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(54) **Title**: A SYSTEM COMPRISING AN AIR PURIFIER AND A CONTAINER

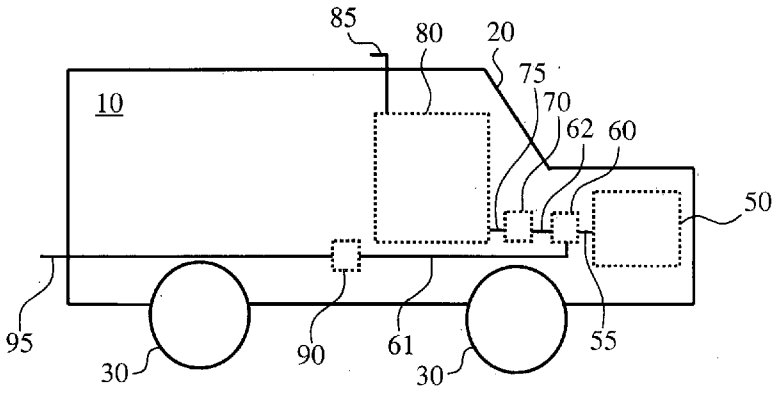


Fig. 1

(57) **Abstract**: There is provided a system comprising an air purifier and a container, the air purifier configured to output purified air into the container, wherein the air purifier comprises an adiabatic compression stage for purifying the air. The air purifier may comprise an internal combustion engine and a contaminant removal stage, and wherein the contaminant removal stage is configured to receive combusted exhaust gases from the internal combustion engine, to remove contaminants from the combusted exhaust gases, and to output the combusted exhaust gases after the removal of the contaminants as the purified air.

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A SYSTEM COMPRISING AN AIR PURIFIER AND A CONTAINER

Technical Field of the Invention

The invention relates to a system comprising an air purifier and a container, the air purifier configured to output purified air into the container.

Background to the Invention

Air purifiers find applications in defending against chemical and biological agents, the air purifiers being used to render potentially polluted air as safe to breath. Known air purifiers include thermocatalytic air purifiers which involve contacting potentially contaminated air with a suitable catalyst at high temperatures, for example 250°C to 400°C. Chemical agents are deactivated by oxidation and biological agents are rendered ineffective by the high-temperature exposure. However, these air purifiers typically need considerable power to heat the incoming air to the required temperature.

One use of such air purification systems comprises drawing potentially polluted air from the external environment, purifying it using an air purification system, and ejecting the air into a container such as a tent where people can safely breathe the ejected air.

However, such air purification systems require significant dedicated equipment which may be heavy, bulky, costly, or otherwise inconvenient to implement.

It is therefore an aim of the invention to improve upon known air purifiers.

Summary of the Invention

According to one aspect of the invention, there is provided a system comprising an air purifier and a container, the air purifier configured to output purified air into the container, wherein the air purifier comprises an adiabatic compression stage for purifying the air.

The use of an adiabatic compression stage raises the temperature of the air without requiring an external heat source, the heating being achieved as a result of the compression of the air. The inventors have discovered that heat and pressurisation of the air within the adiabatic compression stage is capable of breaking down various harmful chemical/biological agents.

The adiabatic compression stage may optionally be augmented with a heating stage, for example an electrical, gas, solar, or nuclear heating stage, to help in destroying chemical and/or biological agents.

The heating stage may be placed before or after the adiabatic compression stage, or may be placed within the adiabatic compression stage to provide additional heat during the adiabatic compression.

The adiabatic compression stage may for example comprise compression cylinders in a similar manner to an internal combustion engine.

The adiabatic compression stage may be configured to burn fuel within the air that is compressed to help assist in destroying chemical and/or biological agents, for example the fuel may be burnt within a compression chamber of the adiabatic compression stage.

The adiabatic compression stage may be an internal combustion engine, and may be followed by a contaminant removal stage.

The adiabatic compression stage may be an internal combustion engine that is operated without any fuel and turned over by external means, for example by a motor. Operating the internal combustion engine without any fuel avoids combustion products to help allay any health concerns when the purified air is to be breathed by humans.

Alternatively, the internal combustion engine may be operated with fuel, in combinations with a contaminant removal stage.

Accordingly, in a second aspect of the invention there is provided a system comprising an air purifier and a container, the air purifier configured to output purified air into the container, wherein the air purifier comprises an internal combustion engine and a contaminant removal stage, and wherein the contaminant removal stage is configured to receive combusted exhaust gases from the internal combustion engine, to remove contaminants from the combusted exhaust gases, and to output the combusted exhaust gases after the removal of the contaminants as the purified air. The air purifier may be configured to output purified air into the container for breathing by a human.

The inventors have discovered that the high temperatures and pressures present within internal combustion engines are very effective at destroying and/or breaking down various chemical or biological agents that are harmful to humans and/or sensitive equipment. Accordingly, the purified air that is directed into the container substantially consists of combusted exhaust gases of the internal combustion engine. The contaminant removal stage is configured to remove contaminants that are normally present in combusted exhaust gases, for example particulates and/or carbon monoxide, to render the exhaust gases more breathable by humans and/or less harmful to sensitive equipment.

Whilst the exhaust gases of internal combustion engines are known to present some danger to humans, after the contaminant removal stage the danger presented by the exhaust gases can be considerably less than the danger presented by chemical and/or biological agents in the external environment. The term "air purifier" as used herein denotes a device which can improve the purity of air by removing certain chemical or biological agents. The purified air does not have to be sufficiently pure for humans to be able to breathe it completely safely for long periods of time, but in the presence of certain chemical or biological agents in the external environment, the purified air will be safer to breathe than the air that is in the external environment. The purified air may be relatively safe for humans to breathe for a short period of time, for example until a person is able to leave a polluted area.

The purified air may also help to protect valuable and sensitive equipment inside the container from Chemical, Biological, and/or Radiological contamination.

The container may be a cabin that is suitable for occupation by a person, and may for example be a vehicle cabin, a tent, or a collective protection shelter. The air purifier takes air from the ambient environment, purifies it, and outputs it into the cabin.

Preferably, the container is sufficiently well sealed when the air purifier outputs purified air into the container so that only air from the air purifier enters the container, and that any other holes in the container all act as air outlets due to the purified air entering the container slightly raising the pressure inside the container. Accordingly, the container may be sealed except for air inlet(s) that are configured to only allow air in from the air purifier, and air outlet(s) that are configured to only allow air out of the container. The configuration (for example the size and/or position) of the air inlets and air outlets may be determined with reference to the flow rate of air from the air purifier. The container may be permanently sealed in the above-described way, or it may be switched to being sealed in the above-described way when the combusted exhaust gases are input into the container. Optionally, one or more or all of the air outlets may comprise one-way valves to help ensure that air cannot enter into the container through the air outlets.

Advantageously, the system may be switchable between outputting the combusted exhaust gases into the container and outputting the combusted exhaust gases into the external environment. Preferably, the system is electrically switchable between outputting the combusted exhaust gases into the container and outputting the combusted exhaust gases into the external environment for ease of control, for example automatic control by an electronic sensor.

The system may further comprise a switch stage that is configured to switch between outputting the combusted exhaust gases into the container, and outputting the combusted exhaust gases into the external environment. Accordingly, the system may be automatically and/or manually switched between outputting the combusted exhaust gases into the container, and outputting the combusted exhaust gases into the external environment. The decision to switch to outputting the combusted exhaust gases into the container or outputting the combusted exhaust gases into the external environment may be based upon actual levels of chemical/biological agent in the surrounding environment, and/or upon the likelihood of there being dangerous levels of chemical/biological agent in the surrounding environment at the present time or in the near future.

The switch stage may switchably direct the combusted exhaust gases into a first conduit or into a second conduit, the first conduit routing the combusted exhaust gases on a path leading to an external exhaust, and the second conduit routing the combusted exhaust gases on a path leading to an inside of the container.

The external exhaust may be part of an external exhaust stage, the external exhaust venting the combusted exhaust gases into the external environment.

Advantageously, the switching of the system between outputting the combusted exhaust gases into the external environment and outputting the combusted exhaust gases into the container may comprise switching between sending the combusted exhaust gases into the contaminant removal stage, and sending the combusted exhaust gases into an external exhaust stage. Accordingly, the contaminant removal stage may only receive combusted exhaust gases if the combusted exhaust gases are to be input into the container. Therefore, the contaminant removal stage may only be used when it is required to generate breathable air, and not be used when the combusted exhaust gases are destined for the external exhaust stage and external environment, thereby maintaining the contaminant removal stage in a good condition for when it is actually needed.

The system may further comprise an actuator configured to be actuated by a person inside the container to switch the system between outputting the combusted exhaust gases into the external environment and outputting the combusted exhaust gases into the container. Accordingly, a person wishing to switch to receiving breathable air from the air purifier does not need to leave the inside of the container and go into potentially polluted air outside of the container. The actuator may for example be a manually actuated switch, such as a button or slider.

Advantageously, the system may further comprise a detector configured to detect an external chemical or biological agent, and a controller configured to switch the system from outputting the combusted exhaust gases into the external environment to outputting the combusted exhaust gases into the container in response to the detector detecting an excessive level of the chemical or biological agent. Accordingly, a person inside the vehicle does not have to remember to manually switch the system from outputting the combusted exhaust

gases into the external environment to outputting the combusted exhaust gases into the container, or to themselves be aware of the excessive level of the chemical or biological agent. When the system switches over to outputting the combusted exhaust gases into the container, the system may give an indicator signal such as a light or a sound to alert the person inside the vehicle that they are now breathing combusted exhaust gases.

Preferably, the contaminant remover stage comprises a filter for removing particulates from the combusted exhaust gases. The filter may be configured to remove at least 99.97% of particles that are 0.3μm or larger in diameter, for example the filter may be a HEPA filter.

The contaminant remover stage may comprise a catalytic converter incorporating a catalyst such as Hopcalite for removing carbon monoxide from the combusted exhaust gases.

Advantageously, the system may further comprise a cooling stage that is configured to cool the combusted exhaust gases before they are input into the container. The cooling helps prevent the temperature inside the container from rising to excessive levels, and the cooling stage may for example comprise heat exchangers and the use of an air conditioning unit to reduce the temperature and the water content of the exhaust. Then, the air purifier may output the purified air into the container via the cooling stage.

The internal combustion engine may be a diesel internal combustion engine. The use of a diesel internal combustion engine may be particularly advantageous since diesel engines typically run with an oxygen surplus, for example the oxygen content of the exhaust may be in the region of 15% - 20%.

The term "combusted exhaust gases" is used to apply to the gases that result from combustion in the internal combustion engine. The combusted exhaust gases comprise contaminants before the contaminant removal stage, and do not comprise contaminants (or comprise reduced levels of contaminants) after the contaminant removal stage. The contaminants are the constituent parts of the combusted exhaust gases which the contaminant removal stage is configured to remove. The combusted exhaust gases may comprise particulate elements, for example soot particles.

Brief Description of the Drawings

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Fig. 1 shows a schematic diagram of a vehicle comprising a system according to a first embodiment of the invention;
Fig. 2 shows a schematic diagram of a system according to a second embodiment of the invention;
Fig. 3 shows a mass spectrum graph of exhaust from a diesel engine under normal conditions;
Fig.4 shows a mass spectrum graph taken at an air inlet of the diesel engine of Fig. 3 when the inlet air was contaminated with 1,1,1 trichloroethane (TCE); and
Fig. 5 shows a mass spectrum graph taken at the exhaust of the diesel engine when the inlet air was contaminated with 1,1,1 trichloroethane (TCE).

The drawings are for illustrative purposes only and are not to scale.

Detailed Description

A first embodiment of the invention will now be described with reference to the schematic diagram of Fig. 1, which shows a vehicle 10 having a windshield 20, wheels 30, and a container in the form of a cabin 80 for a driver and optionally passengers. The vehicle 10 comprises a diesel internal combustion engine 50 for providing motive force to the vehicle, and a pipe 55 for taking combusted exhaust gases away from the engine 50.

The pipe 55 leads to a switch stage 60, which is connected to a first conduit 61 and a second conduit 62.

The first conduit 61 is connected to an external exhaust stage comprising an exhaust cleaner 90 for removing particulates and carbon monoxide, and an external exhaust 95 for venting exhaust gases to the external environment. In this particular embodiment, the exhaust cleaner 90 includes a diesel particulate filter and a diesel oxidation catalytic converter.

The second conduit 62 is connected to a contaminant removal stage 70, and the contaminant removal stage 70 is connected to an air inlet 75 of the vehicle cabin 80. The vehicle cabin 80 has an air outlet 85 to allow air to escape from the cabin 80. In this particular embodiment, the contaminant removal stage comprises a HEPA filter that filters at least 99.97% of particles that are 0.3μm or larger in diameter, and a catalytic converter with a Hopcalite catalyst. The air outlet 85 comprises a 1-way valve so that air can only move from through the air outlet 85 from inside the cabin to outside the cabin.

During normal use of the vehicle, the engine 50 ejects combusted exhaust gases into the pipe 55, and the switch stage directs the combusted exhaust gases from the pipe 55 into the first conduit 61, where they are carried to the exhaust cleaner 90 for filtering and CO removal, and subsequently vented to the outside environment through the external exhaust 95.

If the air outside the vehicle may be contaminated, then the switch stage 60 is used to switch the combusted exhaust gases from being directed down the first conduit 61, to being directed down the second conduit 62.

In this particular embodiment, the switching of the switch stage 60 is controlled by a controller (not shown in Fig. 1) that is connected to the switch stage 60. The controller may be connected to an actuator such as a button inside the cabin, and/or to various detectors around the vehicle for detecting the presence of potentially dangerous contaminants in the external environment. The controller is configured to switch the switch stage from outputting the combusted exhaust gases into the conduit 61 to outputting the combusted exhaust gases into the second conduit 62 in response to a cabin occupant actuating the actuator, or in response to the detector(s) detecting potentially dangerous contaminants in the external environment.

The controller also checks that the cabin is sealed apart from the air inlet 75 and the air outlet 85, so that air from the external environment cannot enter the cabin, unless it has been first purified by the diesel combustion engine 50 and contaminant removal stage 70. Upon switching the switch stage 60 to direct combusted exhaust gases to the conduit 62, the controller may automatically close any cabin air vents and/or windows, and/or issue a visual or auditory warning to the driver that any such air vents and/or windows need to be manually closed.

When the switch stage 60 directs the combusted exhaust gases into the second conduit 62, the combusted exhaust gases pass into a contaminant removal stage 70 which comprises various filters and catalysts such as Hopcalite for improving the breathability of the air to humans. The purified air then passes through the air inlet 75 into the cabin 80, where it can be breathed by the occupant(s) of the cabin. The diesel combustion engine 50 and contaminant removal stage 70 therefore collectively constitute an air purifier that purifier air from the external environment and outputs it into the cabin for breathing by a human.

The switch stage continues to direct the combusted exhaust gases into the second conduit 62 until the air in the external environment is considered to be safer, for example until the vehicle has driven a certain distance away from a given incident, at which time a person in the cabin may use the actuator to change the switch stage 60 back to outputting the combusted exhaust gases into the conduit 61.

The use of separate catalytic converters within the exhaust cleaner 90 and the contaminant removal stage 70, means that the catalytic converter within the contaminant removal stage 70 is not used (and therefore not degraded) during the normal use of the vehicle, and should therefore always be in good condition when called upon to help produce breathable air. As a variation to the first embodiment, a catalytic converter may be incorporated between the diesel internal combustion engine 50 and the switch stage 60, so that the combusted exhaust gases are partially purified before they reach the contaminant removal stage 70, and so that a separate catalytic converter does not need to be included within the exhaust cleaner 90.

Optionally, a cooling stage may be fitted between the contaminant removal stage 70 and the cabin 80 to cool the purified air before it enters the cabin 80, for example if the purified air is still too hot after it leaves the contaminant removal stage 70. The cooling stage comprises a repetitive meandering of part of the air inlet pipe 75, so that heat is lost from the air inlet pipe 75 to air in the external environment surrounding the repetitive meandering of the air inlet pipe 75, or so that heat is lost from the air inlet pipe 75 to a cooling fluid surrounding the repetitive meandering of the air inlet pipe 75, in the manner of a heat exchanger.

Such a cooling stage could alternatively be fitted between the engine 50 and the contaminant removal stage 70, for example by applying repetitive meandering to the pipe 55 or to the

second conduit 62. However, it may be advantageous to place the cooling stage between the contaminant removal stage 70 and the cabin 80, so that the contaminant removal stage 70 can take advantage of the higher exhaust temperature to work more efficiently.

In an alternate embodiment, the switch stage 60 and external exhaust stage 90, 95 may not be implemented, for example the pipe 55 could eject exhaust gases directly into the contaminant removal stage 70 so that exhaust gases were always vented through the cabin 80. However the switch stage 60 and the exhaust stage 90, 95 are useful since they prevent the contamination stage 70 from degrading during the normal use of the vehicle, and protect the occupants in the cabin from breathing exhaust gases all of the time, for example if the exhaust gases are still less than desirable for breathing after the contaminant removal stage 70.

A second embodiment of the invention will now be described with reference to the schematic diagram of Fig. 2, which shows a system comprising an air purifier 130 and a container which is a cabin in the form of a collective protection tent 100. Collective protection tents are typically designed to help protect people from Chemical, Biological, and/or Radiological threats in the external environment.

The collective protection tent 100 has a door 110 for one or more persons to enter the tent, and an actuator switch 158. A person inside the tent may use the actuator switch 158 to start the air purifier 130 via an electrical cable 157 that runs between the air purifier 130 and the collective protection tent 100.

The collective protection tent 100 is sealed to the external environment except for an outlet pipe 115 that is used to direct purified air from the air purifier 130 into the collective protection tent 100, and for an air outlet pipe 120 that vents air out of the collective protection tent 100. The air outlet 120 comprises a 1-way valve so that air can only move from inside the collective protection tent to outside the collective protection tent.

The air purifier 130 comprises a detector 156 for detecting excessive levels of chemical, biological, and/or radiologically active substances in the external environment, and the detector is connected to a controller 155. The controller 155 is connected to the actuator switch 158 by the electrical cable 157.

The controller 155 is connected to a diesel internal combustion engine 150, and is configured to start and stop the internal combustion engine from running according to the signals that it receives from the actuator switch 158 and the detector 156.

The diesel internal combustion engine 150 has an exhaust manifold connected to a contaminant removal stage 170. The contaminant removal stage 170 is configured to reduce contaminants in combusted exhaust gases from the diesel internal combustion engine 150 to a level where the combusted exhaust gases can be breathed by a human, and is substantially the same as the contaminant removal stage 70 hereinbefore described.

The contaminant removal stage 170 ejects purified air into the collective protection tent 100 via the air inlet pip 115, so that the purified air can be breathed by the persons inside the tent.

The air purifier 130 may be an individual unit, or it may be part of a larger system. For example, the air purifier 130 may be part of a vehicle such as the vehicle 10, the engine 150 may be the engine 50, the contaminant removal stage 170 may be the contaminant removal stage 70, and the vehicle 10 may provide the air outlet 115 in addition or instead of the air outlet 75.

A test was carried out to demonstrate the effectiveness of internal combustion engines in breaking down chemical agents, which will now be described with reference to Figs. 3 - 5.

A 2.6 KVA diesel generator internal combustion engine was used for the test, and Fig. 3 shows a mass spectrum of the exhaust gases of the diesel generator when operating under normal conditions.

Then, the diesel generator was modified by introducing 1,1,1 trichloroethane (TCE) into the generator air inlet using a syringe pump. Fig. 4 shows a mass spectrum of the air inlet gases with a large peak between 95 – 100 m/z corresponding to the added TCE.

The chemical agent 1,1,1-Trichloroethane was chosen to investigate aromatic C-C and C-Cl bond breaking within the diesel engine generator. As reported in "Toxicological Profile for 1,1,1-Trichloroethane", Agency for Toxic Substances and Disease Registry (ATSDR). 2006,

TCE can act as a central nervous system depressant and inhaling high levels can cause dizzyness and lightheadedness, and exposure to much higher levels can cause unconsciousness or fatality.

The exhaust gases of the diesel generator were measured at the air outlet, and no TCE was found, i.e. the TCE had been broken down within the diesel generator. Fig. 5 shows a mass spectrum of the air outlet gases of the diesel generator, and it can be seen that the large peak between 95 – 100 m/z corresponding to the added TCE has virtually disappeared.

A third embodiment of the invention is the same as the second embodiment of the invention, except for that the collective protection shelter 100 is substituted for a sensitive equipment container for housing sensitive equipment, for example computers, communications equipment and airframes.

Further embodiments falling within the scope of the appended claims will also be apparent to those skilled in the art, for example various combinations of the features disclosed in relation to the first, second, and third embodiments.

CLAIMS

1. A system comprising an air purifier and a container, the air purifier configured to output purified air into the container, wherein the air purifier comprises an adiabatic compression stage for purifying the air.

2. The system of claim 1, wherein the air purifier comprises an internal combustion engine and a contaminant removal stage, and the adiabatic compression stage is provided by the internal combustion engine.

3. The system according to Claim 2 wherein the contaminant removal stage is configured to receive combusted exhaust gases from the internal combustion engine, to remove contaminants from the combusted exhaust gases, and to output the combusted exhaust gases after the removal of the contaminants as the purified air.

4. The system of claim 3, wherein the container is sealed during the time when the air purifier outputs purified air into the container, except for one or more air inlets that only allow air in from the air purifier, and for one or more air outlets that only allow air out of the container.

5. The system of claim 3 or 4, wherein the system is switchable between outputting the combusted exhaust gases into the container and outputting the combusted exhaust gases into the external environment.

6. The system of claim 5, wherein the system further comprises a switch stage configured to switch between outputting the combusted exhaust gases into the container and outputting the combusted exhaust gases into the external environment, and wherein the switch stage switchably directs the combusted exhaust gases into a first conduit or into a second conduit, the first conduit routing the combusted exhaust gases on a path leading to an external exhaust and the second conduit routing the combusted exhaust gases on a path leading to an inside of the container.

7. The system of claim 5 or 6, wherein switching of the system between outputting the combusted exhaust gases into the external environment and outputting the combusted exhaust

gases into the container comprises switching between sending the combusted exhaust gases into the contaminant removal stage and sending the combusted exhaust gases into an external exhaust stage.

8. The system of claim 5, 6, or 7, further comprising an actuator configured to be actuated by a person inside the container to switch the system between outputting the combusted exhaust gases into the external environment and outputting the combusted exhaust gases into the container.

9. The system of claim 5, 6, 7, or 8, further comprising a detector configured to detect an external chemical or biological agent, and a controller configured to switch the system from outputting the combusted exhaust gases into the external environment to outputting the combusted exhaust gases into the container in response to the detector detecting an excessive level of the chemical or biological agent.

10. The system of any preceding claim, wherein the contaminant remover stage comprises a filter for removing particulates from the combusted exhaust gases.

11. The system of claim 10, wherein the filter is configured to remove at least 99.97% of particles that are 0.3μm or larger in diameter.

12. The system of any preceding claim, wherein the contaminant remover stage comprises a catalytic converter for removing carbon monoxide from the combusted exhaust gases.

13. The system of any preceding claim, further comprising a cooling stage that is configured to cool the combusted exhaust gases before the combusted exhaust gases are input into the container.

14. The system of claim 13, wherein the air purifier outputs the purified air into the container via the cooling stage.

15. The system of any preceding claim, wherein the internal combustion engine is a diesel internal combustion engine.

16. The system of any preceding claim, wherein the container is a cabin, for example a vehicle cabin, a tent, or a collective protection shelter.

17. A system comprising an air purifier and a container, the system being substantially as described herein with reference to the accompanying drawings.

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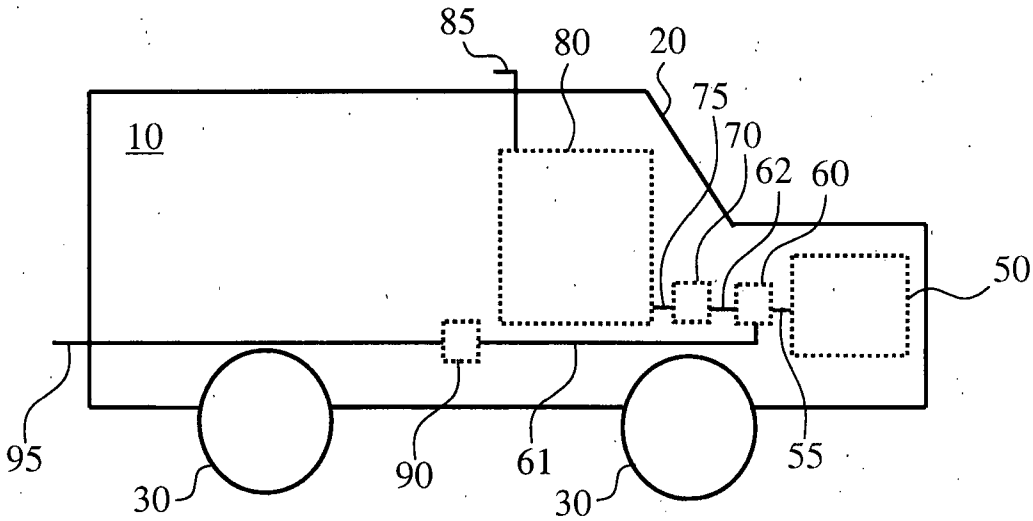

85
80
20
75
70
62
60
10
50
95
30
90
61
30
55

Fig. 1

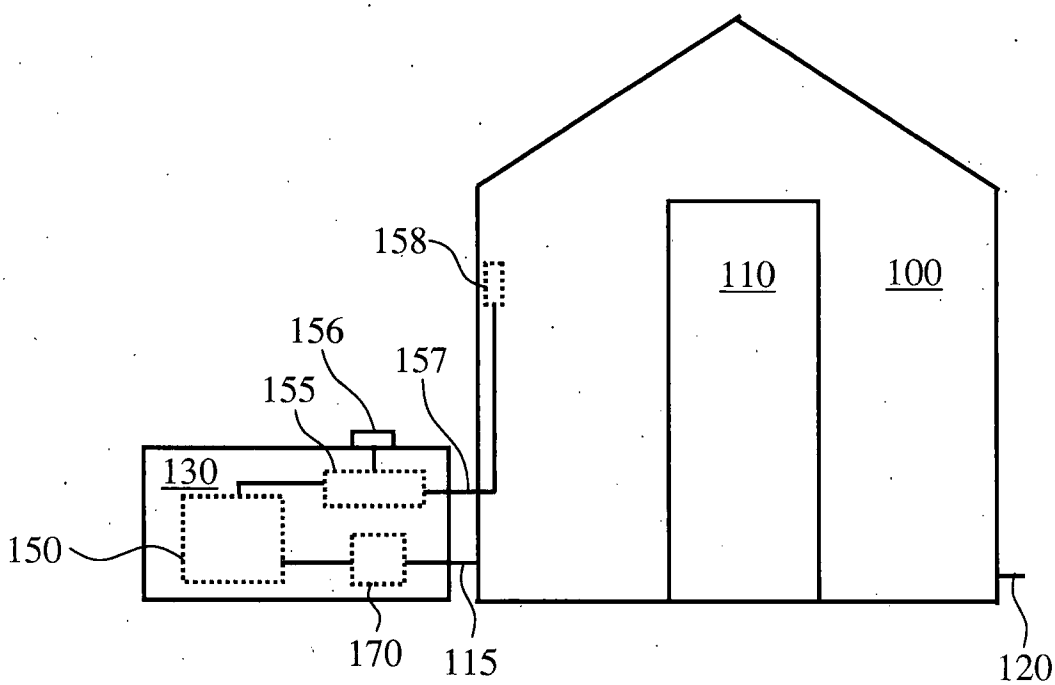

158
110
100
156
157
155
130
150
170
115
120

Fig. 2

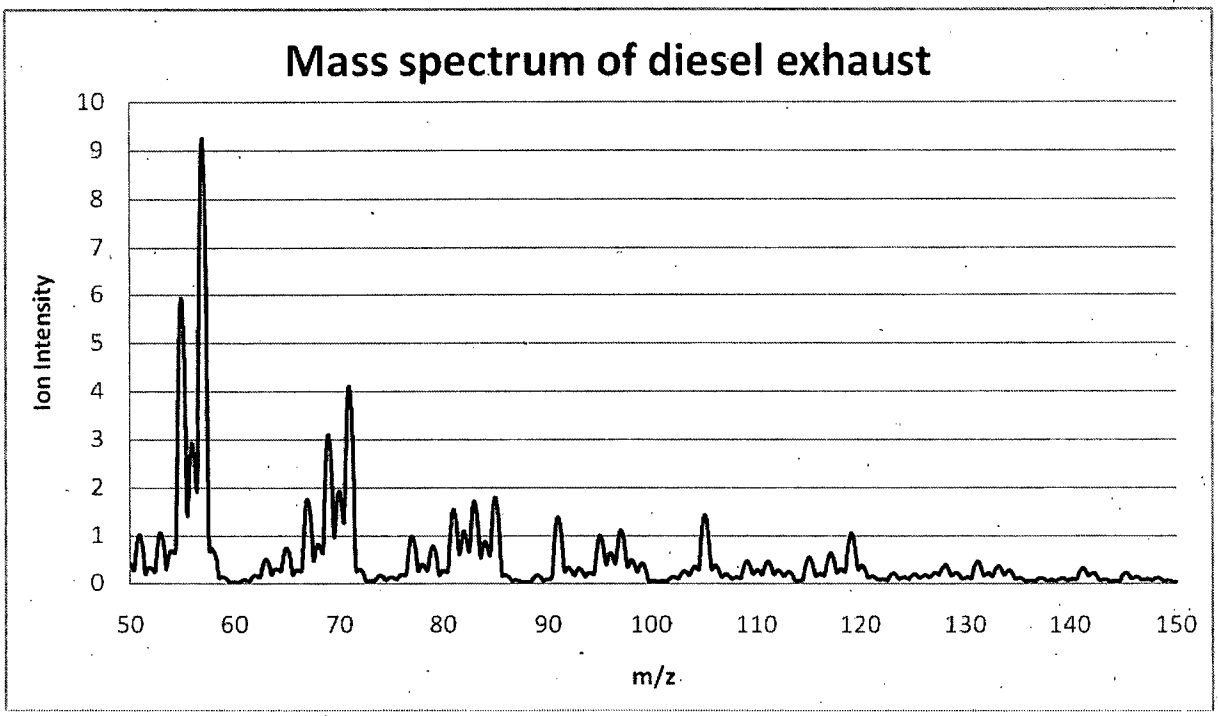

Mass spectrum of diesel exhaust
Ion Intensity
10
9
8
7
6
5
4
3
2
1
0
50
60
70
80
90
100
110
120
130
140
150
m/z

Fig. 3

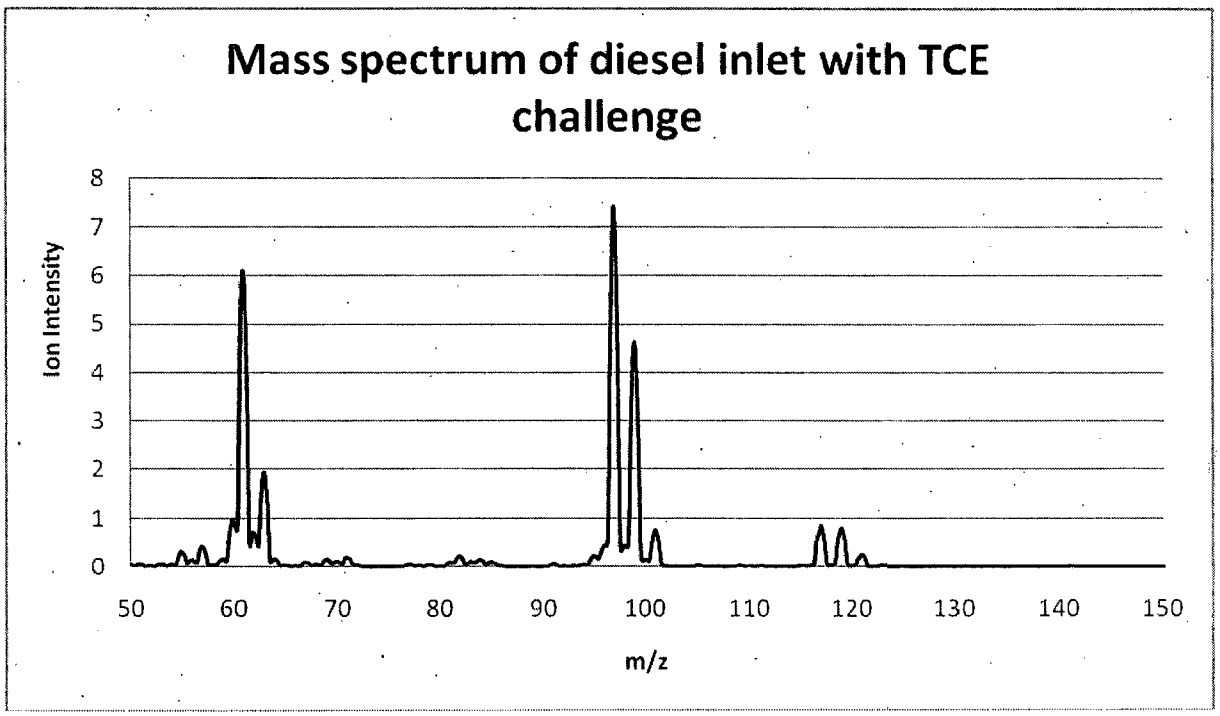

Mass spectrum of diesel inlet with TCE challenge
Ion Intensity
8
7
6
5
4
3
2
1
0
50
60
70
80
90
100
110
120
130
140
150
m/z

Fig. 4

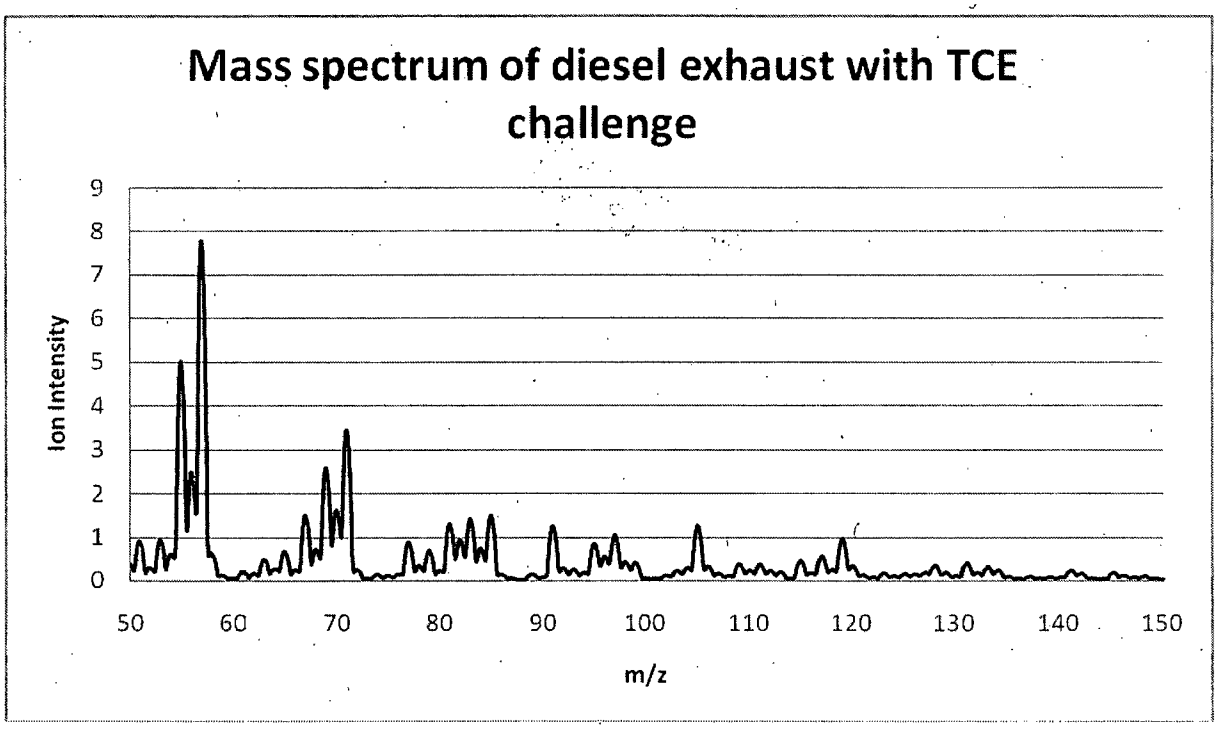

Mass spectrum of diesel exhaust with TCE challenge
Ion Intensity
0
1
2
3
4
5
6
7
8
9
50
60
70
80
90
100
110
120
130
140
150
m/z

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/000397

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60H1/00 B60H3/06 F41H7/03 F24F1/44 F24F3/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60H F41H F24F B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 0 935 102 A2 (HOWDEN AIRCONTROL LTD [GB] AIRCONTROL TECHNOLOGIES LTD [GB]) 11 August 1999 (1999-08-11) paragraph [0010] - paragraph [0021] paragraph [0023] - paragraph [0029] figures	1,2, 10-12, 15-17 3-9,13, 14

A	US 4 732 579 A (VELTMAN JOOST [US] ET AL) 22 March 1988 (1988-03-22) column 1, line 45 - column 2, line 17 column 2, line 65 - column 4, line 65 figures	1

A	FR 2 938 795 A1 (RENAULT SAS [FR]) 28 May 2010 (2010-05-28) page 9, line 1 - line 18 figures 2-6	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 November 2013	22/11/2013

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/000397

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/105008 A1 (HAGH BIJAN F [US] ET AL) 5 May 2011 (2011-05-05) paragraph [0029] - paragraph [0031] figures 4,5 -----	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2013/000397

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0935102 A2	11-08-1999	EP 0935102 A2	11-08-1999
		GB 2334094 A	11-08-1999
		US 6099617 A	08-08-2000
US 4732579 A	22-03-1988	NONE	
FR 2938795 A1	28-05-2010	NONE	
US 2011105008 A1	05-05-2011	NONE	