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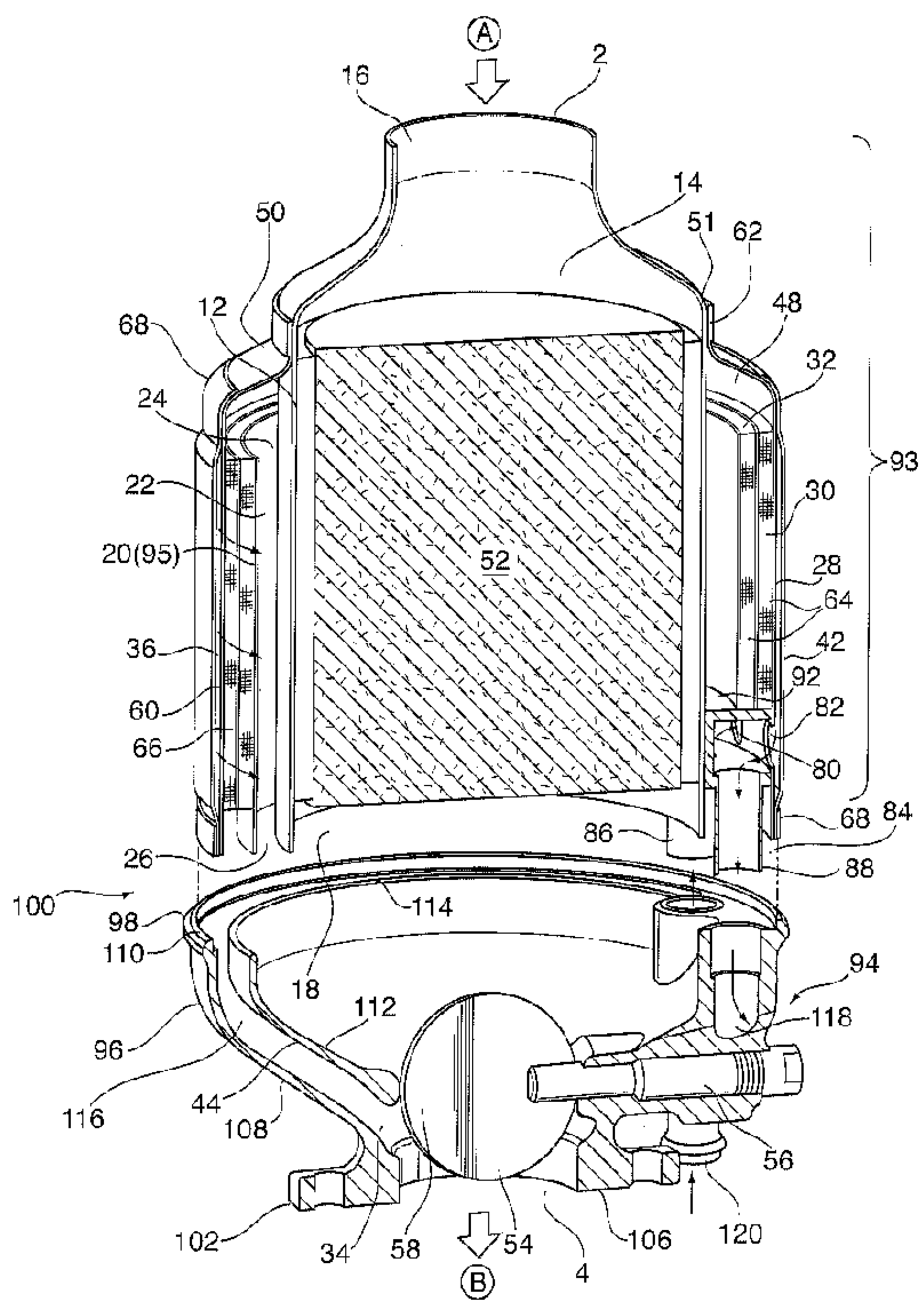

(57) **Abrégé/Abstract**:
An annular heat exchanger for cooling hot gases comprises an inner shell, an intermediate shell and an outer shell. Where the heat exchanger is integrated with a catalytic converter for treatment of hot exhaust gases in a motor vehicle, the inner shell contains a catalyst for treatment of the exhaust gases. Inner and outer gas flow passages are provided between the shells, and a coolant flow passage is provided, either on the outer surface of the outer shell, or inbetween the intermediate and outer shells. The exhaust gases change direction twice as they pass through the heat exchanger, and the annular structure of the heat exchanger provides a large surface area, and a large flow section, relative to volume, and thereby provides effective heat exchange without significantly increasing space requirements.

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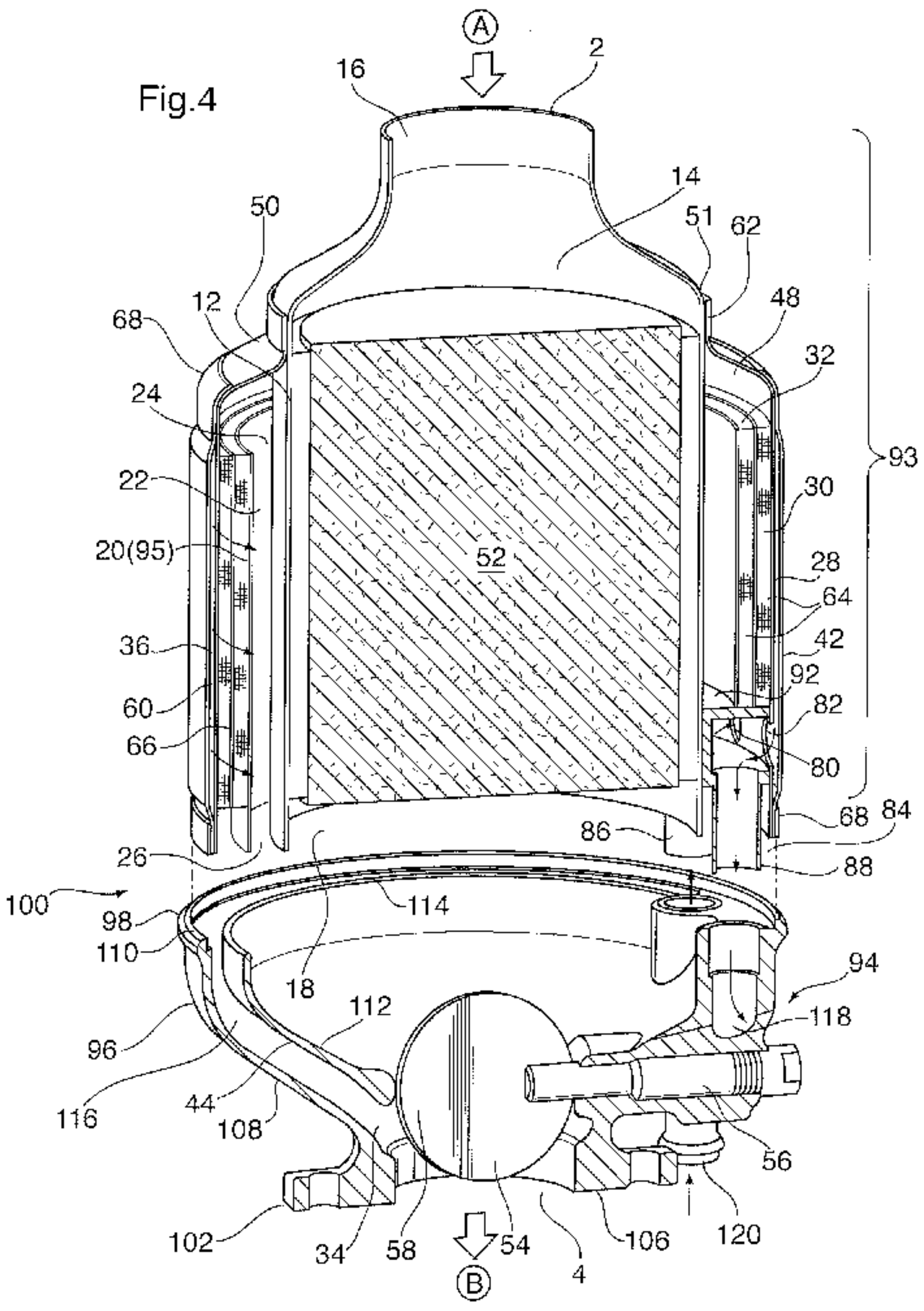
Fig.4



(57) Abstract: An annular heat exchanger for cooling hot gases comprises an inner shell, an intermediate shell and an outer shell. Where the heat exchanger is integrated with a catalytic converter for treatment of hot exhaust gases in a motor vehicle, the inner shell contains a catalyst for treatment of the exhaust gases. Inner and outer gas flow passages are provided between the shells, and a coolant flow passage is provided, either on the outer surface of the outer shell, or inbetween the intermediate and outer shells. The exhaust gases change direction twice as they pass through the heat exchanger, and the annular structure of the heat exchanger provides a large surface area, and a large flow section, relative to volume, and thereby provides effective heat exchange without significantly increasing space requirements.

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ANNULAR HEAT EXCHANGER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and priority to U.S. Patent Application No. 12/813,830 filed June 11, 2010.

[0002]

FIELD OF THE INVENTION

[0003] The invention relates to annular heat exchangers for use in removing heat from a gas stream, particularly for use in cooling hot exhaust gas or charge air in a motor vehicle.

BACKGROUND OF THE INVENTION

[0004] The need to remove heat from gas streams arises in numerous applications. In motor vehicles, for instance, it may be necessary to remove heat from the intake and/or exhaust gas streams. For example, intake air (or "charge air") requires cooling in some applications, for example in turbocharged or supercharged engines. In vehicles incorporating exhaust gas recirculation (EGR) or exhaust gas heat recovery (EGHR) systems, heat is removed from the exhaust gas stream. The heat removed from the intake or exhaust gas stream is typically transferred to a liquid coolant in a heat exchanger.

[0005] In motor vehicle exhaust applications, heat recovery devices are usually located in series with other under-vehicle exhaust components such as catalytic converters. Series arrangement of individual exhaust components is wasteful of space, may increase the cost and weight of the vehicle, and limits the ability to control the temperature of exhaust components upstream of the heat recovery device. The incorporation of a bypass flow path into the heat recovery device usually involves the addition of an external pipe to the exhaust system, and is yet another component which must be accommodated under the vehicle.

[0006] An example of an annular heat recovery device for use in an exhaust system of a motor vehicle is disclosed in US 2009/0038302 A1 (Yamada et al.), published on February 12, 2009. While the Yamada et al. device provides a central bypass flow path and thereby eliminates the need for an external bypass, its installation downstream of the catalytic converter (Fig. 6 of Yamada et al.) fails to address the other issues noted above.

[0007] There remains a need for simple and effective heat recovery devices for motor vehicle intake and exhaust gas systems which minimize usage of space, weight, and number of components, and which provide enhanced opportunities for temperature control of other system components.

SUMMARY OF THE INVENTION

[0008] The invention provides a heat exchanger having a first end with a first gas flow opening and a second end with a second gas flow opening, wherein the first and second ends of the heat exchanger are spaced apart along a gas flow axis.

The heat exchanger comprises an inner shell, an intermediate shell and an outer shell. The inner shell defines an inner gas flow passage extending along the gas flow axis. The inner gas flow passage has a first open end and a second open end, wherein the first open end of the inner gas flow passage is in flow communication with the first gas flow opening of the heat exchanger. The intermediate shell surrounds the inner shell, wherein a space between the inner shell and the intermediate shell defines an intermediate gas flow passage extending along the gas flow axis. The intermediate gas flow passage has a first open end and a second open end, and wherein the second open end of the intermediate gas flow passage is in flow communication with the second open end of the inner gas flow passage. The outer shell surrounds the intermediate shell, wherein a space between the intermediate shell and the outer shell defines an outer gas flow passage extending along the gas flow axis. The outer gas flow passage has a first open end and a second open end, wherein the first open end of the outer gas flow passage is in flow communication with the first open end of the intermediate gas flow passage and the second open end of the outer gas flow passage is in flow communication with the second gas flow opening of the heat exchanger. The heat exchanger further comprises a coolant flow passage having an inlet and an outlet and extending along the gas flow axis, wherein the coolant flow passage is in heat exchange communication with one or both of the intermediate gas flow passage and the outer gas flow passage.

[0009] Where the first end of the heat exchanger is upstream of the second end of the heat exchanger, the first gas flow opening defines a gas inlet opening and the second gas flow opening defines a gas outlet opening. In this case, the first open end of each of the inner, intermediate and outer gas flow passage is upstream of the respective second end of each gas flow passage.

[0010] Where the first end of the heat exchanger is downstream of the second end of the heat exchanger, the first gas flow opening defines a gas outlet opening and the second gas flow opening defines a gas inlet opening. In this case, the first open end of each of the inner, intermediate and outer gas flow passage is downstream of the respective second end of each gas flow passage.

[0011] In one aspect, the outer shell has a radially inwardly extending wall portion which is sealingly connected to the inner shell at a location between the first end of the heat exchanger and the first open ends of the intermediate and outer gas flow passages, wherein the radially inwardly extending wall portion of the outer shell defines a turnaround plenum in which the gas flow changes direction between the intermediate and outer gas flow passages.

[0012] In another aspect, the intermediate shell includes a radially inwardly extending wall portion which is located between the second end of the heat exchanger and the second open ends of the inner and intermediate gas flow passages, wherein the radially inwardly extending wall portion of the intermediate shell defines a turnaround plenum in which the gas flow changes direction between the inner and intermediate gas flow passages.

[0013] In yet another aspect, the radially inwardly extending wall portion of the intermediate shell has an opening which is selectively opened and closed by a valve, wherein opening of the valve permits direct flow communication between the first and second gas flow openings through the inner gas flow passage, thereby providing a bypass flow passage for the gas. The complete closing of the valve substantially prevents direct flow communication between the first and second gas flow openings through the inner gas flow passage.

[0014] In yet another aspect, the gas is a motor vehicle exhaust gas, and the inner gas flow passage contains a catalyst for treating the motor vehicle exhaust gas.

[0015] In yet another aspect, the coolant flow passage comprises a cooling jacket attached to an outer surface of the outer shell, such that the coolant circulating through the jacket is in heat exchange communication with the outer gas flow passage.

[0016] In yet another aspect, the intermediate shell comprises an inner jacket wall and an outer jacket wall between which the coolant flow passage is defined, wherein the coolant circulating through the coolant flow passage is in heat exchange communication with both the intermediate gas flow passage and the outer gas flow passage.

[0017] In yet another aspect, the inlet and outlet of the coolant flow passage are provided in the outer jacket wall and are axially spaced from one another, and the inlet and outlet are each provided with fittings which extend radially outwardly from the outer jacket wall, through the outer gas flow passage and through the outer shell.

[0018] In yet another aspect, at least those portions of the inner, intermediate and outer shells defining the gas flow passages are generally cylindrical about the gas flow axis, such that the inner gas flow passage is generally cylindrical and each of the intermediate and outer gas flow passages is generally annular and concentric with the inner gas flow passage.

[0019] In yet another aspect, at least one of the inner gas flow passage and the outer gas flow passage is provided with a turbulence-enhancing insert, wherein each turbulence-enhancing insert is located between and in contact with two of the shells.

[0020] In yet another aspect, the outer gas flow passage is provided with turbulence-enhancing insert is rigidly bonded to one of said shells and unbonded to another of the shells.

[0021] In yet another aspect , the outer gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with the intermediate shell and said outer shell, and wherein the turbulence-enhancing insert is rigidly bonded to the outer shell and unbonded to the intermediate shell.

[0022] In yet another aspect, the coolant flow passage is provided with a turbulence-enhancing insert which is located between and in contact with the outer shell and the cooling jacket, and wherein the turbulence-enhancing insert of the coolant passage is rigidly bonded to the outer shell and unbonded to the cooling jacket.

[0023] In yet another aspect, the outer gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with the intermediate shell and the outer shell, and wherein the turbulence-enhancing insert is rigidly bonded to the outer jacket wall of the intermediate shell and unbonded to the outer shell.

[0024] In yet another aspect, the intermediate gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with the intermediate shell and the inner shell, and wherein the turbulence-enhancing insert is rigidly bonded to the inner jacket wall of the intermediate shell and unbonded to the inner shell.

[0025] In yet another aspect, the coolant flow passage is provided with a turbulence-enhancing insert which is located inbetween and in contact with the inner jacket wall and the outer jacket wall, and wherein the turbulence-enhancing insert of the coolant passage is rigidly bonded to both the inner jacket wall and the outer jacket wall.

[0026] In yet another aspect, the intermediate shell has a downstream end which extends past the second open ends of the inner gas flow passage and the intermediate gas flow passage, and includes an inwardly extending wall portion which defines a first turnaround plenum in which the gas changes direction between the inner gas flow passage and the intermediate gas flow passage.

[0027] In yet another aspect, the inwardly extending wall portion includes an opening provided with a valve element, wherein the valve element is movable between open and closed positions, and wherein, with the valve in the open position, at least a portion of the gas is permitted to flow through the heat exchanger by passing through the inner gas flow passage and bypass the intermediate gas flow passage and the outer gas flow passage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

[0029] Figure 1 is a schematic, axial cross-section through an annular heat exchanger according to a first embodiment of the invention;

[0030] Figures 2a and 2b are schematic, axial cross-sections through an annular heat exchanger according to a second embodiment of the invention;

[0031] Figure 3 is a perspective view of an exhaust gas heat recovery device incorporating an annular heat exchanger according to a third embodiment of the invention;

[0032] Figure 4 is an axial cross-section through the exhaust gas heat recovery device of Figure 3, showing the device in a partially assembled state;

[0033] Figure 5 is an axial cross-section similar to Figure 4, showing the heat recovery device in a fully assembled state;

[0034] Figure 6 is an exploded view illustrating the components of the exhaust gas heat recovery device of Figure 3;

[0035] Figures 7 and 9 are axial cross-sections through an exhaust gas heat recovery device according to a fourth embodiment of the invention;

[0036] Figure 8 is a radial cross-section along line 8-8 of Figure 7;

[0037] Figure 8a is an enlargement of area D of Figure 8;

[0038] Figures 10 and 11 are schematic, axial cross-sections of an exhaust gas heat recovery device incorporating a heat exchanger according to fifth embodiment of the invention;

[0039] Figure 12 is a partial, transverse cross-section through a heat exchanger according to the invention;

[0040] Figure 13 is a close-up of area A of Figure 12;

[0041] Figure 14 is a close-up of area B of Figure 12; and

[0042] Figure 15 is a close-up of area C of Figure 12.

DETAILED DESCRIPTION

[0043] In the following description, several embodiments of heat exchangers according to the invention are described. The specific heat exchangers described below are adapted to remove or recover heat from the exhaust gas stream of a motor vehicle, and are integrated with the vehicle's catalytic converter. However, the invention is not restricted to exhaust gas heat exchangers for motor vehicles, but rather includes annular gas-to-liquid heat exchangers for numerous other applications, for example as intake air coolers for motor vehicles.

[0044] Illustrated in Figure 1 is an annular heat exchanger 10 according to a first embodiment of the invention. Heat exchanger 10 is generally in the shape of an open-ended, hollow cylinder having a side wall which is comprised of a plurality of cylindrical layers. The side wall of heat exchanger 10 extends parallel to a longitudinal axis A-B passing centrally through the hollow interior space of heat exchanger 10. The heat exchanger 10 includes a number of gas flow passages, described in detail below, and the direction of gas flow through each of the gas flow passages is shown by the arrows in Figure 1. Although the overall direction of gas flow through heat exchanger 10 is from A to B along axis A-B, it can be seen that there are two changes in the direction of flow as the gas flows through the heat exchanger 10.

[0045] In the following description, the heat exchanger 10 and the various gas flow passages defined therein are described as having a first end and a second end. In the embodiment of Figure 1, the first end of the heat exchanger 10 is situated closest to A and serves as the inlet opening 2, and the second end of heat exchanger 10 is situated closest to B and serves as the outlet opening 4. Similarly, the first end of each gas flow passage described below is located closer to A and the second end of each gas flow passage is located downstream from the first end, closer to B.

[0046] In the following description, terms such as "axial" and the like refer to directions which are parallel to the axis A-B, and terms such as "inner", "outer", "inward" and "outward" and the like refer to radial directions extending outwardly from or inwardly toward axis A-B, and which are transverse to axis A-B.

[0047] Heat exchanger 10 includes a cylindrical inner shell 12 which extends along axis A-B and defines an inner gas flow passage 14. The inner gas flow passage 14 extends along axis A-B and has a first open end 16 and a second open end 18. The first open end 16 of inner gas flow passage 14 defines the inlet opening 2 of heat exchanger 10, and the second open end 18 is located downstream of the inlet opening toward B. It will be appreciated that the inlet opening 2 may be provided with means, such as a flange, for connection to other exhaust system components upstream of heat exchanger 10. Such connection means are included in some of the other embodiments of the invention, described below.

[0048] Heat exchanger 10 further comprises an intermediate shell 20 which is located outwardly of, and surrounds, the inner shell 12. The annular space between the inner shell 12 and intermediate shell 20 defines an intermediate gas flow passage 22 which extends along axis A-B. The intermediate gas flow passage 22 has a first open end 24 and a second open end 26 which are spaced apart along axis A-B, with the first open end 24 being located closer to A and the second end 26 being located downstream of the first open end 24, closer to B. As can be seen from Figure 1, the second open end 26 of the intermediate gas flow passage 22 is in flow communication with the second open end 18 of the inner gas flow passage 14 to permit gas flow between the second open ends 18, 26 of the inner and intermediate gas flow passages 14, 22. More specifically, in the configuration shown in Figure 1, gas exiting the inner gas flow passage 14 through its second open end 18 enters the second open end 26 of the intermediate gas flow passage 22.

[0049] Heat exchanger 10 further comprises an outer shell 28 located radially outwardly of, and surrounding, the intermediate shell 20. The annular space between the intermediate shell 20 and outer shell 28 defines an outer gas flow passage 30 extending along the axis A-B. The outer gas flow passage 30 has a first open end 32 and a second open end 34 which are spaced apart along axis A-B, with the first open end 32 being located closer to A and the second open end 34 being located downstream of the first open end 32, closer to B. As shown in Figure 1, the first open end 32 of the outer gas flow passage 30 is in flow communication with the first open end 24 of the intermediate gas flow passage 22 to permit gas flow between the first open ends 24, 32 of the intermediate and outer gas flow passages 22, 30. More specifically, in the configuration shown in Figure 1, gas exiting the first open end 24 of the intermediate gas flow passage 22 enters the first open end 32 of the outer gas flow passage 30. Also, the second open end 34 of the outer gas flow passage 30 defines the outlet opening 4 of the heat exchanger 10. It will be appreciated that the outlet opening 4 may be provided with means, such as a flange, for connection to other exhaust system components downstream of heat exchanger 10. Such connection means are included in some of the other embodiments of the invention, described below.

[0050] Heat exchanger 10 further comprises a coolant flow passage 36 having an inlet and an outlet provided with fittings 38, 40 which are connected to coolant conduits (not shown) of a coolant circulation system. The coolant flow passage 36 extends along the axis A-B and is in heat exchange communication with one or both of the intermediate gas flow passage 22 and the outer gas flow passage 30. In order to maximize heat transfer, the coolant flow passage 36 may extend along substantially the entire length of the outer gas flow passage 30. The length of the outer gas flow passage 30 is defined as the distance, measured along axis A-B, between the first and second open ends 32, 34 of the outer gas flow passage 30.

[0051] The coolant flow passage 36 in Figure 1 is enclosed within a cooling jacket 42 in the form of a cylindrical shell which extends along the axis A-B. The cooling jacket 42 surrounds, and is sealingly connected to, the outer shell 28, such that the outer shell 28 defines an inner wall of the coolant flow passage 36. The coolant flow passage 36 therefore comprises the annular space between the cooling jacket 42 and the outer shell 28. Therefore, in the embodiment of Figure 1, the coolant flow passage 36 is located outwardly of the outer shell 28, such that the coolant circulating through coolant flow passage 36 is in direct heat exchange communication with only the outer gas flow passage 30, being separated from the gas in passage 30 by only the outer shell 28. Therefore, most of the heat transfer from the gas to the coolant takes place as the gas flows through the outer gas flow passage 30.

[0052] The flow of gas through heat exchanger 10 may be reversed so that the gas flows along axis A-B in the direction from B to A. Where the gas flow is reversed, the first open ends 16, 24, 32 of the gas flow passages 14, 22, 30 are located downstream of the second open ends 18, 26, 34, the second open end 34 of the outer gas flow passage 30 defines the inlet opening of heat exchanger 10, and the first open end 16 of the inner gas flow passage defines the outlet of heat exchanger 10. Where the gas flow is reversed, the inlet opening is identified by reference 4 and the outlet opening is identified by reference 2.

[0053] As shown in Figure 1, the gas flow changes direction twice as it flows through heat exchanger 10. In order to accomplish these changes in direction, the heat exchanger 10 incorporates a pair of turnaround plenums, and these are now described below with reference to Figure 1.

[0054] Firstly, as shown in Figure 1, the downstream end of the intermediate shell 20 extends past the second open ends of the 18, 26 of the inner and intermediate gas flow passages 14, 22 and includes an inwardly extending wall portion 44 which is spaced from the second open ends 18, 26 of the inner and intermediate gas flow passages 14, 22, so as to define a first turnaround plenum 46 in which the gas changes direction between the inner and intermediate gas flow passages 14, 22. In the embodiment of Figure 1, the inwardly extending wall portion 44 is located downstream of the second open ends 18, 26 and is simply shown as a solid, radially extending wall which is free of perforations, and which directs all of the gas exiting the inner gas flow passage 14 to change direction and enter the intermediate gas flow passage 22. Thus, the heat exchanger 10 does not permit the gas to bypass the intermediate and outer gas flow passages 22, 30 where heat is transferred to the coolant in the coolant passage 36.

[0055] A second turnaround plenum is provided between the first open end 24 of the intermediate gas flow passage 22 and the first open end 32 of the outer gas flow passage 30. In order to create this second turnaround plenum 48, the outer shell 28 extends past the first open ends 24, 32 of the intermediate and outer gas flow passages 22, 30 and includes an inwardly extending wall portion 50 which is spaced from the first open ends 24, 32 of the intermediate and outer gas flow passages 22, 30. The inwardly extending wall portion 50 has a central opening 51 within which the inner shell 12 is received and sealingly connected. The inwardly extending wall portion 50 therefore directs all of the gas exiting the intermediate gas flow passage 22 to change direction and enter the outer gas flow passage 30.

[0056] The heat exchanger 10 can be used in the cooling of various gas streams, such as intake air or exhaust gases in a motor vehicle. Where the gas being cooled is an exhaust gas, a catalytic converter may also be present in the exhaust system. The annular structure of heat exchanger 10 lends itself to integration with a catalytic converter, thereby permitting a reduction in the number of components of the exhaust system and providing potential opportunities for temperature control of the catalyst contained in the catalytic converter. For example, in heat exchanger 10 the inner shell 12 may comprise the housing of a catalytic converter and a catalyst 52 may be provided in the inner gas flow passage 14.

[0057] Where the heat exchanger 10 comprises an integrated device for cooling and catalytic treatment of exhaust gases, the direction of gas flow may be from A to B as shown in Figure 1, in which case the exhaust gases flow through the catalyst 52 prior to being cooled by heat exchange with the liquid coolant. It may, however, be preferred to pre-cool the exhaust gases before they contact the catalyst 52, for example where the temperature of the catalyst must be maintained within a specific temperature range. The heat exchanger 10 may be used in such situations, for example by reversing the gas flow through the heat exchanger so that the overall flow of gas through heat exchanger is from B to A, as described above. In this reverse flow configuration, the exhaust gas is cooled by the coolant prior to passing through the catalyst 52, thereby providing the ability to control the temperature of the catalytic converter. Temperature control of the catalyst 52 can alternatively, or additionally, be provided, by controlling the flow of coolant through the heat exchanger 10.

[0058] It can be seen from Figure 1 and the above discussion that integration of the heat exchanger 10 with a catalytic converter eliminates one component from the exhaust system. The addition of the intermediate shell 20, outer shell 28 and cooling jacket 42 to the outer surface of a catalytic converter can be done without requiring significantly more space than is already required by the catalytic converter alone. Because the intermediate and outer gas flow passages 22, 30 and the coolant flow passage 36 are annular, a relatively large surface area for cooling can be accommodated within a relatively small diameter (i.e. volume). In addition to having a large surface area to volume ratio, the heat exchanger 10 also provides a large flow section relative to volume, which is favourable for maximizing heat exchange per unit volume. These advantages are possessed by heat exchanger 10 and also the heat exchangers according to other embodiments of the invention, which will be described below.

[0059] Furthermore, because the coolant flow passage 36 is located on the outside of the heat exchanger 10, the use of this structure may eliminate the need for an external heat shield, which may bring about a further reduction in the number of components and space requirements.

[0060] In some embodiments of the invention, some or all of the gas flow is allowed to selectively bypass the intermediate and outer gas flow passages 22, 30, and thereby flow through heat exchanger 10 without being significantly cooled by the liquid coolant in coolant passage 36. Figures 2a and 2b schematically illustrate a heat exchanger 10b according to a second embodiment of the invention. Heat exchanger 10b is similar to heat exchanger 10 described above and includes a number of components which are similar or identical to the components of heat exchanger 10. Therefore, the components of heat exchanger 10b are identified with like reference numerals, and the above description of the elements of heat exchanger 10 apply equally to like elements of heat exchanger 10b.

[0061] The heat exchanger 10b differs from heat exchanger 10 in that the inwardly extending wall portion 44 of the intermediate shell 20 is provided with a bypass valve including a valve element 54 which can be partly or completely opened. The bypass valve can be of any convenient form. In heat exchanger 10, the bypass valve comprises a butterfly valve in which the valve element 54 comprises a disc mounted on a transversely extending rod 56 which pivots the valve element 54 in a circular opening 58. The rod 56 extends outwardly of the valve and its operation may be controlled by an external controller (not shown) based on a number of operating parameters, such as the temperature of the exhaust gas or a heating requirement in the vehicle.

[0062] In Figure 2b the valve element 54 is aligned with axis A-B, and therefore the bypass gas flow through opening 58 is at a maximum. This has the effect of reducing heat exchange with the coolant in passage 36 since very little of the exhaust gas will flow through the intermediate and outer gas flow passages 22, 30. The valve element 54 may be completely opened, for example, once the vehicle's engine coolant has reached a desired operating temperature and further heat transfer to the coolant is not required.

[0063] When completely closed, the valve element 54 completely blocks bypass gas flow (Figure 2a), and all the gas is then forced to flow through the intermediate and outer gas flow passages 22, 30 where it transfers heat to the coolant circulating within the coolant flow passage 36. This is essentially identical to the flow through heat exchanger 10 of Figure 1. The valve element 54 may be closed, for example, when it is desired to quickly heat the engine coolant on initial start-up of the vehicle.

[0064] The valve element 54 may adopt positions which are intermediate those shown in Figures 2a and 2b, such that a portion of the gas flows through the intermediate and outer gas flow passages 22, 30, and a portion of the gas bypasses the heat exchanger portion of heat exchanger 10 by flowing through the bypass port 58 and exiting the heat exchanger 10b. When the valve is partly open, the valve element 54 is at an angle of greater than 0° and less than 90° relative to the axis A-B.

[0065] In addition to providing all the benefits of heat exchanger 10 described above, the provision of heat exchanger 10b with a bypass valve eliminates the need for an external bypass conduit to be incorporated into the exhaust system, which further reduces the number of components and space requirements of the exhaust system.

[0066] Although not shown in Figures 1, 2a or 2b, at least one of the intermediate gas flow passage 22, the outer gas flow passage 30 and the coolant passage 36 may be provided with turbulence-enhancing inserts, such as corrugated fins or turbulizers, so as to improve heat transfer between the hot gas and the coolant. This is discussed in more detail below.

[0067] Figures 3 to 6 illustrate a heat exchanger 100 in accordance with a third embodiment of the invention. Heat exchanger 100 incorporates many of the same elements as are present in heat exchangers 10 and 10b described above. Accordingly, these like elements of heat exchanger 100 are numbered using like reference numerals and the above description of the elements of heat exchanger 10 applies equally to like elements of heat exchanger 100.

[0068] Heat exchanger 100 is integrated with a catalytic converter and, as shown in Figure 4, is comprised of two main sections: a heat exchange and catalytic converter section 93, and a liquid-cooled valve section 94. Heat exchanger 100 is similar to heat exchangers 10 and 10b shown above in that it includes an inner shell 12 (also serving as the catalytic converter housing), an intermediate shell 20 surrounding the inner shell 12, an outer shell 28 surrounding the intermediate shell 20, and a cooling jacket 42 surrounding the outer shell 28. The overall direction of gas flow through heat exchanger 100 is from A to B. The inner shell 12 has a straight, cylindrical portion and is narrowed at its upstream end (closest to A) to define the inlet opening 2 of heat exchanger 100. The inlet opening may be provided with a flange or other connection means (not shown) for attachment to other exhaust system components. The intermediate shell 22 comprises an open-ended cylindrical portion 95 having straight, axially extending side walls, and being of constant diameter. The outer shell 28 includes a cylindrical portion 60 having a constant diameter which is greater than the diameter of the intermediate shell 20 so as to create an annular space between the intermediate and outer shells 20, 28 which defines the outer gas flow passage 30. The outer shell 28 also includes inwardly extending wall portion 50 located at its upstream end which reduces the diameter of the outer shell 28 and terminates in an annular, axially extending collar 62 surrounding opening 51. The collar 62 is sealingly connected to the outer surface of the inner shell 12 (catalyst housing), for example by brazing or welding.

[0069] To optimize heat transfer between the hot gases flowing through the outer gas flow passage 30 and the coolant circulating in coolant flow passage 36, the outer gas flow passage 30 may be provided with turbulence-enhancing inserts, such as corrugated fins or turbulizers which in order to create turbulence in the gas flow and improve heat transfer with the coolant. These turbulizers are only schematically shown in Figures 3 to 6 and are identified by reference numeral 64. The turbulizers 64 are in the form of sheets which are wrapped around the intermediate shell 20 and substantially completely fill the annular space between shells 20 and 28 in which the outer gas flow passage 30 is defined.

[0070] The turbulizers 64 may comprise offset or lanced strip fins of the type described in U.S. Patent No. Re. 35,890 (So) and U.S. Patent No. 6,273,183 (So et al.). The offset strip fins may be received within the outer gas flow passage 30, such that the low pressure drop direction of the fin (i.e. with the fluid encountering the leading edges of the corrugations) is oriented in the axial direction. With the fin in this orientation there is a relatively low pressure drop in the axial flow direction and a relatively high pressure drop in the transverse, or circumferential, flow direction. In the offset strip fin the axially-extending ridges defining the corrugations are interrupted along their length, so that the axially-extending spaces are tortuous and create turbulence in the gas flow. It will be appreciated, that an offset strip fin could instead be oriented such that the high pressure drop orientation of the fin (i.e. with the fluid encountering the side surfaces of the corrugations) is oriented in the axial direction.

[0071] In the embodiment shown in Figures 3 to 6, the height of the outer gas flow passage 30 (measured radially) is sufficient to accommodate two layers of turbulizer 64 arranged one on top of the other, with a thin separator sheet 66 between them. In order to enhance heat transfer between the gas and the coolant, both layers of turbulizer 64 in the outer gas flow passage 30 may be rigidly connected to the separator sheet 66, for example by brazing. Also to enhance heat transfer, the outermost layer of turbulizer 64 may be rigidly connected, for example by brazing, to the inner surface of outer shell 28, which separates the outer gas flow passage 30 from the coolant flow passage 36. Meanwhile, the inner layer of turbulizer 64 is in contact with the outer surface of intermediate shell 20, but is optionally not brazed or otherwise rigidly connected to shell 20 for the following reason. Both sides of the intermediate shell 20 are in contact with hot exhaust gases, whereas the outer shell 28 is in contact with coolant. Therefore, there will be a temperature difference between the intermediate and outer shells 20, 28. Leaving the inner layer of turbulizer 64 unbonded from intermediate shell 20 has the effect of permitting limited axial thermal expansion of the intermediate shell 20 relative to the outer shell 28, thereby avoiding thermal stresses due to differential thermal expansion of shells 20 and 28.

[0072] As mentioned above, the coolant flow passage 36 may also be provided with a fin or turbulizer 80 (shown in Fig. 12). In order to maximize heat transfer, the inner surface of the turbulizer 80 in the coolant flow passage 36 may be rigidly connected to the outer surface of the outer shell 28, for example by brazing. However, the outer surface of the turbulizer 80 is in contact with the inner surface of the cooling jacket 42, but is optionally not brazed or otherwise rigidly attached to the cooling jacket 42. This is not done for the purpose of minimizing thermal stresses. Rather, in some embodiments, the lack of a bond between the turbulizer 80 and cooling jacket 42 may be desired in order to minimize unwanted heat transfer between the surroundings of the heat exchanger 100, and the coolant circulating through coolant flow passage 36. For example, it may be desired to leave turbulizer 80 unbonded from the cooling jacket 42 in situations where the heat exchanger is surrounded by ambient air and/or where the heat exchanger is used as a component of an active warm-up system, in which case it is undesirable to lose excessive amounts of thermal energy from the coolant.

[0073] The same comments regarding selective bonding of fins and turbulizers to surrounding shells of the heat exchanger apply equally to heat exchangers 10 and 10b illustrated in Figs. 1, 2a and 2b. In this regard, the turbulizers in the outer gas flow passage 30 and/or the turbulizers in the coolant flow passage 36 may be bonded only to the outer shell 28 in order to maximize heat transfer, but may optionally be left unbonded to the respective intermediate shell 20 and cooling jacket 42 for the reasons set out above.

[0074] It will be noted that turbulizers 64 are not provided in the intermediate gas flow passage 22 of heat exchanger 100. Since the cooling jacket 42 is provided on the outer surface of the outer shell 28, only the gas flowing through the outer gas flow passage 30 is in direct heat exchange communication with the coolant circulating within coolant flow passage 36. In this configuration, there will be little heat exchange between the coolant and the gas flowing through the intermediate gas flow passage 22, and the intermediate gas flow passage 22 may be regarded as a return passage. Any additional heat transfer provided by including turbulence-enhancing inserts in the intermediate gas flow passage 22 would be outweighed by hydraulic resistance caused by the turbulence-enhancing insert.

[0075] The outer gas flow passage 30 may be provided with other types of turbulence-enhancing inserts instead of turbulizers 64. For example, one or both of the intermediate shell 20 and the outer shell 28 may be provided with protrusions (not shown), such as ribs or dimples, which project into the outer gas flow passage 30 and are arranged to create a tortuous gas flow path within the passage 30.

[0076] The cooling jacket 42 of heat exchanger 100 extends axially along substantially the entire length of the cylindrical portion of outer shell 28, and is provided with a continuous peripheral flange 68 by which it is sealingly connected to the outer surface of the outer shell 28, for example by brazing or welding. Cooling jacket 42 of heat exchanger 100 is constructed so as to promote a circumferential flow of liquid coolant throughout the coolant flow passage 36. Accordingly, the cooling jacket 42 is provided with a pair of manifolds 70, 72 which permit the coolant to be distributed axially throughout the coolant flow passage 36. Where the manifolds 70, 72 are arranged side-by-side as in heat exchanger 100, an additional structure is provided to prevent short circuiting of the coolant flow between the two manifolds 70, 72. For example, in heat exchanger 100, the manifolds 70, 72 are separated by an axial rib 74 which extends radially inwardly to the outer surface of the outer shell 28 and physically separates the manifolds 70, 72. In addition, the cooling jacket 42 is provided with a pair of circumferential ribs 76, 78 which extend radially inwardly to the outer surface of the outer shell 28, so as to improve the pressure resistance of the cooling jacket 42. It will be appreciated that side-by-side location of manifolds 70, 72 is not required. Rather, the manifolds may be spaced apart from one another by an angle of up to about 180 degrees.

[0077] The manifolds 70, 72 are connected to coolant conduits (not shown) of a coolant circulation system. For example, the manifolds 70, 72 could be provided with inlet and outlet openings formed in cooling jacket 42 and provided with fittings 38, 40, as in heat exchanger 10. However, due to the incorporation of a specific type of valve, described below, the coolant flow passage 36 is provided with coolant inlet and outlet openings 80, 82 formed in the outer shell 28, and located so as to communicate with the interiors of manifolds 70 and 72, respectively. The inlet and outlet openings are formed proximate to the downstream end of the outer shell 28.

[0078] As best seen in Figures 4 and 5, the heat exchanger 100 further comprises a fitting block 84 including coolant fittings 86, 88 which are in communication with the coolant openings 80, 82 and which provide means for connecting the coolant flow passage 36 with the vehicle's cooling system. The fitting block 84 includes an arcuate outer surface 90 which is sealingly connected to the inner surface of the outer shell 28, for example by brazing or welding. The body of the fitting block 84 is accommodated within a rectangular cutout 92 in the downstream end of the intermediate shell 20.

[0079] The coolant fittings 86, 88 of heat exchanger 100 extend along axis A-B so as to connect to coolant passages within the valve section 94, which comprises a valve body 96 having a first (upstream) end 98 at which it is attached to the heat exchange and catalytic converter section 93 of heat exchanger 100, and a second (downstream) end 102 defining the outlet opening 4 of heat exchanger 100, the second end 102 being provided with an outlet flange 106 for connection to other exhaust system components (not shown).

[0080] The valve body 96 includes an outer sidewall 108 extending from the first end 98 to the second end 102 of valve body 96 and defining an outer circumferential lip 110 at the first end 98 of valve body 96. The open downstream end of outer shell 28 and the outer circumferential lip 110 overlap and are sealingly connected about their entire circumference, for example by brazing or welding.

[0081] The valve body 96 also includes an inner sidewall 112 extending from the first end 98 of valve body 96 to proximate the second end 102 thereof, and defining an inner circumferential lip 114 at the first end 98 of valve body, which is concentric with outer lip 110. The cylindrical portion 95 of intermediate shell 20 overlaps and is sealingly connected to the inner circumferential lip 114 about its entire circumference. A space 116 between the inner and outer sidewalls 112, 108 comprises a partial annulus and forms part of the outer gas flow passage 30 which is in communication with the outlet opening 4.

[0082] It will be apparent from Figure 5, the assembled view of heat exchanger 100, that the intermediate shell 20 comprises both the inner sidewall 112 of the valve body 96 and the cylindrical portion 95. The inwardly extending wall portion 44 of inner shell 20 and the circular opening 58 are both defined by the inner sidewall 112.

[0083] Like heat exchanger 10b, the circular opening 58 in the inwardly extending wall portion 44 is selectively opened and closed by disk-like valve element 54 mounted on pivoting rod 56 so as to selectively open and close the opening 58, and thereby control the bypass flow of gas through the heat exchanger 100. With the valve 54 completely closed, all of the gas entering heat exchanger 100 through inlet opening 2 flows through inner gas flow passage 14 and passes through catalyst 52. The gas then changes direction in the first turnaround plenum 46 created by the inwardly extending wall portion 44 of intermediate shell 20, and because valve 54 is closed, the gas is caused to flow through intermediate and outer gas flow passages 22, 30, after which the cooled gases exiting the outer gas flow passage 30 pass through the space 116 and exit heat exchanger 100 through outlet 4. With the valve 54 completely open as in Figure 5 substantially all of the gas flowing through the inner gas flow passage 14 will flow through opening 58 and exit the heat exchanger through outlet 4, without being cooled by the coolant circulating in passage 36.

[0084] The valve body 96 also includes an internal cooling jacket 118. The axially extending fittings 86, 88 of fitting block 84 are received in overlapping, sealed engagement with corresponding axial openings in the valve body 96 which are in communication with an internal cooling jacket 118 which circulates the coolant in the vicinity of the pivot rod 56. The internal cooling jacket 118 of valve body 96 is formed between the inner and outer sidewalls 112, 108 and interrupts the space 116 between the inner and outer sidewalls 112, 108. The internal cooling jacket 118 is in flow communication with the vehicle's cooling system through inlet and outlet fittings 120 and 122, best seen in Figure 6.

[0085] A heat exchanger 200 according to a fourth embodiment of the invention is now described below with reference to Figures 7 to 9. Heat exchanger

200 incorporates many elements which are either the same as or similar to elements of heat exchangers 10, 10a and 100 described above. Like elements of heat exchanger 200 are therefore described by like reference numerals, and the above descriptions of these elements apply equally to the like elements of heat exchanger 200.

[0086] Heat exchanger 200 includes an inner shell 12, an intermediate shell 20 and an outer shell 28 which are arranged in spaced relation to one another, so as to define an inner gas flow passage 14, an intermediate gas flow passage 22 and an outer gas flow passage 30, all as described above. Heat exchanger 200 integrates the functions of a heat exchanger and a catalytic converter, and therefore includes a catalyst 52 in the inner gas flow passage 14, and the inner shell 12 of the heat exchanger 200 is also the housing of the catalytic converter. The overall direction of gas flow through heat exchanger 200 is from A to B, having an inlet opening 2 and an outlet opening 4.

[0087] Heat exchanger 200 differs from the heat exchangers 10, 10b and 100 described above in that the coolant flow passage 36 of heat exchanger 200 is located inwardly of the outer shell 28. In this regard, the coolant flow passage 36 of heat exchanger 200 is incorporated in the intermediate shell 20, which includes an axially extending double-walled cylindrical portion comprised of an inner jacket wall 124 and an outer jacket wall 126. The inner and outer jacket walls 124, 126 are spaced apart from one another and are sealingly joined together at their edges to define a cooling jacket in which coolant flow passage 36 is enclosed. In addition, the outer jacket wall 126 is provided with a pair of openings 128, 130 which provide an inlet and outlet for the coolant circulating through flow passage 36. The openings 128, 130 are provided with fittings 132, 134 which extend radially outwardly from the outer jacket wall 126, through the outer gas flow passage 30 and through apertures 136, 138 in the outer shell 28, to connect with the vehicle's cooling system. The fittings 132, 134 are therefore sealingly connected to both the outer jacket wall 126 and to the peripheral edges of the apertures 136, 138 in the outer shell 28, for example by brazing or welding.

[0088] One advantage of providing the coolant flow passage 36 within the intermediate shell 20 is that the coolant flow passage 36 is located between the intermediate gas flow passage 22 and the outer gas flow passage 30, and is therefore in heat exchange communication with gases flowing through both passages 22 and 30. In order to enhance heat transfer, both the intermediate gas flow passage 22 and the outer gas flow passage 30 may be provided with at least one layer of turbulizer 64.

[0089] The intermediate shell 20 of heat exchanger 200 is in direct contact with the liquid coolant, and will therefore be at a lower temperature than the inner shell 12 and outer shell 28 during operation of heat exchanger 200. As a result, there is likely to be differential thermal expansion between the shells 12, 20, 28 of heat exchanger 200, with the potential for damaging thermal stresses. These thermal stresses may at least partially be avoided, while maximizing heat transfer, by selectively bonding the turbulizers 64 to surrounding surfaces, for example as shown in Figure 8a. In this regard, the turbulizer 64 in the outer gas flow passage 30 is bonded along its inner surface to the outer jacket wall 126 of intermediate shell 20 in order to maximize heat transfer between the gas and the coolant, while the outer surface of this turbulizer 64 is in contact with the outer shell 28, but is not bonded thereto in order to reduce thermal stresses due to differential thermal expansion. Similarly, the turbulizer 64 in the intermediate gas flow passage 22 is bonded along its outer surface to the inner jacket wall 124 of intermediate shell 20 to maximize heat transfer, while the inner surface of this turbulizer 64 is in contact with the inner shell 12, but is not bonded thereto in order to reduce thermal stresses due to differential thermal expansion. The bonding between turbulizers 64 and intermediate shell 20 may be accomplished by brazing, as shown by braze fillets 82 in Figure 8a.

[0090] Also, where a turbulizer 80 is provided inside the coolant flow passage 36 of heat exchanger 200 as shown in Figure 8a, it may be rigidly bonded to the surrounding intermediate shell 20 along its inner and outer surfaces, for example by braze fillets 82, in order to maximize heat transfer between the coolant and the gases circulating through the intermediate and outer gas flow passages 22, 28.

[0091] Figure 8 illustrates a possible position of the inlet and outlet fittings 132, 134 for the coolant flow passage 36. As shown in Figure 8, the inlet and outlet fittings 132, 134 and corresponding openings 128, 130 may be located close together circumferentially, with an axial rib 140 or other means to prevent short-circuiting of flow between the inlet and outlet 128, 130. As indicated by the arrows in Figure 8, the coolant flows circumferentially between the inlet and outlet 128, 130. The inlet and outlet 128, 130 and the corresponding fittings 132, 134 are not necessarily located as in Figure 8, but may instead be spaced apart circumferentially by up to about 180 degrees.

[0092] As with heat exchangers 10b and 100 described above, the intermediate shell 20 of heat exchanger 200 includes an inwardly extending wall portion 44 having an opening 58 which is selectively closed by a valve element 54 mounted on a pivoting rod 56.

[0093] Similar to heat exchanger 100, the outlet end of heat exchanger 200 includes an outer sidewall 108 which extends inwardly proximate the outlet end 4 of heat exchanger 200, and terminates in a flange 106 for connection of the heat exchanger 200 to another exhaust system component. A space 116 of annular cross-section is formed between the outer sidewall 108 and an inner sidewall 112, comprising the inwardly extending wall portion 44 of the intermediate shell 20, forming part of the outer gas flow passage 30 and providing communication between the outer gas flow passage 30 and the outlet opening 4 of heat exchanger 200.

[0094] With the valve element 54 closed as in Figure 7, all the gas entering the heat exchanger 200 through inlet opening 2 is caused to change direction and flow through the intermediate and outer gas flow passages 22, 30, transferring heat to the coolant being circulated in the coolant passage 36 before exiting the heat exchanger through outlet opening 4. With the valve element 54 completely open as in Figure 9, substantially all of the gas entering the heat exchanger through inlet opening 2 will flow through opening 58 of the bypass valve and out through the outlet opening 4, bypassing the intermediate and outer gas flow passages.

[0095] Figures 10 and 11 illustrate yet another heat exchanger 300 according to the invention, the heat exchanger 300 including many of the same elements as described above in connection with heat exchangers 10, 10b, 100 and 200. Accordingly, the like elements of heat exchanger 300 are numbered using like reference numerals and the above description of the elements of heat exchangers 10, 10b, 100 and 200 applies equally to like elements of heat exchanger 300.

[0096] Heat exchanger 300 bears a high degree of similarity to heat exchanger 10b, the main difference being that the overall direction of gas flow in heat exchanger 300 is from B to A, opposite that of heat exchanger 10b, such that the inlet opening of heat exchanger 300 is at 4 and the outlet opening of heat exchanger 300 is at 2. Thus, as shown in Figure 11, when the valve 54 is closed, the gas entering the heat exchanger 300 through inlet opening 4 is caused to flow through the outer and intermediate gas flow passages 30, 22 before passing through the catalyst 52. When the valve 54 is open as in Figure 10, substantially all of the gas flow passes from the inlet opening 4, through the catalyst 52, and out through the outlet opening 2 without being cooled. Therefore, by selectively cooling the exhaust gas before it comes into contact with the catalyst 52, the heat exchanger 300 provides a means for controlling the temperature of the catalyst 52. The turbulizer 64 in heat exchanger 300 is positioned between the intermediate and outer shells 20, 28 and, as in heat exchangers 10, 10b and 100, the turbulizer 64 may be bonded to the outer shell 28 to maximize heat transfer, but not bonded to the intermediate shell 20 to reduce thermal stresses due to differential thermal expansion. Where a turbulizer is provided inside the coolant flow passage 36, it may be rigidly connected to the outer shell 28, but not bonded to the cooling jacket 42.

[0097] The schematic cross-sectional views of Figures 12 to 15 provide a more detailed illustration of the concept of selective bonding of a turbulizer 64 in gas flow passage 30 and a turbulizer 80 in the coolant flow passage 36, and are applicable to all embodiments disclosed herein. As shown in Figures 12 to 15, the outer gas flow passage 30 is provided with a turbulizer 64, and the coolant flow passage 36 is provided with a turbulizer 80. The top (radially outer) and bottom (radially inner) surfaces of turbulizer 64 are in contact with the intermediate shell 20 and the outer shell 28, respectively, while the top and bottom surfaces of turbulizer 80 are in contact with the outer shell 28 and the cooling jacket 42, respectively.

[0098] The turbulizer 80 in the coolant flow passage 36 has its bottom surface rigidly connected, for example by brazing, to the outer surface of the outer shell 28

(Fig. 14), so as to enhance heat transfer between the coolant and the hot gases. Meanwhile, the top surface of turbulizer 80 is in contact with the inner surface of cooling jacket 42 but is optionally not brazed or otherwise rigidly attached to the cooling jacket 42 (Fig. 13). This has the effect of minimizing unwanted heat loss to the surroundings of the heat exchanger, and is not related to minimizing thermal stresses.

[0099] The turbulizer 64 may have its top surface rigidly connected, for example by brazing, to the inner surface of the outer shell 28 (Fig. 14), so as to enhance heat transfer between the coolant and the hot gases. Meanwhile, the bottom surface of turbulizer 64 is in contact with the outer surface of the intermediate shell 20 but is optionally not brazed or otherwise rigidly attached to the shell 20 (Fig. 15). The lack of a rigid connection between turbulizer 64 and intermediate shell 20 permits some limited differential thermal axial expansion of the relatively hot intermediate shell 20 relative to the relatively cooler outer shell 28, thereby reducing thermal stresses which may cause damage to the heat exchanger.

[00100] Braze fillets 82 are shown in Fig. 14 are shown as providing rigid connections between the outer shell and the respective turbulizers 64 and 80. It will be seen that turbulizer bonding is preferentially provided along surfaces which separate a coolant flow passage 36 from a gas flow passage, whereas the other surfaces along which turbulizers are provided are optionally left unbonded. These same principles are applicable to all embodiments of the invention, including the embodiment of Figs. 7 to 9 where the coolant flow passage 36 is located between the inner gas flow passage 22 and the outer gas flow passage 30.

[00101] Although the invention has been described in the context of heat exchangers for cooling a gas stream with a liquid coolant, it will be appreciated that the heat exchangers according to the invention could instead be used for transferring heat from a heated liquid to a relatively cool gas.

[00102] Although the invention has been described in connection with certain embodiments thereof, it is not limited thereto. Rather, the invention includes all embodiments which may fall within the scope of the following claims.

What is claimed is:

1. A heat exchanger having a first end with a first gas flow opening and a second end with a second gas flow opening, wherein the first and second ends of the heat exchanger are spaced apart along a gas flow axis, and wherein the heat exchanger comprises:

an inner shell defining an inner gas flow passage extending along the gas flow axis, wherein the inner gas flow passage has a first open end and a second open end, wherein the first open end of the inner gas flow passage is in flow communication with the first gas flow opening of the heat exchanger;

an intermediate shell surrounding the inner shell, wherein a space between the inner shell and the intermediate shell defines an intermediate gas flow passage extending along the gas flow axis, wherein the intermediate gas flow passage has a first open end and a second open end, and wherein the second open end of the intermediate gas flow passage is in flow communication with the second open end of the inner gas flow passage;

an outer shell surrounding the intermediate shell, wherein a space between the intermediate shell and the outer shell defines an outer gas flow passage extending along the gas flow axis, wherein the outer gas flow passage has a first open end and a second open end, wherein the first open end of the outer gas flow passage is in flow communication with the first open end of the intermediate gas flow passage and the second open end of the outer gas flow passage is in flow communication with the second gas flow opening of the heat exchanger;

a coolant flow passage having an inlet and an outlet and extending along the gas flow axis, wherein the coolant flow passage is in heat exchange communication with the outer gas flow passage or with both the intermediate gas flow passage and the outer gas flow passage;

wherein the intermediate shell includes a radially inwardly extending wall portion which is located between the second end of the heat exchanger and the second open ends of the inner and intermediate gas flow passages, wherein the radially inwardly extending wall portion of the intermediate shell defines a turnaround plenum in which the gas flow changes direction between the inner and intermediate gas flow passages;

wherein the radially inwardly extending wall portion of the intermediate shell has an opening which is selectively opened and closed by a valve;

wherein opening of the valve permits direct flow communication between the first and second gas flow openings through the inner gas flow passage, thereby providing a bypass flow passage for the gas; and

wherein complete closing of the valve substantially prevents direct flow communication between the first and second gas flow openings through the inner gas flow passage.

2. A heat exchanger according to claim 1, wherein the first gas flow opening defines a gas inlet opening and the second gas flow opening defines a gas outlet opening.

3. A heat exchanger according to claim 1, wherein the first gas flow opening defines a gas outlet opening and the second gas flow opening defines a gas inlet opening.

4. A heat exchanger according to any one of claims 1 to 3, wherein the outer shell has a radially inwardly extending wall portion which is sealingly connected to the inner shell at a location between the first end of the heat exchanger and the first open ends of the intermediate and outer gas flow passages, wherein the radially inwardly extending wall portion of the outer shell defines a turnaround plenum in which the gas flow changes direction between the intermediate and outer gas flow passages.

5. The heat exchanger according to any one of claims 1 to 4, wherein said gas is a motor vehicle exhaust gas, and wherein the inner gas flow passage contains a catalyst for treating said motor vehicle exhaust gas.

6. The heat exchanger according to any one of claims 1 to 5, wherein the coolant flow passage comprises a cooling jacket attached to an outer surface of the outer shell, such that the coolant circulating through the jacket is in heat exchange communication with the outer gas flow passage.

7. The heat exchanger according to any one of claims 1 to 6, wherein the intermediate shell comprises an inner jacket wall and an outer jacket wall between which said coolant flow passage is defined, wherein the coolant circulating through the coolant flow passage is in heat exchange communication with both the intermediate gas flow passage and the outer gas flow passage.

8. The heat exchanger according to claim 7, wherein the inlet and outlet of the coolant flow passage are provided in the outer jacket wall and are axially spaced from one another, and wherein each of said inlet and said outlet are provided with fittings which extend radially outwardly from the outer jacket wall, through the outer gas flow passage and through the outer shell.

9. The heat exchanger according to any one of claims 1 to 8, wherein at least those portions of the inner, intermediate and outer shells defining said gas flow passages are generally cylindrical about said gas flow axis, such that the inner gas flow passage is generally cylindrical and each of the intermediate and outer gas flow passages is generally annular and concentric with the inner gas flow passage.

10. The heat exchanger according to any one of claims 1 to 9, wherein at least one of said inner gas flow passage and said outer gas flow passage is provided with a turbulence-enhancing insert, wherein each said turbulence-enhancing insert is located between and in contact with two of said shells.

11. The heat exchanger according to claim 10, wherein the outer gas flow passage is provided with a turbulence-enhancing insert which is rigidly bonded to one of said shells and unbonded to another of said shells.

12. The heat exchanger according to claim 6, wherein said outer gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said intermediate shell and said outer shell, and wherein the turbulence-enhancing insert is rigidly bonded to the outer shell and unbonded to the intermediate shell.

13. The heat exchanger according to claim 12, wherein the coolant flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said outer shell and the cooling jacket, and wherein the turbulence-enhancing insert of the coolant passage is rigidly bonded to the outer shell and unbonded to the cooling jacket.

14. The heat exchanger according to claim 7 or 8, wherein said outer gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said intermediate shell and said outer shell, and wherein the turbulence-enhancing insert is rigidly bonded to the outer jacket wall of the intermediate shell and unbonded to the outer shell.

15. The heat exchanger according to claim 14, wherein said intermediate gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said intermediate shell and said inner shell, and wherein the turbulence-enhancing insert is rigidly bonded to the inner jacket wall of the intermediate shell and unbonded to the inner shell.

16. The heat exchanger according to claim 14 or 15, wherein the coolant flow passage is provided with a turbulence-enhancing insert which is located inbetween and in contact with said inner jacket wall and said outer jacket

wall, and wherein the turbulence-enhancing insert of the coolant passage is rigidly bonded to both the inner jacket wall and the outer jacket wall.

17. The heat exchanger according to any one of claims 1 to 16, wherein the intermediate shell has a downstream end which extends past the second open ends of the inner gas flow passage and the intermediate gas flow passage, and includes an inwardly extending wall portion which defines a first turnaround plenum in which the gas changes direction between the inner gas flow passage and the intermediate gas flow passage.

18. The heat exchanger according to claim 17, wherein the inwardly extending wall portion includes an opening provided with a valve element, wherein the valve element is movable between open and closed positions, and wherein, with the valve in the open position, at least a portion of the gas is permitted to flow through the heat exchanger by passing through the inner gas flow passage and bypass the intermediate gas flow passage and the outer gas flow passage.

19. A heat exchanger having a first end with a first gas flow opening and a second end with a second gas flow opening, wherein the first and second ends of the heat exchanger are spaced apart along a gas flow axis, and wherein the heat exchanger comprises:

an inner shell defining an inner gas flow passage extending along the gas flow axis, wherein the inner gas flow passage has a first open end and a second open end, wherein the first open end of the inner gas flow passage is in flow communication with the first gas flow opening of the heat exchanger;

an intermediate shell surrounding the inner shell, wherein a space between the inner shell and the intermediate shell defines an intermediate gas flow passage extending along the gas flow axis, wherein the intermediate gas flow passage has a first open end and a second open end, and wherein the second open end of the intermediate gas flow passage is in flow communication with the second open end of the inner gas flow passage;

an outer shell surrounding the intermediate shell, wherein a space between the intermediate shell and the outer shell defines an outer gas flow passage extending along the gas flow axis, wherein the outer gas flow passage has a first open end and a second open end, wherein the first open end of the outer gas flow passage is in flow communication with the first open end of the intermediate gas flow passage and the second open end of the outer gas flow passage is in flow communication with the second gas flow opening of the heat exchanger;

a coolant flow passage having an inlet and an outlet and extending along the gas flow axis;

wherein the intermediate shell comprises an inner jacket wall and an outer jacket wall between which said coolant flow passage is defined, wherein the coolant circulating through the coolant flow passage is in heat exchange communication with both the intermediate gas flow passage and the outer gas flow passage.

20. The heat exchanger according to claim 19, wherein the inlet and outlet of the coolant flow passage are provided in the outer jacket wall and are axially spaced from one another, and wherein each of said inlet and said outlet are provided with fittings which extend radially outwardly from the outer jacket wall, through the outer gas flow passage and through the outer shell.

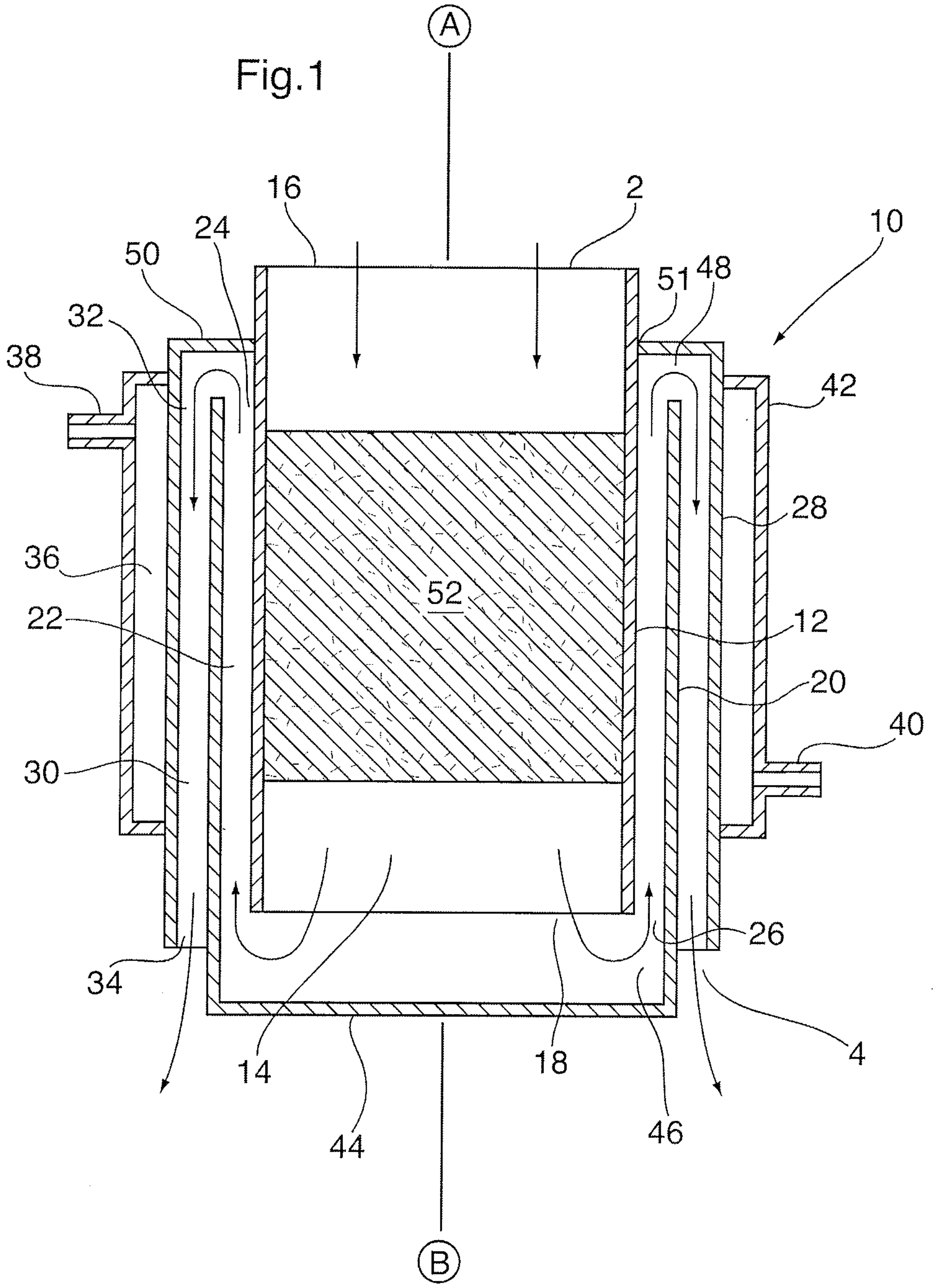
21. The heat exchanger according to claim 19 or 20, wherein said outer gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said intermediate shell and said outer shell, and wherein the turbulence-enhancing insert is rigidly bonded to the outer jacket wall of the intermediate shell and unbonded to the outer shell.

22. The heat exchanger according to claim 21, wherein said intermediate gas flow passage is provided with a turbulence-enhancing insert which is located between and in contact with said intermediate shell and said inner

shell, and wherein the turbulence-enhancing insert is rigidly bonded to the inner jacket wall of the intermediate shell and unbonded to the inner shell.

23. The heat exchanger according to claim 21 or 22, wherein the coolant flow passage is provided with a turbulence-enhancing insert which is located inbetween and in contact with said inner jacket wall and said outer jacket wall, and wherein the turbulence-enhancing insert of the coolant passage is rigidly bonded to both the inner jacket wall and the outer jacket wall.

Fig.1


A
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B

Fig.2a

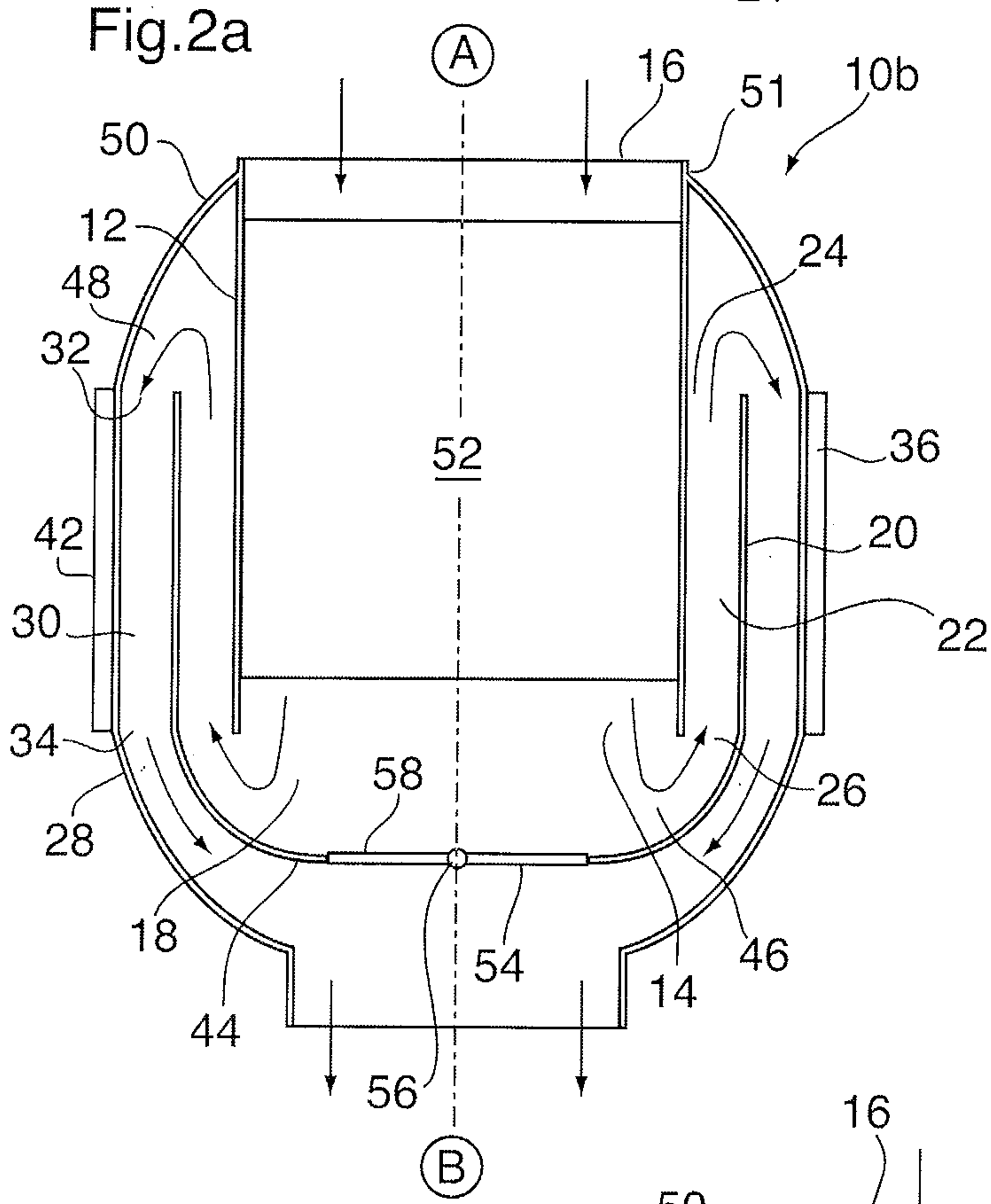
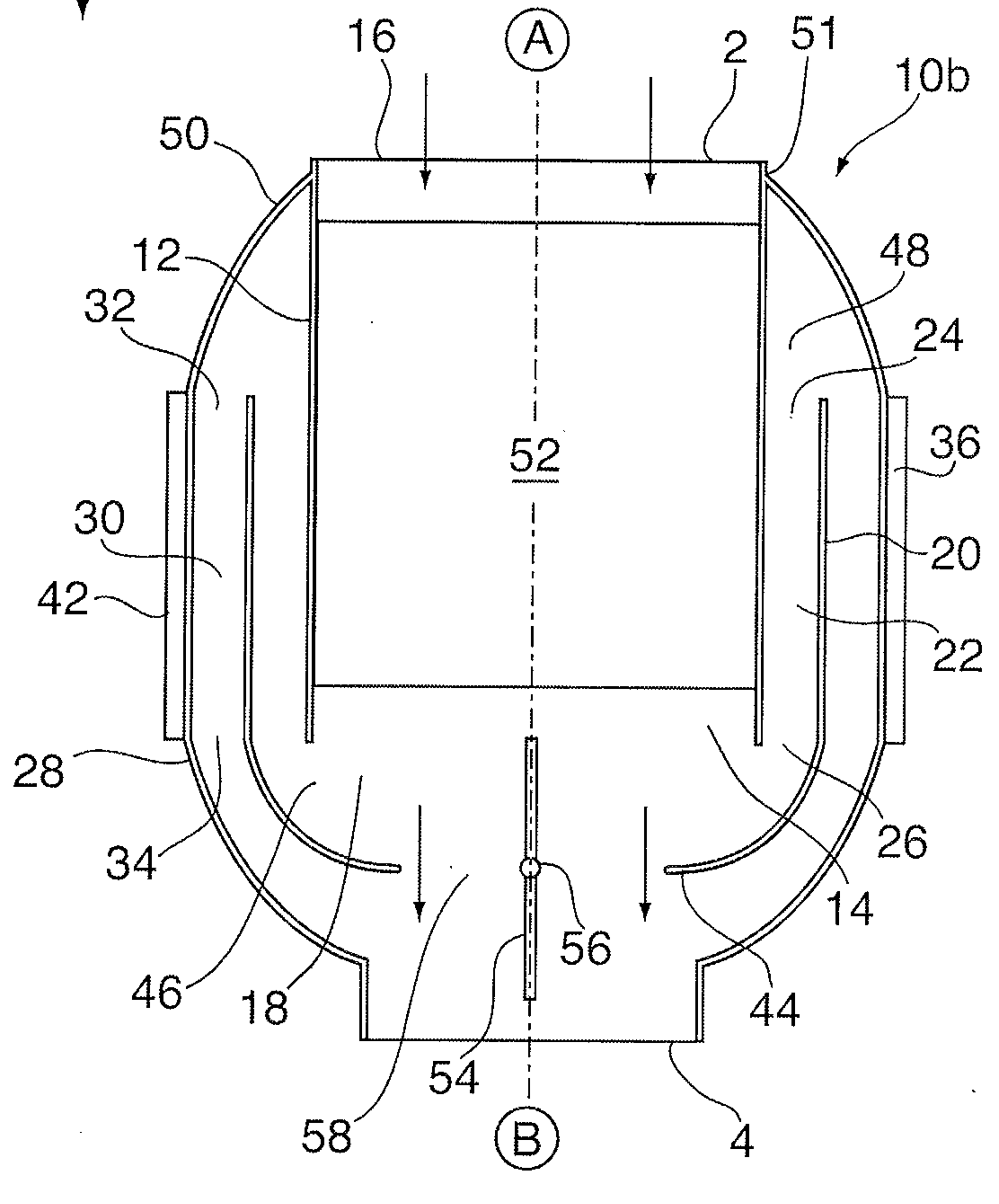

A
16
51
10b
50
12
48
32
24
52
36
42
20
30
22
34
58
26
28
18
54
46
44
14
56
B

Fig.2b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A
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10b
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12
48
32
24
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14
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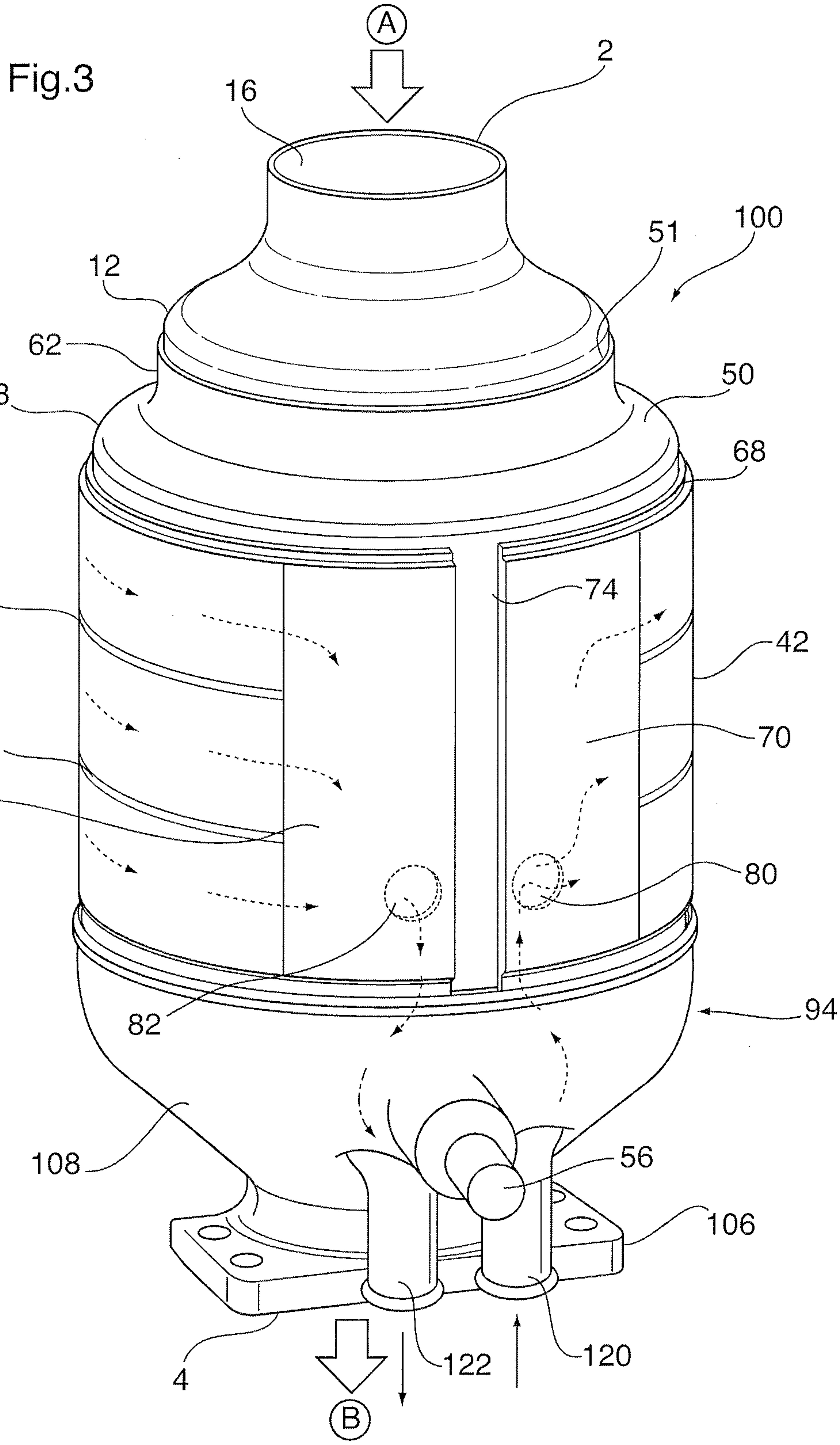
58
B
4

Fig.3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12
62
50
28
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93
78
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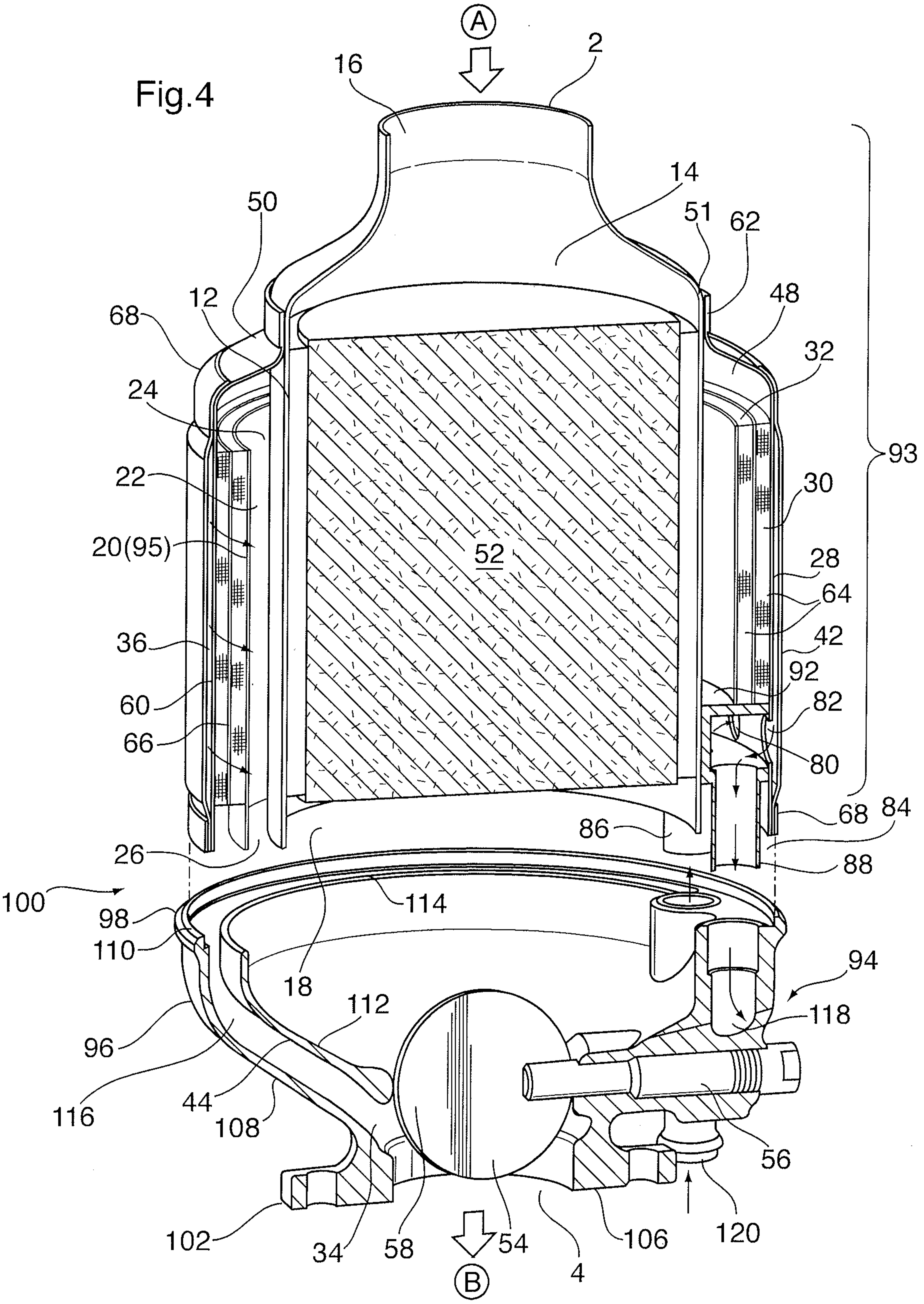
72
80
82
94
108
56
106
4
122
120
B

Fig.4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B
2
4
12
14
16
18
20(95)
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34
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42
44
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51
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64
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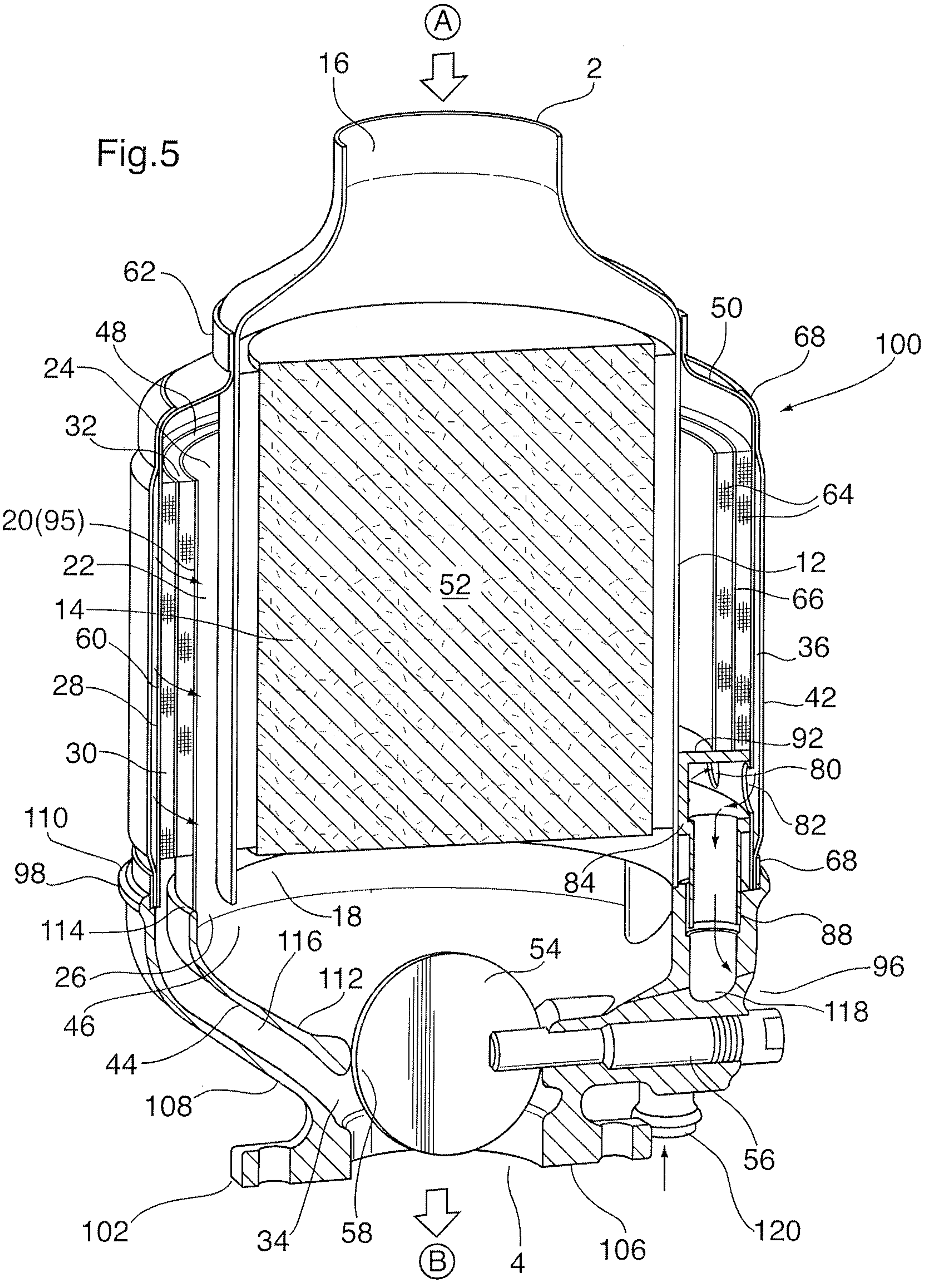
118
120

Fig.5


A
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24
32
20(95)
22
14
60
28
30
110
98
114
26
46
44
108
102
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58
B
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106
120
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118
96
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82
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92
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36
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100
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52
18
116
112
54

Fig.6

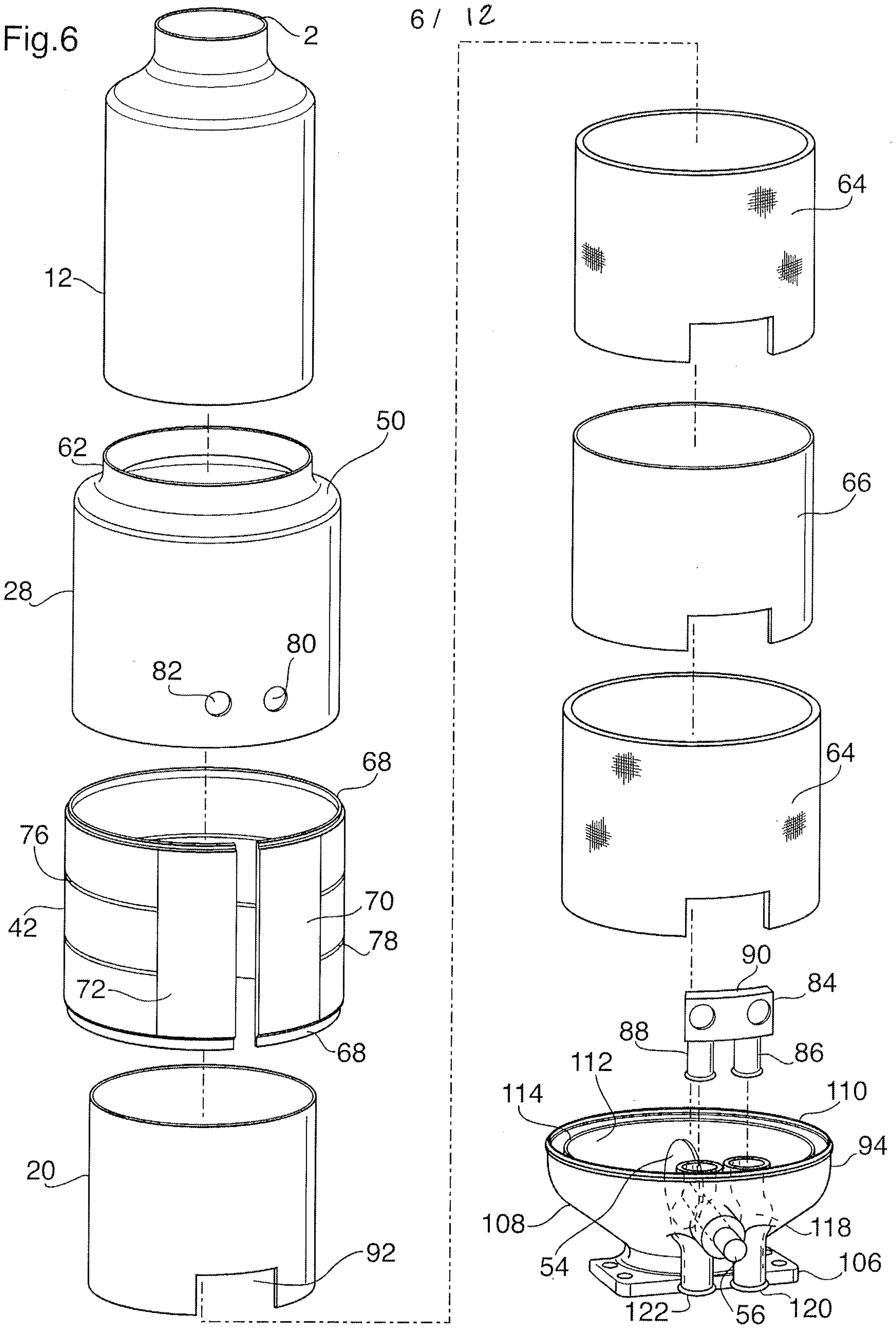
2
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Fig.7

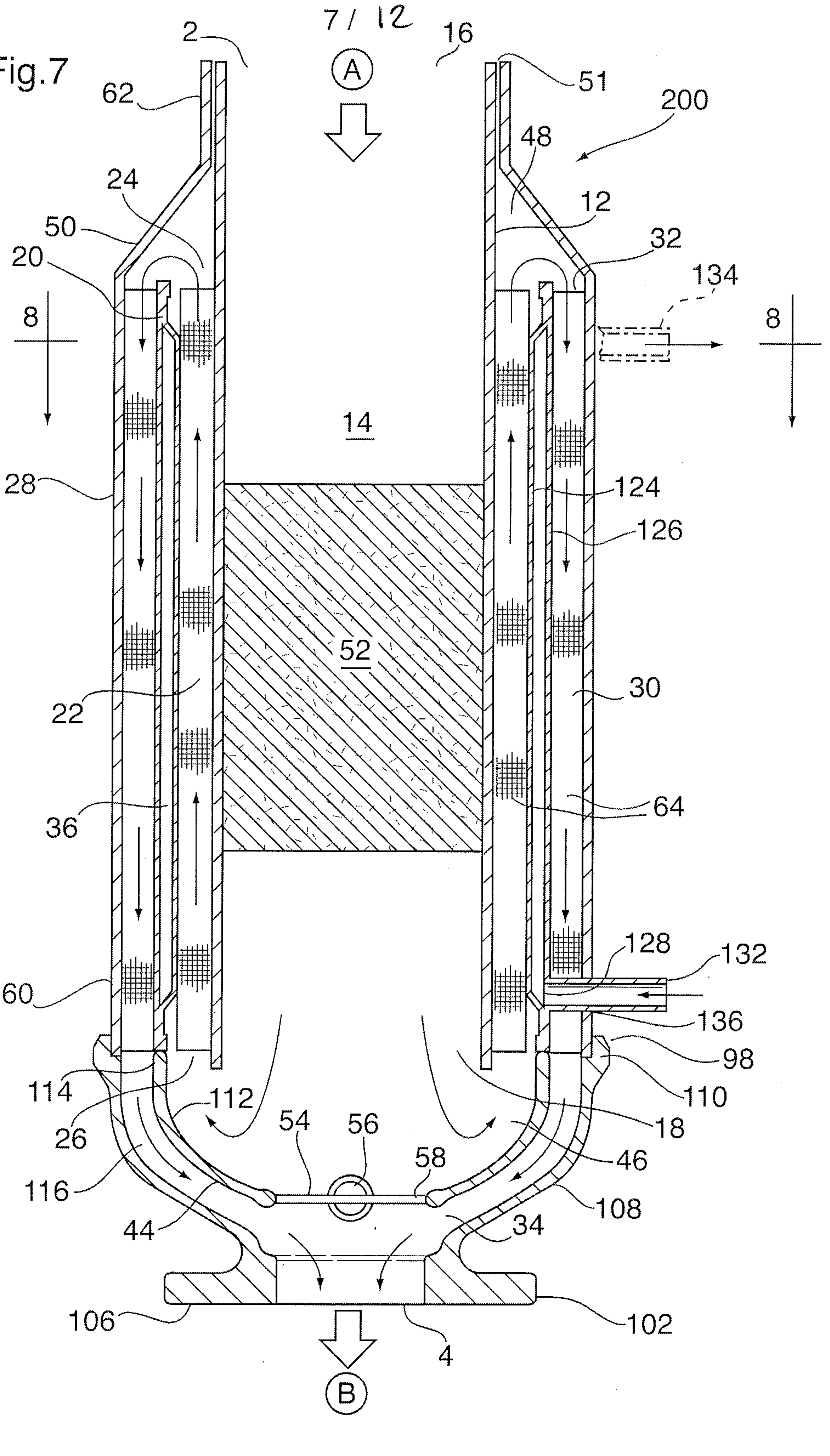
2
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Fig.8

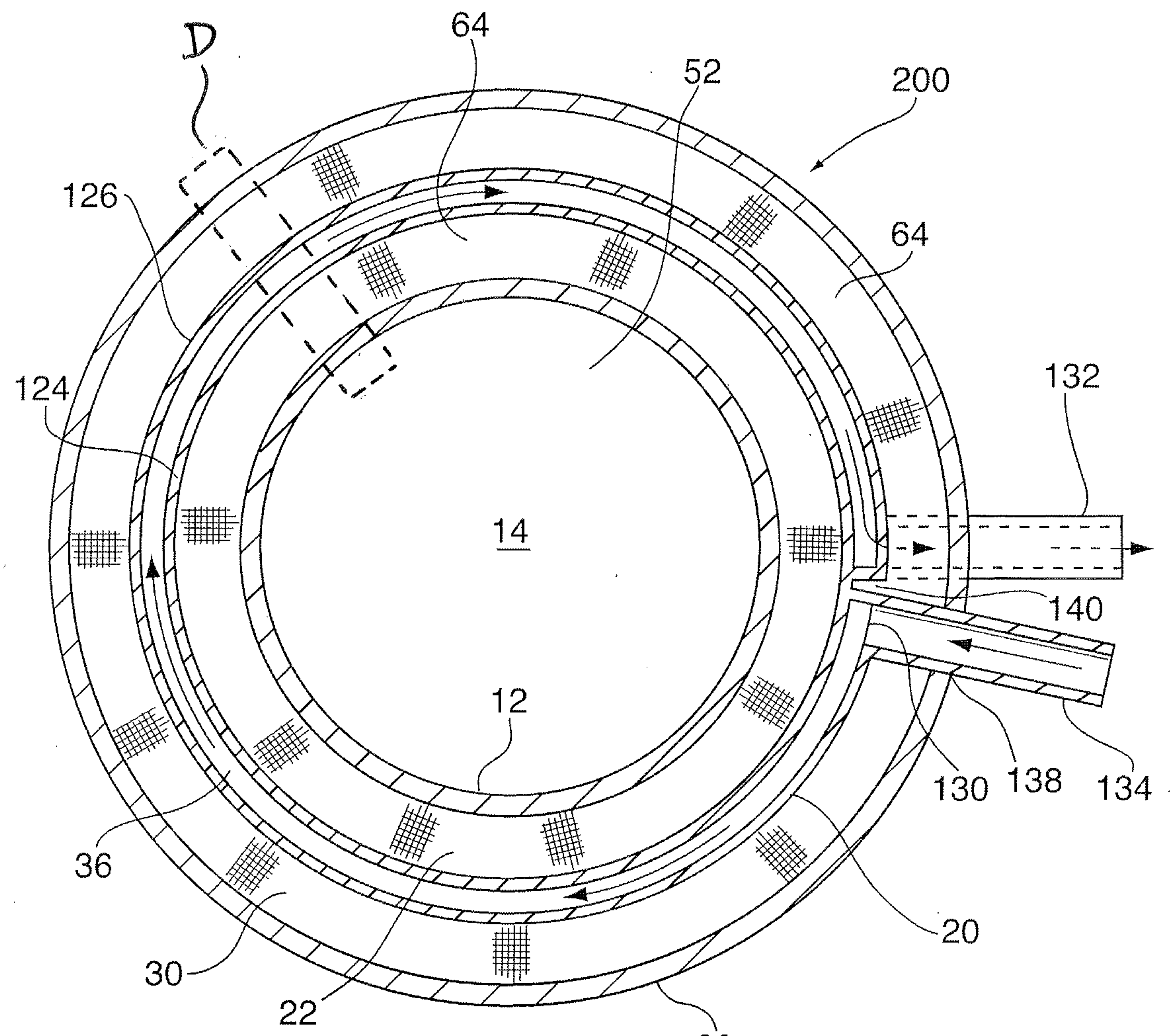
D
64
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FIG. 8a

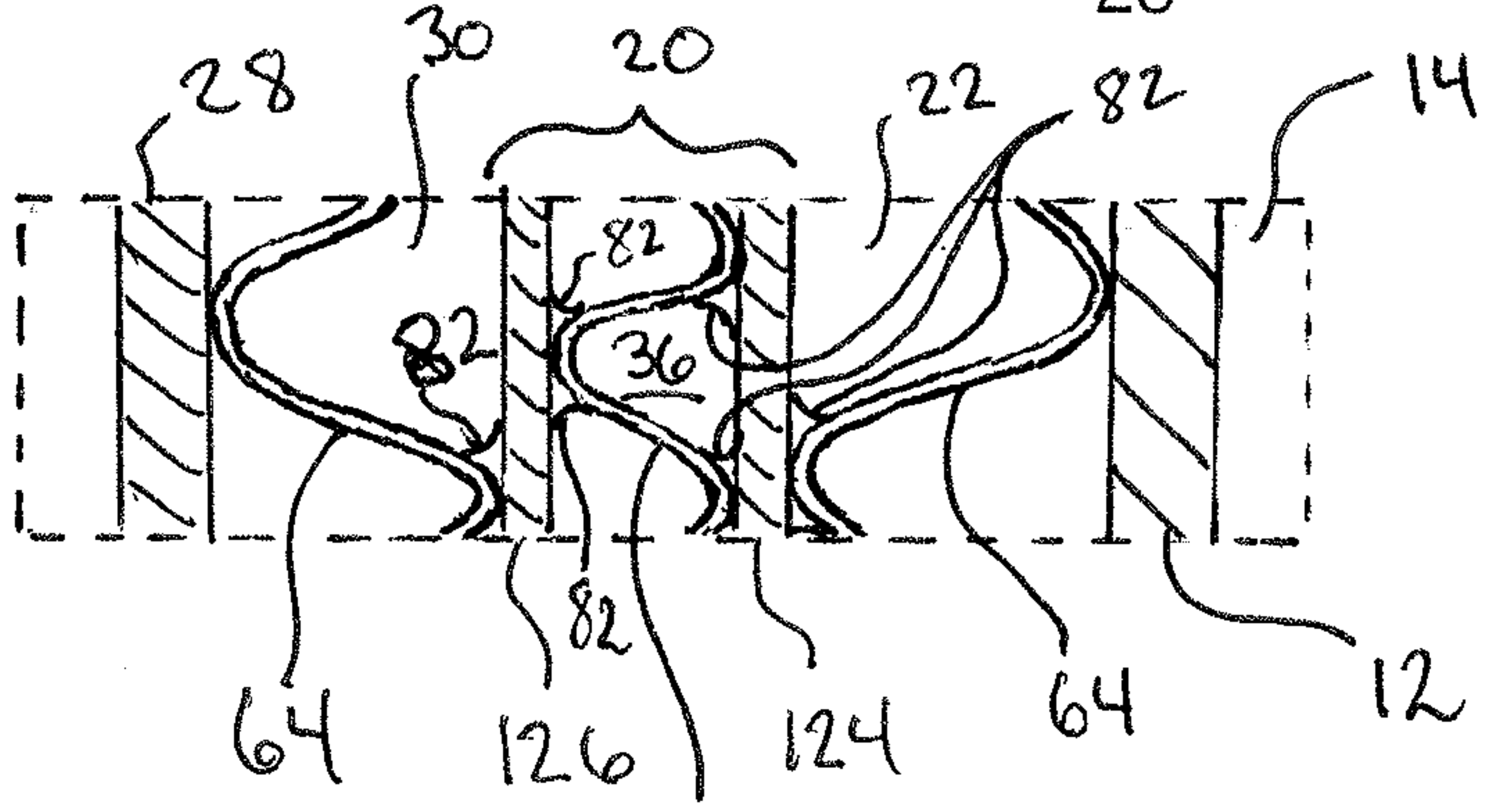
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Fig.9

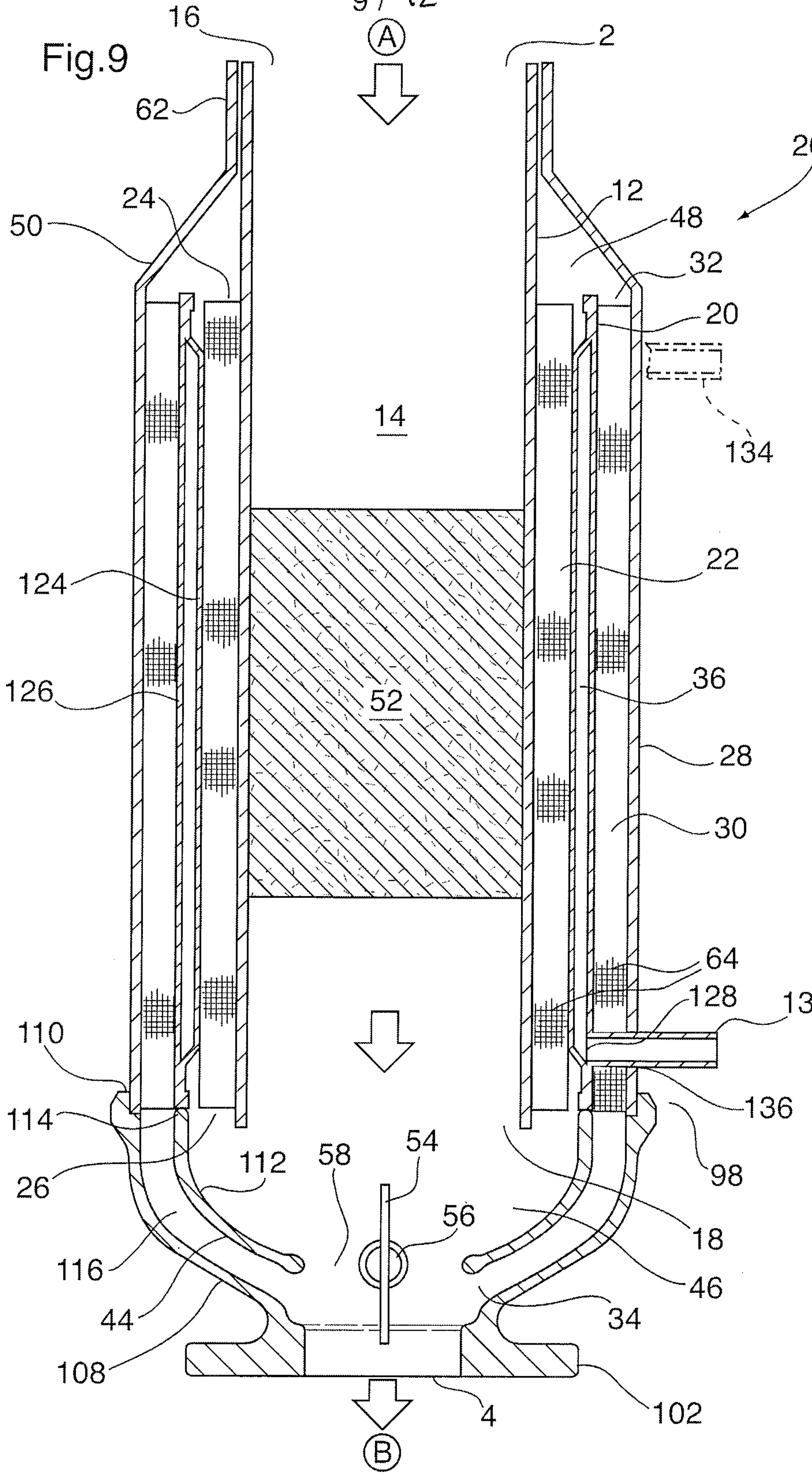
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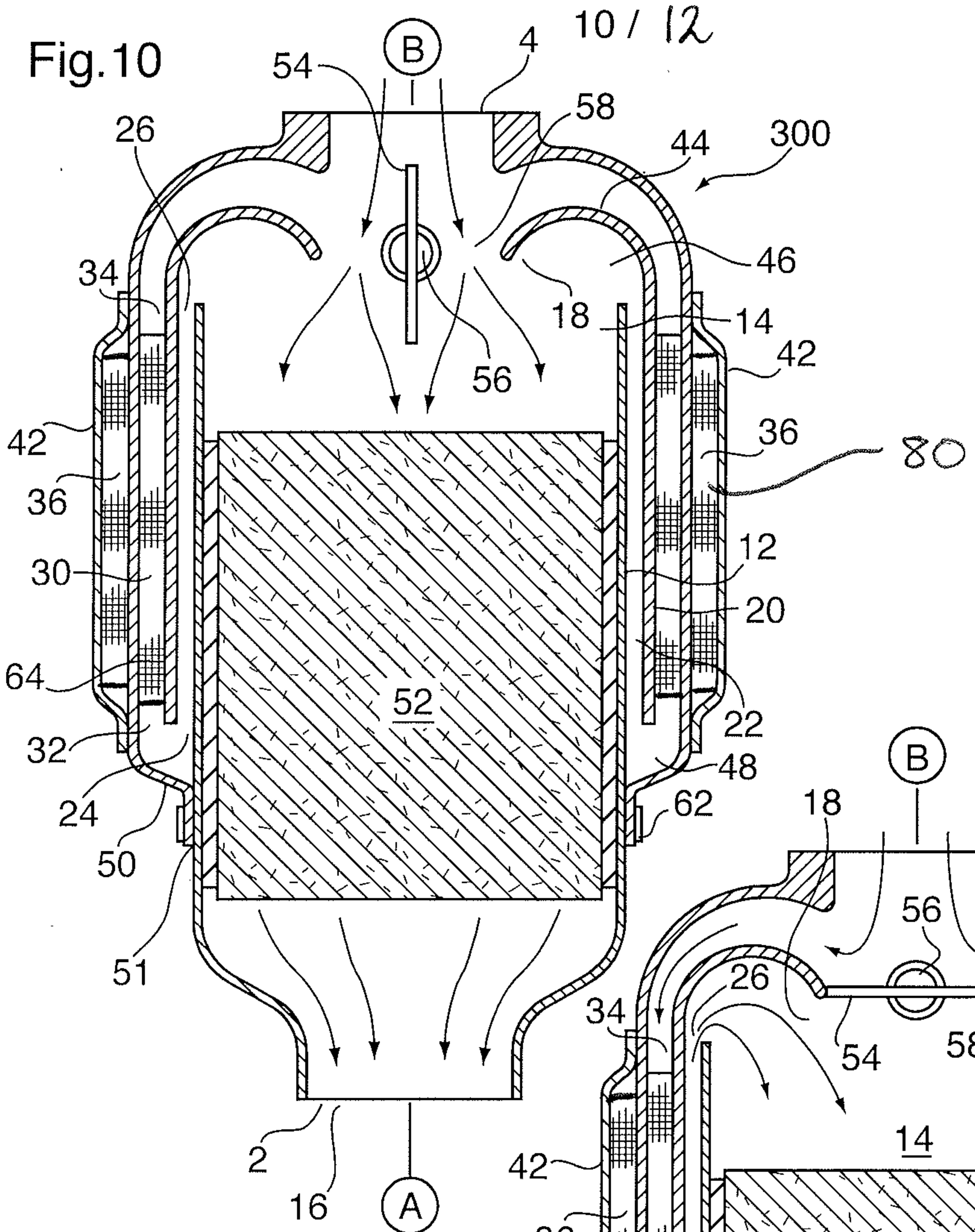
Fig.10


B
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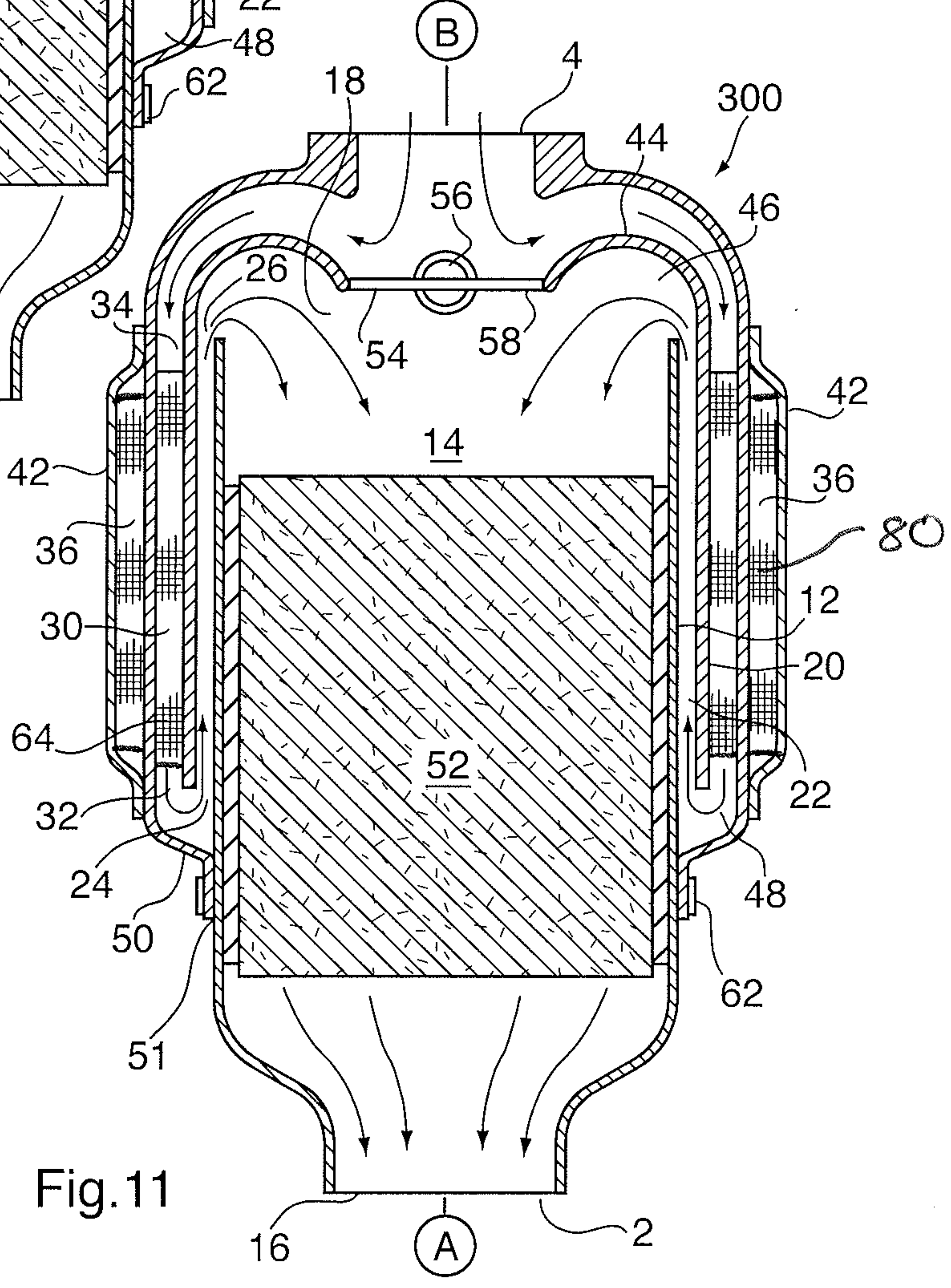
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Fig.11

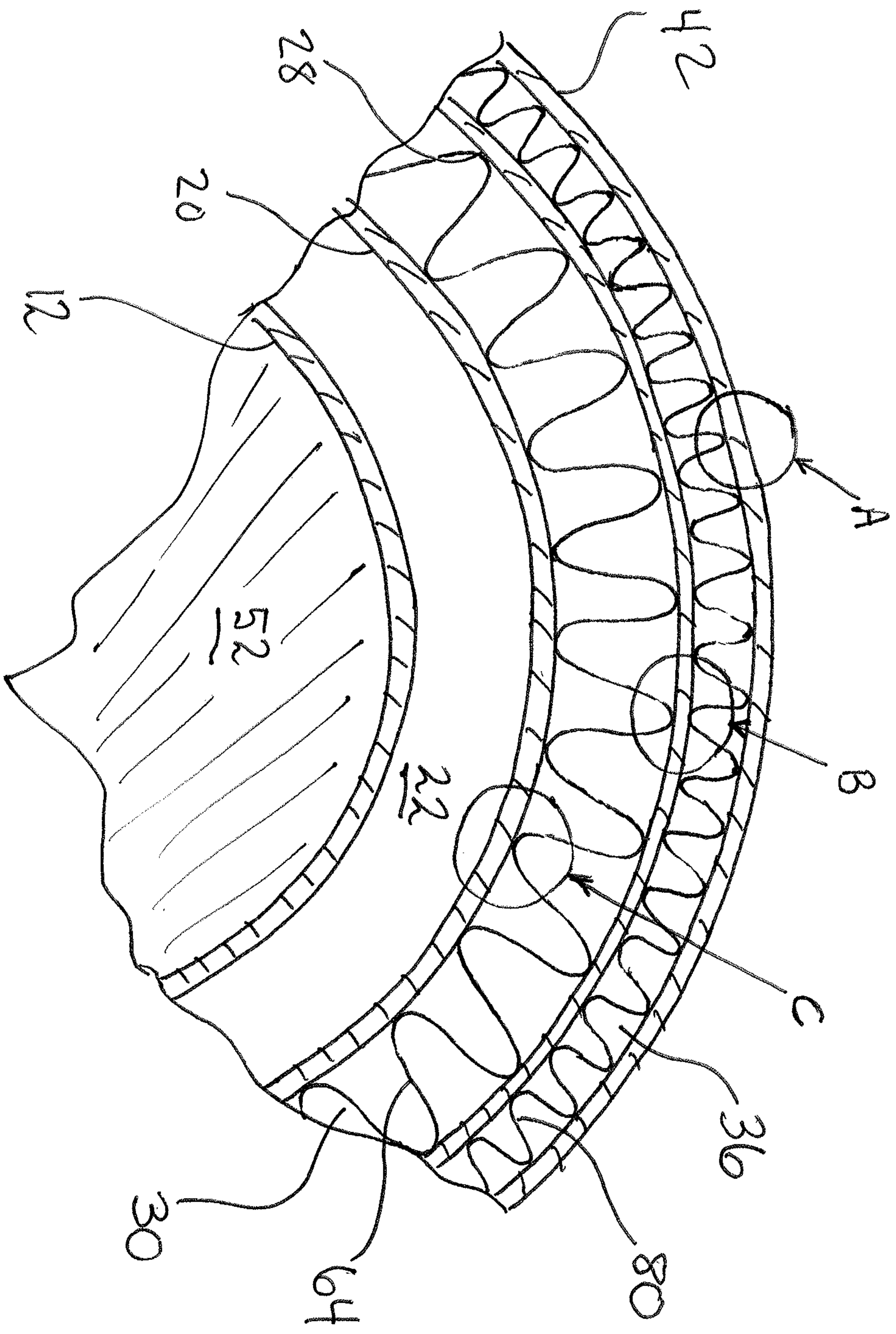


FIG. 12

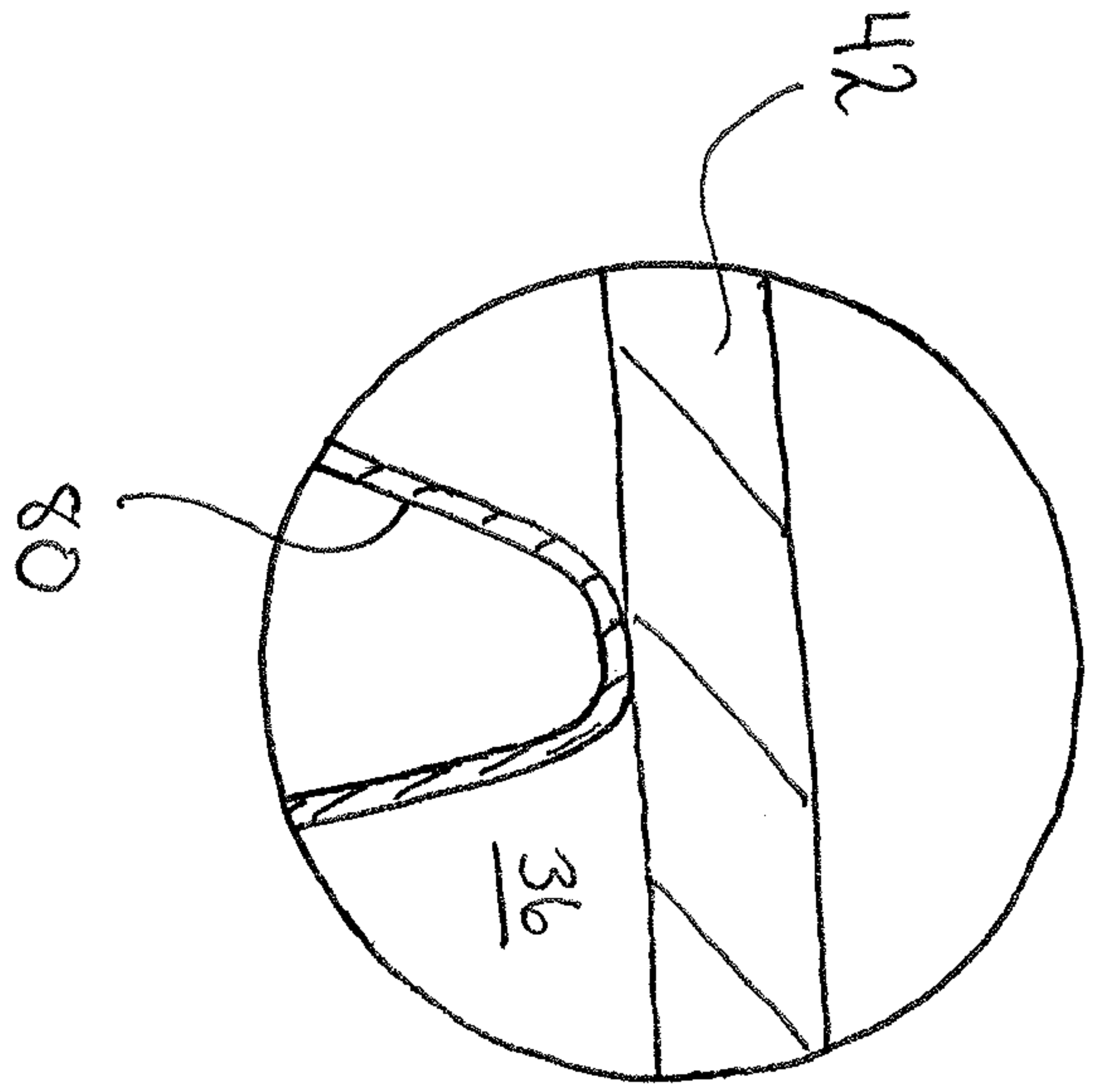


FIG. 13

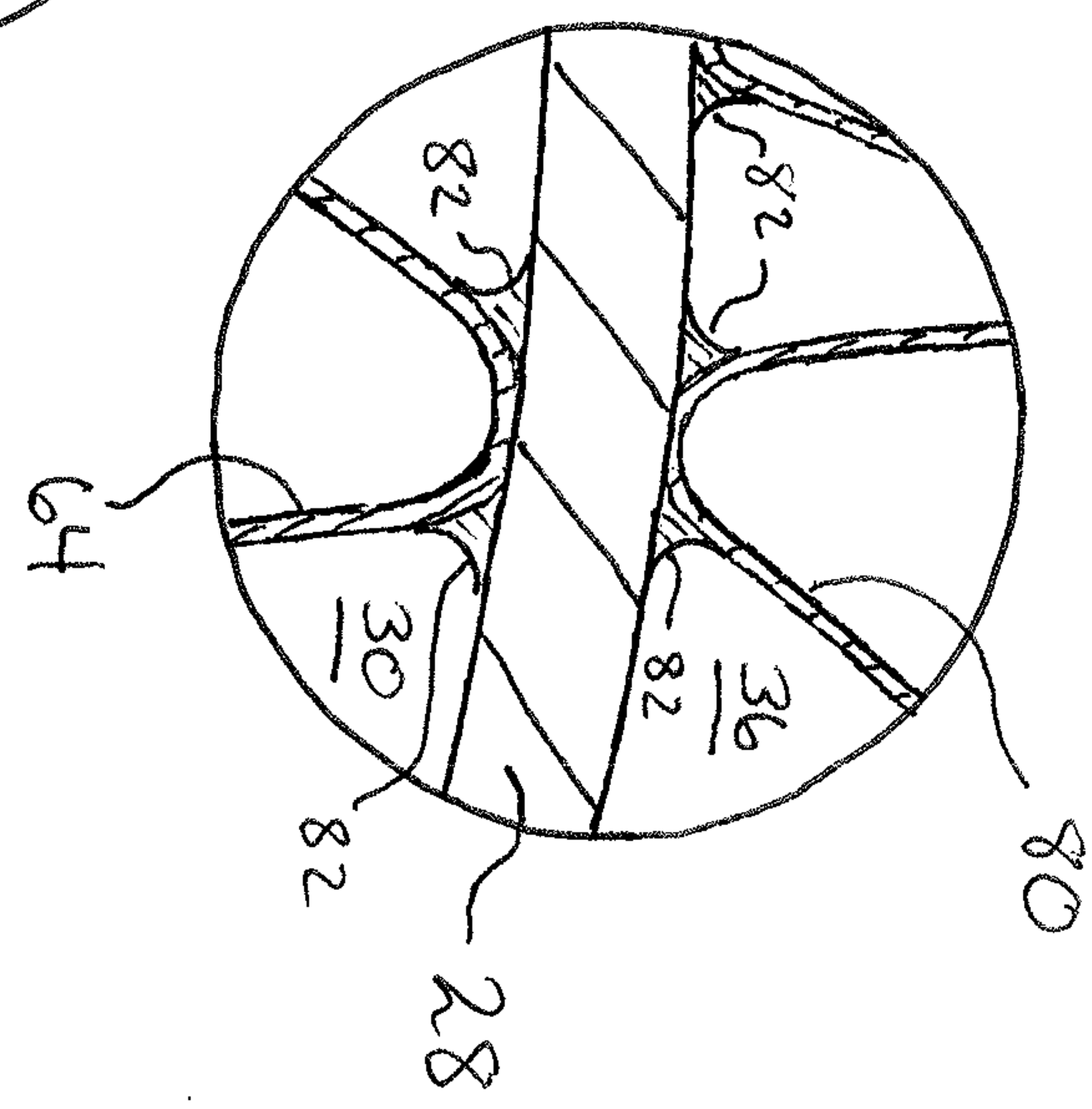


FIG. 14

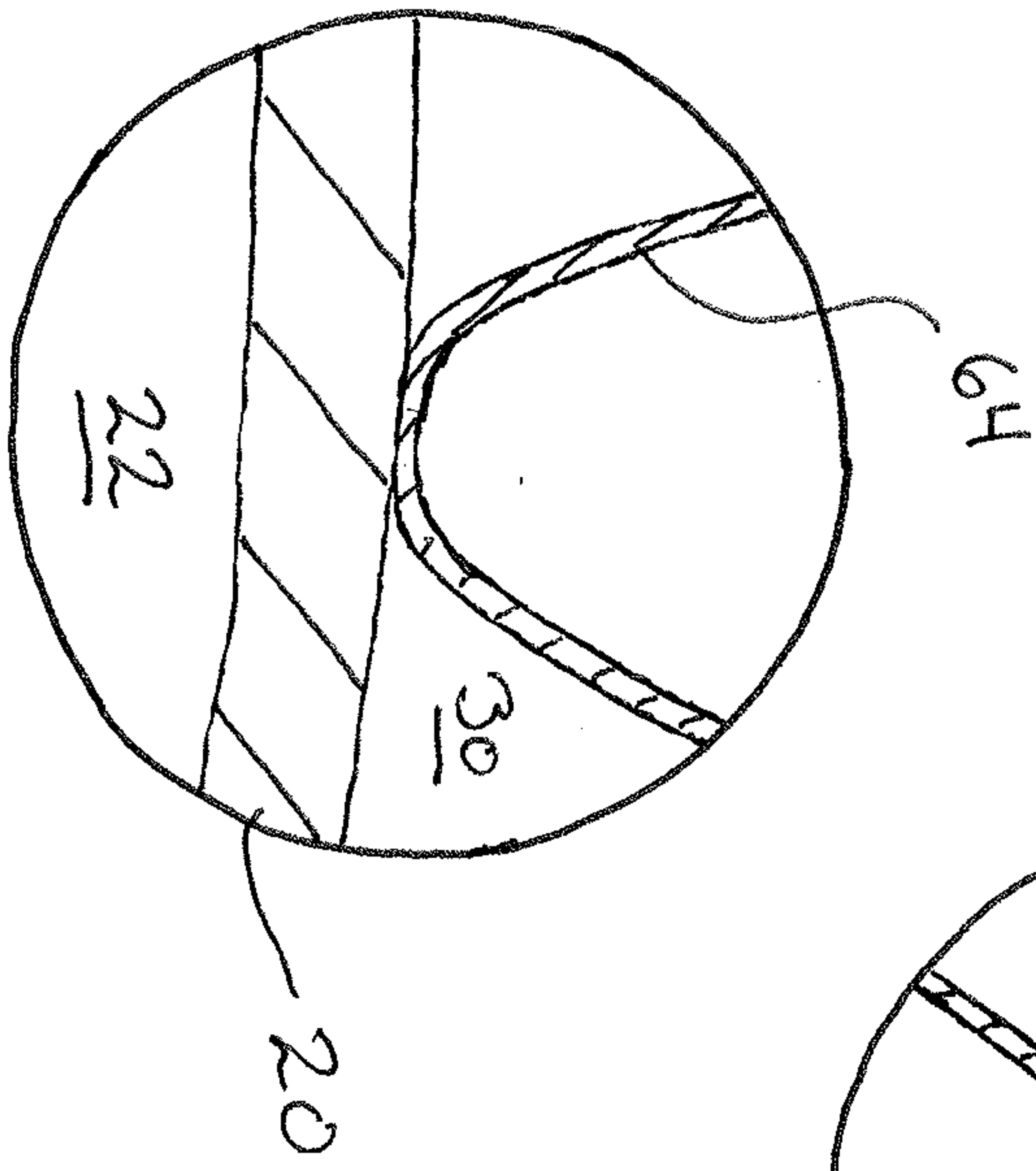
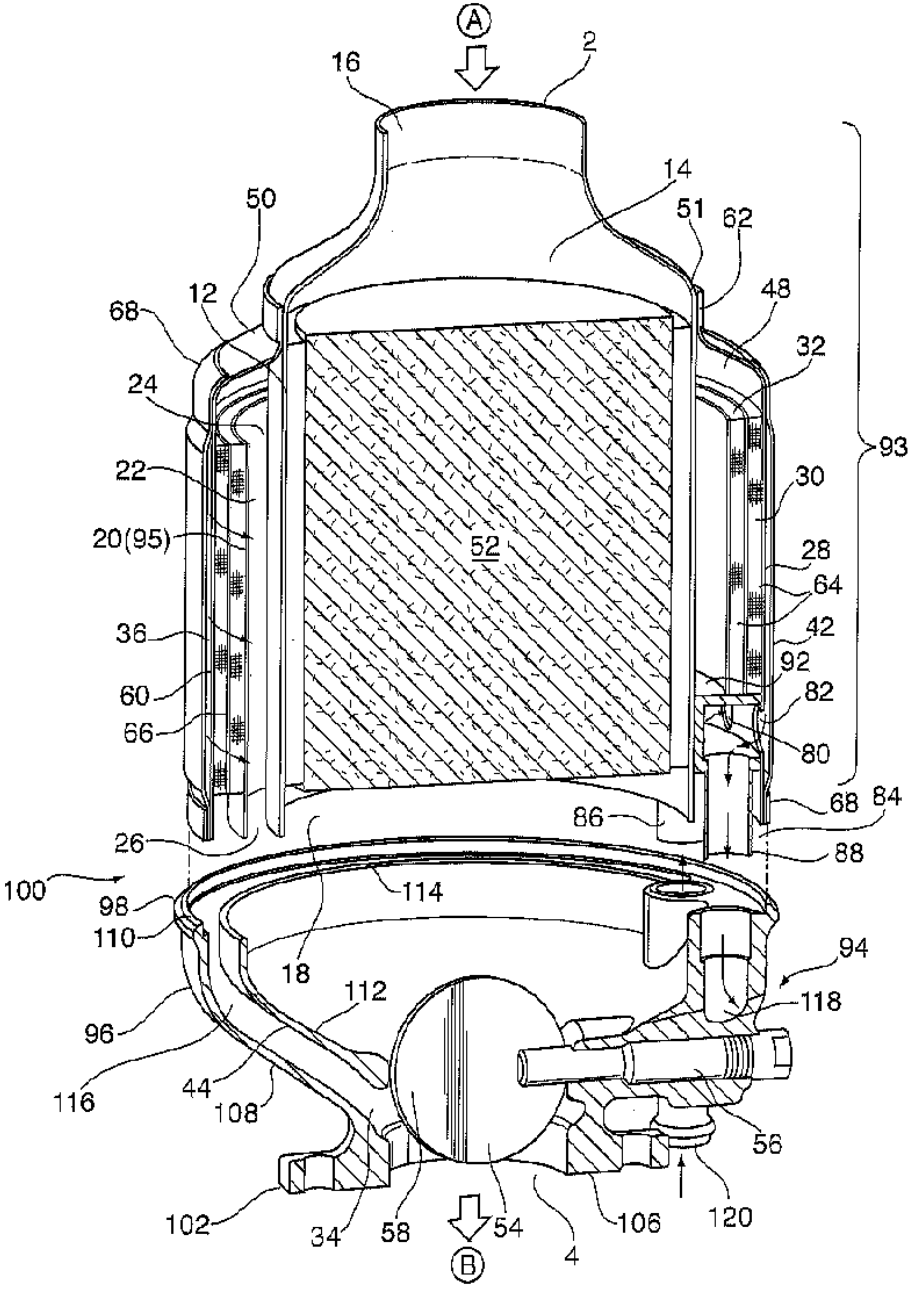


FIG. 15



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