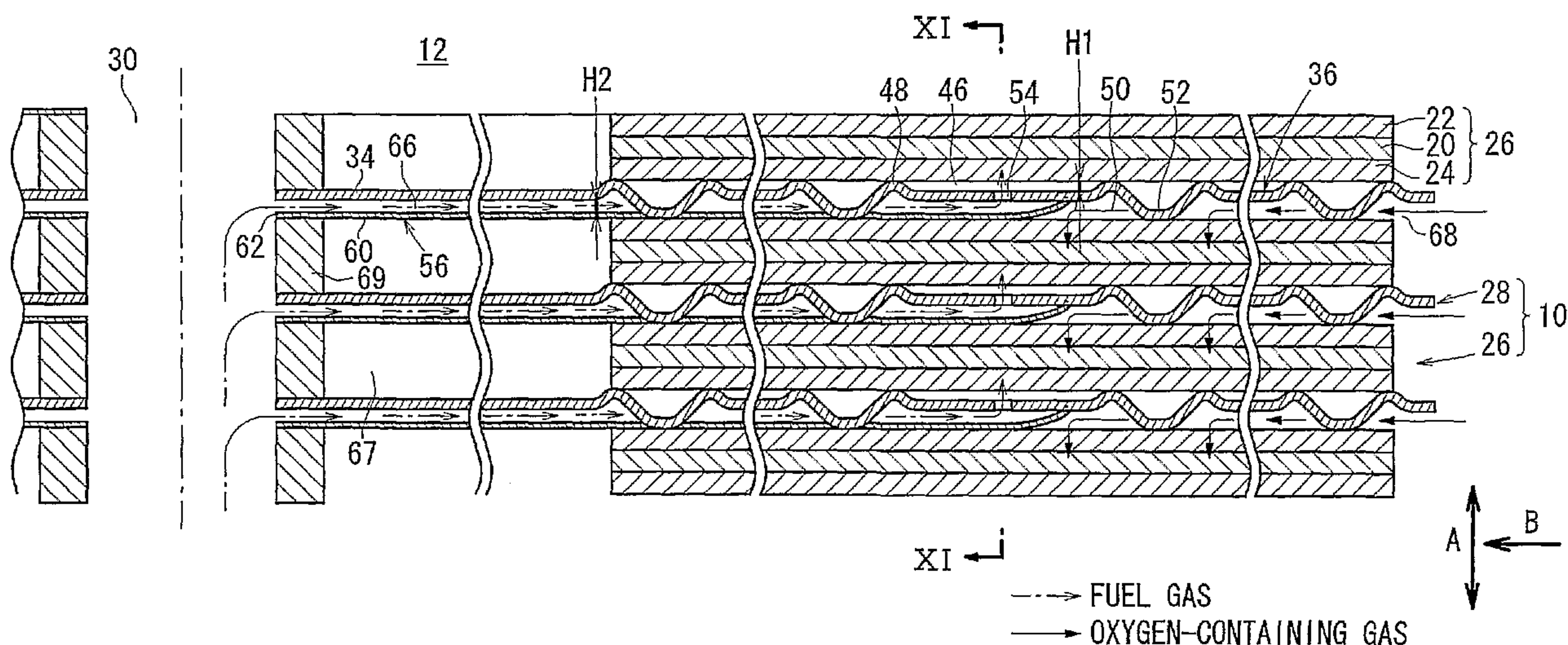




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(54) Titre : PILE A COMBUSTIBLE A OXYDE SOLIDE POURVUE D'UN CONDUIT FORMANT PLUSIEURS CANAUX D'ALIMENTATION EN GAZ COMBUSTIBLE
(54) Title: SOLID OXIDE FUEL CELL HAVING CHANNEL MEMBER FORMING PLURALITY OF FUEL GAS SUPPLY CHANNELS



(57) Abrégé/Abstract:

A fuel cell includes an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly. Each of the separators is single plate, and includes a plurality of circular disks. First protrusions and second protrusions are provided on both surfaces of the circular disk. The first protrusions contact the anode of the electrolyte electrode assembly, and the second protrusions contact the cathode of the electrolyte electrode assembly. A channel member is provided on a surface of the separator facing the cathode. The channel member forms a plurality of fuel gas supply channels connected between a fuel gas supply passage and a fuel gas inlet for supplying a fuel gas into a fuel gas flow field.

Abstract

A fuel cell includes an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly. Each of the separators is a single plate, and includes a plurality of circular disks. First protrusions and second protrusions are provided on both surfaces of the circular disk. The first protrusions contact the anode of the electrolyte electrode assembly, and the second protrusions contact the cathode of the electrolyte electrode assembly. A channel member is provided on a surface of the separator facing the cathode. The channel member forms a plurality of fuel gas supply channels connected between a fuel gas supply passage and a fuel gas inlet for supplying a fuel gas into a fuel gas flow field.

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DESCRIPTION

SOLID OXIDE FUEL CELL HAVING CHANNEL MEMBER FORMING
PLURALITY OF FUEL GAS SUPPLY CHANNELS

5 Technical Field

The present invention relates to a fuel cell including an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly. The electrolyte electrode assembly includes an anode, a cathode,
10 and an electrolyte interposed between the anode and the cathode. Each of the separators is a single plate. Further, the present invention relates to a fuel cell stack formed by staking a plurality of fuel cells.

15 Background Art

Typically, a solid oxide fuel cell (SOFC) employs an electrolyte of ion-conductive solid oxide such as stabilized zirconia. The electrolyte is interposed between an anode and a cathode to form an electrolyte electrode assembly
20 (unit cell). The electrolyte electrode assembly is interposed between separators (bipolar plates). In use, a predetermined numbers of the unit cells and the separators are stacked together to form a fuel cell stack.

In the fuel cell, an oxygen-containing gas or air is
25 supplied to the cathode. The oxygen in the oxygen-containing gas is ionized at the interface between the cathode and the electrolyte, and the oxygen ions (O^{2-}) move

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toward the anode through the electrolyte. A fuel gas such as a hydrogen-containing gas or CO is supplied to the anode. Oxygen ions react with the hydrogen in the hydrogen-containing gas to produce water or react with CO to produce CO₂. Electrons released in the reaction flow through an external circuit to the cathode, creating a DC electric energy.

In the fuel cell, various proposals for reducing the thickness of the separator and the number of components of the separator have been made in order to reduce the dimension in the stacking direction of the fuel cell. For example, as shown in FIG. 17, according to the disclosure of Japanese Laid-Open Patent Publication No. 2002-75408, a separator 1 of a fuel cell includes a thin sheet of separator body 2, and a large number of first micro-protrusions 3 formed integrally on one surface of the separator body 2, and a large number of second micro-protrusions 4 formed integrally on the other surface of the separator body 2. The first micro-protrusions 3 form a fuel gas flow field 6 between the separator 1 and a fuel electrode 5, and the second micro-protrusions 4 form an oxygen-containing gas flow field 8 between the separator 1 and an air electrode 7.

However, according to the disclosure of Japanese Laid-Open Patent Publication No. 2002-75408, the fuel gas flow field 6 and the oxygen-containing gas flow field 8 are simply formed on both surfaces of the separator 1, and the

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supply of fuel gas and the supply of the oxygen-containing gas are performed in a limited manner. That is, the fuel gas is simply supplied from one end of the fuel electrode 5 to the other end of the fuel electrode 5, and the oxygen-containing gas is simply supplied from one end of the air electrode 7 to the other end of the air electrode 7. Therefore, the fuel cell cannot be used in wide applications. Depending on the shapes of the fuel electrode 5 and the air electrode 7, it may not be possible to supply the fuel gas and the oxygen-containing gas uniformly to the entire electrode surfaces, respectively.

Further, since it is necessary to maintain the sealing performance for preventing the leakage of the fuel gas and the sealing performance for preventing the leakage of the oxygen-containing gas suitably, the sealing structure is complicated.

Disclosure of Invention

A general object of the present invention is to provide a fuel cell having a simple and compact structure in which the thickness in a stacking direction of the fuel cell is reduced, while maintaining the desired sealing performance.

A main object of the present invention is to provide a fuel cell in which the efficient power generation is achieved.

Another object of the present invention is to provide a fuel cell stack in which damage of an electrolyte electrode

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assembly is prevented, and improvement in the current collection performance is achieved.

According to the present invention, a solid oxide fuel cell comprises a plurality of electrolyte electrode assemblies and a pair of separators sandwiching the electrolyte electrode assemblies. The electrolyte electrode assembly includes an anode, a cathode, and an electrolyte interposed between the anode and the cathode. Each of the separators is composed of a single plate. The separator has a plurality of sandwiching portions, so that each electrolyte electrode assembly is stacked on each sandwiching portion. The separator also has a fuel gas supply unit at a center thereof for letting a fuel gas prior to consumption flow therethrough in a stacking direction. First protrusions are provided on one surface of the sandwiching portion of the separator. The first protrusions form a fuel gas flow field for supplying a fuel gas along an electrode surface of the anode. Second protrusions are provided on the other surface of the sandwiching portion of the separator. The second protrusions form an oxygen-containing gas flow field for supplying an oxygen-containing gas along an electrode surface of the cathode.

A channel member forming a plurality of fuel gas supply channels connecting the fuel gas supply unit and the fuel gas flow fields is provided on the one surface of the separator or the other surface of the separator. The fuel gas supply channels are connected to a fuel gas inlet for allowing the fuel gas to flow into the fuel gas flow field from the center of the electrolyte electrode assembly through the fuel gas inlet.

According to the present invention, the separator comprises one single plate, and the channel member forming

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the fuel gas supply channels is provided on the separator. With the simple structure, the dimension in the stacking direction of the separator (thickness) is significantly

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reduced. Further, with the use of the channel member, it is possible to place the electrolyte electrode assembly in the oxygen-containing gas atmosphere. It is not necessary to prevent the leakage of the oxygen-containing gas.

5 Therefore, the number of sealing members for the oxygen-containing gas is reduced. Reduction in the production cost is achieved.

The fuel gas flows from the center of the electrolyte electrode assembly into the fuel gas flow field. In
10 particular, if the electrolyte electrode assembly has a circular shape, the fuel gas flows from the central region to the outer circumferential region of the fuel gas flow field, and the fuel gas is supplied uniformly over the entire electrode surface of the anode. Thus, the stable
15 power generation is carried out reliably. In the circular electrolyte electrode assembly, the thermal expansion is uniform. Therefore, the damage of the circular electrolyte electrode assembly is prevented.

Further, it is preferable that the fuel cell further
20 comprises an exhaust gas channel for discharging a reactant gas consumed in reaction in the electrolyte electrode assemblies as an exhaust gas into the stacking direction of the electrolyte electrode assemblies and the separators. It is preferable that the fuel gas supply unit for supplying
25 the fuel gas before consumption in the stacking direction is provided hermetically in the exhaust gas channel, and extends in the stacking direction, and the fuel gas supply

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channels are connected between the fuel gas flow field and the fuel gas supply unit, and extend along a surface of the separator which intersects the exhaust gas channel extending in the stacking direction.

5 It is preferable that the exhaust gas channel is provided in a central region of the separator. Further, it is preferable that the fuel gas supply unit is provided hermetically in a central position of the exhaust gas channel.

10 Further, it is preferable that the fuel gas inlet is provided at the center of the electrolyte electrode assembly or an upstream position deviated from the center of the electrolyte electrode assembly in the flow direction of the oxygen-containing gas. It is also preferable that the fuel
15 cell comprises an oxygen-containing gas supply unit for supplying the oxygen-containing gas before consumption from the outer circumferential region of the electrolyte electrode assembly toward the oxygen-containing gas flow field.

20 Further, it is preferable that one of the first and second protrusions is an annular protrusion and the other of the first and second protrusions is a mountain shaped protrusion.

25 Further, it is preferable that the mountain shaped protrusion is disposed in a recess formed by the annular protrusion. With this structure, the tightening load is efficiently transmitted to the electrolyte electrode

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assembly. Further, since the volume of the gas flow field is not decreased excessively, the pressure loss is not increased excessively, and the desired power generation reaction is induced.

5 Further, it is preferable that the mountain shaped protrusion and the annular protrusion are coaxial with each other.

Further, a plurality of electrolyte electrode assemblies are arranged along a circle concentric with the
10 center of the separator.

Further, it is preferable that a baffle member extends along a space between adjacent electrolyte electrode assemblies in the stacking direction for preventing the oxygen-containing gas from entering the oxygen-containing
15 gas flow field in directions other than the flow direction of the oxygen-containing gas in the oxygen-containing gas flow field.

Further, according the present invention, a fuel cell stack is formed by stacking a plurality of fuel cells in a
20 stacking direction. Each of the fuel cells comprises an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly. The electrolyte electrode assembly includes an anode, a cathode, and an electrolyte interposed between the anode and the
25 cathode. Each of the separators comprises a single plate.

The fuel cell stack further comprises a tightening load applying mechanism for applying a tightening load to the

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fuel cells in the stacking direction. A fuel gas supply unit extends through a central region of the fuel cells in the stacking direction, and the electrolyte electrode assembly is provided in an outer region of each of the fuel cells. A load applied to the central region of the fuel cells in the stacking direction by the tightening load applying mechanism is larger than a load applied to the outer region of the fuel cells in the stacking direction by the tightening load applying mechanism.

In the fuel cell stack, the tightening load applying mechanism applies a large tightening load to the fuel gas supply unit to maintain the desired sealing performance for the fuel gas supply unit. Further, the tightening load applying mechanism applies a relatively small tightening load to the electrolyte electrode assemblies such that the separators tightly contact the electrolyte electrode assemblies for improving the current collection performance without any damages in the electrolyte electrode assemblies.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which preferred embodiments of the present invention are shown by way of illustrative example.

Brief Description of Drawings

FIG. 1 is a perspective view schematically showing a fuel cell stack formed by stacking a plurality of fuel cells

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according to a first embodiment of the present invention;

FIG. 2 is a cross sectional view showing part of a fuel cell system in which the fuel cell stack is disposed in a casing;

5 FIG. 3 is an exploded perspective view showing the fuel cell;

FIG. 4 is a partial exploded perspective view showing gas flows in the fuel cell;

FIG. 5 is a view showing one surface of a separator;

10 FIG. 6 is a view showing the other surface of the separator;

FIG. 7 is a perspective view showing first and second protrusions formed on the separator;

15 FIG. 8 is a cross sectional view showing the fuel cell stack;

FIG. 9 is a cross sectional view schematically showing operation of the fuel cell;

FIG. 10 is a partially enlarged perspective view showing a channel member fixed to the separator;

20 FIG. 11 is a cross sectional view showing the fuel cell, taken along a line XI-XI in FIG. 8;

FIG. 12 is an exploded perspective view showing a fuel cell according to a second embodiment of the present invention;

25 FIG. 13 is a cross sectional view showing a fuel cell stack formed by stacking a plurality of the fuel cells;

FIG. 14 is a cross sectional view schematically showing

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operation of the fuel cell;

FIG. 15 is a plan view showing first and second protrusions that are different from the first and second protrusions shown in FIG. 7;

5 FIG. 16 is a perspective view showing first and second protrusions that are different from the first and second protrusions shown in FIGS. 7 and 15; and

FIG. 17 is a cross sectional view showing a separator of a fuel cell disclosed in Japanese Laid-Open Patent
10 Publication No. 2002-75408.

Best Mode for Carrying Out the Invention

FIG. 1 is a perspective view schematically showing a fuel cell stack 12 formed by stacking a plurality of fuel
15 cells 10 according to a first embodiment of the present invention indicated by an arrow A. FIG. 2 is a cross sectional view showing part of a fuel cell system 16 in which the fuel cell stack 12 is disposed in a casing 14.

The fuel cell 10 is a solid oxide fuel cell (SOFC) used
20 in various applications, including stationary and mobile applications. As shown in FIGS. 3 and 4, the fuel cell 10 includes electrolyte electrode assemblies 26. Each of the electrolyte electrode assemblies 26 includes a cathode 22, an anode 24, and an electrolyte (electrolyte plate) 20
25 interposed between the cathode 22 and the anode 24. For example, the electrolyte 20 is made of ion-conductive solid oxide such as stabilized zirconia. The electrolyte

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electrode assembly 26 has a circular disk shape. The electrolyte electrode assembly 26 includes a barrier layer at least on its outer circumferential end for preventing entry of an oxygen-containing gas.

5 A plurality of, e.g., eight electrolyte electrode assemblies 26 are interposed between a pair of separators 28 to form the fuel cell 10. The electrolyte electrode assemblies 26 are concentric with a fuel gas supply passage (fuel gas supply unit) 30 extending through the center of
10 the separators 28.

 As shown in FIG. 3, for example, each of the separators 28 comprises a metal plate of, e.g., stainless alloy or a carbon plate. The separator 28 has a first small diameter end portion 32. The fuel gas supply passage 30 extends
15 through the center of the first small diameter end portion 32. The first small diameter end portion 32 is integral with circular disks 36 each having a relatively large diameter through a plurality of first bridges 34. The first
20 bridges 34 extend radially outwardly from the first small diameter end portion 32 at equal angles (intervals). The circular disk 36 and the electrolyte electrode assembly 26 have substantially the same size.

 As shown in FIGS. 3, 5, and 6, the adjacent circular disks 36 are separated from each other through slits 38.
25 Each of the circular disks 36 includes extensions 40a, 40b protruding toward the adjacent circular disks 36 on both sides, respectively. Spaces 42 are formed between the

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adjacent extensions 40a, 40b. A baffle plate 44 is provided in each of the spaces 42 for preventing the oxygen-containing gas from entering an oxygen-containing gas flow field 50 as described later, in directions other than the flow direction indicated by the arrow B. The baffle plates 44 extend along the spaces 42 in the stacking direction. Though the baffle plate 44 illustrated in FIGS. 3, 5, and 6 has a V-shape, the baffle plate 44 may have any shape as long as the baffle plate 44 is capable of preventing the entry of the oxygen-containing gas.

Each of the circular disks 36 has first protrusions 48 on its surface 36a which contacts the anode 24. The first protrusions 48 form a fuel gas flow field 46 for supplying a fuel gas along an electrode surface of the anode 24 (see FIG. 5). Each of the circular disks 36 has second protrusions 52 on its surface 36b which contacts the cathode 22. The second protrusions 52 form the oxygen-containing gas flow field 50 for supplying the oxygen-containing gas along an electrode surface of the cathode 22 (see FIG. 6). As shown in FIG. 7, the first protrusions 48 and the second protrusions 52 protrude in opposite directions.

In the embodiment of the present invention, the first protrusions 48 are ring shaped protrusions, and the second protrusions 52 are mountain shaped protrusions (the second protrusions 52 have a conical shape having a flat top surface). The second protrusions (mountain shaped protrusions) 52 are surrounded by the first protrusions

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(ring shaped protrusions) 48.

The second protrusions 52 are formed on the surface where recesses 53 corresponding to the first protrusions 48 are formed. Therefore, the second protrusions 52 are
5 provided in the recesses 53.

In the embodiment of the present invention, the central axis L1 of the first protrusion 48 having the perfectly circular ring shape matches the central axis L2 of the second protrusion 52. Stated otherwise, the center of the
10 first protrusion 48 is coaxial with the center of the second protrusion 52.

As shown in FIGS. 8 and 9, a plurality of the first and second protrusions 48, 52 are provided, and the height H1 of the first protrusion 48 is smaller than the height H2 of the
15 second protrusion 52 ($H1 < H2$). Therefore, the volume of the oxygen-containing gas flow field 50 is larger than the volume of the fuel gas flow field 46. The first and second protrusions 48, 52 of these shapes may be formed by, e.g., press forming, an etching process or a cutting process.

20 The first protrusion 48 may be the mountain shaped protrusion, and the second protrusion 52 may be the ring shaped protrusion. In this case, it is preferable that the height of the ring shaped protrusion is larger than the height of the mountain shaped protrusion.

25 As shown in FIGS. 3 through 6, a fuel gas inlet 54 is provided in each of the circular disks 36. The fuel gas flows through the fuel gas inlet 54 into the fuel gas flow

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field 46. The fuel gas is supplied from the central region of the anode 24. The position of the fuel gas inlet 54 is determined by the pressure of the fuel gas and the pressure of the oxygen-containing gas. For example, the fuel gas inlet 54 is provided at the center of the circular disk 36. Alternatively, the fuel gas inlet 54 may be provided at an upstream position deviated from the center of the circular disk 36 in the flow direction of the oxygen-containing gas indicated by the arrow B.

A channel member 56 is fixed to the separator 28 by brazing or laser welding on a surface facing the cathode 22. As shown in FIG. 10, the channel member 56 includes a second small diameter end portion 58. The fuel gas supply passage 30 is formed at the center of the second small diameter end portion 58. Eight second bridges 60 extend radially from the second small diameter end portion 58. Each of the second bridges 60 is fixed to the first bridge 34 to the circular disk 36 of the separator 28 and reaches the fuel gas inlet 54.

A plurality of slits 62 are formed on the second small diameter end portion 58 of the channel member 56. The slits 62 are formed radially on a surface of the second small diameter end portion 58 which is joined to the separator 28. The slits 62 are connected to the fuel gas supply passage 30. Further, the slits 62 are connected to a recess 64 formed in the outer circumferential region of the second small diameter end portion 58. The recess 64 prevents the

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flow of the brazing material, and achieves the uniform flow of the fuel gas. A plurality of fuel gas supply channels 66 are formed between the first and second bridges 34, 60.

Each of the fuel gas supply channels 66 is connected to the fuel gas flow field 46 through the slits 62 and the recess 64. As shown in FIG. 11, the channel member 56 joined to each of the separators 28 has a curved cross section so that the second bridge 60 can be deformed elastically in the stacking direction indicated by the arrow A.

As shown in FIGS. 8 and 9, the oxygen-containing gas flow field 50 is connected to the oxygen-containing gas supply unit 68. The oxygen-containing gas is supplied in the direction indicated by the arrow B through the space between the outer circumferential edge of the electrolyte electrode assembly 26 and the outer circumferential edge of the circular disk 36. The oxygen-containing gas supply unit 68 is provided between the extensions 40a, 40b of each of the circular disks 36. The baffle plate 44 provided in the space 42 between the adjacent extensions 40a, 40b prevents the entry of the oxygen-containing gas from the source other than the oxygen-containing gas supply unit 68.

As shown in FIG. 8, insulating seals 69 for sealing the fuel gas supply passage 30 is provided between the separators 28. For example, the insulating seals 69 are made of mica material, or ceramic material. Exhaust gas channels 67 extend through the fuel cells 10 in the stacking direction at positions internal from the respective circular

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disks 36.

As shown in FIGS. 1 and 2, the fuel cell stack 12 includes a plurality of fuel cells 10 stacked together, and circular end plates 70a, 70b provided at opposite ends in the stacking direction. The fuel cells 10 of the fuel cell stack 12 are tightened together by a tightening load applying mechanism 72 in the stacking direction.

The tightening load applying mechanism 72 includes a first tightening unit 74a for applying a first tightening load T1 to a position near the fuel gas supply passage 30, and a second tightening unit 74b for applying a second tightening load T2 to the electrolyte electrode assemblies 26. The second tightening load T2 is smaller than the first tightening load T1 ($T1 > T2$).

The end plate 70a is insulated from the casing 14. A fuel gas supply port 76 is provided at the center of the end plate 70a. The fuel gas supply port 76 is connected to the fuel gas supply passage 30 in each of the fuel cells 10. The end plate 70a has two bolt insertion holes 78a. The fuel gas supply port 76 is positioned between the two bolt insertion holes 78a. The bolt insertion holes 78a are provided at positions corresponding to the exhaust gas channels 67 of the fuel cell stack 12.

Eight circular openings 80 are provided along a circular line which is concentric with the fuel gas supply port 76. That is, the circular openings 80 are arranged at positions corresponding to the respective electrolyte

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electrode assemblies 26. The circular openings 80 are connected to rectangular openings 82 extending toward the fuel gas supply port 76. The rectangular openings 82 are partially overlapped with the exhaust gas channels 67.

5 Therefore, the exhaust gas is discharged from the rectangular openings 82.

The end plate 70b is a conductive member. As shown in FIG. 2, a connection terminal 84 protrudes axially from the center of the end plate 70b, and the end plate 70b has two
10 bolt insertion holes 78b. The connection terminal 84 is positioned between the two bolt insertion holes 78b. The bolt insertion holes 78a are in alignment with the bolt insertion holes 78b. Two tightening bolts (tightening members) 86 are inserted into the bolt insertion holes 78a,
15 78b. The tightening bolts 86 are insulated from the end plate 70b. Tip ends of the tightening bolts 86 are screwed into nuts 88 to form the first tightening unit 74a. The first tightening unit 74a applies the desired tightening load for tightening the fuel cells 10 between the end plates
20 70a, 70b.

The connection terminal 84 is electrically connected to an output terminal 92a fixed to the casing 14.

The second tightening unit 74b is provided in each of the circular openings 80 of the end plate 70a. The second
25 tightening unit 74b includes a presser member 94 as a terminal plate. The presser member 94 electrically contacts the end of the fuel cell stack 12 in the stacking direction.

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One end of a spring 96 contacts the presser member 94, and the other end of the spring 96 is supported by an inner wall of the casing 14. The spring 96 has a spring load which is smaller than the first tightening load T1. For example, the
5 spring 96 is made of ceramics to prevent the influence of heat at the time of power generation, and to provide insulation.

A tubular conductor 98 is connected to an end of each presser member 94. The tubular conductor 98 and one end of
10 a tightening bolt 86 are electrically connected through a conductive wire 100. The other end (head) of the tightening bolt 86 is positioned near the connection terminal 84, and electrically connected to the output terminal 92b through a
conductive wire 102. The output terminals 92a, 92b are
15 arranged in parallel, and are adjacent to each other. The output terminals 92a, 92b are also electrically insulated from each other and fixed to the casing 14.

The casing 14 has an air supply port 104 adjacent to the output terminals 92a, 92b. An exhaust port 106 is
20 provided on the side of the other end plate 70a. A fuel gas supply port 108 is provided adjacent to the exhaust port 106. Therefore, heat is exchanged between the exhaust gas and the fuel gas. The fuel gas supply port 108 is connected to the fuel gas supply passage 30 through a reformer 110 as
25 necessary. A heat exchanger 111 is provided around the reformer 110.

Next, operation of the fuel cell stack 12 will be

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described below.

As shown in FIG. 3, in assembling the fuel cell 10, firstly, the separator 28 is joined to the channel member 56 on its surface facing the cathode 22. Therefore, each fuel gas supply channel 66 connected to the fuel gas supply passage 30 is formed between the separator 28 and the channel member 56. Each fuel gas supply channel 66 is connected to the fuel gas flow field 46 through the fuel gas inlet 54 (see FIG. 8). The ring shaped insulating seal 69 is provided on each of the separators 28 around the fuel gas supply passage 30.

In this manner, the separator 28 is fabricated. The eight electrolyte electrode assemblies 26 are interposed between the separators 28 to form the fuel cell 10. As shown in FIGS. 3 and 4, the electrolyte electrode assemblies 26 are interposed between the surface 36a of one separator 28 and the surface 36b of the other separator 28. The fuel gas inlet 54 of the circular disk 36 is positioned at the center in each of the anodes 24.

A plurality of the fuel cells 10 are stacked in the direction indicated by the arrow A, and the end plates 70a, 70b are provided at opposite ends in the stacking direction. As shown in FIGS. 1 and 2, the tightening bolts 86 are inserted into the respective bolt insertion holes 78a, 78b of the end plates 70a, 70b. Tip ends of the tightening bolts 86 are screwed into the nuts 88. Thus, the fuel cell stack 12 is produced. The components of the fuel cell stack

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12 are tightened together by the tightening load applying mechanism 72 in the stacking direction, and the fuel cell stack 12 is attached in the casing 14 (see FIG. 2).

Then, a fuel gas such as a hydrogen-containing gas is supplied to the fuel gas supply port 108 of the casing 14, and an oxygen-containing gas (hereinafter also referred to as the air) is supplied to the air supply port 104 of the casing 14. The fuel gas flows through the reformer 110, and is supplied to the fuel gas supply passage 30 of the fuel cell stack 12. The fuel gas flows in the stacking direction indicated by the arrow A, and flows through the slit 62 of the separator 28 in each of the fuel cells 10, and flows into the fuel gas supply channels 66 (see FIG. 8).

The fuel gas flowing along one of the fuel gas supply channels 66 between the first and second bridges 34, 60 flows into the fuel gas flow field 46 through the fuel gas inlet 54 of the circular disk 36. The fuel gas inlet 54 is positioned at the substantially central position of the anode 24 in each of the electrolyte electrode assemblies 26. Alternatively, the fuel gas inlet 54 may be provided at an upstream position deviated from the central position of the anode 24 in the flow direction of the oxygen-containing gas indicated by the arrow B. Therefore, the fuel gas is supplied to the central region of the anode 24 from the fuel gas inlet 54. The fuel gas flows from the central region of the anode 24 to the outer circumferential region of the anode 24 (see FIG. 9).

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The oxygen-containing gas is supplied to the oxygen-containing gas supply unit 68 in the outer circumferential region in each of the fuel cells 10. The oxygen-containing gas flows into the space between the outer circumferential region of the electrolyte electrode assembly 26 and the outer circumferential region of the circular disk 36 in the direction indicated by the arrow B, and flows toward the oxygen-containing gas flow field 50. As shown in FIGS. 8 and 9, in the oxygen-containing gas flow field 50, the oxygen-containing gas flows from one end of the outer circumferential region (outer region of the separator 28) to the other end of the outer circumferential region (central region of the separator 28) of the cathode 22 of the electrolyte electrode assembly 26.

Thus, in the electrolyte electrode assembly 26, the fuel gas flows from the central region to the outer circumferential region of the anode 24, and the oxygen-containing gas flows in one direction indicated by the arrow B on the electrode surface of the cathode 22 (see FIGS. 9 and 11). At this time, oxygen ions flow through the electrolyte 20 toward the anode 24 for generating electricity by electrochemical reactions.

The fuel cells 10 are connected in series in the stacking direction indicated by the arrow A. As shown in FIG. 2, one of the poles is connected from the connection terminal 84 of the electrically conductive end plate 70b to the output terminal 92a through a conductive wire 90. The

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other pole is connected from the tightening bolts 86 to the output terminal 92b through the conductive wires 102. Thus, the electrical energy can be collected from the output terminals 92a, 92b.

5 After the fuel gas and the oxygen-containing gas are consumed in the reactions, the fuel gas and the oxygen-containing gas flow toward the outer circumferential regions of the anode 24 and the cathode 22, respectively, in each of the electrolyte electrode assemblies 26, and are mixed
10 together. The mixed gas flows as an exhaust gas into the exhaust gas channels 67 extending through the separators 28, and flows in the stacking direction. Then, the exhaust gas is discharged to the outside of the casing 14 from the exhaust port 106.

15 In the first embodiment, the separator 28 is a single plate, and the first and second protrusions 48, 52 are provided on both surfaces 36a, 36b of each of the circular disks 36 of the separator 28. The first protrusions 48 contact the anode 24, and the second protrusions 52 contact
20 the cathode 22. The channel member 56 is fixed to the separator 28. The channel member 56 forms the fuel gas supply channels 66 connecting the fuel gas supply passage 30 and the fuel gas flow fields 46 through the fuel gas inlets 54.

25 Therefore, the oxygen-containing gas flows from the outer region to the central region of the fuel cell 10 in one direction indicated by the arrow B, and the fuel gas

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flows from the central region of the anode 24 to the outer circumferential region of the anode 24. Thus, not only is the dimension in the stacking direction of the separator 28 (thickness) significantly reduced, but also the fuel gas is
5 uniformly distributed (supplied) to the entire electrode surface of the anode 24. With the compact structure of the separator, the reactions for power generation occur uniformly over the entire electrode surfaces of the electrolyte electrode assembly 26. Therefore, the power
10 generation can be performed stably.

Further, since the channel member 56 forms the fuel gas supply channels 66 hermetically, each of the electrolyte electrode assemblies 26 can be placed in the oxygen-containing gas atmosphere. No sealing material sealing the
15 oxygen-containing gas supply unit 68 is required. The number of sealing members is reduced to simplify the sealing structure, and reduction in the production cost is achieved easily.

Each of the circular disks 36 includes extensions 40a, 40b protruding toward the adjacent circular disks 36 on both
20 sides, respectively. Spaces 42 are formed between the adjacent extensions 40a, 40b. A baffle plate 44 is provided in each of the spaces 42 for reliably preventing the oxygen-containing gas from entering the electrolyte electrode
25 assembly 26 from the space 42. Therefore, the oxygen-containing gas flows smoothly in one direction indicated by the arrow B in the oxygen-containing gas flow field 50.

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Therefore, the amount of the oxygen-containing gas which is not consumed in the reaction, and passes through the oxygen-containing gas flow field 50 is reduced.

Further, in the first embodiment, it is possible to
5 provide the fuel gas inlet 54 provided at an upstream
position deviated from the center of the circular disk 36 in
the flow direction of the oxygen-containing gas. The
pressure of the oxygen-containing gas in the exhaust gas
channel 67 is low in comparison of the pressure of the
10 oxygen-containing gas in the oxygen-containing gas supply
unit 68. Due to the influence by the pressure of the
oxygen-containing gas, the fuel gas tends to flow back to
the center of the separator 28. Therefore, by determining
the position of the fuel gas inlet 54, it is possible to
15 uniformly supply the fuel gas over the entire surface of the
anode 24. Thus, the desired power generation reaction is
induced easily.

Further, in each of the circular disks 36, the height
H1 of the first protrusions 48 is smaller than the height H2
20 of the second protrusions 52. It is because the flow rate
(volume) and the pressure of the fuel gas flowing through
the fuel gas flow field 46 formed by the first protrusions
48 are smaller than the flow rate (volume) and the pressure
of the oxygen-containing gas flowing through the oxygen-
25 containing gas flow field 50 formed by the second
protrusions 52. The height H1 of the first protrusions 48
and the height H2 of the second protrusions 52 can be

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changed freely depending on the pressures of the fuel gas and the oxygen-containing gas supplied to the fuel cell 10, for example.

Further, in the first embodiment, the first and second
5 bridges 34, 60 are provided in the exhaust gas channels 67. The fuel gas supply channels 66 formed between the first and second bridges 34, 60 extends along the surface of the separator 28 which intersects the exhaust gas channels 67 extending in the stacking direction. Therefore, the fuel
10 gas flowing through the fuel gas supply channels 66 is heated by the waste heat effectively, and improvement in the thermal efficiency is achieved advantageously.

Further, the exhaust gas channel 67 is provided in the central region of the separators 28. Therefore, the fuel
15 gas is heated uniformly by the heat transmission from the central region. Thus, improvement in the power generation efficiency is achieved. Further, the fuel gas supply passage 30 is provided hermetically in a central position of the exhaust gas channel 67. Therefore, the waste heat of
20 the exhaust gas is used for heating the fuel gas supplied to the electrolyte electrode assemblies 26. Therefore, improvement in the power generation efficiency is achieved.

In the first embodiment, as shown in FIG. 2, the fuel
cells 10 of the fuel cell stack 12 are tightened together by
25 a tightening load applying mechanism 72 in the stacking direction. The tightening load applying mechanism 72 includes a first tightening unit 74a for applying a first

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tightening load T1 to a position near the fuel gas supply passage 30, and a second tightening unit 74b for applying a second tightening load T2 to the electrolyte electrode assemblies 26. The second tightening load T2 is smaller than the first tightening load T1.

Specifically, the large tightening load (first tightening load T1) is applied to the portion around the fuel gas supply passage 30 to maintain the desired sealing performance for the fuel gas supply passage 30. The relatively small tightening load (second tightening load T2) is applied to the portions sandwiching the electrolyte electrode assemblies 26 such that the separators 28 tightly contact the electrolyte electrode assemblies 26 for improving the current collection performance without any damages or the like in the electrolyte electrode assemblies 26.

FIG. 12 is an exploded perspective view showing a fuel cell 120 according to a second embodiment of the present invention. FIG. 13 is a cross sectional view showing a fuel cell stack 122 formed by stacking a plurality of the fuel cells 120. FIG. 14 is a cross sectional view schematically showing operation of the fuel cell 120. The constituent elements that are identical to those of the fuel cell 10 according to the first embodiment are labeled with the same reference numeral, and description thereof will be omitted.

A channel member 124 is fixed to each of the separators 28 of the fuel cell 120, on a surface facing the anode 24.

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The channel member 124 includes second bridges 126 fixed to the first bridges 34 of the separator 28. A plurality of fuel gas supply channels 66 are formed between the first and second bridges 34, 126. Tip ends of the respective second
5 bridges 126 terminate at positions near the centers of the anodes 24 of the electrolyte electrode assemblies 26. A plurality of fuel gas inlets 128 are formed at the tip ends of the second bridges 126. The fuel gas flows through the fuel gas inlets 128 toward the anodes 24. The circular
10 disks 36 of the separators 28 do not have any fuel gas inlet 54 of the first embodiment.

In the second embodiment of the present invention, the fuel gas supplied to the fuel gas supply passage 30 flows along the fuel gas supply channels 66 between the separator
15 28 and the channel member 124. Then, the fuel gas flows toward the anodes 24 through the fuel gas inlets 128 formed at the tip ends of the channel member 124.

Therefore, the fuel gas is supplied suitably and uniformly from the central region of the anode 24 to the
20 outer circumferential region of the anode 24, and improvement in the power reaction efficiency is achieved advantageously. Further, it is not necessary to provide the fuel gas inlets 54 in the circular disks 36 in each of the separators 28. Therefore, the separators 28 have the simple
25 structure, and reduction in the production cost is achieved easily.

In the first and second embodiments, as shown in FIG.

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7, the first protrusion 48 has a ring shape perfectly circular (annular shape). Alternatively, for example, as shown in FIG. 15, the first protrusion 48 (recess 53) may have an oval ring shape. In this case, assuming that the intersection of the major diameter "a" and the minor diameter "b" is the center of the first protrusion 48, if an axis extending through the center matches the central axis of the second protrusion 52, "the first and second protrusions 48, 52 are coaxial".

10 In an example shown in FIG. 7, the second protrusion 52 has a conical shape, and a flat surface on its top. The cross section of the second protrusion 52 in the horizontal direction (e.g., the top surface) has a perfectly circular shape. However, the "mountain shaped protrusion" of the present invention is not limited in this respect. The mountain shaped protrusion may include a protrusion having a vertical cross section (cross section along the height of the protrusion) in a trapezoidal shape. That is, the mountain shaped protrusion may include a protrusion having a horizontal cross section (e.g., the top surface) in an oval shape.

25 Further, in FIG. 7, the first and second protrusions 48, 52 are coaxial, i.e., the central axis L1 of the ring shaped first protrusion 48 matches the central axis L2 of the second protrusion 52. However, it is not essential that the central axis L1 of the first protrusion 48 matches the central axis L2 of the second protrusion 52, i.e., the first

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and second protrusions 48, 52 are not necessarily coaxial with each other. For example, as shown in FIG. 16, the central axis L2 of the second protrusion 52 may be deviated from the central axis L1 of the first protrusion 48. It is
5 a matter of course that the first protrusion 48 may have an oval ring shape in this case, and the second protrusion 52 may have a horizontal cross section in an oval shape.

While the invention has been particularly shown and described with reference to preferred embodiments, it will
10 be understood that variations and modifications can be effected thereto by those skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

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CLAIMS:

1. A solid oxide fuel cell comprising a plurality of electrolyte electrode assemblies and a pair of separators sandwiching the electrolyte electrode assemblies, the
5 electrolyte electrode assemblies each including an anode, a cathode, and an electrolyte interposed between the anode and the cathode, the separators each being formed of a single plate, wherein:

the separator has a plurality of sandwiching
10 portions, each of the electrolyte electrode assemblies being stacked on each of the sandwiching portions,

the separator has a fuel gas supply unit at a center thereof for letting a fuel gas prior to consumption flow therethrough in a stacking direction,

15 first protrusions are provided on one surface of the sandwiching portion, and the first protrusions form a fuel gas flow field for supplying a fuel gas along an electrode surface of the anode;

second protrusions are provided on the other
20 surface of the sandwiching portion, and the second protrusions form an oxygen-containing gas flow field for supplying an oxygen-containing gas along an electrode surface of the cathode;

a channel member forming a plurality of fuel gas
25 supply channels connecting the fuel gas supply unit and the fuel gas flow fields is provided on the one surface of the separator or the other surface of the separator; and

the fuel gas supply channels are connected to a fuel gas inlet for allowing the fuel gas to flow into the

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fuel gas flow field from the center of the electrolyte electrode assembly through the fuel gas inlet.

2. The solid oxide fuel cell according to claim 1, further comprising an exhaust gas channel for discharging a
5 reactant gas consumed in reaction in the electrolyte electrode assembly as an exhaust gas into the stacking direction of the electrolyte electrode assembly and the separators, wherein:

the fuel gas supply unit is provided hermetically
10 in the exhaust gas channel for supplying the fuel gas before consumption in the stacking direction; and

the fuel gas supply channels extend along a surface of the separator which intersects the exhaust gas channel extending in the stacking direction.

15 3. The solid oxide fuel cell according to claim 2, wherein the exhaust gas channel is provided in a central region of the separator.

4. The solid oxide fuel cell according to claim 2 or 3, wherein the fuel gas supply unit is provided
20 hermetically in a central position of the exhaust gas channel.

5. The solid oxide fuel cell according to any one of claims 1 to 4, wherein the fuel gas inlet is provided at the center of the electrolyte electrode assembly or an upstream
25 position deviated from the center of the electrolyte electrode assembly in the flow direction of the oxygen-containing gas.

6. The solid oxide fuel cell according to any one of claims 1 to 5, further comprising an oxygen-containing gas
30 supply unit for supplying the oxygen-containing gas before

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consumption from the outer circumferential region of the electrolyte electrode assembly toward the oxygen-containing gas flow field.

7. The solid oxide fuel cell according to any one of
5 claims 1 to 6, wherein one of the first and second protrusions is an annular protrusion and the other of the first and second protrusions is a mountain shaped protrusion.

8. The solid oxide fuel cell according to claim 7,
wherein the mountain shaped protrusion is disposed in a
10 recess formed by the annular protrusion.

9. The solid oxide fuel cell according to claim 8,
wherein the mountain shaped protrusion and the annular protrusion are coaxial with each other.

10. The solid oxide fuel cell according to any one of
15 claims 1 to 9, wherein a plurality of electrolyte electrode assemblies are arranged along a circle concentric with the fuel gas supply unit formed at the center of the separator.

11. The solid oxide fuel cell according to claim 10,
wherein a baffle member extends along a space between
20 adjacent electrolyte electrode assemblies in the stacking direction for preventing the oxygen-containing gas from entering the oxygen-containing gas flow field in directions other than a flow direction of the oxygen-containing gas in the oxygen-containing gas flow field.

25 12. The solid oxide fuel cell according to any one of claims 7 to 11, wherein the recess has a perfectly circular shape.

13. The solid oxide fuel cell according to any one of claims 7 to 11, wherein the recess has an oval shape.

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14. The solid oxide fuel cell according to any one of claims 7 to 13, wherein the vertical cross section of the mountain shaped protrusion has a trapezoidal shape.

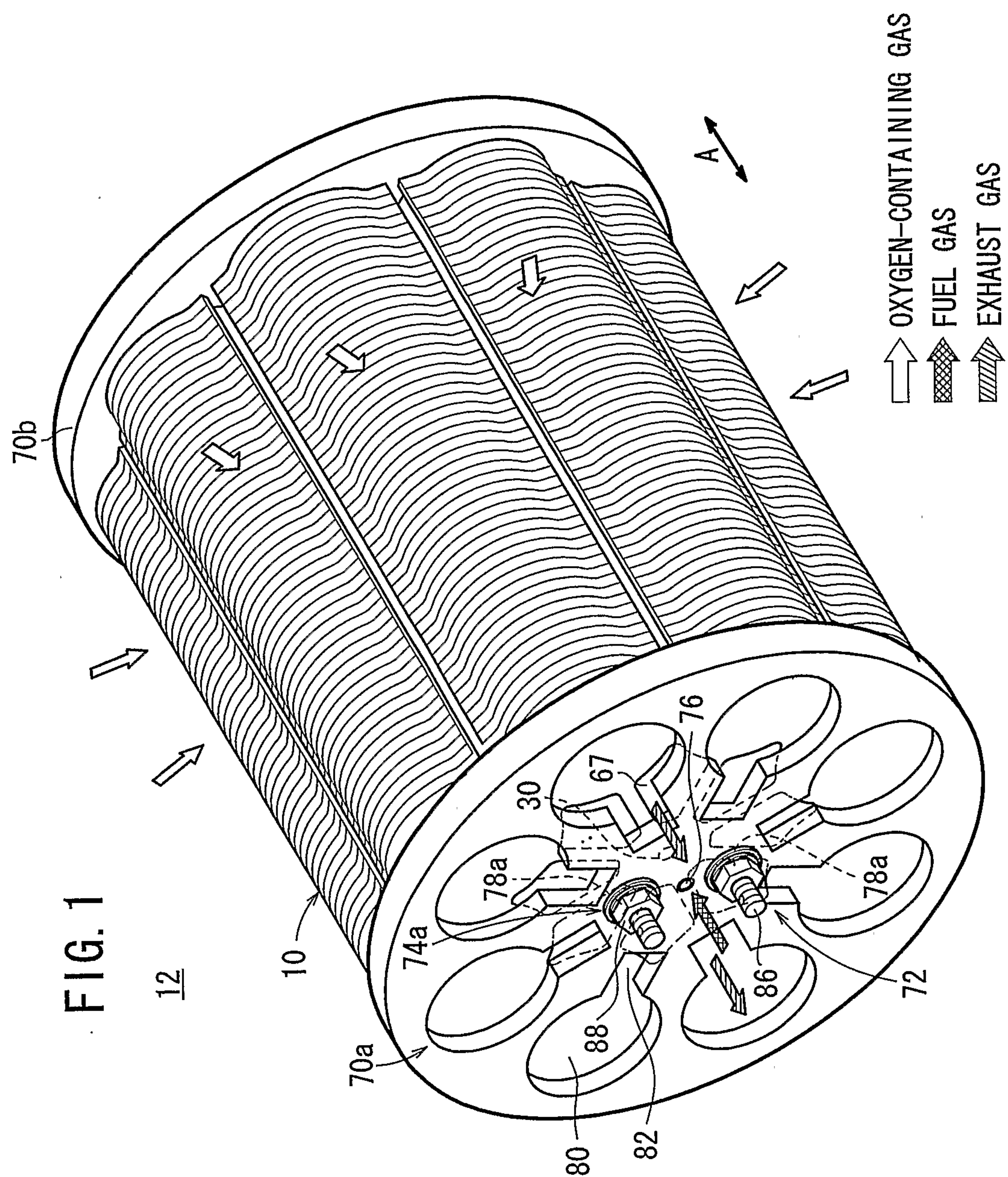
15. The solid oxide fuel cell according to claim 1,
5 wherein each of the sandwiching portions has a size substantially the same as each of the electrolyte electrode assemblies.

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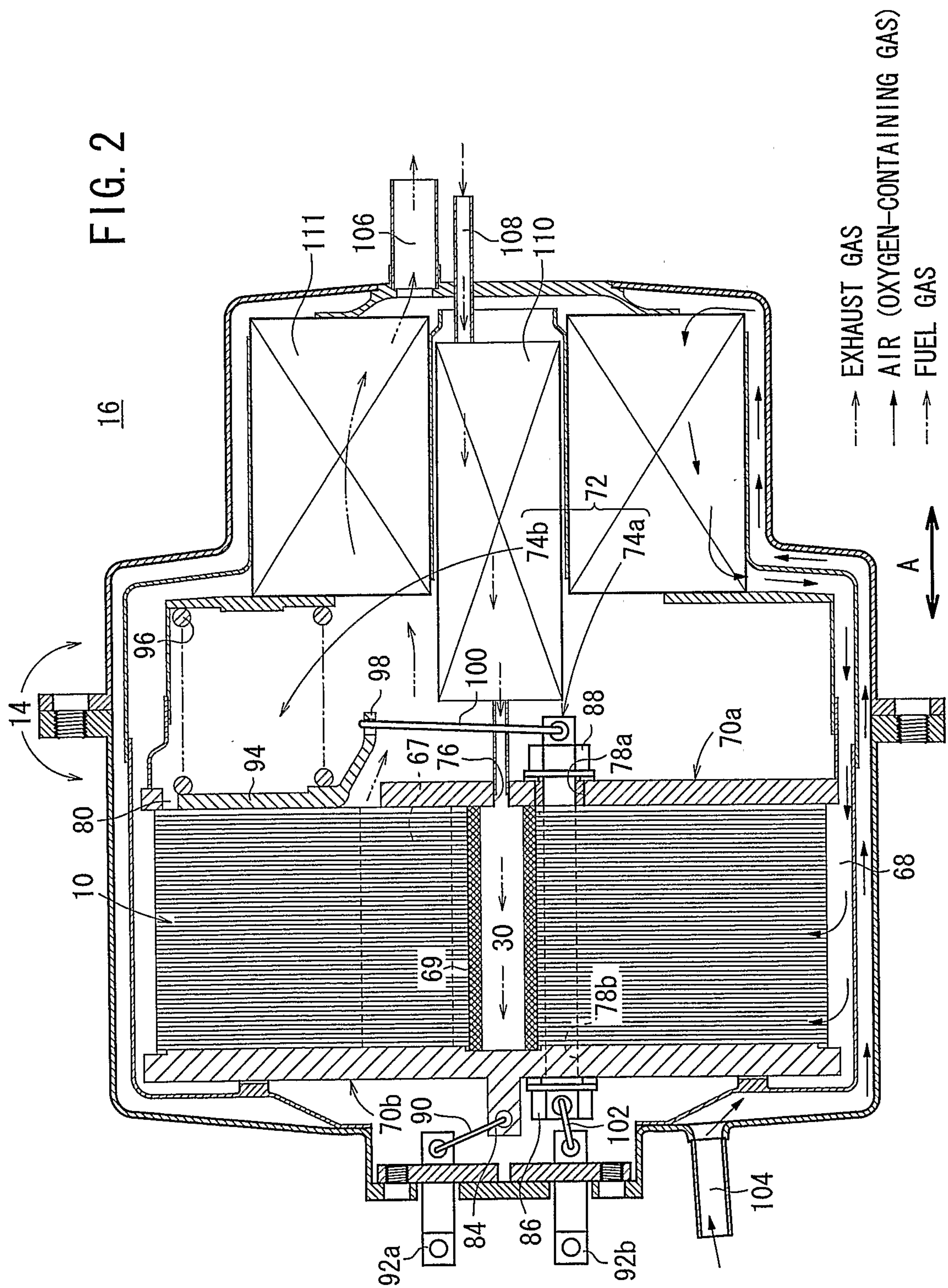
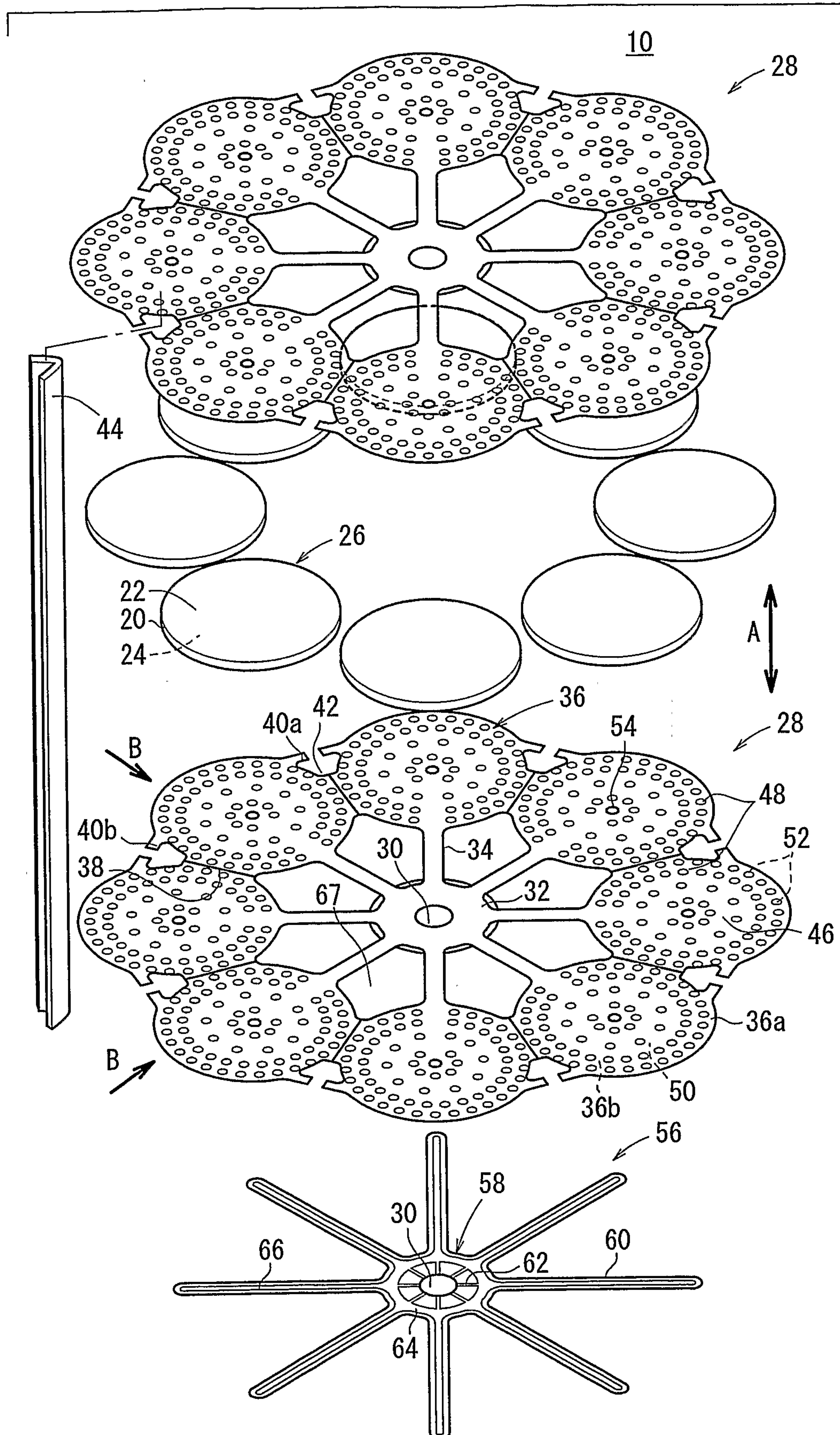
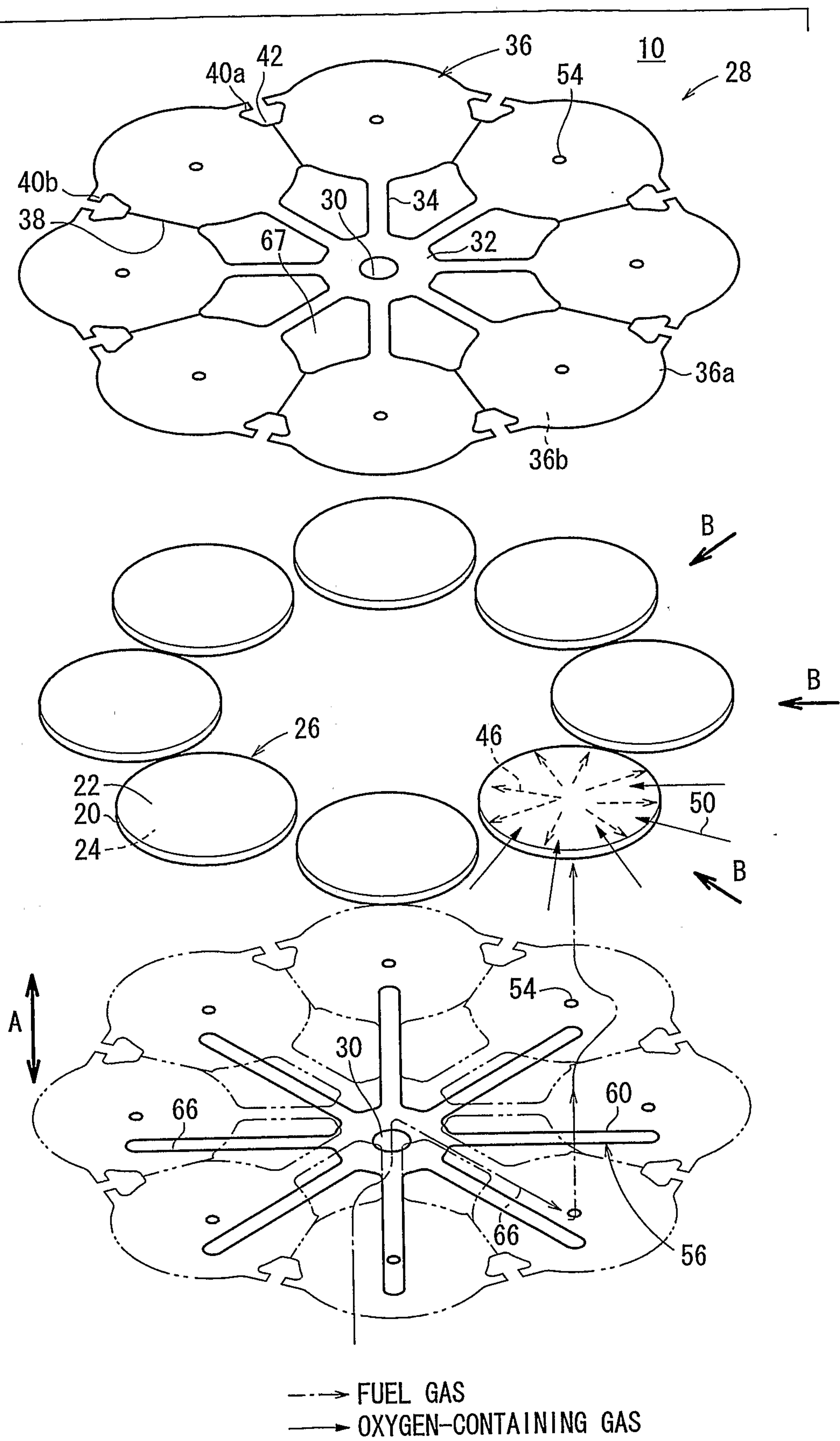


FIG. 3



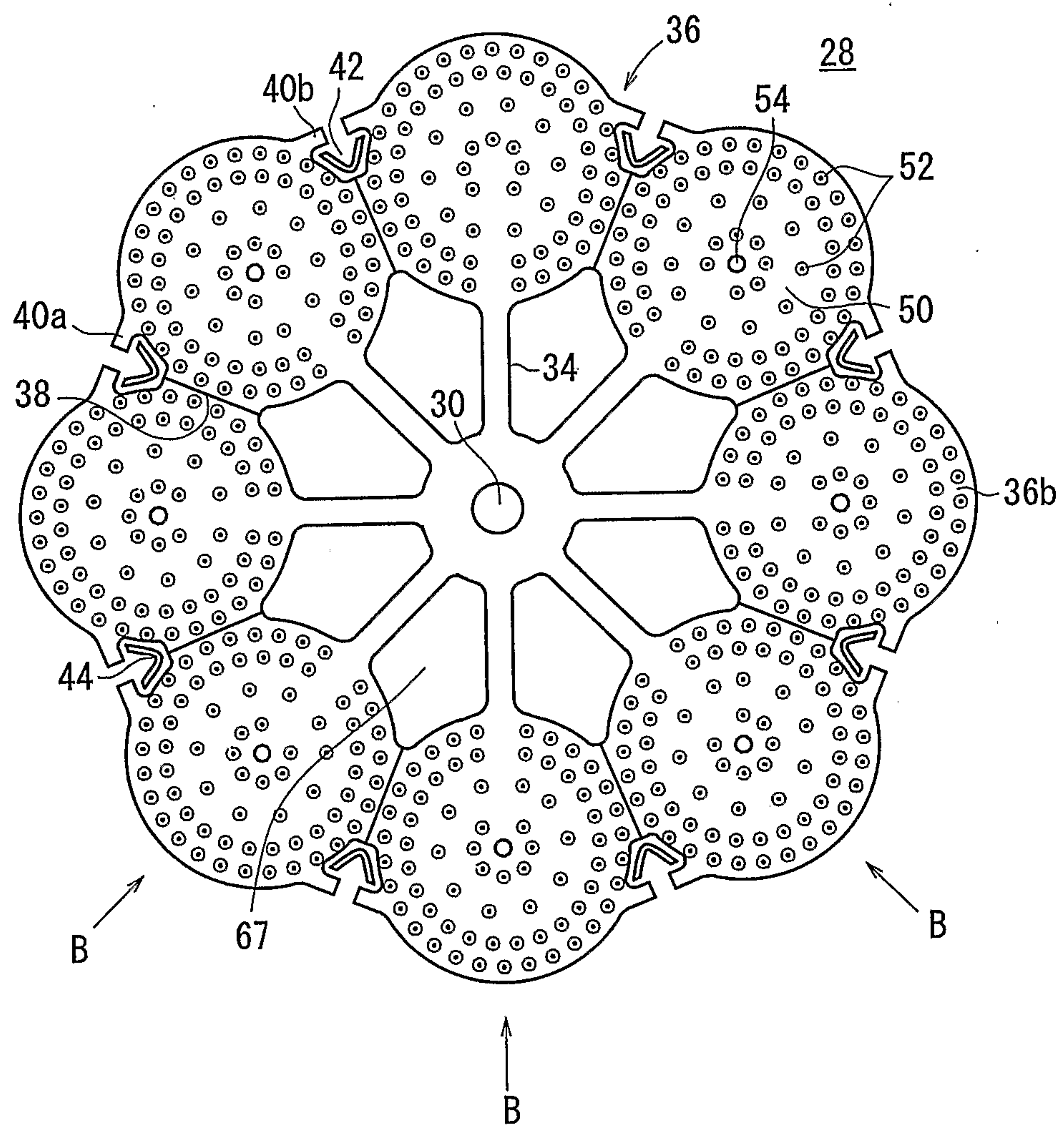
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FIG. 4



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FIG. 6



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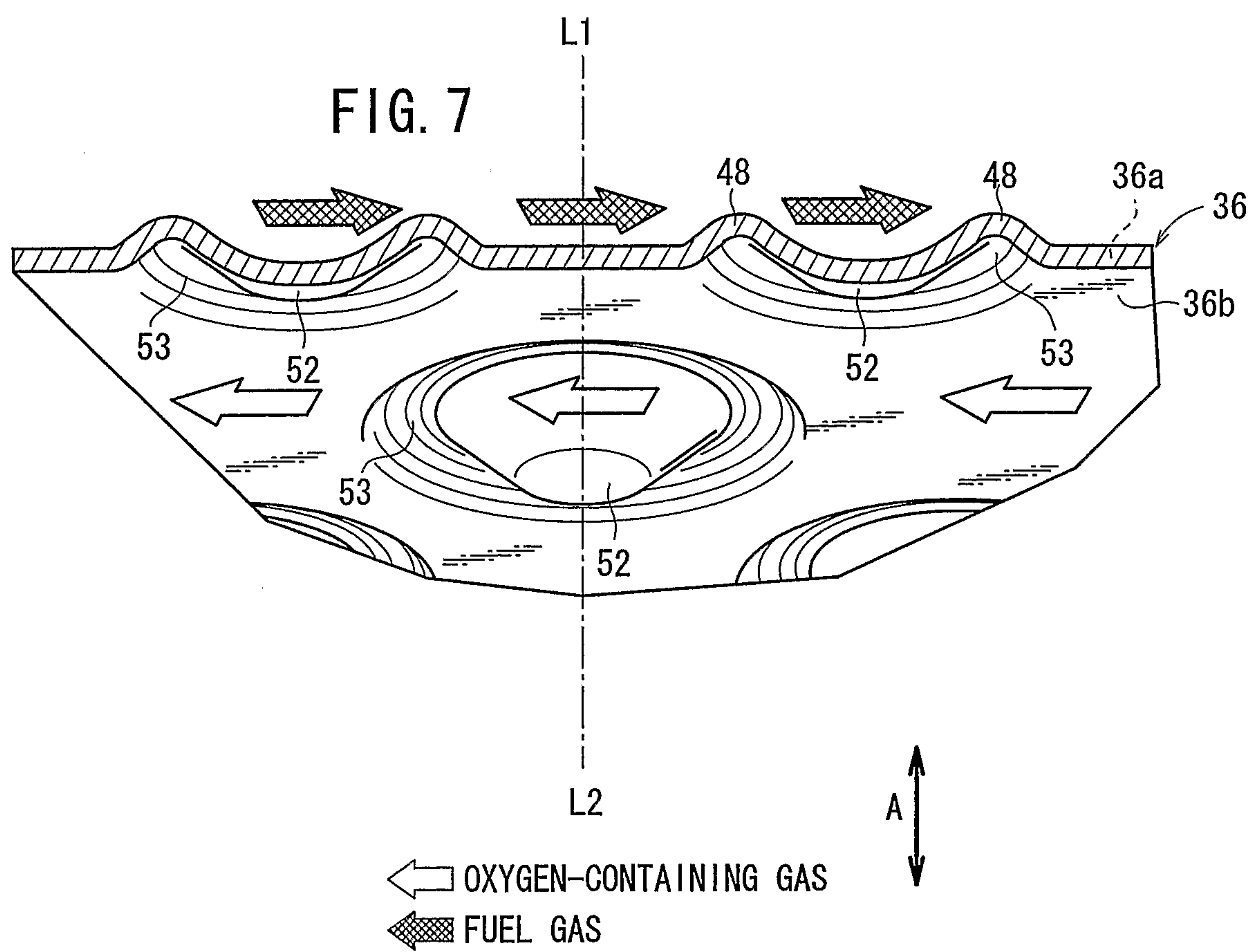


FIG. 8

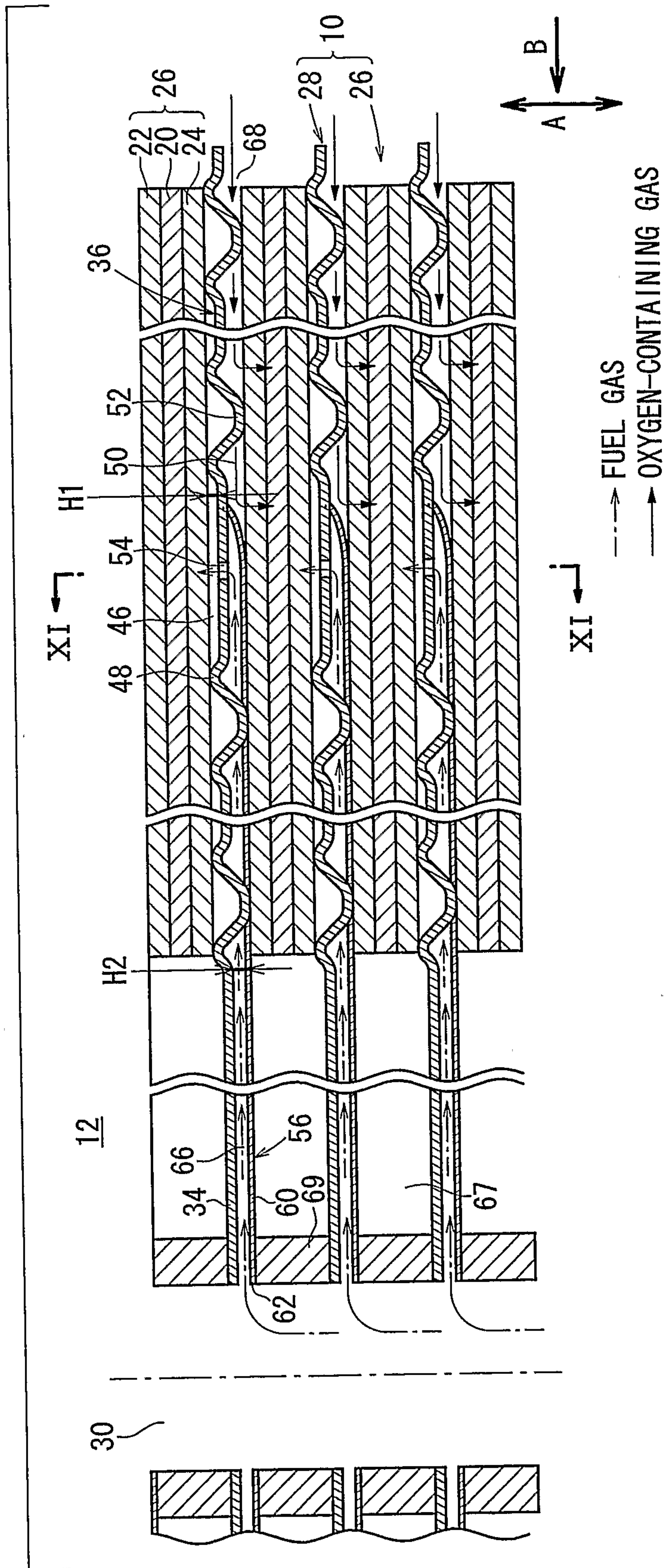
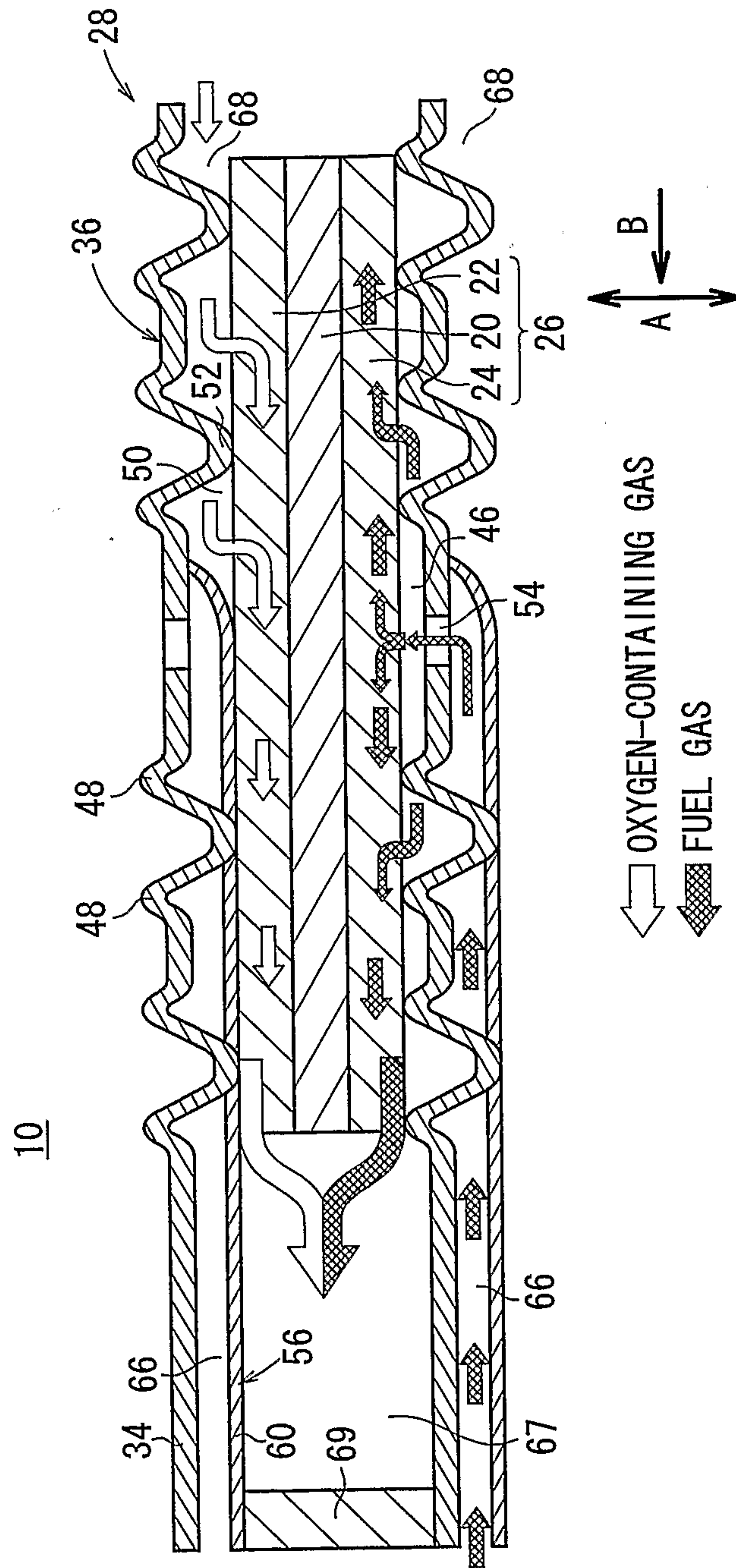


FIG. 9



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FIG. 10

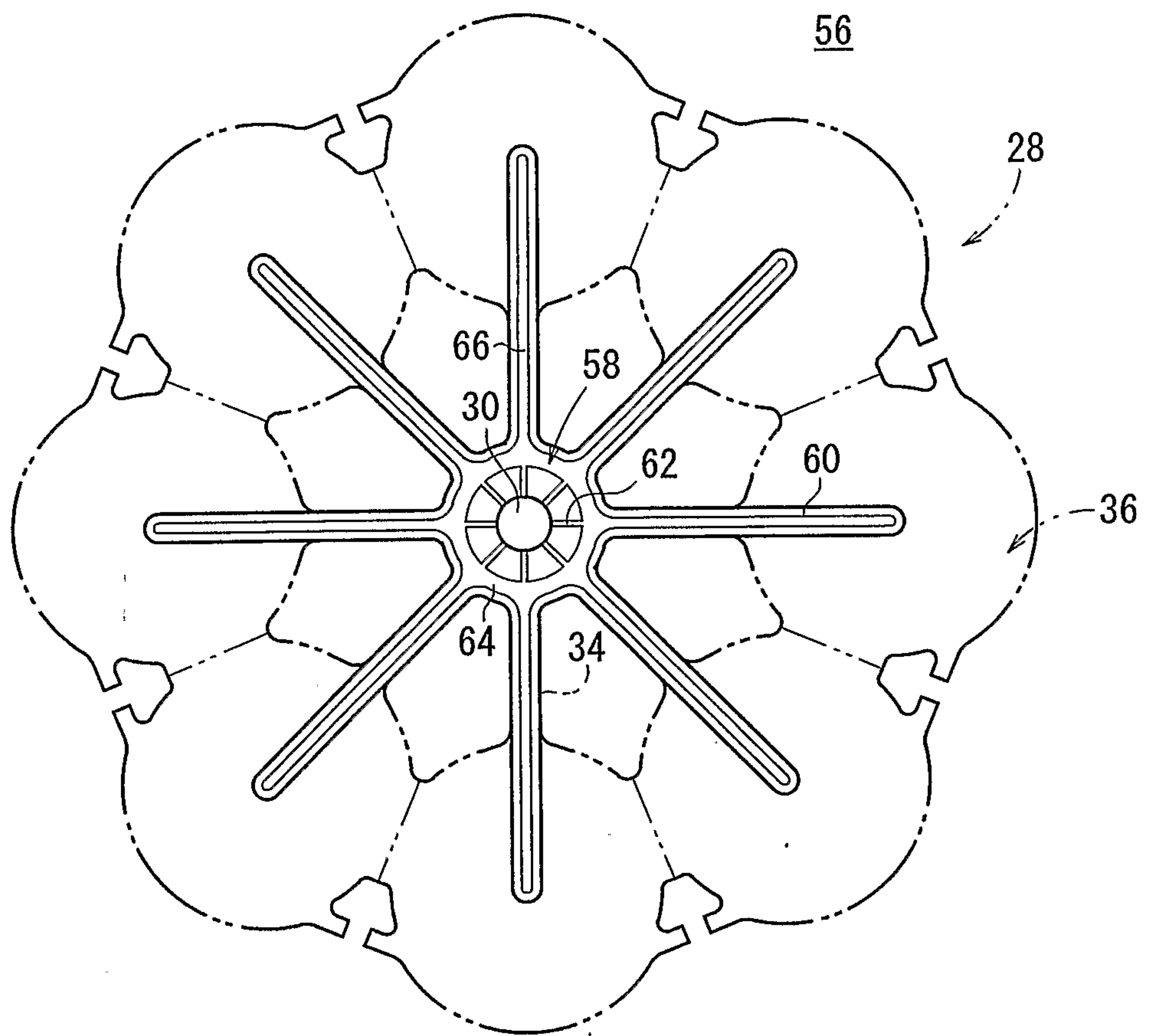
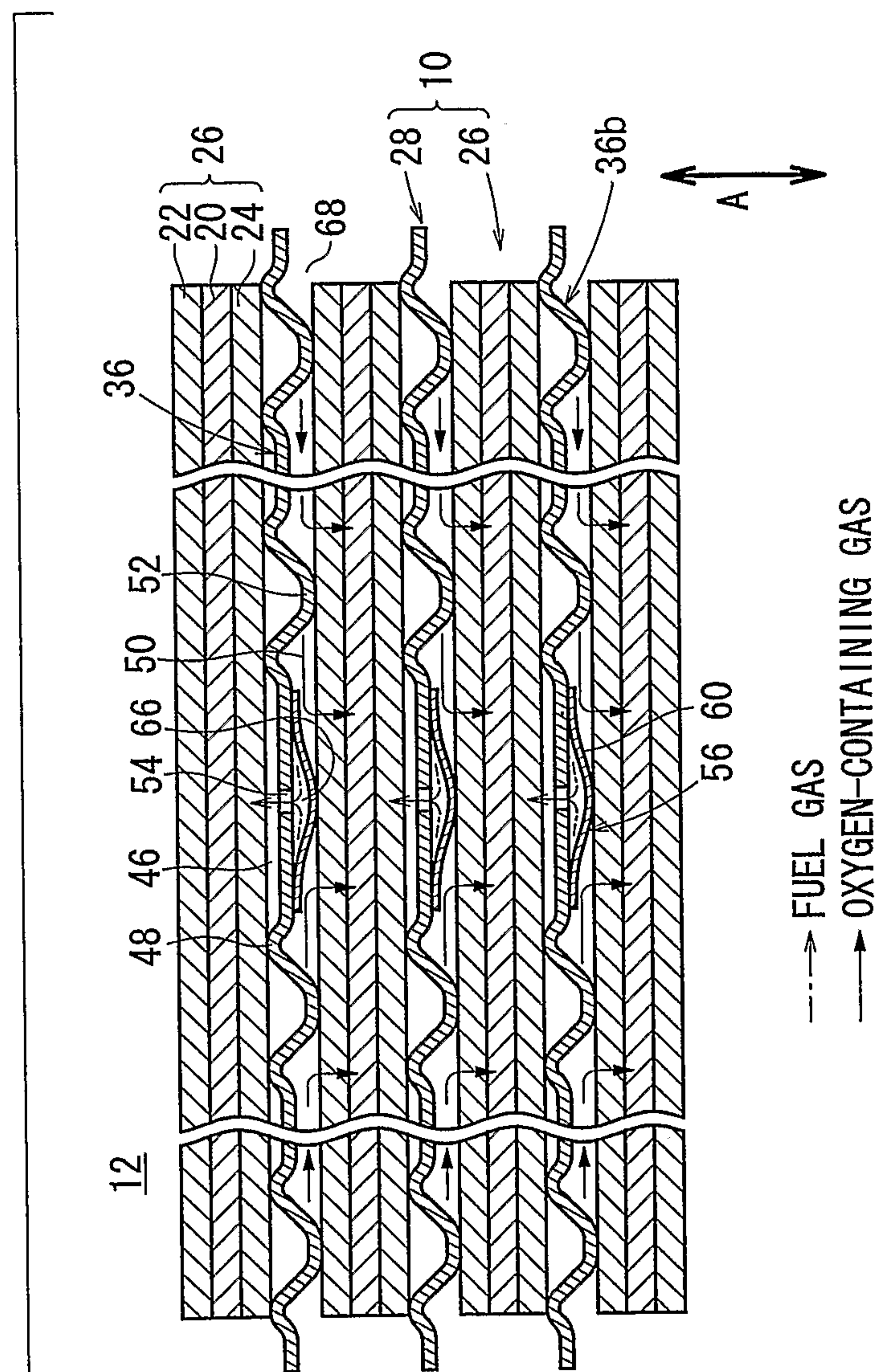


FIG. 11



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FIG. 12

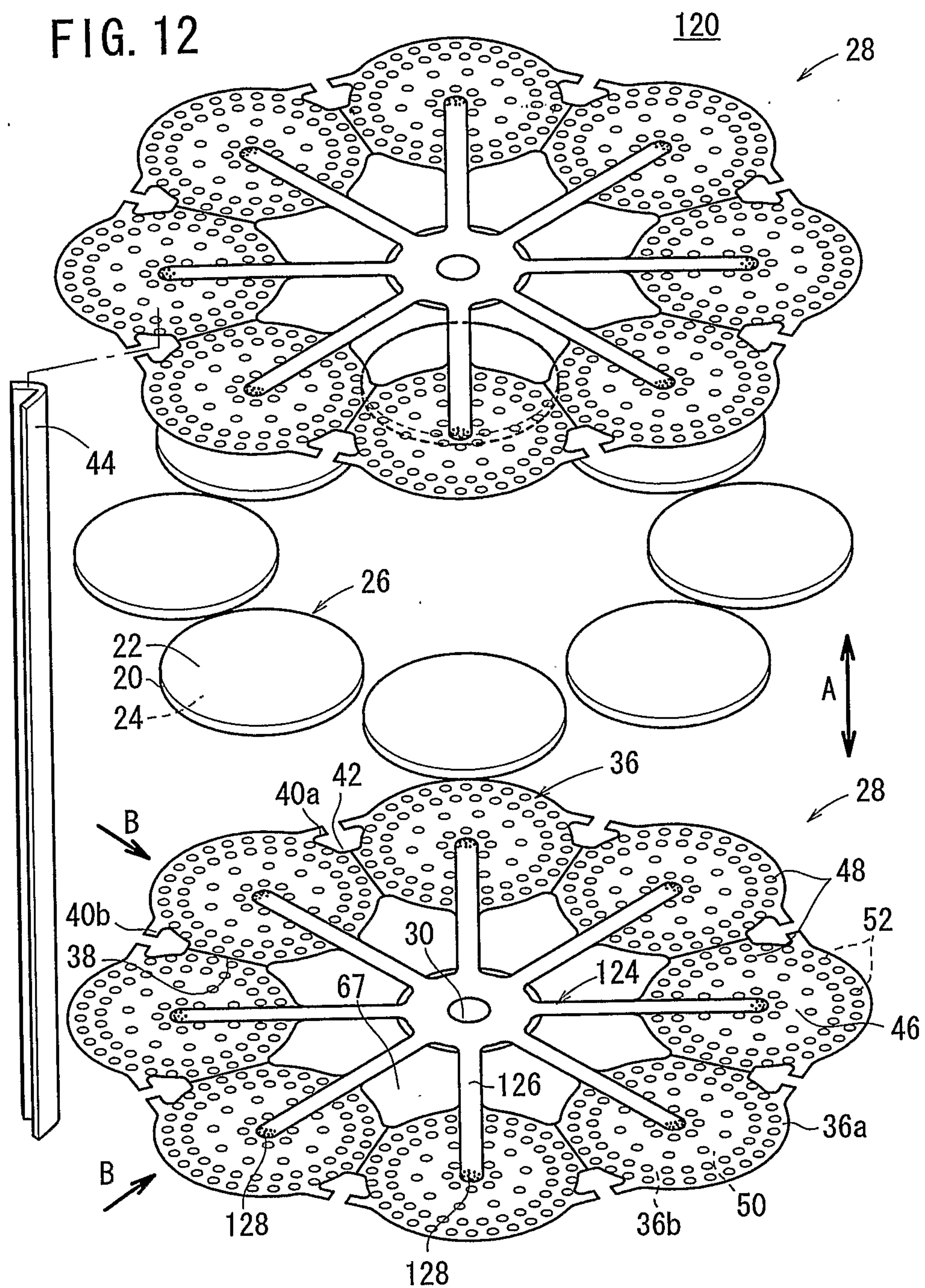
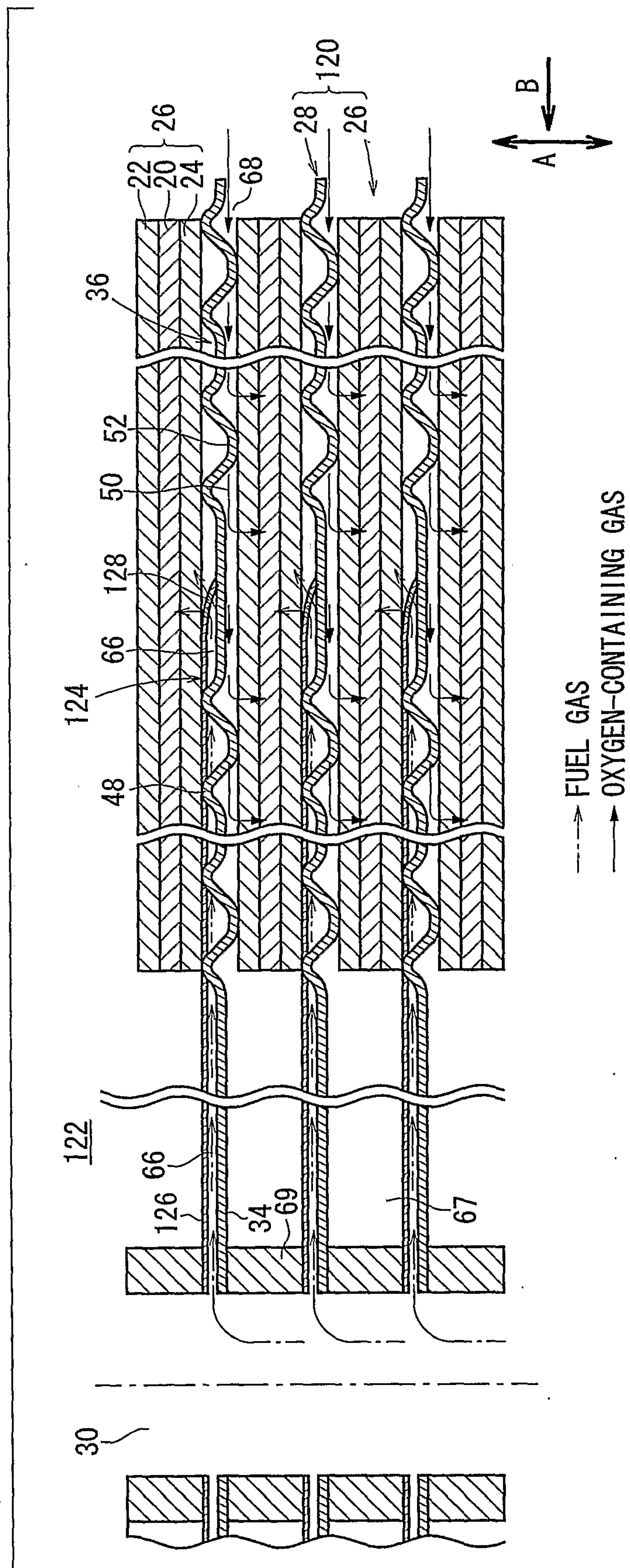
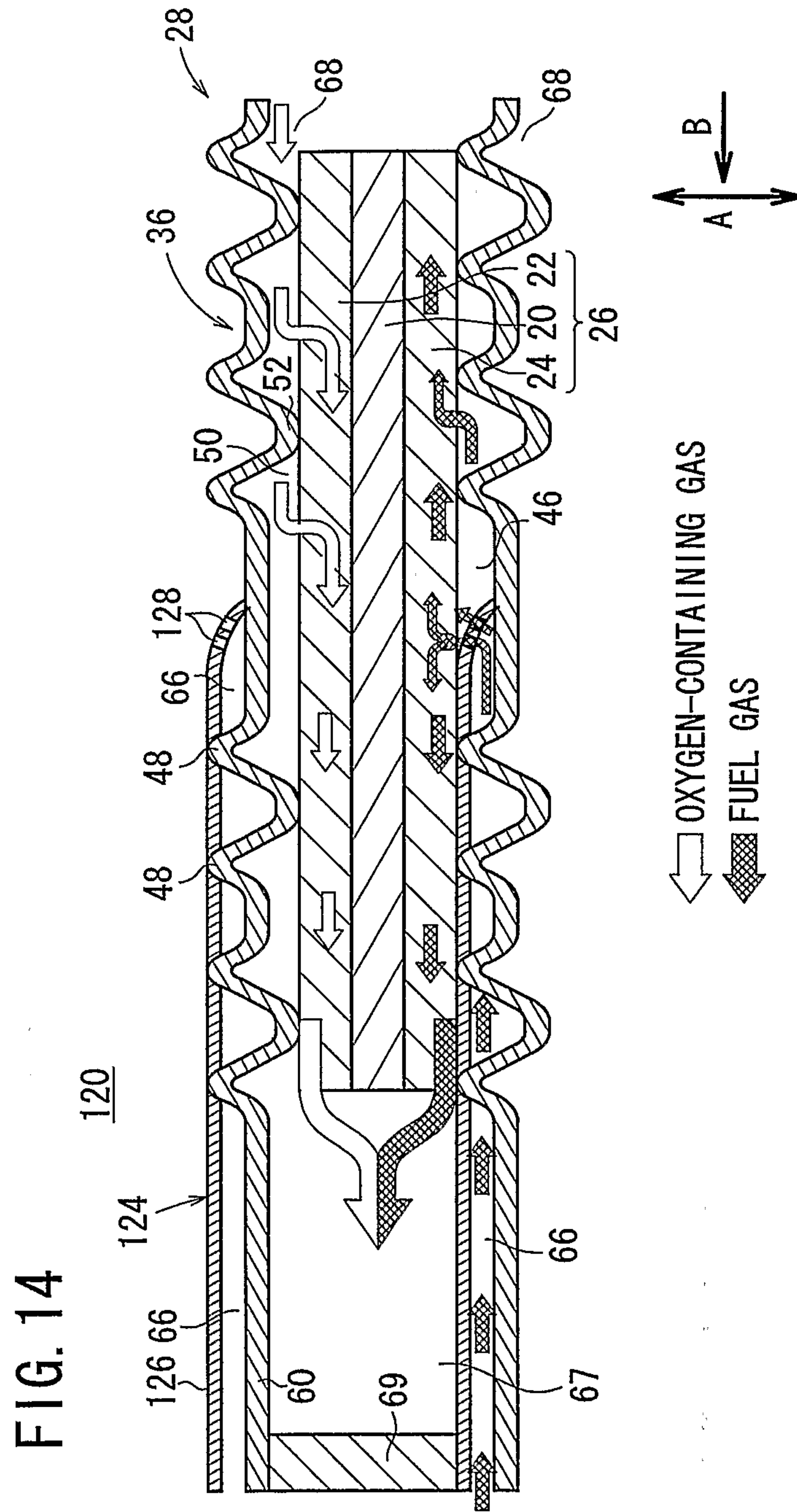


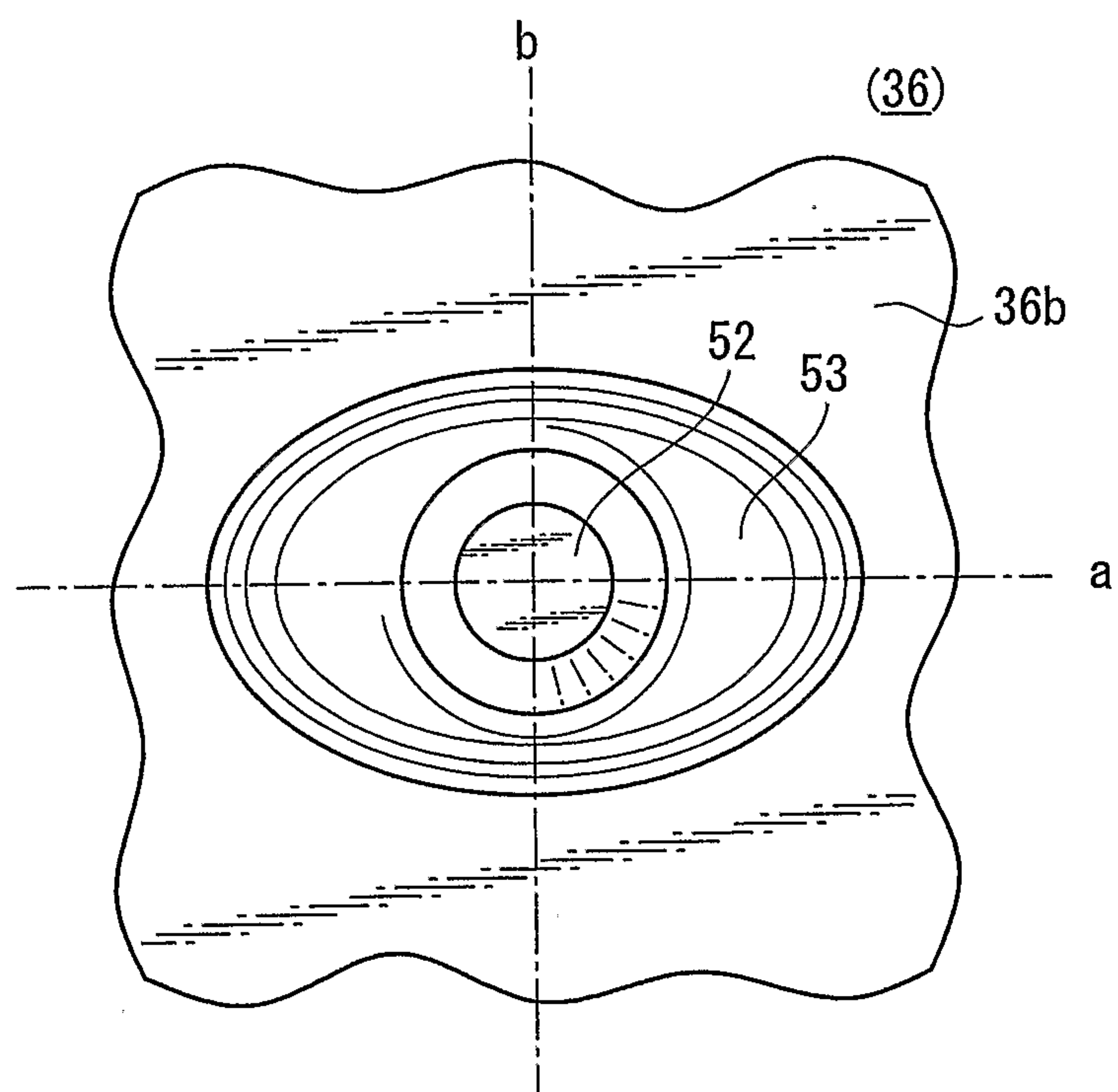
FIG. 13



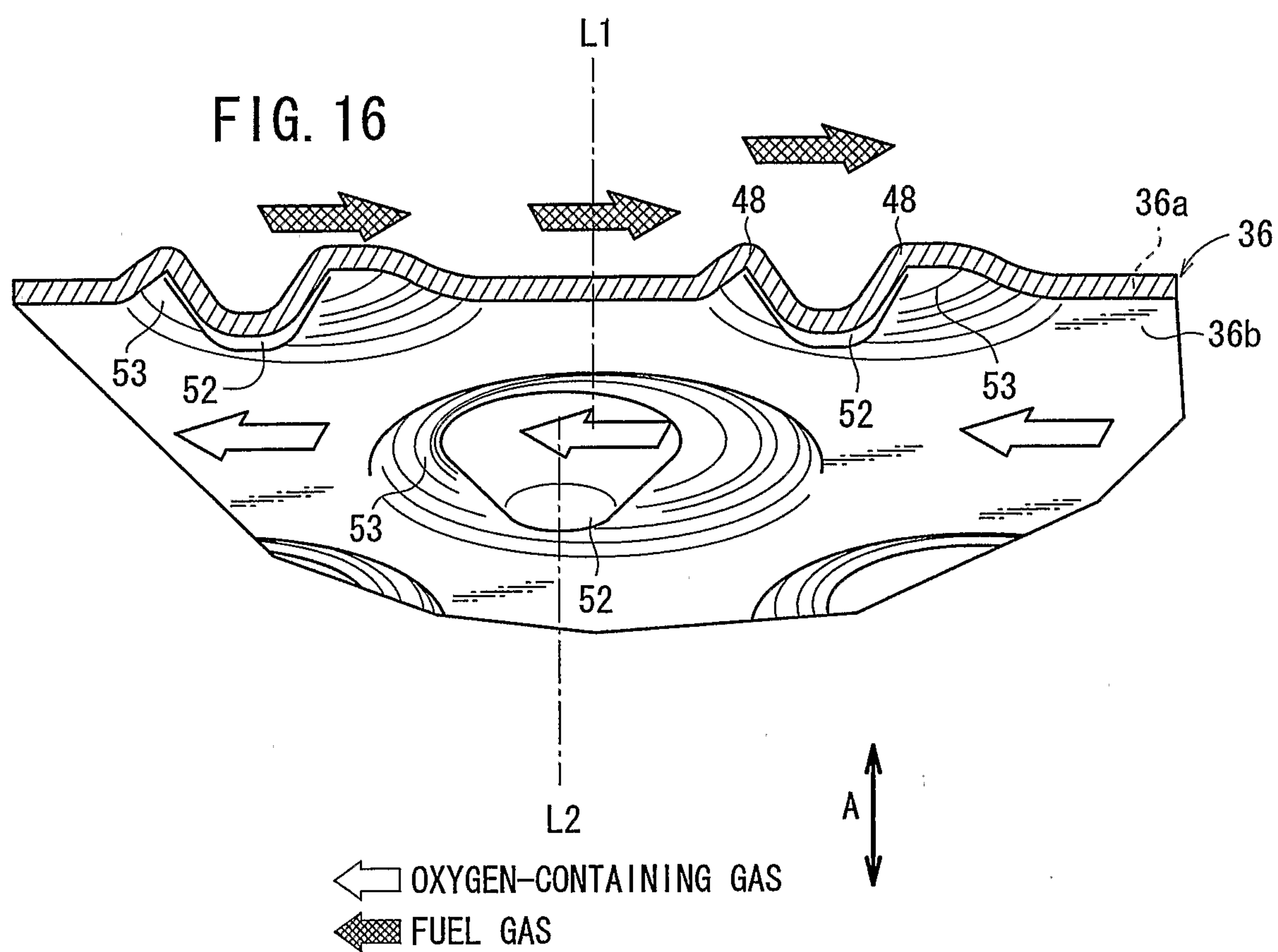


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FIG. 15



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FIG. 17
(Prior Art)

