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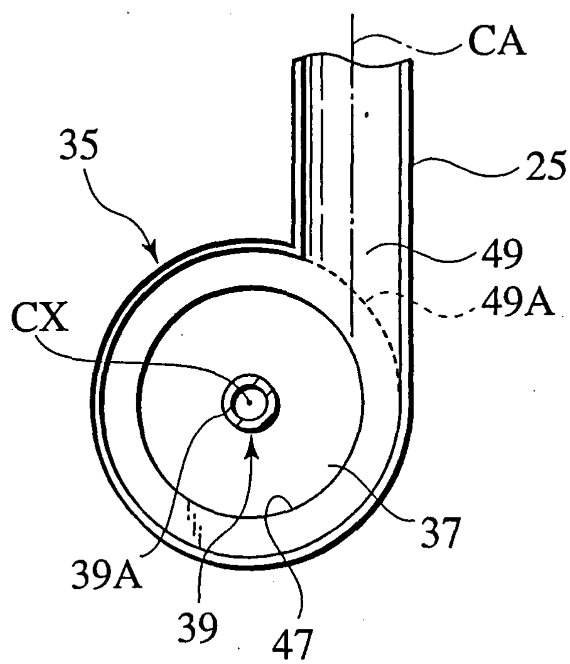
(54) **Catalytic combustor and fuel cell system**

(57) A catalytic combustor is provided with a housing supplied with mixed gas including exhaust fuel gas from a fuel electrode of a fuel cell and exhaust oxidizer gas from an oxidizer electrode of the fuel cell, and a catalyst combusting the mixed gas. At an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, and at least one of the exhaust fuel gas and the exhaust oxidizer gas is supplied to the housing in a way to generate swirl flow in the mixed gas so as to swirl along the inner peripheral surface. Such a catalytic combustor is applied to a fuel cell system provided with a fuel cell having a fuel electrode and an oxidizer electrode.

FIG.4B



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a catalytic combustor and a fuel cell system and, more particularly, to a catalytic combustor and a fuel cell system wherein mixed gas containing exhaust fuel and exhaust oxidizing agent from a fuel electrode and an oxidizer electrode of a fuel cell, respectively, is combusted using a catalyst.

[0002] Japanese Patent Application Laid-Open Publication No. 2002-231294 discloses a structure wherein when discharging exhaust fuel, expelled from a fuel electrode of a fuel cell, to an outside through a purge conduit, exhaust fuel is combusted with a catalytic combustor.

SUMMARY OF THE INVENTION

[0003] However, according to the present inventors, such a structure is conceived to encounter a tendency in that if the catalytic combustor is intermittently supplied with exhaust fuel each for a short time interval, water generated through condensation of exhaust fuel enters an interior of the catalytic combustor with a resultant loss in an activity of a catalyst due to water being absorbed therein.

[0004] The present invention has been completed upon such studies by the present inventors and has an object to provide a catalytic combustor and a fuel cell system that can reliably combust exhaust fuel from a fuel cell in a catalytic combustor.

[0005] To achieve the above object, one aspect of the present invention is a catalytic combustor comprising: a housing supplied with mixed gas including exhaust fuel gas from a fuel electrode of a fuel cell and exhaust oxidizer gas from an oxidizer electrode of the fuel cell; and a catalyst combusting the mixed gas, wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, and at least one of the exhaust fuel gas and the exhaust oxidizer gas is supplied to the housing in a way to generate swirl flow in the mixed gas so as to swirl along the inner peripheral surface.

[0006] In the meantime, another aspect of the present invention is a fuel cell system comprising: a fuel cell having a fuel electrode and an oxidizer electrode; and a catalytic combustor provided with: a housing supplied with mixed gas including exhaust fuel gas from a fuel electrode of a fuel cell and exhaust oxidizer gas from an oxidizer electrode of the fuel cell; and a catalyst combusting the mixed gas, wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, and at least one of the exhaust fuel gas and the exhaust oxidizer gas is supplied to the housing in a way to generate swirl flow in the mixed gas so as to swirl along the inner peripheral surface.

[0007] On the other hand, another aspect of the present invention is a method of supplying gas to a catalytic combustor provided with a housing supplied with mixed gas including exhaust fuel gas from a fuel electrode of a fuel cell and exhaust oxidizer gas from an oxidizer electrode of the fuel cell, and a catalyst combusting the mixed gas, wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, the method comprising: supplying at least one of the exhaust fuel gas and the exhaust oxidizer gas to the housing so as to generate swirl flow to occur in the mixed gas so as to swirl along the inner peripheral surface.

[0008] Other and further features, advantages, and benefits of the present invention will become more apparent from the following description taken in conjunction with the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is an overall structural view showing a fuel cell system equipped with a catalytic combustor of a first embodiment according to the present invention;

Fig. 2A is a side cross sectional view showing an internal structure of the catalytic combustor shown in Fig. 1, and Fig. 2B is a cross sectional view taken on a line A-A of Fig. 2A, respectively in the first embodiment;

Fig. 3A is a cross sectional view showing an internal structure of a nozzle distal end of the catalytic combustor that supplies anode off-gas, Fig. 3B is a cross sectional view taken on a line B-B of Fig. 3A, Fig. 3C is a cross sectional view taken on a line C-C of Fig. 3A and Fig. 3D is a cross sectional view taken on a line D-D of Fig. 3A, respectively in the first embodiment;

Fig. 4A is a side cross sectional view showing an internal structure of a catalytic combustor of a second embodiment according to the present invention, and Fig. 4B is a cross sectional view taken on line E-E of Fig. 4A in the second embodiment;

Fig. 5 is an illustrative view showing a state where cathode off-gas flows in the catalytic combustor of the second embodiment;

Fig. 6A is a side cross sectional view showing an internal structure of a catalytic combustor of a third embodiment of the present invention and Fig. 6B is a cross sectional view taken on line F-F of Fig. 6A in the third embodiment; and

Fig. 7 is an illustrative view showing a state where cathode off-gas and anode off-gas flow in a catalytic combustor of the third embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] A catalytic combustor and a fuel cell system of each embodiment according to the present invention are described hereunder with reference to Figs. 1 to 7.

(First Embodiment)

[0011] First, a catalytic combustor and a fuel cell system of a first embodiment according to the present invention are described in detail with reference to Figs. 1 to 3D.

[0012] Fig. 1 is an overall structural view showing a fuel cell system S equipped with a catalytic combustor of the presently filed embodiment.

[0013] In Fig. 1, a fuel cell 1 is comprised of an anode electrode 3, serving as a fuel electrode, and a cathode electrode 5 serving as an oxidizer electrode. An inlet 3a of the anode electrode 3 is supplied with fuel gas from a fuel gas supply unit 7 via a fuel gas supply conduit 9 and an inlet 5a of the cathode electrode 5 is supplied with oxidizing agent gas from an oxidizing agent gas supply unit 11 via an oxidizing agent gas supply conduit 13, thereby permitting the fuel cell 1 to achieve electrochemical reaction to generate electric power. Here, hydrogen gas is used as fuel gas, and air is used as oxidizing agent gas (oxidizer). Incidentally, interleaved between the anode electrode 3 and the cathode electrode 5 is an electrolyte layer 4, and a plurality of structural bodies, each composed of the anode electrode 3, the electrolyte 4 and the cathode electrode 5, may be employed in a stack via a separator, which is not shown, for suitably intervening between the adjacently disposed structural bodies.

[0014] During electric power generation of the fuel cell 1, anode off-gas, which is not used and remains as exhaust fuel, is expelled from an outlet 3b of the anode electrode 3, and cathode off-gas, which is not used and remains as exhaust oxidizing agent, is expelled from an outlet 5b of the cathode 5. Further, typically, when using a solid polymer electrolyte of a proton conductivity as electrolyte of the electrolyte layer 4, cathode off-gas contains moisture content as a result of electric power generation. Additionally, it is conceived that anode off-gas contains moisture content due to water that is reversely dispersed from the cathode electrode 5 to the anode electrode 3.

[0015] Connected between the outlet 3b of the anode electrode 3 and the fuel gas supply conduit 9 is an anode off-gas recirculation conduit 17 that serves as a recirculation flow passage equipped with an anode off-gas recirculation device 15.

[0016] Connected to the anode off-gas recirculation device 15 through an anode off-gas supply conduit 21 through an anode off-gas exhaust valve 19, serving as an opening and closing valve, is a catalytic combustor 23.

[0017] The catalytic combustor 23 and an outlet 5b of the cathode electrode 5 of the fuel cell 1 are connected to one another through a cathode off-gas supply conduit 25. An exhaust pipe 27 is connected to the catalytic combustor 23 at a position opposite to the inlet to which the cathode off-gas supply conduit 25 is connected.

[0018] Incidentally, each functional component element of the fuel cell system is preferably controlled by a system controller 33. Typically, in respect of control of the anode off-gas exhaust valve 19, a voltage sensor 31 is disposed in the fuel cell 1 and if the voltage sensor 31 detects a lower voltage than a predetermined voltage, the system controller 33 is operative to open the anode off-gas exhaust valve 19 in response to a purge signal delivered from the system controller 33, thereby permitting anode off-gas to be supplied to the catalytic combustor 23 from the anode off-gas recirculation device 15 at a predetermined flow rate.

[0019] Fig. 2A is a side cross sectional view showing an internal structure of the catalytic combustor 23, and Fig. 2B is a cross section taken on line A-A of Fig. 2A.

[0020] As shown in Figs. 2A and 2B, the catalytic combustor 23 includes a housing 35 formed in a cylindrical shape symmetric with respect to a central axis CX. The cathode off-gas supply conduit 25 is connected to a substantially center of one end (an introducing end) 35a of the housing 35, and the exhaust pipe 27 is connected to a substantially center of the other end (an exhausting end) 35b. And, a catalyst 37 is accommodated in the housing 35 in an area closer to the exhaust pipe 27 for enabling combustion of mixed gas (especially anode off-gas) between anode off-gas and cathode off-gas.

[0021] On the other hand, the anode off-gas supply conduit 21 with a circular cross section is inserted to an interior of the housing 35 through a cylindrical section 35c of the housing 35 at an area in the vicinity of the introducing end 35a. The nozzle 39, serving as a fuel supply port of the anode off-gas supply conduit 21 inserted to the interior of the housing 35 from the cylindrical section 35c, includes a base portion 39a extending toward a central portion of the housing 35 in a radial direction perpendicular to the central axis CX of the housing 35, a bent portion 39b bent from the base portion 39a toward the catalyst 37 at an angle of 90 degrees in a circular arc configuration, and a distal end portion 39c extending from the bent portion 39b toward the catalyst 37 so as to allow a distal end of the bent portion 39b to extend along the central axis CX so as to open to the catalyst 37, with a central axis of a circular cross section of the distal end 39c being held in alignment with the central axis CX of the circular cross section of the housing 35.

[0022] Fig. 3A is a cross sectional view showing an internal structure of the distal end portion 39c of the nozzle 39 by which anode off-gas is supplied, Fig. 3B is a cross sectional view taken on line B-B of Fig. 3A, Fig. 3C is a cross sectional view taken on line C-C of Fig. 3A, and Fig. 3D is a cross sectional view taken on line

D-D of Fig. 3A.

[0023] In Figs. 3A to 3D, the distal end portion 39c of the nozzle 39 takes the form of the same channel structure (flow passage structure) as that used for a so-called swirl type liquid injection valve and causes anode off-gas, supplied into the catalytic combustor 23, to generate a swirl flow along an inner peripheral wall of the cylindrical portion 35c.

[0024] That is, as shown in Fig. 3A and Fig. 3B that is the cross section, taken on line B-B, of Fig. 3A, formed on an upstream of the distal end portion 39c are communicating apertures 41, 41 that respectively extend in directions (directions perpendicular to a paper surface of the figure) parallel to the central axis CX at two upper and lower positions in the figure. As shown in Fig. 3A and Fig. 3C that is the cross section, taken along C-C, of Fig. 3A, formed on the distal end portion 39c at a position downstream of the communicating apertures 41, 41 in point symmetry with respect to the central axis CX are respectively communicating channels 43, 43, whose outer peripheral terminal portions 43a, 43a, as shown in Fig. 3C, respectively communicate with the communicating apertures 41, 41, and which respectively extend in directions parallel to one another with a predetermined distance. Additionally, inner peripheral terminal portions 43b, 43b of the respective communicating channels 43, 43, shown in Fig. 3C, respectively communicate with an outer periphery of an ejector channel 45 located at a central position of the cylindrical portion 35c, as shown in Fig. 3D that is the cross section, taken on line D-D, of Fig. 3A. The ejector channel 45 extends parallel to the central axis CX to be in communication with an interior of the cylindrical portion 35c.

[0025] With such a structure of the distal end portion 39c of the nozzle 39, anode off-gas ejecting from the ejector channel 45 is enabled to form swirl flow SW, of mixed gas also containing cathode off-gas, which flows into the cylindrical portion 35c of the housing 35 while swirling along the inner peripheral surface of the cylindrical portion 35c. The uppermost upstream portion (a portion extending along a circumferential direction of an inner periphery of the cylindrical portion 35c and shown as an upstream position P for the sake of convenience) of an area at which such resulting swirl flow SW impinges upon the inner peripheral surface of the cylindrical portion 35c is set to be located upstream (rightward in Fig. 2A) of the catalyst 37.

[0026] Still also, formed between the upstream position P of swirl flow SW and the catalyst 37 is an annular protrusion 47 that protrudes toward a center in the radial direction of the cylindrical portion 35c of the housing 35. Also, in the figure, typically, the protrusion 47 is shown as having a cross sectional shape in a triangular configuration.

[0027] Next, operation of the above-described structure of the fuel cell system S is described in detail.

[0028] During normal operation of the fuel cell system, an entire flow of anode off-gas expelled from the outlet 3b of the anode electrode 3 is recirculated to the fuel gas recirculation conduit 9 via the anode off-gas recirculation conduit 17 by the anode off-gas recirculation device 15 and is supplied to the inlet 3a of the anode electrode 3 again. With such a structure, during normal operation, the fuel cell system provides improved fuel consumption.

[0029] In the meanwhile, cathode off-gas expelled from the outlet 5b of the cathode electrode 5 has no recirculation line and exhausted to the outside of the fuel cell system through the catalytic combustor 23 and the exhaust pipe 27.

[0030] Here, if the hydrogen concentration in anode off-gas to be recirculated through the anode off-gas recirculation device 15 drops equal to or below a predetermined concentration due to nitrogen or moisture reversely diffused to the anode electrode 3 from the cathode electrode 5, the result is that the output voltage of the fuel cell 1 tends to drop.

[0031] The output voltage of such a fuel cell 1 is detected by the voltage sensor 31 and, if the system controller 33 discriminates that such a detected voltage is lower than a predetermined voltage level, the anode off-gas exhaust valve 19 is opened. This allows anode off-gas to be delivered through the anode off-gas supply conduit 21 from the anode off-gas recirculation device 15 at a predetermined flow rate to be mixed with cathode off-gas to form mixed gas, which is supplied to the catalytic combustor 23.

[0032] In the catalytic combustor 23, anode off-gas delivered through the anode off-gas supply conduit 21 is discharged from the nozzle 39 that protrudes in the housing 35. Inside the nozzle 39, as shown in Figs. 3A to 3D, anode off-gas reaches the communicating channels 43, 43 through the communicating apertures 41, 41 and when flowing through the communicating channels 43, 43 toward the center of the cylindrical portion 35c of the housing 35, anode off-gas flows out to the outer peripheral side of the ejecting channel 45 whereby anode off-gas flows toward the catalyst 37 in Fig. 2A and forms swirl flow SW that turns clockwise in Fig. 2B.

[0033] That is, such swirl flow SW flows out into the cylindrical portion 35c of the housing 35 through the ejector channel 45.

[0034] Here, when supplying anode off-gas to the catalytic combustor 23, it is conceived that steam contained in anode off-gas is condensed in the anode off-gas supply conduit 21 to form liquid water that is to enter the housing 35.

[0035] Such condensed water is formed in a substantially hollow cone-shaped mist flow due to swirl flow SW and is dispersed in water droplets W toward the outer peripheral wall in the radial direction of the cylindrical portion 35c of the housing 35 in a way to reach the inner peripheral wall of the cylindrical portion 35c (schematically shown to remain in a regional area outside a dotted area in which swirl flow SW is present). With such a structure, condensed water can be avoided from directly reaching the catalyst 37 of the catalytic combustor 23 and the catalyst 37 can be prevented from being deteriorated in an activity, and thus, anode off-gas can be combusted in the catalyst 37 in a reliable manner.

[0036] Still also, here, with the annular protrusion 47 being formed over the inner peripheral wall of the cylindrical portion 35c of the housing 35 at the area close proximity to the catalyst 37, even in the presence of a situation where water droplets W and a part of hollow cone-shaped mist flow, containing water droplets W, are probable to reach not only the inner peripheral wall of the cylindrical portion 35c, but also the catalyst 37, the water droplets W and the portion of hollow cone-shaped mist flow, which would tend to reach the catalyst 37, can be avoided from reaching the catalyst 37. With such a structure, the water droplets W and the hollow cone-shaped mist flow are blocked from traveling toward the catalyst 37, thereby enabling condensed water to be reliably avoided from being deposited to the catalyst 37.

[0037] Further, in the meanwhile, it is supposed that when cathode off-gas is discharged toward the catalytic combustor 23, steam contained in cathode off-gas is condensed in the cathode off-gas supply conduit 25 to form liquid water which flows into the housing 35. Inside the housing 35, since because of the presence of swirl flow SW, cathode off-gas flows into the upstream area of the catalytic combustor 23 and is mixed with anode off-gas prior to reaching the catalyst 37, condensed water contained in cathode off-gas is similarly dispersed in water droplets W to deposit onto the inner peripheral wall of the cylindrical portion 35c and is also blocked by the annular protrusion 47, water droplets W can be blocked by the annular protrusion 47 and prevented from being deposited onto the catalyst 37 in the same way as that achieved in respect of anode off-gas from which steam is blocked from getting the catalyst 37.

[0038] Incidentally, no limitation for the shapes, positional relationships and the number of pieces of various component parts of the presently filed embodiment is intended, and other shapes or the like may be used provided that similar functions are exhibited. The shape of the nozzle 39 disposed in the anode off-gas supply conduit 21 is not limited to a particular cylindrical shape and may take the form of a configuration to enables swirl flow to be creased with no excess and shortage. The number of pieces and layout of the communicating apertures 41 and the communicating channels 43 are not limitative, and these components may be arranged in a suitable number of pieces and layout capable for swirl flow to be generated. The housing 35 is not limited to a particular cylindrical shape and may be formed in a curved shape, which continuously varies, so as to enable swirl flow to turn, with no undesired attenuation caused in swirl flow, in the direction along the inner peripheral wall of the housing 35. The number of pieces and the shape of the annular protrusion 47 are not limitative and may be suffice to be formed in a suitable arrangement to enable water droplets from getting the catalyst.

(Second Embodiment)

[0039] Next, a catalytic combustor and a fuel cell system of a second embodiment according to the present invention are described below in detail with reference to Figs. 4A to 5. The presently filed embodiment mainly differs from the first embodiment in respect of a connecting structure of the anode of-gas supply conduit 21 and the cathode of-gas supply conduit 25 with respect to the housing 35 of the catalytic combustor 23, and a main differing point resides in that swirl flows are generated not only in anode off-gas but also in cathode off-gas, and the other structure is similar to that of the first embodiment. Thus, like component parts bear the same reference numerals as those of the first embodiment, with description being made in a suitably simplified fashion or omitted.

[0040] Fig. 4A is a side cross sectional view showing an internal structure of the catalytic combustor 23 of the presently filed embodiment, Fig. 4B is a cross section, taken on line E-E, of Fig. 4A and Fig. 5 is an illustrative view showing a status where cathode off-gas flows in the catalytic combustor 23.

[0041] As shown in Figs. 4A and 4B, the anode off-gas supply conduit 21 is connected to a central part of one end wall (introducing end wall) 35a of the housing 35 of the catalytic combustor 23 along the central axis CX and the nozzle 39, forming a fuel supply port, is inserted through the housing 35. The nozzle 39 extends on the central axis CX, with a distal end portion 39A having a structure, similar to that of the first embodiment shown in Fig. 3, which forms swirl flow SW swirling along the inner peripheral surface of the cylindrical portion 35c of the housing 35. That is, the distal end portion 39A of the nozzle 39 is provided with the communicating apertures 41, 41, the communicating channels 43, 43 and the ejector channel 45 in the same manner as shown in Fig. 3.

[0042] In the meanwhile, the cathode off-gas supply conduit 25 is connected to the cylindrical portion 35c, in a way to be oriented along a deviated direction CA that is not directed toward the central axis CX of the cylindrical portion 35c, that is, with respect to the cylindrical portion 35c of the housing 35, in a way to extend along the direction CA that is perpendicular to the central axis CX of the cylindrical portion 35c as shown in Fig. 4A and separated from the central axis CX of the cylindrical portion 35c as shown in Fig. 4B. A distal end of the cathode off-gas supply conduit 25 has a discharge port 49 that serves as a supply section for supplying cathode off-gas involving oxidizing agent.

[0043] In particular, the cathode off-gas supply conduit 25 is connected to the cylindrical portion 35c of the housing 35 with respect of the inner peripheral surface thereof such that, as shown in Fig. 4B, a right end portion, which forms the outermost area to cause swirl flow, extends along a tangential line of the inner peripheral surface of the cylindrical portion 35c while a left end portion, which forms the innermost area to cause swirl flow, terminates in the inner peripheral surface of the cylindrical portion 35c at a position displaced rightward from the central axis CX. Further, as a result of such structure, the discharge port 49 of the cathode off-gas supply conduit 25 penetrates through the cylindrical portion 35c of the housing 35, and a boundary surface 49A between the cathode off-gas supply conduit 25 and the interior of the cylindrical portion 35c of the housing 35 lies along a part of the inner peripheral surface of the cylindrical portion 35c. Also, such a discharge port 49 is located at a position closer to the introducing end wall 35a of the housing 35 than the distal end 39A of the nozzle 39 as viewed in Fig. 4A. With such a structure, as shown in Fig. 5, cathode off-gas ejecting from the discharge port 49 can be supplied into the housing 35 as swirl flow SWA, with no occurrence of undesired interference with swirl flow SW of anode off-gas, while swirling along the circumferential inner peripheral surface of the cylindrical portion 35c of the housing 35. Also, a direction in which swirl flow SWA of cathode off-gas shown in Fig. 5 occurs is clockwise, that is, in the same direction as that of swirl flow SW of anode off-gas.

[0044] Here, when cathode off-gas is discharged into the catalytic combustor 23, it is conceived that steam in cathode off-gas is condensed in the cathode off-gas supply conduit 25 to form liquid water which enters the housing 35.

[0045] Such condensed water is subject to swirl flow SWA of cathode off-gas and is dispersed by a centrifugal force, as shown in Fig. 5, to be formed into water droplets W that deposit to the inner peripheral surface of the cylindrical portion 35c of the housing 35. With such a structure, this avoids condensed water from directly reaching the catalyst 37 to preclude the catalyst 37 from loosing an activity, thereby enabling anode off-gas to be reliably combusted.

[0046] Further, the protrusion 47, which is formed on the inner peripheral wall of the cylindrical portion 35c of the housing 35 in an annular configuration at the area near the catalyst 37, blocks the flow of condensed water from traveling to the catalyst 37, thereby condensed water to be reliably protected from depositing to the catalyst 37.

[0047] Furthermore, like in the first embodiment, since swirl flow SW occurs in anode off-gas supplied from the nozzle 39A of the anode off-gas supply conduit 21, condensed water in anode off-gas is dispersed onto the outer peripheral side within the housing 35, thereby enabling condensed water from depositing to the catalyst 37.

[0048] Incidentally, while the presently filed embodiment has been described in conjunction with the structure wherein the nozzle 39A of the anode off-gas supply conduit 21 also forms swirl flow SW, it is, of course, to be noted that another alternative may be employed wherein such a structure can be omitted to allow only swirl flow SWA to occur in cathode off-gas, with anode off-gas being supplied to the housing 35 without causing swirl flow SW.

(Third Embodiment)

[0049] Next, a catalytic combustor and a fuel cell system of a third embodiment according to the present invention are described below in detail with reference to Figs. 6A to 7. The presently filed embodiment mainly differs from the second embodiment in respect of a connecting structure of the anode of-gas supply conduit 21 and the cathode of-gas supply conduit 25 with respect to the housing 35 of the catalytic combustor 23, and a main different point resides in that, in order for swirl flow to be generated not only in anode off-gas but also in cathode off-gas, the anode off-gas supply conduit 21 and the cathode off-gas supply conduit 25 are concentrically connected to the housing 35, and the other structure is similar to the second embodiment. Thus, like component parts bear the same reference numerals as those of the first embodiment, with description being made in a suitably simplified form or omitted.

[0050] As shown in Figs. 6A and 6B, the connecting structure, in the presently filed embodiment, of the cathode off-gas supply conduit 25 with respect to the housing 35 is identical to that of the cathode off-gas supply conduit 25 in the second embodiment shown in Fig. 4. And, the anode off-gas supply conduit 21 is located inside such structured cathode off-gas supply conduit 25 and connected to the housing 35 concentrically with the cathode off-gas supply conduit 25 along a central axis CX'. More particularly, a nozzle 39B, forming a fuel supply port, of the anode off-gas supply conduit 21 is accommodated in the cathode off-gas supply conduit 25 so as to lie on the same plane as the boundary surface 49A of the discharge port 49 of the cathode off-gas supply conduit 25 or to be located in a position proximity to the boundary surface 49A at an area outside thereof. Such a layout position of the nozzle 39B of the anode off-gas supply conduit 21 is determined so as to assume a position such that a direction in which anode off-gas is supplied into the cylindrical portion 35c is oriented in substantially the same direction as the direction in which cathode off-gas is supplied through the discharge port 49 of the cathode off-gas supply conduit 25 whereby swirl flow is formed in anode off-gas per se without undesirably and adversely affecting swirl flow of cathode off-gas.

[0051] And, a direction in which anode off-gas is supplied through the nozzle 39B of the anode off-gas supply conduit 21 is oriented in the same direction as the direction in which cathode off-gas is supplied through the discharge port 49 of the cathode off-gas supply conduit 25 to allow anode off-gas to be supplied into the housing 35 along the circular inner peripheral surface of the cylindrical portion 35c of the housing 35 and mixed with cathode off-gas to form mixed gas with swirl flow SW swirling along the inner peripheral surface of the cylindrical portion 35c of the housing 35 being formed.

[0052] Even with such a structure, since swirl flow can be generated in cathode off-gas inside the cylindrical portion 35c of the housing 35 of the catalytic combustor 23 and also anode off-gas is supplied in the same direction as cathode off-gas, anode off-gas is similarly able to form swirl flow. That is, as shown in Fig. 7, swirl flows SW can be formed in cathode off-gas and anode off-gas and therefore condensed water contained in anode off-gas and cathode off-gas is dispersed in the inner peripheral surface of the cylindrical portion 35c of the housing 35 due to centrifugal forces exerted by swirl flows SW with a resultant formation of water droplets W that can deposit to the inner peripheral surface of the cylindrical portion 35c. Such a structure enables condensed water to be blocked from directly getting the catalyst 37 and to preclude the catalyst 37 from being deteriorated in activity and thus, anode off-gas can be reliably combusted.

[0053] Incidentally, while the presently filed embodiment has been described with reference to the structure wherein the anode off-gas supply conduit 21 is disposed inside the cathode off-gas supply conduit 25, the cathode off-gas supply conduit 25 may be disposed inside the anode off-gas supply conduit 21.

[0054] With the various embodiments according to the present invention set forth above, since an inner peripheral shape, in cross section, of the housing of the catalytic combustor, intersecting a direction in which mixed gas between exhaust fuel and exhaust air flows into the catalyst, is typically formed to have the substantially circular configuration to allow exhaust fuel and exhaust air to be supplied to the interior of the housing at the areas upstream of the catalyst of the catalytic combustor such that swirl flow occurs along the inner peripheral surface of the housing, condensed water involved in exhaust fuel and exhaust air can be dispersed toward the outer peripheral side of the housing to avoid condensed water from adhering to the catalyst for thereby precluding the catalyst from deteriorated in activity, thereby enabling mixed gas, especially exhaust fuel, expelled from the fuel cell to be reliably combusted.

[0055] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the teachings. The scope of the invention is defined with reference to the following claims.

Claims

1. A catalytic combustor (23) comprising:

a housing (35) supplied with mixed gas including exhaust fuel gas from a fuel electrode (3) of a fuel cell (1) and exhaust oxidizer gas from an oxidizer electrode (5) of the fuel cell; and
a catalyst (37) combusting the mixed gas,

wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, and at least one of the exhaust fuel gas and the exhaust oxidizer gas is supplied to the housing in a way to generate swirl flow (SW) in the mixed gas so as to swirl along the inner peripheral surface.

2. The catalytic combustor according to claim 1, wherein the inner peripheral surface is a cylindrical surface.

3. The catalytic combustor according to claim 1, wherein supplying at least one of the exhaust fuel gas and the exhaust oxidizer gas into the housing while causing swirl flow (SW, SWA) to occur therein allows the swirl flow (SW) to occur in the mixed gas.

4. The catalytic combustor according to claim 3, wherein an exhaust fuel supply port (39) supplying the exhaust fuel gas to the housing (35) is placed in opposition to the catalyst (37) and disposed along a central axis (CX) of the inner peripheral surface of the housing.

5. The catalytic combustor according to claim 4, wherein the exhaust fuel supply port (39) causes swirl flow (SW) in the exhaust fuel gas.

6. The catalytic combustor according to claim 3, wherein an exhaust oxidizer supply port (49) supplying the exhaust oxidizer gas to the housing (35) includes a portion connected to the inner peripheral surface of the housing in a tangential direction thereof.

7. The catalytic combustor according to claim 6, wherein the exhaust oxidizer supply port (49) causes swirl flow (SWA) to occur in the exhaust oxidizer gas.

8. The catalytic combustor according to claim 3, wherein an exhaust fuel supply port (39B) supplying the exhaust fuel gas to the housing (35) is disposed in an exhaust oxidizer supply port (49) supplying the exhaust oxidizer gas to the housing so as to allow the exhaust fuel gas to be supplied in a direction as same as that of the exhaust oxidizer gas.

9. The catalytic combustor according to claim 1, wherein the inner peripheral surface of the housing (35) includes an annular protrusion (47) that protrudes inward from the inner peripheral surface at an area upstream of the catalyst (37).

10. A fuel cell system (S) comprising:

a fuel cell (1) having a fuel electrode (3) and an oxidizer electrode (5); and
a catalytic combustor (23) provided with:

a housing (35) supplied with mixed gas including exhaust fuel gas from a fuel electrode of a fuel cell and exhaust oxidizer gas from an oxidizer electrode of the fuel cell; and
a catalyst (37) combusting the mixed gas,

wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, and at least one of the exhaust fuel gas and the exhaust oxidizer gas is supplied to the housing in a way to generate swirl flow (SW) in the mixed gas so as to swirl along the inner peripheral surface.

11. The fuel cell system according to claim 10, further comprising:

a recirculation passage (17) supplying the exhaust fuel gas from the fuel electrode to the fuel electrode;
an exhaust fuel gas supply passage (21) supplying the exhaust fuel gas from a midcourse of the recirculation passage to the catalytic combustor (23); and
a valve (19) disposed in the recirculation passage and operative to be opened to supply the exhaust fuel gas to the catalytic combustor.

12. The fuel cell system according to claim 10, wherein the inner peripheral surface is a cylindrical surface.

13. The fuel cell system according to claim 10, wherein supplying at least one of the exhaust fuel gas and the exhaust oxidizer gas into the housing while causing swirl flow (SW, SWA) to occur therein allows the swirl flow (SW) to occur in the mixed gas.

14. The fuel cell system according to claim 13, wherein an exhaust fuel supply port (39) supplying the exhaust fuel gas to the housing (35) is placed in opposition to the catalyst (37) and disposed along a central axis (CX) of the inner peripheral surface of the housing.

15. The fuel cell system according to claim 14, wherein the exhaust fuel supply port (39) causes the swirl flow (SW) in the exhaust fuel gas.

16. The fuel cell system according to claim 13, wherein an exhaust oxidizer supply port (49) supplying the exhaust oxidizer gas to the housing (35) includes a portion connected to the inner peripheral surface of the housing in a tangential direction thereof.

17. The fuel cell system according to claim 16, wherein the exhaust oxidizer supply port (49) causes swirl flow (SWA) to occur in the exhaust oxidizer gas.

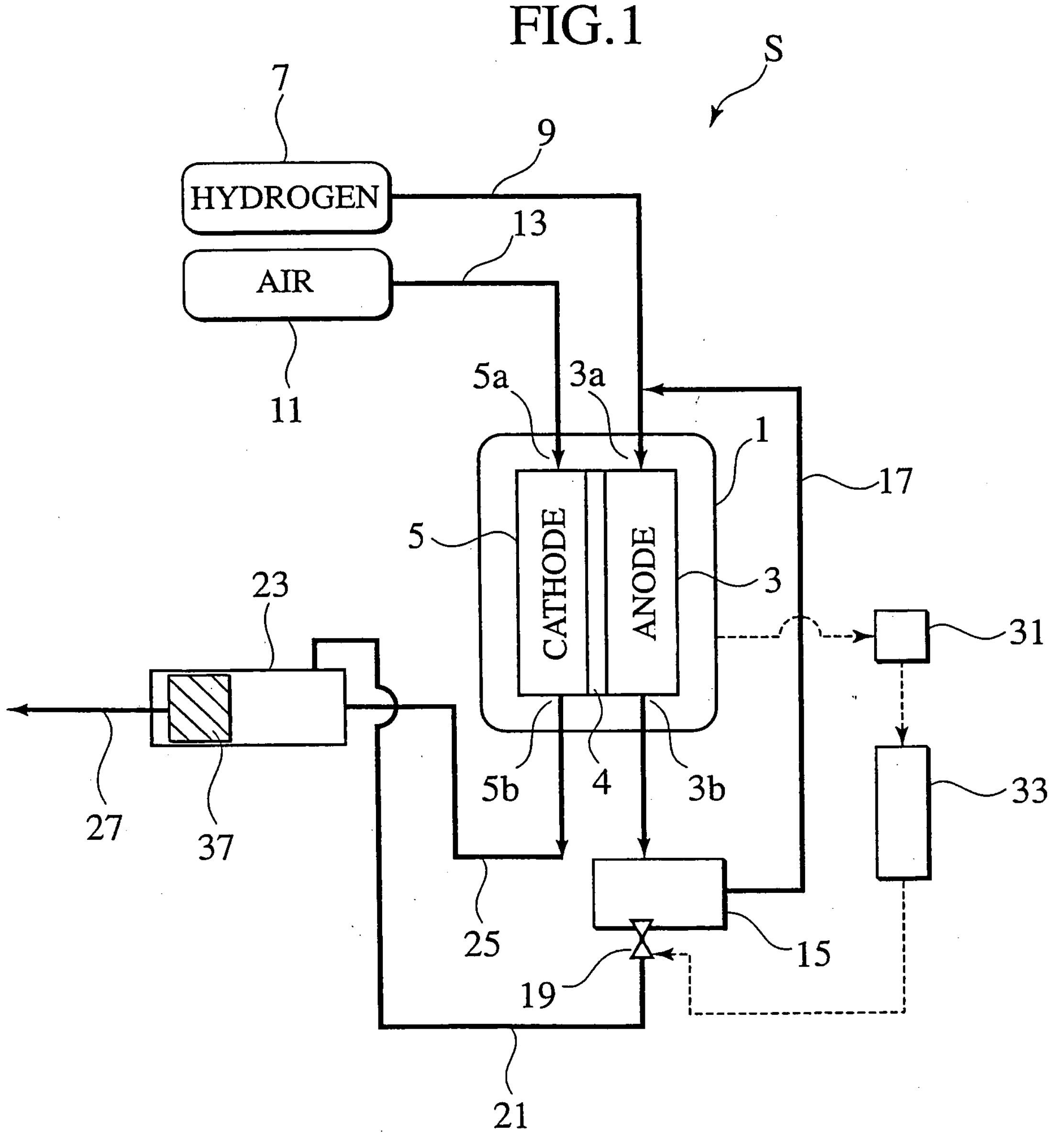
18. The fuel cell system according to claim 13, wherein an exhaust fuel supply port (39B) supplying the exhaust fuel gas to the housing (35) is disposed in an exhaust oxidizer supply port (49) supplying the exhaust oxidizer gas to the housing so as to allow the exhaust fuel gas to be supplied in a direction as same as that of the exhaust oxidizer gas.

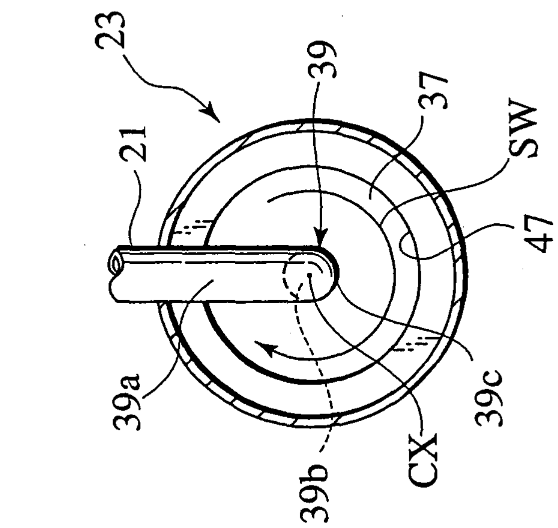
19. The fuel cell system according to claim 10, wherein the inner peripheral surface of the housing (35) includes an annular protrusion (47) that protrudes inward from the inner peripheral surface at an area upstream of the catalyst (37).

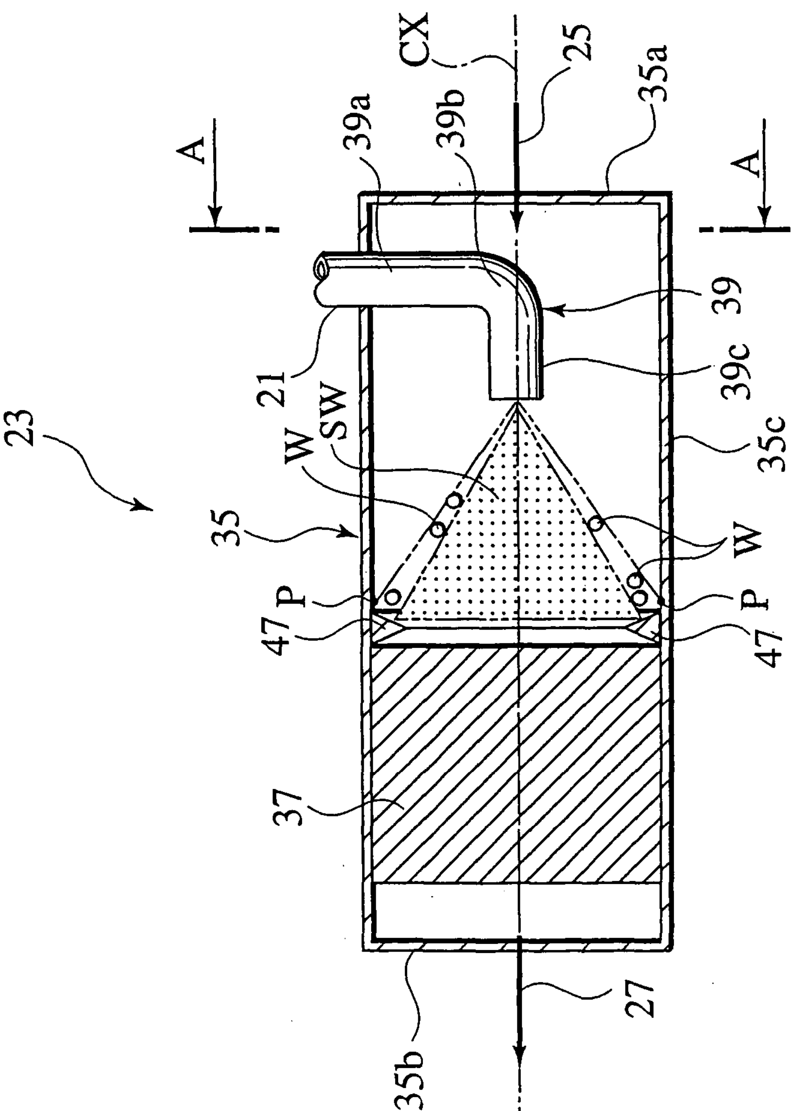
20. A method of supplying gas to a catalytic combustor (23) provided with a housing (35) supplied with mixed gas including exhaust fuel gas from a fuel electrode (3) of a fuel cell (1) and exhaust oxidizer gas from an oxidizer electrode (5) of the fuel cell, and a catalyst (37) combusting the mixed gas, wherein at an area upstream of the catalyst, an inner periphery surface of the housing has a continuous shape, the method comprising:

supplying at least one of the exhaust fuel gas and the exhaust oxidizer gas to the housing so as to generate swirl flow (SW) to occur in the mixed gas so as to swirl along the inner peripheral surface.

FIG.1


S
7
HYDROGEN
9
13
AIR
11
5a
3a
1
17
5
CATHODE
ANODE
3
23
31
33
27
37
5b
4
3b
25
15
19
21


23
21
39
37
SW
47
39a
39b
CX
39c
FIG.2B


23
A
A
CX
25
35a
39a
39b
39
39c
21
SW
W
35
W
35c
P
P
47
47
37
27
35b
FIG.2A

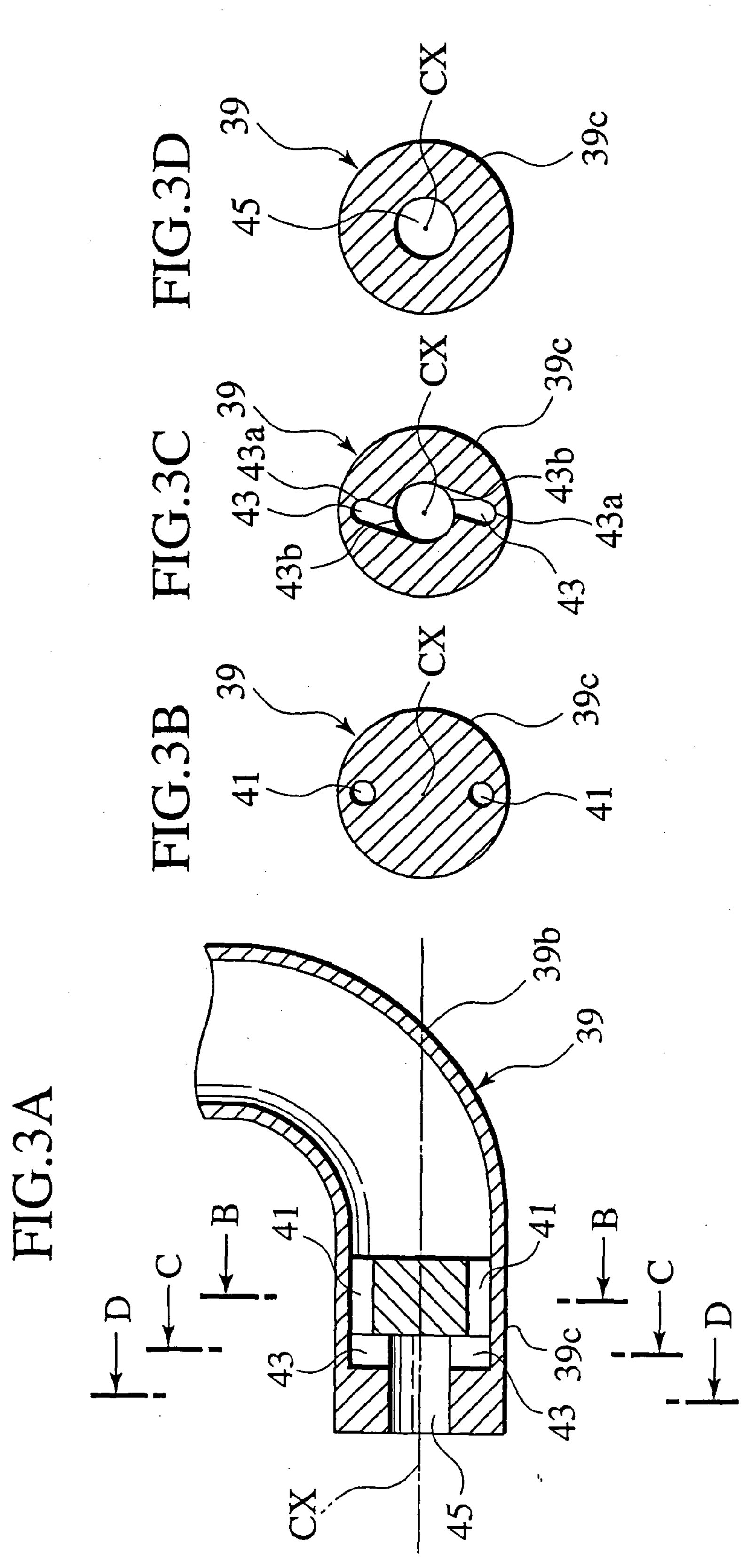


FIG.3A FIG.3B FIG.3C FIG.3D

FIG.4B

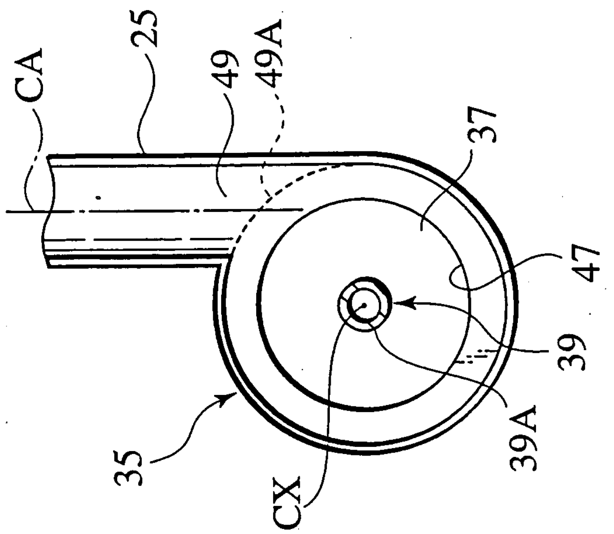

CA
25
49
49A
37
47
39
39A
35
CX

FIG.4A

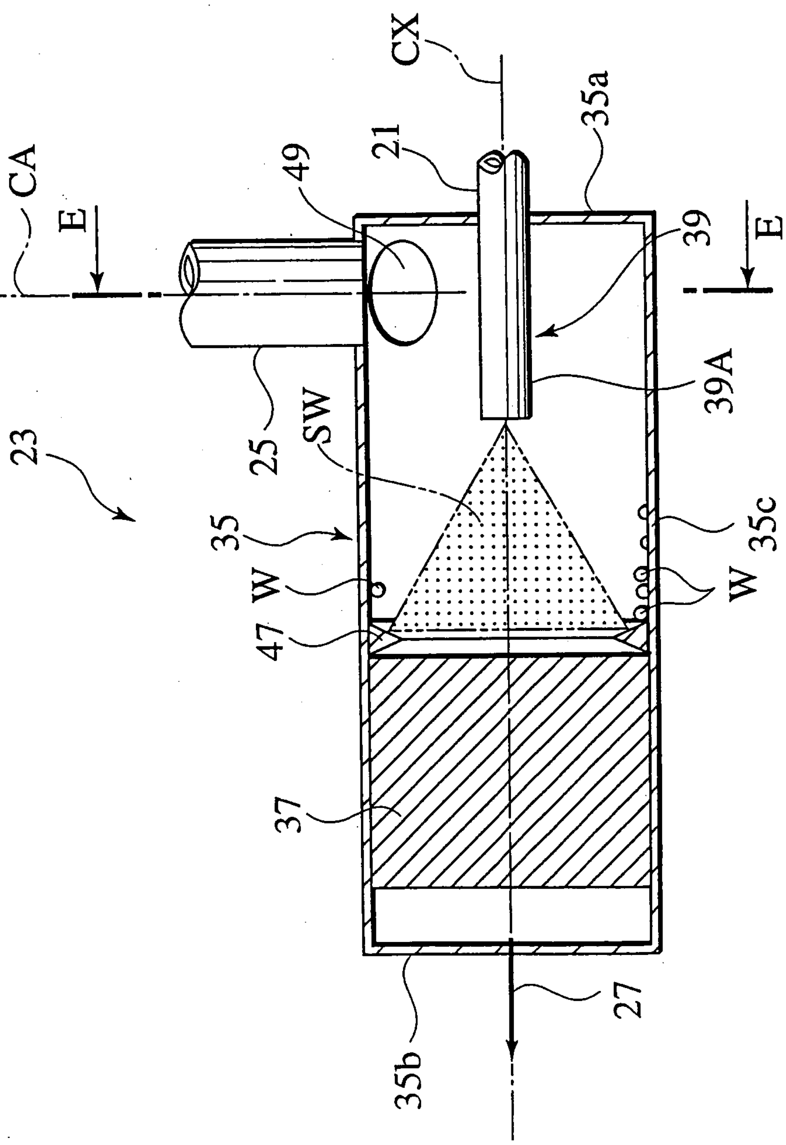

23
CA
E
49
21
CX
35a
39
E
39A
25
SW
35
W
47
35c
W
37
27
35b

FIG.5

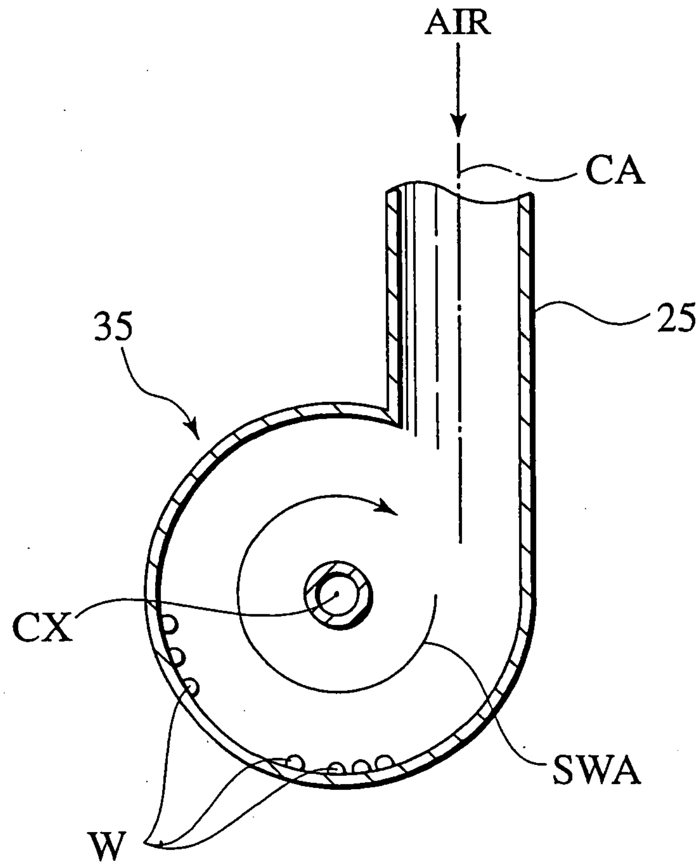


FIG.6B

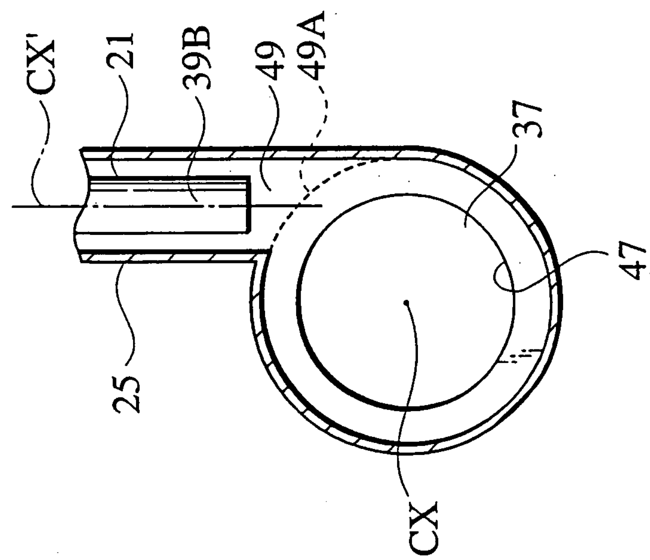

CX'
21
39B
49
49A
37
47
25
CX

FIG.6A

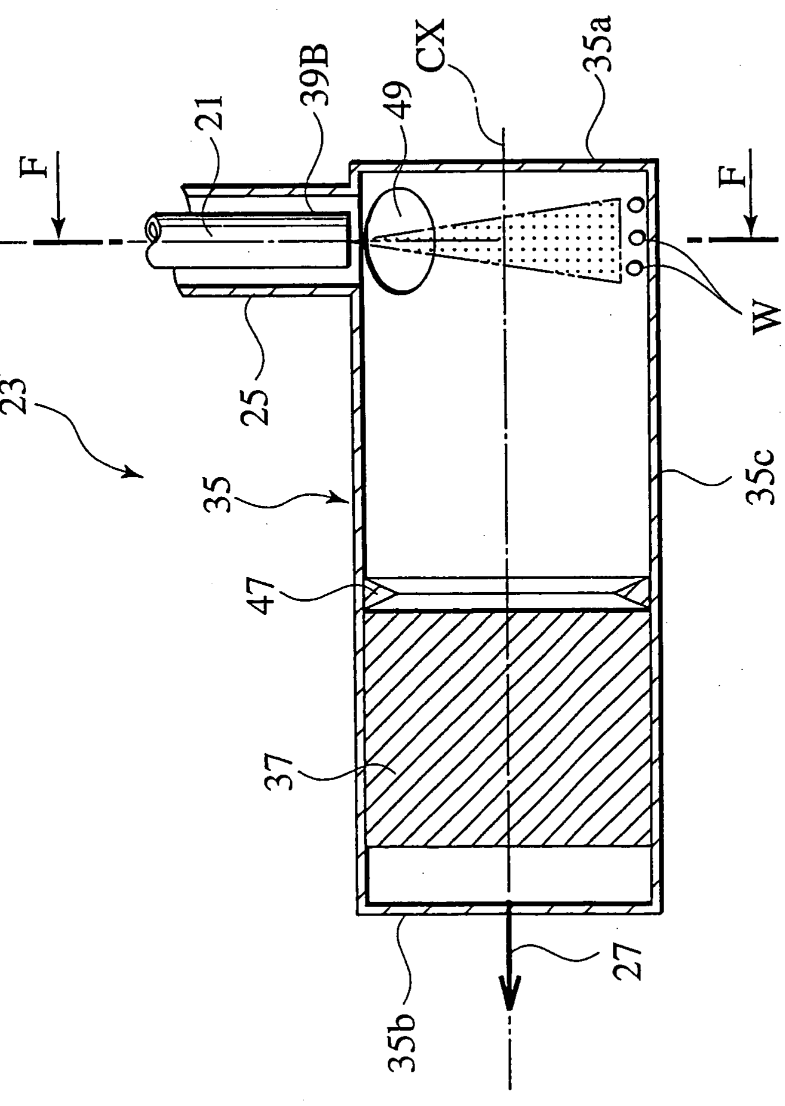

C'
F
21
39B
49
CX
35a
F
W
25
23
35
35c
47
37
27
35b

FIG.7