US 20120291424A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2012/0291424 A1

(43) Pub. Date: Nov. 22, 2012

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(54) DIAGNOSTIC APPARATUS FOR CATALYST IN FUEL-PROPERTY REFORMING SYSTEM

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(21) Appl. No.: **13/474,791**

(22) Filed: **May 18, 2012**

(30) **Foreign Application Priority Data**

May 19, 2011 (JP) ................................ 2011-112142

**Publication Classification**

(51) **Int. Cl.**
*F01N 11/00* (2006.01)
*F01N 3/10* (2006.01)

(52) **U.S. Cl.** ........................................................ **60/299**

(57) **ABSTRACT**

A diagnostic apparatus for a catalyst in a fuel-property reforming system includes an inlet-side temperature sensor disposed upstream of the fuel-reforming catalyst and an outlet-side temperature sensor disposed downstream of the fuel-reforming catalyst. In a reforming driving mode, while the EGR valve is opened to recirculate a part of exhaust gas into the intake pipe, a reforming-fuel injector injects a reforming fuel into the EGR gas. A fuel-reforming catalyst reforms the fuel into a fuel having high-combustibility. A differential temperature between a temperature detected by the inlet-side temperature sensor and a temperature detected by the outlet-side temperature sensor is compared with a deterioration-determination threshold, whereby a computer determines whether the fuel-reforming catalyst is deteriorated.

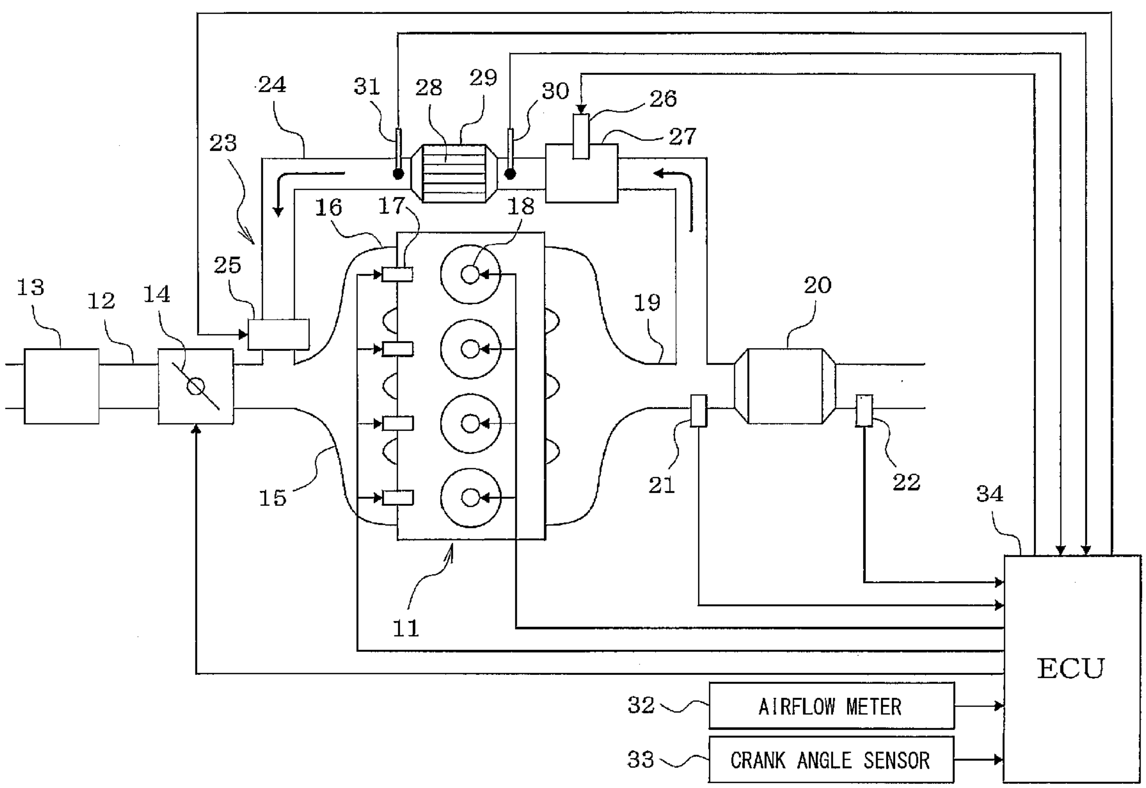
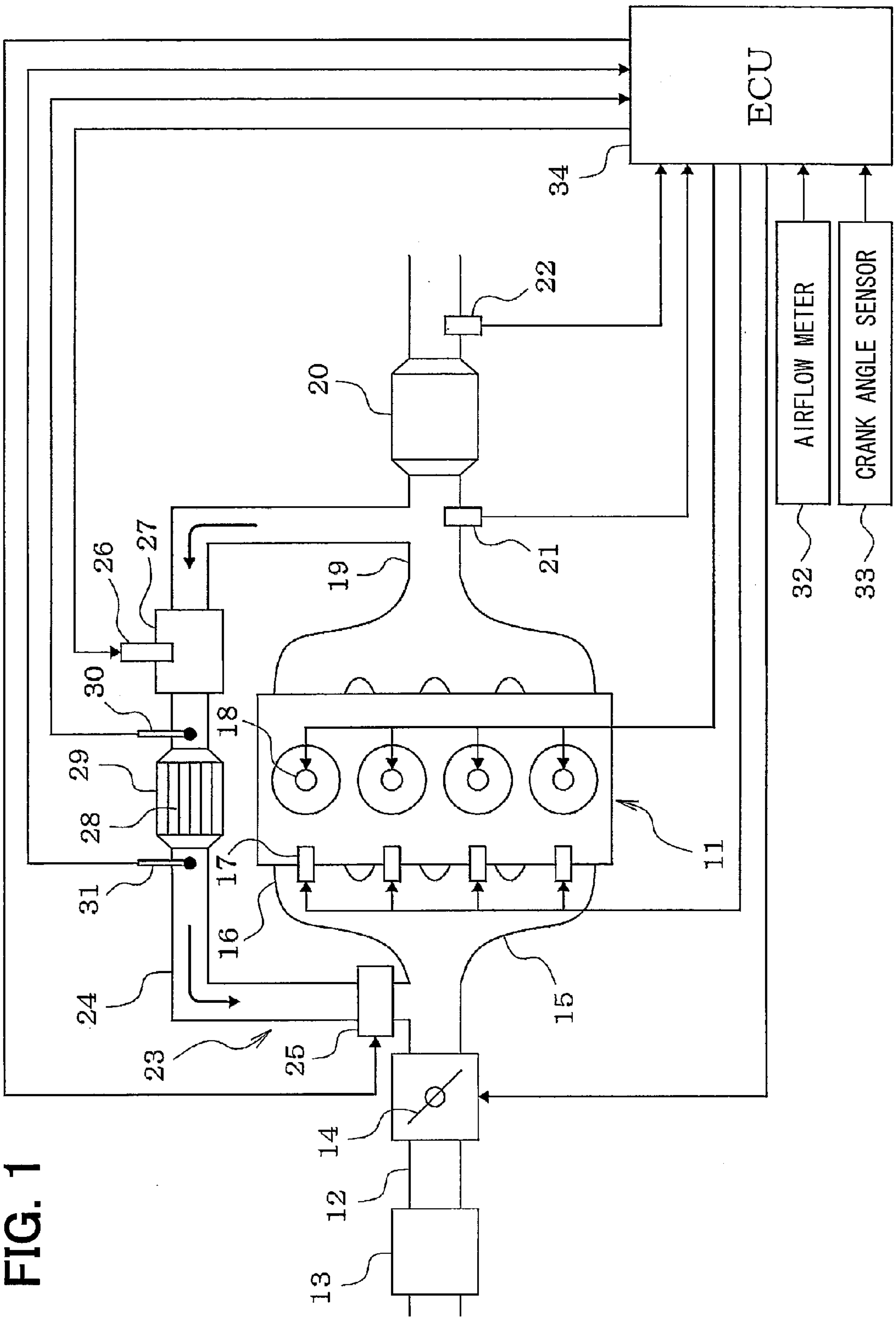


FIG. 1


ECU
AIRFLOW METER
CRANK ANGLE SENSOR
11
12
13
14
15
16
17
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23
24
25
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27
28
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32
33
34

FIG. 2

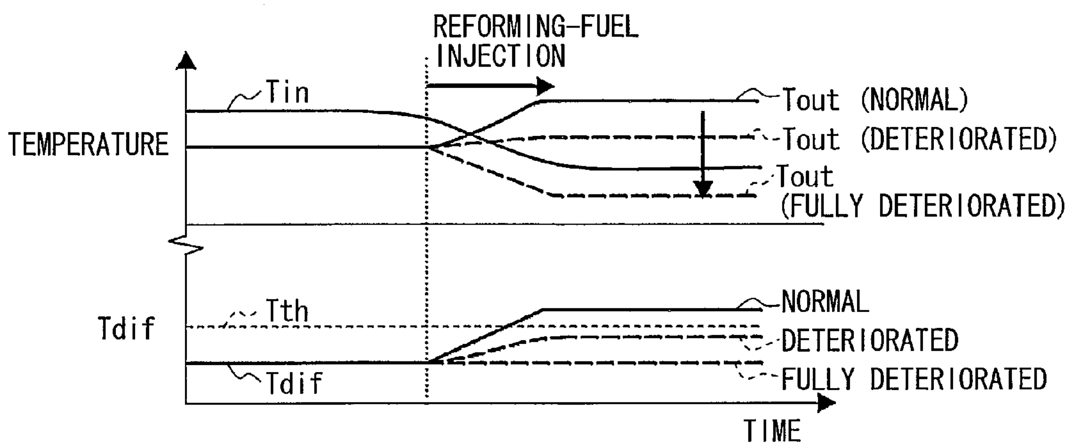

REFORMING-FUEL INJECTION
Tin
TEMPERATURE
Tout (NORMAL)
Tout (DETERIORATED)
Tout (FULLY DETERIORATED)
Tth
Tdif
NORMAL
DETERIORATED
FULLY DETERIORATED
Tdif
TIME

FIG. 3

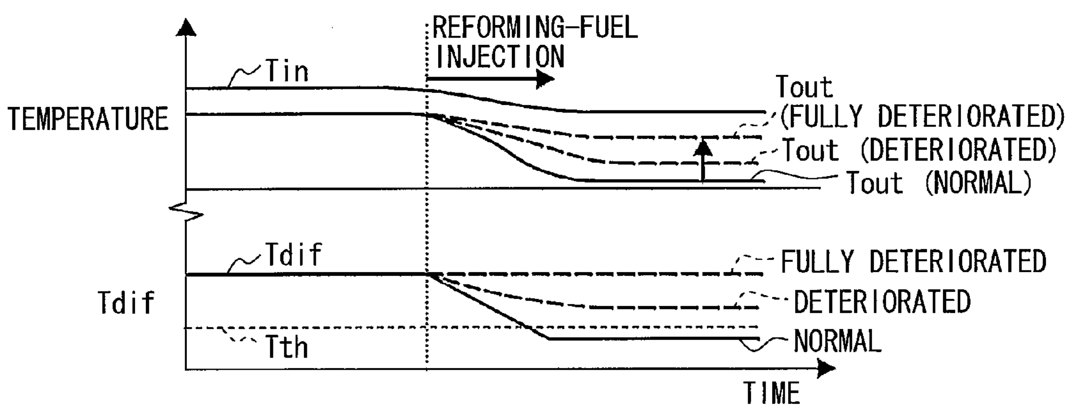

REFORMING-FUEL INJECTION
Tin
TEMPERATURE
Tout (FULLY DETERIORATED)
Tout (DETERIORATED)
Tout (NORMAL)
Tdif
Tdif
FULLY DETERIORATED
DETERIORATED
NORMAL
Tth
TIME

FIG. 4

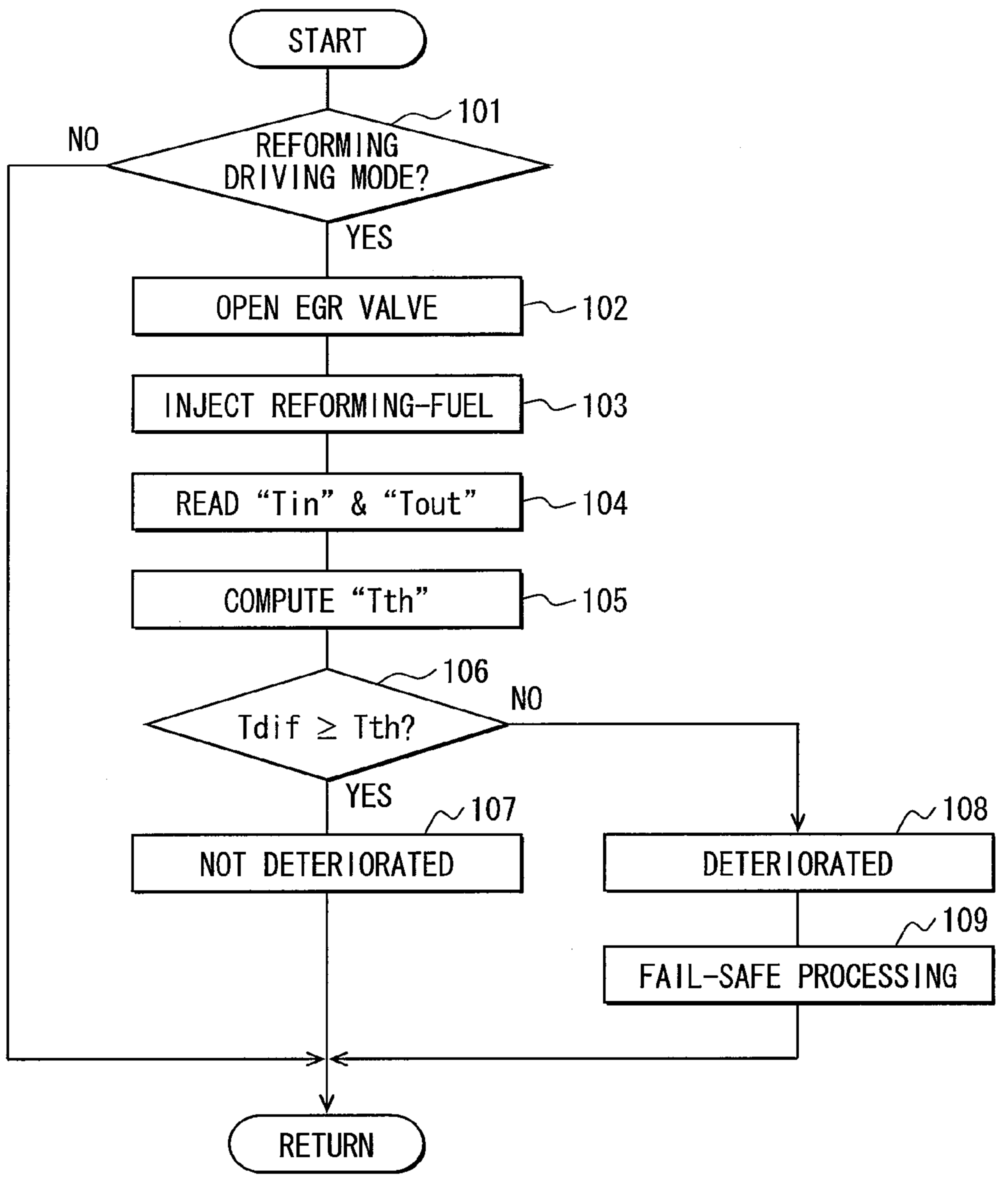

START
REFORMING DRIVING MODE?
101
NO
YES
OPEN EGR VALVE
102
INJECT REFORMING-FUEL
103
READ "Tin" & "Tout"
104
COMPUTE "Tth"
105
Tdif ≥ Tth?
106
NO
YES
NOT DETERIORATED
107
DETERIORATED
108
FAIL-SAFE PROCESSING
109
RETURN

FIG. 5

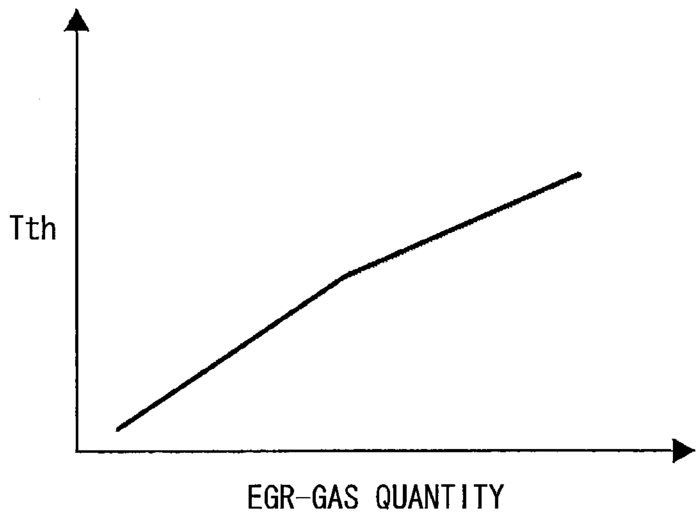

Tth
EGR-GAS QUANTITY

FIG. 6

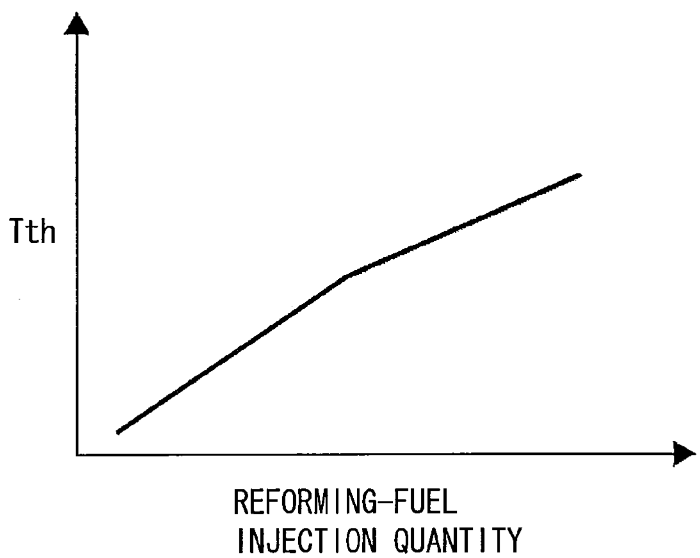

Tth
REFORMING-FUEL
INJECTION QUANTITY

FIG. 7

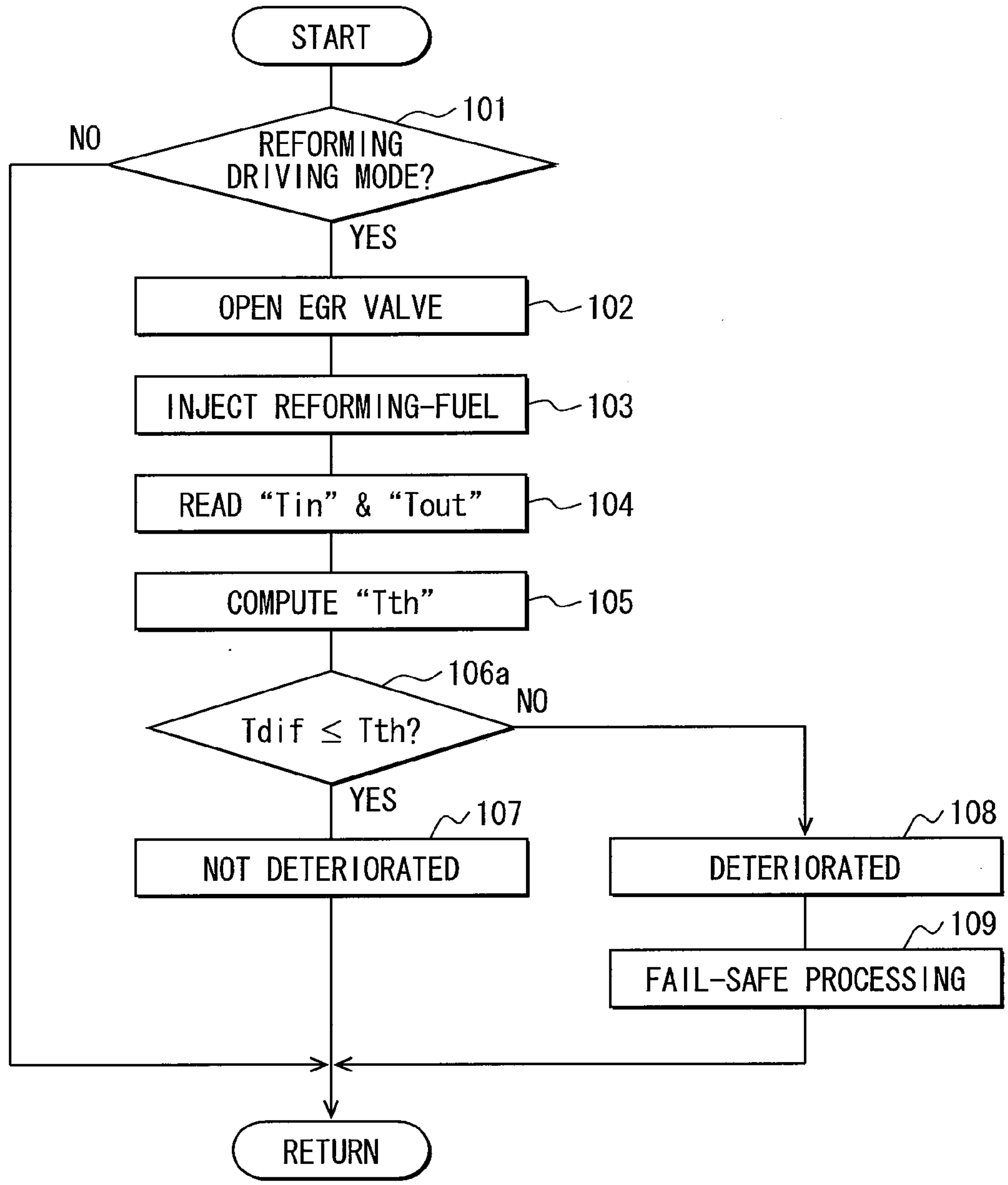
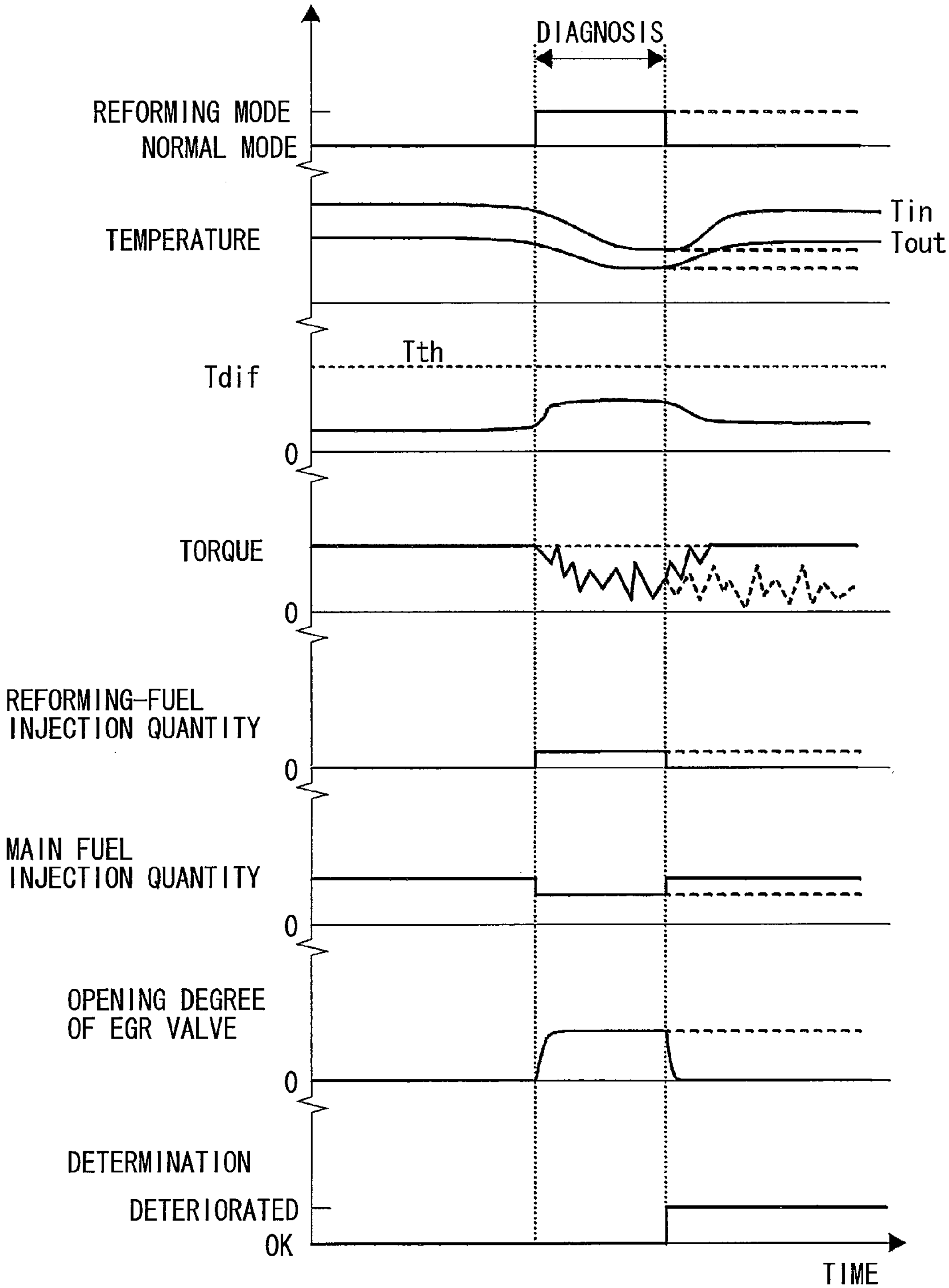

START
REFORMING DRIVING MODE?
101
NO
YES
OPEN EGR VALVE
102
INJECT REFORMING-FUEL
103
READ “Tin” & “Tout”
104
COMPUTE “Tth”
105
Tdif ≤ Tth?
106a
NO
YES
NOT DETERIORATED
107
DETERIORATED
108
FAIL-SAFE PROCESSING
109
RETURN

FIG. 8


DIAGNOSIS
REFORMING MODE
NORMAL MODE
TEMPERATURE
Tin
Tout
Tth
Tdif
0
TORQUE
0
REFORMING-FUEL
INJECTION QUANTITY
0
MAIN FUEL
INJECTION QUANTITY
0
OPENING DEGREE
OF EGR VALVE
0
DETERMINATION
DETERIORATED
OK
TIME

# FIG. 9

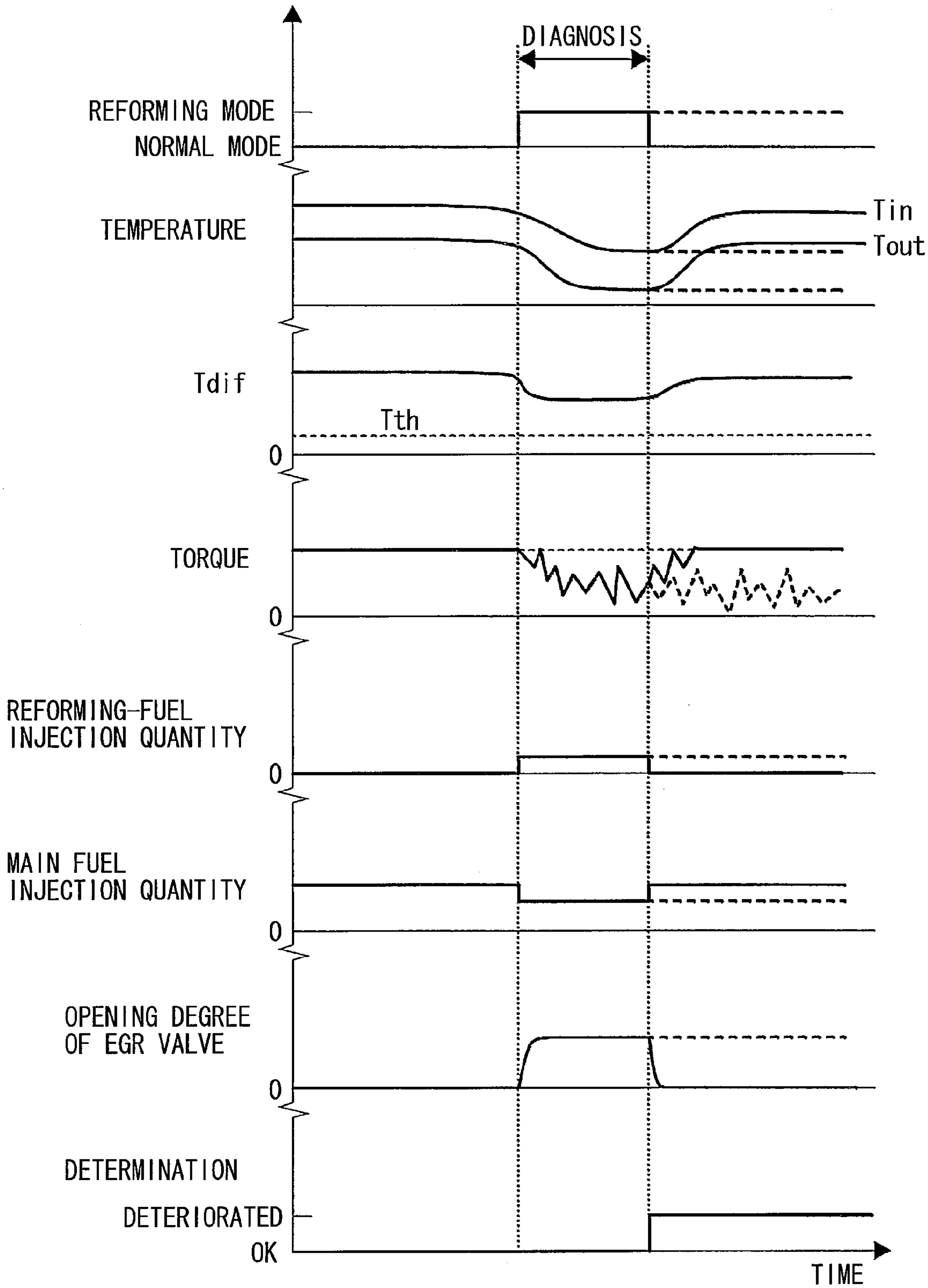

DIAGNOSIS
REFORMING MODE
NORMAL MODE
TEMPERATURE
Tin
Tout
Tdif
Tth
0
TORQUE
0
REFORMING-FUEL
INJECTION QUANTITY
0
MAIN FUEL
INJECTION QUANTITY
0
OPENING DEGREE
OF EGR VALVE
0
DETERMINATION
DETERIORATED
OK
TIME

FIG. 10

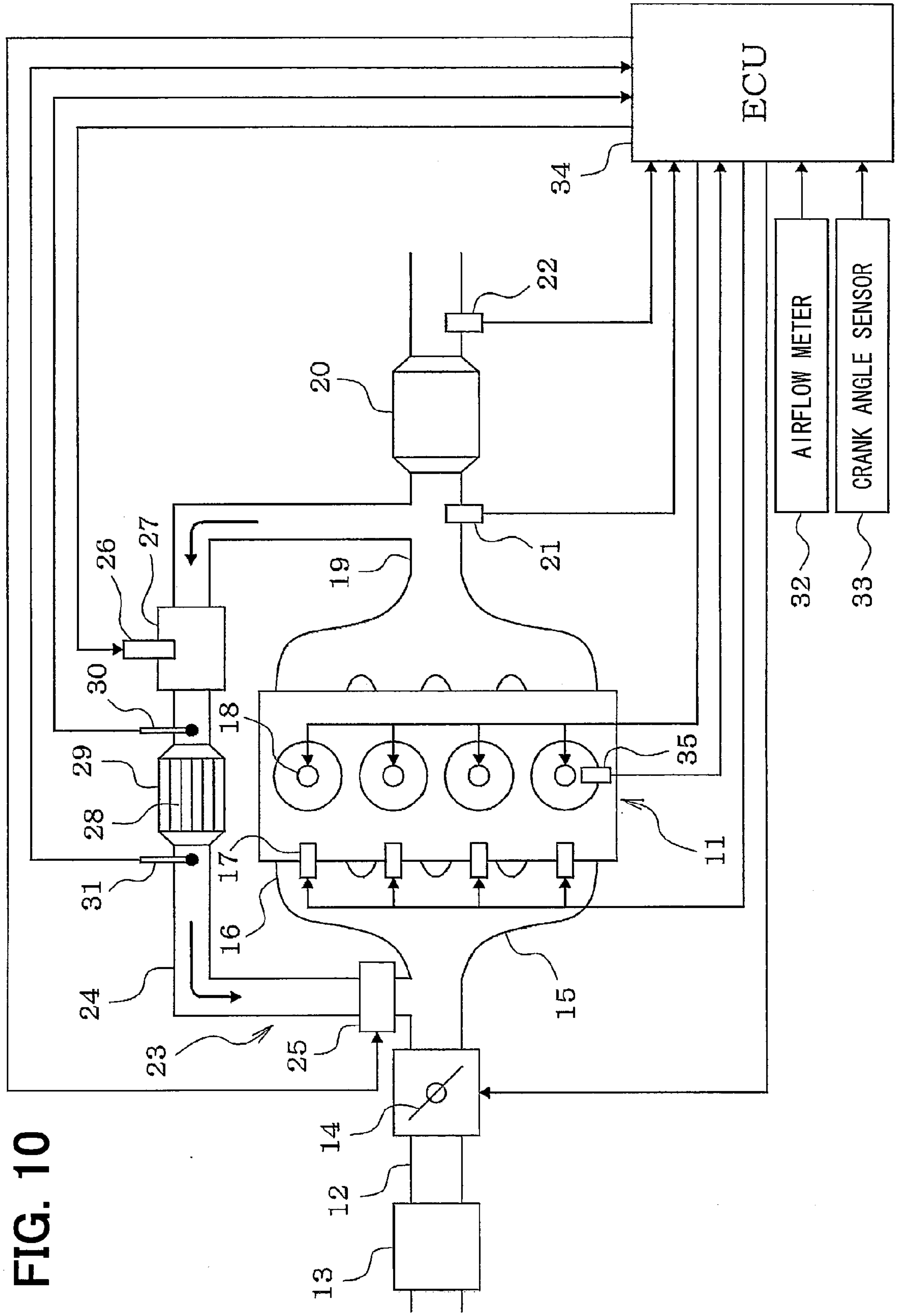

ECU
AIRFLOW METER
CRANK ANGLE SENSOR
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FIG. 11

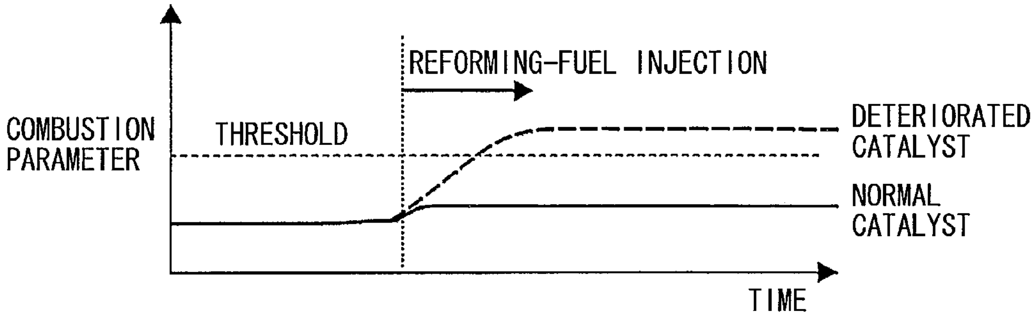

REFORMING-FUEL INJECTION
COMBUSTION PARAMETER
THRESHOLD
DETERIORATED CATALYST
NORMAL CATALYST
TIME

FIG. 12

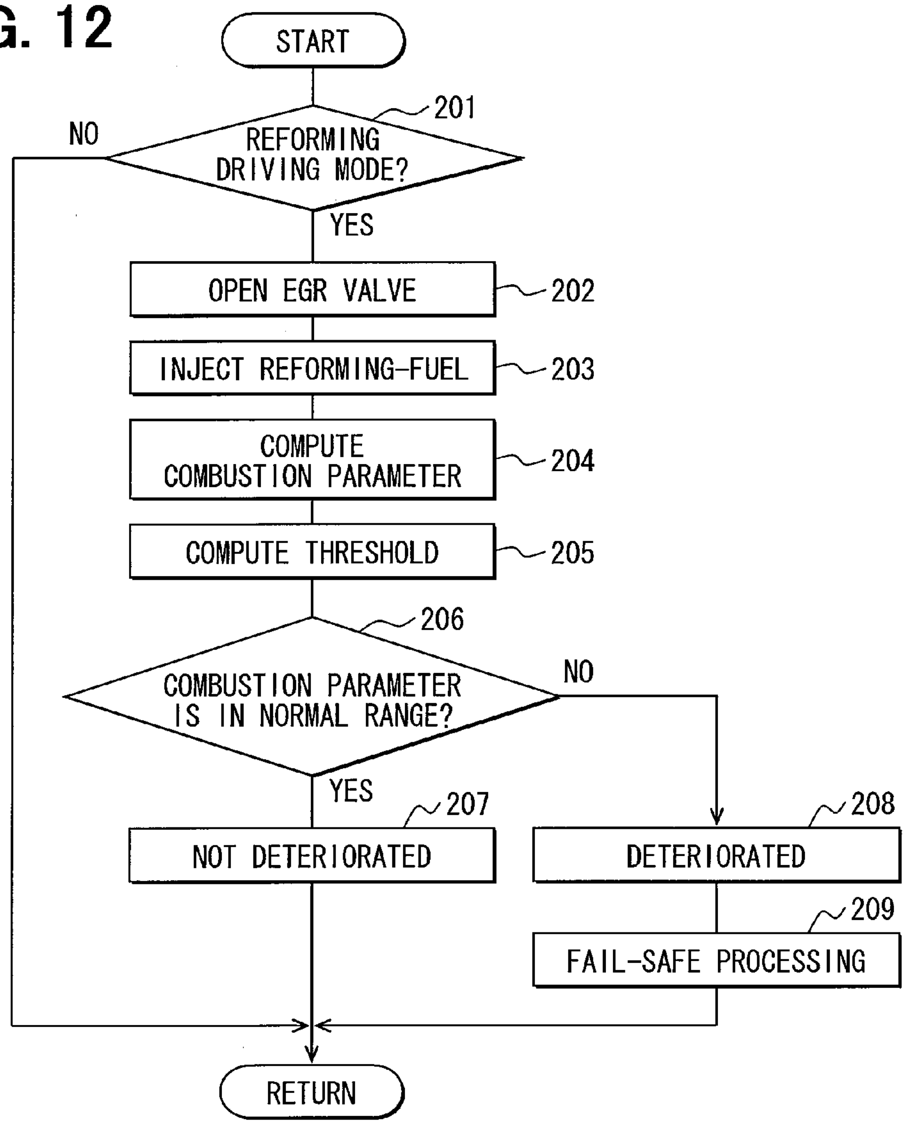

START
201
REFORMING DRIVING MODE?
NO
YES
OPEN EGR VALVE
202
INJECT REFORMING-FUEL
203
COMPUTE COMBUSTION PARAMETER
204
COMPUTE THRESHOLD
205
206
COMBUSTION PARAMETER IS IN NORMAL RANGE?
NO
YES
NOT DETERIORATED
207
DETERIORATED
208
FAIL-SAFE PROCESSING
209
RETURN

FIG. 13

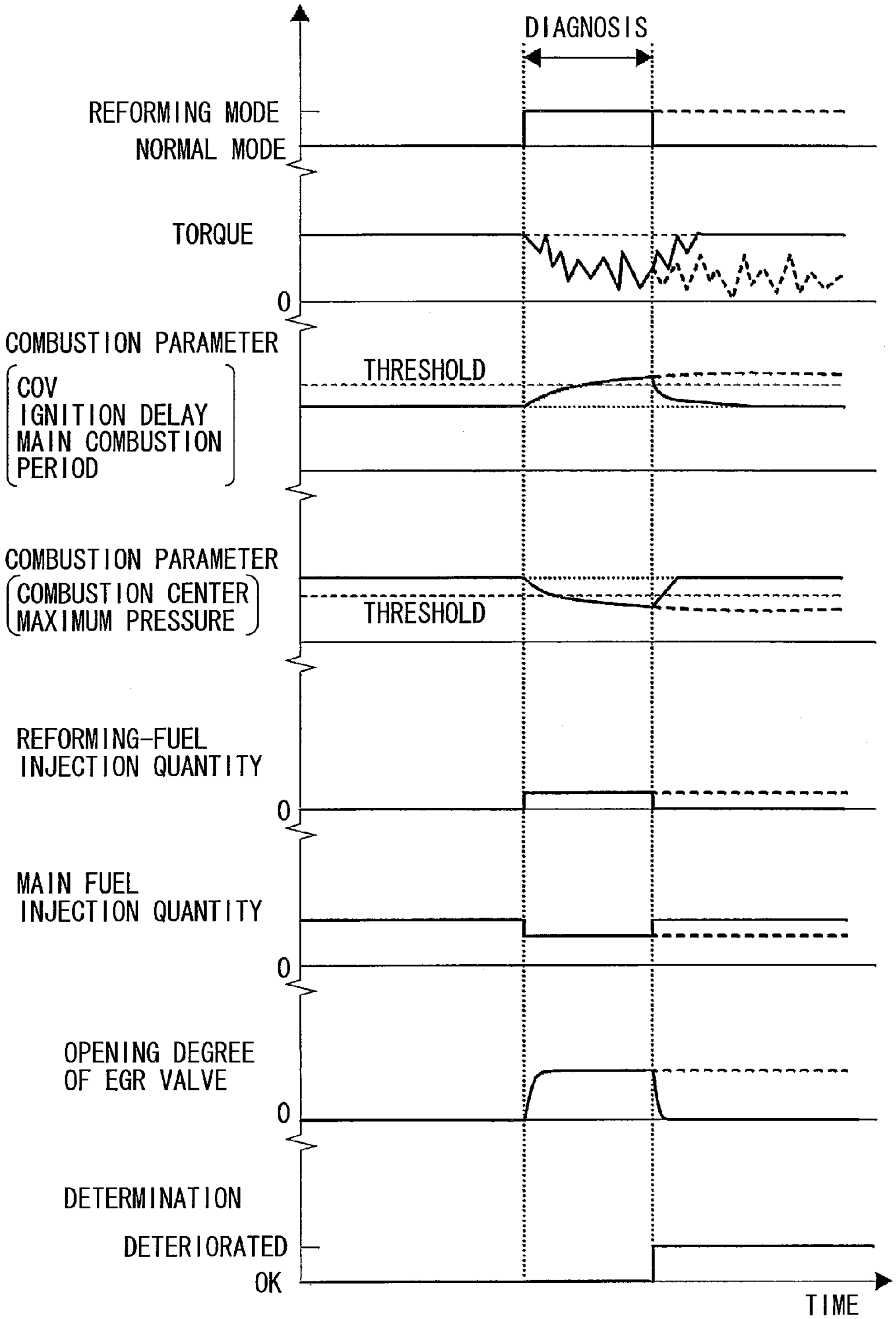
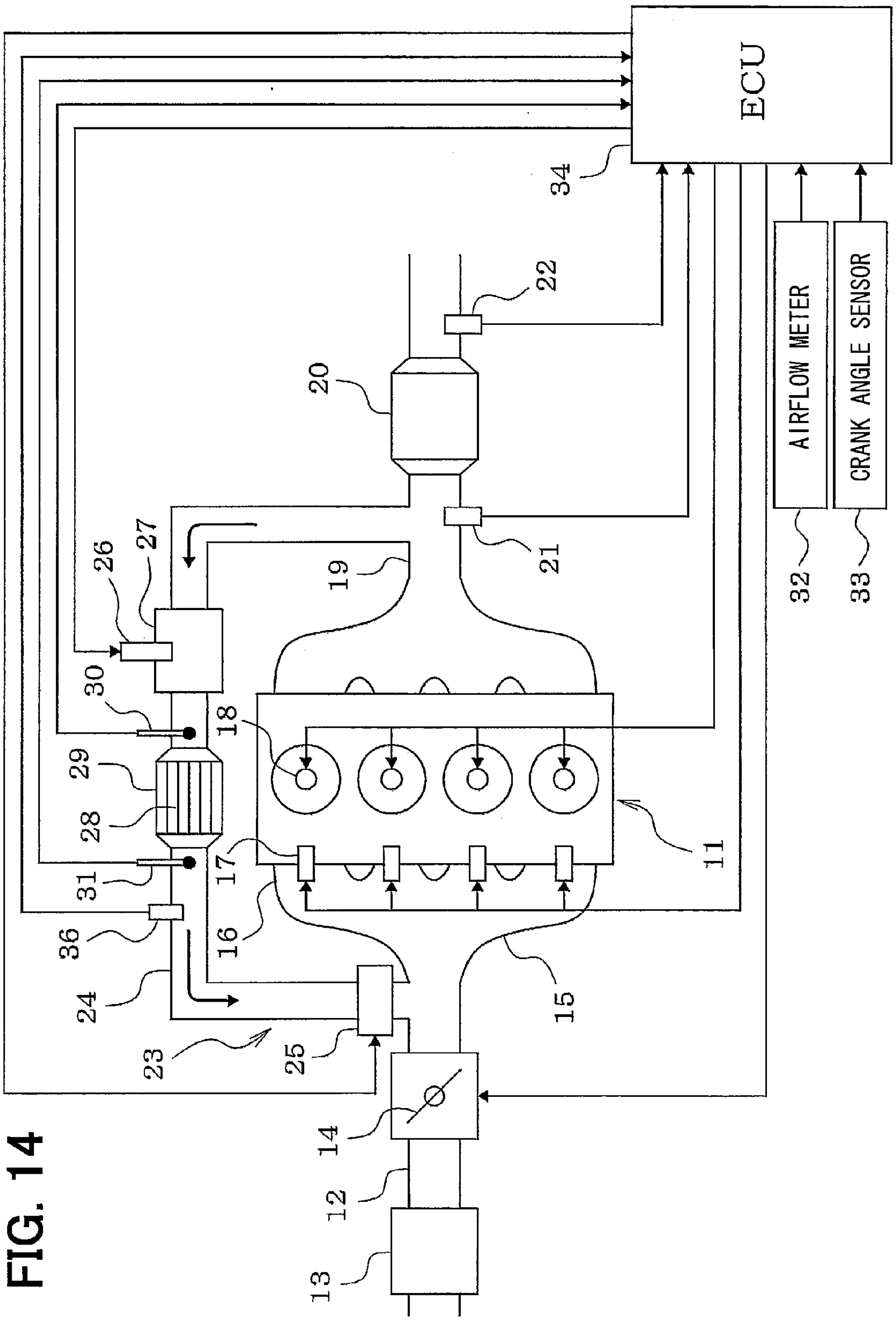

DIAGNOSIS
REFORMING MODE
NORMAL MODE
TORQUE
0
COMBUSTION PARAMETER
COV
IGNITION DELAY
MAIN COMBUSTION
PERIOD
THRESHOLD
COMBUSTION PARAMETER
COMBUSTION CENTER
MAXIMUM PRESSURE
THRESHOLD
REFORMING-FUEL
INJECTION QUANTITY
0
MAIN FUEL
INJECTION QUANTITY
0
OPENING DEGREE
OF EGR VALVE
0
DETERMINATION
DETERIORATED
OK
TIME

FIG. 14


ECU
AIRFLOW METER
CRANK ANGLE SENSOR
11
12
13
14
15
16
17
18
19
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23
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25
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32
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FIG. 15

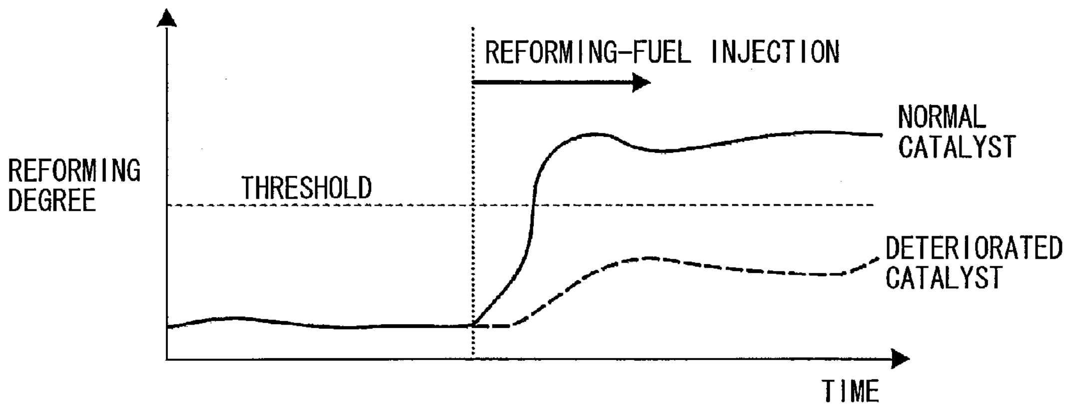

REFORMING-FUEL INJECTION
NORMAL CATALYST
REFORMING DEGREE
THRESHOLD
DETERIORATED CATALYST
TIME

FIG. 16

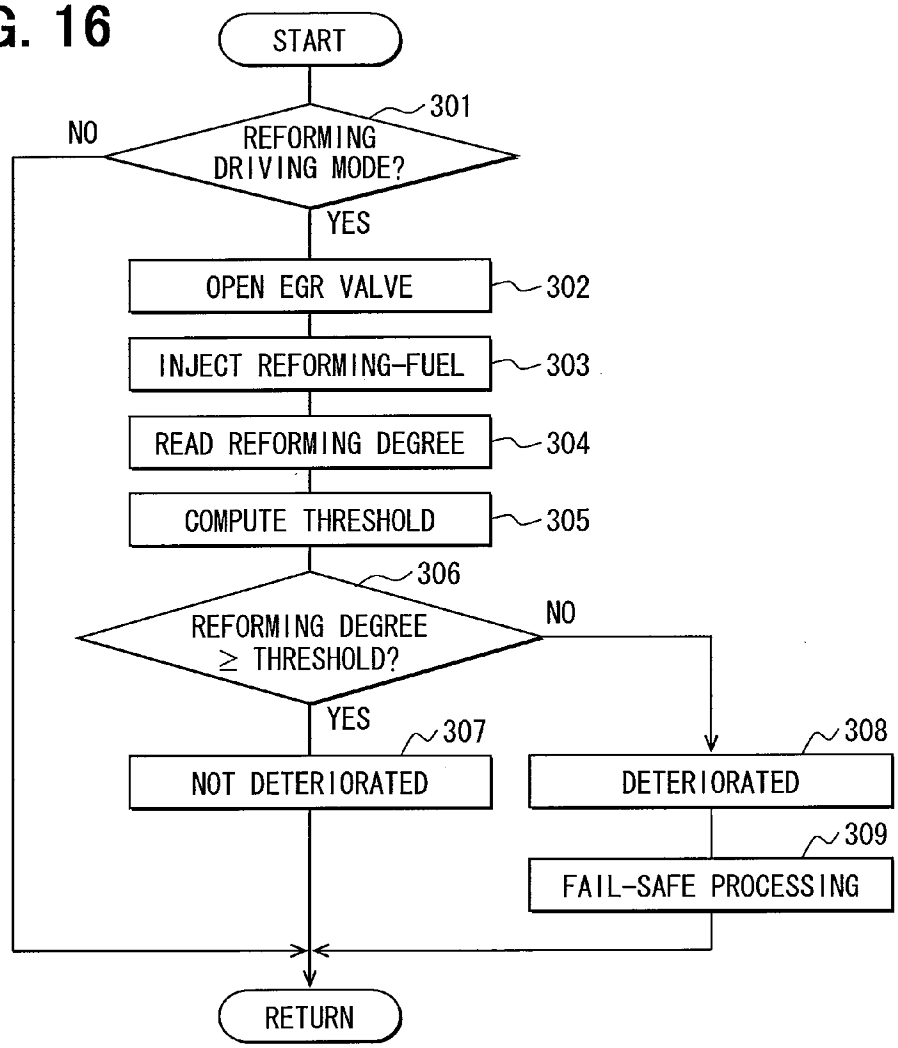
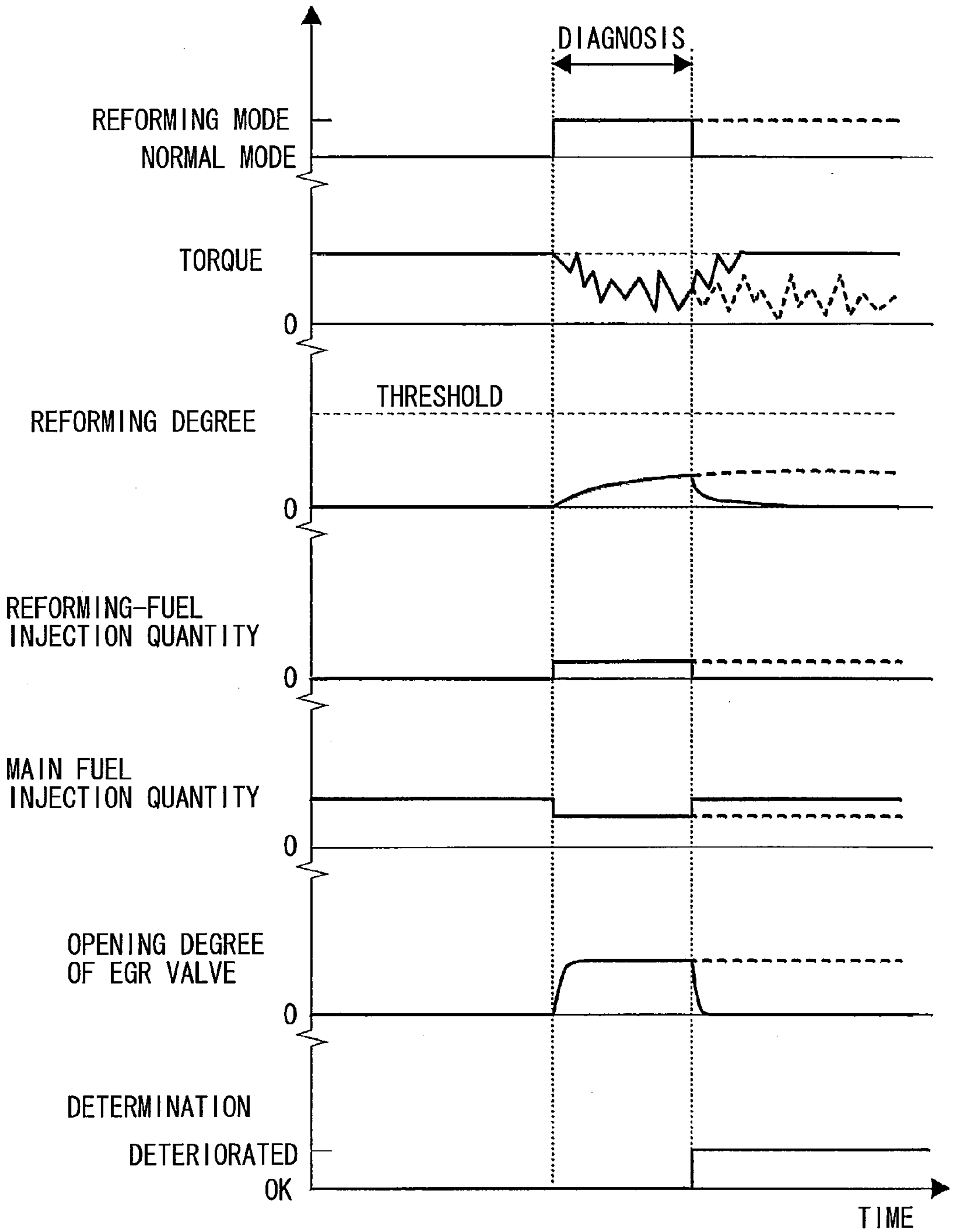

START
301
NO
REFORMING DRIVING MODE?
YES
OPEN EGR VALVE
302
INJECT REFORMING-FUEL
303
READ REFORMING DEGREE
304
COMPUTE THRESHOLD
305
306
NO
REFORMING DEGREE ≥ THRESHOLD?
YES
307
308
NOT DETERIORATED
DETERIORATED
309
FAIL-SAFE PROCESSING
RETURN

FIG. 17


DIAGNOSIS
REFORMING MODE
NORMAL MODE
TORQUE
0
THRESHOLD
REFORMING DEGREE
0
REFORMING-FUEL
INJECTION QUANTITY
0
MAIN FUEL
INJECTION QUANTITY
0
OPENING DEGREE
OF EGR VALVE
0
DETERMINATION
DETERIORATED
OK
TIME

# DIAGNOSTIC APPARATUS FOR CATALYST IN FUEL-PROPERTY REFORMING SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** This application is based on Japanese Patent Application No. 2011-112142 filed on May 19, 2011, the disclosure of which is incorporated herein by reference.

## TECHNICAL FIELD

**[0002]** The present disclosure relates to a diagnostic apparatus for a catalyst in a fuel-property reforming system. The fuel-property reforming apparatus reforms a property of fuel supplied to an internal combustion engine. The property of fuel is referred to as fuel property, hereinafter.

## BACKGROUND

**[0003]** JP-2004-218548A shows a fuel-property reforming apparatus which is provided with a heater and a catalyst for reforming fuel property in a fuel supply passage through which fuel flows from a fuel tank to a fuel injector.

**[0004]** If a malfunction occurs in the fuel-property reforming apparatus, it is likely that a combustion condition of the engine may be deteriorated. Thus, such a malfunction should be detected as early as possible.

**[0005]** If a reforming condition of fuel (for example, a containing ratio of high boiling point component) is varied due to a malfunction of the fuel-property reforming apparatus, the fuel property (relative density and vapor pressure) is varied. In view of this, the apparatus shown in JP-2004-218548A is provided with a tank for storing the fuel flowing out from a fuel-property reforming apparatus, and a property sensor for detecting the fuel-property (relative density and vapor pressure) in the tank. By comparing the detected fuel-property with a reference value, it is determined whether a malfunction occurs in a fuel-property reforming apparatus.

**[0006]** However, in the fuel-property reforming apparatus shown in JP-2004-218548A, the tank and the property sensor are necessary, which increases a product cost thereof.

## SUMMARY

**[0007]** It is an object of the present disclosure to provide a diagnostic apparatus for a catalyst in a fuel-property reforming system with low product cost.

**[0008]** According to the present disclosure, a diagnostic apparatus for a catalyst in a fuel-property reforming system includes: a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid; a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reaction-heat information.

**[0009]** Since no fuel tank for reforming fuel and no property sensor are necessary, the apparatus can be configured with low cost.

**[0010]** According to another aspect, a diagnostic apparatus includes: a combustion condition detecting portion which detects a combustion condition information of the internal combustion engine; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition information.

**[0011]** According to the other aspect, a diagnostic apparatus includes: a reforming-degree detecting portion which detects a reforming degree of the fuel at an outlet of the fuel-reforming catalyst; and a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming degree of the fuel.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]** The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

**[0013]** FIG. **1** is a schematic view of an engine control system according to a first embodiment of the present invention;

**[0014]** FIG. **2** is a time chart for explaining a diagnosis method of an exothermal-reaction catalyst, according to a first embodiment;

**[0015]** FIG. **3** is a time chart for explaining a diagnosis method of an endothermal-reaction catalyst, according to the first embodiment;

**[0016]** FIG. **4** is a flow chart showing a processing of a diagnosis of an exothermal-reaction catalyst according to the first embodiment;

**[0017]** FIG. **5** is a chart for explaining a relationship between a reforming-fuel injection quantity and a deterioration-determination threshold;

**[0018]** FIG. **6** is a chart for explaining a relationship between an EGR-gas quantity and a deterioration-determination threshold;

**[0019]** FIG. **7** is a flow chart showing a processing of a diagnosis of an endothermal-reaction catalyst according to the first embodiment;

**[0020]** FIG. **8** is a time chart for explaining a diagnosis method of an exothermal-reaction catalyst, according to a first embodiment;

**[0021]** FIG. **9** is a time chart for explaining a diagnosis method of an endothermal-reaction catalyst, according to a first embodiment;

**[0022]** FIG. **10** is a schematic view of an engine control system according to a second embodiment of the present invention;

**[0023]** FIG. **11** is a time chart for explaining a diagnosis method according to the second embodiment;

**[0024]** FIG. **12** is a flow chart showing a processing of a diagnosis method according to the second embodiment;

**[0025]** FIG. **13** is a time chart for explaining a diagnosis method according to the second embodiment;

**[0026]** FIG. **14** is a schematic view of an engine control system according to a third embodiment of the present invention;

**[0027]** FIG. **15** is a time chart for explaining a diagnosis method according to the third embodiment;

**[0028]** FIG. **16** is a flow chart showing a processing of a diagnosis method according to the third embodiment; and

**[0029]** FIG. **17** is a time chart for explaining a diagnosis method according to the third embodiment.

## DETAILED DESCRIPTION

**[0030]** Embodiments of the present invention will be described, hereinafter.

### First Embodiment

**[0031]** Referring to FIGS. **1** to **9**, a first embodiment will be described hereinafter.

**[0032]** First, referring to FIG. **1**, an engine control system is explained. An air cleaner **13** is arranged upstream of an intake pipe **12** of an internal combustion engine **11**. A throttle valve **14** is arranged downstream of the air cleaner **13**. An opening degree of the throttle valve **14** is adjusted by a motor (not shown).

**[0033]** A surge tank **15** is provided downstream of the throttle valve **14**. An intake manifold **16** introducing air into each cylinder of the engine **11** is provided downstream of the surge tank **15**, and the fuel injector **17** injecting the fuel is provided at a vicinity of an intake port (not shown) connected to the intake manifold **20** of each cylinder. A spark plug **18** is mounted on a cylinder head of the engine **11** corresponding to each cylinder to ignite air-fuel mixture in each cylinder.

**[0034]** An exhaust pipe **19** of the engine **11** is provided with a three-way catalyst **20** purifying CO, HC, NOx in the exhaust gas. Exhaust gas sensors **21** and **22**, such as an air-fuel ratio sensor and an oxygen sensor, are disposed upstream and downstream of the three-way catalyst **20** to detect air-fuel ratio and rich/lean of the exhaust gas.

**[0035]** The engine **11** is provided with an exhaust gas recirculation (EGR) apparatus **23** for recirculating a part of exhaust gas into the intake pipe **12**. The EGR apparatus **23** has an EGR pipe **24** connecting the exhaust pipe **19** upstream of the catalyst **20** and the intake pipe **12** downstream of the throttle valve **14**. An EGR valve **25** is provided in the EGR pipe **24** to adjust an exhaust gas recirculation quantity (external EGR quantity).

**[0036]** The EGR pipe **24** has a reforming-fuel injection apparatus **27** which is provided with a fuel injector **26** injecting reforming-fuel into the EGR gas. This fuel injector **26** injecting the reforming-fuel is referred to as a reforming-fuel injector **26**, hereinafter. Further, the EGR pipe **24** has a fuel-property reforming apparatus **29** which is provided with a fuel-reforming catalyst **28**. An inlet-side temperature sensor **30** is disposed upstream of the fuel-reforming catalyst **28** in order to detect temperature of EGR gas upstream of the fuel-reforming catalyst **28**. An outlet-side temperature sensor **31** is disposed downstream of the fuel-reforming catalyst **28** in order to detect temperature of EGR gas downstream of the fuel-reforming catalyst **28**. These temperature sensors **30** and **31** function as a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst **28**. The fuel injector **17** and the reforming-fuel injector **26** receive the fuel from a common fuel tank (not shown).

**[0037]** An airflow meter **32** detecting intake air flow rate and a crank angle sensor **33** are disposed at outer circumference of a crank shaft (not shown) to output a pulse signal every when the crank shaft rotates a specified crank angle. Based on the output signal of the crank angle sensor **33**, a crank angle and an engine speed are detected.

**[0038]** The outputs of the above sensors are transmitted to an electronic control unit (ECU) **34**. The ECU **34** includes a microcomputer which executes an engine control program stored in a Read Only Memory (ROM) to control a fuel injection quantity, an ignition timing, a throttle position (intake air flow rate) and the like.

**[0039]** When the driving condition of the engine **11** is a specified reforming-condition, for example, when the engine speed is low and the engine load is low, the ECU **34** switches an engine driving mode from a normal driving mode to a reforming driving mode. In the reforming driving mode, while the EGR valve **25** is opened to recirculate a part of exhaust gas into the intake pipe **12**, the reforming-fuel injector **26** injects the reforming fuel into the EGR pipe **24**. The injected reforming fuel is vaporized, whereby combustibility of the fuel in the EGR gas improved by the fuel-reforming catalyst **28**. For example, hydrogen concentration of the EGR gas becomes higher. This reformed fuel is supplied to the intake pipe **12** of the engine **11**.

**[0040]** In a case that the fuel-reforming catalyst **28** is an exothermal-reaction catalyst, the ECU **34** executes a diagnosis shown in FIG. **4**. In this diagnosis, a differential temperature "Tdif" between the temperature detected by the inlet-side temperature sensor **30** (Tin) and the temperature detected by the outlet-side temperature sensor **31** (Tout) during a fuel-reforming control is compared with a deterioration-determination threshold "Tth", whereby the computer determines whether the fuel-reforming catalyst **28** is deteriorated.

**[0041]** In a case that the fuel-reforming catalyst **28** is an exothermal-reaction catalyst, if the fuel-reforming catalyst **28** is deteriorated, the calorific value of the fuel-reforming catalyst **28** is decreased and variation rate of the temperature "Tout" relative to the temperature "Tin" is also varied, as shown in FIG. **2**. Thus, by comparing the differential temperature "Tdif" with the threshold "Tth", it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0042]** Referring to FIG. **4**, a processing of the diagnosis will be described hereinafter. The ECU **34** executes this diagnosis in a case that the fuel-reforming catalyst **28** is an exothermal-reaction catalyst.

**[0043]** The diagnosis routine shown in FIG. **4** is executed at a specified cycle while the ECU **34** is ON. This diagnosis routine corresponds to a catalyst diagnosis portion. In step **101**, the computer determines whether the engine driving mode is the reforming driving mode. When the answer is NO, the procedure ends.

**[0044]** When the answer is YES in step **101**, the procedure proceeds to step **102**. In step **102**, the EGR valve **25** is opened to recirculate a part of the exhaust gas into an intake pipe **12**. Then, in step **103**, the reforming-fuel injector **26** injects the reforming-fuel into the exhaust gas flowing through the EGR pipe **24**. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst **28**. The fuel-reforming catalyst **28** reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe **12**. The reforming fuel quantity and the EGR gas quantity are computed according to the engine driving condition (engine speed and engine load) in view of a map. The above control is referred to as a fuel-reforming control.

**[0045]** Then, in step **104**, the computer reads the temperature "Tin" and the temperature "Tout". In step **105**, the computer computes the threshold "Tth" in view of a map which defines the threshold "Tth" according to the reforming-fuel injection quantity and the EGR gas quantity. In a case that the fuel-reforming catalyst **28** is an exothermic-reaction catalyst, as the reforming-fuel injection quantity becomes larger, the threshold "Tth" becomes higher, as shown in FIG. **5**. Further, as the reforming-fuel injection quantity becomes larger, the threshold "Tth" becomes higher, as shown in FIG. **6**. Besides, the threshold "Tth" may be corrected based on the temperature "Tin".

**[0046]** Then, the procedure proceeds to step **106** in which the computer determines whether the differential temperature "Tdif" is greater than or equal to the threshold "Tth". When the answer is YES in step **106**, the procedure proceeds to step **107** in which the computer determines that the fuel-reforming catalyst **28** is not deteriorated.

**[0047]** When the answer is NO in step **106**, the procedure proceeds to step **108** in which the computer determines that the fuel-reforming catalyst **28** is deteriorated. Then, the procedure proceeds to step **109** in which a fail-safe processing is conducted. In this fail-safe processing, an opening degree of the EGR valve **25** is decreased to reduce the EGR gas quantity and the reforming-fuel injector **26** stops the reforming-fuel injection, whereby the fuel reforming is prohibited.

**[0048]** Meanwhile, in a case that the fuel-reforming catalyst **28** is an endothermal-reaction catalyst, the ECU **34** executes a diagnosis routine shown in FIG. **7**. In this diagnosis, a differential temperature between the temperature detected by the inlet-side temperature sensor **30** and the temperature detected by the outlet-side temperature sensor **31** is compared with a deterioration-determination threshold, whereby the computer determines whether the fuel-reforming catalyst **28** is deteriorated.

**[0049]** In a case that the fuel-reforming catalyst **28** is an endothermal-reaction catalyst, if the fuel-reforming catalyst **28** is deteriorated, the endothermic value of the fuel-reforming catalyst **28** is decreased and variation rate of the temperature "Tout" relative to the temperature "Tin" is also varied, as shown in FIG. **3**. Thus, by comparing the differential temperature "Tdif" with the threshold "Tth", it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0050]** Referring to FIG. **7**, a processing of the diagnosis will be described hereinafter. The ECU **34** executes this diagnosis in a case that the fuel-reforming catalyst **28** is an endothermal-reaction catalyst.

**[0051]** In step **101**, the computer determines whether the engine driving mode is the reforming driving mode. When the answer is YES in step **101**, the procedure proceeds to step **102** in which the EGR valve **25** is opened to recirculate a part of the exhaust gas into an intake pipe **12**. Then, in step **103**, the reforming-fuel injector **26** injects the reforming-fuel into the exhaust gas flowing through the EGR pipe **24**. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst **28**. The fuel-reforming catalyst **28** reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe **12**.

**[0052]** Then, in step **104**, the computer reads the temperature "Tin" and the temperature "Tout". In step **105**, the computer computes the threshold "Tth" in view of a map which defines the threshold "Tth" according to the reforming-fuel injection quantity and the EGR gas quantity. In a case that the fuel-reforming catalyst **28** is an endothermal-reaction catalyst, as the reforming-fuel injection quantity becomes larger, the threshold "Tth" becomes lower. Further, as the EGR-gas quantity becomes larger, the threshold "Tth" becomes lower. Besides, the threshold "Tth" may be corrected based on the temperature "Tin".

**[0053]** Then, the procedure proceeds to step **106***a* in which the computer determines whether the differential temperature "Tdif" is less than or equal to the threshold "Tth". When the answer is YES in step **106***a*, the procedure proceeds to step **107** in which the computer determines that the fuel-reforming catalyst **28** is not deteriorated.

**[0054]** When the answer is NO in step **106***a*, the procedure proceeds to step **108** in which the computer determines that the fuel-reforming catalyst **28** is deteriorated. Then, the procedure proceeds to step **109** in which the fail-safe processing is conducted.

**[0055]** Referring to time charts shown in FIGS. **8** and **9**, a catalyst diagnosis will be described hereinafter. FIG. **8** shows a case of an exothermal-reaction catalyst, and FIG. **9** shows a case of endothermal-reaction catalyst.

**[0056]** When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve **25** is opened to recirculate a part of the exhaust gas into an intake pipe **12**. Then, the reforming-fuel injector **26** injects the reforming-fuel into the exhaust gas flowing through the EGR pipe **24**. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst **28**. The fuel-reforming catalyst **28** reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe **12**.

**[0057]** According to the first embodiment, while the reforming control is executed, the differential temperature "Tdif" between the temperature "Tout" and the temperature "Tin" is computed, and then the differential temperature "Tdif" is compared with the threshold "Tth" in order to determine whether the fuel-reforming catalyst **28** is deteriorated. Thus, it can be accurately determines whether the fuel-reforming catalyst **28** is deteriorated. Furthermore, since no fuel tank for reforming-fuel and no property sensor are necessary, the apparatus can be configured with low cost.

**[0058]** In a system having no catalyst diagnosis function, as shown by dashed lines in FIGS. **8** and **9**, even if the fuel-reforming catalyst **28** is deteriorated, this deterioration can not be detected and no fail-safe processing can be conducted. Thus, it is likely that a combustion condition of the engine **11** is deteriorated and variation in torque occurs, which may deteriorate drivability.

**[0059]** According to the first embodiment, by comparing the differential temperature "Tdif" with the threshold "Tth", it is determined whether the fuel-reforming catalyst **28** is deteriorated. When it is determined that the fuel-reforming catalyst **28** is deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

**[0060]** In the first embodiment, by comparing the differential temperature "Tdif" with the threshold "Tth", it is determined whether the fuel-reforming catalyst **28** is deteriorated. The diagnosis method is not limited to this. For example, a ratio between the temperature "Tout" and the temperature "Tin" is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst **28** is deteriorated.

**[0061]** Alternatively, a differential temperature or a ratio between the temperature "Tout" detected before the fuel-reforming control is started and the temperature "Tout" detected after the fuel-reforming control is started may be compared with a deterioration-determination threshold, whereby the computer determines whether the fuel-reforming catalyst **28** is deteriorated. Alternatively, a catalyst temperature sensor is provided in the fuel-reforming catalyst **28**. A catalyst temperature detected before the fuel-reforming control is started and a catalyst temperature detected after the fuel-reforming control is started are compared with each other. Based on this differential temperature or its ratio, it can be determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0062]** When the fuel-reforming catalyst **28** is deteriorated, a reaction heat quantity of the fuel-reforming catalyst **28** is decreased. The catalyst temperature or the temperature "Tout" detected before the fuel-reforming control is started becomes different from the catalyst temperature or the temperature "Tout" detected after the fuel-reforming control is started. Thus, based on these temperatures, it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0063]** Alternatively, by comparing a catalyst temperature or the temperature "Tout" detected after the fuel-reforming control is started with a deterioration-determination threshold, it may be determined whether the fuel-reforming catalyst **28** is deteriorated.

## Second Embodiment

**[0064]** Referring to FIGS. **10** to **13**, a second embodiment will be described hereinafter. In the second embodiment, the same parts and components as those in the first embodiment are indicated with the same reference numerals and the same descriptions will not be reiterated.

**[0065]** As shown in FIG. **10**, a combustion pressure sensor **35** is provided in the cylinder head **11** with respect to each cylinder. The combustion pressure sensor **35** detects combustion pressure in a cylinder. The combustion pressure sensor **35** may be integrated with a spark plug **18**. The temperature sensors **30** and **31** may not be provided.

**[0066]** According to the second embodiment, the ECU **34** executes a diagnosis routine shown in FIG. **12**. During a fuel-reforming control, the computer computes a combustion parameter indicative of a combustion condition of the engine, based on an output signal of the combustion pressure sensor **35**. This combustion parameter is compared with a deterioration-determination threshold, whereby it is determined whether the fuel-reforming catalyst **28** is deteriorated. As the combustion parameter, one of a combustion stability index (COV), an ignition delay period, main combustion period, combustion center, and maximum value of combustion pressure is computed.

**[0067]** As shown in FIG. **11**, when the catalyst **28** is deteriorated, the reforming degree of the fuel by the catalyst **28** is deteriorated and the combustion condition is varied, so that the combustion parameter is also varied. Thus, by comparing the combustion parameter detected during the fuel-reforming control with the threshold, it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0068]** Referring to FIG. **12**, a processing of the diagnosis routine will be described hereinafter.

**[0069]** This diagnosis routine is executed at specified intervals while the ECU **34** is ON. In step S**201**, the computer determines whether the engine driving mode is the reforming-driving mode. When the answer is YES, the procedure proceeds to step **202** in which the EGR valve **25** is opened. Then, the procedure proceeds to step **203** in which the reforming-fuel injector **26** injects the reforming-fuel into the EGR gas. The fuel is reformed in the fuel-reforming catalyst **28**.

**[0070]** Then, the procedure proceeds to step **204** in which the combustion parameter is computed based on the output signal of the combustion pressure sensor **35**. The process in step **204** corresponds to a combustion-condition-information detecting portion.

**[0071]** Then, the procedure proceeds to step **205** in which a deterioration-determination threshold is computed according to the reforming fuel injection quantity and the EGR gas quantity in view of a map. Besides, the deterioration-determination threshold may be corrected based on the combustion parameter detected before the fuel-reforming control is started.

**[0072]** Then, the procedure proceeds to step **206** in which the computer determines whether the combustion parameter is within a normal range. In a case that the combustion parameter is the combustion stability index, the ignition delay time or the main combustion period, if the combustion parameter is less than the deterioration-determination threshold, the computer determines that the combustion parameter is within the normal range. In a case that the combustion parameter is the combustion center or the maximum combustion pressure, if the combustion parameter is greater than the deterioration-determination threshold, the computer determines that the combustion parameter is within the normal range.

**[0073]** When the answer is YES in step **206**, the procedure proceeds to step **207** in which the computer determines that the fuel-reforming catalyst **28** is not deteriorated.

**[0074]** When the answer is NO in step **206**, the procedure proceeds to step **208** in which the computer determines that the fuel-reforming catalyst **28** is deteriorated. Then, the procedure proceeds to step **209** in which the fail-safe processing is conducted.

**[0075]** Referring to a time chart shown in FIG. **13**, a catalyst diagnosis according to the second embodiment will be described hereinafter.

**[0076]** When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve **25** is opened to recirculate a part of the exhaust gas into an intake pipe **12**. Then, the reforming-fuel injector **26** injects the reforming-fuel into the exhaust gas flowing through the EGR pipe **24**. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst **28**. The fuel-reforming catalyst **28** reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe **12**.

**[0077]** According to the second embodiment, the computer computes the combustion parameter based on the output of the combustion pressure sensor **35** while the fuel-reforming control is performed. This combustion parameter is compared with the threshold in order to determine whether the fuel-reforming catalyst **28** is deteriorated. Thus, it can be accurately determines whether the fuel-reforming catalyst **28** is deteriorated.

**[0078]** In a system having no catalyst diagnosis function, as shown by dashed lines in FIG. **13**, even if the fuel-reforming catalyst **28** is deteriorated, this deterioration can not be detected and no fail-safe processing can be conducted. Thus, it is likely that the combustion condition of the engine **11** is deteriorated and variation in torque occurs, which may deteriorate drivability.

**[0079]** According to the second embodiment, by comparing the combustion parameter with the threshold, it is determined whether the fuel-reforming catalyst **28** is deteriorated. When it is determined that the fuel-reforming catalyst **28** is deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

**[0080]** In the second embodiment, by comparing the combustion parameter with the threshold, it is determined whether the fuel-reforming catalyst **28** is deteriorated. The diagnosis method is not limited to this. For example, a difference or a ratio between the combustion parameter detected before the fuel-reforming control is started and the combustion parameter detected after the fuel-reforming control is started is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst **28** is deteriorated.

**[0081]** As shown in FIG. **11**, when the catalyst **28** is deteriorated, the reforming degree of the fuel by the catalyst **28** is deteriorated and the combustion condition is varied before and after the fuel-reforming control. Thus, based on these combustion parameters, it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0082]** As the combustion parameter, an EGR limit, combustion speed, a variation in engine speed, or variation in engine torque may be detected.

**[0083]** Instead of the combustion pressure sensor **35**, a current sensor detecting ion current flowing through the spark plug **18** may be applied.

## Third Embodiment

**[0084]** Referring to FIGS. **14** to **17**, a third embodiment will be described hereinafter. In the third embodiment, the same parts and components as those in the first and the second embodiment are indicated with the same reference numerals and the same descriptions will not be reiterated.

**[0085]** As shown in FIG. **14**, a reforming-degree sensor **36** is provided downstream of the fuel-reforming catalyst **28** for detecting a reforming degree of the fuel. The reforming-degree sensor **36** is, for example, a hydrogen sensor which detects hydrogen concentration of the exhaust gas flowing through the EGR pipe **24**. Besides, the temperature sensors **30** and **31** may not be provided.

**[0086]** According to the third embodiment, the ECU **34** executes a diagnosis routine shown in FIG. **16**. In this diagnosis, while the fuel-reforming control is performed, a reforming degree of the fuel is compared with a threshold, whereby the computer determines whether the fuel-reforming catalyst **28** is deteriorated.

**[0087]** As shown in FIG. **15**, when the catalyst **28** is deteriorated, the reforming degree of the fuel by the catalyst **28** is deteriorated. Thus, by comparing the reforming degree of the fuel with the threshold, it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0088]** Referring to FIG. **16**, a processing of the diagnosis routine will be described hereinafter.

**[0089]** This diagnosis routine is executed at specified intervals while the ECU **34** is ON. In step S**301**, the computer determines whether the engine driving mode is the reforming-driving mode. When the answer is YES, the procedure proceeds to step **302** in which the EGR valve **25** is opened. Then, the procedure proceeds to step **303** in which the reforming-fuel injector **26** injects the reforming-fuel into the EGR gas. The fuel is reformed in the fuel-reforming catalyst **28**.

**[0090]** Then, in step **304**, the computer reads the reforming degree detected by the sensor **36**. In step **305**, the computer computes the threshold in view of a map which defines the threshold according to the reforming-fuel, injection quantity and the EGR gas quantity. Besides, the deterioration-determination threshold may be corrected based on a reforming degree which is detected before the fuel-reforming control is started.

**[0091]** In step **306**, the computer determines whether the reforming degree is greater than or equal to a deterioration-determination threshold. When the answer is YES in step **306**, the procedure proceeds to step **307** in which the computer determines that the fuel-reforming catalyst **28** is not deteriorated.

**[0092]** When the answer is NO in step **306**, the procedure proceeds to step **308** in which it is determined that the fuel-reforming catalyst **28** is deteriorated. Then, in step **309**, the fail-safe processing is conducted.

**[0093]** Referring to a time chart shown in FIG. **17**, a catalyst diagnosis according to the third embodiment will be described hereinafter.

**[0094]** When the engine driving mode is changed from the normal driving mode to a reforming driving mode, the EGR valve **25** is opened to recirculate a part of the exhaust gas into an intake pipe **12**. Then, the reforming-fuel injector **26** injects the reforming-fuel into the exhaust gas flowing through the EGR pipe **24**. The injected reforming-fuel is vaporized and flows into the fuel-reforming catalyst **28**. The fuel-reforming catalyst **28** reforms the fuel in the exhaust gas into the fuel having high combustibility. The reformed fuel is supplied to the intake pipe **12**.

**[0095]** According to the third embodiment, while the fuel-reforming control is performed, the reforming-degree sensor **36** detects the reforming degree of the fuel (for example, hydrogen concentration) and then the reforming degree of the fuel is compared with the threshold to determine whether the fuel-reforming catalyst **28** is deteriorated. Thus, it is accurately whether the fuel-reforming catalyst **28** is deteriorated.

**[0096]** In a system having no catalyst diagnosis function, as shown by dashed lines in FIG. **17**, even if the fuel-reforming catalyst **28** is deteriorated, this deterioration can not be detected and no fail-safe processing can be conducted. Thus, it is likely that the combustion condition of the engine **11** is deteriorated and variation in torque occurs, which may deteriorate drivability.

**[0097]** According to the third embodiment, by comparing the reforming degree with the threshold, it is determined whether the fuel-reforming catalyst **28** is deteriorated. When it is determined that the fuel-reforming catalyst **28** is deteriorated, the fail-safe processing is conducted. Thus, it is restricted that the combustion condition is deteriorated and the drivability is deteriorated.

**[0098]** In the third embodiment, the reforming degree is detected while the fuel-reforming control is preformed. Then, the reforming degree is compared with the threshold, whereby it is determined whether the fuel-reforming catalyst **28** is deteriorated. The diagnosis method is not limited to this. For example, a difference or a ratio between the reforming degree detected before the fuel-reforming control is started and the reforming degree detected after the fuel-reforming control is started is compared with a threshold value, whereby the computer can determine whether the fuel-reforming catalyst **28** is deteriorated.

**[0099]** When the catalyst **28** is deteriorated, the reforming degree of the fuel by the catalyst **28** is deteriorated and the reforming degree is varied before and after the fuel-reforming control. Thus, based on these reforming degrees, it can be accurately determined whether the fuel-reforming catalyst **28** is deteriorated.

**[0100]** The reforming-fuel injector and the fuel-reforming catalyst may be arranged downstream of a supercharger in the intake pipe.

**[0101]** The present invention is not limited to an intake port injection engine. The present invention can be applied to a direct injection engine or a dual injection engine.

What is claimed is:

**1**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:

a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine;

a fuel-reforming catalyst for reforming the fuel in the medium fluid;

a reaction-heat detection portion which detects a reaction-heat information of the fuel-reforming catalyst; and

a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reaction-heat information.

**2**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **1**, wherein:

the reaction-heat detection portion includes an inlet-side temperature sensor disposed upstream of the fuel-reforming catalyst and an outlet-side temperature sensor disposed downstream of the fuel-reforming catalyst;

the catalyst-inlet temperature and the catalyst-inlet temperature are detected while a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is executed; and

the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on a catalyst-inlet temperature detected by the inlet-side temperature sensor and a catalyst-outlet temperature detected by the outlet-side temperature sensor.

**3**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **1**, wherein:

the reaction-heat detection portion includes a temperature detecting portion which detects a temperature of the fuel-reforming catalyst or a temperature at an outlet of the fuel-reforming catalyst;

the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the temperatures of fuel-reforming catalyst or a temperatures at an outlet of the fuel-reforming catalyst which are detected before and after the fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

**4**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:

a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid;

a combustion-condition detecting portion which detects a combustion-condition information of the internal combustion engine;

a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition information.

**5**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **4**, wherein:

the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the combustion-condition informations which are detected before and after a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

**6**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **4**, wherein:

the combustion-condition detecting portion detects, as the a combustion-condition information, at least one of a combustion stability index, an ignition delay period, a main combustion period, a combustion center, a maximum combustion pressure, an EGR limit, and a combustion speed.

**7**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, comprising:

a reforming-fuel injector injecting a reforming-fuel into a medium fluid which will be supplied to an intake pipe of the internal combustion engine; a fuel-reforming catalyst for reforming the fuel in the medium fluid;

a reforming-degree detecting portion which detects an reforming degree of the fuel at an outlet of the fuel-reforming catalyst; and

a catalyst-deterioration diagnosing portion which diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming degree of the fuel.

**8**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **7**, wherein:

the catalyst-deterioration diagnosing portion diagnoses whether the fuel-reforming catalyst is deteriorated based on the reforming-degrees of the fuel which are detected before and after a fuel-reforming control in which the fuel is reformed in the fuel-reforming catalyst is started.

**9**. A diagnostic apparatus for a catalyst in a fuel-property reforming system of an internal combustion engine, according to claim **7**, wherein:

the reforming-degree detecting portion is a hydrogen sensor which detects hydrogen concentration in the fuel as the reforming-degree of the fuel.

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