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Demande de brevet d’invention

- Loi du 20 juillet 1982 portant modification du régime des brevets d’invention
- Règlements grand-ducaux du 17 novembre 1997 - concernant la procédure et les formalités administratives en matière de brevets d’invention et de certificats complémentaires de protection - portant fixation des taxes et rémunérations à percevoir en matière de brevets et de certificats complémentaires de protection

Demande N° 90795 Date de dépôt: 27 juin 2001

Référence du déposant ou mandataire: P-DELPHI-045/LU

A. REQUETE

Le demandeur requiert (Les demandeurs requièrent) la délivrance d’un brevet d’invention.

1. Titre de l’invention:

NOx release index.

2. Demandeur

Nom, prénom ou dénomination sociale: DELPHI TECHNOLOGIES, INC.

Adresse: P.O. Box 5052, Troy Michigan 48007 / US

Etat dans lequel est situé le domicile ou siège du demandeur: US

 Téléphone: Telefax: E-mail:

☐ Un (Des) demandeur(s) supplémentaire(s) est (sont) mentionné(s) sur une feuille en annexe

3. Mandataire(s)

Nom(s), prénom(s):

FREYLINGER, Ernest T./ SCHMITT, Armand / KIHIN, Pierre / BEISSEL, Jean / LAMBERT Romain / OCVIRK Philippe

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 Téléphone: 31 38 30-1 Telefax: 31 38 33 E-mail: office@freylinger.lu

☒ Le(s) demandeur(s) déclare(nt) être domicilié auprès du (des) mandataire(s)
☐ Un pouvoir général est déposé au Service de la Propriété Intellectuelle

DELPHI-045.doc
4. Adresse postale au Grand-Duché de Luxembourg:
Les communications du Service sont à envoyer à:
☐ l'adresse du demandeur mentionnée au point 2.
☒ l'adresse des mandataire(s) mentionné(s) au point 3.
☐ l'adresse suivante:

5. Désignation d'inventeur(s)
Nom, prénom(s): 
Adresse:
BALLAND Jean 13 Boulevard Clemenceau, F-57000 METZ / FR

☐ Un (Des) inventeur(s) supplémentaires est (sont) mentionné(s) sur une feuille en annexe
☐ Une désignation d'inventeur(s) séparée est jointe en annexe

6. Déclaration de priorité
Demande No Date de dépôt: Pays: Déposant:

☐ D'autre(s) déclaration(s) de priorité sont mentionnées sur une feuille en annexe

7. Déclaration lorsqu'il s'agit d'une demande divisionnaire
☐ La présente demande est une demande divisionnaire de la demande de brevet:
No: Date de dépôt:

8. Déclaration lorsqu'il s'agit d'une demande fondée sur une demande internationale
☐ La présente demande est fondée sur la demande internationale identifiée ci-dessous:
Date de dépôt: No de dépôt: No de Publ.:

9. Demande d'établissement d'un rapport de recherche d'antériorités
Il est demandé l'établissement d'un rapport de recherche d'antériorités relatif à la présente demande:
☒ oui ☐ non
10. Annexes

☐ Description + revendication(s)  Nbre de pages:  13
☐ Figures  Nbre de revendic.:  8
☒ Abrégé  Nbre de planches:  1
☐ Figure à publier avec l’abrégué  Figure N°:
☐ Traduction des revendications  Nbre de pages:

☐ Feuille avec demandeur(s) supplémentaire(s)
☐ Feuille avec mandataire(s) supplémentaire(s)
☐ Feuille avec déclaration(s) de priorité supplémentaire(s)
☐ Feuille avec inventeur(s) supplémentaire(s)
☐ Désignation séparée d’inventeur(s)

☐ Document(s) de priorité
☐ Traduction document(s) de priorité
☐ Document(s) de cession du droit de priorité

☐ Pouvoir
☐ Copie d’un pouvoir général

☐ Autres:

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B. PROCÈS-VERBAL DE DÉPÔT

La présente demande de brevet d’invention a été déposée au Ministère de l’Economie, Direction de la Propriété Industrielle et des Droits Intellectuels à Luxembourg,

en date du 27 juin 2001 à 15.00 heures.

Le(s) déposant(s) / mandataire(s):

Nom du signataire
Pierre KIHN

Pour le Ministre de l’Economie,

Serge ALLEGREZZA
Conseiller de Gouvernement 1ère classe
Chargé de la Direction du Service de la Propriété Industrielle et des Droits Intellectuels

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REVENDICATION DE LA PRIORITE

de la demande de brevet

En
Du
No.

Mémoire Descriptif
déposé à l’appui d’une demande de

BREVET D’INVENTION

au

Luxembourg

au nom de : DELPHI TECHNOLOGIES, INC.
P.O. Box 5052
Troy, Michigan 48007 / US

pour : « NOₓ release index ». 
**NO\textsubscript{x} RELEASE INDEX**

This invention relates to a method and a system for monitoring the adsorptive capacity of NO\textsubscript{x} adsorber devices of internal combustion engines.

NO\textsubscript{x} adsorber devices are currently used to address one of the drawbacks of lean burn engines, namely difficulty to reduce nitrogen oxides (NO\textsubscript{x}) in a lean environment. NO\textsubscript{x} adsorber technology typically uses alkali or alkali-earth metals in order to temporarily store NO\textsubscript{x} under lean operating conditions and to release the NO\textsubscript{x} during periodic and relatively short rich pulses.

The mechanism for NO\textsubscript{x} storage involves the oxidation of NO to NO\textsubscript{2} followed by the subsequent formation of a nitrate complex with alkaline or alkaline earth metals. Under stoichiometric or rich conditions, the nitrate complexes are thermodynamically unstable and the stored NO\textsubscript{x} is released and catalytically reduced to nitrogen by the excess of CO, H\textsubscript{2}, and hydrocarbon compounds in the exhaust gases.

The storage capacity of such an NO\textsubscript{x} adsorber degrades over time due to thermal ageing, but mainly due to sulfur poisoning, with resultant increase in atmospheric pollution and fuel consumption. The same alkali and alkali-earth metals that can store NO\textsubscript{x} under lean conditions are also excellent scavengers for SO\textsubscript{2} and SO\textsubscript{3} under these same conditions. The resulting sulfates are very stable and result in rapid deactivation of the NO\textsubscript{x} adsorber. Unfortunately, the levels of sulfur in gasoline are usually quite high and very variable, the average being about 50 to 300 parts per million (ppm). To purge the sulfur, frequent periods of extended hot, rich operation, so called desulfation processes, may thus be required with the known effects on overall fuel consumption.

Current diagnostic methods and systems are based on semi-empirical models to estimate the actual performance of an adsorber and thus to control the duration of lean and/or rich operating conditions, to identify sulfur poisoning and to trigger a desulfation process to regenerate the adsorber. To get a sufficient level of accuracy, these models need to be carefully calibrated and
are generally acceptable or valid only for steady operation or a relatively small range of operating conditions. They are therefore less appropriate for automobile engines which are operating under very fluctuating conditions of temperature, load, fuel characteristics, etc.

Accordingly, it is desirable to provide a method that allows a better NOx adsorber diagnostic indicating the actually available NOx storage capacity at any time without the drawbacks described above.

The present invention provides in accordance to a first aspect of the present invention a method of monitoring the adsorptive capacity of a NOx adsorber of an internal combustion engine, comprising the following steps:

1) identification of O₂ moles released from the adsorber during rich pulse regeneration,

2) calculation of NO₂ moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO₂ from said adsorber

3) optional storage of successive results of steps 1 and 2

4) use of the results of step 2 and/or 3 to update an adaptative capacity model to control the duration of the lean phase and/or of the rich pulse.

By estimating the quantity of NOₓ stored during the previous lean period, it is possible to calculate an average storage capacity or efficiency of the NOₓ adsorber in order to maximise the fuel economy and to minimise tailpipe NOₓ emissions. The major advantage of the present method over the state of the art is that the model used to estimate or calculate the quantity of NOₓ released by the adsorber during rich operating conditions is based on a physical model of the release chemistry, not on empirical parameters. Besides a greater accuracy, the benefits of this approach are generic formulae independent of calibration, engine conditions, regeneration air to fuel ratio, etc. The ease of calibration dramatically reduces the calibration time needed for previous methods usually prone to a large number of fluctuations. Another interesting feature of the present method is its independence of the fuel characteristics, underlining its generic character.
As mentioned above, the current absorber materials are relatively sensitive to sulfur poisoning which degrades the storage capacity of the NO\textsubscript{x} adsorber. When the storage capacity drops under a predetermined value, i.e. when the maximum quantity of NO\textsubscript{x} stored during lean phase and released during rich pulse reaches an insufficient level, actions must be taken to restore at least part of the initial capacity.

Therefore, the present method comprises preferably the following additional step: 5) use of the results of step 2 and/or 3 to update an adaptative capacity model to detect sulfur poisoning of the adsorber and to trigger a desulfation process.

Due to a better monitoring of the adsorber capacity, an improved sulfur contamination diagnostic can be achieved. This not only results in reduced fuel consumption, but decreases also drastically adsorber replacement costs owing to a more efficient regeneration and hence a greater durability.

Another benefit of this better NO\textsubscript{x} adsorber capacity usage and diagnostic is a possible downsizing of the adsorber with concomitant cost and space requirement reductions.

In a preferred embodiment of the present method wherein the release model in step 2 is based on following equation:

$$ANO_{2\text{released}} = \left(1 - \frac{AO_{2\text{released}}}{FO_{2\text{released}}}\right) FNO_{2\text{released}}$$

wherein:

$ANO_{2\text{released}}$ : actual (calculated) moles of NO\textsubscript{2} released from the adsorber during rich pulse regeneration

$AO_{2\text{released}}$ : measured O\textsubscript{2} moles during rich pulse

$$FO_{2\text{released}} = \left(\frac{\text{mole O}_2}{\text{mole air}}\right)_{\text{air}} \left(\frac{\lambda_{\text{LTP}}}{\lambda_{\text{EO}}\text{Airflow}_{\text{rich pulse}}} - 1\right) \text{Airflow}_{\text{rich pulse}} \text{dt}$$

$FO_{2\text{released}}$ represents a fictive mole amount of O\textsubscript{2} released assuming that the lambda deviation was caused only by O\textsubscript{2}
\[ FNO_2\text{released} = \frac{4}{3} \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \cdot \int_{\text{rich pulse}} \left( \frac{\lambda_{\text{TLP}}}{\lambda_{\text{EO}}} - 1 \right) \left( \frac{1}{1 + \frac{2}{3} \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} \lambda_{\text{TLP}}} \right) \text{Airflow}_{\text{rich pulse}} \cdot dt \]

\( FNO_2\text{released} \) represents a fictive mole amount of \( O_2 \) released assuming that the lambda deviation was caused only by \( NO_2 \)

\( \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} \) : oxygen to carbon ratio at stoichiometric operating conditions

\( \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \) : molar oxygen to air ratio in ambient air

\( \lambda_{\text{EO}} = \frac{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{EO}}}{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}}} \) : lambda value upstream of the adsorber (EO, engine out)

\( \lambda_{\text{TLP}} = \frac{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{TLP}}}{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}}} \) : lambda value downstream of the adsorber (TLP, tailpipe)

\( \text{Airflow}_{\text{rich pulse}} \) : airflow during rich pulse.

As stated above, the present method is base on the lambda variation across the adsorber and the release chemistry of the \( NO_x \) from said adsorber. The following description will try to support and to illustrate the above formulae.

The reaction which summarizes the \( NO_x \) release from a \( NO_x \) adsorber using a current technology could be represented as follows:

\[ M(NO_3)_2 + CO \rightarrow MCO_3 + 2 NO_2 \]

- Oxygen balance in the exhaust gas:
  
  Net \( O_2 \) moles transferred to the gas = \( (2 - \frac{1}{2}) \) \( O_2 \) moles = 1.5 \( O_2 \) moles

  For each mole \( NO_2 \) released, 0.75 mole \( O_2 \) are added to the exhaust gases.

- Carbon balance in the exhaust gas:

  Net \( C \) moles transferred to the gas = -1 \( C \) mole

  Thus, for each mole \( NO_2 \) released, 0.5 mole \( C \) are subtracted to the exhaust gases.
To know the impact of NO\textsubscript{x} release on lambda deviation across NO\textsubscript{x} adsorber during rich regeneration:

\[
\text{Lambda engine out} = \lambda_{EO} = \frac{\left( \frac{\text{mole} O_2}{\text{mole} C_{EO}} \right)}{\left( \frac{\text{mole} O_2}{\text{mole} C} \right)_{\text{stoich}}} \quad \text{(Eq. a)}
\]

\[
O_2 \text{ TLP} = O_2 \text{ EO} + O_2 \text{ released}
\]

\[
C_{\text{TLP}} = C_{\text{EO}} + C_{\text{stored}}
\]

From oxygen and carbon balance relations:

\[
C_{\text{stored}} = \frac{2}{3} O_2 \text{ released}
\]

\[
\text{Lambda tailpipe} = \lambda_{\text{TLP}} = \frac{\left( \frac{\text{mole} O_2}{\text{mole} C_{\text{TLP}}} \right)}{\left( \frac{\text{mole} O_2}{\text{mole} C} \right)_{\text{stoich}}} \quad \text{(Eq. b)}
\]

From Eq. a and Eq. b:

\[
O_2 \text{ released} = O_2 \text{ EO}.\left( (\lambda_{\text{TLP}} - \lambda_{\text{EO}}) / \lambda_{\text{EO}} \right) / (1 + 2/3 (O_2/C)_{\text{stoich}} \lambda_{\text{TLP}}) \cdot dt
\]

As 1 NO\textsubscript{2} release transfers 0.75 moles of oxygen to the gas, NO\textsubscript{2} release is related to lambda deviation as follows:

\[
F_{\text{NO}_2 \text{ released}} = \frac{4}{3} \int O_2 \text{ EO} \left( \frac{\lambda_{\text{TLP}}}{\lambda_{\text{EO}}} - 1 \right) \left( \frac{1}{1 + \frac{2}{3} \frac{\text{mole} O_2}{\text{mole} C}_{\text{stoich}} \lambda_{\text{TLP}}} \right) \cdot dt
\]

\[
O_2 \text{ flow (O}_2 \text{ EO) can be replaced with Airflow} \left( \frac{\text{mole} O_2}{\text{mole} C} \right)_{\text{air}}:
\]

\[
F_{\text{NO}_2 \text{ released}} = \frac{4}{3} \left( \frac{\text{mole} O_2}{\text{mole} \text{ air}} \right)_{\text{air}} \int \left( \frac{\lambda_{\text{TLP}}}{\lambda_{\text{EO}}} - 1 \right) \left( \frac{1}{1 + \frac{2}{3} \frac{\text{mole} O_2}{\text{mole} C}_{\text{stoich}} \lambda_{\text{TLP}}} \right) \cdot \text{Airflow} \cdot \text{rich pulse} \cdot dt
\]

(Eq. c)

But this formula is not strictly applicable as such, because oxygen is also stored during lean phase on oxygen storing material (OSM) and later released during rich pulse. If lambda deviation was only due to O\textsubscript{2} release, the fictive O\textsubscript{2} release (FO\textsubscript{2} release) would be:
\[ \text{FO}_2 \text{ released} = \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \left( \frac{\lambda_{NP}}{\lambda_{EQ}} - 1 \right) \text{Airflow}_{\text{rich pulse}} dt \quad (\text{Eq. d}) \]

To differentiate actual NO\textsubscript{2} contribution from total release:

\[ \text{NO}_2 \text{ contribution} = 1 - \text{O}_2 \text{ contribution} \quad (\text{Eq. e}) \]

with

\[ \text{O}_2 \text{ contribution} = \frac{\text{O}_2 \text{ released}}{\text{FO}_2 \text{ released}} \quad (\text{Eq. f}) \]

wherein \( \text{FO}_2 \text{ released} = \text{Sum(} \text{O}_2 \text{ released} \text{,} dt \text{)} \) over the complete rich pulse.

To calculate Actual NO\textsubscript{2} released:

\[ \text{ANO}_2 \text{ released} = \frac{\text{NO}_2 \text{ contribution}}{\text{FNO}_2 \text{ released}} \quad (\text{Eq. g}) \]

wherein \( \text{FNO}_2 \text{ released} = \text{Sum(} \text{NO}_2 \text{ released} \text{,} dt \text{)} \) over the complete rich pulse.

The final equation is:

\[ \text{ANO}_2 \text{ released} = [1 - (\frac{\text{O}_2 \text{ released}}{\text{FO}_2 \text{ released}})] \cdot (\text{FNO}_2 \text{ released}) \quad (\text{Eq. h}) \]

A second aspect of the present invention is a system for monitoring the adsorptive capacity of a NO\textsubscript{x} adsorber of an internal combustion engine, comprising:

- oxygen detection means upstream and/or downstream of the NO\textsubscript{x} adsorber
- means to generate a command to switch the operation of the internal combustion engine from lean to rich and from rich to lean operating conditions
- means to perform the calculation of NO\textsubscript{x} released during rich pulse using the output of the oxygen detection means in a release model based on lambda deviation across the adsorber and the release chemistry of NO\textsubscript{2} from said adsorber
- optional means to store successive calculation values, and
- means to use at least one of the calculation values to update an adaptative capacity model to determine the duration of the lean phase and/or of the rich pulse.

In practice, such a system used e.g. in an automobile, enables a close control of the performance of the NO\textsubscript{x} adsorber without tedious calibration steps, while keeping the fuel consumption due to NO\textsubscript{x} reduction as low as possible.
The oxygen detecting means that could be used are generally known in the art and comprise stoichiometry sensors for detection of the stoichiometry (also called switching type oxygen sensors) or wide range sensors (such as UEGO Universal Exhaust Gas oxygen Sensor).

The means to generate a command, to perform the calculations, to optionally store any necessary values and to update the adaptive capacity model may be integrated in one dedicated logical unit or even be part of a larger unit of engine diagnostic and control.

In a preferred embodiment of the present invention, the system also controls sulfur poisoning of the adsorber and further comprises:
- means to use at least one of the calculation values to update an adaptative capacity model to determine the necessity of a desulfation of the NO\textsubscript{x} adsorber due to excessive sulfur poisoning, and
- means to generate a command to trigger a desulfation of the NO\textsubscript{x} adsorber.

The model used by the present system may be based on the following equation:

\[
\text{AN}_2\text{O}_2\text{released} = \left[1 - \frac{\text{AO}_2\text{released}}{\text{FO}_2\text{released}}\right] \text{FNO}_2\text{released}
\]

with the above defined meanings.

A specific embodiment of the invention provides a system, wherein
- the oxygen detection means comprise an UEGO type oxygen sensor upstream and a switching type oxygen sensor downstream of the adsorber
- the release model is based on following equation:

\[
\text{AN}_2\text{O}_2\text{released} = \frac{4}{3} \left[1 + \frac{2}{3} \left(\frac{\text{mole O}_2}{\text{mole air}}\right)_{\text{stoich}} - \text{AO}_2\text{release} \right] - \int_{\text{rich pulse}} \left(\frac{1}{\lambda_{EO}} - 1\right) \text{Airflow}_{\text{rich pulse}} \cdot dt
\]

(Eq. i)

with the above defined meanings.

This equation is obtained by replacing the FO\textsubscript{2}\text{released} and FNO\textsubscript{2}\text{released} in Eq. h by Eq. c and Eq. d, respectively. In this particular case, lambda EO (\lambda_{EO}) is measured, whereas lambda TLP (\lambda_{TLP}) = 1. This assumption is valid if rich pulse is terminated before a significant rich drift at the tailpipe side occurs.
In a further specific embodiment, there is provided a system wherein
- the oxygen detection means comprise an UEGO type oxygen sensor
downstream and a switching type oxygen sensor upstream of the adsorber
- the release model is based on following equation:

$$5 \quad ANO_2 \text{ released} = \frac{4}{5} k \left[ \left( \frac{\text{mole } O_2}{\text{mole air}} \right)_{\text{air}} \int \frac{1}{\lambda_{EO}} - 1 \right]_{\text{rich pulse}} \text{Airflow} \left[ \int_{\text{rich pulse}} \text{dt} \right] - AO_2 \text{ release}$$

(Eq. j)

wherein:

$$k = \frac{\left( \frac{1}{\lambda_{EO}} - 1 \right)}{\left[ 1 + \frac{2}{3} c \lambda_{TLP} \right]_{\text{rich pulse}}} \int_{\text{rich pulse}} \text{Airflow \left[ \int_{\text{rich pulse}} \text{dt} \right]}$$

and

$$10 \quad c : \left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{mole}}$$

all other terms having the meanings defined above.

In this embodiment, injecting Eq. c and Eq. d in Eq. h, gives the
following theoretical formula:

$$\begin{align*}
1.5 \text{NO}_2 \text{ released} &= \frac{4}{5} \left( \frac{\text{mole } O_2}{\text{mole air}} \right)_{\text{air}} \int_{p} \left( \frac{1}{\lambda_{EO}} - 1 \right)_{p} \text{Airflow}_{r,p} \int_{\text{rich pulse}} \text{dt} - \left( \frac{1}{\lambda_{EO}} - 1 \right)_{\text{rich pulse}} \text{Airflow}_{r,p} \int_{\text{rich pulse}} \text{dt} \right) \text{ANO}_2 \text{ released}
\end{align*}$$

(Eq. k)

In practice, this theoretical formula may be simplified to Eq. j with the
meanings given above for k and c.
CLAIMS

1. Method of monitoring the adsorptive capacity of a NO\textsubscript{x} adsorber of an internal combustion engine, comprising the following steps:
   1) identification of O\textsubscript{2} moles released from the adsorber during rich pulse regeneration,
   2) calculation of NO\textsubscript{2} moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO\textsubscript{2} from said adsorber
   3) optional storage of successive results of steps 1 and 2
   4) use of the results of step 2 and/or 3 to update an adaptive capacity model to control the duration of the lean phase and/or of the rich pulse.

2. Method as claimed in claim 1, comprising the following additional step:
   5) use of the results of step 2 and/or 3 to update an adaptive capacity model to detect sulfur poisoning of the adsorber and to trigger a desulfation process.

3. Method as claimed in any one of the preceding claims, wherein the release model in step 2 is based on following equation:

   \[ ANO_{2s} = \left[ 1 - \frac{AO_{2s}}{FO_{2s}} \right] FNO_{2s} \]

   wherein:

   - $ANO_{2 \text{ released}}$ : actual (calculated) moles of NO\textsubscript{2} released from the adsorber during rich pulse regeneration
   - $AO_{2 \text{ released}}$ : measured O\textsubscript{2} moles during rich pulse

   \[
   FO_{2s} = \left( \frac{\text{mole O}_2}{\text{mole air}} \right) \int_{t}^{T} \left( \frac{\lambda_{\text{L}}}{\lambda} \right) \text{Flow}_{\text{ich}} \ dt
   \]
\[ FNO_2 s = 4 \left( \frac{\text{mole } O_2}{\text{mole air}} \right) \int_{s}^{\text{Airflow}_{\text{rich pulse}}} \left( \frac{\lambda_{\text{TLP}}}{\lambda} \right)^{-1} \left( \frac{1}{1 + \frac{2}{3} \left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{stoich}}} \right) \lambda_{\text{TLP}} \, dt \]

\[
\frac{\text{mole } O_2}{\text{mole } C}_{\text{stoich}} : \text{oxygen to carbon ratio at stoichiometric operating conditions}
\]

\[
\frac{\text{mole } O_2}{\text{mole air}}_{\text{air}} : \text{molar oxygen to air ratio in ambient air}
\]

\[
\lambda_{\text{EO}} = \frac{\frac{\text{mole } O_2}{\text{mole } C}_{\text{EO}}}{\frac{\text{mole } O_2}{\text{mole } C}_{\text{stoich}}} : \text{lambda value upstream of the adsorber (EO, engine out)}
\]

\[
\lambda_{\text{TLP}} = \frac{\frac{\text{mole } O_2}{\text{mole } C}_{\text{TLP}}}{\frac{\text{mole } O_2}{\text{mole } C}_{\text{stoich}}} : \text{lambda value downstream of the adsorber (TLP, tailpipe)}
\]

Airflow_{\text{rich pulse}} : airflow during rich pulse.

4. System for monitoring the adsorptive capacity of a \( NO_x \) adsorber of an internal combustion engine, comprising:

- oxygen detection means upstream and/or downstream of the \( NO_x \) adsorber
- means to generate a command to switch the operation of the internal combustion engine from lean to rich and from rich to lean operating conditions
- means to perform the calculation of \( NO_x \) released during rich pulse using the output of the oxygen detection means in a release model based on lambda deviation across the adsorber and the release chemistry of \( NO_2 \) from said adsorber
- optional means to store successive calculation values, and
- means to use at least one of the calculation values to update an adaptive capacity model to determine the duration of the lean phase and/or of the rich pulse.
5. System as claimed in claim 4, further comprising:
- means to use at least one of the calculation values to update an adaptative capacity model to determine the necessity of a desulfation of the NO$_x$ adsorber due to excessive sulfur poisoning, and
- means to generate a command to trigger a desulfation of the NO$_x$ adsorber.

6. System as claimed in any one of claims 4 or 5, wherein the release model is based on following equation:

\[
\text{ANO}_2\text{released} = \left[ 1 - \frac{\text{AO}_2\text{released}}{\text{FO}_2\text{released}} \right] \text{FNO}_2\text{released}
\]

wherein:

10 \text{ANO}_2\text{released} : actual (calculated) moles of NO$_2$ released from the adsorber during rich pulse regeneration

\text{AO}_2\text{released} : measured O$_2$ moles during rich pulse

\[
\text{FO}_2\text{released} = \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \int_{\text{rich pulse}} \left( \frac{\lambda_{\text{LTP}} - 1}{\lambda_{\text{EO}}} \right) \text{Airflow}_{\text{rich pulse}} dt
\]

\[
\text{FNO}_2\text{released} = \frac{4}{3} \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \int_{\text{rich pulse}} \left( \frac{\lambda_{\text{LTP}} - 1}{\lambda_{\text{EO}}} \right) \left( 1 + \frac{2}{3} \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} \right) \text{Airflow}_{\text{rich pulse}} dt
\]

\[
\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} : \text{oxygen to carbon ratio at stoichiometric operating conditions}
\]

\[
\left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} : \text{molar oxygen to air ratio in ambient air}
\]

\[
\lambda_{\text{EO}} = \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} : \text{lambda value upstream of the adsorber (EO, engine out)}
\]

\[
\lambda_{\text{LTP}} = \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}} : \text{lambda value downstream of the adsorber (TLP, tailpipe)}
\]

\text{Airflow}_{\text{rich pulse}} : \text{airflow during rich pulse.}
7. System as claimed in claim 6, wherein
- the oxygen detection means comprise an UEGO type oxygen sensor upstream and a switching type oxygen sensor downstream of the adsorber
- the release model is based on following equation:

\[
\text{ANO}_2 \text{ released} = \frac{4}{3} \left[ \frac{1}{1 + \frac{2}{3} \left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}}} \right] \left[ \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \int \left( \frac{1}{\lambda_{EO, \text{rich pulse}}} - 1 \right) \text{Airflow}_{\text{rich pulse}} \, dt \right] - \text{AO}_2 \text{ release}
\]

wherein:

ANO2 released: actual (calculated) moles of NO2 released from the adsorber during rich pulse regeneration

\[
\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}}
\]

: oxygen to carbon ratio at stoichiometric operating conditions

\[
\left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}}
\]

: molar oxygen to air ratio in ambient air

\[
\lambda_{EO} = \frac{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{EO, rich pulse}}}{\left( \frac{\text{mole O}_2}{\text{mole C}} \right)_{\text{stoich}}}
\]

: lambda value upstream of the adsorber (EO, engine out)

Airflowrich pulse: airflow during rich pulse

AO2 released: measured O2 moles during rich pulse.

8. System as claimed in claim 6, wherein
- the oxygen detection means comprise an UEGO type oxygen sensor downstream and a switching type oxygen sensor upstream of the adsorber
- the release model is based on following equation:

\[
\text{ANO}_2 \text{ released} = \frac{4}{3} \left[ \left( \frac{\text{mole O}_2}{\text{mole air}} \right)_{\text{air}} \int \left( \frac{1}{\lambda_{EO, \text{rich pulse}}} - 1 \right) \text{Airflow}_{\text{rich pulse}} \, dt \right] - \text{AO}_2 \text{ release}
\]

wherein:

ANO2 released: actual (calculated) moles of NO2 released from the adsorber during rich pulse regeneration
\[ k = \frac{\left( \frac{1}{\lambda_{EO}} - 1 \right)}{\int \left( \frac{1 + \frac{2}{3} c \lambda_{TLP}}{\lambda_{EO}} - 1 \right) \text{Airflow}_{\text{rich pulse}} dt} \]

\[ \int \text{Airflow}_{\text{rich pulse}} dt \]

c : constant

\[ \left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{stoich}} : \text{oxygen to carbon ratio at stoichiometric operating conditions} \]

\[ \left( \frac{\text{mole } O_2}{\text{mole air}} \right)_{\text{air}} : \text{molar oxygen to air ratio in ambient air} \]

5 \[ \lambda_{EO} = \frac{\left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{stoich}}}{\left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{EO}}} : \text{lambda value upstream of the adsorber (EO, engine out)} \]

\[ \lambda_{TLP} = \frac{\left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{stoich}}}{\left( \frac{\text{mole } O_2}{\text{mole } C} \right)_{\text{TLP}}} : \text{lambda value downstream of the adsorber (TLP, tailpipe)} \]

Airflow_{rich pulse} : airflow during rich pulse

AO_2 \text{ released} : \text{measured } O_2 \text{ moles during rich pulse.}
ABSTRACT

Method of monitoring the adsorpive capacity of a NO\textsubscript{x} adsorber of an internal combustion engine, comprising the following steps:

1) identification of O\textsubscript{2} moles released from the adsorber during rich pulse regeneration,

2) calculation of NO\textsubscript{2} moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO\textsubscript{2} from said adsorber

3) optional storage of successive results of steps 1 and 2

4) use of the results of step 2 and/or 3 to update an adaptative capacity model to control the duration of the lean phase and/or of the rich pulse.
**RAPPORT DE RECHERCHE**

étalé en vertu de l'article 35.1 a)
de la loi luxembourgeoise sur les brevets d'invention
du 20 juillet 1992

**DOCUMENTS CONSIDERES COMME PERTINENTS**

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**DATE D'ACHIVEMENT DE LA RECHERCHE**

27 mars 2002

**Examinateur**

Faria, C
ANNEXE AU RAPPORT DE RECHERCHE
RELATIF À LA DEMANDE DE BREVET LUXEMBOURGOISE NO. LO 256 
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