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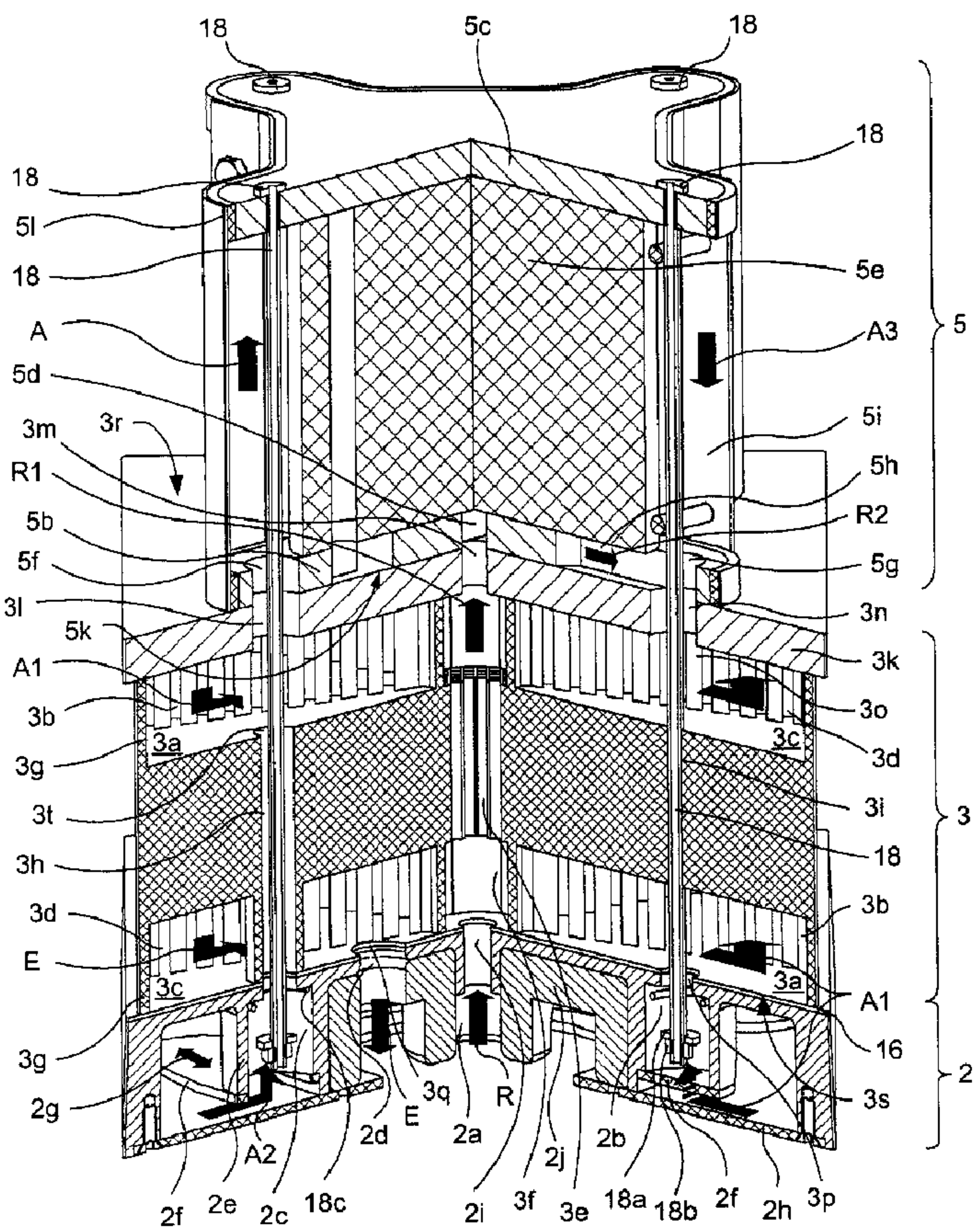
(54) **Titre :** SYSTEME DE PILE A OXYDE SOLIDE (SOFC)
(54) **Title:** SOLID OXIDE FUEL CELL SYSTEM



(57) **Abrégé/Abstract:**
A SOFC system (1) for generating electric power by combination of oxygen with a fuel gas stream (R), including a fuel cell (5) having a fuel gas inlet port (5d), an air stream inlet port (5f) and an exhaust gas stream outlet port (5g), and comprising a heat

(57) **Abrégé(suite)/Abstract(continued):**
exchanger (3) with a fuel channel (3f), wherein said heat exchanger (3) comprises a first fluid path (3a) with an inlet port (3p) connected to an air supply and an air stream outlet port (31) connected to the air stream inlet port (5f); and wherein said heat exchanger (3) comprises a second fluid path (3c) with an outlet port (3q) and an exhaust gas stream inlet port (3n) connected to the exhaust gas stream outlet port (5g); and wherein said fuel channel (3f) comprises a fuel supply and a fuel gas outlet port (3m) connected to the fuel gas inlet port (5d), and wherein said heat exchanger (3) is a unit separate from the fuel cell (5) and consisting of ceramics, and wherein said heat exchanger (3) comprising a base plate (3k) on which the fuel cell (5) being arranged.

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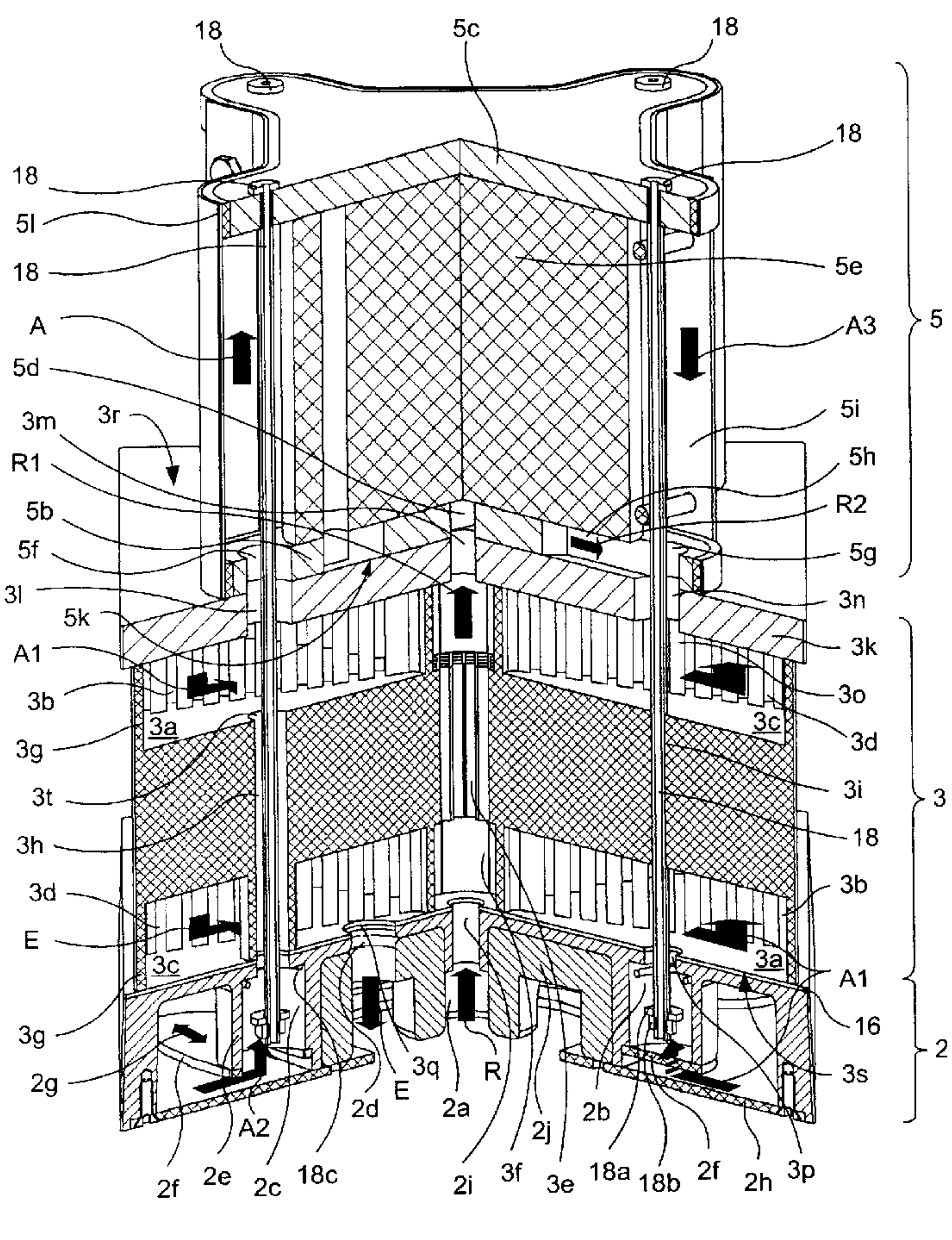

(57) Abstract: A SOFC system (1) for generating electric power by combination of oxygen with a fuel gas stream (R), including a fuel cell (5) having a fuel gas inlet port (5d), an air stream inlet port (5f) and an exhaust gas stream outlet port (5g), and comprising a heat exchanger (3) with a fuel channel (3f), wherein said heat exchanger (3) comprises a first fluid path (3a) with an inlet port (3p) connected to an air supply and an air stream outlet port (31) connected to the air stream inlet port (5f); and wherein said heat exchanger (3) comprises a second fluid path (3c) with an outlet port (3q) and an exhaust gas stream inlet port (3n) connected to the exhaust gas stream outlet port (5g); and wherein said fuel channel (3f) comprises a fuel supply and a fuel gas outlet port (3m) connected to the fuel gas inlet port (5d), and wherein said heat exchanger (3) is a unit separate from the fuel cell (5) and consisting of ceramics, and wherein said heat exchanger (3) comprising a base plate (3k) on which the fuel cell (5) being arranged.

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SOLID OXIDE FUEL CELL SYSTEM

TECHNICAL FIELD

The present invention relates to a solid oxide fuel cell (SOFC) system for generating electric power by combination of oxygen with a fuel gas stream, including a solid oxide fuel cell and a heat exchanger.

BACKGROUND OF THE INVENTION

Fuel cells which generate electric power by the electrochemical combination of hydrogen and oxygen are well known. In one form of such a fuel cell, an anodic layer and a cathodic layer are separated by an electrolyte formed of a ceramic solid oxide. Such a fuel cell is known in the art as a “solid oxide fuel cell” (SOFC). A fuel gas stream comprising hydrogen, either pure or reformed from hydrocarbons, and oxygen, typically air, are to be brought into the fuel cell. A complete SOFC system typically includes auxiliary subsystems for, among other requirements, generating the fuel gas stream by processing hydrocarbons into carbon monoxide and hydrogen, tempering the reformate fuel and air entering the fuel cell, providing air to the cathode for reaction with hydrogen in the fuel cell, providing air for cooling the fuel cell stack, and burning unused fuel in an afterburner. Such an auxiliary subsystem can attain a complexity comparable to that of the fuel cell.

SUMMARY OF THE INVENTION

It is an object of the present invention to improve this type of SOFC system in such a manner that the system as a whole can be simplified.

According to an aspect of the present invention, there is provided a SOFC system for generating electric power by combination of oxygen with a fuel gas stream, including a fuel cell having a fuel gas inlet port, an air stream inlet port and an exhaust gas stream outlet port, and comprising a heat exchanger with a fuel channel. The heat exchanger comprises a first fluid path with an inlet port connected to an air supply and an air stream outlet port connected to the air stream inlet port. The heat exchanger comprises a second fluid path with an outlet port and an exhaust gas stream inlet port connected to the exhaust gas stream outlet port; the fuel channel comprises a fuel supply and a fuel gas outlet port connected to the fuel gas inlet port. The heat exchanger is a unit separate from the fuel cell, and consists of ceramics. The heat exchanger comprises a base plate on which the fuel cell being directly arranged. At least one of said air stream outlet port, exhaust gas stream inlet port and fuel gas outlet port is formed in the base plate so as to extend through the base plate. At least one of the corresponding inlet ports and outlet ports enabling the gas stream flow between the fuel cell and the heat exchanger are arranged opposite to each other, to enable a direct flow transition between the fuel cell and the heat exchanger.

In one embodiment, the base plate is of a material different from a material of the heat exchanger.

In another embodiment, the fuel cell is arranged on top of the base plate, and the base plate is carrying the fuel cell.

In a further embodiment, the heat exchanger is a monolithic type heat exchanger.

In a still further embodiment, the base plate is of ceramics material.

In yet another embodiment, the base plate is part of the monolithic type heat exchanger.

In yet a further embodiment, the air stream outlet port, the fuel gas outlet port and the exhaust gas stream inlet port are arranged on a common front surface of the heat exchanger.

In yet another embodiment, the inlet port connected to the air supply, the outlet port of an exhaust gas stream and the fuel channel connected to the fuel supply are arranged on a side of the heat exchanger opposite to the front surface.

In a further embodiment, the fuel gas inlet port, the air stream inlet port and the exhaust gas stream outlet port are arranged on a common front surface of the fuel cell.

In a still further embodiment, the fuel cell is arranged on top of the heat exchanger. The corresponding inlet ports and outlet ports enabling the gas stream flow between the fuel cell and the heat exchanger are arranged opposite to each other, to enable a direct flow transition between the fuel cell and the heat exchanger.

In yet another embodiment, the first fluid path comprises a first channel. The second fluid path comprising a second channel separated by a wall, to allow a heat exchange between the exhaust gas stream flowing in the second channel and the air stream flowing in the first channel.

In a further embodiment, there is a plurality of first and second channels.

In a still further embodiment, the first and second channels are arranged to form a counter cross flow between the first and second fluid path.

In another embodiment, the heat exchanger comprises an afterburner arranged in the second fluid path.

In yet another embodiment, the fuel channel comprises a catalytic fuel processor.

In a further emobdiment, the fuel channel comprises a layer of catalytic substances.

In a still further embodiment, the heat exchanger comprises an air stream bypass with an inlet port connected to an air supply and an air stream bypass outlet port disposed in fluid communication with the air stream outlet port.

In another embodiment, at least one valve is disposed to control at least one of an air stream in the first fluid path and an air stream bypass.

In yet another embodiment, the valve is disposed below the heat exchanger.

In a further embodiment, an interface base is disposed below the heat exchanger, the interface base comprising the fuel gas stream inlet port, the air stream inlet port and the exhaust gas stream outlet port. The fuel gas stream inlet port is fluidly connected to the fuel gas stream channel, and the air stream inlet port is fluidly connected to the first fluid path, and the exhaust gas stream outlet port is fluidly connected to the exhaust gas stream outlet port of the heat exchanger.

In a still further embodiment, the fuel gas stream inlet port, the air stream inlet port and the exhaust gas stream outlet port are arranged at the bottom of the interface base.

In another embodiment, the interface base is coupled to the heat exchanger so that there is a direct flow transition from the interface base to the heat exchanger, the heat exchanger being placed on top of the interface base and the fuel cell being placed on top of the heat exchanger.

In yet another embodiment, the interface base and the fuel cell are connected by compressing means extending through the heat exchanger.

In a further embodiment, at least one of the first and second fluid path comprises a channel with a rough surface.

In a still further embodiment, the fuel cell is arranged within an insulation, the insulation comprising a fluid tight room with a fluid inlet and outlet, to create a vacuum within the room and/or to pressurize the room.

In another embodiment, a control unit as well as temperature sensors and a valve being connected with the control unit, the valve determines the flow of an air stream and a bypass air stream, the air stream and the bypass air stream forming a fuel cell air stream supplied to the fuel cell, and the temperature and/or the amount of the fuel cell air stream depending on the sensed values of the temperature sensors and being controlled by the control unit. The temperature sensors being provided in a path of the fuel call air stream.

According to another aspect of the present invention, there is provided a heat exchanger for a SOFC system, comprising a fuel channel with a fuel gas outlet port, comprising a first fluid path with an air stream outlet port, comprising a second fluid path with an exhaust gas stream inlet port. The heat exchanger consists of ceramics. The heat exchanger comprises a base plate on which a fuel cell is to be provided, and at least one of air stream outlet port, exhaust gas stream inlet port and fuel gas outlet port extending through the base plate. The heat exchanger, with the exception of the base plate is a monolithic type heat exchanger.

In one embodiment the base plate is a part of the monolithic type heat exchanger.

Accordingly, it is an inventive concept to integrate and thermally couple a fuel channel with a heat exchanger, wherein the heat exchanger is a unit separate from the fuel cell and consisting of ceramics. In one preferred embodiment the heat exchanger and the fuel cell are combined with one another in such a manner that the heat exchanger is disposed directly at the fuel cell, and that corresponding inlet port and outlet ports of the fuel cell and the heat exchanger, enabling the gas stream flow between the fuel cell and the heat exchanger, are arranged opposite to each other. By this arrangement, a direct flow transition from the heat exchanger to the fuel cell can be achieved. The heat exchanger comprises various conveying means which are arranged in a way that a separate socalled manifold can be omitted. In other words the heat exchanger itself comprises various conveying means and forms therefore a kind of manifold. The heat exchanger, consisting of ceramics with poor thermal conductivity, forms also a heat insulation element between the side directed to the fuel cell side having high gas temperatures, and the opposite side having lower gas temperatures. As a result of this coupling, space is saved, since an additional housing and pipeline systems can be omitted, and because of the poor thermal conductivity a small heat exchanger is sufficient to separate the high temperature side from the low temperature side. In addition, the manufacturing costs of the heat exchanger are low, leading to a fuel cell system with a reduction in space and costs. Moreover the fuel channel in the heat exchanger may also comprise a catalytic fuel processor. Moreover, to increase the preheating of the air, the heat exchanger may comprise a chamber which allows the residual gas from the fuel cell to be subjected to an afterburning process. Due to the successful combustion in the heat exchanger, this residual energy is then also, at least partly, supplied to the reactants, which are to be heated, preferably air or oxygen is used for this purpose. Moreover to improve the control of the reactant's temperature and/ or the reactant's amount, the heat exchanger may comprise a separate air stream bypass, which joins the preheated air stream before entering the fuel cell. A temperature sensor, a control system and a valve may be suitable to control temperature and/ or amount of the air stream supplied into the fuel cell. Moreover the whole fuel cell system may be built very small, preferably in form of a pile, the fuel cell being arranged on top of the heat exchanger. Moreover all conveying means between the fuel cell and the heat exchanger may be arranged within the area in common of the heat exchanger and the fuel cell, which allows building a stack without, from the outside, any visible connection between the fuel cell and the heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the invention will be more fully understood and appreciated from the following description of certain exemplary embodiments of the invention taken together with the accompanying drawings, in which like numerals represent like components:

Fig. 1 is a schematic diagram of a SOFC system;

Fig. 2 is an isometric cross-sectional view of a SOFC system;

Fig. 3 is an isometric cross-sectional view of another SOFC system;

Fig. 4 is an isometric view of a heat exchanger;

Fig. 5a is a cross-sectional view of the heat exchanger taken along line A-A in Fig. 4;

Fig. 5b is a cross-sectional view of the heat exchanger taken along line B-B in Fig. 4;

Fig. 6 is an isometric view of the SOFC system from below;

Fig. 7 is a schematic diagram of another SOFC system without an air stream bypass;

Fig. 8 is a schematic view of a fuel cell stack with internal manifolding;

Fig. 9 is a schematic view of a fuel cell stack with internal fuel gas and air manifolding but external exhaust air manifolding;

Fig. 10 is a schematic view of a fuel cell stack with combined external air and internal fuel gas manifolding;

Fig. 11 is a schematic view of a fuel cell stack with external manifolding;

Fig. 12 is an isometric cross-sectional view of a further SOFC system;

Fig. 13 is an isometric cross-sectional view of a further heat exchanger.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 discloses a SOFC system 1 comprising an interface base 2, a heat exchanger 3 and a high temperature unit 4, comprising a SOFC fuel cell 5 and insulation 6. The interface base 2, the heat exchanger 3 and the fuel cell 5 are arranged one on top of the other, forming an arrangement similar to a pile. This pile can be arranged in different ways, for example also vice versa as disclosed in figure 1, with the fuel cell 5 on the bottom end and the interface base 2 on the top end. The fuel cell 5 is supplied with an air stream A and a fuel gas stream R1. An electrochemical reaction 5a takes place within the fuel cell stack. A cathode exhaust A3 and an anode exhaust R2 leaving the fuel cell stack. The cathode exhaust A3 is typically primarily air (oxygen depleted). The anode exhaust R2 contains unoxidized fuel species such as carbon monoxide, hydrogen containing some remaining hydrocarbons.

The heat exchanger 3 comprises a first fluid path 3a, a second fluid path 3c and a fuel channel 3f, which might be catalytic fuel processor 3e, wherein all of them are thermally coupled. The heat exchanger 3 consisting of ceramics with various gas stream conveying means. The interface base 2 is connected with a reactant gas supply 7, an exhaust gas outlet 9 and an air supply 8 leading to a valve 2f which is electrically operated by a drive 14. Depending on the position of the valve 2f, the ratio between the air stream A1 and the bypass air stream A2 is varied. The air stream A1 is preheated by passing through the first fluid path 3a of the heat exchanger 3. The anode exhaust R2 and the cathode exhaust A3 is directed into an afterburner 3o which is part of the heat exchanger 3. The afterburner 3o burns the unused fuel in the SOFC stack exhaust. The afterburner 3o may be a separate chamber within the heat exchanger 3, or for example arranged within the second fluid path 3c. The afterburner 3o may comprise catalytic material, for example a catalytic coating of the walls. The exhaust gas E is fed through the second fluid path 3c and the heat produced by the afterburner 3o is exchanged to the first fluid path 3a and the fuel channel 3f, to preheat the air stream A1, and, if necessary the fuel gas stream R. It is preferred to use the cathode exhaust A3 in the afterburner 3o, as this oxygen containing stream A3 is heated in the fuel cell 5, in addition a separate oxygen containing stream may be added, to permit complete combustion of the remaining fuel in the afterburner 3o.

The SOFC system 1 comprises a control unit 11, which is connected to various sensors 15a-15e, in particular temperature sensors, as well as to drive means 14, to move the valve 2f and to control the various temperatures in the SOFC system 1. The control unit 11 also comprises an electrical output 10, which is connected with the cathode and anode current collector 10a, 10b, as well as a electronic switch 12.

The heat exchanger 3 consists of ceramics. This means the heat exchanger 3 is made of hard brittle material produced from non-metallic minerals by firing at high temperatures. These materials include, but are not limited to ceramics, zirconium phosphate, silicon nitride, aluminium nitride, molybdenum disilicide, zirconia toughened aluminium oxide, aluminium phosphate, zirconium oxide, titanium carbide, aluminium oxide, zirconium carbide, zirconium disilicide, alumino-silicates, and silicon carbide. Ceramics is an excellent choice for the heat exchanger 3 because of the low thermal conductivity and the low thermal expansion coefficient.

The SOFC system 1 according to figure 2 includes a fuel cell 5 having a fuel gas inlet port 5d, an air stream inlet port 5f and an exhaust gas stream outlet port 5g, and comprises a heat exchanger 3 with a fuel channel 3f comprising a catalytic fuel processor 3e, wherein said heat exchanger 3 comprises a first fluid path 3a with an inlet port 3p connected to an air supply 7 and an air stream outlet port 3l connected to the air stream inlet port 5f, and wherein said heat exchanger 3 comprises a second fluid path 3c with an outlet port 3q connected to the exhaust gas outlet 9 and an exhaust gas stream inlet port 3n connected to the exhaust gas stream outlet port 5g, and wherein said catalytic fuel processor 3e comprising an inlet port 2i connected to a fuel supply 7 and a fuel gas outlet port 3m connected to the fuel gas inlet port 5d, wherein the catalytic fuel processor 3e is thermally coupled to at least one of the first and second fluid path 3a,3c, and wherein said heat exchanger 3 is a unit separate from the fuel cell 5 and consisting of ceramics. The fuel cell 5 comprising a bottom plate 5b, a top plate 5c and there between a plated stack 5e. Where the cathode exhaust stream A3 and the anode exhaust stream R2 meet, they form an afterburner 3o.

The heat exchanger 3 is a monolithic ceramic. The heat exchanger 3 could also consist of various ceramic parts joined together to form the heat exchanger 3. The heat exchanger 3 comprising a base plate 3k suitable to be connected with the fuel cell 5. In one preferred embodiment the base plate 3k is sintered with the part of the heat exchanger 3 below the base plate 3k, forming one single, monolithic piece of ceramic. In one preferred embodiment the fuel cell 5 is arranged on top of the base plate 3k, and the base plate 3k having a thickness of being able to carry the fuel cell 5. In one preferred embodiment the air stream outlet port 3l, the fuel gas outlet port 3m and the exhaust gas stream inlet port 3n are arranged on a common front surface 3r of the base plate 3k. In one preferred embodiment are the inlet port 3p connected to the air supply, the outlet port 3q of the exhaust gas stream E and the inlet port 2i connected to the fuel supply R arranged on a side 3s of the heat exchanger 3 opposite to the front surface 3r.

In one preferred embodiment are the fuel gas inlet port 5d, the air stream inlet port 5f and the exhaust gas stream outlet port 5g arranged on a common front surface 5k of the fuel cell 5. In the most preferred embodiment the fuel cell 5 is arranged on top of the heat exchanger 3, wherein the corresponding inlet ports 5f, 3n,5d and outlet ports 3l,5g,3m, enabling the gas stream flow between the fuel cell 5 and the heat exchanger 3, are arranged opposite to each other, to enable a direct flow transition between the fuel cell 5 and the heat exchanger 3, as shown in figure 2. As can be seen, this arrangement allows building a very compact SOFC system 1. The interface base 2 being the cold side and the fuel cell 5 being the hot side of the SOFC system 1, and the interface base 2 and the fuel cell 5 being separated by the ceramic heat exchanger 3. The heat exchanger 3 has poor thermal conductivity from the fuel cell 5 to the interface base 2. The heat exchanger 3 also comprises all fluid conducting connections between the fuel cell 5 and the interface base 2, thus forming a manifold of ceramics. All fluid conducting connections are arranged within the heat exchanger 3. This ceramic heat exchanger 3 allows building a very compact, cheap and reliable SOFC system 1.

In a preferred embodiment each of the first and second fluid path 3a,3c comprise a plurality of first and second channels 3b,3d separated by a thin wall, to allow a heat exchange between the exhaust gas stream E flowing in the second channel 3d and the air stream A1 flowing in the first channel 3b. Figure 4 shows the heat exchanger 3 according to figure 2 in detail, with a plurality of first and second channels 3b,3d. Figure 5a discloses a cross-sectional view of the heat exchanger 3 taken along line A-A in figure 4, and figure 5b a cross-sectional view along the line B-B in figure 4. The plurality of first and second channels 3b,3d are arranged to form a counter cross flow between the first and second fluid path 3a,3c, as can be seen with the crossing flow of the air stream A1 and exhaust gas stream E in figures 5a,5b.

The afterburner 3o may also be arranged within the second fluid path 3c, in that the cathode exhaust stream A3 and the anode exhaust stream R2 are guided either separately or as disclosed in figure 2 within the heat exchanger 3, to form therein an afterburner 3o.

The catalytic fuel processor 3e disclosed in figure 2 is arranged within the channel 3f, therein a ceramic cell structure forming channels in the direction of flow. The walls of this cell structure carrying catalytic substances to form a catalytic fuel processor. Preferable these catalytic substances are arranged on the ceramic material of the heat exchanger. In combination with preprocessed fuel or pure hydrogen the catalytic fuel processor 3e may be replaced by a channel 3f only, without further structures inside.

In a preferred embodiment, the heat exchanger 3 comprises an air stream bypass 3h with an inlet port 2c connected to an air supply 8 and an air stream bypass outlet port 3t disposed in fluid communication with the air stream outlet port 3l. At least one valve 2f, comprising a valve seat 2e and a plate 2f moveable in direction 2g by a drive 14, is disposed to control at least one of the air streams A1,A2 in the first fluid path 3a and the air stream bypass 3h. This allows to control the temperature of the air stream A entering the air stream inlet port 5f. The valve 2f is part of the interface base 2. In a preferred embodiment, the interface base 2 comprises two or four valves 2f, one for each air stream A1,A2. Each valve 2f can be activated independently, to control each air stream A1, A2 as well as the total amount of the air stream A. The interface base 2 is disposed below the heat exchanger 3, the interface base 2 comprising a fuel gas stream inlet port 2a, an air stream inlet port 2b,2c and a exhaust gas stream outlet port 2d, which are fluidly connected to the corresponding first and second fluid path 3a,3c, the fuel gas stream channel 3f and the exhaust gas stream outlet port 3q of the heat exchanger 3. The fuel gas stream inlet port 2a, the air stream inlet port 2b, 2c and the exhaust gas stream outlet port 2d are arranged at the bottom of the interface base 2. The interface base 2 is coupled to the heat exchanger 3 so that there is a direct flow transition from the interface base 2 to the heat exchanger 3, the heat exchanger 3 being placed on top of the interface base 2 and the fuel cell 5 being placed on top of the heat exchanger 3. In a preferred embodiment, the interface base 2 and the fuel cell 5 are connected by compressing means 18 extending in holes 3i or in the bypass 3h through the heat exchanger 3. The compressing means 18 disclosed in figure 2 comprising a ceramic disk 18a, a nut 18b and a spring 18c.

To improve the heat exchange, the walls of the heat exchanger 3 forming the first and second fluid path 3a,3c as well as the catalytic fuel processor 3e may be structured or rough. According to figure 2, the interface base 2 is of metal, comprising a exhaust gas insulation 2j of ceramics, and being covered by a thin sealing material 16. The outer wall 3g of the heat exchanger 3 lying on the sealing material 16, to enact a preferable gas tight connection, so the first and second fluid path 3a,3c is gastight to the outside of the SOFC system 1.

Figure 3 shows another SOFC system 1 built in form of a stack comprising the interface base 2, the heat exchanger 3 and the high temperature unit 4. The high temperature unit 4 comprises the fuel cell 5 arranged within an insulation 6 with an inner and outer metallic shell 6a,6b. Due to the low thermal conductivity of the ceramic heat exchanger 3, the height of the heat exchanger 3 may be very small, for example in the range of 5 cm to 30 cm. This allows building a small and compact SOFC system 1, as shown in figure 6. In a preferred embodiment all gas stream inlet and outlet ports, the fuel gas stream inlet port 2a, the exhaust gas stream outlet port 2d, the air stream inlet port 2k as well as other ports and electric connectors are arranged on the bottom side of the interface base 2. In one embodiment, the inner and outer metallic shell 6a,6b may comprise or form a fluid tight room, in particular a gas tight room. This room may contain a vacuum to improve insulation. This room may also comprise a fluid inlet and outlet, to create a vacuum or to pressurize the room with a certain substance like air. The insulation value of this insulation 6 may be varied depending on the pressure and the used substance, allowing modifying the insulation value during operation of the SOFC system 1 by increasing the pressure or the vacuum within the insulation 6 by means like a pump and sensors, which are not shown in figure 3.

Figure 7 shows a heat exchanger 3 without a bypass air stream A2, which means the whole air stream A is guided through the first fluid path 3a.

Figures 8 to 11 show in schematic views different embodiments of fuel cell stack 5e which are connected to a heat exchanger 3, which is not shown, but which would be ranged below the fuel cell stack 5e. All heat exchangers 3 suitable to accommodate a fuel cell stack 5e as disclosed in figures 8 to 11 may be built as disclosed in figure 2 or 3.

In the embodiment according to figure 10, the fuel cell stack 5e is arranged on top of the heat exchanger 3, and regarding the fuel gas stream R1 and the anode exhaust stream R2, there is a direct flow transition between them. In contrast, the air stream A is not feed from the bottom but from the side of the fuel cell stack 5e, and the cathode exhaust stream A3 escaping also from a side of the fuel cell stack 5e, but both streams A and A3 escaping within the fuel cell 5 to the heat exchanger 3. This embodiment requires manifolding means like pipes to provide gas connecting means between the heat exchanger 3 and the fuel cell stack 5e for the streams A and A3. The embodiment disclosed in figure 2 comprises a fuel cell stack 5e as disclosed in figure 10, whereas the manifolding means for the streams A and A3 are formed between the fuel cell stack 5e and a thin metal 5l surrounding the fuel cell stack 5e. This metal 5l is gas tightly connected with the bottom plate 5b and the top plate 5c.

Figure 8 discloses a further embodiment, with a fuel cell stack 5e having an air stream A and a fuel gas stream R1 entering at the bottom and the anode exhaust stream R2 and the cathode exhaust stream A3 escaping on the same side at the bottom of the fuel cell stack 5e. The fuel cell stack 5e and the heat exchanger 3 are built to comprise also the entire manifolding. Between the heat exchanger 3 and the fuel cell 5, additional pipes may be arranged, to allow an additional gas flow between the heat exchanger 3 and the fuel cell 5 or the insulation 6.

In the embodiment according to figure 9, the fuel cell stack 5e is arranged on top of the heat exchanger 3, and regarding the fuel gas stream R1, the anode exhaust stream R2 and the Air stream A, there is a direct flow transition between them. In contrast, the cathode exhaust stream A3 is not escaping at the bottom but from the side of the fuel cell stack 5e. This embodiment may require additional manifolding means like pipes to provide gas connecting means between the heat exchanger 3 and the fuel cell stack 5e for the stream A3. But in case of a gas tight Insulation 5l surrounding the fuel cell 5, the cathode exhaust may be guided without additional piping to the heat exchanger 3.

In the embodiment according to figure 11, the fuel cell 5 including the fuel cell stack 5e may be arranged separate from the heat exchanger 3. This embodiment requires additional manifolding means like pipes, to provide gas connecting means between the heat exchanger 3 and the fuel cell 5 for the streams A, A3, R1 and R2.

Figure 12 shows another SOFC system 1 build in form of a stack, comprising the heat exchanger 3 and the fuel cell 5, all together arranged within an insulation 6 with an inner and outer metallic shell 6a,6b. Advantageously, there is an interface base 2, not disclosed in figure 12, arranged below the heat exchanger 3. The heat exchanger 3 disclosed comprises also a base plate 3k as well as a second base plate 3k'. The interface base 2, if required, is arranged below the second base plate 3k'. There is an inner space 19 between the fuel cell 5 and the insulation 6, which is fluidly connected to the fuel cell 5 by the anode exhaust gas stream outlet port 5h, the exhaust gas outlet port 5g as well as by the exhaust gas stream inlet port 3n. The fuel cell 5 is arranged such on the base plate 3k, that the exhaust gas stream inlet port 3n is not directly connected to within the fuel cell 5, but leads into the inner space 19. Therefore, exhaust gas leaving the port 5h, 5g will enter the inner space 19 and thereafter exit the inner space 19 at inlet port 3n.

Figure 13 shows another embodiment of a heat exchanger 3. The base plate 3k as well as the second base plate 3k' consists also of ceramics and at least one of them is connected with the rest of the heat exchanger 3, for example sintered or glued, thereby forming a single, monolitic heat exchanger 3. This heat exchanger 3 has several advantages. The heat exchanger 3 is very compact, comprises all necessary fluid channels, is easy and cheap to manufacture, is very small and also very reliable. This heat exchanger 3 could be used in the SOFC system 1 as disclosed in figure 12. In an advantageous embodiment the heat exchanger 3 may, as disclosed in figure 12, also comprise the lower part of the fuel cell 5, which comprises fluid channels and the air stream inlet port 5f as well as the reactant gas stream inlet port 5d. This allows to further improve connecting the fluid channels of the heat exchanger 3 with the fuel cell 5. In an advantageous embodiment, as disclosed in figure 13, the air stream inlet port 5f and the reactant gas stream inlet port 5d entering the fuel cell 5 on the same side, allowing an about parallel flow of the air stream A and the reactant gas stream R1 within the fuel cell 5. Employing the heat exchanger 3 as disclosed in figure 13 in the fuel cell system 1 of figure 12 would mean that, according to the view of figure 12, both the air stream A and the reactant gas stream R1 entering the fuel cell 5 on the left side, the reactant gas exhaust stream R2 exiting the fuel cell 5 at port 5h and the air stream A3 exiting the fuel cell at port 5g on the right side, and both R2 and A3 entering the heat exchanger 3 at port 3n, and leaving the heat exchanger 3 as exhaust gas E at port 3q.

The heat exchanger 3 in a preferred embodiment comprises a base plate 3k suitable to be connected with the fuel cell 5. This base plate 3k is preferably able to carry the fuel cell 5, also when the fuel cell 5 is fixed by compression rods 18 with the heat exchanger 3, wherein the pressure load caused by the compression rods 18 exceeds the total weight of the fuel cell 5. Such a fuel cell 1 may be arranged in any direction, because the fuel cell 5 and the heat exchanger 3 are fixed to one another.

The term used herein “monolithic type heat exchanger” or “monolithic heat exchanger” means, that the heat exchanger consists of one single peace. For example the heat exchanger 3 disclosed in Figure 4, 5a und 5b is a monolithic heat exchanger, in that the heat exchanger 3 is made of hard brittle material produced from non-metallic minerals by firing at high temperatures, and being one single peace. As used herein the term “monolithic type heat exchanger” or “monolithic heat exchanger” also means a heat exchanger as disclosed in figure 12, which, beside the part 3 disclosed in figure 4, also comprises a base plate 3k and/or a second base plate 3k’, which for example are sintered or glued together, to form the heat exchanger 3. As disclosed in figure 12, the material of the base plate 3k, 3k’ may be different from the material of the rest of the heat exchanger 3. As disclosed in figure 13, the whole heat exchanger 3, including base plates 3k, 3k’, may also consist in the same material.

CLAIMS:

1. A SOFC system for generating electric power by combination of oxygen with a fuel gas stream, including a fuel cell having a fuel gas inlet port, an air stream inlet port and an exhaust gas stream outlet port, and comprising a heat exchanger with a fuel channel, wherein said heat exchanger comprises a first fluid path with an inlet port connected to an air supply and an air stream outlet port connected to the air stream inlet port; and wherein said heat exchanger comprises a second fluid path with an outlet port and an exhaust gas stream inlet port connected to the exhaust gas stream outlet port; and wherein said fuel channel comprises a fuel supply and a fuel gas outlet port connected to the fuel gas inlet port, and wherein said heat exchanger is a unit separate from the fuel cell, and wherein the heat exchanger consisting of ceramics, and wherein said heat exchanger comprising a base plate on which the fuel cell being directly arranged, and wherein at least one of said air stream outlet port, exhaust gas stream inlet port and fuel gas outlet port is formed in the base plate so as to extend through the base plate, and wherein at least one of the corresponding inlet ports and outlet ports enabling the gas stream flow between the fuel cell and the heat exchanger are arranged opposite to each other, to enable a direct flow transition between the fuel cell and the heat exchanger.

2. The SOFC system of claim 1 wherein the base plate is of a material different from a material of the heat exchanger.

3. The SOFC system of claim 1 wherein the fuel cell is arranged on top of the base plate, and the base plate is carrying the fuel cell.

4. The SOFC system of claim 1 wherein the heat exchanger is a monolithic type heat exchanger.

5. The SOFC system of claim 4 wherein the base plate is of ceramics material.

6. The SOFC system of claim 5 wherein the base plate is part of the monolithic type heat exchanger.

7. The SOFC system of claim 1 wherein the air stream outlet port, the fuel gas outlet port and the exhaust gas stream inlet port are arranged on a common front surface of the heat exchanger.

8. The SOFC system of claim 7 wherein the inlet port connected to the air supply, the outlet port of an exhaust gas stream and the fuel channel connected to the fuel supply are arranged on a side of the heat exchanger opposite to the front surface.

9. The SOFC system of claim 1 wherein the fuel gas inlet port, the air stream inlet port and the exhaust gas stream outlet port are arranged on a common front surface of the fuel cell.

10. The SOFC system of claim 1 wherein the fuel cell is arranged on top of the heat exchanger, and wherein the corresponding inlet ports and outlet ports enabling the gas stream flow between the fuel cell and the heat exchanger are arranged opposite to each other, to enable a direct flow transition between the fuel cell and the heat exchanger.

11. The SOFC system of claim 1 wherein the first fluid path comprises a first channel and wherein the second fluid path comprise a second channel separated by a wall, to allow a heat exchange between the exhaust gas stream flowing in the second channel and the air stream flowing in the first channel.

12. The SOFC system of claim 11 wherein there is a plurality of first and second channels.

13. The SOFC system of claim 11 wherein the first and second channels are arranged to form a counter cross flow between the first and second fluid path.

14. The SOFC system of claim 1 wherein the heat exchanger comprises an afterburner arranged in the second fluid path.

15. The SOFC system of claim 1 wherein the fuel channel comprises a catalytic fuel processor.

16. The SOFC system of claim 15 wherein the fuel channel comprises a layer of catalytic substances.

17. The SOFC system of claim 1 wherein the heat exchanger comprises an air stream bypass with an inlet port connected to an air supply and an air stream bypass outlet port disposed in fluid communication with the air stream outlet port.

18. The SOFC system of claim 17 wherein at least one valve is disposed to control at least one of an air stream in the first fluid path and an air stream bypass.

19. The SOFC system of claim 18 wherein the valve is disposed below the heat exchanger.

20. The SOFC system of claim 1, wherein an interface base is disposed below the heat exchanger, the interface base comprising the fuel gas stream inlet port, the air stream inlet port and the exhaust gas stream outlet port, wherein the fuel gas stream inlet port is fluidly connected to the fuel gas stream channel, and wherein the air stream inlet port is fluidly connected to the first fluid path, and wherein the exhaust gas stream outlet port is fluidly connected to the exhaust gas stream outlet port of the heat exchanger.

21. The SOFC system of claim 20 wherein the fuel gas stream inlet port, the air stream inlet port and the exhaust gas stream outlet port are arranged at the bottom of the interface base.

22. The SOFC system of claim 20 wherein the interface base is coupled to the heat exchanger so that there is a direct flow transition from the interface base to the heat exchanger, the heat exchanger being placed on top of the interface base and the fuel cell being placed on top of the heat exchanger.

23. The SOFC system of claim 22 wherein the interface base and the fuel cell are connected by compressing means extending through the heat exchanger.

24. The SOFC system of claim 1 wherein at least one of the first and second fluid path comprises a channel with a rough surface.

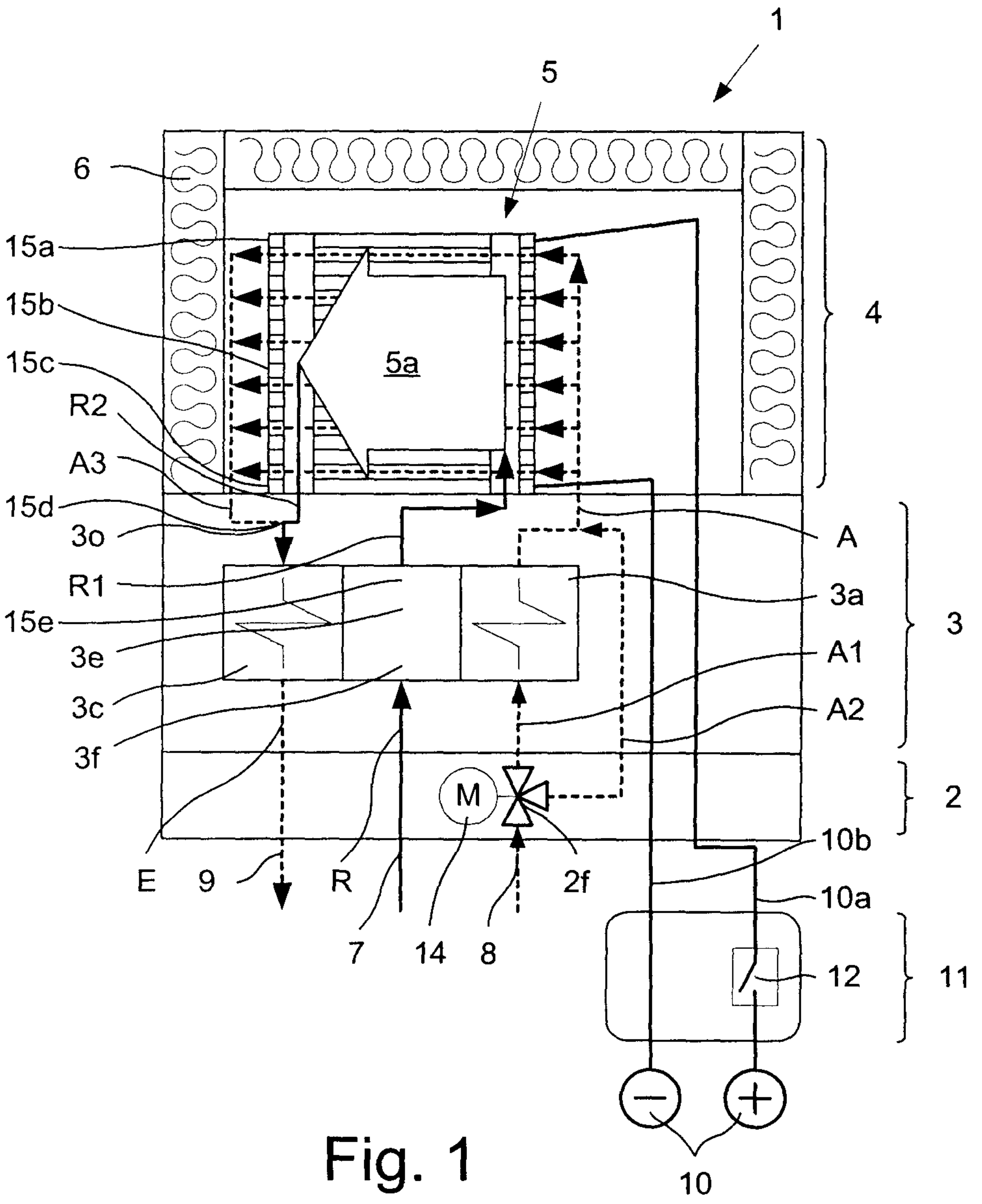
25. The SOFC system of claim 1 wherein the fuel cell is arranged within an insulation, the insulation comprising a fluid tight room with a fluid inlet and outlet, to create a vacuum within the room to pressurize the room, or both.

26. The SOFC system of claim 1 comprising a control unit as well as temperature sensors and a valve being connected with the control unit, the valve determines the flow of an air stream and a bypass air stream, the air stream and the bypass air stream forming a fuel cell air stream supplied to the fuel cell, and the temperature or the amount of the fuel cell air stream or both, depending on the sensed values of the temperature sensors and being controlled by the control unit, said temperature sensors being provided in a path of the fuel cell air stream.

27. A heat exchanger for a SOFC system, comprising a fuel channel with a fuel gas outlet port, comprising a first fluid path with an air stream outlet port, comprising a second fluid

path with an exhaust gas stream inlet port, wherein said heat exchanger consists of ceramics, and wherein said heat exchanger comprises a base plate on which a fuel cell is to be provided, and wherein at least one of air stream outlet port, exhaust gas stream inlet port and fuel gas outlet port extending through the base plate, and wherein the heat exchanger, with the exception of the base plate is a monolithic type heat exchanger.

28. The heat exchanger of claim 27, wherein the base plate is a part of the monolithic type heat exchanger.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A
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Fig. 1

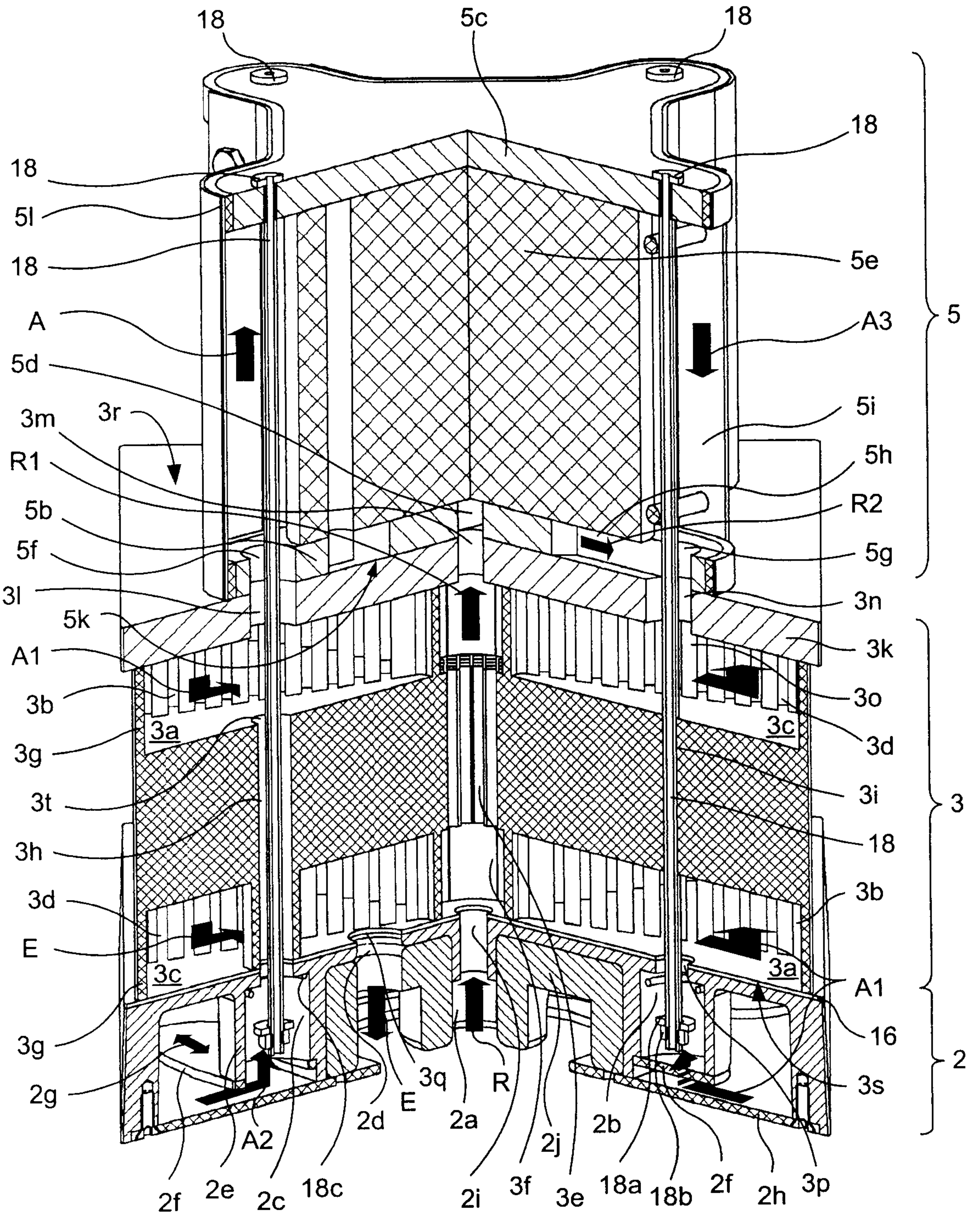
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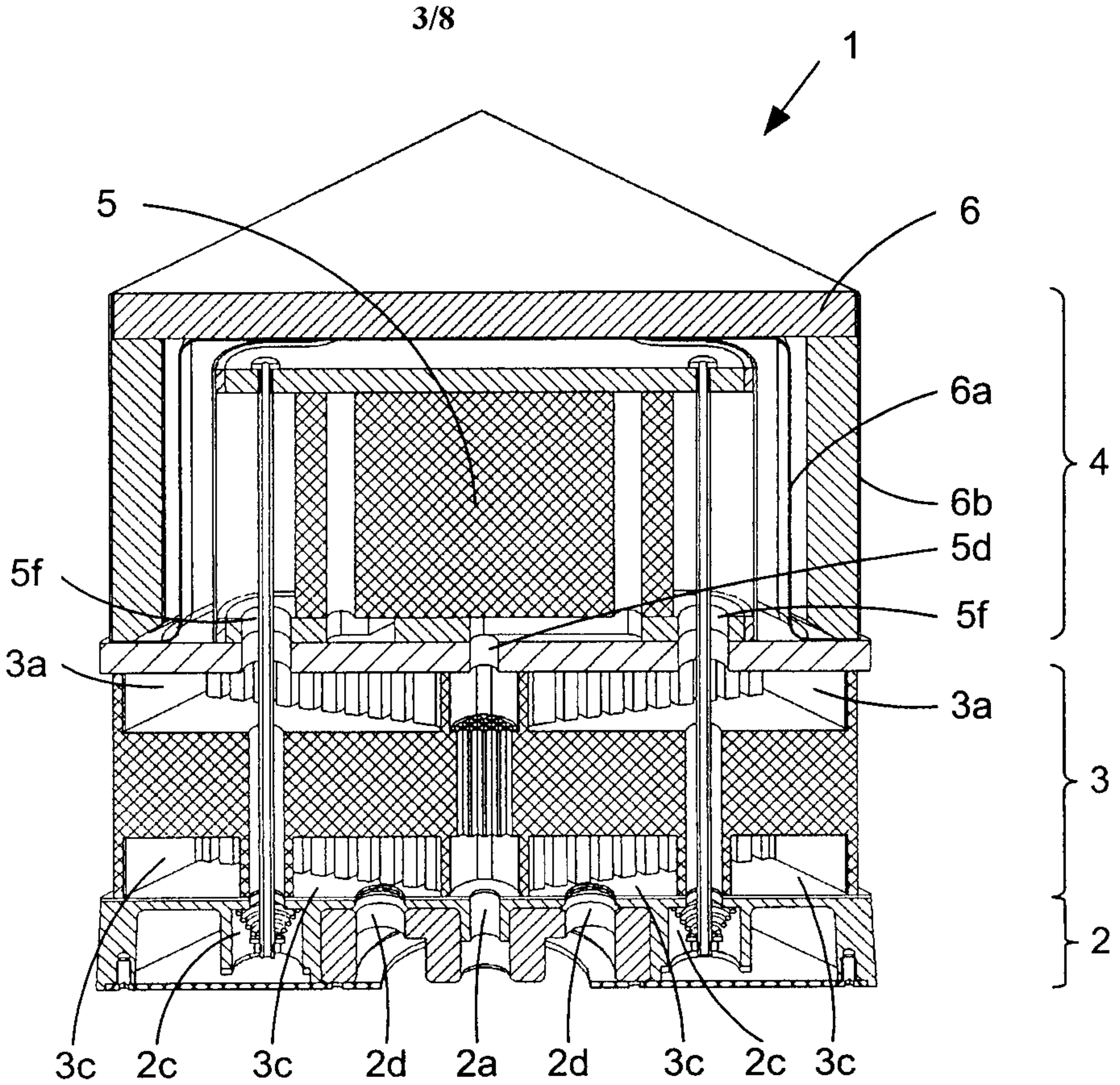
Fig. 2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3c

Fig. 3

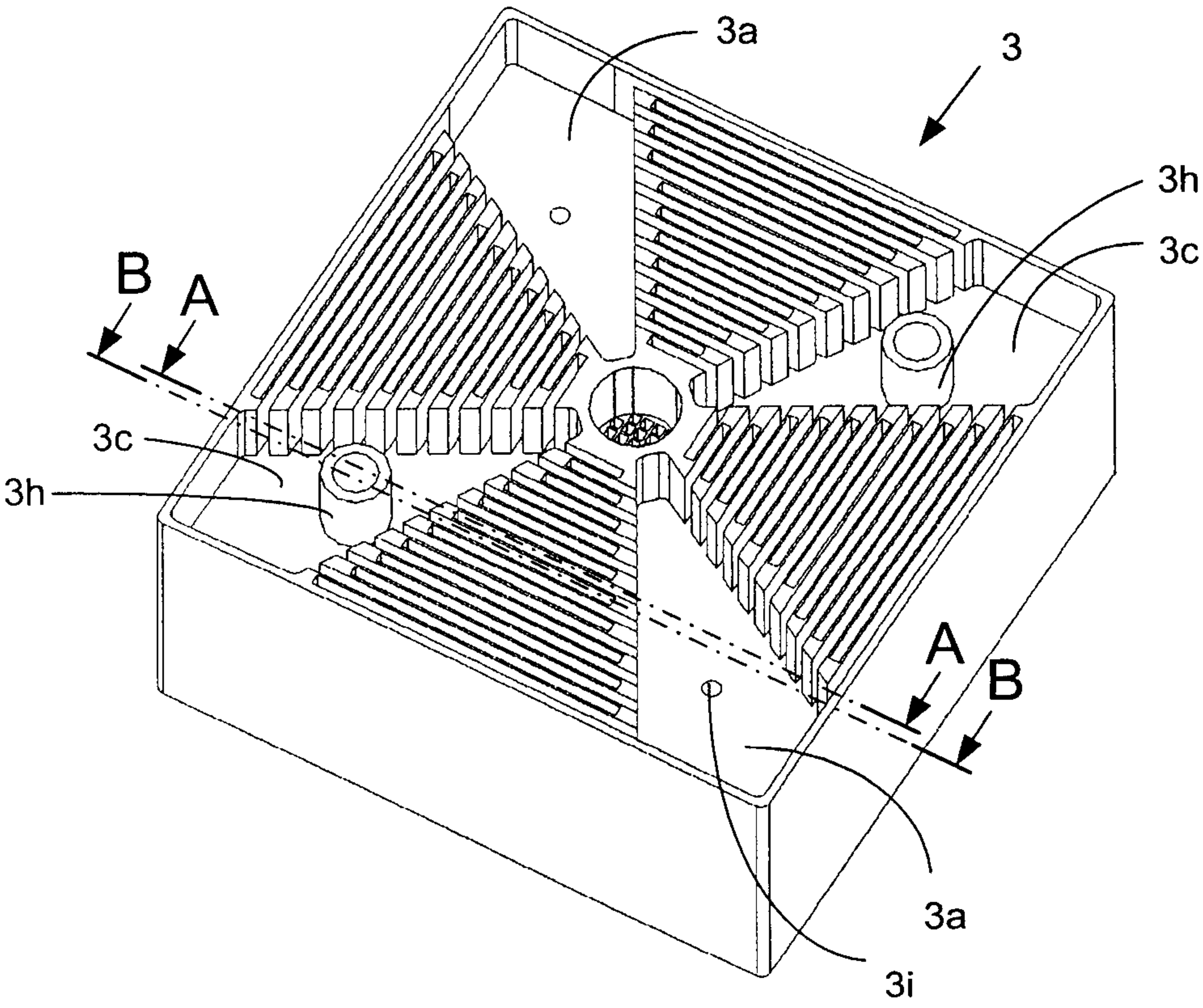
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Fig. 4

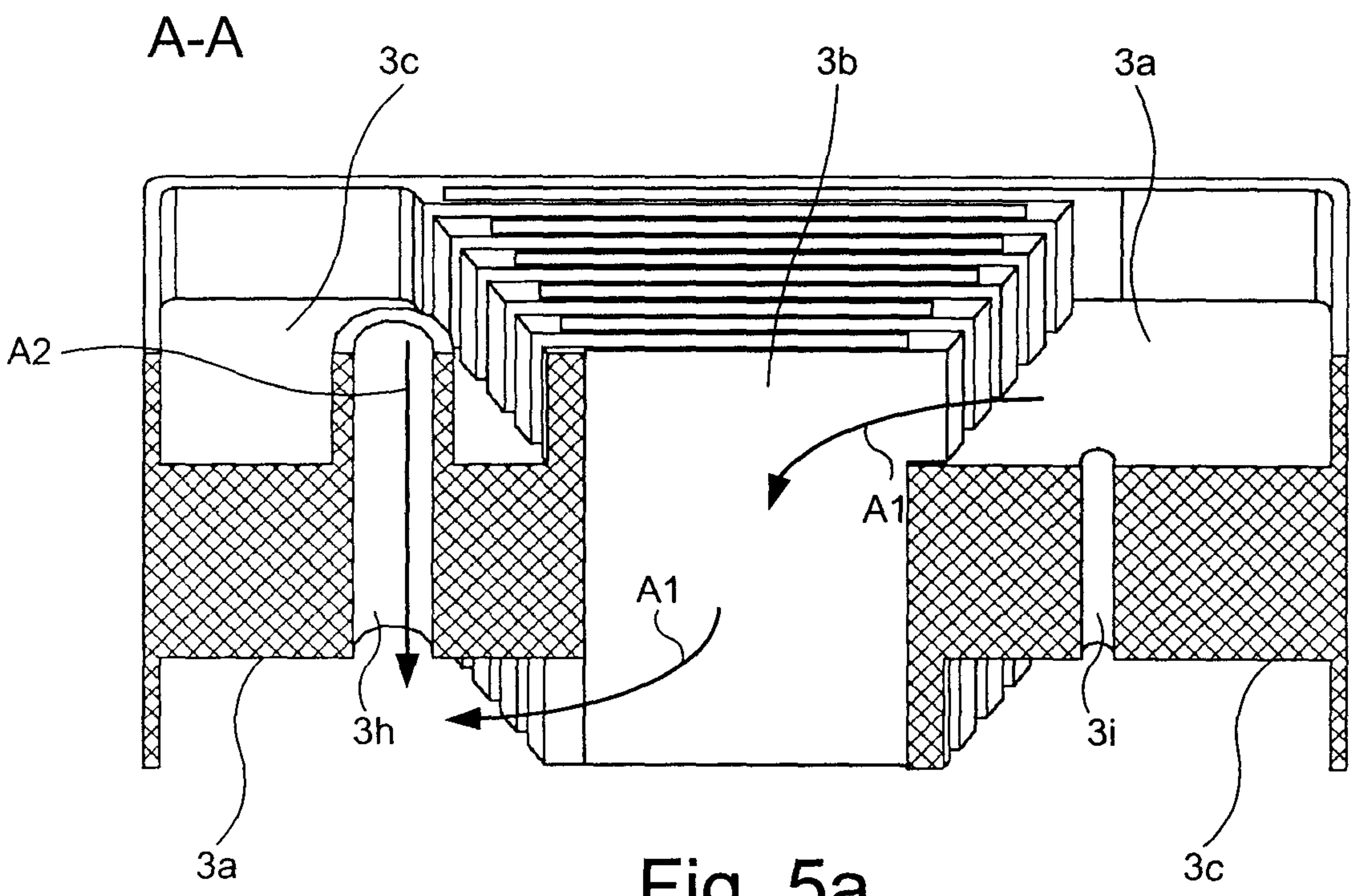


Fig. 5a

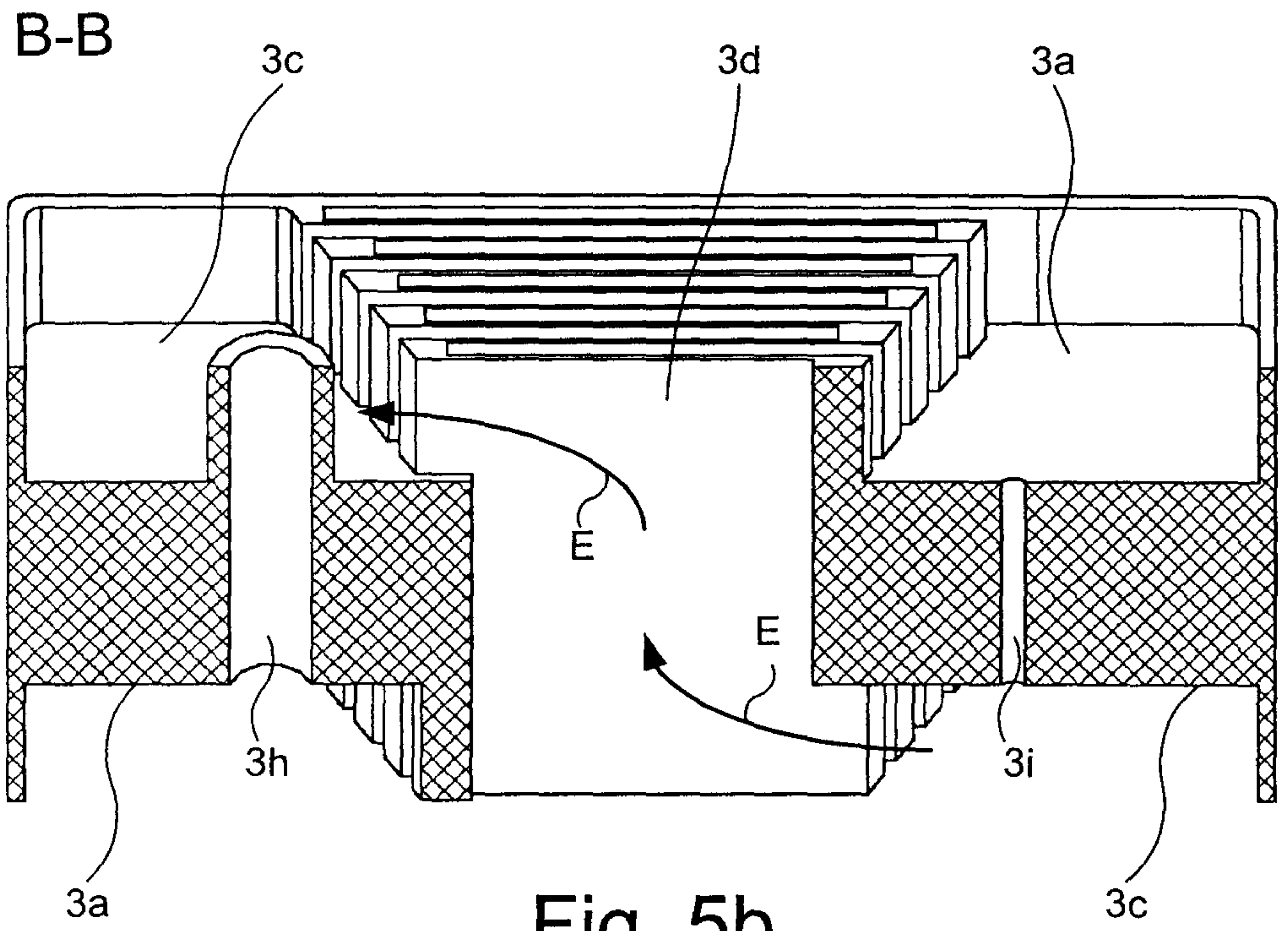


Fig. 5b

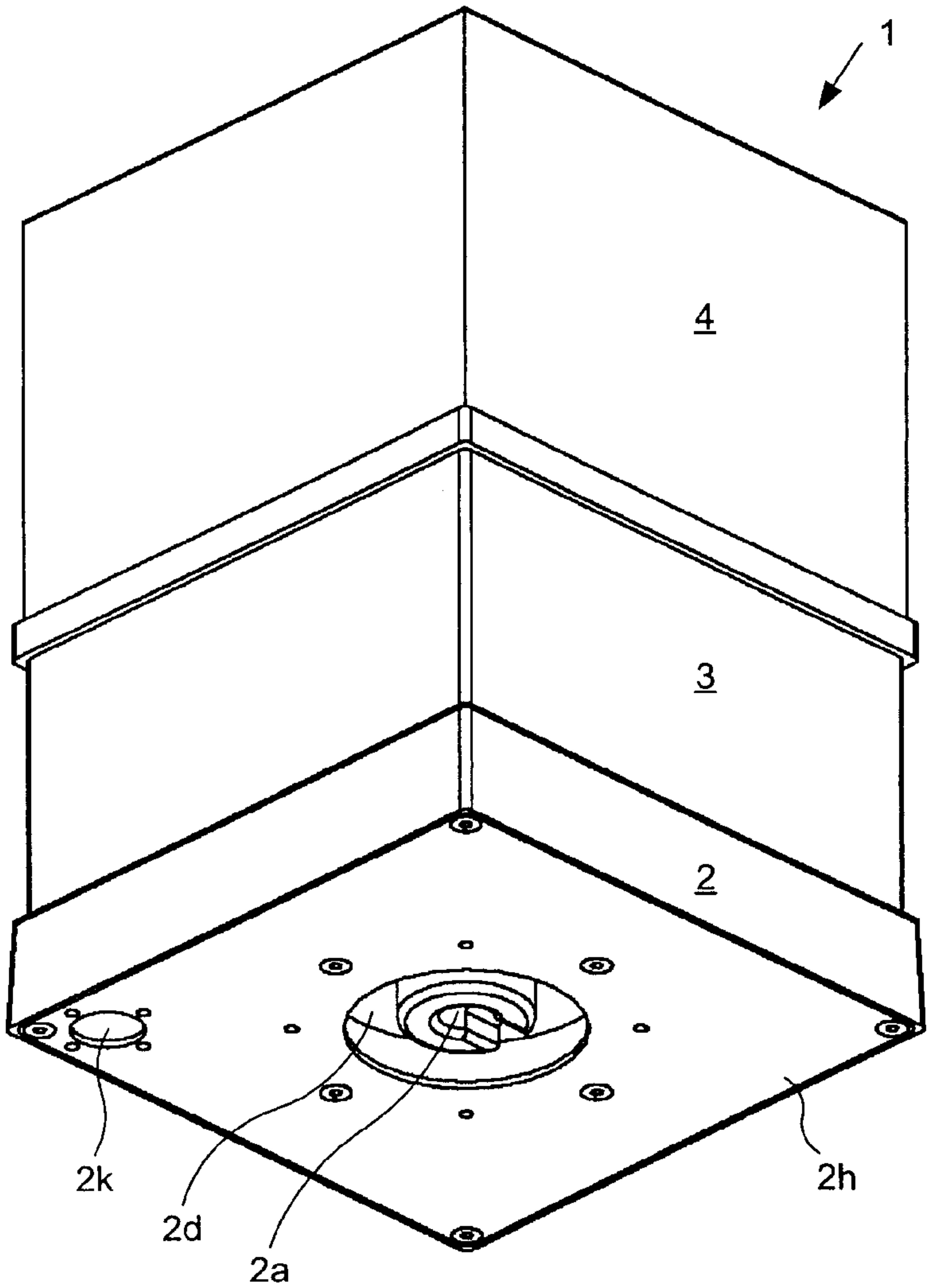


Fig. 6

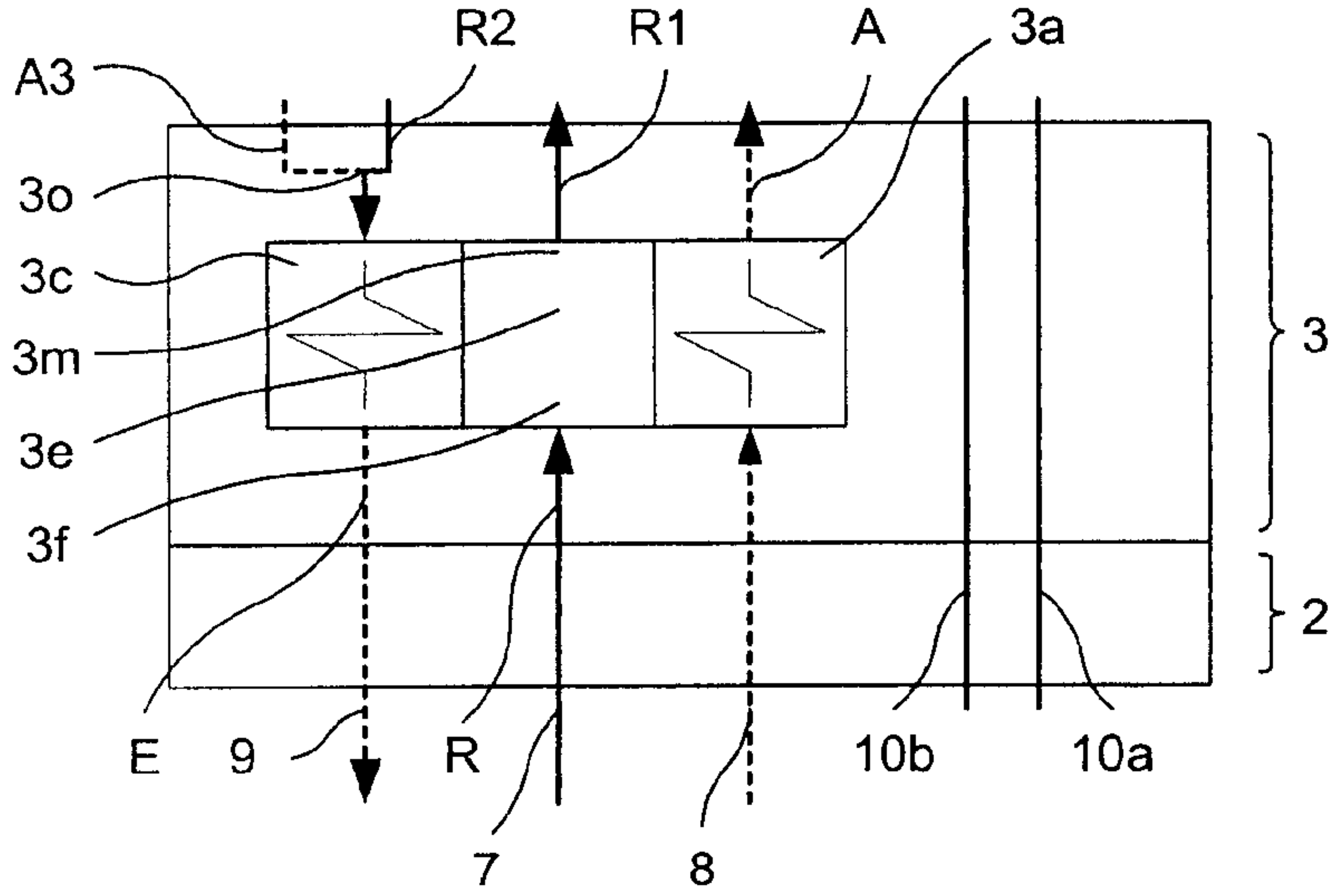


Fig. 7

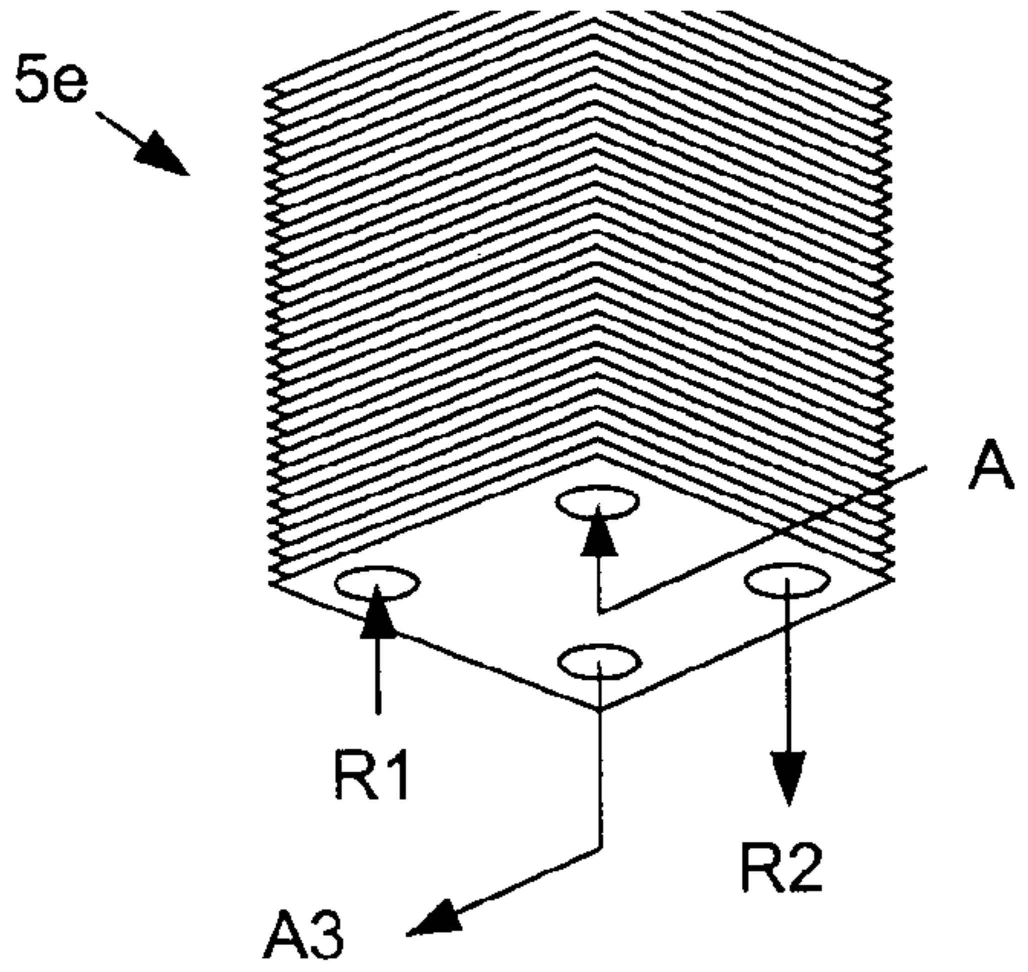


Fig. 8

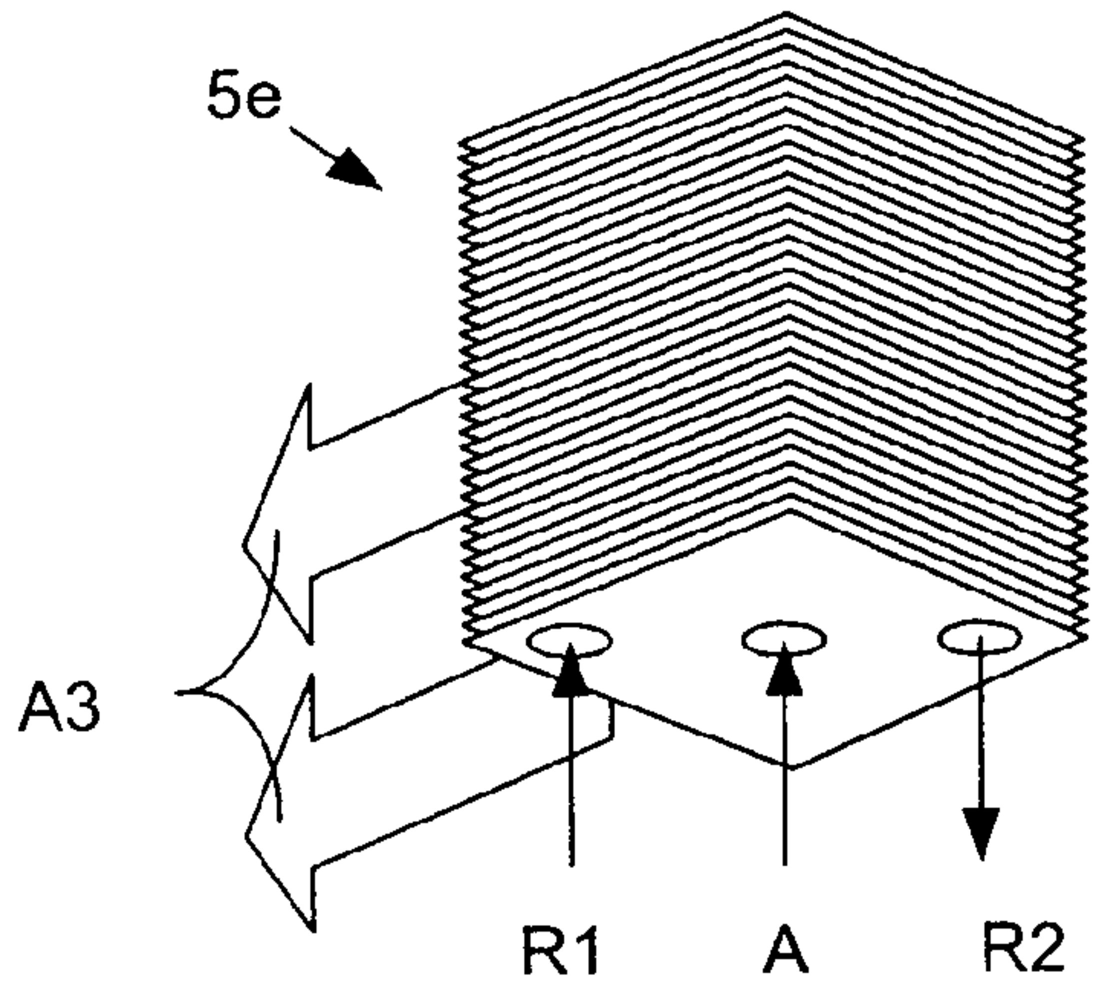


Fig. 9

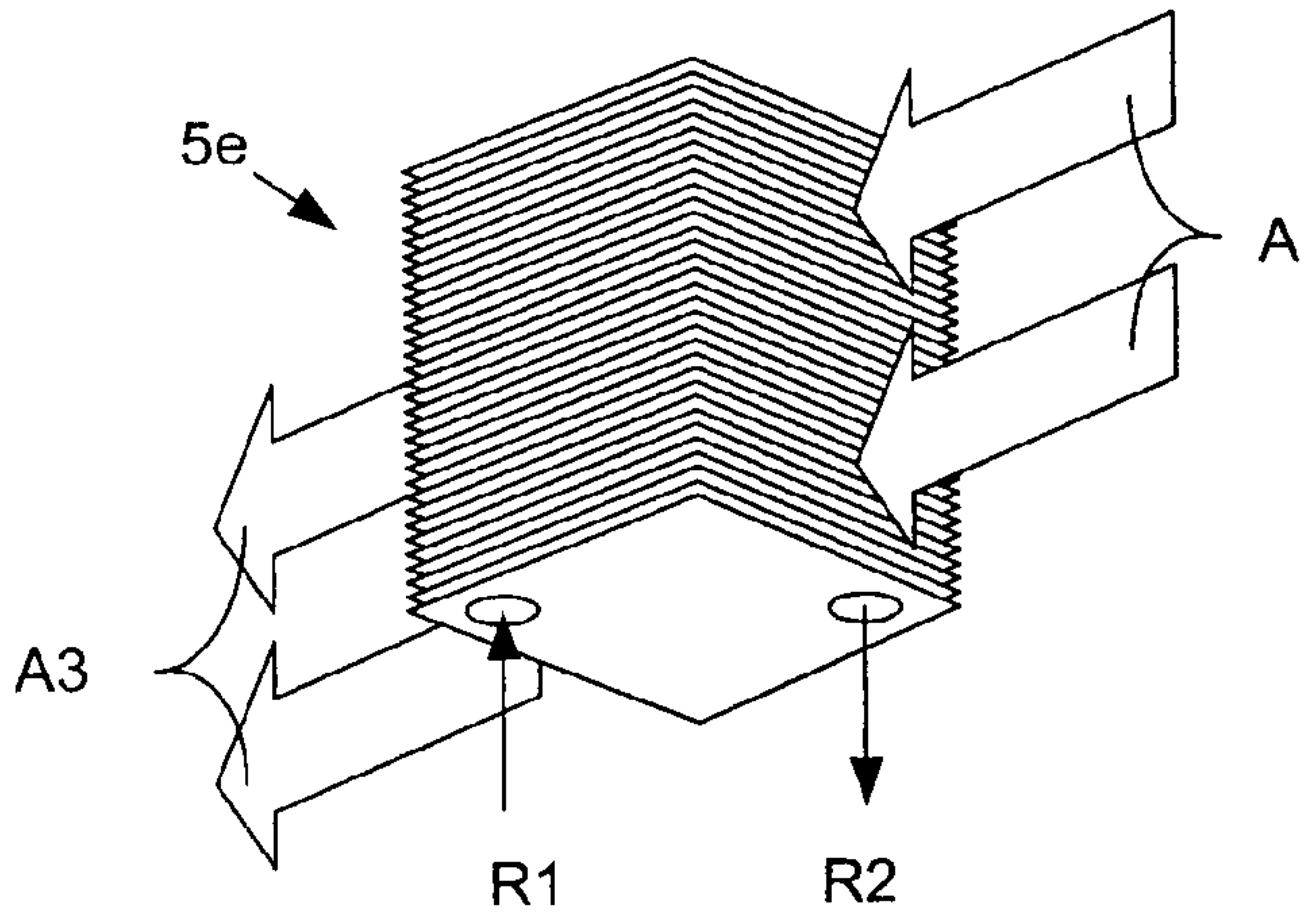


Fig. 10

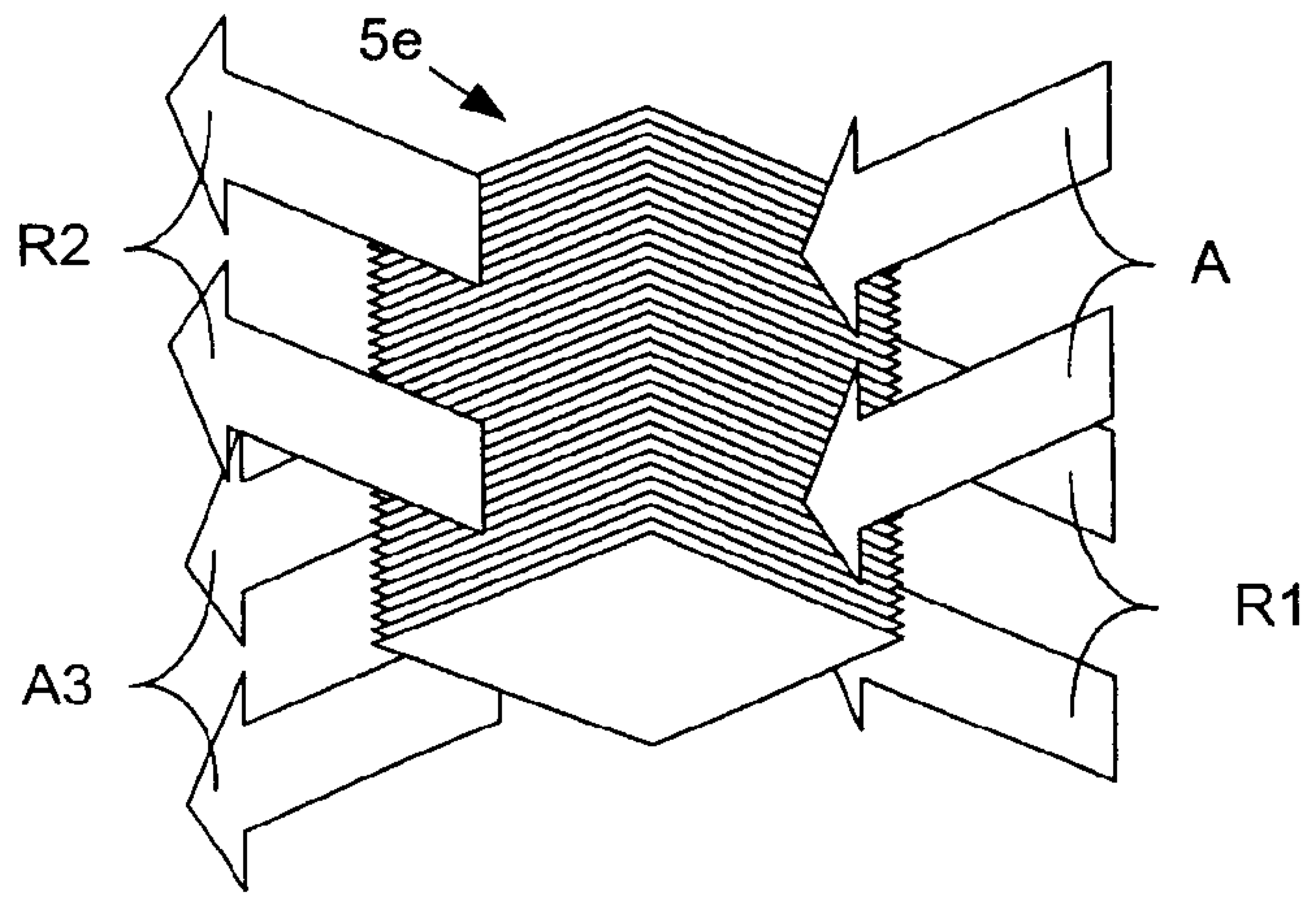
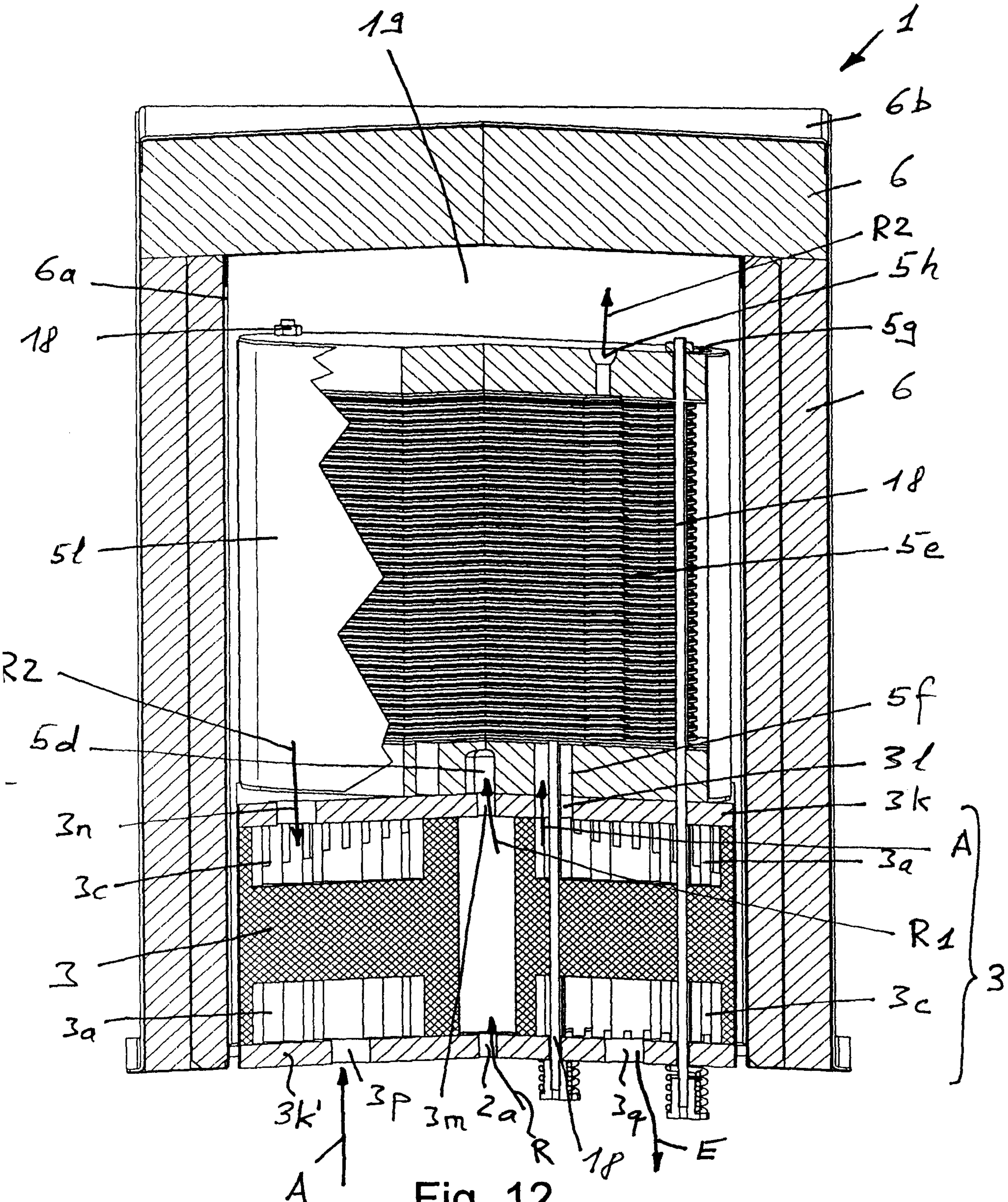


Fig. 11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3n
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3a
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3k'
3P
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R
18
E
A

Fig. 12

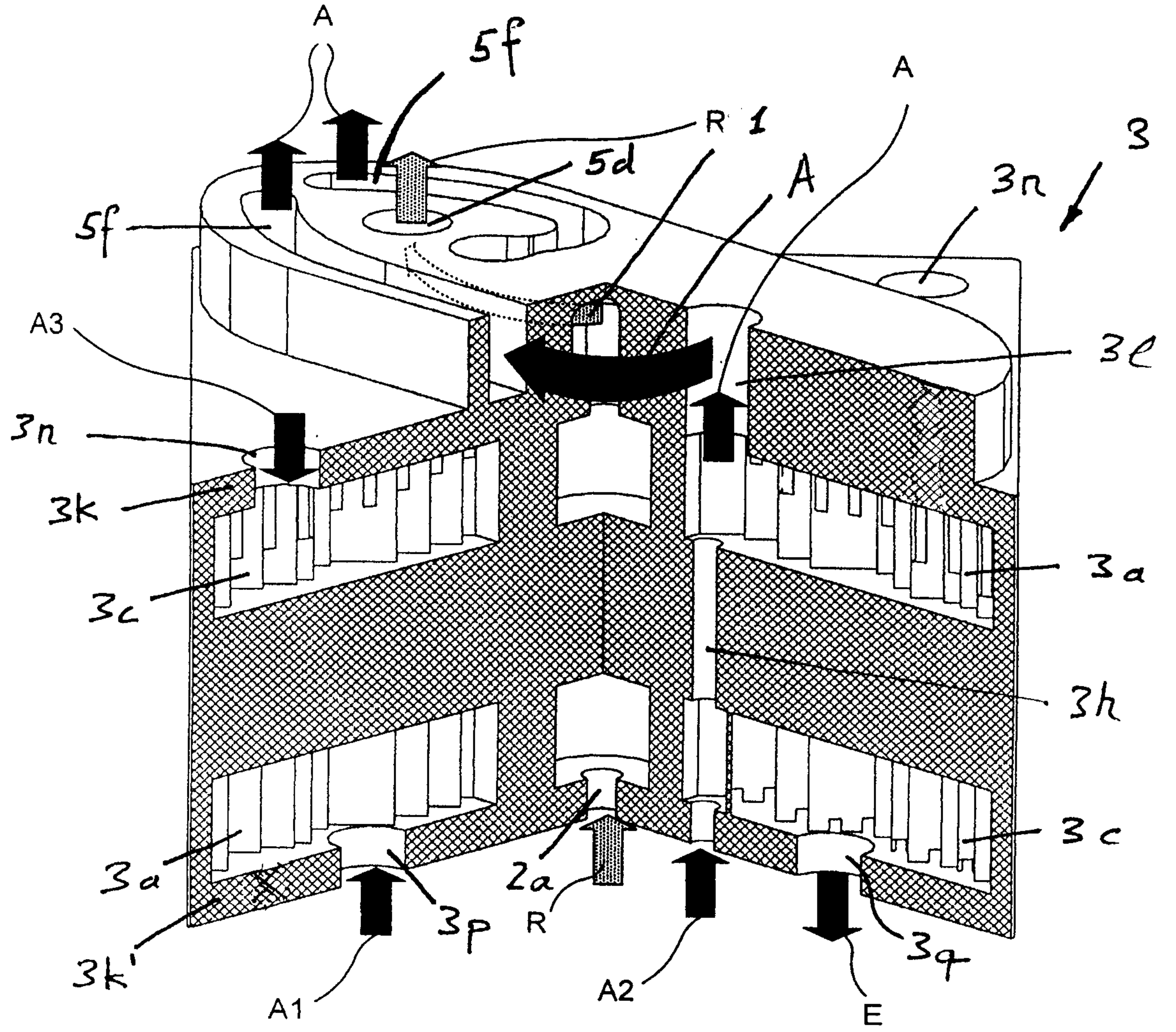
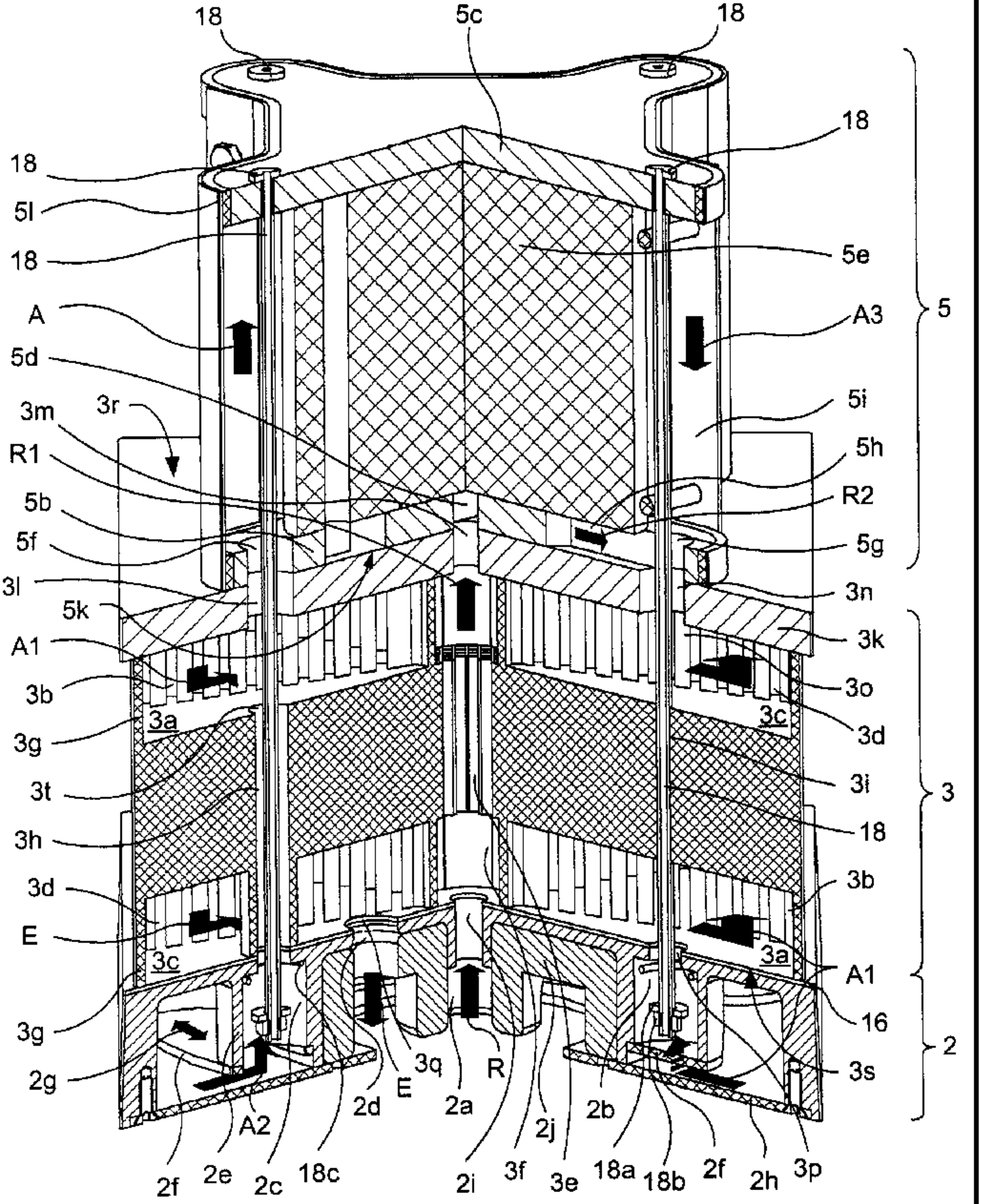


Fig. 13



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