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(71) Applicant: **CRMT**
69570 Dardilly (FR)

(72) Inventor: **GUIOT, Bernard**
69250 ALBIGNY SUR SAONE (FR)

(74) Representative: **Nony**
11 rue Saint-Georges
75009 Paris (FR)

(54) **A SYSTEM AND METHOD FOR ACCURATELY MEASURING NOX AND NH3 CONTENTS IN EXHAUST FUMES**

(57) The present invention relates to a system (1) for accurately measuring NOx and NH_3 contents in exhaust fumes, including for stoichiometric combustion engines, comprising:
- an exhaust (2) to evacuate exhaust fumes connected at its free end to an exhaust evacuation outlet (4),
- at least one first sensor (3) adapted to measure NOx and O_2 contents, said first sensor being placed upstream from the exhaust evacuation outlet,
- at least one second sensor (61) adapted to measure NOx and O_2 contents, said second sensor being placed downstream from the exhaust evacuation outlet and,
- at least one third sensor (62) adapted to measure NH_3, said third sensor being placed downstream from the exhaust evacuation outlet.

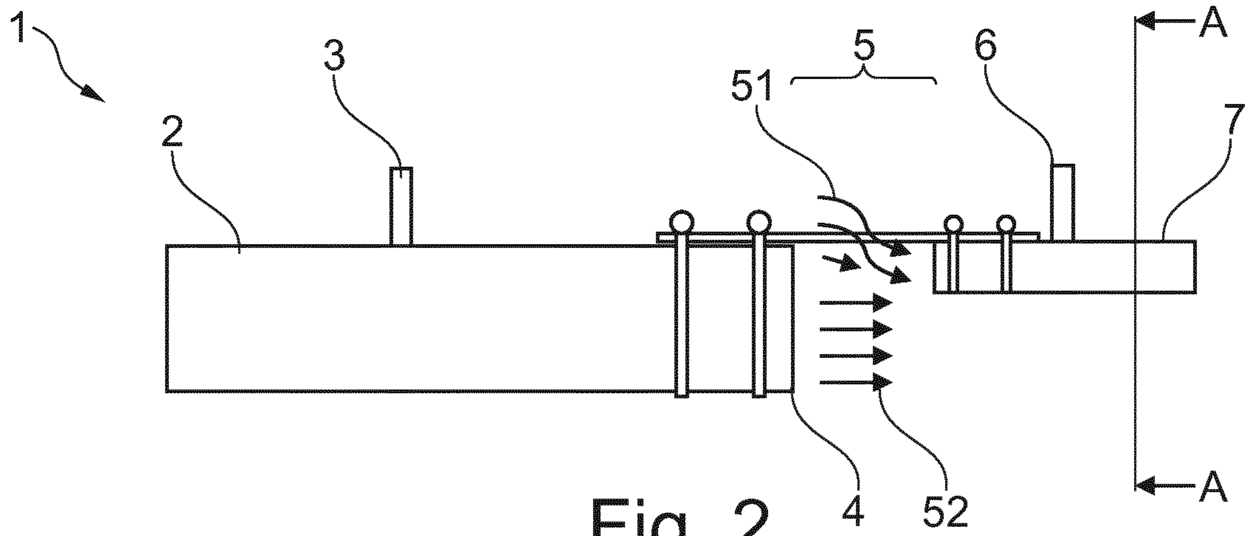

Fig. 2

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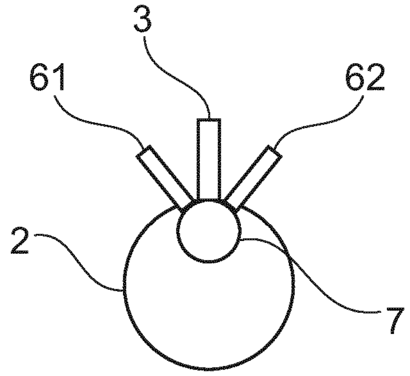


Fig. 2A

Description

TECHNICAL FIELD

[0001] The present invention relates to a system and method for accurately measuring the nitrogen oxides, i.e. NOx and ammonia i.e. NH_3 contents in exhaust fumes.
[0002] More particularly, it concerns a novel arrangement of sensors to measure NOx and NH_3 in exhaust fumes that can be produced by combustion.
[0003] Throughout this application, the term "exhaust fumes" designates gases formed during the combustion process for example in vehicle engines, and include among others nitrogen oxides (NOx) such as NO, NO_2 and the like and ammonia (NH_3).
[0004] Throughout this application, the term "sensor" designates a module that can detect the presence and content of a particular gas and process the signal to convert said signal into a usable data.
[0005] Throughout this application, the term "exhaust" designates a duct or a pipe through which exhaust fumes from a combustion process are evacuated.
[0006] Throughout this application, the term "interfere" when used for a gas designates the phenomena by which a given gas can alter the measurement of a target gas. Cross-sensitivity is one example of interference.
[0007] Throughout this application, the term "downstream" and "upstream" are used with reference to the exhaust evacuation outlet.

BACKGROUND ART

[0008] The ever growing desire by policy makers to reduce the emissions from vehicle engines is followed by tougher regulations on emitted gases. Particularly, the emissions of NOx are closely monitored by regulators as these gases were identified as pollutants. Hence, the accurate monitoring of NOx is an important aspect.
[0009] The emissions from exhaust can be measured using different methods and instruments.
[0010] Portable emissions measurement system (PEMS) devices can give reliable NOx contents in exhaust fumes. These devices are designed for measurement campaigns and the bulkiness of such devices make them not suitable for long term measurements and for control systems on vehicles.
[0011] Sensors on the other hand are commonly used for long term measurements and for engine controls. Commercially available NOx sensors can give an accurate measurement of NOx contents in exhaust fumes, but in some circumstances NH_3 also present in the exhaust fumes can interfere with NOx measurements. The cross-sensitivity of NOx sensors to NH_3 can thus give false readings.
[0012] The inventors have compared the NOx contents measured by a PEMS commercialized by SENSORS, INC. under the designation SEMTECH and by NOx and O_2 sensors under the designation EGS-NX commercialized by the BOSCH company. The measurements were carried out on a NH_3 non-emitting vehicle.
[0013] The data collected by the PEMs and the NOx and O_2 sensors are presented on Figure 1A and 1B. The two signals are almost identical. On the data recorded by the PEMS the signal is filtered by the long length of the sampling line while the NOx recorded by the sensor is seen more dynamic. Nevertheless the cumulative contents of NOx obtained with the two methods overlap almost perfectly. If NH_3 interference is suppressed, therefore NOx sensors alone can give reliable NOx contents measurements almost as accurate as the ones obtained with a PEMS. The robustness and the relative lower cost of sensors are also an advantage over PEMS.
[0014] The challenge also consists to obtain accurate measurements for stoichiometric combustion engine, because NOx and NH3 sensors are not designed to operate in such conditions.
[0015] The ECM company has already commercialized a NOx and NH_3 analyzer following this strategy. The analyzer uses two NOx sensors placed in series. The first sensor is used to measure the combined NOx and NH_3 contents in the raw exhaust fumes i.e. untreated exhaust fumes. The second sensor measures the NOx contents in treated exhaust fumes where the NH_3 is removed using a NH_3 scrubber. The difference between the contents measured by the first sensor and the contents measured by the second sensor gives the NH_3 contents. One of the drawbacks of such analyzer is the fact that the NH_3 scrubber needs to be regenerated now and then, cupric sulfate is used to prepare the scrubber solution. The system also requires a sampling pump which makes combined with the NH_3 scrubber the analyzer bulky.
[0016] In a similar approach, WO2016/068831 patent application discloses a system with a NH_3 oxidation catalyst layered on top of a NOx sensor. The oxidation catalyst converts the NH_3 present in the exhaust fumes into N_2 while leaving the NOx intact, which can then be analyzed without the interference of NH_3. One of the drawback of this system is related to the deactivation process of catalysts on the long run, which eventually will require regeneration or replacement of the catalyst.
[0017] There is therefore a need to improve the systems for the accurate measurement of NOx and NH_3 contents in exhaust fumes, in particular to effectively use robust and cost effective sensors for reliable long term measurements

and control systems.

[0018] The general aim of the invention is to meet at least partially this need.

SUMMARY OF THE INVENTION

[0019] To that end, a first subject of the present invention is a system for accurately measuring NOx and NH_3 contents in exhaust fumes including for stoichiometric combustion engines, comprising:

- an exhaust to evacuate exhaust fumes connected at its free end to an exhaust evacuation outlet,
- at least one first sensor adapted to measure NOx and O_2 contents, said first sensor being placed upstream from the exhaust evacuation outlet,
- at least one second sensor adapted to measure NOx and O_2 contents, said second sensor being placed downstream from the exhaust evacuation outlet,
- at least one third sensor adapted to measure NH_3, said third sensor being placed downstream from the exhaust evacuation outlet.

[0020] Thus, the invention consists essentially in measuring NOx and O_2 contents in exhaust fumes at two locations, respectively inside the exhaust and downstream from the exhaust evacuation outlet. NH_3 contents in the exhaust fumes are also measured downstream from the exhaust evacuation outlet.

[0021] The NOx contents measured by the first and second sensors are actually measuring the combined NOx and NH_3 contents because of the cross-sensitivity of the sensors to said gases.

[0022] In order to calculate the NOx contents emitted by the exhaust two approaches are envisaged. The first approach is to subtract the NH_3 contents measured by the third sensor to the NOx contents measured by the second sensor. This gives the NOx contents downstream from the exhaust evacuation outlet.

[0023] By using the O_2 contents measured by the first upstream sensor and the second downstream sensor, it is possible to calculate the dilution ratio of the exhaust fumes from the exhaust and after being evacuated through the exhaust evacuation outlet. The NOx content inside the exhaust can then be calculated using the dilution ratio.

[0024] The second approach is to calculate first the NH_3 contents in the exhaust using the dilution ratio and the NH_3 contents measured by the third sensor. By subtracting the calculated NH_3 contents to the NOx contents measured by the first sensor the NOx contents without the NH_3 contents can be determined.

[0025] The measured NOx and NH_3 contents can be used to monitor the performance of the combustion process for example in vehicle engines or other combustion processes. But also to evaluate the efficiency of a treatment process of exhaust fumes. Indeed, the measured contents can give for example information on the performance of a three way catalytic converter.

[0026] The measured contents can also be used for control systems. The data can be transmitted to a control unit to fine tune the different parameters for the exhaust fumes treatment processes or the performance of a combustion process.

[0027] The collected data can be stored on a memory unit for future studies or transmitted in real time intermittently to another location via wireless communications, which can be a telematics system.

[0028] In an advantageous embodiment, the second and third downstream sensors are placed in such a way that the exhaust fumes reaching said sensors are diluted with at least one gas not interfering with the sensors. Preferably, the diluting gas is air.

[0029] In a first variant, the second and third downstream sensors are placed in a sensor housing designed to allow exhaust fumes reach the sensors while protecting the sensors from external factors.

[0030] Alternatively, the exhaust evacuation outlet is configured as a venturi tube having an air inlet at the constriction. Preferably, the venturi tube has a protective hood on the air inlet.

[0031] According to an advantageous embodiment, the system comprises a memory unit to store collected data of NOx, NH_3 and O_2 contents. Preferably, the system comprises a transmitter to send the collected NOx, NH_3 and O_2 data to an engine control unit or to another location by a wireless protocol. Preferably, the transmitter is a telematics system.

[0032] In another aspect, the invention concerns an assembly comprising:

- an internal combustion engine producing exhaust fumes which are evacuated to the external environment through an exhaust connected to said engine.
- a system according to the invention in which the exhaust is the exhaust of the engine.

[0033] In a variant, the engine of the assembly is adapted to operate on a stoichiometric mixture of air and fuel, the fuel is preferably natural gas.

[0034] In another variant, the assembly has a three-way catalytic converter to treat the fumes leaving the engine before reaching the exhaust.

[0035] The invention concerns also, a method for accurately measuring the NOx and NH_3 contents in exhaust fumes comprising the following steps:

1/ measuring the NOx and O_2 contents in exhaust fumes by a at least one first upstream sensor (3) placed inside the exhaust,
2/ measuring the NOx and O_2 contents in the exhaust fumes by at least one second sensor and measuring the NH_3 content by at least one third sensor, said second and third sensors are placed downstream from the exhaust evacuation outlet,
3/ calculating the instantaneous dilution factor of O_2 contents, between the first upstream sensor and the second downstream sensor,
4/ subtracting the NH_3 content measured by the third sensor and corrected with the calculated dilution factor to the NOx content measured by the second sensor and corrected with the calculated dilution factor, or subtracting the NH_3 content measured by the third sensor and corrected with the calculated dilution factor to the NOx contents measured by the first sensor and corrected with the calculated dilution factor.

[0036] The invention concerns also the use of a system according to the invention for control systems of a combustion process or an exhaust treatment process.
[0037] In another aspect, the invention concerns a vehicle comprising a system according to the invention.
[0038] The system according to the present invention can be used on exhaust fumes emanating from the combustion of fossil fuels or any other type of combustion susceptible to produce NH_3 and NOx or simply containing these gases.
[0039] The system can be used particularly on vehicles with an internal combustion engine using gasoline, diesel, natural gas, biogas, synthetic fuel and multiple fuels.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] Other advantages and characteristics of the invention will emerge more clearly upon perusal of the detailed description of exemplary embodiments of the invention given as an illustration and not a limitation, making reference to the following figures, in which:

- Figure 1A and 1B are graphs presenting the instantaneous and the cumulative NOx contents measured by a NOx and O_2 sensor and a PEMS analyzer for a NH_3 non-emitting engine, according to the prior art;
- Figure 2 is a schematic side view of an example of a system according to the invention for measuring NOx and NH_3 in exhaust fumes;
- Figure 2A is a cross sectional view of system of Figure 2 according to A-A axis;
- Figure 3 is a schematic side view of another example of a system according to the invention, with an exhaust having a Venturi tube at its free end;
- Figure 4 is a graph presenting the engine rpm and the speed of a vehicle during a given trajectory, said vehicle being equipped with a system according to the invention;
- Figures 5A and 5B are graphs presenting the O_2 contents measured by the first sensor upstream from the exhaust evacuation outlet and by the second sensor downstream from the exhaust evacuation outlet, and the calculated dilution ratio;
- Figure 6A to 6D are graphs presenting the instantaneous and the cumulative NOx contents measured by the first and second sensors corrected by the dilution ratio;
- Figures 7A and 7B are graphs presenting the NOx contents measured by the second downstream sensor and a PEMS analyzer, and the NH_3 contents measured by the third sensor downstream sensor;
- Figure 8 is a graph presenting the cumulative NOx contents as measured by the second downstream sensor and the PEMS and the contents of NOx subtracted of the NH_3 contents measured by the third downstream sensor, the contents measured by the downstream sensors are corrected by the dilution ratio.

[0041] For clarity reasons, the same elements of a NOx and NH_3 measurement system will have the same the numeral references.

DETAILED DESCRIPTION OF THE INVENTION

[0042] Other advantages and features of the invention will become more apparent upon reading the detailed description of exemplary implementations of the invention, given as illustrative and non-limiting examples with reference to the figures.
[0043] The NOx formation from combustion involves multiple step reactions and depend on the temperature range, the stoichiometric ratio (air to fuel) and the nitrous species present in the combustion zone.

[0044] There are basically three recognized mechanisms for NOx formation: thermal, fuel and prompt.

[0045] Thermal NOx is formed when atmospheric oxygen and nitrogen react at elevated temperatures.

[0046] Fuel NOx is formed when a fuel containing organically bound nitrogen reacts with oxygen.

[0047] Finally, prompt NOx is formed when hydrocarbon radicals react with atmospheric nitrogen to produce HCN and is oxidized to NOx.

[0048] In order to reduce the emission of NOx in exhaust fumes nowadays vehicles are equipped with systems to either convert or trap NOx gases.

[0049] For example for gasoline and natural gas fueled vehicles a three way catalyst (TWC) is used to simultaneously convert NOx, unburned hydrocarbons and carbon monoxide (CO) into less harmful gases. Under slightly lean operation the three way catalyst oxidizes hydrocarbons (HC) and CO and under slightly rich environment NOx species are reduced.

[0050] But, in some cases, operating under rich conditions favors a water gas shift and a steam reforming reactions that form hydrogen according to the following reaction paths:

$$CO + H_2O \rightarrow CO_2 + H_2$$

$$HC + H_2O \rightarrow CO_2 + H_2$$

$$2NO + 5H_2 \rightarrow 2\ NH_3 + 2H_2O$$

$$2NO + 2CO + 3H_2 \rightarrow 2NH_3 + 2CO_2$$

[0051] The hydrogen molecules can further react with NOx and CO to form NH_3. This kind of emission was observed in diesel and natural gas engines.

[0052] For diesel fueled vehicles additional treatments can be used to reduce efficiently NOx contents. To this end Selective Catalytic Reduction (SCR) systems were suggested as viable technology and are already integrated in diesel vehicles. Systems implementing the SCR technology use NH_3 as the reducing agent to convert NOx with a dedicated catalyst. A urea solution can be used to generate the NH_3 when decomposed. In order for the SCR system to perform efficiently the right amount of NH_3 must be injected, but the injected amount of NH_3 must also be monitored to prevent over-dosing the SCR system and causing the emission of NH_3 to the atmosphere (referred to as NH_3-slip).

[0053] When a three way catalyst is used, the system according to this invention can give reliable NOx and NH_3 measurements. Using this information an engine control unit (ECN) or other control units can fine tune the exhaust fumes treatment process.

[0054] In the case where a SRC system is used, the system according to the present invention can be used to adapt the amount of NH_3 injected in the system for efficient conversion of NOx gases without NH_3-slip.

[0055] Figure 2 shows a system 1 for the measurement of NOx and NH_3 in exhaust fumes embodying the principle of the present invention.

[0056] The system 1 according to the invention comprises an exhaust 2 adapted to evacuate exhaust fumes 52 produced by the combustion of a fuel.

[0057] At its free end the exhaust 2 has an exhaust evacuation outlet 4 for the evacuation of exhaust fumes to the ambient atmosphere.

[0058] At least one first sensor 3, adapted to measure NOx and O_2 contents, is installed upstream from the exhaust outlet 4. The first sensor 3 can be a unique sensor capable of measuring NOx and O_2 at the same time or includes two separate sensors one dedicated to NOx measurements and another one dedicated to O_2 measurements.

[0059] Before reaching the sensors housing 7 which is installed downstream from the exhaust evacuation outlet, the exhaust fumes 52 come into contact in the zone 5 with a diluting gas 51. This diluting gas must not interfere with the NOx and NH_3 measurements. In a particular embodiment, the diluting gas can be air. The sensor housing 7 is designed to allow exhaust fumes reach the sensors while protecting the sensors from external factors.

[0060] Inside the sensor housing 7, downstream from the exhaust evacuation outlet 4, a pair of sensors 6 is installed to measure the NOx, O_2 and NH_3 contents.

[0061] As illustrated in figure 2A, the pair of sensors 6 inside the sensor housing 7 includes two sensors 61, 62, each separately dedicated for NOx and O_2 and for NH_3 measurements. More particularly, the sensor for NOx and O_2 contents measurement is referred to as the second sensor 61 and the sensor for NH_3 contents measurements is referred to as the third sensor 62. The two sensors are preferably placed at an equal distance from the exhaust evacuation outlet.

[0062] In another embodiment illustrated on figure 3, the exhaust 2 has at its free end a venturi tube 8 with a diluting gas inlet 9 at the constriction of the venturi tube. Indeed, the diluting gas is introduced in the exhaust by suction caused by the venturi effect. Preferably, the venturi tube 8 has a protective hood 100 on the air inlet which allows to protect from the external environment, and hence to the external conditions, notably humidity, rain...

[0063] The exhaust fumes 52 can thus be diluted in the zone 5 with a diluting gas 51 before reaching the sensor 6 installed downstream from the venturi tube.

[0064] In a particular embodiment the diluting gas can be air. Similarly as in the previous embodiment the sensor 6 can be two sensors, each separately dedicated for NOx and O_2 and for NH_3 measurements. Also, a first sensor 3 adapted to measure NOx and O_2 contents is installed upstream from the venturi tube 8.

Example

[0065] The following example illustrates how the system according to the present invention can be implemented on a vehicle.

[0066] In this example, the measurements presented here were recorded on a vehicle with a truck trailer of 18 tons loading equipped with a 9 liter natural gas engine.

[0067] The composition of the natural gas used in the vehicle for the measurements of emissions is presented on Table 1. Methane is the main component of the gas used with a molar percentage of 90.594. The natural gas used also contains ethane and other alkanes, generally the measured concentrations of the different components of the natural gas are within a range of commonly used natural gases.

[0068] Other characteristics such as the carbon to hydrogen ratio (C/H), the molecular weight and the density also remain within a range of commonly used natural gases.

Table 1

Component	Molar %
N_2	2.632
CH_4	90.594
CO_2	1.214
C_2H_6	4.685
C_3H_8	0.542
iC4	0.230
nC4	0.089
neoC5	0.003
iC5	0.043
nC5	0.021
C6	0.005
Total	100.058
C/H	3.938
Molecular weight	17.681 g/mol
Density	0.791 kg/m^3

[0069] The composition the natural gas used is assumed to be stable during the measurement campaign.

[0070] The engine is operating with stoichiometric air-fuel mixture without Enhanced Gas Recovery (EGR) and is equipped with a three way catalytic converter to treat exhaust fumes.

[0071] The Air-fuel ratio also referred to as AFR defines the ratio between the mass of air and the mass of fuel. The air-fuel ratio will have an impact on the energy released and the extent of the combustion. Indeed, depending on the amount of air the combustion reaction can be total, partial or none.

[0072] A complete combustion occurs when all the fuel is burned and there is no unburned fuel in the exhaust fumes. This ideal combustion is also called stoichiometric air to fuel ratio. For example, the stoichiometric air to fuel ratio for a combustion with natural gas is an AFR of 17: 1. In other words, 17.2 kg of air is needed for the total combustion of 1 kg of natural gas. The value of the coefficient λ (lambda) defines the ratio of actual AFR to stoichiometry for a given mixture. For the given example when the AFR ratio is equal to 16.97:1, the λ equals to 1.

[0073] Since the engine for this example is operating with a stoichiometric AFR ratio, the λ equals to 1.

[0074] On the exhaust a first sensor 3 adapted to measure NOx and O_2 contents is installed upstream from the exhaust evacuation outlet. In the example, the sensor is one commercialized by the BOSCH company under the designation

EGS-NX.

[0075] The sensor is in contact with exhaust fumes produced by the internal combustion of natural gas and treated by a three way catalytic converter.

[0076] A second sensor 61 adapted to measure NOx and O_2 contents is installed downstream from the exhaust evacuation outlet and finally a third sensor 62 adapted to measure NH_3 contents is also installed downstream from the exhaust evacuation outlet. The distance between the upstream and downstream sensors is one meter, the dephasing is assumed to be negligible.

[0077] The second and the third sensors are placed in such a way that the exhaust fumes reaching them is diluted with the ambient air, such as shown on figures 2 and 2A.

[0078] In order to control the NOx contents measured by the sensors a sampler with a flow meter is installed in the exhaust fume and is connected to a PEMS under the designation SEMTECH commercialized by SENSORS, INC.

[0079] The measurements recorded by the PEMS are assumed to be the accurate measurements of NOx contents in the exhaust fumes.

[0080] Figure 4 presents the engine rpm and the speed of the vehicle during the measurements. It was previously noticed that the highest NH_3 emissions were recorded when the engine was operating at a stabilized regime for example on highways.

[0081] In order to have measurements on different regimes, during the test a route with different driving speed was chosen. The different measurements were rephased using the engine rpm measurements.

[0082] The O_2 contents measured by the first and the second sensors are presented on figure 5A, this data is used to calculate the dilution ratio of the exhaust fumes by the ambient air between the first sensor and the second sensor. The following formula was used to calculate the dilution ratio:

$$\text{Dilution ratio} = \frac{21 - O_{2\,\text{first sensor}}}{21 - O_{2\,\text{second sensor}}}$$

[0083] In this ratio, the number 21 represents the ratio of oxygen in natural air (vol%).

[0084] The calculated dilution ratio is presented on figure 5B, the values remain below 50% and rarely goes below 2%.

[0085] Using this dilution ratio, the NOx contents measured by the second sensor were compared to the NOx contents measured by the first sensor.

[0086] The contents measured by the first and second sensors actually measured the NOx content and the NH_3 which might be present in the exhaust fumes.

[0087] The comparison of the contents are presented on figures 6A to 6C. The contents recorded by the first sensor saturated at 3000 ppm which is obvious since the sensor used is designed to accurately measure NOx levels between 0 ppm and 1650 ppm. Nevertheless, the trend of curves recorded by the two sensors are almost identical for NOx levels below 3000 ppm.

[0088] The cumulative NOx contents measured by the first and the second sensor are presented on figure 6D. The difference observed between the two curves is explained by the saturation of the first sensor for NOx contents above 3000 ppm but the trends are identical.

[0089] The comparison of the NOx contents measured by the first and the second sensor proves that the calculation of the dilution ratio using the O_2 contents from the first and the second sensor is a satisfactory approach.

[0090] Now referring to figures 7A and 7B, the data collected for NOx contents by the second sensor and by the PEMS and the data collected for NH_3 contents by the third sensor are compared.

[0091] Generally speaking, the trends of NOx contents measured by the second sensor and the PEMS are quite similar, however some signals detected by the second sensor are not detected by the PEMS, these signals are NH_3 detected by the NOx sensor.

[0092] This is confirmed by the signals observed by the third sensor measuring NH_3 contents. For example, at around 1560s and 1850s the signal observed on the NOx contents measured by the second sensor and the signal observed on the NH_3 curve overlap, these peaks are the contribution of NH_3.

[0093] On figure 8, different cumulative NOx contents are presented. The cumulative NOx contents are measured by the second sensor is distinctly different from the cumulative NOx contents measured by the PEMS. Indeed, the cumulative NOx contents measured by the second sensor has the NH_3 contribution. By subtracting the cumulative NH_3 contents to the cumulative NOx contents measured by the second a curve which overlaps the NOx contents measured by the PEMS is obtained. This example illustrates how this invention can be implemented on a vehicle and how reliable NOx and NH_3 contents can be measured using sensors.

[0094] The invention has been shown and described with respect to certain aspects, example, and embodiments. While a particular feature of the invention may have been disclosed with respect to only one of several aspects, example, or embodiments, the feature may be combined with one or more other features of the other aspects, example, or embodiments as may be advantageous for any given or particular application.

Claims

1. A system (1) for accurately measuring NOx and NH_3 contents in exhaust fumes, including for stoichiometric combustion engines, comprising:

   - an exhaust (2) to evacuate exhaust fumes connected at its free end to an exhaust evacuation outlet (4),
   - at least one first sensor (3) adapted to measure NOx and O_2 contents, said first sensor being placed upstream from the exhaust evacuation outlet,
   - at least one second sensor (61) adapted to measure NOx and O_2 contents, said second sensor being placed downstream from the exhaust evacuation outlet and,
   - at least one third sensor (62) adapted to measure NH_3, said third sensor being placed downstream from the exhaust evacuation outlet.

2. A system according to claim 1, the second and third downstream sensors being placed in such a way that the exhaust fumes reaching said sensors are diluted with at least one gas not interfering with the sensors.

3. A system according to claim 2, the diluting gas being air.

4. A system according to one of the preceding claims, the second and third downstream sensors being placed in a sensor housing designed to allow exhaust fumes reach the sensors while protecting the sensors from external factors.

5. A system according to claim 1 to 3, the exhaust evacuation outlet being configured as a venturi tube (8) having an air inlet (9) at the constriction.

6. A system according to claim 5, the venturi tube having a protective hood (10) on the air inlet.

7. A system according to one of the preceding claims, comprising a memory unit to store collected data of NOx, NH_3 and O_2 contents.

8. A system according to claim 7, comprising a transmitter to send the collected NOx, NH_3 and O_2 data to an engine control unit or to another location by a wireless protocol.

9. A system according to claim 8, the transmitter being a telematics system.

10. An assembly comprising:

    - an internal combustion engine producing exhaust fumes which are evacuated to the external environment through an exhaust connected to said engine.
    - a system according to one of the preceding claims, in which exhaust (2) is the exhaust of the engine.

11. An assembly according to claim 10, the engine being adapted to operate on a stoichiometric mixture of air and fuel, fuel being preferably natural gas.

12. An assembly according to claims 10 or 11, having a three-way catalytic converter to treat the fumes leaving the engine before reaching the exhaust.

13. A method for accurately measuring the NOx and NH_3 contents in exhaust fumes comprising the following steps:

    1/ measuring the NOx and O_2 contents in exhaust fumes by a at least one first upstream sensor (3) placed inside the exhaust,
    2/ measuring the NOx and O_2 contents in the exhaust fumes by at least one second sensor and measuring the NH_3 content by at least one third sensor, said second and third sensors are placed downstream from the exhaust evacuation outlet,
    3/ calculating the instantaneous dilution factor of O_2 contents, between the first upstream sensor and the second downstream sensor,

4/ subtracting the NH_3 content measured by the third sensor and corrected with the calculated dilution factor to the NOx content measured by the second sensor and corrected with the calculated dilution factor, or subtracting the NH_3 content measured by the third sensor and corrected with the calculated dilution factor to the NOx contents measured by the first sensor and corrected with the calculated dilution factor.

14. Use of a system according to one of claims 1 to 9 for control systems of a combustion process or an exhaust treatment process.

15. A vehicle comprising a system according to one of claims 1 to 9 or an assembly to one of claims 10 to 12.

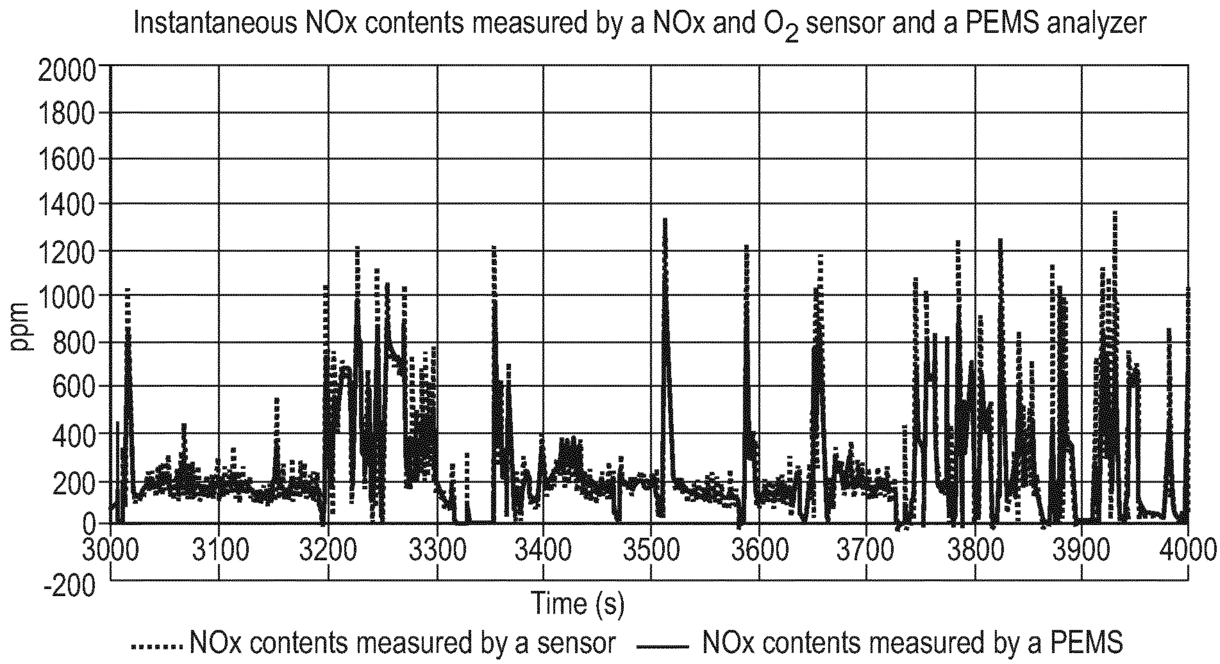


Fig. 1A
(PRIOR ART)

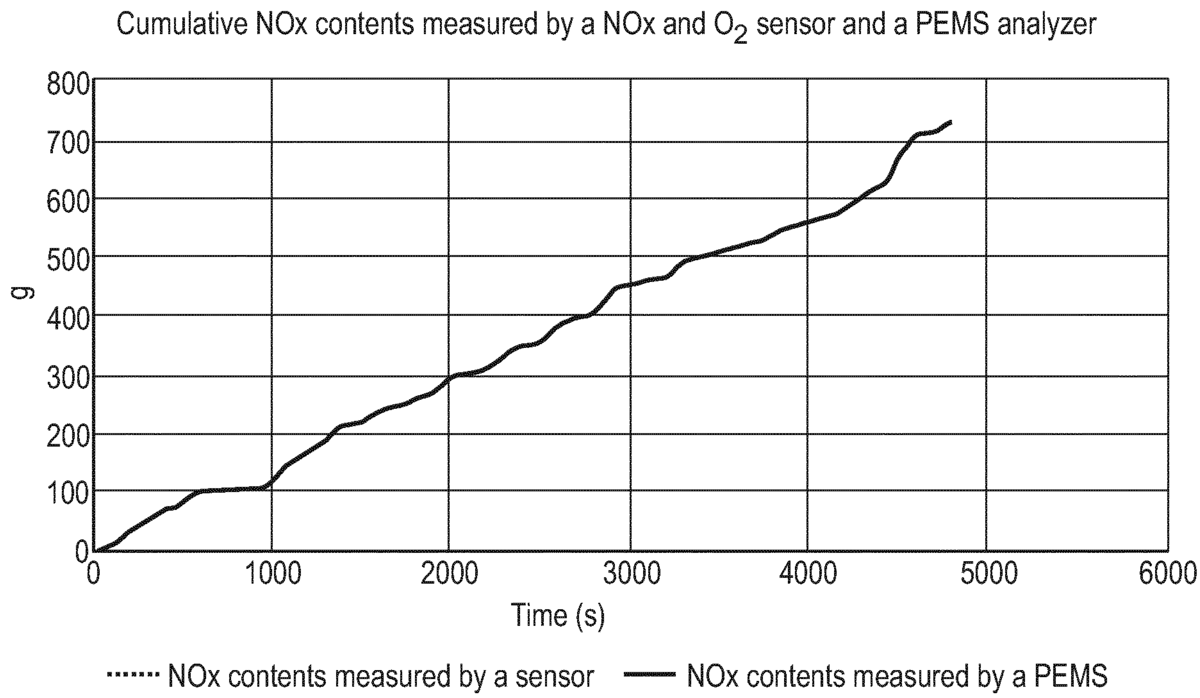


Fig. 1B
(PRIOR ART)

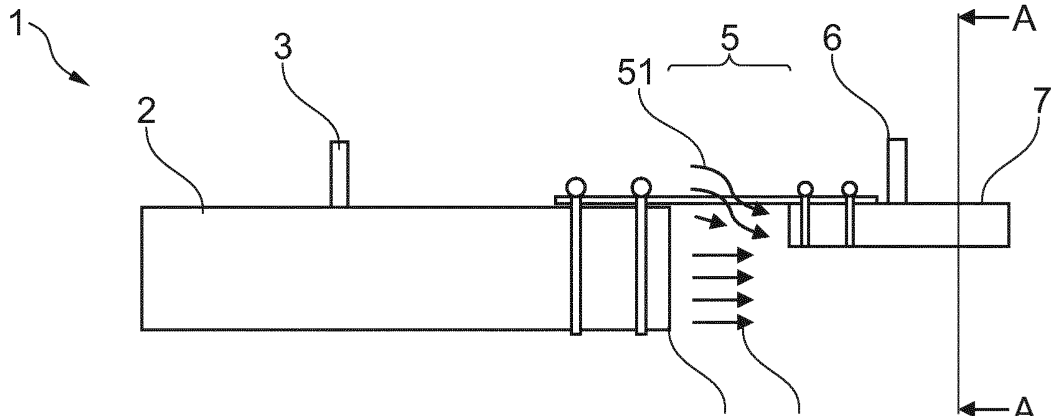


Fig. 2

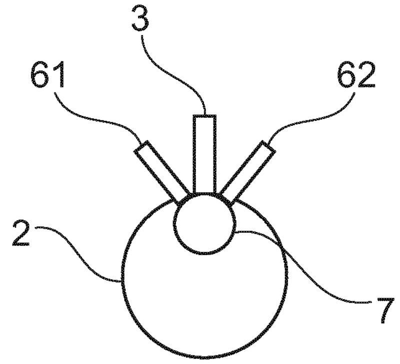


Fig. 2A

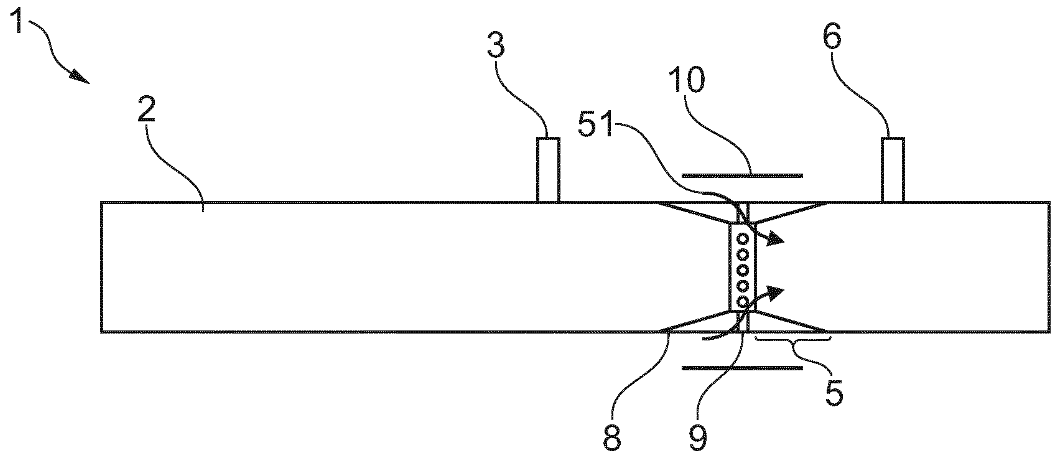


Fig. 3

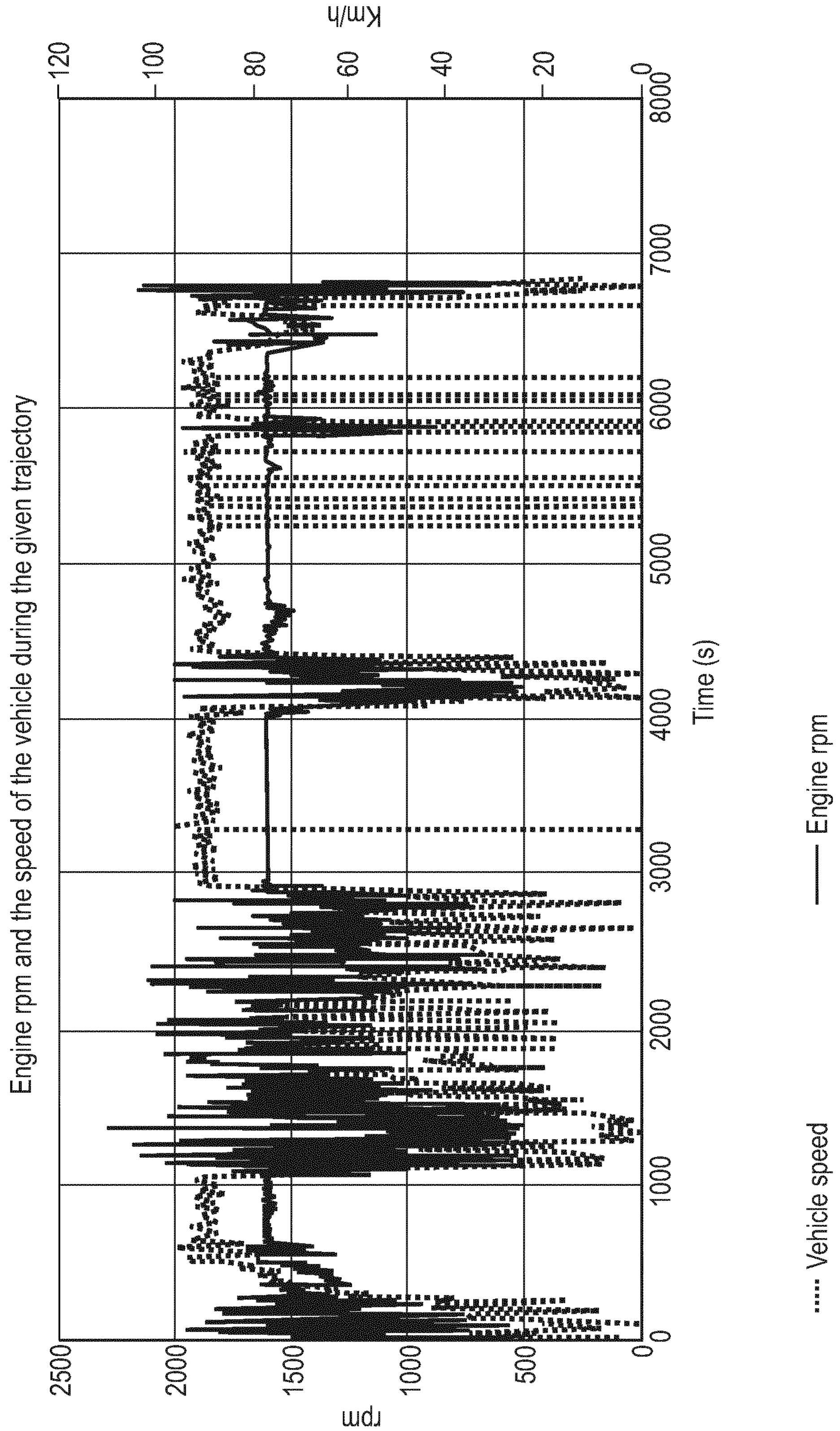
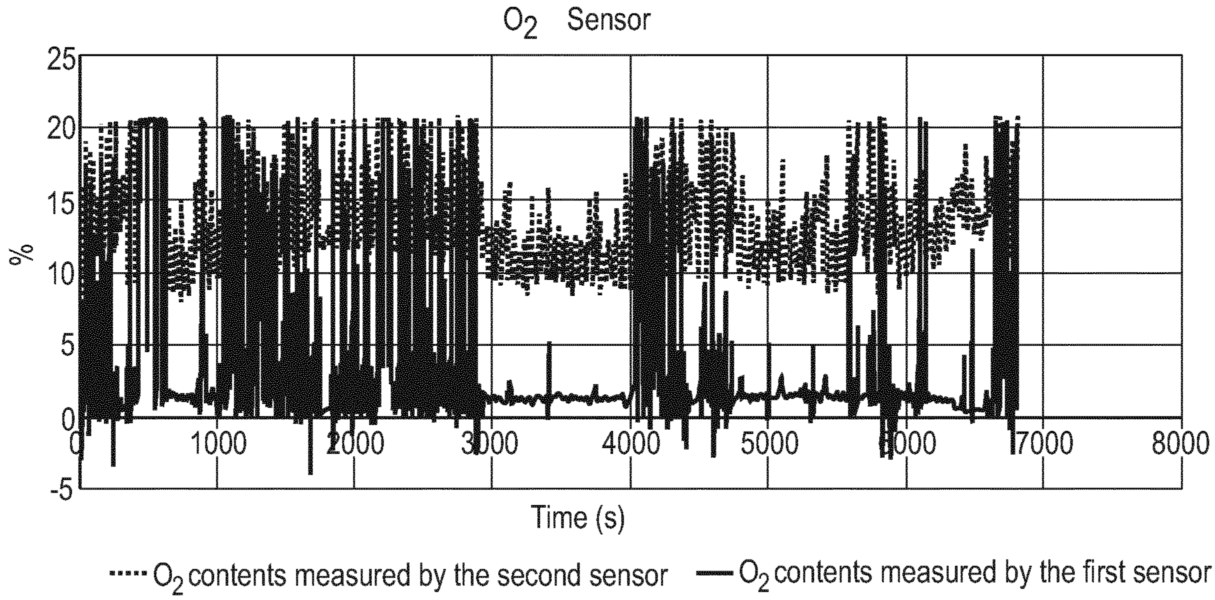
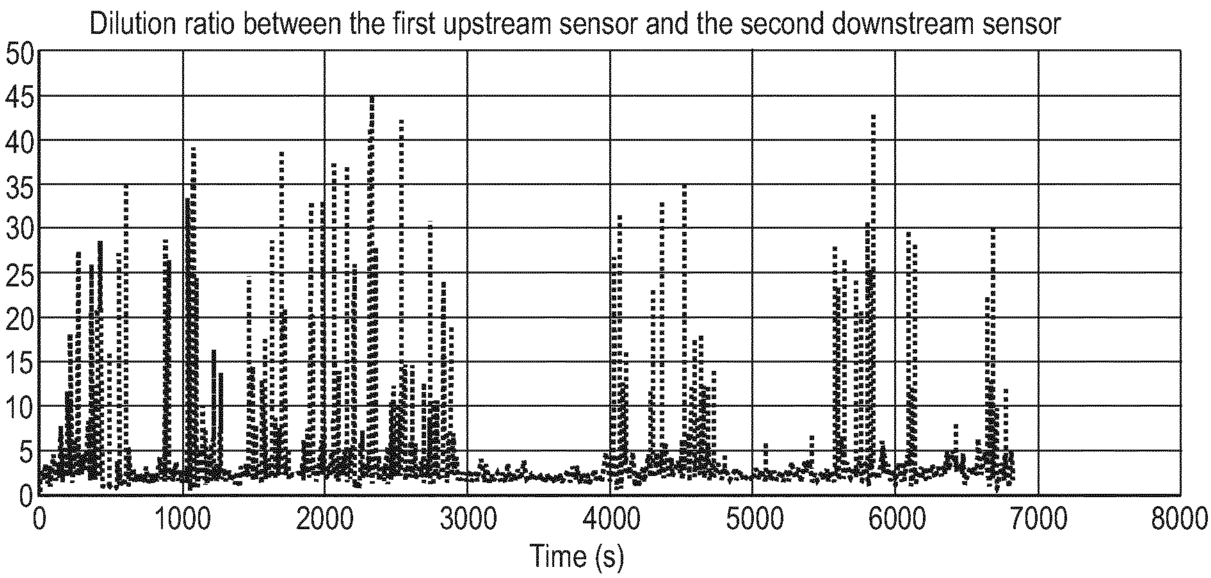

Engine rpm and the speed of the vehicle during the given trajectory
rpm
2500
2000
1500
1000
500
0
Km/h
120
100
80
60
40
20
0
Time (s)
0
1000
2000
3000
4000
5000
6000
7000
8000
Vehicle speed
Engine rpm

Fig. 4



O_2 Sensor
25
20
15
10
5
0
-5
%
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)
O_2 contents measured by the second sensor
O_2 contents measured by the first sensor

Fig. 5A



Dilution ratio between the first upstream sensor and the second downstream sensor
50
45
40
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)

Fig. 5B

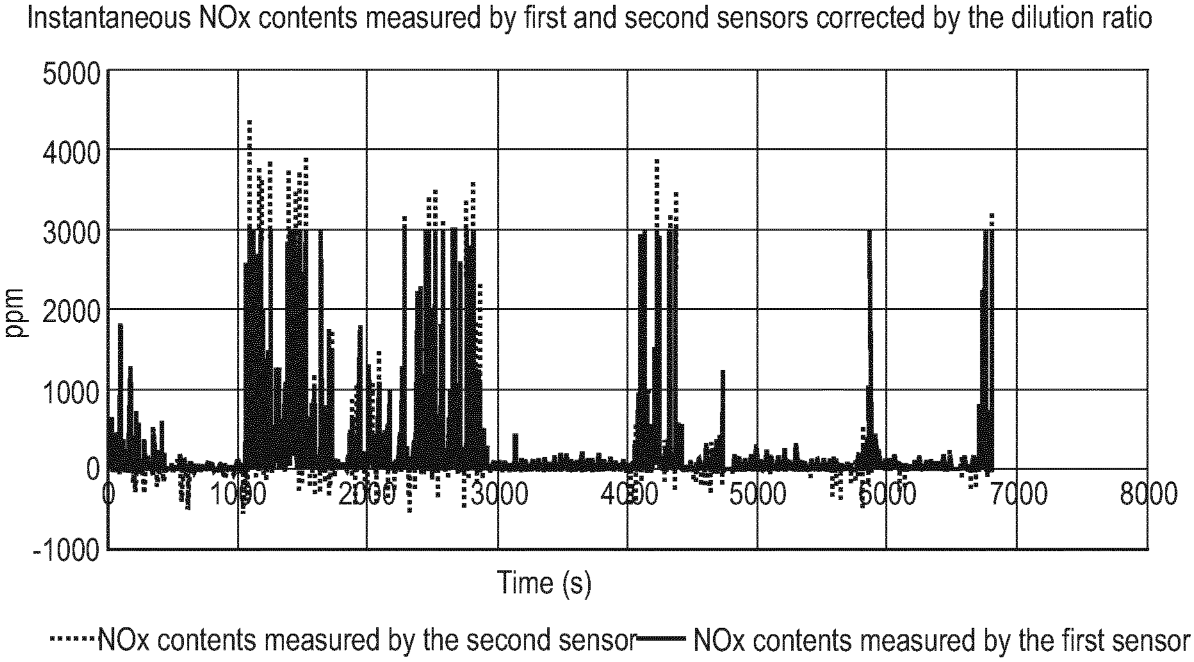

Instantaneous NOx contents measured by first and second sensors corrected by the dilution ratio
5000
4000
3000
2000
1000
0
-1000
ppm
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)
NOx contents measured by the second sensor
NOx contents measured by the first sensor

Fig. 6A

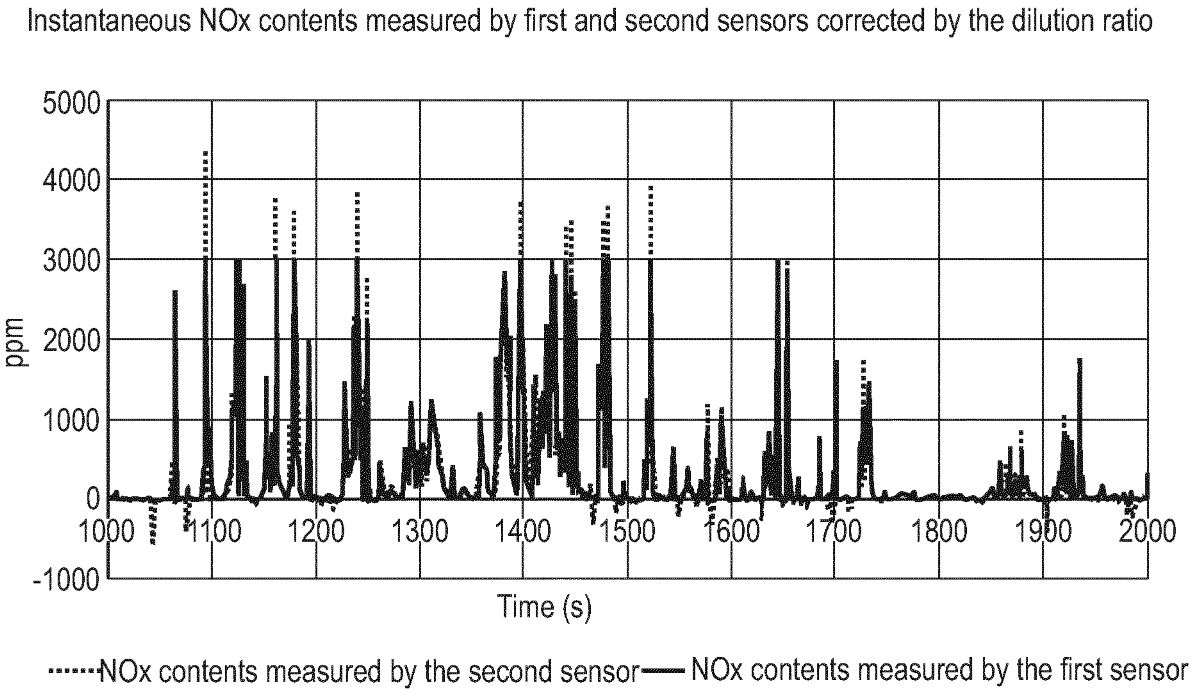

Instantaneous NOx contents measured by first and second sensors corrected by the dilution ratio
5000
4000
3000
2000
1000
0
-1000
ppm
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Time (s)
NOx contents measured by the second sensor
NOx contents measured by the first sensor

Fig. 6B

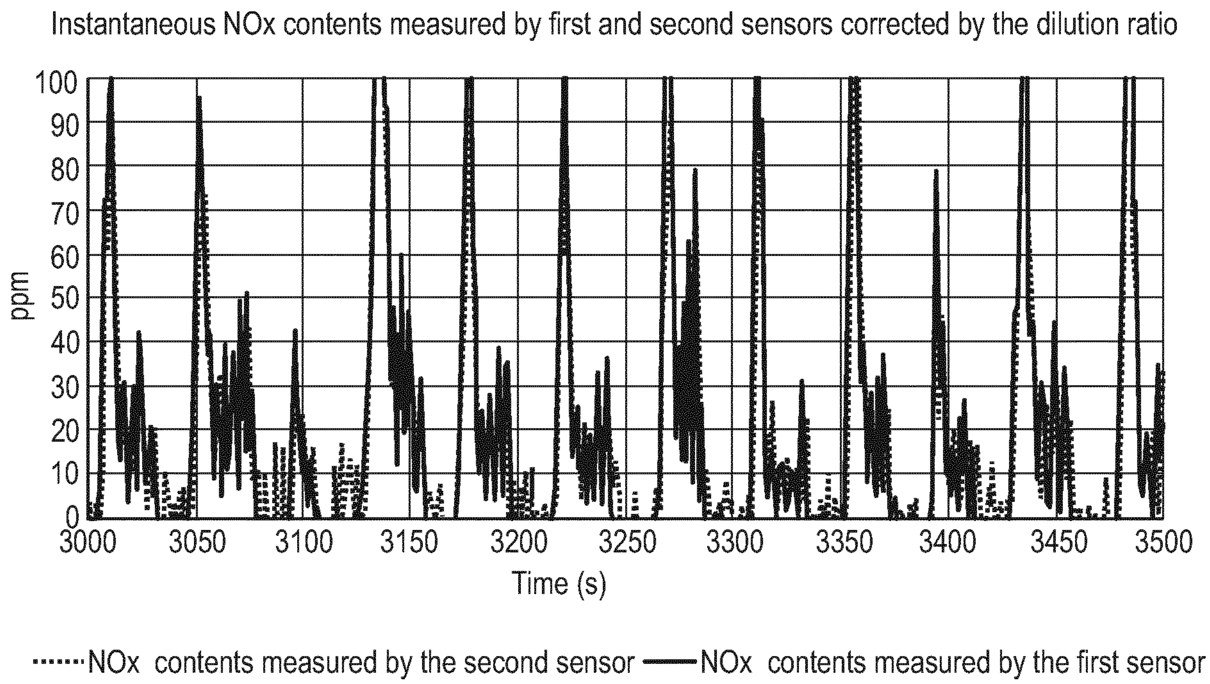

Instantaneous NOx contents measured by first and second sensors corrected by the dilution ratio
ppm
100
90
80
70
60
50
40
30
20
10
0
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
Time (s)
NOx contents measured by the second sensor
NOx contents measured by the first sensor

Fig. 6C

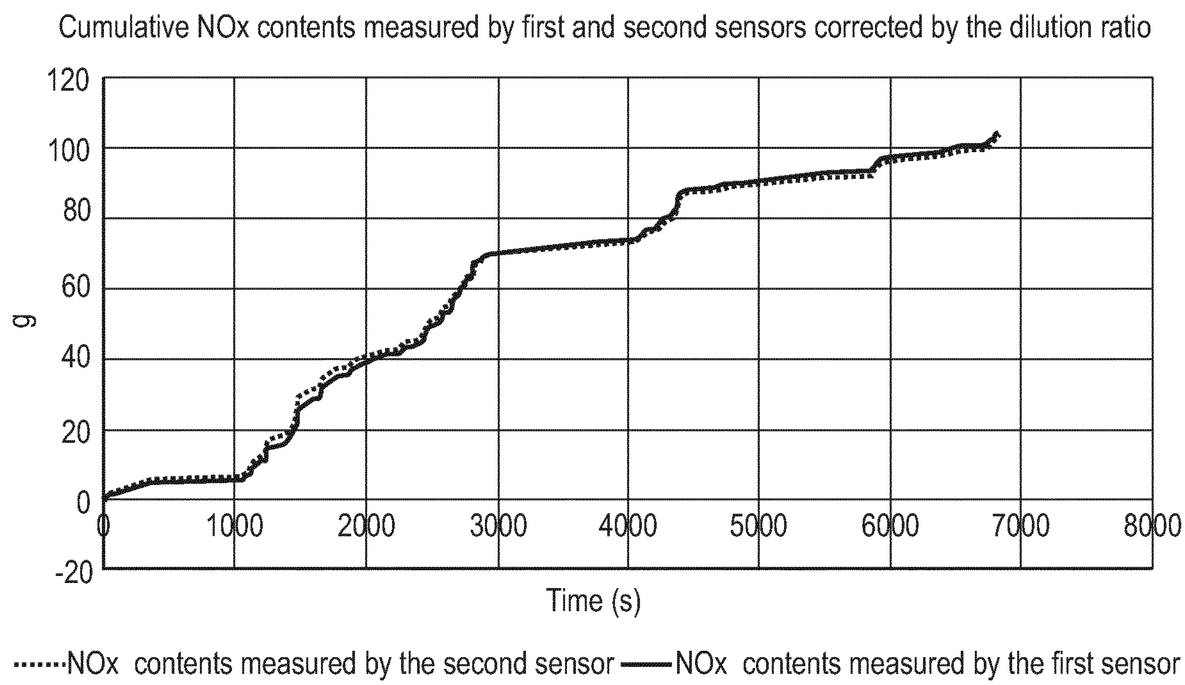

Cumulative NOx contents measured by first and second sensors corrected by the dilution ratio
g
120
100
80
60
40
20
0
-20
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)
NOx contents measured by the second sensor
NOx contents measured by the first sensor

Fig. 6D

NOx contents measured by the second sensors and a PEMS analyzer, and the NH_3 contents measured by the third sensor

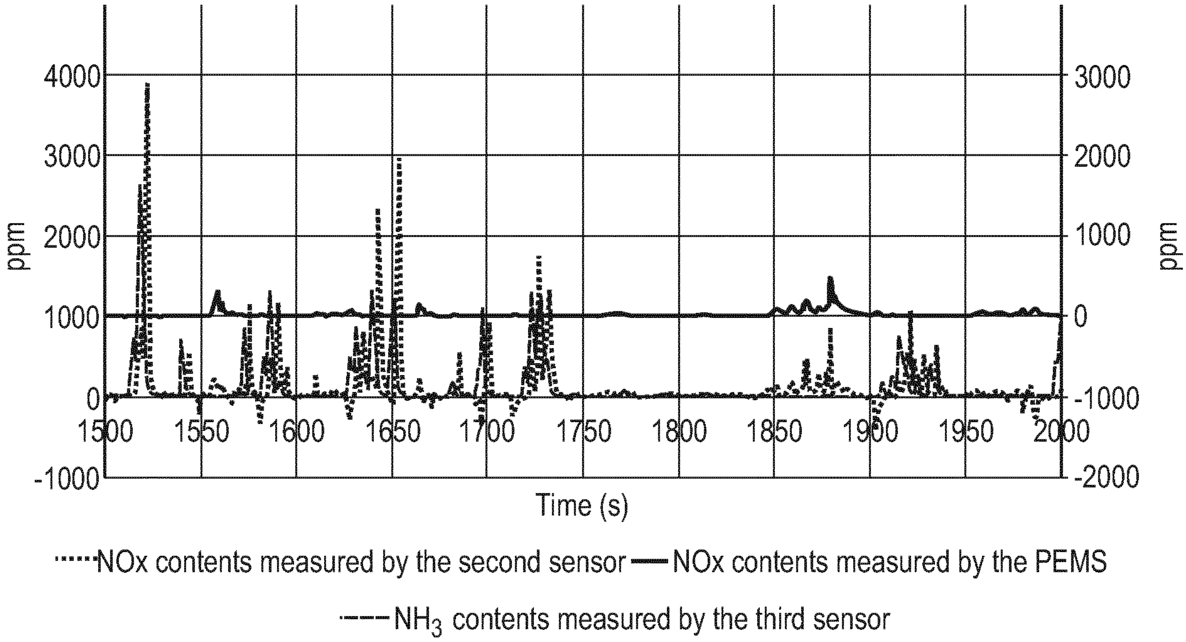


Fig. 7A

NOx contents measured by the second sensors and a PEMS analyzer, and the NH_3 contents measured by the third sensor

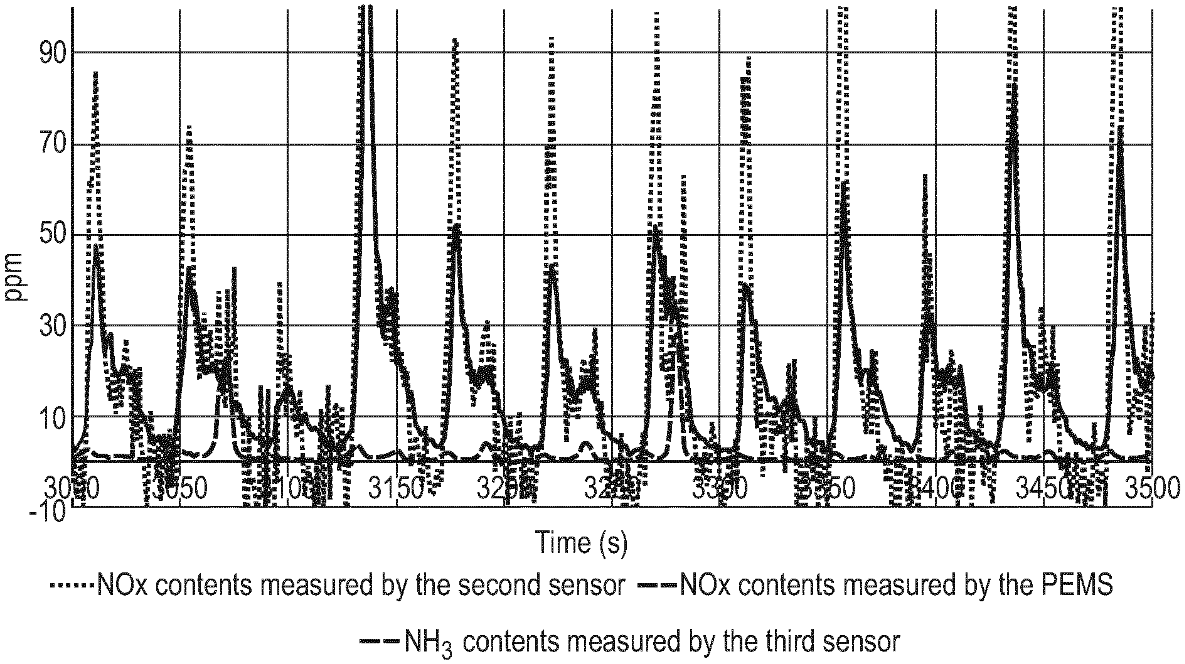
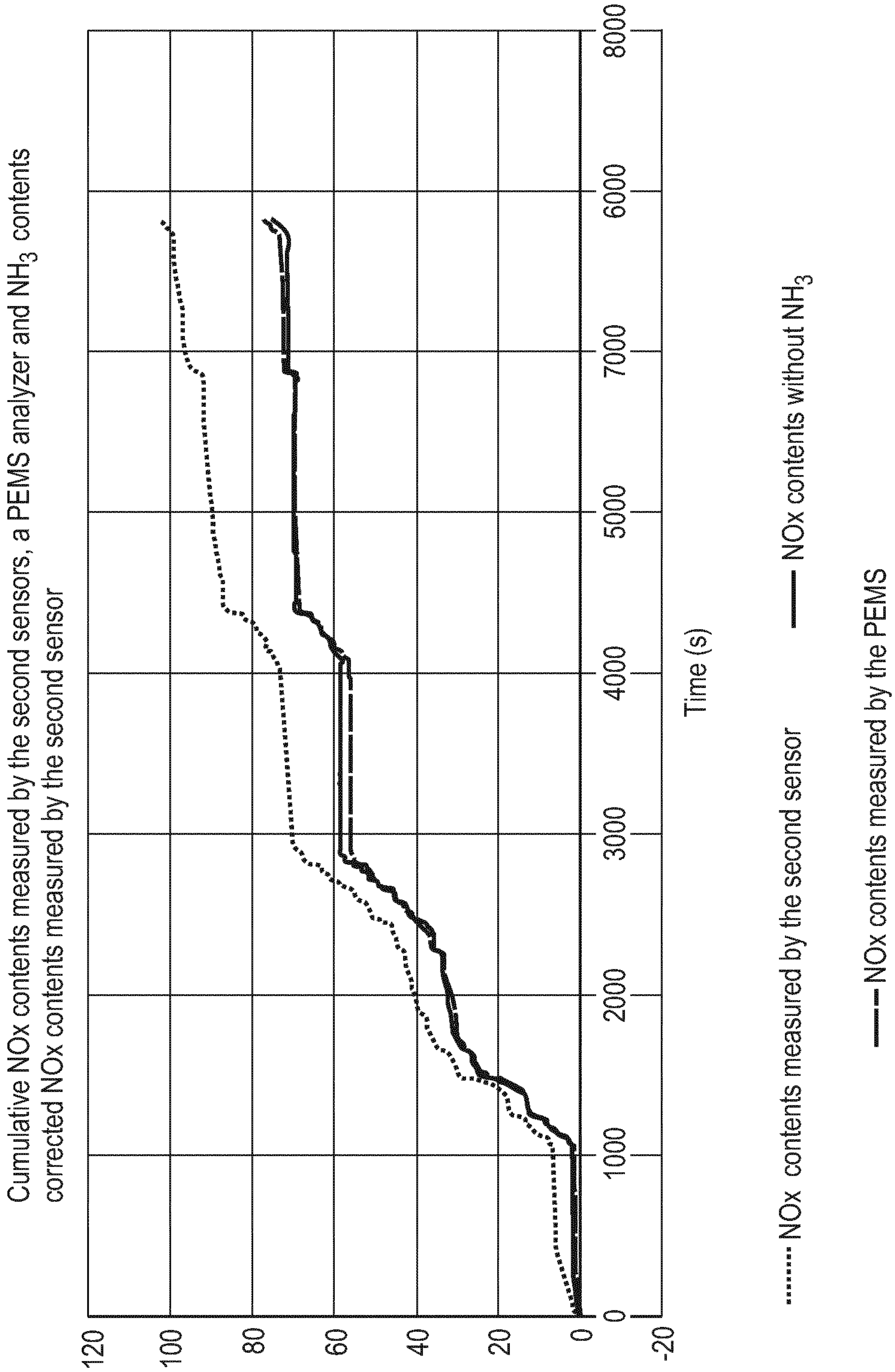


Fig. 7B



Cumulative NOx contents measured by the second sensors, a PEMS analyzer and NH_3 contents
corrected NOx contents measured by the second sensor
120
100
80
60
40
20
0
-20
g
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)
NOx contents measured by the second sensor
NOx contents without NH_3
NOx contents measured by the PEMS

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 0410

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2010/107605 A1 (BRINKMAN NORMAN D [US] ET AL) 6 May 2010 (2010-05-06) * paragraphs [0022], [0023], [0036], [0049], [0053]; figure 1 * -----	1,4,7-15	INV. F01N13/00
A	WO 01/84111 A1 (PP & L RESOURCES INC [US]) 8 November 2001 (2001-11-08) * page 1, line 26 - page 2, line 19 * * page 6, line 12 - page 9, line 10; figures 1,2 * -----	2-9,13, 14	
A	US 2002/178714 A1 (SHI GUOJUN [US] ET AL) 5 December 2002 (2002-12-05) * paragraphs [0010], [0043] - [0046]; figures 1,2 * -----	1,7, 10-15	

TECHNICAL FIELDS SEARCHED (IPC)

F01N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 September 2018	Kolland, Ulrich

CATEGORY OF CITED DOCUMENTS

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18-09-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010107605 A1	06-05-2010	CN 102084096 A	01-06-2011
		DE 112009001034 T5	09-06-2011
		US 2010107605 A1	06-05-2010
		WO 2009134831 A2	05-11-2009
WO 0184111 A1	08-11-2001	AU 5924401 A	12-11-2001
		US 2002059033 A1	16-05-2002
		WO 0184111 A1	08-11-2001
US 2002178714 A1	05-12-2002	NONE	

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Patent documents cited in the description

- WO 2016068831 A **[0016]**