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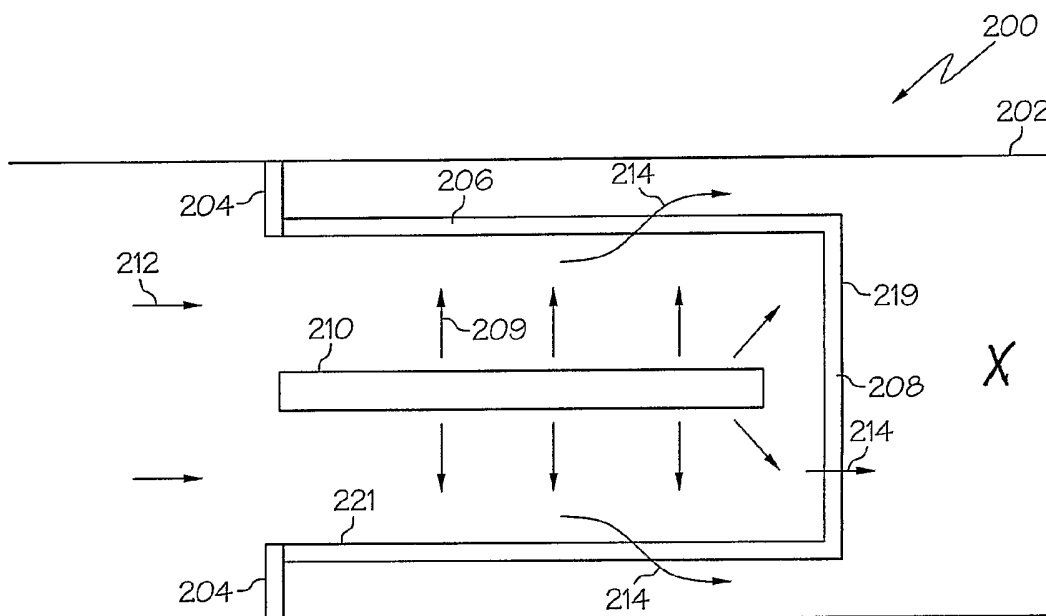
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(54) Title: INFRARED HEAT REGENERATION DEVICE AND METHOD



(57) Abstract: A regenerable emission control system (200) including an infrared energy source (210), such as an infrared lamp or a resistance heated filament; and an exhaust emission trap (206), that at least partially surrounds the infrared energy source (210), where in a typical embodiment at least a portion of a trapping surface of the emission trap and/or at least a portion of a trapped pollutant on the trapping surface are directly heated by the infrared energy source (210).

INFRARED HEAT REGENERATION DEVICE AND METHOD

5 This application claims the benefit of U.S. Provisional Application No. 60/605,101, filed August 27, 2004.

 The entire disclosure of the provisional application is incorporated herein by reference.

10 FIELD OF THE INVENTION

 This invention discloses the use of low wavelength or infrared heating to regenerate emission control devices by removing soot, nitrogen oxides (NO_x), sulfur, and other pollutants from the emission control device.

15 BACKGROUND OF THE INVENTION

 Combustion engine exhaust (particularly diesel exhaust) contains three general classes of pollutants that have potential adverse health or environmental impact and which are being regulated to progressively lower concentrations by the U.S. EPA and state and local regulatory authorities:
20 unburned hydrocarbons (HC), particulate matter (PM) and oxides of nitrogen (NO_x). Unburned hydrocarbons are dealt with principally with in-cylinder combustion technology and are not currently a major technology problem. Particulate matter (PM) is a current and growing health concern, is an increasing focus of regulation, and, in extremely small particle sizes, will be a
25 major technical challenge. Oxides of nitrogen (NO_x) are ozone precursors, are the focus of the mostly regulatory attention, and will be very difficult to reduce to the concentrations mandated by the EPA for 2007.

 Combustion engine particulate matter (PM) consists mostly of a dry carbon core with adsorbed organic combustion byproducts. Ash from
30 lubricating oil, wear metals, and adsorbed water are also present, but are not currently of major concern, either because of low quantities (ash and wear metals) or benign nature (water). Sulfur compounds are also typically

present. Sulfur compounds contribute to particulate mass and numbers, and also degrade the performance of catalysts and any materials designed to remove PM, HC and NOx. The dry carbon core is thought to be a health hazard through irritation of cell walls, with very fine particulates currently receiving much attention. The adsorbed combustion byproducts, while present in very small quantities, are known to contain very active carcinogens and mutagens.

Current technology uses a wall flow ceramic trap (a honeycomb structure oriented parallel to the exhaust gas flow) that captures nearly all of these particles. The trap quickly fills and becomes plugged. The particles/adsorbate must be burned off to regenerate (clean) the trap. To initiate oxidation/combustion, trap surface temperatures must reach 600°C to 650°C. If the trap is coated with a catalyst, the temperature needed for burnoff can be reduced to about 300°C. The energy released by the initial combustion of the particulate can maintain the process until most of the particulate is burned. This process with a catalyzed trap works well when the exhaust temperature is above ~300°C and the duty cycle is relatively severe (i.e., high exhaust gas energy content), but on-highway certified vehicles must function well in severe climates and severe duty cycles. This currently is a serious problem to be overcome.

BRIEF DESCRIPTION OF THE INVENTION

A first embodiment of the invention includes radiant heating of emissions traps, designed to remove particulate matter, NOx, sulfur, and sulfur compounds, partially burned hydrocarbons, soot, and/or other pollutants from the emissions of diesel or gasoline engines or other hydrocarbon combustion sources. This radiant heating would typically reduce time to heat and maximum temperature, and therefore reduce heating related damage to the trap and reduce energy required to regenerate or clean the trap.

A second embodiment includes trap and radiant heat source geometries designed to take advantage of the line of sight nature of heat

transfer by radiant heating, and materials selection to match radiant heat transfer physics and fabrication need for the required geometry. Radiant energy obtained from reflectors of radiant energy (e.g. reflector of an infrared (IR) lamp) is included in the line of sight discussion herein, not just the
5 radiant energy obtained directly from an IR lamp.

A third embodiment of the invention includes active control of the heating of emission control devices. The use of a temperature measurement device, such as a pyrometer or thermocouple, combined with closed loop control for sensing and controlling the surface temperature of a particulate,
10 sulfur, or NO_x trap used for controlling diesel emissions is described. This approach is thought to be uniquely advantageous when combined with a heating source, such as infrared, that selectively heats the active surface of the trap.

In a further embodiment of the invention radiation sources such as IR
15 lamps can be used to heat the upstream face of a particulate trap to begin regeneration of the trap in its most heavily laden first few millimeters. This would be done, preferably, in low gas flow conditions. Heat released from the regeneration process would propagate downstream in the trap to adjacent trapped pollutant and the regeneration process would propagate
20 through the length of the trap. The need for regeneration and its progress could be monitored with pressure and temperature. To make the best use of the IR energy, some or most of the exhaust gas is typically diverted away from the particulate trap during regeneration so that only a small amount of exhaust gas would be heated in the trap during regeneration.

25 For long term use, dual exhaust emission traps can be used whereby one is regenerated while the other is trapping emissions. Typical emissions are disclosed in detail herein.

A yet further embodiment of the invention provides for a method for removing a pollutant from an exhaust emission trap by the steps of providing
30 an exhaust emission trap through which an exhaust gas flows, wherein the trap has a trapping surface; and providing an infrared energy source and heating the trapping surface and/or a pollutant trapped on the trapping

surface wherein the pollutant is removed. Typically the trap used has an upstream trapping surface, a downstream trapping surface, an internal trapping surface, or combinations thereof. The infrared energy source is typically controlled to provide a desired temperature for trap regeneration and
5 in some aspects of the invention is controlled by providing pulses of infrared energy. The flow of exhaust gas may or may not be stopped during the heating and pollution removal step.

Another aspect of the invention provides for a regenerable emission control system made up of an infrared energy source; and an exhaust
10 emission trap, that at least partially surrounds the infrared energy source. The emission control system typically has a trapping surface and the trapping surface and/or a pollutant trapped on the trapping surface is/are directly heated by the infrared energy source.

A yet another aspect of the invention provides for a method for
15 providing emission control for an exhaust gas by the steps of providing a regenerable control system; flowing the exhaust gas through an exhaust emission trap of the system, wherein pollutants are trapped therein; and heating the exhaust emission trap with the infrared energy source wherein trapped pollutants are removed.

20

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of an infrared energy source and an emission control trap according to another aspect of the invention.

Figure 2 is a schematic of another embodiment for a regenerable
25 emission control trap according to one aspect of the invention.

Figure 3 is a schematic of another aspect of the regenerable emission control trap having reverse flow.

Figure 4 is a graph showing temperature history of a test for one embodiment of a regenerable emission control device according to the
30 invention.

Figure 5 is a graph showing pressure history for the same test as in Figure 4.

Figure 6 is a block diagram of some typical configurations of Figure 2.

Figure 7 is a block diagram of some typical configurations of Figure 3.

Figure 8 is a block diagram of some other typical configurations of Figure 2 combined with nonthermal plasma.

5 Figure 9 is a block diagram of some other typical configurations of Figure 3 combined with nonthermal plasma.

DETAILED DESCRIPTION OF THE INVENTION AND BEST MODE

10 Radiant heating, particularly rapid heating by pulse heating, can be applied emission traps, pollution traps, diesel particulate traps, sulfur traps, and NO_x adsorber/traps currently discussed in the literature. The geometries of many of these traps are characterized by small gas-passage cross-sections normal to the mean exhaust flow direction and long passages parallel to the
15 mean gas flow direction. Typical examples would be flow-through honeycomb structures and wall-flow honeycomb structures (with alternate ends -- upstream and downstream -- of adjacent honeycomb cells being blocked). In these cases, line-of-sight access to the trapping surfaces (cell walls) for infrared energy is difficult, so the infrared energy is typically applied to the
20 upstream face of the trap or adsorber/trap surface. The portion of the structure on direct line of sight to the infrared energy source (e.g., IR lamp) could be heated very rapidly and controllably, or at any rate desired. However, heating of other (downstream) portions of these structures would depend on conduction, convection, and release of chemical energy (for
25 exothermic reactions) in previously heated areas.

Referring now to Figure 1, this figure is a schematic of a typical emission control system 100 with honeycomb or small passages 102 that comprise the exhaust emission trap enclosed in a housing 104. The flow of exhaust gas 106 is from left to right. An infrared energy source 108 is shown
30 facing the inlet 110 of the housing 104. Direct heating is easy to achieve at the inlet 110, however heating of the remainder of the system is limited to convection or conduction typically at long distances. In this embodiment the

heated pollutant begins to burn off at the exposed surface at the inlet and continues to burn down into the interior of the exhaust emission trap.

Example 1

5 In this example, a soot filter prototype was built using a conventional honeycomb substrate with alternate (upstream & downstream) of adjacent honeycomb cells being plugged. (See Fig. 1) The soot filter substrate was 5.66" x 6" and four 500 watt quartz halogen bulbs were installed in the housing to focus on the front face (inlet) of the soot filter.

10 The soot filter was loaded to about 11" Hg backpressure with a medium truck diesel engine in a test cell. Regeneration was done off-line with compressed air flowing at 0.85 CFM. The lamps were turned on and after 15 minutes had raised the face of the soot filter to 660°C. Soot burning began at this point and an exotherm of 1034°C was reached. Soot burning was complete after

15 37 minutes and the soot filter was observed to be clean at the end of the experiment. This regeneration represented an off-line regeneration because of the low airflow rate and this regeneration was successful.

 Regeneration, in some applications can be accomplished periodically with the engine shut down. Alternatively, exhaust could be bypassed from

20 the after-treatment system, perhaps through a similar parallel trap during regeneration. Alternatively, the filter could be regenerated continuously or at selected intervals even when the engine was running in cases where the exhaust gases contained enough oxygen for regeneration or where some additional air was added to the upstream side of the trap.

25 It is believed that a critical mass of pollutant is required for the embodiment of Figure 1 so that regeneration propagates to the rest of the trap surface. This is expected to be true where only a portion of the trapping surface or trapped pollutant is heated.

 Another embodiment is a trap or adsorber/trap geometry designed to

30 allow line-of-sight access to essentially all trap or adsorber/trap surfaces for much more complete and uniform radiant heating. This type of design, together with rapid radiant heating, would make much better use of available

support/substrate/catalyst/adsorber/trap material and would allow for both uniform and simultaneous trap, or adsorber/trap regeneration. One example of such a design is shown in Figures 2 and 3.

Figure 2 illustrates a regenerable emission control system 200 consisting of a housing 202. Within housing 202 a supporting seal 204 holds a trap 206 that is permeable to exhaust gas. The end 208 of the trap 206 may be plugged with an impermeable material or may be of the same permeable material as the rest of the trap. Exhaust gas flow 212 is from left to right with exhaust gases passing through the trap as shown by arrows 214. Radiant heat 209 for regeneration of the trap 206 is provided by radiant heater 210. Radiant heater 210 is typically an infrared heater or a resistance heater.

Example 2

In this example, the trap (soot filter) / lamp geometry according to Figure 2 was tested and regeneration attempted with the engine running. In this configuration, the soot filter consisted of a cordierite tube with exhaust flow from inside to outside. The quartz halogen lamp was mounted internally and concentrically to the trap 206 in order to obtain the best radiant coupling to the soot layer formed on the internal surface of the trap. The lamp was 500 watts with a filament length of 1.25 inches. The cordierite tube was 1.5" OD x 6" LG x 2mm wall thickness.

Engine testing was done with a 500 cc single cylinder Hatz engine in order to match the small filter tube size with engine exhaust flow rate. Several compromises were made in the soot filter assembly design in order to simplify assembly and to obtain rapid qualitative performance data. These are discussed below.

A loading and soot burning test was conducted with the new soot filter assembly. In this test, the engine was run for 40 minutes with the soot filter installed. Engine backpressure increased due to soot loading and periodic regenerations were attempted by powering the quartz halogen lamp. Data for this test is shown in Figure 4, which illustrates temperature history for engine

exhaust (A), soot filter inlet (B), and soot filter internal near the lamp (C). The periodic spikes on soot filter (C) temperature indicate periods of time where the lamp was on (pulses of heat) and the temperatures reached. The first two lamp-on times were 10 seconds and 15 seconds and all later ones were 2 minutes. The data spike at 8:24am was a reset of the data system.

Figure 5 illustrates the soot filter pressure history for the same test in both gage and absolute temperature. The lower curve (A) indicates the gage backpressure and the upper curve (B) indicates the absolute pressure in psi.

In this example, the engine was started at 8:22am (refer to timing marks in Figures 4 and 5) and temperature and backpressure began to build due to higher volumetric flow rate and from the accumulation of the soot in the filter. At 8:24am, the data system was reset to be sure data was being recorded. At 8:32am, backpressure began to drop and then leveled out. It is believed that this was due to a small hole which developed over several minutes in one of the soot filter end gaskets. Soot leakage was also observed through the lamp connector. A total of eight lamp-on intervals were conducted through 9:01am with the last six lamp-on intervals being 2 minutes each. During the latter lamp-on intervals, temperatures reached up to 690°C inside the filter tube and each lamp event was accompanied by a small drop in exhaust backpressure, indicating some soot burning. During the lamp-on interval, the outside of the soot filter was observed to develop an orange glow in the vicinity of the lamp filament after about 45 seconds of heating. When the soot filter was disassembled, a cleaner band (not black) was seen internally and adjacent to the lamp filament. The lamp filament was damaged by the high temperatures experienced and began to sag and distort under these conditions. Clearly a more robust lamp is needed and preferred or temperature conditions need to be controlled.

The soot filter, under engine running conditions, reached up to 690°C internally when the lamps were lit. An orange glow was also observed on the outside of the filter. This temperature was sufficient to cause some soot burning and reduction in backpressure. The soot filter tube was observed to be cleaner internally in the vicinity of the filament where soot burning

occurred. This experiment demonstrates that a quartz halogen lamp can cause high temperatures in an operating soot filter and initiate soot burning and a subsequent drop in backpressure.

This test was performed with a lamp shorter than the filter tube (1.25" vs. 6") to expedite construction and assembly. It was expected that regeneration would occur in a short section of the filter and would be detectable, which succeeded. The lamp filament was damaged by overheating during the experiment. Those skilled in the art will appreciate that additional thermocouples could be installed in order to better define and control temperatures in the vicinity of the filament. Regeneration may also be made at a lower engine load in order to prevent damage to the lamp from overheating. Shorter lamp on times (shorter power pulses) may also prevent the heating damage.

It is important to note that the present geometry is very different from traditional soot filters and the filter face velocity of the present invention is about 15 to 20 times that of traditional soot filters. The test showed the importance of convective heat transfer to soot surface temperature. The soot was being heated by radiation from the lamp and cooled convectively by the exhaust flowing through it. This made it more difficult to predict the behavior of the trap and regeneration conditions.

However, the present invention using infrared radiation (IR) to heat diesel exhaust particulate traps, NO_x traps (adsorbers), and sulfur traps, allows regeneration (removal of trapped pollutant) to be accomplished at essentially all ambient air and exhaust temperatures

If the device in Figure 2 was a sulfur trap based on a ceramic or metal permeable wall (substrate) coated with a sulfur-trapping material, the sulfur-trapping coating could be placed either on the upstream side of the substrate/wall or on its downstream side. If placed on the upstream (preferred) side, the sulfur-trapping material would be heated directly by the radiant heat source. If placed on the downstream side, the sulfur-trapping material would be heated indirectly by conduction from the substrate wall material and by

gas flowing through the wall. Note that the upstream side of the trap or adsorber/trap is heated directly.

In Figure 2 the exhaust gas flows from left to right as shown. Figure 3 illustrates the same trap or adsorber/trap geometry, but with exhaust gas 213 flow in the opposite direction, here from right to left. Flow of exhaust gas through the trap is indicated by arrows 217.

In Figure 3, the downstream side 219 of the trap or adsorber/trap is heated directly by the infrared energy source. By changing the direction of exhaust gas flow in this geometry, therefore, either the upstream 221 or downstream 219 surface of the trap or adsorber/trap wall can be heated directly by infrared energy. Also, in the case of a sulfur trap, the sulfur-trapping coating can be placed on either upstream or downstream surfaces (or both) and can, therefore, be heated directly by radiation or by conduction and convection. In Figures 2 and 3 an infrared energy source may located at "X" as an alternative to or in addition to the infrared energy source 210.

In the case of a NO_x trap/adsorber (which would need to be regenerated to release NO₂ for NO₂ → N₂ + O₂ conversion and also to remove contaminant sulfur from the NO_x adsorber material), the same geometry, coating location (on permeable ceramic or metal substrate walls), and exhaust gas flow direction would be available as configuration options, in much the same logic as described for a sulfur trap.

With both the sulfur trap and the NO_x trap/adsorber, preferred arrangements would involve direct radiant heating of the coating to be regenerated (cleaned), to allow maximum control of heating and regeneration and to minimize coating degradation. That is, the preferred arrangements would have a coating on the upstream side in Figure 2 and on the downstream side in Figure 3 or on both sides, with respect to gas flow through the permeable trap or trap/adsorber walls, so that the coatings would directly face the radiant heat source. Schematically, these embodiments are represented in Figures 6A, 6B, 6C, 7A, 7B, and 7C.

Referring now to Figures 6A, 6B, and 6C, the arrows indicate the direction of gas flow. Radiant heat (e.g. infrared lamp) is provided to the

upstream side of a trap for PM, HC, S with a NO_x adsorber (Figure 6A); the upstream side of a trap for PM, HC with a NO_x adsorber (Figure 6B); and the upstream side of a trap for PM, HC, with a NO_x catalyst (Figure 6C). Radiant heat is provided to the downstream side of a trap for PM, HC, S with a NO_x adsorber (Figure 7A); the downstream side of a trap for PM, HC with a NO_x adsorber (Figure 7B); and the downstream side of a trap for PM, HC, with a NO_x catalyst (Figure 7C).

If combined sulfur trapping and NO_x adsorber/trap functions were desired in a single component, sulfur-trapping and NO_x adsorbing coatings could be co-deposited on one or both upstream and downstream sides of permeable substrate walls, with choices made with respect to the direction of exhaust gas flow and the surface(s) to be radiantly heated being made to maximize NO_x reduction, sulfur trapping, and device durability/lifetime or to optimize regeneration cycles and regeneration power consumption.

These same concepts can also be applied to the trapping and removal of particulate matter (PM) and unburned or partially burned hydrocarbons (HC). In the simplest example, the geometry in Figure 2 would be used, with the material in the permeable wall chosen for PM and HC trapping, minimum flow restriction, durability, cost, etc. Regeneration would be accomplished by direct radiant heating to oxidize the trapped PM and HC. Since the (short-term) temperature required to directly oxidize PM and HC in the presence of excess oxygen is similar to that required to directly (thermally) remove sulfur from commonly used NO_x adsorber materials (600°C to 650°C), a combination of PM+HC trapping, sulfur trapping, and NO_x conversion into a single component is feasible. Additional catalyst, such as precious metal oxidizers, to expedite PM+HC oxidation or to oxidize NO to NO₂ for the NO_x adsorber, can also be incorporated if desired. Widely available oxide catalysts include those based on precious and non-precious metal oxides. Typical NO_x adsorbers include those based on barium.

Another application of these concepts would involve the use of a nonthermal plasma (NTP) to convert NO to NO₂ selectively (without extensive oxidation of SO₂ to SO₃, although this is not a necessary feature). Some

variations are shown below in block function form (Figures 8 and 9). Figures 8A, 8B, and 8C illustrate three typical configurations of Figure 2, and Figures 9A, 9B, and 9C illustrate three typical configurations of Figure 3. Figures 8A-8C and 9A-9C illustrate the same configuration as Figures 6A-6C and 7A-7C except that the exhaust gas is pretreated with a nonthermal plasma NTP.

In applications of PM+HC trapping, combined with sulfur trapping and/or NO_x adsorber, selection of coating location on the permeable substrate wall, with respect to both gas flow and direct radiant heating, would be made with full consideration of the much higher sensitivity to thermal degradation of NO_x adsorber coatings and sulfur trapping coatings, relative to PM+HC trapping materials and PM+HC oxidation catalysts.

Very short regeneration times (seconds) and short cycle times are anticipated for PM+HC and NO_x removal with trap area being adjusted as required through trap length, diameter, wall shape (smooth cylinder, corrugated, multilayer, etc.), etc. The concepts described here also apply to various wall/substrate materials and configurations, including but not limited to, free standing supported fiber aggregate, fiber composite, mesh, multilayer mesh, paper, monolithic ceramic, metal foam, metal or ceramic honeycomb. These concepts also apply to pebble and particle beds.

Temperature Controlled Heating of Emission Control Devices

Radiant heating (specifically infrared heating) is advantageous in that it preferentially heats the surface of the body exposed to it. In the case of PM, sulfur, and NO_x traps, heating the active surface of these devices (especially when the surface is coated with a catalyst) is the primary heating objective. Restricting the heating to the surface minimizes the amount of heat required to reach a given temperature, thus minimizing parasitic energy requirements, and minimizes the time required for regeneration at any given heat flux, thus shortening the time spent in the regeneration mode.

A first embodiment for temperature control involves the use of surface temperature sensors in combination with closed loop control of the regeneration cycle. A preferably fast responding, low cost, robust and non-

contacting pyrometer would be placed permanently in the emission control device and set to sense the temperature of the active surface to be heated e.g., the catalyst surface in a PM, sulfur, or NO_x trap. The output of the sensor would be fed back to a control system that would vary the intensity and/or duration of the heat output of the infrared lamp used to heat the surface, thus controlling the temperature of the heated surface to a desired level. So doing would help prevent overshooting of the desired temperature, which can cause catalyst damage, or undershooting which can cause inadequate regeneration.

10 The second embodiment for temperature control involves tailoring the characteristics of the substrate used in the PM, sulfur, or NO_x trap to take unique advantage of the use of closed loop control described above. For example, in passively heated traps today, (or even in actively heated traps) it is advantageous to use substrates having high thermal conductivity and high thermal mass to minimize the potential for temperature excursions, which could result in overheating of the catalyst surface, thus damaging temperature-sensitive catalysts. However, use of such substrates requires more heat and time than would be ideally needed to heat just the active surface. When closed-loop control, as described above, is employed to control surface temperatures, using low thermal conductivity and low thermal mass substrates is possible and preferred. Such substrates would reduce the amount of heat required, reduce the time spent in regeneration mode, and also reduce the on-board weight for the emission control system.

25 Additionally, substrates having radiative properties (reflectivity, absorptivity, emissivity) or surface properties such as porosity that are selected or engineered to be matched to the radiative source and the general method of using a radiative source for rapid and controlled heating of a catalyst surface as described above are expected to yield unique advantages for this embodiment.

Rapid Heating of Emission Control Devices

Loss of the functionality of NO_x adsorbers due to regeneration (cleaning by heating), particularly when regeneration is designed to remove sulfur as well as to desorb NO₂, is due to excessively long exposure to elevated temperatures and exposure to temperatures higher than required for regeneration. This may result from the nature of the heating process used (usually either by increasing the exhaust temperature by manipulation of engine combustion conditions, or by the introduction of burning fuel into the exhaust system of the NO_x adsorber element, or by heating the exhaust gas stream with a resistance heater). The difficulty in predicting and controlling temperature usually leads to the practice of driving the temperature well over the minimum required for regeneration (600°C to 650°C for sulfur regeneration). Temperature increase can be slow for these heating methods as well, since they generally are configured to heat all of the exhaust stream and the ceramic or metal substrate that is coated with the adsorber material to temperatures above the desorption temperature. Further, the most common adsorber geometry is a honeycomb or similar structure with the majority of the adsorber surface area oriented parallel to the exhaust flow along several inches of length. Heating schemes such as those described above heat the upstream portion of these adsorber structures first, with downstream portions of the adsorber structure being heated more slowly. The result, then, is heating, to increasing temperatures over an extended time, only part of which time is above the temperature required for (NO₂ or S) regeneration, and heating to temperatures much above those required for (NO₂ or S) regeneration. Since microstructural changes associated with degradation in adsorber function are usually a direct result of time at temperature, these regeneration methods degrade adsorber function much more rapidly than is necessary. The same argument applies to sulfur traps and their regeneration.

Improvements to the regeneration process that reduce heating time (and thus, time at temperature), that avoid heating to excessively high temperatures above those required for (NO₂ or S) regeneration or that

damage the trap coating, and that increase the uniformity with which NO_x traps or adsorbers and sulfur traps or adsorbers can be heated will, therefore, decrease degradation of these devices and increase their useful life.

Heating by radiation is one approach to much more rapid and
5 controllable heating that will offer a major improvement over conventional methods that function through convection or conduction heating of the adsorber or trap (NO₂ or S). This is particularly true for very rapid (pulse) heating.

If pulse heating with infrared energy (e.g., infrared light) is applied to
10 regenerate sulfur traps, the traps' effectiveness for higher sulfur concentrations in the exhaust gas will be increased. This will help to extend the lifetime of sulfur traps, as applied to EPA-mandated 2007 (or 2006) fuels containing less than 15 ppm sulfur, to commercially viable times.

Similarly, if pulse heating with infrared energy (including, but not
15 restricted to, IR heating) is applied to NO_x and/or sulfur regeneration of NO_x adsorbers/traps, and with EPA-mandated fuel (2007 or 2006) containing less than 15 ppm sulfur, the lifetimes of these NO_x adsorbers/traps can be extended to commercially viable times.

Application of pulse heating with infrared energy to sulfur traps and
20 NO_x adsorbers/traps also will extend the applicability of the traps to higher sulfur fuels by allowing much more rapid and frequent sulfur regeneration and greatly extending the traps' lifetimes.

The same approach and technology can also be applied to particulate (PM) traps to minimize thermal degradation and extend effective trap life.

25 In another embodiment, the exhaust emissions trap is oriented such that the radiant heat source heats a portion of the trap surface and the regeneration propagates through the remainder of the trap.

Focusing Device

30 Reflector type infrared focusing devices common to the optical arts are contemplated. As is commonly known to those skilled in the art, a reflective

coating can be used to concentrate energy. The reflector is typically selected to withstand the heat and oxidizing conditions in the exhaust environment.

5 While the forms of the invention herein disclosed constitute presently preferred embodiments, many others are possible. It is not intended herein to mention all of the possible equivalent forms or ramifications of the invention. It is to be understood that the terms used herein are merely descriptive, rather than limiting, and that various changes may be made without departing from the spirit of the scope of the invention.

10

INFRARED HEAT REGENERATION DEVICE AND METHOD

5

CLAIMS

We claim:

1. A method for removing a pollutant from an exhaust emission trap comprising:
 - A. providing an exhaust emission trap through which an exhaust gas flows, wherein the trap comprises a trapping surface; and
 - B. providing an infrared energy source and heating the trapping surface and/or a pollutant trapped on the trapping surface wherein the pollutant is removed.
2. The method according to Claim 1, comprising a trap having an upstream trapping surface, a downstream trapping surface, an internal trapping surface, or combinations thereof.
3. The method according to Claim 1, comprising:
 - C. controlling the infrared energy source to provide a desired temperature for trap regeneration.
4. The method according to Claim 1, comprising:
 - C. controlling the infrared energy source to provide pulses of infrared energy.
5. The method according to Claim 1, wherein the flow of exhaust gas is stopped during the heating and pollution removal step.
6. The method according to Claim 1, wherein the flow of exhaust gas is continued during the heating and pollution removal step.

7. The method according to Claim 1, wherein the trapped pollutant comprises particulate matter and/or unburned or partially burned hydrocarbons.

8. The method according to Claim 1, wherein the trapping surfaces are at least partially coated with a catalyst, an NO_x adsorber, a sulfur compound adsorber, or combinations thereof.

9. The method according to Claim 1, wherein the trapped pollutant comprises NO_x.

10. The method according to Claim 1, wherein the trapped pollutant comprises sulfur or contains sulfur.

11. A regenerable emission control system comprising:

A. an infrared energy source; and

B. an exhaust emission trap, that at least partially surrounds the infrared energy source.

12. The regenerable control system trap according to claim 11, wherein the infrared energy source comprises an infrared lamp or a resistance heated filament.

13. The regenerable exhaust control system according to claim 11, wherein the exhaust emission trap has a trapping surface and the trapping surface and/or a pollutant trapped on the trapping surface is/are directly heated by the infrared energy source.

14. A method for providing emission control for an exhaust gas comprising:

A. providing the regenerable control system according to Claim 11;

- B. flowing the exhaust gas through the exhaust emission trap, wherein pollutants are trapped therein;
 - C. heating the exhaust emission trap with the infrared energy source wherein trapped pollutants are removed.
15. The method according to Claim 14, wherein the flow of exhaust gas is stopped during the heating and pollution removal step.
16. The method according to Claim 14, wherein the flow of exhaust gas is continued during the heating and pollution removal step.
17. The method according to Claim 14, wherein steps B and C are repeated.
18. The method according to Claim 14, comprising:
- D. controlling the infrared energy source to provide a desired temperature for trap regeneration.
19. The method according to Claim 14, comprising:
- D. controlling the infrared energy source to provide pulses of infrared energy.
20. The method according to claim 14, wherein the infrared energy source comprises an infrared lamp or a resistance heated filament.

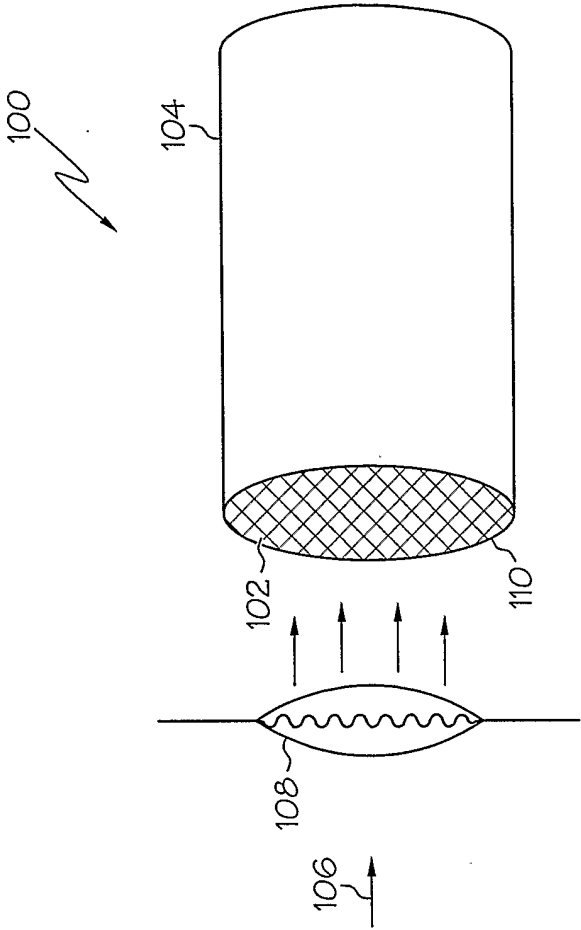


FIG. 1

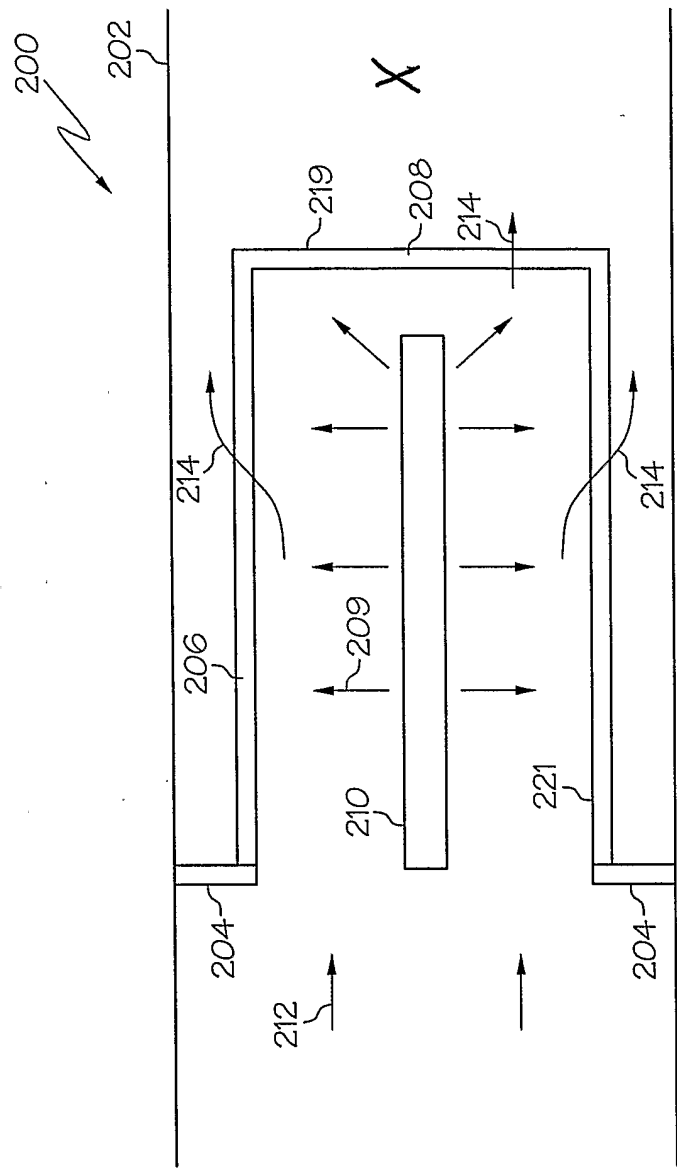


FIG. 2

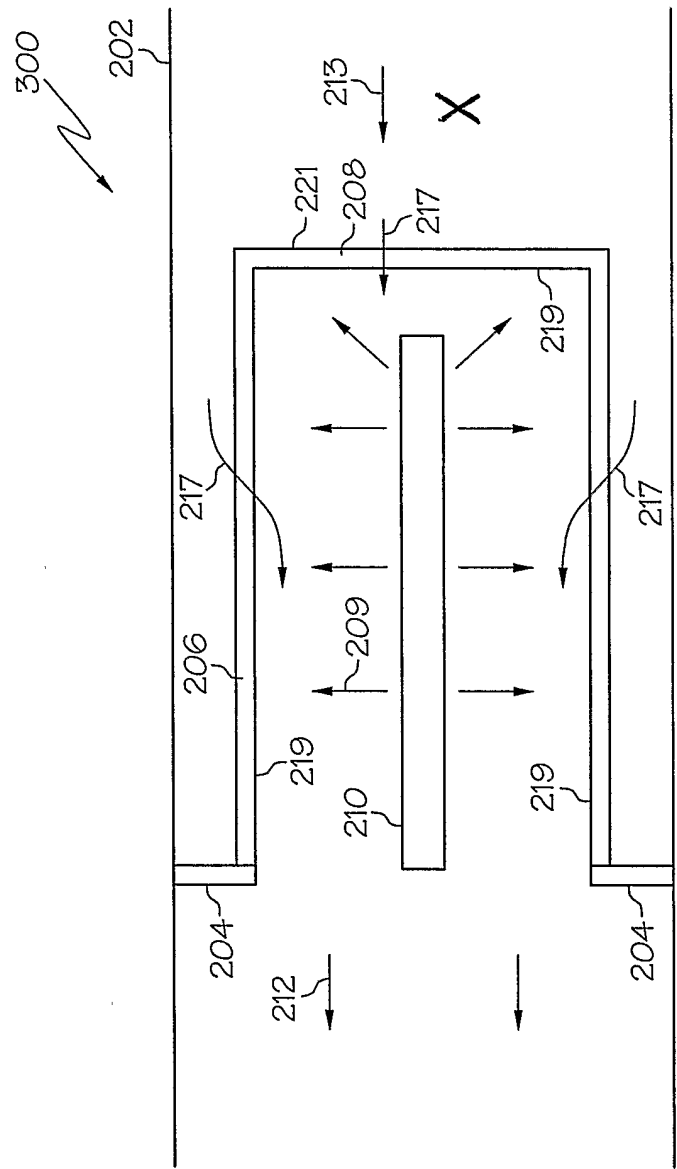


FIG. 3

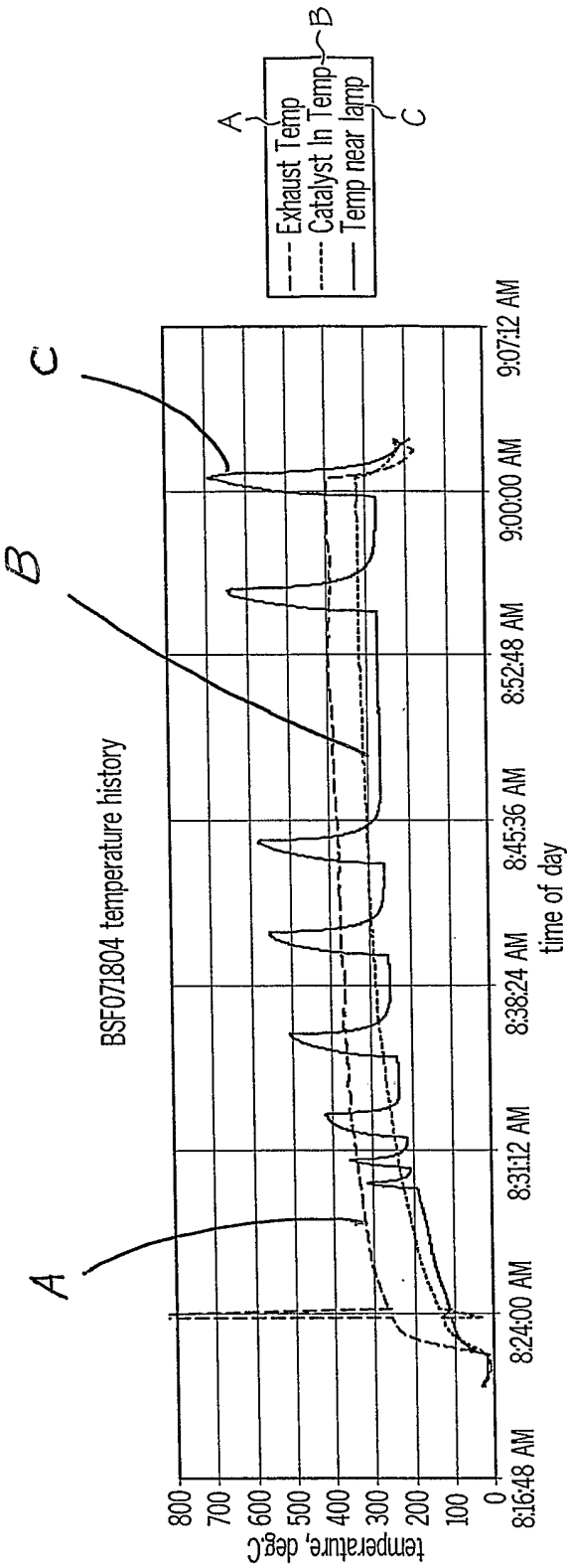


FIG. 4

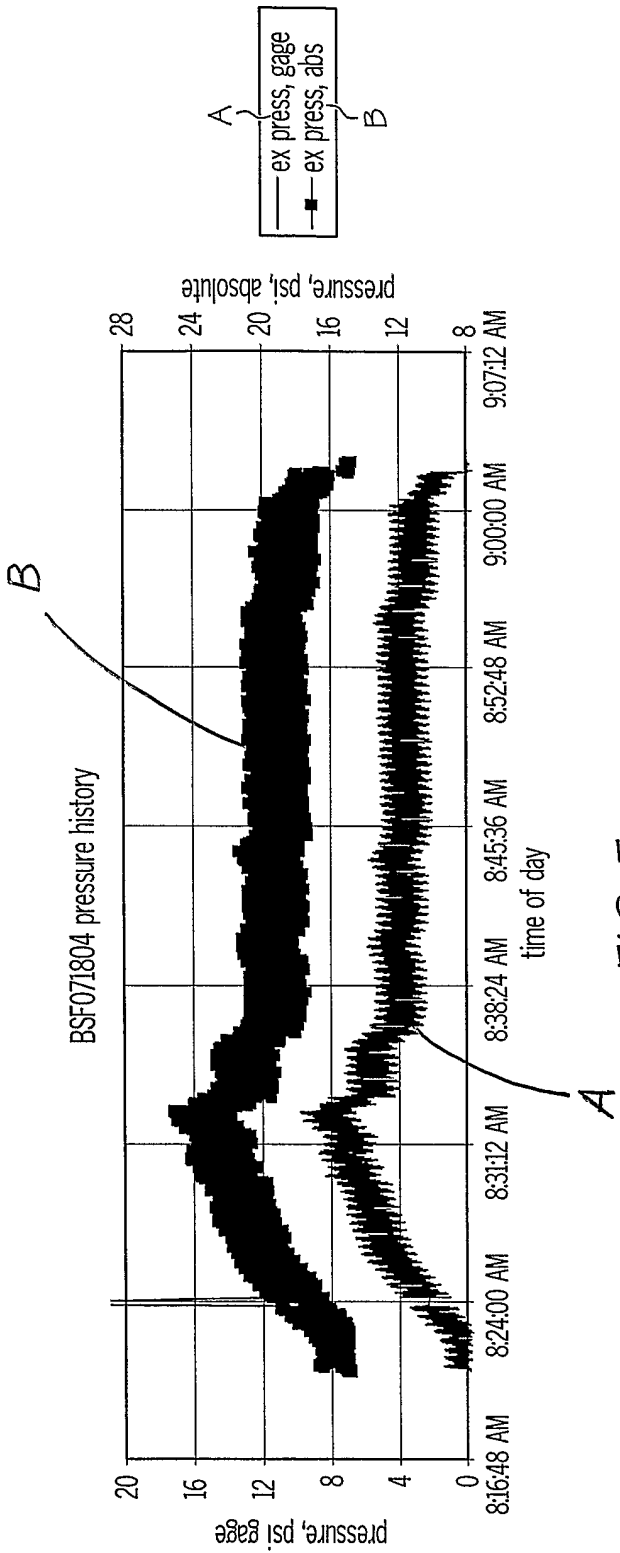


FIG. 5

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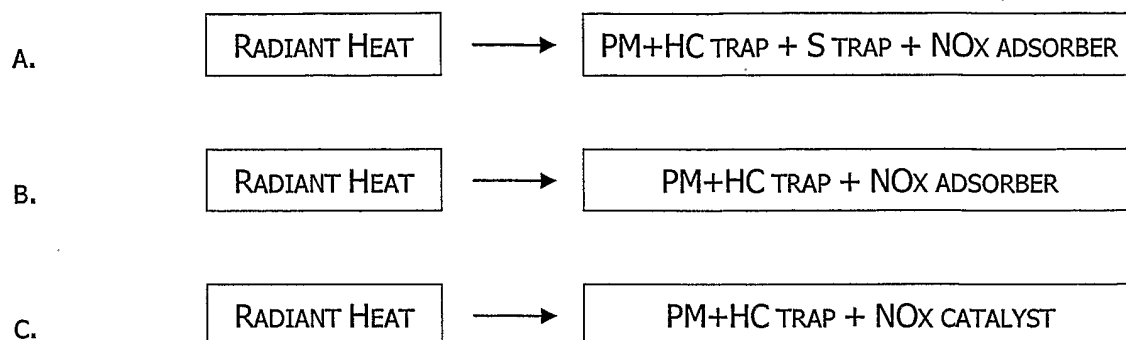


FIGURE 6

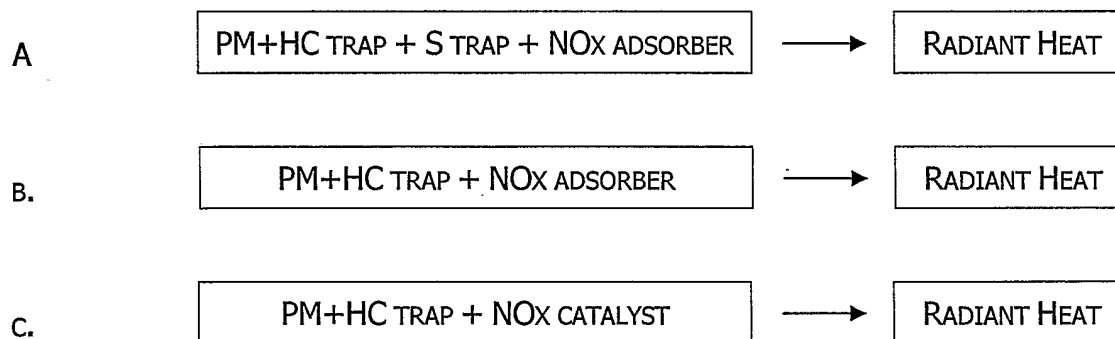


FIGURE 7

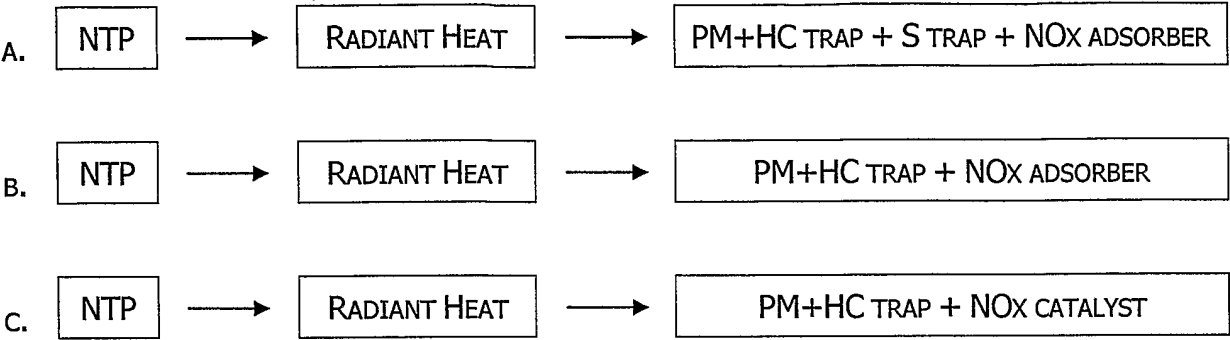


FIGURE 8

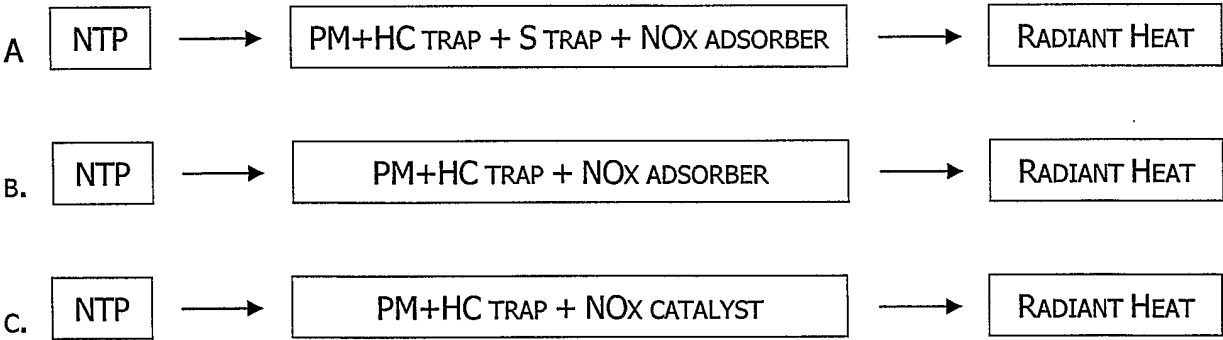


FIGURE 9

INTERNATIONAL SEARCH REPORT

Internationa lization No
PCT/US2005/029911

A. CLASSIFICATION OF SUBJECT MATTER

F01N3/021 F01N3/023 F01N3/027 F01N3/035 F01N3/20

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)

F01N

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 practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 270 (M-344), 11 December 1984 (1984-12-11) & JP 59 141708 A (NIPPON DENSO KK), 14 August 1984 (1984-08-14) abstract	1, 3, 7
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 203 (M-1116), 24 May 1991 (1991-05-24) & JP 03 054312 A (MITSUBISHI MOTORS CORP), 8 March 1991 (1991-03-08) abstract	1, 8, 11, 14
A	US 2004/037754 A1 (VAN SETTEN BARRY ET AL) 26 February 2004 (2004-02-26) abstract	1, 8

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Further documents are listed in the continuation of box C.

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Patent family members are listed in annex.

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Date of the actual completion of the international search

7 November 2005

Date of mailing of the international search report

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Information on patent family members

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