# EXPERIMENTAL RESEARCHES REGARDING THE PHENOMENON OF ENVIRONMENTAL POLLUTION BY VEHICLES

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**Abstract:** The paper brings forward the study of systems which reduce the amount of modern pollution coming from vehicles which are destined for transportation. The technical and construction characteristics of vehicles are presented as well as the tests which they undergo for the assessment of their efficiency. It is necessary to test emissions in order to verify if the pollution norms written in the operation and maintenance book of the vehicle are respected as well as to ensure an optimum operation of the motor and of the environment.

**Key-words:** normative, reduce emissions, lambda sensor, catalytic converters, EGR, SCR.

## 1. GENERAL CONSIDERATIONS

When the engine of a car is running, several types of gases and particles are emitted, having therefore a negative impact on the environment. A special interest is born by carbon dioxide, a greenhouse gas; hydrocarbons – a dozen of volatile organic compounds, some of which are known as cancerous agents, nitric oxides, sulphur oxides, as well as suspended powders, minute solid particles such as metals and smut. Other health affecting emissions and which create the smog include ozone and carbon monoxide. The good news is that, although the number of cars on the roads has increased, air quality today is better than it used to be in the 1970s, due to the laws brought into force during that period. In fact, lead emissions from vehicles have been completely eradicated due to the elimination of lead petrol.

Car emissions may affect the environment in several ways. Cars emit

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greenhouse gases such as carbon dioxide, which contributes to global warming. Some of the polluting substances found in air and suspended powders emitted by cars are laid on the ground and end up in surface waters reaching therefore the food chain; these substances may also affect the respiratory, immunity and neurologic systems of animals; nitric oxides and sulphur oxides have a major contribution to acid rains which modify the pH of water bodies and soil.

### 1.1. Polluting emissions verification norms. SIE vehicles running on petrol, LPG or CNG

When *emissions are not limited by a perfected regulation system*, such as a three component catalyser managed by the lambda sensor, the following verifications are carried out

- Visual inspection of the exhaust system, in order to check if it is complete and in a satisfactory state and there are no leaks;
- Visual inspection of all the emissions' regulating equipments installed by the producer, in order to check if it is complete and in a satisfactory state and there are no leaks.
- After having brought the engine to normal operating parameters, considering the recommendations of the producer, the concentration of the emissions of carbon monoxide (CO) and hydrocarbons (HC) is measured, with the engine idle running and the gear stick in neutral (in the case of automated gearboxes, the gear changing stick shall be put in "Neutral" or "Park" position).
- The maximum admissible CO content in exhaust fumes shall not exceed the following values:
  a) For vehicles produced up to 1986: CO (cor): 4.5% in vol.;
  b) For vehicles produced after 1987: CO (cor): 3.5% in vol.
- The maximum admissible HC content in exhaust fumes shall not exceed 1000 ppm.
- HC measurements are not carried out for vehicles which run on LPG or GNC.
- The control of engines running both on petrol and LPG or GNc shall be made for both operating solutions.

This type of verification is not carried out for hybrid vehicles and for two-cycle engine vehicles.

If *emissions are controlled by a perfected regulating system*, such as three component catalyser managed by the lambda sensor, the following verifications are carried out:

- Visual inspection of the exhaust system, in order to check if it is complete and in a satisfactory state and there are no leaks;
- Visual inspection of all the emissions' regulating equipments installed by the producer, in order to check if it is complete and in a satisfactory state

and there are no leaks.

- Determining the efficiency of the emissions' regulating system by measuring values of the lambda sensor and the CO and hydrocarbons emissions in the exhaust fumes. For each of the two tests the engine is brought to normal operating conditions, according to the producer of the vehicle.
- Emissions at the outlet of the exhaust pipe – limit values
- The maximum admissible CO content of the exhaust fumes shall not exceed the following values:
  a) Measurements made for an idle run, with the clutch on and the gear lever on zero (in the case of automated gearboxes it should be on "Neutral" or "Park"): the maximum admissible CO content in the exhaust fumes shall not exceed the value CO (cor): 0.5% in vol. For Euro 3 and 4 vehicles; id shall not exceed the value CO (cor): 0.3% in vol. For Euro 5 and 6 vehicles;
  b) Measurements made for an accelerated idle running motor, at least 2000 revs/min and maximum 3000 revs/min, with the clutch on and the gearshift on zero (in the case of automated gearboxes it should be on "Neutral" or "Park"): the maximum admissible CO content in the exhaust fumes shall not exceed the value CO (cor): 0.3% in vol. For euro 3 and 4 vehicles; it shall not exceed the value CO (cor): 0.2% in vol. For euro 5 or 6 vehicles
- Lambda: 1±0.03
- The maximum admissible HC content of the exhaust fumes for an accelerated idle run 100 ppm.
- HC measurements are not carried out for vehicles which run on LPG or GNC.
- The control of engines running both on petrol and LPG or GNC shall be made for both operating solutions.
- For vehicles equipped with an onboard diagnostics system (OBD), the correct operation of the emissions' control system may be verified by reading the OBD and checking that it operates accordingly instead of carrying out the measurements according to the specified requirements.

This type of verification is not carried out for hybrid vehicles.

### 1.2. Testing processes using the gases analyser

#### *1.2.1. Measuring the carbon oxide concentration*

The measurement of the CO concentration in exhaust fumes may be carried out using electrical or IR analysers. Most of the gases analysis methods are based on thermal conductibility of the mixture of gases, and the devices used may be either with combustion or without combustion.

Although a lot more simple, *combustionless analysers* are used with an acceptable precision especially while measuring the concentration of gases which have a thermal conductibility much more different compared to other gases ($H_2$, $CO_2$, $SO_2$, etc.). The used sensors are heat resistant with metallic line or termistors.

*Electric combustion analysers (figure 1)* allow a more exact determination of the concentration of combustible gases (CO, $CH_4$, $H_2$, ethylene, fuel vapours), using heat reaction produced through catalytic burning.

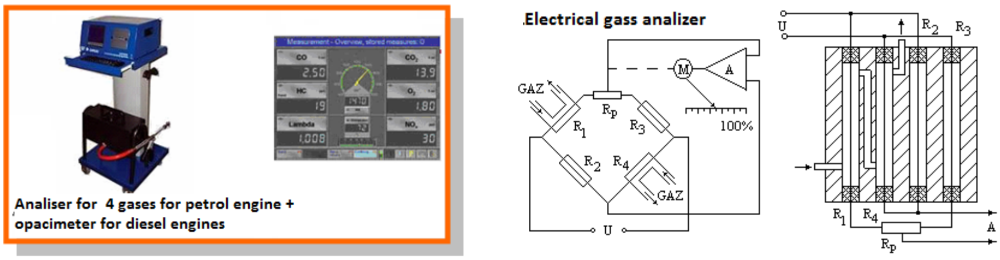


**Fig. 1.** Electric combustion analyser

Other gas analysers use the *spectrometry method* which is based on the properties of substances to absorb, reflect, dissipate or selectively refract different types of radiation. These radiations may have a large frequency spectrum, from an audio level (10 kHz) to X and γ radiations. The gas analysers using *infrared absorption* are largely used. The non-elementary gases are characterised through specific absorption spectrums.

*Engine testing methodology* using infrared radiation electric analysers supposes that two preliminary conditions be met: the engine ignition installation be in a good technical state, and the trajectory of the gases from the motor to the exhaust pipe be air tight.

Before the trial begins, the engine is heated up to the normal operation temperature (the oil has to be at minimum 60 $^oC$), and the indicator needle of the analyser is brought to zero. The sampling sensor is introduced then onto the exhaust pipe of the vehicle, on a depth of 30 cm, in order to avoid possible air imixtures produced by the pulsation of gases, after which the connection of the sensor to the device is made and the analyser is then turned on. The analyser allows the verification of the quality of the mixture and CO concentration while idling, average RPM and accelerated. While idling, the readings are made by leaving starting the warm engine and leaving it run at the prescribed rev count prescribed by the producer, until the indications of the analyser stabilise (90 – 120 s). Therefore, the CO concentration does not have to exceed either the limit indicated by the constructor, or the legal admissible limit, namely 4.5%.

The causes for superior concentrations are following:

- the high content of fuel in the mixture, due to the faulty setting while idling
- the wear of nozzles

- the blockage of the air channels of the idling circuit
- a high level of fuel in the constant level chamber
- the high pressure of the fuel charged by the pump
- an extremely dirty air filter

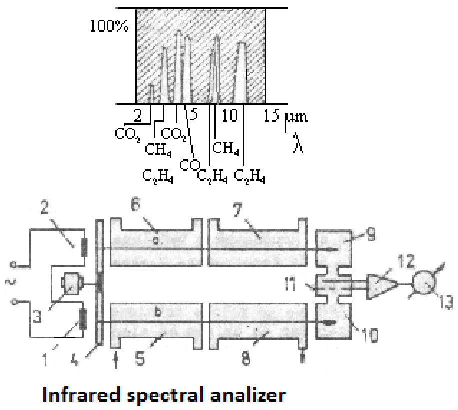

**Fig. 2.** Infrared radiation spectral analyzer

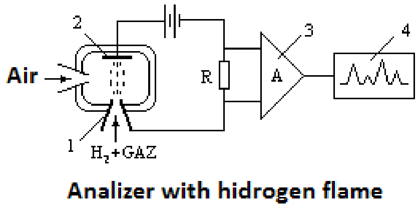

**Fig. 3.** Hydrogen flame analyzer

The revolution count is progressively increased from 2000 – 3000 rpm, observing if the indicator of the analyser goes towards the area of poor mixtures in relation to the value read while idling, respectively the CO concentration decreases. The stabilisation of the indicator for values of the dosage smaller than 12, indicate a rich mixture delivered to the engine for average revolutions per minute, while if the indications of the analyser stabilise for large values of 14, meaning that the mixture is too poor.

Following this verification, the revolution of the engine is reduced to 1000-1400 rpm and it is abruptly accelerated. The CO percentage needs to increase rapidly, while the indication of the device shall occur in the area of rich mixtures for an engine operating normally. After having seized the acceleration regime, the indications of the analyser need to come back to the normal values corresponding to the idle run.

*1.2.2. Measuring the hydrocarbons concentration*

The methods used for measuring the hydrocarbons concentration in exhaust fumes are based on either an infrared technology or a technology using flame ionisation. A special sensitivity is obtained for the *substance analysis with a hydrogen flame*. By burning into the air, clean hydrogen does not practically produce ions and therefore the resistance of the hydrogen flame is quite large ($10^{12}...10^{14}\Omega$). If the analysed gas is also brought together with the hydrogen, then the ionisation of its molecules occurs and also the more the resistance between electrodes (1) and (2) of the transducer decreases the more the concentration of the analysed gas increases. As the cost of ionisation analysers is increased, they are used only for research, in current practice the use infrared ones is preferred.

*1.2.3. Measuring the concentration of nitric oxides*

Infrared of chemical-luminescence analysers may be used, the first ones being preferred although their performances are decreased with regards to sensitivity, precision and measuring domain, due to a more accessible price.

*1.2.4. Measuring the carbon dioxide concentration*

The operation becomes useful when the combustion quality of the engine is analysed. Usually, infrared analysers are used.

*1.2.5. Measuring the oxygen concentration*

## 3. PRACTICAL MEASUREMENTS

The assessment of the state of the auto park depending on the degree of pollution of vehicles, the analysis carried out based on the recorded measurements between 2013 and 2014. The measurements of the polluting emissions consist in the analysis of exhaust fumes with the help of the opacity meter. This type of device uses the measurement principle of light dispersion, a high resolution technology for the measurement of the opacity.

Table comprising the measurements of the exhaust fumes recorded at an PIS of Petrosani in a working day with an average number of clients.

*Table 1.* Measurements of the exhaust at a PIS in Petrosani

| No. | Fuel | Temp [$^0$C] | Revolutions [RPM] | $O_2$ | $CO_{cor}$ | Lambda Coef. | HC | Result |
|---|---|---|---|---|---|---|---|---|
| 1 | Petrol | 66 | 950 | 0.01 | 0.00 | 0.997 | 57 | PASS |
| | | 66 | 2293 | 0.18 | 0.01 | 1.005 | 49 | |
| 2 | Petrol | 66 | 766 | 0.09 | 0.00 | 1.003 | 24 | PASS |
| | | 66 | 2201 | 0.12 | 0.00 | 1.002 | 67 | |
| 3 | Petrol | 69 | 951 | 0.75 | 0.03 | 1.031 | 31 | **REJECTED** |
| | | 69 | 2357 | 0.84 | **2.00** | **0.968** | **260** | |
| 4 | Petrol | 68 | 767 | 0.007 | 0.01 | 1.003 | 12 | PASS |
| | | 68 | 2259 | 0.09 | 0.01 | 1.003 | 13 | |
| 5 | Petrol | 69 | 778 | 0.38 | 0.25 | 1.003 | 132 | **REJECTED** |
| | | 69 | 2369 | 0.53 | **0.51** | 0.999 | **193** | |
| 6 | Petrol | 69 | 869 | 1.16 | **0.54** | 1.023 | 267 | **REJECTED** |
| | | 69 | 3160 | 0.98 | **0.50** | 1.015 | **286** | |
| 7 | LPG | 79 | 857 | 1.81 | 0.48 | 1.055 | 134 | PASS |
| | Petrol | 79 | 850 | 1.87 | 0.49 | 1.067 | 127 | |
| 8 | Petrol | 67 | 778 | 0.31 | 0.26 | 0.999 | 141 | **REJECTED** |

| No. | Fuel | Temp [$^0$C] | Revolutions [RPM] | $O_2$ | $CO_{cor}$ | Lambda Coef. | HC | Result |
|---|---|---|---|---|---|---|---|---|
| | | 69 | 2490 | 0.32 | 0.25 | 1.000 | **140** | |
| 9 | LPG | 69 | 764 | 0.75 | 0.01 | 1.029 | 22 | PASS |
| | | 71 | 2300 | 0.11 | 0.01 | 1.003 | 25 | |
| 10 | Petrol | 62 | 769 | 0.01 | 0.01 | 1.000 | 14 | PASS |
| | | 62 | 2039 | 0.04 | 0.01 | 1.001 | 17 | |

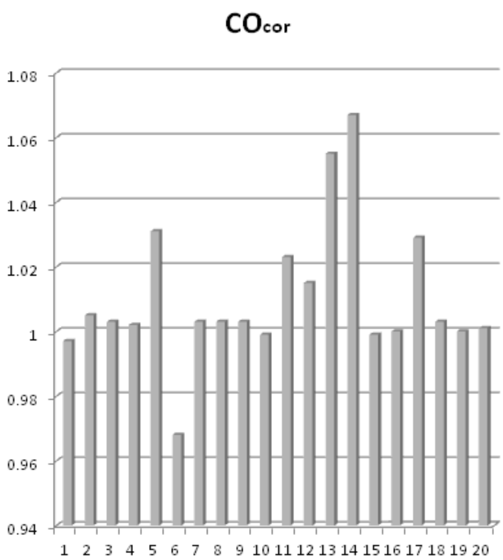


**Fig. 4.** $CO_{cor}$ Measurement Graph

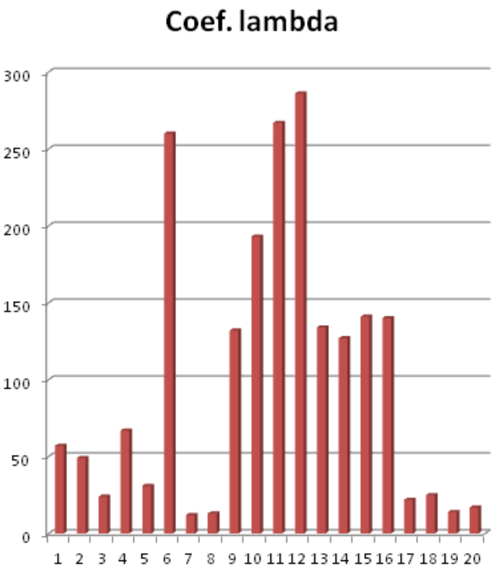


**Fig. 5.** Lambda Coef. Measurement Graph

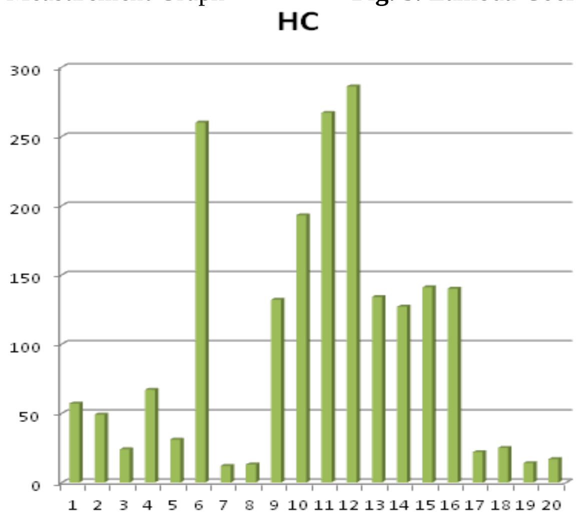


**Fig. 6.** Hidro-Carbons Measurement Graph

Practical example of exhaustion fumes measurement are presented in figures 7, 8, 9, 10.

**Fig. 7.** Placing the measurement sensors

**Fig. 8.** Idling measurements


**Fig. 9.** Accelerated idle run measurements


**Fig. 10.** Exhaust fumes measurement sensor

## 4. CONCLUSIONS

If the reduction with 30% of polluting emissions is not realised by 2030 and with 60 – 80% by 2050 compared to the level of 1990, the consequences of the environmental impact may be irreparable.

The best applicable methods for the fight against global warming are the increase to a double of the investments in the field of green, non-polluting, technologies and the increase of costs for the emissions of future gases to force the reorientation towards alternative non-polluting sources.

The comparative analysis of the two types of fuel – spark or compression – notices that in general ICEs realise a more reduced pollution level, managing to do so by the genesis of nitric oxides, the emission of CO being practically insignificant. Due to the adding of additives in diesel fuels, the ICE emissions contains sulphur dioxide which constitutes a highly aggressive pollutant, contributing to the emission of the stinging smell of burnt gases. Smoke as well, characteristic to ICE is extremely harmful, being limited by the basic conditions regarding environmental quality. Nowadays, the most performant equipments – but also the most expensive ones, may ensure an efficient reduction of polluting emissions in the environment, are also based on the chemical principle on which the catalytic reactions of the compound of exhaust fumes occur, in the presence of favouring factors (pressure, temperature, etc.).

Additional measurements for the reduction of vehicle pollution.

The reduction of air pollution may be realised in three different ways, with the following priority:

- the reduction of traffic;
- the change of traffic: from those type of traffic with a large impact on air pollution or the environment and the use of trains for a more reduced type of impact (for instance rail transport, bicycles, etc.;
- traffic improvement: the reduction of air pollution through technical solutions or through a better traffic management.

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