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(54) **EVAPORATOR-RESERVOIR MODULAR UNIT**

MODULARE VERDAMPFERRESERVOIREINHEIT

UNITÉ MODULAIRE ÉVAPORATEUR-RÉSERVOIR

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(73) Proprietor: **Allatherm SIA**
2015 Jurmala (LV)

(72) Inventor: **MISHKINIS, Donatas**
28813 Madrid (ES)

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to the field of thermal management systems and, more particularly, to an evaporator-reservoir modular unit according to the preamble of claim 1. JP 2014-114962 discloses such a unit.

BACKGROUND OF THE INVENTION

[0002] Heat loops (also known as capillary pumped loops and loop heat pipes) are highly efficient passive devices for the transport of heat from a thermal source (for instance, power electronic block) to a thermal sink (ambient air, cold plate, chilled water, etc.).

[0003] Nowadays, heat loops are widely used for thermal management in many fields. Doubtless, the most recognized heat loop application today is in spacecraft thermal control systems, but these devices also have very high potential for terrestrial applications (especially micro- and power electronics). There are two main deterrents which are currently preventing wide penetration of the market for the heat loop technology: (1) a very high level of "customization" and, as consequence, (2) a low level of unification and automatization in manufacturing. This leads to very high cost and long delivery time of the final system. Even though heat loops have outstanding performances, thermal designers often prefer to use alternative, much less efficient, but more common, easily reconfigurable, and less expensive technologies. The proposed modular approach in evaporator design and manufacturing allows to overcome this tendency and to offer a unitized and standardized, competitive, and fast deliverable product to the market.

[0004] A typical heat loop is a hermetically sealed closed circuit charged by a specified amount of working fluid. Heat loop functioning is based on the same physical phenomena as for heat pipes. As soon as waste heat from an equipment is applied to an evaporator and heat sink is activated, the working fluid circulation is started. Closed evaporation/condensation cycle associated with corresponding mass and heat flows from heat source to heat sink is realized inside of the operating heat loop. Liquid evaporates in the evaporator. Generated vapor moves to condenser through the vapor line due to pressure drop, driven by positive temperature difference between the evaporator and condenser. Then heat is released in the condenser by means of vapor-liquid transition. Condensed liquid returns back to the evaporator through the liquid line as a result of capillary pumping action developed by a microporous wick which is located in the evaporator. The wick provides necessary capillary potential to overcome all pressure losses during vapor and liquid circulation movement round the heat loop.

[0005] Thus, a heat loop consists of five major elements: evaporator, reservoir, condenser, liquid transport

line and vapor transport line (Figure 1). Transport lines and condenser are generally a small inner diameter (1-8mm) simple metallic tubing. Typical reservoir design is cylindrical volume which can be directly attached to the evaporator (most common heat loop architecture, named in technical literature loop heat pipe, Figure 1a) or the reservoir can be distantly separated from the evaporator and located along the liquid transport line (Less popular design, named capillary pumped loop, Figure 1b).

[0006] A typical present-day evaporator with attached reservoir is shown in Figure 2. Evaporator 1 is the principal and the most complex element of the heat loop. It has two functions: to absorb the waste heat by liquid-to-vapor transition (evaporation) and to supply the liquid from a condenser (not shown) (pumping). The heat source often has flat geometry (for instance, side of an electronic box, a printed circuit board, chip, etc.). Since the heat loop works on a working fluid saturation line, the internal pressure can significantly vary during operation with temperature changes. To withstand high pressures levels, cylindrical geometry is preferable for heat loop elements and is the most typical. A saddle 3 is an interface unit between the cylindrical shape evaporator 1 and the flat (or other shaped) heat source (not shown). Evaporation process takes place on the outer surface of a primary wick 4. Generated, due to above mentioned evaporation process, vapor moves through vapor collecting grooves 6 to an evaporator outlet 12. Liquid returned from the condenser enters liquid inlet 11, moved inside central channel 7 through secondary wick 5 and primary wick 4 to evaporation surface, formed by outer surface of the primary wick 4. Reservoir 9 is necessary to manage liquid volume variations due to operational and ambient temperature changes. If the heat loop is working in unfavorable gravitational conditions (reservoir 9 below evaporator 1) a tertiary wick 10 will supply the liquid to the secondary wick 5 and the secondary wick 5 will supply liquid to the primary wick 4. The primary wick 4 has the smallest pore size among the wicks and tertiary wick 10 has the biggest porous size. For practical applications, typical overall pressure drop over the loop is in the range of ~0.1 up to 1-2 bar. To overcome such pressure differences the porous size (effective diameter of the pores) of the primary wick 4 should be in the range of 1-10 microns. The smaller the porous size, the higher capillary potential of the wick. However, the decrease of porous size also leads to reducing wick permeability. It means that overall pressure drop in the loop is increasing and more pumping capacity is required from the primary wick 4. Finally, certain optimal ratio between wick porous size and permeability values should be found in practical applications. The most common material of the wick is metal: stainless steel, titanium, nickel, copper and others. Primary wick 4 is usually manufactured from metal particles or fibers by the sintering process. Then it is machined to specified dimensions and inserted into an evaporator case 2. High and low pressure sides of the primary

wick 4 (external vapor surface and internal liquid central channel) should be well separated. The capillary pumping will not work properly if there is any leakage between two sides larger than primary wick 4 porous size. A sealing 8 provides such separation. Sealing can be performed by different techniques: welding, soldering, co-sintering, pressing, etc.

[0007] As it is clear from Figure 2, the evaporator design is asymmetric: liquid inlet 11 and evaporator vapor outlet 12 are placed on opposite sides of the evaporator 1, each primary and secondary wicks 4,5 have one open and one closed end, the reservoir 9 is attached to one side. This design is not flexible. Every heat loop has to be designed for the given thermal task. If the specifications of a new thermal system have different geometry, different distance between heat source and heat sink, or power and conductance requirements, then the design should be started from the beginning and generally a new evaporator should be developed with other capillary pumps (primary, secondary and tertiary wicks), dimensions and geometry of reservoir. The type of evaporator described here cannot serve as a universal building block for various applications.

[0008] Another limitation of this design of evaporator is related to manufacturing restrictions. Today the longest evaporator on the market has a length around 0.5 m. It is practically impossible to fabricate larger evaporators because of multiple problems connected with primary wick sintering and machining, considering small diameters, high fragility of the wick and the tight tolerance requirements. The cost of the evaporator is also increasing dramatically as a function of the length, which is limiting applications of the technology. For instance, to increase overall thermal conductance of the system, multiple heat loops can be installed as an alternative solution to one loop with a large contact area evaporator. However, the cost of such a system increases, because every loop should be manufactured, charged and tested separately, flexibility of integration is reduced (multiple lines, condensers, etc.) and overall system volume/mass characteristics degrade. There are some developments of multiple-evaporator heat loops, but they are quite far from having practical applications today due to the high complexity and low reliability of such systems.

[0009] The modular capillary evaporator design is proposed in order to expand applications of heat loops and overcome current technology limits.

[0010] The subject matter of the present invention is defined in claim 1, embodiments of which are subject of subclaims 2 to 13.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Figure 1 is a schematic diagram of the typical heat loop showing main elements and fluid flow directions:

- a) loop heat pipe
- b) capillary pumped loop.

Figure 2 is a cut away view illustrating the interior design of the present-day evaporator with reservoir.

Figure 3 is a cut away view illustrating the interior design of evaporator-reservoir modular unit:

- a) linear modular unit with one evaporator two reservoirs (reservoir-evaporator-reservoir, RE-R)
- b) linear modular unit with two evaporators two reservoirs (R-E-E-R)
- c) curved modular unit with three evaporators two reservoirs (R-E-E-E-R)

Figure 4 is a schematic diagram of different linear evaporator-reservoir modular unit arrangements illustrating flexibility and great variety of possible configurations:

- a) E-R-E;
- b) R-E-R;
- c) R-E-E;
- d) R-E-E-R;
- e) R-E-R-E-R;
- f) R-E-E-E;
- g) R-E-E-E-R;
- h) R-E-R-E-E-R;
- i) R-E-R-E-R-E;
- j) R-E-R-E-R-E-R.

Figure 5 is a schematic diagram of several curved evaporator-reservoir modular unit arrangements illustrating flexibility and great variety of possible configurations:

- a) R-E-E-R-E-E-R with two 90° bends and evaporator outlets joined by common manifold;
- b) R-E-E-E-R with two 180° bends, and interconnected evaporator outlets;
- c) R-E-R-E-R-E-E with four 90° bends, closed loop secondary wick and evaporator outlets joined by common manifold.

Figure 6 is a schematic diagram of evaporator-reservoir modular unit arrangements integrated in heat loops with multiple condensers illustrating flexibility and great variety of possible configurations:

- a) linear R-E-E-R modular unit in a heat loop with two condensers connected to every evaporator-reservoir module
- b) curved R-E-R-E-R-E-R-E modular unit heat loop with four condensers connected to every evaporator-reservoir module

DETAILED DESCRIPTION

[0012] Figure 3 illustrates the overall design of the evaporator-reservoir modular unit for heat loops to which the present invention is applied. Separate features of this embodiment are applicable for each of the following embodiments unless otherwise specified. A simple unit, which consists of one evaporator 1 and two reservoirs 9a, 9b (reservoir-evaporator-reservoir: R-E-R) is shown in Figure 3a. Subcooled liquid from a condenser (not shown) enters into a liquid inlet 11, then flows through a secondary wick 5 to a primary wick 4. Evaporation takes place on the outer surface of the primary wick 4. Vapor moves through vapor collecting grooves 6 toward an evaporator outlet 12. The longitudinal vapor collecting grooves 6 are joined together by a circumferential groove 20 arranged between the outer surface of the primary wick 4 and inner surface of the evaporator envelope 2 in the plane of the evaporator outlet 12. At least one vapor collecting groove 6 has to be machined on the outer surface of the primary wick 4 or/and on the inner surface of evaporator envelope 2. The connecting circumferential groove 20 is necessary if there are more than one longitudinal vapor collecting grooves 6, if evaporator outlet 12 is not on the same line with vapor collecting groove 6 or if there are more than one evaporator outlet 12. The presence of a central open end hole in the primary wick 4 in combination with the above-mentioned vapor collecting groove 6 being connected directly or through the circumferential groove 20 to the evaporator outlet 12, which is located on the outer surface of the evaporator envelope 2, is the distinguishing feature of the design. It allows to perform cascade (or series) connection of multiple evaporators 1 and reservoirs 9 in any combination. Each of the two reservoirs 9a, b on Figure 3a has a smaller size than present-day design reservoir 9 shown on Figure 2 because the required total reservoir volume is divided into two parts. The evaporator 1 and reservoirs 9a, b are joined by one common secondary wick 5 with a liquid central channel 7. The evaporator outlet 12 can be positioned in any place of the outer surface of the evaporator envelope 2: inside or outside of an evaporator saddle 3 zone. This position is usually defined by customer specification. However, the preferable position is in the middle of the evaporator 1 as it is shown in Figure 3a. In this case, the vapor pressure drop in the vapor collecting groove(s) 6 has the lowest value since the vapor passing distance before entering into the evaporator outlet 12 is the shortest. The evaporator-reservoir modular unit design has at least two sealings 8 which are assigned on two cap ends of every primary wick 4, covering thereby at least part of end surface of the primary wick 4.

[0013] If the heat loop has one condenser (not shown), all side evaporator outlets 12 of several evaporators 1 should be joined together by a common manifold line 14 which is connected to the condenser.

[0014] In one particular embodiment, the example is a linear design of the evaporator-reservoir modular unit

with two evaporators 1 and two reservoirs 9a, 9b, which is illustrated by Figure 3b.

[0015] The secondary wick 5 can be manufactured by the same manner as the primary wick 4: by sintering from metal powder or fiber. In this case, the secondary wick 5 is not flexible and the evaporator-reservoir modular unit has a linear configuration: All evaporators 1 and reservoirs 9 are put on the same straight secondary wick 5, side by side wherein the two next surfaces of two primary wicks 4 contact each other via the sealings 8 and two opposite surfaces of the primary wicks 4 each contact the corresponding reservoir 9a, 9b via the sealings 8. All reservoirs and evaporators of a modular unit have to be hermetically joined (for instance by welding brazing or soldering).

[0016] Further, according to this particular embodiment, the configuration of the evaporator-reservoir modular unit includes a highly thermally conductive (for instance, metallic) bayonet tube 30 placed into the central liquid channel 7. This design permits to cool down fluid, which is accumulated in the end-capping reservoirs 9a and 9b by the subcooled liquid returned from the condenser before the liquid arrives to primary wick 4. The cooling effect of liquid in the chambers is achieved by conductive heat exchange through the bayonet tube wall. This helps to avoid intense boiling on the inner part of the primary wick 4 and to achieve better functional stability and overall performances of the heat loop. The bayonet tube 30 can have lateral apertures (not shown). In such instance the cooling can be additionally intensified by the convection heat transfer in the reservoirs 9a and 9b. The evaporator outlets 12 connect vapor collecting groove(s) 6 of each primary wick 4 with the common manifold 14 being connected to the condenser.

[0017] If the secondary wick 5 is made from wires of fibers, it is possible to perform bends between multiple evaporators/reservoirs of the modular unit as it is shown in a further particular embodiment, in Figure 3c. The secondary wick 5 is manufactured in the shape of rolled metallic or non-metallic woven-wire mesh or in the shape of braided sleeving. This flexible design allows to perform different angle 2- and 3-dimensional bends between evaporators 1 or/and reservoirs 9a, b of the modular unit. At first, the straight flexible secondary wick 5 should be inserted into reservoir(s) 9, fluid-tight coupling element(s) 15 and the central hole(s) 13 of primary wick(s) 4 and then, bending of coupling element(s) 15 with internal flexible secondary wick 5 should be performed. According to this embodiment, three primary wicks 4, each inside of evaporator 1, are serially connected to each other by means of a common secondary wick 5, wherein outer end surfaces of two last primary wicks 4 are connected to an own reservoir 9a, 9b, one of which, namely the first reservoir 9a is connected to a condenser via a liquid inlet 11 and the other one, the second reservoir 9b, is blank flanged.

[0018] The secondary wick 5 can also have a composite design: The internal part in the evaporator 1 and the

reservoir **9** is inflexible (for instance, sintered), but it is attached (by co-sintering, welding, brazing etc.) to flexible portions located inside of the coupling elements **15**. There are two possible coupling element **15** designs: It can be rigid (bended metallic tube) and flexible (metallic bellows) as it is demonstrated in Figure 3c. Alternatively, all coupling elements **15** can be rigid or flexible (not shown).

[0019] Three evaporator outlets **12a, b, c** are connected together via the common manifold **14** to the condenser (not shown). Vapor outlets **12a** and **12b** are in the central part of the primary wicks **4** (and, consequently, in the middle of the saddles **3**), but outlet **12c** is located outside of the saddle **3**, on the right side of the primary wick **4**. Thus, Figure 3c also illustrates possible alternatives in the evaporator outlet **12** positioning on the side of the evaporator envelope **2** as it was discussed above. It gives added advantage (better design flexibility) to the evaporator-reservoir modular unit thermal architecture against present-day evaporator thermal systems because the evaporator outlet **12** can be mounted in any point along the evaporator **1**.

[0020] In general, only primary wick **4** presence is necessary for the typical heat loop (Figure 1) operation for terrestrial applications (1-g conditions). Secondary and tertiary wicks **5, 10** are necessary for microgravity or unfavorable gravitational operational conditions (if the reservoir **9** is located below evaporator **1**). However, the presence of the secondary wick **5** is the distinguishing feature of the evaporator-reservoir modular unit, since it is working as a capillary pumping link between multiple evaporators **1** and reservoirs **9**, and provides and redistributes liquid inside the unit. The secondary wick **5** guarantees proper heat loop operation in steady state and transient operational scenarios. It serves as a common joining core element which allows to quickly build numerous multi-evaporator, multi-reservoir modular units configurations for terrestrial and microgravity applications.

[0021] In further particular embodiments, Figure 4 shows the possible linear evaporator-reservoir modular unit arrangements for one evaporator **E** (Figure 4b), two evaporators **E** (Figure 4a, c, d, e), and three-evaporators **E** (Figure 4f-j). Evaporator **E** in this embodiment corresponds to a separate primary wick **4** settled on a single secondary wick **5** for the whole evaporator-reservoir modular unit in combination with corresponding evaporator outlet **12**. The modular units reservoirs **R** are located alternately with the at least one evaporator **E** and/or in the ends of the unit. The arrangements with two reservoirs **R** located at the both ends of the unit (Figure 4b, d, e, g, h, j) can operate in any orientation in the gravity field since one of the two end reservoirs **R** will always be on the same level or above the evaporator(s) **E** assembly.

[0022] Three curved evaporator-reservoir modular units, in further particular embodiments, are shown in Figure 5 to demonstrate the flexibility of the proposed approach in relation to accommodation on different heat generating elements/surfaces.

[0023] R-E-E-R-E-E-R modular unit with two 90° coupling elements **15** in Figure 5a illustrates a possible U-shape system configuration for large heat generating rectangular areas, wherein two pairs of segmentally connected evaporators **E** are arranged in the legs of "U", two reservoirs **R** - at the ends and one reservoir **R** - at the bottom of the U-shaped portion of the modular unit, wherein the opposed arrangement of the reservoirs **9** allows to operate this unit in any spatial orientation. One common manifold **14** joins all four evaporator outlets **12**.

[0024] Figure 5b depicts a curved R-E-E-E-R modular unit with two 180° bends of coupling elements **15**. Such an S-shaped arrangement can be used for elongated heat generating surfaces and the design can be customized for specific areas by increasing the number of intermediate evaporators **E2** and coupling elements **15**. In this scheme, the intermediate second evaporator **E2** has two evaporator outlets **12-2** and **12-3**, which are interconnected via circumferential groove **20** (not shown in the figures) of evaporator **E2** and connected to the circumferential grooves **20** (not shown in the figures) in the plane of the evaporator outlets of evaporators **E1** and **E3** correspondingly. Evaporator outlet **12-1** connects the first evaporator **E1** with the condenser. It allows to avoid tee-type connections in the heat loop and complex vapor line manifold routing.

[0025] Modular square-shaped looped unit R-E-R-E-R-E-R-E with four 90° bends (Figure 5c) has a single closed secondary wick **5**, wherein evaporator outlets **12** of each evaporator **E** are joined by common manifold **14**. For example, every evaporator **E** can be connected to one side of the cooled electronic box (not shown).

[0026] It is obvious from figures 4 and 5 that a vast number of one-, two-, and three-dimensional arrangements of evaporator-reservoir modules that comply with specific requirements for thermal management of various heat generating systems is possible. Standardized evaporator **1** and reservoir **9** modules can be used for this purpose.

[0027] In further particular embodiments, Figure 6 demonstrates another advantage of the invention: The possibility to develop multi-evaporator, multi-condenser heat loops based on evaporator-reservoir modular unit technology. The linear R-E-E-R modular unit, shown in Figure 6a, has two evaporator outlets **12a, b** and two liquid inlets **11a, b**. Two evaporators **1** are joined together at one end, and joined to reservoirs **9a** and **9b** at another end. The individual evaporator outlets **12a** and **12b** are linked with two independent condensers **C1** and **C2**. Returned from every condenser **C1** and **C2** liquid is entering the separate liquid inlets **11a, b** which are located on the end caps of two opposite reservoirs **9a, b**. By this arrangement, it is possible to connect the modular unit with two condensers in the same heat loop by separate vapor and liquid lines and to avoid the installation of additional elements, such as capillary blockers, for example (present-day design).

[0028] In further particular embodiments, the configu-

ration of a curved four-sided modular unit in Figure 6b is presented, which is similar to the unit in Figure 5c but instead of common manifold **14** it has multiple liquid outlets **11**. This gives the possibility to perform connection to several condensers. The square-shaped unit has four linear single reservoir **R** - evaporator **E** modules which are linked to each other by four 90° coupling elements **15**. The closed circuit R-E-R-E-R-E-R-E is formed as a result of such arrangement, wherein all reservoirs **9** and evaporators **1** are interconnected via the common central liquid channel **7** located inside of the common closed secondary wick **5**. The evaporator outlet **12** of every evaporator **E** is connected to the inlet of dedicated condenser **C1**, **C2**, **C3**, **C4** and every coupling element **15** (between the adjacent evaporator **E** and reservoir **R**) is connected to the outlet of dedicated condenser **C1**, **C2**, **C3**, **C4** via corresponding liquid outlet **11**.

[0029] This configuration can be used, for instance, for spacecraft electronics thermal control. Evaporators **E** have to be connected to internal panels or to four sides of the electronic box inside a satellite (not shown), and the condensers **C** have to be connected to four external radiators (not shown), for instance, to East-West-North South panels for a geostationary satellite. This gives the possibility to use efficiently all available external spacecraft surfaces for heat dissipation by means of a single heat loop.

[0030] It should be noted, that the liquid inlet **11** can be located on any of three basic components of the modular unit: on the end cap of the reservoir **9** (see, for instance Figures 3a,b,c, 4b), on the end cap of evaporator **1** (Figure 4a) or on the side of coupling element **15** (Figure 6b). However, the evaporator outlet **12** can be placed only on the outer side surface of the evaporator **1**.

[0031] Active control of the evaporator-reservoir modular unit heat loop operating temperature can be achieved by installing the heater on any one of the reservoirs **R** in the unit. In this case, the controlled reservoir **R** will always have two phases (vapor and liquid) inside during temperature regulation but other reservoirs **R** can be totally filled by liquid phase. The temperature of this reservoir **R** will drive the pressure inside of the heat loop and, consequently, temperatures of all evaporators **E** in the unit. Large heat dissipating areas can be thermally controlled by this method.

Claims

1. Evaporator-reservoir modular unit for heat loops to cool at least one heat generating element comprising
 - at least one evaporator **(1)** comprising an envelope **(2)** with inlying at least a primary wick **(4)**, wherein between the outer surface of the primary wick **(4)** and the inner surface of the envelope **(2)** is arranged at least one vapor collecting groove **(6)** connected to an evaporator outlet

(12).

- at least one reservoir **(9)**,
- a single common secondary wick **(5)** joining, at least partially, with its outer surface the inner surface of the at least one primary wick **(4)** and the at least one reservoir **(9)**,
- a single common central liquid channel **(7)** inside the secondary wick **(5)** joining at least one condenser with a liquid inlet **(11)** located in the cap end of the reservoir **(9)** or in the cap end of the evaporator **(1)**,
- wherein the hollow cylindrical shape of the primary wick **(4)** with two seals **(8)** on cap ends_covers at least partially the end surfaces of the primary wick **(4)**,

wherein the evaporator outlet **(12)** is arranged on the outer side surface of the evaporator **(1)**,

characterized by

at least one evaporator **(1)** and at least one reservoir **(9)** being connected in a sequential order in a group of at least three elements, hydraulically linking them by means of the common secondary wick **(5)** and the central liquid channel **(7)**, wherein the elements are the evaporator **(1)** and the reservoir **(9)**.

2. Unit according to claim 1 wherein the at least two vapor collecting grooves **(6)** are connected together by a circumferential groove **(20)** on the outer cylindrical surface of the primary wick **(4)** or/and on the inner cylindrical surface of the envelope **(2)** being arranged against the evaporator outlet **(12)**.
3. Unit according to claim 2, wherein the circumferential groove **(20)** and the evaporator outlet **(12)** are arranged adjacent to the middle part of the primary wick **(4)**.
4. Unit according to one of the preceding claims, wherein at least two reservoirs **(9)** are arranged on opposite sides of the at least one evaporator **(1)**.
5. Unit according to one of the preceding claims, wherein at least two evaporators **(1)** are arranged sequentially.
6. Unit according to claim 5, wherein the primary wicks **(4)** contact each other with their end surfaces by the seal **(8)**.
7. Unit according to one of the preceding claims, wherein a bayonet tube **(30)** is located in the central liquid channel **(7)** of the unit.
8. Unit according to one of the preceding claims, wherein the secondary wick **(5)** is made either from flexible fibers or wires in the shape of braided sleeving, or of flexible rolled woven-wire mesh.

9. Unit according to one of the preceding claims, wherein the secondary wick (5) has a looped circuit configuration with one or several liquid inlets (11).
10. Unit according to one of the preceding claims, wherein the evaporators (1) and reservoirs (9) are connected by cylindrical rigid bendable coupling elements (15) with the secondary wick (5) inside or by flexible bendable coupling elements (15) with the secondary wick (5) inside.
11. Unit according to one of the preceding claims, wherein the multiple evaporator outlets (12) of multiple evaporators (1) are connected to each other and to the heat loop condenser through a manifold (14).
12. Unit according to one of the preceding claims, wherein every evaporator (1) is connected with the dedicated condenser by means of the evaporator outlet (12) and the liquid inlet (11).
13. Unit according to one of the preceding claims, wherein a tertiary wick (10) is located in the reservoir (9) and attached to the secondary wick (5).

Patentansprüche

1. Modulare Verdampfer-Reservoir-Einheit für die Wärmekreisläufe zur Kühlung mindestens eines wärmeerzeugenden Elementes, die
- mindestens einen Verdampfer (1) mit einer Hülle (2) mit mindestens einem darin liegenden Hauptdocht (4), wobei eine Dampfsammelrinne (6) zwischen der Außenfläche des Hauptdochtes (4) und der Innenfläche der Hülle (2) mindestens ein Docht angeordnet ist, die mit dem Verdampferaustritt (12) verbunden ist.
 - mindestens einen Reservoir (9),
 - einen gemeinsamen Hilfsdocht (5), der die Innenfläche mit der Außenfläche von mindestens einem Hauptdocht (4) und mindestens einem Reservoir (9) zumindest teilweise verbindet,
 - eine gemeinsame zentrale Flüssigkeitsleitung (7) innerhalb des Hilfsdochtes (5), die mindestens einen Kondensator mit einem am Deckelende des Reservoirs (9) oder am Deckelende des Verdampfers (1) befindlichen Flüssigkeitseintritt (11) verbindet,
 - wobei eine hohlzylindrische Form des Hauptdochtes (4) mit zwei Dichtungen (8) an den Deckelenden, die zumindest teilweise die Endflächen des Hauptdochtes (4) bedecken, umfasst,

wobei der Verdampferaustritt (12) außen Seitenfläche des Verdampfers (1) angeordnet ist. **gekennzeichnet durch**

mindestens ein Verdampfer (1) und mindestens ein Reservoir (9) in einer sequentiellen Reihenfolge in einer Gruppe von mindestens drei Elementen verbunden sind, die sie hydraulisch mit Hilfe des gemeinsamen Hilfsdochtes (5) und der zentralen Flüssigkeitsleitung (7) verbinden, wobei die Elemente der Verdampfer (1) und des Reservoirs (9) sind,

2. Die Einheit nach Anspruch 1, bei der mindestens zwei Dampfsammelrinne (6) durch eine Umfangsnut (20) an der äußeren zylindrischen Oberfläche des Hauptdochtes (4) oder/und an der inneren zylindrischen Oberfläche der Hülle miteinander verbunden sind, die gegen den Verdampferaustritt (12) angeordnet ist.
3. Die Einheit nach Anspruch 2, wobei die Umfangsnut (20) und der Verdampferaustritt (12) nahe dem Mittelteil des Hauptdochtes (4) angeordnet sind.
4. Die Einheit nach einem der vorhergehenden Ansprüche, wobei auf gegenüberliegenden Seiten des mindestens einen Verdampfers (1) mindestens zwei Reservoir (9) angeordnet sind.
5. Die Einheit nach einem der vorhergehenden Ansprüche, wobei mindestens zwei Verdampfer (1) hintereinander angeordnet sind.
6. Die Einheit nach Anspruch 5, wobei die Hilfsdochte (4) mit ihren Endflächen durch die Dichtung (8) in Kontakt miteinander stehen.
7. Die Einheit nach einem der vorhergehenden Ansprüche, wobei sich in der zentralen Flüssigkeitsleitung (7) der Einheit ein Bajonettrohr (30) befindet.
8. Die Einheit nach einem der vorhergehenden Ansprüche, wobei der Hilfsdocht (5) entweder aus flexiblen Fasern oder Drähten in Form eines geflochtenen Schlauchs oder aus einem flexiblen gewalzten Drahtgeflecht besteht.
9. Die Einheit nach einem der vorhergehenden Ansprüche, wobei der Hilfsdocht (5) eine Kreislaufkonfiguration mit einem oder mehreren Flüssigkeitseintritten (11) aufweist.
10. Die Einheit nach einem der vorhergehenden Ansprüche, bei dem die Verdampfer (1) und Reservoir (9) durch zylindrische starre biegbare Verbindungselemente (15) mit dem Hilfsdocht (5) innerhalb oder durch flexible biegbare Verbindungselemente (15) mit einem Hilfsdocht (5) innerhalb verbunden sind.
11. Die Einheit nach einem der vorhergehenden Ansprüche, wobei die mehreren Verdampferaustritte (12) mehrerer Verdampfer (1) miteinander und durch ei-

nen Eintrittssammler (14) mit dem Wärmekreis-Kondensator verbunden sind.

12. Die Einheit nach einem der vorhergehenden Ansprüche, wobei jeder Verdampfer (1) durch den Verdampferaustritt (12) und den Flüssigkeitseintritt (11) mit dem zugeordneten Kondensator verbunden ist.
13. Die Einheit nach einem der vorhergehenden Ansprüche, wobei sich im Reservoir (9) der Tertiärdocht (10) befindet, der am Hilfsdocht (5) befestigt ist.

Revendications

1. Unité Modulaire évaporateur-réservoir pour des circuits thermiques pour refroidir au moins un élément combustible contenant
 - au moins un évaporateur (1) comprenant une bouteille (2) avec au moins une mèche intérieure principale (4) dans laquelle entre la surface extérieure de la mèche principale (4) et la surface intérieure de la bouteille (2) au moins un évitement de vapeur (6) relié à la sortie de l'évaporateur (12) se trouve.
 - au moins un réservoir (9),
 - une mèche auxiliaire commune (5) reliant au moins en partie la surface intérieure à la surface extérieure d'au moins une mèche principale (4) et d'au moins un réservoir (9),
 - une ligne liquide centrale commune (7) à l'intérieur de la mèche auxiliaire (5) reliant au moins un condensateur à l'entrée de liquide (11) située à l'extrémité du réservoir (9) ou à l'extrémité de l'évaporateur (1)
 - la forme cylindrique creuse de la mèche principale (4) avec deux joints (8) aux extrémités du couvercle ferme au moins partiellement les extrémités de la mèche principale (4),dans ce cas, l'orifice de sortie (12) de l'évaporateur est situé sur la surface latérale extérieure de l'évaporateur (1),
caractérisé par le fait qu'
au moins un évaporateur (1) et au moins un récipient (9) sont reliés en séquence en un groupe d'au moins trois éléments, reliant hydrauliquement au moyen d'une commune mèche auxiliaire (5) et la ligne centrale de liquide (7), en même temps l'évaporateur (1) et le réservoir (9) sont les éléments.
2. L'unité, selon le paragraphe de la formule de l'invention 1, dans lequel au moins deux évidements (6) pour recueillir la vapeur sont reliés les uns aux autres par une rainure circulaire (20) sur la surface cylindrique externe de la mèche principale (4) ou / et sur la surface cylindrique interne de la bouteille (2), est

situé en face de la sortie de l'évaporateur (12).

3. L'unité, selon le paragraphe de la formule de l'invention 2, dans lequel la rainure circulaire (20) et la sortie de l'évaporateur (12) sont situés près de la partie médiane de la mèche principale (4).
4. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel au moins deux réservoirs (9) sont situés sur les côtés opposés d'au moins un évaporateur (1).
5. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel au moins deux évaporateurs (1) sont disposés séquentiellement.
6. L'unité, selon le paragraphe de la formule de l'invention 5, dans lequel les mèches principales (4) sont reliées les unes aux autres avec les surfaces de bout au moyen d'un joint (8).
7. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans laquelle le tube à baïonnette (30) est situé dans la ligne de liquide centrale (7) du bloc.
8. L'unité, selon le paragraphe de la formule de l'invention 1, dans lequel la mèche auxiliaire (5) est faite soit de fibres souples, soit de fils en forme de tube tressé, soit d'un treillis métallique souple tissé en rouleau.
9. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel la mèche auxiliaire (5) a une configuration en boucle fermée avec une ou plusieurs entrées de liquide (11).
10. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel les évaporateurs (1) et les réservoirs (9) sont reliés par des éléments de connexion flexibles cylindriques rigides (15) avec une mèche auxiliaire (5) à l'intérieur ou des connecteurs pliés flexibles (15) avec une mèche auxiliaire (5) à l'intérieur.
11. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel un ensemble de sorties (12) des évaporateurs à plusieurs étages évaporateurs (1) sont connectés les uns aux autres et au condensateur du circuit thermique au moyen d'un collecteur d'entrée (14).
12. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel chaque évaporateur (1) est connecté à un condensateur spécialement conçu par la sortie de l'évaporateur (12) et l'entrée (11) pour le liquide.

13. L'unité, selon l'un des paragraphes précédents de la formule de l'invention, dans lequel la mèche tertiaire (10) est située dans le réservoir (9) et fixée à la mèche auxiliaire (5).

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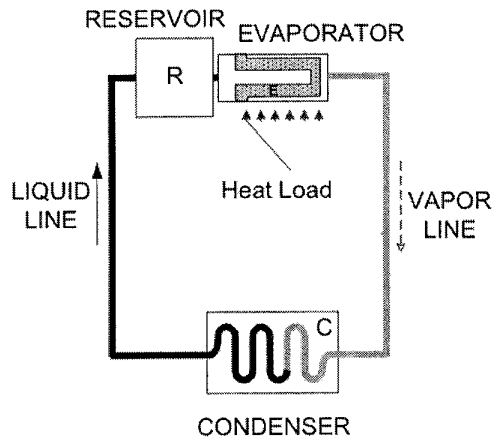
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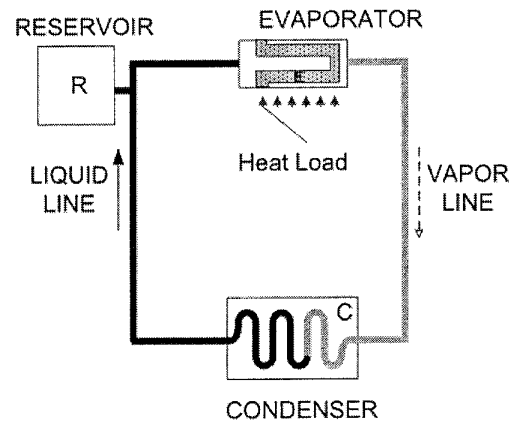
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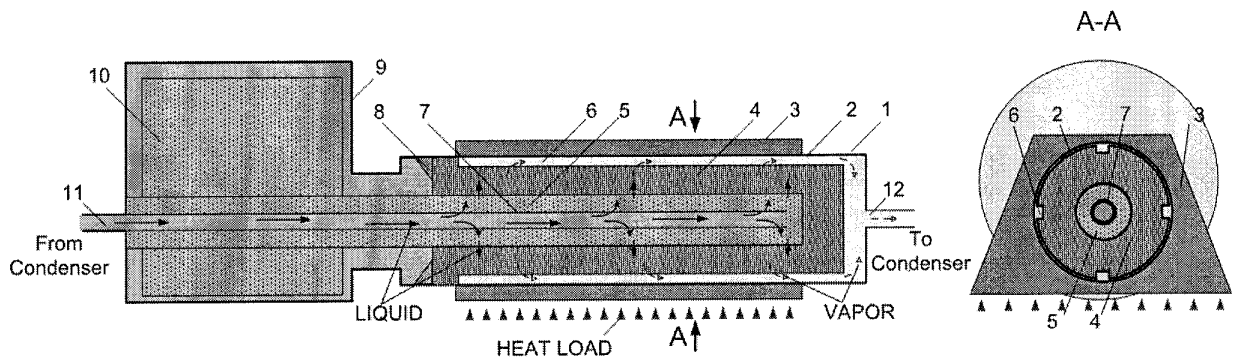
a) Loop Heat Pipe



b) Capillary Pumped Loop

PRIOR ART

Figure 1



PRIOR ART

Figure 2

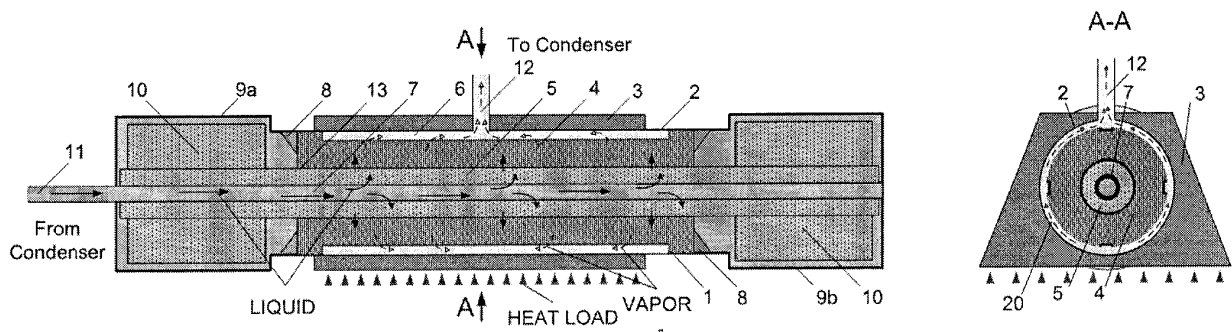


Figure 3a)

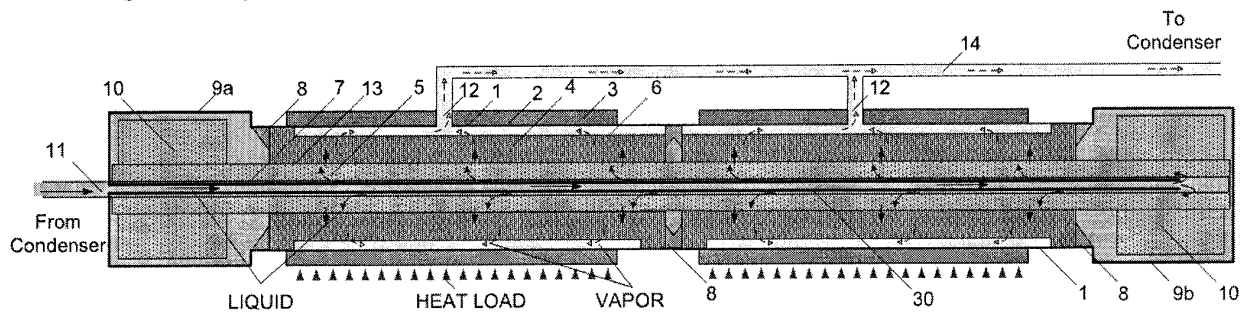


Figure 3b)

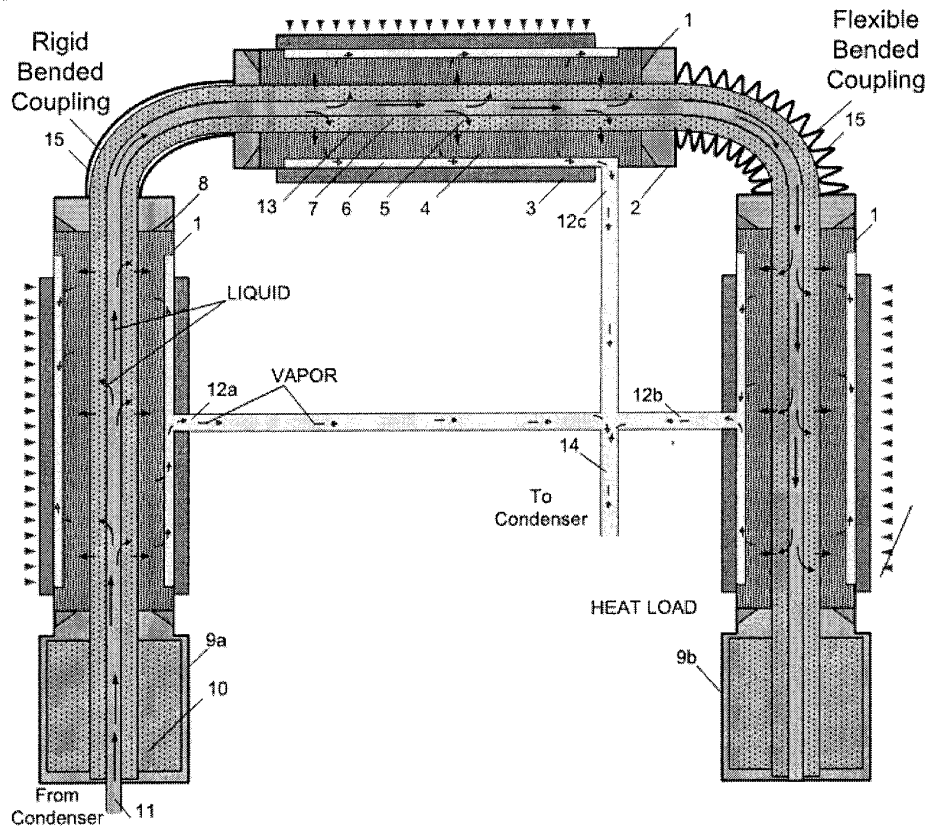


Figure 3c)

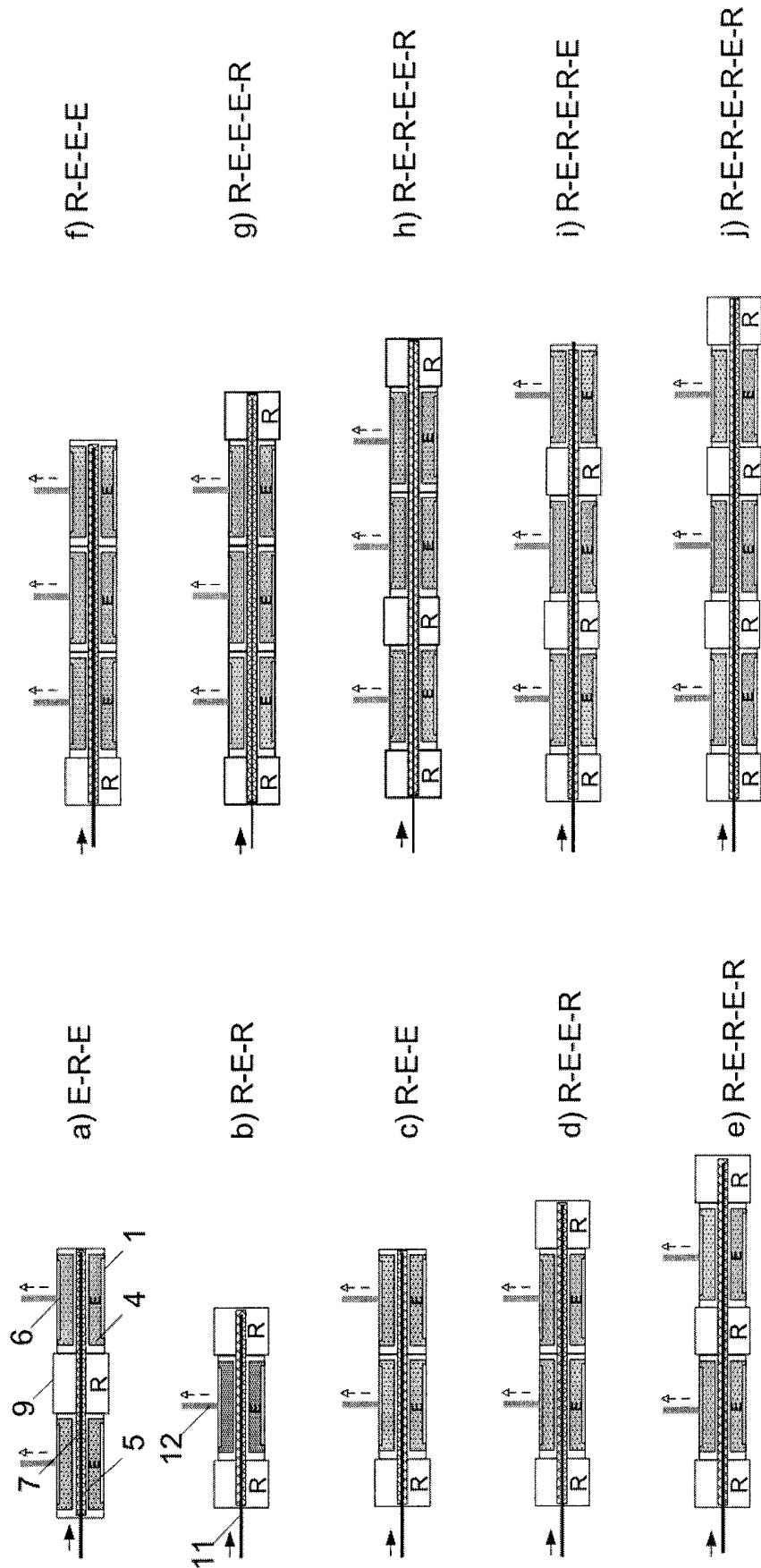


Figure 4

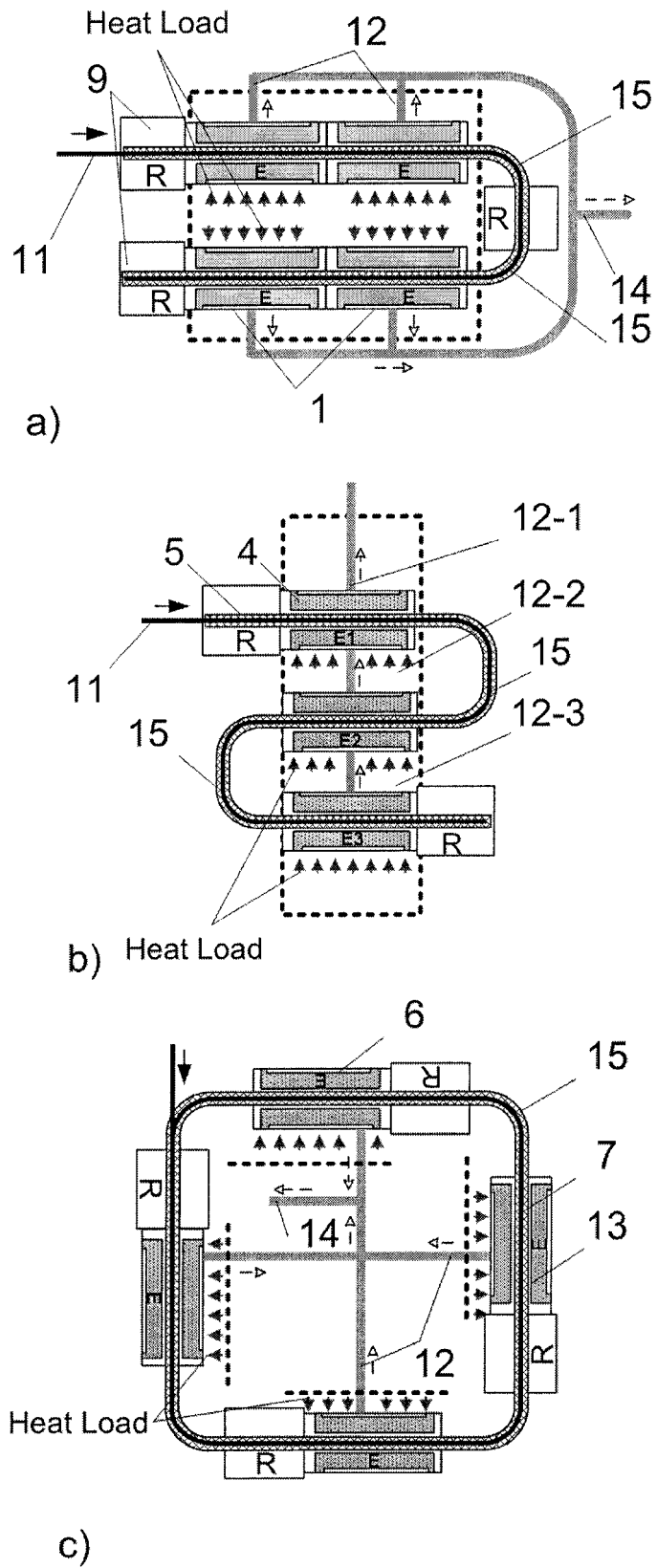


Figure 5

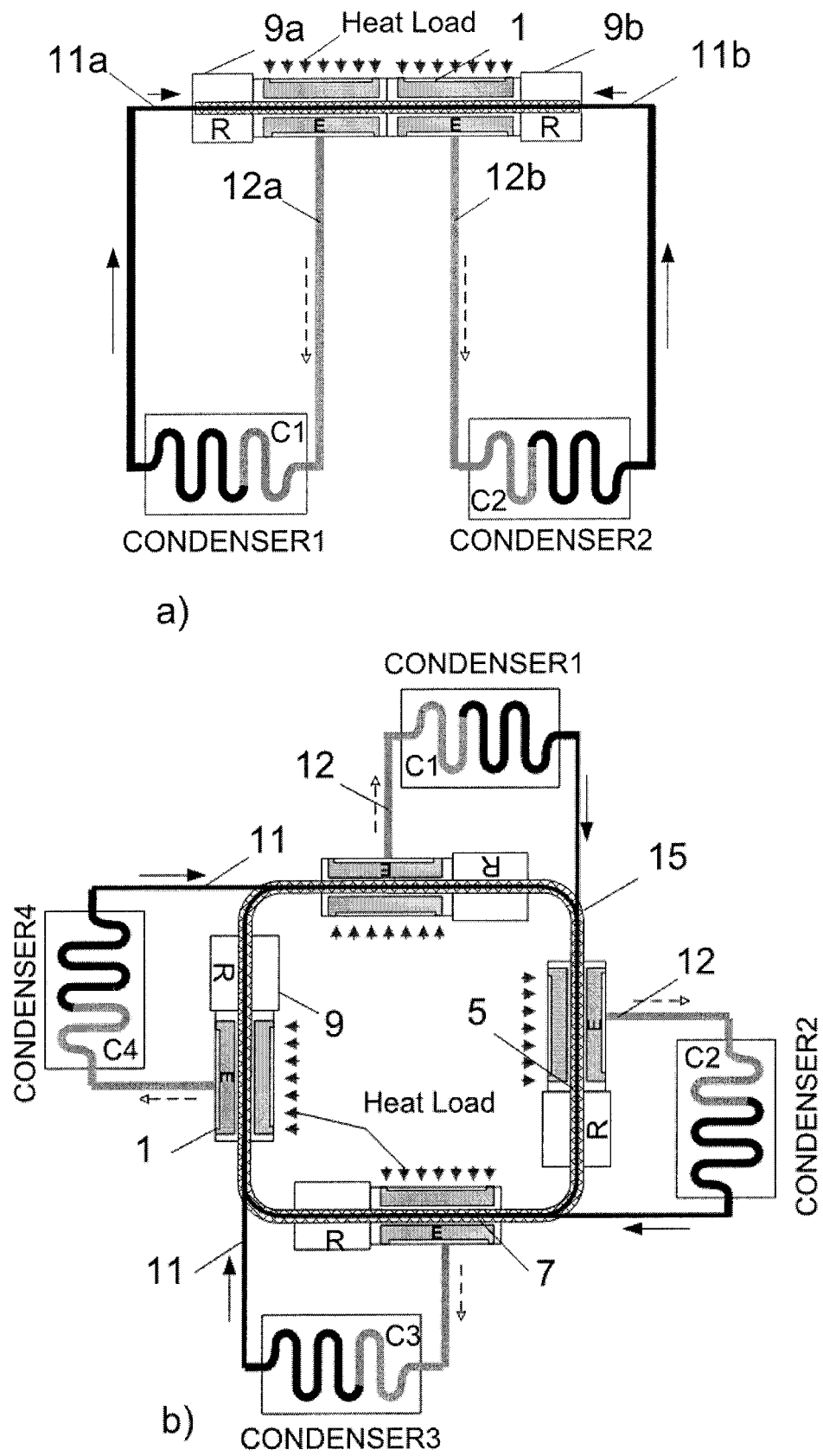


Figure 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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