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(54) **SYSTEM AND METHOD FOR REDUCING NOX EMISSIONS**

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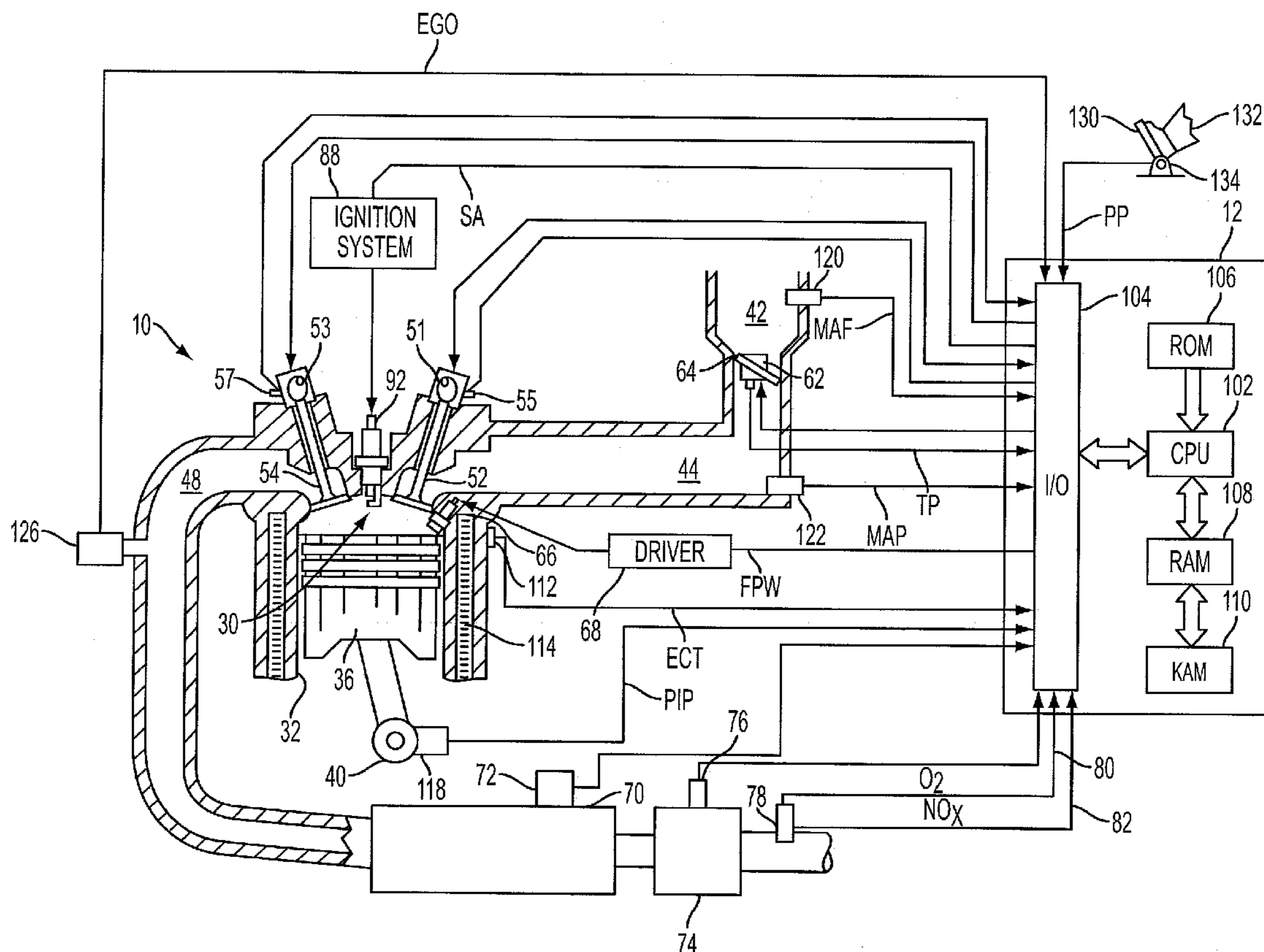
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(57) **ABSTRACT**

An exhaust system, comprising of a first emission control system in the exhaust system, said emission control system having a at least a first region and a second region, said second region physically segregated from the first region and at least partially downstream of the first region, said first region including a precious metal component dispersed on a metal oxide support that stores NOx and said second region including a precious metal component and a NOx sorbent component dispersed on a metal oxide support, where said second region includes more of said NOx sorbent component than said first region; and a second emission control system including an SCR catalyst coupled downstream of said first emission control system.

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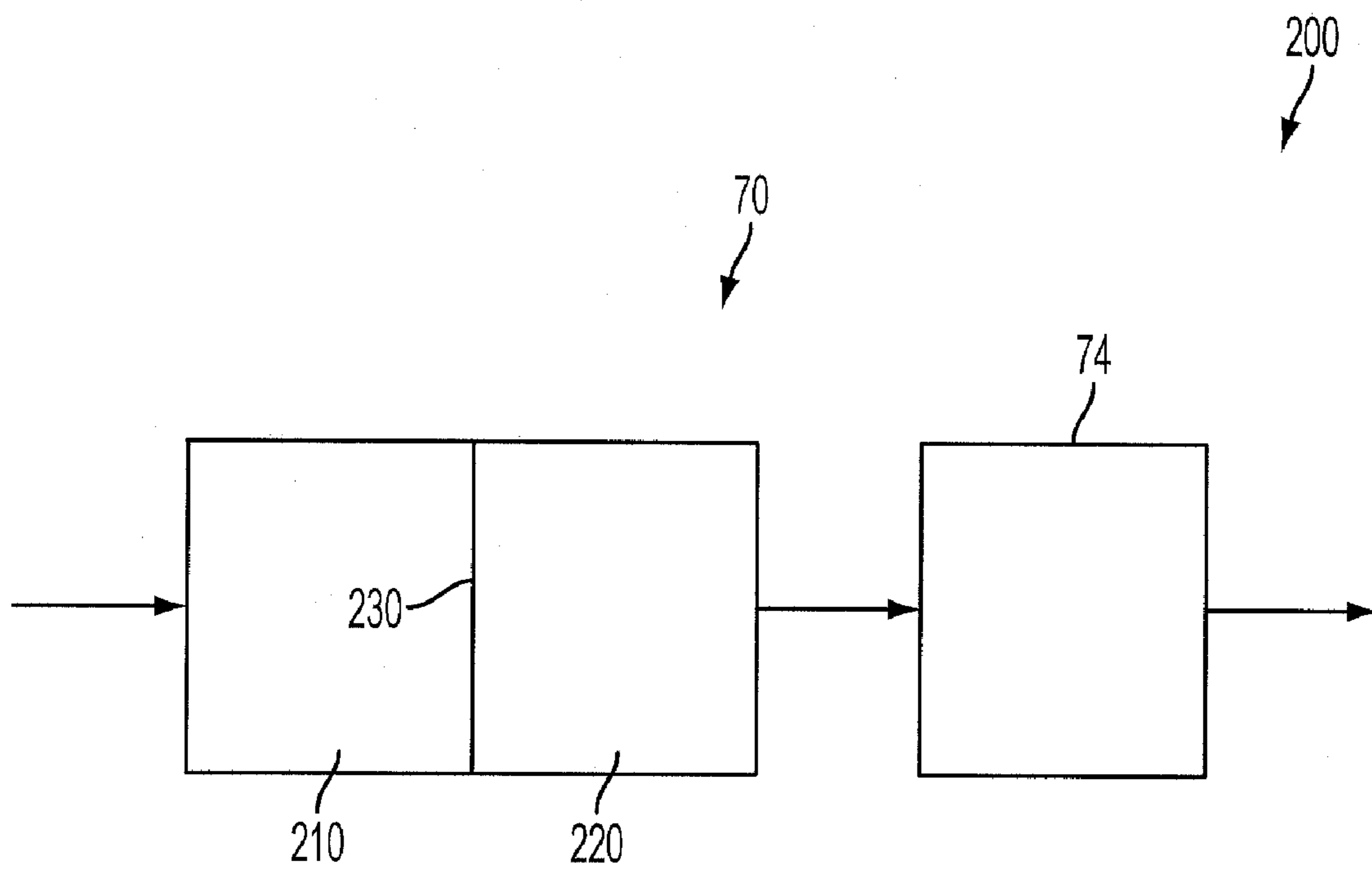


FIG. 2

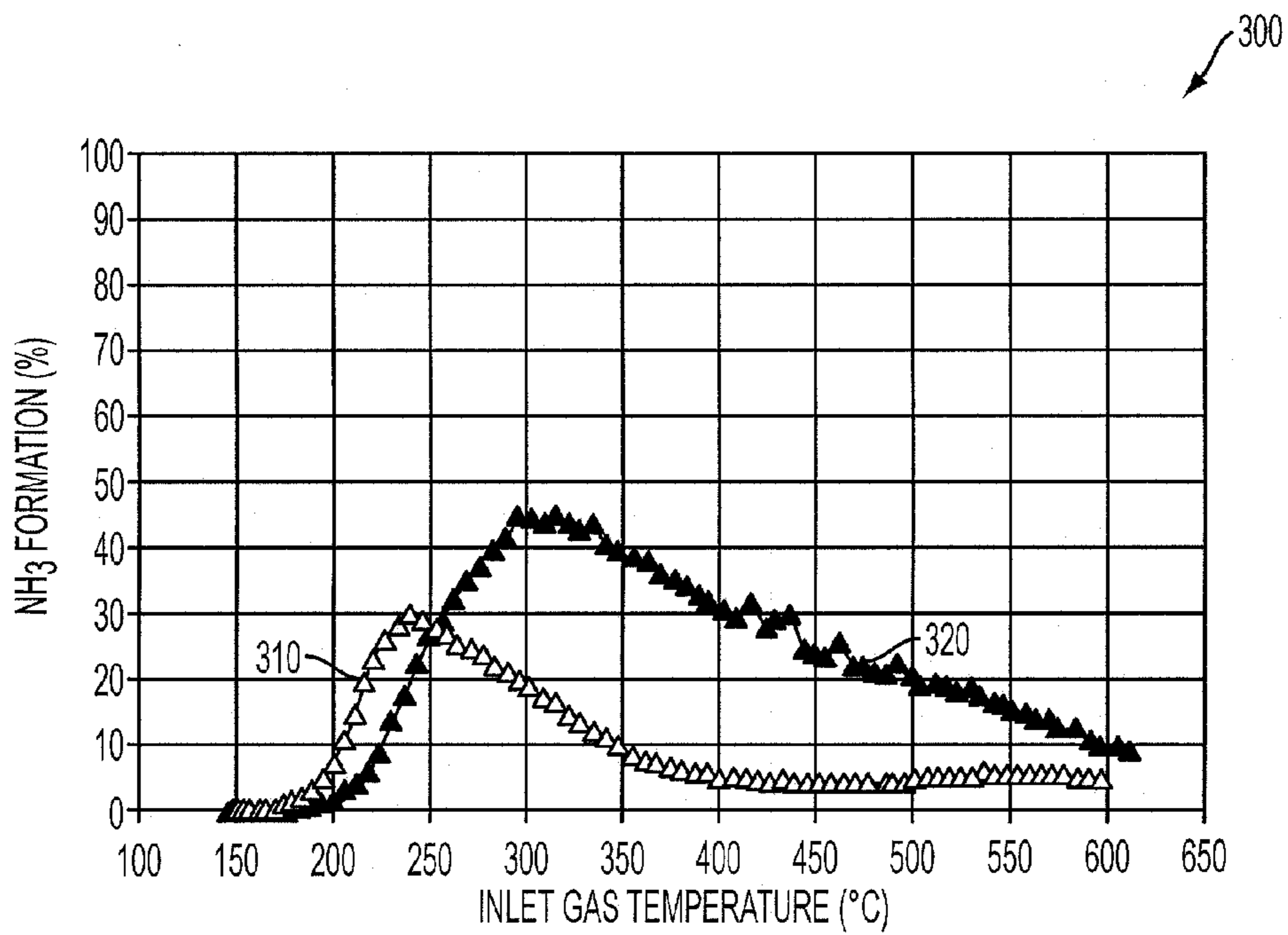


FIG. 3

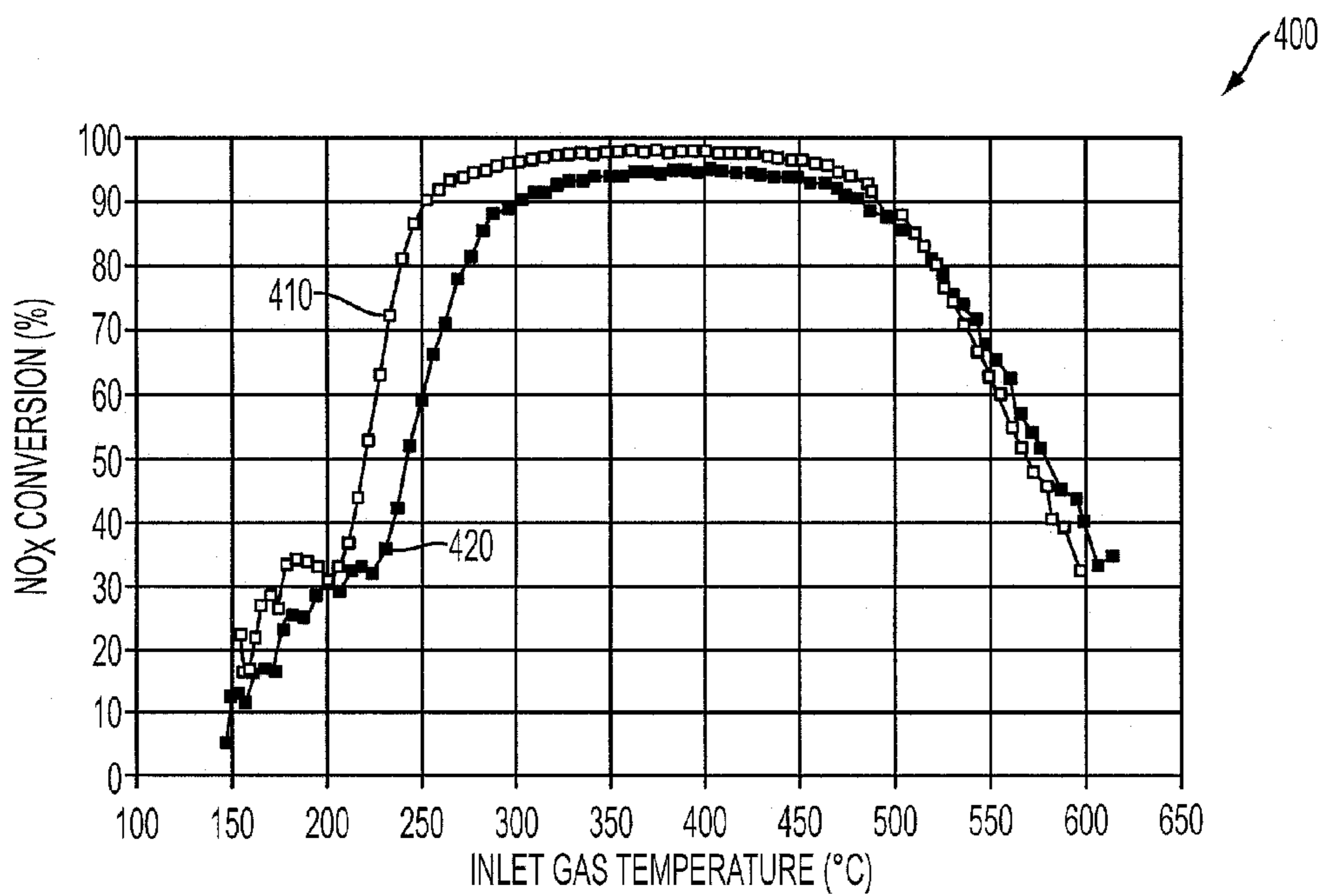


FIG. 4

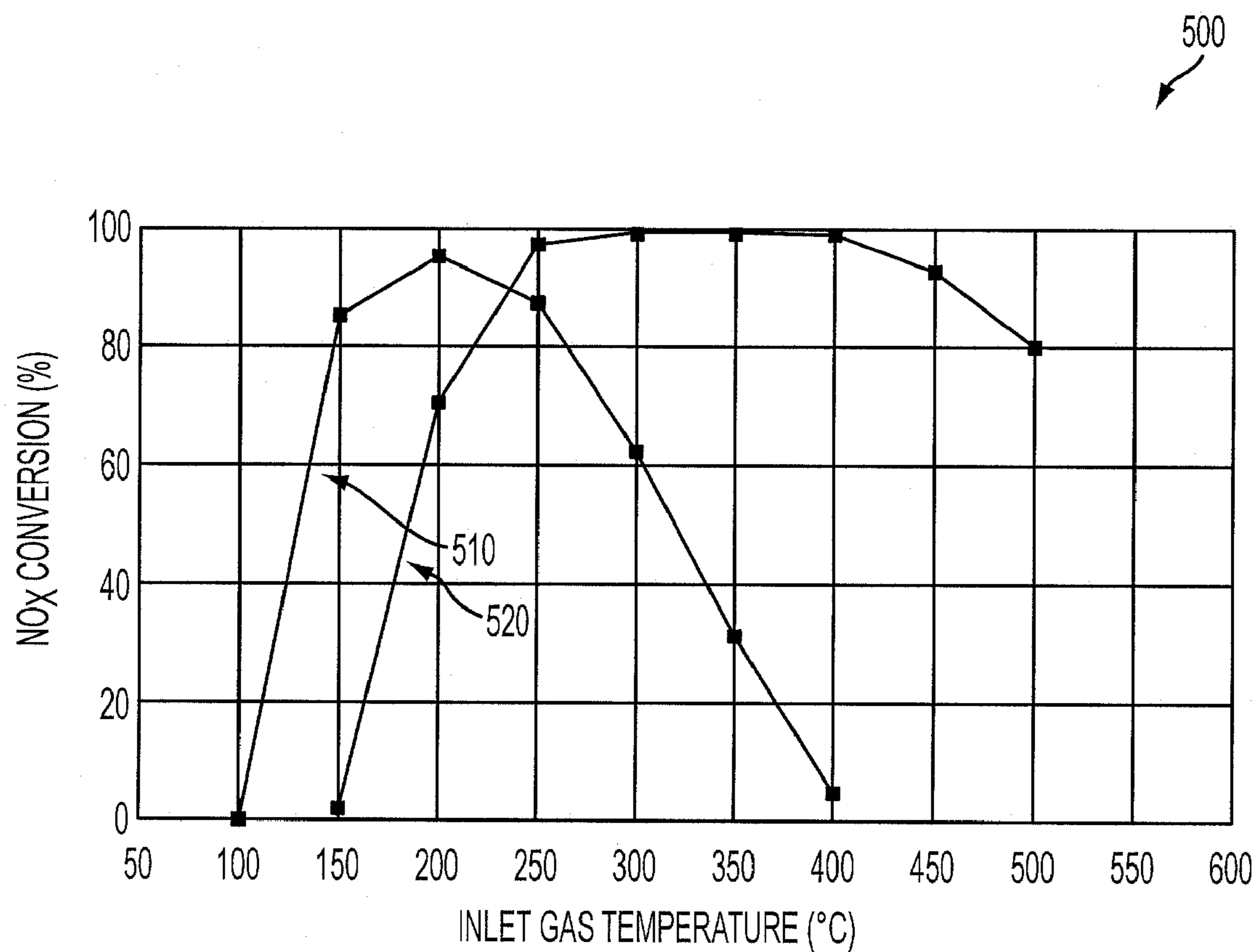


FIG. 5

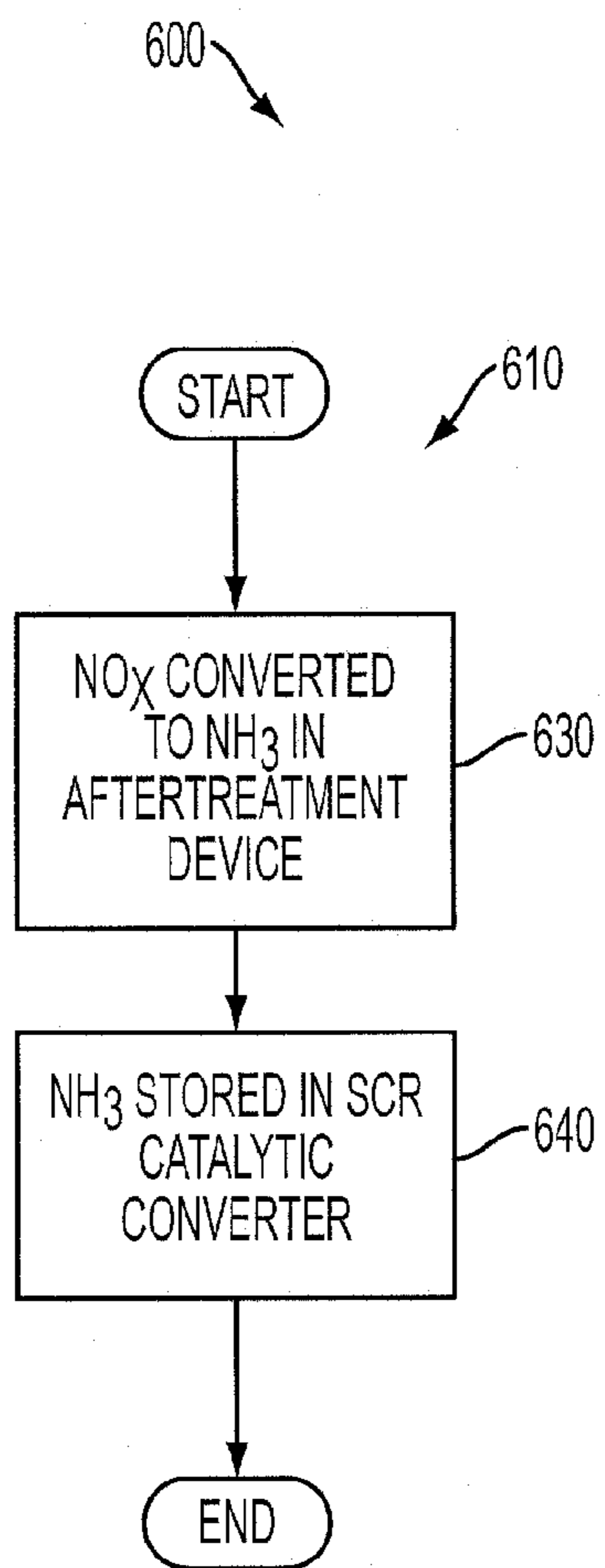


FIG. 6A

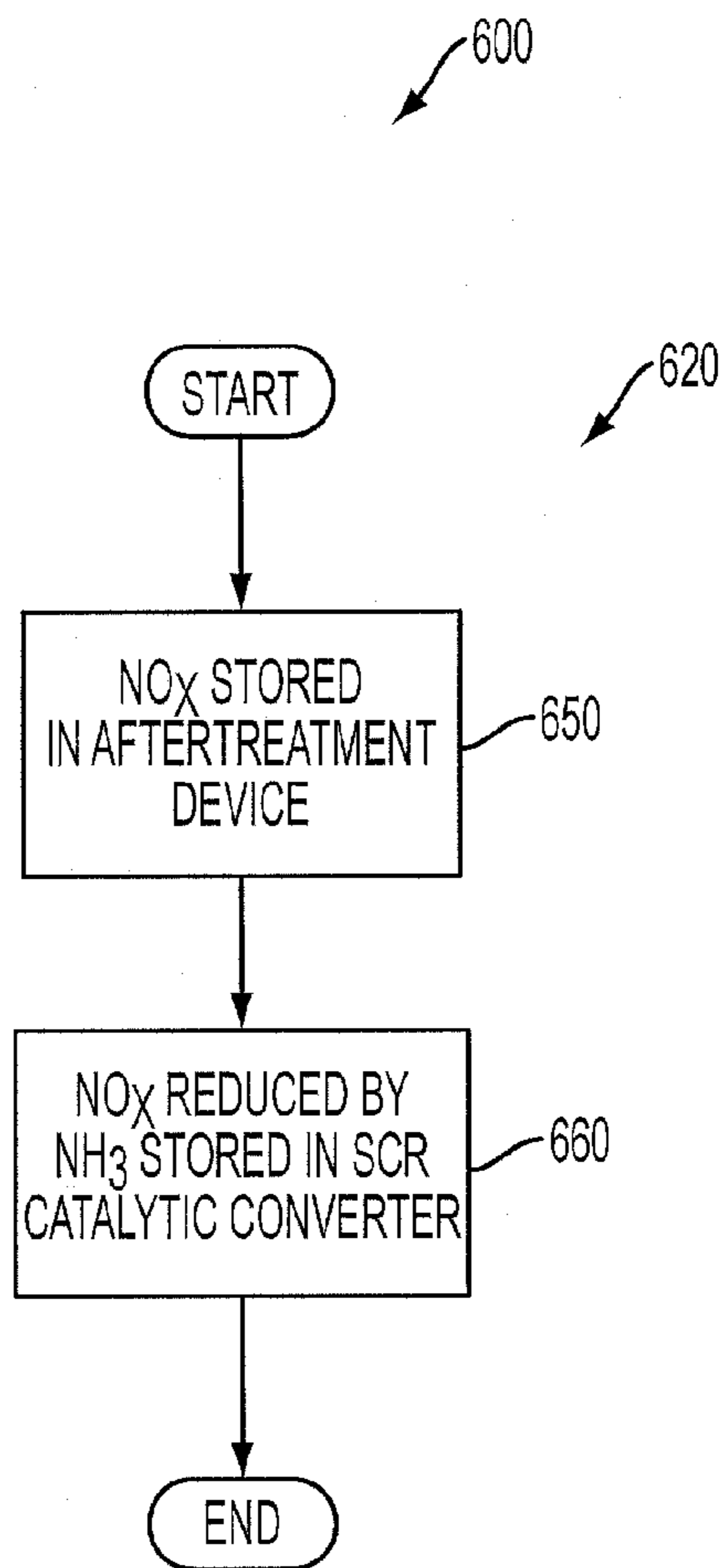


FIG. 6B

SYSTEM AND METHOD FOR REDUCING NOX EMISSIONS

TECHNICAL FIELD

[0001] The present application relates to the field of automotive emission control systems and methods.

BACKGROUND

[0002] Emission treatment systems may optimize the abatement of nitrogen oxides (NOx) by using a downstream a selective catalytic reduction (SCR) catalytic converter to adsorb ammonia (NH₃) produced by a NOx trap during rich excursions to reduce any NOx that slips past the NOx trap during lean operation. In this regard, a NOx trap capable of high NH₃ generation may be advantageous combined with a SCR catalytic converter to reduce NOx emissions. Further, the development of a low temperature NOx abatement system may be attractive for emission control, particularly for light duty diesel vehicles. Sufficient NH₃ generation from the NOx trap may be beneficial to delete a reservoir needed to supply a reductant to the downstream SCR catalytic converter.

[0003] One approach to convert NOx to NH₃ in a NOx trap upstream of a SCR catalytic converter is described in U.S. Application No. 2005/0129601. In the '601 reference, the NOx trap combines a NOx sorbent and a platinum group metal (PGM) dispersed on a substrate. The NOx sorbent is an alkali or alkaline earth metal oxygenated compound. PGMs can selectively convert stored NOx to NH₃ during rich excursions, while the NOx sorbent component effectively traps NOx during lean operation. Specifically, in one example, a two-layered substrate is used with less NOx sorbent material in the top layer than in the bottom layer. Optionally, the NOx trap contains oxygen storage components (OSCs), such as ceria, which have benefits such as improving desulfation, however OSCs limit NH₃ production.

[0004] However, the inventors herein have recognized that NOx sorbents may deactivate PGMs, thereby reducing NOx conversion at low temperatures. Further, the inventors herein have recognized NOx traps that contain OSCs may provide low temperature NOx abatement, however OSCs may limit NH₃ production over the broad temperature range of operation on vehicles. Thus, the approach of '601 may improve low temperature NOx conversion if OSCs are used, but may result in insufficient NH₃ generation over the broad range of operating temperatures for optimum NOx conversion.

[0005] Another approach to achieve low temperature NOx abatement is described in U.S. Pat. No. 6,182,443. Therein, a catalyst composed of PGM dispersed on an aluminum oxide containing support is located upstream of an SCR catalyst, and this catalyst system operates in lean exhaust without any rich excursions. At low temperatures, PGM may facilitate oxidation and storage of NOx as aluminum nitrate. As temperatures rise, this nitrate decomposes back to NOx, which may be reduced to N₂ over the downstream SCR with added NH₃ or hydrocarbon reductant.

[0006] However, the inventors herein have recognized that, for the '443 catalyst system, since the NOx storage catalyst upstream of the SCR catalyst does not provide NOx reduction, NOx conversion is less efficient than if both catalysts provide NOx reduction. Further, the inventors

herein have recognized that if the upstream PGM/aluminum oxide catalyst were exposed to rich excursions, a different operation than described in '443, its stored NOx may be reduced to NH₃, but limited to low temperature operation. Thus, the approach and the catalyst configuration of '443 may be insufficient to provide optimum overall NOx conversion.

SUMMARY

[0007] In one approach, the above issues may be addressed by an exhaust system, comprising: a first emission control system in the exhaust system, said emission control system having at least a first region and a second region, said second region physically segregated from the first region and at least partially downstream of the first region, said first region including a precious metal component dispersed on a metal oxide support that stores NOx and said second region including a precious metal component and a NOx sorbent component dispersed on a metal oxide support, where said second region includes more of said NOx sorbent component than said first region; and a second emission control system including an SCR catalyst coupled downstream of said first emission control system. In this way, it is possible to advantageously achieve NOx storage and ammonia generation across a larger temperature range, which includes low temperatures, so that NOx abatement improves.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic depiction of an exemplary embodiment of an engine.

[0009] FIG. 2 is a block diagram illustrating an exemplary combination NOx trap/NH₃-SCR emission treatment system.

[0010] FIG. 3 is an exemplary graph of data acquired from a NOx trap illustrating the effect of a ceria component on the selective conversion of NOx to NH₃ at a range of temperatures.

[0011] FIG. 4 is an exemplary graph of data acquired from a NOx trap illustrating the effect of a ceria component on the total conversion over a range of temperatures.

[0012] FIG. 5 is an exemplary graph of data acquired from a NOx trap illustrating the effect of a NOx sorbent component on the total conversion of at a range of temperatures.

[0013] FIG. 6A-B is a flowchart of an exemplary method for the treatment of exhaust from a combustion engine by the emission control system described respecting FIG. 2 at rich operation (FIG. 6A) and at lean operation (FIG. 6B).

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

[0014] FIG. 1 is a schematic diagram showing one cylinder of multi-cylinder engine 10, which may be included in a propulsion system for a vehicle. Engine 10 may be controlled at least partially by a control system including controller 12 and by input from a vehicle operator 132 via an input device 130. In this example, input device 130 includes an accelerator pedal and a pedal position sensor 134 for generating a proportional pedal position signal PP. Combustion chamber (e.g., cylinder) 30 of engine 10 may include combustion chamber walls 32 with piston 36 positioned therein. Piston 36 may be coupled to crankshaft 40 so that reciprocating motion of the piston is translated into rotational motion of the crankshaft. Crankshaft 40 may be

coupled to at least one drive wheel of the passenger vehicle via a transmission system. Further, a starter motor may be coupled to crankshaft 40 via a flywheel to enable a starting operation of engine 10.

[0015] Combustion chamber 30 may receive intake air from intake passage 44 via intake manifold 42 and may exhaust combustion gases via exhaust passage 48. Intake passage 44 and exhaust passage 48 can selectively communicate with combustion chamber 30 via respective intake valve 52 and exhaust valve 54. In some embodiments, combustion chamber 30 may include two or more intake valves and/or two or more exhaust valves.

[0016] Fuel injector 66 is shown coupled directly to combustion chamber 30 for injecting gasoline or diesel fuel directly therein in proportion to the pulse width of signal FPW received from controller 12 via electronic driver 68. In this manner, fuel injector 66 provides what is known as direct injection of fuel into combustion chamber 30. The fuel injector may be mounted in the side of the combustion chamber or in the top of the combustion chamber, for example. Fuel may be delivered to fuel injector 66 by a fuel system (not shown) including a fuel tank, a fuel pump, and a fuel rail. In some embodiments, combustion chamber 30 may alternatively or additionally include a fuel injector arranged in intake passage 44 in a configuration that provides what is known as port injection of fuel into the intake port upstream of combustion chamber 30.

[0017] Intake manifold 42 may include a throttle 62 having a throttle plate 64. In this particular example, the position of throttle plate 64 may be varied by controller 12 via a signal provided to an electric motor or actuator included with throttle 62, a configuration that is commonly referred to as electronic throttle control (ETC). In this manner, throttle 62 may be operated to vary the intake air provided to combustion chamber 30 among other engine cylinders. The position of throttle plate 64 may be provided to controller 12 by throttle position signal TP. Intake manifold 42 may include a mass air flow sensor 120 and a manifold air pressure sensor 122 for providing respective signals MAF and MAP to controller 12.

[0018] Ignition system 88 can provide an ignition spark to combustion chamber 30 via spark plug 92 in response to spark advance signal SA from controller 12, under select operating modes. Though spark ignition is shown in FIG. 1, in some embodiments, combustion chamber 30 or one or more other combustion chambers of engine 10 may be operated in a compression ignition mode, with or without an ignition spark. For example, engine 10 may be a diesel engine without a spark plug.

[0019] Exhaust gas sensor 126 is shown coupled to exhaust passage 48 upstream of emission control device 70. Sensor 126 may be any suitable sensor for providing an indication of exhaust gas air/fuel ratio such as a linear oxygen sensor or UEGO (universal or wide-range exhaust gas oxygen), a two-state oxygen sensor or EGO, a HEGO (heated EGO), a NOx, HC, or CO sensor.

[0020] Aftertreatment device 70 is shown arranged along exhaust passage 48 downstream of exhaust gas sensor 126 where in aftertreatment device 70 may be a three way catalyst (TWC), NOx trap, various other emission control devices, or combinations thereof as to be detailed further in FIG. 2. Aftertreatment device 70 may be configured to adsorb NOx when engine 10 is operating with a lean air to fuel ratio. Controller 12 may be configured to periodically

provide a rich exhaust stream (for example, by performing an additional injection of fuel after top dead center of the compression stroke, or by operating with rich combustion) to at least react some adsorbed NOx with HC and CO to purge aftertreatment device 70 of stored NOx. Selective catalytic reduction (SCR) catalytic converter 74 is configured to adsorb NH3 that exits aftertreatment device 70. SCR catalytic converter 74 is shown arranged along exhaust passage 48 downstream of aftertreatment device.

[0021] Controller 12 is shown in FIG. 1 as a microcomputer, including microprocessor region 102, input/output ports 104, an electronic storage medium for executable programs and calibration values shown as read only memory chip 106 in this particular example, random access memory 108, keep alive memory 110, and a data bus. Controller 12 may receive various signals from sensors coupled to engine 10, in addition to those signals previously discussed, including measurement of inducted mass air flow (MAF) from mass air flow sensor 120; engine coolant temperature (ECT) from temperature sensor 112 coupled to cooling sleeve 114; a profile ignition pickup signal (PIP) from Hall effect sensor 118 (or other type) coupled to crankshaft 40; throttle position (TP) from a throttle position sensor; and absolute manifold pressure signal, MAP, from sensor 122. Engine speed signal, RPM, may be generated by controller 12 from signal PIP. Manifold pressure signal MAP from a manifold pressure sensor may be used to provide an indication of vacuum, or pressure, in the intake manifold. Note that various combinations of the above sensors may be used, such as a MAF sensor without a MAP sensor, or vice versa.

[0022] Controller 12 may determine various conditions of aftertreatment device 70 and SCR catalytic converter 74 in any suitable manner. For example, the temperature T_{atd} of aftertreatment device 70 may be provided by a temperature sensor 72 and the temperature T_{cat} of SCR catalytic converter 74 may be provided by a temperature sensor 76. In addition, sensor 110 provides an indication of both the oxygen concentration in the exhaust gas as well as NOx concentration. Signal 112 provides controller 12 a voltage indicative of the O₂ concentration while signal 114 provides a voltage indicative of NOx concentration. Under some conditions, controller 12 may be configured to provide a rich exhaust stream based on various conditions, such as NOx concentration downstream of SCR catalytic converter 74.

[0023] As described above, FIG. 1 shows only one cylinder of a multi-cylinder engine, and that each cylinder may similarly include its own set of intake/exhaust valves, fuel injector, etc.

[0024] FIG. 2 is an exemplary embodiment of an emission treatment system 200 that may include an aftertreatment device 70 and a SCR catalytic converter 74. In general, the aftertreatment device may store NOx and reduce stored NOx to nitrogen (N₂) or NH₃ or some combination thereof, although some NOx that may not be stored or converted may pass through the aftertreatment device. The SCR catalytic converter generally may adsorb NH₃ on the catalyst wherein the adsorbed NH₃ may selectively and catalytically reduce NOx exiting the aftertreatment device. While not shown in FIG. 2, a particular filter may be included upstream and/or downstream of device 70 and/or device 74.

[0025] The aftertreatment device and the SCR catalytic converter may be arranged in various configurations. In the embodiment described herein, the SCR catalytic converter may be arranged downstream from the aftertreatment

device. By doing this, NH₃ that may be generated by the aftertreatment device under some conditions may be used as the reductant in the SCR catalytic converter for the selective and catalytic reduction of NO_x leaving the aftertreatment device.

[0026] Referring back to FIG. 2, the SCR catalytic converter may facilitate the adsorption of NH₃ and the reduction of NO_x by the adsorbed NH₃. Various catalysts may be suitable to adsorb NH₃ and reduce NO_x accordingly. For example, base metal (e.g., copper, iron) exchanged zeolite compositions or various vanadia-based compositions may be used to form the SCR catalyst. The SCR catalyst may be in the form of self supporting catalyst particles or as a honeycomb monolith formed of the SCR catalyst. Further, the SCR catalyst may be disposed on a substrate, such as a ceramic or metal honeycomb structure, for example. Various other catalyst compositions and forms may be disposed on substrates suitable for the application described herein.

[0027] The aftertreatment device may facilitate the storage of NO_x and the reduction of stored NO_x to N₂ or NH₃ or some combination thereof. In the embodiment described herein, it may be desirable to substantially convert stored NO_x to NH₃ such that NH₃ leaving the aftertreatment device may be adsorbed in the SCR catalytic converter wherein the adsorbed NH₃ may reduce NO_x exiting the aftertreatment device.

[0028] The aftertreatment device may include a first catalyst region **210** and a second catalyst region **220** wherein the first catalyst region may be upstream of the second catalyst region. The catalyst regions may include one or more components dispersed on a support wherein a catalyst region may be disposed on a substrate, such as a ceramic or metal honeycomb monolith.

[0029] The components and support may further include one or more elements or compounds or some combination thereof. For example, a precious metal component may include the element Pt, a NO_x sorbent component may include the compound barium oxide (BaO), and a support may include the compound alumina (Al₂O₃).

[0030] Further, a component as well as the support may exhibit various properties under some conditions. For example, a property of a precious metal component, such as Pt, may be to catalyze the oxidation and storage of NO_x. A property of a NO_x sorbent component, such as BaO, may be NO_x storage when catalyzed at high temperature ranges. A property of a refractory metal oxide support, such as Al₂O₃, may also be NO_x storage but when catalyzed at low temperature ranges. Another property of a precious metal component, such as Pt, may be to catalyze the preferential conversion of stored NO_x to NH₃ during rich excursions.

[0031] Accordingly, one exemplary embodiment of the catalyst regions for the components and support described herein (e.g., Pt, BaO, and Al₂O₃) may include a precious metal component (e.g., Pt) and a support (e.g., Al₂O₃) for the first catalyst region **210** and a precious metal component (e.g., Pt), a NO_x sorbent component (e.g., BaO), and a support (e.g., Al₂O₃) for the second catalyst region **220**, wherein the precious metal component may include at least one precious metal element (e.g., Pt), the NO_x sorbent component may include at least one suitable alkali or alkaline earth compound (e.g., BaO), and the support may include at least one suitable refractory metal oxide (e.g., Al₂O₃).

[0032] The properties of the catalyst regions may relate to the properties of the components and the support included therein. However, the components and the support in the catalyst region may interact such that the aggregate properties of the components and the support included therein may be distinct for the properties of the catalyst region. In particular, the properties of the components and the support included in the catalyst region may be diluted by various other components included therein.

[0033] For example, the first catalyst region having a precious metal component may have no constituents of a NO_x sorbent component (e.g., it may be substantially pure of NO_x sorbent components, for example the precious metal component may be Pt), and may exhibit properties that may include catalyzing the oxidation and storage of NO_x on the Al₂O₃ support at low temperatures. However, the precious metal component may be at least partially deactivated by the presence, or an increased amount, of a NO_x sorbent component, such as BaO. As such, the contaminated precious metal component may be less able to abate NO_x at low temperatures.

[0034] For the aftertreatment device described herein, the catalyst regions may include a precious metal component and a NO_x sorbent component wherein the ratio of the precious metal component to the NO_x sorbent component may be greater in one catalyst region than the ratio in another catalyst region from which it is physically segregated, where the region with a higher ratio may be located upstream of the region with a lower ratio. Likewise, the catalyst regions may include a precious metal component and a NO_x sorbent component wherein the amount or weight of the NO_x sorbent component may be greater in one catalyst region than in another catalyst region from which it is physically segregated, where the region with a higher amount of NO_x sorbent may be located downstream of the region with a lower amount (or substantially no) NO_x sorbent.

[0035] In one particular embodiment, it may be advantageous to distribute the components such that the components may be disposed in the aftertreatment device such that the ratio of the precious metal component to the NO_x sorbent component may be greater in the first catalyst region than the ratio in the downstream second catalyst region from which it is physically segregated. By doing this, the first catalyst region including a relatively higher percent of the precious metal may be exposed to the exhaust when the concentration of NO_x may be the greatest (e.g. as the exhaust from the engine enters the emission treatment system). As such, the amount of NO_x stored and subsequently converted to NH₃ for the SCR catalytic converter may be increased. Conversely, the components may be disposed in the aftertreatment device such that the ratio of the precious metal component to the NO_x sorbent component may be less in the first catalyst region than said ratio in the upstream second catalyst region for various other reasons.

[0036] Referring back to the embodiment illustrated in FIG. 2, the first catalyst region may be physically segregated from the second catalyst region. In one approach, the first catalyst region may be housed in a first NO_x abatement device and the second catalyst region may be housed in a second separate downstream NO_x abatement device. Further, the first catalyst region may be segregated to various degrees from the second catalyst region by an area of separation **230** within the aftertreatment device wherein the

catalyst regions may be segregated to at least partially reduce or prevent the deactivation of a component in one catalyst region by a component in another catalyst region. For example, a precious metal component in one catalyst region may be deactivated by a NO_x sorbent component, such as BaO, in another catalyst region, and thus by providing an appropriate degree of segregation, improved performance may be achieved.

[0037] The area of separation may employ various approaches or structures to segregate the catalyst regions. For example, the area of separation may include a divider wherein the divider may include suitable materials capable of at least partially segregating the catalyst regions while facilitating suitable exhaust flow. In another example, the area of separation may be a void wherein a void of some distance segregates the catalyst regions. In another embodiment of the aftertreatment device segregated washcoat may be used to configure the catalyst regions. Further, the area of separation may be configured perpendicular or parallel or to various other degrees relative to the exhaust flow.

[0038] As noted herein, the aftertreatment device may store NO_x and reduce stored NO_x into N₂ or NH₃. In the embodiment described herein, it may be desirable to substantially convert NO_x to NH₃ such that NH₃ leaving the aftertreatment device may be adsorbed in the SCR catalytic converter wherein the adsorbed NH₃ may reduce NO_x exiting the aftertreatment device. Conversely, in another approach, a NO_x abatement device may include catalyst regions wherein the components of the catalyst may not form relatively high amounts of NH₃ or at least one component of the catalyst may hinder NH₃ generation, although some NH₃ may be generated. For example, some NO_x abatement devices may include an oxygen storage component (OSC) such as ceria (CeO₂) wherein the CeO₂ component may limit the formation of NH₃. The CeO₂ component may be used for various other reasons, such as improving low temperature NO_x conversion, and also the intermittent storage of oxygen.

[0039] FIG. 3 is a graph 300 of an exemplary embodiment of data that may demonstrate the effect of a CeO₂ component on the selective conversion of NO_x to NH₃ at a range of temperatures. For example, graph 300 may show the percentage of NO_x converted to NH₃ at various temperatures for a Pt—BaO—CeO₂ catalyst region as indicated by 310 and for a Pt—BaO catalyst region as indicated by 320. It may be understood that the catalyst regions described herein (e.g., Pt—BaO—CeO₂ and Pt—BaO) may generally be disposed on a suitable support, such as alumina (Al₂O₃), although the support may be excluded from the description so as to focus specifically on the behavior of the various catalyst combinations.

[0040] Referring back to graph 300, the exclusion of the CeO₂ component in the catalyst region may convert a higher percentage of NO_x to NH₃ at a wider temperature range relative to the catalyst that includes a CeO₂ component. As such, it may be beneficial under some conditions to exclude the CeO₂ component from one or more catalyst regions, such as region 210, 220, or both. By doing this, the aftertreatment device may generate sufficient NH₃ such that a liquid urea tank or ammonia storage vessel may be excluded from the emission treatment system described herein. However, the liquid tank may also be included, if desired.

[0041] The inclusion of the CeO₂ component in the Pt—BaO catalyst composition may convert at least partially

higher percentage of NO_x to NH₃ at lower temperatures, although the percentage of NO_x converted to NH₃ may still not be sufficient for low temperature ranges. As such, it may be desirable to include at least a component such as Pt—BaO substantially or at least partially free of CeO₂ so as to generate higher NH₃ amounts over a wider temperature range and at least another component that may facilitate at least sufficient NH₃ generation at a lower temperature range.

[0042] The NO_x that may not react to form NH₃ may be converted by various other mechanisms or may not be stored or converted and exit the aftertreatment device. The percentage of the NO_x that may react to form NH₃ or other products by various mechanisms or some combination thereof may be referred to cumulatively as the percentage of total NO_x conversion. Specifically, the percentage of total NO_x conversion may include the intermittent conversion of NO_x in a catalyst region for storage or the reduction of NO_x to N₂ or the formation of NH₃ from NO_x or a variety of other mechanisms of NO_x conversion or some combination thereof.

[0043] While it may be advantageous to convert a substantial percentage of NO_x to NH₃ to use as a reductant in the SCR catalytic converter, the emission system described herein may further benefit by converting the residual NO_x not used to generate NH₃. By doing this, a more modest amount of NH₃ may be suitable to substantially reduce the NO_x in the SCR catalytic converter. Even further, the NO_x that may be stored in a catalyst region in the aftertreatment device may be utilized to generate additional NH₃ under some conditions, such as the exhaust composition. As such, a high percentage of total NO_x conversion may be advantageous to facilitate the optimization of NO_x abatement, as will be described further with regard to FIG. 4 and the corresponding structure described herein

[0044] FIG. 4 is a graph 400 of another exemplary embodiment of data that may demonstrate the effect of a CeO₂ component on the percentage of total NO_x conversion at a range of temperatures. For example, graph 400 may show the percentage of total NO_x converted at various temperatures for a Pt—BaO—CeO₂ catalyst region as indicated by 410 and for a Pt—BaO catalyst region as indicated by 420. In particular, graph 400 may show that the exclusion of CeO₂ component in the catalyst region may convert lower levels of total NO_x.

[0045] While the inclusion of CeO₂ in the catalyst compositions may convert a higher percentage of total NO_x, NH₃ generation may still be insufficient for the emission treatment system described herein. As such, it may be desirable to include a precious metal component and a NO_x sorbent component such as Pt—BaO in one catalyst region so as to facilitate NH₃ generation and NO_x conversion over a relatively wider higher temperature range (FIGS. 3-4) and a component or combination of components in another physically segregated catalyst region that may facilitate NO_x conversion at lower temperatures in the aftertreatment device. Such an approach may be applied to regions 210 and 220 of FIG. 2. For example, region 220 may include more CeO₂ than region 210, or region 210 may be substantially free of CeO₂.

[0046] FIG. 5 is a graph 500 of an exemplary embodiment of data that may demonstrate the effect of a NO_x sorbent component such as BaO on the catalyst region. For example, graph 500 may show the percentage of total NO_x converted at various temperatures for precious metal catalyst region

such as the Pt—Rh region as indicated by **510** and for a precious metal catalyst region such as the Pt—Rh—BaO region as indicated by **520** wherein the precious metal catalyst region may include the elements Pt and Rh. In particular, graph **500** may show that a catalyst region that includes a substantially pure precious metal component such as Pt—Rh may convert high levels of total NOx at low temperatures. Said another way, the exclusion of or reduction of the NOx sorbent component from a catalyst region to a greater degree than another catalyst region may facilitate low temperature NOx conversion.

[0047] While the exclusion or reduction of a NOx sorbent component such as BaO in an upstream region, such as **210**, may facilitate low temperature NOx conversion, NOx conversion at higher temperature ranges may be substantially reduced. As such, it may be desirable to combine the properties of a catalyst region that that may exhibit the NOx conversion properties a precious metal and NOx sorbent catalyst region (e.g., NH3 generation and total NOx conversion over a relatively wider higher temperature range) such as Pt—BaO and the properties of a catalyst region that may exhibit properties of a region with precious metals having less NOx sorbent materials (e.g., low temperature NOx conversion) such as Pt—Rh as demonstrated by FIGS. **3-5** and shown in FIG. **2**.

[0048] The combination of a Pt—Rh catalyst region (substantially free of CeO2) physically segregated and upstream of a Pt—BaO catalyst region (also substantially free of CeO2) is one exemplary embodiment of a combination that may be included in the aftertreatment device. Various other suitable ceria and non-ceria combinations of components may be used. In general, the catalyst regions may include at least a first precious metal component wherein a precious metal component may include one or more precious metals (e.g. Pt, Pd, Rh, Ir, Ru, Os, Re, Ag, and Au) wherein precious metals include PGMs (e.g., Pt, Pd, Rh) with a first amount of a NOx sorbent (which may be zero) and at least a second precious metal component with a second amount of the NOx sorbent component, where the second amount is greater than the first amount and where a NOx sorbent component may include one or more NOx sorbents, such as an oxide or carbonate of an alkali metal (e.g. Li, Na, K, Rb, Cs) or an alkaline earth metal (e.g. Be, Mg, Ca, Sr, Ba.), or some combination thereof. The above components may be dispersed on a high surface area metal oxide support (e.g., alumina, titania, zirconia, zeolites, etc), such that the first support is a metal oxide that may store NOx (e.g., alumina or zeolite). The components and their support typically are disposed on a monolithic flow-through substrate, wall flow filter substrate, honeycomb structures, layered materials, or spun fibers, among other configurations.

[0049] In one approach, the first precious metal component may be blended with the second precious metal component and the NOx sorbent component wherein the blend may be housed in at least one catalyst region. However, the function of some components may be reduced or deactivated in the presence of other components. For example, the NOx sorbent component may reduce the activity of precious metal components such that higher temperatures may be required to achieve suitable levels of NOx conversion. Said another way, the first precious metal component may convert substantially less NOx at lower temperatures in the presence of the NOx sorbent component.

[0050] In the embodiment described herein, the first precious metal component may be physically segregated from the NOx sorbent component to address the deactivation of the precious metal component by the NOx sorbent component. In particular, the first precious metal component may be disposed in one catalyst region and the second precious metal component with the NOx sorbent may be disposed in another catalyst region wherein the catalyst regions may be segregated by various modes as described herein.

[0051] Generally, the physical segregation of the catalyst regions within the aftertreatment device may facilitate various mechanisms wherein at least one catalyst region may promote the formation of NH3 from NOx (e.g., adsorbed NOx or NOx in the exhaust) or the reduction of stored NOx to N2 or some combination thereof during rich excursions and one catalyst region may promote the storage of NOx during lean operation.

[0052] Referring back to FIG. **2**, the aftertreatment device and the SCR system described herein may interact to regulate the exhaust constituents introduced to the system and various intermediary byproducts that may be generated within the system. Accordingly, the SCR catalytic converter responds to the exhaust exiting the aftertreatment device so as to adsorb NH3 generated during rich excursions or utilize adsorbed NH3 to reduce NOx. As such, the aftertreatment device and the SCR catalytic converter engage to facilitate the optimization of NOx abatement in the emission treatment system.

[0053] In the embodiment described herein, rich excursions may include a condition wherein a reducing agent (e.g. hydrocarbons from fuel not combusted in the engine, injected fuel, etc.) may be present in the exhaust and relatively low concentrations of NOx may be detected, while lean operation may include a condition wherein NOx and excess oxygen may be abundant in the exhaust.

[0054] FIGS. **6A-B** may generally describe the method for the treatment of exhaust from a combustion engine by the emission control system described herein. In particular, method **600** is a generalized sequence of actions responsive to the engine operating conditions wherein the sequence may be schematically illustrated by the flowchart of **6A** during rich excursions and by flowchart of **6B** during normal lean operation.

[0055] The flowcharts are a conceptual representation that may be simplified for clarity.

[0056] Referring specifically to FIG. **6A**, the exhaust from a rich excursion enters the aftertreatment device at the inlet of the emission treatment system where. In particular, hydrocarbons (HC) and relatively low amounts of NOx may enter the aftertreatment device as constituents of the exhaust wherein HC may reduce NOx under some conditions.

[0057] At **630**, NOx may be reduced to NH3 or reduced to N2 or some combination thereof in the aftertreatment device. The aftertreatment device as described herein may promote the conversion of a relatively high percentage of NOx to NH3, although some NOx may be reduced to N2 wherein the reducing agent may include HC in the exhaust. The NOx may be adsorbed in the aftertreatment device during lean operation or may enter with the exhaust or some combination thereof. The NH3 generated at the aftertreatment device may proceed to a downstream SCR catalytic converter accordingly. Continuing with the figure of **6A**, the NH3 entering the SCR catalytic converter may substantially adsorb the NH3 at **640**.

[0058] Referring now to FIG. 6B, the method begins again at the inlet of the emission treatment system where the exhaust from lean operation of the engine enters the after-treatment device. In particular, relatively high amounts of NO_x may enter the aftertreatment device as constituents of the exhaust. At **650**, the NO_x may be adsorbed in the aftertreatment device, although some NO_x may escape adsorption. As such, residual NO_x exiting the aftertreatment device may proceed to the SCR catalytic converter accordingly. Continuing with flowchart **620**, NH₃ adsorbed in the SCR catalytic converter during a rich excursion may reduce the residual NO_x from the aftertreatment device. Accordingly, the exhaust from the SCR catalytic converter may exit the emission treatment system substantially free of NO_x.

[0059] The emission control system may be regulated by the controller to follow the above approaches. In particular, the controller may facilitate the release of NO_x and/or NH₃ from the aftertreatment device to the SCR catalytic device during various conditions by adjusting fuel injection, engine airflow, or combinations thereof. For example, it may be advantageous to end a rich excursion and initiate lean operation when the SCR catalytic converter may be approaching the threshold capacity of NH₃ adsorption. At this condition, the controller may prompt lean operation in response to a signal from a sensor (e.g., oxygen sensor, NO_x sensor, NH₃ sensor, etc.), for example, at the SCR catalytic converter. By doing this, NO_x abundant in the exhaust during lean operation may be reduced by the NH₃ saturated in the SCR catalytic converter.

[0060] Note that the example control and estimation routines included herein can be used with various engine and/or vehicle system configurations. The specific routines described herein may represent one or more of any number of methoding strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various steps, operations, or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Likewise, the order of methoding is not necessarily required to achieve the features and advantages of the example embodiments described herein, but are provided for ease of illustration and description. One or more of the illustrated steps or functions may be repeatedly performed depending on the particular strategy being used. Further, the described steps may graphically represent code to be programmed into the computer readable storage medium in the engine control system.

[0061] It will be appreciated that the configurations and routines disclosed herein are exemplary in nature, and that these specific embodiments are not to be considered in a limiting sense, because numerous variations are possible. For example, the above technology can be applied to V-6, I-4, I-6, V-12, opposed 4, and other engine types. The subject matter of the present disclosure includes all novel and nonobvious combinations and subcombinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

[0062] The following claims particularly point out certain combinations and subcombinations regarded as novel and nonobvious. These claims may refer to “an” element or “a first” element or the equivalent thereof. Such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and subcombinations of the disclosed features, functions, elements, and/or properties

may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

What is claimed is:

1. An exhaust system, comprising:
 - a first emission control system in the exhaust system, said emission control system having a at least a first region and a second region, said second region physically segregated from the first region and at least partially downstream of the first region, said first region including a precious metal component dispersed on a metal oxide support that stores NO_x and said second region including a precious metal component and a NO_x sorbent component dispersed on a metal oxide support, where said second region includes more of said NO_x sorbent component than said first region; and
 - a second emission control system including an SCR catalyst coupled downstream of said first emission control system.
2. The exhaust system of claim 1, wherein the precious metal component is selected from at least one of platinum, palladium, rhodium, iridium, ruthenium, osmium, rhenium, silver, gold and/or mixtures thereof.
3. The exhaust system of claim 1, wherein the precious metal component includes platinum.
4. The exhaust system of claim 1, wherein the NO_x sorbent component is selected from at least one of alkali metal (lithium, sodium, potassium, rubidium, cesium) and alkaline earth metal (beryllium, magnesium, calcium, strontium, barium) oxides and carbonates of said groups and/or mixtures thereof.
5. The exhaust system of claim 1, wherein the NO_x sorbent component includes barium oxide, and wherein the metal oxide support that stores NO_x is selected from at least one of alumina, zeolite, silica dispersed on alumina, titania dispersed on alumina, zirconia dispersed on alumina, and/or mixtures thereof.
6. The exhaust system of claim 1, wherein the metal oxide support that stores NO_x includes alumina.
7. The exhaust system of claim 1, wherein the metal oxide support is selected from at least one of alumina, zeolite, silica, titania, zirconia, and/or mixtures thereof.
8. The exhaust system of claim 1, wherein a washcoat in the first catalyst region consists essentially of a precious metal component dispersed on a metal oxide support that stores NO_x.
9. The exhaust system of claim 1, wherein the first catalyst region further comprises a NO_x sorbent component.
10. The exhaust system of claim 1, wherein at least the second region further comprises a ceria component.
11. The exhaust system of claim 1, where the first region and the second region further comprise a ceria component where said second region includes more of said ceria component than said first region.
12. The exhaust system of claim 1, where the first region and the second region further comprise a ceria component where said first region includes more of said ceria component than said second region.
13. The exhaust system of claim 1, wherein the first and second regions are disposed on a monolithic flow-through substrate.

14. The exhaust system of claim **1**, wherein the first and second regions are disposed on a wall flow filter substrate.

15. The exhaust system of claim **1**, wherein the first region and the second region are disposed on a single substrate.

16. The exhaust system of claim **15**, wherein the first region and the second region are segregated by a segment of the substrate.

17. The exhaust system of claim **1** wherein the first region and the second region are separated by an area of separation.

18. The exhaust system of claim **1** further comprising a urea reductant injection system, wherein urea from the urea reductant injection system is introduced between the first emission control system and the second emission control system.

19. The exhaust system of claim **1** further comprising a particulate filter system, wherein said filter system is located upstream of the first emission control system.

20. The exhaust system of claim **1** further comprising a particulate filter system, wherein said filter system is located downstream of the second emission control system.

21. The exhaust system of claim **1** further comprising a sensor coupled in the exhaust system and a controller for adjusting engine operation to vary an exhaust air-fuel ratio in response to said sensor.

22. An exhaust system, comprising:

a first emission control device with a washcoat having a first amount of precious metal physically segregated from NOx storage material and a second amount of precious metal physically mixed with NOx storage material, where first amount is upstream of said second amount; and

a second emission control device downstream of said first device, said second device including an SCR catalyst configured to store NH₃.

23. An exhaust system, comprising:

a first emission control system in the exhaust system, said emission control system having a at least a first region and a second region, said second region physically segregated from the first region and at least partially downstream of the first region, said first region including a precious metal component and said second region including a precious metal component and a NOx sorbent component, where said second region includes more of said NOx sorbent component than said first region, and said first and second regions are substantially free of ceria; and

a second emission control system including an SCR catalyst coupled downstream of said first emission control system.

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