



- (51) **International Patent Classification:**
A62D 3/40 (2007.01) *A62D 101/20* (2007.01)
- (21) **International Application Number:**
PCT/US2012/048277
- (22) **International Filing Date:**
26 July 2012 (26.07.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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- (54) **Title:** APPARATUS AND METHOD OF OPERATING AN INJECTOR FOR AN EXHAUST GAS AFTERTREATMENT APPARATUS

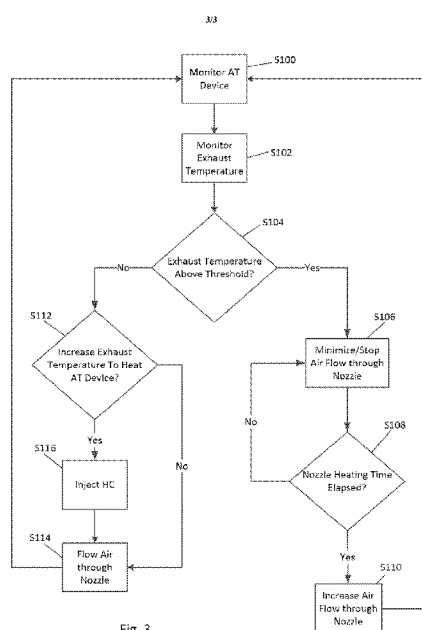


Fig. 3

(57) **Abstract:** A method for operating an exhaust aftertreatment system injector to prevent coking includes steps of injecting fuel for heating the aftertreatment devices, when not injecting fuel, flowing air to purge and cool the nozzle to prevent carbon deposits when exhaust gas temperature is low, and substantially stop air flow to allow passive heating of the nozzle by the exhaust for oxidation of any accumulated carbon when exhaust temperature is high enough to support oxidation. Preferably, the nozzle has a catalytic material coating to reduce the temperature necessary for oxidation of the coking material.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

Apparatus and Method of Operating an Injector for an Exhaust Gas Aftertreatment Apparatus

Field of the Invention

5 The invention is directed to exhaust gas aftertreatment apparatuses for internal combustion engines and methods for their operation. More particularly, the invention is directed to an apparatus and method for preventing coke fouling of an aftertreatment injector nozzle of an aftertreatment system.

Background and Summary of the Invention

10 Exhaust gas aftertreatment apparatuses in automotive vehicles are used to convert or remove targeted substances from the exhaust gas. Aftertreatment devices include, for example, diesel oxidation catalysts (DOC), which can remove particulate matter and oxidize carbon monoxide and uncombusted hydrocarbons in the exhaust gas, diesel particulate filters (DPF), which remove particulate matter from the exhaust gas, and selective catalytic reduction (SCR) systems, that inject
15 an ammonia-based reductant in the presence of a catalyst to convert oxides of nitrogen (NO_x) to nitrogen gas and water. Certain aftertreatment devices operate only at or above a threshold temperature, for example, the SCR devices. Other devices, such as the DPF, require the regular removal of collected particulate matter from the filter body. One such process, known as regeneration, occurs by oxidation of the collected particulate matter, which requires the filter body
20 to be at an elevated temperature, typically above 600° C.

 At engine start up, aftertreatment components may be at or near ambient temperature, which is typically too low for operation of those devices. In addition, automotive exhaust, and diesel engine exhaust in particular, is not consistently at temperatures high enough for operation of certain exhaust aftertreatment systems on the vehicle, in particular, regeneration of DPFs. Accordingly,
25 some device or method for increasing the temperature of the exhaust gas when necessary is provided. Exhaust heating methods and devices include engine management for control of exhaust gas temperature, resistive heating coils placed in the exhaust, and burners. One such device is a system for injecting hydrocarbon, typically diesel fuel, into the exhaust gas, including an injector with a nozzle positioned to inject fuel into the exhaust gas flow.

30 A problem with hydrocarbon injectors is fouling of the injector nozzle from decomposed liquid hydrocarbon, particulate matter, and other residue collecting on the nozzle, called "coking".

 The invention proposes an apparatus and method for solving these problems.

According to the invention, an exhaust gas aftertreatment apparatus having a hydrocarbon injector includes an injector nozzle coated with a catalytic material. The catalytic coating allows hydrocarbon that collects on the nozzle to oxidize at a temperature lower than non-catalyzed oxidation.

5 An apparatus according to the invention further includes a device for providing and controlling an air flow through the injector responsive to the exhaust gas temperature.

 A method of the invention for operating the injector has three states: (1) fuel injection for heating the aftertreatment devices, (2) after fuel injection, air flow through the nozzle to purge residual fuel and/or cool the nozzle to prevent carbon deposits when exhaust gas temperature is
10 low, and (3) no (or low) air flow to allow passive heating of the nozzle by the exhaust for oxidation of any accumulated carbon when exhaust temperature is high enough to support oxidation. Immediately following state (3) the method may include an additional air purge to remove ash.

 A method of operating an injector for an exhaust gas aftertreatment apparatus to avoid coke
15 deposits, the injector nozzle having a catalyst coating, includes the steps of injecting a hydrocarbon fluid into an exhaust gas flow over a selected duration, causing air to flow through the injector nozzle when an exhaust gas temperature is below a threshold temperature, and, substantially stopping the flow of air through the injector nozzle when the exhaust gas temperature is above the threshold temperature.

20 According to another aspect of the invention, the method includes the steps of monitoring a condition of the aftertreatment apparatus, monitoring an exhaust gas temperature, and, responsive to the condition of the aftertreatment apparatus and responsive to the exhaust gas temperature, controlling the injection of hydrocarbon in the exhaust gas flow.

 According to another aspect of the invention, air flow is preferably pulsed, the air flow
25 parameters, volume, frequency, and duration, being controlled responsive to exhaust gas temperature.

Brief Description of the Drawings

The invention will be better understood by reference to the following detailed description read in conjunction with the appended drawings, in which:

Figure 1 is a schematic drawing of an internal combustion engine and exhaust system having an aftertreatment system in accord with an exemplary embodiment of the invention;

Figure 2 is a simplified drawing of an exemplary aftertreatment injector; and,

Figure 3 is a flow diagram of a method according to the invention.

5 Detailed Description of the Invention

Figure 1 illustrates an apparatus including an internal combustion engine 10 with an exhaust gas aftertreatment system 12 according to the invention. The engine 10 is connected to an exhaust gas conduit 14 that receives exhaust gas from the engine. Exhaust gas is carried by the conduit to an aftertreatment system 16, which may include a Diesel Oxidation Catalyst (DOC), a Diesel Particulate
10 Filter (DPF), and a device for treating Nitrogen Oxides, such as a selective catalytic reaction device (SCR) or Lean NOx Catalyst (LNC). After the exhaust gas is treated, it is released to the environment through an exhaust stack or pipe 18.

The DPF filters the exhaust gas and collects soot and other particulate matter, which must be removed at intervals or the DPF becomes clogged. One common method for removing
15 particulate matter, which is mainly carbon based, is to raise the temperature of the DPF filter body to a temperature sufficient to oxidize the particulate matter. The temperature of the DPF filter body can be increased in various ways, as is known in the art. One way is to add hydrocarbon (or fuel) to the exhaust gas, which is oxidized, releasing heat energy. An injector 20 connected to a source of hydrocarbon 22 is shown in Figure 1 for such a purpose. The injector 20 includes a nozzle 24 to
20 introduce hydrocarbon into the exhaust gas flow. The injector 20 in the illustrated embodiment is also connected to an air source 26. A controller 28 is programmed to control the flow of hydrocarbon and air through the injector 20, as will be described in more detail below. Temperature sensors 30, 34 are positioned at the entry and exit, respectively, of the aftertreatment device 16 to monitor the temperature of the exhaust gas as it enters and exits the device. Alternatively, for
25 aftertreatment apparatuses including a DOC and DPF, temperature sensors may be arranged upstream of the DOC, downstream of the DOC and upstream of the DPF, and downstream of the DPF. In addition, pressure sensors 32, 36 are provided at the aftertreatment device 16 entry and exit, respectively, to monitor a pressure change of the exhaust gas across the DPF. The difference between entry and exit exhaust gas pressure is useful to determine the soot loading of the DPF.

30 Because the injector 20 is upstream of the aftertreatment device 16, it is exposed to exhaust gas carrying particulate matter. In addition, the injector nozzle 24 and the hydrocarbon liquid at and

exiting the nozzle 24 of the injector are exposed to the heat of the exhaust. This can result in coking of the nozzle as hydrocarbon liquid and particulate matter deposits form on the nozzle.

Maintaining the nozzle at a relative low temperature can help avoid, although not eliminate, coking. Coke deposits may be removed by heating the nozzle to a sufficiently high temperature to oxidize the carbon, and devices for heating nozzles are known. However, these add expense and complexity to the injector system.

According to the invention, an injector nozzle 24 is provided with a coating of a catalytic material that allows coke deposits to oxidize at a relatively low temperature. Suitable catalytic materials include precious metal catalysts such as platinum and palladium. Referring to Figure 2, an injector nozzle 24 includes a nozzle body 40 having a flow channel 42 for a liquid fuel. The flow channel 42 ends in a tip 44, which may include fluid distribution devices to control flow volume or induce swirl or spray angle, for example. The injector 20 may be any suitable fluid injector, and may include an injector body 50 having an interior passage 52 for the injected fluid, a needle 54 movable in the passage 52 operable by a spring 56 and an actuator device (not shown) to control the flow into the nozzle channel 42 and to the tip 44.

A catalytic coating is preferably applied to surfaces exposed to exhaust gas heat and the fuel injected by the nozzle 24. Such surfaces include the exterior surface 46 of the nozzle body 24, the tip 44, and a surface 48 defining the flow channel 42.

The catalytic coating on these surfaces will reduce the temperature necessary to oxidize carbon deposits on those surfaces. Figure 3 is a diagram of a method according to the invention for preventing coke fouling of an injector. According to the method, the aftertreatment (AT) device is monitored for operational condition (S100) by monitoring a pressure differential between incoming and outgoing exhaust gas and/or by monitoring a temperature of the device. A temperature of the exhaust gas entering the AT device is also monitored (S102).

The method determines if the exhaust gas is above a temperature threshold at which the exhaust gas can heat the catalyst coated nozzle to a temperature sufficient for oxidization of deposited carbon (S104). Using a precious metal as a catalyst, heating the nozzle to about 240°C or higher will promote oxidation.

Although described in a sequential manner, it should be understood that the method of the invention is not performed entirely sequentially; the steps of monitoring the AT device, monitoring

the exhaust gas temperature, and determining if the exhaust gas temperature is above the threshold are performed continually or in a repeating sequence as the rest of the method is performed.

If the exhaust gas temperature is above the threshold of Step S104, the method at Step S106 stops air flow through the injector or substantially stops air flow to provide a minimal amount of air flow, for example, to prevent ingress of exhaust gas into the nozzle, but not effectively cool the nozzle. The lack of air flow or low amount of air flow allows the nozzle to heat to the temperature sufficient for oxidizing any carbon deposits. A timer may be started to measure an interval during which the nozzle is heated and oxidation occurs. Alternatively, according to the method, the air flow will remain off or at a minimum as long as the exhaust gas temperature is above the threshold as determined in Step S104.

When the heating/oxidizing time interval has elapsed (Step S108) or the exhaust gas temperature falls below the threshold temperature, the method increases air flow through the nozzle (S110), to provide cooling to inhibit coking.

Returning to Step S104, if the exhaust gas temperature is below the threshold temperature, the condition of the AT device is evaluated to determine if it is necessary to increase the exhaust gas temperature (Step S112). For example, a DPF device may require a regeneration procedure to remove collected particulate matter.

If the AT device does not require heating, the method causes air to flow through the nozzle (Step S114). Air flow will help cool the nozzle to prevent or inhibit coking fouling.

If the AT device requires heating, hydrocarbon is injected through the injector (Step S116) while the exhaust gas temperature is monitored. An amount of hydrocarbon and a frequency of injections are controlled to the exhaust gas temperature to heat the DPF device to a target temperature and maintain that temperature for a time interval sufficient for regenerating the DPF. Alternatively, the DPF may be heated until the exhaust gas pressure differential between the entry and exit drops below a threshold.

When the regeneration process is completed, the hydrocarbon injection is stopped and air is caused to flow through the nozzle (Step S114). The flow of air after hydrocarbon injection will help purge the nozzle of residual hydrocarbon and the continued flow of air helps cool the nozzle to help inhibit or prevent coke fouling.

It is noted that according to the invention, at low exhaust temperatures where the temperature is not sufficiently high to oxidize carbon, air flows continuously through the nozzle to

maintain nozzle temperatures as low as possible to slow carbon deposition. At exhaust temperatures high enough to support oxidation of carbon deposited on the nozzle, air flow through the nozzle is completely or substantially completely shut off to avoid cooling the nozzle and allow oxidation of any coking.

5 In the present application, the use of terms such as “including” is open-ended and is intended to have the same meaning as terms such as “comprising” and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as “can” or “may” is intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To
10 the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

While this invention has been illustrated and described in accordance with a preferred embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

What is claimed is:

1. A method of operating an injector for an exhaust gas aftertreatment apparatus to avoid coke deposits, the injector nozzle having a catalyst coating, the method comprising the steps of:

5 selectively injecting a hydrocarbon fluid into an exhaust gas flow to increase the temperature of the exhaust flow;

when not injecting hydrocarbon, causing air to flow through the injector nozzle when an exhaust gas temperature is below a threshold temperature; and,

when not injecting hydrocarbon, substantially stopping the flow of air through the injector nozzle when the exhaust gas temperature is above the threshold temperature.

10 2. The method as in claim 1, further comprising:

monitoring a condition of the aftertreatment apparatus;

monitoring an exhaust gas temperature; and,

responsive to the condition of the aftertreatment apparatus and responsive to the exhaust gas temperature, controlling the injection of hydrocarbon in the exhaust gas flow.

15 3. The method as in claim 1, comprising the step of causing air to flow through the injector immediately following injecting hydrocarbon to purge residual hydrocarbon from the injector.

4. The method as in claim 1, wherein the flow of air through the injector nozzle when the exhaust gas temperature is above the threshold temperature is substantially stopped until the exhaust gas temperature is below the threshold temperature.

20 5. The method as in claim 1, wherein the flow of air through the injector nozzle when the exhaust gas temperature is above the threshold temperature is substantially stopped for a predetermined time interval.

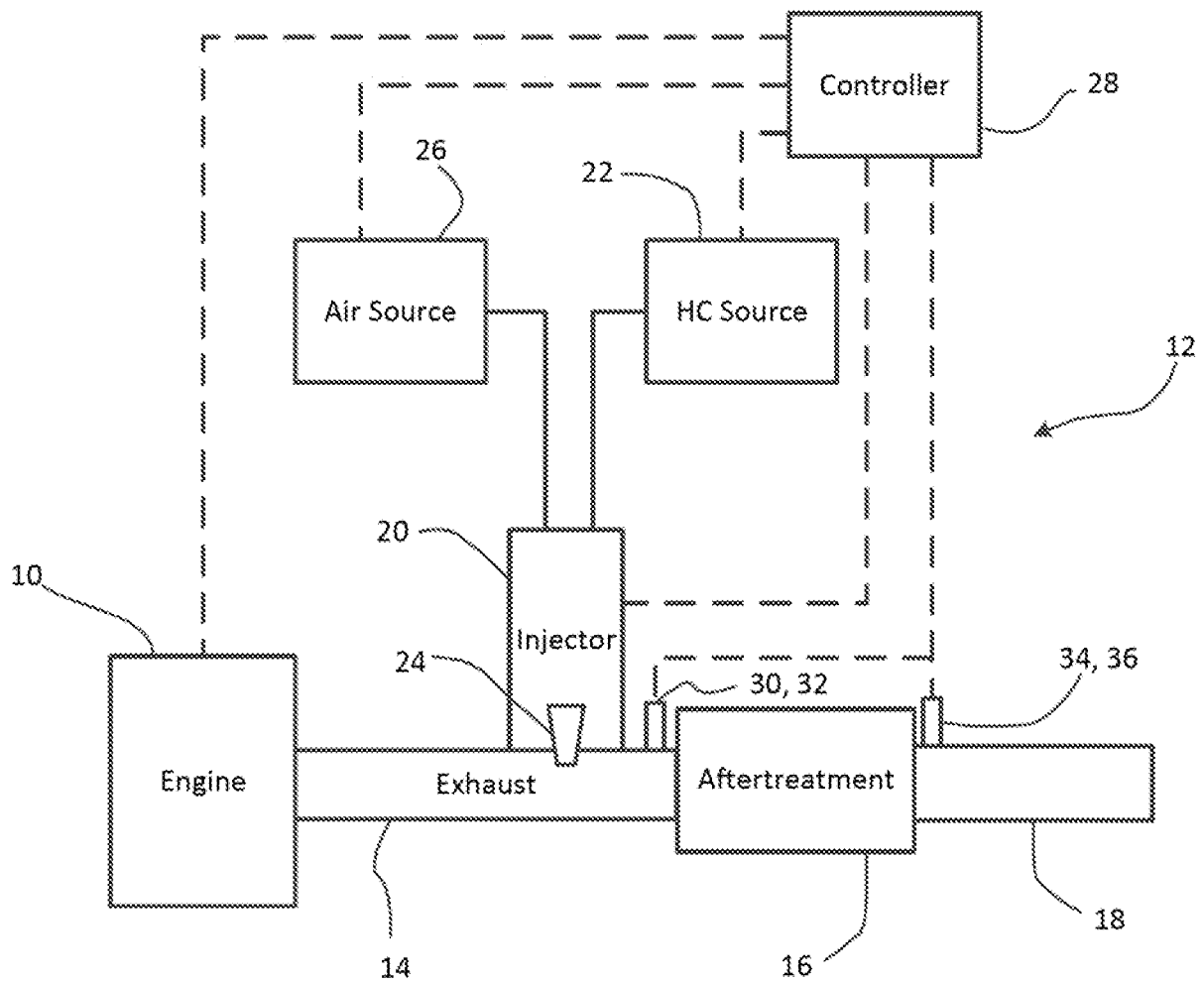


Fig. 1

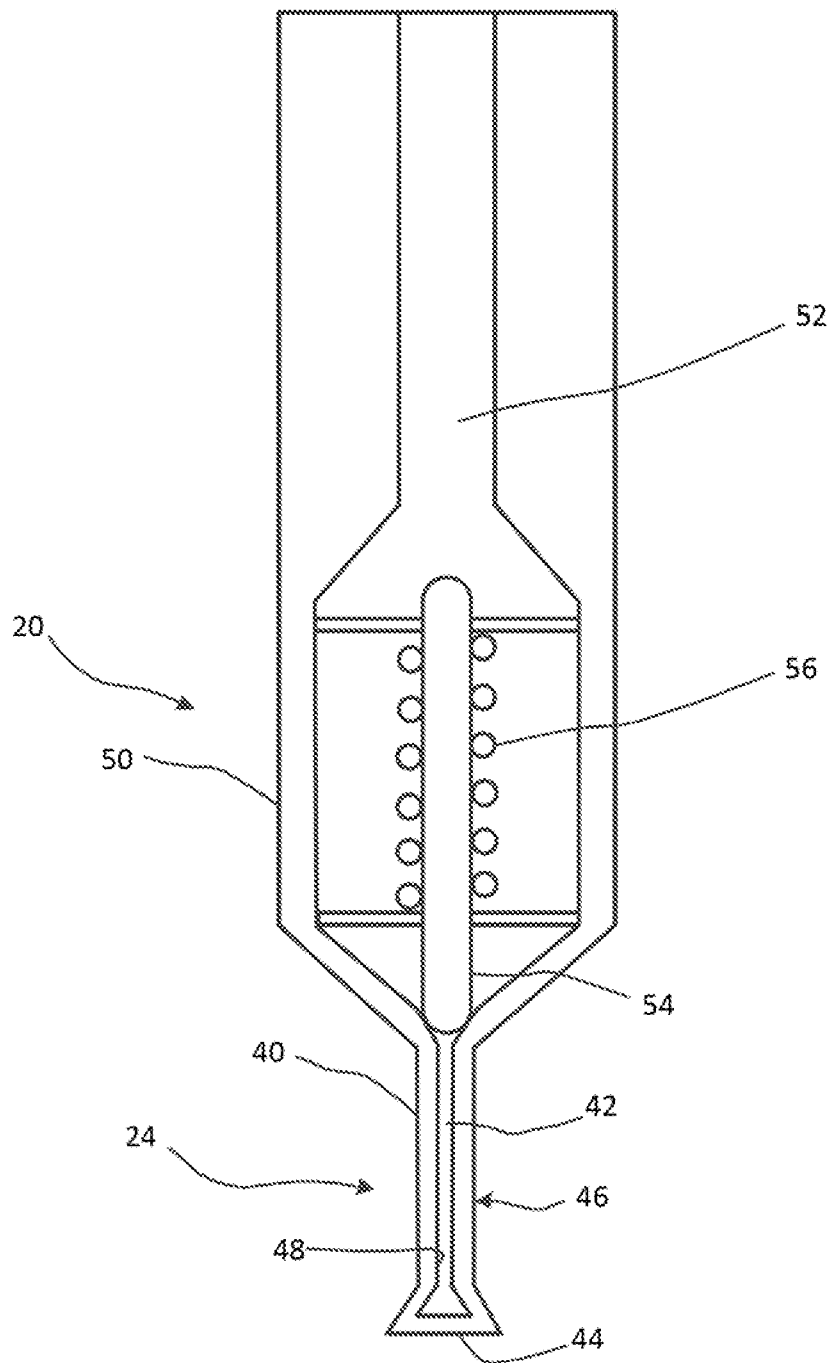


Fig. 2

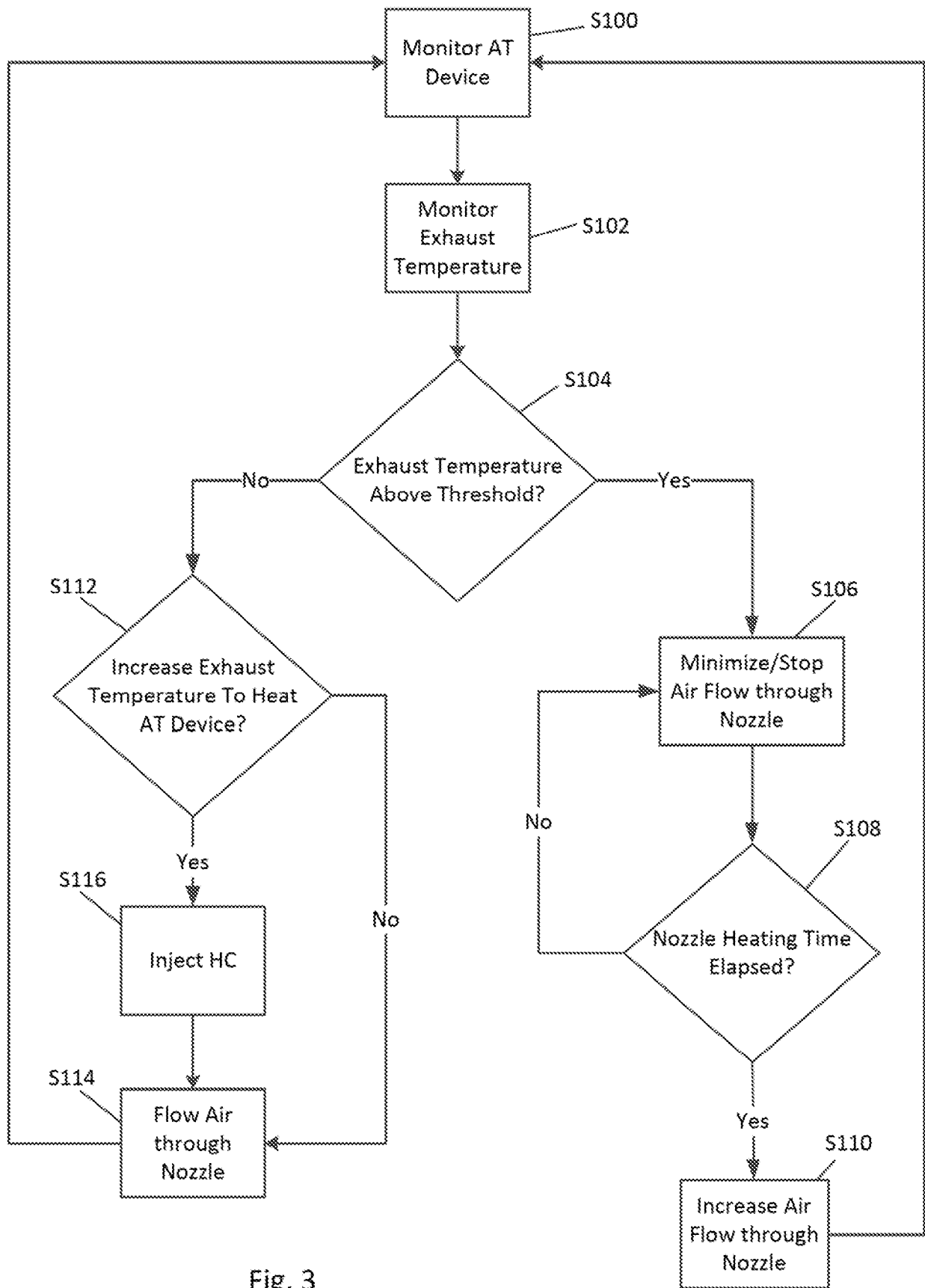


Fig. 3