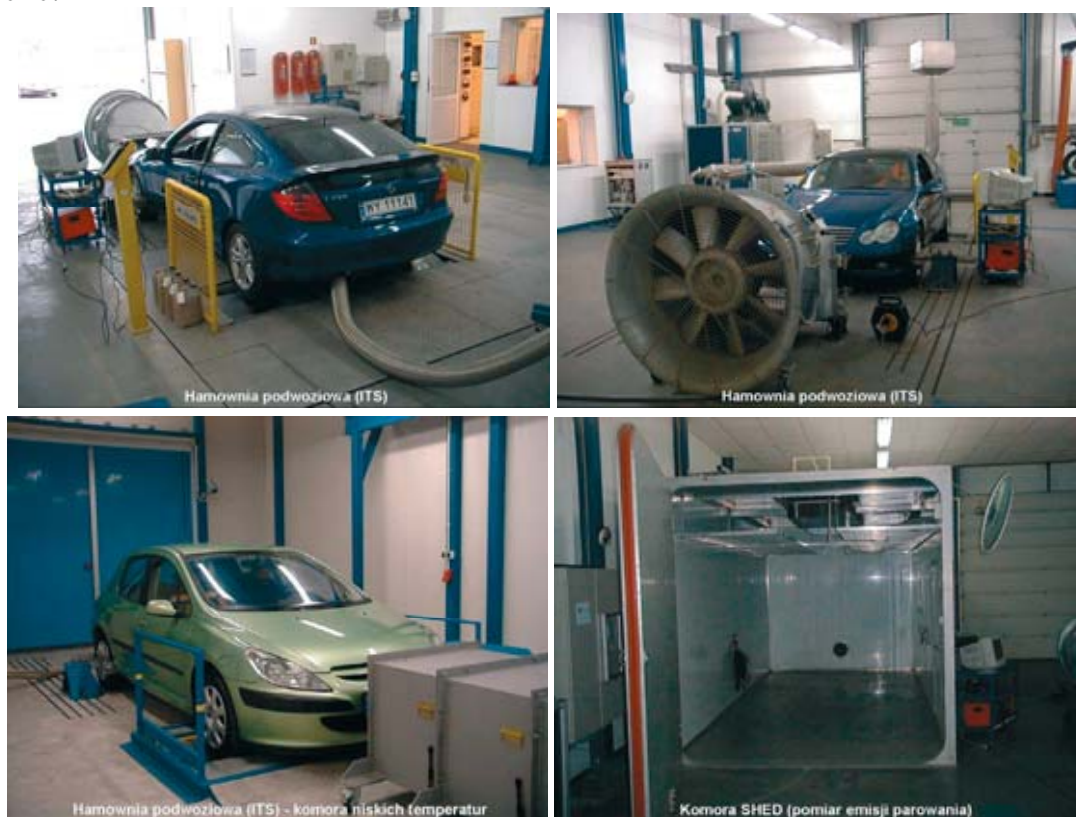


Fig. 4. Examples of type approval tests for cars

Requirement concerning OBD system:

EOBD system - compulsory in CI engines - was introduced on 1.01.2005 - for the M1 category passenger cars and N1 category, class I trucks, as well as on 1.01.2006 - for trucks of N1 category, class II and III. Also the serviceability period of all elements having influence on the exhaust emission after 100.000 km, has been extended.

Future requirements for all vehicles encompass:

- comprehensive electronic checkup of all devices limiting exhaust emission,
- registering the periodic vehicle usage since the moment of the fault occurrence,
- individual diagnosing of the front catalytic converter or together with the next placed in the direction of the exhaust flow,
- not monitoring of the ignition misfiring, if the influence of other factors is being taken into consideration,
- normalization of the fault codes, data transfers, diagnostic tools, connections according to the ISO standards,
- transger of information for the repair needs by the vehicle manufacturers, except for the intellectual property protected by law or significant know - how (refers to the dealers operation on the EU territory),
- OBD system operation for the given vehicle mileage.

## 2. Remote sensing examinations under real conditions of road traffic

In the United States it has been observed that the remote sensing tests, which consist in indirect evaluation of the exhaust toxicity, are being used increasingly. Measurements are taken

on separate stands for the trucks and passenger cars. The diagram of such stands is shown in Fig. 5. The test relies on measuring toxic components using NDIR type analyzers (placed at the height of the exhaust pipe outlet: for the passenger vehicles - about 30 cm above the road surface, for trucks - they are placed at the height of 3-3.5 m) with the vehicles moving with a speed of about 40 km/h (Fig. 6). The results of the toxicity test is signalled with the appropriate colour light (green - serviceable, red - toxicity limit exceeded) upon leaving the test section.

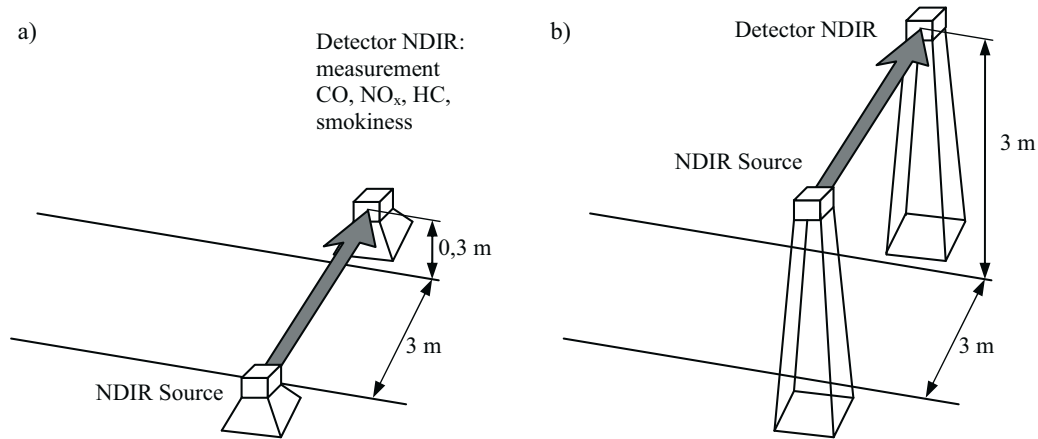


Fig. 5. Diagram of remote sensing examinations of: a) cars, b) trucks



Fig. 6. Remote sensing examinations of trucks

### 3. Road testing (on-board) under real conditions of road traffic

Most desirable are the road tests though, in real traffic conditions, because only then is it possible to obtain information about a vehicle real emission [9].

Portable measurement systems for testing pollutants in the exhaust gasses of the vehicles in

real traffic conditions, the so called PEMS (Portable Emissions Measurement Systems) enable a measurement of the exhaust gas toxic components both in the road conditions and in the laboratory. This pertains to vehicles powered by engines fuelled with: gasoline, diesel oil, LPG, CNG and hybrid vehicles. Sets available ensure simultaneous measurement of: CO, CO<sub>2</sub>, THC, NO, NO<sub>2</sub> (if necessary NO<sub>x</sub>). Sets enable work at least at the ambient temperature between 0 to 45°C, relative humidity up to 80% and at the elevation above the sea level of up to 1500 m. They have bottles filled with operating gasses (work and calibration) with regulators.

Tests are conducted, for example, on the sections of several dozens to several hundreds of kilometres in varying road conditions (Fig. 7). At present the biggest inconvenience of such test is the cost of measuring equipment. On the benefits side are reliable tests results that are impossible to obtain under the simulation conditions on the chassis dynamometer. Such tests are conducted at present, among other in the USA (but also in Poland) in order to compare measurement capabilities for a variety of cars, using this type of equipment incorporating NDIR analyzers (CO<sub>2</sub>), HFID (THC), CLA or NDUV (NO<sub>x</sub>) or enabling PM measurement (for example Micro Soot Sensor & Conditioning Unit). Results obtained testify for a very high changeability of the emission level from the vehicles, because the total dispersion of the values measured was: for NO<sub>x</sub> - 700:1, for HC - 10:1, for CO - 1000:1 and for fuel consumption - 4:1.

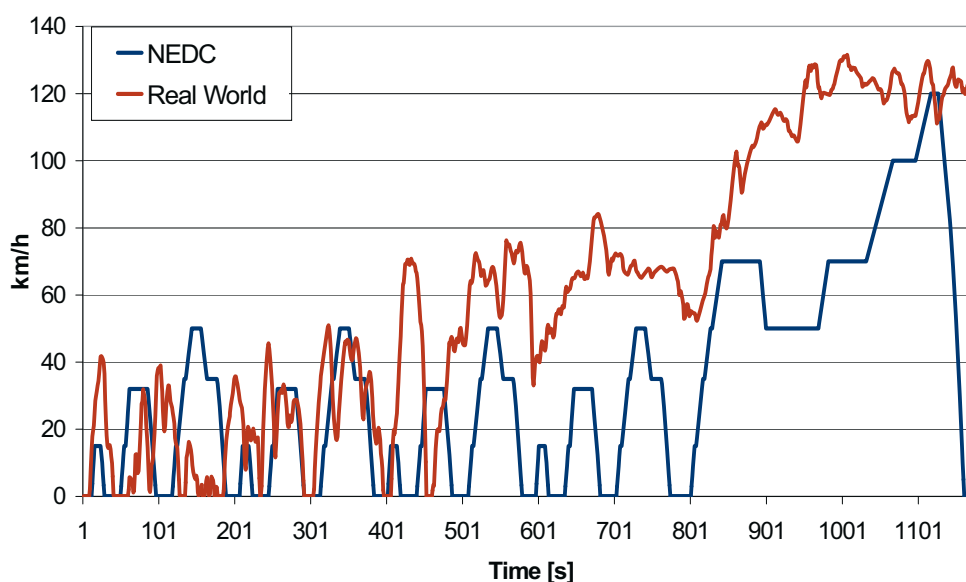


Fig. 7. Course of vehicle speed under real conditions of road traffic and in NEDC test [8]

Using PEMS for the needs of the inspection station seems to be possible e.g. using NEDC tests, FTP 75, IM 240, US06 etc. in station or on the road. It will be necessary to set the appropriate limits. In the USA PEMS instruments comply with the new regulations, including part 1065; sub - part „J”. Fig. 8-11 presents a comparison of the emission of selected exhaust gasses toxic components for various types of tests using PEMS and analytic equipment of the chassis dynamometer.

Portable measuring sets can also be used for measuring exhaust toxic emission from different vehicle category i.e. for example agricultural tractors or other such as ships, aircraft or engines for non-road applications (construction machinery, agricultural etc.). Mobile emission measurement is a new approach in the evaluation of the exhaust toxic substances emission from the vehicles and is by far cheaper than the measurements carried out on the test stands.

#### 4. A concept of vehicle technical inspections in Poland

Taking advantage of the experience of other countries, which use the OBD system information in the technical tests, the inspection procedures in Poland should be as follows (Fig. 12) [4]:

- 1) Filler cap tightness test - test simulation in the SHED test, type IV tests in the type approval tests (lack of positive result of such test disqualifies the vehicle for further test algorithms, repair and a retake of the inspection tests is required),
- 2) Idle test - equivalent of the type II test in the type approval test algorithm (admissible CO concentration level is 0.5% vol.),
- 3) Simplified test on the chassis dynamometers - simulation of the test I (NEDC cycle) in the type approval tests (in the admissible emission level of the toxic substances, a warmed up engine should be taken into consideration - contrary to the type approval test, which begins from a cold engine start) [option - test while using PEMS],
- 4) OBD test - equivalent of a type VII test in the type approval test algorithm (positive - meeting the following conditions: serviceability of MIL indicator, lack of registered fault codes and realisation of all monitors).



Fig. 8. Road measurements carried out in the USA [7]

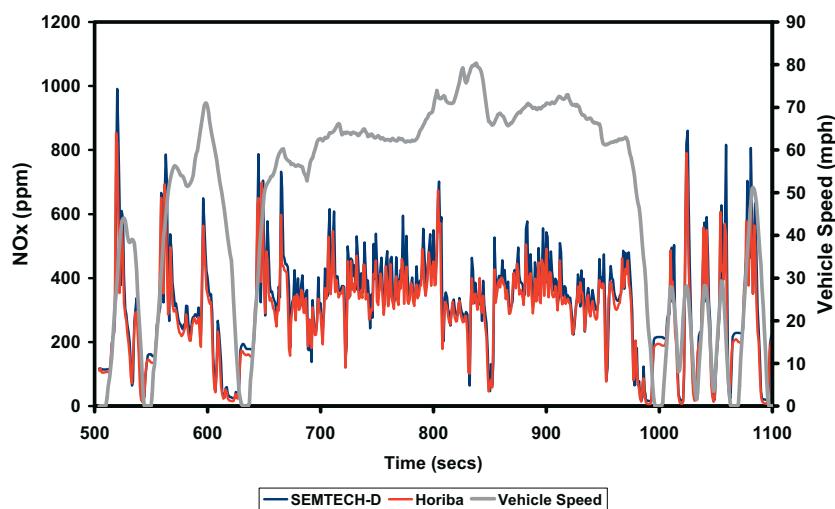


Fig. 9. Course of  $\text{NO}_x$  concentration (ppm) in time during research on chassis dynamometer while using portable measurement system and analytical equipment of chassis dynamometer (test US06) [2]

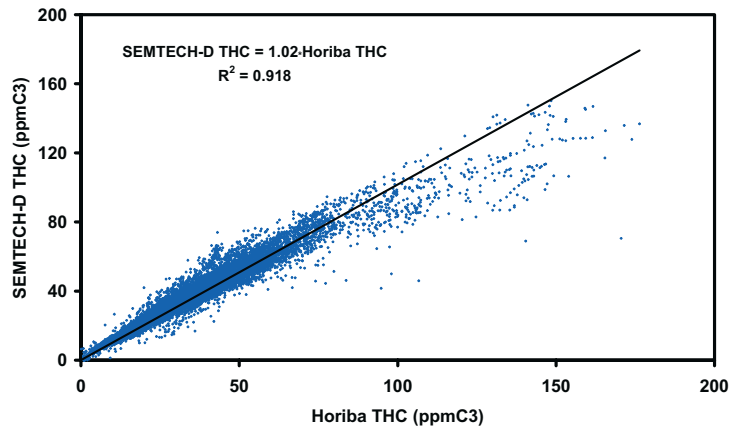


Fig. 10. THC emissions comparison data during FTP 75 test on chassis dynamometer at utilization of portable measurement system and analytical equipment of chassis dynamometer [2]

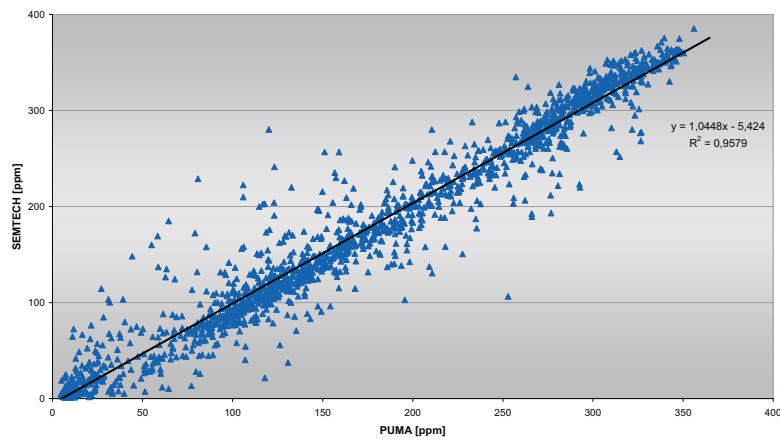


Fig. 11.  $NO_x$  emissions comparison data during ETC test on engine test bench while using portable measurement system and analytical equipment of engine test bench

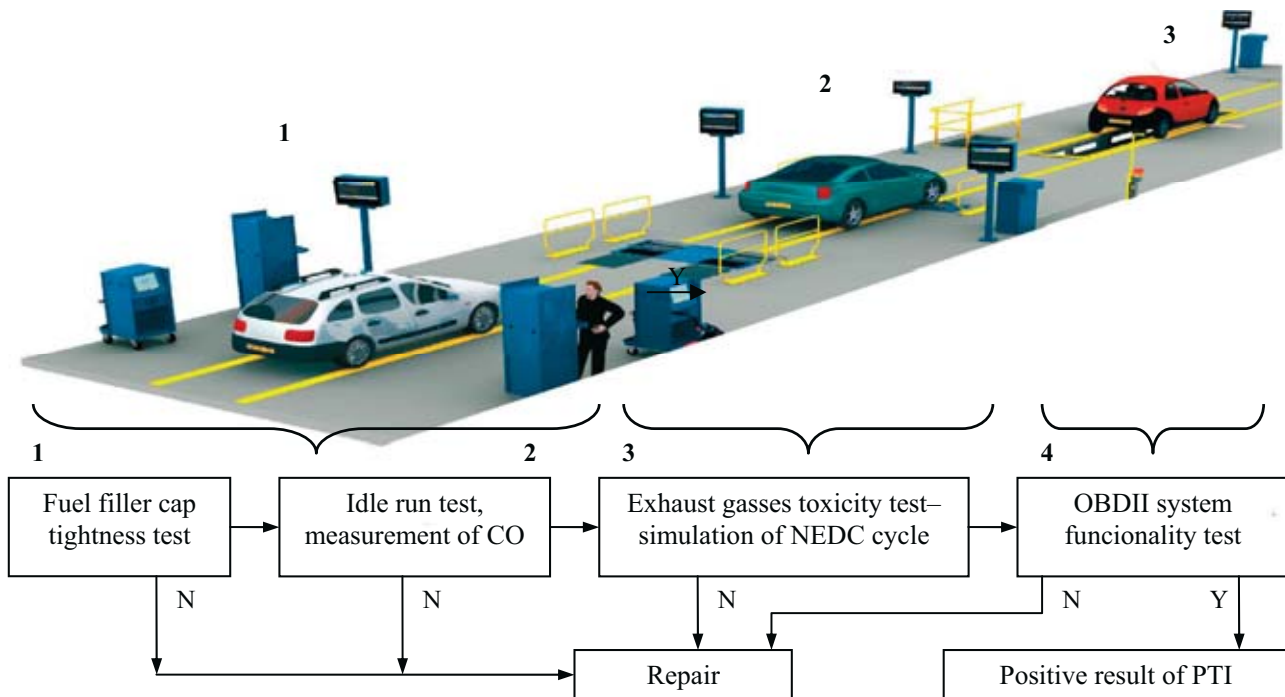


Fig. 12. Algorithm of a technical inspection according to the authors



Based on the presented description of the vehicle test procedures - the best and the most reliable is the road test in the real traffic conditions. These tests, although showing certain dispersion, are reliable - reflecting a real level of vehicle emissions. They are being developed in Poland.

Remote sensing tests are less precise and conducted with the use of NDIR type analyzers, are characterised by different test for trucks and passenger cars.

Based on the periodical tests of vehicles conducted in Europe, in comparison to the previous methods, less emission information is obtained; lack of the road test and the engine loads do not provide information on the vehicle's emission. They provide information on the concentration of the components at the increased engine speed only. Periodical tests in the USA conducted on the chassis dynamometers in the drive test enable to get more information about the technical condition of a vehicle, at the same time showing technological advancement of those emission testing centres.

## **Conclusions**

Drastically stricter type approval values acc. to Euro VI must also be taken into account during exhaust emission measurements and PTI [11]:

- high resolution exhaust emission test,
- OBD extended functions.

It is possible to execute such tests on a chassis dyno of an inspection station. IM 240 test can be suggested. A Station equipped in a chassis dyno should be placed in each province. Vehicles should be controlled at least once in two years. Inspection stations should be equipped with a video surveillance system.

Roadside inspections should be concerned with control of the OBD system, responsible for toxicity control. Using OBD in vehicle roadside inspections depends on each EU member state [10]. Unfortunately, in the case of HDVs road - worthiness EU emission directives do not refer to OBD [10].

Euro IV OBD is a pure truck operator oriented system because [10]:

- several kinds of failures are recorded whatever their environmental impact,
- in the same cases, Euro IV OBD may anticipate a malfunction occurrence and considers this anticipated malfunction in the same way as an active failure,
- previously active failures are recorded in the same manner as active failures - while they cannot actually be repaired.

Purposes of the GTR (Global Technical Regulation) [WWH - OBD] are to improve the use of the OBD system as a roadworthiness indicator. Major new and specific features are:

- classification of the failures according to their environmental effect,
- improved alert and record systems,
- capability to retrieve failure information according to the need (road side check, periodic inspection, repair).

The off-board WWH - OBD communication mechanism addresses 3 possible use cases of the OBD system:

- for roadside check:  
control of the presence of class A and unrepaired class B1 malfunctions<sup>1</sup>,
- for vehicle inspection:
- access to the failures that impair the engine compliance,

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<sup>1</sup> A malfunction shall be identified as class A when the relevant OBD threshold limits (OTLs) are assumed to be exceeded. A malfunction shall be identified as class B1 where circumstances exist that have the potential to lead to emissions being above the OTLs but for which the exact influence on emission cannot be estimated and thus the actual emissions according to circumstances may be above or below the OTLs.

- for repair:
- access to all the emission related failures and their parameters.  
Important is to keep Euro VI OBD based on WWH - OBD.

Tests conducted under real conditions indicates that emission of toxic components is greater than in the case of tests on a chassis dyno. While using on - board equipment it is always possible to know precisely the impact of the malfunction or a deterioration on the actual toxic emission from a vehicle. Investigations in Poland are underway.

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