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(54) **HEAT EXCHANGER AND HEAT PUMP TYPE HOT WATER SUPPLY APPARATUS EQUIPPED WITH SAME**

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(52) **U.S. Cl.** **62/324.1**; 165/177

(57) **ABSTRACT**

A heat exchanger **21** is provided with a metal tube **47** that has a support member **55** inhibiting deformation in the thickness direction in a fluid flow channel **53**, and a multiple-hole metal tube **45** that is stacked on one side of the metal tube **47** in the thickness direction and has an opposing surface disposed opposite an outer surface **61** on the one side of the metal tube **47** and joined by at least part thereof to the outer surface **61** on the one side.

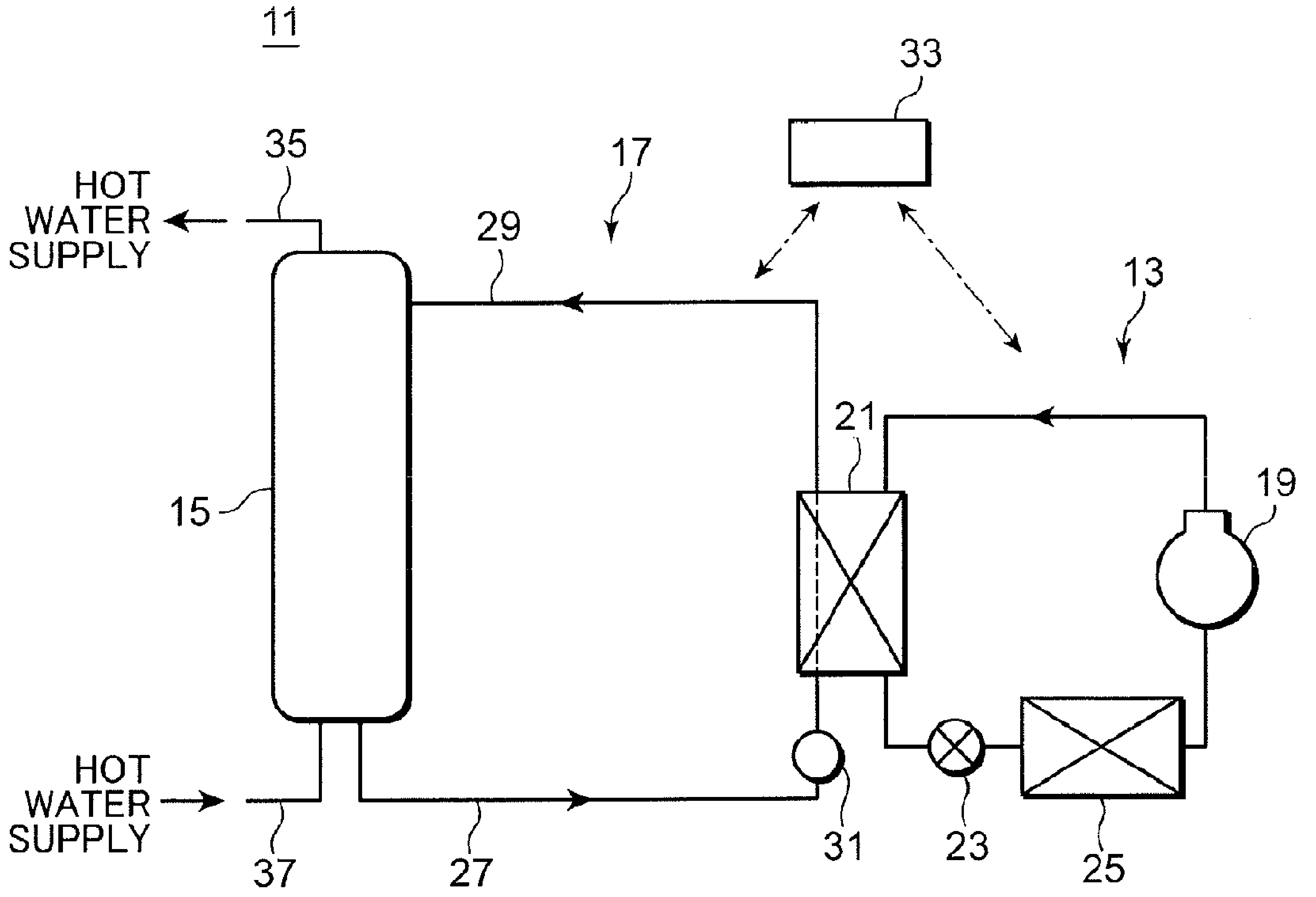


FIG.1

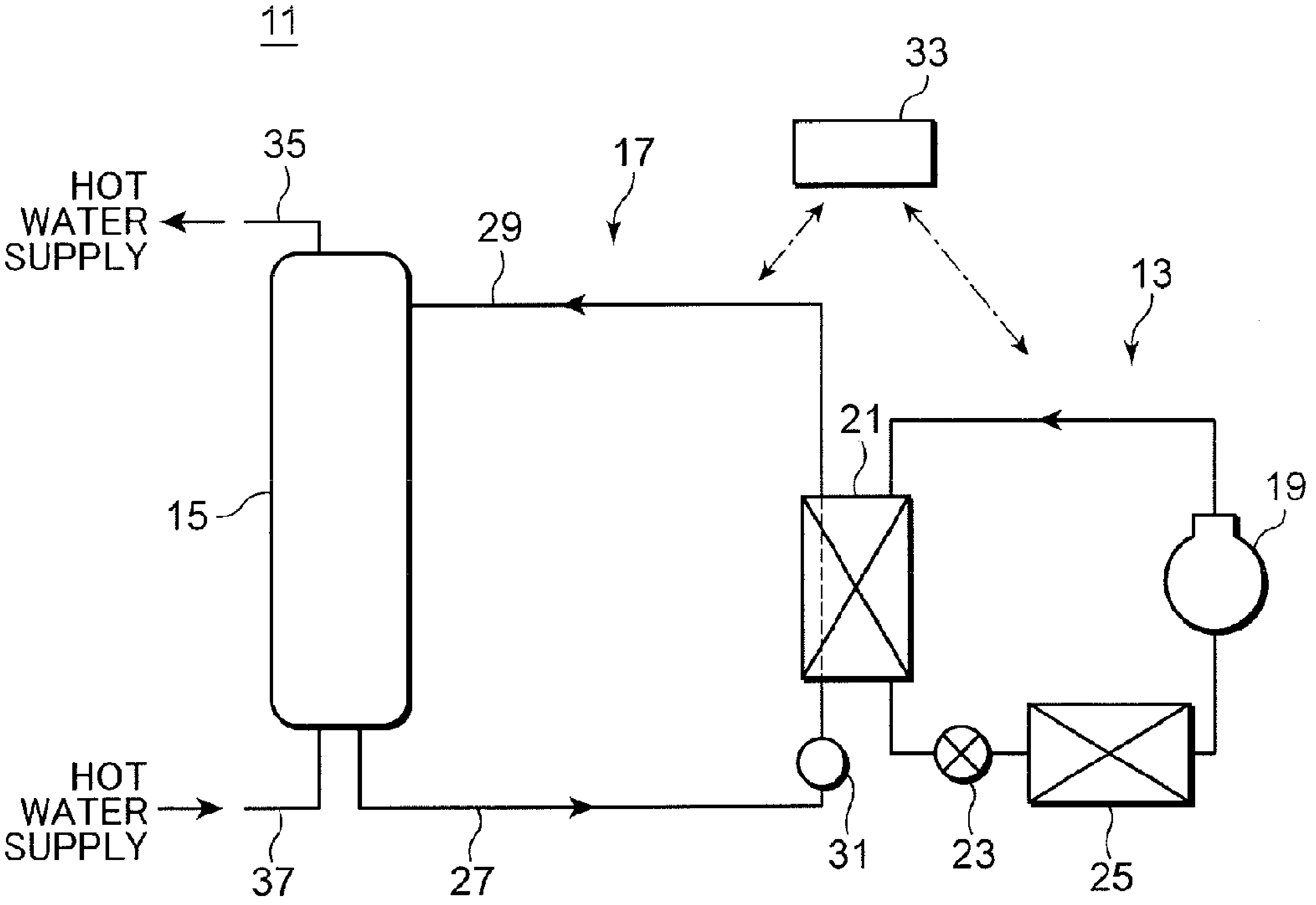

11
33
35
17
29
13
HOT WATER SUPPLY
21
19
15
HOT WATER SUPPLY
37
27
31
23
25

FIG.2

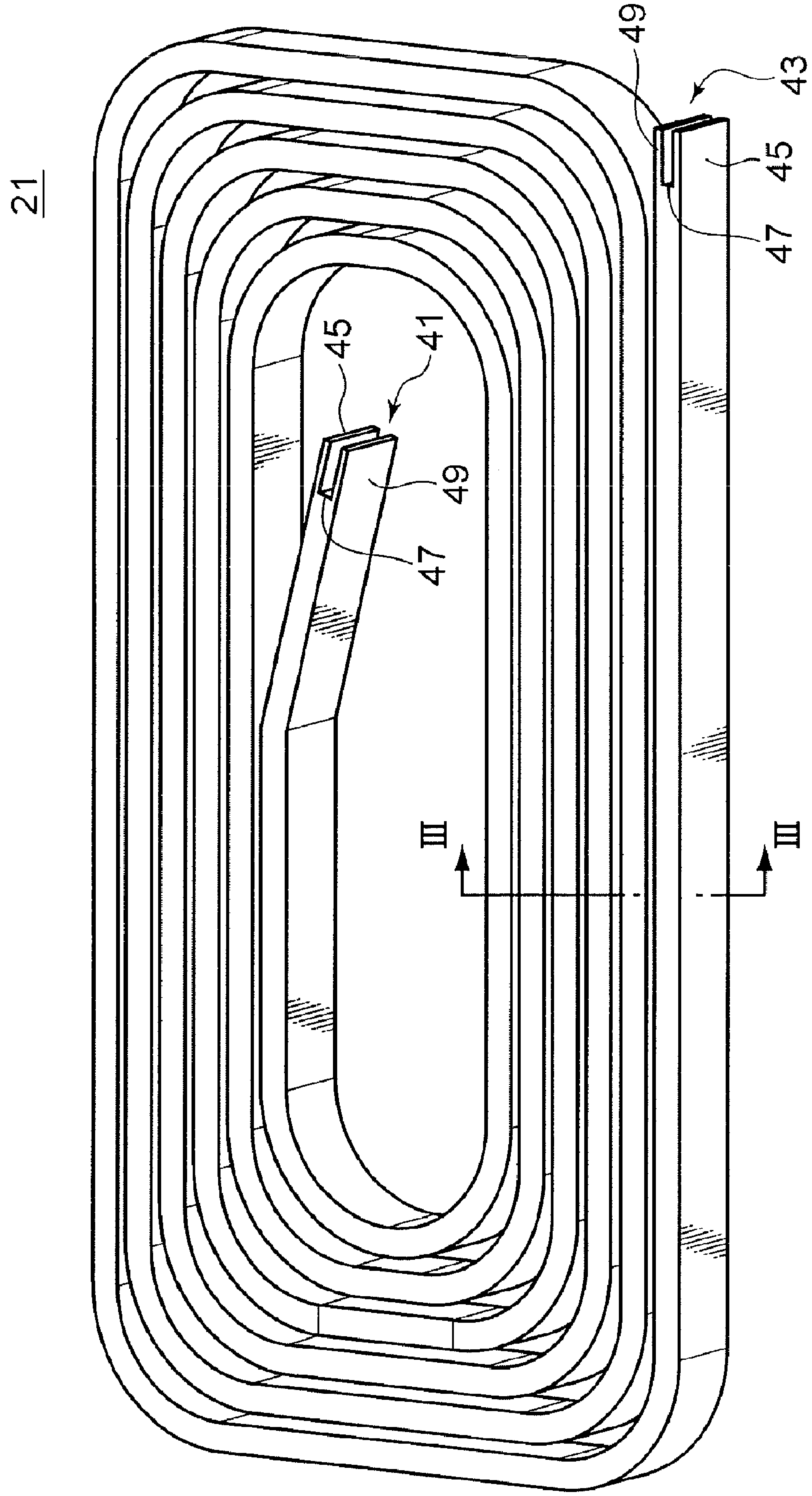


FIG.3

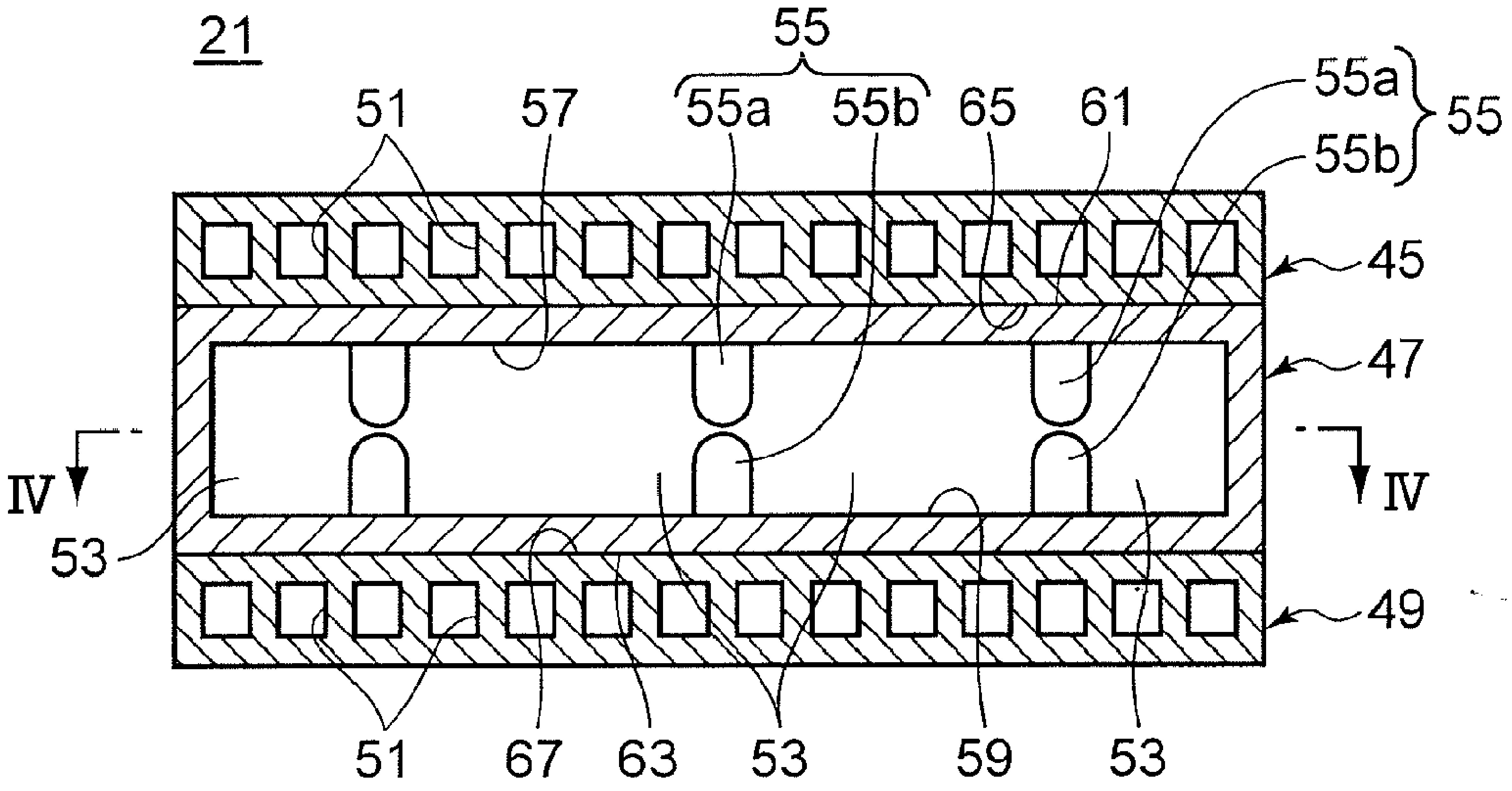

21
55
51
57
55a
55b
65
61
55a
55b
55
45
47
IV
IV
53
49
51
67
63
53
59
53

FIG.4

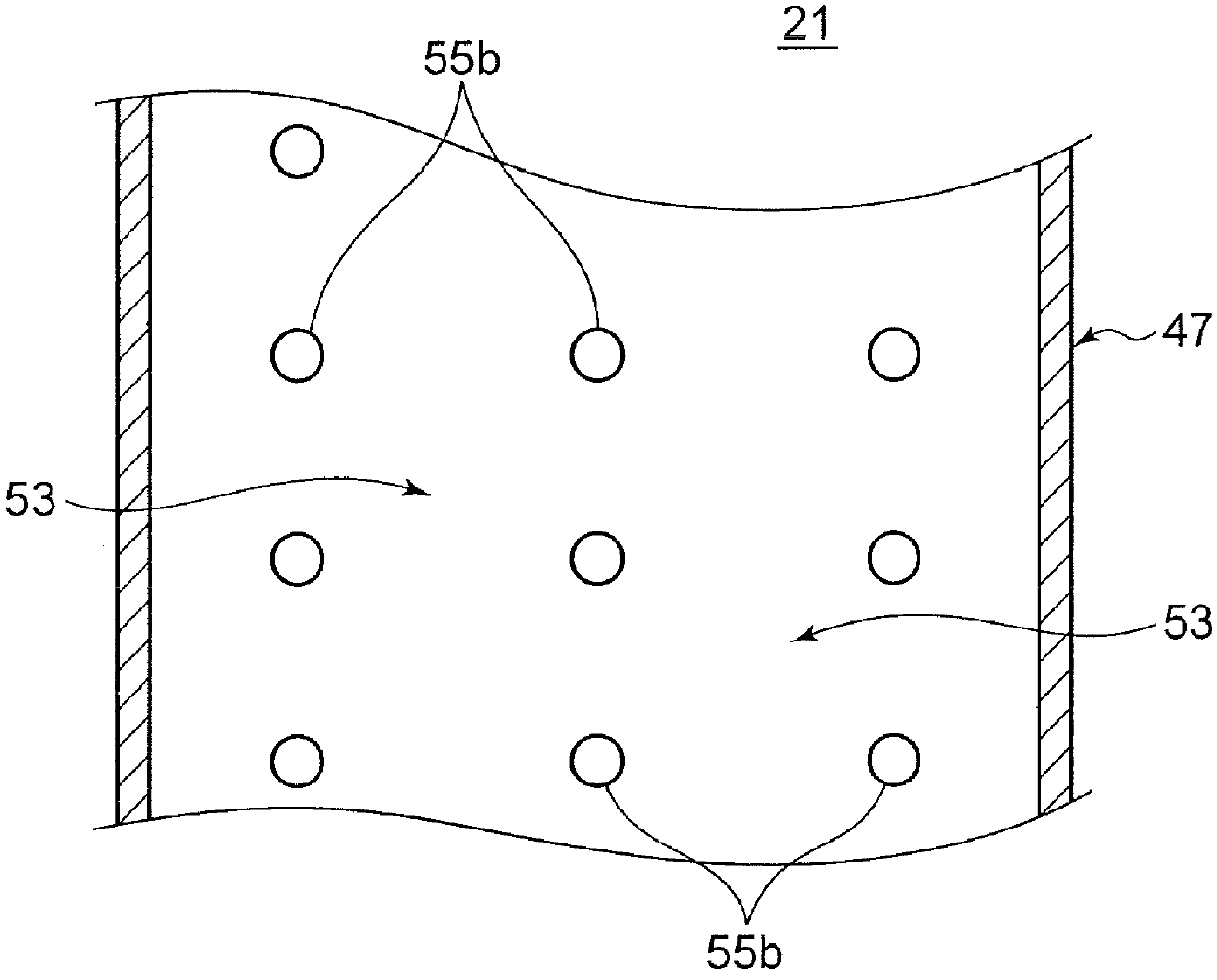


FIG.5

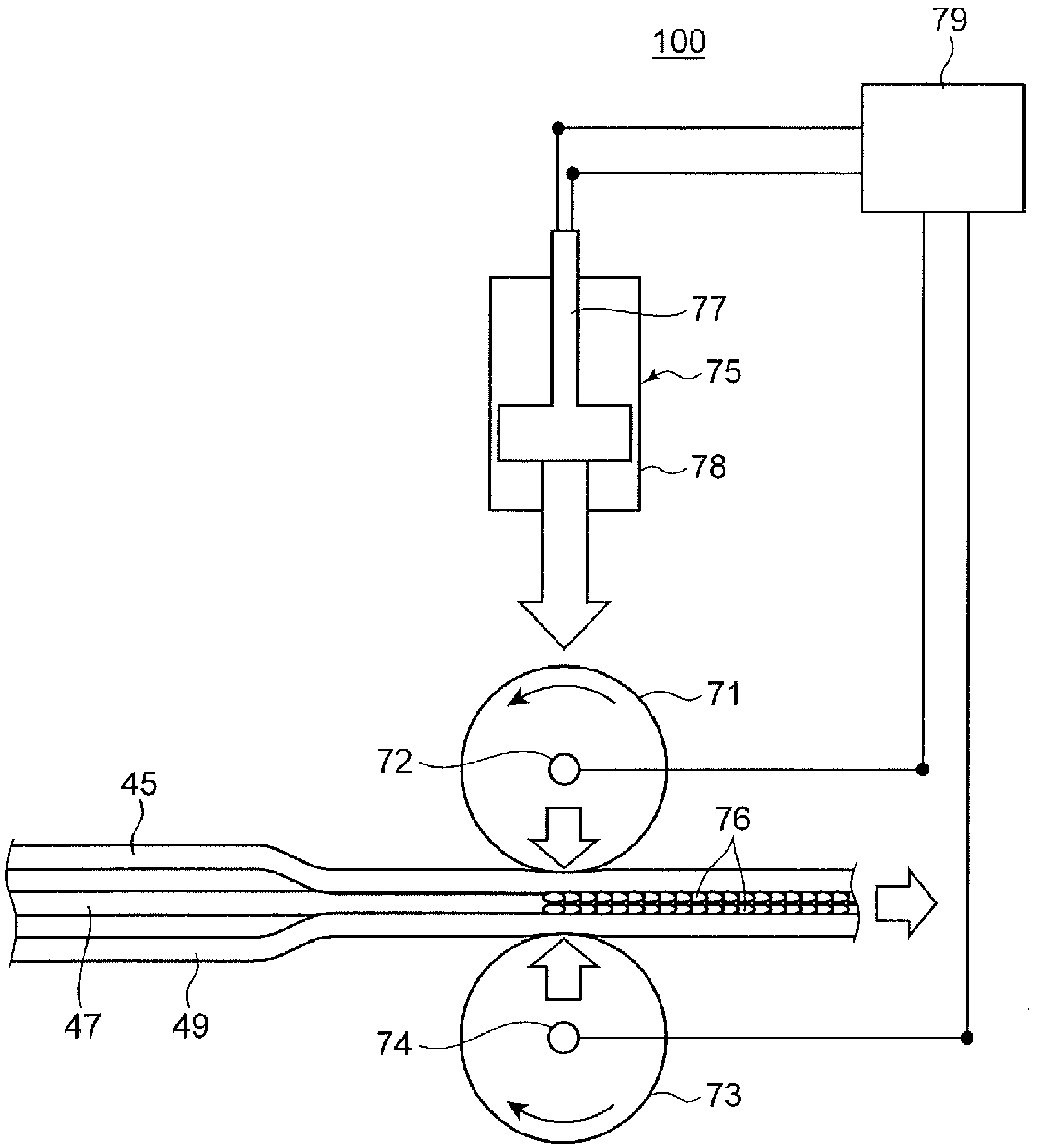


FIG.6

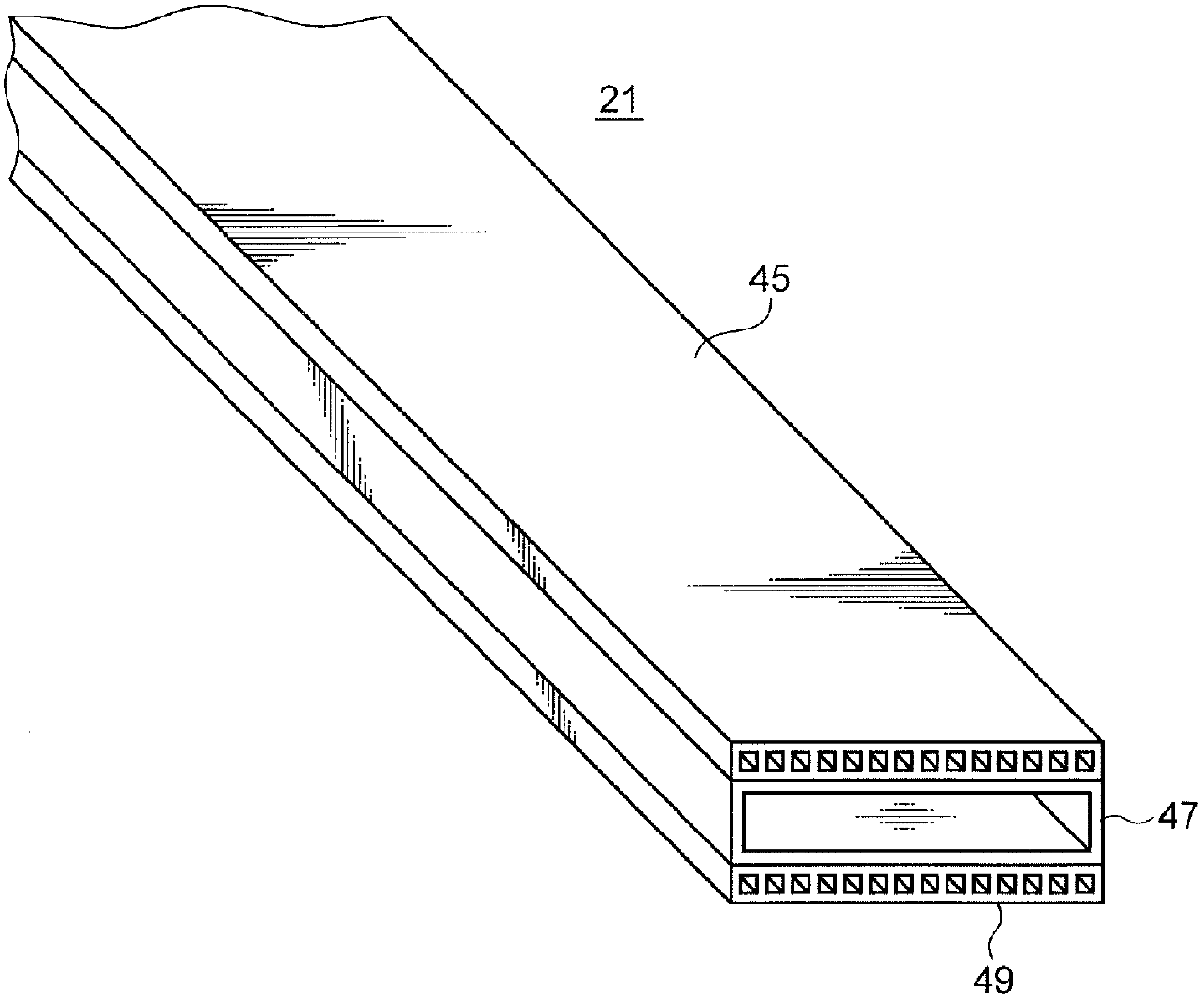


FIG.7

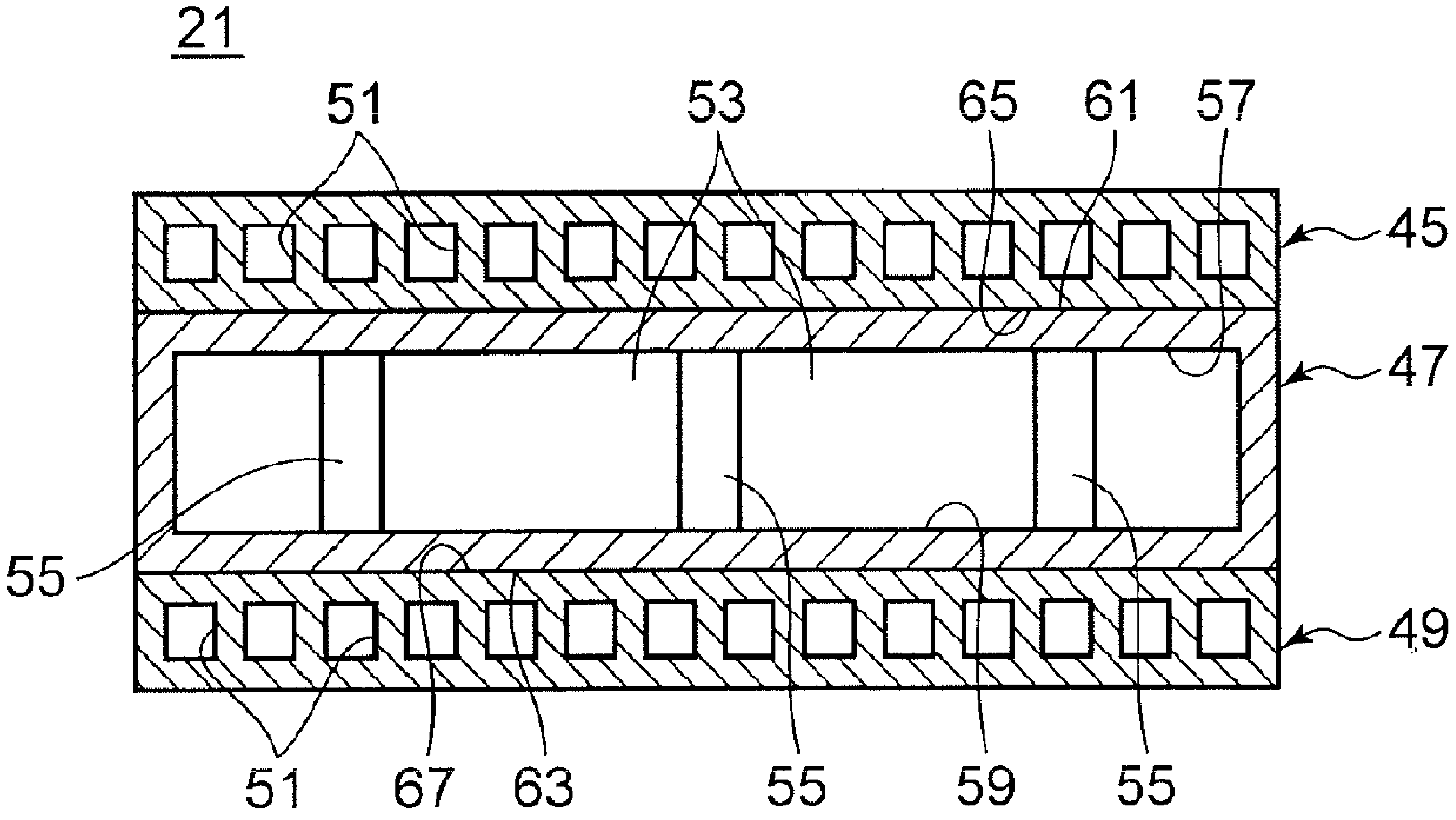


FIG.8

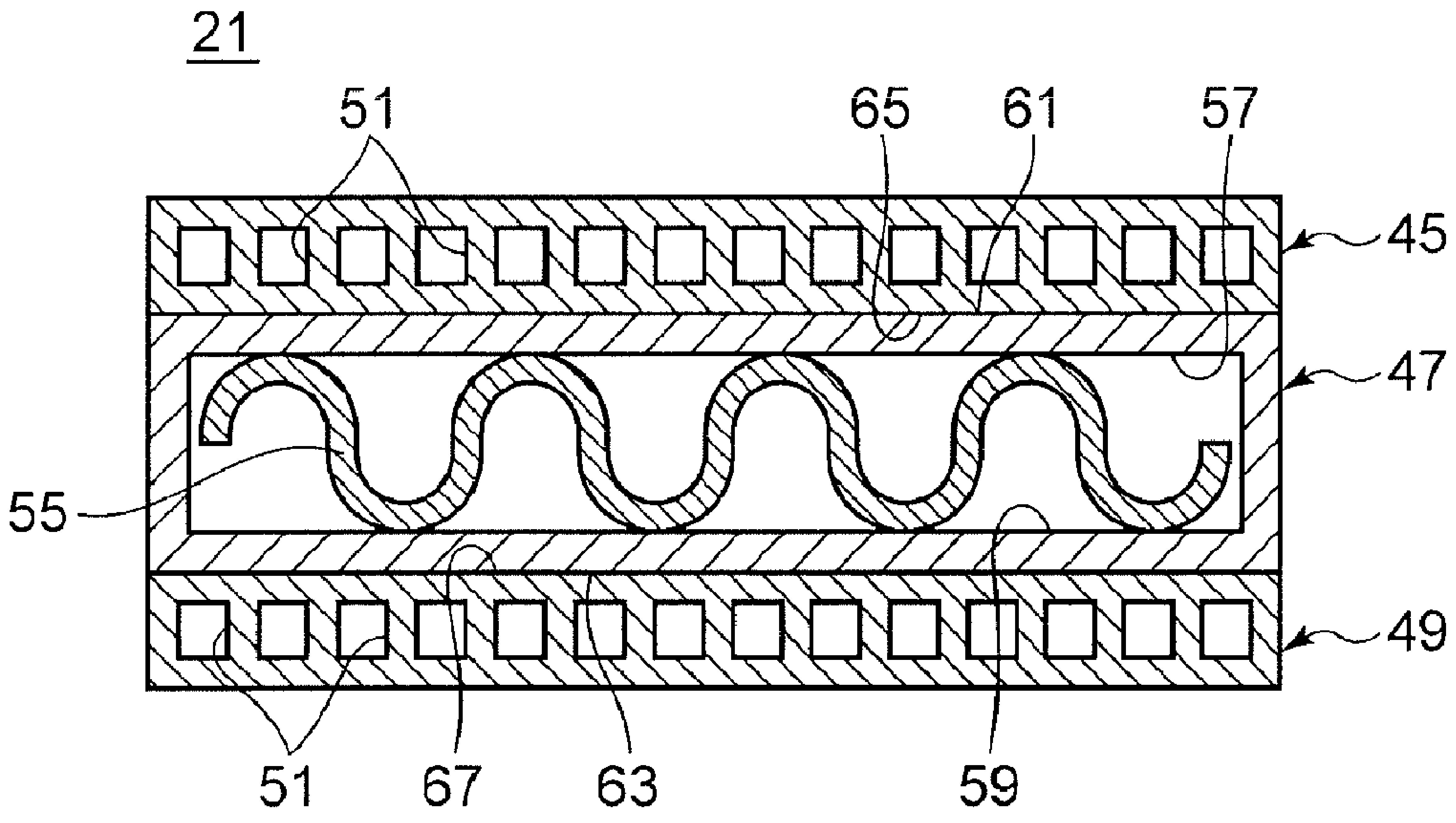


FIG.9

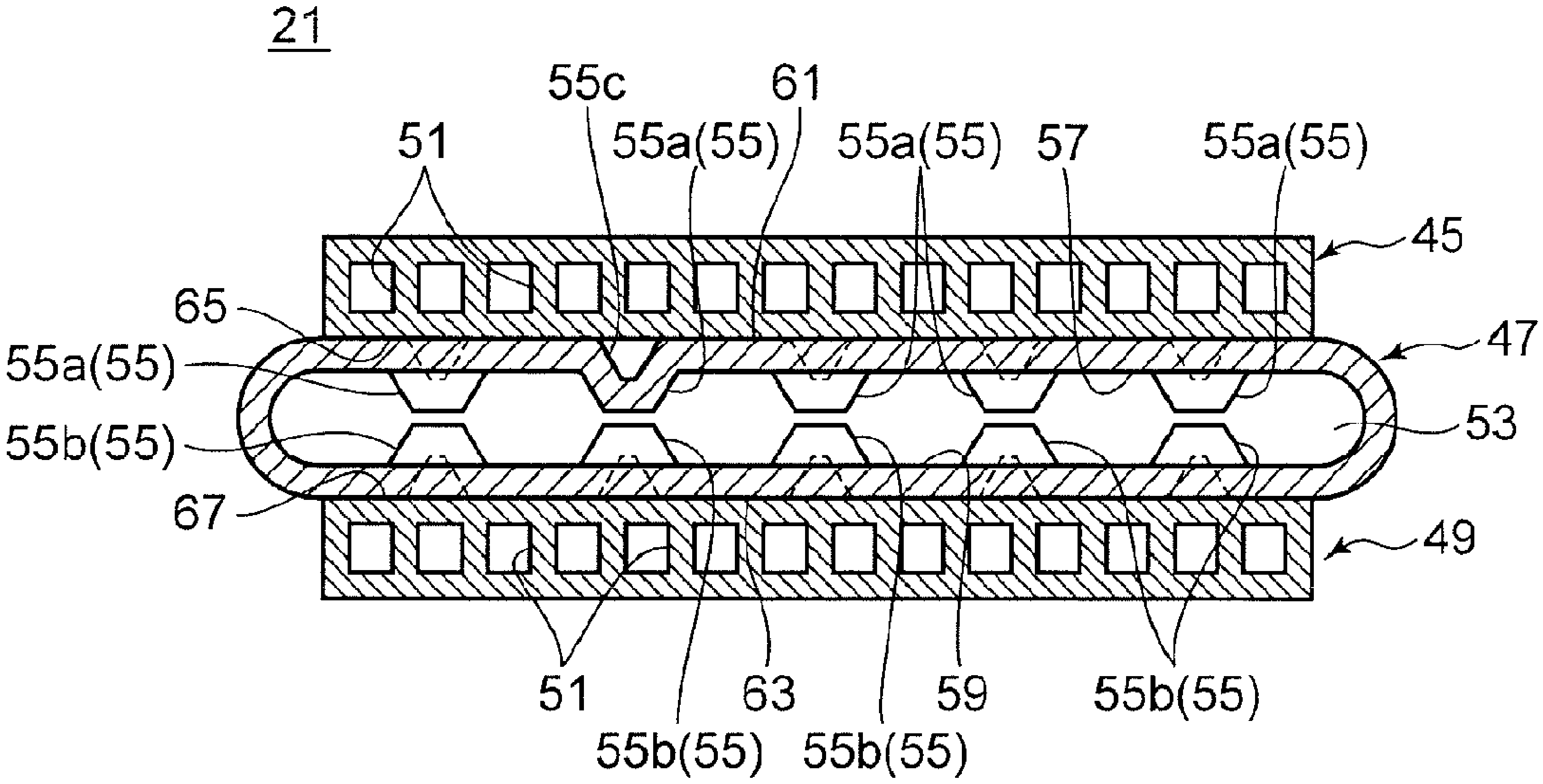

21
55c
61
51
55a(55)
55a(55)
57
55a(55)
45
65
47
55a(55)
53
55b(55)
67
49
51
63
59
55b(55)
55b(55)
55b(55)

FIG.10

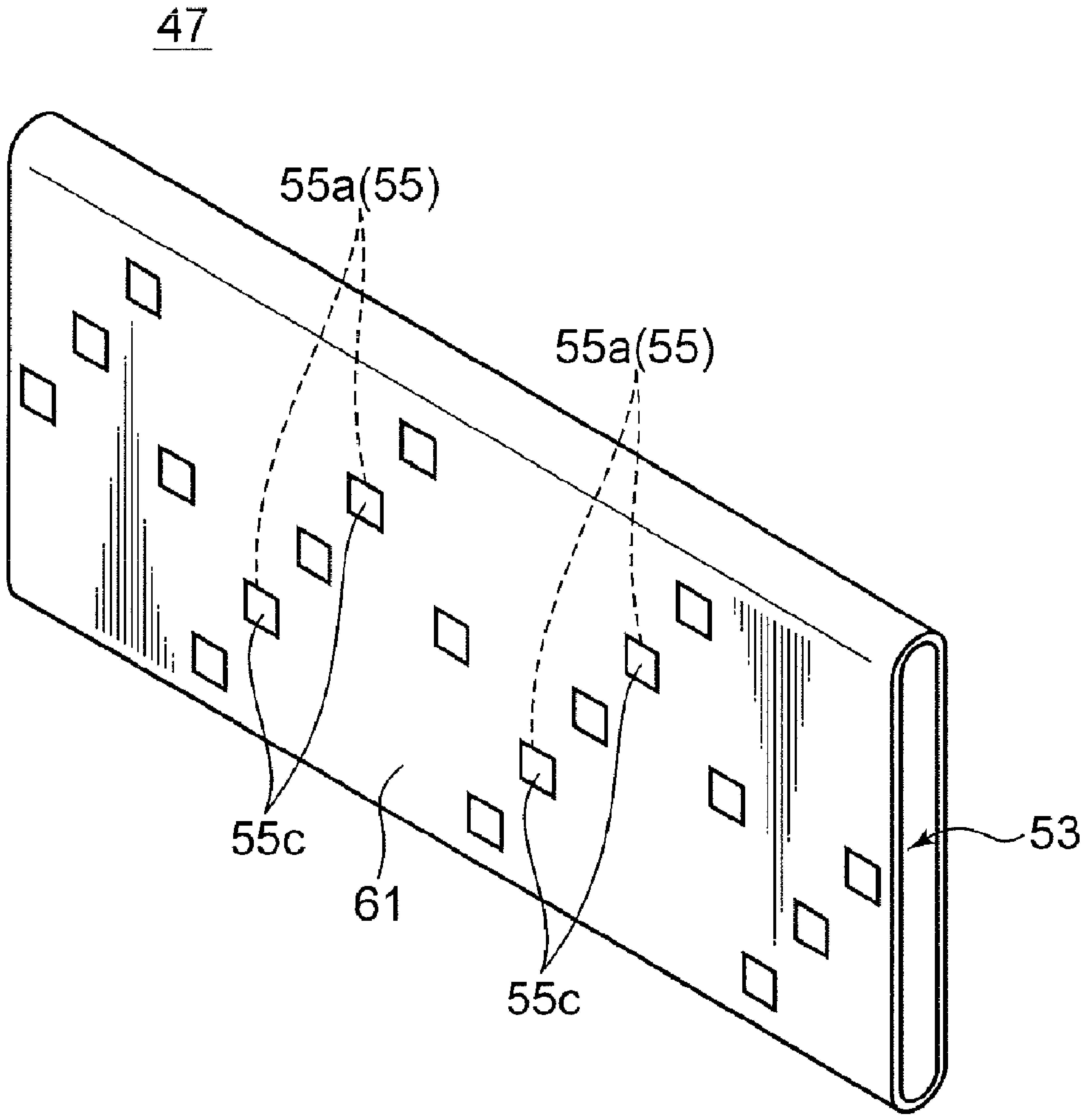
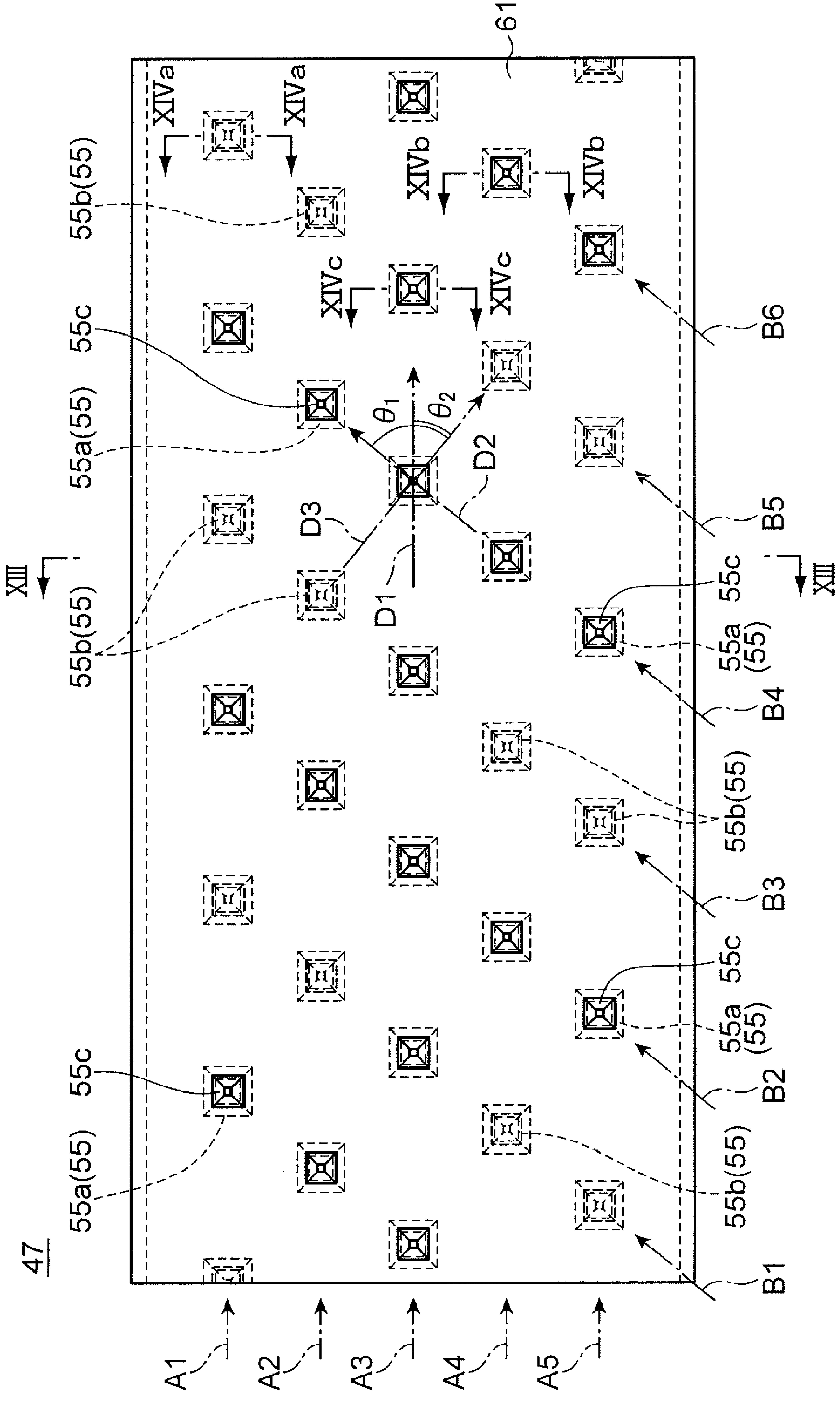


FIG.11


47
61
55a(55)
55c
55b(55)
55a(55)
55b(55)
55a
(55)
55c
55b(55)
55a
(55)
55c
55b(55)
D1
D2
D3
θ_1
θ_2
XIII
XIII
XIVa
XIVa
XIVb
XIVb
XIVc
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B4
B5
B6

FIG.12

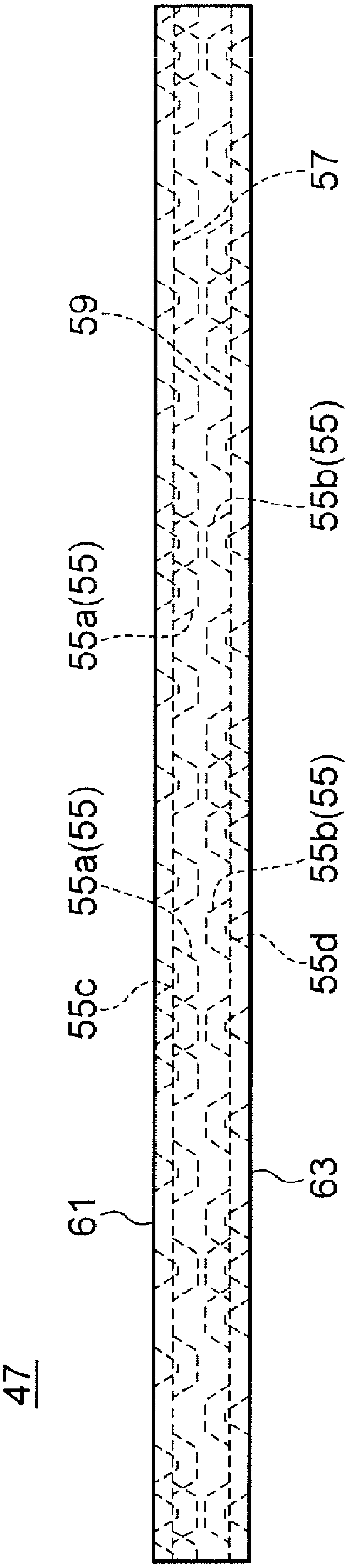


FIG.13

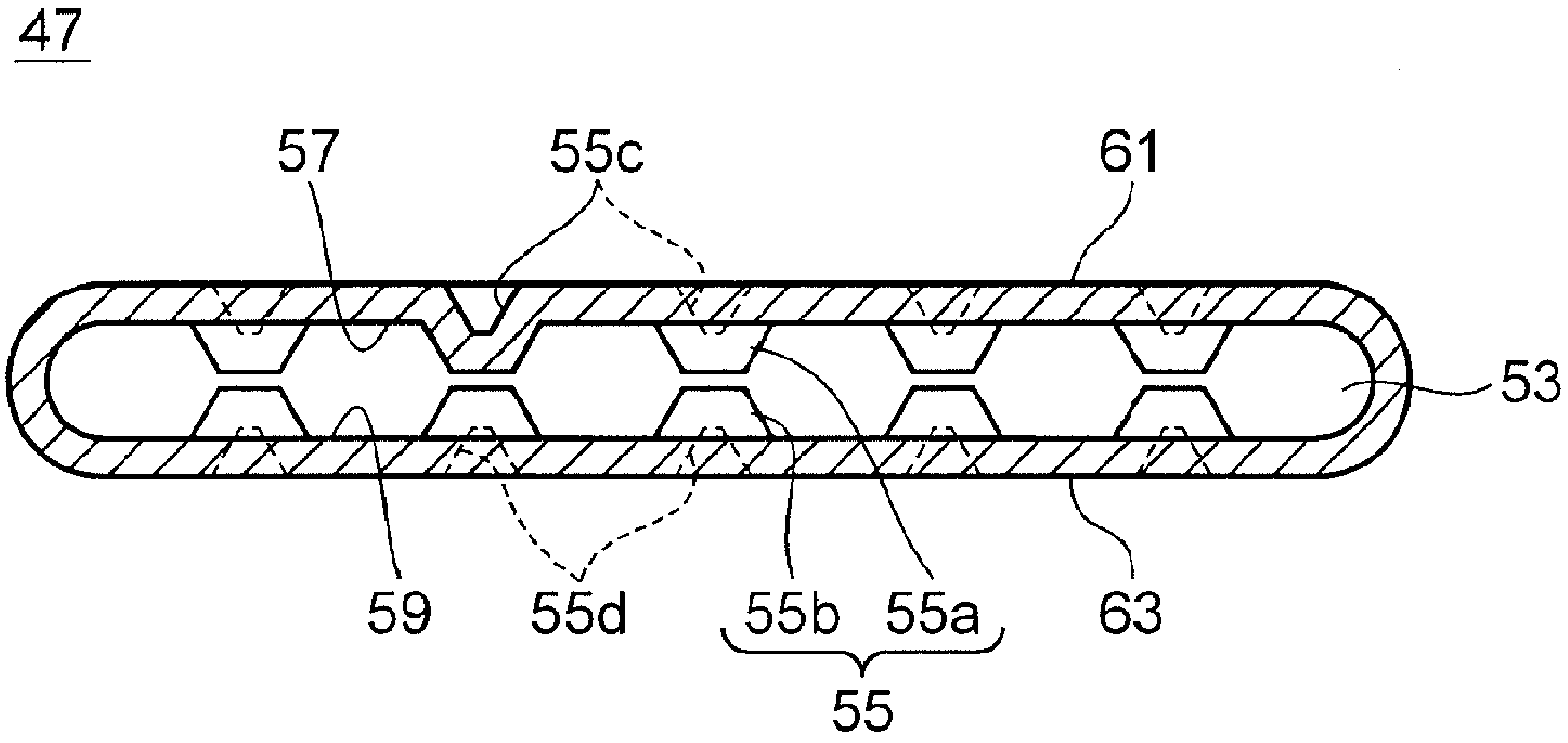


FIG.14A

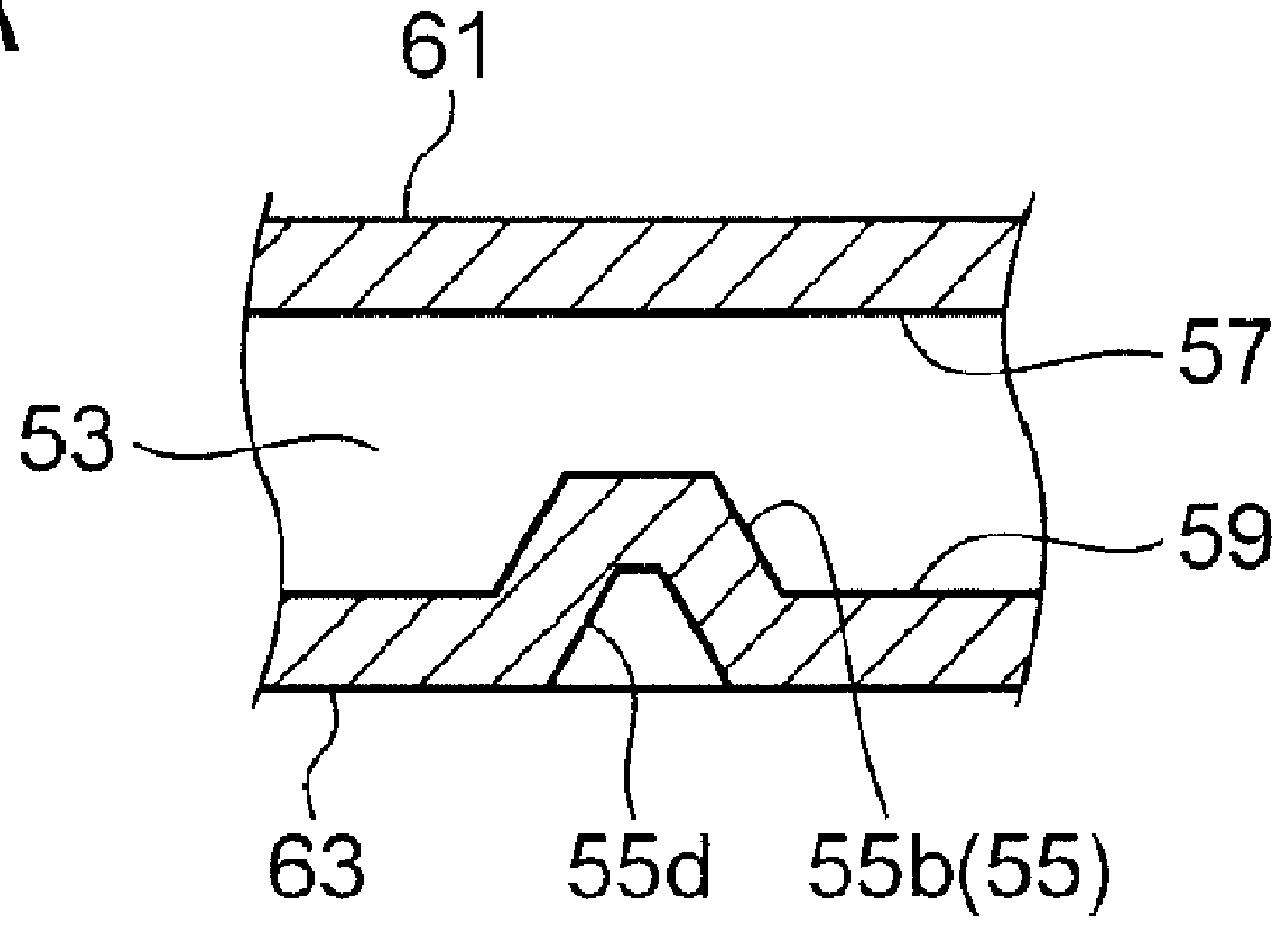


FIG.14B

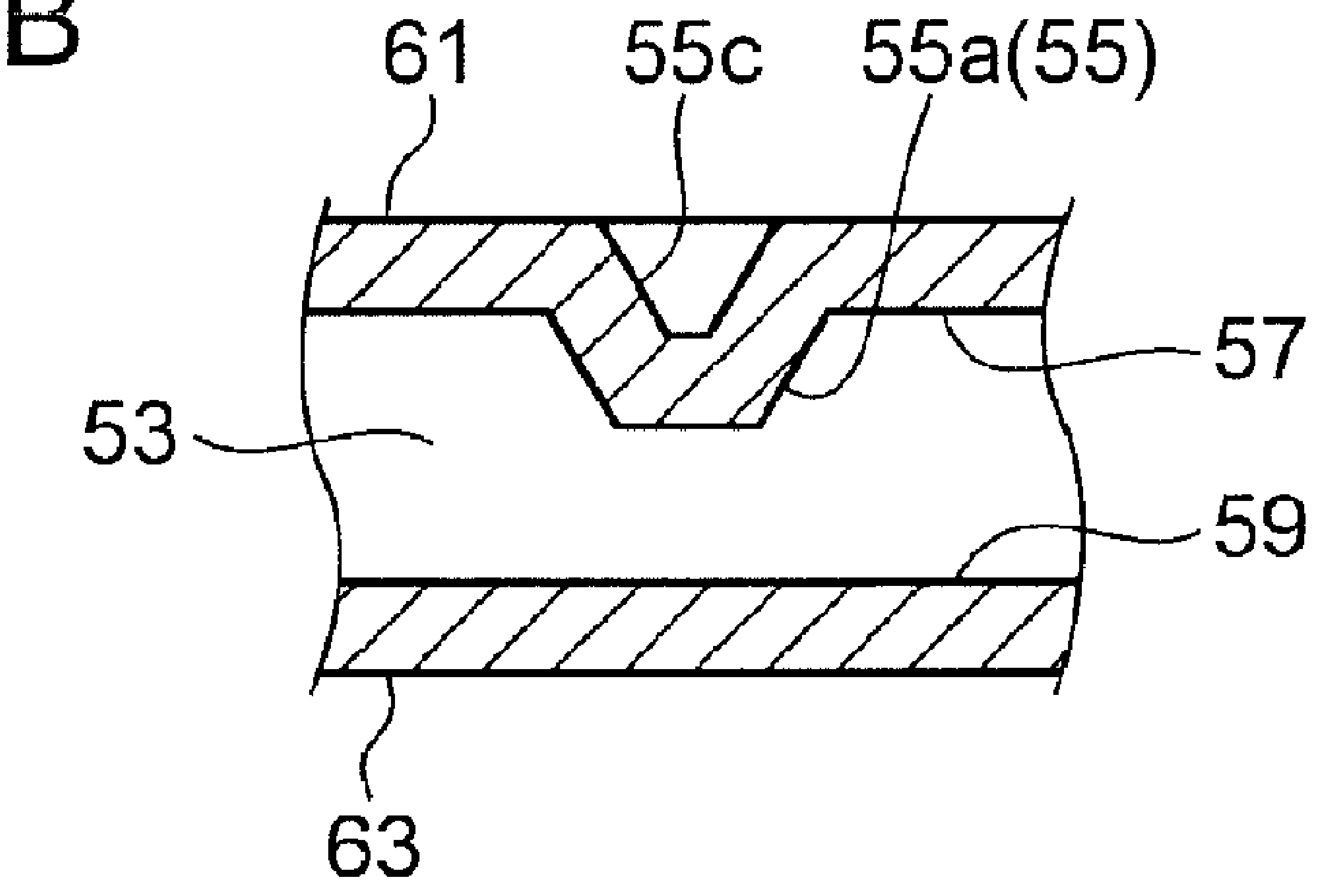


FIG.14C

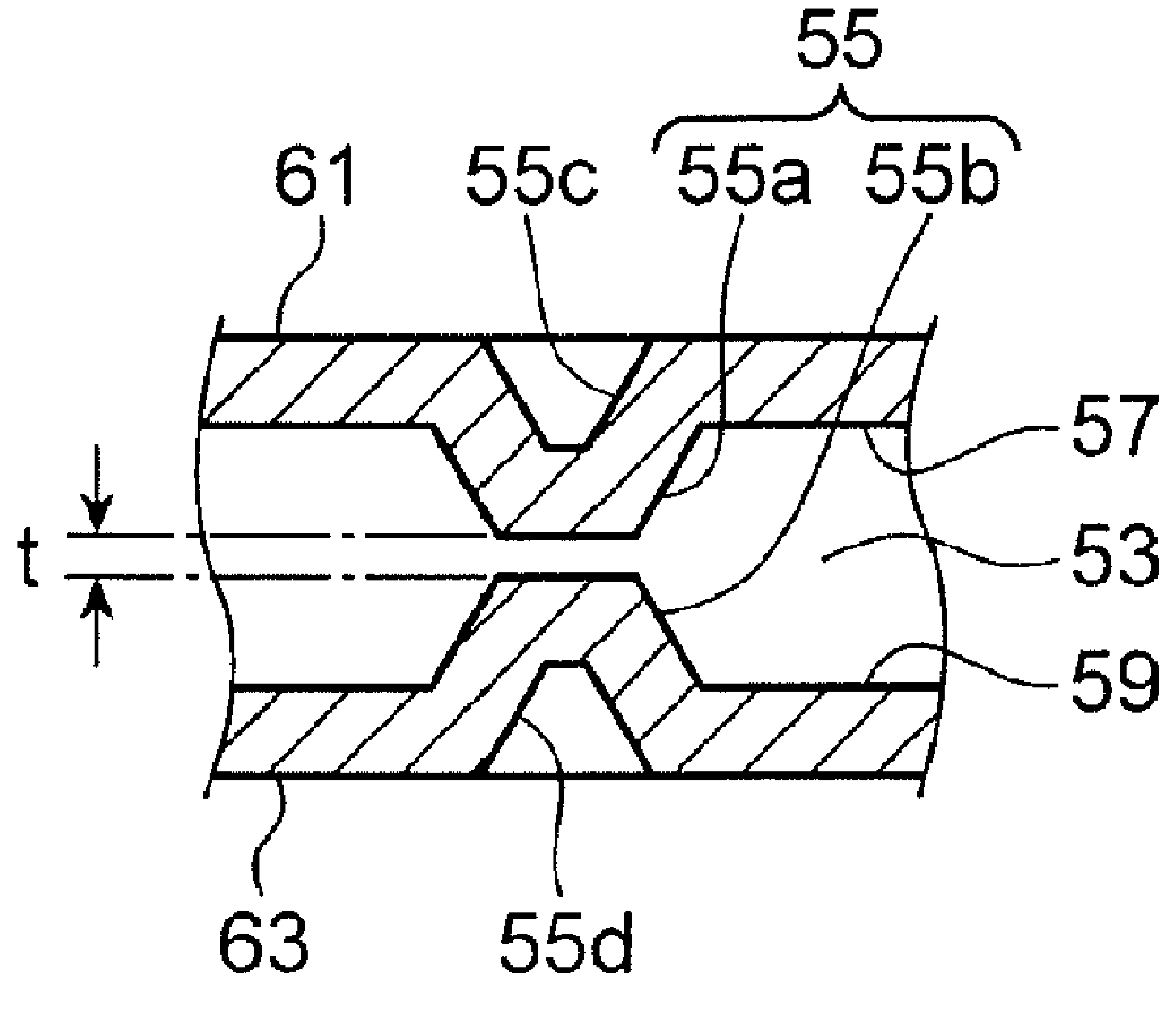


FIG.15

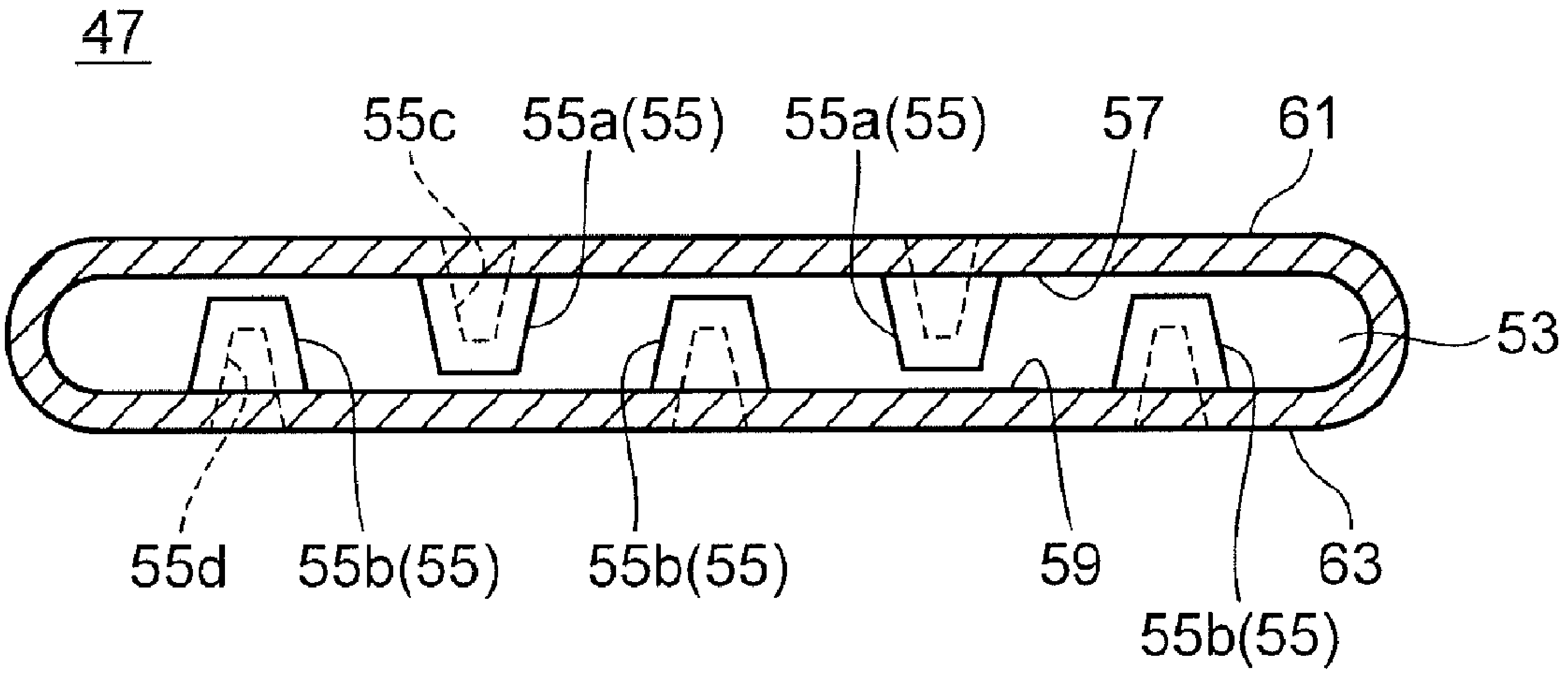


FIG.16

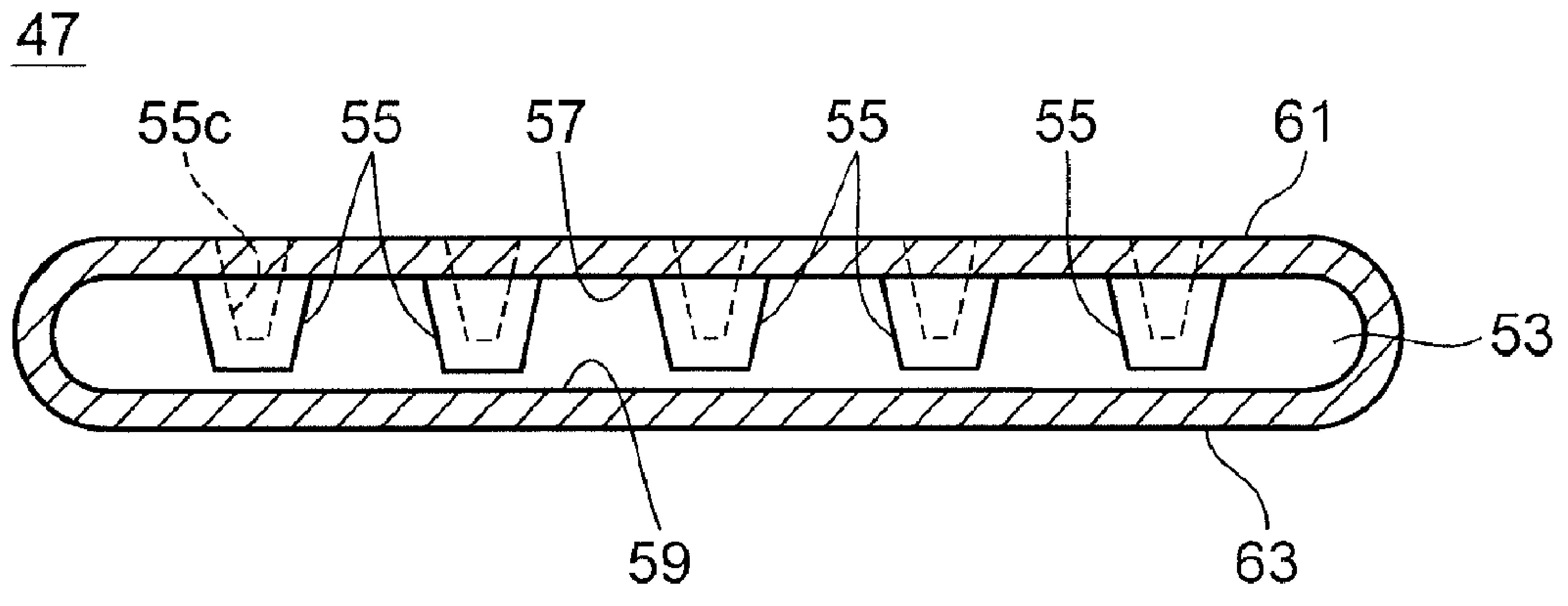


FIG.17A

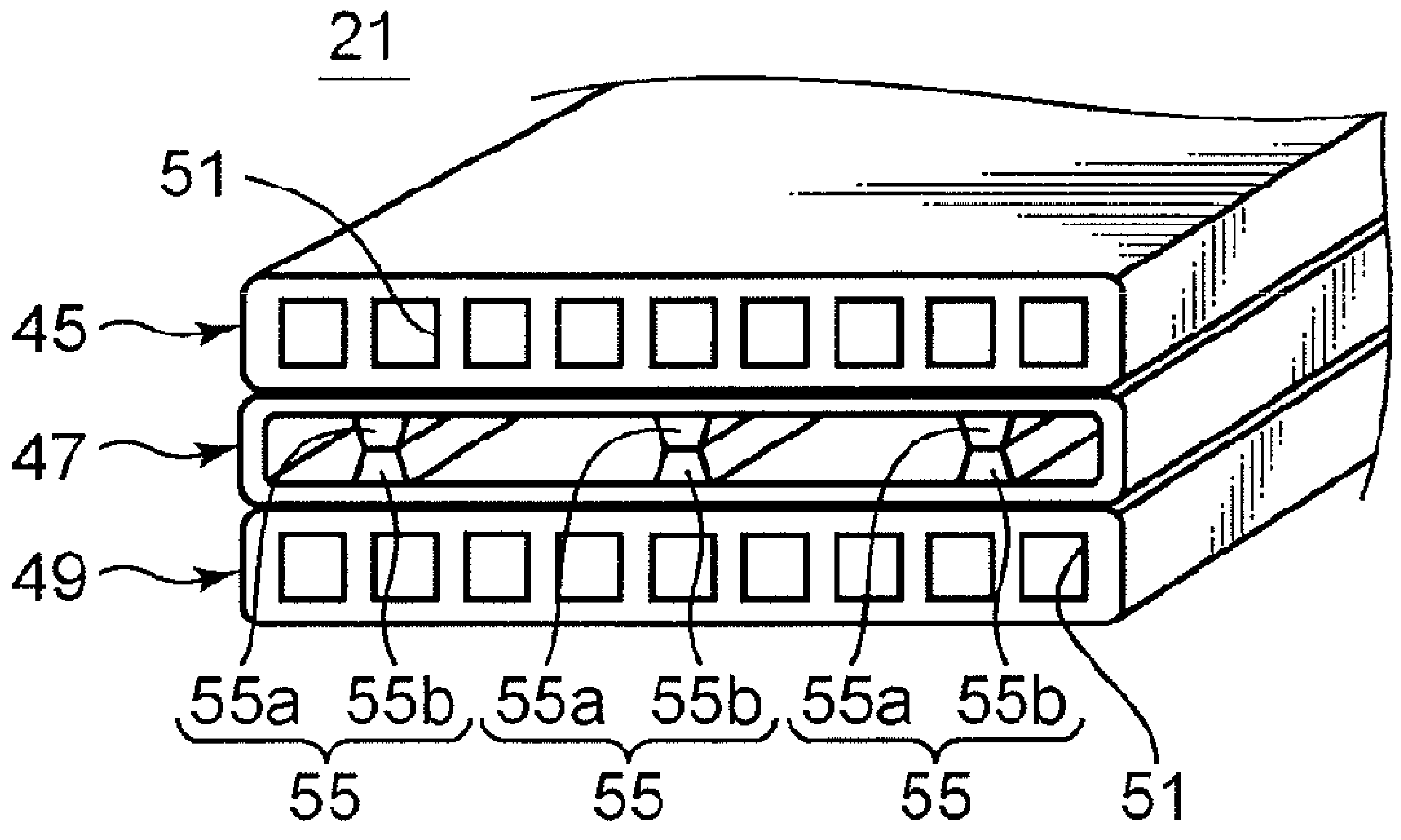


FIG.17B

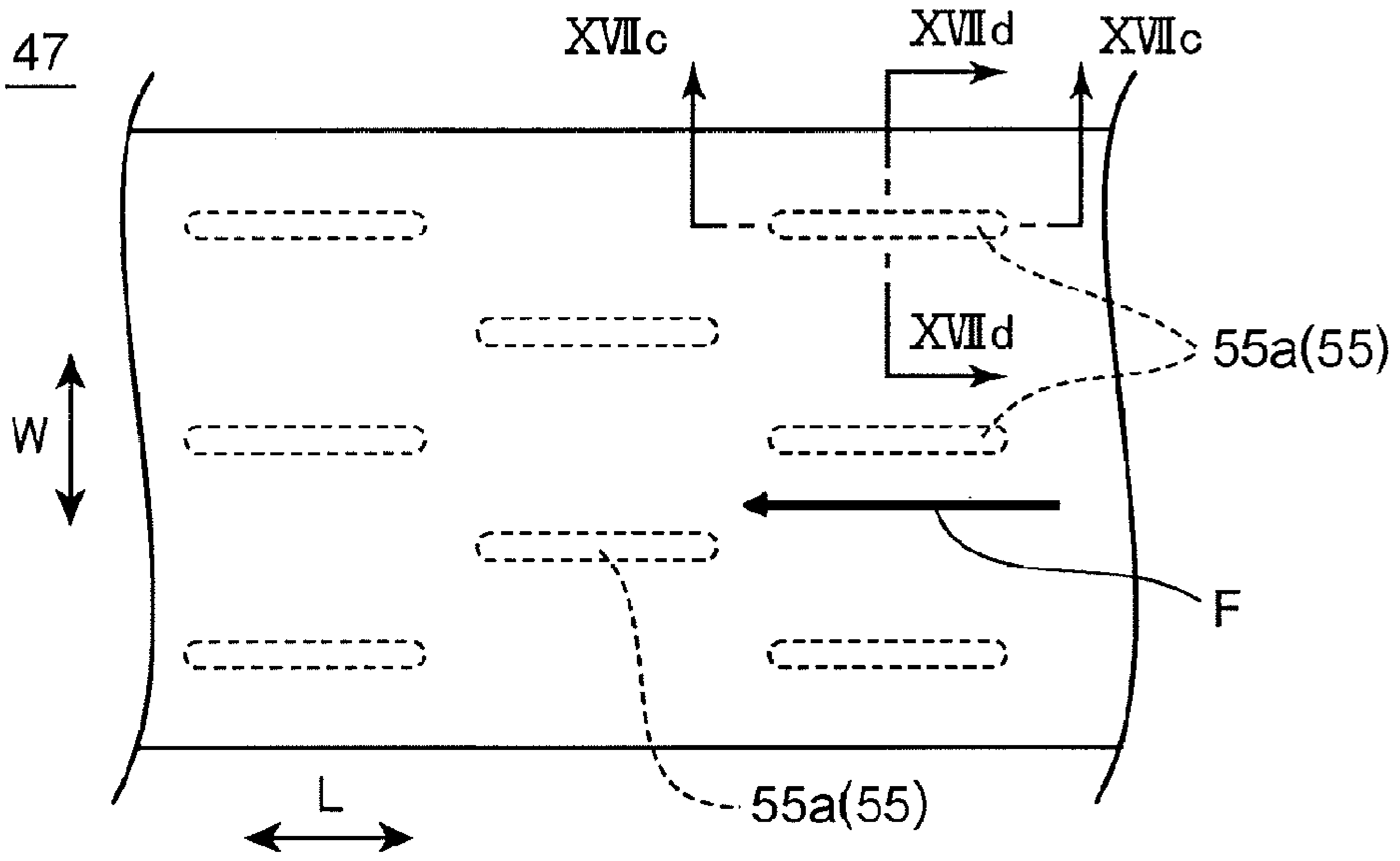


FIG.17C

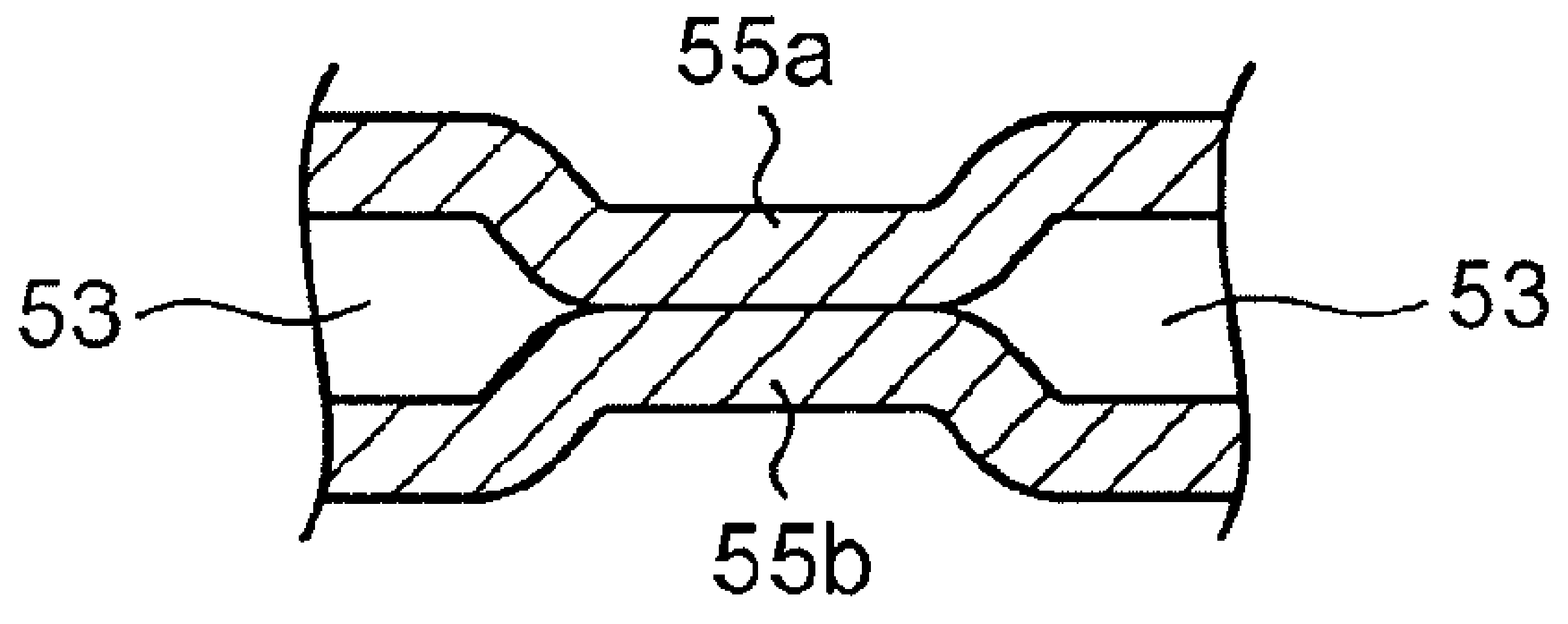


FIG.17D

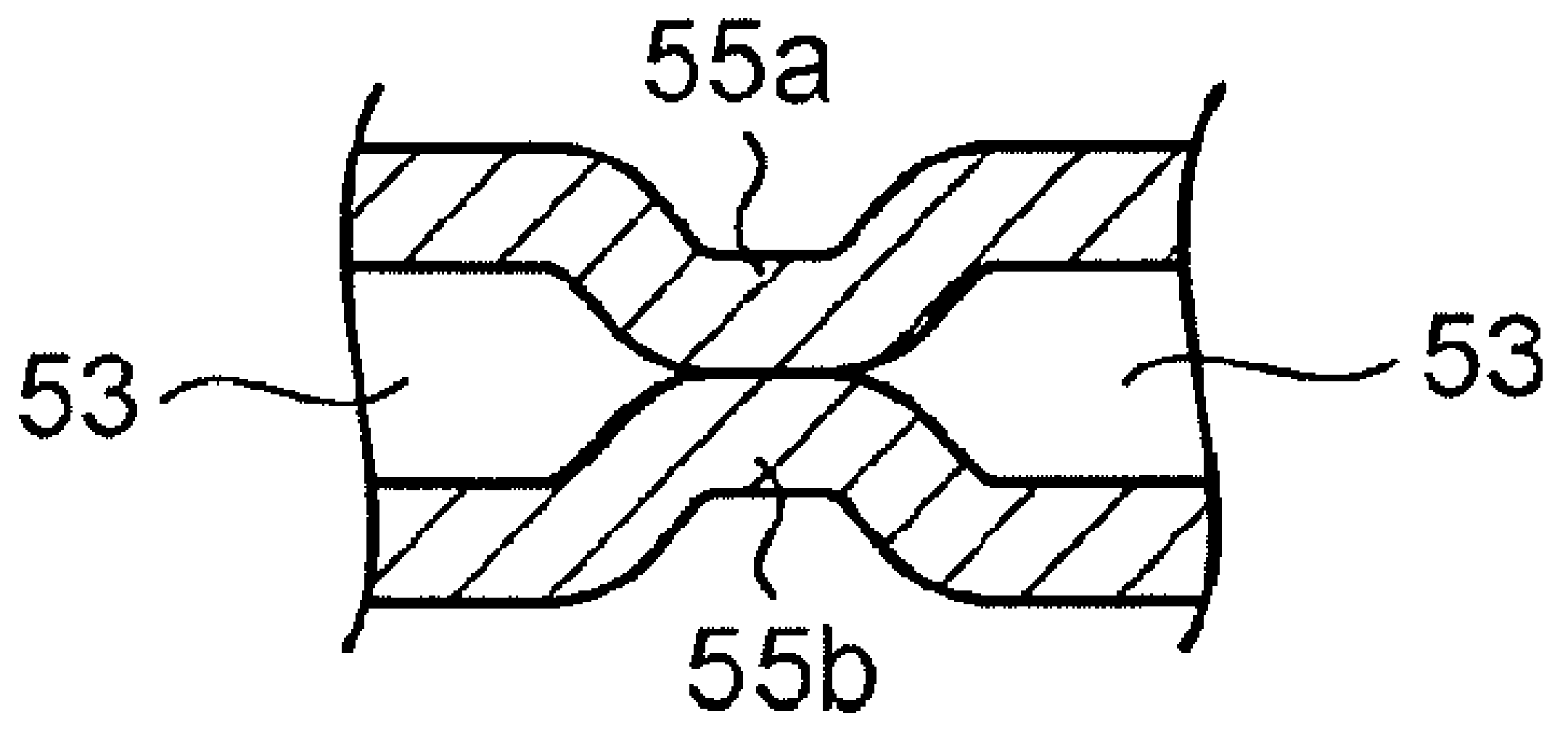


FIG.18A

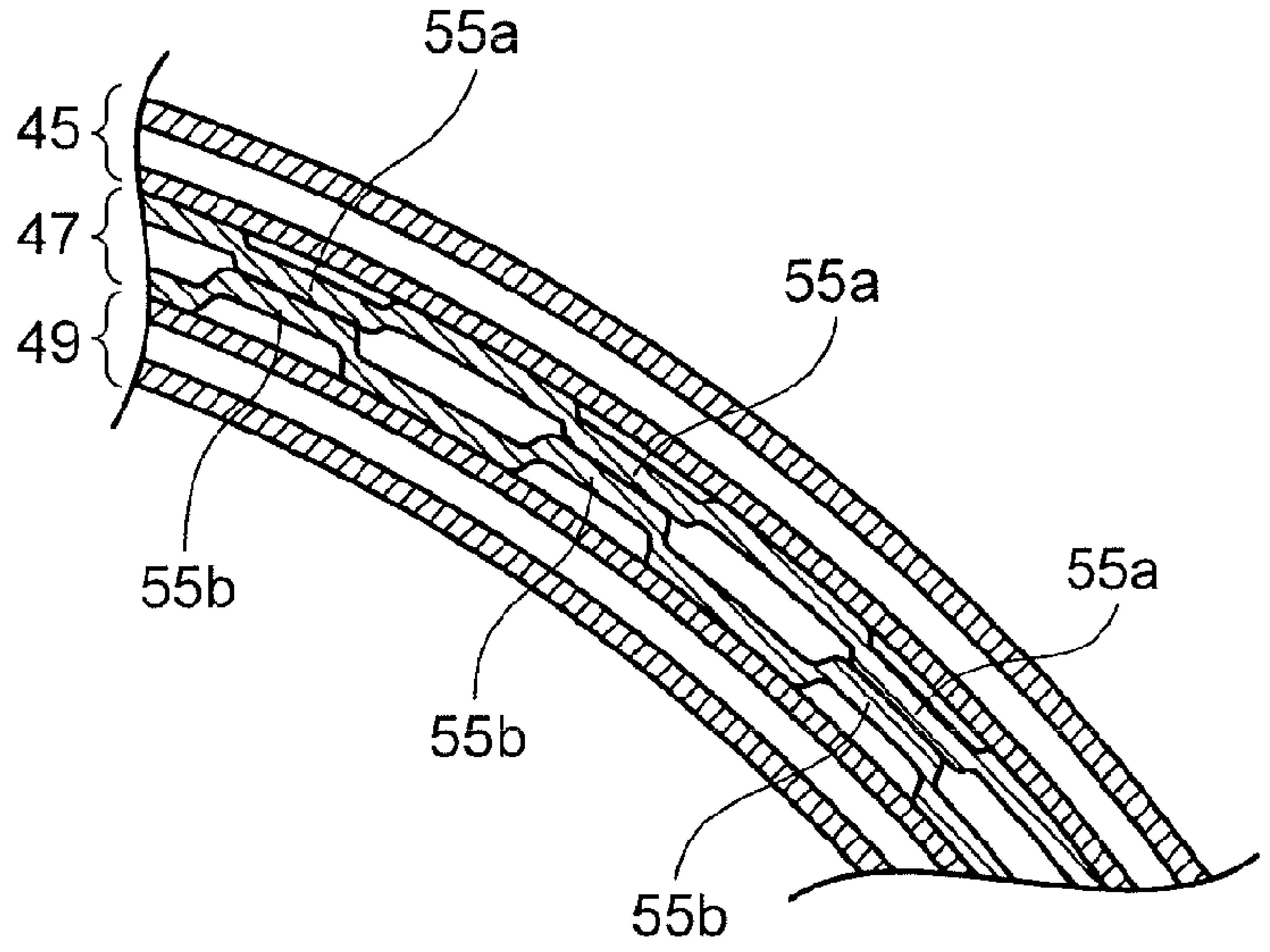


FIG.18B

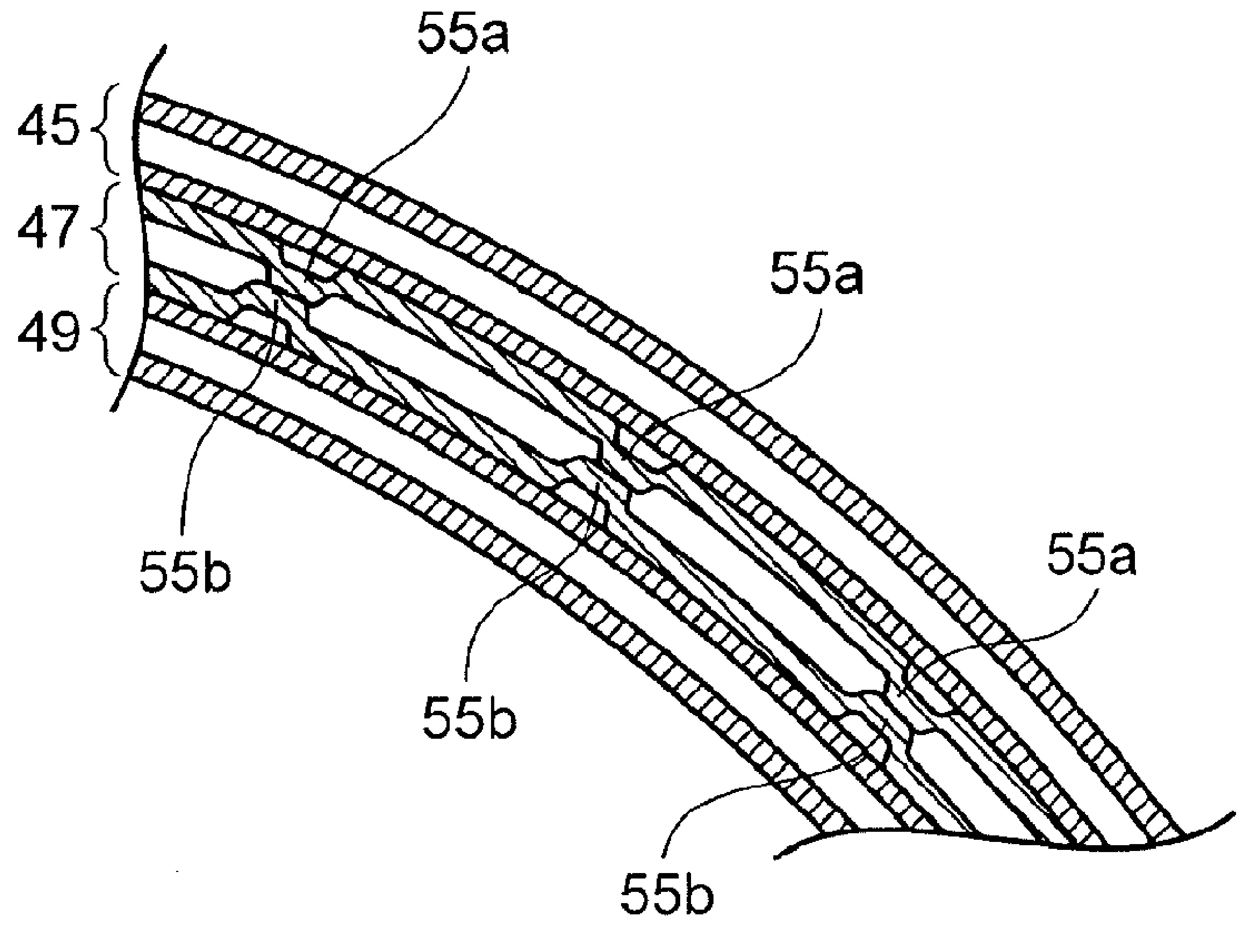


FIG.19

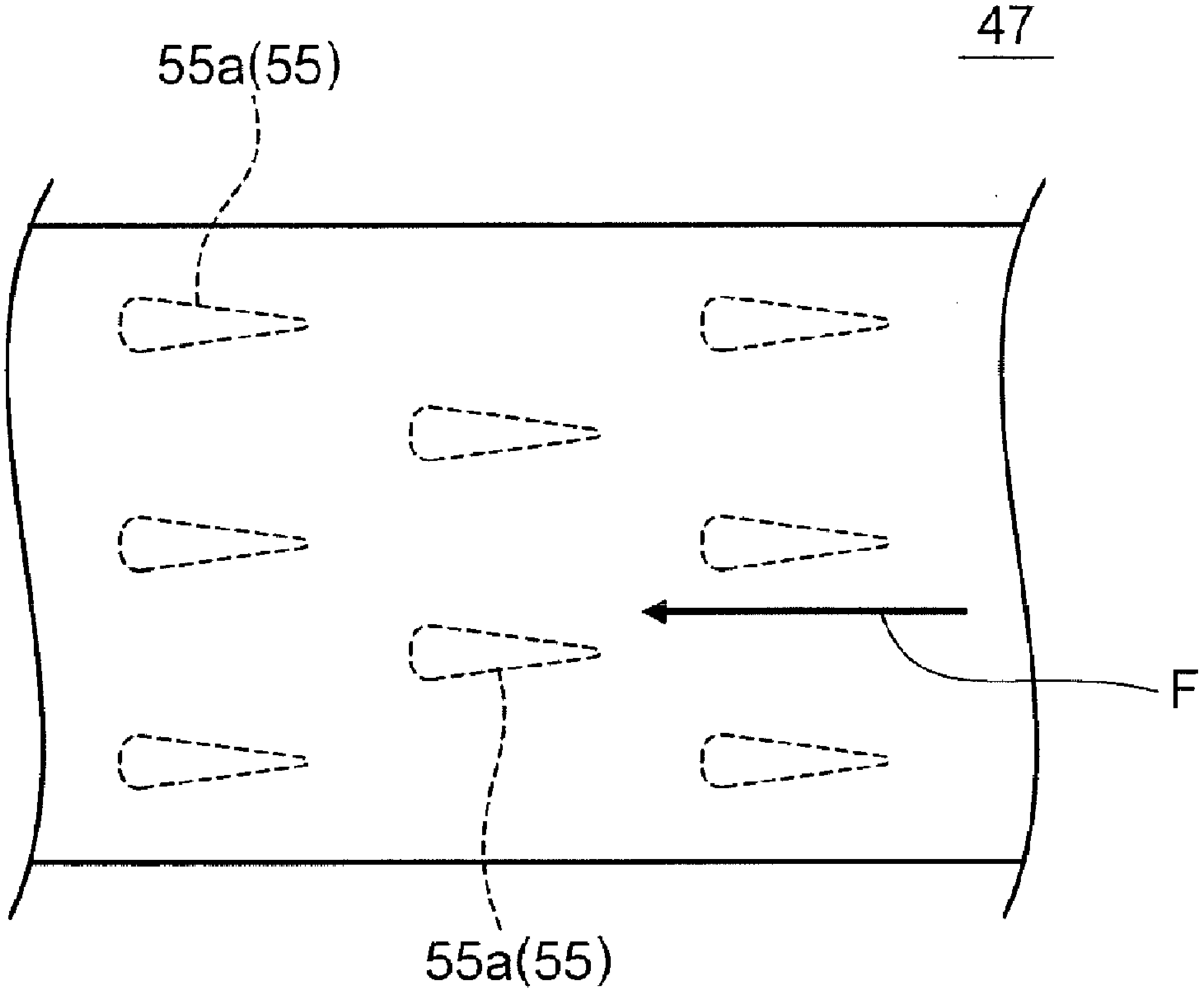


FIG.20

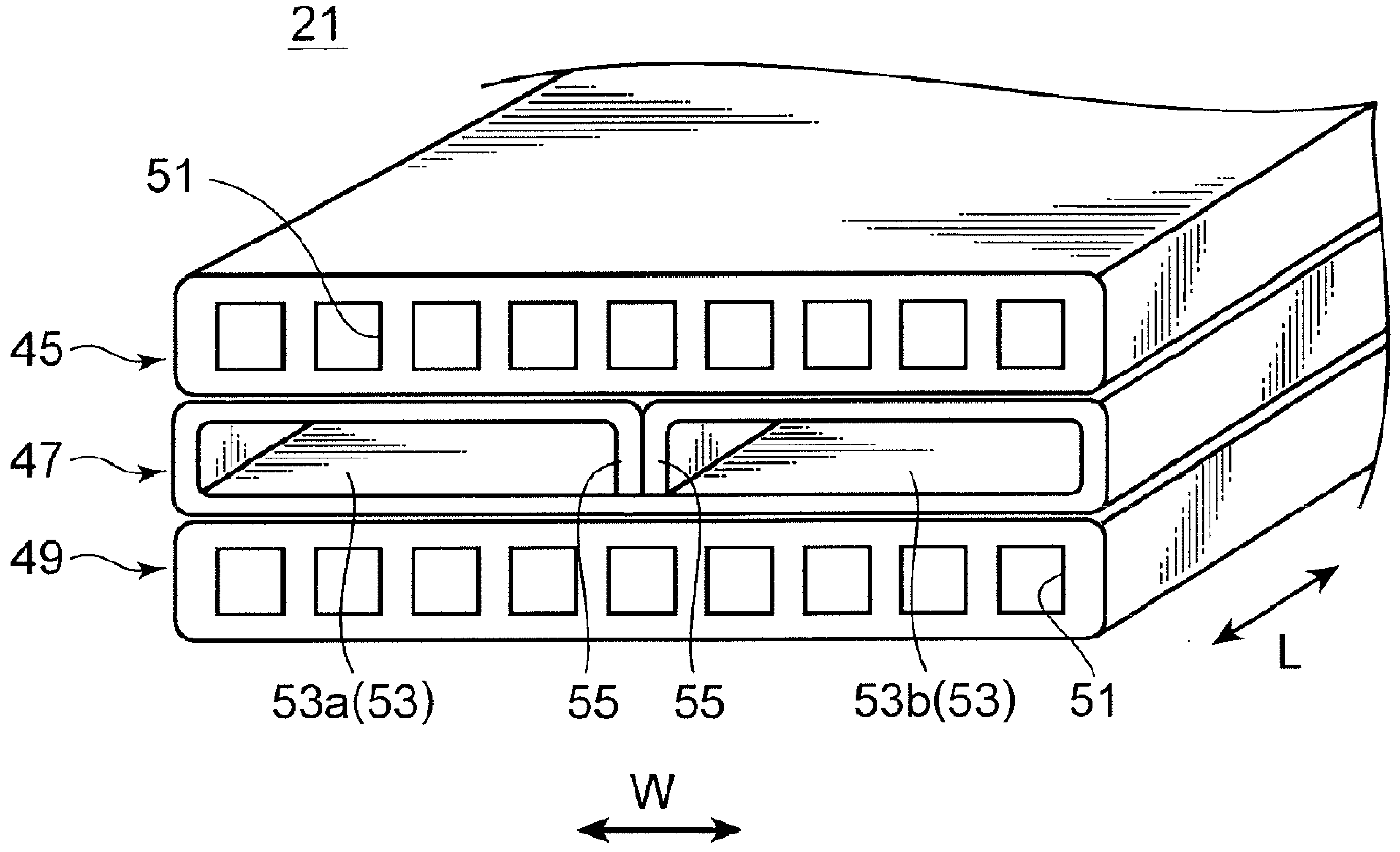


FIG.21A

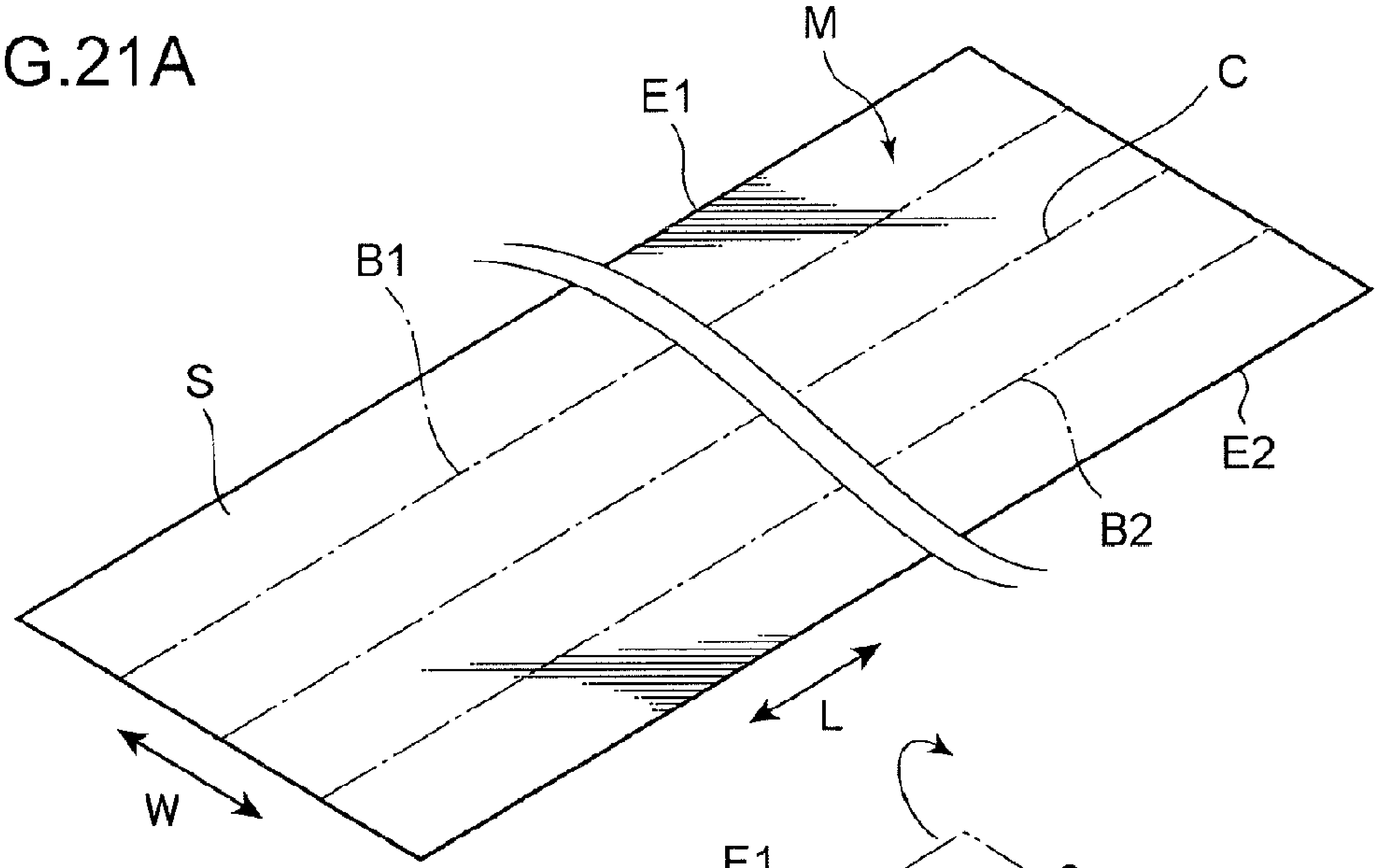


FIG.21B

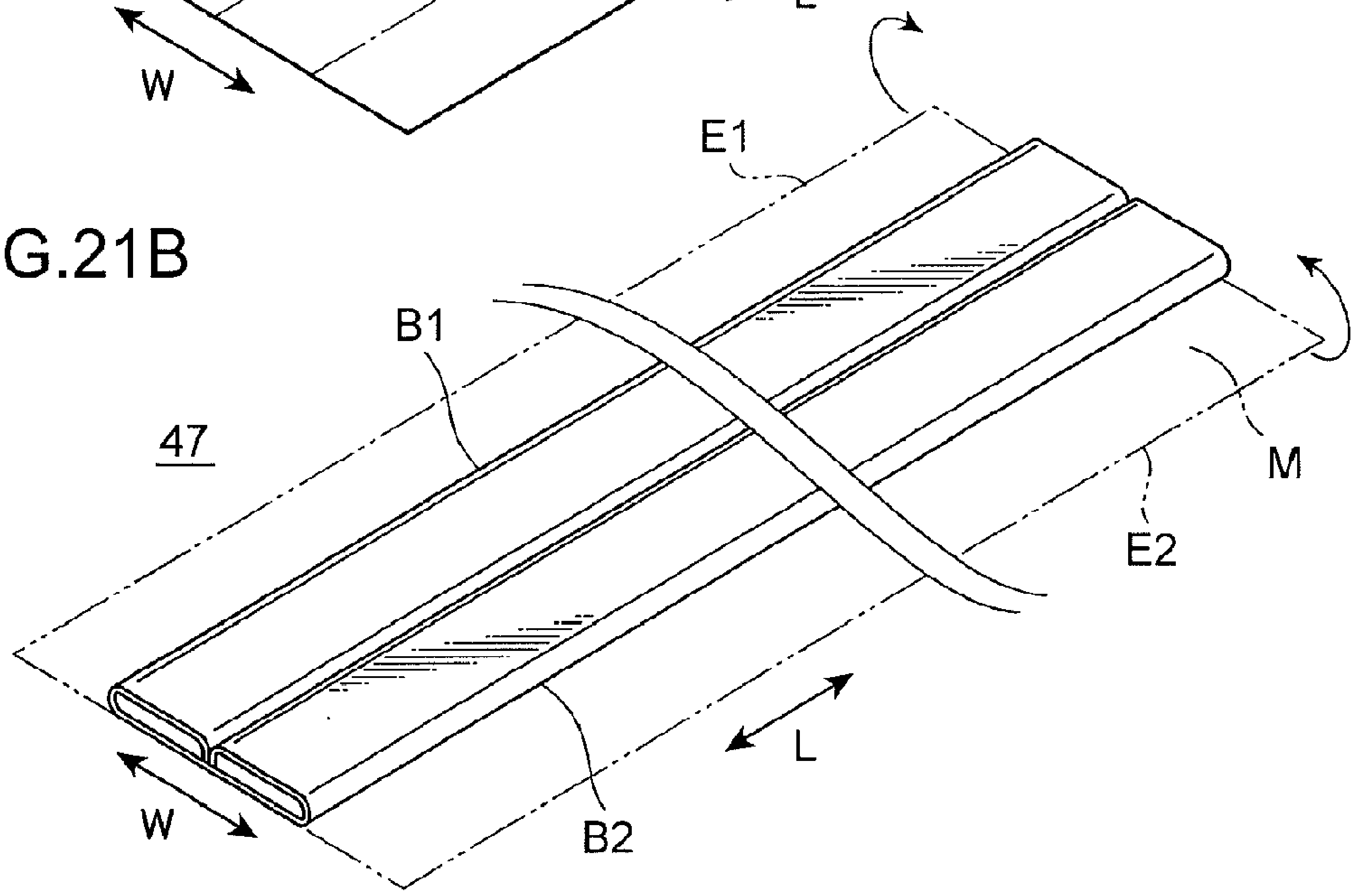


FIG.21C

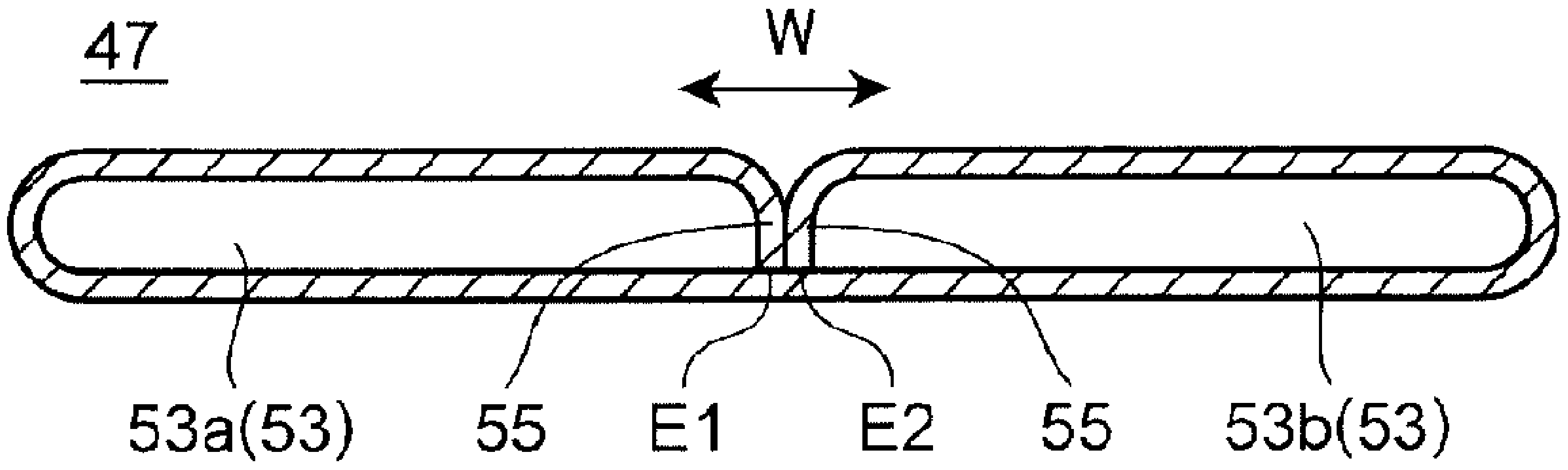


FIG.22A

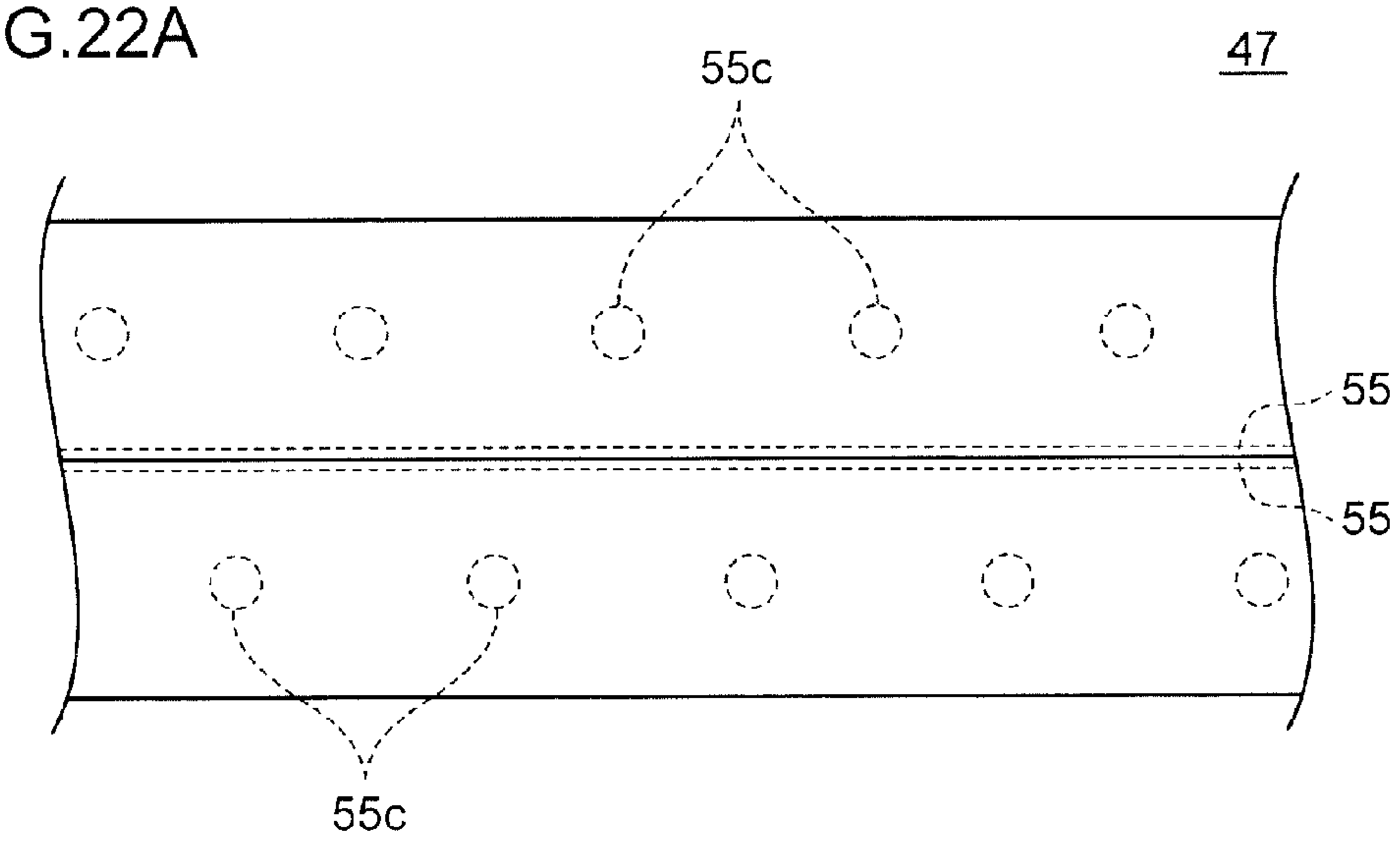


FIG.22B

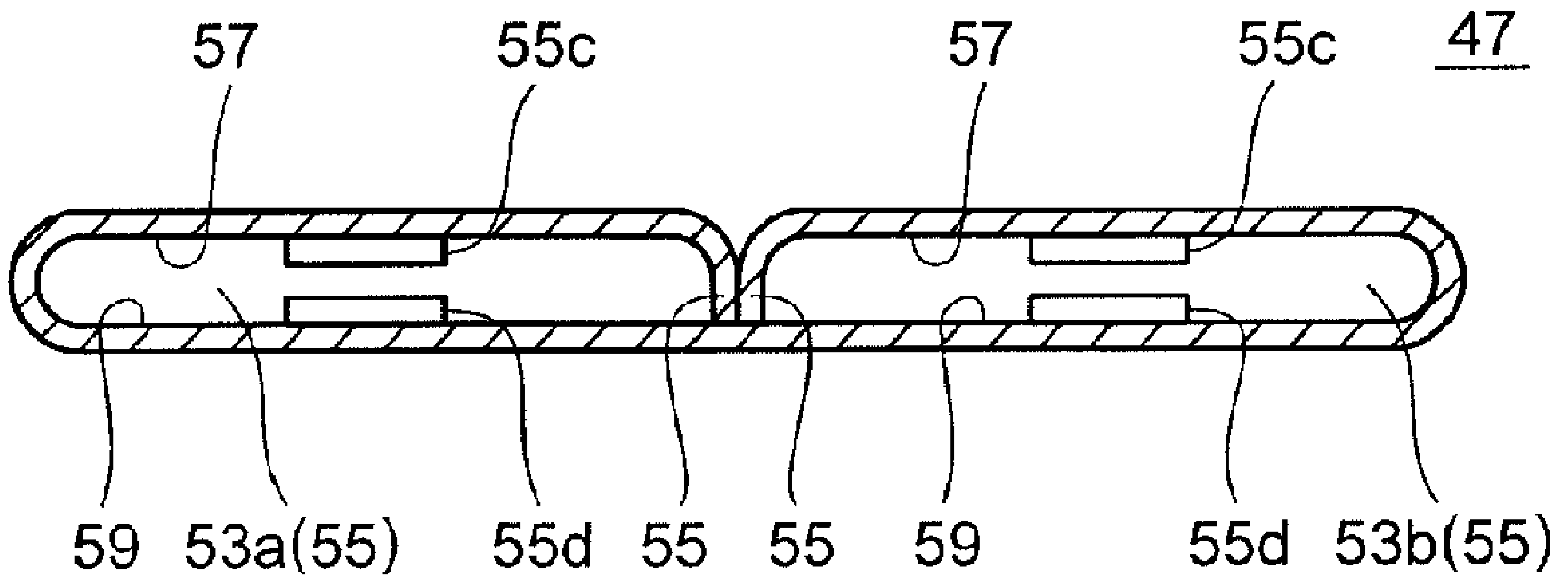


FIG.23A

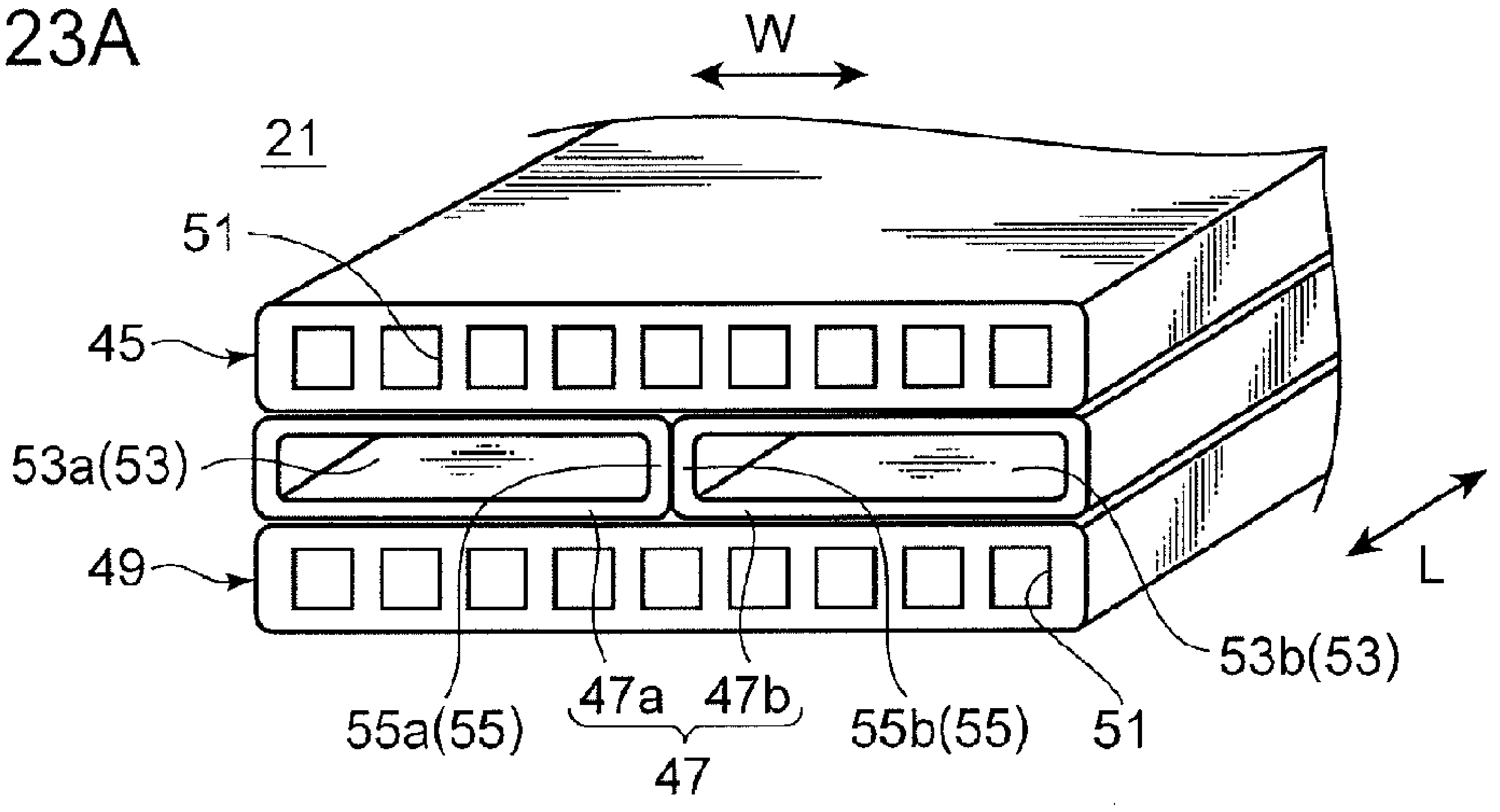


FIG.23B

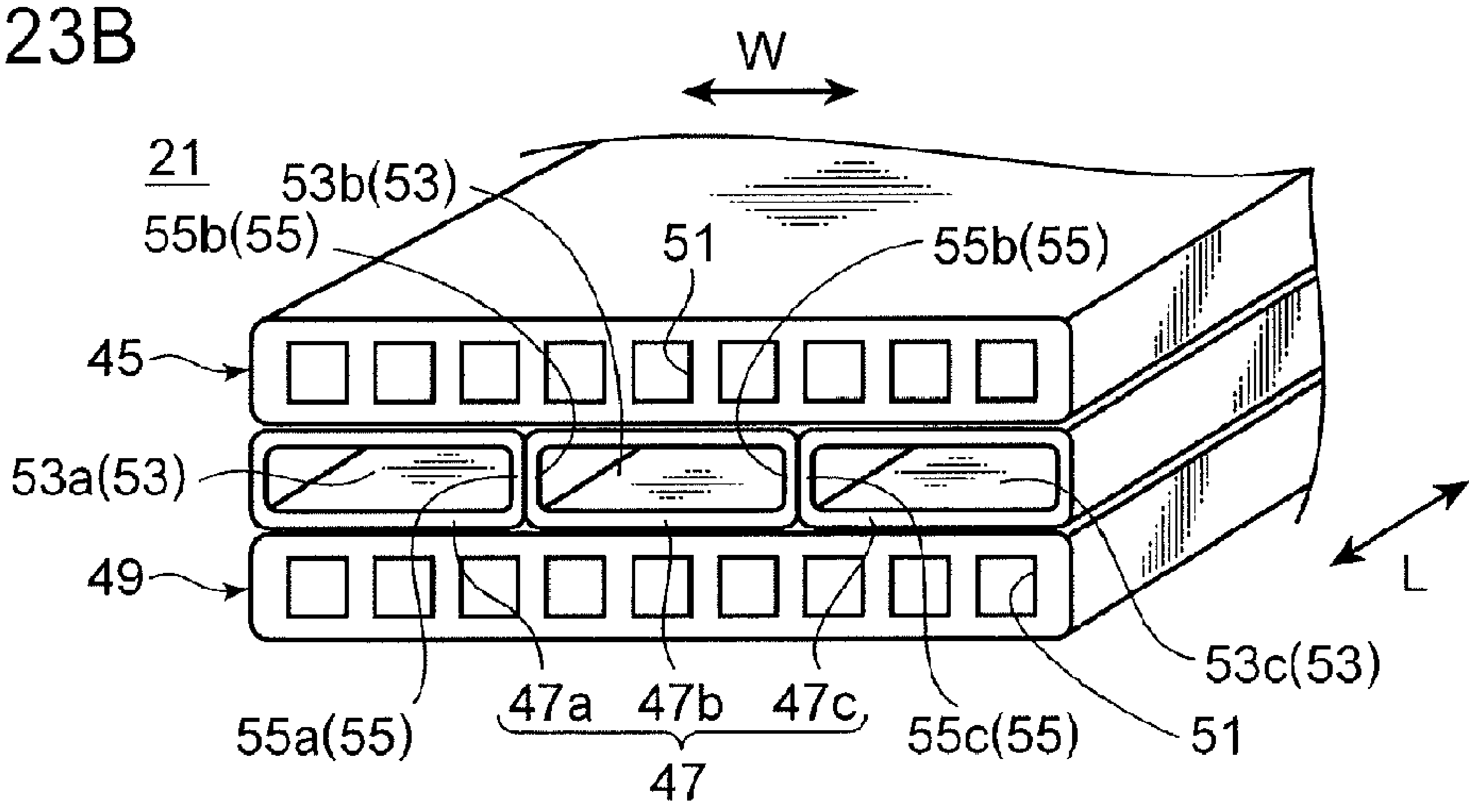


FIG.23C

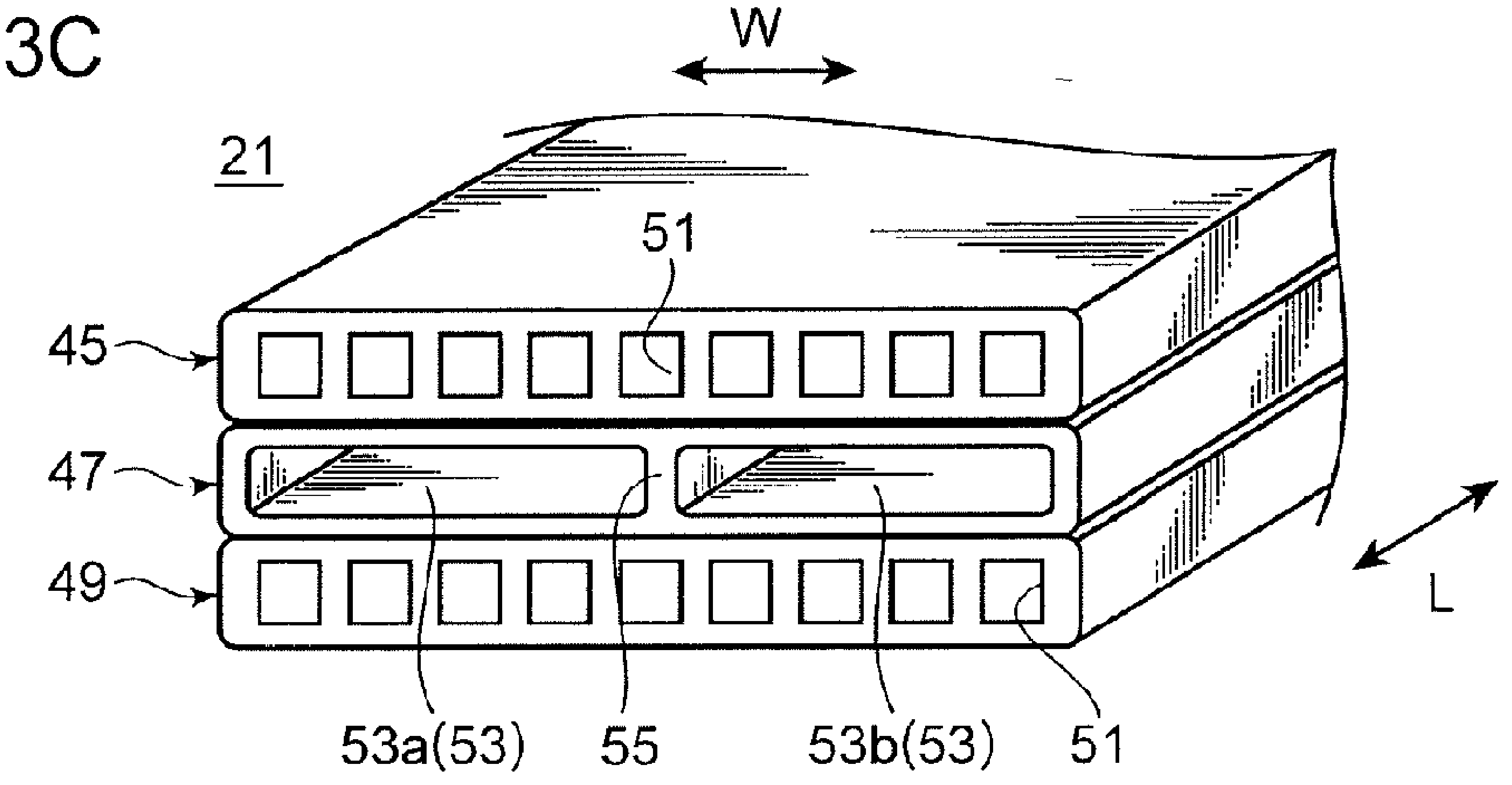


FIG.24A

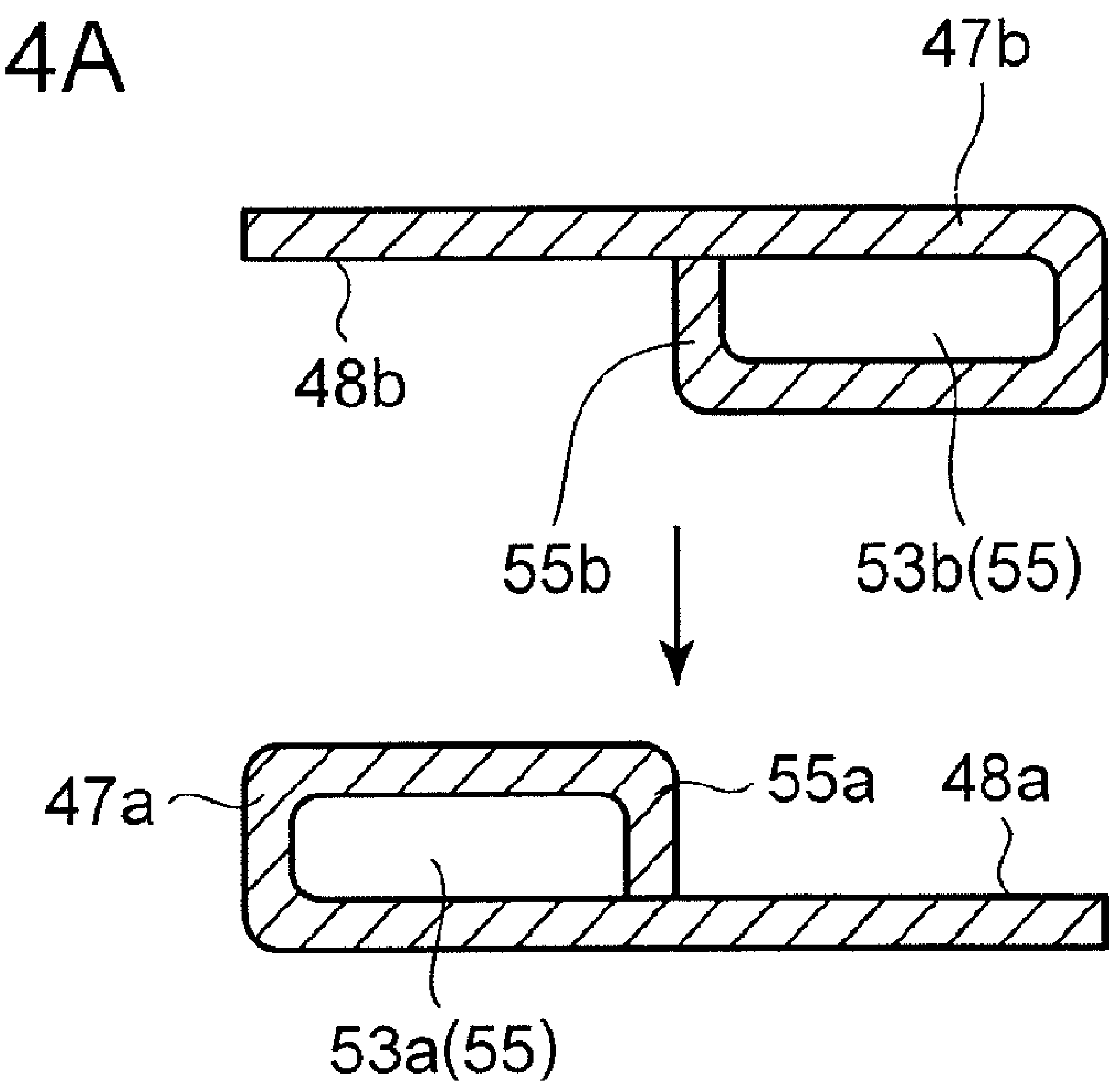


FIG.24B

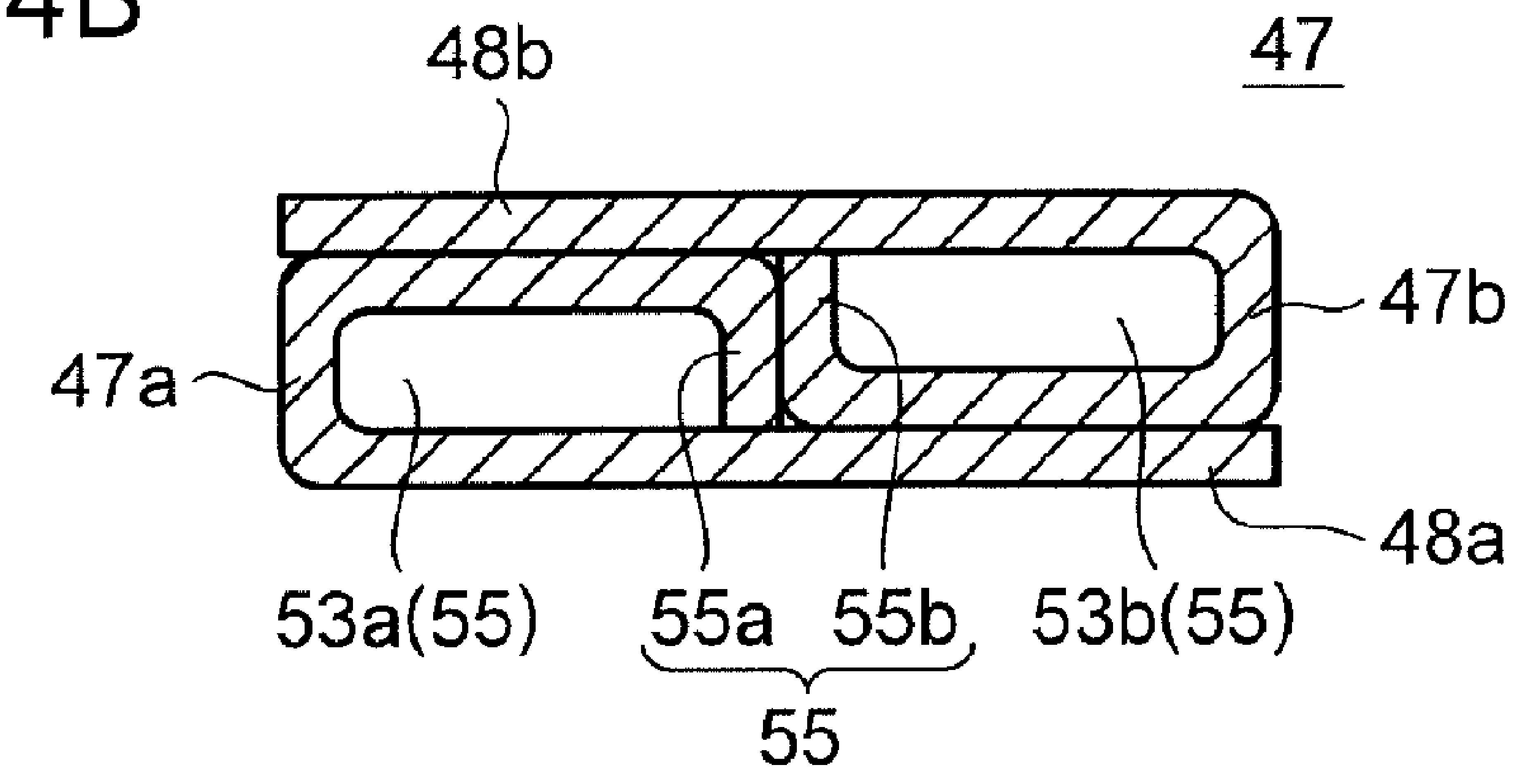


FIG.24C

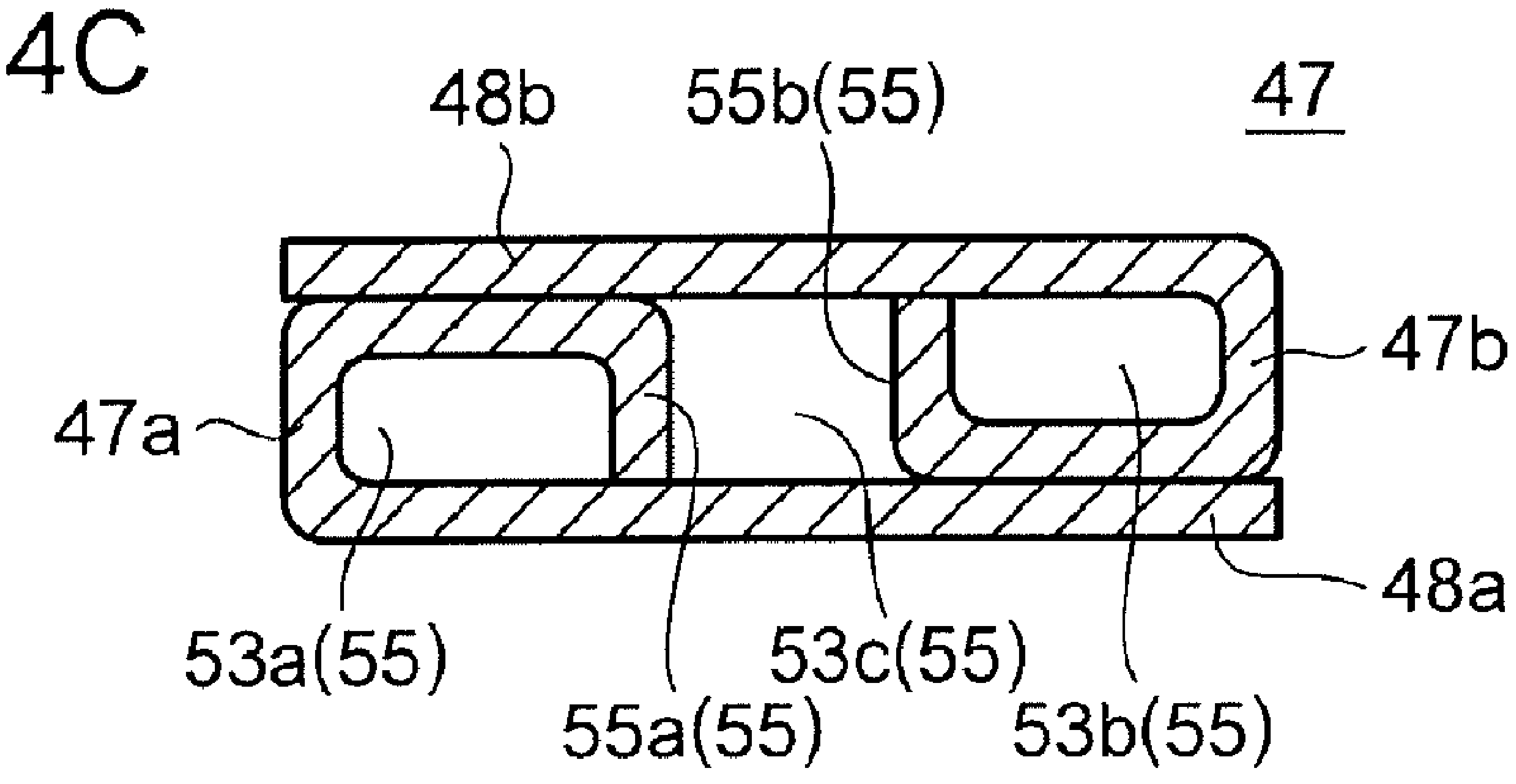


FIG.25

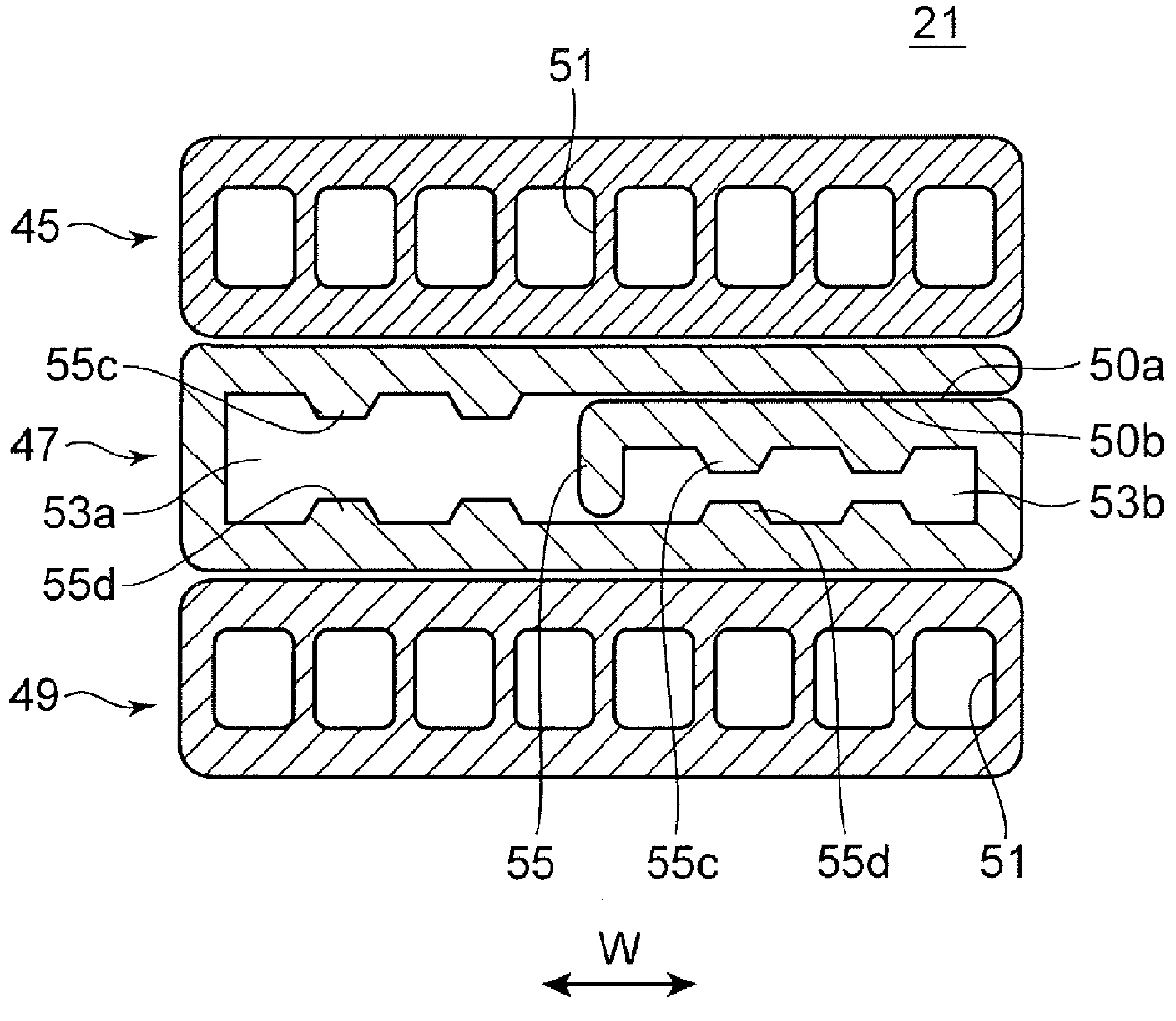


FIG.26A

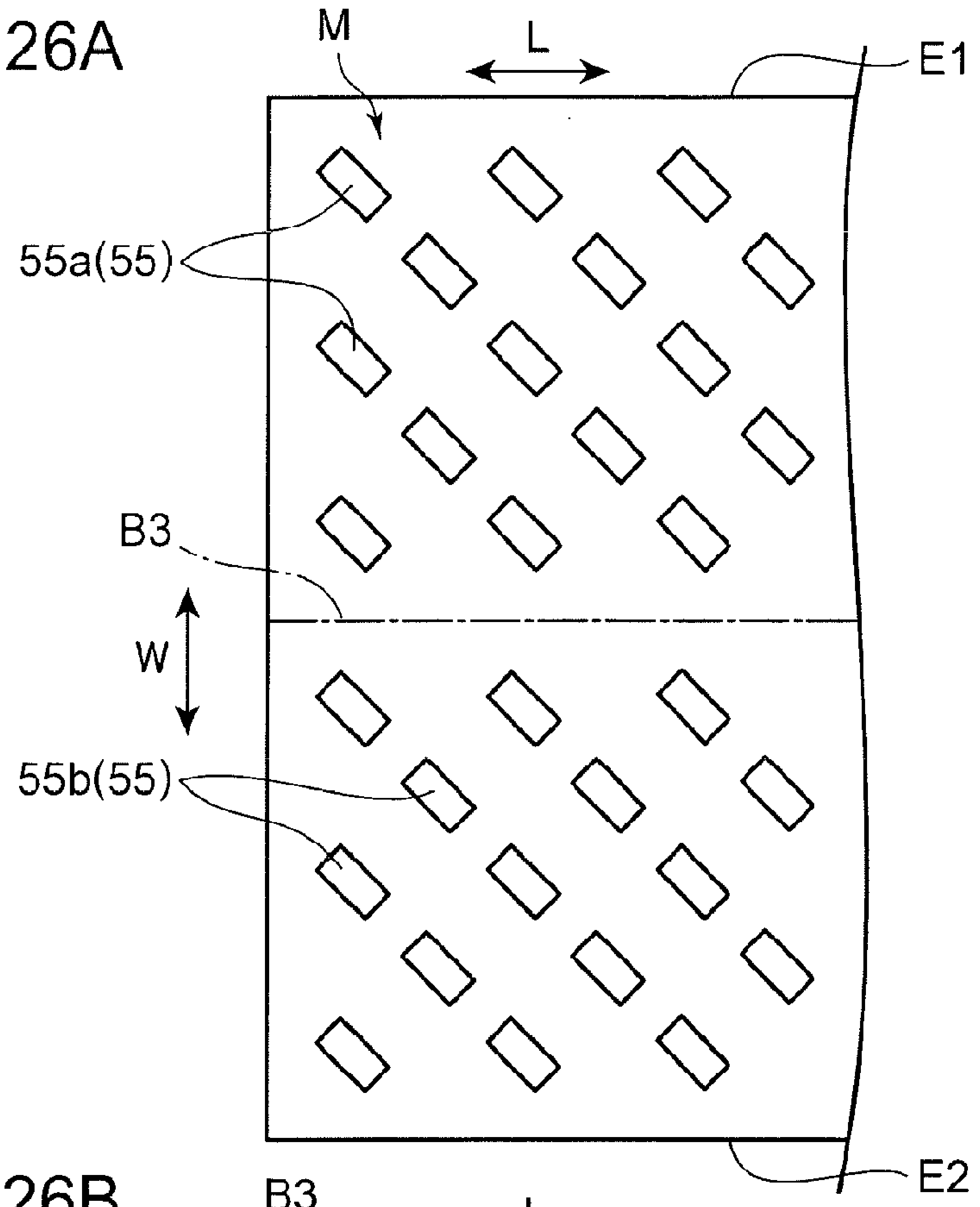


FIG.26B

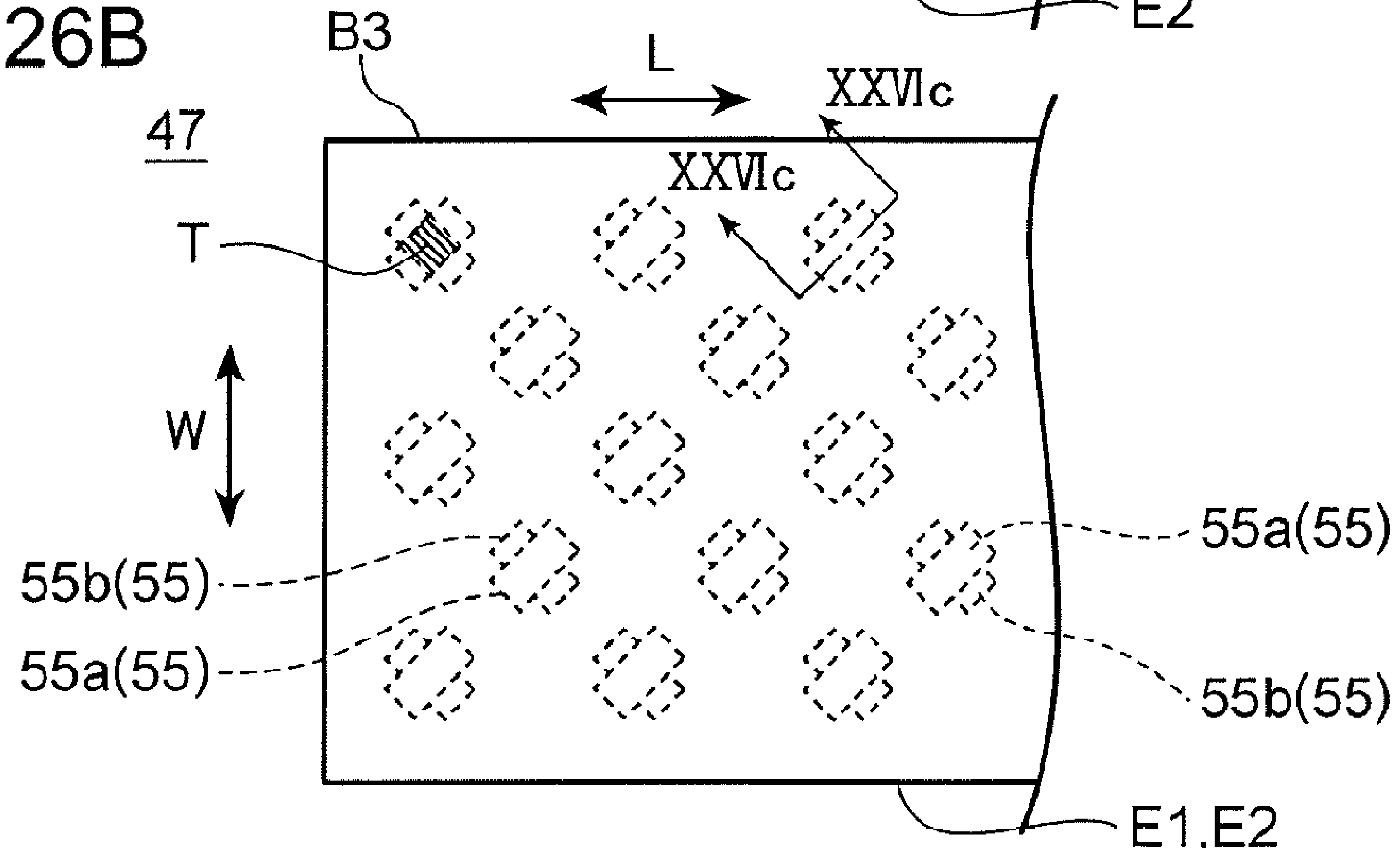


FIG.26C

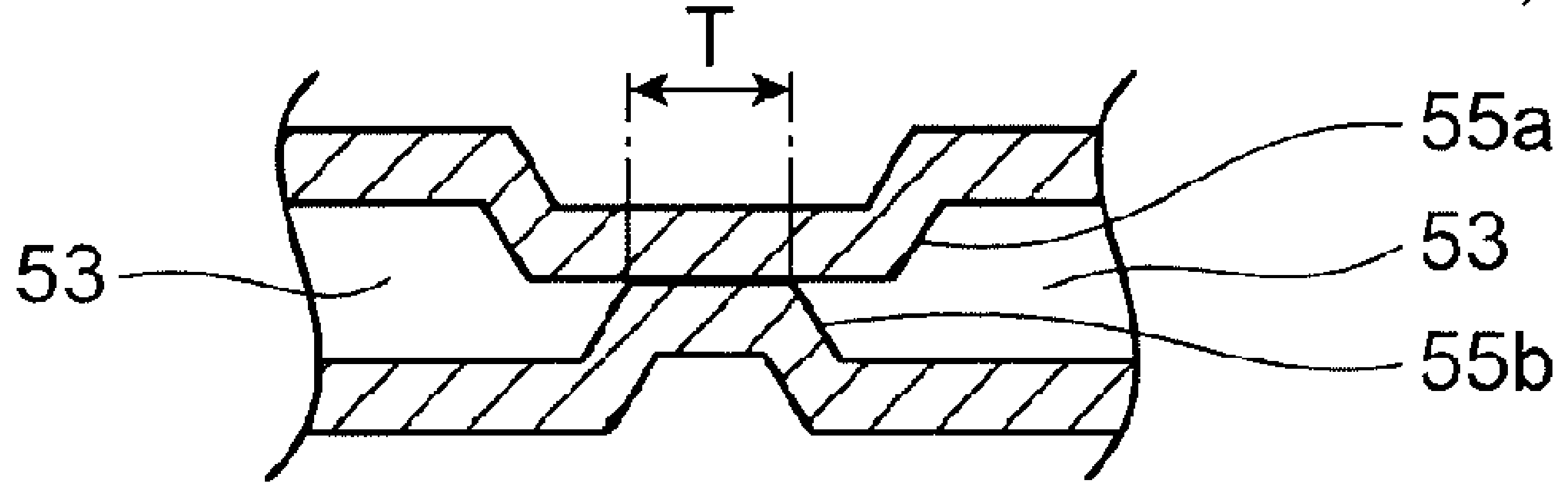


FIG.27A

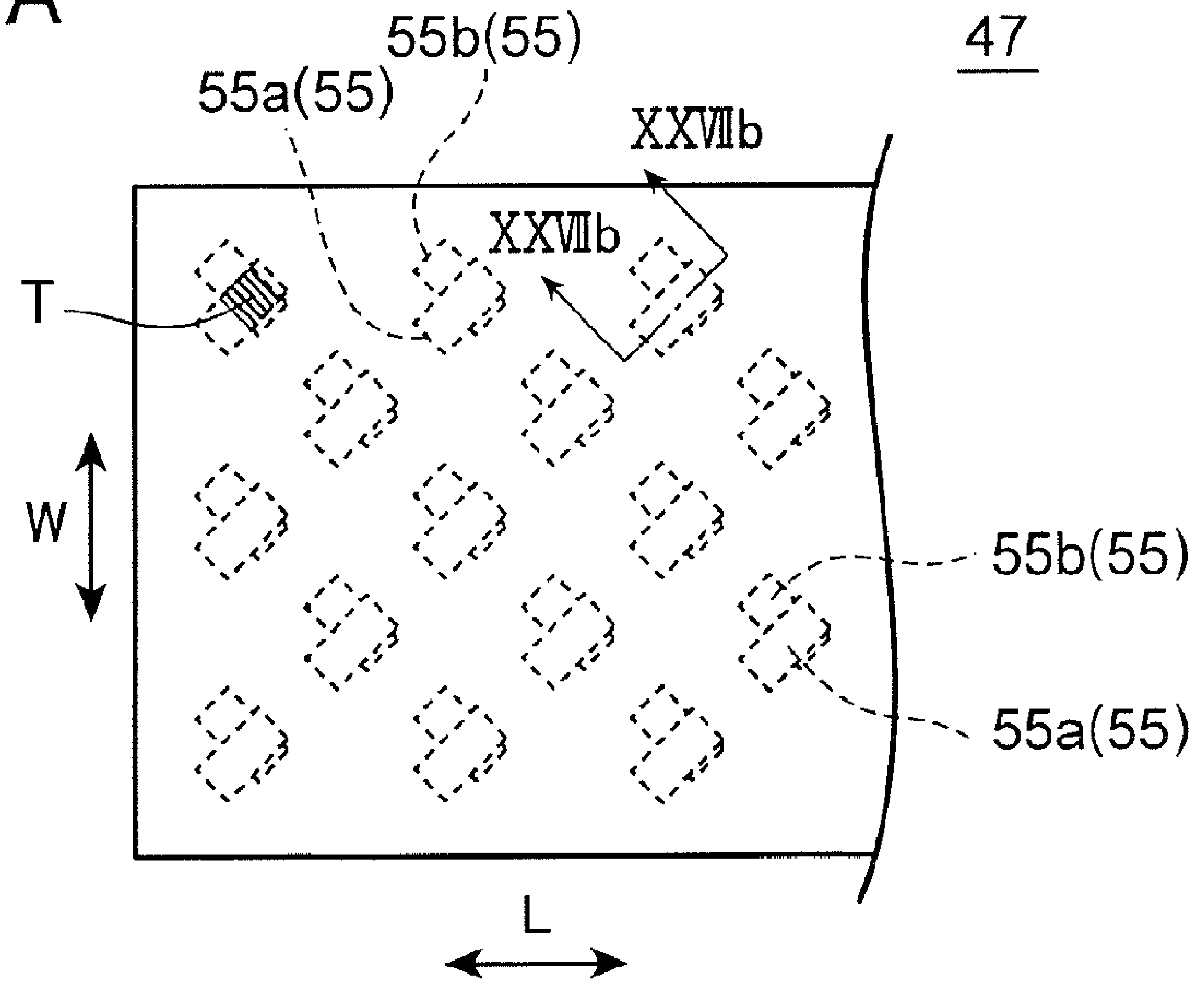
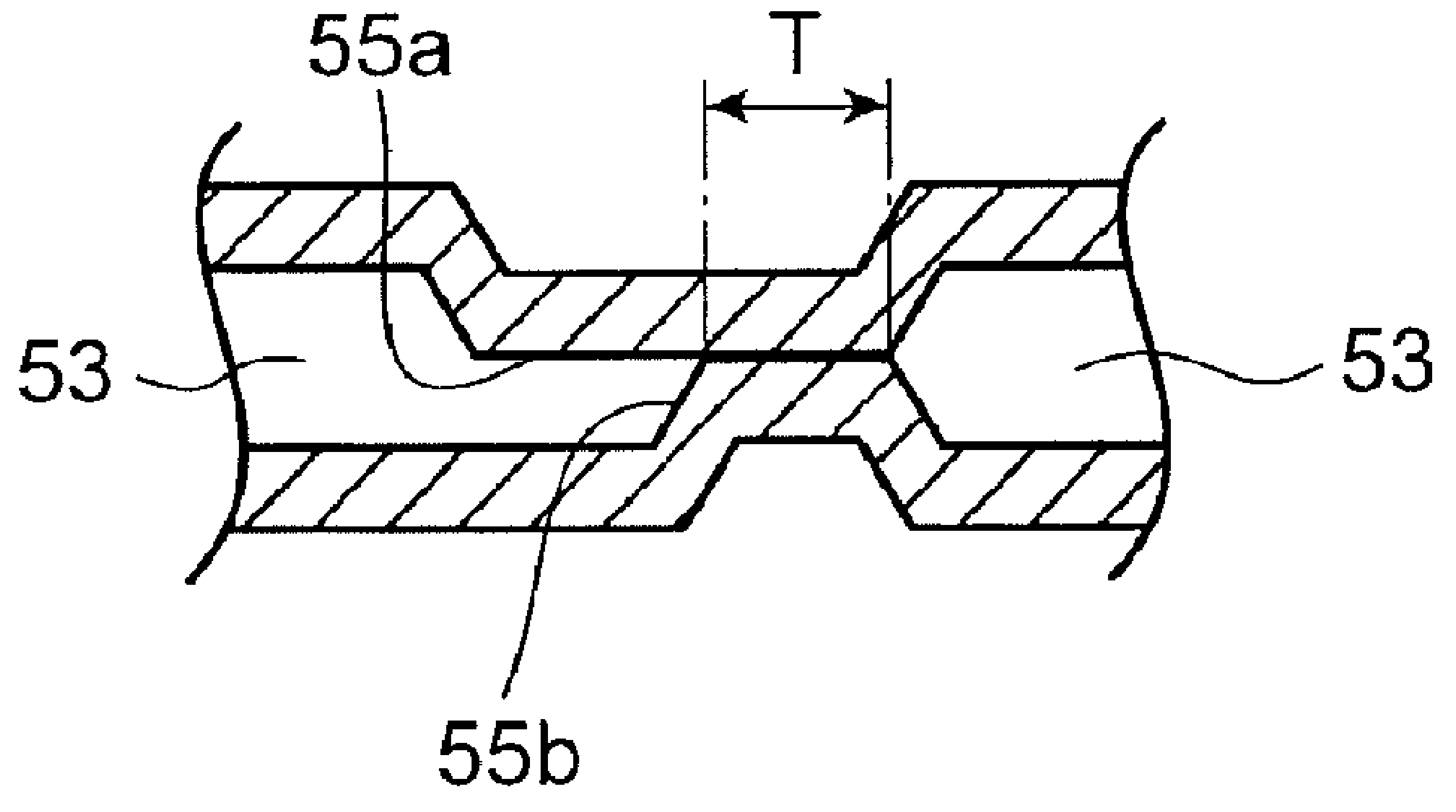


FIG.27B



HEAT EXCHANGER AND HEAT PUMP TYPE HOT WATER SUPPLY APPARATUS EQUIPPED WITH SAME

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger and a heat pump type hot water supply apparatus equipped with same.

BACKGROUND ART

[0002] Seam welding, which is a type of resistance welding, excels in productivity because the zones that are to be joined can be joined continuously, and seam welding is used for various applications.

[0003] For example, as disclosed in Patent Documents 1 and 2, seam welding is used when rounding a steel sheet to form a metal tube. More specifically, a steel tube is manufactured by disposing electrodes in the vicinity of two end surfaces of a steel sheet that has been rounded in a tubular shape such that the end surfaces face each other and forming a continuous seam by passing an electric current to the steel sheet via the electrodes, while moving the electrodes relative to the end surfaces.

[0004] Further, seam welding is also used in manufacturing fuel tanks for vehicles. More specifically, flange portions provided on the circumference of two metal sheets having receding portions are overlapped and the flange portions are welded together to manufacture a fuel tank by passing an electric current, while clamping the flange portions between a pair of roller electrodes.

[0005] Patent Document 1: Japanese Patent Application Publication No. S 62-50088.

[0006] Patent Document 2: Japanese Patent Application Publication No. S 54-112370.

[0007] When a heat exchanger for use in an air conditioner, a heat pump type hot water supply apparatus, or the like is manufactured, it is necessary to join together a metal tube having inside thereof a coolant flow channel where a coolant flows and a metal tube having inside thereof a fluid flow channel where fluid such as water or coolant flows. When the aforementioned resistance welding is used for joining these metal tubes together, the following problems are encountered.

[0008] Thus, when metal tubes are joined together by resistance welding, it is necessary to weld a plurality of stacked metal tubes, while pressurizing the metal tubes in the stacking direction by a pair of roller electrodes. However, where hollow metal tubes are resistance welded, while being pressurized with a pair of roller electrodes, the metal tubes collapse and the hollow portions are almost entirely eliminated. Therefore, the metal tubes cannot function sufficiently as flow channels for coolants or fluids and the desired efficiency of heat exchange cannot be obtained. Where the pressurization in the stacking direction of the plurality of metal tubes is insufficient, the metal tubes cannot be sufficiently joined and the efficiency of heat exchange is therefore decreased.

[0009] Further, an elongated heat exchanger obtained by joining metal tubes is sometimes used in a compact form obtained by bending in order to save space. In such a case, the metal tubes sometimes collapse in the bending zone and the hollow portions are almost entirely eliminated. Where the hollow portions of metal tubes are eliminated, the metal tubes cannot function sufficiently as flow channels for coolants or fluids and the desired efficiency of heat exchange cannot be obtained.

SUMMARY OF THE INVENTION

[0010] The present invention has been created with the foregoing in view and it is an object of the present invention to provide a heat exchanger with excellent heat exchange efficiency and a heat pump type hot water supply apparatus equipped with such a heat exchanger.

[0011] The heat exchanger in accordance with the present invention includes a metal tube (**47**) that has a flat shape with a width greater than a thickness, a fluid flow channel (**53**) formed inside thereof along a longitudinal direction, respective outer surfaces (**61**, **63**) formed on one side and the other side in a thickness direction, and a support portion (**55**) formed in the fluid flow channel (**53**) and inhibiting deformation in the thickness direction; and a multiple-hole metal tube (**45**) stacked on one side of the metal tube (**47**) in the thickness direction and having a flat shape with a width greater than a thickness, a plurality of fluid flow channels (**51**) formed inside thereof along the longitudinal direction, and the multiple-hole metal tube (**45**) having an opposing surface (**65**) disposed opposite the outer surface (**61**) on the one side of the metal tube (**47**) and joined by at least part thereof to the outer surface (**61**) on the one side.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a configuration diagram illustrating a heat pump type hot water supply apparatus according to an embodiment of the present invention.

[0013] FIG. **2** is a perspective view illustrating a heat exchanger according to the first embodiment of the present invention.

[0014] FIG. **3** is a cross-sectional view taken along the line in FIG. **2**.

[0015] FIG. **4** is a cross-sectional view taken along the IV-IV line in FIG. **3**.

[0016] FIG. **5** is a front view illustrating a method for manufacturing a heat exchanger by resistance welding.

[0017] FIG. **6** is a perspective view illustrating a metal tube and a multiple-hole metal tube that have been resistance welded.

[0018] FIG. **7** is a cross-sectional view illustrating a heat exchanger according to the second embodiment of the present invention.

[0019] FIG. **8** is a cross-sectional view illustrating a heat exchanger according to the third embodiment of the present invention.

[0020] FIG. **9** is a cross-sectional view illustrating a heat exchanger according to the fourth embodiment of the present invention.

[0021] FIG. **10** is a perspective view illustrating a metal tube in the heat exchanger according to the fourth embodiment.

[0022] FIG. **11** is a plan view illustrating the metal tube in the heat exchanger according to the fourth embodiment.

[0023] FIG. **12** is a side view illustrating the metal tube in the heat exchanger according to the fourth embodiment.

[0024] FIG. **13** is a cross-sectional view taken along the XIII-XIII line in FIG. **11**.

[0025] FIG. **14**A is a cross-sectional view taken along the XIVa-XIVa line in FIG. **11**. FIG. **14**B is a cross-sectional view taken along the XIVb-XIVb line in FIG. **11**. FIG. **14**C is a cross-sectional view taken along the XIVc-XIVc line in FIG. **11**.

[0026] FIG. **15** is a cross-sectional view illustrating Variation Example 1 of the metal tube.

[0027] FIG. **16** is a cross-sectional view illustrating Variation Example 2 of the metal tube.

[0028] FIG. **17**A is a perspective view illustrating a heat exchanger according to the fifth embodiment of the present invention. FIG. **17**B is a plan view illustrating a metal tube of the heat exchanger. FIG. **17**C is a cross-sectional view taken along the XVIIc-XVIIc line in FIG. **17**B. FIG. **17**D is a cross-sectional view taken along the XVIId-XVIId line in FIG. **17**B.

[0029] FIG. **18**A is a cross-sectional view illustrating bending of the heat exchanger according to the fifth embodiment. FIG. **18**B is a cross-sectional view illustrating bending of a heat exchanger with a shape of protruding portions different from that of the aforementioned heat exchanger.

[0030] FIG. **19** is a plan view illustrating a variation example of the metal tube in the heat exchanger according to the fifth embodiment.

[0031] FIG. **20** is a perspective view illustrating a heat exchanger according to the sixth embodiment of the present invention.

[0032] FIG. **21**A is a perspective view illustrating a metal sheet for forming a metal tube of the heat exchanger according to the sixth embodiment. FIG. **21**B is a perspective view illustrating the metal tube of the heat exchanger according to the sixth embodiment. FIG. **21**C is a cross-sectional view illustrating the metal tube of the heat exchanger according to the sixth embodiment.

[0033] FIG. **22**A is a plan view illustrating a variation example of the metal tube in the heat exchanger according to the sixth embodiment. FIG. **22**B is a cross-sectional view thereof.

[0034] FIG. **23**A is a perspective view illustrating a heat exchanger according to the seventh embodiment of the present invention. FIG. **23**B is a perspective view illustrating a variation example thereof. FIG. **23**C is a perspective view illustrating another variation example.

[0035] FIGS. **24**A and **24**B are cross-sectional views illustrating yet another variation example of the heat exchanger according to the seventh embodiment. FIG. **24**C is a cross-sectional view illustrating yet another variation example of the heat exchanger according to the seventh embodiment.

[0036] FIG. **25** is a cross-sectional view illustrating a heat exchanger according to the eighth embodiment of the present invention.

[0037] FIGS. **26**A and **26**B are plan views illustrating a process for manufacturing a metal tube for a heat exchanger according to the ninth embodiment of the present invention. FIG. **26**C is a cross-sectional view taken along the XXVIc-XXVIx line in FIG. **26**B.

[0038] FIG. **27**A is a plan view illustrating the state in which the relative positions of the first protruding portion and second protruding portion of the metal tube in the heat exchanger according to the ninth embodiment have shifted. FIG. **27**B is a cross-sectional view taken along the XXVIIb-XXVIIb line in FIG. **27**A.

DETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

[0039] An embodiment of the present invention will be described below in greater detail with reference to the appended drawings.

[0040] <Heat Pump Type Hot Water Supply Apparatus>

[0041] FIG. **1** is a configuration diagram illustrating a heat pump type hot water supply apparatus **11** according to an embodiment of the present invention. As shown in FIG. **1**, the heat pump type hot water supply apparatus **11** is provided with a coolant circuit **13** where a coolant is circulated and a hot water storage circuit **17** for boiling low-temperature water by heat exchange with the coolant of the coolant circuit **13** and storing high-temperature water in a tank **15**.

[0042] The coolant circuit **13** has a compressor **19**, a heat exchanger (water heat exchanger) **21**, an expansion valve (pressure reducing mechanism) **23**, an evaporator **25**, and pipes connecting these components. For example, carbon dioxide can be used as the coolant circulating in the coolant circuit **13**. When carbon dioxide is used as the coolant, the coolant is compressed to a pressure equal to or higher than a critical pressure by the compressor **19**.

[0043] The hot water storage circuit **17** has the tank **15** for storing water, a water inlet pipe **27** for introducing water from the tank **15** into the heat exchanger **21**, a hot water outlet pipe **29** for returning water heated by heat exchange with the heat exchanger **21** into the tank **15**, and a pump **31** that causes water to circulate in the hot water storage circuit **17**.

[0044] The hot water supply apparatus **11** is provided with a control unit **33** that controls the coolant circuit **13** and the hot water storage circuit **17**. By driving the compressor **19** of the coolant circuit **13** and the pump **31** of the hot water storage circuit **17**, the control unit **33** introduces low-temperature water located in the tank **15** from a water outlet port provided in the bottom portion of the tank **15** into the heat exchanger **21** through the water inlet pipe **27**. The low-temperature water introduced into the heat exchanger **21** is heated in the heat exchanger **21** and returned into the tank **15** from the water inlet port provided in the upper portion of the tank **15** via the hot water outlet pipe **29**. As a result, high-temperature water is stored in the upper portion inside the tank **15**, and the water temperature decreases toward the lower portion of the tank.

[0045] The tank **15** is provided with a hot water supply pipe **35** for taking out the high-temperature water stored in the tank **15** from the upper portion thereof and supplying the high-temperature water into a bath or the like and a water supply pipe **37** for supplying low-temperature water such as tap water to the bottom portion of the tank **15**.

[0046] <Heat Exchanger>

First Embodiment

[0047] FIG. **2** is a perspective view illustrating the heat exchanger **21** according to the first embodiment of the present invention. As shown in FIG. **2**, the heat exchanger **21** has a structure that is spirally wound so that one end **41** in the longitudinal direction is disposed on the inner side and the other end **43** in the longitudinal direction is disposed on the outer side.

[0048] The heat exchanger **21** performs heat exchange between the coolant circulating in the coolant circuit **13** and water circulating in the hot water storage circuit **17** in the hot water supply apparatus **11** shown in FIG. **1**. The directions of the coolant and water flowing in the heat exchanger **21** are mutually opposite directions as shown in FIG. **1**. Therefore, where either of the coolant and water flows from the one end **41** to the other end **43** of the heat exchanger **21**, the other fluid flows from the other end **43** toward the one end **41**. The temperature of water can thus be regulated by performing heat exchange between the water and coolant as the coolant and water pass through inside the heat exchanger **21**.

[0049] FIG. **3** is a cross-sectional view taken along the line in FIG. **2**. As shown in FIG. **3**, the heat exchanger **21** has a structure in which a first multiple-hole metal tube **45**, a metal tube **47**, and a second multiple-hole metal tube **49** are stacked in the thickness direction in the order of description. These metal tubes **45**, **47**, **49** are integrated by joining the opposing outer surfaces thereof by joining by the below-described resistance welding.

[0050] The first multiple-hole metal tube **45** and the second multiple-hole metal tube **49** have a flat shape with a width greater than a thickness. A plurality of coolant flow channels **51** extending in the longitudinal direction are formed inside these multiple-hole metal tubes **45**, **49**. The plurality of coolant flow channels **51** are mutually independent and arranged side by side in a row in the width direction. The coolant circulating in the coolant circuit **13** flows in the coolant flow channels **51**. In the first multiple-hole metal tube **45** and the second multiple-hole metal tube **49**, a drift current of the coolant flowing in the coolant flow channels **51** can be inhibited because the tubes have multiple holes.

[0051] The metal tube **47** has a flat shape with a width greater than a thickness. A fluid flow channel **53** extending in the longitudinal direction is formed inside the metal tube **47**. Water circulating in the hot water storage circuit **17** flows in the fluid flow channel **53**. The metal tube **47** has an outer surface **61** at one side and an outer surface **63** at the other side in the thickness direction. The first multiple-hole metal tube **45** has an opposing surface **65**, which is opposite the outer surface **61** on one side of the metal tube **47**, and is stacked on the one side in the thickness direction of the metal tube **47**. The second multiple-hole metal tube **49** has an opposing surface **67**, which is opposite the outer surface **63** on the other side of the metal tube **47**, and is stacked on the other side in the thickness direction of the metal tube **47**.

[0052] At least part of the opposing surface **65** of the first multiple-hole metal tube **45** is fused to the outer surface **61**. At least part of the opposing surface **67** of the second multiple-hole metal tube **49** is fused to the outer surface **63**. By increasing the ratio of fusion of the opposing surfaces **65**, **67** to the outer surfaces **61**, **63**, it is possible to increase the degree of intimate contact between the opposing surfaces **65**, **67** and the outer surfaces **61**, **63** and increase the heat exchange efficiency of the heat exchanger **21**. The ratio of fusion of the opposing surfaces **65**, **67** to the outer surfaces **61**, **63** can be adjusted by changing welding conditions during resistance welding. More specifically, the ratio of fusion of the opposing surfaces **65**, **67** to the outer surfaces **61**, **63** can be increased by setting conditions such as to decrease the welding rate (feed rate) during resistance welding, increase the current value during welding, and increase the pressurizing force in the thickness direction during welding. Therefore, from the standpoint of heat exchange efficiency of the heat exchanger **21**, it is preferred that substantially the entire opposing surfaces **65**, **67** be fused to the outer surfaces **61**, **63**.

[0053] FIG. **4** is a cross-sectional view taken along the Iv-Iv line in FIG. **3**. As shown in FIG. **3** and FIG. **4**, the metal tube **47** has, in a fluid flow channel **53** thereof, support members (support portions) **55** that inhibit deformation in the thickness direction. The support members **55** are constituted by a plurality of first columnar bodies **55***a* arranged side by side in three rows along the longitudinal direction of the fluid flow channel **53** at an inner surface **57** on one side in the thickness direction of the fluid flow channel **53** and a plurality of second columnar bodies **55***b* that are arranged side by side in three rows along the longitudinal direction of the fluid flow channel **53** at an inner surface **59** on the other side in the thickness direction of the fluid flow channel **53**.

[0054] The first columnar body **55***a* is joined by the base end portion thereof to the inner surface **57** and extends toward the inner surface **59**. The second columnar body **55***b* is joined by the base end portion thereof to the inner surface **59** and extends toward the inner surface **57**. The plurality of first columnar bodies **55***a* and the plurality of second columnar bodies **55***b* are arranged in a spot-like pattern almost equidistantly from the one end **41** to the other end **43** of the heat exchanger **21** in each of the rows.

[0055] The distal end portion of the first columnar body **55***a* abuts on or is disposed close to the distal end portion of the opposite second columnar body **55***b*. The first columnar body **55***a* and the second columnar body **55***b*, which are thus disposed opposite each other, form a pair and restrict deformation of the metal tube **47** in the thickness direction during resistance welding.

[0056] The first columnar body **55***a* and the second columnar body **55***b* may be also joined by the distal end portions thereof. Whether the distal end portions are joined to each other can be regulated by changing welding conditions during resistance welding. More specifically, the ratio of the distal end portions joined together can be increased, for example, by decreasing the welding rate (feed rate) during resistance welding, increasing the current value during welding, and increasing the pressurizing force in the thickness direction during welding.

[0057] By increasing the joining ratio of the distal end portions of the first columnar body **55***a* and second columnar body **55***b*, it is possible to increase the rigidity of the metal tube **47**. By contrast, when the joining ratio of the distal end portions is low, flexibility of the metal tube **47** can be maintained at a certain level. Therefore, the expansion-shrinkage of the metal caused by temperature variations and strains caused by vibrations can be moderated even when the heat exchanger **21** is used in an environment in which temperature variations and vibrations can easily occur.

[0058] Metals having thermal conductivity, corrosion resistance, rigidity, and machinability can be used as materials of the metal tube **47**, first multiple-hole metal tube **45**, and second multiple-hole metal tube **49**. Examples of suitable metals include aluminum and aluminum alloys. The support members **55** may be from a material identical to that of the outer peripheral portion of the metal tube **47**.

[0059] As described hereinabove, in the present embodiment, the support members **55**, which inhibit deformation of the metal tube **47** in the thickness direction, are located in the fluid flow channel **53**. Therefore, the metal tube **47** and multiple-hole metal tubes **45**, **49** that are stacked in the thickness direction can be joined by resistance welding, while pressurizing the tubes in the thickness direction by a pair of roller electrodes **71**, **73**. Since the heat exchanger can be manufactured by resistance welding that excels in productivity, the cost can be reduced. Further, in the present embodiment, the metal tube **47** has support members **55** in the fluid flow channel **53**. Therefore, deformation of the metal tube **47** can be inhibited even in long-term use of the heat exchanger.

[0060] Further, according to the present embodiment, the plurality of first columnar bodies **55***a* and second columnar bodies **55***b* that have distal end portions abutted on each other or disposed close to each other are arranged along the longitudinal direction of the fluid flow channel **53**. Therefore, deformation of the metal tube **47** along the longitudinal direction can be inhibited over a long period. Moreover, since a configuration is used in which these columnar bodies **55***a*, **55***b* are arranged in a spot-like pattern in the longitudinal direction, the increase in resistance to flow of fluid in the fluid flow channel **53** caused by the arrangement of support members **55** can be inhibited and smooth fluid flow can be ensured.

[0061] Further, in the present embodiment, when some or all of the plurality of first columnar bodies **55***a* and the plurality of second columnar bodies **55***b* are joined to each other by the distal end portions thereof, the rigidity of the metal tube **47** can be increased. As a result, deformation of the metal tube **47** can be inhibited over a long period.

[0062] According to the present embodiment, since the multiple-hole metal tubes **45**, **49** are stacked on both sides in the thickness direction of the metal tube **47**, the efficiency of heat exchange between the coolant and water can be further increased.

[0063] In the present embodiment, when the opposing surfaces of the multiple-hole metal tubes **45**, **49** facing the outer surfaces of the metal tube **47** are substantially entirely fused, the efficiency of heat exchange between the coolant and water can be further increased.

[0064] In the present embodiment, since a spirally wound configuration is used in which the one end **41** in the longitudinal direction is disposed on the inner side and the other end **43** in the longitudinal direction is disposed on the outer side, the dead space can be reduced and the heat exchanger **21** can be reduced in size.

[0065] Further, in the present embodiment, since the support members **55** that inhibit deformation of the metal tube **47** in the thickness direction are present in the fluid flow channel **53**, the following effect can be obtained in addition to the abovementioned effect of inhibiting deformation during resistance welding. Thus, the heat exchanger **21** of the present embodiment is sometimes used in a bent form for example such as shown in FIG. **2**. For example, in the case of the form illustrated by FIG. **2**, some portions of the entire heat exchanger **21** in the longitudinal direction are curved, whereas other portions remain straight. In the curved portions, the support members **55** of the metal tube **47** have a function of inhibiting deformation of the metal tube **47** in the thickness direction during bending. Meanwhile, in the straight portions, the support members **55** of the metal tube **47** function as barriers such that collide with the fluid flowing inside the metal tube **47** and cause moderate turbulence. Heat transfer between the fluid and the metal tube **47** is enhanced by the moderate turbulence of the fluid. This result is likewise demonstrated in the below-described other embodiments.

[0066] (Manufacturing Method)

[0067] An example of the method for manufacturing the heat exchanger **21** will be described below. FIG. **5** is a front view illustrating the method for manufacturing the heat exchanger **21**. As shown in FIG. **5**, for example, a resistance welding apparatus **100** can be used for manufacturing the heat exchanger **21**.

[0068] First, the resistance welding apparatus **100** will be explained. The resistance welding apparatus **100** is provided with a pair of roller electrodes **71**, **73**, a pressurizing device **75** that applies pressure to the roller electrode **71**, a power supply device **79** that supplies electric power to the pressurizing device **75** and the roller electrodes **71**, **73**, and a control unit (not shown in the figure) that controls the operation of each unit.

[0069] The roller electrode **71** and the roller electrode **73** have a substantially round columnar shape and respectively have rotating shafts **72**, **74** in the center thereof. The rotating shaft **72** and the rotating shaft **74** are disposed substantially parallel to each other. The width of the roller electrodes **71**, **73** in the axial direction is designed to be greater than the width of the metal tube **47** and multiple-hole metal tubes **45**, **49** that are the welding objects.

[0070] A motor (not shown in the figure) is connected to the rotating shaft **72**, **74**, and the shafts are supported on a support table (not shown in the figure) in a state in which each shaft can rotate about the axis thereof. The motor is connected to the power supply device **79**. The roller electrode **71** and the roller electrode **73** rotate in the mutually opposite direction. For example, in the configuration shown in FIG. **5**, the roller electrode **71** rotates counterclockwise and the roller electrode **73** rotates clockwise. Further, the roller electrode **71** is supported on the support table so as to enable the movement thereof in the direction of approaching the roller electrode **73** and in the opposite direction (up-down direction in FIG. **5**). These roller electrodes **71**, **73** are connected to the power supply device **79**, and electric power is supplied thereto from the power supply device **79** during resistance welding. It is possible to use a configuration in which only the roller electrode **71** moves in the up-down direction, as in the present embodiment, or a configuration in which the two roller electrodes **71**, **73** move in the up-down direction.

[0071] The pressurizing device **75** is provided with a cylindrical cylinder **78**, a piston **77** disposed inside the cylinder **78**, and a pump (not shown in the figure) that generates energy such as air pressure or oil pressure. Where electric power is supplied from the power supply device **79** to the pressurizing device **75**, the pump is driven and the piston **77** is slidingly moved in a predetermined direction inside the cylinder **78**. As a result, the roller electrode **71** is pressurized. The pressurized roller electrode **71** moves toward the roller electrode **73**, and the metal tube **47** and the multiple-hole metal tubes **45**, **49** disposed between the roller electrodes **71**, **73** are pressurized in the thickness direction.

[0072] Each manufacturing step will be described below. First, in a metal tube forming step, the metal tube **47**, first multiple-hole metal tube **45**, and second multiple-hole metal tube **49** are fabricated.

[0073] The metal tube **47** is obtained by bending a long thin metal sheet (not shown in the figure) so that the end portions thereof in the width direction face each other and an internal space is formed along the longitudinal direction and then joining together the opposing end sides. The internal space extending in the longitudinal direction serves as the fluid flow channel **53**.

[0074] Prior to bending the metal sheet, the base end portions of the first columnar bodies **55***a* and the base end portions of the second columnar bodies **55***b* are joined by welding or the like at predetermined positions in the regions that will be the opposing inner surface **57** and inner surface **59** after the bending is completed. Then, the metal sheet is bent, while controlling the bending position so that the first columnar bodies **55***a* and the second columnar bodies **55***b* face each other, and the end portions of the metal sheet are joined together. As a result, the metal tube **47** is obtained in which the first columnar bodies **55***a* and the second columnar bodies **55***b* are provided in the internal fluid flow channel **53**.

[0075] The first multiple-hole metal tube **45** and the second multiple-hole metal tube **49** are obtained, for example, by extruding a metal material by using a die provided with an extrusion outlet port having a cross-sectional shape such as shown in FIG. **3**.

[0076] The metal tube **47**, first multiple-hole metal tube **45**, and second multiple-hole metal tube **49** obtained in the metal tube forming step are then stacked. As shown in FIG. **5**, the first multiple-hole metal tube **45**, metal tube **47**, and second multiple-hole metal tube **49** are arranged so that longitudinal directions and thickness directions thereof are oriented in the same respective directions and the metal tubes are stacked in the thickness direction in the order of description.

[0077] The first multiple-hole metal tube **45**, metal tube **47**, and second multiple-hole metal tube **49** that have thus been stacked in the stacking step are supplied between the roller electrodes **71**, **73**, fed along the longitudinal direction, while being pressurized in the thickness direction by the roller electrodes **71**, **73**. In this process, an electric current is supplied through the roller electrodes **71**, **73** and the opposing outer surfaces of the metal tubes are resistance welded (seam welded) together. As a result, the linear heat exchanger **21** is obtained in which the metal tubes are integrated as shown in FIG. **6**. In the heat exchanger **21**, the outer surfaces **61**, **63** of the metal tube **47** and the opposing surfaces **65**, **67** of the multiple-hole metal tubes **45**, **49** are fused and a nugget **76** is continuously formed along the longitudinal direction in the side portion.

[0078] The resistance welding conditions include the pressurizing force created by the roller electrodes **71**, **73**, conduction time, standby time, current value during welding, welding rate (feed rate), electrode shape, and the like. These conditions are set as appropriate according to the welding object, application, etc. The abovementioned resistance welding may be intermittent welding in which conduction periods and standby periods are repeated or continuous welding in which the conduction is continuous.

[0079] In the present embodiment, since the first columnar bodies **55***a* and the second columnar bodies **55***b* are provided in the fluid flow channel **53** of the metal tube **47**, where pressurization is performed by the roller electrodes **71**, **73** in the thickness direction, the metal tube **47** is slightly deformed in the thickness direction and the distal end portions of some or all of the plurality of first columnar bodies **55***a* and the plurality of second columnar bodies **55***b* abut on each other. Where the distal end portions thus abut on each other, deformation of the metal tube **47** in the thickness direction can be inhibited. Further, since the electric current flowing through the roller electrodes **71**, **73** to the metal tube **47** flows not only through the outer peripheral portion of the metal tube **47**, but also through the first columnar bodies **55***a* and the second columnar bodies **55***b* that abut on each other by the distal end portions thereof, the fusion of the adjacent opposing surfaces **65**, **67**, which are provided with the first columnar bodies **55***a* and the second columnar bodies **55***b* that abut on each other by the distal end portions thereof, and the outer surfaces **61**, **63** is enhanced. As a result, the fusion ratio of the opposing surfaces **65**, **67** and the outer surfaces **61**, **63** can be increased.

[0080] Further, when an electric current flows through the roller electrodes **71**, **73**, the electric current also flows through the first columnar bodies **55***a* and the second columnar bodies **55***b*. Therefore, depending on the resistance welding conditions, the distal end portions are joined together in some or all of the pairs of the plurality of columnar bodies.

[0081] The heat exchanger **21** can be used as is, that is, in the linear form such as shown in FIG. **6**, or may be used upon bending spirally as shown in FIG. **2**. In the case of the form shown in FIG. **2**, the bending is performed so that the thickness direction of the metal tubes **45**, **47**, **49** is in the radial direction of the spiral.

[0082] As described hereinabove, with the manufacturing method using resistance welding, the metal tube **47** having the support members **55** in the fluid flow channel **53** and the multiple-hole metal tubes **45**, **49** are stacked and disposed between the roller electrodes **71**, **73**, and the metal tube **47** and the multiple-hole metal tubes **45**, **49** are moved along the longitudinal direction and resistance welded, while being pressurized in the thickness direction. Therefore, deformation of the metal tube **47** by pressure during resistance welding can be inhibited.

[0083] Thus, during such resistance welding, the welding can be performed in a state in which a sufficient pressure is applied by the roller electrodes **71**, **73** in the thickness direction so that the outer surfaces **61**, **63** of the metal tube **47** and the opposing surfaces **65**, **67** of the multiple-hole metal tubes that are disposed opposite the outer surfaces are brought into intimate contact with each other. As a result, the joining surface area of the outer surfaces **61**, **63** and the opposing surfaces **65**, **67** can be increased, deformation of the fluid flow channel **53** is inhibited and a flow channel necessary for the fluid to flow smoothly is ensured. Therefore, the efficiency of heat exchange between the coolant and fluid can be increased. Furthermore, since the metal tubes can be joined by resistance welding, which is a simple method, productivity can be increased.

Second Embodiment

[0084] FIG. **7** is a cross-sectional view illustrating the heat exchanger according to the second embodiment of the present invention. As shown in FIG. **7**, in the heat exchanger **21**, the structure of the support members **55** is different from that of the first embodiment. Other components are assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0085] The support members (support portions) **55** according to the second embodiment are constituted by a plurality of columnar bodies arranged along the longitudinal direction of the fluid flow channel **53**. One end in an axial direction of each columnar body is joined to an inner surface (inner surface **57** or inner surface **59**) on either side in the thickness direction of the fluid flow channel **53**, and the other end in the axial direction of each columnar body is disposed on the inner surface side on the other side in the thickness direction of the fluid flow channel **53**. All of the plurality of columnar bodies may be joined by one end thereof to the inner surface on the same side, or some of them may be joined to the inner surface on the other side.

[0086] Both ends in the axial direction of some or all of the plurality of columnar bodies are respectively joined to the inner surface **57** on one side and the inner surface **59** on the other side of the fluid flow channel **53**. When both ends of the columnar bodies are joined, the rigidity of the metal tube **47** can be increased. Where only one end of the columnar bodies is joined and the other end is not joined, the flexibility of the metal tube **47** can be maintained at a certain level.

[0087] The metal tube **47** according to the second embodiment may be fabricated in the same manner as the metal tube **47** according to the first embodiment. Thus, the metal tube **47** is obtained by bending a flat metal sheet (not shown in the figure) so as to form a hollow portion along the longitudinal direction and joining by welding the side end portions thereof. The hollow portion along the longitudinal direction serves as the fluid flow channel **53**.

[0088] Prior to bending the metal sheet, one end of each columnar body is joined by welding or the like in the region that will be the inner surface **57** or the inner surface **59** after the bending is completed. Then, the metal sheet is bent and the side end portions of the metal sheet are joined together. As a result, the metal tube **47** is obtained in which the support members **55** constituted by a plurality of columnar bodies are provided in the internal fluid flow channel **53**.

[0089] According to the second embodiment, since a plurality of columnar bodies are arranged along the longitudinal direction of the fluid flow channel **53**, deformation of metal tube **47** in the longitudinal direction can be inhibited over a long period. Furthermore, since the columnar bodies are arranged in a spot-like pattern in the longitudinal direction, the increase in resistance to the flow of fluid in the fluid flow channel **53** that is caused by the support members **55** can be inhibited and the fluid can smoothly flow in the fluid flow channel.

[0090] Further, according to the second embodiment, one end of each columnar body is joined to the inner surface **57** or the inner surface **59** in the thickness direction of the fluid flow channel **53**. Therefore, the columnar bodies can be prevented from displacing when pressurized in the thickness direction by the roller electrodes **71**, **73** during resistance welding. As a result, a sufficient pressure can be applied in the thickness direction by the roller electrodes **71**, **73** to the metal tube **47** and the multiple-hole metal tubes **45**, **49** during resistance welding.

[0091] Further, in the present embodiment, a plurality of columnar bodies are provided in the fluid flow channel **53** of the metal tube **47**. Therefore, where pressurization is performed in the thickness direction by the roller electrodes **71**, **73**, the metal tube **47** is slightly deformed in the thickness direction and other ends of some or all of the plurality of columnar bodies abut on the inner surface **57** or the inner surface **59** of the metal tube **47**. Such an abutment of other ends of the columnar bodies inhibits deformation of the metal tube **47** in the thickness direction. Further, since the electric current flowing through the roller electrodes **71**, **73** to the metal tube **47** flows not only through the outer peripheral portion of the metal tube **47**, but also through the columnar bodies that abut by the other ends thereof on the inner surface, the fusion of the adjacent opposing surfaces **65**, **67**, which are provided with the columnar bodies that abut by the other ends thereof on the inner surface, and the outer surfaces **61**, **63** is enhanced. As a result, the fusion ratio of the opposing surfaces **65**, **67** and the outer surfaces **61**, **63** can be increased.

[0092] Further, since the electric current also flows through the columnar bodies when flowing through the roller electrodes **71**, **73**, the columnar bodies can be joined to the inner surface **57** or the inner surface **59** under certain conditions of resistance welding.

Third Embodiment

[0093] FIG. **8** is a cross-sectional view illustrating the heat exchanger according to the third embodiment of the present invention. As shown in FIG. **8**, the structure of the support member **55** of the heat exchanger **21** is different from that of the first embodiment. Other components are assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0094] The support member (support portion) **55** according to the third embodiment is a plate-like body that is disposed along the longitudinal direction of the fluid flow channel **53** and has a corrugated cross-section perpendicular to the longitudinal direction. The plate-like body is disposed so that peaks of depressions and protrusions are continuous along the width direction of the fluid flow channel **53**.

[0095] The metal tube **47** according to the third embodiment may be fabricated by bending a flat metal sheet (not shown in the figure) so as to form a hollow portion along the longitudinal direction, joining the side end portions together by welding or the like, and then inserting a corrugated plate-like body into the hollow portion, or by disposing a corrugated plate-like body at a predetermined position of the metal sheet prior to bending and then performing bending and welding the side end portions to each other.

[0096] According to the third embodiment, since the support member **55** is a corrugated plate-like body, deformation of the metal tube **47** in the longitudinal direction can be inhibited over a long period. Further, since the rigidity of the support member **55** itself can be increased over that attained when the support member **55** is in the form of the above-described columnar bodies, such a configuration is particularly advantageous when a larger pressurization force is desired to be obtained with the pair of roller electrodes **71**, **73**. Furthermore, since the corrugated plate-like body acts to disperse the fluid flow, it is possible to regulate the fluid flow and produce a flow with low turbulence.

Fourth Embodiment

[0097] FIG. **9** is a cross-sectional view illustrating the heat exchanger **21** according to the fourth embodiment of the present invention. FIGS. **10** to **13** illustrate the metal tube **47** used in the heat exchanger **21**. As shown in FIGS. **9** to **13**, the structure of the support portion of the metal tube **47** of the heat exchanger **21** is different from that of the first embodiment. Other components are assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0098] The metal tube **47** according to the fourth embodiment has a flat shape with a width greater than a thickness. Side portions at both sides in the width direction of the metal tube **47** have a circular-art cross-sectional shape, but such a shape is not limiting. For example, the side portions of the metal tube **47** may have a linear cross-sectional shape as shown in FIG. **3** or other shape. Further, the side portions at both sides in the width direction of the metal tube **47** protrude outward in the width direction from the first multiple-hole metal tube **45** and the second multiple-hole metal tube **49**, but such a configuration is not limiting. For example, the side portions of the metal tube **47** may have a shape that does not protrude outward in the width direction as shown in FIG. **3**. The fluid flow channel **53** extending in the longitudinal direction is formed inside the metal tube **47**.

[0099] As shown in FIGS. **11** to **13**, the metal tube **47** has, in the fluid flow channel **53** thereof, the support portions **55** that inhibit deformation in the thickness direction. The support portions **55** are constituted by a plurality of first protruding portions **55***a* arranged along the longitudinal direction of the fluid flow channel **53** at the inner surface **57** on one side in the thickness direction of the fluid flow channel **53** and a plurality of second protruding portions **55***b* arranged along the longitudinal direction of the fluid flow channel **53** at the inner surface **59** on the other side in the thickness direction of the fluid flow channel **53**. Each first protruding portion **55***a* extends from the inner surface **57** on one side toward the inner surface **59** on the other side, and each second protruding portion **55***b* extends from the inner surface **59** on the other side toward the inner surface **57** on one side.

[0100] These first protruding portions **55***a* and second protruding portions **55***b* are formed by press forming a metal sheet as described hereinbelow. Therefore, the outer surface **61** on the one side in the thickness direction recedes on the inner surface **59** side, thereby causing the first protruding portions **55***a* to protrude to the inner surface **59** side in the fluid flow channel **53**. The outer surface **63** on the other side in the thickness direction recedes on the inner surface **57** side, thereby causing the second protruding portions **55***b* to protrude to the inner surface **57** side in the fluid flow channel **53**. A first receding portion **55***c* is formed on the rear surface (outer surface **61**) of the first protruding portion **55***a,* and a second receding portion **55***d* is formed on the rear surface (outer surface **63**) of the second protruding portion **55***b.*

[0101] As shown in FIG. **11**, in a plan view of the metal tube **47**, the support portions **55** have the following specific features because the first protruding portions **55***a* and second protruding portions **55***b* are arranged in a regular manner.

[0102] The support portions **55** are arranged regularly so as to form five rows (row A**1** to row A**5**), each row extending in the longitudinal direction. The first protruding portions **55***a* and second protruding portions **55***b* are arranged together in the row A**1** to row A**5**. In the row A**3** among these rows, the second protruding portions **55***b* are disposed at positions facing the first protruding portions **55***a* in the thickness direction. Thus, the second protruding portions **55***b* are provided at all of the respective positions facing the first protruding portions **55***a* of the row A**3** shown in FIG. **11**. This row A**3**, from among the five rows, is positioned in the central portion in the width direction of the metal tube **47**.

[0103] Further, the support portions **55** are arranged regularly so as to form a plurality of rows, namely, row B**1**, row B**2**, row B**3**, . . . extending in the oblique direction at an angle to the longitudinal direction. The first protruding portions **55***a* are disposed by five protruding portions in each of rows B**2**, B**4**, B**6**, but disposed by one protruding portion in each of rows B**1**, B**3**, B**5**. This one first protruding portion **55***a* is disposed in the row A**3**. The second protruding portions **55***b* are disposed by five protruding portions in each of rows B**1**, B**3**, B**5**, but disposed by one protruding portion in each of rows B**2**, B**4**, B**6**. This one second protruding portion **55***b* is disposed in the row A**3**. Thus, the rows B**2**, B**4**, B**6** of the first protruding portions **55***a* in the oblique direction and the rows B**1**, B**3**, B**5** of the second protruding portions **55***b* in the oblique direction are arranged alternately along the longitudinal direction.

[0104] Therefore, in the fourth embodiment, the first protruding portions **55***a* and second protruding portions **55***b* are disposed opposite each other only in the row A**3** (see FIG. **14**C), and in other rows A**1**, A**2**, A**4**, A**5**, the first protruding portions **55***a* and the second protruding portions **55***b* are disposed alternately in the longitudinal direction (see FIGS. **14**A and **14**B). In other words, in the rows A**1**, A**2**, A**4**, A**5**, the first protruding portions **55***a* are provided at positions shifted in the longitudinal direction with respect to the second protruding portions **55***b*. Thus, only the row A**3** is configured such that the first protruding portions **55***a* and the second protruding portions **55***b* are opposite each other.

[0105] Further, as shown in FIG. **11**, an angle θ**1** between an oblique direction D**2** and the longitudinal direction D**1** and an angle θ**2** between an oblique direction D**3** and the longitudinal direction D**1** are set to mutually different values. The oblique direction D**2** as referred to herein is an arrangement direction of the aforementioned rows B**1**, B**2**, ... The oblique direction D**3** is a regular arrangement direction crossing the rows B**1**, B**2**, ... In the present embodiment, the angle θ**1** is set to about 50 degrees and the angle θ**2** is set to about 40 degrees, and the oblique direction D**2** and the oblique direction D**3** cross each other at about 90 degrees.

[0106] In the configuration according to the fourth embodiment, since the angle θ**1** and the angle θ**2** are set to different values, as mentioned hereinabove, protruding portions **55***a,* **55***b* are not disposed on the same line in the width direction with a position at which a random first protruding portion **55***a* (or second protruding portion **55***b*) is disposed. The first protruding portions **55***a* and second protruding portions **55***b* can thus be disposed with a certain degree of randomness in the fluid flow channel **53** and therefore pulsations can be generated in the flow of fluid in the fluid flow channel **53**. As a result, for example, the occurrence of drift in the fluid flow channel **53** can be inhibited and the development of turbulent flow of the fluid in the fluid flow channel **53** can be enhanced, thereby increasing the efficiency of heat exchange.

[0107] Further, as shown in FIG. **14**C, the distal end of the first protruding portion **55***a* is disposed at a predetermined distance t from the distal end of the second protruding portion **55***b* opposite thereto in the thickness direction. Therefore, the gap between the distal ends of the first protruding portions **55***a* and the second protruding portions **55***b* also serves as a flow channel for coolant. As a result, the reduction of the fluid flow channel **53** caused by the provided first protruding portions **55***a* and second protruding portions **55***b* can be inhibited. Further, in the present embodiment, the distal end portions of the first protruding portions **55***a* are disposed at the predetermined distance from the distal end portions of the second protruding portions **55***b* opposite thereto in the thickness direction, but the protruding portions may be also disposed without the distance t therebetween and the distal end portions thereof may abut on each other.

[0108] The metal tube **47** can be formed, for example, in the following manner. First, a plate-like metal sheet is pressed to form a plurality of protruding portions in predetermined positions, the protruding portions protruding in the thickness direction of the metal sheet. Then, the metal sheet is bent at positions corresponding to circular-arc side portions at both sides in the width direction of the metal tube **47** and a flat shape is obtained. The end portions of the obtained metal sheet are joined together by welding or the like. The plurality of protruding portions formed by pressing serve as the first protruding portions **55***a* and second protruding portions **55***b.*

[0109] As described hereinabove, in the fourth embodiment, some of the plurality of first protruding portions **55***a* are provided at positions opposite the second protruding portions **55***b* in the thickness direction. Therefore, where the first protruding portions **55***a* and the second protruding portions **55***b* disposed at positions opposite thereto abut on each other, subsequent deformation of the metal tube **47** is inhibited even when a pressure is applied in the thickness direction to the metal tube **47** during the resistance welding or bending such as described hereinabove. As a result, deformation in the thickness direction of the metal tube **47** during resistance welding or bending can be effectively inhibited.

[0110] Further, in the fourth embodiment, the first protruding portions **55***a* and second protruding portions **55***b* are disposed opposite each other in the central portion in the width direction. Therefore, the effect of inhibiting the deformation of the metal tube **47** can be further increased.

[0111] Further, in the fourth embodiment, the first protruding portions **55***a* and second protruding portions **55***b* are disposed opposite each other in the central portion in the width direction, as mentioned hereinabove, but in the rows positioned at both sides, the first protruding portions **55***a* are provided at positions displaced in the longitudinal direction with respect to the second protruding portions **55***b*. Therefore, deformation in the thickness direction of the metal tube **47** in the central portion in the width direction can be effectively inhibited, and narrowing of the fluid flow channel can be inhibited and a smooth fluid flow can be realized at both sides in the width direction. Further, since the first protruding portions **55***a* or second protruding portions **55***b* are provided on both sides in the width direction, when an unexpectedly high pressure is applied in the thickness direction, the distal end portions of the first protruding portions **55***a* abut on the inner surface **59** of the metal tube **47** and the distal end portions of the second protruding portions **55***b* abut on the inner surface **57** of the metal tube **47**, thereby making it possible to inhibit subsequent deformation of the metal tube **47**.

[0112] Further, in the forth embodiment, as described hereinabove, the plurality of first protruding portions **55***a* are arranged so as to form five rows A**1** to A**5**, each row extending in the longitudinal direction, and the first protruding portions **55***a* are also arranged so as to form a plurality of rows B**2**, B**4**, B**6** extending in the oblique direction at an angle to the longitudinal direction. The second protruding portions **55***b* are also arranged so as to form a plurality of rows B**1**, B**3**, B**5**, each row extending in the oblique direction. The oblique rows of the first protruding portions **55***a* and the oblique rows of the second protruding portions **55***b* are disposed alternately along the longitudinal direction. When such a configuration is used, steps (protruding portions) in the thickness direction can be disposed continuously and at an angle with respect to the longitudinal direction in the fluid flow channel **53**. In addition, steps (first protruding portions **55***a*) on one side in the thickness direction and steps (second protruding portions **55***b*) on the other side can be disposed alternately. Therefore, the occurrence of pulsations in the flow of fluid in the fluid flow channel **53** can be effectively prevented. As a result, drift in the fluid flow channel can be inhibited and the development of turbulent flow of the internal fluid can be enhanced, thereby making it possible to enhance the heat transfer effect.

[0113] Further, in the fourth embodiment, the metal tube **47** is shaped by pressing a metal sheet to form a plurality of protruding portions, which protrude in the thickness direction of the metal sheet, at predetermined positions, bending the metal sheet to obtain the aforementioned flat shape, and then joining together the end portions of the metal sheet. Therefore, it is not necessary to join by welding, for example, the columnar bodies serving as support portions to the metal sheet. As a result, the process is simplified and the production cost can be reduced.

Fifth Embodiment

[0114] FIG. **17**A is a perspective view illustrating the heat exchanger **21** according to the fifth embodiment of the present invention. The structure of the protruding portion **55** serving as the support portion of the heat exchanger **21** is different from that of the first embodiment. Other components are identical to those of the heat exchanger **21** according to the first embodiment and therefore assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0115] FIG. **17**B is a plan view illustrating the metal tube **47** of the heat exchanger **21**. This metal tube **47** is provided with a plurality of first protruding portions **55***a* and a plurality of second protruding portions **55***b* as support portions **55**. The plurality of first protruding portions **55***a* are arranged along the longitudinal direction of the fluid flow channel **53** at the inner surface on one side in the longitudinal direction of the fluid flow channel **53**. The plurality of second protruding portions **55***b* are disposed along the longitudinal direction of the fluid flow channel **53** at the inner surface on the other side in the thickness direction of the fluid flow channel **53**. Each first protruding portion **55***a* protrude from the inner surface on the one side toward the inner surface on the other side, and each second protruding portion **55***b* protrude from the inner surface on the other side toward the inner surface on the one side. Each first protruding portion **55***a* and each second protruding portion **55***b* can be formed, for example, by press forming a metal sheet in the same manner as in the fourth embodiment.

[0116] As shown in FIG. **17**B, the size in the width direction W of each first protruding portion **55***a* and second protruding portion **55***b* is less than the size thereof in the longitudinal direction L. Thus, each of the first protruding portions **55***a* and second protruding portions **55***b* has an elongated shape in the plan view thereof. The longitudinal direction of the first protruding portions **55***a* and second protruding portions **55***b* is substantially parallel to the longitudinal direction L of the metal tube **47**.

[0117] In the fifth embodiment, all of the plurality of first protruding portions **55***a* are provided, as shown in FIGS. **17**C and **17**D, at positions that are opposite the second protruding portions **55***b* in the thickness direction. It is also possible to provide some of the plurality of first protruding portions **55***a* at positions that are opposite the second protruding portions **55***b* in the thickness direction and provide the remaining first protruding portions **55***a* at positions that are not opposite the second protruding portions **55***b*. In such a configuration, the first protruding portions **55***a* provided at positions that are not opposite the second protruding portions **55***b* function as obstacles that create appropriate turbulence in the fluid in the fluid flow channel **53**. Where the fluid becomes appropriately turbulent, heat transfer between the fluid and the metal tube **47** is enhanced. Therefore, heat exchange efficiency of the heat exchanger can be increased.

[0118] According to the fifth embodiment, the opposing first protruding portions **55***a* and second protruding portions **55***b* are disposed along the longitudinal direction. Therefore, such a configuration is particularly advantageous in terms of the effect of ensuring contact surface area of the first protruding portions **55***a* and second protruding portions **55***b* when the heat exchanger **21** is bent, for example, spirally as shown in FIG. **2**.

[0119] When the heat exchanger **21** is bent as shown in FIG. **2**, the elongation of material in the portion of the metal tube **47** on the radially outer side is large and the elongation of material in the portion on the radially inner side is small, as shown in FIG. **18**A. Therefore, relative positions of the first protruding portions **55***a* and second protruding portions **55***b* can be easily displaced. In the fifth embodiment, the longitudinal direction of the first protruding portions **55***a* and the longitudinal direction of the second protruding portions **55***b* are arranged along the longitudinal direction of the metal tube **47**. Therefore, the contact state of the first protruding portions **55***a* and second protruding portions **55***b* can be maintained even when the relative positions of the first protruding portions and second protruding portions are somewhat displaced. As a result, bending with a small curvature radius can be performed.

[0120] Where the size of the first protruding portions **55***a* in the longitudinal direction and the size of the second protruding portions **55***b* in the longitudinal direction are decreased, as shown in FIG. **18**B, the allowance range in which the aforementioned contact state can be maintained against the displacement of the relative positions is decreased accordingly.

[0121] FIG. **19** is a plan view illustrating a variation example of the metal tube **47** in the heat exchanger **21** according to the fifth embodiment. As shown in FIG. **19**, in the metal tube **47** according to this variation example, the first protruding portions **55***a* and the second protruding portions **55***b* have a wedge-like shape. In other words, the first protruding portions **55***a* and the second protruding portions **55***b* have a substantially triangular shape in a plan view thereof. In this variation example, the first protruding portions **55***a* and the second protruding portions **55***b* are disposed so that the apexes of the triangles face the flow direction F of the fluid in a plan view. As a result, the fluid flows smoothly along the side surfaces of the first protruding portions **55***a* and second protruding portions **55***b* and therefore the occurrence of pressure loss inside the metal tube **47** can be inhibited.

[0122] Further, in the fifth embodiment illustrated by FIGS. **17** to **19**, the size of the protruding portions **55** in the width direction, that is, the size in the direction perpendicular to the flow direction F of the fluid, is less than the size of the protruding portions **55** in the longitudinal direction. As a result, the increase in resistance encountered by the fluid flowing in the metal tube **47** can be inhibited.

Sixth Embodiment

[0123] FIG. **20** is a perspective view illustrating the heat exchanger **21** according to the sixth embodiment of the present invention. The structure of the metal tube **47** of the heat exchanger **21** according to the sixth embodiment is different from that of the first embodiment. Other components are identical to those of the heat exchanger **21** according to the first embodiment and therefore assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0124] The metal tube **47** in this heat exchanger **21** is provided with the fluid flow channel **53** and the support portion **55**. The fluid flow channel **53** has a first fluid flow channel **53***a* and a second fluid flow channel **53***b* extending in the longitudinal direction L and arranged parallel to each other in the width direction W. The support portion **55** is provided in the fluid flow channel **53** constituted by the first fluid flow channel **53***a* and the second fluid flow channel **53***b* arranged parallel to each other in the width direction W. The metal tube **47** is obtained by bending a flat metal sheet M and joining the predetermined portions as shown in FIG. **21**A.

[0125] The first fluid flow channel **53***a* is formed in the following manner. First, the metal sheet M is bent at a bending position B**1** extending along the longitudinal direction L and the metal sheet M is bent into a tube so that the end side El on one side in the width direction of the metal sheet M comes into contact with a surface S on one side of the metal sheet M. Then, the end side E**1** is joined for example by welding to the surface S along the longitudinal direction L, thereby forming the first fluid flow channel **53***a.*

[0126] Likewise, the second fluid flow channel **53***b* is formed in the following manner. First, the metal sheet M is bent at a bending position B**2** extending along the longitudinal direction L and the metal sheet M is bent into a tube so that the end side E**2** on one side in the width direction of the metal sheet M comes into contact with the surface S on one side of the metal sheet M. Then, the end side E**2** is joined for example by welding to the surface S along the longitudinal direction L, thereby forming the second fluid flow channel **53***b.*

[0127] As shown in FIG. **21**C, the support portion **55** is constituted by portions of the metal sheet M, that is, by portions extending upward in the height direction (thickness direction of the metal tube **47**) from the end side E**1** and end side E**2**. In the support portion **55**, zones in the vicinity of the end side E**1** and end side E**2** abut on each other. Further, the support portion **55** branches to both sides in the width direction W from the vicinity of the central portion in the height direction. The branched portions of the support portion **55** extend obliquely from the height direction to the left and to the right.

[0128] Since the metal tube **47** according to the sixth embodiment is formed in the above-described mariner by using the metal sheet M, the metal tube has a substantially B-like cross-sectional shape. The support portion **55** thus extending along the longitudinal direction L can be formed by a simple manufacturing method. Further, since the support portion **55** of the metal tube **47** extends continuously along the longitudinal direction L, the configuration demonstrates excellent effect of inhibiting deformation in the thickness direction.

[0129] FIG. **22**A is a plan view illustrating a variation example of the metal tube **47** according to the sixth embodiment. FIG. **22**B is a cross-sectional view of the metal tube. As shown in FIGS. **22**A and **22**B, the metal tube **47** has a plurality of protruding portions **55***c* and a plurality of protruding portions **55***d* in the first fluid flow channel **53***a* and in the second fluid flow channel **53***b,* respectively.

[0130] The plurality of protruding portions **55***c* are arranged in a row along the longitudinal direction L at the inner surface **57** on one side in the thickness direction of the fluid flow channels **53***a,* **53***b.* The plurality of protruding portions **55***d* are arranged in a row along the longitudinal direction L at the inner surface **59** on the other side in the thickness direction of the fluid flow channels **53***a,* **53***b.* The protruding portions **55***c* extend from the inner surface **57** on one side toward the inner surface **59** on the other side, and the protruding portions **55***d* extend from the inner surface **59** on the other side toward the inner surface **57** on one side.

[0131] The protruding portions **55***c* and protruding portions **55***d* may be disposed opposite each other in the thickness direction or at positions that are not opposite each other. When the protruding portions are disposed at the opposing positions, the protruding portions **55***c* and the protruding portions **55***d,* together with the support portion **55**, function as support portions inhibiting deformation of the metal tube **47** in the thickness direction. When the protruding portions are disposed at positions that are not opposite each other, the protruding portions **55***c* and the protruding portions **55***d* function as obstacles that create appropriate turbulence in the fluid in the fluid flow channel **53**. Where the fluid becomes appropriately turbulent, heat transfer between the fluid and the metal tube **47** is enhanced.

[0132] In the metal tube **47** according to the sixth embodiment, the support portion **55** can be formed in the fluid flow channel **53** by using the above-described manufacturing method. Therefore, the protruding portions for increasing the heat transfer performance can be provided in the fluid flow channels **53***a*, **53***b* by a free design (design focused on the increase in heat transfer performance), as in the variation example illustrated by FIGS. **22**A and **22**B.

Seventh Embodiment

[0133] FIG. **23**A is a perspective view illustrating the heat exchanger **21** according to the seventh embodiment of the present invention. The structure of the metal tube **47** of the heat exchanger **21** according to the seventh embodiment is different from that of the first embodiment. Other components are identical to those of the heat exchanger **21** according to the first embodiment and therefore assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0134] The metal tube **47** in the heat exchanger **21** according to the seventh embodiment is constituted by a first metal tube **47***a* and a second metal tube **47***b* arranged parallel to each other in the width direction W. The first metal tube **47***a* and the second metal tube **47***b* are cylindrical flat pipes formed separately from each other by an appropriate method, for example, extrusion forming. Therefore, the fluid flow channel **53** of the metal tube **47** is constituted by the first fluid flow channel **53***a* inside the first metal tube **47***a* and the second fluid flow channel **53***b* inside the second metal tube **47***b*. These first fluid flow channel **53***a* and second fluid flow channel **53***b* are partitioned by the support portion **55**. In other words, the support portion **55** is provided in the fluid flow channel **53** constituted by the first fluid flow channel **53***a* and the second fluid flow channel **53***b* arranged parallel to each other in the width direction W.

[0135] The support portion **55** is constituted by a side wall **55***a* of the first metal tube **47***a* and a side wall **55***b* of the second metal tube **47***b*. The side wall **55***a* and the side wall **55***b* are in surface contact with each other. Protruding portions **55***c* and protruding portions **55***d* such as shown in FIGS. **22**A and **22**B may be provided in the fluid flow channels **53***a*, **53***b*.

[0136] In the seventh embodiment, the cylindrical flat pipes can be formed in a simple manner by an appropriate method, for example, extrusion forming. Therefore, the production cost can be reduced.

[0137] The number of flat tubes arranged parallel to each other in the width direction W is not limited to 2 and may be 3, as shown in FIG. **23**B, or 4 or more.

[0138] As shown in FIG. **23**C, an integrated flat tube in which the first fluid flow channel **53***a* and second fluid flow channel **53***b* are partitioned by the support portion **55** by using a method such as extrusion forming can be also used as the metal tube **47**. The support portion **55** of the metal tube **47** is formed continuously in the longitudinal direction L and partitions the first fluid flow channel **53***a* and second fluid flow channel **53***b*.

[0139] The metal tube **47** such as shown in FIG. **24**B may be also used. This metal tube **47** is obtained by combining two tubular members **47***a*, **47***b* with a substantially P-like cross-sectional shape, as shown in FIG. **24**A. The tubular members **47***a*, **47***b* are formed by bending a metal sheet. Thus, the tubular member **47***a* is formed by folding the metal sheet at a bending position extending along the longitudinal direction and bending the metal sheet to a substantially P-like shape such that the end side on one side in the width direction of the metal sheet is brought into contact with the surface on one side of the metal sheet. The tubular member **47***b* is formed in a similar manner.

[0140] The tubular member **47***a* has the first fluid flow channel **53***a*, and the tubular member **47***b* has the second fluid flow channel **53***b*. The tubular member **47***a* and the tubular member **47***b* have flat portions **48***a*, **48***b* extending in the width direction W from cylindrical portions constituting the fluid flow channels **53***a*, **53***b*. The first fluid flow channel **53***a* and the second fluid flow channel **53***b* are arranged parallel to each other in the width direction W. The flat portion **48***a* is disposed below the tubular member **47***b*, and the flat portion **48***b* is disposed below the tubular member **47***a*. The side wall of the tubular member **47***a* functions as the support portion **55***a*, and the side wall of the tubular member **47***b* functions as the support portion **55***b*. The support portion **55***a* and the support portion **55***b* are in surface contact with each other.

[0141] With the metal tube **47** in which the tubular members **47***a*, **47***b* are thus combined, the entire upper surface and the entire lower surface in the thickness direction are flat. Therefore, the surface area of contact with the multiple-hole metal tubes **45**, **47** can be increased. As a result, heat exchange efficiency of the heat exchanger **21** can be increased.

[0142] Further, in the metal tube **47** shown in FIG. **24**C, the fluid flow channels **53***a*, **53***b* of the tubular member **47***a* and tubular member **47***b* are less than those shown in FIG. **24**B, and the support member **55***a* and the support member **55***b* are separated so as to avoid surface contact thereof. As a result, a third fluid flow channel **53***c* is additionally formed between the first fluid flow channel **53***a* and the second fluid flow channel **53***b*.

Eighth Embodiment

[0143] FIG. **25** is a cross-sectional view illustrating the heat exchanger **21** according to the eighth embodiment of the present invention. The structure of the metal tube **47** of the heat exchanger **21** according to the eighth embodiment is different from that of the first embodiment. Other components are identical to those of the heat exchanger **21** according to the first embodiment and therefore assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0144] The metal tube **47** of this heat exchanger **21** is formed by spirally bending a metal sheet. The metal tube **47** has the support portion **55** and the fluid flow channel **53**. The fluid flow channel **53** is constituted by the first fluid flow channel **53***a* and the second fluid flow channel **53***b* partitioned in the width direction W by the support portion **55**. In other words, the support portion **55** is provided in the fluid flow channel **53** constituted by the first fluid flow channel **53***a* and the second fluid flow channel **53***b* arranged parallel to each other in the width direction W.

[0145] The support portion **55** corresponds to a portion obtained by bending the end portion on one side of the metal sheet in the width direction W in a L-like shape with a width substantially of the same order as the thickness of the first fluid flow channel **53***a*. The metal sheet is bent spirally so that the support portion **55** is positioned close to the center of the metal tube **47** in the width direction W. Because of such spiral bending, a joining surface **50***a* and a joining surface **50***b* are in surface contact with each other. The joining surface **50***a* and the joining surface **50***b* can be joined by an appropriate method such as the above-described resistance welding, brazing, and soldering.

[0146] When joining by brazing, for example, the following joining can be performed. First, a braze layer is formed in advance over the entire both surfaces of the metal sheet. Then, the sheet is spirally bent in the above-described manner and processed into the shape of the metal tube **47**. In this case, since the braze layer has been formed on the joining surface **50***a* and the joining surface **50***b*, the joining surfaces **50***a*, **50***b* can be joined together by heating the metal tube **47** in a heating furnace (not shown in the figure) or the like. Further, as shown in FIG. **25**, a pre-assembled body obtained by pre-assembling the metal tube **47** in a state prior to joining the joining surfaces **50***a*, **50***b* and the multiple-hole metal tubes **45**, **49** may be heated in a heating furnace or the like. Since the braze layer has been formed on both surfaces (upper and lower surfaces) in the thickness direction of the metal tube **47**, not only the joining surfaces **50***a*, **50***b*, but also the metal tube **47** and the multiple-hole metal tubes **45**, **49** can be joined together at the same time by heating the pre-assembled body in the heating furnace.

[0147] In the eighth embodiment, the entire upper surface and the entire lower surface in the thickness direction of the metal tube **47** can be flat. Therefore, the contact surface area with the multiple-hole metal tubes **45**, **47** can be increased. As a result, heat exchange efficiency of the heat exchanger **21** can be improved.

[0148] Further, the metal tube **47** has a plurality of protruding portions **55***c* and a plurality of protruding portions **55***d* in the first fluid flow channel **53***a* and the second fluid flow channel **53***b*, respectively. As described above, in the metal tube **47** according to the eighth embodiment, the support portion **55** can be formed, by forming the tube by the above-described manufacturing method. Therefore, the protruding portions for increasing the heat transfer performance can be provided in the fluid flow channels **53***a*, **53***b* by a free design (design focused on the increase in heat transfer performance).

Ninth Embodiment

[0149] FIGS. **26**A and **26**B are plan views illustrating the process for manufacturing the metal tube **47** for the heat exchanger **21** according to the ninth embodiment of the present invention. FIG. **26**C is a cross-sectional view taken along the XXVIc-XXVIc line in FIG. **26**B. The structure of the protruding portion **55** serving as the support portion of the heat exchanger **21** is different from that of the first embodiment. Other components are identical to those of the heat exchanger **21** according to the first embodiment and therefore assigned with same reference numerals as in the first embodiment and the explanation thereof is herein omitted.

[0150] The metal tube **47** is provided with a plurality of first protruding portions **55***a* and a plurality of second protruding portions **55***b* serving as support portions **55**. The plurality of first protruding portions **55***a* are arranged along the longitudinal direction of the fluid flow channel **53** at the inner surface on one side in the thickness direction of the fluid flow channel **53**. The plurality of second protruding portions **55***b* are provided along the longitudinal direction of the fluid flow channel **53** at the inner surface on the other side in the thickness direction of the fluid flow channel **53**. Each first protruding portion **55***a* protrudes from the inner surface on the one side toward the inner surface on the other side, and each second protruding portion **55***b* protrudes from the inner surface on the other side toward the inner surface on the one side. The first protruding portions **55***a* and the second protruding portions **55***b* are formed by press forming a metal sheet in the same manner as in the fourth embodiment.

[0151] As shown in FIG. **26**B, the first protruding portions **55***a* and the second protruding portions **55***b* have an elongated shape in a plan view therefor. The first protruding portion **55***a* and the second protruding portion **55***b* opposing each other in the thickness direction are provided so as to cross each other in a plan view thereof. The longitudinal direction of the first protruding portions **55***a* is inclined to one side in the width direction W of the metal tube **47** with respect to the longitudinal direction L of the metal tube **47**. The longitudinal direction of the second protruding portions **55***b* is inclined toward the other side in the width direction W with respect to the longitudinal direction L of the metal tube **47**. The inclination angle of the first protruding portions **55***a* with respect to the longitudinal direction is equal to the inclination angle of the second protruding portions **55***b* with respect to the longitudinal direction.

[0152] As shown in FIGS. **26**B and **26**C, the end surfaces of the first protruding portion **55***a* and second protruding portion **55***b* abut on each other in a contact region T.

[0153] The metal tube **47** according to the ninth embodiment is formed in the following manner. First, as shown in FIG. **26**A, the plurality of protruding portions **55** are formed with a predetermined spacing on almost the entire surface of the metal sheet M. These protruding portions **55** include a plurality of first protruding portions **55***a* formed in a region on one side (upper side in FIG. **26**A) on a central line B**3** positioned as a boundary close to the center of the metal tube M in the width direction W and a plurality of second protruding portions **55***b* formed in a region on the other side (lower side in FIG. **26**A). In the metal sheet M, the first protruding portions **55***a* and second protruding portions **55***b* are formed in the same direction at the same inclination angle.

[0154] Where the metal sheet M is folded along the central line B**3**, the first protruding portions **55***a* and the second protruding portions **55***b* are disposed in a mutual arrangement such as to cross each other, as shown in FIG. **26**B, and the end side El on one side and the end side E**2** on the other side in the width direction W of the metal sheet M come close to each other. The metal tube **47** is obtained by joining the end sides E**1**, E**2** together by an appropriate method, for example, welding.

[0155] When the abovementioned metal sheet M is folded, the opposing positions of the corresponding first protruding portions **55***a* and second protruding portions **55***b* are somewhat displaced as shown in FIGS. **27**A and **27**B. Even in such cases, since the first protruding portions **55***a* and second protruding portions **55***b* are disposed to cross each other, the contact surface area of the mutual contact region T assumes an almost same value, provided that the displacements in various directions take place within a range in which the crossed state of the first protruding portions **55***a* and second protruding portions **55***b* is maintained. As a result, even where a certain displacement occurs when the metal tube **47** is formed, the effect of inhibiting the deformation in the thickness direction of the metal tube **47** can be prevented from reducing.

[0156] Further, when the heat exchanger **21** is fabricated by stacking the metal tube **47** and the multiple-hole metal tubes **45**, **49** and then the heat exchanger **21** is spirally bent, for example as shown in FIG. **2**, even if the relative positions of the opposing first protruding portions **55***a* and second protruding portions **55***b* are somewhat displaced, the mutual contact surface area can be prevented from decreasing. Thus, even if a certain displacement occurs, the contact surface area of the contact region T assumes an almost same value. Therefore, the variation in of the effect of inhibiting the deformation in the thickness direction can be inhibited over the entire metal tube **47**. As a result, such inconveniences as the occurrence of an extremely large deformation in part of the metal tube **47** can be inhibited. Therefore, the variation in the degree of pressure loss among the zones of the metal tube **47** can be inhibited.

[0157] Thus, as mentioned hereinabove, portions where the elongated first protruding portions **55***a* and second protruding portions **55***b* are in contact with each other function to inhibit deformation in the thickness direction. Meanwhile, portions where the elongated first protruding portions **55***a* and second protruding portions **55***b* are not in contact with each other function as obstacles that create appropriate turbulence in the fluid in the fluid flow channel **53**. Where the fluid becomes appropriately turbulent, heat transfer between the fluid and the metal tube **47** is enhanced. Therefore, heat exchange efficiency of the heat exchanger **21** can be increased.

[0158] Further, in the ninth embodiment, the first protruding portions **55***a* and second protruding portions **55***b* provided in the metal sheet M may be formed at the same inclination angle with respect to the same direction. Therefore, the design is simple. Moreover, in the ninth embodiment, the size of the first protruding portions **55***a* or second protruding portions **55***b* in the width direction W can be reduced by comparison with the case in which either the first protruding portions **55***a* or the second protruding portions **55***b* are disposed parallel to the width direction W of the metal tube **47**. As a result, the increase in resistance encountered by the fluid flowing inside the metal tube **47** can be inhibited.

[0159] (Other Manufacturing Methods)

[0160] In the heat exchanger **21** according to the above-described first to ninth embodiments, the metal tube **47** and the multiple-hole metal tubes **45**, **49** can be joined by using not only the above-described method based on resistance welding, but also other methods such as brazing and soldering. Brazing as referred to herein is a joining method performed using a braze having a melting point equal to or higher than 450° C. and soldering is a joining method performed using a solder having a melting point of less than 450° C.

[0161] With the joining method using brazing, a braze is disposed, for example, between the metal tube **47** and the multiple-hole metal tube **45** and between the metal tube **47** and the multiple-hole metal tube **49**, and the components are heated in this state in a heating furnace or the like. As a result, the braze is melted and the metal tube **47** and the multiple-hole metal tubes **45**, **49** are joined to each other.

[0162] For example, ultrasonic soldering can be used as a joining method based on soldering. With this method, a solder is disposed between the metal tube **47** and the multiple-hole metal tube **45** and between the metal tube **47** and the multiple-hole metal tube **49**, an ultrasonic soldering probe is brought into contact with at least one component from among the metal tube **47**, multiple-hole metal tube **45**, and multiple-hole metal tube **49**, and ultrasonic vibrations are applied thereto under heating. As a result, the solder is melted and the metal tube **47** and the multiple-hole metal tubes **45**, **49** are joined to each other.

Summary of Embodiments

[0163] The embodiments are summarized below.

[0164] (1) The heat exchanger includes a metal tube that has a flat shape with a width greater than a thickness, a fluid flow channel formed inside thereof along a longitudinal direction, respective outer surfaces formed on one side and the other side in a thickness direction, and a support portion formed in the fluid flow channel and inhibiting deformation in the thickness direction; and a multiple-hole metal tube stacked on one side of the metal tube in the thickness direction, the multiple-hole metal tube that has a flat shape with a width greater than a thickness, a plurality of fluid flow channels formed inside thereof along the longitudinal direction, and an opposing surface disposed opposite the outer surface on the one side of the metal tube and joined by at least part thereof to the outer surface on the one side.

[0165] In such a configuration, a support portion that inhibits deformation in the thickness direction is provided in the fluid flow channel of the metal tube. Therefore, the heat exchanger can be manufactured by using resistance welding by which the flat metal tube and flat multiple-hole metal tube stacked in the thickness direction are welded, while being pressurized in the thickness direction by a pair of roller electrodes. Since the heat exchanger can thus be manufactured by resistance welding that excels in productivity, the cost can be reduced.

[0166] Further, since the support portion is provided in the fluid flow channel, the metal tube and multiple-hole metal tubes can be sufficiently pressurized in the thickness direction by the pair of roller electrodes during resistance welding. As a result, the joining surface area of the outer surfaces of the metal tube and the opposing surfaces of the multiple-hole metal tubes opposite thereto can be increased and therefore a heat exchanger with excellent heat exchange efficiency can be obtained.

[0167] Further, with such a configuration, since the metal tube has a support portion in the fluid flow channel, deformation of the metal tube can be inhibited even in a long-term use of the heat exchanger.

[0168] Moreover, with such a configuration, since the metal tube has a support portion in the fluid flow channel, for example, even when the heat exchanger is bent as shown in the below-described FIG. **2**, the excess deformation of the metal tube can be inhibited. As a result, the fluid flow channel can be prevented from being excessively narrowed or closed.

[0169] (2) The support portion may have a plurality of columnar bodies arranged along the longitudinal direction of the fluid flow channel, one end of each of the columnar bodies in an axial direction may be joined to an inner surface on either side in the thickness direction of the fluid flow channel, and the other end of each of the columnar bodies in the axial direction may be disposed on an inner surface side on the other side in the thickness direction of the fluid flow channel.

[0170] In such a configuration, since a plurality of columnar bodies are arranged along the longitudinal direction of the fluid flow channel, deformation of the metal tube in the longitudinal direction can be inhibited over a long period. Furthermore, since the columnar bodies are arranged in a spot-like pattern in the longitudinal direction, the increase in resistance to the flow of fluid in the fluid flow channel that is caused by the support portion can be inhibited and the fluid can smoothly flow in the fluid flow channel. In addition, in this configuration, one end of each columnar body is joined to the inner surface of the fluid flow channel. Therefore, the columnar bodies can be prevented from tilting or tumbling even when pressurized in the thickness direction by roller electrodes during resistance welding. As a result, deformation of the fluid flow channel is inhibited and the desired flow channel can be ensured.

[0171] (3) Both ends in the axial direction of at least one of the plurality of columnar bodies may be respectively joined to the inner surface on one side and the inner surface on the other side of the fluid flow channel.

[0172] In such a configuration, since columnar bodies are provided that are joined to the inner surface on one side and the inner surface on the other side of the fluid flow channel, the rigidity of the metal tube can be further increased. As a result, deformation of the metal tube can be inhibited over a longer period.

[0173] (4) In another possible configuration, the support portion has a plurality of first columnar bodies arranged along the longitudinal direction of the fluid flow channel on an inner surface on one side in the thickness direction of the fluid flow channel and a plurality of second columnar bodies arranged along the longitudinal direction of the fluid flow channel on an inner surface on the other side in the thickness direction of the fluid flow channel; the first columnar bodies extend from the inner surface on the one side toward the inner surface on the other side; and the second columnar bodies extend from the inner surface on the other side toward the inner surface on the one side, and distal end portions thereof abut on or are disposed close to respective distal end portions of the plurality of first columnar bodies.

[0174] In such a configuration, when a pressure is applied in the thickness direction to the metal tube and multiple-hole metal tubes by a pair of roller electrodes during resistance welding, the first columnar bodies and second columnar bodies that have been abutted on each other by the distal end portions are in the abutted state and the columnar bodies that have distal end portions disposed close to each other abut on each other by the distal end portions, thereby making it possible to receive and stop the pressure in the thickness direction. As a result, deformation of the metal tubes in the thickness direction during resistance welding can be effectively inhibited. In the present configuration, a plurality of first columnar bodies and a plurality of second columnar bodies that have distal portions abutted on each other or disposed close to each other are arranged in the longitudinal direction of the fluid flow channel. Therefore, deformation of the metal tubes in the longitudinal direction can be inhibited over a long period. Furthermore, since the columnar bodies are arranged in a spot-like pattern in the longitudinal direction, the increase in resistance to the flow of fluid in the fluid flow channel that is caused by the support portion can be inhibited and the fluid can smoothly flow in the fluid flow channel.

[0175] (5) At least one of the plurality of first columnar bodies and at least one of the plurality of second columnar bodies may be joined together at the distal end portions thereof.

[0176] In such a configuration, since the first columnar bodies and second columnar bodies are provided that are joined together at the distal end portions thereof, the rigidity of the metal tubes can be further increased. As a result, deformation of the metal tubes can be inhibited over a longer period.

[0177] (6) The support portion may be a corrugated plate-like body disposed along the longitudinal direction of the fluid flow channel.

[0178] In such a configuration, since the corrugated plate-like body is disposed along the longitudinal direction, deformation of the metal tubes in the longitudinal direction can be inhibited over a long period. Further, the corrugated plate-like body acts to disperse the fluid flow. Therefore, it is possible to regulate the fluid flow and produce a flow with low turbulence. Since the rigidity of the support body itself can be increased over that in the case of the above-described columnar bodies, such a configuration is particularly advantageous when a larger pressurization force is desired to be obtained with the pair of roller electrodes.

[0179] (7) The support portion may have a plurality of protruding portions arranged along the longitudinal direction of the fluid flow channel, and each of the protruding portions may protrude from an inner surface on either side in the thickness direction of the fluid flow channel toward an inner surface on the other side in the thickness direction.

[0180] In such a configuration, since a plurality of protruding portions are arranged along the longitudinal direction of the fluid flow channel, deformation of the metal tubes can be inhibited over a long period.

[0181] (8) A size of each of the protruding portions in a width direction may be set less than the size thereof in the longitudinal direction.

[0182] In such a configuration, by reducing the size of each protrusion in the width direction, that is, the size in the direction perpendicular to the fluid flow direction, below the size in the longitudinal direction, it is possible to inhibit an excess increase in the resistance encountered by the fluid flowing in the metal tube. Further, the size of each protruding portion in the longitudinal direction may be designed as appropriate to a value required to inhibit deformation of the metal tubes in the thickness direction. As a result, the resistance encountered by the fluid can be reduced and the effect of inhibiting the deformation of the metal tube in the thickness direction can be maintained.

[0183] (9) The protruding portions are not limited to the abovementioned columnar bodies and can be formed, for example, by causing the outer surface on one side in the thickness direction to recede toward the other side or the outer surface on the other side in the thickness direction to recede toward the one side.

[0184] In such a case, the protruding portions can be formed, for example, by pressing a metal sheet. Therefore, the production is simple and cost can be reduced.

[0185] (10) The support portion may have a plurality of first protruding portions arranged along the longitudinal direction of the fluid flow channel on an inner surface on one side in the thickness direction of the fluid flow channel, and a plurality of second protruding portions arranged along the longitudinal direction of the fluid flow channel on an inner surface on the other side in the thickness direction of the fluid flow channel, the first protruding portions may protrude from the inner surface on the one side toward the inner surface on the other side, and the second protruding portions may protrude from the inner surface on the other side toward the inner surface on the one side.

[0186] With such a configuration, the plurality of the first protruding portions and the plurality of the second protruding portions are arranged along the longitudinal direction of the fluid flow channel Therefore, deformation of the metal tube in the longitudinal direction can be inhibited over a long period.

[0187] (11) Such first protruding portions and second protruding portions are not limited to the abovementioned first columnar bodies and second columnar bodies and can be formed, for example, by causing the outer surface on one side and the outer surface on the other side in the thickness direction to recede.

[0188] In the case of such a configuration, the protruding portions can be formed, for example, by pressing a metal sheet. Therefore, the production is simple and cost can be reduced.

[0189] (12) Some or all of the plurality of first protruding portions are preferably provided at positions opposite the second protruding portions in the thickness direction.

[0190] With such a configuration, where the first protruding portions and the second protruding portions disposed at positions opposite thereto abut on each other, subsequent deformation of the metal tube **47** is inhibited even when a pressure is applied in the thickness direction to the metal tube **47** during the resistance welding or bending such as described hereinabove. As a result, deformation in the thickness direction of the metal tube during resistance welding or bending can be effectively inhibited.

[0191] (13) The first protruding portions and the second protruding portions may respectively have elongated shapes in a plan view thereof, and the first protruding portions and the second protruding portions, which are facing each other in the thickness direction, may be provided so as to cross each other in a plan view thereof.

[0192] With such a configuration, even when the relative positions of the opposing first protruding portions and second protruding portions are somewhat displaced in various directions when forming the metal tube **47**, bending of the heat exchanger, and the like, changes in the mutual contact surface area thereof can be inhibited. Thus, where displacements in various directions take place within a range in which the crossed state of the first protruding portions and second protruding portions is maintained, the mutual contact surface area assumes an almost same value. Therefore, even when a certain displacement occurs, the first protruding portions and second protruding portions come into contact with each other over a contact surface area of an almost same value. Therefore, the variation in the effect of inhibiting the deformation in the thickness direction decreases over the entire metal tube. As a result, when the heat exchanger is bent, a stable deformation inhibition effect can be obtained over the entire metal tube. Therefore, the variation in the degree of pressure loss among the zones of the metal tube can be inhibited.

[0193] In this configuration, elongated first protruding portions and second protruding portions are disposed to cross each other, and there are portions in which the first protruding portions and second protruding portions are in contact with each other and portions adjacent thereto in which the first protruding portions and second protruding portions are not in contact with each other. These contact-free portions function as obstacles that create appropriate turbulence in the fluid in the fluid flow channel Where the fluid becomes appropriately turbulent, heat transfer between the fluid and the metal tube is enhanced. Therefore, heat exchange efficiency of the heat exchanger can be increased.

[0194] Further, this configuration is effective when the metal tube is formed by bending a metal sheet (flat sheet) and joining together the end sides of the metal sheet. In this case, the first protruding portions and second protruding portions are formed at the metal sheet in advance, before the metal sheet is bent. Even when the opposing positions of the opposing first protruding portions and second protruding portions somewhat shift during bending, where the displacement in various directions takes place within the range in which the crossing state of the first protruding portions and second protruding portions is maintained, the mutual contact surface area assumes an almost same value. As a result, decrease in the deformation inhibition effect in the thickness direction of the metal tube can be suppressed even if the displacement occurs when the metal tube is formed.

[0195] (14) It is preferred that a longitudinal direction of the first protruding portions be inclined to one side in a width direction of the metal tube with respect to the longitudinal direction of the metal tube; a longitudinal direction of the second protruding portions be inclined to the other side in the width direction with respect to the longitudinal direction of the metal tube; and an inclination angle of the first protruding portions with respect to the longitudinal direction be equal to an inclination angle of the second protruding portions with respect to the longitudinal direction.

[0196] In this configuration, the first protruding portions and the second protruding portions provided at the metal tube may be formed in the same direction and at the same inclination angle. Therefore, the design and processing are simple. Furthermore, in this configuration, the size component of the first protruding portions **55***a* or the second protruding portions **55***b* in the width direction of the metal tube can be reduced by comparison with that in the case in which either of the first protruding portions and second protruding portions are disposed parallel to the width direction of the metal tube. As a result, an excess increase in the resistance encountered by the fluid flowing in the metal tube can be inhibited.

[0197] (15) The first protruding portions and the second protruding portions may respectively have elongated shapes in a plan view thereof, and a longitudinal direction of the first protruding portions and the second protruding portions, which are facing each other in the thickness direction, may be parallel to the longitudinal direction of the metal tube.

[0198] In such a configuration, the effect of ensuring the contact surface area of the opposing first protruding portions and second protruding portions is especially advantageous when the heat exchanger is bent spirally or in a zigzag shape. Thus, when the heat exchanger is bent as mentioned above, in the curved portion of the metal tube, the elongation of material on the radially outer side is less than the elongation of material on the radially inner side. Therefore, relative positions of the first protruding portions and second protruding portions are easily displaced. Accordingly, in this configuration, the longitudinal direction of the first protruding portions and the second protruding portions is along the longitudinal direction of the metal tube and therefore excellent effect of maintaining the mutual contact state is demonstrated even when the relative positions are displaced in the longitudinal direction by the abovementioned bending. As a result, bending with a small curvature radius is possible.

[0199] (16) It is preferred that the plurality of first protruding portions be arranged so that three or more rows thereof extending in the longitudinal direction are formed, and in a row positioned in a central portion in the width direction from among these rows, the first protruding portions be provided at positions opposite the second protruding portions in the thickness direction.

[0200] With such a configuration, since the first protruding portions and the second protruding portions are opposite each other in the central portion in the width direction, deformation of the metal tube can be inhibited with good balance in the central portion in the width direction. Further, "the row positioned in the central portion in the width direction" as referred to herein means the row closest to the center of the metal tube in the width direction. Therefore, when the number of the plurality of rows (the aforementioned three or more rows) extending in the longitudinal direction is an even number, "the row positioned in the central portion in the width direction" can mean two rows.

[0201] (17) It is preferred that in rows positioned at both sides of the row positioned in the central portion in the width direction, the first protruding portions be provided at positions displaced in the longitudinal direction with respect to the second protruding portions.

[0202] With such a configuration, as mentioned hereinabove, in the central portion in the width direction, the first protruding portions and the second protruding portions are disposed opposite each other, whereas in the rows positioned at both sides, the first protruding portions are provided at positions displaced in the longitudinal direction with respect to the second protruding portions. Therefore, deformation of the metal tube in the thickness direction in the central portion in the width direction can be inhibited with good balance, narrowing of the fluid flow channel at both sides in the width direction is inhibited, and a smooth flow of the fluid can be realized. Further, since the first protruding portions and the second first protruding portions are provided at both sides in the width direction, when an unexpectedly high pressure is applied in the thickness direction, the distal end portions of the first protruding portions or the distal end portions of the second protruding portions abut on an inner surface or an inner surface of the metal tube, thereby making it possible to inhibit subsequent deformation of the metal tube.

[0203] (18) It is preferred that the plurality of first protruding portions be arranged, as described hereinabove, so that three or more rows thereof extending in the longitudinal direction are formed, and also that the first protruding portions be arranged so that a plurality of rows thereof extending in a inclination direction inclined with respect to the longitudinal direction are formed; the second protruding portions be also arranged so that a plurality of rows thereof extending in the inclination direction are formed; and the rows of the first protruding portions in the inclination direction and the rows of the second protruding portions in the inclination direction be disposed alternately along the longitudinal direction.

[0204] Where such a configuration is used, steps (protruding portions) in the thickness direction can be disposed continuously with an inclination against the longitudinal direction and the steps (first protruding portions) on one side and the steps (second protruding portions) on the other side in the thickness direction can be disposed alternately. Therefore pulsations can be effectively generated in the flow of fluid in the fluid flow channel As a result, the drift in the fluid flow channel can be inhibited and the development of turbulent flow of the fluid in the fluid flow channel can be enhanced, thereby increasing the efficiency of heat exchange.

[0205] (19) The configuration is preferred in which the fluid flow channel includes a first fluid flow channel and a second fluid flow channel provided parallel to each other in the width direction and extending in the longitudinal direction; the first fluid flow channel is formed by folding a metal sheet at a position along the longitudinal direction and bending the metal sheet into a tubular shape so that one end side in the width direction of the metal sheet abuts on a surface on one side of the metal sheet, and the one end side is joined to the one surface along the longitudinal direction; the second fluid flow channel is formed by folding the metal sheet at another position along the longitudinal direction and bending the metal sheet into a tubular shape so that another end side in the width direction of the metal sheet abuts on the one surface at a position adjacent to the one end side, and the other end side is joined to the one surface along the longitudinal direction; and the support portion is constituted by parts of the metal sheet, each part extending from the one end side and the other end side in the thickness direction or a direction inclined from the thickness direction.

[0206] With such a configuration, a metal with a substantially B-like cross section can be obtained by forming a metal sheet in the above-described manner. In such a metal tube, the support portion extending along the longitudinal direction can be formed and a pair of fluid flow channel can be formed by forming the metal sheet in the above-described manner. Therefore, the metal tube is manufactured in a simple manner. Further, since the support portion of the metal tube extends continuously along the longitudinal direction, an excellent effect of inhibiting deformation in the thickness direction is demonstrated.

[0207] (20) In the heat exchanger, the multiple-hole metal tube may be a first multiple-hole metal tube and the heat exchanger may further include a second multiple-hole metal tube stacked on the other side of the metal tube in the thickness direction, the second multiple-hole metal tube that has a flat shape with a width greater than a thickness, a plurality of fluid flow channels formed inside thereof along the longitudinal direction, and an opposing surface that is disposed opposite an outer surface on the other side of the metal tube and joined by at least part thereof to the outer surface on the other side.

[0208] In such a configuration, multiple-hole metal tubes are stacked on both sides in the thickness direction of the metal tube. Therefore, the heat exchange surface area can be increased and the efficiency of heat exchange between the coolant and the fluid can be further increased.

[0209] (21) It is preferred that substantially the entire opposing surfaces be joined to the outer surfaces.

[0210] In such a configuration, substantially entire opposing regions of the metal tube and multiple-hole metal tubes are joined to each other. Therefore, the efficiency of heat exchange between the coolant and the fluid can be further increased.

[0211] (22) For example, the heat exchanger may be configured by spirally winding so that one end in the longitudinal direction is disposed inside and another end in the longitudinal direction is disposed outside.

[0212] With such a configuration, because the heat exchanger is spirally wound, dead space can be reduced and the heat exchanged can be reduced in size. Further, since the support portion is provided in the fluid flow channel of the metal tube, the fluid flow channel can be prevented from decreasing is size or closing due to deformation of the metal tube occurring during bending from a linear shape to the spiral shape and the decrease in heat exchange efficiency can be inhibited.

Other Embodiments

[0213] The present invention is not limited to the abovementioned embodiments and can be variously changed or modified without departing from the essence thereof. For example, in the fourth embodiment, an exemplary configuration is explained in which the first protruding portions **55***a* protrude from one inner surface **57**, the second protruding portions **55***b* protrude from the other inner surface **59**, and some of the first protruding portions **55***a* and some of the second protruding portions **55***b* are disposed at mutually opposing positions, but such a configuration is not limiting.

[0214] For example, in Variation Example **1** shown in FIG. **15**, the first protruding portions **55***a* protrude from one inner surface **57**, the second protruding portions protrude from the other inner surface **59**, and these first protruding portions **55***a* and second protruding portions **55***b* are disposed alternately in the longitudinal direction and thickness direction, instead of being disposed at the mutually opposing positions. With such a configuration, the distal end portions of the first protruding portions **55***a* extend close to the other inner surface **59**, and the distal end portions of the second protruding portions **55***b* extend close to the one inner surface **57**. As a result, when a pressure is applied to the metal tube **47** in the thickness direction, the first protruding portions **55***a* abut on the other surface **59**, and the second protruding portions **55***b* abut on the one inner surface **57** and therefore subsequent deformation of the metal tube **47** is inhibited. In the Variation Example 1, the first protruding portions **55***a* and the second protruding portions **55***b* are formed by pressing.

[0215] Further, for example, in Variation Example 2 shown in FIG. **16**, the protruding portions **55** may protrude only from one inner surface **57**. In such a configuration, the distal end portions of the protruding portions **55** extend to the vicinity of the other inner surface **59**. As a result, the protruding portions **55** abut on the other inner surface **59** and subsequent deformation of the metal tube **47** is inhibited even when a pressure is applied to the metal tube **47** in the thickness direction. In this Variation Example **2** the protruding portions **55** are formed by pressing.

[0216] Further, in the abovementioned embodiments, a heat exchanger that is spirally bent is explained by way of example, but the heat exchanger in accordance with the present invention is not limited to the spiral configuration and can be used in a linear configuration or can be processed into a variety of other shapes. A plurality of spiral heat exchangers such as shown in FIG. **1** may be stacked.

[0217] Further, in the abovementioned embodiments, the case of heat exchange between water and a coolant is explained by way of example, but the heat exchanger in accordance with the present invention may be used for heat exchange between coolants or for heat exchange between the coolant and another fluid.

[0218] Further, in the abovementioned embodiments, the case in which the support member is a columnar body or a corrugated plate-like body is explained by way of example, but a variety of other configurations such as a configuration in which a plurality of plate-like bodies are arranged in a spot-like pattern in the fluid flow channel of the metal tube substantially parallel to the thickness direction thereof and a configuration in which a plurality of spherical bodies are disposed in the fluid flow channel can be also used. Further, in addition to the case in which the support member is a corrugated plate-like body in the form of an S-like curve, as in the abovementioned embodiments, the support member can be in the form of a corrugated plate-like body composed by angular protrusions and depressions.

[0219] Further, in the abovementioned first embodiment and second embodiment, the configuration in which the columnar bodies are arranged in three rows is explained by way of example, but the columnar bodies in accordance with the present invention may be disposed in one row, in two rows, or in a plurality of rows (four or more rows).

[0220] Further, in the abovementioned embodiments, the case is explained in which the first embodiment, second embodiment, and third embodiment are implemented individually, but two or more implementation modes thereof may be combined.

[0221] Further, in the abovementioned embodiments, a three-layer configuration is explained that is obtained by stacking the first multiple-hole metal tube, metal tube, and second multiple-hole metal tube in the order of description, but a two-layer configuration including only one multiple-hole metal tube and the metal tube or a configuration including four or more layers may be also used.

[0222] Further, in the abovementioned embodiments, the case in which each metal tube has a flat shape having a substantially quadrangular cross section is explained by way of example, but another flat shape, for example, such that has a cross section with a curved side portion in the width direction, may be also used.

[0223] Further, in the abovementioned embodiments, the case is explained in which the metal tube and the multiple-hole metal tube are joined by a melt joining method by which the outer surface of the metal tube and the opposing surface of the multiple-hole metal tube are locally fused together in the vicinity of the boundary thereof, but in accordance with the present invention, the joining may be also performed by resistance welding in a state in which a fusion metal with a melting point lower than those of the metal tube and the multiple-hole metal tube is disposed between the outer surface of the metal tube and the opposing surface of the multiple-hole metal tube.

[0224] Further, in the abovementioned embodiments, the case in which the roller electrode is fixed and welding is performed by moving the metal tube which is the object of welding is explained by way of example, but the resistance welding may be also performed by fixing the metal tube and moving the roller electrode.

[0225] Further, in the abovementioned embodiments, the case in which the heat exchanger is used in a heat pump type hot water supply apparatus is explained by way of example, but the heat exchanger in accordance with the present invention can be also used for other applications such as air conditioners.

[0226] Further, in the abovementioned fourth embodiment, the case in which the metal sheet is pressed to form the protruding portions is explained by way of example, but the protruding portions may be also formed by joining another member to the metal sheet, for example, by welding.

[0227] Further, in the abovementioned fourth embodiment, the configuration in which the plurality of protruding portions are arranged in a spot-like pattern is explained by way of example, but the protruding portions may also have a continuous ridge-like shape along the longitudinal direction.

[0228] Further, in the abovementioned fourth embodiment, the case is explained in which some of the plurality of first protruding portions are provided at positions opposite the second protruding portions in the thickness direction, but all of the plurality of first protruding portions may be provided at positions opposite the second protruding portions in the thickness direction.

[0229] Further, in the abovementioned fourth embodiment, the configuration is explained in which the first protruding portions and second protruding portions are arranged in five rows extending in the longitudinal direction, but the first protruding portions and second protruding portions may be disposed in different rows.

[0230] Further, in the abovementioned embodiments, the case is explained in which the protruding portions with the size in the width direction such as shown, for example, in FIG. **17**B and FIG. **19**, less than the size in the longitudinal direction are provided on one inner surface and other inner surface in the thickness direction of the metal tube **47**, but such protruding portions may be provided only on either inner surface in the thickness direction of the metal tube **47**.

[0231] Further, in the abovementioned ninth embodiment, the case is explained in which the inclination angle of the first protruding portions **55***a* with respect to the longitudinal direction L is equal to that of the second protruding portions **55***b*, but such configuration is not limiting and the inclination angle of the first protruding portions **55***a* may be different from the inclination angle of the second protruding portions **55***b*. Further, a configuration may be used in which the first protruding portions **55***a* are disposed along the longitudinal direction L and the second protruding portions **55***b* are disposed along the width direction.

EXPLANATION OF REFERENCE NUMERALS

[0232] **11** hot water supply apparatus
[0233] **13** coolant circuit
[0234] **15** tank
[0235] **17** hot water storage circuit
[0236] **19** compressor
[0237] **21** heat exchanger
[0238] **23** expansion valve
[0239] **25** evaporator
[0240] **45** first multiple-hole metal tube
[0241] **47** metal tube
[0242] **49** second multiple-hole metal tube
[0243] **51** coolant flow channel
[0244] **53** fluid flow channel
[0245] **55** support member (support portion)
[0246] **55***a* first columnar body
[0247] **55***b* second columnar body
[0248] F flow direction of fluid

1. A heat exchanger comprising:

a metal tube that has a flat shape with a width greater than a thickness, a fluid flow channel formed inside thereof along a longitudinal direction, respective outer surfaces formed on one side and the other side in a thickness direction, and a support portion formed in the fluid flow channel and inhibiting deformation in the thickness direction; and

a multiple-hole metal tube stacked on one side of the metal tube in the thickness direction, the multiple-hole metal tube that has a flat shape with a width greater than a thickness, a plurality of fluid flow channels formed inside thereof along the longitudinal direction, and an opposing surface disposed opposite the outer surface on said one side of the metal tube and joined by at least part thereof to the outer surface on said one side.

2. The heat exchanger according to claim **1**, wherein

the support portion has a plurality of columnar bodies arranged along the longitudinal direction of the fluid flow channel, one end of each of the columnar bodies in an axial direction is joined to an inner surface on either side in the thickness direction of the fluid flow channel, and the other end of each of the columnar bodies in the axial direction is disposed on an inner surface side on the other side in the thickness direction of the fluid flow channel.

3. The heat exchanger according to claim **2**, wherein

both ends in the axial direction of at least one of the plurality of columnar bodies are respectively joined to the inner surface on one side and the inner surface on the other side of the fluid flow channel.

4. The heat exchanger according to claim **1**, wherein

the support portion has a plurality of first columnar bodies arranged along the longitudinal direction of the fluid flow channel on an inner surface on one side in the thickness direction of the fluid flow channel and a plurality of second columnar bodies arranged along the longitudinal direction of the fluid flow channel on an inner surface on the other side in the thickness direction of the fluid flow channel,

the first columnar bodies extend from the inner surface on said one side toward the inner surface on said other side, and

the second columnar bodies extend from the inner surface on said other side toward the inner surface on said one side, and distal end portions thereof abut on or are disposed close to respective distal end portions of the plurality of first columnar bodies.

5. The heat exchanger according to claim **4**, wherein

at least one of the plurality of first columnar bodies and at least one of the plurality of second columnar bodies are joined together at the distal end portions thereof

6. The heat exchanger according to claim **1**, wherein

the support portion is a corrugated plate-like body disposed along the longitudinal direction of the fluid flow channel.

7. The heat exchanger according to claim **1**, wherein

the support portion has a plurality of protruding portions arranged along the longitudinal direction of the fluid flow channel, and each of the protruding portions protrudes from an inner surface on either side in the thickness direction of the fluid flow channel toward an inner surface on the other side in the thickness direction.

8. The heat exchanger according to claim **7**, wherein

a size of each of the protruding portions in a width direction is less than a size thereof in said longitudinal direction.

9. The heat exchanger according to claim **7**, wherein

the protruding portions are formed by causing the outer surfaces on one side and other side in the thickness direction to recede toward said other side or said one side.

10. The heat exchanger according to claim **1**, wherein

the support portion has a plurality of first protruding portions arranged along the longitudinal direction of the fluid flow channel on an inner surface on one side in the thickness direction of the fluid flow channel, and a plurality of second protruding portions arranged along the longitudinal direction of the fluid flow channel on an inner surface on the other side in the thickness direction of the fluid flow channel, and

the first protruding portions protrude from the inner surface on said one side toward the inner surface on said other side, and the second protruding portions protrude from the inner surface on said other side toward the inner surface on said one side.

11. The heat exchanger according to claim **10**, wherein

the first protruding portions are formed by causing the outer surface on one side in the thickness direction to recede toward said other side, and the second protruding portions are formed by causing the outer surface on said other side in the thickness direction to recede toward said one side.

12. The heat exchanger according to claim **10**, wherein

some or all of the plurality of first protruding portions are provided at positions opposite the second protruding portions in the thickness direction.

13. The heat exchanger according to claim **12**, wherein

the first protruding portions and the second protruding portions respectively have elongated shapes in a plan view thereof, and

the first protruding portions and the second protruding portions, which are facing each other in the thickness direction, are provided so as to cross each other in a plan view thereof.

14. The heat exchanger according to claim **13**, wherein

a longitudinal direction of the first protruding portions is inclined to one side in a width direction of the metal tube with respect to the longitudinal direction of the metal tube,

a longitudinal direction of the second protruding portions is inclined to the other side in the width direction with respect to the longitudinal direction of the metal tube, and

an inclination angle of the first protruding portions with respect to the longitudinal direction is equal to an inclination angle of the second protruding portions with respect to the longitudinal direction.

15. The heat exchanger according to claim **12**, wherein

the first protruding portions and the second protruding portions respectively have elongated shapes in a plan view thereof, and

a longitudinal direction of the first protruding portions and the second protruding portions, which are facing each other in the thickness direction, is parallel to the longitudinal direction of the metal tube.

16. The heat exchanger according to claim **12**, wherein

the plurality of first protruding portions are arranged so that three or more rows thereof extending in the longitudinal direction are formed, and in a row positioned in a central portion in the width direction from among these rows, the first protruding portions are provided at positions opposite the second protruding portions in the thickness direction.

17. The heat exchanger according to claim **16**, wherein in rows positioned at both sides of the row positioned in the central portion in the width direction, the first protruding portions are provided at positions displaced in the longitudinal direction with respect to the second protruding portions.

18. The heat exchanger according to claim **17**, wherein

the plurality of first protruding portions are arranged so that a plurality of rows thereof extending in a inclination direction inclined with respect to the longitudinal direction are formed,

the plurality of second protruding portions are arranged so that a plurality of rows thereof extending in the inclination direction are formed, and

the rows of the first protruding portions in the inclination direction and the rows of the second protruding portions in the inclination direction are disposed alternately along the longitudinal direction.

19. The heat exchanger according to claim **1**, wherein

the fluid flow channel includes a first fluid flow channel and a second fluid flow channel provided parallel to each other in the width direction and extending in the longitudinal direction,

the first fluid flow channel is formed by folding a metal sheet at a position along the longitudinal direction and bending the metal sheet into a tubular shape so that one end side in the width direction of the metal sheet abuts on a surface on one side of the metal sheet, and said one end side is joined to said one surface along the longitudinal direction,

the second fluid flow channel is formed by folding the metal sheet at another position along the longitudinal direction and bending the metal sheet into a tubular shape so that another end side in the width direction of the metal sheet abuts on said one surface at a position adjacent to said one end side, and the other end side is joined to said one surface along the longitudinal direction, and

the support portion is constituted by parts of the metal sheet, each part extending from said one end side and said other end side in the thickness direction or a direction inclined from the thickness direction.

20. The heat exchanger according to claim **1**, wherein the multiple-hole metal tube is a first multiple-hole metal tube, and

the heat exchanger further comprises a second multiple-hole metal tube stacked on said other side of the metal tube in the thickness direction, the second multiple-hole metal tube that has a flat shape with a width greater than a thickness, a plurality of fluid flow channels formed inside thereof along the longitudinal direction, and an opposing surface that is disposed opposite an outer surface on said other side of the metal tube and joined by at least part thereof to the outer surface on said other side.

21. The heat exchanger according to claim **1**, wherein substantially the entire opposing surfaces are joined to the outer surfaces.

22. The heat exchanger according to claim **1**, which is spirally wound so that one end in the longitudinal direction is disposed inside and another end in the longitudinal direction is disposed outside.

23. A heat pump type hot water supply apparatus comprising:

a coolant circuit having a compressor, the heat exchanger according to claim **1**, a pressure reducing mechanism, an evaporator, and a pipe for connecting these elements; and

a hot water storage circuit having a tank storing water, a water inlet pipe for introducing water from the tank into the fluid flow channel of the heat exchanger, and a hot water outlet pipe for returning water heated by the heat exchanger into the tank.

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