Description

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an apparatus for evaluating an oxygen sensor. More particularly, it is an apparatus which includes a burner.

Description of the Prior Art

There are known several types of apparatus for the evaluation of an oxygen sensor. They include the following:

(1) An apparatus of the type in which the oxygen sensor to be evaluated contacts the exhaust gas of an engine;
(2) An apparatus of the type in which the oxygen sensor to be evaluated contacts a model gas, such as a mixture of H_2, CO, HC, O_2 and N_2, for example, as disclosed in Japanese Patent Publication No. 42224/1986.
(3) An apparatus of the type in which the oxygen sensor to be evaluated contacts the combustion gaseous product of a fuel, such as propane or butane, for example, as disclosed in Society of Automotive Engineers of the United States (SAE) Paper 790143, and in Japanese Patent Application No. 93057/1981.

These three types of apparatus, however, have the following drawbacks, respectively:

(1) Although the apparatus which employs the exhaust gas of an engine is more accurate than the other two types, it is difficult to accurately establish the desired conditions for evaluation, such as an excess air ratio (fuel-air ratio) and temperature. It requires excessive time for evaluation and therefore it is expansive.
(2) Although the use of a mixture of various kinds of pure gas makes it possible to establish an excess air ratio of high stability as compared with what can be achieved by the apparatus employing the exhaust gas of an engine or propane gas burner, a large amount of gas is required to attain a flow rate which is comparable to that of the exhaust gas of an internal combustion engine. It is difficult to accurately establish the temperature of the gas which is employed in a large quantity. The gas is expensive, as it is a mixture of various kinds of gases.
(3) This type of apparatus employs the gas which is obtained as a combustion product when a mixture of combustable gas and air is burned by a burner, thus a gas heater is not required. Moreover, a large volume of gas can be obtained which makes it easy to achieve a high flow rate, therefore, it is used for a wide range of inspection purposes in various fields of industry. However, the combustion gas is a product of nearly perfect combustion and contains only a small amount of an uncombusted matter, as opposed to the exhaust gas of the internal combustion engine of an automobile. Therefore, it is often the case that the characteristics of a sensor which are determined by the previous burner apparatus differ from those which are obtained when the sensor is actually used with the internal combustion engine.

SUMMARY OF THE INVENTION

It is an object of this invention to provide an apparatus which can overcome the drawbacks of the prior art as hereinabove pointed out and can evaluate an oxygen sensor quickly, accurately and economically under desired conditions by employing a combustion product containing an appropriate amount of uncombusted matter.

This object is attained by an apparatus essentially comprising:

a device for mixing a fuel and an oxygen-containing gas in an appropriate ratio to prepare a fuel mixture;
a burner connected to the mixing device for burning the fuel mixture to produce a gaseous combustion product;
a tubular member extending from the burner for supplying the combustion product;
a nozzle connected to the tubular member for introducing a fuel and an oxygen-containing gas into the tubular member downstream of said burner so that the combustion product may have a desired excess air ratio; and
a mounting device of said sensor to be evaluated disposed, at a point downstream of said nozzle, on said tubular member.

The apparatus of this invention is applicable to various types of oxygen sensors. They include a sensor of the type which employs an oxygen-ion conductive solid electrolyte, such as zirconia, and detects a difference in partial pressure of the oxygen gas between the opposite sides of the electrolyte to determine the amount of oxygen gas that is in a particular environment, a sensor of the type which employs a semiconductor, such as titania, having an electrical

conductivity varying with the partial pressure of the surrounding oxygen gas, and a sensor of the type which employs a combination of an oxygen pumping element and an oxygen gas detecting element.

Any combustible gas can be used as the fuel. It is, however, preferable to use propane, butane, or any other gas that is easy to transport. Moreover, it is also possible to use CO, H_2, etc. as the fuel which is introduced into the tubular member downstream of the burner.

Oxygen gas or air can be used as the oxygen-containing gas. The use of air is preferred for the reason of safety and economy.

The device which is connected to the tubular member downstream of the burner can be so connected thereto as to introduce a mixture of a fuel and an oxygen-containing gas thereinto not only at a single point, but also at a plurality of points. In the latter case, it is possible to introduce different gases from one point to another, for example, a mixture of a fuel and an oxygen-containing gas at one point and only an oxygen-containing gas at another.

The combustive product must have a flow rate of at least 5m/sec. to ensure the accurate evaluation of an oxygen sensor.

The gaseous mixture is introduced into the tubular member downstream of the burner without being burned combines with the combustion product of the burner to produce in the evaluating chamber, an appropriately controlled atmosphere which still contains a certain proportion of uncombusted matter and is, therefore, similar in composition to the exhaust gas of the internal combustion engine. Therefore, the apparatus of this invention can determine the performance of an oxygen sensor accurately.

The ratio of the fuel and the oxygen-containing gas which are supplied to the burner and the ratio of the fuel and the oxygen-containing gas which are introduced downstream of the burner can both be varied easily and independently of each other.

Therefore, it is easy to produce in the evaluating chamber, an atmosphere which is very similar in composition to the exhaust gas of any of various types of internal combustion engines operating under any of various conditions. This makes it possible to accurately control the excess air ratio of the atmosphere, the proportion of the uncombusted matter which it contains, the temperature of the atmosphere, and other conditions.

Moreover, the apparatus of this invention can evaluate an oxygen sensor at minimal cost due to the fact that it employs a gas of low cost as the fuel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a diagram showing the principle of this invention;
FIGURE 2 is a diagrammatic representation of the essential features of an apparatus embodying this invention;
FIGURE 3 is a graph showing the output characteristics of a sensor tested by the apparatus embodying this invention (excess air ratio for engine control) in relation to the ratio of a "rich" signal;
FIGURE 4 is a graph showing the output characteristics of a sensor tested by a conventional apparatus in relation to the ratio of a "rich" signal;
FIGURE 5 is a graph showing the output characteristics of the sensor tested by the apparatus embodying this invention in relation to the ratio of reaction time;
FIGURE 6 is a graph similar to FIGURE 5, but showing the results obtained by employing the conventional apparatus;
FIGURE 7 is a graph showing the output characteristics of the sensor tested by the apparatus embodying this invention in relation to its resistance;
FIGURE 8 is a graph similar to FIGURE 7, but showing the results obtained by employing the conventional apparatus,
FIGURE 9 is a graph showing the output characteristics of the sensors tested by the apparatus embodying this invention at a flow rate of 9m/sec. in relation to the ratio of a "rich" signal;
FIGURE 10 is a graph similar to FIGURE 9, but showing the results obtained at a flow rate of 1m/sec.;
FIGURE 11 is a graph showing the output characteristics of the sensors tested by employing the conventional apparatus in relation to the ratio of a "rich" signal;
FIGURE 12 is a diagram showing a modified form of the apparatus according to this invention;
FIGURE 13 is a graph showing the output characteristics of the sensors tested by the second embodied apparatus embodying this invention in relation to the ratio of reaction time;
FIGURE 14 is a graph similar to FIGURE 13, but showing the results obtained by employing the conventional apparatus;
FIGURE 15 is a graph showing the output characteristics of the sensors tested by the modified apparatus in relation to excess air ratio controlled by second embodied apparatus.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIGURE 1 of the drawings, the apparatus of this invention essentially comprises a housing defining an evaluating chamber M2 in which an oxygen sensor M1 is positioned, a device M3 for mixing a fuel and an oxygen-containing gas in an appropriate ratio to prepare a fuel mixture, a burner M4 connected to the mixing device M3 for burning the fuel mixture to produce a gaseous combustion product, a tubular member M5 extending from the burner M4 to the evaluating chamber M2 for supplying the combustable product into the chamber M2, and a device M6 connected to the tubular member M5 between the burner and the evaluating chamber for introducing a fuel, an oxygen-containing gas into the tubular member M5 so that the combustable product may have an appropriate excess air ratio when it is supplied into the evaluating chamber M2. An oxygen sensor M8 to be evaluated (not shown) is mounted on a mounting device M7 disposed at a portion downstream of the device M6 on the tubular member 5.

The evaluating chamber M2 may or may not form an integral part of the tubular member M5. The mixing device M3 may, for example, comprise of a valve for regulating the amount of the fuel which is supplied, and a valve for regulating the amount of oxygen-containing gas. The introducing device M6 may also be provided with a fuel valve and a valve for the oxygen-containing gas. The ratio of the fuel and oxygen-containing gas which are introduced through the device M6 can be varied independently of the ratio of the fuel and gas which are mixed by the device M3.

Referring to FIGURE 2, there is diagrammatically shown an apparatus 100 embodying this invention. It comprises a burner 10 which enables the control of a variable excess air ratio, a combustion tube 120 having one end at which the burner 110 is provided, and defining both a tubular member for conducting its combustion product and an evaluating chamber, a device 130 provided on the combustion tube 120 downstream of the burner 110 for introducing an appropriate mixture of gas and air into the combustion tube 120, a device 141 provided downstream of the introducing device 130 for mounting a sensor 140 to be tested in the combustion tube 120, a standard oxygen sensor 150 provided downstream of the mounting device 141, and a gas sampling device 161 provided downstream of the standard oxygen sensor 150 and connected to a gas analyzer 160.

A main air supply tube 111, an auxiliary air supply tube 113, a main gas supply tube 114 and an auxiliary gas supply tube 116 are connected to the burner 110. The auxiliary air supply tube 113 is provided with a valve 112, and the auxiliary gas supply tube 116 with a valve 115, too. Air is supplied from a compressor (not shown) to the air supply tubes 111 and 113, while propane gas is supplied from a gas bottle (not shown) to the gas supply tubes 114 and 116.

The introducing device 130 comprises a nozzle 133 connected to an air supply tube 132 having a valve 131, and a nozzle 138 to which an air supply tube 135 having a solenoid valve 134 and a gas supply tube 137 having a solenoid valve 136 are connected. Air is supplied from the compressor to the air supply tubes 132 and 135, while propane gas is supplied to the gas supply tube 137.

The signals from the sensors 140 and 150 and the output signal of the gas analyzer 100 are processed by a flow control device 170. The flow control device 170 controls the amounts of gas and air which are introduced into the combustion tube 120, and outputs the results of its processing to a recording device 180.

The sensor 140 causes the feedback control of the control device 170 so that the atmosphere surrounding the sensor 140 may have an excess air ratio which is equal to 1 at a theoretical air-fuel ratio ($\lambda = 1$) and $\lambda = 1$ corresponds to 450-500 mV output of the sensor 140. The excess air ratio obtained by any such feedback control or the output of the standard sensor 150 against the sensor 140 is utilized to determine the characteristics of the sensor 140. The excess air ratio is equal to the amount of the air which is supplied for burning the fuel, divided by the amount of the air which is required for the perfect combustion of the fuel. When $\lambda = 1$ (i.e. when the mixture has a theoretical air-fuel ratio), the fuel is perfectly burned. If λ is larger than 1, the mixture is gas lean containing an excess of air, and if it is smaller than 1, it is gas rich having a shortage of air and its combustion leaves an uncombusted matter.

The output voltage of a normal oxygen sensor is 200 mV at the highest if the atmosphere surrounding it is a gas lean, and is at least 700 mV if it is a gas rich. If the output of the sensor exceeds a voltage of 450 to 500 mV, the atmosphere surrounding it is a gas rich and if it is lower than a voltage of 450 to 500 mV, it is a gas lean. Therefore, the atmosphere has a theoretical air-fuel ratio ($\lambda = 1$) if the control device 170 controls the solenoid valves 134 and 136 in accordance with the output of the sensor 140 in such a way that in the former case, a smaller amount of gas and a larger amount of air may be supplied to the nozzle 138, while a larger amount of gas and a smaller amount of air are supplied thereto in the latter case.

However, if the output characteristics of the sensor 140 differ from what has hereinabove been described, the atmosphere surrounding it does not show the theoretical air-fuel ratio as a result of any such feedback control, but shows a ratio which depends on its output characteristics.

A plurality of oxygen sensors 140 formed from titania and having different output characteristics were, therefore, tested one after another. The excess air ratio of the combustable product which had been formed by the feedback control of each sensor 140 was determined as the output of the gas analyzer 160 or the standard sensor 150. Every sensor 140 was of the type containing the same additive and having an equally shaped protector.

The output characteristics of each sensor 140 had been accurately determined by its positioning in the exhaust

gas of an engine, as stated at (1) in page 1 hereof. These characteristics and the results of evaluation by the apparatus 100 were compared for evaluating the apparatus. The tests which will hereinafter be described were conducted by mounting the sensor to the internal combustion engine of the automobile, effecting the feedback control of the engine in accordance with the output signal of the sensor and determining the excess air ratio of the controlled engine as the output characteristics of the sensor.

Prior to the feedback control by the sensor 140, the valves 112 and 115 had been so adjusted that the mixture of air and propane gas to be supplied to the burner 110 might have a ratio of 0.9, and the valve 131 had been adjusted to control the amount of air through the nozzle 133 so that the combustion product of the burner 110 might have a ratio of 0.95.

The solenoid valves 134 and 136 were adjusted by the control device 170 in accordance with the output of the sensor 140 to vary the excess air ratio and amount of the mixture of air and propane gas to be supplied through the nozzle 138 so that the combustion product might have an excess air ratio varying in the range of 0.90 to 1.05

TEST 1-1

FIGURE 3 is a graph showing the output characteristics of the sensors 140 which were tested (excess air ratio as obtained by an engine control) in relation to the ratio of the time of the "rich" signal as indicated by the standard sensor 150 to the total measuring time (hereinafter said as the ratio of the "rich" signals) when the apparatus embodying this invention was controlled by the sensors 140. The "rich" signal of the standard sensor 150 is the signal which was output by the control device 170 when the output of the standard sensor 150 exceeded a voltage of 450 to 500 mV. As is obvious from FIGURE 3, the apparatus 100 embodying this invention showed a very high correlation between the ratio of the time for which the "rich" signal of the standard sensor 150 was output, to the testing time and the output characteristics of the sensor 140. The ratio of the "rich" signal, therefore, enabled the evaluation of the characteristics of the sensor 140 for the control of an internal combustion engine.

FIGURE 4 is a graph similar to FIGURE 3, but showing the results obtained when the conventional apparatus employing a burner as stated at (3) in page 1 hereof was controlled by the sensors. The apparatus was of the same construction with the apparatus embodying this invention except that it did not include the introducing device 130, but that only the amounts of gas and air to be supplied to the burner 110 were controlled for the feedback control of the ratio of the combustion product. As is obvious from FIGURE 4, the conventional apparatus hardly showed any correlation between the ratio of the time for which the "rich" signal of the standard sensor was output, to the testing time and the output characteristics of the sensor which was tested. By considering of the time ratio of the "rich" signal, the conventional apparatus employing a burner could, therefore, not be used for evaluating the characteristics of the sensor for the control of an internal combustion engine.

TEST 1-2

FIGURE 5 is a graph showing the output characteristics (λ) of the sensors 140 in relation to the ratio of reaction time of the sensor 140 which was determined as will herein be described. The combustion product of the apparatus 100 embodying this invention and carrying the sensor 140 to be tested was alternately changed between a gas rich having a ratio λ of 0.90 and a gas lean having a ratio of 1.05. This change was effected by changing the composition of the fuel mixture introduced through the device 130 by a timer provided in the control device 170. Measurement was made of the time required for the sensor 140 to output a standard voltage of 450 to 500 mV after each change had been effected. The ratio of the reaction time is expressed as:

$$T_{LS}/(T_{RS} + T_{LS})$$

where "T_{RS}" represents the length of time required for the sensor to output the standard voltage after the combustion product has been changed to a gas lean mixture and "T_{LS}" represents the length of time required for the sensor to output the standard voltage after the combustion product had been changed to a gas rich mixture. As is obvious from FIGURE 5, the apparatus 100 of this invention showed a very high correlation between the ratio of the reaction time of the sensor 140 and its output characteristics (λ). The ratio of reaction time, therefore, enabled the evaluation of the characteristics of the sensor 140 for the control of an internal combustion engine. In other words, the apparatus of this invention corresponds rapidly to the change from a gas rich mixture to a gas lean mixture and vice versa.

FIGURE 6 is a graph similar to FIGURE 5, but showing the results obtained when the conventional apparatus employing a burner as stated at (3) in page 1 hereof was controlled by the sensor. As is obvious from FIGURE 6, the conventional apparatus hardly showed any correlation between the ratio of reaction time of the sensor and its output characteristics (λ). By considering the ratio of the reaction time, the conventional apparatus employing a burner could, therefore, not be used to evaluate the characteristics of the sensor for the control of the internal combustion engine.

TEST 1-3

FIGURE 7 is a graph showing the output characteristics (λ) of the sensors 140 in relation to their resistance when the combustion product had a ratio λ of 0.90. This resistance was determined as will herein set forth. The valves 112 and 115 were so controlled that the combustion product of the burner 110 might have a ratio of 1.02, and propane gas was introduced through the nozzle 138 until the combustion product had a ratio λ of 0.90. When it had a ratio λ of 0.90, the resistance of the sensor 140 was measured. As is obvious from FIGURE 7, the apparatus 100 of this invention showed a very high correlation between the resistance which the sensor 140 showed when the combustion product had a ratio λ of 0.90 and the output characteristics (λ) thereof. The resistance, therefore, made it possible to evaluate the characteristics of the sensor 140 for the control of the internal combustion engine.

FIGURE 8 is a graph similar to FIGURE 7, but showing the results obtained when the conventional apparatus employing a burner was used. The resistance of the sensor was measured when the combustion product of the burner had a ratio of 0.90, as the ratio of the atmosphere in the vicinity of the sensor was equal to that of the combustion product of the burner. As is obvious from FIGURE 8, the apparatus hardly showed any correlation between the resistance which the sensor showed when the combustion product had a ratio of 0.90 and the output characteristics (λ) thereof. Therefore, the conventional apparatus employing a burner could not be used to evaluate the characteristics of the sensor for the control of the internal combustion engine.

TEST 1-4

FIGURES 9 and 10 are graphs showing the relation between the output characteristics (λ) of the sensors 140 and the time ratio of the "rich" signals which were indicated by the standard sensor 150 when the apparatus of this invention was controlled by the sensors 140. FIGURE 9 shows the results which were obtained when the combustable product had a flow rate of 9 m/sec., while FIGURE 10 shows the results obtained when it had a flow rate of 1 m/sec. This test was conducted by using three types of sensors 140, as opposed to TESTS 1 to 3. Type A and B sensors were both formed from titania and were of the same shape, but contained different additives. Type C sensors contained the same additives as that which type A sensors contained, but their protectors had a different shape.

In FIGURES 9 and 10, each circle, triangle and square denote type A, B and C sensors, respectively. The procedure of TEST 1 was repeated for determining the ratio of the "rich" signals which had been output by the standard sensor 150. As is obvious from FIGURES 9 and 10, the apparatus 100 of this invention showed a high correlation between the ratio of the time for which the "rich" signals were output by the standard sensor 150, to the testing time and the output characteristics (λ) of the sensors 140, irrespective of the flow rate of the combustion product, if the sensors were of the same type. Therefore, the ratio of the "rich" signals could be used to evaluate the characteristics of the sensors 140 for the control of an internal combustion engine. Their correlation was very high irrespective of the type of the sensors 140 when the combustion product had a high flow rate, as is obvious from FIGURE 9. The results which were similar to those shown in FIGURE 9 could be obtained when the combustion product had a flow rate of at least 5 m/sec.

FIGURE 11 is a graph similar to FIGURE 9 or 10, but showing the results which were obtained when the conventional apparatus including a burner was employed. As is obvious therefrom, the conventional apparatus hardly showed any correlation between the ratio of the time for which the "rich" signals were output by the standard sensor, to the testing time and the output characteristics (λ) of the sensors, even if the sensors of the same type were compared. Therefore, by considering the time ratio of the "rich" signals the conventional apparatus employ a burner could not be used to evaluate the sensors for the control of an internal combustion engine.

The results of TESTS 1 to 4 confirmed that the apparatus 100 of this invention could evaluate the oxygen sensors accurately. Although the foregoing results were obtained by comparing the output characteristics of the sensors 140, which had been previously determined, with the ratio of the output of the standard sensor, the ratio of reaction time, or the resistance of the sensors, similar results were obtained when the excess air ratio obtained from the analysis by the gas analyzer 160 of the combustion product of the apparatus 100 controlled by the sensor 140, or the excess air ratio obtained by an air-fuel ratio sensor provided on the combustion tube 120 was employed instead of the output characteristics of the sensor 140.

FIGURE 12 shows an explanatory illustration showing the construction of another apparatus for evaluating an oxygen sensor according to the present invention. This apparatus 200 is mainly composed of an exhaust gas generator 210 generating exhaust gas including CO, etc., an offsetting portion 220 allowing a basis excess air ratio including CO, O_2 by adding air to the exhaust gas, and a rich/lean setting portion 230 which forms excess air condition by adding exhaust gas or air to the basis excess air ratio (hereafter called "lean") or forms excess fuel ratio (hereafter called "rich"). A oxygen-gas sensor 240 to be evaluated is exposed to combustion tube 216 adjusted at the rich/lean setting portion 230. The combustion tube 216 is connected by a flange 272.

The exhaust gas generator 210 generates the exhaust gas which contains enough flow volume and appropriate

temperature for evaluating the sensor 240. The excess air ratio of this exhaust gas is set to $\lambda = 0.95$ for example. The offsetting portion 220 functions to compensate the excess air ratio to $\lambda = 1.0$ for example by adding air to this exhaust gas. The exhaust gas compensated in this offsetting portion 220 contains both lean components such as O_2 and rich components such as CO simultaneously which are of generally the same composition as those present in the exhaust gas of an internal combustion engine.

The rich/lean setting 230 functions to change the exhaust gas thus compensated to rich phase by adding fuel to a value (for example $\lambda = 0.95$) or lean phase by adding air to a value (for example $\lambda = 1.05$) respectively based on the excess air ratio (1.0) set at the offsetting part 220. By exposing the sensor 240 to be evaluated to the exhaust gas in this manner, the sensor 240 is placed under the same conditions as it is incorporated really in the car.

The construction of the offsetting portion 220 is explained as follows. First, the fuel exhaust gas generator 210 is explained. The fuel exhaust gas generator 210 is provided with propane gas (hereafter called "gas") as a fuel supplied from a fuel tank (not shown), a flow control device 261 to mix air supplied from a compressor not shown, a burner 211 for burning this mixed air to generate the exhaust gas and a A/F sensor 251 fixed on a combustion tube 214 at a downstream of the burner 211.

The aforesaid flow control device 261 serves to adjust the mixture ratio of air or gas so that the excess air ratio detected by the A/F sensor 251 is coincided with the excess air ratio ($\lambda = 0.95$) for example which has already been predetermined. This adjustment is performed by regulating the opening degree of a mass flow regulator (not shown) which consists of the flow control device 261 equipped with the thermostatic valve (not shown). The combustion chamber 212 of the burner 211 is formed of an adiabatic material 213. The combustion tube 214 is cooled by water-cooled jacket 215 and connected to combustion tube 216 by a flange 271.

The A/F sensor 251 may be a sensor combining oxygen pump element using oxyugen ionized solid electroliquid material such as zirconia for example, with an oxygen battery element. This A/F sensor 251 can measure the excess air ratio from lean phase ($\lambda > 1$) to rich phase ($\lambda < 1$).

Next, the offsetting portion 220 is explained. The offsetting portion 220 is provided with a nozzle 255 adding air to the exhaust gas from the exhaust gas generating part 210, a flow control device 262 adjusting air quantity supplied to this nozzle 255, an A/F sensor fixed on the downstream of the nozzle 255.

The flow control device 262 functions to adjust air quantity in the same manner as the flow control device 261 so that the excess air ratio detected by A/F sensor 252 is coincided with the pre-determined excess air ratio ($\lambda = 1.0$ for example). The combustion tube 216 is water cooled covered by the water-cooled jacket 217. Through this tube, the exhaust gas is set to nearly the same temperature as that of exhaust gas from the car. The A/F sensor 252 used is the same type as the A/F sensor 251.

Further, the rich/lean setting portion 230 is explained. The rich/lean setting portion 230 is provided with a nozzle 256 adding gas or air to the exhaust gas adjusted at the offsetting portion 220, a flow control device 263 adjusting air quantity or fuel gas quantity supplied to this nozzle, and the A/F sensor 253 fixed on the downstream of the nozzle 256.

The flow control device 263 functions in the same manner as the flow control device 261 to add air or fuel gas so that the excess air ratio of the fuel exhaust gas detected by the A/F sensor 253 is coincided with the pre-determined excess air ratio ($\lambda = 1.05$ or $\lambda = 0.95$ for example). Moreover, the A/F sensor 253 used is the same type as the A/F sensor 251. On the other hand, the flow control device 263 may be controlled by using the sensor 240 to be evaluated depending on a evaluated value of the sensor 240 shown by the dotted line in FIGURE 12.

The output of sensor 240 to be evaluated is recorded in a recording device 264. For precise flow regulation, the A/F sensors 251, 252, 253 are correlated as required by using standard gas (a gas of which air/fuel ratio is predetermined). Moreover, when required, it is possible to equip a standard A/F sensor or gas analyzer measuring the excess air ratio of the fuel exhaust gas to which the sensor to be evaluated 240 is exposed, in a near area or downstream thereof. Further, controlling the flow control devices 261, 262, 263 and recording the output of sensor 240 to be evaluated can be undertaken all by one electronic control unit.

TEST 2-1

The excess air ratio of the exhaust gas generator 210 and the offsetting portion 220 are as shown in the table below, wherein the excess air ratio of rich/lean setting portion 230 is changed between rich and lean phases shown in table below in 0.5 seconds intervals by using a timer (not shown). At the same time, the gas components of exhaust gas emitted from respective portions are tabled.

TABLE

		GAS COMPOSITION
BURNER PORTION	0.95	CO, CO_2, H_2O, N_2

TABLE (continued)

			GAS COMPOSITION
OFFSET PORTION		1.0	CO, O_2, CO_2, H_2O, N_2
RICH LEAN SETTING PORTION	LEAN	1.05	CO, O_2, CO_2, H_2O, N_2
	RICH	0.95	CO, C_3H_8, O_2, CO_2, H_2O, N_2

Measuring the lapse of time "T_{LS}" from when the exhaust gas of the sensor 240 to be evaluated is changed to rich, to the time when it reaches standard voltage (450-500 mV) and the lapse of time "T_{RS}" from when the fuel exhaust gas is changed to lean, to when it reached the standard voltage, the sensor 240 to be evaluated is evaluated depending on the time ratio $T_{RS}/(T_{RS} + T_{LS})$ obtained by the reaction of sensor 240.

FIGURE 13 is a diagram showing relationship between excess air ratio for engine control and the ratio of reaction times as for various types of sensors to be evaluated.

In the preferred embodiment of the present invention, the apparatus 200 for evaluating the oxygen sensor is evaluated by comparing the detected characteristic values of the sensor 240 pre-measured precisely in the conventional method 1 where the sensor is inserted into the exhaust gas previously described with the measured according to the present evaluation method.

The sensor to be evaluated is mounted on a car and the engine is feed-back, controlled by the output of the sensor. In so doing, the detected characteristics values are expressed in the excess air ratio for engine control in this manner. As shown clearly in FIGURE 13, there is a sharp interrelationship between ratio of reaction time of sensor 240 and detected characteristics (excess ratio for engine control) of sensor 240. Accordingly, the apparatus 200 of the present invention proved to be quite instrumental in evaluating the oxygen sensor with high precision.

For comparison, another diagram is prepared in FIGURE 14 showing a relationship between the ratio of the reaction time and the excess air ratio for an engine control and when the conventional burner type apparatus (prior art) for evaluating oxygen sensor is used. As shown in FIGURE 14, there is not much interrelationship as is appreciably approved with the significant tangential rise along coordinate axis though there is some tendency of interrelationship between the ratio of reaction time and excess air ratio for engine control when the conventional burner type apparatus for evaluating the oxygen sensor is used.

Judging from the ratio of reaction time, this conventional burner type apparatus for evaluating the oxygen sensor proves to be unable to evaluate the characteristics of the sensor.

TEST 2-2

First, the excess air ratio of exhaust gas generator 210 and the offsetting portion 220 are set in the same manner as in the above evaluation method 1. Secondly, the rich/lean setting portion 230 is feed-back controlled to gain $\lambda = 1$ by using the sensor to be evaluated 240 of rich/lean setting portion 230. Then, the excess air ratio (excess air ratio for controlling the apparatus) is obtained. Based on this value, the sensor 240 to be evaluated is evaluated. When the engine is feed-back controlled, the excess air ratio is measured by the A/F sensor 253 or separately installed gas analyzer (not shown).

FIGURE 15 is a diagram showing a relationship between excess air ratio for engine control and the excess air ratio controlled by the apparatus 200 as for various sensor 240 to be evaluated when the apparatus 200 for evaluating the oxygen sensor according to the present embodiment is used.

In this embodiment, comparing the detected characteristics of sensor 240 to be evaluated which is precisely measured by the method where the sensor is inserted beforehand into the exhaust gas emitted from previously described engine in the same manner as in the evaluation test 1 with measured values according to the present evaluation method, the apparatus 200 of the present invention for evaluating the oxygen sensor of the present embodiment is evaluated.

As shown in FIGURE 15, there is an appreciable sharp interrelationship between the excess air ratio obtained when the apparatus 200 for evaluating the oxygen sensor is feed-back controlled by using the sensor 240 to be evaluated in the present evaluation method using the apparatus for evaluating the oxygen sensor of the present embodiment and the detected characteristics of the sensor 240. Accordingly, the sensor 240 evaluated by the apparatus 200 can evaluate the excess air ratio of an engine with high precision when it is mounted actually on the engine.

According to the evaluation method 2 as described above, the sensor 240 to be evaluated is evaluated by using the excess air ratio controlled by the evaluation apparatus.

Instead of this excess air ratio controlled by the apparatus, the ratio in which the A/F sensor 253 for measuring the excess air ratio generates a rich signal can be used when an engine is feed back controlled. This rich signal is a

signal outputted when the output of A/F sensor exceeds the rated voltage (450-500 mV) as previously described.

Moreover, the apparatus 200 for evaluating the oxygen sensor can also evaluate the sensor 240 to be evaluated by using the resistance value of the sensor 240 at the excess air ratio of $\lambda = 0.90$.

As so far explained, it has been confirmed that the apparatus for evaluating the oxygen sensor of the present invention can evaluate the oxygen sensor in various methods. The apparatus for evaluating the oxygen sensor according to the present embodiment employs the evaluating manner in which engine feed back control is executed in exhaust gas generator 210, the offsetting portion 220 and rich/lean setting portion 230 respectively. Therefore, the excess air ratio of exhaust gas into which sensor 240 to be evaluated is inserted can be controlled with high precision.

In the apparatus for evaluating the oxygen sensor using the conventional burner for example, the air ratio was controlled with a precision of $\pm 0.01\ \lambda$ while the apparatus 200 for evaluating the oxygen sensor can be controlled with a precision below $\pm 0.001\ \lambda$ according to the present embodiment.

Further, the lower priced gas is used in this embodiment as compared with the oxygen gas evaluation in which the oxygen sensor is evaluated by using model gas or internal combustion engine. Thus, the oxygen sensor can be evaluated economically.

Claims

1. An apparatus for evaluating an oxygen sensor comprising:

   a device for mixing a fuel and an oxygen-containing gas in an appropriate ratio to prepare a fuel mixture;
   a burner connected to said mixing device for burning said mixture to produce a geasous combustion product;
   a tubular member extending from said burner for supplying said combustion product;
   a nozzle connected to said tubular member for introducing a fuel and an oxygen-containing gas into said tubular member downstream of said burner so that said combustion product may have a desired excess air ratio; and
   a mounting device of said sensor to be evaluated and disposed, at a point downstream of said nozzle, on said tubular member.

2. An apparatus as claimed in claim 1, wherein said apparatus further comprises a flow control device for controlling the excess air ratio at said nozzle so that the excess air ratio is substantially equal to said desired excess air ratio.

3. An apparatus as claimed in claim 2, wherein said apparatus further comprises a standard oxygen sensor disposed, near said mounting portion of said oxygen sensor to be evaluated, on said tubular member, said standard oxygen sensor substantially equalizing said excess air ratio at said nozzle with said desired excess air ratio in cooperation with said flow control device.

4. An apparatus as claimed in claim 2, wherein said apparatus further comprises a gas analyzer disposed downstream of said mounting device of said oxygen sensor to be evaluated, said gas analyzer substantially equalizing said excess air ratio at a portion of said nozzle with said desired excess air ratio in cooperation with said flow control device.

5. An apparatus as claimed in claim 1, wherein said apparatus further comprising;

   a second nozzle to supply air into said tubular member disposed, between said burner and said nozzle, on said tubular member;
   a second flow control device for substantially equalizing a value of an excess air ratio at said second nozzle with a predetermined value by sensing an excess air ratio at a point downstream of said second nozzle; and
   a third flow control device for substantially equalizing an excess air ratio of the mixture supplied to said burner with a predetermined excess air ratio.

6. An apparatus as claimed in claim 5, wherein said third flow control device includes an oxygen sensor, at a upstream portion of said second nozzle, on said tubular member.

7. An apparatus as claimed in claim 5, wherein said second flow control device includes an oxygen sensor between said nozzle and said second nozzle, on said tubular member.

8. An apparatus as claimed in claim 1, wherein flow speed of said gaseous combustion product in said tubular member

signal outputted when the output of A/F sensor exceeds the rated voltage (450-500 mV) as previously described.

Moreover, the apparatus 200 for evaluating the oxygen sensor can also evaluate the sensor 240 to be evaluated by using the resistance value of the sensor 240 at the excess air ratio of $\lambda = 0.90$.

As so far explained, it has been confirmed that the apparatus for evaluating the oxygen sensor of the present invention can evaluate the oxygen sensor in various methods. The apparatus for evaluating the oxygen sensor according to the present embodiment employs the evaluating manner in which engine feed back control is executed in exhaust gas generator 210, the offsetting portion 220 and rich/lean setting portion 230 respectively. Therefore, the excess air ratio of exhaust gas into which sensor 240 to be evaluated is inserted can be controlled with high precision.

In the apparatus for evaluating the oxygen sensor using the conventional burner for example, the air ratio was controlled with a precision of $\pm 0.01\ \lambda$ while the apparatus 200 for evaluating the oxygen sensor can be controlled with a precision below $\pm 0.001\ \lambda$ according to the present embodiment.

Further, the lower priced gas is used in this embodiment as compared with the oxygen gas evaluation in which the oxygen sensor is evaluated by using model gas or internal combustion engine. Thus, the oxygen sensor can be evaluated economically.

Claims

1. An apparatus for evaluating an oxygen sensor comprising:

   a device for mixing a fuel and an oxygen-containing gas in an appropriate ratio to prepare a fuel mixture;
   a burner connected to said mixing device for burning said mixture to produce a geasous combustion product;
   a tubular member extending from said burner for supplying said combustion product;
   a nozzle connected to said tubular member for introducing a fuel and an oxygen-containing gas into said tubular member downstream of said burner so that said combustion product may have a desired excess air ratio; and
   a mounting device of said sensor to be evaluated and disposed, at a point downstream of said nozzle, on said tubular member.

2. An apparatus as claimed in claim 1, wherein said apparatus further comprises a flow control device for controlling the excess air ratio at said nozzle so that the excess air ratio is substantially equal to said desired excess air ratio.

3. An apparatus as claimed in claim 2, wherein said apparatus further comprises a standard oxygen sensor disposed, near said mounting portion of said oxygen sensor to be evaluated, on said tubular member, said standard oxygen sensor substantially equalizing said excess air ratio at said nozzle with said desired excess air ratio in cooperation with said flow control device.

4. An apparatus as claimed in claim 2, wherein said apparatus further comprises a gas analyzer disposed downstream of said mounting device of said oxygen sensor to be evaluated, said gas analyzer substantially equalizing said excess air ratio at a portion of said nozzle with said desired excess air ratio in cooperation with said flow control device.

5. An apparatus as claimed in claim 1, wherein said apparatus further comprising;

   a second nozzle to supply air into said tubular member disposed, between said burner and said nozzle, on said tubular member;
   a second flow control device for substantially equalizing a value of an excess air ratio at said second nozzle with a predetermined value by sensing an excess air ratio at a point downstream of said second nozzle; and
   a third flow control device for substantially equalizing an excess air ratio of the mixture supplied to said burner with a predetermined excess air ratio.

6. An apparatus as claimed in claim 5, wherein said third flow control device includes an oxygen sensor, at a upstream portion of said second nozzle, on said tubular member.

7. An apparatus as claimed in claim 5, wherein said second flow control device includes an oxygen sensor between said nozzle and said second nozzle, on said tubular member.

8. An apparatus as claimed in claim 1, wherein flow speed of said gaseous combustion product in said tubular member

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is greater than 5 m/sec.

Patentansprüche

1. Vorrichtung zur Auswertung eines Sauerstoffühlers, umfassend:

   eine Vorrichtung zum Mischen eines Brennstoffes und eines sauerstoffhaltigen Gases in einem geeigneten Verhältnis zur Herstellung eines Brennstoffgemisches;
   einen Brenner, der mit der Mischvorrichtung verbunden ist, um das Gemisch zu verbrennen, so daß ein gasförmiges Verbrennungsprodukt entsteht;
   ein rohrförmiges Element, welches von dem Brenner ausgeht, um das Verbrennungsprodukt weiterzuleiten;
   eine Düse, die mit dem rohrförmigen Element verbunden ist, um einen Brennstoff und ein sauerstoffhaltiges Gas in das rohrförmige Element stromab von dem Brenner einzuleiten, so daß das Verbrennungsprodukt ein gewünschtes Luftüberschußverhältnis aufweist; und
   eine Vorrichtung zum Befestigen des Fühlers, der auszuwerten ist und an einem Punkt stromab von der Düse an dem rohrförmigen Element anzubringen ist.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Vorrichtung ferner eine Strombegrenzungseinrichtung aufweist, die das Luftüberschußverhältnis an der Düse so steuert, daß das Luftüberschußverhältnis im wesentlichen dem gewünschten Luftüberschußverhältnis entspricht.

3. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Vorrichtung ferner einen Standard-Sauerstoffühler umfaßt, der im Bereich des Befestigungsabschnitts des auszuwertenden Sauerstoffühlers auf dem rohrförmigen Element angeordnet ist, wobei der Standard-Sauerstoffühler im wesentlichen das Luftüberschußverhältnis an der Düse mit dem gewünschten Luftüberschußverhältnis in Zusammenarbeit mit der Strombegrenzungseinrichtung ausgleicht.

4. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Vorrichtung ferner ein Gasanalysegerät umfaßt, welches stromab von der Befestigungseinrichtung für den auszuwertenden Sauerstoffühler angeordnet ist, wobei das Gasanalysegerät im wesentlichen das Luftüberschußverhältnis an einem Abschnitt der Düse mit dem gewünschten Luftüberschußverhältnis in Zusammenarbeit mit der Strombegrenzungseinrichtung ausgleicht.

5. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Vorrichtung ferner umfaßt:

   eine zweite Düse, die Luft in das rohrförmige Element leitet und zwischen dem Brenner und der Düse auf dem rohrförmigen Element angeordnet ist;
   eine zweite Strombegrenzungseinrichtung, die im wesentlichen einen Wert für ein Luftüberschußverhältnis an der zweiten Düse mit einem vorbestimmten Wert ausgleicht durch Erfassen eines Luftüberschußverhältnisses an einem Punkt stromab von der zweiten Düse; und
   eine dritte Strombegrenzungseinrichtung, die im wesentlichen ein Luftüberschußverhältnis des Gemisches ausgleicht, das dem Brenner mit einem vorbestimmten Luftüberschußverhältnis zugeführt wird.

6. Vorrichtung nach Anspruch 5, dadurch gekennzeichnet, daß die dritte Strombegrenzungseinrichtung einen Sauerstoffühler aufweist in einem stromauf gelegenen Abschnitt der zweiten Düse auf dem rohrförmigen Element.

7. Vorrichtung nach Anspruch 5, dadurch gekennzeichnet, daß die zweite Strombegrenzungseinrichtung einen Sauerstoffühler zwischen der Düse und der zweiten Düse auf dem rohrförmigen Element aufweist.

8. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Geschwindigkeit des gasförmigen Verbrennungsproduktes in dem rohrförmigen Element größer ist als 5 m/sek.

Revendications

1. Appareil d'évaluation d'un capteur d'oxygène comportant:

   un dispositif pour mélanger un carburant et un gaz contenant de l'oxygène selon un rapport approprié pour

préparer un mélange de carburant;
un brûleur relié audit dispositif de mélange pour brûler ledit mélange afin de produire un produit de combustion gazeux;
un élément tubulaire s'étendant depuis ledit brûleur pour délivrer ledit produit de combustion;
une buse reliée audit élément tubulaire pour introduire un carburant et un gaz contenant de l'oxygène dans ledit élément tubulaire en aval dudit brûleur de sorte que ledit produit de combustion peut présenter un rapport d'air en excès désirée; et
un dispositif de montage dudit capteur à évaluer et disposé, en un point en aval de ladite buse, sur ledit élément tubulaire.

2. Appareil selon la revendication 1, dans lequel ledit appareil comporte en outre un dispositif de commande d'écoulement pour commander le rapport d'air en excès sur ladite buse de sorte que le rapport d'air en excès est sensiblement égal audit rapport d'air en excès désiré.

3. Appareil selon la revendication 2, dans lequel ledit appareil comporte en outre un capteur d'oxygène normalisé disposé, près de ladite partie de montage dudit capteur d'oxygène à évaluer, sur ledit élément tubulaire, ledit capteur d'oxygène normalisé égalisant sensiblement ledit rapport d'air en excès sur ladite buse avec ledit rapport d'air en excès désiré en coopération avec ledit dispositif de commande d'écoulement.

4. Appareil selon la revendication 2, dans lequel ledit appareil comporte en outre un analyseur de gaz disposé en aval dudit dispositif de montage dudit capteur d'oxygène à évaluer, ledit analyseur de gaz égalisant sensiblement ledit rapport d'air en excès en une partie de ladite buse avec ledit rapport d'air en excès désiré en coopération avec ledit dispositif de commande d'écoulement.

5. Appareil selon la revendication 1, dans lequel ledit appareil comporte en outre:

une seconde buse pour délivrer de l'air dans ledit élément tubulaire disposée,entre ledit brûleur et ladite buse, sur ledit élément tubulaire;
un second dispositif de commande d'écoulement pour égaliser sensiblement une valeur d'un rapport d'air en excès sur ladite seconde buse avec une valeur prédéterminée en détectant un rapport d'air en excès en un point en aval de ladite seconde buse; et
un troisième dispositif de commande d'écoulement pour égaliser sensiblement un rapport d'air en excès du mélange délivré audit brûleur avec un rapport d'air en excès prédéterminé.

6. Appareil selon la revendication 5, dans lequel ledit troisième dispositif de commande d'écoulement comprend un capteur d'oxygène, en une partie en amont de ladite seconde buse, sur ledit élément tubulaire.

7. Appareil selon la revendication 5, dans lequel ledit second dispositif de commande d'écoulement comprend un capteur d'oxygène entre ladite buse et ladite seconde buse, sur ledit élément tubulaire.

8. Appareil selon la revendication 1, dans lequel la vitesse d'écoulement dudit produit de combustion gazeux dans ledit élément tubulaire est supérieure à 5 m/seconde.