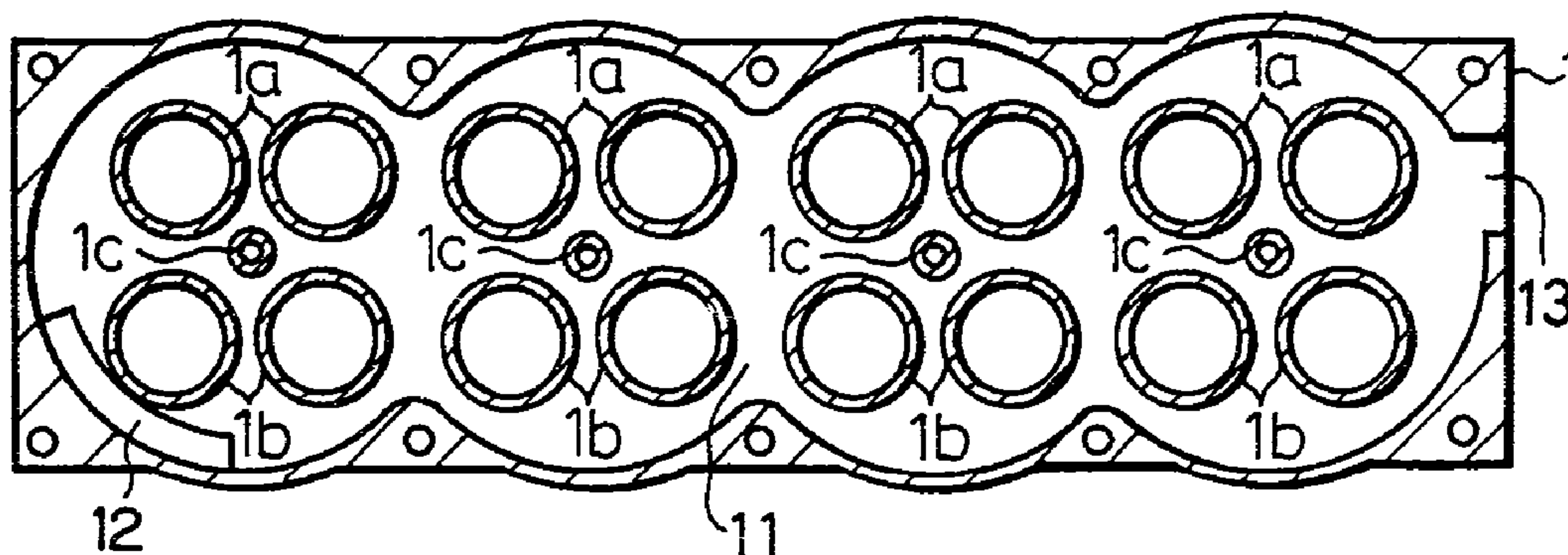


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(54) **SYSTEME DE REFROIDISSEMENT DE MOTEUR**
(54) **COOLING SYSTEM FOR AN ENGINE**



(57) A cooling system for an engine is disclosed. The engine has a plurality of cylinder bores which are arranged along a longitudinal axis thereof. First and second coolant passages continuously extend along the periphery of the bores on each side of the axis, from the bore located in one end of the engine to the bore located in the other end of the engine. The first and second passages are connected to each other by a connector at one end of the engine. A connecting passage is formed in each of a series of intermediate walls, which are formed between adjacent bores, for connecting the first and second passages. Water as a coolant flows from an inlet, which is formed at another end of the first passage, through, in turn, the first passage, the connector, and the second passage, and flows out from an outlet, which is formed at another end of the second passage. Also, water flows through the connecting passages.

A COOLING SYSTEM FOR AN ENGINEABSTRACT OF THE DISCLOSURE

A cooling system for an engine is disclosed. The engine has a plurality of cylinder bores which are arranged along a longitudinal axis thereof. First and second coolant passages continuously extend along the periphery of the bores on each side of the axis, from the bore located in one end of the engine to the bore located in the other end of the engine. The first and second passages are connected to each other by a connector at one end of the engine. A connecting passage is formed in each of a series of intermediate walls, which are formed between adjacent bores, for connecting the first and second passages. Water as a coolant flows from an inlet, which is formed at another end of the first passage, through, in turn, the first passage, the connector, and the second passage, and flows out from an outlet, which is formed at another end of the second passage. Also, water flows through the connecting passages.

A COOLING SYSTEM FOR AN ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a cooling system for an engine.

2. Description of the Related Art

Japanese unexamined patent publication No. 4-214951 discloses a cooling system for an engine having a plurality of cylinder bores which are arranged along a longitudinal axis of the engine. The system is provided with a first coolant passage continuously extending, on one side of the axis, from the bore arranged in one end of the engine to the bore arranged in another end of the engine along the periphery of the bores; a second coolant passage continuously extending, on the side of the axis, from the bore arranged in the one end of the engine to the bore arranged in the other end of the engine along the periphery of the bores; a connector for connecting the ends of the first and the second passages located at one end of the engine; a coolant inlet formed at the one end of the first coolant passage located at the other end of the engine; and a coolant outlet formed at the end of the second coolant passage located at the other end of the engine. A coolant flows from the inlet through, in turn, the first passage, the connector, and the second coolant passage, and flows out from the outlet.

An intermediate wall is provided between every two adjacent bores. However, in the system described above, the intermediate walls are not cooled sufficiently. Therefore, it is difficult to reduce undesirable deformation of the bores.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a cooling system for an engine which reduces the deformation of the cylinder bores.

According to one aspect of the present invention, there is provided a cooling system for an engine having a plurality of cylinder bores which are arranged along a longitudinal axis of the engine, an intermediate wall being provided between every two adjacent bores, the system comprising: a first coolant passage continuously extending, on one side of the axis, from the bore arranged in one end of the engine to the bore arranged in another end of the engine along the periphery of the bores; a second coolant passage continuously extending, on another side of the axis, from the bore arranged in the one end of the engine to the bore arranged in the other end of the engine along the periphery of the bores; a connector for connecting ends of the first and second coolant passages located at the one end of the engine; a coolant inlet formed at the end of the first coolant passage located at the other end of the engine; a coolant outlet formed at the end of the second coolant passage located at the other end of the engine; and a connecting passage

formed in at least one intermediate wall for connecting the first and second coolant passages to each other, wherein a coolant flows from the coolant inlet through, in turn, the first coolant passage, the connector, and the second coolant passage, and flows out from the coolant outlet, and wherein the coolant flows through the connecting passage, and wherein an amount of coolant flowing through the first and second coolant passages and the connector is substantially constant over these passages.

According to a further aspect of the present invention, there is provided a cooling system for an engine having a plurality of cylinder bores which are arranged along a longitudinal axis of the engine, an intermediate wall being provided between every two adjacent bores, the engine further having a cylinder head, the system comprising: a first coolant passage continuously extending, on one side of the axis, from the bore arranged in one end of the engine along the periphery of the bores; a second coolant passage continuously extending, on another side of the axis, from the bore arranged in the one end of the engine to the bore arranged in the other end of the engine along the periphery of the bores; a connector for connecting ends of the first and the second coolant passages located at the one end of the engine; a coolant inlet formed at the end of the first passage located at another end of the engine; a coolant outlet formed at the end of the second passage located at another end of the engine; a cylinder head coolant passage formed in the cylinder head; and a conducting passage in every intermediate wall for connecting either the first or the second coolant passage to the cylinder head coolant passage, each of the conducting passage extending from their first or the second coolant passage over a majority of the length of the intermediate wall, and to the cylinder head passage, wherein a coolant flows from the coolant inlet through, in turn, the first coolant passage, the connector, and the second coolant passage, and flows out from the coolant outlet, and wherein the coolant flows through the conducting passages. The present invention may be more fully understood from the description of preferred embodiments of the invention set forth below, together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1A is a cross sectional view of a cylinder head along the line IA-IA in Fig. 2,

Fig. 1B is a top view of a gasket,

Fig. 1C is a cross sectional view of a cylinder block along the line IC-IC in Fig. 2,

Fig. 2 is a cross sectional view of the cylinder head and the cylinder block along the line II-II in Fig. 1,

Fig. 3 is a schematic illustration showing a water flow in the system, according to a first embodiment of the present invention,

Fig. 4 is a schematic illustration showing a water flow in the system, according to a

second embodiment of the present invention,

Fig. 5 is a cross sectional view of a cylinder block, according to a third embodiment of the present invention,

Fig. 6 is a cross sectional view of the cylinder head and cylinder block along the line VI-VI in Fig. 5,

Fig. 7 is a cross sectional view of a cylinder block, according to a fourth embodiment of the present invention,

Fig. 8A is a cross sectional view of a cylinder head, according to a fifth embodiment of the present invention,

Fig. 8B is a top view of a gasket, according to the fifth embodiment of the present invention,

Fig. 8C is a cross sectional view of a cylinder block, according to the fifth embodiment of the present invention,

Fig. 9 is a cross sectional view of the cylinder head and the cylinder block along the line IX-IX in Fig. 8,

Fig. 10 is a schematic illustration showing a water flow in the system, according to the fifth embodiment of the present invention,

Fig. 11A is a cross sectional view of a cylinder head, according to a sixth embodiment of the present invention,

Fig. 11B is a top- view of a gasket, according to the sixth embodiment of the present invention,

Fig. 11C is a cross sectional view of a cylinder block, according to the sixth embodiment of the present invention,

Fig. 12 is a schematic illustration showing a water flow in the system, according to the sixth embodiment of the present invention,

Fig. 13A is a cross sectional view of a cylinder head, according to a seventh embodiment of the present invention.

Fig. 13B is a top view of a gasket, according to the seventh embodiment of the present invention,

Fig. 13C is a cross sectional view of a cylinder block, according to the seventh embodiment of the present invention,

Fig. 14 is a schematic illustration showing a water flow in the system, according to the seventh embodiment of the present invention,

Fig. 15 is a schematic illustration showing a water flow in the system, according to an eighth embodiment of the present invention,

Fig. 16 is a schematic illustration showing a water flow in the system, according to a ninth embodiment of the present invention,

Fig. 17A is a cross sectional view of a cylinder head, according to a tenth embodiment of the present invention,

Fig. 17B is a top view of a gasket, according to the tenth embodiment of the present invention,

Fig. 17C is a cross sectional view of a cylinder block, according to the tenth embodiment of the present invention, and

Fig. 18 is a schematic illustration showing a water flow in the system, according to the tenth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A cooling system for an engine according to a first embodiment of the present invention is shown in Fig. 1A through Fig. 1C. Fig. 1A illustrates a cross sectional view of a cylinder head 1 of the engine along the line IA-IA in Fig. 2, Fig. 1B illustrates a top view of a gasket 2, and Fig. 1C illustrates a cross sectional view of a cylinder block 3 of the engine along the line IC-IC in Fig. 2. The cylinder head 1 is fixed on the cylinder block 3 via the gasket 2.

Four cylinder bores 4a, 4b, 4c and 4d are arranged in the cylinder block 3 along a longitudinal axis K-K of the cylinder block 3. The first bore 4a is defined by a cylinder wall 16a, and the second, the third, and the fourth bores 4b, 4c, and 4d are defined by corresponding cylinder walls 16b, 16c, and 16d, respectively. Between the first bore 4a and the second bore 4b, a first intermediate wall 14a, common to the cylinder walls 16a and 16b, is provided. Similarly, a second intermediate wall 14b is provided extending between the second bore 4b and the third bore 4c, and a third intermediate wall 14c is provided between the third bore 4c and the fourth bore 4d. The second intermediate wall 14b is common to the cylinder walls 16b and 16c, and the third intermediate wall 14c is common to the cylinder walls 16c and 16d.

On the upper side of the axis K-K, in Fig. 1C, a first coolant passage 5 continuously extends from the first bore 4a, located on the left end in the drawings, to the fourth bore 4d, located on the right end, along the periphery of the walls 16a - 16d on the lower side of the axis K-K, in Fig. 1C, a second coolant passage 6 continuously extends from the first bore 4a to the fourth bore 4d along the periphery of the walls 16a - 16d. The first and the second passages 5 and 6 are connected in series by a connector 7. The connector 7 extends along the periphery of the wall 4d.

At an opposite end of the first passage 5 relative to the connector 7, a coolant inlet 8 is provided. At an opposite end of the second passage 6 relative to the connector 7, a coolant outlet 9 is provided.

As shown in Fig. 1A, a pair of intake ports 1a, a pair of exhaust ports 1b, and a spark

plug port 1c is provided for each cylinder in the cylinder head 1. A cylinder head coolant passage 11 formed in the cylinder head 1 is defined by a space between intake ports 1a, exhaust ports 1b, and spark plug ports 1c. A pressure drop in the cylinder head passage 11 is relatively large. The intake ports 1a are arranged substantially parallel to the axis K-K, on the upper side of the axis K-K. The exhaust ports 1b are arranged substantially parallel to the axis K-K, on the lower side of the axis K-K.

The cylinder head passage 11 is provided with a cylinder head passage inlet 12 formed at one end of the cylinder head 1, and a cylinder head passage outlet 13 formed at the other end of the cylinder head 1. The outlet 9 is connected to the cylinder head passage inlet 12, via apertures 10 formed in the gasket 2. As shown in Fig. 3, the cylinder head passage outlet 13 is connected to an inlet of a coolant pump P, via a radiator R for cooling the coolant. An outlet of the pump P is connected to the inlet 8. The pump P is driven by the engine. When the engine is driven, the coolant pumped by the pump P is forced to flow through, in turn, the first passage 5, the second passage 6, the cylinder head passage 11, and the radiator R. Accordingly, water is circulated in the system.

As shown in Figs. 1C and 2, a first connecting passage 15a is formed in the first intermediate wall 14a, for connecting the first and the second passages 5 and 6 to each other. Similarly, a second connecting passage 15b and a third connecting passage 15c are formed in the second and the third intermediate wall 14b, 14c, respectively.

Next, referring to Fig. 3, the operation of the system will be described.

When the engine is driven and thereby the pump is driven, water as a coolant is forced to flow into the first passage 5 through the inlet 8. The water flows through the first passage 5 from the first bore 4a toward the fourth bore 4d, and flows into the second passage 6 through the connector 7. Next, the water flows through the second passage 6 from the fourth bore 4d toward the first bore 4a. Finally, the water flows out through the outlet 9, and flows into the cylinder head passage 11, through the cylinder head passage inlet 12. This water cools the cylinder walls 16a - 16d, and thereby the deformation of the cylinder walls 16a - 16d is reduced.

Water also flows through each of the connecting passages 15a - 15c, from the first passage 5 to the second passage 6. The water cools the intermediate walls 14a - 14c, and thus the deformation of the cylinder walls 16a - 16d is further reduced. Accordingly, friction between the cylinder walls 16a - 16d and a corresponding piston of the engine (not shown) is reduced, whereby the output power of the engine is enhanced and the consumption of engine oil is reduced. Spaces formed between the cylinder walls 16a - 16d and the corresponding piston are reduced, whereby the amount of blow-by gas is reduced. Local temperature increases on the inner surfaces of the cylinder walls 16a - 16d are also prevented.

In a known cooling system for the engine, the first and the second passages 5, 6 are connected in parallel, so that the direction in which water flows through the first passage 5 and the direction in which water flows through the second passage 6 are substantially the same. In the known system, the ends of the first and the second passages 5 and 6 adjacent to the first bore 4a are respectively connected to the pump, and the ends of the first and the second passages adjacent to the fourth bore 4d are respectively connected to, for example, cylinder head passage 11. In this arrangement, the temperature of water flowing through the first and the second passages rises as water flows toward the fourth bore 4d, and the fourth wall 16d, which is situated downstream in the water flow, is difficult to cool sufficiently.

Further, the pressure difference between the first and the second passages 5 and 6 is substantially zero. If connecting passages connecting the first and the second passages 5 and 6 are provided in the intermediate walls, water does not flow through such connecting passages, and thus the intermediate walls 14a - 14c are not cooled sufficiently.

In the present system, the first and the second passages 5 and 6 are connected to each other in series, whereby the amount of water flowing therethrough is twice that in the known system, when the power for the pump is identical. Accordingly, the walls 16a - 16d are cooled sufficiently and uniformly. The pressure difference between the first and the second passages 5, 6 ensures that the water flows through the connecting passages 15a - 15c, whereby the intermediate walls 14a - 14c are cooled sufficiently.

In the present system, the first passage 5 is formed on the side of the intake ports 1a, and the second passage 6 is formed on the side of the exhaust ports 1b. Since water flows through the first passage 5 and then through the second passage 6, the temperature of water in the first passage 5 is lower than that in the second passage 6. Therefore, the intake ports and the intake air flowing therethrough are cooled by water flowing through the first passage 5, which is at relatively low temperature. Accordingly, the trapping efficiency of the engine is enhanced.

As shown in Fig. 2, the top portions of the first and the second passages are respectively closed by the cylinder block 3 itself. Alternatively, the top portions of the first and the second passages may be open to the top of the cylinder block 3 and closed by the gasket 2.

Fig. 4 shows a second embodiment of the present invention.

In the first embodiment described above, the outlet 9 is connected to the cylinder head passage inlet 12 so that water flows through, in turn, the first passage 5, the second passage 6, and the cylinder head passage 11. In the second embodiment shown in Fig. 4, the cylinder head passage outlet 13 is connected to the inlet 8 so that water flows through, in turn, the cylinder head passage 11, the first passage 5, and the second passage 6.

The cylinder head shown in Fig. 1A and the cylinder block shown in Fig. 1c can be

applied to this second embodiment. With this arrangement, the first and the second passages in Fig. 1C form the second and the first passages, respectively. The inlet and the outlet in Fig. 1C form the outlet and the inlet, respectively. Further, the cylinder head passage inlet and the cylinder head passage outlet in Fig. 1A form the cylinder head passage outlet and the cylinder head passage inlet, respectively. Furthermore, the intake and the exhaust ports in Fig. 1A form the exhaust and the intake ports, respectively. As shown in Fig. 4, water flowing out of the outlet 9 is introduced to the radiator R, and then to the pump P. The other constructions and operations of the system in this embodiment are the same as those in the first embodiment, and thus the descriptions thereof are omitted.

Figs. 5 and 6 show a third embodiment of the present invention.

Referring to Figs. 5 and 6, a resisting member 17a, for increasing the flow resistance of the first passage 5, is arranged in the first passage 5 between the opening of the first connecting passage 15a and the opening of the second connecting passage 15b. Similarly, a resisting member 17b is arranged in the first passage 5, between the opening of the second connecting passage 15b and the opening of the third connecting passage 15c, and a resisting member 17c is arranged in the first passage 5 between the openings of the third connecting passage 15c. Preferably, the resisting members 17a - 17c are arranged just downstream of the openings of the corresponding connecting passages 15a - 15c. The resisting members 17a - 17c are fixed to the inner surface of the first passage 5.

A resisting member 18a, for increasing the flow resistance of the second passage 6, is arranged in the second passage 6, between the opening of the first connecting passage 15a and the opening of the second connecting passage 15b. Similarly, a resisting member 18b is arranged in the second passage 6 between the opening of the second connecting passage 15b and the opening of the third connecting passage 15c, and a resisting member 18c is arranged in the second passage 6 between the openings of the third connecting passage 15c. Preferably, the resisting members 18a - 18c are arranged just downstream of the openings of the corresponding connecting passages 15a - 15c. The resisting members 18a - 18c are fixed to the inner surface of the second passage 6.

The resisting members 17a - 17c reduce a flow area of the first passage 5 at their respective positions. The resisting members 18a - 18c reduce a flow area of the second passage 6 at their respective positions. As a result, the resisting members 17a - 17c and 18a - 18c act as throttles. In this condition, when water is forced to flow through the first and second passages 5 and 6, the water pressure in the first passage 5 at the inlet of the first connecting passage 15a rises. The water pressure in the second passage 6 at the outlet of the first connecting passages 15a decreases. Therefore, the pressure difference between the inlet and the outlet of the first connecting passage 15a rises. As a result, the amount of water flowing through the first connecting

passage 15a is increased, and thus, the intermediate wall 14a is cooled more effectively. Similarly, the pressure differences between the inlet and the outlet of the second connecting passage 15b and between the inlet and the outlet of the third connecting passage 15c increase and the intermediate walls 14b and 14c are also cooled more effectively.

As described above, the resisting members 17a and 18a are fixed to the cylinder walls 16b. These members 17a and 18a reinforce the wall 16b, whereby the deformation of the bore 4b is reduced. Similarly, the resisting members 17b and 18b, which are attached to the wall 16c, and resisting members 17c and 18c, which are attached to the wall 16d reinforce the corresponding walls and deformation of the bores 4c and 4d is reduced. The other constructions and operations of the system in this embodiment are the same as those in the first embodiment, and thus the descriptions thereof are omitted.

Fig. 7 shows a fourth embodiment of the present invention.

In the embodiments described above, the widths of the connecting passages 15a - 15c are substantially the same. In this embodiment, the width of the second connecting passage hb is larger than that of the first connecting passage ha, and the width of the third connecting passage hc is larger than that of the second connecting passage hb. The depths of the connecting passages 15a - 15c are substantially the same. Therefore, the flow resistance of the connecting passages 15a - 15c decreases as the distance between the inlet 8 and the connecting passage increases. In other words, the flow area of the connecting passages 15a - 15c increases, as the distance between the inlet 8 and the connecting passage increases.

The water pressure in the first passage 5 drops as the distance from the inlet 8 increases, and the water pressure in the second passage 6 drops as the distance from the outlet decreases. As a result, the pressure difference between the inlet and the outlet of the connecting passage decreases, as the distance between the inlet 8 and the connecting passage increases. Therefore, if the flow areas of the connecting passages are substantially the same, the amount of water flowing therethrough decreases as the distance between the inlet 8 and the connecting passage increases. That is, the intermediate wall is less cooled as the distance between the inlet 8 and the intermediate wall increases.

In this embodiment, however, the flow area of the connecting passage increases as the distance between the inlet and the connecting passage increases. Therefore, the cooling effect upon the intermediate wall is not reduced as the distance between the inlet 8 and the intermediate wall increases. Further, the amount of water flowing through the connecting passages can be made substantially the same and the intermediate walls 14a - 14c are cooled substantially uniformly. The other constructions and operations of the system in this embodiment are the same as those in the first embodiment, and thus the descriptions thereof are omitted.

Figs. 8A, 8B, 8C, and 9 show a fifth embodiment of the present invention.

Referring to Figs. 8A, 8B, 8C, and 9, the connecting passages 15a and 15b, as in the first embodiment, are provided in the corresponding intermediate walls 14a and 14b, adjacent the inlet 8. However, in the intermediate wall 14c, which is furthest from the inlet 8, a conducting passage 19 for conducting coolant from the first passage 5 to the cylinder head passage 11 is formed. The conducting passage 19 extends from the first passage 5 toward the second passage 6 over substantially the entire length of the intermediate wall 14c, and is connected to the cylinder head passage 11 via an aperture 20 formed in the gasket 2 and via an opening 21 formed in the cylinder head 1.

When water is forced to flow through, in turn, the first passage 5, the second passage 6, and the cylinder head passage 11, the pressure in the second passage 6 is lower than that in the first passage 5, and the pressure in the cylinder head passage 11 is lower than that in the second passage 6. As a result, the large pressure difference is obtained between the first passage 5 and the cylinder head passage 11. In the first embodiment, the intermediate wall 14c, which is furthest from the inlet 8, is not cooled sufficiently, since the amount of water flowing through the connecting passage 15c is relatively small.

In this embodiment, in order to cool the intermediate wall 14c sufficiently, the conducting passage 19 extending between the first passage 5 and the cylinder head passage 11 is formed. The pressure difference between the first passage 5 and the cylinder head passage 11 is relatively large, ensuring that a large amount of water flows through the conducting passage 19. With this arrangement, sufficient cooling of the intermediate wall 14c is ensured.

The opening 21 is located directly above the conducting passage 19, as shown in Fig. 9 so that the length of the conducting passage 19 need not be greater than that of the connecting passage 15c in the first embodiment. The conducting passage 19 is able to cool the intermediate wall 14c sufficiently, without increasing the flow resistance of the conducting passage 19. In this connection, Fig. 9 illustrates the water flow in the system of this embodiment.

In the fifth embodiment described above, the conducting passage 19 extends in the intermediate wall 14c between the first passage 5 and the cylinder head passage 11. Alternatively, the conducting passage 19 may extend in the intermediate wall 14c from the second passage 6 toward the first passage 5 over substantially the entire length of the intermediate wall 14c, and may be connected to the cylinder head passage 11. The pressure difference between the inlet and the outlet of the conducting passage is relatively large, and thus, sufficient cooling of the intermediate wall 14c is also obtained. The other constructions and operations of the system in this embodiment are the same as those in the first embodiment, and thus the descriptions thereof are omitted.

Figs. 11A, 11B, 11C and 12 show a sixth embodiment of the present invention. In this embodiment, the conducting passage 19, as in the fifth embodiment, is provided in the intermediate wall 14c.

Referring to the figures, the cylinder head passage inlet 12 is arranged at the end of the cylinder head 1, and is connected to the pump outlet, and the inlet 8 is also connected to the pump outlet. Therefore, water pumped by the pump P flows into both the inlet 8 and the cylinder head passage inlet 12. The outlet 9 is connected to the radiator, and the cylinder head passage outlet 13 is also connected to the radiator. As a result, the first and the second passages 5 and 6, and the cylinder head passage 11 are connected in parallel.

The pressure drop in the cylinder head passage 11 is relatively large. Therefore, the pressure in the cylinder head passage 11 is low enough to allow water to flow through the conducting passage 19 from the first passage 5 to the cylinder head passage 11, even when the first and the second passages 5 and 6 and the cylinder head passage 11 are connected in parallel. Accordingly, the intermediate wall 14c is sufficiently cooled. The other constructions and operations of the system in this embodiment are the same as those in the fifth embodiment, and thus descriptions thereof are omitted.

Figs. 13A, 13B, 13C and 14 show a seventh embodiment of the present invention.

Referring to the figures, conducting passages 22a, 22b, and 22c, which are similar to the conducting passage 19 in the fifth embodiment, are provided in the corresponding intermediate walls 14a, 14b, and 14c. The conducting passages 22a, 22b, and 22c extend in the corresponding intermediate walls 14a, 14b, and 14c from the first passage 5 toward the second passage 6. They are connected to the cylinder head passage 11 via corresponding apertures 23a, 23b, and 23c formed in the gasket 2 and corresponding openings 24a, 24b, 24c formed in the cylinder head 1.

Also, in this embodiment, the outlet 9 is connected to the cylinder head passage inlet 12 so that water flowing through the first passage 5 next flows through the second passage 6 and then flows through the cylinder head passage 11, ensuring the relatively large pressure difference between the first passage 5 and the cylinder head passage 11. As a result, the amount of water flowing through the respective conducting passages 22a - 22c is enough to cool the corresponding intermediate walls 14a - 14c.

In the seventh embodiment described above, each of the conducting passages 22a - 22c extend in the corresponding intermediate wall 14a - 14c between the first passage 5 and the cylinder head passage 11. Alternatively, each of the conducting passages 22a - 22c may extend in the corresponding intermediate wall 14a - 14c from the second passage 6 toward the first passage 5 over substantially the entire length of the intermediate wall. With this construction, the pressure difference between the inlet and the outlet of the conducting passage is also relatively large, and

thus, sufficient cooling of the intermediate wall 14c is obtained. The other constructions and operations of the system in this embodiment are the same as those in the first embodiment, and thus the descriptions thereof are omitted.

Fig.15 shows an eighth embodiment of the present invention.

In the seventh embodiment described above, the outlet 9 is connected to the cylinder head passage inlet 12 so that water flows through, in turn, the first passage 5, the second passage 6, and the cylinder head passage 11. In this embodiment, as shown in Fig. 15, the cylinder head passage outlet 13 is connected to the inlet 8 so that water flows through, in turn, the cylinder head passage 11, the first passage 5, and the second passage 6.

The cylinder head shown in Fig. 13A and the cylinder block shown in Fig. 13C can be applied to this embodiment. In this case, the first and the second passages in Fig. 13C form the second and the first passages, respectively. The inlet and the outlet in Fig. 13C form the outlet and the inlet, respectively. Further, the cylinder head passage inlet and the cylinder head passage outlet in Fig. 13A form the cylinder head passage outlet and the cylinder head passage inlet, respectively. Furthermore, the intake and the exhaust ports in Fig. 13A form the exhaust and the intake ports, respectively. In this embodiment, water flows through each of the conducting passages 22a - 22c from the cylinder head passage 11 to the second passage 6, ensuring a large pressure difference is ensured between the cylinder head passage 11 and the second passage 6, and thus sufficient cooling of the intermediate walls 14a - 14c. The other constructions and operations of the system in this embodiment are the same as those in the seventh embodiment and thus descriptions thereof are omitted.

Fig. 16 shows a ninth embodiment of the present invention.

Referring to Fig. 16, the cylinder head passage inlet 12 is connected to the pump outlet, and the inlet 8 also is connected to the pump outlet. Water pumped by the pump P flows into both the inlet 8 and the cylinder head passage inlet 12. Both the outlet 9 and the cylinder head passage outlet 13 are connected to the radiator. As a result, the first and second passages 5 and 6, and the cylinder head passage 11 are connected in parallel, as in the sixth embodiment.

The pressure in the cylinder head passage 11 is low enough to allow water to flow through the conducting passage 19 from the first passage 5 to the cylinder head passage 11, even when the first and the second passage 5 and 6 and the cylinder head passage 11 are connected in parallel. Accordingly, the intermediate walls 14a - 14c are sufficiently cooled. The other constructions and operations of the system in this embodiment are the same as those in the seventh embodiment, and thus the descriptions thereof are omitted.

Figs. 17A, 17B, 17C and 18 show a tenth embodiment of the present invention.

Referring to the figures, a bypass passage 25 is provided for connecting the inlet 8 to

the cylinder head passage 11. An inlet 26 of the bypass passage 25 is formed in the cylinder block 3, and an outlet 27 of the bypass passage 25 is formed in the cylinder head 1. The bypass passage 25 passes through an aperture 28 formed in the gasket 2.

As shown in the figures, the outlet 27 of the bypass passage 25 is adjacent to the cylinder head passage inlet 12. If the water pressures at the cylinder head passage inlet 12 and that at the outlet 27 of the bypass passage 25 are substantially the same, and the water pressure at the outlet 27 of the bypass passage 25 and at the inlet 26 of the bypass passage 25 are also substantially the same, water will not flow in the first and the second passages 5 and 6. However, the aperture 28 acts as a throttle for reducing the water pressure at the outlet 27 of the bypass passage 25 so that the flow in the first and the second passages 5 and 6 is not prevented.

In this embodiment, the quantity of heat which is to be removed from the cylinder block 3 by water is about 30 - 40% of the total quantity of heat which is to be removed from both the cylinder head 1 and the cylinder block 3. When about 40% in volume of the total water pumped by the pump operates for cooling the cylinder block 3, sufficient cooling of the cylinder block 3 can be obtained.

The aperture 28 is dimensioned so that about 40% in volume of the total water pumped by the pump flows through the first and the second passages 5 and 6, and that the remainder flows through the cylinder head passage 11 via the bypass passage 25. The pressure drop between the inlet 8 and the outlet 9 through the first and the second passage 5 and 6 is reduced in comparison with the first embodiment and the pressure drop between the inlet 8 and the cylinder head passage outlet 13 through the first and the second passages 5 and 6 and the cylinder head passage 11 is reduced. As a result, the amount of water flowing therethrough can be increased without having to improve the performance of the pump. Further, in this embodiment, the cooling ability in the cylinder block 3 is not reduced, while the cooling ability in the cylinder head 1 is enhanced.

In the tenth embodiment, the aperture 28 serves as a throttle. Alternatively, the opening 27 may serve as a throttle. Further, the opening 27 may be dimensioned so that the ratio between the amount of water flowing through the first and the second passages 5 and 6, and that flowing through the opening 27 is predetermined.

According to the present invention, it is possible to cool the intermediate walls, as well as the cylinder wall sufficiently, thereby reducing deformation of the cylinder bores.

While the invention has been described by reference to specific embodiments chosen for purposes of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

CLAIMS

1. A cooling system for an engine having a plurality of cylinder bores which are arranged along a longitudinal axis of the engine, an intermediate wall being provided between every two adjacent bores, the system comprising:

a first coolant passage continuously extending, on one side of the axis, from a bore arranged on one end of the engine to a bore arranged in another end of the engine along the periphery of the bores;

a second coolant passage continuously extending, on another side of the axis, from the bore arranged in said one end of the engine to the bore arranged in said another end of the engine along the periphery of the bores;

a connector for connecting ends of the first and second coolant passages located at said one end of the engine;

a coolant inlet formed at the end of the first coolant passage located at said another end of the engine;

a coolant outlet formed at the end of the second coolant passage located at said another end of the engine; and

a connecting passage formed in at least one intermediate wall for connecting the first and the second coolant passages to each other, wherein a coolant flows from the coolant inlet through, in turn, the first coolant passage, the connector, and the second coolant passage, and flows out from the coolant outlet, wherein the coolant flows through the connecting passage, and wherein an amount of coolant flowing through the first coolant passage, the connector, and the second coolant passage is substantially constant over these passages.

2. The system according to claim 1, wherein a connecting passage is provided in every intermediate wall.

3. The system according to claim 2, further comprising a resisting member arranged at at least one position in either the first or the second coolant passage, the position being located between two adjacent openings, of the connecting passages, for increasing the flow resistance in either the first or the second coolant passage, respectively.

4. The system according to claim 3, wherein the resisting member is a rib fixed to a wall defining either the first or the second coolant passage, the rib decreasing an area of either the first or the second coolant passage.

5. The system according to claim 3, wherein the resisting member is arranged substantially just downstream of an opening of the connecting passage in the first coolant passage.

6. The system according to claim 3, wherein the resisting member is arranged substantially just upstream of an opening of the connecting passage in the second coolant passage.

7. The system according to claim 1, the engine having at least three bores so that at least two intermediate walls are provided, wherein the connecting passages are provided in at least two intermediate walls.

8. The system according to claim 7, wherein the connecting passages are structured such that a flow resistance of the connecting passage becomes smaller as a distance between the inlet and the connecting passage becomes larger.

9. The system according to claim 8, wherein the connecting passages are structured such that an area of the connecting passage becomes larger as a distance between the inlet and the connecting passage becomes larger.

10. The system according to claim 7, the engine further having a cylinder head, the system further comprising a cylinder head coolant passage formed in the cylinder head, and a conducting passage formed in one of the at least two intermediate walls, which is furthest from the coolant inlet, for connecting either the first or the second coolant passage and the cylinder head coolant passage, the conducting passage extending from either the first or the second coolant passage over a majority of the length of the intermediate wall, and to the cylinder head coolant passage.

11. The system according to claim 1, the engine further having a cylinder head, the system further comprising a cylinder head coolant passage formed in the cylinder head, wherein the coolant outlet is connected to a cylinder head passage inlet formed in the cylinder head coolant passage so that the coolant flowing out from the coolant outlet flows through the cylinder head passage.

12. The system according to claim 11, further comprising a bypass passage for connecting the inlet to the cylinder head coolant passage.

13. The system according to claim 12, wherein an area of the bypass passage is structured to provide a predetermined ratio between an amount of the coolant flowing into the coolant inlet and an amount of coolant flowing into the cylinder head coolant passage.

14. The system according to claim 1, the engine further having a cylinder head, the system further comprising a cylinder head coolant passage formed in the cylinder head, wherein a cylinder head passage outlet formed in the cylinder head is connected to the coolant inlet so that the coolant flowing out from the cylinder head passage outlet flows through the first and the second coolant passages.

15. The system according to claim 1, the engine further having a cylinder head, the system further comprising a cylinder head coolant passage formed in the cylinder head, and a pump for pumping the coolant, wherein an outlet of the pump is connected to both the coolant inlet and a cylinder head passage inlet formed in the cylinder head coolant passage.

16. The system according to claim 1, the engine further having a cylinder head, the system further comprising a cylinder head coolant passage formed in the cylinder head, wherein the coolant outlet and the coolant inlet are connected to each other via the cylinder head coolant passage, a radiator, and a pump so that the coolant is circulated in the system.

17. The system according to claim 1, the engine further having a cylinder head with intake ports formed therein, the intake ports being arranged on one side of the axis, wherein the first passage is formed on the side of the axis in which the intake ports are arranged.

18. The system according to claim 1, wherein the coolant is water.

19. A cooling system for an engine having a plurality of cylinder bores which are arranged along a longitudinal axis of the engine, an intermediate wall being provided between every two adjacent bores the engine further having a cylinder head, the system comprising:

a first coolant passage continuously extending, on one side of the axis, from a bore arranged in one end of the engine to a bore arranged in another end of the engine along the periphery of the bores;

a second coolant passage continuously extending, on another side of the axis, from the bore arranged in one said end of the engine to the bore arranged in said another end of the engine along the periphery of the bores;

a connector for connecting ends of the first and the second coolant passages located at the one end of the engine;

a coolant inlet formed at the end of the first coolant passage located at said another end of the engine;

a coolant outlet formed at the end of the second coolant passage located at said another end of the engine;

a cylinder head coolant passage formed in the cylinder head; and

a conducting passage formed in every intermediate wall for connecting the first or the second coolant passage to the cylinder head coolant passage, each of the conducting passages extending from either the first or the second coolant passage over a majority of the length of the intermediate wall, and to the cylinder head coolant passage, wherein a coolant flows from the coolant inlet through, in turn, the first coolant passage, the connector, and the second coolant passage, and flows out from the outlet, and wherein the coolant flows through the conducting

passages.

20. The system according to claim 19, wherein the coolant outlet is connected to a cylinder head passage inlet formed in the cylinder head coolant passage so that the coolant flowing out from the coolant outlet flows through the cylinder head coolant passage.

21. The system according to claim 20, wherein each conducting passage extends between the first coolant passage and the cylinder head coolant passage.

22. The system according to claim 19, wherein a cylinder head passage outlet formed in the cylinder head is connected to the coolant inlet so that the coolant flowing out from the cylinder head passage outlet flows through the first and the second coolant passages.

23. The system according to claim 22, wherein each conducting passage extends between the second coolant passage and the cylinder head coolant passage.

24. The system according to claim 19, further comprising a pump for pumping the coolant, wherein an outlet of the pump is connected to both the coolant inlet and a cylinder head passage inlet formed in the cylinder head coolant passage.

25. The system according to claim 19, wherein the coolant outlet and the coolant inlet are connected to each other via the cylinder head coolant passage, a radiator, and a pump so that the coolant is circulated in the system.

26. The system according to claim 19, the engine further having a cylinder head and intake ports formed therein, the intake ports being arranged on one side of the axis, wherein the first coolant passage is formed in the side of the axis in which the intake ports are arranged.

27. The system according to claim 19, wherein the coolant is water.

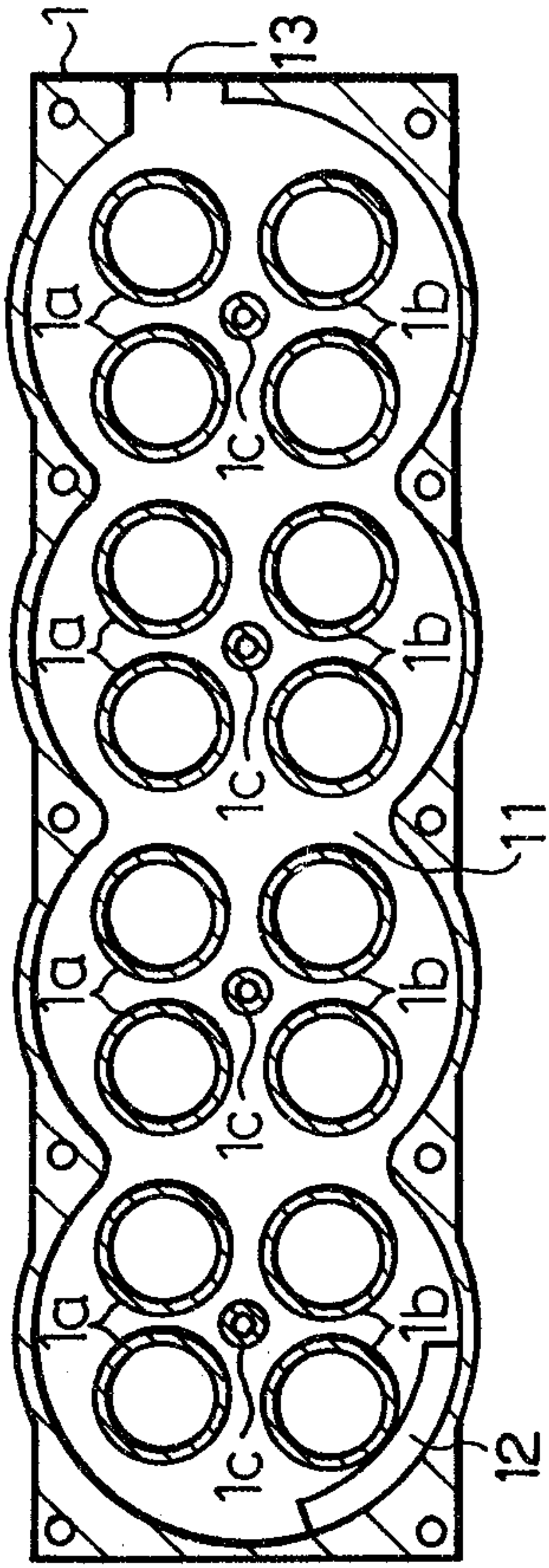


Fig. 1A

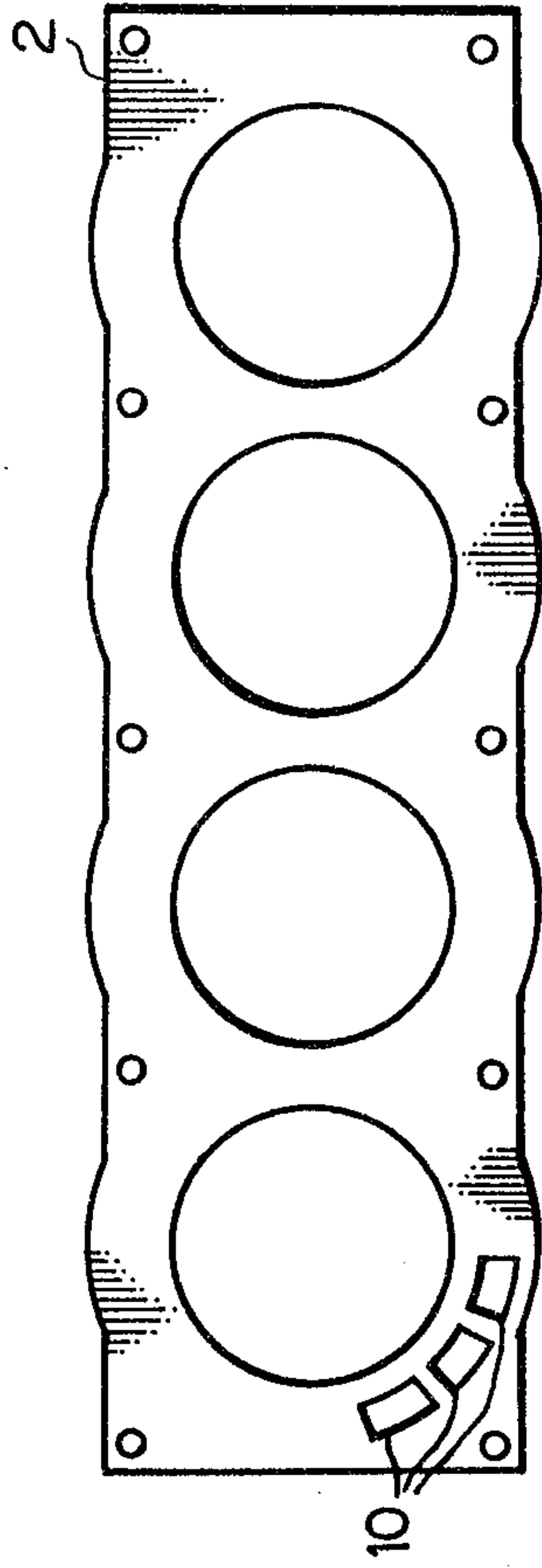


Fig. 1B

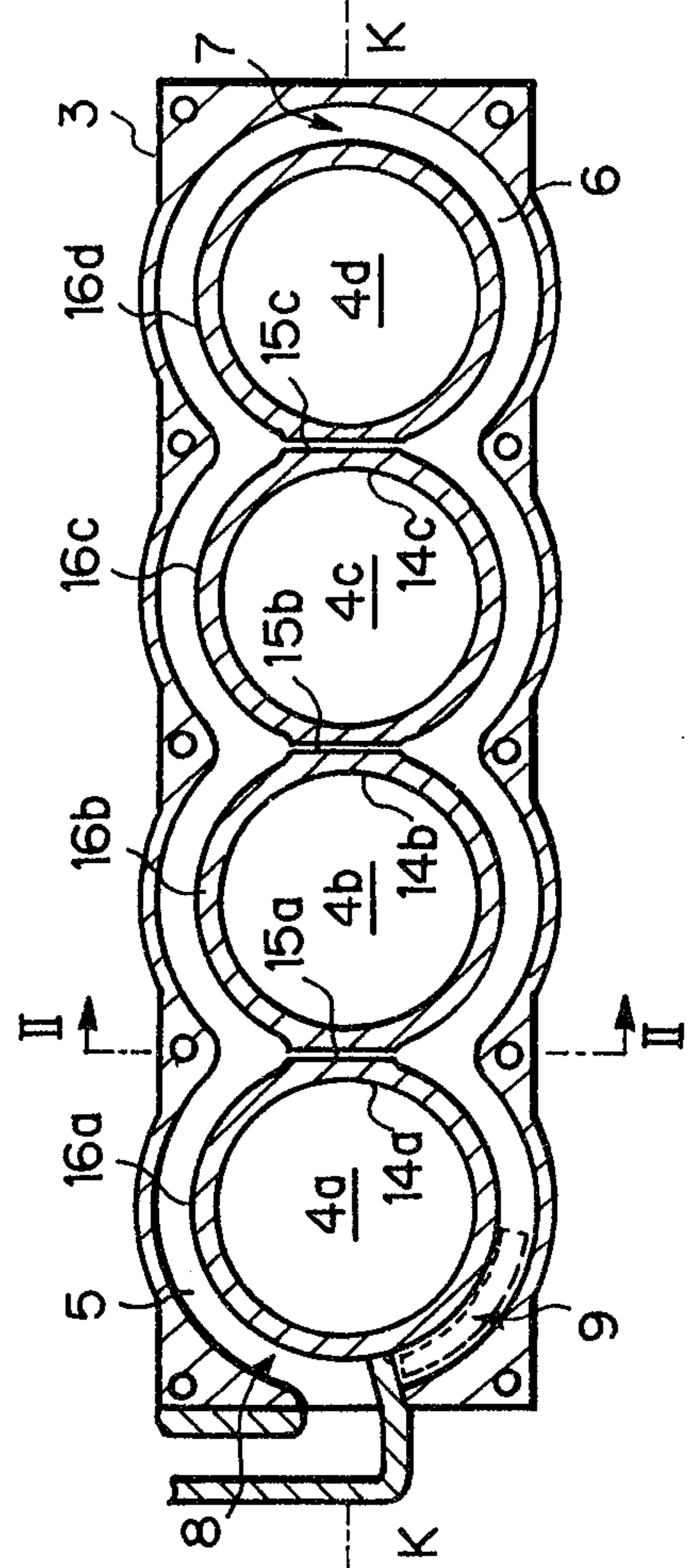
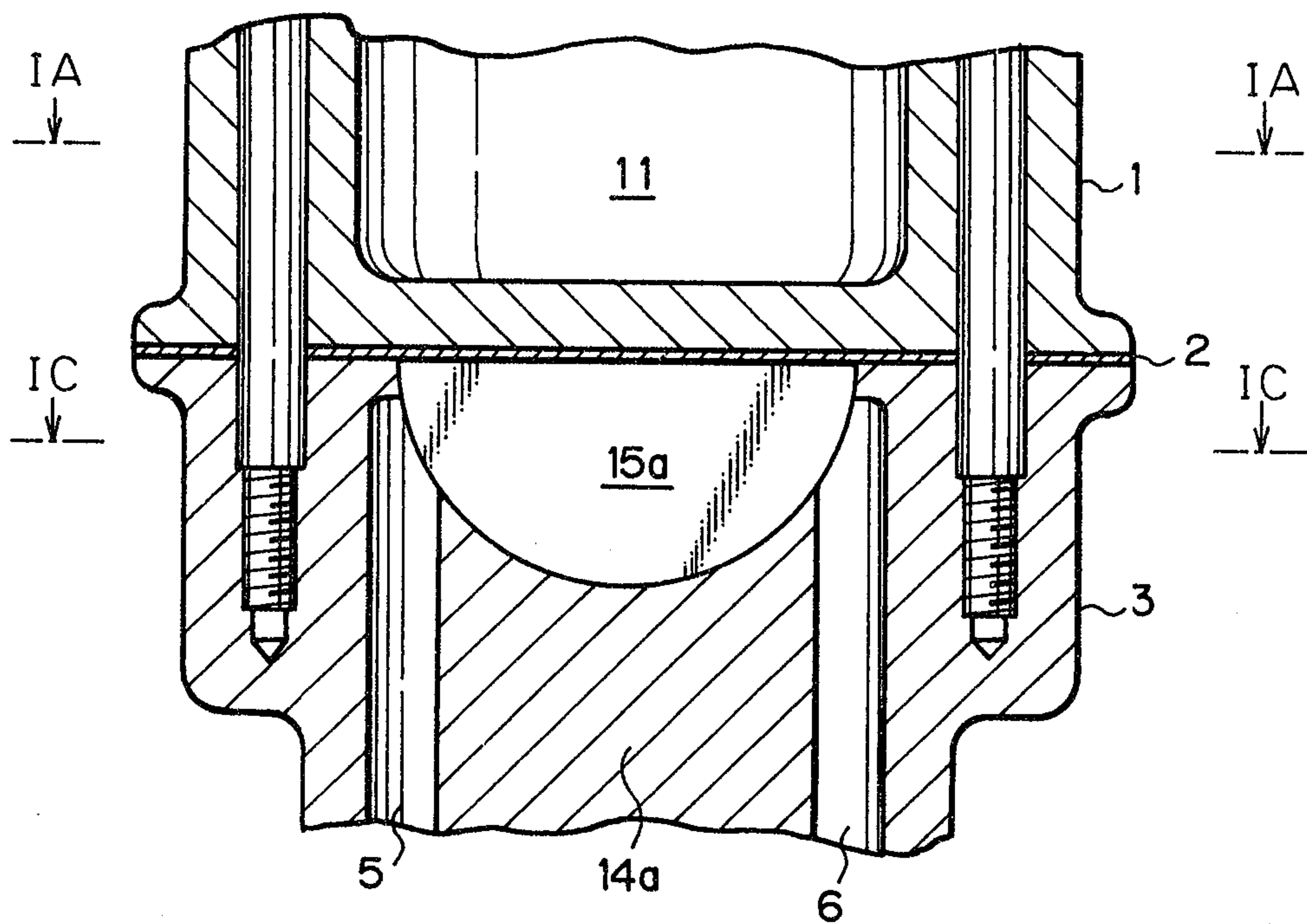


Fig. 1C

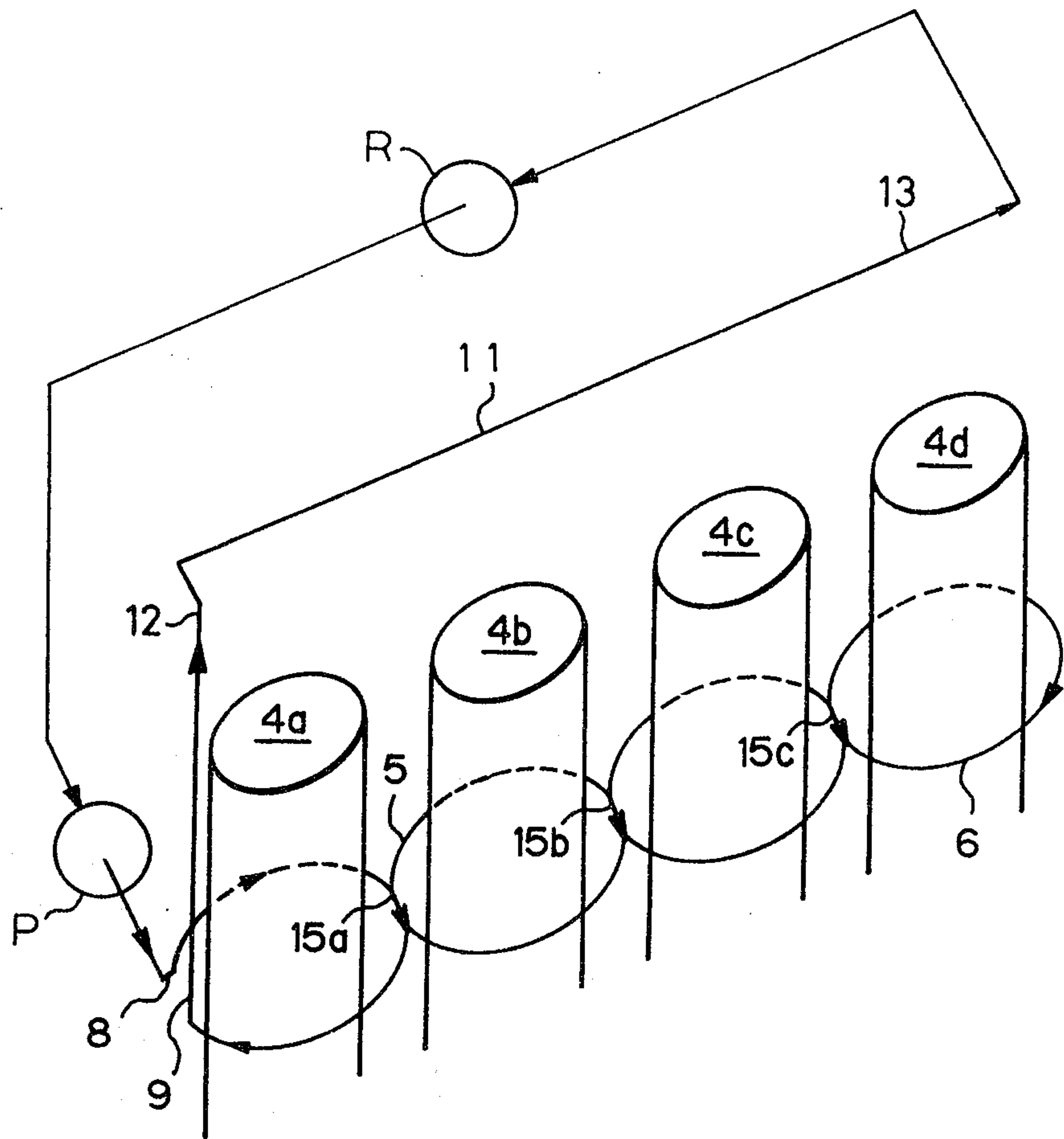
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Fig.2



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Fig. 3



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Fig. 4

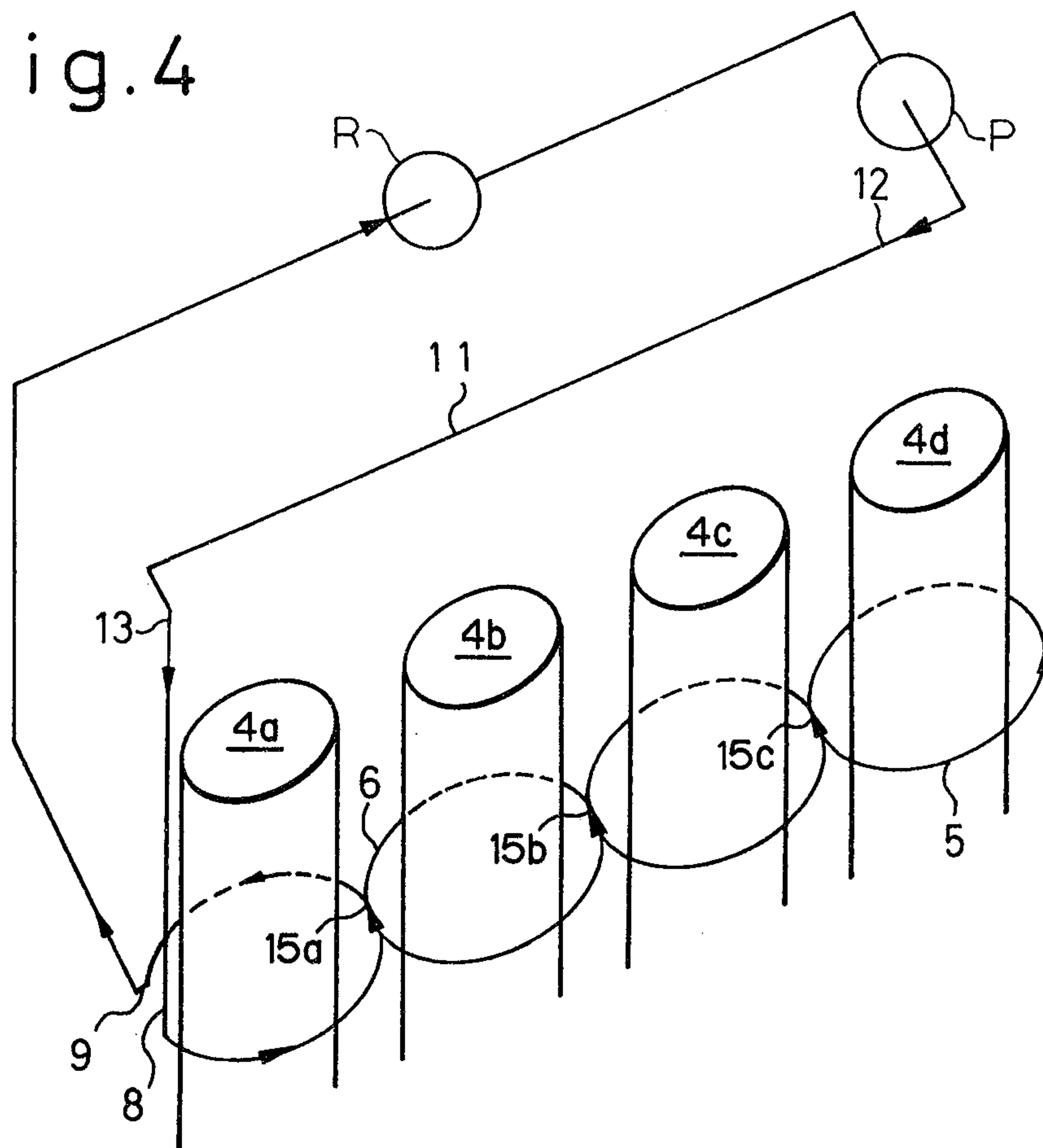
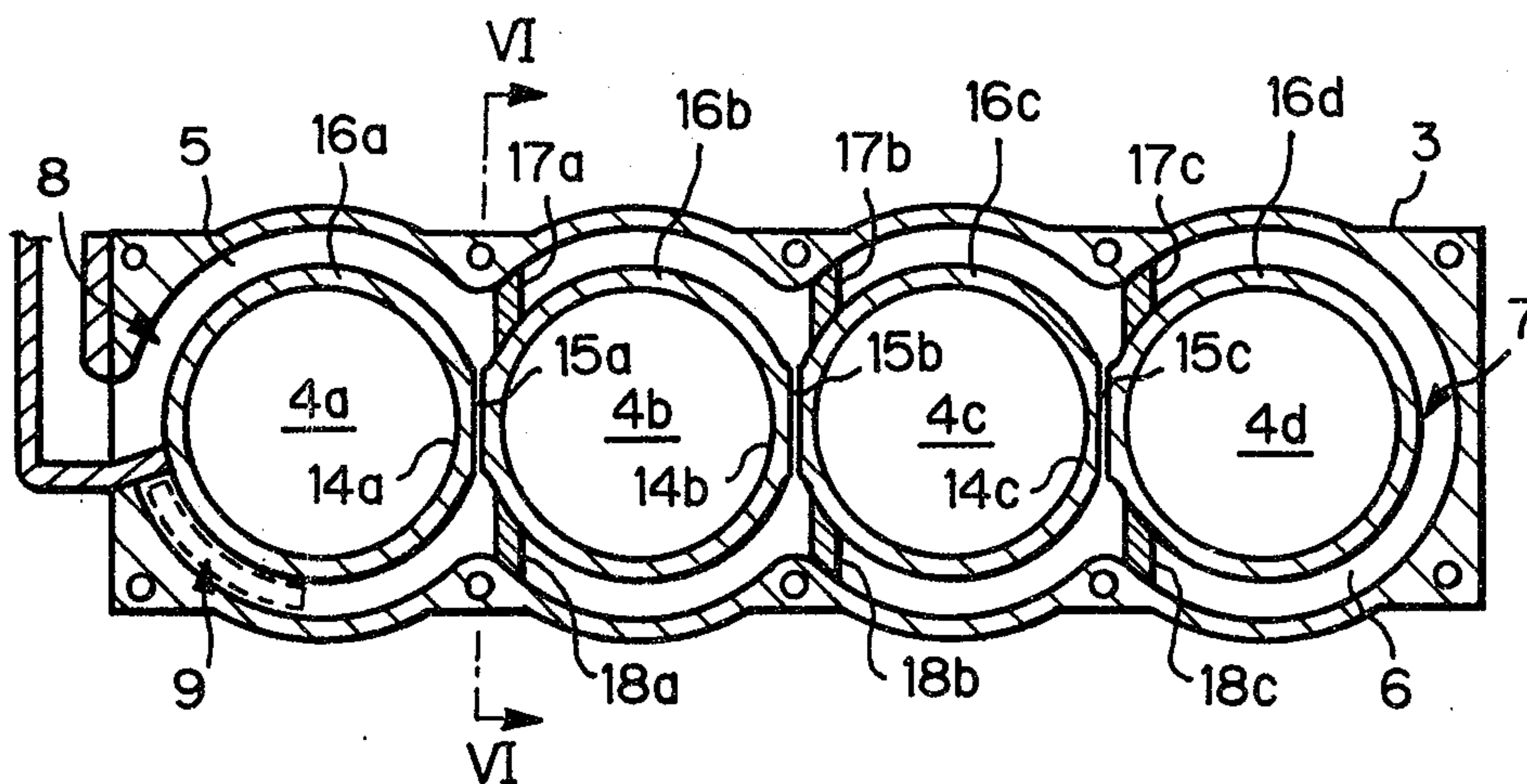


Fig. 5



Scott & Aylson

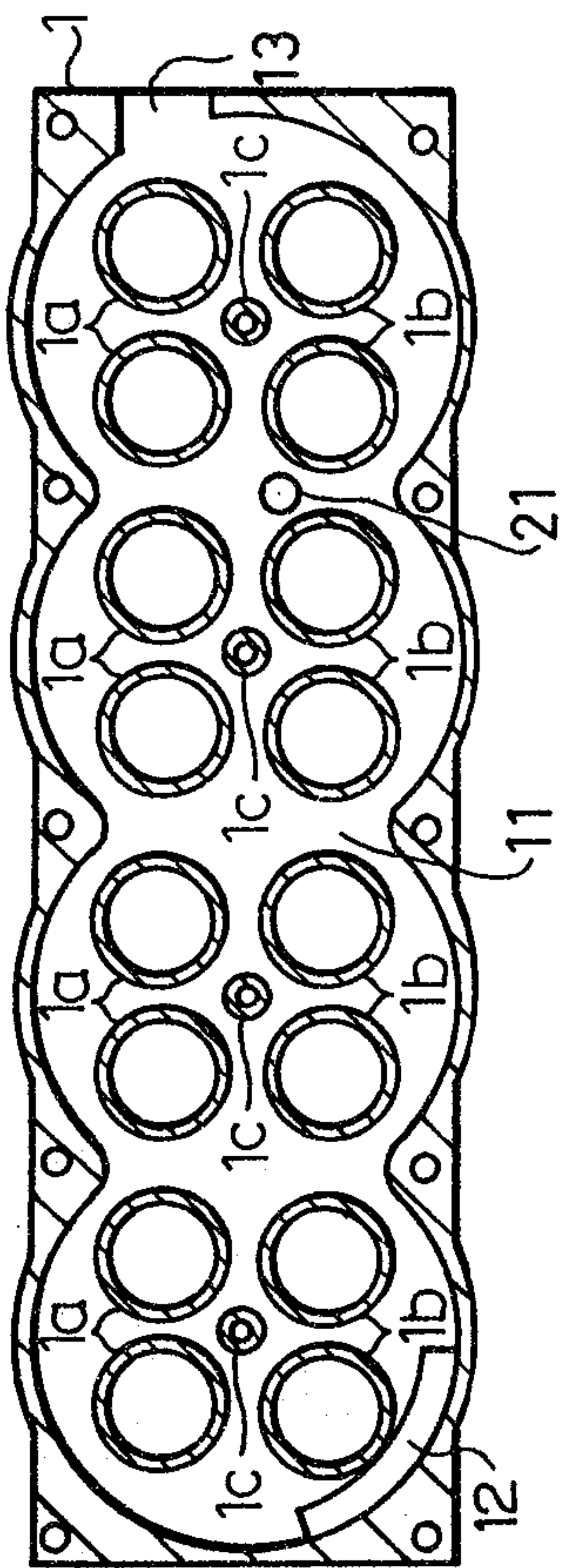


Fig. 8A

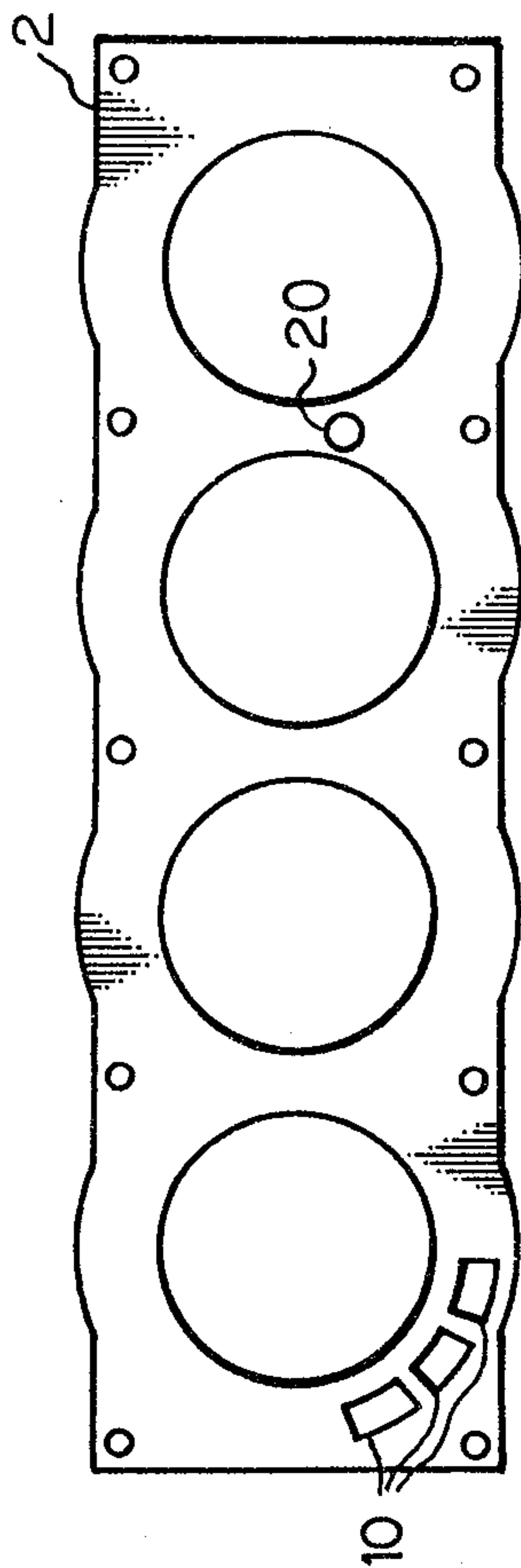


Fig. 8B

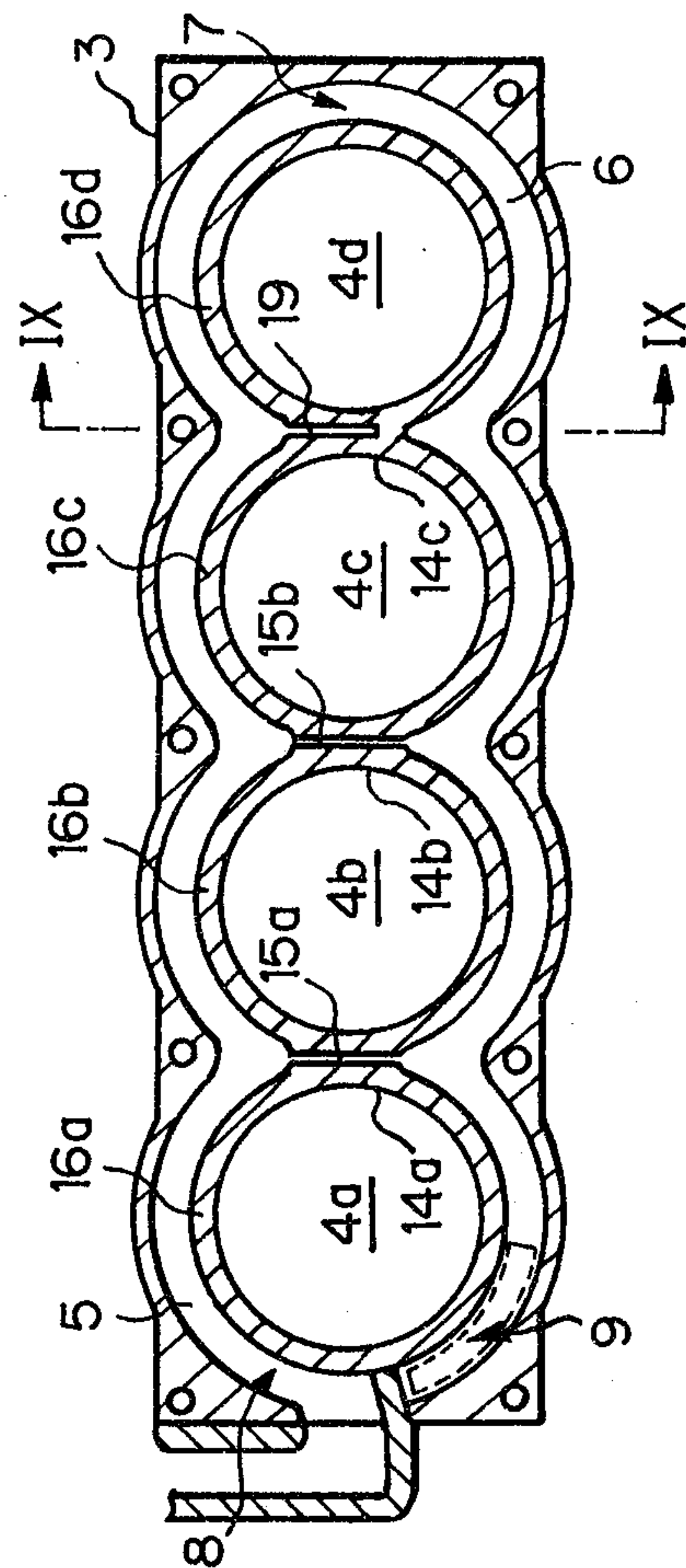


Fig. 8C

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Fig. 9

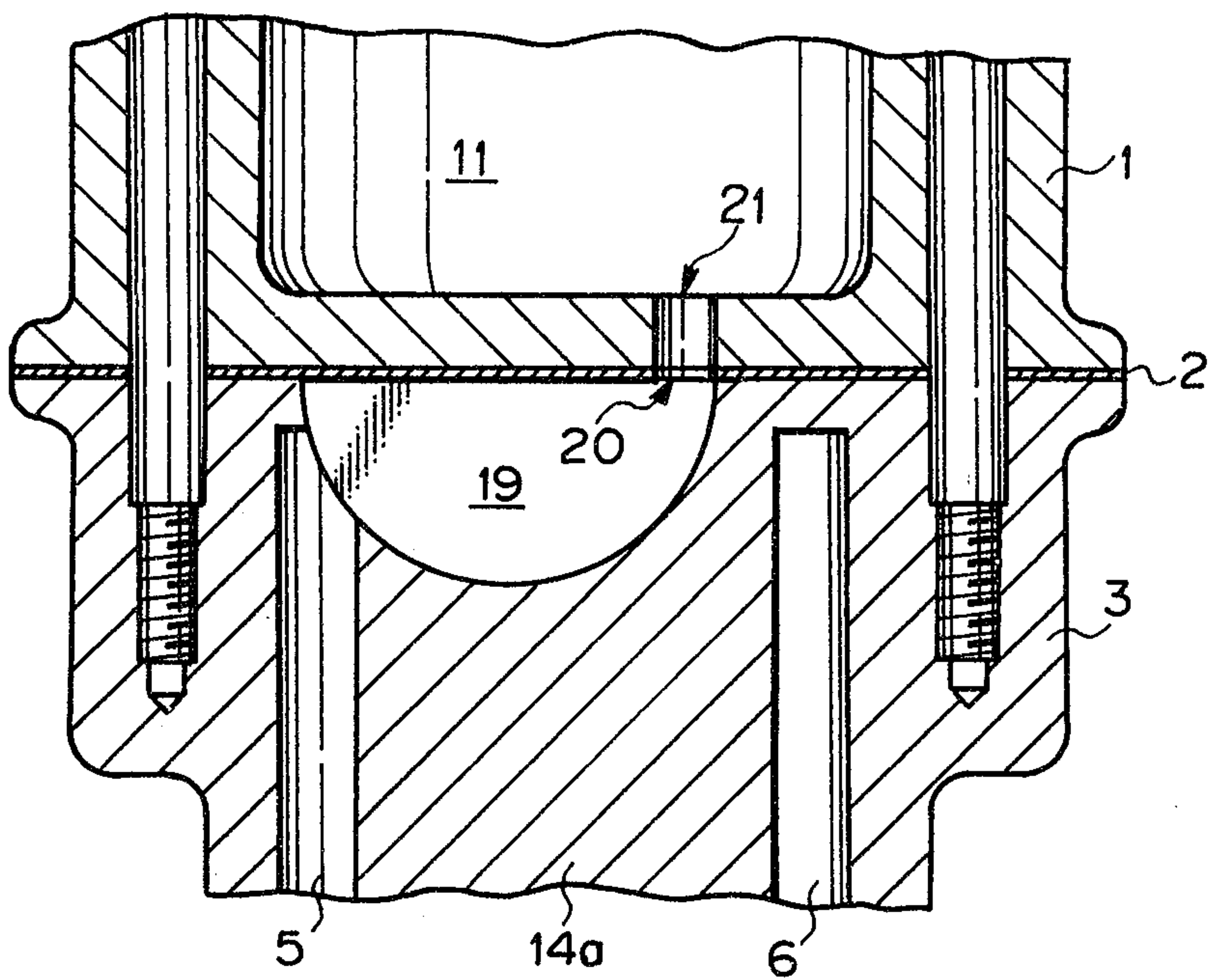
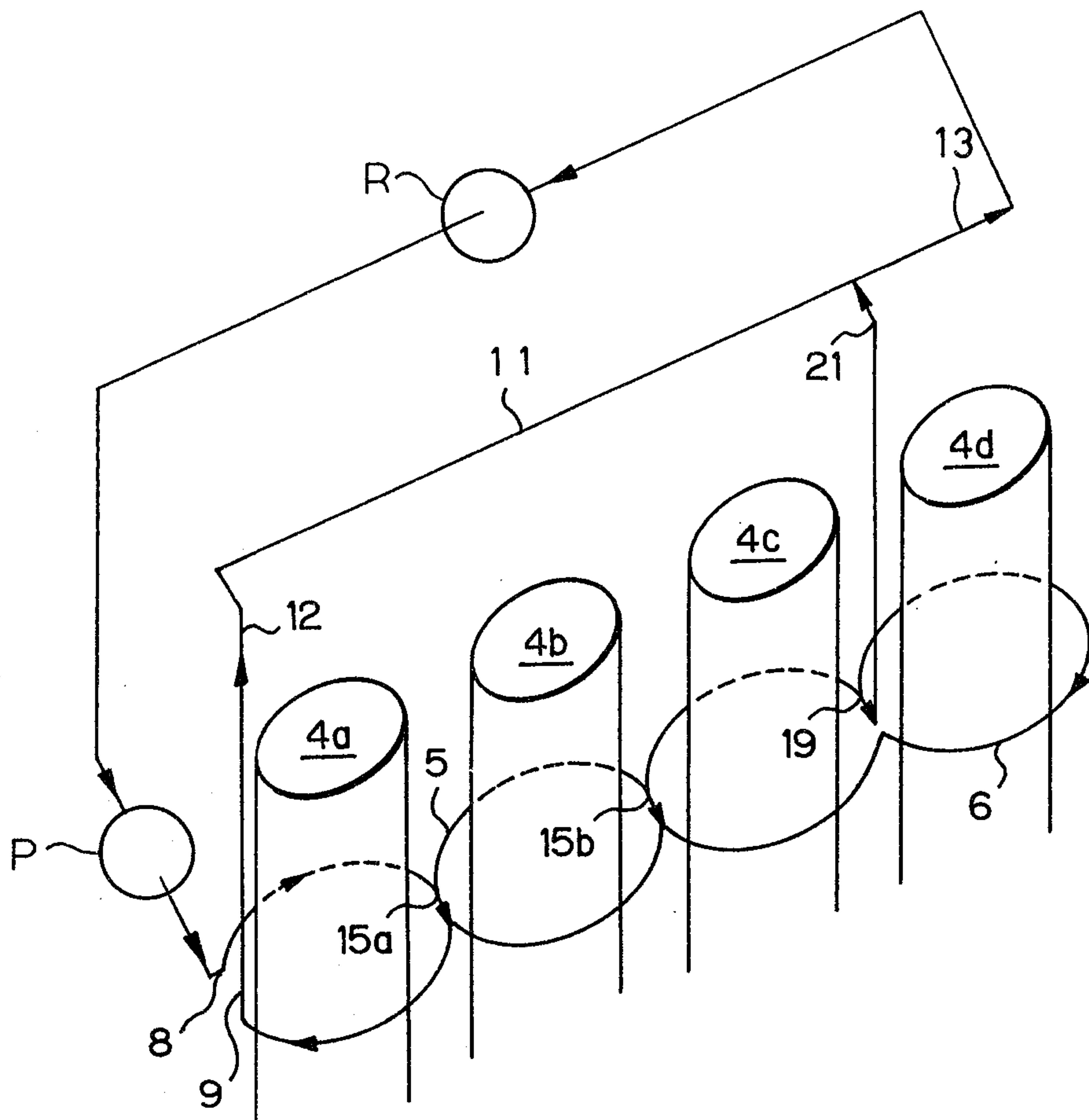
*Latt & Aylen*

Fig. 10

*Scott & Aylen*

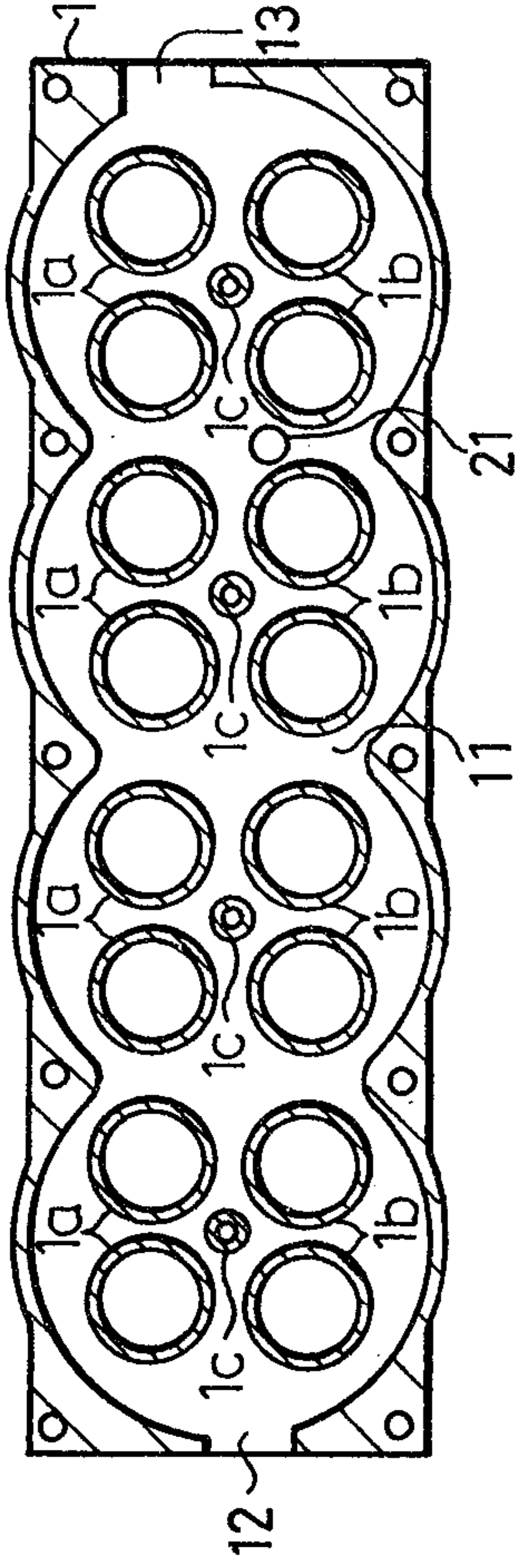


Fig. 11A

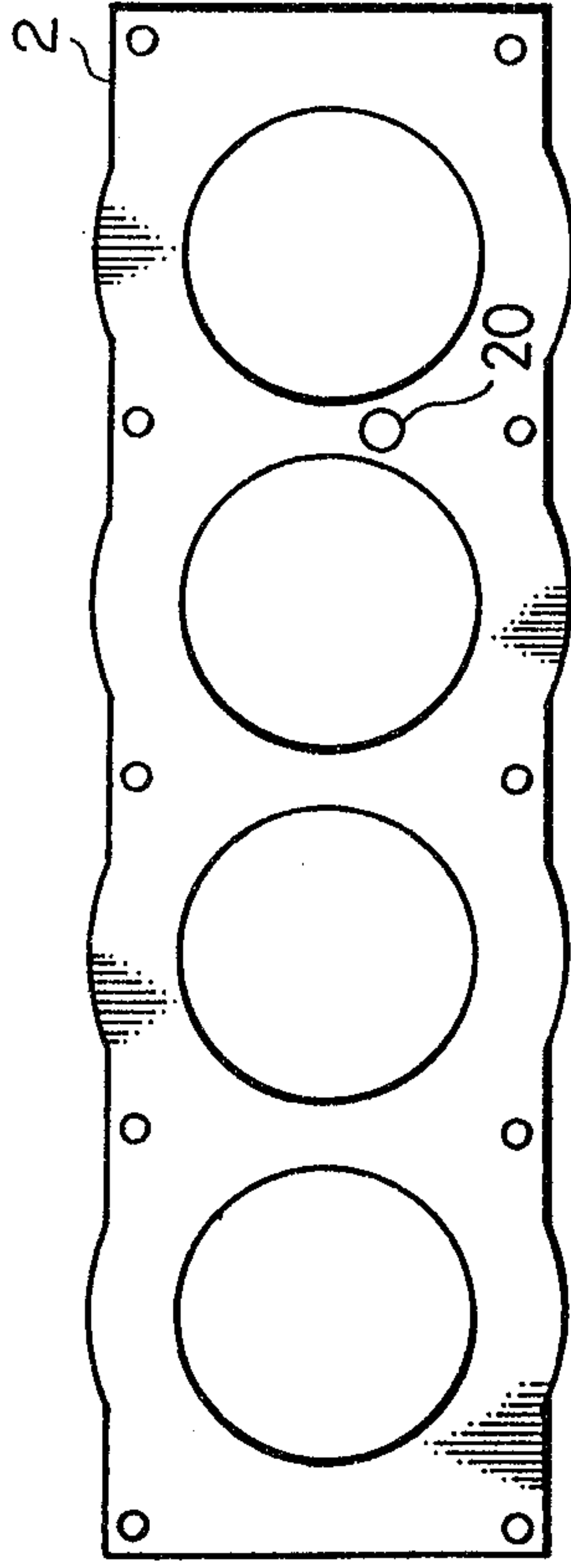


Fig. 11B

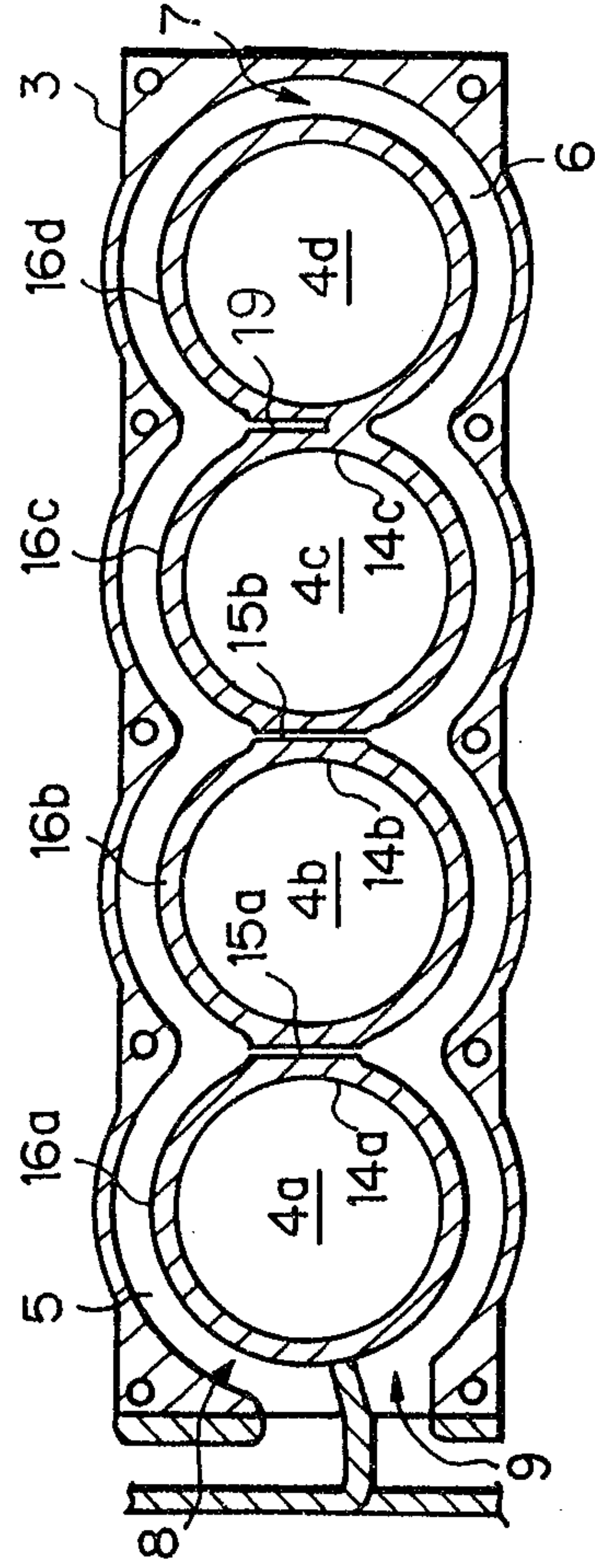
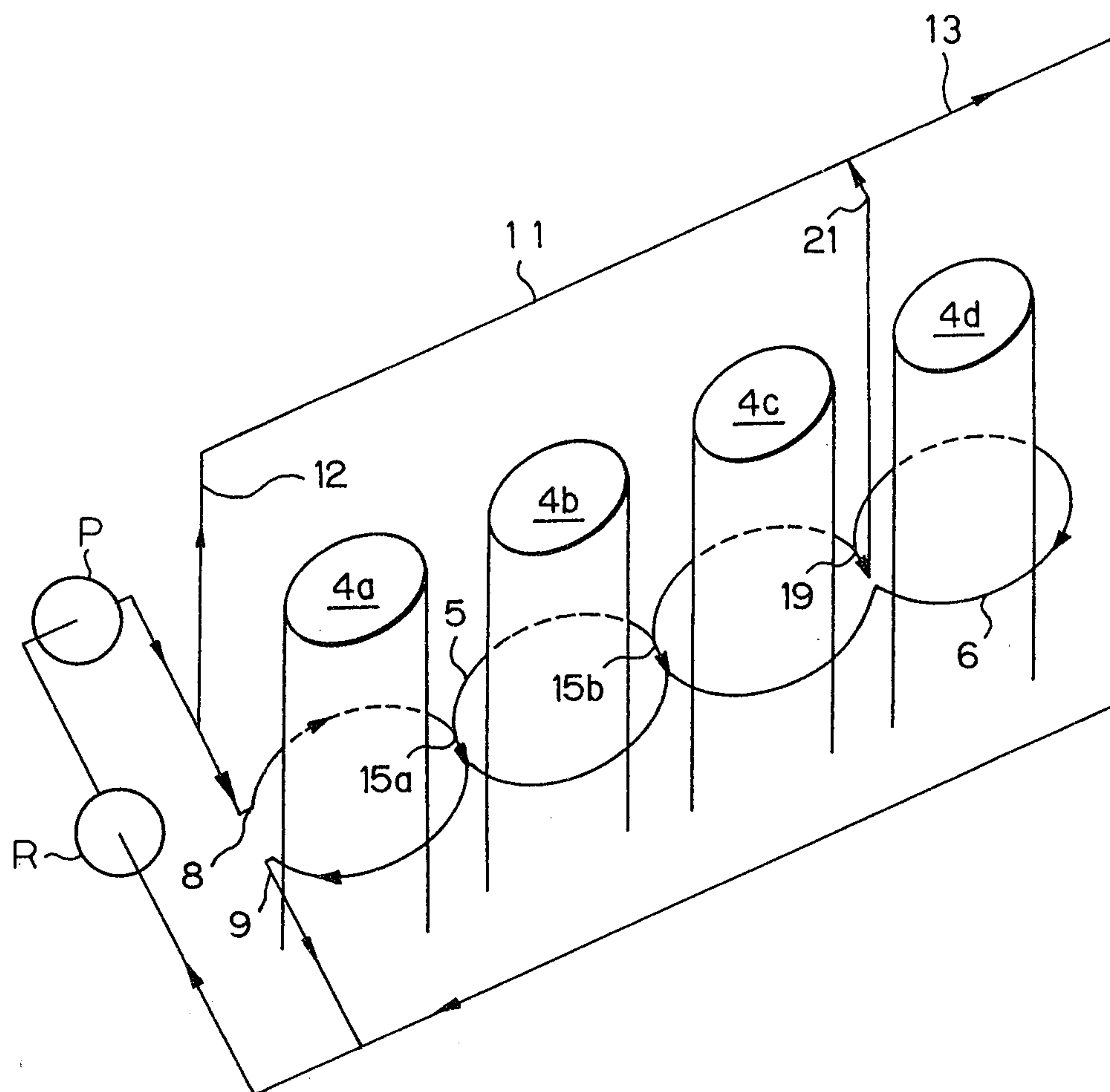


Fig. 11C

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Fig. 12



Scott & Sykes

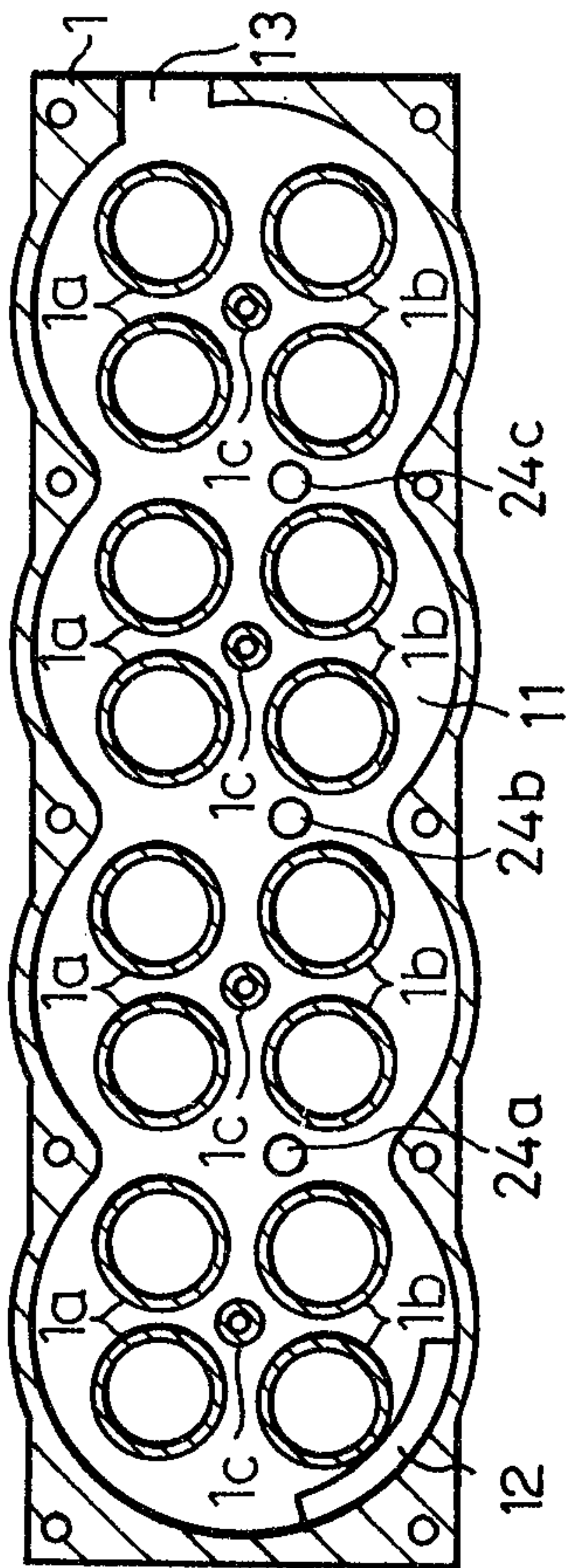


Fig. 13A

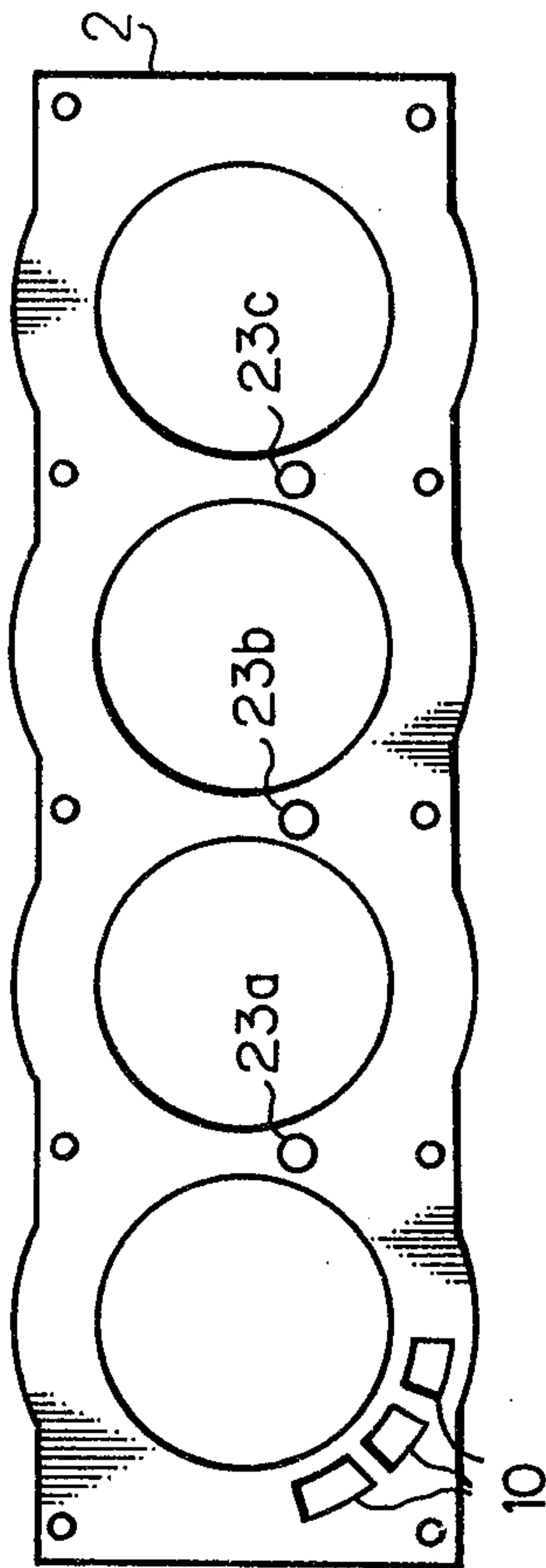


Fig. 13B

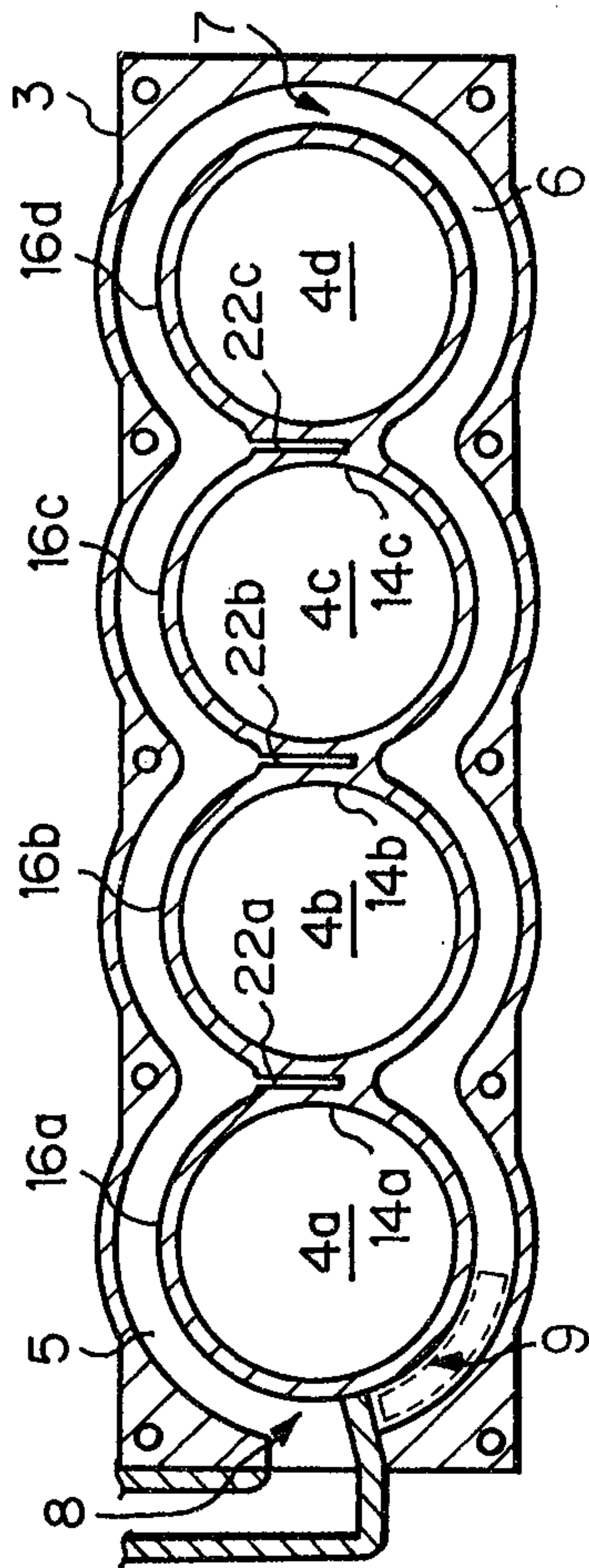
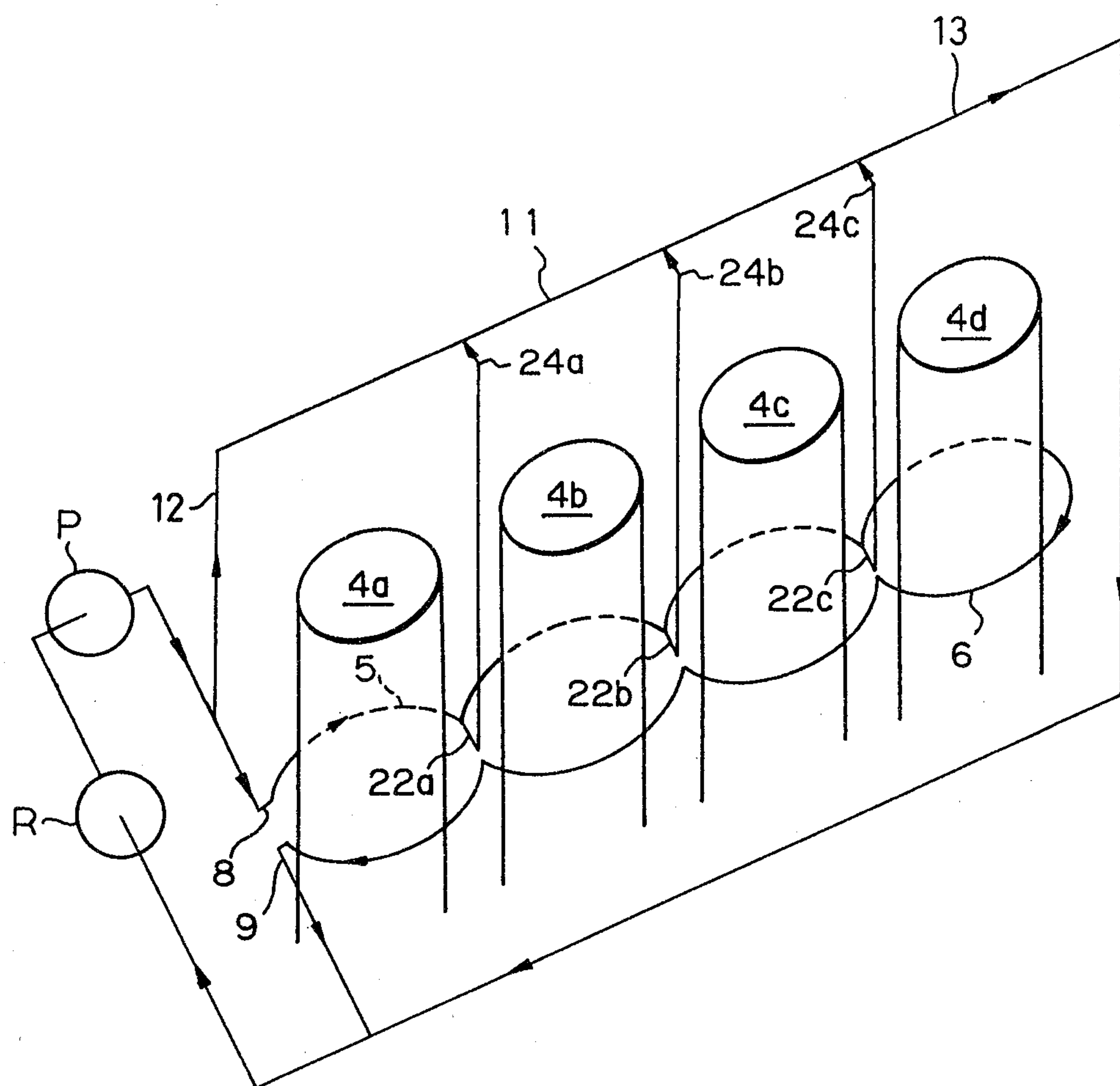


Fig. 13C

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Fig. 16

*Scott & Sykes*

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Fig. 17A

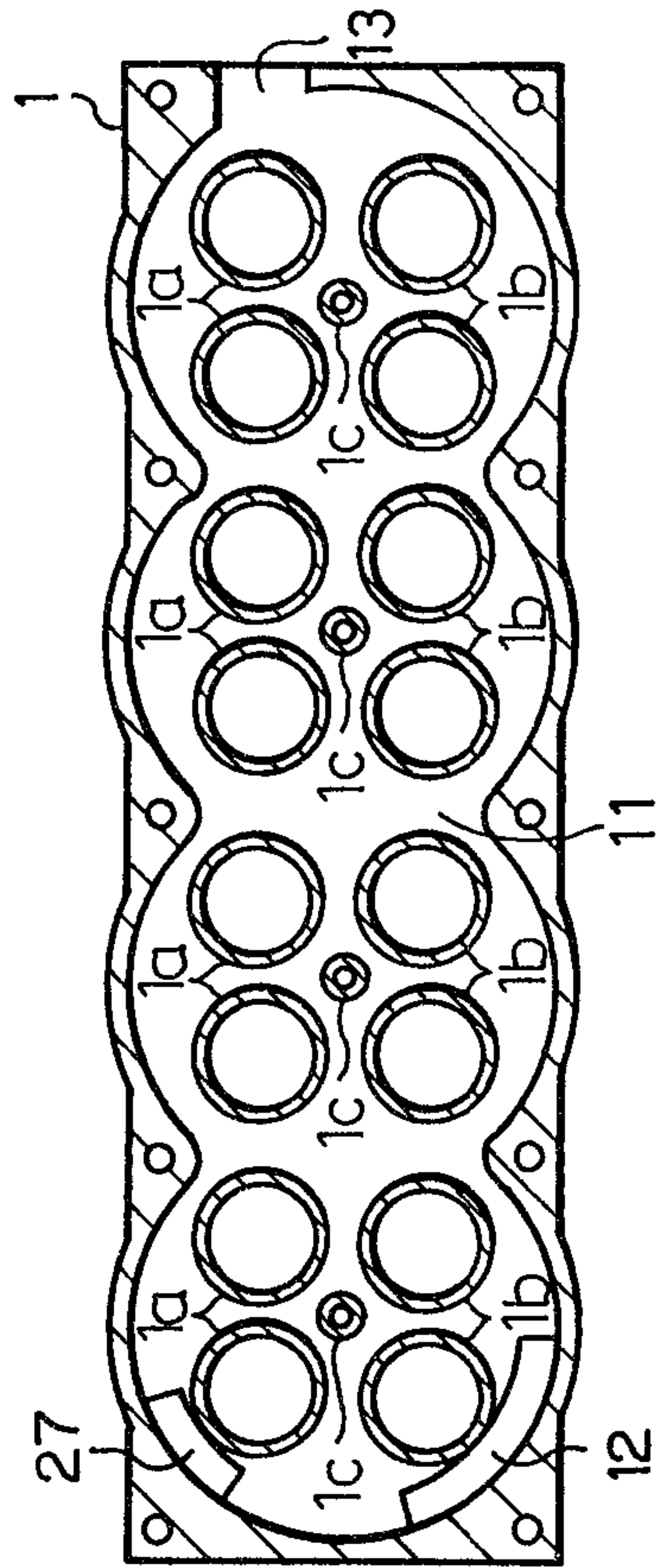


Fig. 17B

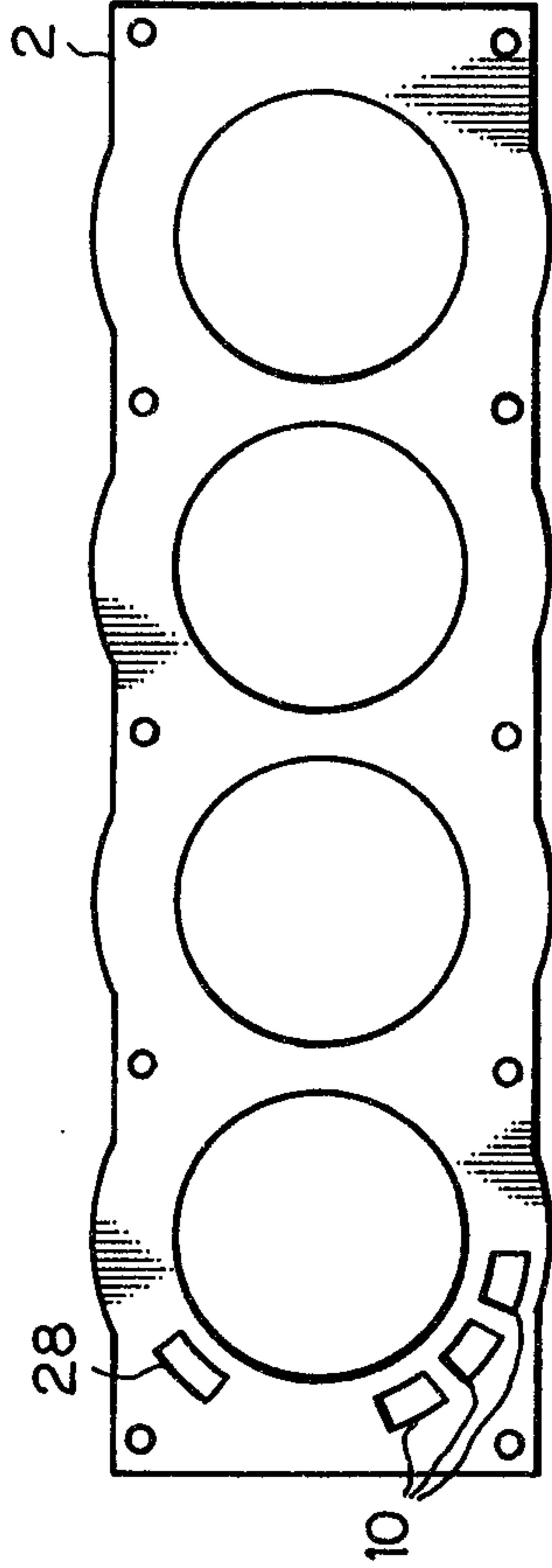
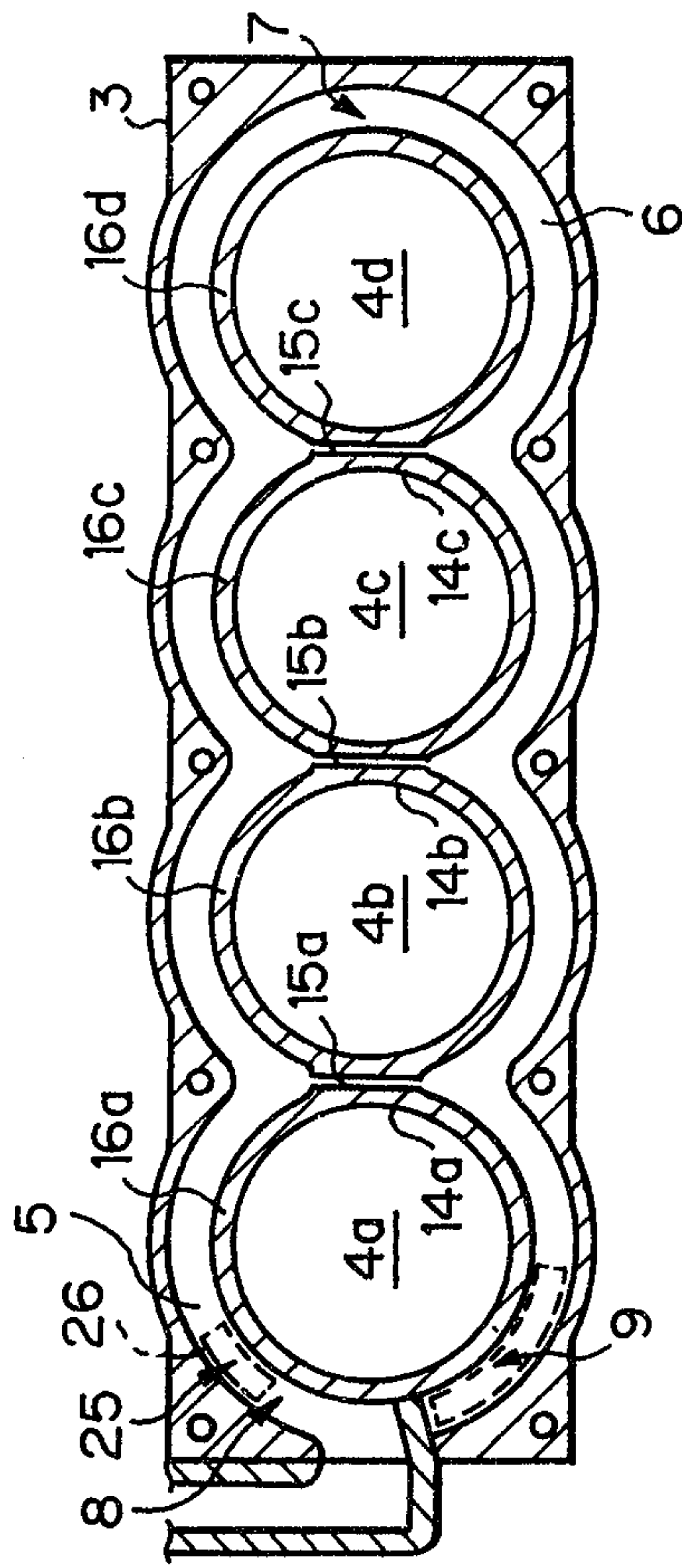
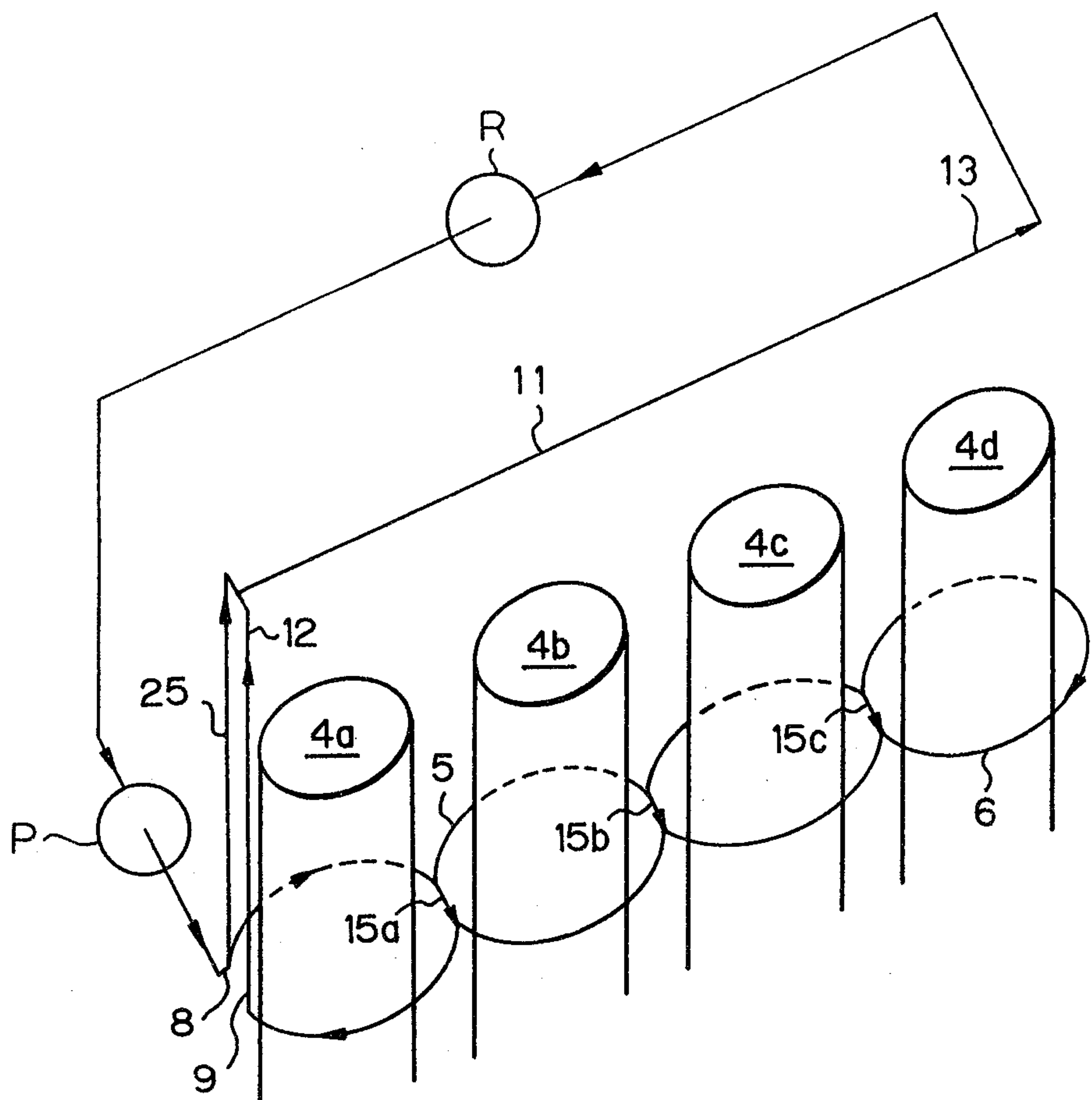


Fig. 17C



Scott & Aylen

Fig. 18



Scott & Aylen