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(54) HEAT EXCHANGE DEVICE

(57) A heat exchange device comprising an assembly (2). The assembly (2) comprises a stack and at least one means for fastening (11) configured to hold the assembly (2) together. The stack comprises (i) at least two first modules (3a, 3b), each comprising a first surface (16), a second surface (15) opposite the first surface, a first fluid inlet (4a, 4b) and a first fluid outlet (5a, 5b) connected by a first fluid channel interposed between the first surface and the second surface, (ii) a second module (6a, 6b) comprising a third surface (16), a fourth surface (15) opposite the third surface, a second fluid inlet (7a, 7b) and a second fluid outlet (8a, 8b) connected by a second fluid channel interposed between the third surface and the fourth surface, (iii) at least two thermoelectric elements (9a, 9b), wherein each thermoelectric element is at least partially sandwiched between one of said at least two first modules (3a, 3b) and said second module (6a, 6b). The first and second modules and the thermoelectric elements are stacked along a stacking direction, wherein one of the at least two first modules is positioned at a first end of the stack along the stacking direction and another one of the at least two first modules is positioned at a second end of the stack opposite the first end. The first surface (16) and the third surface (16) are surfaces of contact contacting with at least one of the thermoelectric elements such that a first fluid in the respective first module and a second fluid in the respective second module are in indirect contact with the respective thermoelectric element.

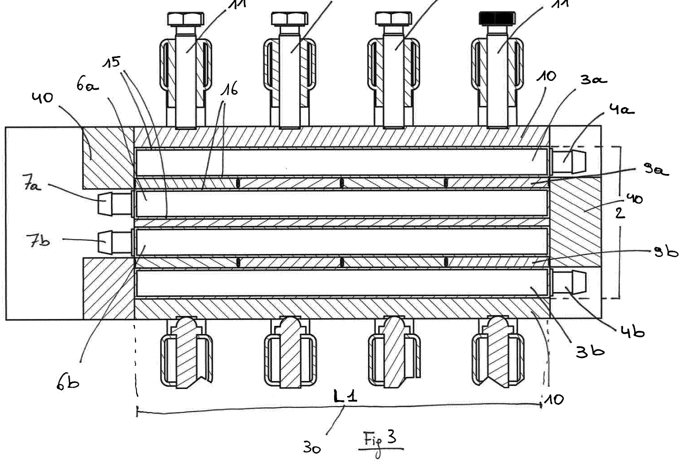

Fig 3

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Description

Technical field

[0001] The present invention relates to the field of thermoelectricity, and in particular to a heat exchange devices comprising at least one assembly and at least one means for fastening the assembly. Such heat exchange devices may be used to thermally condition a fluid comprising container.

Background art

[0002] Heat exchange devices used in the field of thermoelectricity make use of the thermoelectric effect, also known as the Peltier effect, for thermally conditioning, i.e. heating and/or cooling, a fluid comprising container. These heat exchange devices generally include thermoelectric elements disposed between fluid carriers, i.e. sandwiched, to enable heat transfer between the fluids contained in the fluid carriers. Indeed, the thermoelectric elements consist in conductors or semiconductors connected electrically in series and thermally in parallel together to pump heat from one fluid to another. Typically, a thermoelectric module is constructed of N-type and P-type semiconductor material electrically connected in series. When an electric current is passed through the circuit, heat is absorbed at the cold junction of the circuit and is transferred to the hot Junction of the circuit. By associating the hot and cold Junctions with the fluid carriers, e.g. liquid heat exchanger blocks known in the prior art, heat can be transferred from one flow stream to another. Typically, the fluid carrier is filled with either gas or liquid media, thereby resulting in a heating of one media and the cooling of the other media.

[0003] Historically, practical applications of thermoelectric cooling and heating using heat exchange devices have been primarily limited to small scale specialized uses because of high cost and low energy efficiency. In the last 30 to 40 years, applications of thermoelectric modules have been developed to utilize them in large scale projects such as cooling on marine vessels and passenger trains. However, the heat exchange devices known in the prior art generally exhibit still some drawbacks concerning a reduced energy efficiency over the life-time of the heat exchange device, and high assembly costs due to the use of expensive materials and bulky construction schemes.

[0004] From EP 0338283 a heat exchange device is known comprising a stack of thermoelectric elements alternating with fluid carriers. An alternative arrangement is described in WO 2004/054007, in which the thermoelectric elements are juxtaposed to form a strip and sandwiched between two fluid carriers. In both cases, the fluid carriers have openings to respectively the hot face and the cold face of the thermoelectric elements so that the fluid is in direct contact with the respective face of the thermoelectric element in order to eliminate interfacial resistance between a metal surface of the fluid carriers and the ceramic plates of the thermoelectric elements. The fluid carriers are mostly made from a flexible material, such as for example plastic, rubber, silicone or a polymer to facilitate sealing, or if made of metal, gaskets must be provided. One drawback of such devices is that it may be difficult or cumbersome to obtain a good leak-proof sealing between the thermoelectric elements and fluid carriers, or when the fluid carriers are made from flexible materials, to obtain a sufficiently robust design.

[0005] In particular, it has been observed that in the long term, warping of the thermoelectric elements may occur due to the temperature gradient over the thin thermoelectric element, and the devices may start leaking. Furthermore, it will be required to provide fluid sealing about every thermoelectric element separately, so that a portion of the surface area of the faces of the elements are not available for heat transfer.

Summary of the invention

[0006] It is therefore an object of the invention to provide heat exchange devices which are less complex and easier to assemble, resulting in more economical devices. It is an object of the invention to provide heat exchange devices which are more reliable and have longer lifetime.

[0007] It is an object of the invention to provide heat exchange devices with an improved energy efficiency.

[0008] According to aspects of the present invention, there is provided a heat exchange device as set out in the appended claim 1. Advantageous aspects are set out in the dependent claims.

[0009] According to one aspect, the heat exchange device comprises at least one assembly comprising a stack and at least one means for fastening configured to hold the assembly together. The stack comprises at least two first modules, at least one second module and at least two thermoelectric elements. Each of the first modules comprises a first surface, a second surface opposite the first surface, a first fluid inlet and a first fluid outlet connected by a first fluid channel interposed between the first surface and the second surface. The first fluid channel defines a first fluid flow path advantageously defining a first fluid flow direction. Each of the second modules comprises a third surface, a fourth surface opposite the third surface, a second fluid inlet and a second fluid outlet connected by a second fluid channel interposed between the third surface and the fourth surface. The second fluid channel defines a second fluid flow path advantageously defining a second fluid flow direction at least substantially parallel to said first fluid flow direction. Each thermoelectric element is at least partially sandwiched between one of said at least two first modules and one of said at least one second module. Advantageously, the stack comprises a plurality of second modules, and, may comprise a plurality of further first modules. The second modules and the further first modules are advantageously arranged in pairs in the stack, in a back-to-back configuration, i.e. with the respective surfaces of contact facing away from each other. The pairs of second modules and of (further) first modules alternate in the stack. Advantageously, arrays of thermoelectric elements are interposed between the alternating pairs.

[0010] Heat exchange devices according to the above aspects enable a very simple assembly of the stack. There are no problems due to possible fluid leakage because the first and second modules are formed as closed vessels, except for the fluid inlets and outlets. Therefore, special seals between the fluid channels and the thermoelectric elements can be omitted.

[0011] Advantageously, the first fluid outlet of one of the first modules is connected to the first fluid inlet of another one (e.g., successive) of the first modules in the stack such that the first modules are fluidly connected in series. Likewise, the second fluid outlet of one second module can be connected to the second fluid inlet of another (e.g., successive) second module in the stack. A series fluid connection of the first modules and/or of the second modules facilitates obtaining a turbulent flow regime in the fluid channels of the respective first and second modules, since all the channels receive the entire fluid flow rate. This is in contrast to parallel arrangements, where the total flow rate is divided amongst the various modules (i.e. each module only receives part of the total flow rate). It is known that a turbulent flow regime improves heat transfer between the solid wall and the fluid.

[0012] According to an advantageous aspect, the thermoelectric elements are arranged in a plurality of arrays of thermoelectric elements, wherein the thermoelectric elements in each array contact with the first surface of an adjacent one of the first modules. Advantageously, a plurality of the means for fastening are positioned in correspondence of each of the thermoelectric elements in the array. The fastening means may for example comprise braces which frame the stack along at least part of its perimeter. The means for fastening may comprise tightening means such as though not limited to bolts, clamps and springs, which interface between the stack and the brace to hold the stack together. A brace is advantageously positioned in correspondence of each thermoelectric element in the array. One advantage of the above fastening configuration is that clamping force can be adjusted for each thermoelectric element of an array separately. This allows for obtaining optimal contact between the surfaces of contact and the corresponding thermoelectric elements. Therefore, errors of planarity in the thermoelectric elements or in the surfaces of the modules and which would deteriorate thermal transfer, are compensated.

[0013] A heat exchange device is described herein, comprising:

a. at least one assembly, wherein said at least one assembly comprises a stack of at least two first modules adapted to carry a first fluid, wherein said first module comprises a first fluid flow path, wherein said first fluid flow path defines a first fluid flow direction,
ii. at least one second module adapted to carry a second fluid, wherein said second module comprises a second fluid flow path, wherein said second fluid flow path defines a second fluid flow direction at least substantially parallel to said first fluid flow direction,
iii. at least two thermoelectric elements, wherein each thermoelectric element is at least partially sandwiched between said first module and said second module,
stacked along a stacking direction, wherein said at least one assembly is defined by two outer modules, wherein said two outer modules are said first modules,
b. at least one means for fastening, said means for fastening configured to hold the assembly together.

[0014] Advantageously, embodiments of the present invention provide heat exchange devices with better and/or improved cold-bridging properties and less bulky, e.g. compact, construction schemes.

[0015] It is an advantage of embodiments of the present invention that back-to-back heat exchanging devices are provided which are compact and achieve optimal operation and increased efficiency of the thermoelectric means and therefore the efficiency of the heating (exchange) and cooling system in general.

[0016] It is an advantage of embodiments of the present invention that by enabling the fluid flow directions of the both first and second modules to be at least substantially parallel with respect to each other, this parallel flow in both modules provides a more energy efficient heat exchanging device since the temperature difference between the first and second fluid in contact with the thermoelectric elements may be more constant as compared to other set ups known in the art.

[0017] In preferred embodiments the at least substantially parallel first and second fluid flow path comprise a counter-flow direction with respect to each other, preferably a parallel counterflow direction.

[0018] It is an advantage of embodiments of the present invention that the counter-flow further improves the heat exchange hence the efficiency of the heat exchanging device of the present invention.

[0019] In preferred embodiments the at least one thermoelectric element is provided as a layer, wherein said layer is a continuous layer, a row of a plurality of thermoelectric elements or an array of thermoelectric elements.

[0020] It is an advantage of embodiments of the present invention that the contact area between the thermoelectric element and fluid can be maximized having the advantage that during its flow through the fluid flow path, heat exchange with the other fluid takes place almost on a continuous basis. Hence, the fluid can be substantially cooled/heated without the need to pass several times through the module. Therefore embodiments of the present invention provide energy efficient heat exchanging devices.

[0021] In preferred embodiments the plurality of thermoelectric elements provided in a row or array are positioned such that the thermoelectric elements are adjacent or joining each other.

[0022] In preferred embodiments the at least second module may comprise: a pair of second modules, or a plurality of modules comprising alternating pairs of second modules, and pairs of first modules, defining inner modules, and wherein the inner modules are sandwiched in between the two outer first modules such that the outer first modules is paired with a second module of the inner modules.

[0023] In preferred embodiments the at least one means for fastening is adapted to frame said assembly along at least a part of its outer perimeter.

[0024] It is an advantage of embodiments of the present invention that said at least one means for fastening frames at least a part of the assembly and is not provided throughout the assembly enabling heat loss or a less efficient transport of fluid.

[0025] It is advantage of embodiments of the present invention that there is a lower probability for the presence of cold bridges and for thermal leaks. In addition there is no need to penetrate the assembly or thermoelectric element or for making the thermoelectric elements smaller in size e.g. such to avoid bolts though the assembly.

[0026] It is an advantage of embodiments wherein a row or array of a plurality of thermoelectric elements are used, one can position them close to each other as this Is enabled by not having a need to use a bolt as fastening means for the system.

[0027] In preferred embodiments the at least one means for fastening is a closed object defining an opening, said opening suitable for receiving the assembly and framing the assembly.

[0028] It is an advantage of embodiments of the present invention that said closed means for fastening, after having received the assembly, has room or at least one void to receive additional materials such as insulation material or other materials which are provided in between the fastening means and the stack enabling one to further hold the stack.

[0029] In preferred embodiments of the present invention the closed object's plane is substantially perpendicular to a major surface of the outer module.

[0030] In preferred embodiments a heat exchange device according to the present invention further comprises insulating material, preferably thermally and/or electrically insulating material, disposed between at least a part of said assembly and the at least one means for fastening.

[0031] It is an advantage of embodiments of the present invention that the thermally and/or electrically insulating material provides minimizes heat exchange of the assembly with the environment.

[0032] It is an advantage of embodiments of the present invention that by enabling the easy provision of thermally and/or electrically insulating material in the assembly, one provides insulation for e.g. cold modules of the stack improving the heat exchange properties of the assembly.

[0033] It is an advantage that more energy efficient heat exchanging devices are enabled since the amount of heat exchange with the environment is limited, and there is lower probability that condensation is formed improving the lifetime of device.

[0034] In preferred embodiments the thermally and/or electrically insulating material is provided substantially perpendicular with respect to a major surface of the outer module.

[0035] In further preferred embodiments the thermally and/or electrically insulating material surrounds at least part of the assembly.

[0036] In preferred embodiments of the present invention the at least one means for fastening is disposed per column of the thermoelectric elements 9a, 9b, wherein the thermoelectric element is provided as a layer comprising a row of thermoelectric elements, which are preferably adjacent to each other.

[0037] It is an advantage of embodiments of the present invention improved contact between fluid and thermoelectric element is enabled and less materials have to be used. It is an advantage that force through the fastening means can be provided on each thermoelectric element of the row or array separately.

[0038] In preferred embodiments the heat exchange device of the present invention may comprise a plurality of assemblies according to embodiments of the present invention, wherein the plurality of assemblies are arranged in parallel.

[0039] In a second aspect the present invention provides means for fasting a stack of modules and thermoelectric elements wherein the stack is defined by two outer modules, like for example but limited to the stack according to the first aspect of the present invention, said means for fastening comprising:

- at least one means for clamping adapted to generate a clamping force on at least a part of said assembly, wherein the at least one means for clamping is made of or comprises thermally and/or electrically insulating material and contacts the outer modules of the assembly.

[0040] It is an advantage of embodiments of the present invention that bolts which are provided throughout an assembly in the state of the art and which generate heat loss, are avoided. In further embodiments the at least means for clamping may be a C-clamp with enlarged gripping surfaces providing a more distributed clamping force on the assembly.

[0041] In a third aspect the present invention provides means for fasting a stack of modules and thermoelectric elements wherein the stack is defined by two outer modules, like for example but limited to the stack according to the first aspect of the present invention, said means for fastening comprising:

- a means for clamping, said at least one means for clamping adapted to generate a clamping force on said assembly;
- at least one means for transferring, said at least one means for transferring provided on at least a part of a major outer surface of the outer module such that the at least one means for transferring Is configured to at least transfer said clamping force on said assembly at least along the stacking direction.

[0042] It is an advantage of embodiments of the present invention that a compact heat exchange device may be provided which may be easily amended in function of the desired application.

[0043] In addition, embodiments of the present invention advantageously enable one to adjusted the means fastening means based on the amount of elements of which the assembly consists and the required clamping force to be exerted on the assembly.

[0044] It is an advantage of embodiments of the present invention is that the means for transferring is adapted to provide a properly distributed compression force on the at least one thermoelectric element without introducing too much sideways or other forces or moments.

[0045] It is an advantage of embodiments of the present invention that the at least one means for transferring said clamping force is configured to grip the assembly.

[0046] It is an advantage of embodiments of the present invention that the at least one means for transferring said clamping force is configured to break a thermal bridge which otherwise would be formed when directly contacting the at least one means for clamping with the assembly.

[0047] It is an advantage of embodiments of the present invention that the means for fastening can be made of one piece or an assembly of elements. In preferred embodiments the means for transferring is provided between the clamping means and the outer major surface of the stack.

[0048] It is an advantage of embodiments of the present invention that the fastening means are designed to develop a clamping force which is adequate to assure a good contact between the heat exchange module and the thermoelectric modules in a large range of changes in operating conditions in order to reduce thermal resistance.

[0049] In preferred embodiments the means for clamping and the means for transferring of the fastening means are provided as one element.

[0050] In preferred embodiments the at least one means for clamping or at least one means for fastening frames the assembly along and/or encloses the assembly along at least a part of its outer perimeter.

[0051] It is an advantage of embodiments of the present invention that the at least one means for clamping is a C-shaped clamping means or a circumferential clamping means, e.g. wherein the clamping means surrounds the assembly, and has a width which is equal to or smaller than the length of the stack. In embodiments where a C-shaped clamping or a circumferential clamping means are provided, the clamping means surrounds the stack and preferably indirectly connects to the stack via the transferring means using connecting means.

[0052] In preferred embodiments the means for clamping is selected from the group consisting of C-shaped objects, angular-shaped objects, rectangular-shaped objects, round-shaped objects, oval-shaped objects, ellipse-shaped objects, circle-shaped objects or stadium-shaped objects defining an opening adapted to receive the assembly.

[0053] In preferred embodiments the means for clamping or means for fastening is a closed object defining an opening adapted to receive and enclose the assembly entirely.

[0054] In preferred embodiments the means for clamping may be a closed object defining an opening or may be an open object defining an opening, like e.g. a C-clamp, and closed by the connecting means resulting in a closed means for fastening. Once the means for clamping is closed by for example the means for connecting, by e.g. using securing means, a clamping force is generated in the assembly, which is transferred via the means for transferring.

[0055] In preferred embodiments the fastening means preferably frames the assembly, at least partially or completely, and there is a void present between the fastening means and the assembly, after the assembly has been positioned in the opening of the closed object along its length direction.

[0056] In preferred embodiments the fastening means further may comprise means for connecting wherein said means for connecting are adapted to directly or indirectly connect the at least one means for fastening to the stack.

[0057] In preferred embodiments the means for transferring may be a C-shaped object, wherein said C-shaped object is adapted to grip along of fit with the width of the major surface of the stack and part of an edge of the stack.

[0058] In preferred embodiments the means for transferring is a mass element, preferably a block, disposed on at least 90%, preferably 95%, more preferably 100%, of the area of said at least one outer major surface of said outer module.

[0059] According to a fourth aspect, the invention provides the use of heat exchange devices according embodiments of the present invention for thermally conditioning a fluid comprising room or container, further comprising a first fluid supply and a first fluid drainage, wherein said first fluid supply and said first fluid drainage are fluidly connected to said fluid comprising room or container.

[0060] According to a fifth aspect, the present invention provides methods for producing or assembling a heat exchange device according to embodiments of the present invention comprising the steps of providing at least one assembly and at least a fastening means according to embodiments of the present invention.

Brief description of the figures

[0061] Aspects of the invention will now be described in more detail with reference to the appended drawings, wherein same reference numerals illustrate same or analogous features.

FIG. 1 is a schematic isometric view of a heat exchange device, comprising a plurality of fastening means, e.g. four, according to a preferred embodiment of the invention.
FIG. 2 is a schematic front view of the preferred embodiment depicted in FIG. 1.
FIG. 3 is a schematic side view of the preferred embodiment depicted in FIG. 1.
FIG. 4 is a schematic isometric view of a preferred embodiment according to the invention, comprising insulating material.
FIG. 5 is a schematic front view of the preferred embodiment depicted in FIG. 4.
FIG. 6 Is a schematic isometric view of a preferred embodiment according to the invention, comprising a combination of three stacks, as depicted in FIG. 1, stacked on each other.
FIG. 7 is a schematic isometric view of a preferred embodiment depicted in FIG.6, comprising insulating material.
FIG. 8 is a schematic perspective view of a heat exchange device according to an alternative preferred embodiment of the invention comprising an assembly and at least one (e.g. four) means for fastening.
FIG. 9 is a schematic front view of a heat exchange device as illustrated in FIG 8.
FIG. 10 is a schematic cross-section along sectional line 1-1 of a heat exchange device as illustrated in FIG. 8.

Description of embodiments

[0062] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0063] Where in embodiments of the present invention reference is made to sandwiched, reference may be made to placed between or disposed between.

[0064] Where in embodiments of the present invention reference is made to "circumferential", reference may be made to of, at, or near the circumference or at the outskirt or surrounding, directly or indirectly contacting each other.

[0065] Where in embodiments of the present invention reference is made to "outer modules", reference may be made to modules limiting the assembly.

[0066] In embodiments reference is made to a first and second module, however these are interchangeable and may refer to a module supporting a hot fluid or a module supporting a cold fluid. As a result the modules itself may be physically the same but are configured to be used differently.

[0067] FIGS. 1 to 10 demonstrate a heat exchange device according to particular embodiments of the present invention. Such heat exchange devices may typically be used for thermally conditioning, i.e. cooling and/or heating, a fluid, e.g. air, water, comprised in a room or container (not demonstrated on the figures), both in the domestic and/or industrial field. A first module 3a, 3b, is adapted to carry a first fluid and a second module 6a, 6b, is adapted to carry a second fluid, although the first fluid and/or second fluid may be a gas or a liquid. Where in embodiments of the present invention reference is made to "fluid", reference may be made to a "gas", a "liquid", a combination of a "gas" and a "liquid", or a supercritical fluid. Preferably, the present invention may be used as a liquid-to-liquid heat exchange devices, and more preferably back-to-back liquid-to-liquid heat exchange devices, wherein the first fluid and the second fluid are liquids. In the further description examples are provided for liquid-to-liquid systems, however the invention is not limited thereto and principles provided may be used to construct liquid-to-gas or gas-to-gas heat exchange devices.

[0068] According to preferred embodiments of the invention, a first fluid may refer to at least a first fluid, wherein said at least first fluid may be supported by at least one first circuit connected to at least one first module. The first circuits may be separated or connected.

[0069] According to preferred embodiments of the invention, a second fluid may refer to at least a second fluid, wherein said at least second fluid may be supported by at least one second circuit connected to at least one second module. The second circuits may be separated or connected.

[0070] Referring to FIG. 1, a heat exchange device according to a preferred embodiment of the invention comprises an assembly 2 and means for fastening the assembly 2, wherein "means for fastening" may be referred to as "means for holding" the assembly together. The assembly 2 comprises a stack of (i) at least two first modules 3a, 3b, adapted to carry a first fluid, wherein said first module 3a, 3b, comprises a first fluid flow path, wherein said first fluid flow path defines a first fluid flow direction, (ii) at least one second module 6a, 6b, adapted to carry a second fluid, wherein said second module comprises a second fluid flow path, wherein said second fluid flow path defines a second fluid flow direction at least substantially parallel to said first fluid flow direction, and (iii) at least two thermoelectric elements 9a, 9b, wherein each thermoelectric element is at least partially sandwiched between said first module 3a, 3b, and said second module 6a, 6b.

[0071] The aforementioned elements of the stack are stacked along a stacking direction, wherein said assembly 2 is defined by two outer modules, wherein said two outer modules are said first modules 3a, 3b.

[0072] According to preferred embodiments of the invention, the at least one thermoelectric element 9a, 9b, is provided as a layer sandwiched between the first and second modules, more specifically between the thermoelectric element contacting surfaces 16 of a first 3a, 3b, and a second 6a, 6b, module. Said layer may be a continuous layer, a row of a plurality of thermoelectric elements or an array of thermoelectric elements. A continuous layer may refer to a layer substantially spanning over the length and width of the thermoelectric element contacting surface 16 preferably without defining cavities or openings in the volume defined by the thermoelectric element contacting surfaces 16 of two neighbouring first and second modules. In embodiment where a row of a plurality of thermoelectric elements and/or an array of thermoelectric elements are provided, they may define openings or cavities between neighbouring or adjacent thermoelectric elements 9 however these openings or cavities are such that no heat leaks are present. Preferably the neighbouring or adjacent thermoelectric elements of the row or array are adjoining. When sandwiched between a first module 3a, 3b, and a second module 6a, 6b, the layer of thermoelectric elements may cover between 80% to 120%, preferably between 90% and 110%, more preferably between 95% and 105% of the surface of the first 3a, 3b, and second 6a, 6b, module.

[0073] Preferably, the heat exchange device depicted in FIG. 1 comprises an assembly 2 comprising two first modules 3 a, 3 b, for carrying a first fluid, preferably a first liquid. These first modules 3a, 3b, are stacked in the assembly 2 as outer modules of the assembly 2, indicating that the two first modules 3a, 3b, limit the assembly 2 in the stacking direction. Modules interposed between the outer modules in the stack may be referred to as "inner modules". Preferably, where outer modules are first modules, the inner modules may be selected from the group consisting of a single second module 6a, 6b, a pair of second modules 6a, 6b, or a plurality comprising alternating pairs of second modules 6a, 6b, and pairs of first modules 3a, 3b. The number Z of pairs of second modules 6a, 6b, in relation with the number Y of pairs of first modules 3a,3b, is Y=Z- 1, wherein Z is an integer equal to or at least larger than 1.

[0074] In further embodiments according to the invention, the outer modules may have a shape which is not stackable at one side with respect to the other modules, like for example a module comprising a comb shape, whereby the teeth of the comb are provided on the outer side of the assembly.

[0075] According to a specific embodiment of the invention, the first modules 3a, 3b, are configured for carrying a first fluid, preferably a first liquid, and may comprise a first fluid flow passage, such as a channel or fluid chamber, connecting a first inlet 4a, 4b, and a first outlet 5a, 5b, disposed on at least one first side of the first module 3a, 3b, preferably on the same first side of the first module 3a, 3b. The first fluid flow path defines a first fluid flow direction indicating the flow direction of a first fluid when the heat exchange device is in use. The fluid passage advantageously has a cross-section with closed circumference.

[0076] The second modules 6a, 6b, are configured for carrying a second fluid, preferably a second liquid, and may comprise a second fluid flow passage, such as a channel or fluid chamber, connecting a second inlet 7a, 7b, and a second outlet 8a, 8b, disposed on at least one second side of the second module 6a, 6b, preferably on the same second side of the second module 6a, 6b. The second fluid flow path defines a second fluid flow direction indicating the flow direction of a second fluid when the heat exchange device is in use. In a particular embodiment of the invention, the number of inlets and outlets is not limited to the aforementioned number.

[0077] According to a preferred embodiment of the invention, at least a part of the at least two first modules 3a, 3b, are fluidly connected, preferably in series. At least a part of the at least one second modules 6a, 6b, are fluidly connected, preferably in series.

[0078] According to a preferred embodiment of the invention, the first fluid flow direction and the second fluid flow direction are substantially parallel, wherein "parallel" refers to the parallel flow and/or counter-flow directions of the first fluid with respect to the second fluid, assuming an average laminar flow of the fluids and neglecting any turbulence effects. The flow direction may preferably be determined for at least a substantial part of the fluid wherein the direction of the average flow velocity may be defined when the first and second fluid are in direct/indirect contact with the thermoelectric elements 9a, 9b.

[0079] Preferably, the thermoelectric elements may be of the type readily available in the industry, for example Peltier elements. Such elements may be a thermoelectric couple which comprises an n-type element and p-type element. Multiple of these couples are assembled electrically in series and thermally in parallel. The multiple couples are sandwiched between two flat plates, referred to as substrates, forming the outer faces of the thermoelectric element, and which are intended to be electrically insulating and thermally conducting. The n-type and p-type elements are typically constructed respectively from semiconductor material, such as n-type bismuth telluride and p-type bismuth telluride. The thermoelectric elements 9a, 9b, are connected to at least one electric power supply 14.

[0080] Each one of the first modules 3a, 3b and the second modules 6a, 6b comprise a surface of contact 16 configured to interface with the substrate (hot face or cold face) of the thermoelectric elements 9a, 9b. Surface of contact 16 is referred to as a thermoelectric element contacting surface. At a face opposite the surface of contact, each first and second module comprises a second surface 15. The surfaces 15 and 16 are advantageously solid, i.e. material, surfaces, formed by layers of the respective module which close the internal fluid passage in correspondence of the surfaces 15 and 16. As a result, the sealing for the fluid is provided internal to each of the first and second modules and no sealing is required between the modules and the thermoelectric elements, which eases assembly.

[0081] One advantage of the above configurations, is that the stack may be formed with standard off-the-shelf components, including standard first and second modules, which may be commercially available heat exchange modules, and standard off-the-shelf thermoelectric elements. This makes heat exchange devices according to aspects described herein more economical and less labour-intensive.

[0082] The fluid passages internal in the first and second modules are interposed between the surfaces 15 and 16. The fluid passage within a module may comprise partition walls subdividing the fluid passage in a plurality of advantageously parallel channels extending between the inlet and the outlet. The partition walls may act as fins improving heat transfer between the casing material of the module and the fluid flowing through it. Alternatively, or in addition, other types of projections extending in the fluid passage may act as heat fins.

[0083] Advantageously, a turbulent fluid flow through the fluid passages of the various modules is sustained. Turbulent flow can be obtained through appropriate geometry of the fluid passage in combination with maintaining an appropriate flow rate. Heat exchange devices according to aspects described herein advantageously comprise one or more fluid pumps connected to the fluid inlets and/or fluid outlets of the modules. In particular, each circuit of the first modules and of the second modules may have its proper fluid pump. The fluid pump is configured to sustain a flow rate of the respective fluid such that a turbulent flow in the flow passages of the connected modules is obtained. It is advantageous to provide series connections between the first modules on the one hand and between the second modules on the other. With a series connection, the outlet of a module is connected to the inlet of a successive module, so that each module receives the same fluid serially, and hence a same flow rate. This ensures that the fluid flow will be turbulent in all modules, which eliminates the need of providing special manifolds.

[0084] According to an aspect of the invention, at least one thermoelectric element 9a, 9b, may be sandwiched between at least a part of the thermoelectric contacting surface 16 and/or opposite surface 15 of a first module 3a, 3b, and at least a part of the thermoelectric contacting surface 16 and/or opposite surface 15 of a second module 6a, 6b. According to this particular configuration, a first fluid, preferably liquid, contained in a first module may be in indirect contact with one surface of the thermoelectric element 9a, 9b, whereas a second fluid, preferably liquid, contained in a second module may be in indirect contact with another surface of the thermoelectric 9a, 9b, opposed to the one surface, for exchanging heat between the first fluid and the second fluid (i.e. "dry system").

[0085] Advantageously, in the "dry system", the first 3a, 3b, and/or second 6a, 6b, modules may comprise or may be made of a material comprising a thermally conductive solid material, such as a thermally conductive metal e.g. aluminium or copper. The layers forming surfaces 15 and 16 are advantageously made of the above material. The first inlet 4a, 4b and the first outlet 5a, 5b, are preferably constructed of the same thermally conductive material as the construction material of the first module 3a, 3b, such as e.g. aluminium or copper, and are shaped to be connected with a hose or circuit to enable the supply (via the first inlet 4a, 4b) or disposal (via the first outlet 5a, 5b) of the first fluid, preferably liquid. Preferably, the second inlet 7a, 7b and the second outlet 8a, 8b, are preferably constructed of the same thermally conductive material as the construction material of the second module 6a, 6b, such as e.g. aluminium or copper, and arc shaped to be connected with a hose or circuit to enable the supply (via the second inlet 7a, 7b) or disposal (via the second outlet 8a, 8b) of the second fluid, preferably liquid.

[0086] The thermoelectric contacting surface 16 may be suitably processed, e.g. milled, for optimizing the arrangement of thermoelectric elements 9a, 9b, on the surface 16.

[0087] Thermoelectric elements 9a, 9b, may also be arranged on the opposite surface 15. However, the opposite surface 15 may or may not be processed for arranging thermoelectric elements on it since it is merely used to connect with other first and/or second modules. A first plurality of at least one spacer 12 may be sandwiched between the opposite surfaces 15 of first modules, and/or between opposite surfaces 15 of second modules. The spacer 12 comprises or may be composed of at least one synthetic material for distributing the force and decreasing the possibility that the modules 3a, 3b, 6a, 6b, start to wring and turn. The spacer 12 is advantageously made of a resilient and flexible material, such as an elastomeric material. The at least one spacer 12 may provide an improved stability of the assembly 2 and may reduce the chance that the modules 3a, 3b, 6a, 6b, start to slide in a plane parallel to the major outer surfaces of the assembly 2 due to mechanical and thermodynamic stress in the assembly 2. The surfaces 16, 15, of a same first module 3a, 3b, may be separated by first sides. The surfaces 16, 15 and first sides of a first module 3a, 3b, define a container for a first fluid, preferably liquid. Preferably, the first inlet 4a, 4b, and first outlet 5a, 5b, may be disposed on a same first side of the first module 3a, 3b. The surfaces 16, 15, of a same second module 6a, 6b, may be separated by second sides. The surfaces 16, 15 and second sides of a second module 6a, 6b, define a container for a second fluid, preferably liquid. Preferably, the second inlet 7a, 7b, and second outlet 8a, 8b, may be disposed on a same second side of the second module 6a, 6b. In alternative embodiments the inlet and/or outlets may provided on the side of the assembly.

[0088] According to preferred embodiments of the invention, the opposite surface 15 of a first module is opposed to the thermoelectric element contacting surface 16 of said first module.

[0089] According to preferred embodiments of the invention, the opposite surface 15 of a second module is opposed to the thermoelectric element contacting surface 16 of said second module.

[0090] The first 3a, 3b, and second 6a, 6b, modules may be block-shaped, wherein a block refers to a module comprising a rectangular-shaped thermoelectric element contacting surface 16 and a rectangular-shaped opposite surface 15, separated by four first sides (in case of the first module 3a, 3b) or by four second sides (in case of the second module 6a, 6b). The width of the first module may be defined then as the direction or shortest distance between two opposed first sides, whereas the width of the second module may be defined then as the direction of shortest distance between two opposed second sides. Preferably, the width of the surfaces 16, 15, is at least larger, more preferably substantially equal to the width of a thermoelectric element 9a, 9b, as depicted in FIG. 1, FIG. 4, FIG. 6, FIG. 7, and FIG. 8. However, the shape of the first 3a, 3b, and second 6a, 6b, modules is not limited to block-shaped modules but may also be triangular-shaped or polygonal-shaped modules that are preferably stackable on top of each other, preferably sandwiching at least one spacer (12) between modules provided to comprise a fluid of a same supply/drainage circuit, preferably sandwiching at least one thermoelectric element 9a, 9b, between first and second modules. Indeed, a spacer 12 may be placed between at least one part of the first (second) module, and at least one part of another first (second) module.

[0091] The first and/or second fluid, preferably liquid, may be selected from, but is not limited to, the group consisting of air, water, mixture water and glycol, mineral oil, terphenyl, liquid metals, or liquefied gases. According to a preferred embodiment of the invention, the first and/or second fluid is preferably a nearly incompressible fluid that conforms to the shape of the first module, but retains a (nearly) constant volume independent of pressure, and that can be pumped from a to be thermally conditioned fluid comprising container through a first fluid supply (for the first fluid), the first inlet 4a, 4b, the first fluid flow path contained in the first module 3a, 3b, the first outlet 5a, 5b, and the first fluid drainage, back to the fluid comprising container.

[0092] According to a preferred embodiment of the invention, a second fluid supply (for the second fluid), the second inlet 7a, 7b, the second fluid flow path contained in the second module 6a, 6b, the second outlet 8a, 8b, and the second fluid drainage, back to the fluid comprising container. The first and/or second fluid preferably has a high heat capacity, able to meet the cooling and heating requirements of the heat exchange device. Preferably, in embodiments according to the invention wherein the first fluid is a liquid, it preferably remains liquid in the operating conditions.

[0093] The first 3a, 3b, and second 6a, 6b, modules are preferably configured to be stackable, i.e. placed on top of each other forming a pile of modules, preferably connected by thermoelectric elements 9a, 9b, and/or spacers 12, defining two major outer surfaces, and at least three outer minor surfaces. The number of outer minor surfaces depends on the shape of the thermoelectric element contacting surface 16 and opposite surface 15 of the modules. The outer minor surfaces are side surface comprising at least a part of the side surface of each component of the stack. The major outer surfaces are defined as the opposite surfaces of the outer modules of the stack. Hence, the major outer surfaces of the assembly 2 may only be defined by two first modules 3a, 3b, provided to comprise a first fluid, preferably liquid, having similar temperatures. Hence, an indirect connection between the outer modules, preferably with means for fastening, may not be assumed as a heat leak or cold-bridge.

[0094] Referring to a preferred embodiment of the invention depicted in FIG. 1, the first inlet 4a, 4b and the first outlet 5a, 5b, are disposed on a first side 17a, 17b, of She first module 3a, 3b, and the second inlet 7a, 7b, and the second outlet 8a, 8b, are disposed on a second side 18a, 18b, of the second module 6a, 6b, wherein said second side 18a, 18b, is opposed to said first side 17a, 17b. The modules 3a, 3b, 6a, 6b, are configured in a back-to-back configuration, wherein "back-to-back" may refer to the configuration of the modules in the assembly 2 as described above. In particular, according to a preferred embodiment of the invention, the structure of the first module and second module if not connected may be the same, i.e. the modules may comprise an inlet and an outlet on a same side, a (processed) surface for placing thermoelectric element and an (unprocessed) opposite surface. When connecting the first 3a, 3b, and the second 6a, 6b, modules for assembling the assembly 2 according to embodiments of the invention, wherein first modules 3a, 3b, may be connected with at least one spacer 12 sandwiched between the opposite surfaces 15, and first 3a, 3b, and second 6a, 6b, modules are mutually connected with thermoelectric elements 9a, 9b, sandwiched between the thermoelectric element contacting surface 16, preferably with the first inlets/outlets at opposite sides than the second inlets/outlets, the stack is defined as being in a "back-to-back" configuration.

[0095] According to preferred embodiments of the invention, the heat exchange device comprises a plurality of assemblies 2 and means for fastening according to the invention, wherein the assemblies 2 are fluidly arranged in parallel, i.e. the first inlets 4a, 4b, are fluidly connected to a first fluid supply, wherein the first outlets 5a, 5b, are fluidly connected to a first fluid drainage, wherein the second inlets 7a, 7b, are fluidly connected to a second fluid supply, wherein the second outlets 8a, 8b, are fluidly connected to a second fluid drainage, wherein the first fluid supply and said first fluid drainage are fluidly connected to be thermally conditioned fluid comprising container, wherein the second fluid supply and said second fluid drainage are provided to support the second fluid.

[0096] According to a preferred embodiment of the invention, the at least one means for fastening comprises at least one means for clamping 11 adapted to generate a clamping force on at least a part of the assembly 2. The means for clamping 11 is advantageously made of or comprises thermally and/or electrically insulating material and advantageously contacts the outer modules of the assembly.

[0097] Advantageously, a means for clamping 11 is selected from the group consisting of C-shaped objects, angular-shaped objects, rectangular-shaped objects, squared-shaped object, round-shaped objects, oval-shaped objects, ellipse-shaped objects, circle-shaped objects or stadium-shaped objects defining an opening adapted to receive said assembly 2. The means for clamping 11 advantageously comprises one or more braces defining an open (C-shaped) or preferably closed (ringshaped) circumference. The braces define an internal opening in which the stack of assembly 2 is positioned. One or more bolts or other suitable tightening members co-operate with the braces to clamp the stack. By way of example, each brace may comprise a threaded hole configured for receiving a bolt. A plurality of threaded holes may be provided at opposite sides of the brace. These holes advantageously have axes which are aligned with the stacking direction.

[0098] Referring to a preferred embodiment of the invention depicted in FIG. 1, the heat exchange device comprises at least one means for fastening adapted to hold the assembly 2 together, wherein said at least one means for fastening comprises a means for clamping 11. The means for clamping 11 is adapted to generate a clamping force on at least a part of the assembly 2.

[0099] The means for fastening further advantageously comprises at least one means for transferring 10, wherein the at least one means for transferring is configured to at least transfer the clamping force on said assembly along the stacking direction on at least a part of the major outer surface of the stack.

[0100] According to preferred embodiments of the invention depicted in FIG. 1, FIG. 4, FIG. 6, FIG. 7, and FIG. 8, the means for fastening are disposed per column of the thermoelectric element 9a, 9b, stacked in the assembly 2. As shown in the figures, a plurality of layers of thermoelectric elements are arranged in the stack. Each of these layers comprises an array of thermoelectric elements which are juxtaposed such that the cold faces and the hot faces are substantially arranged in same planes, i.e. a row of thermoelectric elements extending in a direction cross to the stacking direction is obtained. The thermoelectric elements in the various layers of the stack are aligned with one another to form a plurality of columns in the stacking direction. The column hence refers to a group of thermoelectric elements disposed over the height of the assembly 2, wherein the height is measured as the shortest distance between the two outer blocks of the assembly 2. In particular, preferred embodiments of the invention depicted in FIG. 1, FIG. 4, FIG. 6, FIG. 7, and FIG. 8 comprise four columns of thermoelectric elements 9a, 9b.

[0101] A plurality of clamping means (braces) 11 are advantageously provided in correspondence of each column of thermoelectric elements. The clamping force for each brace can be adjusted independently, e.g. by adjusting the respective bolts, and therefore, the clamping force is adjusted for each column of thermoelectric elements independently. This allows for eliminating bad surface contacts due to variations and deformations of the modules and/or thermoelectric elements, hence obtaining an optimal contact between the faces of the thermoelectric elements and the contacting surfaces 16 for all the thermoelectric elements of the stack.

[0102] Referring to preferred embodiments of the invention depicted in FIG. 1, FIG. 4, FIG, 6, FIG. 7, and FIG. 8, the at least one means for clamping 11 frames the assembly 2 along at least a part of its outer perimeter. Preferably, the outer perimeter is defined as a circumference of an imaginary surface being perpendicular on the major outer surface. According to a preferred embodiment of the invention, the means for clamping 11 is selected from the group consisting of C-shaped objects, angular-shaped objects, rectangular-shaped objects, round-shaped objects, oval-shaped objects, ellipse-shaped objects, circle-shaped objects or stadium "shaped objects defining an opening adapted to receive the assembly. Preferably, the aforementioned shaped objects may comprise several components connected to each other to define the aforementioned shape, wherein the connection may be performed by welding (for example welded frames), using securing means (for example single or double damping rings) or any other techniques.

[0103] Referring to preferred embodiments of the invention depicted in FIG. 1 - FIG. 10, a means for clamping 11 may be a closed object defining the opening adapted to receive and enclose the assembly 2. Means for clamping 2 may be placed at the circumference of the assembly 2, wherein the circumference may be defined as the outer perimeter of the assembly 2 defining the circumference of an imaginary surface, preferably, this imaginary surface is perpendicular disposed on the major outer surface of the assembly 2. The number of means for fastening 2 may be at least one, preferably equals the number of thermoelectric elements 9a, 9b, comprised in the assembly 2 in order to provide sufficient clamping force on the assembly 2 and over the width of the thermoelectric elements, wherein "the width" is defined as the direction substantially perpendicular to the direction of the length of the major outer surface, wherein the length of the major outer surface is at least larger than the aforementioned width. According to a preferred embodiment of the invention wherein the number of means for fastening 11 equals the number of thermoelectric elements 9a, 9b, each means for fasting 11 may be placed per column of thermoelectric element 9a, 9b. A means for fastening 11 may comprise or is made of material comprising metal or steel.

[0104] According to preferred embodiments of the invention, the at least one means for fastening comprises at least one means for clamping 11 adapted to generate a clamping force on at least a part of said assembly 2, and at least one means for transferring 10 adapted to transfer said clamping force, wherein said means for transferring 10 is disposed on at least a part of a major outer surface of said at least one outer module 2.

[0105] According to a preferred embodiment of the invention, at least a part of the means for clamping 11 is connected to the assembly 2 with means for transferring 10. Means for transferring 10 may be a mass element, wherein the mass element is selected from the group consisting of a block, a cube, or an object comprising at least one curved surface. At least a part of the means for transferring 10 may be placed to at least a part of the assembly 2, to be in direct contact with the assembly 2. Referring to a specific embodiment of the invention depicted in FIG. 8 to FIG. 10, the means for transferring 10 is a curved C-shaped object, wherein the C-shaped object is adapted to grip along or fit with the width of said major outer surface of said outer module and at least a part of an edge of said assembly 2.

[0106] According to a preferred embodiment of the invention, the means for transferring may be placed over the full width of the major outer surfaces of the assembly 2. The number of means for transferring 10 may depend on the selected means for clamping 11 and/or the number of thermoelectric elements 9a, 9b, comprised in the assembly 2. A heat exchange device according to a preferred embodiment of the invention comprising at least one means for clamping 11 wherein the means for clamping 11 is rectangular-shaped frame, may comprise two means for transferring 10, preferably two mass elements, in particular two blocks each of them placed on the major outer surface of the assembly 2. The mass elements, preferably blocks, are disposed on at least 90%, preferably 95%, more preferably 100%, of the area of the at least one outer major surface of the assembly 2.

[0107] According to a preferred embodiment of the invention, a heat exchange device comprising a means for clamping 11 wherein the means for clamping is a round-shaped object, may be connected with a means for transferring 10 wherein the means for transferring 10 is e.g. a C-shaped object or an object comprising at least one curved surface. The means for transferring 10 are in direct contact with the opposite surface 15 of the outer modules, in particular placed at least over the width of the major outer surface of the assembly 2. In embodiments where a C-shaped object is used, the C-shaped object in addition to covering the width of the major outer surface may also cover the edge of the assembly. A lubricant, preferably silicone oil, may be disposed between the means for clamping 11 and the transferring means 10.

[0108] According to a preferred embodiment of the invention, the means for clamping 11 are connected to the means for transferring 10 with means for connecting, wherein a means for connecting is selected from the group consisting of at least bolts or springs. The means for clamping 11 and means for transferring 10 are adapted to comprise at least a part of the means for connecting. For example the means for clamping 11 may comprise cavities to dispose at least a part of the means for connecting.

[0109] According to preferred embodiments of the invention, means for clamping 11 or means for fastening are closed objects defining an opening suitable for receiving the assembly 2 and framing the assembly 2. The means for clamping 11 may be C-shaped objects, preferably C-shaped objects closed by means for connecting, more preferably closed-shaped objects.

[0110] According to a preferred embodiment of the invention, C-shaped means for clamping 11 may be placed along the length of major outer surface and all at the same side, wherein "the same side" is substantially perpendicular to a plane defined by at least one major outer surface.

[0111] Preferably, C-shaped means for clamping may also be placed altering at a same and opposite side of the assembly, enabling a space or void to receive the insulating materials.

[0112] Advantageously, the length of the means for connecting may be adapted depending on the number of first 3a, 3b, and second modules 6a, 6b, comprised in the assembly 2, and/or depending on creep effects of the elements or components comprised In the assembly 2. As a results embodiments of the present invention can be easily fine-tuned in function of the envisioned application. Preferably fastening means, comprising connection for connecting, according to embodiments of the present invention are placed per column of thermoelectric elements 9a, 9b. In preferred embodiments the fastening means are connected to the assembly using the means for connecting in a way such that the means for clamping and/or means for connecting may not contact the assembly resulting in improved thermal properties of the assembly of the present invention. In farther preferred embodiments of the invention, the fastening means are provided such that the means for transferring 10 provide a thermal buffer between the means for clamping 11 and/or means for connecting.

[0113] Referring to the assembly 2 in FIG. 1, the first modules 3a, 3b, of a first plurality may be liquidly connected in series. This implies that at least part of the liquid leaving a first module of an assembly 2 may preferably enter another first module 3a, 3b of the assembly without being first used as a heating and/or cooling fluid for thermally conditioning the fluid comprising room or container (not demonstrated on the figures). Otherwise said and referring to FIG. 1, the first outlet 5a may preferably be connected to the first inlet 4b and vice versa.

[0114] Referring to FIG. 2, there is depicted a schematic front view of a preferred embodiment according to the invention. Reference is made to the description of FIG. 1 and any other relevant aforementioned drawing. The preferred embodiment in FIG. 2 depicts the sandwiching of thermoelectric elements 9a, 9b, between thermoelectric contacting surfaces 16 of the first 3a, 3b, and second modules 6a, 6b, and the placement of a plurality of spacers 12 disposed between opposite surfaces 15 of first 3a, 3b, and second modules 6a, 6b. The means for clamping 11, which are rectangular defining an opening, are connected to the means for transferring 10 by means for connecting, preferably bolts. In the embodiment illustrated in FIG. 2 the means for clamping comprising a closed rectangle defining an opening, wherein the opening is adapted to receive the assembly. The means for clamping of FIG. 2 is made of a single piece, however in other embodiments the clamping means may comprise a plurality of elements. The means of clamping 1 1 in the embodiment depicted in FIG. 2 is connected to the assembly 2 via the means for transferring 10 using the means for connecting. In preferred embodiments the means for transferring comprise openings configured to receive and/or secure the means for connecting.

[0115] Referring to FIG. 3, there is depicted a schematic side view of the preferred embodiment depicted in FIG. 1. Reference is made to the description of FIG. 1 and FIG. 2 for a description of the components. Referring to FIG. 4, there is depicted a schematic isometric view of a preferred embodiment according to the invention, comprising insulating material 40. The insulating material 40 is selected from the group consisting PUR, PIR, EPS, XPS, foam glass, or extruded profiles in aluminum, PVC, polycarbonate. The insulation material 40 may be adapted to fill the space between at least a part of the means for clamping 11 and the at least a part of the assembly 2. According to preferred embodiments of the invention thermally and/or electrically insulating material 40 is provided substantially perpendicular with respect to a major outer surface of the outer module. According to a specific embodiment of the invention, said thermally and/or electrically insulating material 40 surrounds at least a part of the assembly.

[0116] The insulating material 40 advantageously may limit undesired heat transfer between the heat exchange device 2 and the environment, and limit the formation of condense on the heat exchange device 2. The insulating material 40 may contain cavities to allow the guidance of at least one means for supplying electric power 14 for supplying power to the at least one thermoelectric element 9a, 9b. In addition, the insulating material 40 limits the movement shear and displacement of the components of the assembly 2.

[0117] Referring to FIG, 5, there is depicted a schematic front view of the preferred embodiment depicted in FIG. 4.

[0118] Referring to FIG. 6, there is depicted a schematic Isometric view of a preferred embodiment according to the invention, comprising an assembly 2 having two outer modules (selected from the group consisting of first modules 3a, 3b) and inner modules, wherein the inner modules may be an plurality of alternating pairs of first modules 3a, 3b, and second modules 6a, 6b.

[0119] The embodiment comprises four means for fastening, wherein the means for fastening comprise means for clamping II, cf. rectangular-shaped objects, and means for transferring 10 the clamping force, cf. the mass-elements placed on the major outer surface of the assembly 2. According to this embodiment of the invention, the means for connecting are bolts disposed between at least a part of the means for clamping 11 and at least a part of the means for transferring 10. The means for fastening are placed per column of thermoelectric elements 9a, 9b, wherein each column comprises six thermo-electric elements 9a, 9b.

[0120] Referring to FIG. 7, there is depicted a schematic isometric view of a preferred embodiment depicted in FIG. 6, comprising insulating material 40, As illustrated in FIG. 7 the insulating material 40 is provided at least in the remaining opening of the closed means for clamping, e.g. a rectangular-shaped object, after the assembly is provided therein. Preferably, insulating material 40 may also be disposed in the volume limited by the inlet/outlet of a first module, and the inlet/outlet of the following first module. Preferably, insulating material 40 may also be disposed in the volume limited by the inlet/outlet of a second module, and the inlet/outlet of the following second module.

[0121] Referring to FIG. 8, a heat exchange device is illustrated comprising an assembly 2 and at least one means for fastening for holding the assembly together. According to a preferred embodiment of the invention, the assembly 2 comprises two first modules 3a, 3b, for carrying a first fluid, preferably a liquid. Each first module 3a, 3b, comprises a first fluid flow path or first liquid circuit (not shown) connecting a first inlet 4a, 4b, with a first outlet 5a, 5b, wherein the first inlet 4a, 4b, and the first outlet 5a, 5b, are disposed on at least one first side of the module 3 a, 3b.

[0122] According to a preferred embodiment of the invention, the thermoelectric elements 9a, 9b are placed in columns and per column at least one means for fastening for holding said assembly 2 together is placed. This facilitates the configuration of the at least one means for supplying power to the thermoelectric element 9a, 9b.

[0123] Referring to FIG. 1, there is demonstrated a preferred embodiment according to the invention comprising four means for fastening disposed on at least a part of the circumference of the assembly 2 and arranged over the length of the assembly 2. This ensures the presence of a compression force over the width of the module to improve the contact area between the thermoelectric elements 9a, 9b, and the surface of the modules 3a, 3b, 6a, 6b, on which the thermoelectric elements are placed. The means for clamping 11 may provide a sufficient clamping force on at least a part of the assembly 2. The means for clamping 1 1 may be made of galvanized steel in order to decrease the possibility of corrosion.

[0124] Referring to preferred embodiment of the invention depicted in FIG. 8 - FIG. 10, means for clamping 11 are selected from the group consisting of round-shaped objects, oval-shaped objects, ellipse-shaped objects, circle-shaped objects or stadium-shaped objects defining an opening adapted to receive said assembly 2. In particular, means for clamping 11 are selected from the group consisting of single clamping rings and double clamping rings. A single clamping ring comprises a means to secure two ends of the clamping ring to each other. The double clamping ring comprises two means to secure the two halves of the ring to each other.

[0125] The choice of type of means for clamping 11 depends on the application of the heat exchange device and desired cooling and/or heating capacity. The number of means for fastening is not limited to the aforementioned number. Preferably, the means for clamping 11 are placed per column of thermoelectric elements 9a, 9b, to ensure that the highest clamping force may be substantially well distributed across the width of the thermoelectric elements 9a, 9b. In order to transfer the clamping force exerted by the means for clamping 11, a means for transferring 10 the clamping force is provided. The means for transferring 10 are disposed between the means for clamping 11 and at least a part of the assembly 2, preferably at least a part of the major outer surface of the assembly 2. According to a particular embodiment of the invention, a lubricant, preferably silicone oil, is disposed between at least a part of the means for clamping 11 and at the least a part of the means for transferring 10, allowing that the means for clamping 11 may slide on the means for transferring 10 to provide a properly distributed clamping force on the thermoelectric elements 9.

[0126] Referring to FIG. 9, there is depicted a preferred embodiment according to the invention, wherein a means for transferring 10 is disposed on at least a part of the outer module. The carved volume of the means for transferring 10 in which the outer module of the assembly 2 is placed, has a slightly higher depth whereby it fixes the placement of the thermoelectric elements 9a, 9b, in the assembly 2 and disables the displacement of the thermoelectric elements 9 in a direction of the width of the modules.

[0127] According to a preferred embodiment of the invention, means for transferring 10 are preferably not disposed on at least a part of the inner modules since it allows the placement of insulation between the means for clamping 11 and at least a part of the inner modules.

[0128] According to preferred embodiments of the invention, thermally and/or electrically insulating material is provided substantially perpendicular with respect to a major outer surface of the outer module.

[0129] According to a specific embodiment of the invention, said thermally and/or electrically insulating material surrounds at least a part of the assembly.

[0130] According to a preferred embodiment of the invention, the means for clamping 11 is placed on at least a part of the circumference of the assembly 2, wherein said circumference is defined as a circumference of an imaginary surface substantially perpendicular to a plane defined by one of the outer modules.

[0131] Referring to a preferred embodiment of the invention depicted in FIG. 8 - FIG. 10, the means for transferring 11 may comprise or be made a thermoplastic and preferably an engineering thermoplastic used in precision parts requiring high stiffness, low friction and excellent dimensional stability, preferably black POM, made of polyoxymethylene, and also known as acetal. However, the composition of the pressure transferring force is not limited to the aforementioned material. The retaining means 13a, 13b, may be laser cut and disposed between at least one means for fastening and at least a part of the assembly 2. The retaining means 13a, 13b comprise or may be composed of a lightweight or shatter-resistant material such as polymethyl methacrylate (PMMA), also known as acrylic or acrylic glass. However, the material of the retaining means is not limited to the aforementioned material.

[0132] Referring to FIG. 10, there is demonstrated a cross-sectional view of a preferred embodiment according to the invention depicted in FIG. 8. Hence, the heat exchange device includes the elements of the heat exchange device. FIG. 10 demonstrates the stack of the modules, wherein the outer blocks of the assembly have inlet and outlet directed in the same direction.

[0133] The temperature of the first fluid, preferably liquid, comprised in the first modules 3a, 3b, and the temperature of the second fluid, preferably liquid, comprised in the second modules 6a, 6b, preferably differ in order to thermally condition a fluid comprising room or container.

[0134] According to a preferred embodiment of the invention wherein the heat exchange device is used for cooling, the fluid having the highest temperature is comprised in the outer modules of the assembly 2. This decreases the chance for the formation of condensation on at least a part of the assembly 2, and hence, the formation of corrosion.

[0135] According to a preferred embodiment of the invention wherein the heat exchange device is used for heating, the fluid having the lowest temperature is comprised in the outer modules of the assembly 2. Insulation may be used to decrease the chance for the formation of condensation on at least a part of the assembly 2, and hence, the formation of corrosion.

Example of cooling a fluid comprising room or container

[0136] Referring to FIG. 1 to FIG. 10 and according to a preferred embodiment of the invention, and in use, the second modules 6a, 6b, comprise a second fluid, preferably liquid, having a lower temperature than the first fluid, preferably liquid, comprised in the outer modules 3a, 3b. The second modules 6a, 6b, are connected to a fluid comprising room or container to cool. When the second fluid, preferably liquid is transported away from the fluid comprising room or container, it contains heat extracted from the fluid comprising room or container. The second fluid, preferably liquid, enters the second modules 6a, 6b, via the second inlet 7a, 7b and flows through the second fluid flow path or second liquid circuit to the second outlet 8a, 8b. Before the second fluid, preferably liquid, leaves the second modules 6a, 6b, heat has been pumped, or transferred, from the second fluid, preferably liquid, to the first fluid, preferably liquid, through a series of thermoelectric elements 9a, 9b, disposed on the thermoelectric element contacting surface 16. The first fluid, preferably liquid, is transported out of the first modules 3a, 3b, and removes the heat originally comprised in the second fluid, preferably liquid, from the assembly 2. The cooled second fluid, preferably liquid, may be transported back to the fluid comprising room or container to cool it further.

Claims

1. A heat exchange device comprising:

at least one assembly (2), wherein said at least one assembly (2) comprises a stack and at least one means for fastening (11) configured to hold the assembly (2) together,
wherein the stack comprises:

at least two first modules (3a, 3b), each comprising a first surface (16), a second surface (15) opposite the first surface, a first fluid inlet (4a, 4b) and a first fluid outlet (5a, 5b) connected by a first fluid channel interposed between the first surface and the second surface, the first fluid channel defining a first fluid flow path, wherein said first fluid flow path defines a first fluid flow direction,
a second module (6a, 6b) comprising a third surface (16), a fourth surface (15) opposite the third surface, a second fluid inlet (7a, 7b) and a second fluid outlet (8a, 8b) connected by a second fluid channel interposed between the third surface and the fourth surface, the second fluid channel defining a second fluid flow path, wherein said second fluid flow path defines a second fluid flow direction at least substantially parallel to said first fluid flow direction, and
at least two thermoelectric elements (9a, 9b), wherein each thermoelectric element is at least partially sandwiched between one of said at least two first modules (3a, 3b) and said second module (6a, 6b),

stacked along a stacking direction, wherein one of the at least two first modules is positioned at a first end of the stack along the stacking direction and another one of the at least two first modules is positioned at a second end of the stack opposite the first end, and
wherein the first surface (16) and the third surface (16) are surfaces of contact contacting with at least one of the thermoelectric elements such that a first fluid in the respective first module and a second fluid in the respective second module are in indirect contact with the respective thermoelectric element.

2. The heat exchange device of claim 1, wherein the stack comprises plural ones of the second module (6a, 6b) arranged in at least one pair, wherein the second modules of each pair are arranged in a back-to-back configuration, wherein the respective fourth surfaces (15) are facing each other and respective third surfaces (16) are each in contact with at least one of the thermoelectric elements (9a, 9b).

3. The heat exchange device of claim 2, comprising a force distributing spacer (12) between the fourth surfaces of each pair of second modules.

4. The heat exchange device of claim 2 or 3, further comprising additional first modules (3a, 3b) arranged in at least one pair, wherein the first modules of each pair of first modules are arranged in a back-to-back configuration, wherein the respective second surfaces (15) are facing each other and wherein the pairs of first modules and the pairs of second modules alternate in the stack.

5. The heat exchange device according to any one of previous claims, wherein the at least two thermoelectric elements are arranged as arrays of thermoelectric elements, wherein the thermoelectric elements in each array contact with the first surface of an adjacent one of the first modules.

6. The heat exchange device of any one of the previous claims, wherein the first fluid outlet of one of the first modules is connected to the first fluid inlet of another one of the first modules such that the first modules are fluidly connected in series.

7. The heat exchange device of any one of the previous claims, wherein the first fluid channel and/or the second fluid channel comprise a plurality of parallel channel sections separated by channel walls.

8. The heat exchange device according to any one of the previous claims, wherein said at least one means for fastening comprises clamping means (11) adapted to frame said assembly (2) along at least a part of its outer perimeter and one or more connecting means, wherein the clamping means and the connecting means are configured to co-operate to provide a clamping force on the stack.

9. The heat exchange device of claim 8, wherein the connecting means are bolts or springs.

10. The heat exchange device of claim 8 or 9, wherein the at least two thermoelectric elements (9a, 9b) are arranged as a plurality of arrays of thermoelectric elements, wherein the thermoelectric elements in each array contact with the first surface (16) of an adjacent one of the first modules, and comprising a plurality of the means for fastening (11) positioned in correspondence of each of the thermoelectric elements in the array.

11. The heat exchange device of claim 10, wherein the plurality of the means for fastening are configured to provide independently adjustable clamping forces on the stack.

12. The heat exchange device of claim 10 or 11, wherein the plurality of the means for fastening comprise a plurality of braces and respective tightening bolts, each brace framing the stack.

13. The heat exchange device of any one of the claims 8 to 12, wherein the means for fastening comprises one or more mass elements (10) interfacing between the first modules and the means for fastening (11) at the first end and/or the second end of the stack.

14. The heat exchange device according to any one of the preceding claims, comprising a first fluid pump in fluid communication with the first fluid inlets (4a, 4b) and a second fluid pump coupled to the second fluid inlet (7a, 7b), wherein the first fluid pump and the second fluid pump are configured to sustain a flow rate of respective fluids which induces a turbulent flow regime in the first fluid channel and in the second fluid channel.

15. Use of a heat exchange device according to any one of the previous claims for thermally conditioning a fluid comprising room or container, further comprising a first fluid supply and a first fluid drainage, wherein said first fluid supply and said first fluid drainage are fluidly connected to said fluid comprising room or container.

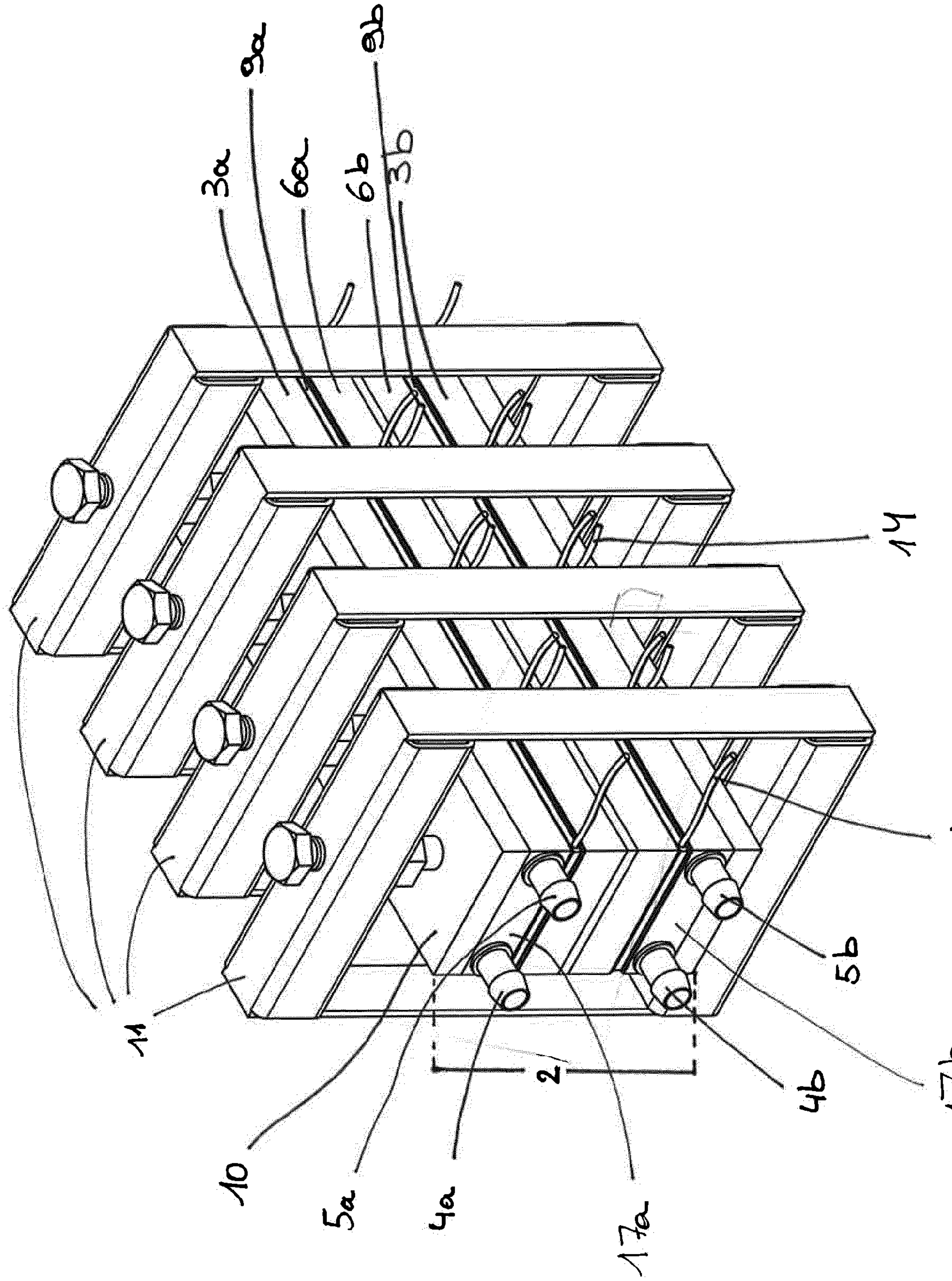


Fig 1

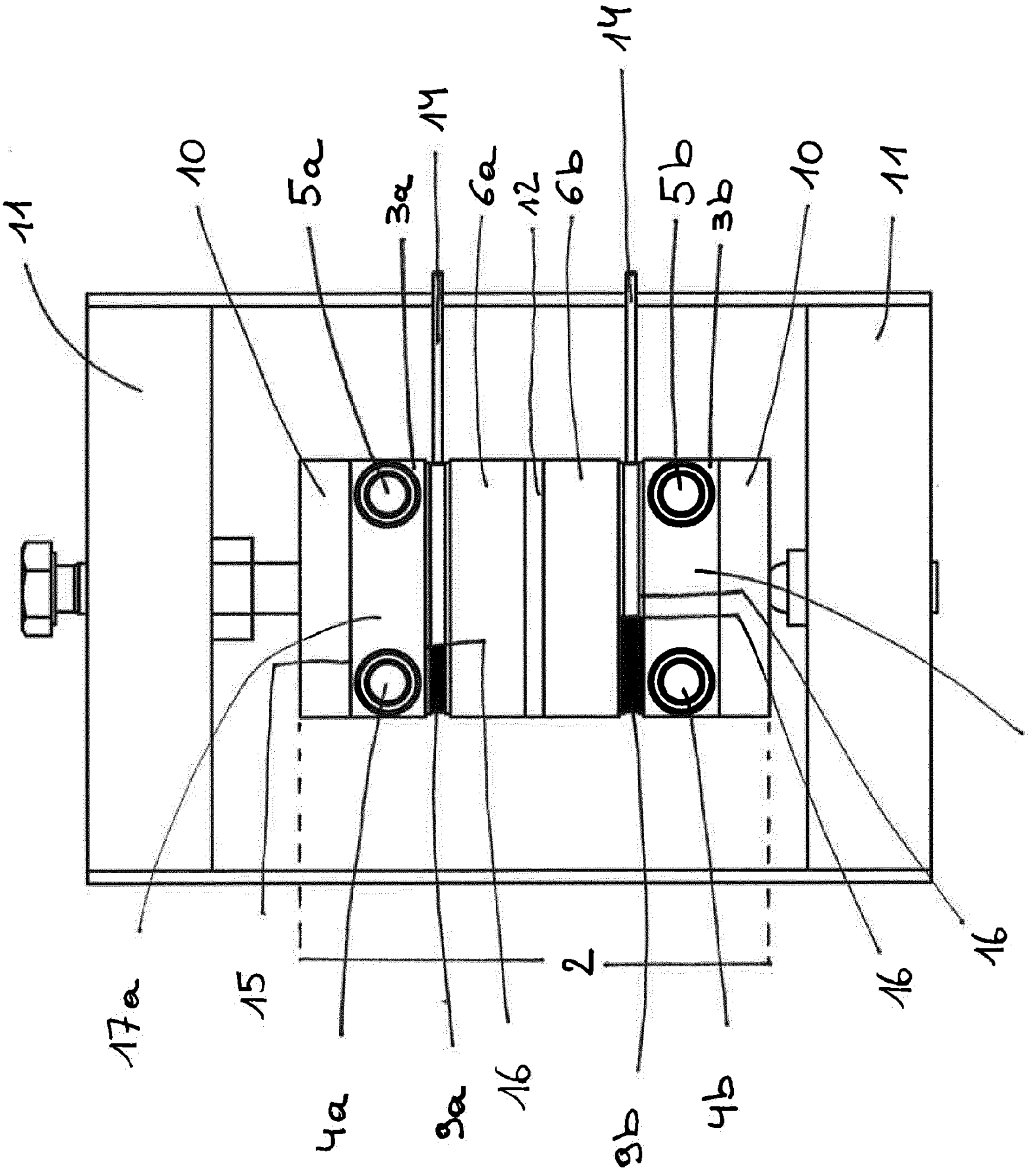


Fig 2

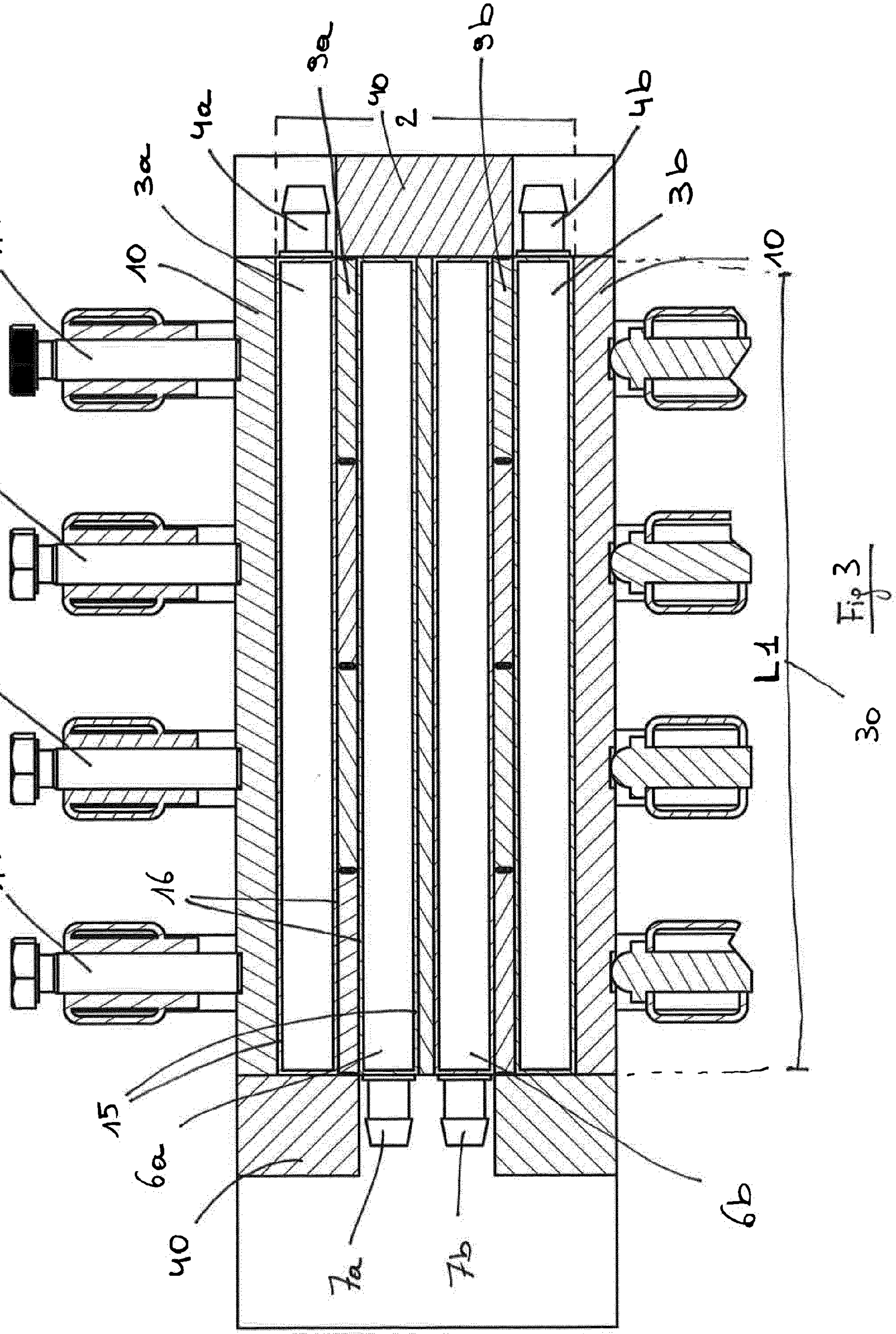


Fig 3

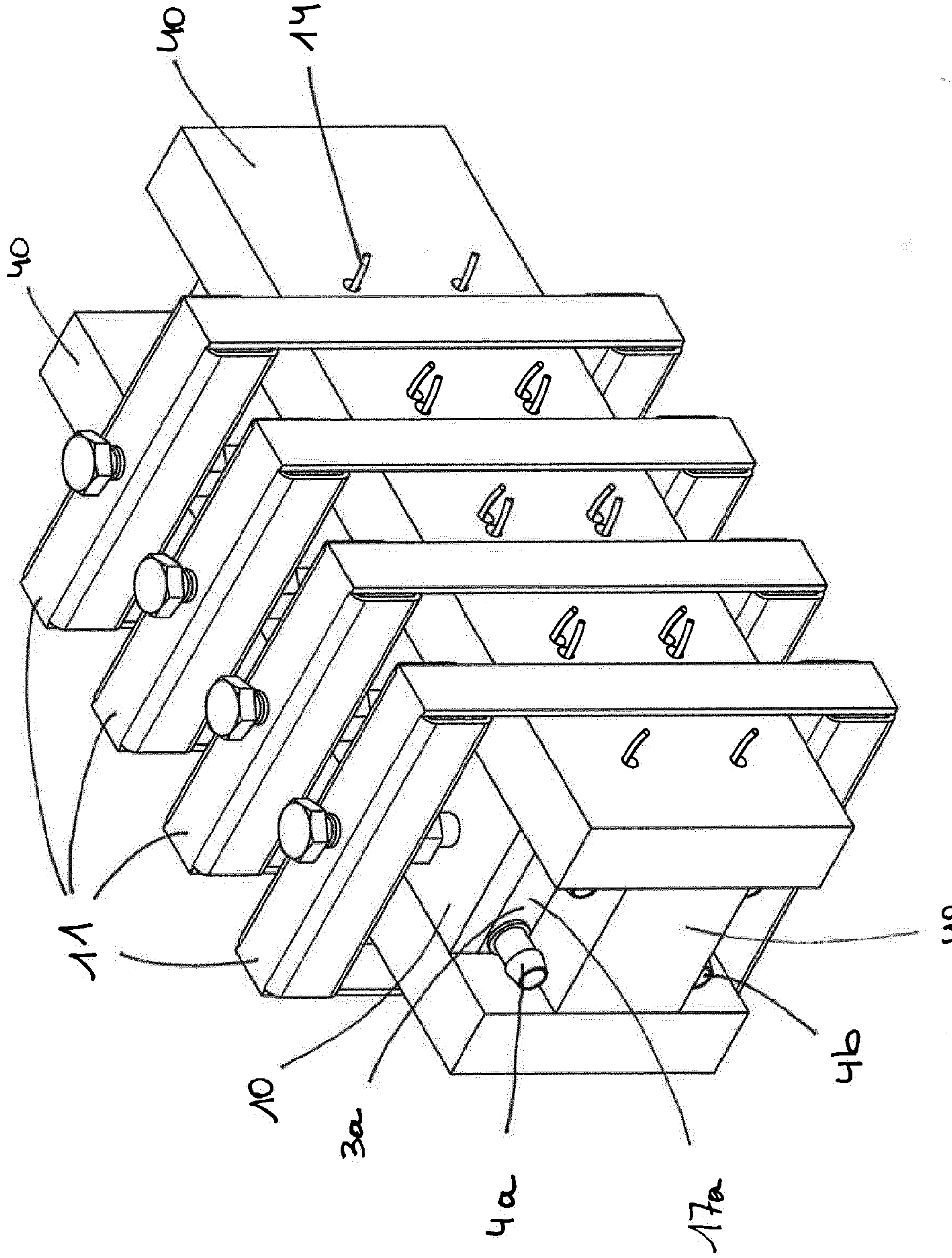


Fig 4

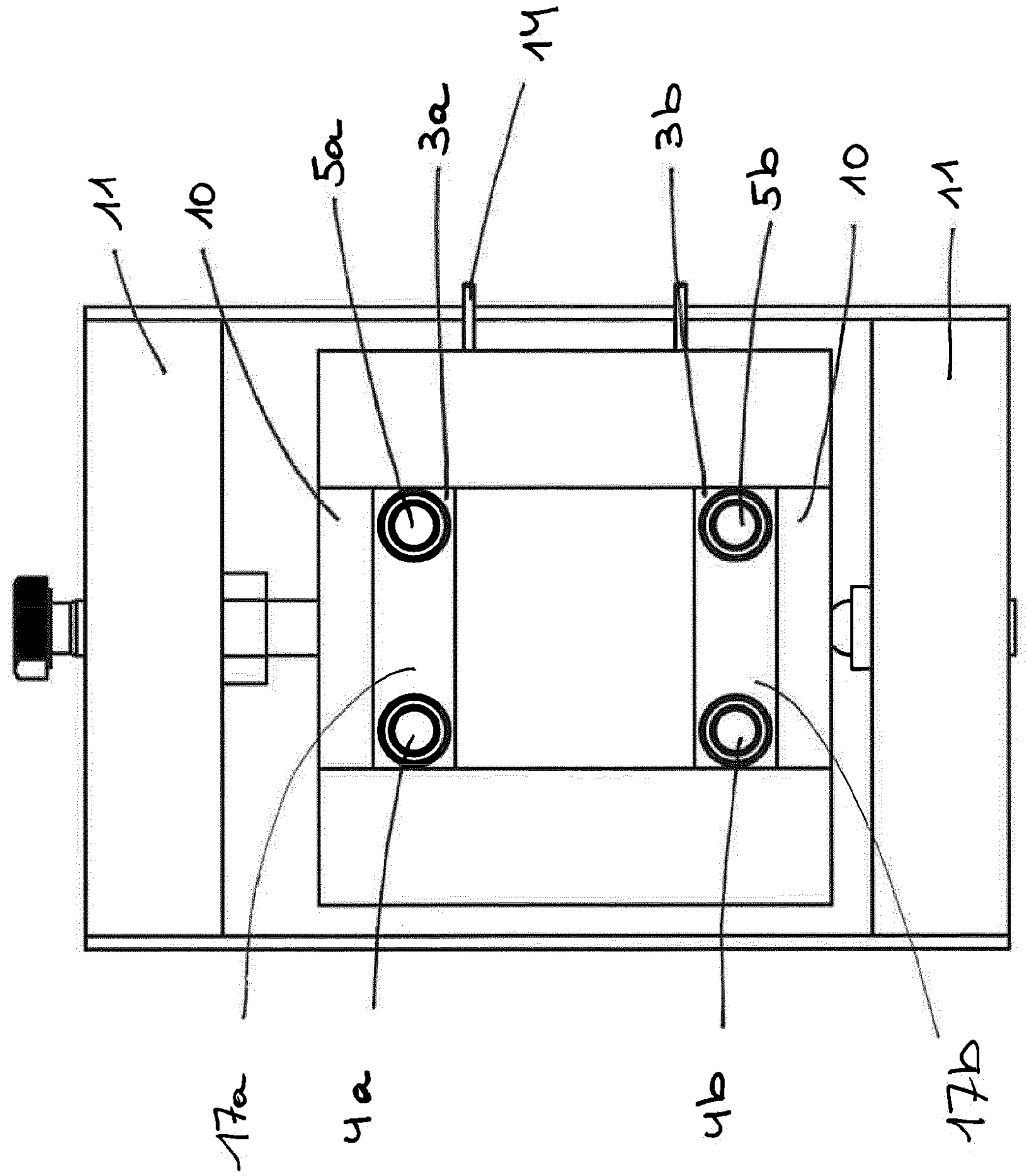


Fig 5

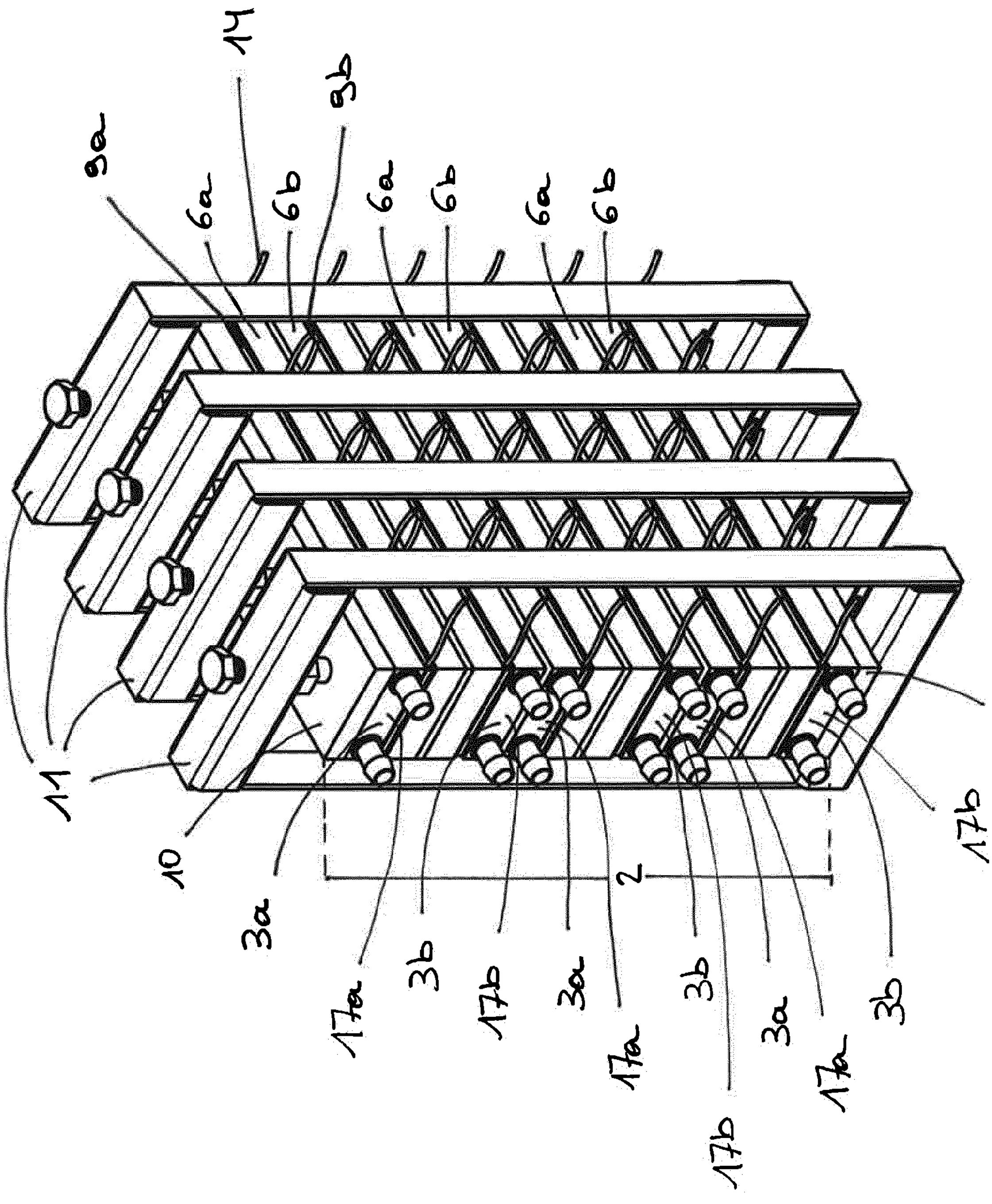


Fig. 6

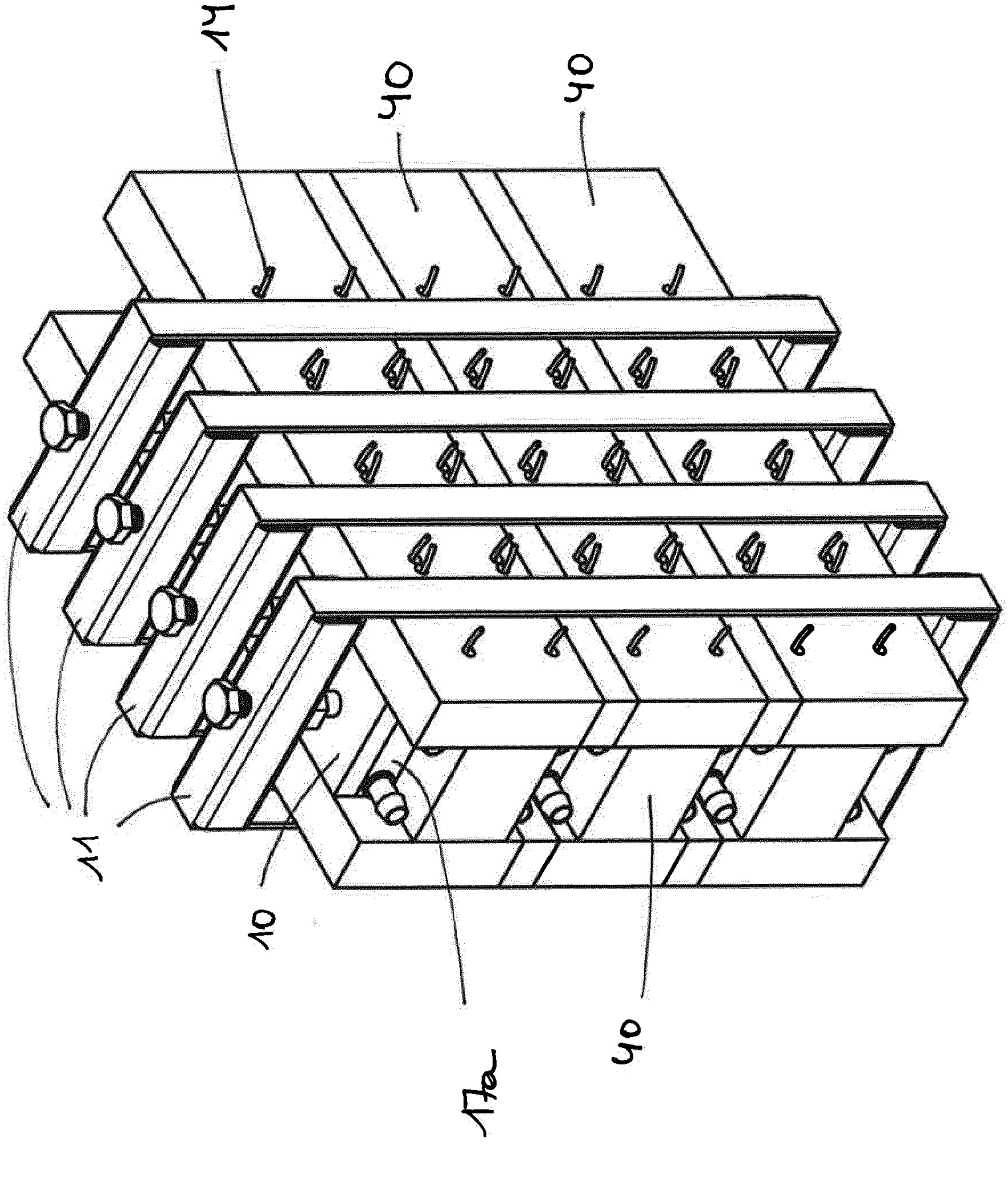
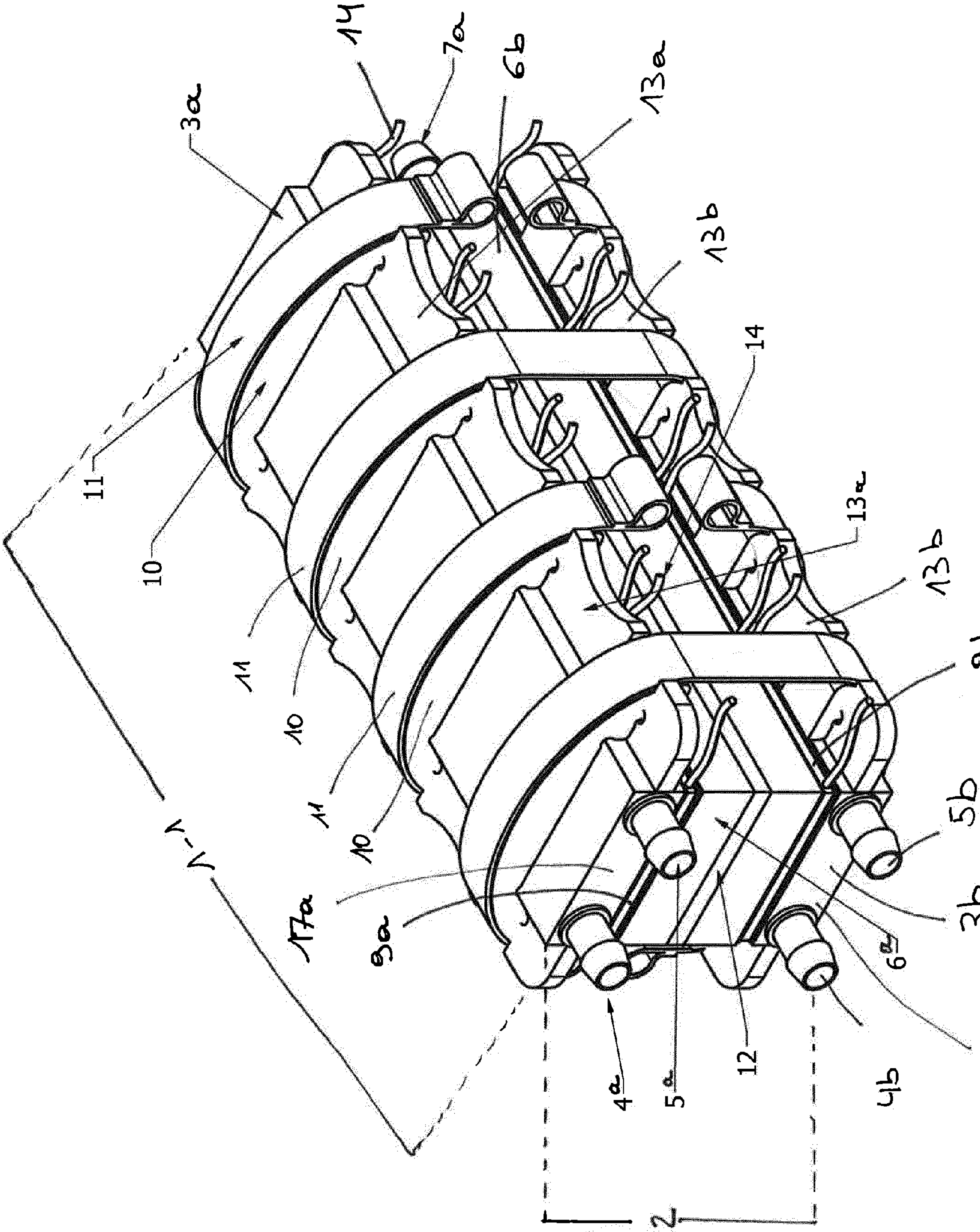


Fig 7



14
7a
6b
13a
3a
13b
14
11
10
13a
13b
11
10
9b
11
10
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17a
9a
5b
3b
6a
17b
4a
5a
12
4b
2

Fig 8

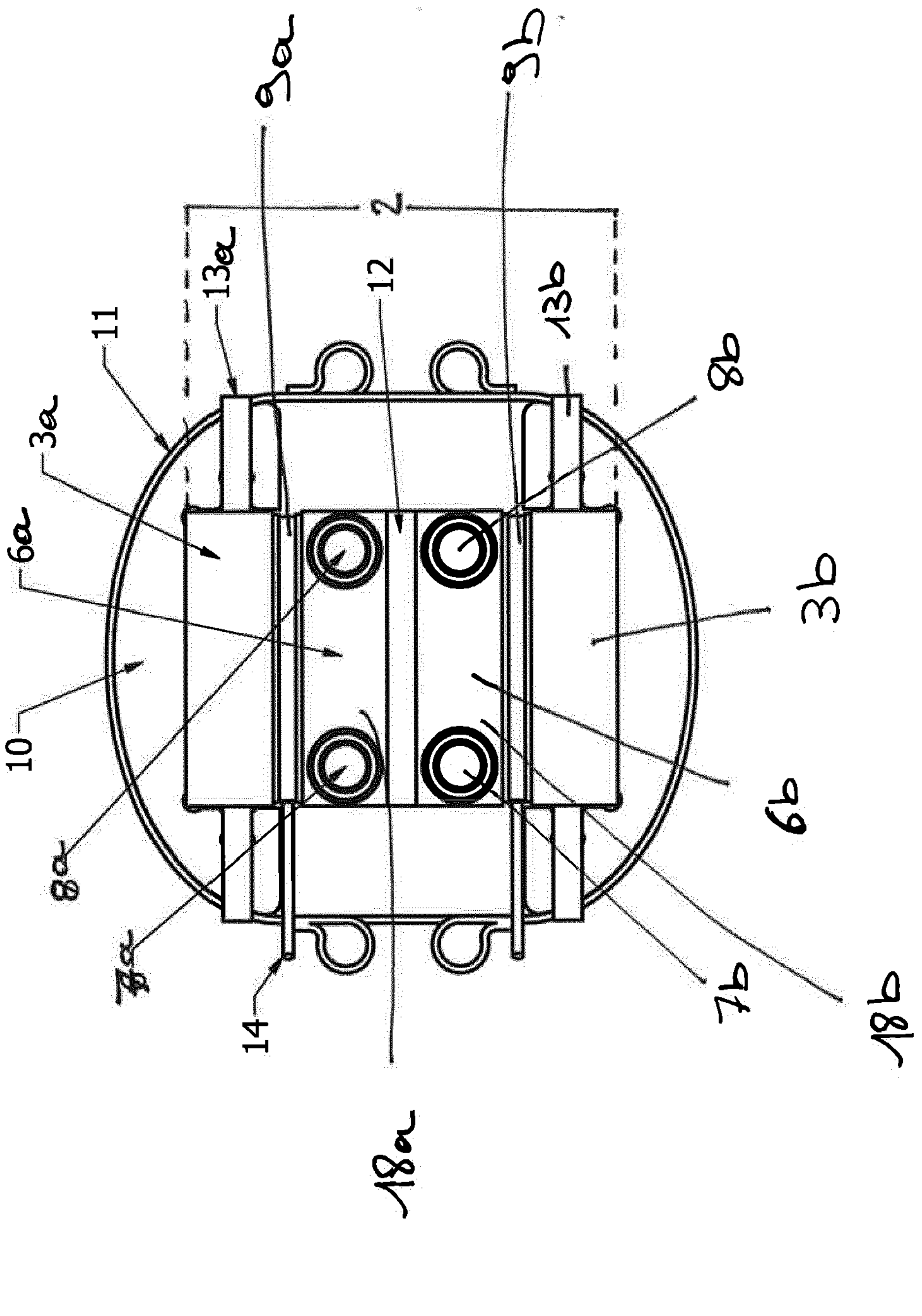

Fig 9

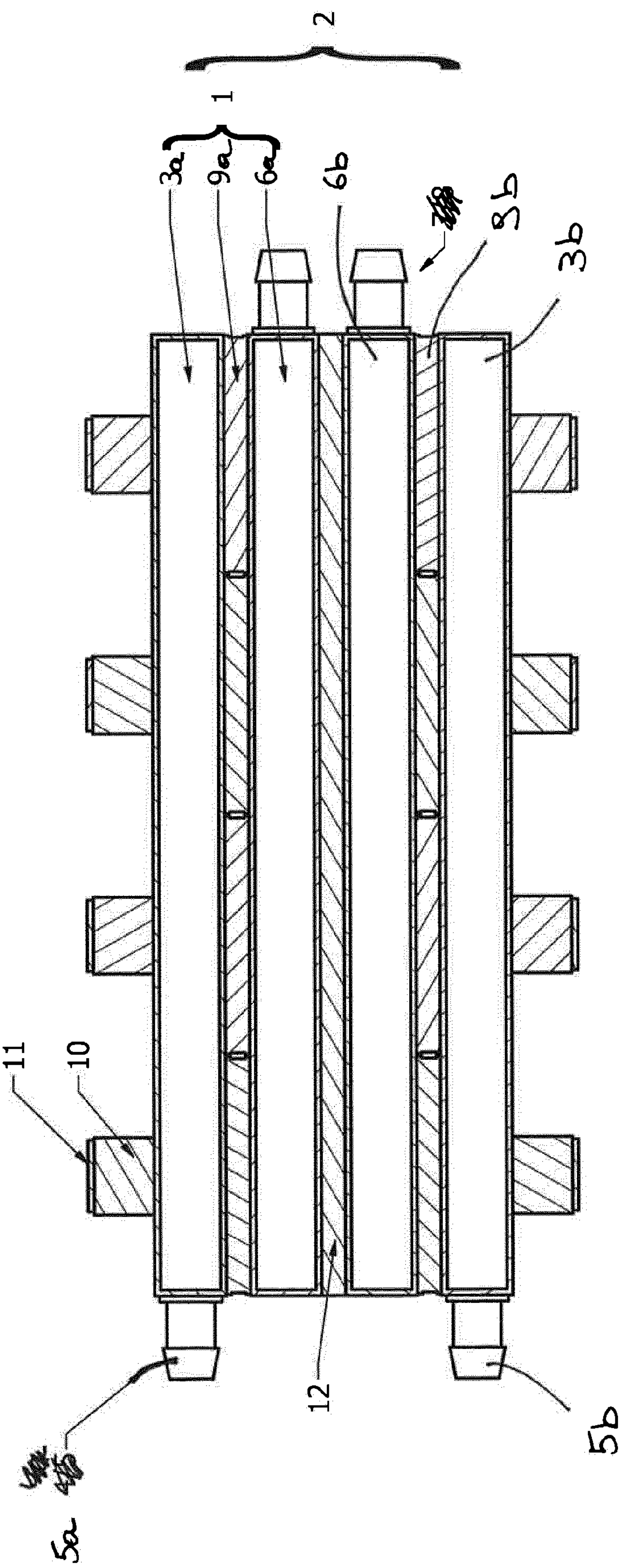

Fig 10

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EUROPEAN SEARCH REPORT

Application Number
EP 17 19 6032

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Place of search	Date of completion of the search	Examiner
Munich	15 February 2018	Gasper, Ralf

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