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(54) HYBRID VEHICLE THERMAL MANAGEMENT USING A BYPASS PATH IN A CATALYTIC CONVERTER UNIT

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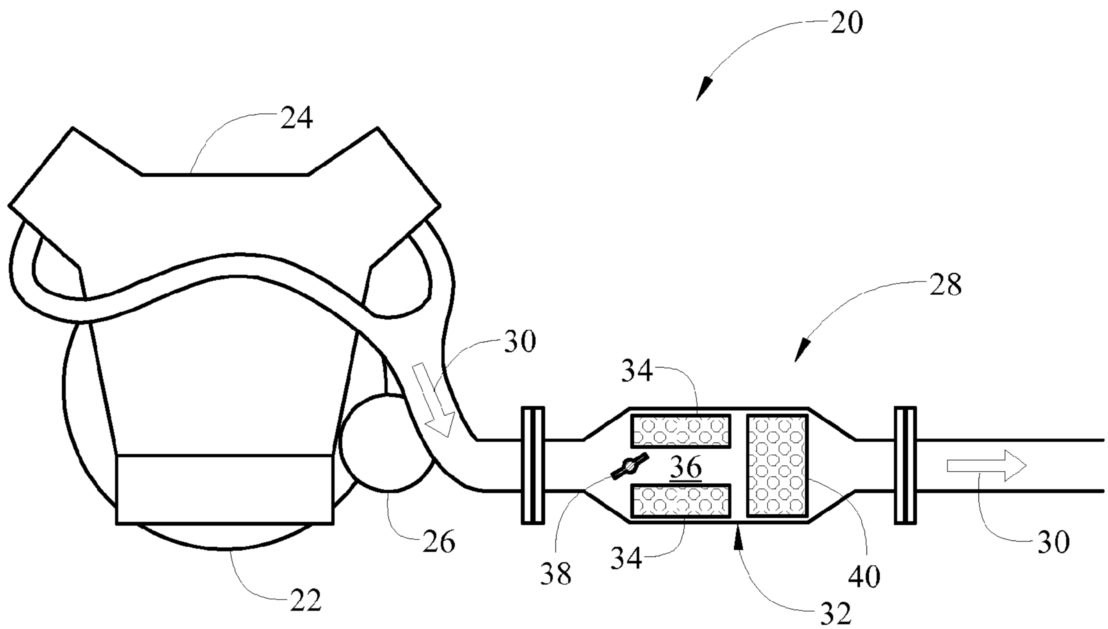
(57) **ABSTRACT**

A hybrid vehicle includes an exhaust gas treatment system having a bypass valve for directing a flow of air or exhaust gas through a bypass path or through a primary catalyst. The hybrid vehicle includes an internal combustion engine and an electric motor, each selectively engageable with a transmission to provide a drive torque. The electric motor spins the internal combustion engine when engaged to provide the drive torque, thereby creating a flow of unheated air from the internal combustion engine that flows through the exhaust gas treatment system. The bypass valve directs the flow of air through the bypass path when the engine is spinning and not fueled to prevent cooling of the primary catalyst. The bypass valve directs the flow of exhaust gas through the primary catalyst when the internal combustion engine is spinning and is being fueled, i.e., running, to treat the flow of exhaust gas.



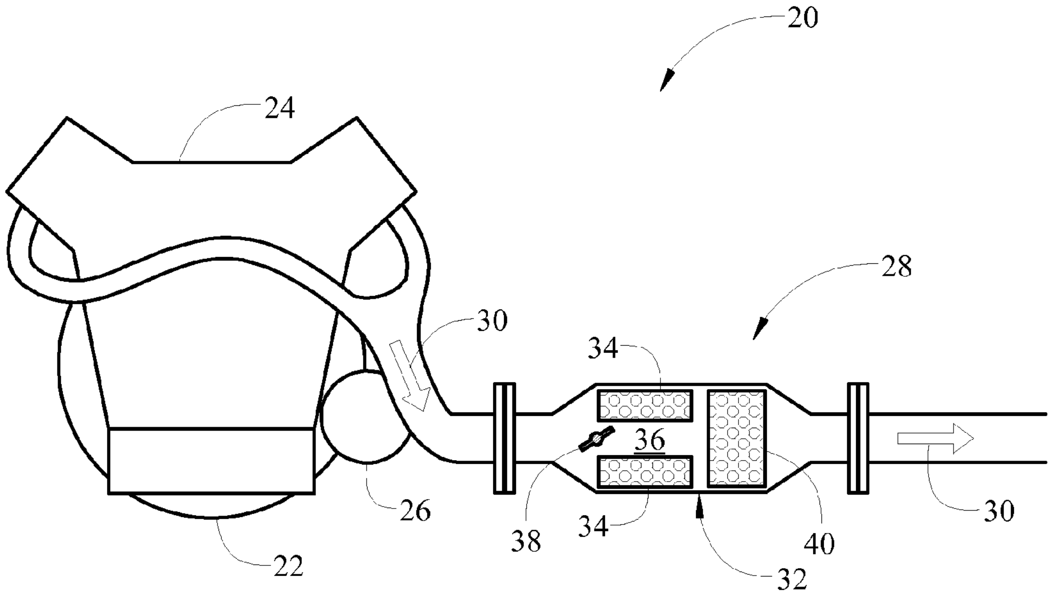


FIG. 1

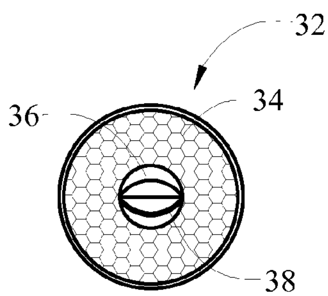


FIG. 2

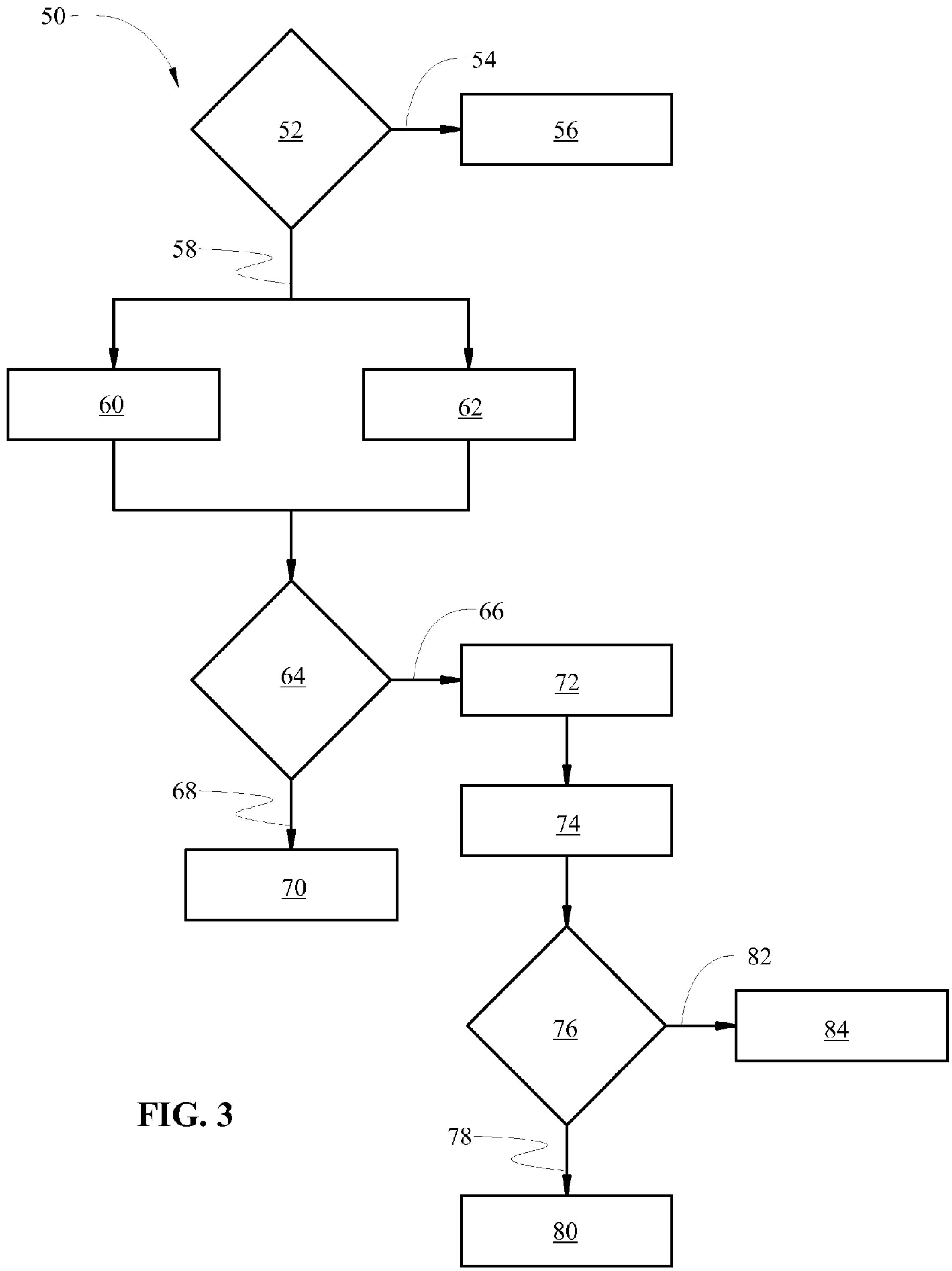


FIG. 3

HYBRID VEHICLE THERMAL MANAGEMENT USING A BYPASS PATH IN A CATALYTIC CONVERTER UNIT

TECHNICAL FIELD

[0001] The invention generally relates to a hybrid vehicle and a method of operating the hybrid vehicle to maintain thermal efficiency of a catalyst of an exhaust gas treatment system for an internal combustion engine when the internal combustion engine is spinning, but is not being fueled.

BACKGROUND

[0002] Hybrid vehicles with an Internal Combustion Engine (ICE) include an exhaust gas treatment system for reducing the toxicity of the exhaust gas from the engine. The treatment system typically includes a catalytic converter unit, which includes a catalyst that reduces nitrogen oxides in the exhaust gas to nitrogen and carbon dioxide or water, as well as oxidizes carbon monoxide (CO) and unburnt hydrocarbons (HCs) to carbon dioxide and water. The catalyst may include, but is not limited to, Platinum Group Metals (PGM). The catalyst must be heated to a light-off temperature of the catalyst before the catalyst becomes operational. Accordingly, the exhaust gas must heat the catalyst to the light-off temperature before the reaction between the catalyst and the exhaust gas begins.

[0003] The hybrid vehicle may further include an electric motor. The internal combustion engine and the electric motor may each be selectively engaged to power the vehicle, i.e., the internal combustion engine and the electric motor may each be selectively engaged to generate a drive torque for a transmission. When the electric motor is being engaged to provide the drive torque to the transmission, the internal combustion engine is typically not being fueled and is not running However, because both the electric motor and the internal combustion engine are coupled to the transmission to provide the drive torque to the transmission, the electric motor may cause the internal combustion engine to spin when the electric motor is engaged to provide the drive torque. When the internal combustion engine is being spun while the electric motor is providing the drive torque, the internal combustion engine produces a flow of air which is directed through the exhaust gas treatment system. This flow of air is not heated, and cools the components of the exhaust gas treatment system, including the catalyst. If the catalyst is cooled to a temperature below the light-off temperature, then the exhaust gas from the internal combustion engine, once fueled and running, may not be properly treated.

SUMMARY

[0004] A method of operating a hybrid vehicle is provided. The method includes determining if an internal combustion engine is spinning or is not spinning, determining if the internal combustion engine is being fueled to generate a drive torque when the internal combustion engine is spinning, or is not being fueled when the internal combustion engine is spinning, and directing a flow of air created by the internal combustion engine through a bypass path that bypasses a primary catalyst to prevent the flow of air from cooling the primary catalyst when the internal combustion engine is spinning and is not being fueled.

[0005] A method of operating a hybrid vehicle is also provided. The method includes determining if an internal combustion engine is spinning or is not spinning, determining if the internal combustion engine is being fueled to generate a drive torque when the internal combustion engine is spinning, or is not being fueled when the internal combustion engine is spinning When the internal combustion engine is spinning and is not being fueled a bypass valve of an exhaust gas treatment system is opened to direct a flow of air created by the internal combustion engine through a bypass path that bypasses a primary catalyst to prevent the flow of air from cooling the primary catalyst. When the internal combustion engine is spinning and is being fueled, the bypass valve is closed to direct a flow of exhaust gas created by the internal combustion engine through the primary catalyst to treat the flow of exhaust gas. The method further includes sensing a temperature of the primary catalyst when the engine is spinning and is being fueled, determining if the sensed temperature of the primary catalyst is greater than a pre-defined temperature, and at least partially opening the bypass valve when the temperature of the primary catalyst is greater than a pre-defined limit to divert at least a portion of the flow of exhaust gas created by the internal combustion engine through the bypass path to prevent the primary catalyst from overheating when the engine is spinning and is being fueled. The method further includes treating the flow of exhaust gas diverted through the bypass path when the temperature of the primary catalyst is greater than the pre-defined limit with a second downstream catalyst.

[0006] A vehicle is also provided. The vehicle includes a transmission configured for receiving a drive torque and transmitting the drive torque to a drive wheel. An internal combustion engine is coupled to the transmission, and is configured for selectively supplying the drive torque to the transmission. An exhaust gas treatment system is coupled to the internal combustion engine, and is configured for treating a flow of exhaust gas created by the internal combustion engine when the internal combustion engine is being fueled. An electric motor is coupled to the transmission and configured for selectively supplying the drive torque to the transmission. When the electric motor is supplying the drive torque to the transmission, the electric motor spins the internal combustion engine in an un-fueled state, thereby creating a flow of unheated air through the exhaust gas treatment system. The exhaust gas treatment system includes a primary catalyst, a bypass path defining a fluid flow path that bypasses the primary catalyst, and a bypass valve configured for controlling fluid flow between the primary catalyst and the bypass path. The bypass valve is disposed in an open position to direct air flow through the bypass path when the electric motor is supplying the drive torque to the transmission and spinning the internal combustion engine. The bypass valve is disposed in a closed position to direct the flow of exhaust gas from the internal combustion engine through the primary catalyst when the internal combustion engine is fueled and supplying the drive torque to the transmission.

[0007] Accordingly, when the electric motor is providing the drive torque for the transmission and thereby spinning the internal combustion engine, the flow of unheated air created by the internal combustion engine is directed through the bypass path, thereby bypassing the primary catalyst. Because the flow of unheated air is directed through the bypass path and not across or through the primary catalyst, the unheated air from the spinning internal combustion engine does not cool the primary catalyst, thereby preventing cooling of the primary catalyst to a temperature below a light-off temperature of the primary catalyst, and maintaining the thermal efficacy of the primary catalyst. The primary catalyst may therefore be ready to treat the exhaust gas from the internal combustion engine once the internal combustion engine is fueled and running

[0008] The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic plan view of an exhaust gas treatment system for an internal combustion engine of a hybrid vehicle.

[0010] FIG. **2** is a schematic cross sectional view of a catalytic converter unit of the exhaust gas treatment system.

[0011] FIG. **3** is a flow chart showing a method of operating the hybrid vehicle to maintain the thermal efficacy of a primary catalyst of an exhaust gas treatment system.

DETAILED DESCRIPTION

[0012] Referring to the Figures, wherein like numerals indicate like parts throughout the several views, a hybrid vehicle is shown generally at **20** in FIG. **1**. Referring to FIG. **1**, the hybrid vehicle **20** includes a transmission **22**. The transmission **22** is configured for receiving a drive torque and transmitting the drive torque to a drive wheel (not shown). The transmission **22** may include but is not limited to an automatic transmission **22**. The transmission **22** receives the drive torque from an internal combustion engine **24** and/or an electric motor **26**. Both the internal combustion engine **24** and the electric motor **26** are coupled to the transmission **22** and configured for selectively supplying the drive torque to the transmission **22**. The internal combustion engine **24** may include but is not limited to a gasoline engine or a diesel engine, and may include any suitable size and/or configuration suitable to satisfy output and performance requirements of the hybrid vehicle **20**. The electric motor **26** may include any suitable size, style and/or configuration of electric motor **26** suitable to satisfy the output and performance requirements of the hybrid vehicle **20**.

[0013] The hybrid vehicle **20** may engage either the internal combustion engine **24** or the electric motor **26** to generate the drive torque. The electric motor **26** supplies all of the drive torque when engaged. As such, when the electric motor **26** is engaged to exclusively supply the drive torque to the transmission **22**, the electric motor **26** also spins the internal combustion engine **24**. However, because the internal combustion engine **24** is not being engaged to supply the drive torque, the internal combustion engine **24** is not fueled. Accordingly, when the electric motor **26** is engaged to supply the drive torque, the electric motor **26** spins the internal combustion engine **24** in an un-fueled state. When the internal combustion engine **24** spins in the un-fueled state, the internal combustion engine **24** creates a flow of unheated air, which flows through an exhaust gas treatment system **28**.

[0014] The exhaust gas treatment system **28** is coupled to the internal combustion engine **24**. The treatment system **28** treats a flow of exhaust gas, indicated by arrow **30**, from the internal combustion engine **24** when the internal combustion engine **24** is being fueled, i.e., when the internal combustion engine **24** is running The exhaust gas treatment system **28** treats the flow of exhaust gas from the internal combustion engine **24** to reduce the toxicity of the exhaust gas, i.e., to reduce toxic emissions of the exhaust gas, including but not limited to, nitrogen oxides (NO), carbon monoxide (CO) and/or hydrocarbons (HC).

[0015] The exhaust gas treatment system **28** includes a catalytic converter unit **32**. The catalytic converter unit **32** is disposed downstream of the internal combustion engine **24**. The catalytic converter unit **32** includes a primary catalyst **34**. The primary catalyst **34** may include, but is not limited to, a three way catalyst. The primary catalyst **34** may include Platinum Group Metals (PGM), and convert a percentage of the nitrogen oxides in the exhaust gas into nitrogen and carbon dioxide or water, as well as oxidizes a percentage of the carbon monoxide to carbon dioxide and oxidizes a percentage of the unburnt hydrocarbons to carbon dioxide and water. The catalytic converter unit **32** also defines a bypass path **36**. The bypass path **36** defines a fluid flow path that bypasses the primary catalyst **34**. Referring also to FIG. **2**, the primary catalyst **34** includes a tubular shape. The tubular shape is disposed annularly about and defines the bypass path **36**, with the bypass path **36** extending along a central opening of the tubular shaped primary catalyst **34**.

[0016] A bypass valve **38** is also disposed within the catalytic converter unit **32**. The bypass valve **38** is configured for controlling fluid flow between the primary catalyst **34** and the bypass path **36**. The bypass valve **38** is disposed upstream of the primary catalyst **34**, and is configured for opening and closing fluid flow through the central region of the tubular shaped primary catalyst **34** defining the bypass path **36**. The bypass valve **38** is moveable between an open position and a closed position. When the bypass valve **38** is disposed in the open position, the bypass valve **38** directs fluid flow, e.g., air and/or exhaust flow, through the bypass path **36**. As such, when the electric motor **26** is exclusively supplying all of the drive torque to the transmission **22** and thereby spinning the internal combustion engine **24**, the bypass valve **38** may be disposed in the open position to direct the flow of air through the bypass path **36**, around and thereby bypassing the primary catalyst **34**. When the bypass valve **38** is disposed in the closed position, the bypass valve **38** directs fluid flow, e.g., air and/or exhaust flow, through the primary catalyst **34**. As such, when the internal combustion engine **24** is fueled to supply the drive torque, the bypass valve **38** may be disposed in the closed position to direct the flow of exhaust gas from the internal combustion engine **24** through the primary catalyst **34**.

[0017] As shown, the catalytic converter unit **32** may further include a secondary catalyst **40**. The secondary catalyst **40** is disposed downstream of the primary catalyst **34**. The secondary catalyst **40** is configured to treat the flow of exhaust gas that flows through either the primary catalyst **34** or through the bypass path **36**. Accordingly, if any exhaust gas from the internal combustion engine **24** is directed through the bypass path **36**, then the secondary catalyst **40** treats the exhaust gas. The secondary catalyst **40** may include, but is not limited to, a three way catalyst. The secondary catalyst **40** may include Platinum Group Metals (PGM), and convert a percentage of the nitrogen oxides in the exhaust gas into nitrogen and carbon dioxide or water, as well as oxidizes a percentage of the carbon monoxide to carbon dioxide and oxidizes a percentage of the unburnt hydrocarbons to carbon dioxide and water.

[0018] Referring to FIG. **3**, a method of operating the hybrid vehicle **20** described above is provided. The method is shown generally at **50** in FIG. **3**. The method **50** includes determining if an internal combustion engine **24** is spinning or is not spinning, generally indicated by block **52**. If the internal combustion engine **24** is determined to not be spinning, indicated at **54**, and is not being fueled, the method **50** may include closing the bypass valve **38**, generally indicated by block **56**. If the internal combustion engine **24** is determined to be spinning, indicated at **58**.

[0019] The method **50** may further include engaging the electric motor **26** to selectively generate the drive torque with the electric motor **26**, generally indicated by block **60**. As noted above, operation of the electric motor **26** also spins the internal combustion engine **24**, thereby creating the flow of air from the internal combustion engine **24** that flows through the exhaust gas treatment system **28**. Alternatively, the method **50** may further include fueling the internal combustion engine **24** to generate the drive torque, generally indicated by block **62**. As noted above, fueling of the internal combustion engine **24**, i.e., running the internal combustion engine **24**, generates a flow of heated exhaust gas that must be treated.

[0020] The method further includes determining if the internal combustion engine **24** is being fueled or is not being fueled, generally indicated by block **64**. When the internal combustion engine **24** is spinning, indicated at **58**, the internal combustion engine **24** may also be fueled to generate the drive torque, indicated at **66**. Alternatively, as described above, the internal combustion engine **24** may be spinning as a result of the electric motor **26** being engaged to generate the drive torque, and as such is not being fueled, indicated at **68**.

[0021] When it is determined that the internal combustion engine **24** is spinning, indicated at **58**, and is not being fueled, indicated at **68**, then the method **50** may further include directing the flow of air created by the internal combustion engine **24** through the bypass path **36**, generally indicated by block **70**, to bypass the primary catalyst **34**. Directing the flow of unheated air around the primary catalyst **34**, thereby bypassing the primary catalyst **34**, prevents the flow of air from cooling the primary catalyst **34**. Accordingly, the primary catalyst **34** may remain at a pre-heated temperature, ready to react with exhaust gas from the internal combustion engine **24** when the internal combustion engine **24** is fueled. Directing the flow of air created by the internal combustion engine **24** through the bypass path **36** may further be defined as opening the bypass valve **38** to direct the flow of air created by the internal combustion engine **24** through the bypass path **36**. However, it should be appreciated that the flow of air from the internal combustion engine **24** may be directed through the bypass path **36** in some other manner not shown or described herein.

[0022] When it is determined that the internal combustion engine **24** is spinning, indicated at **58**, and is being fueled, indicated at **66**, then the method **50** may further include directing the flow of exhaust gas created by the internal combustion engine **24** through the primary catalyst **34**, generally indicated by block **72**, to treat the flow of exhaust gas. Directing the flow of exhaust gas created by the internal combustion engine **24** through the primary catalyst **34** may further be defined as closing the bypass valve **38** to direct the flow of exhaust gas created by the internal combustion engine **24** through the primary catalyst **34**. However, it should be appreciated that the flow of exhaust gas from the internal combustion engine **24** may be directed through the primary catalyst **34** in some other manner not shown or described herein.

[0023] The method **50** may further include sensing a temperature of the primary catalyst **34**, generally indicated by block **74**. The temperature of the primary catalyst **34** may be sensed in any appropriate manner, including but not limited to sensing the temperature of the primary catalyst **34** with a temperature sensor disposed in the catalytic converter unit **32**. The temperature of the primary catalyst **34** may be sensed at any time, but it is particularly important to sense the temperature of the primary catalyst **34** when the engine is spinning and is being fueled. The useful life expectancy of the primary catalyst **34** may be reduced if the temperature of the primary catalyst **34** is overheated. Accordingly, the method **50** includes determining if the sensed temperature of the primary catalyst **34** is greater than a pre-defined temperature, generally indicated by block **76**. The pre-defined temperature is an upper operational temperature of the primary catalyst **34**. The pre-defined temperature is a temperature that is set to a level that ensures the primary catalyst **34** does not overheat. Accordingly, so long as the primary catalyst **34** is at or below the pre-defined temperature, the primary catalyst **34** should not overheat.

[0024] In order to ensure that the primary catalyst **34** does not overheat when the temperature of the primary catalyst **34** is greater than the pre-defined limit, indicated at **78**, the method **50** may further include at least partially opening the bypass valve **38**, generally indicated by block **80**. Opening the bypass valve **38** diverts at least a portion of the flow of exhaust gas created by the internal combustion engine **24** through the bypass path **36**, which prevents the primary catalyst **34** from overheating. The flow of exhaust gas diverted through the bypass path **36** is then treated with the secondary catalyst **40**. When the temperature of the primary catalyst **34** is less than the pre-defined limit, indicated at **82**, the method **50** may further include maintaining the bypass valve **38** in the closed position, generally indicated by block **84**.

[0025] While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims.

1. A method of operating a hybrid vehicle, the method comprising:

determining if an internal combustion engine is spinning or is not spinning;

determining if the internal combustion engine is being fueled to generate a drive torque when the internal combustion engine is spinning, or is not being fueled when the internal combustion engine is spinning; and

directing a flow of air created by the internal combustion engine through a bypass path that bypasses a primary catalyst to prevent the flow of air from cooling the primary catalyst when the internal combustion engine is spinning and is not being fueled.

2. A method as set forth in claim **1** further comprising directing a flow of exhaust gas created by the internal combustion engine through the primary catalyst to treat the flow of exhaust gas when the internal combustion engine is spinning and is being fueled.

3. A method as set forth in claim **2** wherein directing the flow of air created by the internal combustion engine through the bypass path is further defined as opening a bypass valve to direct the flow of air created by the internal combustion engine through the bypass path.

4. A method as set forth in claim **3** wherein directing the flow of exhaust gas created by the internal combustion engine through the primary catalyst is further defined as closing the bypass valve to direct the flow of exhaust gas created by the internal combustion engine through the primary catalyst.

5. A method as set forth in claim **1** further comprising sensing a temperature of the primary catalyst.

6. A method as set forth in claim **5** wherein sensing the temperature of the primary catalyst is further defined as sensing the temperature of the primary catalyst when the engine is spinning and is being fueled.

7. A method as set forth in claim **6** further comprising determining if the sensed temperature of the primary catalyst is greater than a pre-defined temperature.

8. A method as set forth in claim 7 further comprising at least partially opening the bypass valve when the temperature of the primary catalyst is greater than a pre-defined limit to divert at least a portion of the flow of exhaust gas created by the internal combustion engine through the bypass path to prevent the primary catalyst from overheating.

9. A method as set forth in claim 8 further comprising treating the flow of exhaust gas diverted through the bypass path when the temperature of the primary catalyst is greater than the pre-defined limit with a second downstream catalyst.

10. A method as set forth in claim 1 further comprising closing the bypass valve when the internal combustion engine is not spinning and is not being fueled.

11. A method as set forth in claim 1 further comprising selectively generating a drive torque with an electric motor, whereby the electric motor spins the internal combustion engine thereby creating a flow of air from the internal combustion engine that flows through the exhaust gas treatment system.

12. A method as set forth in claim 1 further comprising fueling the internal combustion engine to generate a drive torque.

13. A method of operating a hybrid vehicle, the method comprising:

determining if an internal combustion engine is spinning or is not spinning;

determining if the internal combustion engine is being fueled to generate a drive torque when the internal combustion engine is spinning, or is not being fueled when the internal combustion engine is spinning;

opening a bypass valve of an exhaust gas treatment system to direct a flow of air created by the internal combustion engine through a bypass path that bypasses a primary catalyst to prevent the flow of air from cooling the primary catalyst when the internal combustion engine is spinning and is not being fueled;

closing the bypass valve to direct a flow of exhaust gas created by the internal combustion engine through the primary catalyst to treat the flow of exhaust gas when the internal combustion engine is spinning and is being fueled;

sensing a temperature of the primary catalyst when the engine is spinning and is being fueled;

determining if the sensed temperature of the primary catalyst is greater than a pre-defined temperature;

at least partially opening the bypass valve when the temperature of the primary catalyst is greater than a pre-defined limit to divert at least a portion of the flow of exhaust gas created by the internal combustion engine through the bypass path to prevent the primary catalyst from overheating when the engine is spinning and is being fueled; and

treating the flow of exhaust gas diverted through the bypass path when the temperature of the primary catalyst is greater than the pre-defined limit with a second downstream catalyst.

14. A method as set forth in claim 13 further comprising selectively generating a drive torque with an electric motor, whereby the electric motor spins the internal combustion engine thereby creating a flow of air from the internal combustion engine that flows through the exhaust gas treatment system.

15. A vehicle comprising:

a transmission configured for receiving a drive torque and transmitting the drive torque to a drive wheel;

an internal combustion engine coupled to the transmission and configured for selectively supplying the drive torque to the transmission;

an exhaust gas treatment system coupled to the internal combustion engine and configured for treating a flow of exhaust gas created by the internal combustion engine when the internal combustion engine is being fueled;

an electric motor coupled to the transmission and configured for selectively supplying the drive torque to the transmission;

wherein the electric motor spins the internal combustion engine in an un-fueled state thereby creating a flow of unheated air through the exhaust gas treatment system when the electric motor is supplying the drive torque to the transmission;

the exhaust gas treatment system including:

a primary catalyst;

a bypass path defining a fluid flow path that bypasses the primary catalyst; and

a bypass valve configured for controlling fluid flow between the primary catalyst and the bypass path;

wherein the bypass valve is disposed in an open position to direct air flow through the bypass path when the electric motor is supplying the drive torque to the transmission and spinning the internal combustion engine, and wherein the bypass valve is disposed in a closed position to direct the flow of exhaust gas from the internal combustion engine through the primary catalyst when the internal combustion engine is fueled and supplying the drive torque to the transmission.

16. A vehicle as set forth in claim 15 wherein the primary catalyst, the bypass path and the bypass valve are all disposed within a catalytic converter unit.

17. A vehicle as set forth in claim 16 wherein the catalytic converter unit includes a second downstream catalyst disposed downstream of the primary catalyst.

18. A vehicle as set forth in claim 17 wherein the primary catalyst includes a tubular shape disposed annularly about and defining the bypass path, with the bypass path extending along a central opening of the tubular shaped primary catalyst.

19. A vehicle as set forth in claim 18 wherein the bypass valve is disposed upstream of the primary catalyst and is configured for opening and closing fluid flow through the central region of the tubular shaped primary catalyst defining the bypass path.

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