(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 623 910 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.08.2013 Bulletin 2013/32

(51) Int Cl.:
F28D 9/00 *(2006.01)*

(21) Application number: **13151567.8**

(22) Date of filing: **17.01.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **31.01.2012 JP 2012018128**

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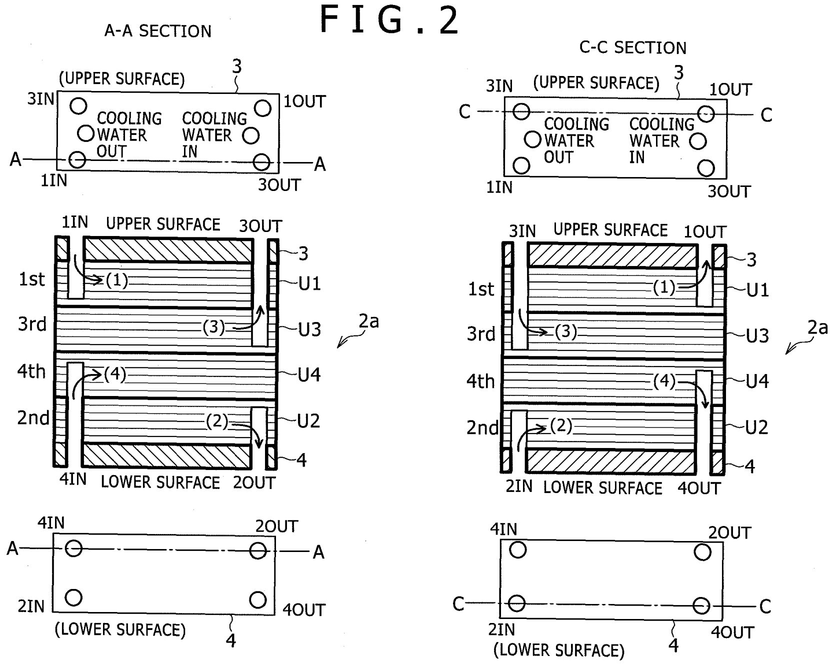
(54) **Multilayer heat exchanger and heat exchange system**

(57) In a multilayer heat exchanger of the present invention, a plurality of heat exchange units for performing heat exchange of a fluid fed from a plurality of compressors is stacked. Each of the heat exchange units has a structure that pluralities of flow passage plates and cooling plates are stacked. Concave grooves formed on surfaces are formed as flow passages of the fluid in the flow passage plates and cooling plates. The flow passage plates and cooling plates are made of metal, the flow passages are formed by chemical etching, and the stacked metal flow passage plates and cooling plates are bonded to each other by diffusion-bonding. Further, each of the heat exchange units is in one-to-one correspondence with each of the compressors.

FIG. 2



EP 2 623 910 A2

Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a multilayer heat exchanger formed by stacking flow passage plates, and a heat exchange system in which this multilayer heat exchanger is used.

(DESCRIPTION OF THE RELATED ART)

[0002] There is a case where a high-temperature gas compressed by a compressor is guided to and cooled in a heat exchanger and the cooled high-pressure gas is charged into a tank or a cylinder. The heat exchanger used at this time includes a so-called fin type or plate type heat exchanger, and for example Japanese Unexamined Patent Application Publication No. 2000-283668 discloses such a heat exchanger. In the plate type heat exchanger having an integral structure that an interior is partitioned into a plurality of units by a partition wall, at least one of the plurality of units has a plurality of fluid inlets or outlets, and at least one side connecting to the inlets and the outlets forms a plurality of different heating flow passages or heated flow passages in the plurality of units. With this plate type heat exchanger, piping is easily performed and size and weight can be reduced.

[0003] A compression of a gas is not limited only to a so-called one-step type compression in which a gas is compressed only once by one compressor but a multi-step type compression in which a gas successively passes through a plurality of compressors so that the gas once compressed by a compressor is further compressed by a next-step compressor may be performed.

[0004] In a case of the multi-step type compression, a temperature of the gas is increased every time when the gas is compressed by the compressor. Thus, the compressed gas passes through and is cooled in a heat exchanger before being supplied to the next-step compressor. That is, there is a need for preparing the same number of heat exchangers as the number of the compressors so as to establish a multi-step type compression system in which the plurality of heat exchangers and also the plurality of compressors are alternately connected in series.

[0005] In a case where the above conventional heat exchanger is used for such a multi-step type compression system, there are a problem that there is a need for a large installment area for arranging the pluralities of compressors and heat exchangers and a problem that there is a larger installment area due to complicated piping when the numbers of the compressors and the heat exchangers are increased.

[0006] Further, due to low pressure resistance, the conventional heat exchanger is not suitable for treating the gas whose pressure is greatly increased by the multi-step type compression. Thus, development of a heat exchanger having high pressure resistance is also an important challenge.

SUMMARY OF THE INVENTION

[0007] In consideration with the above problems and the challenge, an object of the present invention is to provide a compact multilayer heat exchanger having high pressure resistance and a heat exchange system in which the multilayer heat exchanger is used.

[0008] In order to achieve the above object, the present invention adopts the following technical means.

[0009] A multilayer heat exchanger according to the present invention includes a plurality of stacked heat exchange units for performing heat exchange of a fluid fed out from a plurality of machines, wherein each of the heat exchange units has a structure that a plurality of flow passage plates is stacked, and each of the flow passage plates has concave grooves formed on a surface as flow passages of the fluid.

[0010] Each of the plurality of heat exchange units may be paired with each of the plurality of machines. In other words, each of the plurality of heat exchange units may be in one-to-one correspondence with each of the plurality of machines.

[0011] Further, preferably, each of the plurality of heat exchange units is provided with a supply hole through which the fluid is supplied to the heat exchange unit and a discharge hole through which the supplied fluid is discharged, and the supply hole and the discharge hole provided in each of the heat exchange units are formed with length to directly communicate with an exterior along the stacking direction of the heat exchange unit in such a manner that arrangement positions thereof in a plan view are not overlapped with each other.

[0012] In addition, the flow passage plates may be made of metal, and the flow passages of the flow passage plates may be formed by chemical etching.

[0013] Preferably, the stacked metal flow passage plates are bonded to each other by diffusion-bonding.

[0014] A heat exchange system according to the present invention includes a plurality of machines for changing a heat amount of a fluid, and a multilayer heat exchanger formed by stacking heat exchange units for performing heat exchange of the fluid whose heat amount is changed by the plurality of machines, wherein the multilayer heat exchanger is the multilayer heat exchanger described above.

[0015] According to the present invention, the compact heat exchanger having high pressure resistance and the heat exchange system can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a concept view showing a configuration of a multi-step type heat exchange system: Fig. 1A is a concept view showing a configuration of a conventional heat exchange system; and Fig. 1B is a concept view showing a configuration of a heat exchange system according to a first embodiment of the present invention;

Fig. 2 is a view showing a section structure of a multilayer heat exchanger according to the first embodiment;

Fig. 3 is a view showing a section structure of the multilayer heat exchanger according to the first embodiment;

Fig. 4 is a plan concept view showing a configuration of all plates forming the multilayer heat exchanger according to the first embodiment;

Fig. 5 is a plan view showing a configuration of the plates forming the multilayer heat exchanger according to the first embodiment: Fig. 5A is a plan view showing a configuration of a flow passage plate; and Fig. 5B is a plan view showing a configuration of a cooling plate;

Fig. 6 is a view for illustrating differential pressures of a fluid supplied to heat exchange units of the multilayer heat exchanger according to the first embodiment;

Fig. 7 is a plan view showing a configuration of a cooling plate used for a multilayer heat exchanger according to a second embodiment of the present invention;

Fig. 8 is a view showing a section structure of the multilayer heat exchanger according to the second embodiment; and

Fig. 9 is a view showing a section structure of the multilayer heat exchanger according to the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Hereinafter, embodiments of the present invention will be described based on the drawings.

[First Embodiment]

(Outline of Heat Exchange System)

[0018] With reference to the drawings, a heat exchange system according to a first embodiment of the present invention will be described.

[0019] Fig. 1 is a concept view showing a configuration of a multi-step type heat exchange system in which compressors serving as a plurality of machines and a plurality of heat exchangers are used. Fig. 1A is a concept view showing a configuration of a heat exchange system in which conventional heat exchangers are used, and Fig. 1B is a concept view showing a configuration of a heat exchange system 1a in which a multilayer heat exchanger 2a according to the present embodiment is used.

[0020] In the heat exchange system 1a to be described in the present embodiment, in a multi-step type compression process for successively pressurizing and compressing a gas by a plurality of compressors connected in series so as to change the gas into a high-pressure gas, the heat exchanger is provided in a subsequent step to the compressors.

(Conventional Heat Exchange System)

[0021] The heat exchange system shown in Fig. 1A shows the configuration of a case where the conventional heat exchangers are used. The heat exchange system of Fig. 1A includes four compressors of first to fourth compressors denoted by 1st-comp to 4th-comp, and four heat exchangers of first to fourth heat exchangers denoted by 1st-ex to 4th-ex.

[0022] Regarding the four compressors and the four heat exchangers, firstly, a discharge port of the first compressor is connected to a suction port of the first heat exchanger by a pipe, and a discharge port of the first heat exchanger is connected to a suction port of the second compressor by a pipe. In such a way, the conventional heat exchange system is formed as shown in Fig 1A while connecting the discharge ports of the compressors and the suction ports of the heat exchangers.

(Heat Exchange System of the Present Application)

[0023] On the other hand, the heat exchange system 1a shown in Fig. 1B includes compressors serving as four machines of first to fourth compressors C1 to C4 denoted by 1st-comp to 4th-comp, and the multilayer heat exchanger 2a formed by stacking and integrating four heat exchange units of first to fourth heat exchange units U1 to U4 denoted by 1st-unit to 4th unit.

[0024] The first to fourth heat exchange units U1 to U4 of the multilayer heat exchanger 2a shown in Fig. 1B perform operations corresponding to the conventional first to fourth heat exchangers shown in Fig. 1A. The first heat exchange unit U1 performs heat exchange (cooling) of a high-temperature fluid discharged from the first compressor C1, and the second heat exchange unit U2 performs heat exchange (cooling) of the high-temperature fluid discharged from the second compressor C2. The third heat exchange unit U3 performs heat exchange (cooling) of the high-temperature fluid discharged from the third compressor C3, and the fourth heat exchange unit U4 performs heat exchange (cooling) of the high-temperature fluid discharged from the fourth compressor C4.

[0025] In such a way, the heat exchange system 1a according to the present embodiment has the plurality of machines (such as the first to fourth compressors C1 to C4) for changing a heat amount of the fluid (such as a hydrogen gas), and the multilayer heat exchanger 2a formed by stacking the heat exchange units (such as the first to fourth heat exchange units U1 to U4) for performing heat exchange of the fluid whose heat amount is changed by the plurality of machines.

[0026] In the present embodiment, a state that the plurality of machines for changing the heat amount of the fluid is connected in series so as to form one flow passage is called as a state that the plurality of machines is connected in multiple steps. When the plurality of compressors C1 to C4 is connected in multiple steps as in the present embodiment, the hydrogen gas serving as the fluid flows through one flow passage formed by the multiple steps of the compressors C1 to C4 from the first compressor C1, the second compressor C2, the third compressor C3, to the fourth compressor C4 in this order. However, the heat amount of the hydrogen gas is changed and a temperature of the gas is increased every time when the gas passes through the compressors C1 to C4. Thus, every time when the gas passes through the compressors C1 to C4, the hydrogen gas discharged from the first to fourth compressors C1 to C4 flows into the corresponding first to fourth heat exchange units U1 to U4, heat exchange is performed, and the gas is suctioned into the compressor in a next step.

[0027] That is, the high-temperature hydrogen gas compressed (pressurized) in the first compressor C1 flows into the first heat exchange unit U1 of the multilayer heat exchanger 2a so as to be cooled, and is suctioned into the second compressor C2 in the next step. The suctioned hydrogen gas is further compressed by the second compressor C2 so as to have a higher temperature and returned to the multilayer heat exchanger 2a, and flows into the second heat exchange unit U2 so as to be cooled. By repeating such a cycle until the hydrogen gas passes through the fourth compressor C4 and the fourth heat exchange unit U4, the hydrogen gas becomes a greatly high-pressure gas.

[0028] In such a way, the fluid discharged from the first compressor C1 flows into the first heat exchange unit U1, and the fluid discharged from the second compressor C2 flows into the second heat exchange unit U2. Thus, it can be said that the first compressor C1 and the first heat exchange unit U1 are paired with each other, and the second compressor C2 and the second heat exchange unit U2 are paired with each other. Similarly, it can be said that the third compressor C3 and the third heat exchange unit U3 are paired with each other, and the fourth compressor C4 and the fourth heat exchange unit U4 are paired with each other.

[0029] At this time, a flow rate of cooling water can be controlled for each unit according to a layering method so that the cooling water performs cooling, or the cooling water can perform cooling all the units at once.

[0030] The multilayer heat exchanger 2a according to the present embodiment realizes functions of the plurality of heat exchangers in the conventional heat exchange system by an integrated flow passage structure. The multilayer heat exchanger 2a according to the present embodiment can be downsized more than the conventional heat exchangers, and piping with the compressors can be simply and easily organized. Further, an area of an installment place required for installing the heat exchange system including compressors can be reduced.

(Configuration of Multilayer Heat Exchanger)

[0031] With reference to Figs. 2 and 3, a configuration of the multilayer heat exchanger 2a according to the present embodiment will be described.

[0032] Fig. 2 is a view of a structure of the multilayer heat exchanger 2a, showing an A-A section and a C-C section of the multilayer heat exchanger 2a. Fig. 3 is a view showing a B-B section of the multilayer heat exchanger 2a.

[0033] The multilayer heat exchanger 2a is formed by stacking the first to fourth heat exchange units U1 to U4 denoted by 1st to 4th, stacking an upper surface board (upper end plate) 3 on an upper surface of the stacked body, and stacking a lower surface board (lower end plate) 4 on a lower surface. Each of the first to fourth heat exchange units U1 to U4 is formed by alternately stacking a plurality of flat flow passage boards (flow passage plates) in which flow passages of the hydrogen gas serving as the fluid are formed, and a plurality of flat flow passage boards (cooling plates) in which flow passages of the cooling water serving as a cooling medium are formed.

[0034] At this time, depending on a desired heat exchanger performance, the plates may be stacked in such a manner that the both surface sides of the flow passage plate on the hydrogen side are sandwiched by the cooling plates.

[0035] Therefore, an outer appearance of each of the first to fourth heat exchange units U1 to U4 is a cuboid shape in which the flat fluid plates and the cooling plates are stacked. Since such cuboid first to fourth heat exchange units U1 to U4 are stacked, the multilayer heat exchanger 2a is formed in a cuboid shape which is high in the stacking direction of the first to fourth heat exchange units U1 to U4.

[0036] With reference to Figs. 4 and 5, configurations of the first to fourth flow passage plates P1 to P4 and the cooling plate CP1 used for the first to fourth heat exchange units U1 to U4 will be described for illustrating the configuration of the multilayer heat exchanger 2a.

[0037] Fig. 4 is a view showing all the plates forming the multilayer heat exchanger 2a. The first flow passage plate (1st plate) P1 forming the first heat exchange unit U1 is shown in a upper left part of Fig. 4, and the third flow passage plate (3rd plate) P3, the fourth flow passage plate (4th plate) P4, and the second flow passage plate (2nd plate) P2 are shown in this order toward the right side. The flow passage plates P1 to P4 are shown in order of the 1st, 3rd, 4th, and 2nd plates from the left side based on the fact that the first to fourth heat exchange units U1 to U4 are stacked in order of the first, third, fourth, and second heat exchange units from the upper side in Figs. 2 and 3.

[0038] The upper surface board (upper end plate) 3 stacked on the upper surface of the multilayer heat exchanger is shown in a lower left part of Fig. 4, and the cooling plate CP1 stacked between the flow passage plates and the lower surface board (lower end plate) 4 stacked on the lower surface of the multilayer heat exchanger are shown in this order toward the right side.

[0039] Fig. 4 shows the configurations of the plates of the time when the multilayer heat exchanger 2a is seen from the upper surface side, that is, when the multilayer heat exchanger is seen along the direction from the upper side of the upper end plate 3 to the lower end plate 4.

(First Heat Exchange Unit)

[0040] Firstly, the first heat exchange unit (1st heat exchange unit) U1 in the multilayer heat exchanger 2a is formed by alternately stacking the first flow passage plates (1st plates) P1 and the cooling plates CP1.

(First Flow Passage Plate)

[0041] As shown in Fig. 4, the first flow passage plate P1 is a flat rectangular board made of metal such as stainless or aluminum, the board having thickness of a few millimeters. In both ends in the longitudinal direction of the first flow passage plate P1 shown in Fig. 4, a fluid supply hole 1IN through which the hydrogen gas supplied from the first compressor C1 flows into the first flow passage plate P1 is bored so as to form a through hole in a left part of the upper end in the figure. A fluid discharge hole 1OUT through which the hydrogen gas flows out from the first flow passage plate P1 is bored so as to form a through hole in a right part of the lower end. That is, the fluid supply hole 1IN and the fluid discharge hole 1OUT are formed in the diagonal direction of the first flow passage plate P1.

[0042] On one surface of the first flow passage plate P1 in which the fluid supply hole 1IN and the fluid discharge hole 1OUT are formed, that is, an upper surface shown in Fig. 4, flow passages for the hydrogen gas are formed so as to connect the fluid supply hole 1IN and the fluid discharge hole 1OUT. By the flow passages, the hydrogen gas flowing from the fluid supply hole 1IN flows along the formed flow passages, and flows out from the fluid discharge hole 1OUT to an exterior of the first flow passage plate.

[0043] Fig. 5A is a view showing a detailed configuration of the first flow passage plate P1 shown in Fig. 4. The plurality of flow passages is formed in the first flow passage plate P1 so as to meander in the width direction of the first flow passage plate P1 and connect the fluid supply hole 1IN and the fluid discharge hole 1OUT. The plurality of flow passages is formed so as not to cross each other but be substantially parallel to each other. Therefore, the hydrogen gas flowing from the fluid supply hole 1IN reaches the fluid discharge hole 1OUT through only one flow passage into which the gas flows.

[0044] The flow passages of the first flow passage plate P1 meander in the width direction of the first flow passage plate P1 in order to have as long flow passages as possible within a limited area of the first flow passage plate P1. For that purpose, the flow passages may take a track other than the meandering track shown in Figs. 4 and 5.

[0045] Such flow passages are called as micro channels in the technical field of the present invention, the micro channels being thin flow passages having width of about 1 millimeter. The flow passages called as the micro channels are formed with using an etching technique such as chemical etching. Since etching is isotropic work, depth of the flow passages is close to 0.5 times more than the width of the flow passages. However, in the present embodiment, the depth is about 0.4 to 0.6 times more than the width of the flow passages.

[0046] In addition, in both the ends in the longitudinal direction of the first flow passage plate P1, a fluid supply hole 3IN serving as a through hole through which the hydrogen gas supplied from the third compressor C3 flows into the third flow passage plate P3 described later is bored in a right part of the upper end in the figure. A fluid discharge hole 30UT serving as a through hole through which the hydrogen gas flows out from the third flow passage plate P3 is bored in a left part of the lower end. The fluid supply hole 3IN and the fluid discharge hole 30UT are not connected to the flow passages of the first flow passage plate P1.

[0047] A cooling water hole IN serving as a through hole through which the cooling water flows into the cooling plate CP1 described later is bored between the fluid discharge hole 1OUT and the through hole of the fluid discharge hole 30UT, and a cooling water hole OUT serving as a through hole through which the cooling water flows out from the cooling plate CP1 described later is bored between the fluid supply hole 1IN and the through hole of the fluid supply hole 3IN. The cooling water hole IN and the cooling water hole OUT are not connected to the flow passages of the first flow passage plate P1.

[0048] The other surface of such a first flow passage plate P1, that is, a lower surface (not shown) in which no flow passages are formed is a smooth surface.

(Cooling Plate)

[0049] The cooling plate CP1 has a substantially similar configuration to the first flow passage plate P1 and is made of the same material as the first flow passage plate P1. In both ends in the longitudinal direction, a fluid supply hole 1IN, a cooling water hole OUT, and a fluid supply hole 3IN are formed at the same positions as the first flow passage plate P1 in the upper end, and a fluid discharge hole 1OUT, a cooling water hole IN, and a fluid discharge hole 30UT are similarly formed at the same positions as the first flow passage plate P1 in the lower end.

[0050] Fig. 5B is a view showing a detailed configuration of the cooling plate CP1 shown in Fig. 4. A plurality of flow passages is also formed in the cooling plate CP1 so as to meander in the width direction as well as the first flow passage plate P1 and connect the cooling water hole IN and the cooling water hole OUT. The plurality of flow passages is also formed so as not to cross each other but be substantially parallel to each other as well as the first flow passage plate P1. Therefore, the cooling water flowing from the cooling water hole IN reaches the cooling water hole OUT through only one flow passage into which the water flows.

[0051] The other surface of such a cooling plate CP1, that is, a lower surface (not shown) in which no flow passages are formed is a smooth surface.

[0052] The first heat exchange unit U1 is formed by alternately stacking the first flow passage plates P1 and the cooling plates CP1 described above. Firstly, a cooling plate CP1 is used as a lowermost layer of the first heat exchange unit U1, a first flow passage plate P1 is stacked on the cooling plate, and another cooling plate CP1 is further stacked on the first flow passage plate. In such a way, the first flow passage plates P1 and the cooling plates CP1 are alternately stacked to be multiple layers on the lowermost cooling plate CP1, and the other cooling plate CP1 serves as an uppermost layer.

[0053] The number of the stacked first flow passage plates P1 is arbitrary. However, by changing the number of the first flow passage plates P1, a capacity of the first heat exchange unit U1 can be changed. This is applied to the second to fourth heat exchange units U2 to U4 described later. However, in the present embodiment, capacities of the first to fourth heat exchange units U1 to U4 are the same as each other.

[0054] When the first flow passage plates P1 and the cooling plates CP1 stacked to be multiple layers in such a way are pressurized at a predetermined temperature and bonding surfaces of the first flow passage plates P1 and the cooling plates CP1 are diffusion-bonded to each other, the first heat exchange unit U1 in which the plurality of plates is integrated is obtained. That is, the smooth lower surface of the first flow passage plate P1 diffusion-bonded onto the cooling plate CP1 serves as a lid for the flow passages of the cooling plate CP1, and the smooth lower surface of the cooling plate CP1 diffusion-bonded onto the first flow passage plate P1 serves as a lid for the flow passages of the first flow passage plate P1.

[0055] The first flow passage plate P1 and the cooling plate CP1 are firmly bonded to each other by this diffusion-bonding. Thus, the first heat exchange unit U1 has greatly high pressure resistance for the supplied fluid.

[0056] In the first heat exchange unit U1 in which the plates are diffusion-bonded in such a manner that the lower surface of the immediately upper layer serves as a lid, when the hydrogen gas is supplied from the fluid supply hole 1IN, the hydrogen gas flows into the flow passages of the first flow passage plate P1 connected to the fluid supply hole 1IN. However, since the fluid supply hole is isolated from the flow passages of the cooling plate CP1 by bonding of an upper surface of the cooling plate and the lower surface of the first flow passage plate, the hydrogen gas does not flow into the flow passages of the cooling plate CP1.

[0057] Similarly, when the cooling water is supplied from the cooling water hole IN, the cooling water flows into the flow passages of the cooling plate CP1 connected to the cooling water hole IN. However, since the cooling water hole is isolated from the flow passages of the first flow passage plate P1 by bonding of the upper surface of the first flow passage plate P1 and the lower surface of the cooling plate CP1, the cooling water does not flow into the flow passages of the first flow passage plate P1.

(Third Heat Exchange Unit)

[0058] The third heat exchange unit U3 is a heat exchange unit arranged immediately below the first heat exchange unit U1. The third flow passage plate P3 used for the third heat exchange unit U3 is a member of the substantially same material and size as the first flow passage plate P1, and similar flow passages to the first flow passage plate P1 are formed.

(Third Flow Passage Plate)

[0059] In the third flow passage plate P3, a fluid supply hole 1IN and a fluid discharge hole 1OUT as formed in the first flow passage plate P1 are not formed but a fluid supply hole 3IN, a fluid discharge hole 30UT, a cooling water hole IN, and a cooling water hole OUT are formed. On one surface of the third flow passage plate P3, that is, an upper surface shown in Fig. 4, the flow passages serving as micro channels are formed, and the fluid supply hole 3IN and the fluid discharge hole 30UT are connected by the flow passages.

[0060] When the third flow passage plates P3 and the cooling plates CP1 are stacked as well as the first heat exchange unit U1 and the plates are diffusion-bonded to each other, the third heat exchange unit U3 is obtained. In the third heat exchange unit U3, when the hydrogen gas is supplied from the fluid supply hole 3IN, the hydrogen gas flows into the flow passages of the third flow passage plate P3 connected to the fluid supply hole 3IN. However, since the fluid supply hole is isolated from the flow passages of the cooling plate CP1 by bonding of the upper surface of the cooling plate CP1 and a lower surface of the third flow passage plate P3, the hydrogen gas does not flow into the flow passages of the cooling plate CP1.

[0061] Similarly, when the cooling water is supplied from the cooling water hole IN, the cooling water flows into the flow passages of the cooling plate CP1 connected to the cooling water hole IN. However, since the cooling water hole is isolated from the flow passages of the third flow passage plate P3 by bonding of the upper surface of the third flow passage plate P3 and the lower surface of the cooling plate CP1, the cooling water does not flow into the flow passages of the third flow passage plate P3.

(Fourth Heat Exchange Unit)

[0062] The fourth heat exchange unit U4 is a heat exchange unit arranged immediately below the third heat exchange unit U3. The fourth flow passage plate P4 used for the fourth heat exchange unit U4 is a member of the substantially same material and size as the first flow passage plate P1 and the third flow passage plate P3, and similar flow passages to the first flow passage plate P1 and the third flow passage plate P3 are formed.

(Fourth Flow Passage Plate)

[0063] As shown in Fig. 4, the fourth flow passage plate P4 has a configuration formed by mirror-reversing the configuration of the third flow passage plate P3, and through holes formed on a diagonal line are a fluid supply hole 4IN and a fluid discharge hole 40UT. A cooling water hole IN and a cooling water hole OUT are also formed in the fourth flow passage plate P4. On one surface of the fourth flow passage plate P4, that is, an upper surface shown in Fig. 4, the flow passages serving as micro channels are formed, and the fluid supply hole 4IN and the fluid discharge hole 40UT are connected by the flow passages.

[0064] When the fourth flow passage plates P4 and the cooling plates CP1 are stacked as well as the first heat exchange unit U1 and the third heat exchange unit U3 and the plates are diffusion-bonded to each other, the fourth heat exchange unit U4 is obtained. In the fourth heat exchange unit U4, when the hydrogen gas is supplied from the fluid supply hole 4IN, the hydrogen gas flows into the flow passages of the fourth flow passage plate P4 connected to the fluid supply hole 4IN. However, since the fluid supply hole is isolated from the flow passages of the cooling plate CP1 by bonding of the upper surface of the cooling plate CP1 and a lower surface of the fourth flow passage plate P4, the hydrogen gas does not flow into the flow passages of the cooling plate CP1.

[0065] Similarly, when the cooling water is supplied from the cooling water hole IN, the cooling water does not flow into the flow passages of the fourth flow passage plate P4 for a similar reason to the first heat exchange unit U1 and the third heat exchange unit U3.

(Second Heat Exchange Unit)

[0066] The second heat exchange unit U2 is a heat exchange unit arranged immediately below the fourth heat exchange unit U4. The second flow passage plate P2 used for the second heat exchange unit U2 is a member of the substantially same material and size as the first flow passage plate P1, the third flow passage plate P3, and the fourth flow passage plate P4, and similar flow passages to the flow passage plates are formed.

(Second Flow Passage Plate)

[0067] As shown in Fig. 4, the second flow passage plate P2 has a configuration formed by mirror-reversing the configuration of the first flow passage plate P1, and through holes formed on a diagonal line which is different from a diagonal line connecting a fluid supply hole 4IN and a fluid discharge hole 40UT are a fluid supply hole 2IN and a fluid discharge hole 2OUT. A cooling water hole IN and a cooling water hole OUT are also formed in the second flow passage plate P2. On one surface of the second flow passage plate P2, that is, an upper surface shown in Fig. 4, the flow passages serving as micro channels are formed, and the fluid supply hole 2IN and the fluid discharge hole 20UT are connected by the flow passages.

[0068] When the second flow passage plates P2 and the cooling plates CP1 are stacked as well as the first heat exchange unit U1, the third heat exchange unit U3, and the fourth heat exchange unit U4 and the plates are diffusion-bonded to each other, the second heat exchange unit U2 is obtained. In the second heat exchange unit U2, when the hydrogen gas is supplied from the fluid supply hole 2IN, the hydrogen gas flows into the flow passages of the second flow passage plate P2 connected to the fluid supply hole 2IN. However, since the fluid supply hole is isolated from the flow passages of the cooling plate CP1 by bonding of the upper surface of the cooling plate CP1 and a lower surface of the second flow passage plate P2, the hydrogen gas does not flow into the flow passages of the cooling plate CP1.

[0069] Similarly, when the cooling water is supplied from the cooling water hole IN, the cooling water does not flow into the second flow passage plate P2 for a similar reason to the first heat exchange unit U1, the third heat exchange unit U3, and the fourth heat exchange unit U4.

[0070] The heat exchange units U1 to U4 obtained as above are stacked in order of the first heat exchange unit U1, the third heat exchange unit U3, the fourth heat exchange unit U4, and the second heat exchange unit U2 from the upper side. Further, the upper end plate 3 is placed on an upper surface of the first heat exchange unit U1, the lower end plate 4 is placed on a lower surface of the second heat exchange unit U2, and the heat exchange units U1 to U4 and the upper and lower end plates 3 and 4 are bonded to each other by diffusion-bonding.

[0071] Thereby, the multilayer heat exchanger 2a according to the present embodiment is formed. In the upper end plate 3, a fluid supply hole 1IN, a fluid discharge hole 1OUT, a fluid supply hole 3IN, a fluid discharge hole 30UT, a cooling water hole IN, and a cooling water hole OUT are opened as well as the first flow passage plate P1. In the lower end plate 4, a fluid supply hole 2IN, a fluid discharge hole 20UT, a fluid supply hole 4IN, and a fluid discharge hole 40UT are opened.

[0072] Returning to Fig. 2, the A-A section and the C-C section of the multilayer heat exchanger 2a will be referred to.

[0073] The A-A section is a plane including the fluid supply hole 1IN and the fluid discharge hole 3OUT in the upper end plate 3 and the fluid supply hole 4IN and the fluid discharge hole 2OUT in the lower end plate 4, showing a sectional view of the time when the multilayer heat exchanger 2a is cut in the stacking direction.

[0074] The C-C section is a plane including the fluid supply hole 3IN and the fluid discharge hole 1OUT in the upper end plate 3 and the fluid supply hole 2IN and the fluid discharge hole 4OUT in the lower end plate 4, showing a sectional view of the time when the multilayer heat exchanger 2a is cut in the stacking direction.

[0075] In the upper end plate 3, the fluid supply hole 1IN and the fluid discharge hole 1OUT are formed on one diagonal line, and the fluid supply hole 3IN and the fluid discharge hole 3OUT are formed on the other diagonal line. Therefore, the fluid supply hole 1IN shown in the A-A section and the fluid discharge hole 1OUT shown in the C-C section corresponding to the fluid supply hole 1IN are formed in such a manner that an interior of the first heat exchange unit U1 directly communicates with an exterior along the stacking direction of the heat exchange units in the sections. The fluid supply hole 3IN shown in the C-C section and the fluid discharge hole 3OUT shown in the A-A section corresponding to the fluid supply hole 3IN are formed so as to penetrate the first heat exchange unit U1 in such a manner that an interior of the third heat exchange unit U3 directly communicates with the exterior along the stacking direction of the heat exchange units in the sections.

[0076] In the lower end plate 4, the fluid supply hole 4IN and the fluid discharge hole 4OUT are formed on one diagonal line, and the fluid supply hole 2IN and the fluid discharge hole 2OUT are formed on the other diagonal line. Therefore, the fluid supply hole 4IN shown in the A-A section and the fluid discharge hole 4OUT shown in the C-C section corresponding to the fluid supply hole 4IN are formed so as to penetrate the second heat exchange unit U2 in such a manner that an interior of the fourth heat exchange unit U4 directly communicates with the exterior along the stacking direction of the heat exchange units in the sections. Further, the fluid supply hole 2IN shown in the C-C section and the fluid discharge hole 2OUT shown in the A-A section corresponding to the fluid supply hole 2IN are formed in such a manner that an interior of the second heat exchange unit U2 directly communicates with the exterior along the stacking direction of the heat exchange units in the sections.

[0077] The B-B section of the multilayer heat exchanger 2a shown in Fig. 3 will be referred to. The B-B section is a plane including the cooling water hole IN and the cooling water hole OUT in the upper end plate 3, showing a sectional view of the time when the multilayer heat exchanger 2a is cut in the stacking direction. In the upper end plate 3, the cooling water hole IN and the cooling water hole OUT are formed on a B-B line along the longitudinal direction of the upper end plate 3. Therefore, both the cooling water hole IN and the cooling water hole OUT are formed in all the heat exchange units U1 to U4 of the multilayer heat exchanger 2a in the B-B section.

[0078] In such a way, in the multilayer heat exchanger 2a according to the present embodiment, the fluid supply hole (supply hole) through which the fluid is supplied to each of the heat exchange units and the fluid discharge hole (discharge hole) through which the supplied fluid is discharged are provided in each of the plurality of heat exchange units U1 to U4. It can be said that the supply holes and the discharge holes provided in the heat exchange units are formed with length to directly communicate with the exterior along the stacking direction of the heat exchange units U1 to U4 in such a manner that arrangement positions thereof in a plan view seen from the upper end plate 3 and the lower end plate 4 are not overlapped with each other. Since such a structure is adopted, there is no need for partition walls and the like for maintaining pressure between the heat exchange units.

(Operations of Heat Exchange System)

[0079] Next, with reference to Figs. 2 and 3, connection between the multilayer heat exchanger 2a and the compressors will be described. Each of the compressors in one-to-one correspondence with each of the heat exchange units is connected to each of the heat exchange units U1 to U4 of the multilayer heat exchanger 2a in which the fluid supply holes and the fluid discharge holes are formed as described above. That is, a discharge port of the first compressor C1 is connected to the fluid supply hole 1IN of the upper end plate 3, and the fluid discharge hole 1OUT of the upper end plate 3 is connected to a suction port of the second compressor C2. Next, a discharge port of the second compressor C2 is connected to the fluid supply hole 2IN of the lower end plate 4, and the fluid discharge hole 2OUT of the lower end plate 4 is connected to a suction port of the third compressor C3. Then, a discharge port of the third compressor C3 is connected to the fluid supply hole 3IN of the upper end plate 3, and the fluid discharge hole 3OUT of the upper end plate 3 is connected to a suction port of the fourth compressor C4. Finally, a discharge port of the fourth compressor C4 is connected to the fluid supply hole 4IN of the lower end plate 4, and the fluid discharge hole 4OUT of the lower end plate 4 is connected to a charge port of a tank or a cylinder.

[0080] Further, a cooling water discharge port of a cooling water supply pump is connected to the cooling water hole IN of the upper end plate 3, and a drainpipe is connected to the cooling water hole OUT. By this connection, the heat exchange system 1a for compressing the hydrogen gas in multiple steps while performing heat exchange of the compressed hydrogen gas from the suction port of the first compressor C1 to the charge port of the tank or the cylinder is formed.

[0081] Fig. 3 shows a flow of the cooling water. Firstly, the cooling water supply pump is operated so as to continuously supply the cooling water from the cooling water hole IN of the upper end plate 3 of the multilayer heat exchanger 2a. The supplied cooling water flows into the flow passages of the cooling plates of the heat exchange units from the cooling water hole IN penetrating from the first heat exchange unit U1 of the uppermost layer to the second heat exchange unit U2 of the lowermost layer, and is discharged to the cooling water hole OUT penetrating from the first heat exchange unit U1 of the uppermost layer to the second heat exchange unit U2 of the lowermost layer while filling the flow passages. Since the cooling water is continuously supplied by the cooling water supply pump, the cooling water discharged to the cooling water hole OUT through the flow passages of the cooling plates CP1 is brought out from the cooling water hole OUT of the upper end plate 3 and discharged to the drainpipe. In such a way, the flow of the cooling water in all the cooling plates CP1 of the heat exchange units U1 to U4 is ensured.

[0082] Then, the first compressor C1 serving as a first-step machine compresses the hydrogen gas. The hydrogen gas in which pressure is boosted and a temperature is also increased is fed from the discharge port of the first compressor C1 to the fluid supply hole 1IN of the upper end plate 3.

[0083] As shown in the A-A section of Fig. 2, the hydrogen gas supplied to the fluid supply hole 1IN flows into the flow passages of the first flow passage plate P1 of the first heat exchange unit U1 as a hydrogen gas flow (1). While flowing through the flow passages of the first flow passage plate P1, the high-temperature hydrogen gas flowing into the first flow passage plate P1 is cooled by heat exchange with the cooling water flowing through the cooling plates CP1 which are stacked on the upper and lower sides of the first flow passage plate.

[0084] As shown in the C-C section of Fig. 2, the hydrogen gas flow (1) cooled in the first heat exchange unit U1 is discharged from the flow passages of the first flow passage plate P1 to the fluid discharge hole 1OUT, and flows into the suction port of the second compressor C2 serving as a second-step machine from the fluid discharge hole 1OUT of the upper end plate 3. The second compressor C2 compresses the hydrogen gas, and the hydrogen gas in which the pressure and the temperature are increased is fed from the discharge port of the second compressor C2 to the fluid supply hole 2IN of the lower end plate 4.

[0085] As shown in the C-C section of Fig. 2, the hydrogen gas supplied to the fluid supply hole 2IN flows into the flow passages of the second flow passage plate P2 of the second heat exchange unit U2 as a hydrogen gas flow (2). While flowing through the flow passages of the second flow passage plate P2, the high-temperature hydrogen gas flowing into the second flow passage plate P2 is cooled by heat exchange with the cooling water flowing through the cooling plates CP1 which are stacked on the upper and lower sides of the second flow passage plate.

[0086] As shown in the A-A section of Fig. 2, the hydrogen gas flow (2) cooled in the second heat exchange unit U2 is discharged from the flow passages of the second flow passage plate P2 to the fluid discharge hole 2OUT, and flows into the suction port of the third compressor C3 serving as a third-step machine from the fluid discharge hole 2OUT of the lower end plate 4. The third compressor C3 further compresses the hydrogen gas compressed by the first compressor C1 and the second compressor C2, and the hydrogen gas in which the pressure and the temperature are increased is fed from the discharge port of the third compressor C3 to the fluid supply hole 3IN of the upper end plate 3.

[0087] As shown in the C-C section of Fig. 2, the hydrogen gas supplied to the fluid supply hole 3IN flows into the flow passages of the third flow passage plate P3 of the third heat exchange unit U3 as a hydrogen gas flow (3). While flowing through the flow passages of the third flow passage plate P3, the high-temperature hydrogen gas flowing into the third flow passage plate P3 is cooled by heat exchange with the cooling water flowing through the cooling plates CP1 which are stacked on the upper and lower sides of the third flow passage plate.

[0088] As shown in the A-A section of Fig. 2, the hydrogen gas flow (3) cooled in the third heat exchange unit U3 is discharged from the flow passages of the third flow passage plate P3 to the fluid discharge hole 3OUT, and flows into the suction port of the fourth compressor C4 serving as a fourth- or final-step machine from the fluid discharge hole 3OUT of the upper end plate 3. The fourth compressor C4 further compresses the hydrogen gas compressed up to the third compressor C3 at targeted pressure, and the hydrogen gas in which the pressure and the temperature are increased is fed from the discharge port of the fourth compressor C4 to the fluid supply hole 4IN of the lower end plate 4.

[0089] As shown in the C-C section of Fig. 2, the hydrogen gas supplied to the fluid supply hole 4IN flows into the flow passages of the fourth flow passage plate P4 of the fourth heat exchange unit U4 as a hydrogen gas flow (4). While flowing through the flow passages of the fourth flow passage plate P4, the high-temperature hydrogen gas flowing into the fourth flow passage plate P4 is cooled by heat exchange with the cooling water flowing through the cooling plates CP1 which are stacked on the upper and lower sides of the fourth flow passage plate.

[0090] As shown in the A-A section of Fig. 2, the hydrogen gas flow (4) cooled in the fourth heat exchange unit U4 is discharged from the flow passages of the fourth flow passage plate P4 to the fluid discharge hole 4OUT, and supplied to and charged in the charge port of the tank or the cylinder from the fluid discharge hole 4OUT of the lower end plate 4.

[0091] In such a way, in the heat exchange system 1a according to the present embodiment, the multilayer heat exchanger 2a formed by stacking and integrating the plurality of heat exchange units U1 to U4 is used, and every time when the fluid is compressed by the compressors, heat exchange of the fluid compressed by the plurality of compressors C1 to C4 in multiple steps is performed in the corresponding heat exchange unit.

[0092] An A-A section of Fig. 6 shows a differential pressure between the upper end plate 3 and the first heat exchange unit U1, differential pressures between the heat exchange units adjacent to each other, and a differential pressure between the second heat exchange unit U2 and the lower end plate 4 (ΔP). The differential pressure between the upper end plate 3 and the first heat exchange unit U1 is 5 MPa, the differential pressure between the first heat exchange unit U1 and the third heat exchange unit U3 is 20 MPa, the differential pressure between the third heat exchange unit U3 and the fourth heat exchange unit U4 is 30 MPa, the differential pressure between the fourth heat exchange unit U4 and the second heat exchange unit U2 is 40 MPa, and the differential pressure between the second heat exchange unit U2 and the lower end plate 4 is 10 MPa.

[0093] Regarding a configuration of the heat exchange system 1a, for a purpose of preventing damages to devices due to an operation change of the multilayer heat exchanger 2a, a correspondence relationship between each of the compressors and each of the heat exchange units is desirably determined in such a manner that the sum of the differential pressures of the multilayer heat exchanger 2a becomes minimum. In the present embodiment, the first heat exchange unit U1 is in one-to-one correspondence with the first compressor C1. However, the first heat exchange unit may correspond to any of the second to fourth compressors C2 to C4 other than the first compressor C1.

[0094] For example, it assumes that the first heat exchange unit U1 corresponds to the third compressor C3, the second heat exchange unit U2 corresponds to the first compressor C1, the third heat exchange unit U3 corresponds to the fourth compressor C4, and the fourth heat exchange unit U4 corresponds to the second compressor C2. In that case, the hydrogen gas passes through the first compressor C1, the second heat exchange unit U2, the second compressor C2, the fourth heat exchange unit U4, the third compressor C3, the first heat exchange unit U1, the fourth compressor C4, and the third heat exchange unit U3 in this order, and is supplied to and charged in the charge port of the tank or the cylinder.

[Second Embodiment]

[0095] With reference to Figs. 7 to 9, a heat exchange system 1b according to a second embodiment of the present invention will be described.

[0096] In the heat exchange system 1b according to the present embodiment, six compressors C1 to C6 and six heat exchange units U1 to U6 are connected in series so as to perform a six-step compression. That is, a configuration of a multilayer heat exchanger 2b formed by stacking the six heat exchange units U1 to U6 is different from the configuration of the multilayer heat exchanger 2a according to the first embodiment. Thus, the configuration will be described in detail below.

[0097] The multilayer heat exchanger 2b according to the present embodiment is different from the multilayer heat exchanger 2a according to the first embodiment in terms that a configuration of a cooling plate CP2 is different from the cooling plate CP1 of the multilayer heat exchanger 2a according to the first embodiment, and the fifth heat exchange unit U5 and the sixth heat exchange unit U6 are added. The configurations of the first to fourth flow passage plates P1 to P4 and the upper and lower end plates 3 and 4 are the same as the first embodiment.

[0098] Fig. 7 shows the configuration of the cooling plate CP2 used for the multilayer heat exchanger 2b according to the present embodiment. The cooling plate CP2 shown in Fig. 7 is a plate in which a cooling water hole IN for flow passages is opened on the side of one long side along the longitudinal direction of the cooling plate CP2, and a cooling water hole OUT for the flow passages is opened on the side of the other long side. The cooling water hole IN and the cooling water hole OUT are formed at positions substantially along the diagonal direction of the cooling plate CP2. The plurality of flow passages is formed in the cooling plate CP2 so as to meander in the width direction of the cooling plate CP2 and connect the cooling water hole IN and the cooling water hole OUT.

[0099] The cooling plate CP2 has through holes capable of corresponding to fluid supply holes 1IN to 4IN, fluid discharge holes 1OUT to 40UT, fluid supply holes 5IN and 6IN described later, and fluid discharge holes 50UT and 60UT on the both end sides in the longitudinal direction.

[0100] With using such cooling plates CP2, as well as the first embodiment, the first heat exchange unit U1 is formed by stacking the first flow passage plates P1 and the second heat exchange unit U2 is formed by stacking the second flow passage plates P2. Further, the third heat exchange unit U3 is formed by stacking the third flow passage plates P3 and the fourth heat exchange unit U4 is formed by stacking the fourth flow passage plates P4.

[0101] A fifth flow passage plate P5 and a sixth flow passage plate P6 have the substantially same configuration as the cooling plate CP1 according to the first embodiment. The cooling water hole OUT in the cooling plate CP1 according to the first embodiment acts as the hole 5IN in the fifth flow passage plate P5, and the cooling water hole IN acts as the hole 5OUT. Similarly, the sixth flow passage plate P6 is provided with the fluid supply hole 6IN and the fluid discharge hole 6OUT.

[0102] Therefore, as shown in Figs. 8 and 9, in the upper end plate 3, through holes 6IN and 60UT are formed at positions corresponding to the holes 6IN and 60UT of the sixth flow passage plate P6, and in the lower end plate 4, through holes 5IN and 50UT are formed at positions corresponding to the holes 5IN and 50UT of the fifth flow passage plate P5.

[0103] As well as the first to fourth heat exchange units U1 to U4, the fifth heat exchange unit U5 is formed by using the cooling plates CP2 and the fifth flow passage plates P5, and the sixth heat exchange unit U6 is formed by using the cooling plates CP2 and the sixth flow passage plates P6.

[0104] The heat exchange units U1 to U6 obtained as above are stacked in order of the first heat exchange unit U1, the third heat exchange unit U3, the sixth heat exchange unit U6, the fourth heat exchange unit U4, the fifth heat exchange unit U5, and the second heat exchange unit U2 from the upper side. Further, the upper end plate 3 is placed on the upper surface of the first heat exchange unit U1, the lower end plate 4 is placed on the lower surface of the second heat exchange unit U2, and the heat exchange units U1 to U6 and the upper and lower end plates 3 and 4 are bonded to each other by diffusion-bonding.

[0105] Thereby, the multilayer heat exchanger 2b according to the present embodiment is formed. In the upper end plate 3, the fluid supply hole 1IN, the fluid discharge hole 1OUT, the fluid supply hole 3IN, the fluid discharge hole 30UT, and the holes 6IN and 60UT are opened as well as the first flow passage plate P1. In the lower end plate 4, the fluid supply hole 2IN, the fluid discharge hole 20UT, the fluid supply hole 4IN, the fluid discharge hole 40UT, and the holes 5IN and 50UT are opened. In the fourth flow passage plate P4, there may be no through holes corresponding to the fluid supply holes 5IN and 6IN and the fluid discharge holes 50UT and 6OUT.

[0106] By stacking the first to sixth heat exchange units U1 to U6, the cooling water hole IN and the cooling water hole OUT of the cooling plates CP2 are opened along the vertical height direction of the multilayer heat exchanger 2b on the sides of the multilayer heat exchanger 2b. Headers 5 for forming the common flow passages for the cooling water hole IN and the cooling water hole OUT along the vertical height direction of the multilayer heat exchanger 2b are attached to the cooling water hole IN and the cooling water hole OUT. Therefore, the cooling water supplied to the header 5 on the side of the cooling water hole IN flows into the flow passages from the cooling water hole IN of each of the stacked cooling water plates CP2. The cooling water flowing out from the cooling water hole IN of each of the cooling plates CP2 is discharged through the header 5 on the side of the cooling water hole IN. By attaching the headers 5, the multilayer heat exchanger 2b according to the present embodiment is completed.

[0107] In the present embodiment, the fluid supply hole (supply hole) through which the fluid is supplied to each of the heat exchange units and the fluid discharge hole (discharge hole) through which the supplied fluid is discharged are also provided in each of the plurality of heat exchange units U1 to U6 of the multilayer heat exchanger 2b. It can be said that the supply holes and the discharge holes provided in the heat exchange units are formed with length to directly communicate with the exterior along the stacking direction of the heat exchange units U1 to U6 in such a manner that arrangement positions thereof in a plan view seen from the upper end plate 3 and the lower end plate 4 are not overlapped with each other.

[0108] In the present embodiment, the hydrogen gas is compressed in six steps with using the above multilayer heat exchanger 2b and the six compressors C1 to C6. The first heat exchange unit U1 corresponds to the first compressor C1, the second heat exchange unit U2 corresponds to the second compressor C2, ... , the fifth heat exchange unit U5 corresponds to the fifth compressor C5, and the sixth heat exchange unit U6 corresponds to the sixth compressor C6 in order, so as to form the six-step heat exchange system 1b in which the six compressors C1 to C6 are connected in series via the multilayer heat exchanger 2b.

[0109] As shown in Figs. 8 and 9, when the hydrogen gas passes through the heat exchange system 1b as any of hydrogen gas flows (1) to (6), the hydrogen gas is pressurized at targeted pressure by receiving compression in six steps. At that time, the heat exchange system 1b is preferably formed in such a manner that the sum of differential pressures of the heat exchange units adjacent to each other is minimum.

[0110] The embodiments disclosed herein are not limitation but examples in all respects. In particular, matters which are not explicitly disclosed in the embodiments herein such as operation conditions, measurement conditions, various parameters, and size, weight, and mass of constituent elements do not depart from the scope of general implementation of those skilled in the art but take values which can easily be anticipated by those skilled in the art.

[0111] For example, although the four-step compression in which the four compressors C1 to C4 and the four heat exchange units U1 to U4 are connected in series is described in the first embodiment, a configuration that two of a two-step compression in which two compressors and two heat exchange units are connected in series are placed in parallel can also be adopted. Needless to say, a configuration that a one-step compression and a three-step compression are placed in parallel can also be adopted.

[0112] Although the six-step compression in which the six compressors C1 to C6 and the six heat exchange units U1 to U6 are connected in series is described in the second embodiment, a configuration that a one-step compression and a five-step compression are placed in parallel, a two-step compression and a four-step compression are placed in parallel, or a three-step compression and a three-step compression are placed in parallel can also be adopted.

[0113] The hydrogen gas is shown as an example of the fluid of the heat exchange systems 1a and 1b. However, the fluid is not limited to the hydrogen gas but other gases or liquids can be adopted. In that case, a cooling medium supplied to the cooling plates CP1 and CP2 can be appropriately changed in accordance with a type of the supplied fluid. Since the present invention is also the heat exchange system, the fluid may be heated by making a heating medium flow and using the cooling plate as a heating plate.

[0114] In a multilayer heat exchanger of the present invention, a plurality of heat exchange units for performing heat exchange of a fluid fed from a plurality of compressors is stacked. Each of the heat exchange units has a structure that pluralities of flow passage plates and cooling plates are stacked. Concave grooves formed on surfaces are formed as flow passages of the fluid in the flow passage plates and cooling plates. The flow passage plates and cooling plates are made of metal, the flow passages are formed by chemical etching, and the stacked metal flow passage plates and cooling plates are bonded to each other by diffusion-bonding. Further, each of the heat exchange units is in one-to-one correspondence with each of the compressors.

Claims

1. A multilayer heat exchanger, comprising:

a plurality of stacked heat exchange units for performing heat exchange of a fluid fed out from a plurality of machines, wherein
each of the heat exchange units has a structure that a plurality of flow passage plates is stacked, and
each of the flow passage plates has concave grooves formed on a surface as flow passages of the fluid.

2. The multilayer heat exchanger according to claim 1, wherein
each of the plurality of heat exchange units is paired with each of the plurality of machines.

3. The multilayer heat exchanger according to claim 2, wherein
each of the plurality of heat exchange units is provided with a supply hole through which the fluid is supplied to the heat exchange unit and a discharge hole through which the supplied fluid is discharged, and
the supply hole and the discharge hole provided in each of the heat exchange units are formed with length to directly communicate with an exterior along the stacking direction of the heat exchange unit in such a manner that arrangement positions thereof in a plan view are not overlapped with each other.

4. The multilayer heat exchanger according to claim 1, wherein
the flow passage plates are made of metal, and
the flow passages of the flow passage plates are formed by chemical etching.

5. The multilayer heat exchanger according to claim 4, wherein
the stacked metal flow passage plates are bonded to each other by diffusion-bonding.

6. A heat exchange system, comprising:

a plurality of machines for changing a heat amount of a fluid; and
a multilayer heat exchanger formed by stacking heat exchange units for performing heat exchange of the fluid whose heat amount is changed by the plurality of machines, wherein
the multilayer heat exchanger is the multilayer heat exchanger according to claim 1.

FIG.1A

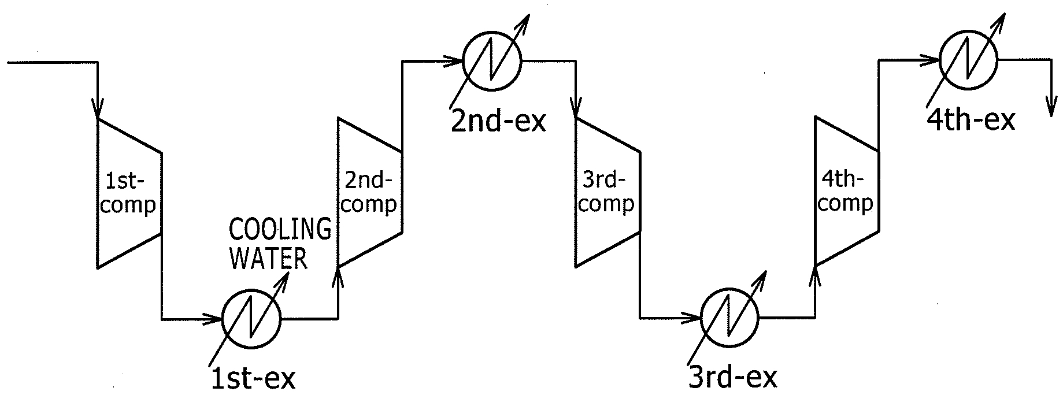

1st-comp
COOLING WATER
1st-ex
2nd-comp
2nd-ex
3rd-comp
3rd-ex
4th-comp
4th-ex

FIG.1B

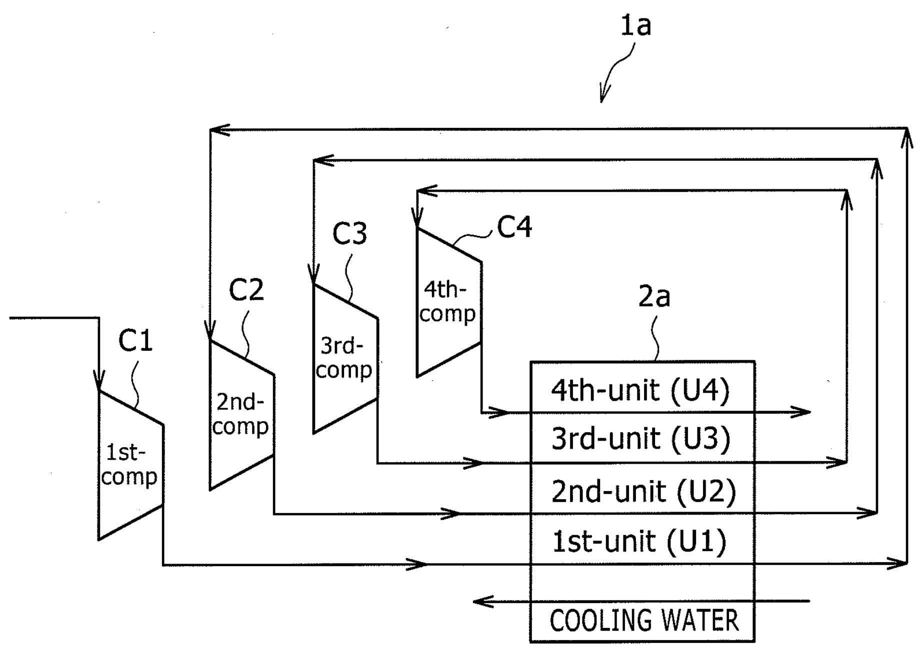

1a
C1
1st-comp
C2
2nd-comp
C3
3rd-comp
C4
4th-comp
2a
4th-unit (U4)
3rd-unit (U3)
2nd-unit (U2)
1st-unit (U1)
COOLING WATER

FIG. 2

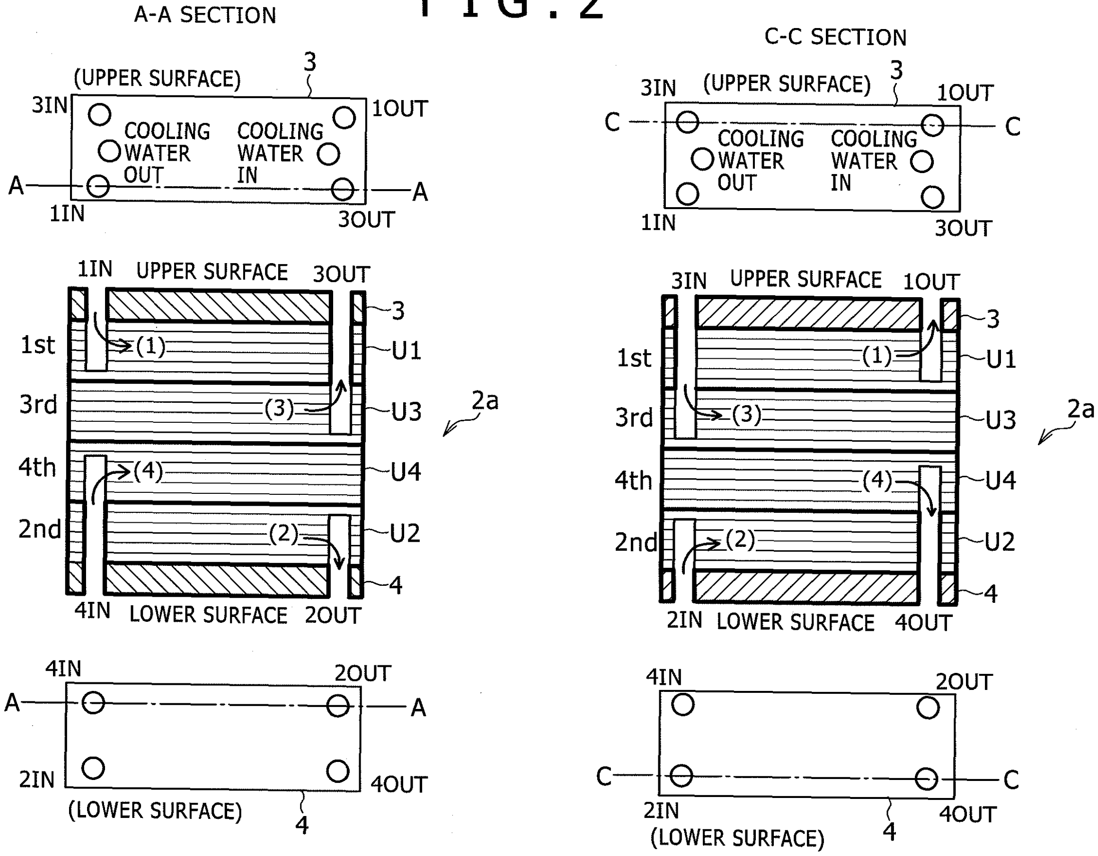

A-A SECTION
(UPPER SURFACE)
3
3IN
1OUT
COOLING WATER OUT
COOLING WATER IN
A
A
1IN
3OUT
1IN
UPPER SURFACE
3OUT
3
1st
(1)
U1
3rd
(3)
U3
2a
4th
(4)
U4
2nd
(2)
U2
4
4IN
LOWER SURFACE
2OUT
4IN
2OUT
A
A
2IN
4OUT
(LOWER SURFACE)
4
C-C SECTION
3IN
(UPPER SURFACE)
3
1OUT
C
C
COOLING WATER OUT
COOLING WATER IN
1IN
3OUT
3IN
UPPER SURFACE
1OUT
3
1st
(1)
U1
3rd
(3)
U3
2a
4th
(4)
U4
2nd
(2)
U2
4
2IN
LOWER SURFACE
4OUT
4IN
2OUT
C
C
2IN
4OUT
(LOWER SURFACE)
4

FIG. 3

B-B SECTION

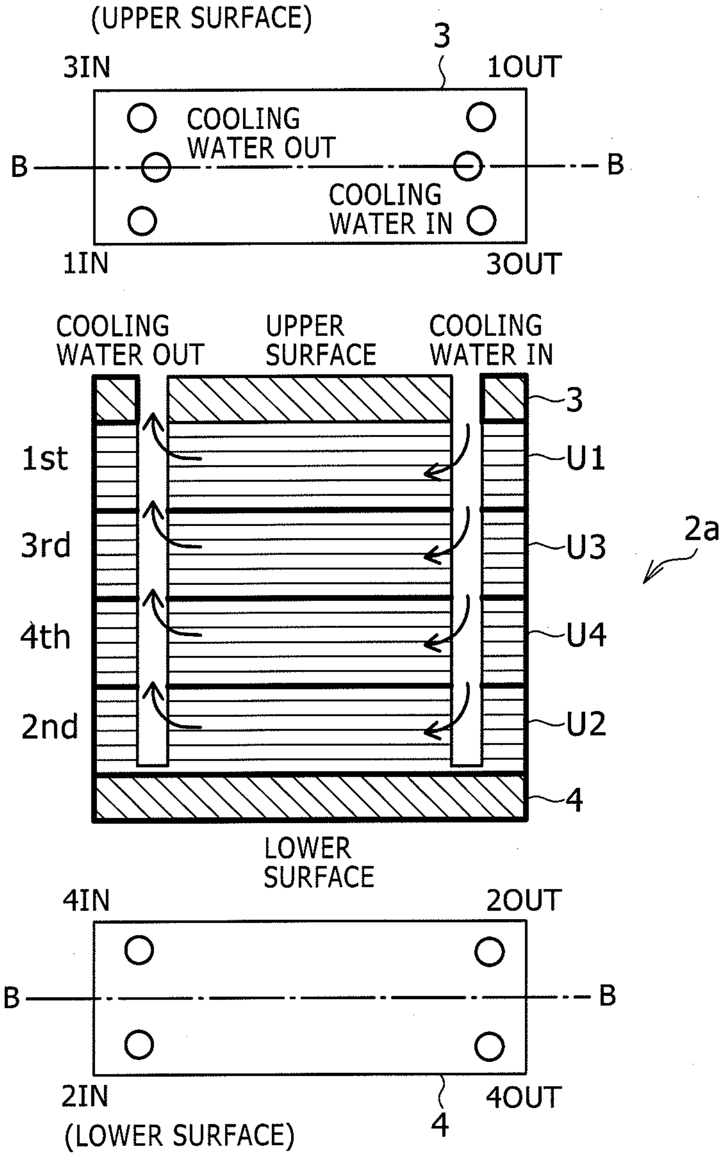
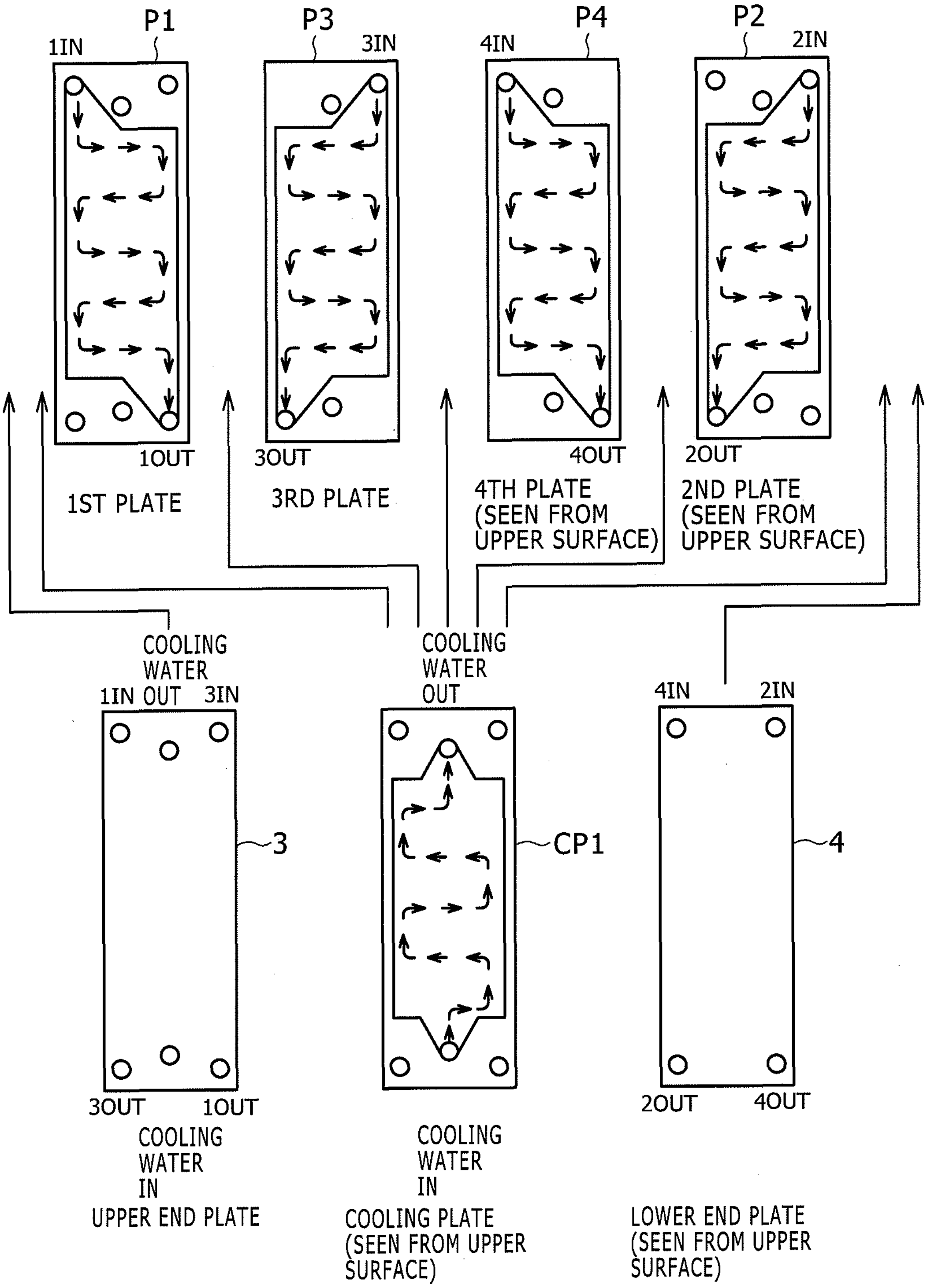
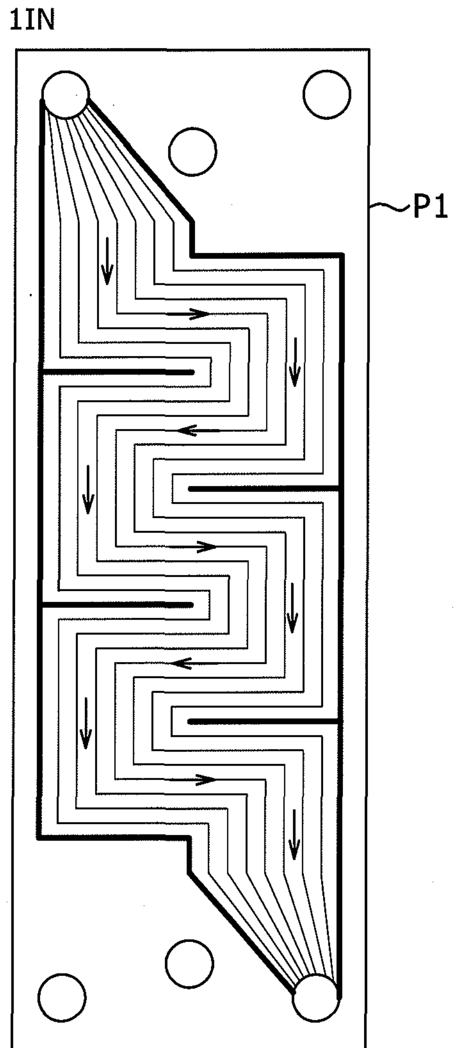


FIG.4



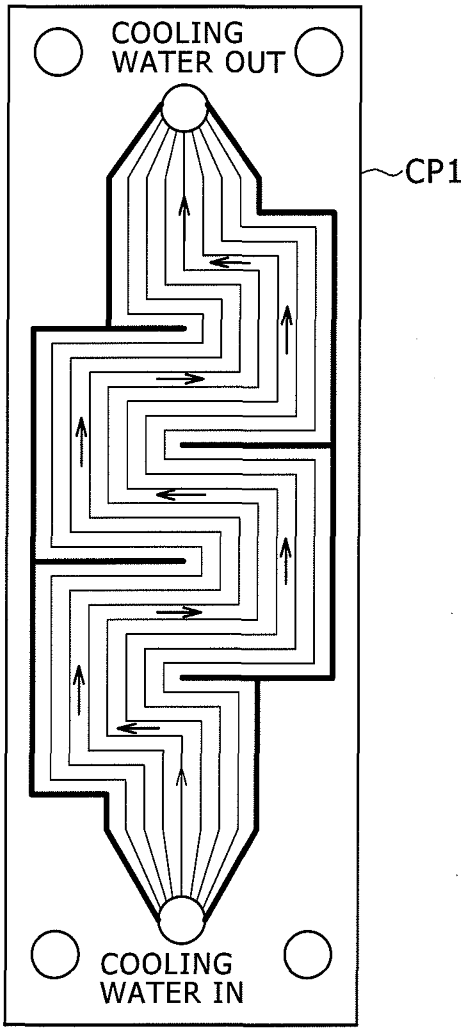
P1
1IN
1OUT
1ST PLATE
P3
3IN
3OUT
3RD PLATE
P4
4IN
4OUT
4TH PLATE
(SEEN FROM
UPPER SURFACE)
P2
2IN
2OUT
2ND PLATE
(SEEN FROM
UPPER SURFACE)
COOLING
WATER
OUT
1IN
3IN
COOLING
WATER
OUT
4IN
2IN
3
CP1
4
3OUT
1OUT
COOLING
WATER
IN
UPPER END PLATE
COOLING
WATER
IN
COOLING PLATE
(SEEN FROM UPPER
SURFACE)
2OUT
4OUT
LOWER END PLATE
(SEEN FROM UPPER
SURFACE)

FIG.5A



(FIRST FLOW PASSAGE PLATE/
1ST PLATE)

FIG.5B



(COOLING PLATE)

FIG. 6

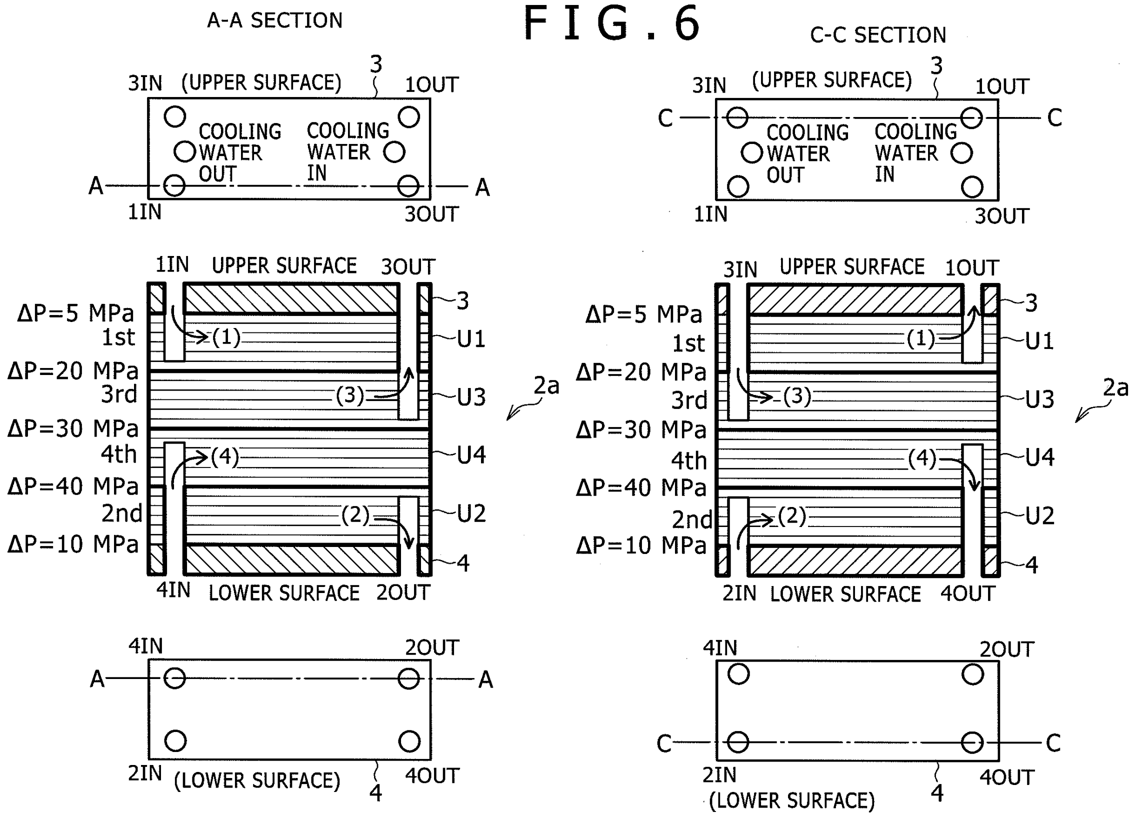

A-A SECTION
3IN (UPPER SURFACE) 3 1OUT
COOLING WATER OUT
COOLING WATER IN
A A
1IN 3OUT
1IN UPPER SURFACE 3OUT
ΔP=5 MPa 1st
ΔP=20 MPa 3rd
ΔP=30 MPa 4th
ΔP=40 MPa 2nd
ΔP=10 MPa
(1) (3) (4) (2)
3 U1 U3 U4 U2 4
2a
4IN LOWER SURFACE 2OUT
4IN 2OUT
2IN (LOWER SURFACE) 4 4OUT
C-C SECTION
3IN (UPPER SURFACE) 3 1OUT
C C
COOLING WATER OUT
COOLING WATER IN
1IN 3OUT
3IN UPPER SURFACE 1OUT
ΔP=5 MPa 1st
ΔP=20 MPa 3rd
ΔP=30 MPa 4th
ΔP=40 MPa 2nd
ΔP=10 MPa
2IN LOWER SURFACE 4OUT
4IN 2OUT
2IN (LOWER SURFACE) 4 4OUT

FIG.7

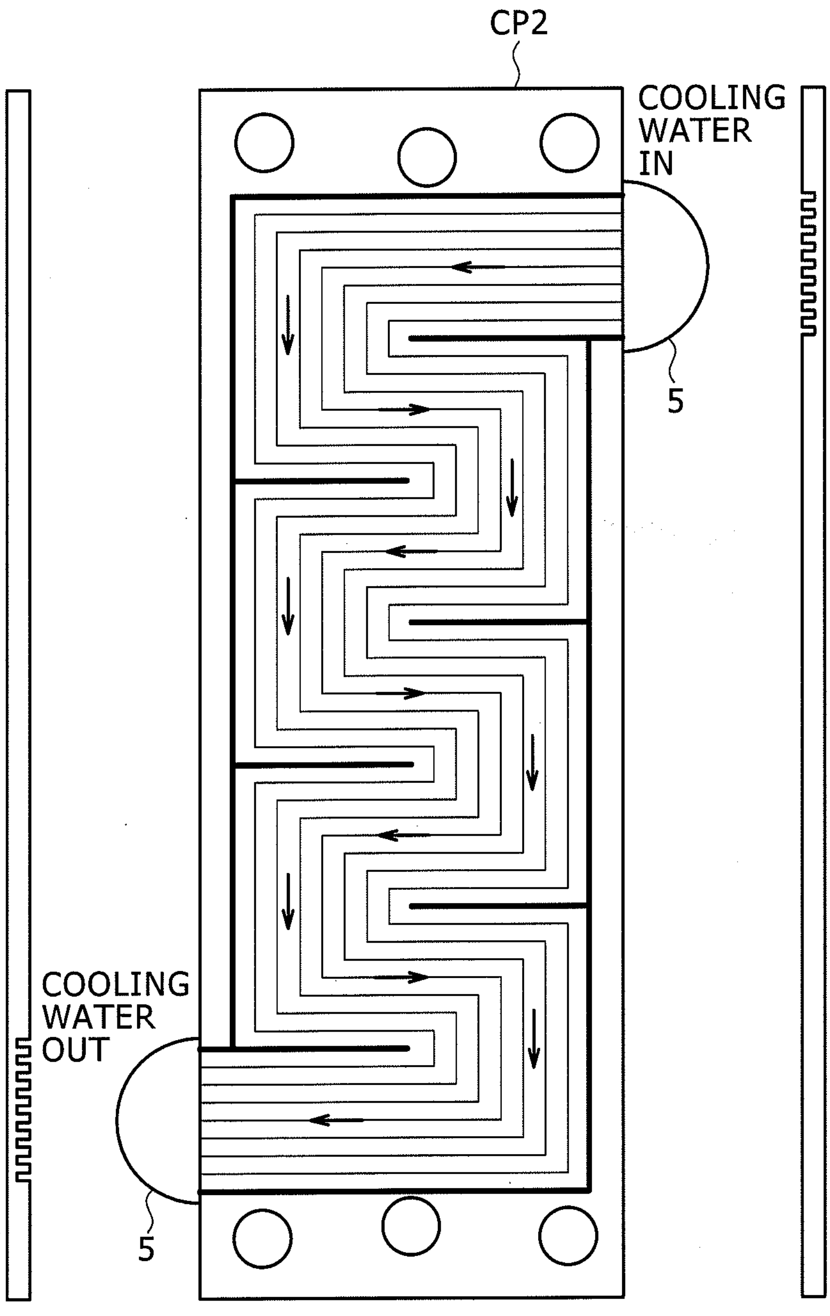


FIG. 8

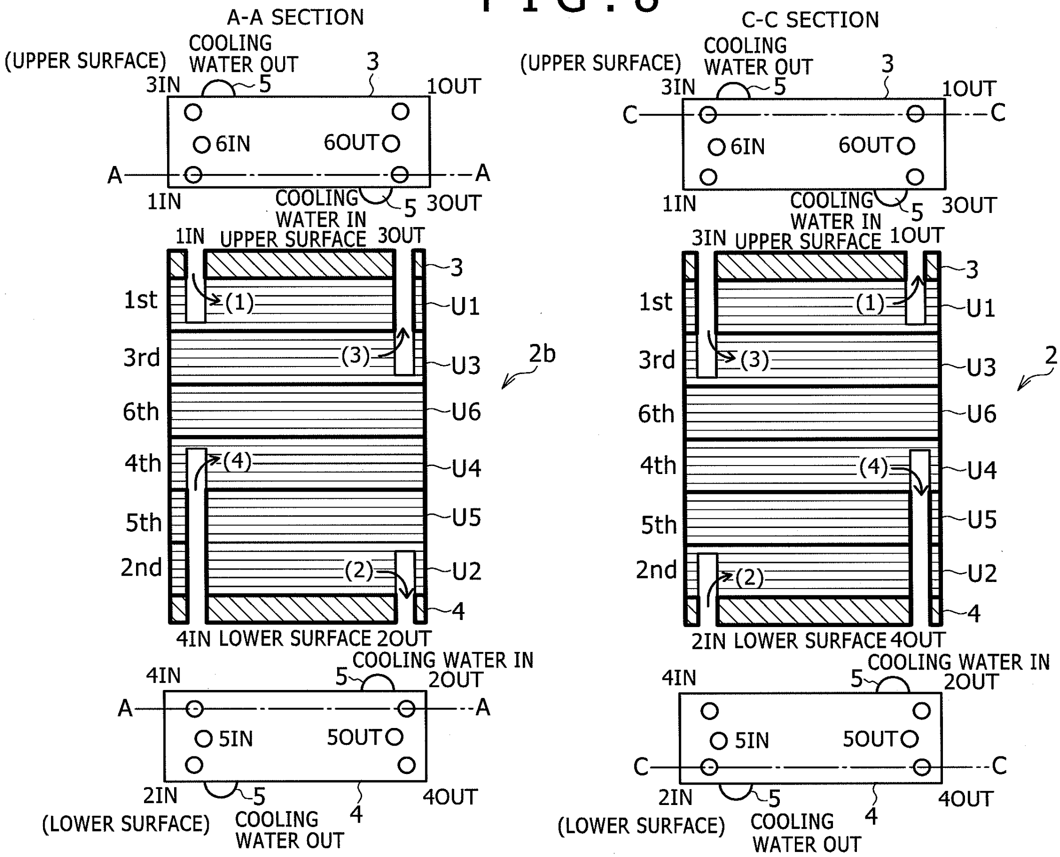
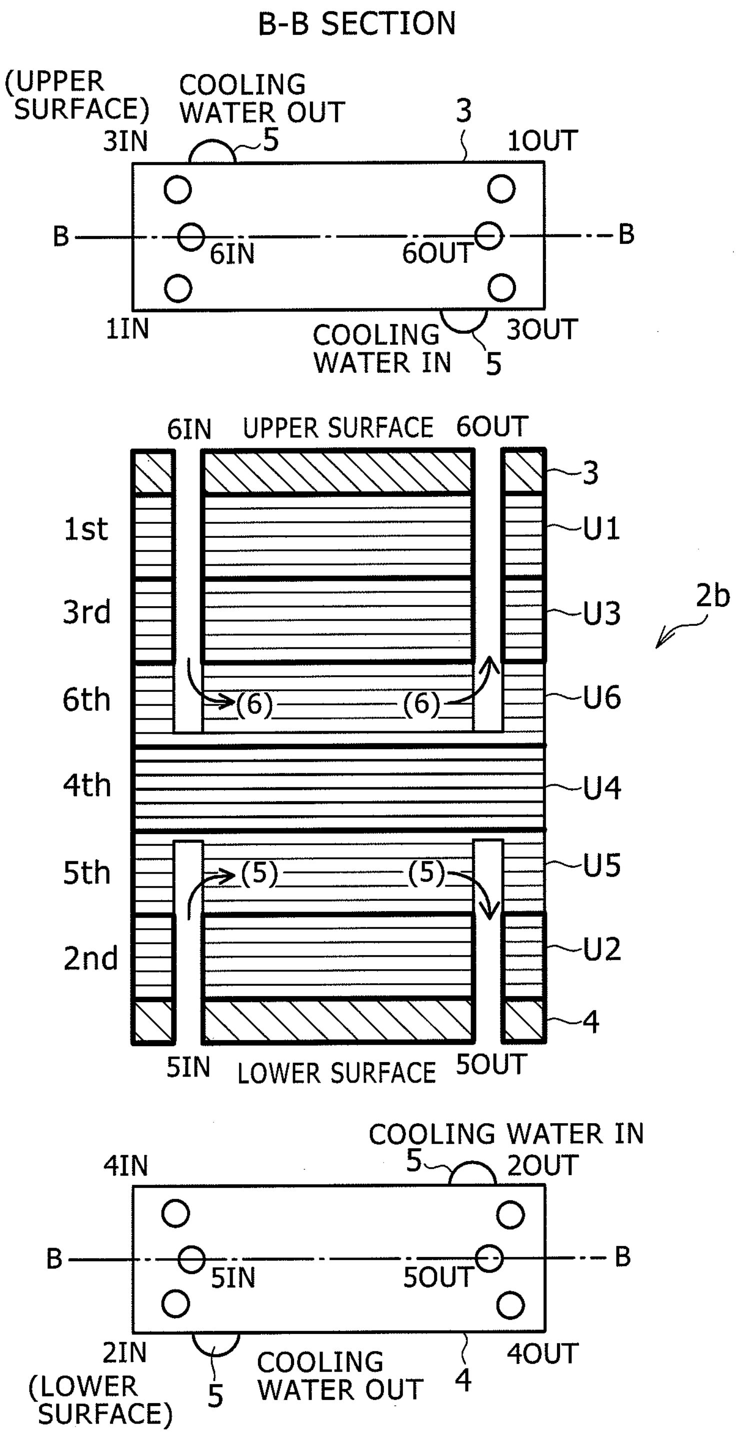

A-A SECTION
(UPPER SURFACE)
COOLING WATER OUT
3
3IN
5
1OUT
6IN
6OUT
A
A
1IN
COOLING WATER IN
5
3OUT
1IN
UPPER SURFACE
3OUT
1st
3rd
6th
4th
5th
2nd
(1)
(3)
(4)
(2)
3
U1
U3
U6
U4
U5
U2
4
2b
4IN
LOWER SURFACE
2OUT
COOLING WATER IN
4IN
5
2OUT
A
A
5IN
5OUT
2IN
5
4OUT
(LOWER SURFACE)
COOLING WATER OUT
4
C-C SECTION
(UPPER SURFACE)
COOLING WATER OUT
3
3IN
5
1OUT
C
C
6IN
6OUT
1IN
COOLING WATER IN
5
3OUT
3IN
UPPER SURFACE
1OUT
1st
3rd
6th
4th
5th
2nd
(1)
(3)
(4)
(2)
3
U1
U3
U6
U4
U5
U2
4
2b
2IN
LOWER SURFACE
4OUT
COOLING WATER IN
4IN
5
2OUT
5IN
5OUT
C
C
2IN
5
4OUT
(LOWER SURFACE)
COOLING WATER OUT
4

FIG. 9


B-B SECTION
(UPPER SURFACE)
3IN
COOLING WATER OUT
5
3
1OUT
B
6IN
6OUT
B
1IN
COOLING WATER IN
5
3OUT
6IN
UPPER SURFACE
6OUT
3
1st
U1
3rd
U3
2b
6th
(6)
(6)
U6
4th
U4
5th
(5)
(5)
U5
2nd
U2
4
5IN
LOWER SURFACE
5OUT
COOLING WATER IN
4IN
5
2OUT
B
5IN
5OUT
B
2IN
(LOWER SURFACE)
5
COOLING WATER OUT
4
4OUT

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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