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(54) **SYSTEMS AND METHODS TO MITIGATE NOX AND HC EMISSIONS AT LOW EXHAUST TEMPERATURES**

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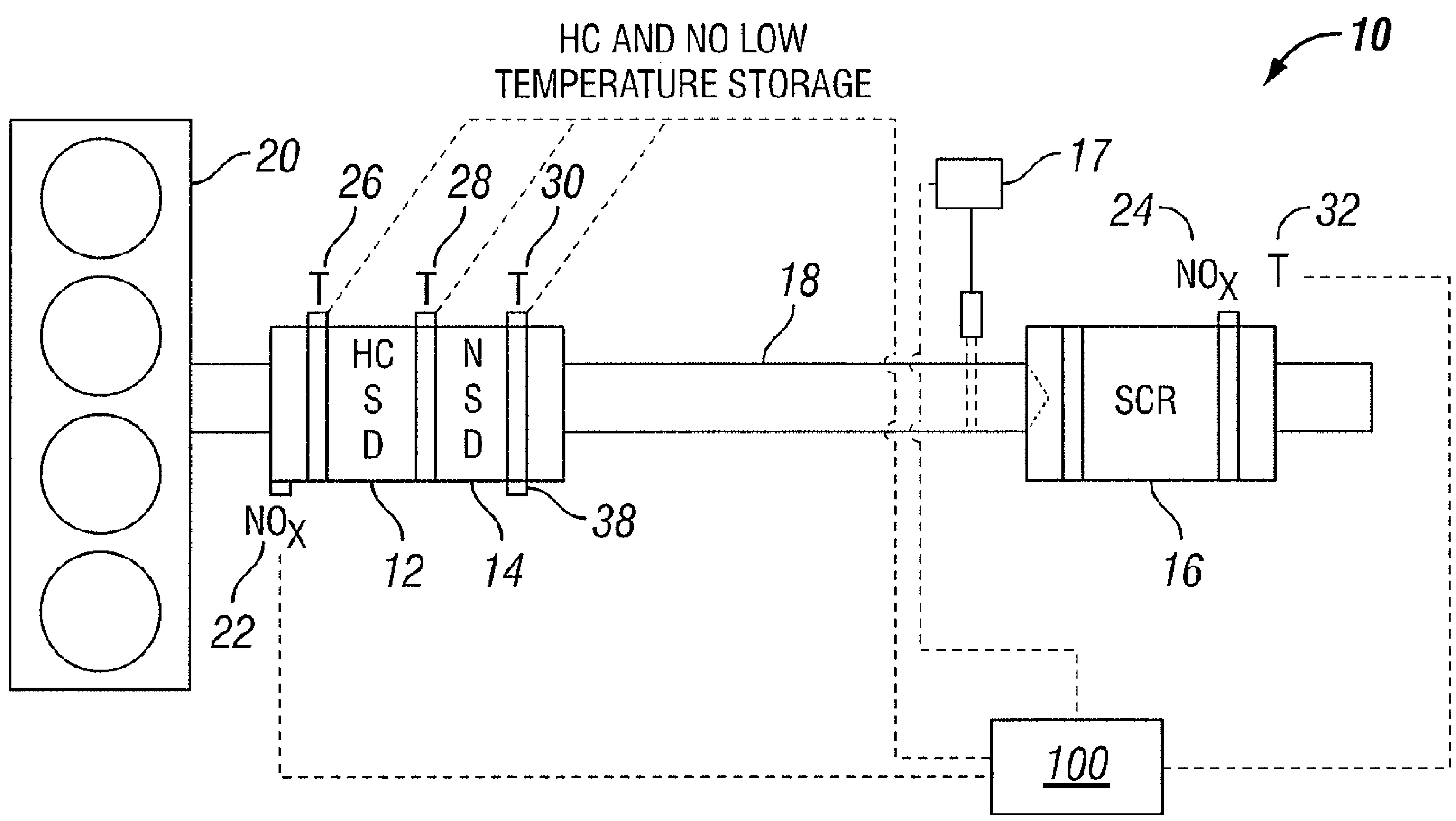
(57) **ABSTRACT**

Systems and methods are provided for managing low temperature NO_x and HC emissions, such as during a cold start of an internal combustion engine. The systems and methods include storing NO_x and HC emissions at low temperatures and passively releasing these emissions as the temperature of the exhaust system increases.



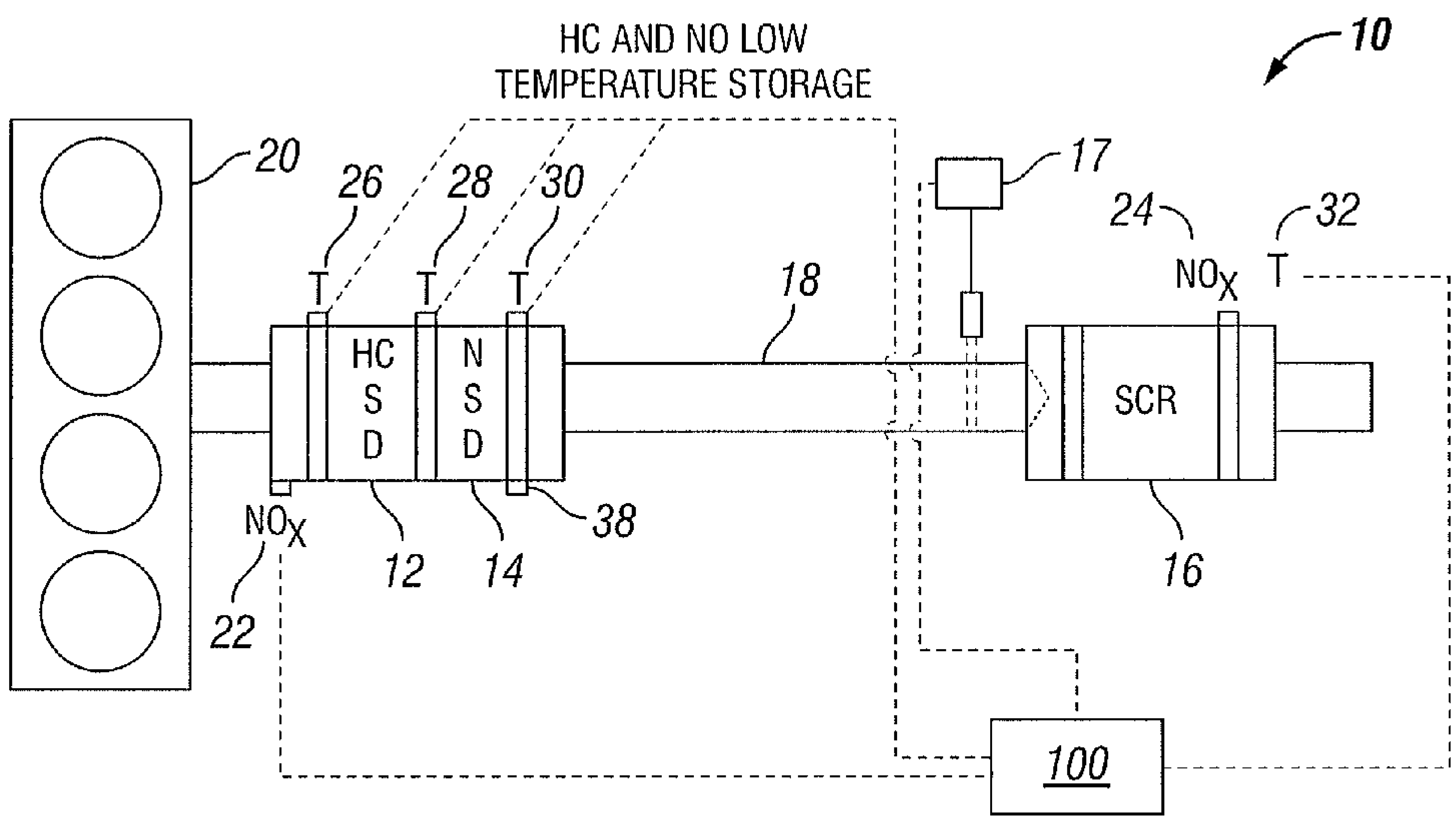

HC AND NO LOW
TEMPERATURE STORAGE
10
20
26
28
30
17
24
32
T
T
T
NOX
T
18
HC
S
D
N
S
D
SCR
NOX
22
12
14
38
16
100

FIG. 1

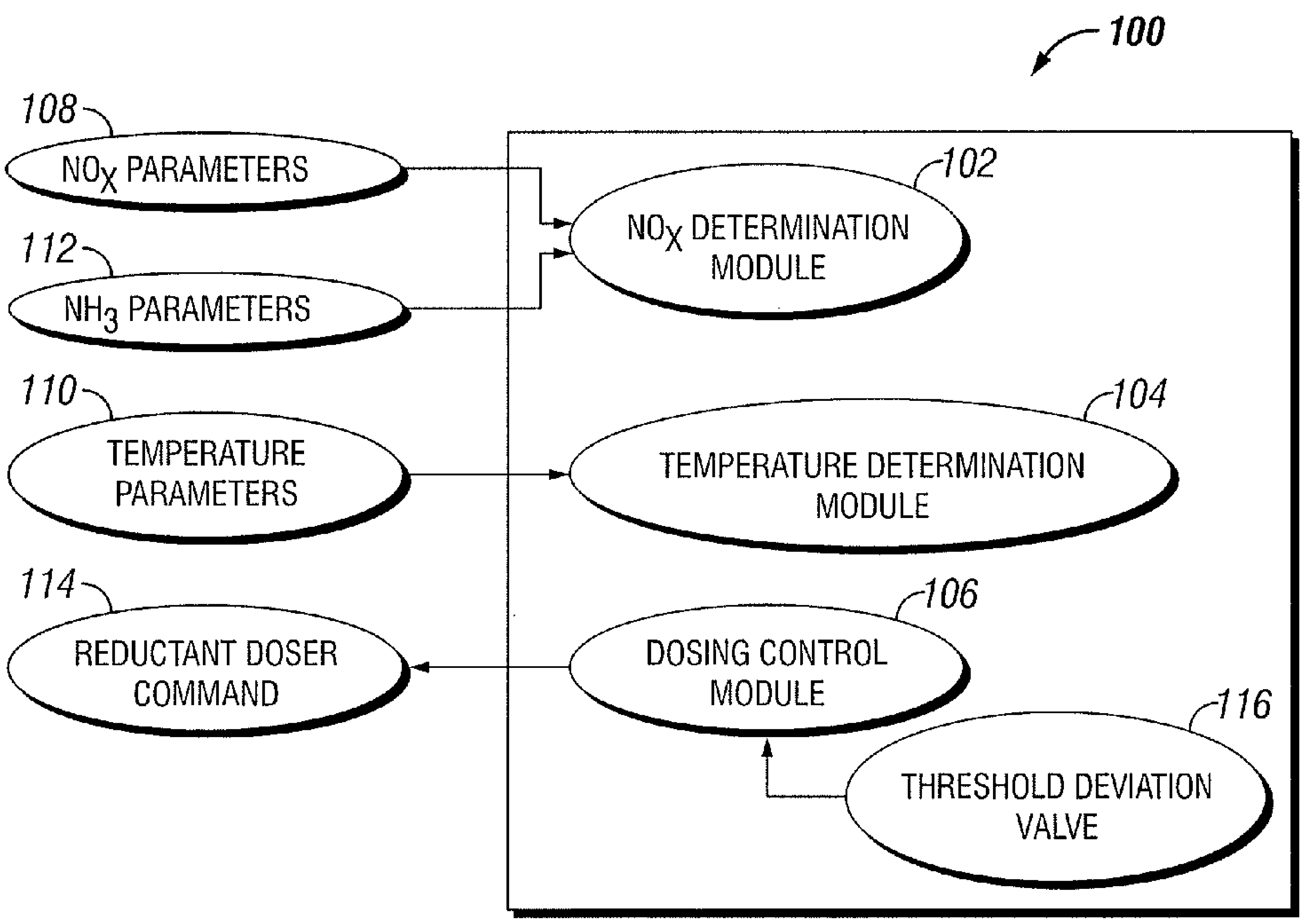

100
108
NOX PARAMETERS
102
NOX DETERMINATION
MODULE
112
NH3 PARAMETERS
110
TEMPERATURE
PARAMETERS
104
TEMPERATURE DETERMINATION
MODULE
114
REDUCTANT DOSER
COMMAND
106
DOSING CONTROL
MODULE
116
THRESHOLD DEVIATION
VALVE

FIG. 2

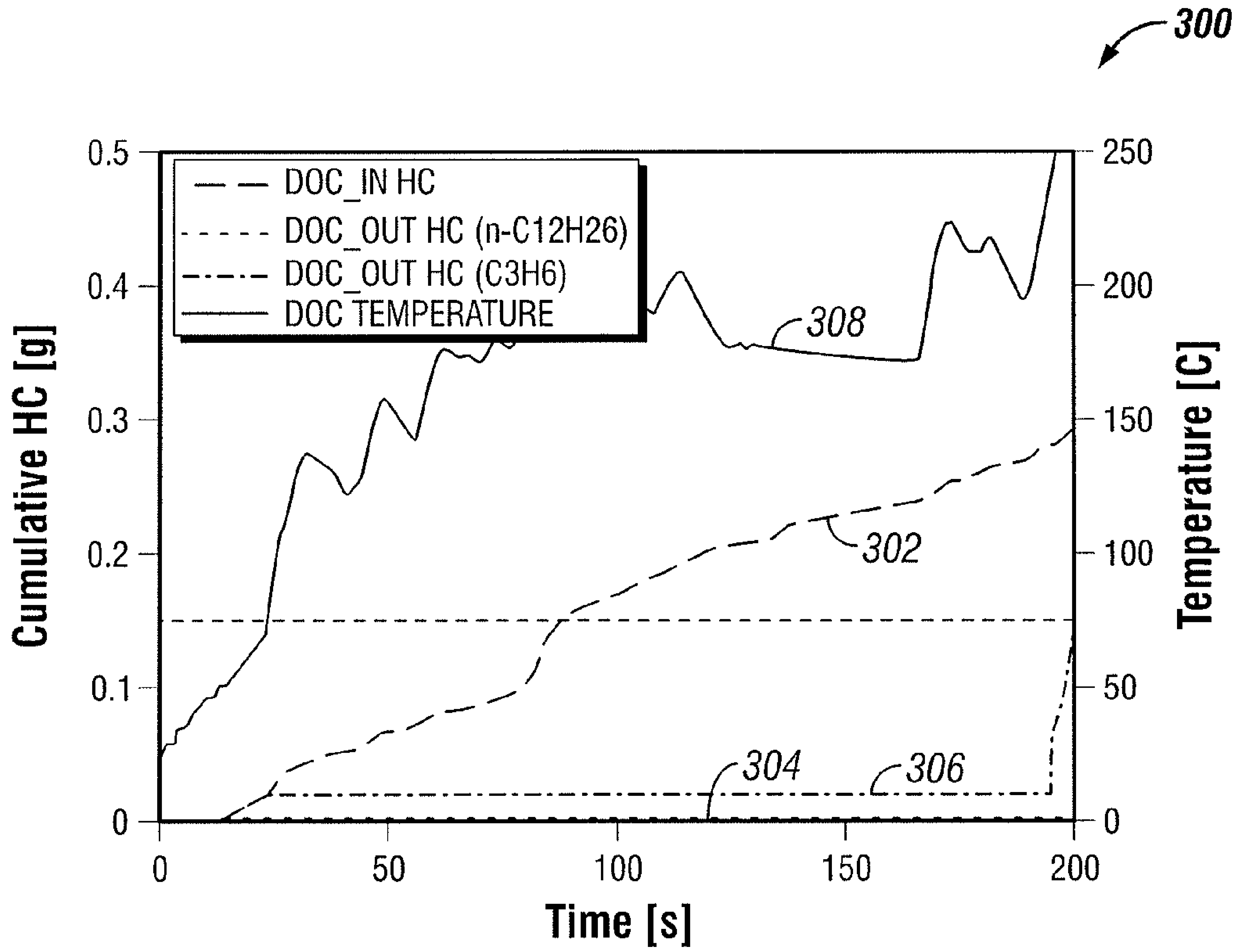

300
DOC_IN HC
DOC_OUT HC (n-C12H26)
DOC_OUT HC (C3H6)
DOC TEMPERATURE
308
302
304
306
Cumulative HC [g]
Temperature [C]
Time [s]
0.5
0.4
0.3
0.2
0.1
0
250
200
150
100
50
0
0
50
100
150
200

FIG. 3

SYSTEMS AND METHODS TO MITIGATE NOX AND HC EMISSIONS AT LOW EXHAUST TEMPERATURES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of the filing date of Provisional Application No. 61/650,722 filed on May 23, 2012, which is incorporated herein by reference.

BACKGROUND

[0002] Control of selective catalytic reduction (SCR) catalysts is of increasing interest to meet modern internal combustion engine emissions standards. The effectiveness of a typical SCR catalyst in removing oxides of nitrogen (NO_x) emissions is sensitive to the temperature of the exhaust gas at the inlet to the SCR catalyst. Copper exchanged zeolite based SCR catalysts are formulated to operate satisfactorily over a fairly wide temperature range. However, current state of the art Cu-Zeolite formulations operate at peak efficiency when subjected to exhaust gas temperatures of 200-400° C. For certification of certain diesel engines, the emissions performance of the engine during the cold portion of the certification cycle is weighted almost equally with the emissions performance of the engine during the hot portion of the certification cycle. For this reason, improvements in preventing hydrocarbon (HC) and NO_x emissions produced by the engine from slipping through the aftertreatment system at low temperature exhaust conditions, such as at temperatures less than 200° C., are desired.

[0003] Typical diesel A/T systems include a diesel oxidation catalyst (DOC) and a diesel particulate filter (DPF) in addition to the SCR. The DOC is responsible for oxidation of hydrocarbons (HC), carbon monoxide (CO), and nitric oxide (NO). Similar to the SCR catalyst, the DOC is not able to effectively and efficiently oxidize these molecules at cold exhaust temperatures. In order to meet NO_x and HC emissions levels (for example, 0.02 and 0.01 g/mile, respectively for Tier 2 Bin 2 federal certification) at low temperature conditions, improvements in aftertreatment designs are required to mitigate the slip of these criteria pollutants through the exhaust flowpath during low temperature operation. Accordingly, further technological developments in this area are desirable.

SUMMARY

[0004] One embodiment is a unique method and system for managing low temperature NO_x and HC emissions to improve the NO_x conversion efficiency of diesel aftertreatment systems under low exhaust temperature conditions. In one embodiment, there is provided a multiple component aftertreatment system that includes passively operated HC and NO_x storage devices for improved low temperature mitigation of NO_x and HC emissions to achieve desired emissions levels for light duty vehicles, although applications with other vehicles are not precluded. The systems and methods reduce the need for external devices intended to artificially increase the exhaust gas temperature for cold start cycles, which is beneficial since such external devices tend to increase fuel consumption and greenhouse gas emissions, although the use of such external devices are not precluded. The systems and methods disclosed herein provide reductions in cost and fuel consumption over current thermal management strategies to mitigate low temperature NO_x and HC emissions. Further embodiments, forms, objects, features, advantages, aspects, and benefits shall become apparent from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is an exemplary system for reducing emissions of HC and NO_x of an internal combustion engine during low exhaust temperature operating conditions.

[0006] FIG. **2** is a schematic of a controller comprising a portion of the system of FIG. **1**.

[0007] FIG. **3** is a graph showing an estimated impact of a hydrocarbon storage device on HC slip flow over time during low temperature exhaust operating conditions.

DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

[0008] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, any alterations and further modifications in the illustrated embodiments, and any further applications of the principles of the invention as illustrated therein as would normally occur to one skilled in the art to which the invention relates are contemplated herein.

[0009] There is disclosed systems and methods for reduction in HC and NO_x emissions at low exhaust temperature operating conditions for an internal combustion engine. The systems and methods reduce criteria pollutants at least during low exhaust temperature conditions. The disclosed systems and methods are configured so that the vehicles equipped therewith are operable to meet emissions standards during low exhaust temperature operating conditions without the need for external aftertreatment heating systems, which increase fuel consumption and greenhouse gas emissions from the vehicle, although the use of such external systems is not precluded. In one embodiment, the systems and methods have application for light duty certified chassis vehicles, although applications with other vehicle types are not precluded.

[0010] The systems and methods include an aftertreatment system architecture configured to temporarily store HC emissions and NO_x emissions during periods of low exhaust temperature operation, and then passively release the stored NO_x and HC emissions for aftertreatment as the exhaust temperature increases. The systems and methods are configured so that at temperatures where HC and NOx emissions are released, the diesel oxidation catalyst (DOC) and SCR catalysts are effective at mitigating the released HC and NO_x emissions from the storage devices before exiting the tailpipe.

[0011] In one embodiment, the aftertreatment system includes a close coupled HC storage device (HCSD) located directly downstream of the turbocharger, with a close coupled NO_x storage device (NSD) located directly downstream of the HCSD. At low exhaust temperatures, the HCSD readily adsorbs and stores HC. In one specific embodiment, the HCSD includes a catalyst, such as a zeolite-based catalyst, for storing and adsorbing HC. As the exhaust temperature increases, the HCSD effectively oxidizes HC in the gas phase that are stored on the surface of the HCSD to form H_2O and CO_2. The NSD is any suitable component, such as a NO_x

adsorber, capable of passively storing NO_x at low exhaust temperature, and then releasing the stored NO_x as the exhaust temperature increases. The NSD may also have an oxidation function, primarily for NO oxidation to NO_2, but under normal operating conditions is not capable of effectively reducing NO_x to N_2 and H_2O. The NSD relies on a downstream selective catalytic reduction (SCR) catalyst or other NO_x reduction catalyst to chemically reduce the NO_x to N_2 and H_2O.

[0012] In a further embodiment, systems and methods for reducing the emission of HC and NO_x from lean burn internal combustion engines for low exhaust temperature operating conditions are disclosed. As shown in FIG. **1**, an exemplary aftertreatment system **10** includes a close coupled HCSD **12** and NSD **14** followed by a standard SCR or NAC-type NO_x reduction catalyst **16** to receive exhaust gas produced by an internal combustion engine **20** into exhaust flowpath **18**. The HCSD **12** and NSD **14** are passively operated devices, which require little or no active control strategies, although the use of active control strategies is not precluded.

[0013] At low exhaust gas temperatures which result in low catalyst temperatures, the HCSD **12** readily adsorbs and stores HC on the surface of a catalyst until the HCSD **12** reaches a surface temperature where it can effectively oxidize the stored HC to form CO_2 and H_2O. The NSD **14** readily adsorbs and stores NO_x on the surface of its catalyst under low exhaust temperature conditions, and then begins to desorb this NO as the exhaust temperature and therefore the NSD catalyst temperature increases. The NSD **14** is configured to release the stored NO_x at an exhaust temperature where the reduction catalyst **16** is highly effective for reducing NO_x to N_2 and H_2O. Once the aftertreatment system **10** reaches operating temperature, either or both of the catalysts of the HCSD **12** and the NSD **14** may operate as DOC catalysts, and together are responsible for the oxidation of HC, CO and NO.

[0014] System **10** may include a controller **100** and other aftertreatment components in addition to those shown in FIG. **1**. For example, system **10** typically includes a reductant doser **17** operationally coupled to the exhaust conduit at a position upstream of the reduction catalyst **16**. The reductant injected into exhaust flowpath **18** is any type of reductant utilized in a NO_x reduction system. For example, the reductant can include at least ammonia (gaseous or aqueous) and urea. System **10** may also include a diesel particulate filter (DPF) forming, with the HCSD **12** and NSD **14**, a DOC/DPF system positioned upstream of reduction catalyst **16** during engine operation where exhaust temperatures are effective for NO_x reduction with reduction catalyst **16**. The system **10** may include an ammonia oxidation catalyst (AMOX) downstream of the reduction catalyst **16**. In certain embodiments, the AMOX may not be present, or the AMOX may be commingled with the reduction catalyst **16** (or the last SCR catalyst, where multiple SCR catalysts are present), for example with a washcoat applied toward the rear portion of the reduction catalyst **16** that is responsive to at least partially oxidize ammonia. In other embodiments, any of these components may be present or missing, catalyzed or not catalyzed, and may be arranged in alternate order. Further, certain components or all components may be provided in the same or separate housings.

[0015] For system **10** including controller **100**, controller **100** can include a number of modules structured to functionally execute operations for controlling the SCR system. In certain embodiments, the controller forms a portion of a processing subsystem including one or more computing devices having memory, processing, and communication hardware. The controller **100** may be a single device or a distributed device, and the functions of the controller may be performed by hardware or software. The controller **100** may be in communication with any sensor, actuator, datalink, and/or network in the system.

[0016] In certain embodiments, such as shown in FIG. **2**, the controller **100** includes a NO_x determination module **102**, a temperature determination module **104**, and a dosing control module **106**. The description herein including modules emphasizes the structural independence of the aspects of the controller **100**, and illustrates one grouping of operations and responsibilities of the controller **100**. Other groupings that execute similar overall operations are understood within the scope of the present application. Modules may be implemented in hardware and/or software on computer readable medium, and modules may be distributed across various hardware or software components. More specific descriptions of certain embodiments of controller operations are included in the section referencing FIG. **2**.

[0017] The exemplary system **10** further includes various sensors. The illustrated sensors in FIG. **1** include a first NO_x sensor **22** positioned upstream of the HCSD **12** and a second NO_x sensor **24** positioned downstream of the reduction catalyst **16**. Alternatively or additionally, a NO_x sensor **38** can be provided at the outlet of NSD **14**, or between the inlet to reduction catalyst **16** and the outlet of NSD **14**. System **10** also includes a first temperature sensor **26** at the inlet of HCSD **12**, a second temperature **28** between HCSD **12** and NSD **14**, a third temperature sensor **30** at the outlet of NSD **14**, and a fourth temperature sensor **32** at the outlet of reduction catalyst **16**. Other sensors can be provided to measure or determine the mass flow through the exhaust system, the temperature of any component of the aftertreatment system, the amount of ammonia stored in reduction catalyst **16** or outlet therefrom, etc.

[0018] The illustrated sensors are exemplary only, and may be re-positioned, removed, substituted, and other sensors may be present that are not illustrated in FIG. **1**. Further, certain sensors may instead be virtual sensors that are calculated from other parameters available to the system **10**, or values that would be indicated by sensors may instead be supplied to a computer readable memory location, via a datalink or network communication, or otherwise be made available to the system **10** where the sensor providing the sensed parameter is not a part of the defined system **10**.

[0019] The exemplary controller **100** in FIGS. **1-2** is configured for executing operations to provide a reductant doser command for the effective removal of NO_x emissions with reduction catalyst **16**. The controller operations of the controller **100** in FIG. **2** include operations that adjust nominal control operations for a NO_x aftertreatment system utilizing a reductant. Nominal control operations for a NO_x aftertreatment system, including an SCR aftertreatment system, are understood in the art and are not described further herein. Any nominal NO_x aftertreatment control operations may be utilized by system **10** disclosed herein.

[0020] The controller **100** includes a NO_x determination module **102** that receives NO_x parameters **108** from NO_x sensors **22**, **24**, **38** and determines an amount of NO_x emitted from engine **20** and from reduction catalyst **16**, respectively. Controller **100** can also be configured to determine or calculate and amount of NO_x at the outlet of NSD **14**. Controller

100 also includes a temperature determination module **104** that receives temperature signals from temperature sensors **26**, **28**, **30**, **32** to determine a temperature of the exhaust gas in flowpath **18** and/or of the various catalysts of the aftertreatment components in flowpath **18**. Controller **100** further includes a dosing control module **106** that determines an appropriate dosing command for reductant to be injected in flowpath **18** to provide a desired emissions level for NO_x at the outlet of reduction catalyst **16** and ultimately to the tailpipe.

[0021] During low temperature operating conditions for engine **20** and for exhaust gas and/or aftertreatment components in flowpath **18**, reduction catalyst **16** is ineffective in treating emissions of NO_x to meet desired emissions level targets. Furthermore, traditional oxidation catalysts upstream of reduction catalyst **16** are ineffective in removing HC to meet criteria emissions levels at low temperature operating conditions. Therefore, HCSD **12** is configured to store HC, and NSD **14** is configured to store NO_x during low exhaust temperature operating conditions until the aftertreatment components of system **10** are raised to a temperature effective to remove the criteria pollutants from the emissions of engine **20**.

[0022] The amount of accumulation during low exhaust temperature operating conditions of NO_x in NSD **14** can be determined by the difference between the amount of NO_x detected by upstream NO_x sensor **22** and the corresponding amount detected by downstream NO_x sensor **24** and converted by oxidation catalyst **16** during low temperature operation. Dosing control module **106** is configured to determine a dosing command that delays reductant dosing during low temperature operating conditions since NO_x sensor **24** senses NO_x levels that are reduced or lower than the levels determined by NO_x sensor **22** due to the NO_x storage at NSD **14**. As the exhaust gas temperature increases to and above an effective temperature, dosing control module **106** is configured to increase reductant dosing to treat the NO_x emissions released from NSD **14** as determined by one or both of NO_x sensor **38** and NO_x sensor **24**, or by a calculated or sensed NO_x amount at the outlet of NSD **14**. Furthermore, in certain embodiments, dosing control module **106** can be configured to anticipate a future NO_x emissions load and timing of the release of the stored NO_x emissions by monitoring temperature parameters **110**. The amount of reductant dosing can be increased prior to release of NO_x emissions to provide a sufficient amount of reductant on reduction catalyst **16** to meet the expected increased in NO_x emissions.

[0023] The dosing control module **106** provides a reductant doser command **114** to reductant doser **17** in response to a threshold deviation value **116**. The threshold deviation value **116** includes a determination that NO_x emissions at NO_x sensor **24** is approaching or meeting a threshold deviation from an emissions level target value which requires reductant to be supplied to reduction catalyst **16**. The reductant doser command **114** provided by the dosing control module **106** may include a reductant amount to be supplied to reduction catalyst **16**. The dosing control module **106** provides the reductant doser command **114** in response to the threshold deviation value **116** indicating that the present NO_x emissions level deviates more than a threshold amount from a NO_x emissions level target. The reductant doser command **114** may be provided under any control scheme understood in the art, and/or under specific control schemes described herein. The reductant doser command **114** may include an actuator command value, a voltage or other electrical signal, and/or a datalink or network command. In certain embodiments, a reductant doser in a system including the controller **100** is responsive to the reductant doser command **114** to provide reductant to an exhaust stream at the position of the reductant doser **17** upstream of the reduction catalyst **16**.

[0024] Dosing control module **106** can further be configured to provide a reductant doser command **114** that can be delayed to account for the amount of NO_x stored by NSD **14** during low temperature exhaust conditions. As used herein, a delayed reductant doser command includes decreasing the rate at which reductant is injected and/or decreasing the range of engine operating conditions in which reduction catalyst **16** is utilized for treatment of NO_x emissions, including those conditions which otherwise would have resulted in treatment of emissions of NOx from engine **20** by supplying reductant to reduction catalyst **16** without NO_x storage by NSD **14** upstream of reduction catalyst **16**. However, injection of reductant for storage on reduction catalyst **16** during low temperature operation is not precluded.

[0025] The descriptions here provide illustrative embodiments of performing procedures for controlling an aftertreatment system for low temperature operating conditions. Operations illustrated are understood to be exemplary only, and operations may be combined or divided, and added or removed, as well as re-ordered in whole or part, unless stated explicitly to the contrary herein. Certain operations illustrated may be implemented by a computer executing a computer program product on a computer readable medium, where the computer program product comprises instructions causing the computer to execute one or more of the operations, or to issue commands to other devices to execute one or more of the operations.

[0026] An exemplary HCSD **12** is operable to store HC over a range of operating temperatures below an effective operating temperature. For example, at temperatures below 200° C., HCSD **12** is effective at storing HC emissions typically seen in operation of a diesel engine. As the exhaust temperatures approach and exceed 200° C., the lightoff of the HC emissions stored in HCSD **12** is effective to oxidize the HC to form CO_2 and H_2O. In one embodiment, the catalyst of HCSD **12** is a zeolite catalyst with an oxidation catalyst thereon.

[0027] As shown in graph **300** of FIG. **3**, line **302** indicates the cumulative HC received at the inlet to HCSD **12** over time at the start of a low temperature operating condition. Lines **304**, **306** indicate the minimal outlet of HC from HCSD **12** over time during the low temperature operating condition. As the operating temperature increases over time, as indicated by line **308**, the stored HC stored until a sufficiently high catalyst temperature for HCSD **12** is attained to oxidize HC.

[0028] As is evident from the figures and text presented above, a variety of embodiments according to the present invention are contemplated.

[0029] An exemplary set of embodiments is a method including storing in an exhaust flowpath, upstream of a NO_x reduction catalyst, hydrocarbon and NO_x emissions from an internal combustion engine during low exhaust temperature operation; releasing the stored hydrocarbons and NO_x emissions into the exhaust flowpath as the exhaust temperature increases toward an effective operating temperature; and treating the released hydrocarbons and NO_x emissions with the NO_x reduction catalyst.

[0030] In certain embodiments of the method, the NO_x reduction catalyst is a selective catalytic reduction catalyst. In other embodiments, the method includes storing hydrocarbon emissions on the surface of a hydrocarbon storage device catalyst. In other embodiments, the method includes storing NO_x emissions includes storing NO_x emissions on the surface of a NO_x storage device catalyst. In other embodiments, the NO_x storage device is a NO_x adsorber. In certain embodiments, the effective operating temperature is around 200° Celsius. In other embodiments, the method further includes delaying reductant dosing during the low exhaust temperature operation so that a reductant amount dosed into the exhaust flowpath during low exhaust temperature operation is insufficient for the NO_x reduction catalyst to treat the NO_x emissions from the internal combustion engine.

[0031] Another set of exemplary embodiments is a method comprising: operating an internal combustion engine to produce hydrocarbon and NO_x emissions into an exhaust flowpath during low exhaust temperature operation; storing, upstream of a NO_x reduction catalyst, HC and NO_x emissions from the internal combustion engine during low exhaust temperature operation; and providing a reductant dosing command that treats the NO_x emissions with the NO_x reduction catalyst when the exhaust temperature reaches an effective operating temperature that releases the stored HC and NO_x emissions.

[0032] In yet other embodiments, the method further comprises delaying reductant dosing during the low exhaust temperature operation so that a reductant amount dosed into the exhaust flowpath during low exhaust temperature operation is insufficient for a NO_x reduction catalyst to treat the NO_x emissions from the internal combustion engine. In another embodiment, storing hydrocarbon emissions includes storing hydrocarbon emissions on the surface of a hydrocarbon storage device catalyst and releasing the stored hydrocarbons includes oxidizing the hydrocarbons as the exhaust temperature increases toward the effective operating temperature. In one refinement of this embodiment, storing NO_x emissions includes storing NO_x emissions on the surface of a NO_x storage device catalyst. In yet another refinement, the NO_x storage device is a NO_x adsorber. In additional embodiments, the effective operating temperature is around 200° Celsius. In other embodiments, the NO_x reduction catalyst is a selective catalytic reduction catalyst.

[0033] Another exemplary set of embodiments is a system including an internal combustion engine; an exhaust conduit fluidly coupled to the internal combustion engine; a hydrocarbon storage device fluidly coupled to the exhaust conduit; a NO_x adsorber fluidly coupled to the exhaust conduit; a NO_x reduction catalyst downstream of the NO_x adsorber; and a reductant doser operationally coupled to the exhaust conduit upstream of the NO_x reduction catalyst and downstream of the NO_x adsorber.

[0034] In certain embodiments, the system includes the NO_x reduction catalyst downstream of the hydrocarbon storage device. In one refinement of this embodiment, the reductant doser is operationally coupled to the exhaust conduit downstream of the hydrocarbon storage device and the NO_x adsorber. In another embodiment, the reductant doser is operationally coupled to the exhaust conduit downstream of the hydrocarbon storage device and the NO_x adsorber.

[0035] In certain embodiments, the system includes a controller comprising a NO_x ratio determination module structured to determine a NO_x amount at an outlet of the NO_x reduction catalyst; a temperature determination module structured to determine a present operating temperature of the exhaust gas in the exhaust flowpath; and a dosing control module structured to determine a reductant doser command in response to the NO_x amount to achieve a desired NO_x emissions from the NO_x reduction catalyst.

[0036] In another exemplary embodiment of the system, the controller is configured to provide a delayed reductant doser command during low exhaust temperature operating conditions. In another embodiment, the hydrocarbon storage device includes a catalyst configured to store hydrocarbon emissions thereon during low exhaust temperature operating conditions and to oxidize the stored hydrocarbons when the exhaust temperature reaches an effective temperature. In a refinement of this embodiment, the NO_x adsorber is structured to adsorb NO_x emissions during low exhaust temperature operating conditions and release and oxidize NO_x emissions when the exhaust temperature reached an effective temperature. In another embodiment, the system includes a first NO_x sensor at an inlet of the hydrocarbon storage device and a second NO_x sensor at an outlet of the nitrous oxide reduction catalyst. In another embodiment, the system includes a NO_x sensor at an outlet of the NO_x storage device.

[0037] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain exemplary embodiments have been shown and described and that all changes and modifications that come within the spirit of the inventions are desired to be protected. In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

What is claimed is:

1. A method, comprising:

storing in an exhaust flowpath, upstream of a NO_x reduction catalyst, hydrocarbon (HC) and oxides of nitrogen (NO_x) emissions from an internal combustion engine during low exhaust temperature operation;

releasing the stored HC and NO_x emissions into the exhaust flowpath as the exhaust temperature increases toward an effective operating temperature; and

treating the released HC and NO_x emissions with an oxidation catalyst and the NO_x reduction catalyst.

2. The method of claim **1**, wherein the NO_x reduction catalyst is a selective catalytic reduction catalyst.

3. The method of claim **1**, wherein the oxidation catalyst is a hydrocarbon storage device catalyst and storing HC emissions includes storing HC emissions on the surface of the hydrocarbon storage device catalyst.

4. The method of claim **3**, further comprising oxidizing the stored HC with the hydrocarbon storage device catalyst.

5. The method of claim **1**, wherein storing NO_x emissions includes storing NO_x emissions on the surface of a NO_x storage device catalyst.

6. The method of claim **5**, wherein the NO_x storage device is a NO_x adsorber.

7. The method of claim **1**, wherein the effective operating temperature is around 200° Celsius.

8. The method of claim **1**, further comprising delaying reductant dosing during the low exhaust temperature operation so that a reductant amount dosed into the exhaust flowpath during low exhaust temperature operation is insufficient for the NO_x reduction catalyst to treat the NO_x emissions from the internal combustion engine.

9. A method, comprising:

operating an internal combustion engine to produce hydrocarbon (HC) and oxides of Nitrogen (NO_x) emissions into an exhaust flowpath during low exhaust temperature operation;

storing, upstream of a NO_x reduction catalyst, HC and NO_x emissions from the internal combustion engine during low exhaust temperature operation; and

providing a reductant dosing command that treats the NO_x emissions with the NO_x reduction catalyst when the exhaust temperature reaches an effective operating temperature that releases the stored HC and NO_x emissions.

10. The method of claim **9**, further comprising delaying reductant dosing during the low exhaust temperature operation so that a reductant amount dosed into the exhaust flowpath during low exhaust temperature operation is insufficient for a NO_x reduction catalyst to treat the NO_x emissions from the internal combustion engine.

11. The method of claim **9**, wherein storing HC emissions includes storing HC emissions on the surface of a hydrocarbon storage device catalyst and wherein releasing the stored HC emissions includes oxidizing the HC as the exhaust temperature increases toward the effective operating temperature.

12. The method of claim **11**, wherein storing NO_x emissions includes storing NO_x emissions on the surface of a NO_x storage device catalyst.

13. The method of claim **12**, wherein the NO_x storage device is a NO_x adsorber.

14. The method of claim **9**, wherein the effective operating temperature is around 200° Celsius.

15. The method of claim **9**, wherein the NO_x reduction catalyst is a selective catalytic reduction catalyst.

16. A system, comprising:

an internal combustion engine;

an exhaust conduit fluidly coupled to the internal combustion engine;

a hydrocarbon storage device fluidly coupled to the exhaust conduit;

a NO_x adsorber fluidly coupled to the exhaust conduit;

a NO_x reduction catalyst downstream of the NO_x adsorber; and

a reductant doser operationally coupled to the exhaust conduit upstream of the NO_x reduction catalyst and downstream of the NO_x adsorber.

17. The system of claim **16**, wherein the NO_x reduction catalyst is downstream of the hydrocarbon storage device.

18. The system of claim **17**, wherein the reductant doser is operationally coupled to the exhaust conduit downstream of the hydrocarbon storage device and the NO_x adsorber.

19. The system of claim **16**, wherein the reductant doser is operationally coupled to the exhaust conduit downstream of the hydrocarbon storage device and the NO_x adsorber.

20. The system of claim **16**, further comprising a controller, comprising:

a NO_x ratio determination module structured to determine an NO_x amount at an outlet of the NO_x reduction catalyst;

a temperature determination module structured to determine a present operating temperature of the exhaust gas in the exhaust flowpath;

a dosing control module structured to determine a reductant doser command in response to the NO_x amount to achieve a desired NO_x emissions from the NO_x reduction catalyst.

21. The system of claim **20**, wherein the controller is configured to provide a delayed reductant doser command during low exhaust temperature operating conditions

22. The system of claim **16**, wherein the hydrocarbon storage device includes a catalyst configured to store hydrocarbon (HC) emissions thereon during low exhaust temperature operating conditions and to oxidize the stored HC when the exhaust temperature reaches an effective temperature.

23. The system of claim **22**, wherein the NO_x adsorber is structured to adsorb NO_x emissions during low exhaust temperature operating conditions and release and oxidize NO_x emissions when the exhaust temperature reached an effective temperature for NO_x conversion over the NO_x reduction device.

24. The system of claim **16**, further comprising a first NO_x sensor at an inlet of the hydrocarbon storage device and a second NO_x sensor at an outlet of the NO_x reduction catalyst.

25. The system of claim **16**, further comprising a NO_x sensor between the NO_x adsorber and the NO_x reduction catalyst.

26. The system of claim **16**, further comprising a NO_x sensor upstream of the NO_x reduction catalyst.

* * * * *