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(54) **HEAT TREATMENT APPARATUS**

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(57) **ABSTRACT**

A heat treatment apparatus includes: a heat exchange unit including a plurality of first channels and a plurality of second channels; a space-forming part having a space facing channel openings of the respective first channels; a first opening located in the space-forming part and having a first aperture; a flow-regulating part installed in the space in the space-forming part to regulate a flow of the first fluid; and an attachment part for removably attaching the flow-regulating part through the first aperture, wherein the space in the space-forming part is a space in which first fluid led out of the respective channel openings flows together, or a space from which the first fluid flowing together is introduced to the respective channel openings, and in a state in which the flow-regulating part is fixed in the space-forming part, the flow-regulating part is opposed to the plural channel openings.

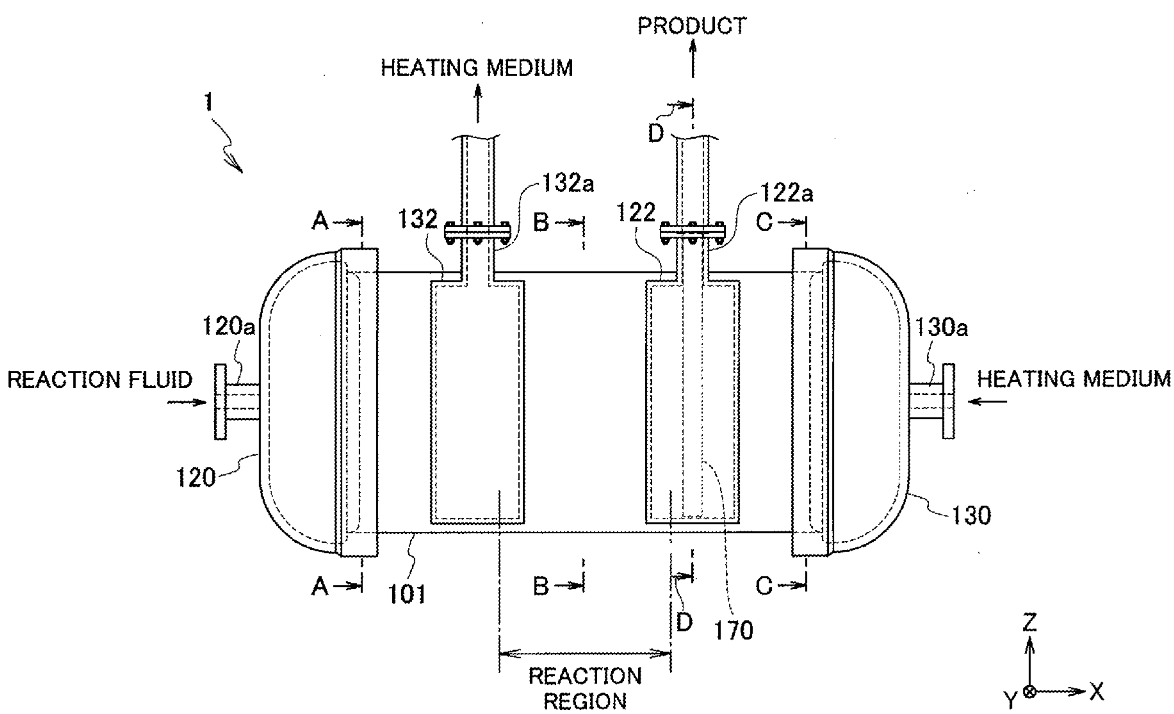
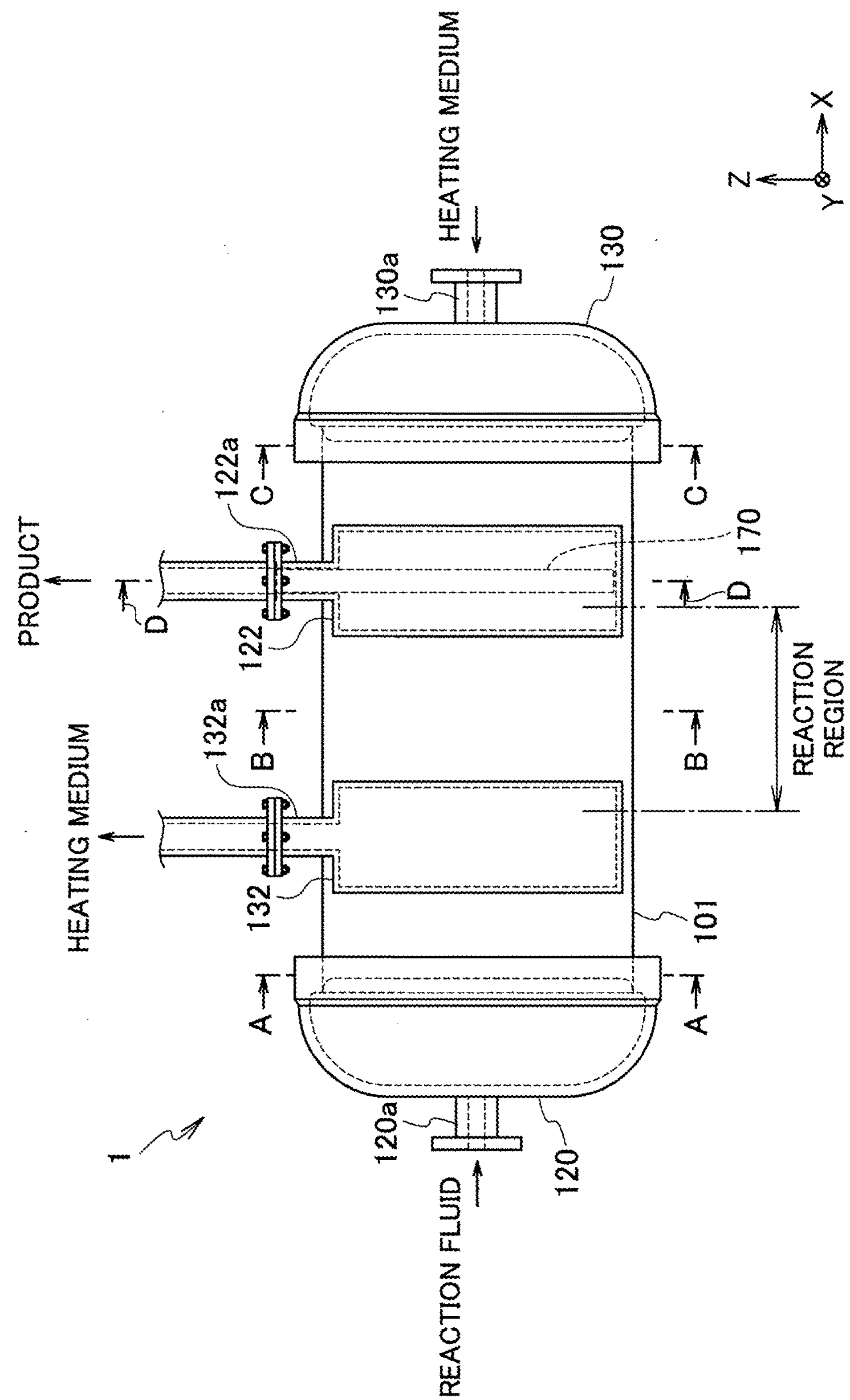


FIG. 1


HEATING MEDIUM
X
Z
Y
130a
130
122a
C
C
PRODUCT
170
D
D
122
REACTION REGION
HEATING MEDIUM
132a
B
B
132
101
A
A
1
120a
120
REACTION FLUID

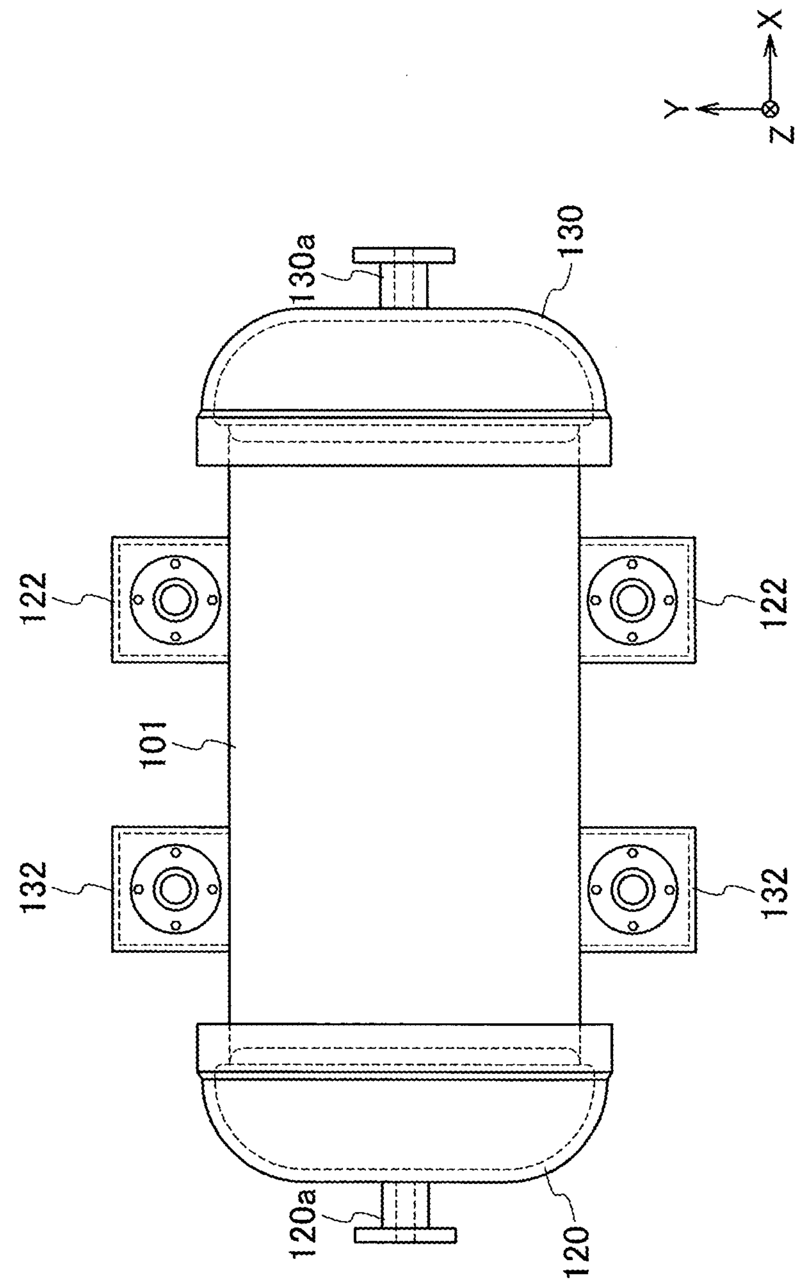


FIG. 2

FIG. 3C

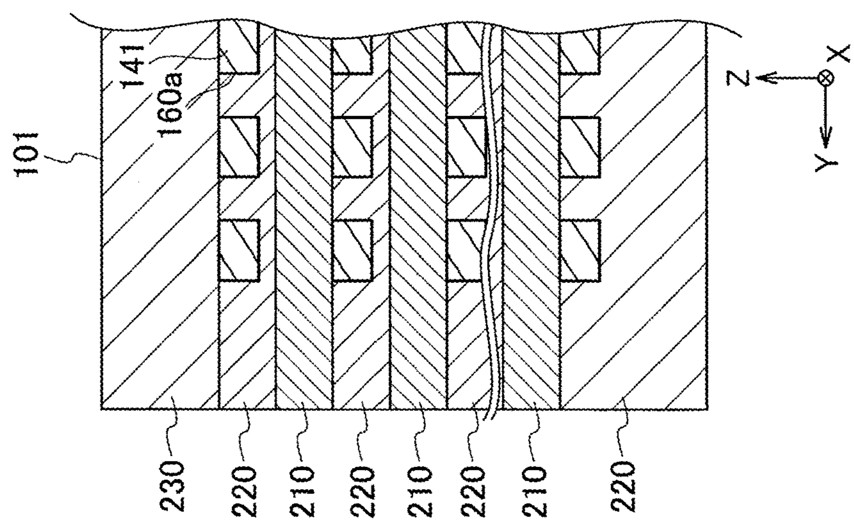


FIG. 3B

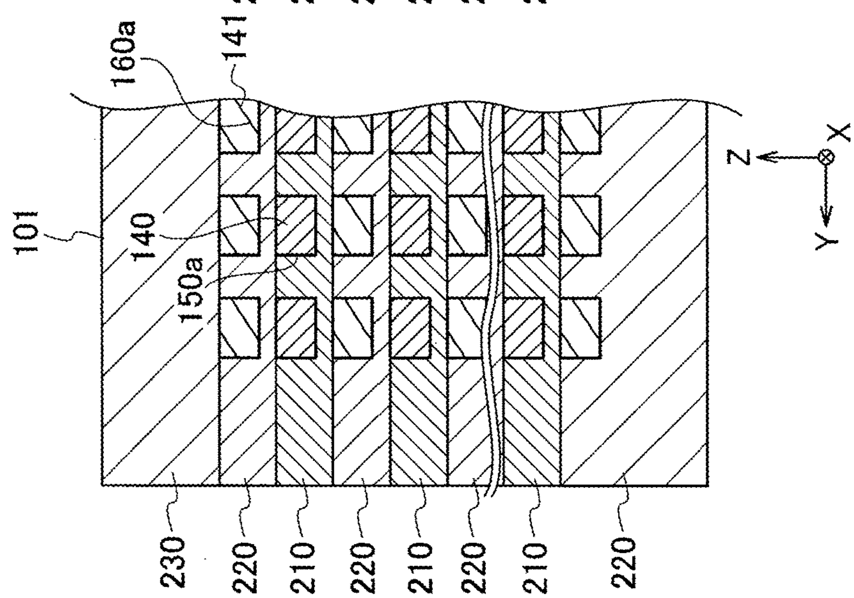


FIG. 3A

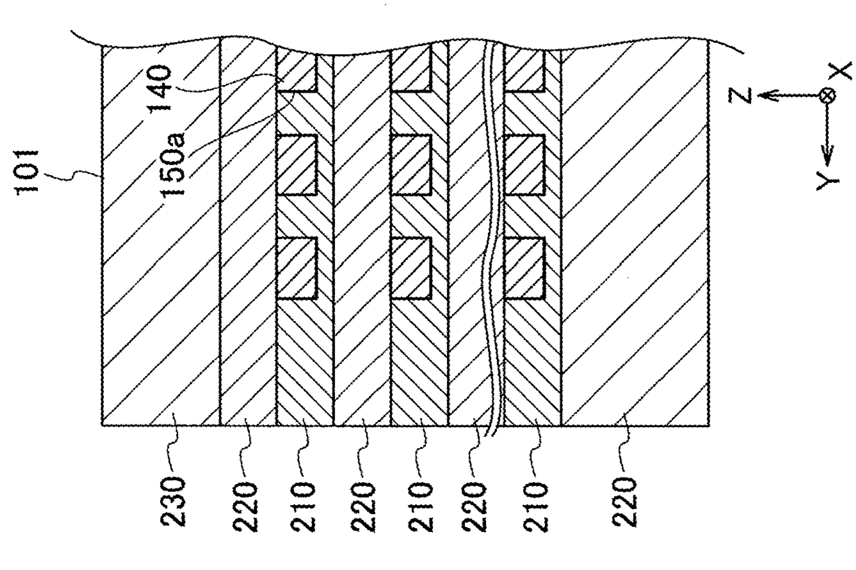


FIG. 4

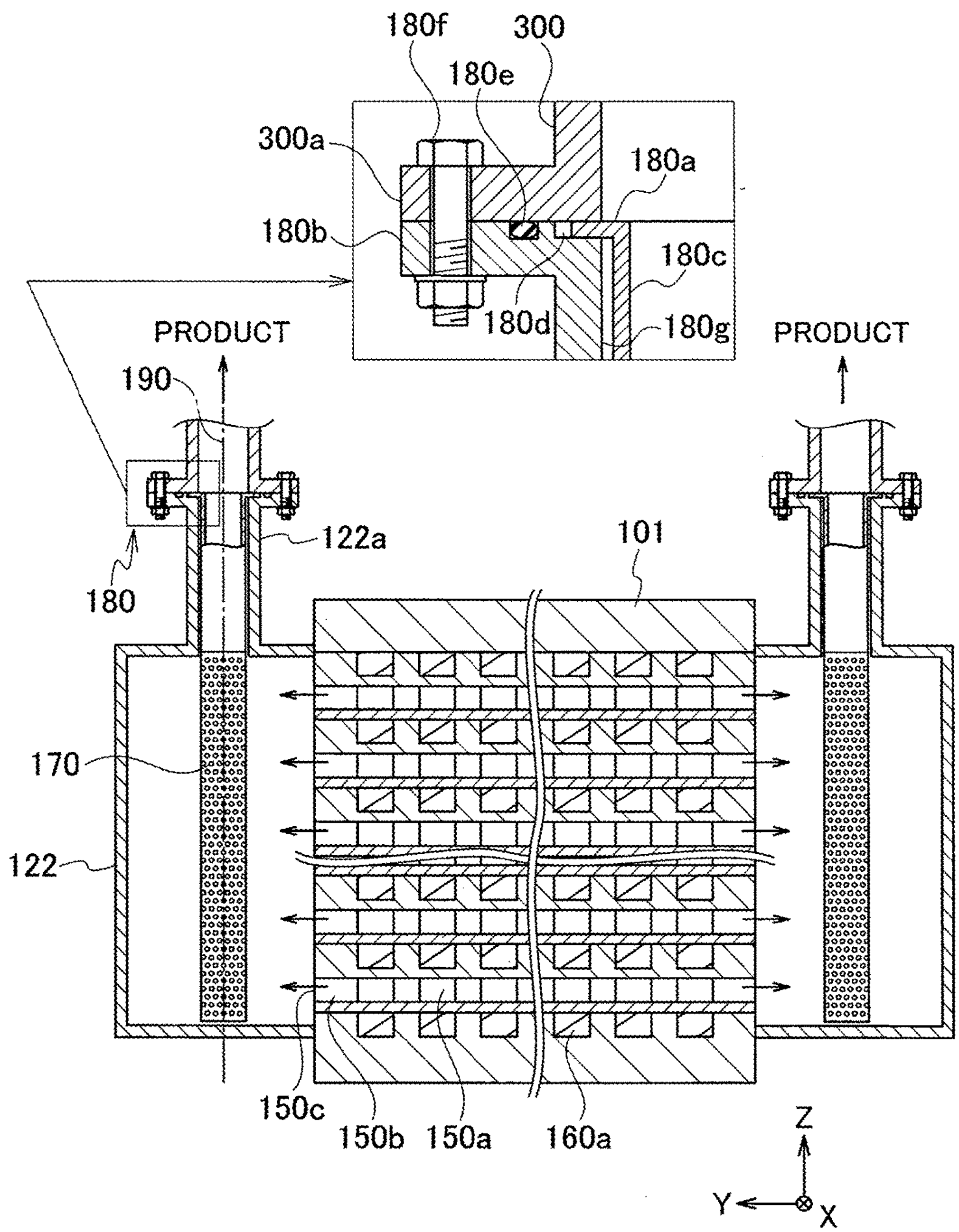
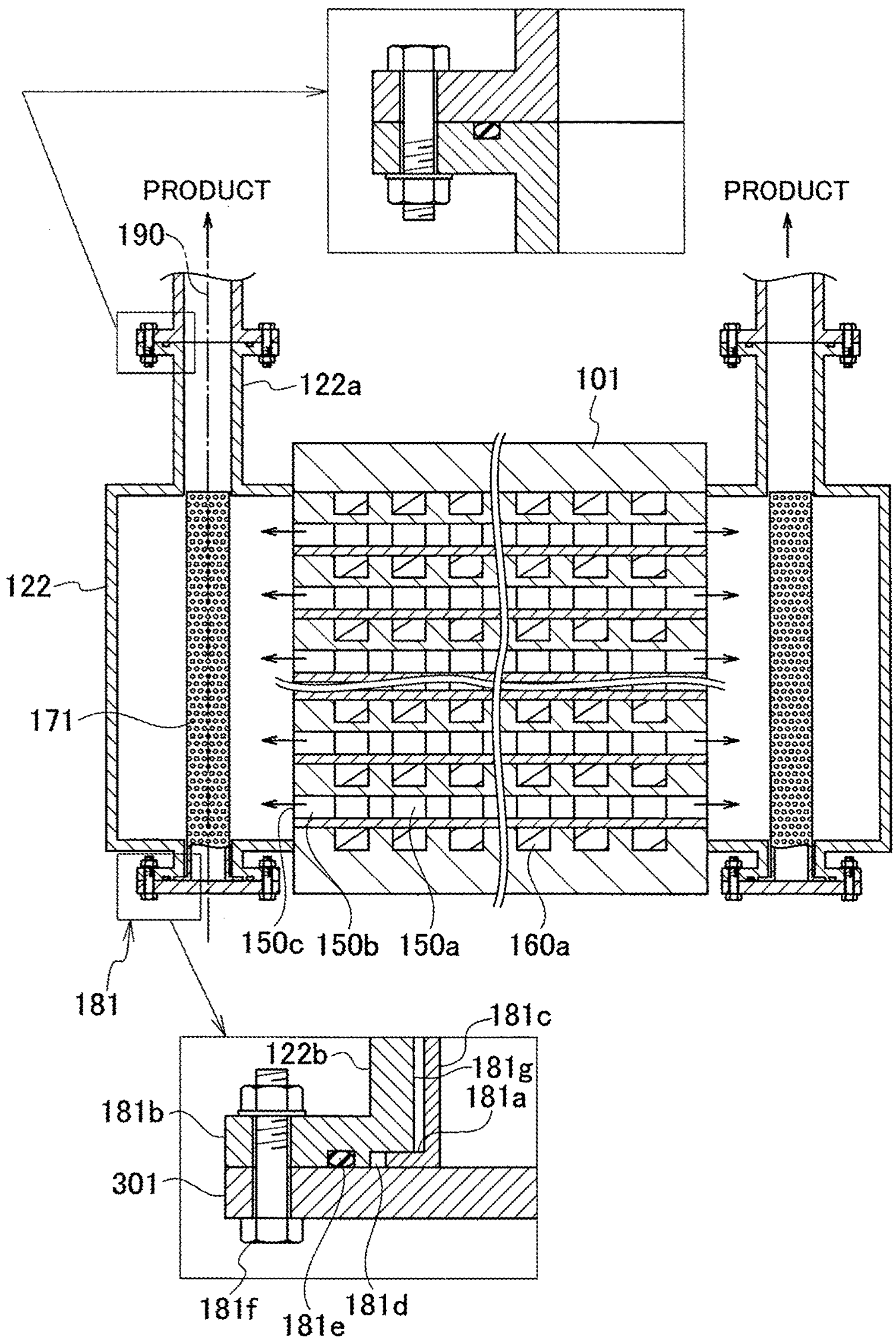

180f
300
180e
300a
180a
180b
180c
180d
180g
PRODUCT
PRODUCT
190
122a
180
101
170
122
150c
150b
150a
160a
Z
Y
X

FIG. 5


PRODUCT
PRODUCT
190
122a
101
122
171
150c
150b
150a
160a
181
181c
122b
181g
181a
181b
301
181f
181e
181d

HEAT TREATMENT APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application of International Application No. PCT/JP2017/005532, filed on Feb. 15, 2017, which claims priority to Japanese Patent Application No. 2016-027605, filed on Feb. 17, 2016, the entire contents of which are incorporated by reference herein.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a heat exchanger-type heat treatment apparatus.

2. Description of the Related Art

[0003] Heat treatment apparatuses such as heat exchangers or reactors using heat exchange between fluids include flow-regulating plates for equalizing the flow of the fluids so as to improve treatment efficiency. Japanese Unexamined Patent Application Publication No. 2010-216749 (Patent Literature 1) discloses a heat exchanger including a plurality of flow-regulating plates made of perforated plates and arranged in an expanded part of a duct.

SUMMARY

[0004] When the distribution of a fluid is required to be changed or when the condition of flow-regulating plates is changed because of the fluid having corrosiveness, the flow-regulating plates need to be replaced or inspected. In the heat treatment apparatus as disclosed in Patent Literature 1, when the expanded part of the duct can open outward from an apparatus body housing a heat-transfer tube bundle, the operator opens the expanded part of the duct, so as to replace the flow-regulating plates installed inside thereof.

[0005] A heat treatment apparatus serving as a reactor in which a chemical reaction proceeds in a heat exchange unit leads a product to flow outward via a fluid chamber serving as a space-forming part located on the downstream side of the heat exchange unit. The reactor is preferably provided with flow-regulating plates arranged in the fluid chamber as appropriate in order to regulate a back pressure of a fluid in the fluid chamber so as to have desirable distribution of the fluid flowing into a plurality of flow channels on the upstream side. Such a reactor typically entirely has an integrated structure because the reactor should ensure air-tightness so as to prevent leakage of the fluid. Therefore, the fluid chamber cannot open outward from the heat exchange unit. Thus, it is difficult to replace the flow-regulating plates once installed in the fluid chamber afterward. When the reactor is configured such that the fluid chamber can open outward from the heat exchange unit in order to facilitate the replacement of the flow-regulating plates, the entire structure of the reactor is complicated accordingly.

[0006] An object of the present disclosure is to provide a heat treatment apparatus having a structure capable of easily replacing a flow-regulating part without the entire structure of the apparatus complicated.

[0007] An aspect of the present disclosure is a heat treatment apparatus using heat exchange between a first fluid and a second fluid, the apparatus including: a heat exchange unit including a plurality of first channels through which the first fluid flows and a plurality of second channels through which the second fluid flows; a space-forming part having a space facing channel openings of the respective first channels; a first opening located in the space-forming part and having a first aperture; a flow-regulating part installed in the space in the space-forming part to regulate a flow of the first fluid; and an attachment part for removably attaching the flow-regulating part through the first aperture, wherein the space in the space-forming part is a space in which the first fluid led out of the respective channel openings flows together, or a space from which the first fluid flowing together is introduced to the respective channel openings, and in a state in which the flow-regulating part is fixed in the space-forming part, the flow-regulating part is opposed to the plural channel openings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a side view showing a structure of a reactor according to an embodiment of the present disclosure.

[0009] FIG. **2** is a plan view showing the structure of the reactor according to an embodiment of the present disclosure.

[0010] FIG. **3**A is a cross-sectional view showing a structure of a heat exchange unit according to an embodiment, taken along line A-A in FIG. **1**.

[0011] FIG. **3**B is a cross-sectional view showing a structure of a heat exchange unit according to an embodiment, taken along line B-B in FIG. **1**.

[0012] FIG. **3**C is a cross-sectional view showing a structure of a heat exchange unit according to an embodiment, taken along line C-C in FIG. **1**.

[0013] FIG. **4** is a view showing a flow-regulating part and an attachment part for attaching the flow-regulating part according to a first embodiment.

[0014] FIG. **5** is a view showing a flow-regulating part and an attachment part for attaching the flow-regulating part according to a second embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0015] Embodiments according to the present disclosure will be described in detail below with reference to the drawings. The following dimensions, materials, and specific numerical values described in the embodiments are shown for illustration purposes only, and the present disclosure is not limited thereto unless otherwise specified. The elements having substantially the same functions and structures illustrated in the Specification and the drawings are designated by the same reference numerals, and overlapping explanations are not repeated below. The elements described below but not related directly to the present disclosure are not shown in the drawings. In the following explanations of the drawings, a vertical direction is defined as a Z-axis, an extending direction of a plurality of branch channels **150***a* of reaction channels **150** described below on a plane perpendicular to the Z-axis is defined as an X-axis, and a direction perpendicular to the X-axis is defined as a Y-axis.

First Embodiment

[0016] A heat treatment apparatus according to a first embodiment of the present disclosure is described below. The heat treatment apparatus according to the present disclosure utilizes heat exchange between a first fluid and a second fluid. Although the heat treatment apparatus according to the present embodiment is illustrated as a reactor, the present embodiment is also applicable to a heat exchanger, for example.

[0017] FIG. **1** is a schematic side view showing a structure of a reactor **1** according to the present embodiment. FIG. **2** is a schematic plan view showing the structure of the reactor **1**. The reactor **1** is of a heat exchanger-type in which a reaction fluid in a gas state or in a liquid state containing a reaction raw material as a reactant is heated or cooled so as to promote a reaction of the reactant. The reactor **1** includes a heat exchange unit **101** as a main body, a reaction fluid introduction part **120** and a product drain part **122**, and a heating medium introduction part **130** and a heating medium drain part **132**.

[0018] FIGS. **3**A to **3**C are cross-sectional views showing the structure of the heat exchange unit **101**. FIG. **3**A is a cross-sectional view taken along line A-A in FIG. **1**, FIG. **3**B is a cross-sectional view taken along line B-B in FIG. **1**, and FIG. **3**C is a cross-sectional view taken along line C-C in FIG. **1**. The heat exchange unit **101** includes a plurality of first heat transfer bodies **210**, a plurality of second heat transfer bodies **220**, and a lid body **230**. The heat exchange unit **101** has a counter flow-type structure in which a reaction fluid or a product as a first fluid flows in a direction opposite to a flowing direction of a heating medium as a second fluid. The first heat transfer bodies **210** and the second heat transfer bodies **220** are each a rectangular plate-like member made of a heat transfer material having thermal resistance.

[0019] The first heat transfer bodies **210** receive heat or cooled air supplied from the heating medium or the second heat transfer bodies **220** to supply the received heat or cold to the reaction fluid. The first heat transfer bodies **210** include a plurality of grooves composing reaction channels **150**, more particularly, branch channels **150***a* and merging channels **150***b* which are first channels. The branch channels **150***a* include a reaction region in which the reaction fluid is reacted to generate a product. The reaction region corresponds to an area in the branch channels **150***a* inside the heat exchange unit **101** as shown in FIG. **1**, that is, a region between the heating medium drain part **132** and the product drain part **122** described below in the extending direction of the branch channels **150***a*. The merging channels **150***b* correspond to a region communicating with the branch channels **150***a* on the downstream side, as described below with reference to FIG. **4**. The branch channels **150***a* are provided with structured catalysts **140** for promoting the reaction of the reactant.

[0020] The second heat transfer bodies **220** supply heat or cooled air supplied from the heating medium directly to and indirectly to the reaction fluid via the first heat transfer bodies **210**. The second heat transfer bodies **220** include a plurality of grooves composing heating medium channels **160**, more particularly, branch channels **160***a* and merging channels which are second channels. As described in the present embodiment, when the first heat transfer bodies **210** include a plurality of branch channels **150***a*, the second heat transfer bodies **220** also preferably include a plurality of branch channels **160***a* arranged in parallel at regular intervals corresponding to the positions of the branch channels **150***a* of the reaction channels **150**. The heating medium channels **160** are provided with heat transfer promoters **141** for increasing the contact area with the heating medium to promote the heat transfer between the heating medium and the heat exchange unit **101**. The heat transfer promoters **141** may be formed into an angularly-corrugated plate-like shape, for example, in order to ensure the contact area with the heat exchange unit **101**. The heat transfer material used for the heat transfer promoters **141** may be metal such as aluminum, copper, stainless steel, and iron-based plated steel.

[0021] The first heat transfer bodies **210** and the second heat transfer bodies **220**, which are arranged alternately, and the lid body **230** are stacked in the vertical direction with the flat plate surfaces parallel to the horizontal plane, so as to form the heat exchange unit **101** as a stacked body. When the heat exchange unit **101** is assembled, the respective members are fixed to each other by a bonding method such as tungsten inert gas (TIG) welding or diffusion bonding, so as to suppress a reduction in heat transfer derived from poor contact between the respective members.

[0022] The heat transfer material used for the respective elements included in the heat exchange unit **101** is preferably thermally-resistant metal such as an iron alloy or a nickel alloy. More particularly, the thermally-resistant alloy may be an iron alloy such as stainless steel, or a nickel alloy such as Inconel alloy 625 (registered trademark), Inconel alloy 617 (registered trademark), and Haynes alloy 230 (registered trademark). These heat transfer materials are preferable because such alloys have durability or corrosion resistance with respect to combustion gas which may be used for promoting the reaction or used as a heating medium in the reaction channels **150**. However, the present embodiment is not limited to these materials. Alternatively, the heat transfer material may be iron-based plated steel, metal covered with thermally-resistant resin such as fluororesin, or carbon graphite.

[0023] Although the heat exchange unit **101** may be composed of a single first heat transfer body **210** and a single second heat transfer body **220**, a larger number of the respective heat transfer bodies can improve the heat exchange performance. The heat exchange unit **101** according to the present embodiment thus includes a plurality of first heat transfer bodies **210** and a plurality of second heat transfer bodies **220**. The number of the second heat transfer bodies **220** is set to be larger by one than the number of the first heat transfer bodies **210**. The second heat transfer bodies **220** are positioned at the uppermost end and the lowermost end on both sides of the heat exchange unit **101** in the vertical direction, so that all of the first heat transfer bodies **210** are held between the second heat transfer bodies **220**. The number of the branch channels **150***a* provided in each first heat transfer body **210** is not particularly limited, and may be determined as appropriate in view of the conditions for designing the heat exchange unit **101** and the heat transfer efficiency of the heat exchange unit **101**. In addition, the grooves composing the reaction channels **150** and the heating medium channels **160** may be arranged on both sides of the respective first heat transfer bodies **210** and second heat transfer bodies **220** in the vertical direction, so as to provide vertically-collective grooves in the stacked state. Although the heat exchange unit **101** is a main body of the reactor **1** in the present embodiment, the heat exchange unit **101** may be covered with a housing or a heat insulating material so as to suppress thermal radiation from the heat exchange unit **101** to prevent heat loss.

[0024] The reaction fluid introduction part **120** is a hemispheric casing covering the side surface of the heat exchange unit **101** on the upstream side on which the plural branch channels **150***a* provided in the first heat transfer bodies **210** are open, so as to provide a space between the heat exchange unit **101** and the reaction fluid introduction part **120**. The reaction fluid introduction part **120** is detachable or openable with respect to the heat exchange unit **101**. The detachable or openable reaction fluid introduction part **120** allows the operator to insert or remove the structured catalysts **140** into or from the plural branch channels **150***a* of the reaction channels **150**, for example. The reaction fluid introduction part **120** includes an introduction pipe **120***a* from which the reaction fluid is externally introduced to the inside of the heat exchange unit **101**. The introduction pipe **120***a* is located substantially in the middle with respect to the side surface of the heat exchange unit **101**, in other words, located in the middle on the Y-Z plane, and integrated with the reaction fluid introduction part **120** in the same direction as the open direction of the plural branch channels **150***a*, as shown in FIG. **1**, for example. The introduction pipe **120***a* thus can distribute the well-balanced amount of the reaction fluid to the respective branch channels **150***a* open as illustrated in FIG. **3**A.

[0025] FIG. **4** is a cross-sectional view taken along line D-D in FIG. **1**. The branch channels **150***a* provided in the first heat transfer bodies **210** communicate with the merging channels **150***b* perpendicular to the branch channels **150***a* and extending in the Y-axis direction on the downstream side of the reaction region. The merging channels **150***b* include flow-out parts **150***c* serving as channel openings open outward through which the product flows out of the heat exchange unit **101**.

[0026] The product drain part **122** is a vertically-elongated box-shaped casing covering a part of the side surface of the heat exchange unit **101** in the vertical direction at which the plural flow-out parts **150***c* are located, so as to serve as a space-forming part providing a space between the heat exchange unit **101** and the product chain part **122**. The box shape of the casing is an example, and the casing may be formed into a semicylindrical shape or curved into a concaved shape similar to the semicylindrical shape. The product drain part **122** is integrally fixed to the side surface of the heat exchange unit **101**. The product drain part **122** is provided on its wall portion with an opening **122***a* having an aperture for draining the product to the outside of the heat treatment apparatus. The extending direction of the central axis of the aperture provided in the opening **122***a* is different from the open direction of the flow-out parts **150***c*. Although the present embodiment is illustrated with the case in which the opening **122***a* has a pipe-like body, the opening **122***a* may be merely a flange not provided with a pipe portion. The opening **122***a* communicates with external equipment outside the heat treatment apparatus, and is connected to an external pipe **300** from which the product is introduced. While the external pipe **300** is integrally provided with a flange **300***a* serving as a connection part, the opening **122***a* is integrally provided with a flange **180***b* serving as a first connection part connected to and released from the flange **300***a*. When the opening **122***a* is not provided with a pipe portion, the opening **122***a* itself serves as a flange. In the space provided between the product drain part **122** and the heat exchange unit **101**, the product led out of the respective flow-out parts **150***c* flows together before introduced into the opening **122***a*. A space inside the product drain part **122** thus serves as a fluid chamber.

[0027] The reactor **1** further includes a flow-regulating part **170** installed in the product drain part **122**, and an attachment part **180** for attaching the flow-regulating part **170** to the product drain part **122**.

[0028] The flow-regulating part **170** equalizes a back pressure of the reaction fluid in the product drain part **122** located on the downstream side of the branch channels **150***a* so as to distribute the reaction fluid flowing into the respective branch channels **150***a* more equally. The flow-regulating part **170** includes a circumferential portion extending into a shaft-like shape in the axial direction into which the product is introduced, and an end portion through which the product introduced into the circumferential portion flows toward the aperture of the opening **122***a* in the axial direction. The flow-regulating part **170** may be a porous member serving as a resistant body provided with a plurality of holes so that the product can penetrate the entire surface of the circumferential portion. Such a porous member can easily be manufactured and exhibit a good regulating effect. The present embodiment is illustrated with the case in which the flow-regulating part **170** has a cylindrical shape having a circular cross section as viewed in the axial direction. The material used for the flow-regulating part **170** is preferably metal having high thermal resistance and also high corrosion resistance when the product is corrosive.

[0029] The flow-regulating part **170** fixed to the product drain part **122** is located on the same axis as the opening **122***a*. As used herein, the term "the same axis" refers to an axis which is the same as the central axis **190** of the aperture **180***g* of the opening **122***a*, as indicated by the dashed and dotted line shown in FIG. **4**, but is not necessarily exactly the same, and may be an axis slightly offset within a range capable of achieving the operations and effects described below. The outer diameter of the flow-regulating part **170** is smaller than the inner diameter of the aperture **180***g*. The flow-regulating part **170** thus can enter the product drain part **122** through the aperture **180***g* with the respective axial directions conforming to each other.

[0030] As described above, the flow-regulating part **170** extends in the extending direction of the central axis **190** of the aperture **180***g* which is different from the open direction of the respective flow-out parts **150***c*. As shown in FIG. **4**, the flow-regulating part **170** fixed to the product drain part **122** is arranged such that the entire circumferential portion is located inside the space described above, and at least part of the circumferential portion is opposed to the plural flow-out parts **150***c*. The flow-regulating part **170** can therefore entirely regulate the flow of the product in the Z-axis direction flowing out of the respective flow-out parts **150***c* aligned in the Z-axis direction. The flow-regulating part **170** can further regulate the flow of the product in the emitting direction on the X-Y plane perpendicular to the extending direction of the circumferential portion. Accordingly, the product flowing out of the respective flow-out parts **150***c* can be led to the flow-regulating part **170** with high efficiency.

[0031] The flow-regulating part **170** is preferably arranged such that the axial direction is parallel to the aligned direction of the flow-out parts **150***c* and preferably has a length sufficient to be opposed to all of the flow-out parts **150***c* so as to further improve the efficiency. The product out of the plural flow-out parts **150***c* thus all flows toward the circumferential portion of the flow-regulating part **170**, as indicated by the arrows in FIG. **4**, and directly reach the circumferential portion. As used herein, the phrase "directly reach" refers to a state in which the product flowing out of the flow-out parts **150***c* reaches the flow-regulating part **170** while hardly circulating in the product drain part **122**, namely, without being scattered. Such a state is preferable since the back pressure can be equalized more efficiently than the case in which the product circulates intricately. In order to improve the accuracy of the direct reach, one end of the flow-regulating part **170** is preferably located inside the opening **122***a*, and the other end preferably has a sufficient length so as to be in contact with the inner wall of the product drain part **122** on the opposite side of the opening **122***a*.

[0032] The attachment part **180** includes an engaging part **180***a* integrally connected to the one end of the flow-regulating part **170**, and an engaged part **180***d* provided at the flange **180***b* on the opening **122***a* side. The engaging part **180***a* projects outward from the flow-regulating part **170**. More particularly, the length of the engaging part **180***a* from the central axis of the flow-regulating part **170** fixed to the product drain part **122** is longer than the radius of the aperture **180***g* of the opening **122***a*. The engaging part **180***a* may have a circular shape as viewed in the axial direction, or may be provided with a plurality of projections projecting radially. The engaging part **180***a* may be connected to the flow-regulating part **170** via a cylindrical member **180***c* having substantially the same diameter as the flow-regulating part **170**. The cylindrical member **180***c* may be a member independent of the flow-regulating part **170** and connected to the end of the flow-regulating part **170** by welding, or may be a member integrated with the flow-regulating part **170**, namely, a part of the circumferential portion without holes.

[0033] In order to distribute the flow described above more efficiently and equally, it is preferable to prevent the product from flowing into the aperture **180***a* of the opening **122***a* without passing through the flow-regulating part **170**, or minimize the amount of the product flowing into the aperture **180***a* of the opening **122***a* without passing through the flow-regulating part **170**. As described above, the product is preferably prevented from circulating in the product drain part **122** as much as possible. In view of this, a gap between the cylindrical member **180***c* or the circumferential portion of the flow-regulating part **170** and the inner wall of the opening **122***a* is reduced as much as possible. The engaging part **180***a* preferably has a circular shape rather than has a plurality of radial projections so as to eliminate the gap.

[0034] The engaged part **180***d* is a groove or a notch engaged with the engaging part **180***a* in the state in which the flow-regulating part **170** is inserted to the product drain part **122** externally through the aperture of the opening **122***a*.

[0035] The heating medium introduction part **130** is a hemispheric casing covering the side surface of the heat exchange unit **101** on the upstream side on which the plural branch channels **160***a* provided in the second heat transfer bodies **220** are open, so as to provide a space between the heat exchange unit **101** and the heating medium introduction part **130**. The heating medium introduction part **130** may be detachable or openable with respect to the heat exchange unit **101**, but is not necessarily detachable or openable as described in the present embodiment when the heat transfer promoters **141** are preliminarily provided in the plural branch channels **160***a* of the heating medium channels **160** at the time of assembling the heat treatment apparatus. The heating medium introduction part **130** includes an introduction pipe **130***a* from which the heating medium is externally introduced to the inside of the heat exchange unit **101**. The introduction pipe **130***a* is located substantially in the middle with respect to the side surface of the heat exchange unit **101**, in other words, located in the middle on the Y-Z plane, and integrated with the heating medium introduction part **130** in the same direction as the open direction of the plural branch channels **160***a*, as shown in FIG. **1**, for example. The introduction pipe **130***a* thus can distribute the well-balanced amount of the heating medium to the respective branch channels **160***a* open as illustrated in FIG. **3**C.

[0036] The heating medium drain part **132** is a vertically-elongated box-shaped casing covering a part of the side surface of the heat exchange unit **101** at which a plurality of flow-out parts for leading out the heating medium are located, so as to serve as a space-forming part providing a space between the heat exchange unit **101** and the heating medium drain part **132**. The heating medium drain part **132** may also be a casing formed into a semicylindrical shape and the like. The branch channels **160***a* provided in the second heat transfer bodies **220** communicate with merging channels (not shown) perpendicular to the branch channels **160***a* and extending in the Y-axis direction on the downstream side of a part corresponding to the reaction region, as in the case of the first heat transfer bodies **210**. The merging channels are open to the outside of the heat exchange unit **101** at flow-out parts (not shown) serving as channel openings. The heating medium drain part **132** is also integrally fixed to the side surface of the heat exchange unit **101**, and provided on its wall portion with an opening **132***a* having an aperture for draining the heating medium to the outside of the heat treatment apparatus. Although the present embodiment is illustrated with the case in which the opening **132***a* has a pipe-like body, the opening **132***a* may be merely a flange not provided with a pipe portion. In the space provided between the heating medium drain part **132** and the heat exchange unit **101**, the heating medium led out of the respective flow-out parts provided in the second heat transfer bodies **220** flows together before introduced into the opening **132***a*. A space inside the heating medium drain part **132** thus serves as a fluid chamber.

[0037] The heat exchange unit **101** may be any of a liquid-liquid heat exchanger, a gas-gas heat exchanger, and a gas-liquid heat exchanger, and the reaction fluid and the heating medium supplied to the reactor **1** may be either gas or liquid. The reactor **1** can cause chemical synthesis through various kinds of thermal reactions such as an endothermic reaction and an exothermic reaction. Examples of such thermal reactions causing synthesis include: a steam reforming reaction of methane as represented by the following chemical equation (1); an endothermic reaction such as a dry reforming reaction of methane as represented by the following chemical equation (2); a shift reaction as represented by the following chemical equation (3); a methanation reaction as represented by the following chemical equation (4); and a Fischer tropsch synthesis reaction as represented by the following chemical equation (5). The reaction fluid used in these reactions is in a gas state.

$$CH_4+H_2O \rightarrow 3H_2+CO \quad (1)$$

$$CH_4+CO_2 \rightarrow H_2+2CO \quad (2)$$

$$CO+H_2O \rightarrow CO_2+H_2 \quad (3)$$

$$CO+3H_2 \rightarrow CH_4+H_2O \quad (4)$$

$$(2n+1)H_2+nCO \rightarrow CnH_{2n+2}+nH_2O \quad (5)$$

[0038] The reactor **1** may also be used for causing other reactions not described above, such as an acetylation reaction, an addition reaction, an alkylation reaction, a dealkylation reaction, a hydrodealkylation reaction, a reductive alkylation reaction, an amination reaction, an aromatization reaction, an arylation reaction, a self-heating reforming reaction, a carbonylation reaction, a decarbonylation reaction, a reductive carbonylation reaction, a carboxylation reaction, a reductive carboxylation reaction, a reductive coupling reaction, a condensation reaction, a cracking reaction, a hydrocracking reaction, a cyclization reaction, a cyclooligomerization reaction, a dehalogenation reaction, a dimerization reaction, an epoxidation reaction, an esterification reaction, an exchange reaction, a halogenation reaction, a hydrogenation reaction, a hydrohalogenation reaction, a homologation reaction, a hydration reaction, a dehydration reaction, a hydrogenation reaction, a dehydrogenation reaction, a hydrocarboxylation reaction, a hydroformylation reaction, a hydrogenolysis reaction, a hydrometalation reaction, a hydrosilylation reaction, a hydrolyzation reaction, a hydroprocessing reaction, an isomerization reaction, a methylation reaction, a demethylation reaction, a metathesis reaction, a nitration reaction, an oxidation reaction, a partial oxidation reaction, a polymerization reaction, a reduction reaction, a reverse water gas shift reaction, a sulfonation reaction, a telomerization reaction, a transesterification reaction, and a trimerization reaction.

[0039] The reactor **1** uses a substance such as a raw material involved in the chemical reaction as described above as a reactant, and uses a fluid including such a reactant as a reaction fluid. The reaction fluid flowing through the branch channels **150***a* receives heat or cold of the heating medium passing through the heating medium channels **160**, and is heated or cooled to promote the reaction, so that the reactant is converted into a target product. The reaction fluid may contain a carrier not involved in the reaction. Such a carrier may be selected as appropriate from substances not influencing the promotion of the reaction while taking account of the chemical reaction to be induced. The carrier usable for the reaction fluid particularly in a gas state may be a gas carrier of inert gas or a gaseous substance with low reactivity. The heating medium is preferably a fluid substance not corroding the constituent materials of the reactor **1**, and may be a liquid substance such as water or oil, or a gaseous substance such as combustion gas. The gaseous substance used as the heating medium is easier to handle than the liquid medium.

[0040] A catalyst included in the structured catalysts **140** is selected as appropriate from substances mainly containing active metal effective in the chemical reaction as described above, and suitable for the promotion of the reaction based on the synthesis reaction executed in the reactor **1**. Examples of active metal as a catalytic component include nickel (Ni), cobalt (Co), iron (Fe), platinum (Pt), ruthenium (Ru), rhodium (Rh), and palladium (Pd). These metals may be used singly, or may be used in combination as long as the combination is effective in the promotion of the reaction. The structured catalysts **140** are prepared such that the catalyst is supported on a structure material. The structure material is selected as appropriate from thermally-resistant metals which can be molded and support the catalyst. The structure, used as the structured catalysts **140**, may have a corrugated plate-like shape having a wave-like form in cross section or a jaggedly corrugated shape, so as to increase the contact area with the reaction fluid. Examples of such thermally-resistant metals include iron (Fe), chromium (Cr), aluminum (Al), yttrium (Y), cobalt (Co), nickel (Ni), magnesium (Mg), titanium (Ti), molybdenum (Mo), tungsten (W), niobium (Nb), tantalum (Ta), and a thermally-resistant alloy mainly containing some of these metals. The structured catalysts **140** may be obtained such that a thin plate structure made of a thermally-resistant alloy such as Fecralloy (registered trademark) is molded. A method of supporting the catalyst may be a method of directly supporting the catalyst on the structure material by surface modification or the like, or a method of indirectly supporting the catalyst on the structure material via a carrier. Practically, the use of the carrier facilitates the process of supporting the catalyst. The carrier is selected as appropriate from materials having durability without impeding the promotion of the reaction and capable of supporting the catalyst satisfactorily in view of the reaction executed in the reactor **1**. The carrier may be a metal oxide such as alumina (Al_2O_3), titania (TiO_2), zirconia (ZrO_2), ceria (CeO_2), or silica (SiO_2). These metal oxides may be used singly, or some of these metal oxides may be selected and combined together. The supporting method by use of the carrier may include a process of forming a mixed layer of the catalyst and the carrier on the surface of the structure material molded, or a process of forming a support layer and then supporting the catalyst on the support layer by surface modification or the like.

[0041] Next, the process of attaching and removing the flow-regulating part **170** is described below. The flange **180***b* on the opening **122***a* side and the flange **300***a* on the external pipe **300** side are typically fastened together with a bolt **180***f* via an O-ring **180***e*. With regard to the attachment, the operator detaches the bolt **180***f* to release the fastened state, and moves the external pipe **300** to open the aperture **180***g* of the opening **122***a*. The operator then inserts the flow-regulating part **170** into the product drain part **122** through the aperture **180***g*. The flow-regulating part **170** stops at a regular position at which the engaging part **180***a* engages with the engaged part **180***d*. The operator then puts back the external pipe **300** and fastens the bolt **180***f* again, so that the engaging part **180***a* is held and fixed between the two flanges **180***b* and **300***a* in the axial direction of the opening **122***a* to complete the operation of attachment of the flow-regulating part **170**. The operator can also easily remove the flow-regulating part **170** from the product drain part **122** through the steps opposite to the steps in the attaching operation. Although the reactor **1** preferably equalizes the distribution of the reaction fluid flowing into the plural branch channels **150***a* as much as possible, a variation in the distribution of the flow may be caused, and as a result, the reaction fluid may flow out of the respective flow-out part **150***c* of the branch channels **150***a* at an uneven flow velocity. In order to deal with such a variation, the flow-regulating part **170** is installed in the product drain part **122** to gradually equalize the back pressure such that the reaction fluid flowing into the product drain part **122** at an uneven flow velocity sequentially hits the flow-regulating part **170**. Accordingly, the distribution of the reaction fluid flowing into the plural branch channels **150***a* is gradually equalized. According to the present embodiment, since the flow-regulating part **170** configured as described above is installed on the same axis as the opening **122***a*, the circulation of the product in the product drain part **122** can be minimized, so as to equalize the back pressure, namely, equalize the distribution of the reaction fluid with high efficiency.

[0042] The regulating performance of the flow-regulating part **170** installed may be insufficient to ensure a desirably regulated distribution depending on the degree of the variation in the distribution of the reaction fluid. According to the present embodiment, since the flow-regulating part **170** can easily be removed, the operator can replace the flow-regulating part **170** with another flow-regulating part **170** having appropriate regulating performance as necessary. For example, when the flow-regulating part **170** is made of a porous member as described above, the flow-regulating part **170** may be replaced with another one having a different pore size. While the flow-regulating part **170** can regulate the distribution of the flow appropriately at first, the regulating performance may be deteriorated gradually with the passage of time or because of corrosion by the reaction fluid. The present embodiment can also deal with such a case by replacing the flow-regulating part **170** to another one as appropriate as described above.

[0043] The present embodiment as described above can provide the heat treatment apparatus having a structure capable of easily replacing the flow-regulating part without the entire structure of the apparatus complicated.

Second Embodiment

[0044] A heat treatment apparatus according to a second embodiment of the present disclosure is described below. The reactor **1** according to the first embodiment includes the flow-regulating part **170** removably installed in the product drain part **122** through the aperture **180***g* of the opening **122***a*. When an opening to which the flow-regulating part **170** is inserted and fixed is defined as a first opening, the opening **122***a* from which a product is drained to the outside of the heat treatment apparatus corresponds to the first opening in the first embodiment. A reactor according to the present embodiment is characterized by including another opening defined as a first opening, instead of the opening **122***a*, but not used for draining a product to the outside of the heat treatment apparatus.

[0045] FIG. **5** is a view showing a flow-regulating part **171** and an attachment part **181** for attaching the flow-regulating part **171** according to the present embodiment, and corresponds to the cross-sectional view of FIG. **4** taken along line D-D in FIG. **1** according to the first embodiment. The flow-regulating part **171** has a structure similar to the flow-regulating part **170** according to the first embodiment. The attachment part **181** includes an engaging part **181***a* integrally connected to one end of the flow-regulating part **171** in the same manner as in the first embodiment. The product drain part **122** includes an opening **122***b* having an aperture **181***g* penetrating the product drain part **122** so that the inside and the outside of the product drain part **122** communicate with each other. When the opening **122***a* communicating with the external equipment outside the heat treatment apparatus described in the first embodiment is defined as a second opening, the product drain part **122** includes at least two openings: the opening **122***b* as a first opening and the opening **122***a* as a second opening. The opening **122***b* is opposed to the opening **122***a* on the same axis. Namely, the central axis of the first aperture **181***g* and the central axis of the second aperture **180***g* substantially conform to each other. The outer diameter of the flow-regulating part **171** is also smaller than the inner diameter of the aperture **181***g* of the opening **122***b*.

[0046] The opening **122***b* is connected with a shielding plate **301** for shielding the aperture **181***g*. The opening **122***b* is integrally provided with a flange **181***b* serving as a second connection pan connected to and released from the shielding plate **301**. Although the present embodiment is illustrated with the case in which the opening **122***b* has a short pipe-like body, the opening **122***b* may also be merely a flange not provided with a pipe portion. The attachment part **181** also includes an engaged part **181***d* provided in the flange **181***b*. The engaged part **181***d* is a groove or a notch engaged with the engaging part **181***a* in the state in which the flow-regulating part **171** is inserted to the product drain part **122** externally through the aperture **181***g* of the opening. **122***b*. A cylindrical member **181***c*, an O-ring **181***e*, and a bolt **181***f* are the same as those in the first embodiment. Accordingly, the flow-regulating part **171** is held and fixed between the flange **181***b* and the shielding plate **301** in the same manner as in the first embodiment.

[0047] The flow-regulating part **171** having the structure described above preferably has a sufficient length in the axial direction so that the other end, that is, the end on the side on which the product is drained can be introduced into the aperture **180***g* of the opening **122***a*, as shown in FIG. **5**. Accordingly, the amount of the product not passing through the flow-regulating part **170** can be minimized. The present embodiment thus can improve the accuracy of direct reach of the product to the flow-regulating pan **170**, as in the case of the first embodiment.

[0048] The present embodiment can achieve the effects similar to those in the first embodiment, and is suitably applicable particularly to the case in which the connection between the opening **122***a* and the external pipe **300** is not easily released. Although the opening **122***b* needs to be provided in the product drain part **122**, the structure of the present embodiment is simplified as compared with a case of including a mechanism which allows the product drain part **122** to open out from the heat exchange unit **101**. The operation of removal of the flow-regulating pan is easier than that in the first embodiment since the operator is only required to remove the shielding plate **301** without moving the external pipe **300**.

OTHER EMBODIMENTS

[0049] The respective embodiments described above have exemplified the flow-regulating part **170** having a cylindrical shape. The cylindrical shape is preferable in order that the shape of the flow-regulating part **170** in cross section, namely, the outline at the end from which the product is drained conforms to the shape of the opening **180***g*, so as to minimize the circulation of the product in the product drain part **122** while minimizing the amount of the product not passing through the flow-regulating part **170**. However, the present disclosure is not limited to the flow-regulating part **170** having a cylindrical shape, and may employ a flow-regulating part formed into a prism of which the outline at the end is a polygon in cross section as long as a back pressure can be equalized. In such a case, the longest diagonal line at the end of the flow-regulating part needs to be smaller than the inner diameter of the drain pipe **122***a*.

[0050] While the respective embodiments described above have exemplified the flow-regulating part **170** made of a porous member, the present disclosure is not limited to this, and may employ a filter-like member prepared such that thin strings of the same material are woven.

[0051] The respective embodiments described above have been illustrated with the reactor **1** as a heat treatment apparatus. The reactor **1** includes the shaft-like flow-regulating part **170** installed in the product drain part **122** located on the downstream side of the flow of the reaction fluid or product, so as to appropriately equalize the back pressure on the downstream side to efficiently distribute the reaction fluid on the upstream side accordingly. However, the present disclosure is not limited to such a reactor.

[0052] For example, the heat treatment apparatus serving as a reactor may need to equally distribute the reaction fluid by regulating the flow directly on the upstream side. The upstream side of the reaction fluid in such a case may be the opening **122***a* side which is opposite to that in the respective embodiments. When the heat treatment apparatus of the present disclosure serves as a heat exchanger, a part from which the first fluid and the second fluid are introduced to the heat exchanger and a part from which the first fluid and the second fluid are led out of the heat exchanger both may have a structure similar to the product drain part **122** according to the respective embodiments. Thus, according to the heat treatment apparatus of the present disclosure, the space-forming part in which the flow-regulating part is installed by use of the attachment part may be located on either the upstream side or the downstream side of the flow of the respective fluids. In other words, in the reactor **1** having the structure as illustrated above, the introduction and leading-out directions of the respective fluids are not particularly limited.

[0053] In view of the other embodiments described above, the first fluid and the second fluid may be different substances or the same substance depending on the heat treatment apparatus employed. In the first and second embodiments described above, the first fluid may be a heating medium, and the second fluid may be a reaction fluid or product, depending on the operations required for the flow-regulating part **170**. When the heat treatment apparatus to which the present disclosure is applied is a heat exchanger, the first fluid and the second fluid both may be a heating medium.

[0054] While the respective embodiments have exemplified the heat exchange unit **101** in which two kinds of plate-like heat transfer bodies are stacked on one another, the heat exchange unit is not necessarily a stacked body. The present disclosure is applicable to a reactor including a heat exchange unit having straight reaction channels such as circular pipes.

[0055] It should be noted that the present disclosure includes various embodiments which are not disclosed herein. Therefore, the scope of the present disclosure is defined only by the matters according to the claims reasonably derived from the description described above.

What is claimed is:

1. A heat treatment apparatus using heat exchange between a first fluid and a second fluid, the apparatus comprising:
- a heat exchange unit including a plurality of first channels through which the first fluid flows and a plurality of second channels through which the second fluid flows;
- a space-forming part having a space facing channel openings of the respective first channels;
- a first opening located in the space-forming part and having a first aperture;
- a flow-regulating part installed in the space in the space-forming part to regulate a flow of the first fluid; and
- an attachment part for removably attaching the flow-regulating part through the first aperture,
- wherein the space in the space-forming part is a space in which the first fluid led out of the respective channel openings flows together, or a space from which the first fluid flowing together is introduced to the respective channel openings, and
- in a state in which the flow-regulating part is fixed in the space-forming part, the flow-regulating part is opposed to the plural channel openings.

2. The heat treatment apparatus according to claim **1**, wherein an extending direction of a central axis of the first aperture is different from an open direction of the respective channel openings.

3. The heat treatment apparatus according to claim **1**, wherein the flow-regulating part has a cylindrical shape.

4. The heat treatment apparatus according to claim **1**, wherein the flow-regulating part is a porous member provided with a plurality of holes through which the first fluid can flow.

5. The heat treatment apparatus according to claim **1**, wherein the first opening includes a first connection part connected to and released from an external pipe outside the apparatus through which the first fluid flows.

6. The heat treatment apparatus according to claim **5**, wherein:
- the attachment pan includes an engaging part integrally provided at one end of the flow-regulating part so as to have a length from a central axis of the flow-regulating part greater than a radius of the first aperture, and an engaged part provided in the first connection part and engaged with the engaging part; and
- in a state in which the engaging part engages with the engaged part, the first connection part is connected to the external pipe outside the apparatus so as to fix the flow-regulating part.

7. The heat treatment apparatus according to claim **1**, further comprising:
- a second opening including a first connection part connected to and released from an external pipe outside the apparatus through which the first fluid flows; and
- a shielding plate capable of shielding the first aperture,
- wherein the first opening includes a second connection pan connected to and released from the shielding plate.

8. The heat treatment apparatus according to claim **7**, wherein:
- the attachment part includes an engaging part integrally provided at one end of the flow-regulating part so as to have a length from a central axis of the flow-regulating part greater than a radius of the first aperture, and an engaged part provided in the second connection part and engaged with the engaging part; and
- in a state in which the engaging part engages with the engaged part, the second connection part is connected to the shielding part so as to fix the flow-regulating part.

9. The heat treatment apparatus according to claim **7**, wherein:

the first opening is opposed to the second opening on an identical axis; and

another end of the flow-regulating part is introduced into a second aperture of the second opening in the state in which the flow-regulating part is fixed in the space-forming part.

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