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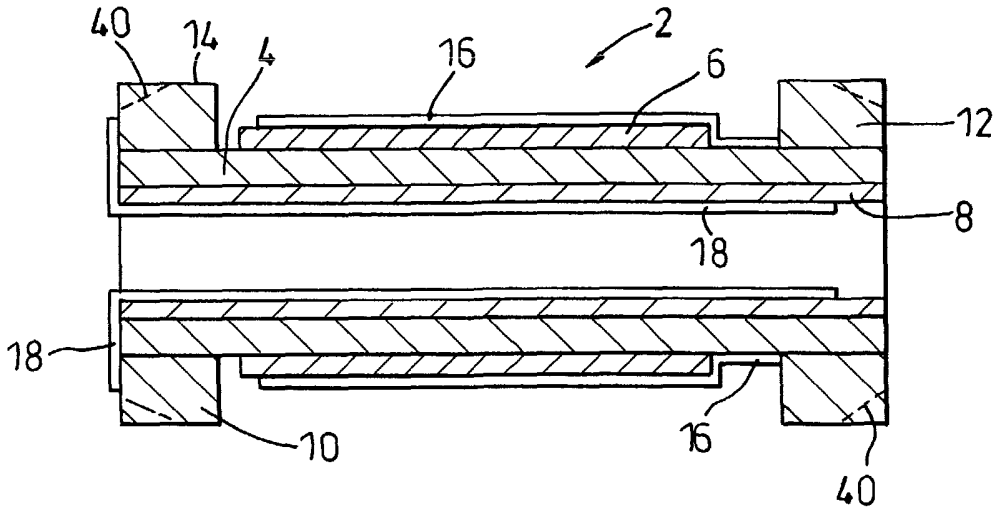

(57) Abstract: A fuel cell element (2) comprising a tube (4) of a solid electrolyte. An outer electrode (6) is provided on an outside of the tube and an inner electrode (8) is provided in an inside of the tube. A ring (10, 12) formed of an electrically conducting material is mounted to the tube (4) and is electrically connected to said tube (4). The ring (10, 12) has a first surface intended to be mountable to and slidingly engageable with a substantially complementary shaped second surface of a wall of conduit means to supply a gaseous consumable to an interior of the tube (4) or to carry gas from said interior. The mounting of the ring (10, 12) to and the engaging of the ring (10, 12) with said second surface is to provide an electrical connection between the fuel cell element (2) and the conduit means.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

FUEL CELL ELEMENT

This invention concerns a fuel cell element, a fuel cell comprising said element, and also a battery of said fuel cells.

Fuel cell elements within a solid oxide fuel cell (SOFC) stack are made up of either planar or tubular elements which are stacked together in racks. One problem with such racks is the seals which separate fuel and oxidant compartments. Another problem is the electrical connections which must be made to the cells. Usually these two issues of sealing and electrical connection are solved separately. For example a standard planar stack described by de Haart et al, SOFC VII, eds.Yokokawa & Singhal, Electrochemical Society, Pennington NJ, 2001, p.111-119 is sealed with glass around the plate edges while the electrical connection is made with metallic interconnect plates. Similarly in a Westinghouse design of tubular stack, the seal is made with a closed end tube into which an air feeder pipe extends, while the electrical connection is made using nickel mesh connectors outside the tubes. In US Patent No. 5 827 620, a small diameter tubular cell is sealed by a rubber joint at the cold end of the tube, whilst the electrical connection is made via wires passing inside and outside the tubes.

For their operation, fuel cells use gaseous consumables in the form of fuel and oxidant. Thus one gaseous consumable is an oxidant, for example oxygen or air, supplied to a cathode of the cell. Another gaseous consumable is the fuel, for example hydrogen or one or more compounds from which hydrogen can be obtained, supplied to an anode of the cell.

According to a first aspect of the invention a fuel cell element comprises a tube comprising solid electrolyte, an outer electrode on an outside of

the tube, an inner electrode in an inside of the tube, a ring comprising electrically conducting material, said ring being mounted to the tube and being electrically connected to a said electrode, said ring having a surface (hereinafter referred to as a first surface) intended to be mountable to and slidingly engageable with a substantially complementary shaped surface (hereinafter referred to as a second surface) of a wall of conduit means to supply a gaseous consumable to an interior of the tube or to carry gas from said interior, and wherein said mounting of the ring to and engaging of the ring with said second surface is to provide an electrical connection between the fuel cell element and the conduit means.

Said mounting of the ring to and engaging of the ring with the second surface may provide obstruction to leakage or passage of gas. For example a gaseous consumable, between the first and second surfaces. Said obstruction may only be partial so at least some leakage or passage may occur. Or said obstruction may be substantially gas tight.

Said ring may be disposed at or adjacent to an end of the tube. Said ring may be substantially continuous or may be interrupted. Said ring may extend substantially wholly or partially about an internal part of the tube. Said ring may be provided on an exterior of the tube. Said ring may be mounted at a substantially fixed position on the tube.

Said solid electrolyte may be a solid oxide electrolyte.

Said fuel cell element may be fittable to said conduit means by a relative push-fit movement between the ring mounted on the tube and said conduit means. Said push-fit may comprise a substantially rectilinear relative movement between the ring and conduit means.

Said fuel cell element may be fittable to said conduit means by a relative rotational, or relative rotary screw, movement between the ring and said conduit means.

Said ring may be secured to the tube by adhesion or adherence thereto and/or by union therewith.

A joint or connection between the ring and the tube may be obstructive to passage of gas through said joint or connection. Said joint or connection may be substantially gas-tight. Electrically conducting sealing means may be provided between the ring and the tube.

The ring may have an elongated portion suitable for insertion into the tube during use which portion acts as an injector for the gas and increases the pressure drop of the gas. The internal diameter of the elongated portion of the ring is preferably about one third of the internal diameter of the tube. Thus if the internal diameter of the tube is from 1.5 to 3.5 mm (preferably about 2 mm), the internal diameter of the elongated portion of the ring is from 0.5 to 1 mm (preferably about 0.6 mm).

The inner electrode is preferably provided with a projection into which the elongated portion of the ring may be inserted in use. The projection is generally formed from electrically conducting material such as metal foil or mesh. The projection is useful as it supports the elongated portion of the ring and provides an electrically conducting path between the inner electrode and the ring. Furthermore there is generally a gap between the projection and the inside of the tube which allows the elongated portion of the ring to expand during use when the fuel cell is operated at high temperature, which substantially reduces the risk of the elongated portion of the ring cracking the tube.

First and second said rings may be mounted on the tube. Said first and second rings may be disposed at or adjacent to a respective end of said tube. The first ring may be electrically connected to one said electrode, and the second ring may be electrically connected to the other said electrode.

Said first and second rings may be substantially similar.

Said first and second said rings may each be of a different shape and/or of a different size.

Said interrupted ring may comprise at least first and second ring portions circumferentially spaced one from another and electrically insulated one from another. The first ring portion may be electrically connected to one said electrode, and the second said ring portion may be electrically connected to the other said electrode.

At least one of said first and second rings may be an interrupted said ring. Each of said first and second said rings may be an interrupted said ring.

Said first and second interrupted rings may each have aforesaid first and second ring portions each electrically connected to a respective said electrode.

The or at least one said ring may have a form of or comprise an apertured cap.

The inner electrode may comprise at least two electrode portions spaced one from the other.

The outer electrode may comprise at least two electrode portions spaced one from the other.

According to a second aspect of the invention a fuel cell comprises a fuel cell element according to the first aspect of the invention, conduit means to supply a gaseous consumable to an interior of the tube or carry gas from said interior, and said conduit means having said second surface with which said first surface of the ring is engaged by a sliding engagement providing an electrical connection between the fuel cell element and the conduit means.

Said first and second surfaces may be so fitted together that there is provided an obstruction to passage of gas between the surfaces. The first and second surfaces may be in a substantially gas tight relationship. Electrically conducting sealing means may be provided between the first and second surfaces.

First said conduit means may be engaged by a said first ring, and second said conduit means may be engaged by a said second ring.

The or a said ring may be provided on an exterior of the tube, and the second surface may be an internal surface of a tubular socket means.

A manifold for flow of gas therethrough may comprise a conduit provided with a plurality of said socket means.

Said manifold may be a first said manifold having a plurality of first said socket means, and another said manifold may be a second manifold having a plurality of second said socket means, a plurality of said fuel cell elements each provided with a respective first and second said ring, said first rings being each slidingly fitted into a respective first socket

means, and said second rings being each slidingly fitted into a respective second socket means, whereby a combination of said manifolds and fuel cell elements forms a battery or rack of fuel cells.

A plurality of said batteries or racks may be stacked or otherwise superimposed one on another to form a larger battery or stack of fuel cells in which at least one said manifold of a said rack is in electrical contact with at least one said manifold of another said rack.

The invention will now be further described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a longitudinal section of a fuel cell element formed according to the first aspect of the invention;

Figure 2 is a section of both (i) a fuel cell formed according to a second aspect of the invention comprising the fuel cell element in Figure 1 and (ii) a battery or rack of such fuel cells;

Figure 3 is a perspective view from above of the battery or rack of fuel cells in Figure 2;

Figure 4 is a diagrammatic end view of a battery of fuel cells comprising a plurality of the batteries or racks of the fuel cells in Figure 3;

Figure 5 is a perspective view of a second embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 6 is a longitudinal section, similar to Figure 1, of a third embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 7 is a side elevation of a fragment of a fourth embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 8 is a side elevation of a fragment of a modification of the fuel cell element in Figure 7;

Figure 9 diagrammatically shows a longitudinal section of an end fragment of a fifth embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 10 diagrammatically shows a longitudinal section of an end fragment of a sixth embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 11 diagrammatically shows a longitudinal section of an end fragment of a seventh embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 12 diagrammatically shows a longitudinal section of an end fragment of a eighth embodiment of a fuel cell element formed according to the first aspect of the invention;

Figure 13 is a fragmentary longitudinal section of a ninth embodiment of a fuel cell element formed according to the first aspect of the invention;

Figures 14 and 15 are respectively views of opposite ends of the fuel cell element in Figure 13;

Figure 16 is a section of both (i) a fuel cell formed according to a second aspect of the invention comprising the fuel cell element in Figure 13 and (ii) a battery or rack of such fuel cells;

Figure 17 is a diagrammatic end view of a battery of fuel cells comprising a plurality of the batteries or racks of the fuel cells in Figure 16;

Figure 18 is a fragmentary longitudinal section of a tenth embodiment of a fuel cell element formed according to the first aspect of the invention; and

Figure 19 is a section of both (i) a fuel cell formed according to a second aspect of the invention comprising the fuel cell element in Figure 18 and (ii) a battery or rack of such fuel cells.

In the following description the same references identify similar or comparable parts.

With reference to Figure 1 a fuel cell element 2 comprises an open-ended tube 4 of solid electrolyte which may be a ceramic, for example a solid oxide electrolyte. The electrolyte tube 4 may be of any desired cross-sectional shape, though conveniently it may be of substantially circular cross-section. An outer electrode 6 of any suitable kind may be applied about the exterior of the electrolyte tube 4 by any suitable method, and an inner electrode 8 of any suitable kind may be applied around the interior of the electrolyte tube by any suitable method. An annular ring or end cap 10 or 12, each with a substantially cylindrical outer face 14 is fitted

onto the respective end of the electrolyte tube 4. The end caps or rings 10, 12 may be formed of any suitable electrically conducting material, for example, metal, graphite, a conducting ceramic material. The end caps 10, 12 may fit snugly on the electrolyte tube 4 and/or may be secured thereto. The end caps 10, 12, may be secured to the electrolyte tube 4 by, and/or may form with the electrolyte tube, substantially gas-tight, conducting joints, for example, comprising using any suitable sealing material or cement for example an electrically conducting ink or by an appropriate brazing or ceramic firing procedure whereby the rings are fixed on. Conducting ink may comprise graphite and/or metal particles or flakes. One or more electrical conductors or current collectors 16, which may be adhered in position, is/are in electrical contact with the outer electrode 6 and with the end cap or ring 12, and one or more electrical conductors or current collectors 18, which may be adhered in position, is/are in electrical contact with the inner electrode 8 and with the end cap or ring 10, for example with the end face of the ring 10 substantially coinciding with an end of the fuel cell element 2.

With reference to Figures 2 and 3, a pair of substantially parallel spaced conduits or manifolds are indicated at 20 and 22 each closed at one end 24 and having a respective pipe 26 or 28 opening into the respective other end. Each manifold 20 or 22 has a plurality of respective, spaced conduits or tubes 30 or 32 mounted on a side wall of the manifold and opening into the manifold interior. The tubes 30 and 32 provide sockets into which the ends of a plurality of said fuel cell elements 2 are fitted. The conduits 20, 22 and their sockets 30, 32 are of electrically conducting material, for example metal. The connector rings or end caps 10 or 12 fit into the sockets 30 or 32 and the wall of each socket 30 or 32 has an inner face 34 or 36 of a shape which substantially corresponds with or substantially complementary to the outer face or periphery of the corresponding end cap 10 or 12. The end caps 12 and the sockets 30

engage together as a push- or sliding-fit by a substantially rectilinear relative movement between the manifold 20 and a said fuel cell element 2. Also the end caps 10 and the sockets 32 engage together as a push- or sliding-fit by a substantially rectilinear relative movement between manifold 22 and a fuel cell element 2. The connector rings or end caps 10, 12 may be a relatively close fit in the sockets 30, 32 so that there is an electrically conducting connection between the manifolds and the end caps. Also the fit may be so close as to provide obstruction to passage or leakage of gas between the sockets and end caps, though some leakage may be tolerated. To make the connection between the sockets 30, 32 and the end caps 12, 14 substantially gas tight suitable sealant, for example a conducting ink, may be introduced into the region between the end caps and sockets.

It can be seen from Figure 3 that the fuel cell elements 2 and the manifolds 20, 22 together form a battery or rack 38 of fuel cells which is substantially flat.

The pipe 26 or 28 may act as inlet for a gaseous consumable which passes from the respective inlet manifold down the fuel cell elements 2 which provide a gaseous output into the respective outlet manifold from whence that output leaves through pipe 28 or 26 acting as an outlet. This gaseous consumable may be fuel or oxidant depending on whether the electrode 8 is an anode or a cathode. For example, if the electrode 8 is an anode, then one of the manifolds 20 or 22 is a fuel inlet manifold and the other manifold is an exhaust or anode gas outlet manifold, and oxidant may be supplied to the exterior of the fuel cell elements as suggested by arrow A in Figures 3 and 4.

The manner in which the fuel cell elements 2 are connected to the manifold 20,22 can lend itself to automated assembly. Also the nature of

the joints between the fuel cell elements 2 and the sockets 30, 32 allows for some tolerance in fitting the fuel cell elements and manifolds together and, during use, some relative movement between the manifolds and the fuel cell elements can take place which will prevent build up of thermal stress. As suggested by the dotted lines 40 in Figure 1 either or both the rings or end caps 10, 12 may be shaped (for example chamfered, or otherwise at least partially reduced in thickness) to reduce stress concentration.

A plurality of batteries or racks 38 of fuel cells may be assembled and stacked on one another in appropriate electrical connection to form an even larger battery 42 of fuel cells as indicated in Figure 4. The manifolds 20, 22 are shaped to allow convenient stacking and/or interengagement of the stacked racks 38, and each rack 38 may be formed as shown in Figure 3 so the manifolds 20, 22 are of asymmetrical disposition whereby the alternating racks in Figure 1 are each upside down and rotated horizontally through 180° relative to the adjacent rack. In Figure 4 electrical insulation, for example an insulating felt, is indicated at 42. The insulating felt may be an aluminium oxide felt. Electrically conducting distance pieces or shims are indicated at 43. The pipes 26 (Figure 3) of one group of racks in Figure 4 are indicated at 26A and the pipes 28 (Figure 3) of that group (Figure 4) at 28A, whereas the pipes 26 (Figure 3) of another group of racks in Figure 4 are indicated at 26B and the pipes 28 of that group indicated at 28B. Thus gas which passes into or leaves the interior of the fuel cell elements 2 can be supplied or flow in the same direction, for example simultaneously, through the pipes 26A, 28A (Figure 4) and can be supplied or flow in the same direction, for example simultaneously through the pipes 26B, 28B.

If for example in Figure 4, the electrodes 8 (Figure 1) are anodes in the fuel cell element 2 gaseous fuel can be supplied to the fuel cell element

through the pipes 26A, 28A simultaneously and anode gas leaves the battery 42 through the pipes 26B, 28B. In this example, the polarities of the different manifolds in the battery or fuel cell stack 42 are indicated by + or -.

The rings or end caps 10, 12 may have any desired external peripheral shape and/or may be any desired size.

The rings or end caps 10 and 12 on a given fuel cell element 2 may be of a different shape and/or size the one relative to the other to ensure that the fuel cell element can only be mounted correctly oriented with respect to manifolds 20 and 22 to which it is desired it be connected. In Figure 5 for example, the end caps 10 and 12 are of different shapes; for example the ring or end cap 12 has a substantially square outer periphery to slidingly fit into a correspondingly shaped socket 30 of a manifold 20 whereas the ring or end cap 10 has a substantially cylindrical or circular outer periphery slidingly fittable into a correspondingly shaped socket 32 of a manifold 22.

In Figure 6 the end caps or rings 10, 12 are of different sizes to fit into respective correspondingly sized sockets.

In Figure 7 the end cap 12 is cylindrical with an external screw thread 44 which screws onto an internal corresponding thread on an inside of a socket 30 of a manifold 20. The end cap 14 (not shown) at the other end of the fuel cell element 2 being preferably a rectilinear push-fit into its corresponding socket 32 of a manifold 32, for example that end cap 14 may have a circular profile allowing it to rotate in its corresponding socket 32 as the end cap 12 is screwed into place. The end cap 12 may be rotated by rotary motion applied to the fuel cell element by a hand or fingers gripping the element. In Figure 8 the threaded end cap 12 has a

nut or other tool engageable formation 46 integral or fast therewith for engagement by a spanner or other appropriate turning tool.

With reference to Figures 9 and 10 either end cap 10 or 12 may have a central web 48 or 50 extending across the corresponding end of the electrolyte tube 4, which web has an aperture 52 or 54 therethrough through which gas may enter or leave the tube; which aperture 52 or 54 may be appropriately sized or shaped for regulating flow of gas therethrough in a desired manner.

In Figure 11 an end cap or ring such as the ring 10 is shown provided with internal sealing in the form of one or more sealing rings 56, whereas in Figure 12 one or more sealing rings 58 is/are shown fitted externally to the end cap. The rings 56, 58 are formed of electrically conducting material, for example graphite.

In Figure 13, the fuel cell element 2 has connector rings or end caps 10, 12 either or both of which may be of an interrupted construction wherein the ring 10 is shown, for example, in Figure 14 comprising two arcuate ring portions 10A and 10B of conducting material electrically insulated from one another by insulation 60. In Figure 15 the ring or end cap 12 of Figure 13 is shown comprising two electrically conducting arcuate portions 12A and 12B insulated one from the other by insulation 60. The outer electrode 6 has two sets of current collectors 16A and 16B, one set connected to the ring portion 10A and the other set connected to the ring portion 12A. If desired, the outer electrode 6 may comprise two electrode portions 6A and 6B interrupted or spaced apart at the region or annular gap demarcated by dotted lines 62. The inner electrode 8 has two sets of current collectors 18A and 18B, one set connected to the ring portion 10B and the other set connected to the ring portion 12B. If desired, the inner electrode 8 may comprise two electrode portions 8A

and 8B interrupted or spaced apart at the region or annular gap demarcated by dotted lines 64. Since the element 2 in Figures 13 to 15 allows electrical power to be taken from each end, the configuration is particularly suited for fuel cell elements 2 which are relatively long.

The fuel cell element 2 of Figure 13 is fitted into the manifolds 20 and 22 in Figure 16. There the manifold 20 and its sockets 30 are divided into an upper or first manifold and socket portion 20A, 30A of conducting material and a lower or second manifold and socket portion 20B, 30B of conducting material spaced by electrical insulating material 66 from the first manifold and socket portion. The manifold 22 and its sockets 32 are divided into an upper or first manifold and socket portion 22A, 32A of conducting material and a lower or second manifold or socket portion 22B, 32B of conducting material spaced by insulating material 68 from the first manifold and socket portion 22A, 32A. A plurality of fuel cell elements 2 (Figure 13) are connected by push fitting to the sockets 30 and 32 of the manifolds 20,22 to form a battery or rack 38A of fuel cells broadly comparable in configuration to the rack 38 of fuel cells in Figure 3. In Figure 16, the upper end cap or ring portion 10A of a fuel cell element 2 is in electrical contact with an upper socket portion 32A and the lower end cap or ring portion 10B is in electrical contact with the corresponding lower socket portion 32B. and the upper end cap or ring portion 12A is in electrical contact with an upper socket portion 30A, and the lower end cap or ring portion 12B is in electrical contact with the corresponding lower socket portion 30B. If, in the rack 38A, the inner electrode of each fuel cell element 2 is an anode and fuel is supplied to the interior of the fuel cell elements through either manifold 20 or 22, the polarities appearing at the upper and lower portions 20A and 20B, 22A and 22B of the manifolds are indicated by + or -.

In Figure 17 the batteries or racks 38A are mounted one on another to form a stack or even larger battery 42A of fuel cells in which the racks 38A are all the same way up and same way round whereby the lower manifold portions 20B, 22B of one rack sit in electrical contact on and with the corresponding upper manifold portions 20A, 22A of the rack immediately adjacent or below.

In Figure 18, the end cap 12 engages with end surface 64 of the tube 4. The end cap 12 has an elongated portion 62 which extends inside tube 4 and acts as a gas injector. The inner electrode 8 has a projection 60 which is of metal mesh projecting axially along the tube 4 from the inner surface 66 of the inner electrode 8. The elongated portion 62 of the end cap 12 is inserted inside projection 60 within the tube. Projection 60 aligns the elongated portion 62 and provides an electrical connection between the end cap 12 and the inner electrode 8.

In Figures 19, conduit or manifold 22 has a plurality of respective, spaced conduits or tubes 32 mounted on a side wall of the manifold and opening into the manifold interior. The tubes 32 provide sockets into which the ends of a plurality of said fuel cell elements 2 are fitted. The fuel cell elements 2 fit into the sockets 32 and the wall of each socket 32 has an inner face 68 of a shape which substantially corresponds with or substantially complementary to the outer face or periphery of the fuel cell element 2.

CLAIMS

1. A fuel cell element comprises a tube comprising solid electrolyte, an outer electrode on an outside of the tube, an inner electrode in an inside of the tube, a ring comprising electrically conducting material, said ring being mounted to the tube and being electrically connected to a said electrode, said ring having a first surface intended to be mountable to and slidingly engageable with a substantially complementary shaped second surface of a wall of conduit means to supply a gaseous consumable to an interior of the tube or to carry gas from said interior, and wherein said mounting of the ring to and engaging of the ring with said second surface is to provide an electrical connection between the fuel cell element and the conduit means.

2. A fuel cell element according to claim 1 wherein said mounting of the ring to and engaging of the ring with the second surface may provide obstruction to leakage or passage of gas.

3. A fuel cell element according to claim 1 or claim 2 wherein said ring is disposed at or adjacent to an end of the tube.

4. A fuel cell element according to any of claims 1-3 wherein said ring is substantially continuous.

5. A fuel cell element according to any of claims 1-4 wherein said solid electrolyte is a solid oxide electrolyte.

6. A fuel cell element according to any of claims 1-5 wherein said fuel cell element is fittable to said conduit means by a relative push-fit movement between the ring mounted on the tube and said conduit means.

7. A fuel cell element according to any of claims 1-5 wherein said fuel cell element is fittable to said conduit means by a relative rotational, or relative rotary screw, movement between the ring and said conduit means.

8. A fuel cell element according to any of claims 1-7 wherein a joint or connection between the ring and the tube is obstructive to passage of gas through said joint or connection.

9. A fuel cell element according to any of claims 1-8 wherein the ring has an elongated portion which is inserted into the tube during use which portion acts as an injector for the gas.

10. A fuel cell element according to claim 9 wherein the inner electrode is provided with a projection into which the elongated portion of the ring may be inserted in use.

11. A fuel cell element according to any of the proceeding claims wherein first and second said rings are disposed at or adjacent to a respective end of said tube.

12. A fuel cell element according to Claim 11 wherein the first ring is electrically connected to one said electrode, and the second ring is electrically connected to the other said electrode.

13. A fuel cell element according to any of claims 1-11 wherein said ring is an interrupted ring including at least first and second ring portions circumferentially spaced one from another and electrically insulated one from another wherein the first ring portion is electrically connected to one said electrode, and the second said ring portion is electrically connected to the other said electrode.

14. A fuel cell element according to any of the preceding claims wherein the or at least one said ring may have a form of or includes an apertured cap.

15. A fuel cell element according to any of the preceding claims wherein the inner electrode includes at least two electrode portions spaced one from the other.

16. A fuel cell element according to any of the preceding claims wherein the outer electrode includes at least two electrode portions spaced one from the other.

17. A fuel cell element substantially as hereinbefore described with reference to any one of Figures 1, 5, 6-15 and 18 of the accompanying drawings.

18. A fuel cell comprises a fuel cell element as defined in any of the preceding claims, conduit means to supply a gaseous consumable to an interior of the tube or carry gas from said interior, and said conduit means having said second surface with which said first surface of the ring is engaged by a sliding engagement providing an electrical connection between the fuel cell element and the conduit means.

19. A fuel cell substantially as hereinbefore described with reference to any one of Figures 2, 16 or 19 of the accompanying drawings.

20. A rack of fuel cells formed from a combination of a plurality of fuel cell elements as defined in any of claims 1 to 17 and at least a first and a second manifold for flow of gas therethrough having a conduit provided with a plurality of socket means wherein said first manifold has a plurality of first said socket means, and said second manifold has a

plurality of second said socket means, and wherein each of said fuel cell elements has a first and a second end wherein a first end of a fuel cell element may be slidingly fitted into a respective first socket means, and a second end may be slidingly fitted into a respective second socket means.

21. A battery formed from a plurality of racks of fuel cells as defined in claim 20 in which at least one said manifold of a said rack is in electrical contact with at least one said manifold of another said rack.

22. A battery substantially as hereinbefore described with reference to any one of Figures 2-4, 16, 17 and 19 of the accompanying drawings.

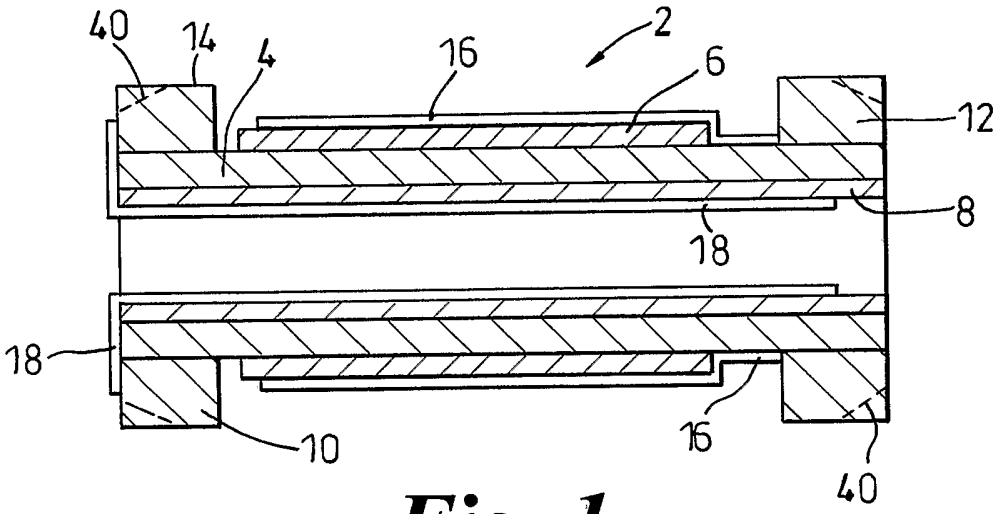

Fig. 1

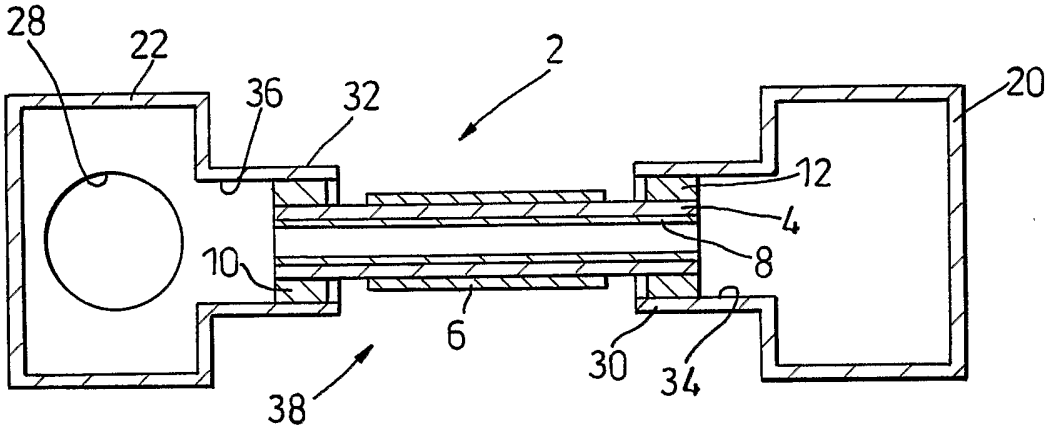

Fig. 2

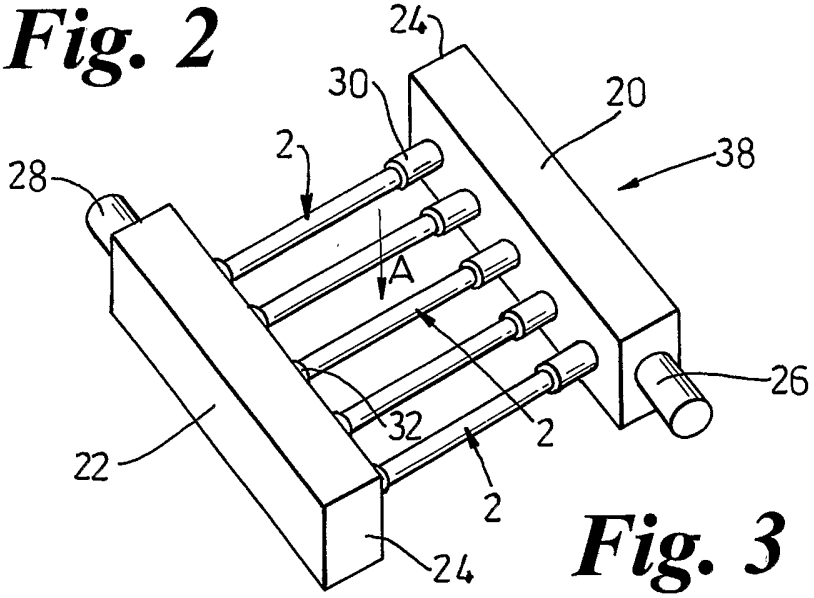

Fig. 3

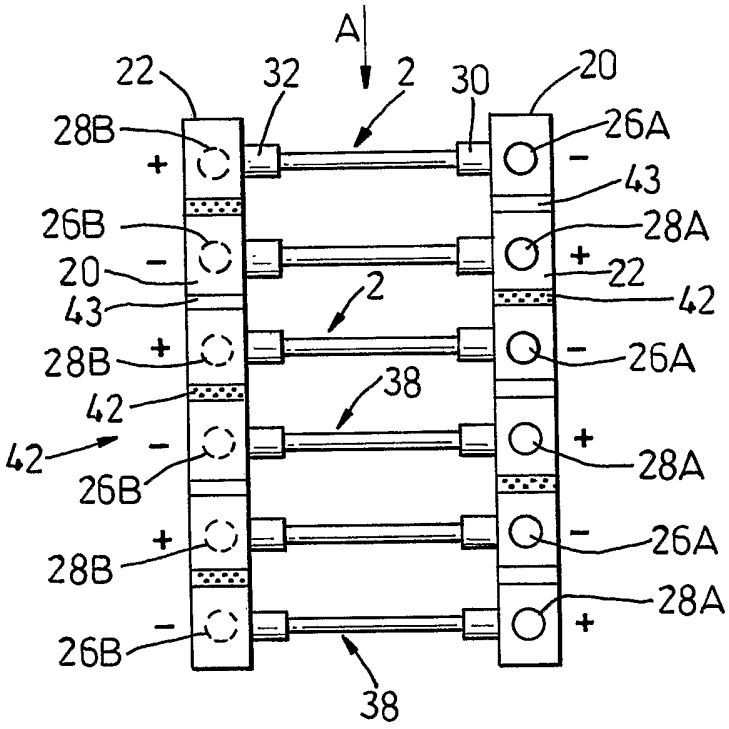

Fig. 4

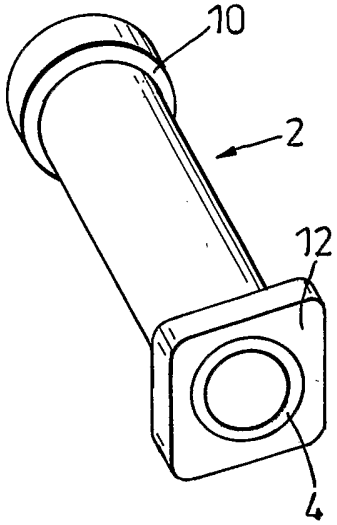

Fig. 5

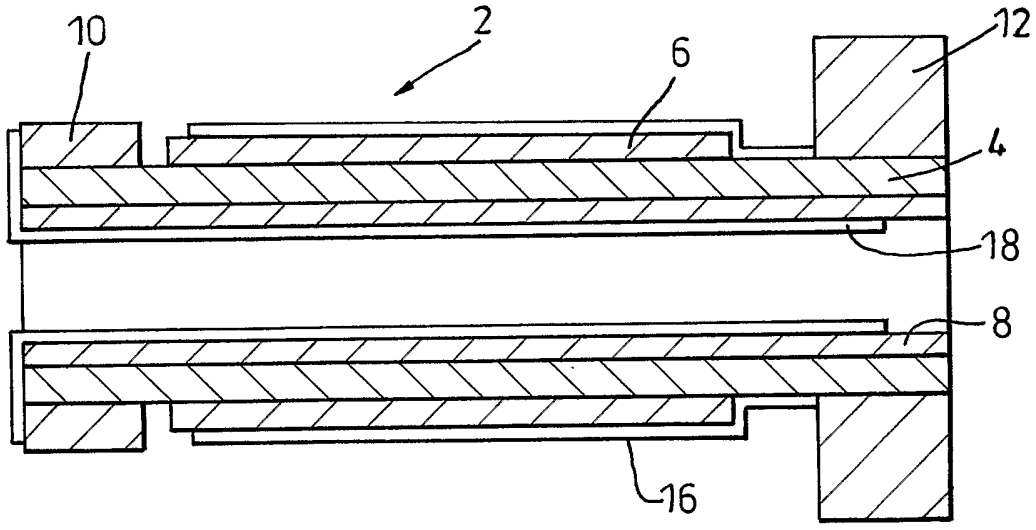

Fig. 6

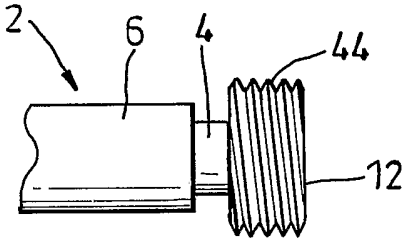

Fig. 7

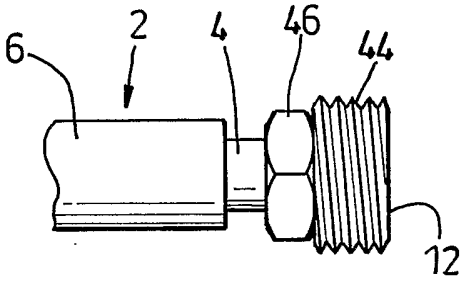

Fig. 8

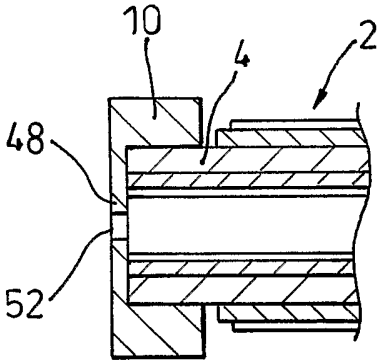

Fig. 9

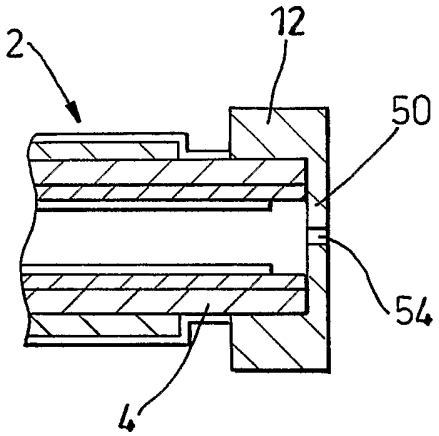

Fig. 10

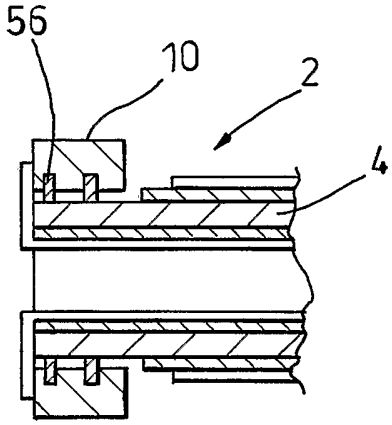

Fig. 11

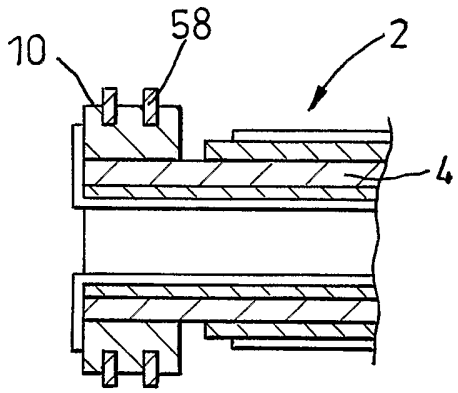

Fig. 12

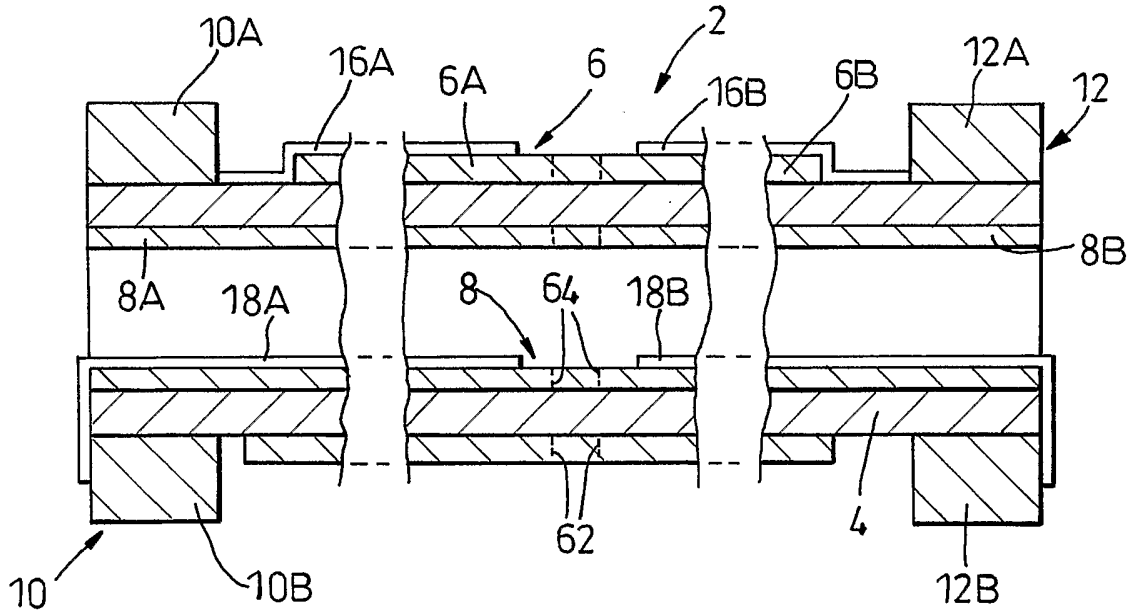

Fig. 13

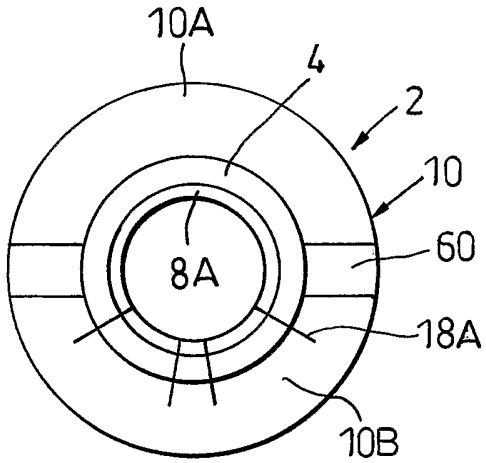

Fig. 14

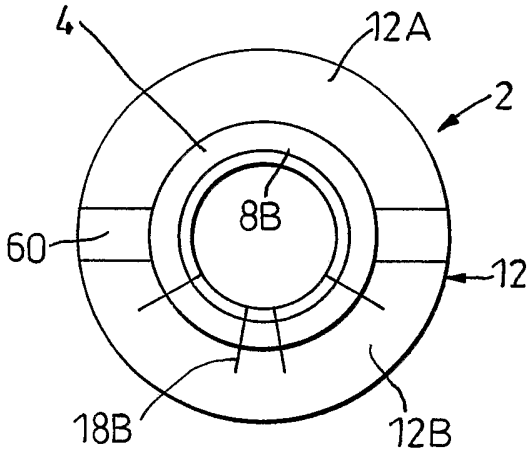

Fig. 15

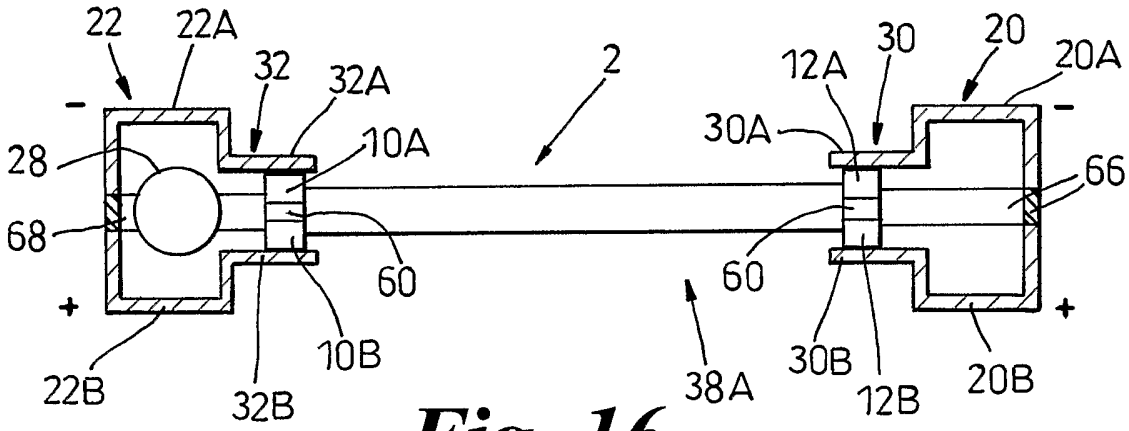

Fig. 16

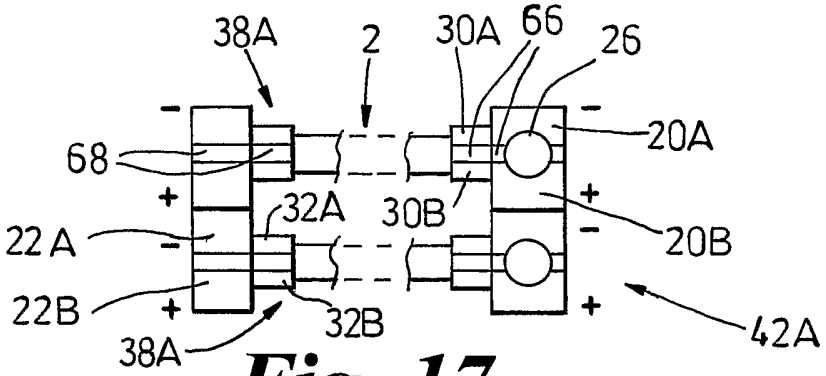

Fig. 17

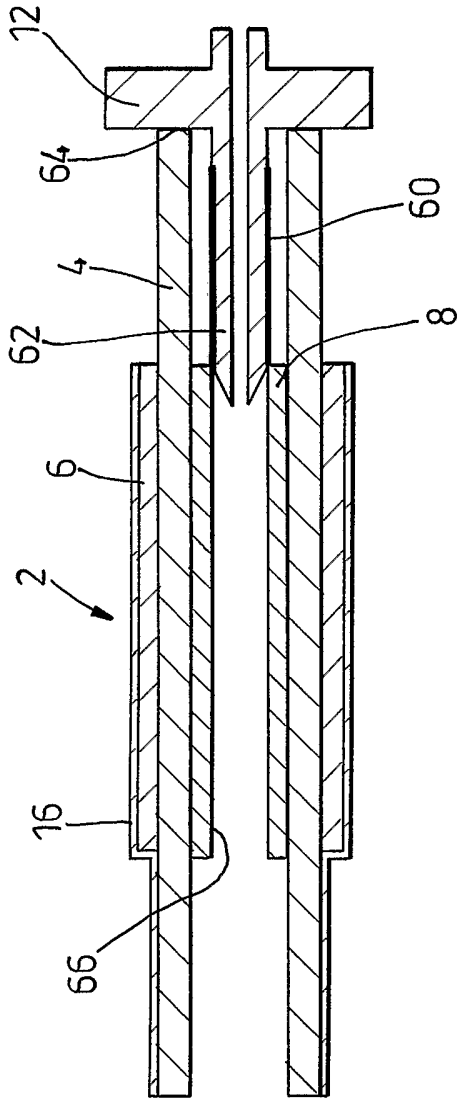

Fig. 18

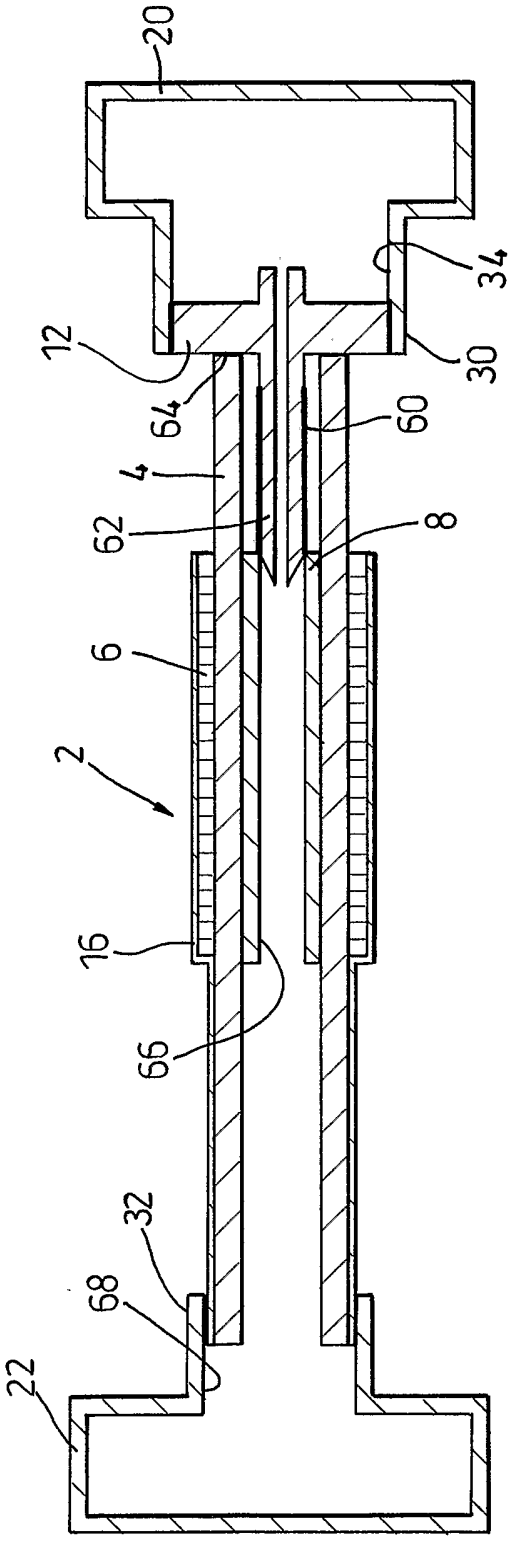

Fig. 19